RADIO - TELEVISION

Practical Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

J. A. ROSENKRANZ, Pres.

Amplifying Systems

LESSON NO. 1

MICROPHONES

YOU ARE NOW PROPERLY PREPARED TO COMMENCE YOUR STUDY OF A.F. AMPLIFYING SYSTEMS AND AS YOU PROGRESS THROUGH THIS SERIES OF LESSONS, CONTINUALLY BEAR IN MIND THAT THIS INFORMATION WHICH IS NOW BEING GIVEN YOU NOT ONLY APPLIES TO PUBLIC ADDRESS SYSTEMS BUT IT APPLIES EQUALLY WELL TO THE A.F. AMPLIFIER SYSTEMS AS USED IN CONJUNCTION WITH TRANSMITTERS, TALKING PICTURES, TELEVISION, ETC.

IT IS PERFECTLY LOGICAL THAT ONE MUST FIRST HAVE A GOOD UNDERSTANDING OF A.F. AMPLIFYING SYSTEMS BEFORE UNDERTAKING AN INTENSIVE STUDY OF PHONE-TRANSMITTERS, BROADCASTING STATIONS, TALKING PICTURES OR TELEVISION SINCE THE AUDIO CHANNEL IN ANY ONE OF THESE CASES MUST NOT ONLY BE PROPERLY DESIGNED AND OPERATED IN ITSELF BUT MUST IN ADDITION BE PROPERLY MATCHED UP WITH THE BALANCE OF THE EQUIPMENT WITH WHICH IT IS BEING USED.

BY PRESENTING A.F. AMPLIFIER SYSTEMS TO YOU THE NATIONAL WAY, YOU WILL FIND THAT UPON COMPLETING THIS SPECIAL SERIES OF LESSONS, YOU WILL NOT ONLY BE CAPABLE OF CONSTRUCTING, INSTALLING AND OPERATING PUBLIC ADDRESS EQUIPMENT BUT YOU WILL IN ADDITION BE IN A POSITION TO APPLY A.F. AMPLIFYING EQUIPMENT CORRECTLY TO EVERY POSSIBLE USE.

FIG. 1

Microphone Arrangement for Voice Pick-up.

THE MICROPHONE

SINCE THE MICROPHONE IS

THE FIRST UNIT WHICH HANDLES THE SOUND IN THE MAJORITY OF CASES WHERE A.F. AMPLIFIERS ARE USED, OUR FIRST STEP WILL BE TO CONSIDER THE CONSTRUCTION, OPERATION AND APPLICATION FOR THE DIFFERENT TYPES OF MICROPHONES NOW IN USE.

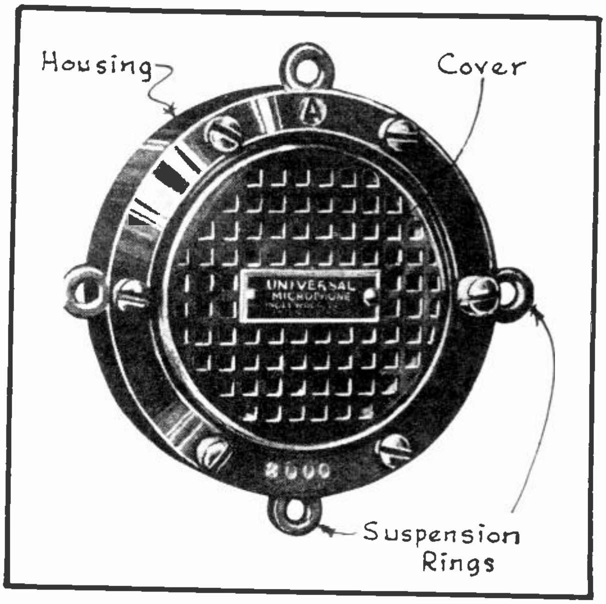

FIG. 2
Single-Button Carbon Microphone

AS YOU WILL RECALL FROM YOUR EARLIER STUDIES, THE PURPOSE OF THE MICROPHONE IS TO CONVERT SOUNDWAVES INTO CORRESPONDING ELECTRIC CURRENT OR VOLTAGE VARIATIONS AND THE FOLLOWING EXPLANATIONS ARE GOING TO SHOW YOU DIFFERENT WAYS IN WHICH THIS CAN BE DONE.

THE SINGLE-BUTTON CARBON MICROPHONE

THE SINGLE-BUTTON CARBON MICROPHONE IS THE MOST EASILY UNDERSTOOD MICROPHONE FROM THE STANDPOINT OF CONSTRUCTION AND OPERATION AND SO WE SHALL CONSIDER THIS UNIT FIRST.

YOU ARE SHOWN A TYPICAL MICROPHONE OF THIS TYPE IN FIG. 2, WHEREAS FIG. 3 SHOWS YOU A DESK-STAND INTO WHICH THIS SAME MICROPHONE CAN BE MOUNTED. THE MICROPHONE, YOU WILL NOTICE, IS HELD IN THE STAND BY MEANS OF SPECIAL SUSPENSION SPRINGS. THIS TYPE OF SUSPENSION, AS SHOWN IN FIG. 4, PROTECTS IT AGAINST MECHANICAL SHOCKS.

THE MICROPHONE UNIT ITSELF IS ENCLOSED IN A METALLIC HOUSING AND A PERFORATED PLATE IS FITTED OVER ITS FRONT SIDE SO AS TO PROTECT THE DIAPHRAGM AND OTHER INTERNAL PARTS, WHILE AT THE SAME TIME PERMITTING THE SOUND WAVES TO PASS THROUGH IT WITHOUT UNDUE OBSTRUCTION SO THAT THEY MAY ACT UPON THE DIAPHRAGM.

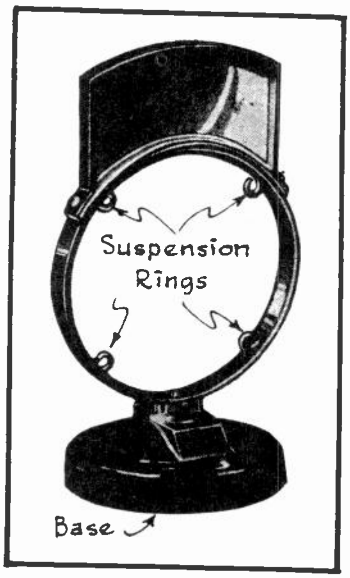

FIG. 3
Desk Type Microphone Stand.

THE BASIC CONSTRUCTIONAL FEATURES OF THE SINGLE-BUTTON CARBON MICROPHONE ARE ILLUSTRATED FOR YOU IN FIG. 5. NOTICE THAT THE THIN DURALUMINUM DIAPHRAGM IS STRETCHED ACROSS THE FRONT PORTION OF THE HOUSING BEHIND THE PERFORATED PLATE, AND ITS RIM IS IN DIRECT CONTACT WITH THE METAL HOUSING, SO THAT THE DIAPHRAGM AND HOUSING IN THIS CASE SERVE TO COMPLETE PART OF THE ELECTRICAL CIRCUIT.

A SMALL CHAMBER OR CUP CONTAINING CARBON GRANULES IS PLACED IN THE REAR PORTION OF THE HOUSING AND A DISC WHICH IS CONNECTED TO THE CENTER OF THE DIAPHRAGM PRESSES AGAINST THE CARBON GRANULES. THIS CONSTITUTES WHAT IS KNOWN AS A "BUTTON".

IF A BATTERY IS CONNECTED ACROSS THE TERMINALS OF THE MICROPHONE AS ILLUSTRATED IN FIG. 5,

THEN BATTERY CURRENT WILL FLOW THROUGH THE COMPRESSED CARBON GRANULES. WHEN SOUND WAVES STRIKE AGAINST THE DIAPHRAGM, THE CORRESPONDING VARIATIONS IN AIR PRESSURE CAUSE IT TO FLEX OR BEND IN ACCORDANCE WITH THE PRESSURE VARIATIONS AND THEREBY COMPRESS OR DECOMPRESS THE GRANULES.

IN OTHER WORDS, WHENEVER THE SOUND WAVE CAUSES THE AIR PRESSURE UPON THE DIAPHRAGM TO INCREASE, BENDING IT INWARDS, THEN THIS MOTION OF THE DIAPHRAGM WILL FORCE THE CARBON GRANULES CLOSER TOGETHER AND THUS REDUCE THE ELECTRICAL RESISTANCE THRU THE BUTTON. THE FLOW OF BATTERY CURRENT WILL THEREFORE BE INCREASED.

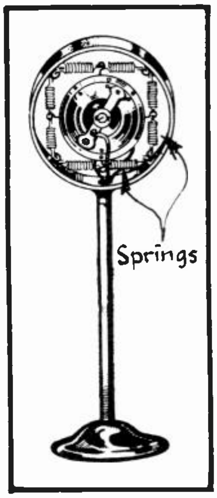

FIG. 4
The Mounted Microphone.

ON THE OTHER HAND, WHENEVER THE SOUND WAVE CAUSES THE AIR PRESSURE UPON THE DIAPHRAGM TO DECREASE SO THAT THE DIAPHRAGM WILL BEND OUTWARDS, THEN THIS MOTION OF THE DIAPHRAGM WILL CAUSE THE CARBON GRANULES TO BE SUBJECTED TO LESS PRESSURE, PERMITTING THEM TO BECOME DECOMPRESSED OR MORE SEPARATED AND THIS WILL SERVE TO INCREASE THE RESISTANCE THROUGH THE BUTTON. THE FLOW OF BATTERY CURRENT WILL THEREFORE BE REDUCED.

MICROPHONE INPUT CIRCUIT

THE COMPLETE INPUT CIRCUIT AS USED WITH A SINGLE-BUTTON MICROPHONE IS ILLUSTRATED IN FIG. 6 AND THE SYSTEM OPERATES AS FOLLOWS:

THE MICROPHONE IS CONNECTED IN SERIES WITH A $1\frac{1}{2}$ TO 3 VOLT BATTERY, A SWITCH AND THE PRIMARY WINDING OF A SPECIAL MICROPHONE TRANSFORMER. THIS MICROPHONE TRANSFORMER IN APPEARANCE AND CONSTRUCTION IS THE SAME AS ANY CONVENTIONAL A.F. TRANSFORMER, ONLY THAT ITS WINDINGS ARE SUCH THAT THE PRIMARY MATCHES THE RESISTANCE OF THE MICROPHONE AND THE SECONDARY IS DESIGNED TO MATCH THE IMPEDANCE OF THE AMPLIFIER CIRCUIT TO WHICH IT IS CONNECTED. TRANSFORMERS OF THIS TYPE ARE GENERALLY KNOWN AS MICROPHONE COUPLING TRANSFORMERS. A POTENTIOMETER, WHICH IS CONNECTED ACROSS THE SECONDARY WINDING, SERVES AS THE VOLUME CONTROL.

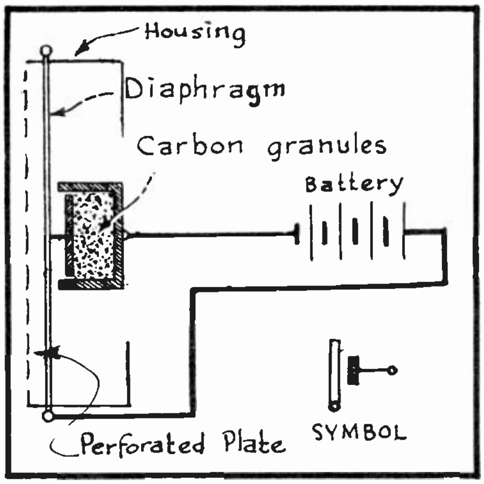

FIG. 5
The microphone circuit.

WITH THE SWITCH CLOSED, A UNIFORM FLOW OF BATTERY CURRENT WILL PASS THROUGH THE MICROPHONE, AS WELL AS THROUGH THE PRIMARY WINDING OF THE TRANSFORMER. THE AMOUNT OF THIS NORMAL MICROPHONE CURRENT WILL DEPEND UPON THE RESISTANCE OF THE BUTTON WITH THE MICROPHONE DIAPHRAGM IN ITS NEUTRAL POSITION, TOGETHER WITH THE RESISTANCE OF THE TRANSFORMER'S PRIMARY WINDING--AT THE SAME TIME BEING DEPENDENT UPON THE BATTERY VOLTAGE BEING USED. IT IS COMMON FOR CARBON MICROPHONES TO HAVE A RESISTANCE OF 200 OHMS, ALTHOUGH OTHER RESISTANCE RATINGS ARE EMPLOYED.

THE CURRENT FLOW AT THIS TIME IS A DIRECT CURRENT OF UNIFORM OR UNVARYING INTENSITY AND CAN BE ILLUSTRATED BY THE HORIZONTAL LINE IN FIG. 7 WHICH IS DRAWN SLIGHTLY ABOVE AND PARALLEL TO THE BASE-

LINE OF ZERO CURRENT. THIS NORMAL FLOW OF CURRENT UPON PASSING THRU THE PRIMARY WINDING WILL PRODUCE A MAGNETIC FIELD OF DEFINITE INTENSITY IN THE TRANSFORMER CORE.

AS SOUND WAVES ARE IMPRESSED UPON THE DIAPHRAGM OF THE MICROPHONE, THE FLOW OF BATTERY CURRENT THROUGH THE MICROPHONE CIRCUIT WILL VARY IN PROPORTION TO THE AIR PRESSURE ACTING UPON THE DIAPHRAGM AT ANY ONE INSTANT. IN OTHER WORDS, THE CURRENT WILL RISE AND FALL WITH RESPECT TO THE NORMAL CURRENT VALUE BUT AT NO TIME DOES IT REVERSE ITS DIRECTION OF FLOW. PUTTING IT ANOTHER WAY, WE NOW HAVE A PULSATING DIRECT CURRENT, WHOSE WAVE FORM WOULD APPEAR SOMEWHAT AS SHOWN IN FIG. 7 AT THE REGION LABELED "CURRENT VARIATIONS" AND WOULD BE AN ELECTRICAL REPRODUCTION OF THE ORIGINAL SOUND WAVES WHICH ACT UPON THE DIAPHRAGM OF THE MICROPHONE.

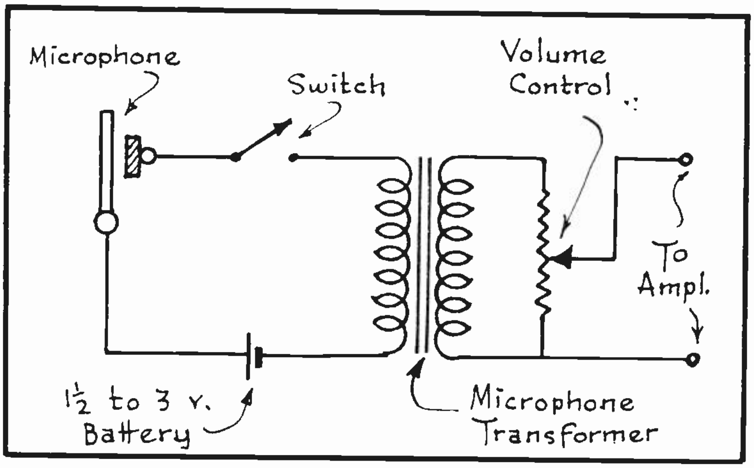

FIG. 6
Microphone Input Circuit.

THIS VARIATION IN CURRENT FLOW WILL CAUSE THE MAGNETIC FIELD OF THE TRANSFORMER TO VARY ITS INTENSITY ACCORDINGLY AND BY MUTUAL INDUCTION INDUCE VOLTAGE VARIATIONS OF CORRESPONDING FREQUENCY ACROSS THE ENDS OF THE TRANSFORMER'S SECONDARY WINDING, AS WELL AS ACROSS THE ENDS OF THE VOLUME CONTROL POTENTIOMETER. THE POSITION OF THE POTENTIOMETER ARM DETERMINES WHAT PROPORTION OF THE MAXIMUM SIGNAL VOLTAGE AVAILABLE ACROSS THE ENDS OF THE SECONDARY WINDING ARE TO BE APPLIED TO THE INPUT OF THE AMPLIFIER AND IN THIS WAY CONTROL THE VOLUME.

THE SINGLE-BUTTON MICROPHONE IS RATHER LIMITED AS TO THE FREQUENCY RANGE OVER WHICH IT WILL SATISFACTORILY RESPOND. GOOD MICROPHONES OF THIS TYPE SELDOM PROPERLY HANDLE A FREQUENCY RANGE EXCEEDING THAT FROM 100 TO 3000 CYCLES AND FOR THIS REASON THEIR USE IS CONFINED CHIEFLY TO SPEECH REPRODUCTION ONLY AND NOT FOR THE REPRODUCTION OF MUSIC.

THE DOUBLE-BUTTON MICROPHONE

THE DOUBLE-BUTTON CARBON MICROPHONE IS BETTER ADAPTED TOWARDS HANDLING A GREATER FREQUENCY RANGE AND A PHOTOGRAPH OF SUCH A UNIT APPEARS IN FIG. 8. THE INTERNAL CONSTRUCTION OF THE SAME TYPE OF MICROPHONE IS SHOWN YOU IN FIG. 9. THE PARTICULAR MICROPHONE WHICH IS ILLUSTRATED IN FIG. 9 IS OF THE HIGH QUALITY TYPE AND WAS DESIGNED FOR USE IN BROADCASTING STATIONS AND FOR OTHER APPLICATIONS WHERE GOOD FREQUENCY CHARACTERISTICS ARE OF IMPORTANCE. HIGH GRADE DOUBLE-BUTTON CARBON MICROPHONES ARE FREQUENTLY CAPABLE OF

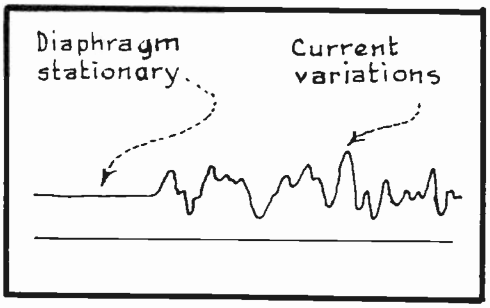

FIG. 7
Microphone current.

satisfactorily handling a frequency range of 50 to 6,000 cycles or more.

In this microphone also, the diaphragm is made of a thin, light disc of duraluminum and which is stretched until its resonant frequency is approximately 5700 cycles. The reason for stretching the diaphragm in this manner is to cause its natural vibrating period to be sufficiently high so that it is above the usual audio range encountered in normal use and will therefore prevent any blasting which would be caused by the sounding of a musical note of the same frequency as the resonant frequency of the diaphragm.

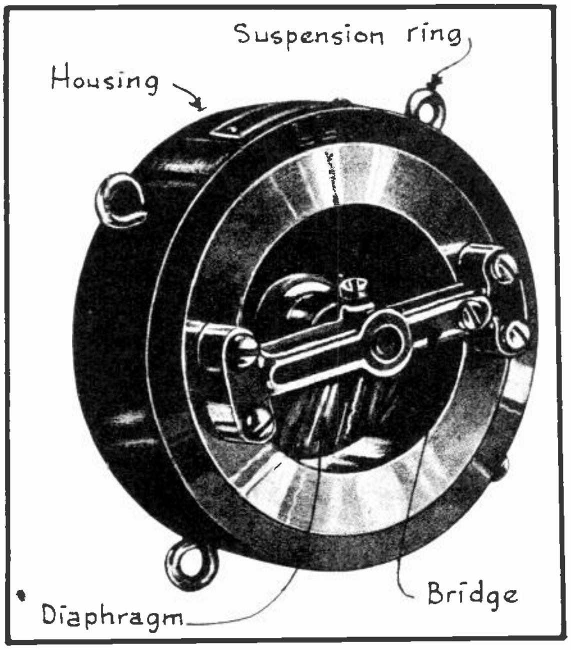

FIG. 8
Double - Button Microphone.

It is also important to note that the diaphragm is placed a short distance from a flat metal plate which is known as the DAMPING PLATE so that air is trapped between this plate and the diaphragm. With this type of construction, a high damping effect is obtained due to the compression of the air between them as the diaphragm is actuated. This action is still further aided by the cushioning effect of the air in the damping plate groove which is also pointed out in Fig. 9. Both of these features together help to make the variations in microphone current to conform exactly to the variations in impressed sound waves throughout the entire frequency range of the instrument.

So much for the constructional features of the double-button microphone. Now let us consider its operation in greater detail and the proper methods of using it.

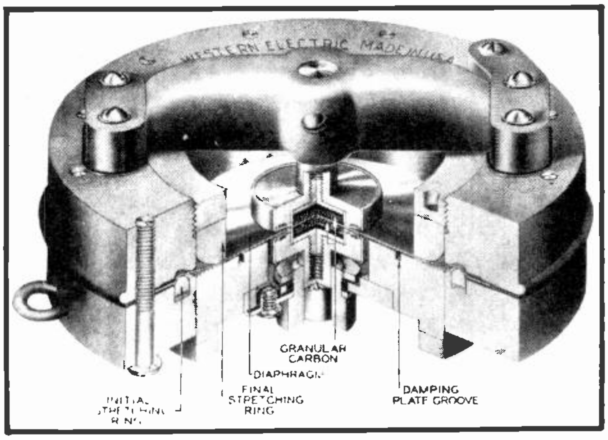

FIG. 9
Construction of Double - Button Microphone.

OPERATION OF THE DOUBLE-BUTTON MICROPHONE

In Fig. 10 you are shown a simplified diagram of the double-button microphone, together with its associated circuit, so that you can obtain a clear mental picture of its operation.

Observe closely in Fig. 10 that the microphone coupling transformer in this case has a center-tapped primary winding and that the center tap is connected to the diaphragm of the microphone with the microphone battery and switch in series. The ends of the coupling transformer's primary wind-

ING ARE CONNECTED ACROSS THE TWO MICROPHONE TERMINALS WHICH MAKE CONTACT WITH THE CUP CONTAINING THE CARBON GRANULES.

THE BATTERY CURRENT THUS HAS TWO PATHS AVAILABLE, THAT IS, IT CAN FLOW THROUGH THE LEFT BUTTON OF THE MICROPHONE, AS WELL AS THE LEFT HALF OF THE PRIMARY WINDING AND ALSO THROUGH THE RIGHT BUTTON AND THE RIGHT HALF OF THE PRIMARY WINDING.

NOW THEN, AS THE AIR PRESSURE CHANGES CORRESPONDING TO THE SOUND WAVES ARE IMPRESSED UPON THE MICROPHONE'S DIAPHRAGM SO AS TO CAUSE IT TO "BEND" IN ONE DIRECTION, THEN THE CURRENT THROUGH ONE SIDE OF THE TRANSFORMER'S PRIMARY WINDING WILL INCREASE WHILE THE CURRENT THROUGH THE OTHER SIDE OR HALF WILL AT THE SAME TIME DECREASE. IN OTHER WORDS, IF IN FIG. 10 THE DIAPHRAGM AT ONE PARTICULAR INSTANT IS BENT TOWARDS THE LEFT, THEN THE CURRENT THROUGH THE LEFT HALF OF THE CIRCUIT WILL INCREASE AND THAT THROUGH THE RIGHT HALF WILL DECREASE; WHEREAS IF THE DIAPHRAGM HAPPENS TO BE BENT TOWARDS THE RIGHT, THE CURRENT THROUGH THE RIGHT HALF OF THE CIRCUIT WILL INCREASE AND THAT THROUGH THE LEFT HALF WILL DECREASE CORRESPONDINGLY. THUS WE HAVE A PUSH-PULL EFFECT AND THE CHARACTERISTIC OF WHICH IS TO ELIMINATE DISTORTION PRODUCED BY EVEN HARMONICS IN THE CURRENT OR VOLTAGE.

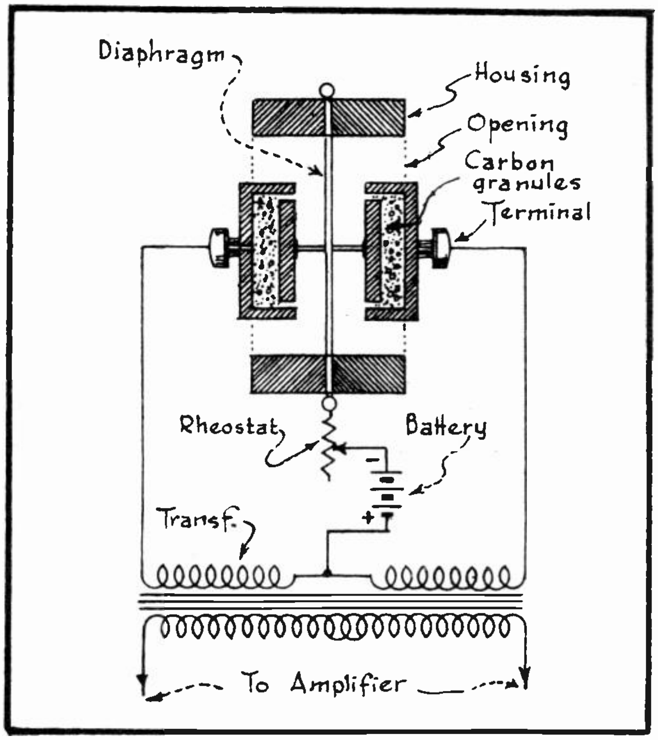

FIG. 10
Principles of the Double-Button Microphone.

THE PURPOSE OF THE RHEOSTAT IN FIG. 10 IS TO OFFER A MEANS OF CONTROLLING THE NORMAL VALUE OF MICROPHONE CURRENT. IN THE MICROPHONE OF FIG. 9, FOR INSTANCE, THE NORMAL OPERATING CURRENT IS 30 MILLIAMPERES PER BUTTON AND QUITE OFTEN, A MILLIAMMETER IS PERMANENTLY INSTALLED IN THE MICROPHONE CIRCUIT FOR CHECKING PURPOSES.

THE CHANGES IN CURRENT THROUGH THE TWO HALVES OF THE PRIMARY WINDING OF THE COUPLING TRANSFORMER, AS BROUGHT ABOUT BY THE ACTION OF THE DIAPHRAGM, PRODUCE A CORRESPONDING RESULTANT CHANGE IN FLUX IN THE TRANSFORMER CORE SO AS TO INDUCE CORRESPONDING VOLTAGE CHANGES IN THE SECONDARY WINDING WHICH ARE TO BE APPLIED TO THE INPUT CIRCUIT OF THE AMPLIFIER.

THE BATTERY VOLTAGE USED FOR ENERGIZING THE MICROPHONE CIRCUIT MAY VARY FROM 3 TO 6 VOLTS IN THE FORM OF DRY CELLS OR A STORAGE BATTERY, DEPENDING UPON THE REQUIREMENTS OF THE PARTICULAR TYPE OF MICROPHONE AND THE MANNER IN WHICH IT IS BEING USED.

ONE OF THE CHIEF ADVANTAGES OF THE CARBON MICROPHONE IS THAT ITS

SENSITIVITY IS COMPARATIVELY HIGH, IN THAT THE AMOUNT OF ELECTRICAL ENERGY WHICH IS CONTROLLED BY THE PRESSURE OF THE SOUND WAVE ON THE DIAPHRAGM IS CONSIDERABLY GREATER THAN THE ENERGY OF THE SOUND. IT IS FOR THIS REASON THAT IN THE MAJORITY OF CASES, THE CARBON MICROPHONE CAN SUPPLY THE SIGNAL ENERGY DIRECTLY INTO THE INPUT OF THE AMPLIFIER THROUGH A COUPLING TRANSFORMER AND WITHOUT THE USE OF AN AUXILIARY OR BOOSTER AMPLIFIER BETWEEN THE MICROPHONE AND THE REGULAR AMPLIFIER.

ONE OF THE MOST NOTICEABLE DISADVANTAGES OF CARBON MICROPHONES IS THE CONTINUOUS HISSING AND FRYING SOUND WHICH THEY EMIT ALTHOUGH THIS HAS IN SOME CASES BEEN REDUCED TO A REMARKABLE DEGREE IN SOME OF THE LATER DESIGNS.

CARBON MICROPHONES ARE AVAILABLE IN A WIDE VARIETY OF DESIGNS AND EACH OF WHICH IS ADAPTED BEST TO SOME PARTICULAR USE. SOME OF THESE HAVE ALREADY BEEN SHOWN YOU IN PREVIOUS ILLUSTRATIONS IN THIS LESSON WHILE FIG. 11 SHOWS YOU FOUR POPULAR MODELS OF UNIVERSAL MICROPHONES.

THE UNIVERSAL BULLET TYPE MICROPHONE IN FIG. 11, FOR INSTANCE, CONSISTS OF A TUBE WITH A CENTER PARTITION, PROVIDING SPACE FOR A STANDARD $1\frac{1}{2}$ VOLT NO. 6 DRY CELL. THE MICROPHONE HEAD IS FIXED, ASSURING A VERTICAL POSITION AT ALL TIMES. FLEXIBLE WIRE CONNECTIONS, LONG ENOUGH TO PERMIT

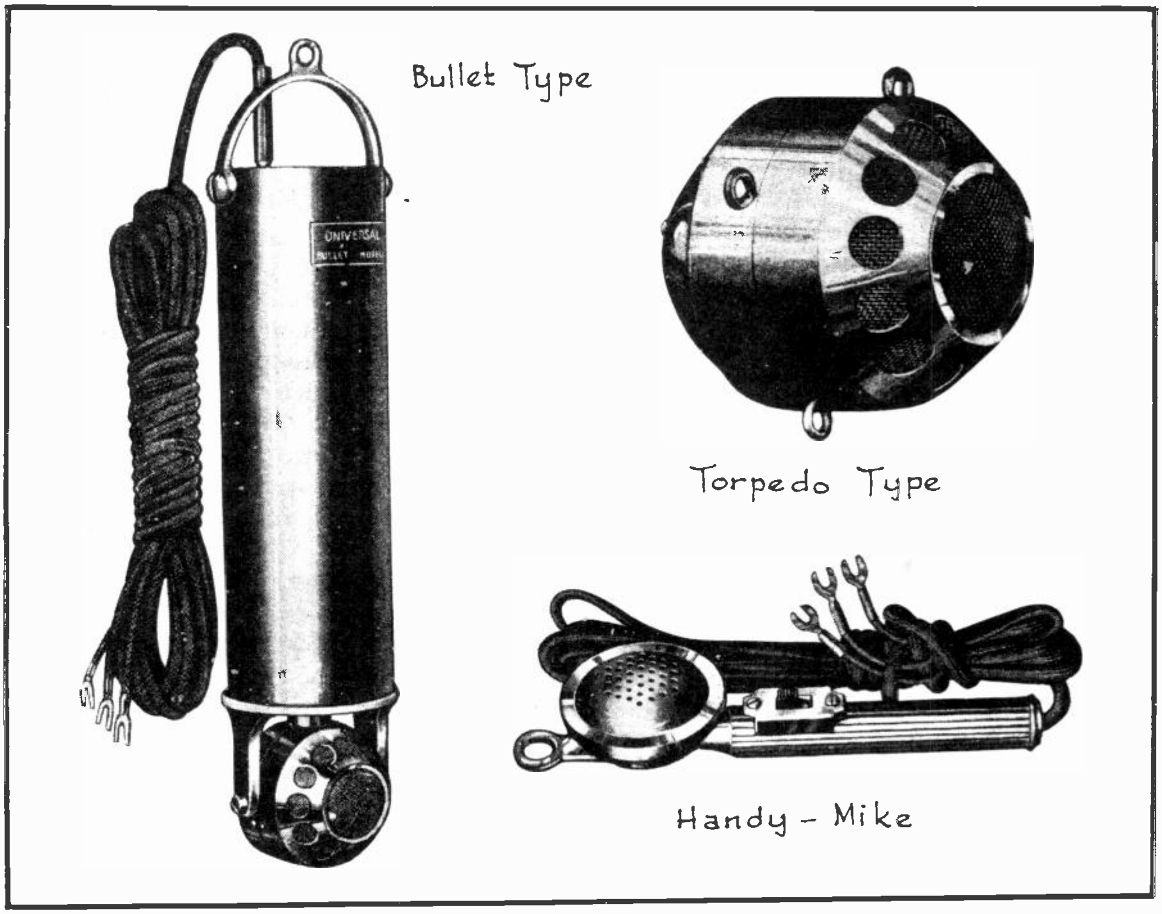

FIG. 11

Various Carbon Microphone Designs.

EASY REPLACEMENT ARE ALSO PROVIDED. RUBBER CUSHIONS AND SPRING TENSION SIDES MAKE A VERY RUGGED ASSEMBLY THAT PERMITS A GREAT DEAL OF HANDLING AND TRANSPORTATION WITHOUT AFFECTING PERFORMANCE.

THE TORPEDO MICROPHONE SHOWN AT THE UPPER RIGHT OF FIG. 11 WAS DESIGNED WITH THE INTENTION OF HAVING A COMPACT UNIT AND WITH THE INTERNAL PARTS OF THE MICROPHONE FULLY PROTECTED AGAINST MECHANICAL INJURY.

THE HANDI-MIKE AT THE LOWER RIGHT OF FIG. 11 IS DESIGNED WHERE EASE OF HANDLING IS REQUIRED, AS IS ALSO THE CASE FOR PUBLIC ADDRESS WORK. THIS MICROPHONE HAS A HANDLE BUILT ON TO IT SO THAT IT CAN BE HELD WITH CONVENIENCE IN THE PROPER POSITION FOR SPEAKING PURPOSES. THE MICROPHONE SWITCH IS BUILT DIRECTLY IN THE HANDLE SO THAT THE MICROPHONE CIRCUIT CAN BE COMPLETED OR INTERRUPTED WITH THE UTMOST OF EASE. A THREE-WIRE CABLE LEADS DIRECTLY FROM THE MICROPHONE TO THE COUPLING TRANSFORMER AND IS OF SUFFICIENT LENGTH THAT IT IS MOST PRACTICAL FOR HANDLING PURPOSES. THE EYE IS PROVIDED FOR SUSPENDING THE MICROPHONE WHEN IT IS EITHER IN OR OUT OF USE.

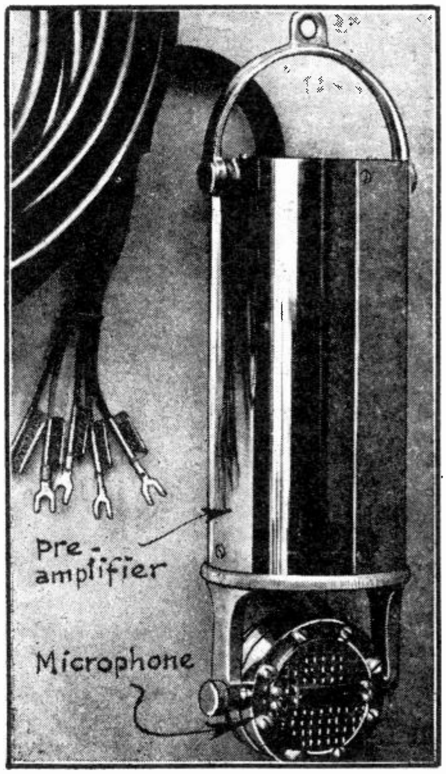

FIG. 12
The Condenser Microphone.

NOW THAT YOU ARE FAMILAIR WITH THE VARIOUS TYPES OF CARBON MICROPHONES, LET US NEXT TURN OUR ATTENTION TO THE CONDENSER MICROPHONE.

THE CONDENSER MICROPHONE

IN FIG. 12 YOU ARE SHOWN A TYPICAL CONDENSER MICROPHONE, TOGETHER WITH ITS PRE-AMPLIFIER. THE MICROPHONE UNIT ITSELF, YOU WILL OBSERVE, IS MOUNTED OVER ONE END OF A CYLINDRICAL HOUSING IN WHICH THE PRE AMPLIFIER IS CONTAINED. ONE LONG WIRE CABLE IS THEN USED TO CONNECT THE COMPLETE ASSEMBLY TO THE CONVENTIONAL AMPLIFIER IN TO WHICH IT IS INTENDED TO OPERATE.

HAVING FAMILIARIZED YOURSELF WITH THE GENERAL APPEARANCE OF THE ASSEMBLY, LET US NOW CONSIDER ITS INTERNAL CONSTRUCTION IN GREATER DETAIL. THE CONSTRUCTION OF THE CONDENSER MICROPHONE ITSELF IS ILLUSTRATED FOR YOU IN FIG. 13 AND BY STUDYING THIS DRAWING IN CONJUNCTION WITH THE FOLLOWING DESCRIPTION, YOU SHOULD ACQUIRE A GOOD MENTAL PICTURE OF THIS UNIT.

THIS MICROPHONE IS IN REALLITY A CONDENSER AS ITS NAME INDICATES AND IN WHICH ONE PLATE IS FIXED, WHILE THE OTHER IS A DIAPHRAGM AGAINST WHICH THE SOUND WAVES ACT.

THE DIAPHRAGM OF THIS MICROPHONE IS DURALUMINUM OF APPROXIMATELY 0.0011" THICKNESS AND STRETCHED UNTIL ITS RESONANT FREQUENCY IS IN THE ORDER OF 5000 CYCLES.

IN THE CONDENSER MICROPHONE, ACOUSTIC DAMPING IS ALSO MADE USE OF AND

IT IS PROVIDED BY THE AIR WHICH IS TRAPPED BETWEEN THE DIAPHRAGM AND THE BACK PLATE AND IS CONTROLLED BY A SERIES OF GROOVES WHICH INTERSECT EACH-OTHER AT RIGHT ANGLES, WITH HOLES DRILLED THROUGH THE BACK PLATE AT THE INTERSECTIONS.

IN ORDER THAT SMALL MOVEMENTS OF THE DIAPHRAGM WILL CHANGE THE CAPACITY APPRECIABLY, THE SPACING BETWEEN THE DIAPHRAGM AND BACK PLATE MUST BE AS SMALL AS POSSIBLE. IN THE PARTICULAR MICROPHONE HERE ILLUSTRATED, THIS SPACING AMOUNTS TO ONLY 0.001".

SINCE A RATHER HIGH POTENTIAL IS TO BE APPLIED ACROSS THE TWO ACTIVE PLATES OF THIS CONDENSER AND THE SPACE BETWEEN THE PLATES BEING SO SMALL, GREAT CARE MUST BE EXERCISED SO THAT NO DUST WILL BECOME LODGED IN THIS SPACE. THIS IS ACCOMPLISHED BY SEALING THE MICROPHONE FROM THE OUTSIDE AIR AND FILLING IT WITH NITROGEN SO AS TO GUARD AGAINST CORROSION. A COMPENSATING DIAPHRAGM MADE OF ORGANIC MATERIAL AND HAVING CONSIDERABLE FLEXIBILITY IS USED AS A PART OF THIS SEAL SO AS TO EQUALIZE THE PRESSURES.

THE SPACE BEHIND THE BACK PLATE IS CONNECTED TO THE REMAINING AIR SPACES THROUGH AN ACOUSTIC VALVE AND WHICH CONSISTS OF A DISK OF SILK CLAMPED BETWEEN TWO ALUMINUM RINGS. THIS IS DONE SO AS TO AVOID RESONANCES IN THE AIR SPACES OF THE MICROPHONE.

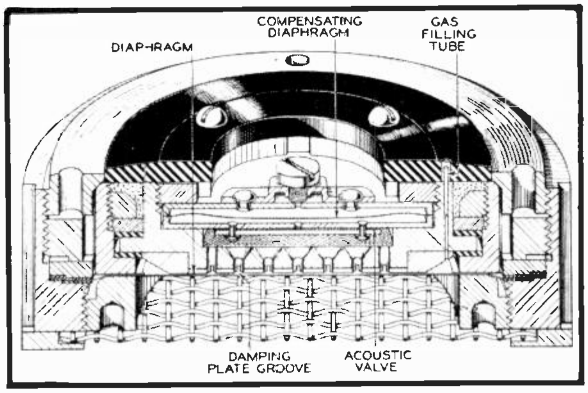

FIG. 13
Construction of the Condenser Microphone

CONNECTING THE CONDENSER MICROPHONE TO THE CIRCUIT

WHERE EXTREMELY FAITHFUL REPRODUCTION IS REQUIRED AND EXPENSE IS NO HANDICAP, THE CONDENSER MICROPHONE WILL BE FOUND TO HAVE AN IMPROVED RESPONSE-CHARACTERISTIC OVER THE CARBON TYPE. HOWEVER, ITS SENSITIVITY IS MUCH LOWER THAN THAT OF THE CARBON MICROPHONE AND FOR THIS REASON A PRE-AMPLIFIER IS NECESSARY. THIS PRE-AMPLIFIER, AS HAS ALREADY BEEN MENTIONED, IS GENERALLY MOUNTED AS A PART OF THE MICROPHONE ASSEMBLY SO THAT IT WILL BE AS CLOSE AS POSSIBLE TO THE MICROPHONE AND IN THIS WAY REDUCE THE LOSS IN ENERGY BETWEEN THE MICROPHONE AND THE PRE-AMPLIFIER TO A MINIMUM. SOMETIMES, THESE PRE-AMPLIFIERS ARE CALLED HEAD AMPLIFIERS.

IN FIG. 14, YOU ARE SHOWN THE CIRCUIT DIAGRAM OF THE INPUT CIRCUIT OF A TYPICAL PRE-AMPLIFIER AND THE MANNER OF CONNECTING THE MICROPHONE TO IT. BY STUDYING FIG. 14, YOU WILL OBSERVE THAT A SOURCE OF "B" VOLTAGE IS APPLIED ACROSS THE PLATES OF THE MICROPHONE THROUGH THE RESISTOR R_1 THEREBY PLACING AN ELECTRICAL CHARGE UPON THE TWO PLATES.

AS SOUND WAVES ACT UPON THE DIAPHRAGM AND THEREBY CAUSE THE PLATES OF THIS CONDENSER TO BE MOVED CLOSER TOGETHER AND FARTHER APART ACCORDINGLY, THE CAPACITY OF THE CONDENSER WILL BE CORRESPONDINGLY VARIED. SINCE THE CAPACITY OF THE CONDENSER IS CHANGED IN PROPORTION TO THE SOUND WAVES ACTING UPON IT, THE CHARGING CURRENT WHICH MUST FLOW THROUGH R_1 IN FIG. 14 WILL VARY ACCORDINGLY AND THE RESULTING VOLTAGE VARIATIONS ACROSS R_1 WILL THUS BE AN ELECTICAL REPRODUCTION OF THE ORIGINAL SOUND WAVES. THESE VOL-

TAGE CHANGES ACROSS R_1 WILL THEN BE APPLIED THROUGH COUPLING CONDENSER "C" AND ACROSS THE GRID CIRCUIT OF THE VACUUM TUBE. IN OTHER WORDS, THIS IS JUST ANOTHER EXAMPLE OF RESISTANCE-CAPACITY COUPLING AND AFTER THE SIGNAL VOLTAGE CHANGES ARE ONCE APPLIED TO THE GRID OF THE FIRST TUBE IN THE PRE-AMPLIFIER, THEY ARE AMPLIFIED IN THE USUAL MANNER.

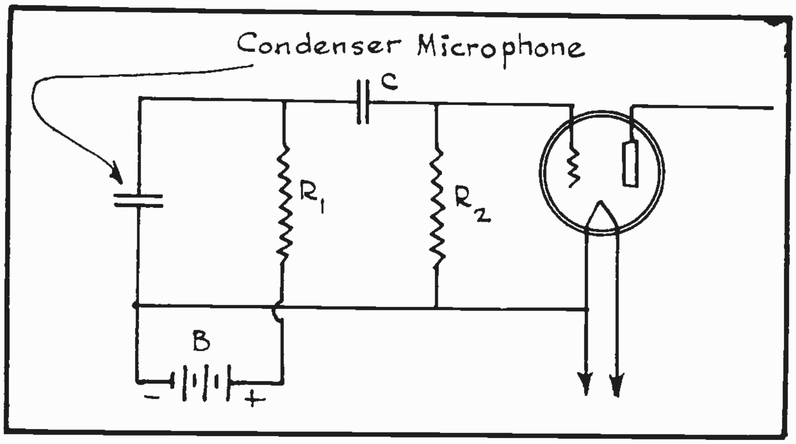

FIG. 14
The Pre-Amplifier.

IN FIG. 15 YOU ARE SHOWN A TWO-STAGE, CONDENSER MICROPHONE, PRE-AMPLIFIER CIRCUIT, WHICH IN ADDITION TO SHOWING YOU HOW THE MICROPHONE IS CONNECTED TO IT, ALSO SHOWS HOW THE OUTPUT OF THE PRE-AMPLIFIER IS TO BE CONNECTED TO THE MAIN AMPLIFIER THROUGH A 400 TO 600 OHM LINE.

CONSIDERABLE CARE MUST BE EXERCISED IN THE DESIGN OF THE PRE-AMPLIFIER AS USED WITH THE CONDENSER MICROPHONE. FOR EXAMPLE, THE CAPACITY WHICH IS SHUNTED ACROSS THE MICROPHONE BY THE LEADS AND AMPLIFIER TUBE MUST BE SMALL IN COMPARISON TO THE CAPACITY OF THE MICROPHONE AND THE EQUIVALENT RESISTANCE WHICH IS FORMED BY R_1 AND R_2 IN PARALLEL IN FIG. 14 SHOULD AT LEAST BE AS GREAT AS THE REACTANCE WHICH THE CAPACITY FORMED BY THE MICROPHONE, ITS LEADS AND THE AMPLIFIER TUBE HAS AT THE LOWEST FREQUENCY WHICH IS TO BE REPRODUCED.

THE EFFECT OF A LOW SHUNTING CAPACITY INCREASES THE SENSITIVITY BECAUSE AS THE DIAPHRAGM VIBRATES AND CHANGES THE CAPACITY OF THE MICROPHONE, THE RESULTING POTENTIAL VARIATIONS ARE PROPORTIONAL TO THE CHANGE IN CAPACITY DIVIDED BY THE TOTAL CAPACITY, PROVIDED THE RESISTANCE R_1 AND R_2 ARE LARGE ENOUGH TO PREVENT APPRECIABLE CHANGE IN THE CHARGE ON THE MICROPHONE PLATES.

IF THESE RESISTANCES ARE NOT LARGE ENOUGH, THERE WILL BE ENOUGH CHARGE FLOWING IN AND OUT OF THE CONDENSER AT LOW FREQUENCIES TO REDUCE THE POTENTIAL VARIATIONS APPRECIABLY.

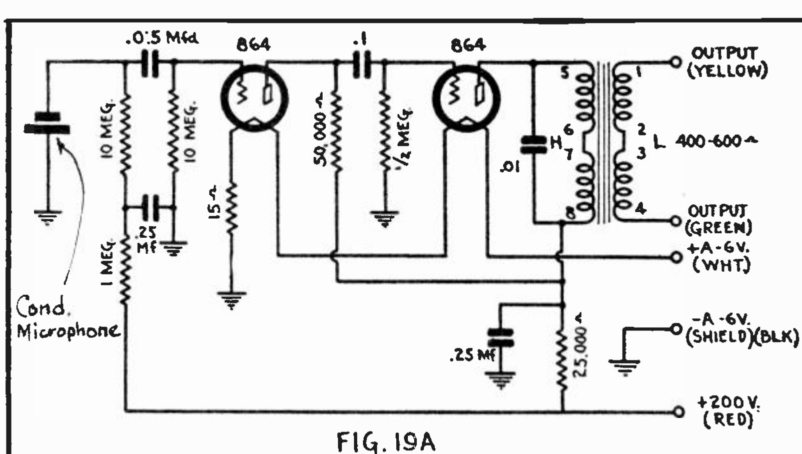

FIG. 15
A Two-Stage Pre-Amplifier.

THE RIBBON MICROPHONE

UNLIKE THE CONDENSER OR CARBON TYPE MICROPHONES, WHICH ARE VALVES OR MECHANICAL GOVER-

NERS, THE RIBBON MICROPHONE OR "VELOCITY MICROPHONE", AS IT IS SOMETIMES CALLED, IS A GENERATOR OF ELECTRICAL IMPULSES SIMILAR TO A PHONOGRAPH PICK UP. THE OUTPUT OBTAINED FROM THE RIBBON MICROPHONE IS ALSO OF A RATHER LOW LEVEL AND FOR THIS REASON A PRE-AMPLIFIER MUST ALSO BE USED WITH IT, THE SAME AS IN THE CASE OF THE CONDENSER MICROPHONE. THE RIBBON MICROPHONE, HOWEVER, IS A LOW IMPEDANCE "PICK UP DEVICE", WHEREAS THE CONDENSER MICROPHONE IS OF A HIGH IMPEDANCE ORDER.

IN FIG. 16 YOU ARE SHOWN A TYPICAL RIBBON MICROPHONE, TOGETHER WITH ITS PRE-AMPLIFIER. THE MICROPHONE ITSELF CONSISTS ONLY OF THE SMALL BOX-LIKE STRUCTURE AT THE LOWER END OF THE UNIT, WHILE THE UPPER PORTION IS THE PRE-AMPLIFIER OR "MICROPHONE AMPLIFIER", AS IT IS SOMETIMES CALLED. THE SAME UNIT AGAIN APPEARS IN FIG. 17 WHERE PORTIONS OF THE HOUSING HAVE BEEN REMOVED SO THAT THE PARTS OF BOTH THE MICROPHONE AND THE PRE-AMPLIFIER CAN BE CLEARLY SEEN.

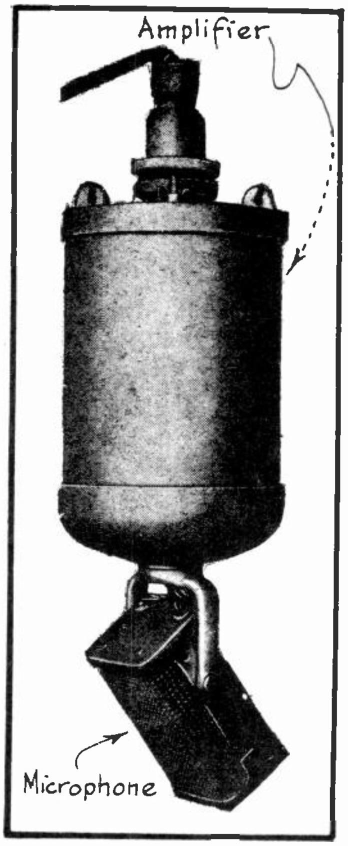

FIG. 16
Ribbon Microphone with Pre-Amplifier.

IN THIS MICROPHONE, THE DIAPHRAGM IS REPLACED WITH A LIGHT RIBBON MADE OF DURALUMINUM, BEING APPROXIMATELY 2 TO 3" LONG, 3/16" WIDE AND ONE-HALF THOUSANDTH OF AN INCH THICK. IT IS CORRUGATED TRANVERSELY IN ORDER TO PREVENT STANDING WAVES ON THE SURFACE OF THE RIBBON AND TO KEEP THE NATURAL FREQUENCY OF THE RIBBON OUT OF THE AUDIO FREQUENCY RANGE.

THE OPERATION OF THIS MICROPHONE CAN NO DOUBT BE DESCRIBED BEST WITH THE AID OF FIG. 18. HERE YOU WILL SEE THE HORSESHOE MAGNET WITH ITS TWO POLE PIECES AND INSTEAD OF BEING A PERMANENT MAGNET, IT IS ENERGIZED BY A FIELD COIL ACROSS WHICH A 6 VOLT BATTERY IS CONNECTED. BY USING AN ELECTROMAGNET AS THIS, THE MAGNETIC FLUX CAN BE MADE MUCH GREATER THAN WOULD BE POSSIBLE WITH A PERMANENT MAGNET OF THE SAME SIZE.

OPERATION OF THE RIBBON MICROPHONE

IN FIG. 18, YOU WILL ALSO OBSERVE HOW THE DURALUMINUM RIBBON IS SUSPENDED BY TWO INSULATORS BETWEEN THE POLE PIECES OF THE MAGNET BUT BEAR IN MIND THAT THE RIBBON IS SUSPENDED LOOSELY AND NOT UNDER TENSION. THE ENDS OF THE RIBBON ARE CONNECTED ACROSS THE PRIMARY WINDING OF AN INPUT TRANSFORMER, THUS PLACING THE RIBBON IN A COMPLETE CIRCUIT.

WITH THE ELECTROMAGNET ENERGIZED, THE RESULTING MAGNETIC LINES OF FORCE WILL BE IN A TRANSVERSE POSITION WITH RESPECT TO THE RIBBON, THAT IS, FROM RIGHT TO LEFT AS WE ARE NOW LOOKING AT IT ON PAPER. NOW THEN, AS SOUND WAVES STRIKE THE FLAT SIDES OF THE RIBBON, THE RIBBON WILL BE FORCED TO MOVE FORWARD AND BACKWARD UNDER THE INFLUENCE OF THE CHANGING AIR PRESSURES, WHICH ARE CAUSED BY THE SOUND WAVE.

THIS MOVEMENT OF THE RIBBON CAUSES IT TO CUT THE LINES OF FORCE BETWEEN THE POLES OF THE ELECTROMAGNET AND SINCE THE RIBBON HAS A COMPLETE CIRCUIT THROUGH THE PRIMARY WINDING OF THE INPUT TRANSFORMER, WEAK ALTERNATING CURRENTS ARE INDUCED IN THE RIBBON AND THUS FLOW THROUGH THE PRI-

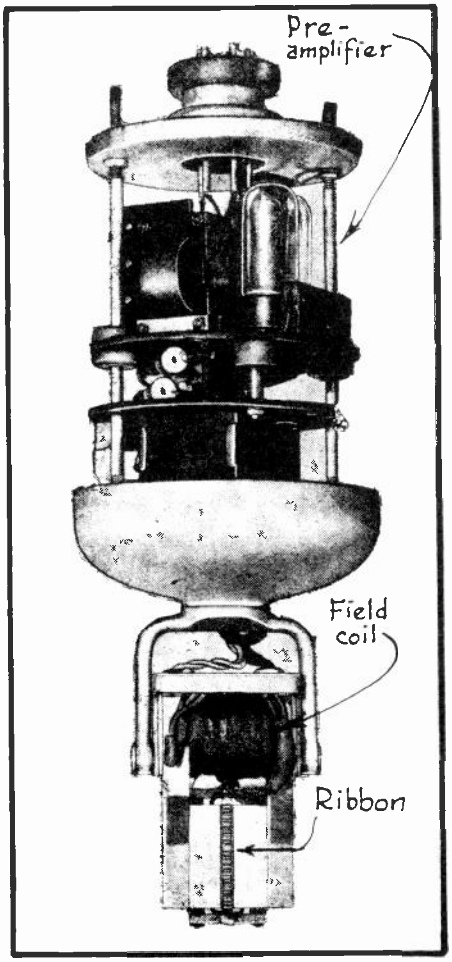

FIG 17

Construction of the Ribbon Microphone.

MARY WINDING OF THE INPUT TRANSFORMER.

THE RAPIDITY WITH WHICH THE RIBBON MOVES BACK AND FORTH IS GOVERNED BY THE SPEED AT WHICH THE AIR COMPRESSIONS AND RAREFACTIONS STRIKE IT AND THESE ARE IN TURN DEPENDENT UPON THE FREQUENCY OF THE SOUND WHICH CAUSES THE AIR DISTURBANCE. IT THUS FOLLOWS THAT THE RIBBON'S MOVEMENT WILL HAVE A FREQUENCY EQUIVALENT TO THAT OF THE SOUND CAUSING ITS MOTION AND THEREFORE, THE INDUCED CURRENTS IN ITS CIRCUIT WILL BE OF A CORRESPONDING FREQUENCY.

THE AMPLITUDE OF THE RIBBON'S MOVEMENT WILL BE INCREASED BY A LOUDER SOUND BECAUSE THE AIR DISTURBANCE UNDER THESE CONDITIONS IS MORE VIGOROUS. THIS WILL CAUSE A GREATER CURRENT FLOW THROUGH THE RIBBON BECAUSE THE RIBBON WILL NOW BE CUTTING MORE LINES OF FORCE.

THESE AUDIO FREQUENCY CURRENT VARIATIONS ARE TRANSFERRED FROM THE RIBBON CIRCUIT TO THE MICROPHONE AMPLIFIER BY MEANS OF THE INPUT TRANSFORMER OF FIG. 18. THE AMPLIFIER CONSISTS OF THREE STAGES, EMPLOYING TUBES OF THE 864 TYPE, WHOSE FILAMENT VOLTAGE IS SUPPLIED BY THE SAME 6 VOLT BATTERY, WHICH ENERGIZES THE ELECTROMAGNET. THE OUTPUT OF THE MICROPHONE AMPLIFIER CAN BE FED INTO THE MAIN AMPLIFIER FOR FURTHER AMPLIFICATION. NOW LET US CONSIDER THE DIRECTIONAL QUALITIES OF THIS MICROPHONE.

DUE TO THE FLAT AND THINLY CONSTRUCTED RIBBON, IT IS OBVIOUS THAT MAXIMUM RESPONSE WILL BE OBTAINED FROM THE MICROPHONE WHEN THE SOUND WAVES STRIKE EITHER OF ITS TWO FLAT SIDES. SHOULD THE SOUND WAVES COME FROM SUCH A DIRECTION AS TO STRIKE EITHER OF THE RIBBON'S THIN EDGES, THEN NO RESPONSE WILL BE OBTAINED. SO IT CAN BE SEEN THAT THIS MICROPHONE DECREASES IN RESPONSE AS THE ANGLE OF THE IMPINGING SOUND WAVE INCREASES TO EITHER SIDE OF THE LINE OF MAXIMUM RESPONSE.

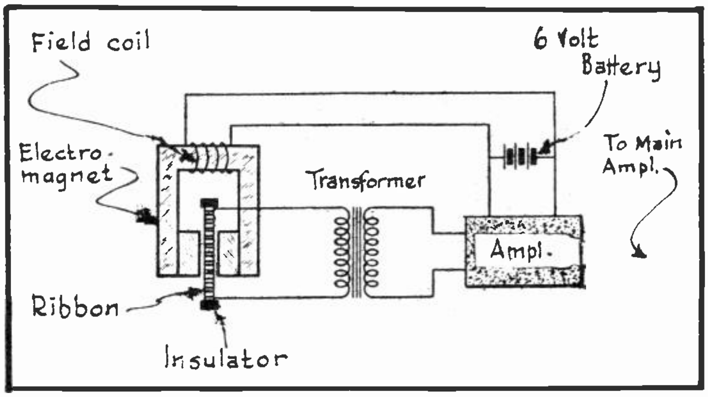

FIG. 18

Operating Principle of the Ribbon Microphone.

THIS BEING THE CASE, IT IS LOGICAL THAT THIS MICROPHONE CAN BE SO ORIENTED IN RESPECT TO EXTRANEOUS NOISES SO AS NOT TO RESPOND TO THEM, YET RESPONDING FAITHFULLY TO THOSE SOUNDS WHICH ARE DESIRED. THIS DIRECTIONAL FEAT

URE OF THE RIBBON MICROPHONE FOR ELIMINATING PICK-UP OF EXTRANEOUS NOISES MAKES IT IDEAL FOR USE WHERE ACOUSTICAL IMPERFECTIONS EXIST.

THE RIBBON MICROPHONE HAS A FREQUENCY RESPONSE COMPARABLE TO THAT OF THE CONDENSER MICROPHONE.

THE DYNAMIC MICROPHONE

A CROSS-SECTION OF THE DYNAMIC MICROPHONE IS ILLUSTRATED FOR YOU IN FIG. 19 AND AS YOU WILL OBSERVE, IT IS ESSENTIALLY COMPOSED OF A DIAPHRAGM "D" SUPPORTING A VOICE COIL "V.C". WHICH IS MADE OF FINE ALUMINUM RIBBON WOUND EDGEWISE IN THE FIELD OF A PERMANENT MAGNET M. WHEN THE SOUND WAVES IMPINGE ON THE DIAPHRAGM, THE COIL TO WHICH IT IS RIGIDLY ATTACHED VIBRATES WITH A PLUNGER-LIKE MOTION CUTTING THE LINES OF FORCE AND THUS GENERATING ACROSS TWO TERMINALS A POTENTIAL WHICH IS SUBSTANTIALLY CONSTANT FROM ABOUT 35 TO 10,000 CYCLES.

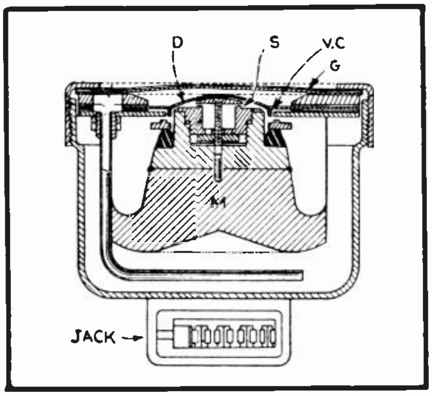

FIG. 19
Cross-Section of the Dynamic Microphone.

THE DIAPHRAGM "D" IS MADE OF DURALUMIN .0011" THICK AND HAS A DOME-SHAPED CENTER PORTION WHICH EXTENDS TO THE INNER EDGE OF THE MOVING COIL. THIS TYPE OF CONSTRUCTION STIFFENS THE CENTER SO THAT THE DIAPHRAGM HAS A PLUNGER ACTION THROUGHOUT THE ENTIRE AUDIO-FREQUENCY RANGE.

THE MOVING COIL V.C. CONSISTS OF ABOUT 65 TURNS OF ALUMINUM RIBBON, .001" THICK AND .008" WIDE, WOUND EDGEWISE; THE TURNS ARE INSULATED WITH PHENOL VARNISH WHICH SERVES ALSO AS A BINDER FOR HOLDING TOGETHER THE ADJACENT TURNS. THE IMPEDANCE RATING OF THE VOICE COIL IS ABOUT 25 OHMS.

A PRE-AMPLIFIER IS NOT ALWAYS NEEDED WITH THIS TYPE OF MICROPHONE, BUT WHEN USED, REQUIRES AN IMPEDANCE MATCHING TRANSFORMER AS ILLUSTRATED IN FIG. 20. IN EFFECT, YOU WILL NOTICE, THIS IS JUST LIKE A DYNAMIC SPEAKER BEING USED BACKWARDS.

A PERFORATED METAL GRID "G" AND WHICH IS COVERED WITH SILK, PROTECTS THE DIAPHRAGM FROM INJURY. THE GRID AND METAL HOUSING FORM A SHIELD WHICH MAY BE GROUNDED THROUGH ONE OF THE JACK CONTACTS PROVIDED ON THE REAR OF THE HOUSING. THE REMAINING JACK TERMINALS ARE CONNECTIONS FOR THE EXTERNAL AMPLIFIER.

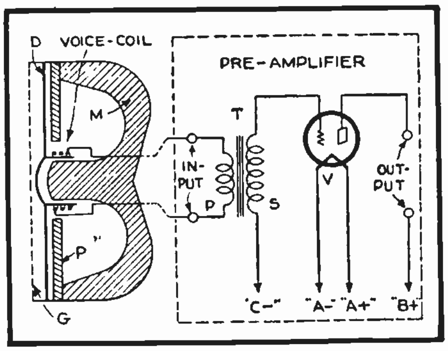

FIG. 20
Circuit of Dynamic Microphone and Pre-Amplifier.

SOME OF THE MORE IMPORTANT ADVANTAGES CLAIMED FOR THE DYNAMIC MICROPHONE ARE: ITS HIGH SENSITIVITY, DOES NOT REQUIRE AN EXITER BATTERY, GOOD FREQUENCY CHARACTERISTICS, AND IS SIMPLE AND RUGGED IN DESIGN.

THE CRYSTAL MICROPHONE

IN ONE OF YOUR EARLIER LESSONS, YOU WERE SHOWN HOW THE "PIEZO ELECTRICAL" CHARACTERISTICS OF ROCHELLE-SALT CRYSTALS COULD BE USED IN THE CONSTRUCTION OF LOUDSPEAKERS. THIS SAME PRINCIPLE IS ALSO BEING APPLIED TO

TO THE CRYSTAL MICROPHONE.

IN THE UPPER PORTION OF FIG. 21 YOU WILL SEE AN ASSEMBLED CRYSTAL MICROPHONE, WHEREAS THE SAME UNIT IS SHOWN IN A COMPLETELY DISASSEMBLED CONDITION DIRECTLY BELOW. IN THIS MICROPHONE, TWO PLATES OF THE CRYSTAL ARE MOUNTED SANDWICH-LIKE, NEAR THE TERMINAL END OF THE SHELL OR HOUSING AND ONE EDGE OF THE CRYSTALS IS CEMENTED TO THE SHELL LEAVING THE OTHER END FREE TO VIBRATE. THE CRYSTAL IS WEDGE-SHAPED AND THE DRIVE ROD IS ATTACHED TO THE FREE END.

THE DIAPHRAGM IS CONE-SHAPED AND ITS APEX IS RIGIDLY ATTACHED TO THE DRIVE ROD. CONTRARY TO THE CONVENTIONAL DIAPHRAGMS USED IN MICROPHONES, THE TYPE MADE USE OF IN THIS CONSTRUCTION IS OF IMPREGNATED, SOFT CARDBOARD. IN THIS MANNER, METALLIC RATTLES ARE DONE AWAY WITH; CRITICAL ANNEALING AND STRETCHING IS ENTIRELY ELIMINATED; AND THE DIAPHRAGM MAY BE DISMANTLED FOR INSPECTION WITHOUT ANY FEAR OF IT NOT FUNCTIONING PROPERLY AFTER IT IS PUT TOGETHER AGAIN.

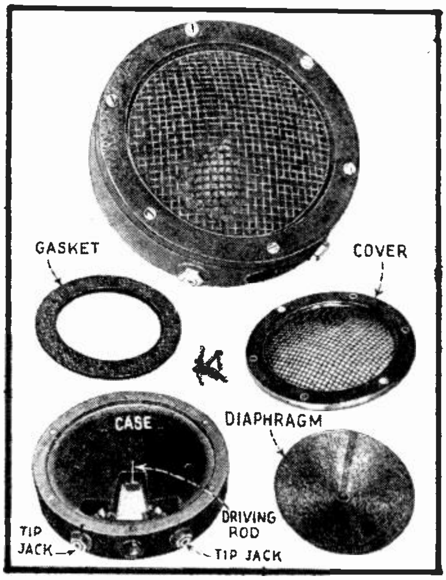

FIG. 21

The Crystal Microphone

WHEN SOUND WAVES ARE IMPINGED UPON THE DIAPHRAGM, THE RESULTING MOVEMENT OF THE DIAPHRAGM WILL THROUGH THE DRIVE ROD CAUSE THE CRYSTAL ASSEMBLY TO VIBRATE CORRESPONDINGLY AND THEREBY GENERATE CORRESPONDING VOLTAGE VARIATIONS ACROSS ITS TERMINALS.

THE ADVANTAGE OF THE UNIT IS THE FACT THAT ITS HIGH IMPEDANCE PERMITS IT TO BE CONNECTED DIRECTLY INTO THE GRID AND FILAMENT OF A TUBE WITHOUT USING A TRANSFORMER AND THE VOLUME CONTROL FOR THE UNIT MAY BE CONNECTED DIRECTLY ACROSS THE MICROPHONE TERMINALS. OF COURSE, IF THE LEADS FROM THE MICROPHONE TO THE AMPLIFIER ARE TO BE VERY LONG, A TRANSFORMER BETWEEN THE MICROPHONE AND THE LINE IS RECOMMENDED. THE FREQUENCY CHARACTERISTIC OF THE CRYSTAL MICROPHONE IS EXCELLENT.

MISCELLANEOUS PRE-AMPLIFIERS

IN THE PRE-AMPLIFIER WHOSE CIRCUIT IS ILLUSTRATED IN FIG. 15, YOU WILL HAVE NOTICED THAT TYPE 864 TUBES ARE USED. THIS TUBE TYPE IS ADAPTED PARTICULARLY TO USE AS AN A.F. AMPLIFIER AND ITS OPERATING CHARACTERISTICS ARE AS FOLLOWS: FILAMENT VOLTAGE = 1.1; FILAMENT CURRENT = .25 AMP.(D.C); PLATE VOLTAGE = 135 VOLTS; GRID BIAS = -9 VOLTS; PLATE CURRENT = 3.5 MA.; AMPLIFICATION FACTOR = 8.2.

IN FIG. 22 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A TWO-STAGE PRE-AMPLIFIER IN WHICH TYPE -30 TUBES ARE USED. A CONDENSER MICROPHONE IS CONNECTED ACROSS THE INPUT OF THE AMPLIFIER AND IN SERIES WITH THE +180 VOLT B TERMINAL AND THE TWO SERIES-CONNECTED RESISTORS OF .25 MEGOHM AND 3 MEGOHM VALUE.

THE PRE-AMPLIFIER IS RESISTANCE-CAPACITY COUPLED THROUGHOUT BUT A

TRANSFORMER IS FURNISHED AT THE OUTPUT, SO THAT THE PRE-AMPLIFIER CAN BE CONVENIENTLY COUPLED TO THE MAIN AMPLIFIER WITH PROPER MATCHING OF IMPEDANCE.

AS WAS STATED PREVIOUSLY IN THIS LESSON, IT IS PREFERABLE THAT THE PRE-AMPLIFIER BE LOCATED AS CLOSE AS POSSIBLE TO THE MICROPHONE AND IT IS FOR THIS REASON THAT THE MICROPHONE AND PRE-AMPLIFIER ARE GENERALLY CONSTRUCTED AS A SINGLE UNIT. A TRANSMISSION LINE OF 200 OR 500 OHMS IS GENERALLY EMPLOYED AS THE CONNECTING LINK BETWEEN THE PRE-AMPLIFIER AND THE MAIN AMPLIFIER AND UNDER THESE CONDITIONS, THE PRIMARY WINDING OF T_1 IN FIG. 22 SHOULD HAVE AN IMPEDANCE RATING OF SUCH A VALUE TO BE SUITABLE AS THE PLATE CIRCUIT LOAD FOR THE 30 TUBE, WHEREAS ITS SECONDARY WINDING SHOULD HAVE AN IMPEDANCE RATING EQUAL TO THAT OF THE TRANSMISSION LINE BEING USED.

THE TRANSMISSION LINE IS CONNECTED TO THE MAIN AMPLIFIER THROUGH ANOTHER TRANSFORMER, WHOSE PRIMARY WINDING HAS AN IMPEDANCE RATING EQUAL TO THAT OF THE TRANSMISSION LINE, WHILE THE IMPEDANCE RATING OF ITS SECONDARY IS EQUAL TO THAT OF THE FIRST GRID CIRCUIT OF THE MAIN AMPLIFIER INTO WHICH THE TRANSMISSION LINE IS TO FEED. WE SHALL CONSIDER IMPEDANCE MATCHING SYSTEMS IN GREATER DETAIL LATER IN THE COURSE.

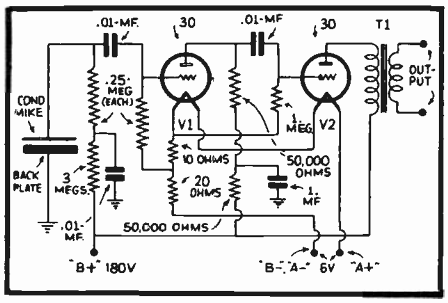

FIG. 22
Two Stage Pre-Amplifier

THE FILAMENTS OF THE 30 TUBES IN FIG. 22, YOU WILL NOTICE, ARE CONNECTED IN SERIES AND ADEQUATE RESISTANCE IS INCLUDED SO THAT THE 6 VOLT "A" SUPPLY WILL BE REDUCED TO THE PROPER AMOUNT FOR THE TUBES. THE B- TERMINAL OF THIS PRE-AMPLIFIER IS TO BE GROUNDED TO THE METAL HOUSING IN WHICH THE UNIT IS CONTAINED.

IN THE NEXT LESSON, YOU WILL BE SHOWN A NUMBER OF DIFFERENT A.F. AMPLIFIER CIRCUITS, THE METHODS OF COUPLING MICROPHONES TO THE AMPLIFIER AND A DETAILED EXPLANATION OF HOW THE SIGNALS PASS THROUGH THE ENTIRE SYSTEM FROM THE MICROPHONE TO SPEAKER.

answered March 30 1941

Examination Questions

LESSON NO. AS-1

"Setbacks never whip a fighter, they only sharpen his faculties, stiffen his backbone and toughen his muscles. And the more he fights the better he becomes. So pick out your goal, roll up your sleeves and pitch into the battle."

1. - MAKE A SIMPLE DRAWING OF A SINGLE-BUTTON CARBON MICROPHONE, SHOWING HOW IT IS CONNECTED IN THE CIRCUIT AND EXPLAIN HOW IT OPERATES.

2. - HOW DOES THE DOUBLE-BUTTON CARBON MICROPHONE DIFFER FROM THE SINGLE-BUTTON CARBON MICROPHONE AND WHAT ADVANTAGES DOES IT OFFER OVER THE SINGLE-BUTTON MICROPHONE?

3. - DESCRIBE A CONDENSER MICROPHONE.

4. - WHY MUST A PRE-AMPLIFIER BE USED IN CONJUNCTION WITH A CONDENSER MICROPHONE?

5. - ILLUSTRATE BY MEANS OF A DRAWING HOW A CONDENSER MICROPHONE MAY BE CONNECTED TO A PRE-AMPLIFIER AND EXPLAIN HOW THE SYSTEM OPERATES.

6. - DESCRIBE THE RIBBON MICROPHONE AND EXPLAIN HOW IT OPERATES.

7. - WHAT ARE SOME OF THE MOST IMPORTANT FEATURES OFFERED BY THE RIBBON MICROPHONE AS REGARDS TO PERFORMANCE?

8. - DESCRIBE THE DYNAMIC MICROPHONE.

9. - DESCRIBE THE CRYSTAL MICROPHONE.

10. - WHAT ARE SOME OF THE MOST DESIRABLE FEATURES OF CRYSTAL MICROPHONES?

NOTICE:- BE SURE TO NUMBER ALL OF YOUR EXAMINATION PAPERS FOR THE ADVANCED LESSON GROUPS TO CORRESPOND WITH THE LESSON NUMBER APPEARING AT THE TOP OF THE EXAMINATION PAGE IN EACH OF THESE LESSONS. FOR EXAMPLE, THE NUMBER OF THIS LESSON IS AS-1. THIS IS IMPORTANT.

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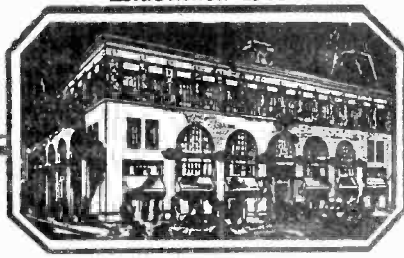

J. A. ROSENKRANZ, Pres.

new from Kvan thraf

Amplifying Systems

LESSON NO. 2

TYPICAL AUDIO AMPLIFIERS

INSTEAD OF PLUNGING DIRECTLY INTO THE DESIGN WORK AND CALCULATIONS INVOLVED IN A.F. AMPLIFIERS, YOU ARE FIRST GOING TO BE SHOWN IN THIS LESSON SOME SAMPLE AMPLIFIER SET-UPS, AND ALSO SOME POPULAR CIRCUITS AS USED IN THESE SYSTEMS. IN THIS WAY, YOU WILL HAVE A BETTER PRACTICAL UNDERSTANDING OF THESE UNITS, AS WELL AS A CLEAR CONCEPTION OF HOW THE MICROPHONES ABOUT WHICH YOU STUDIED IN THE PREVIOUS LESSON ARE CONNECTED TO THEM.

NOT ONLY WILL YOU FIND INFORMATION OF THIS TYPE TO OFFER YOU VALUABLE SUGGESTIONS, SO THAT YOU CAN BUILD AMPLIFIERS ACCORDING TO THE SPECIFICATIONS HEREIN GIVEN, BUT IT WILL IN ADDITION GIVE YOU A BROADER VISION OF THE SUBJECT SO THAT THE DESIGN CALCULATIONS AS PRESENTED IN LATER LESSONS WILL MEAN MORE TO YOU.

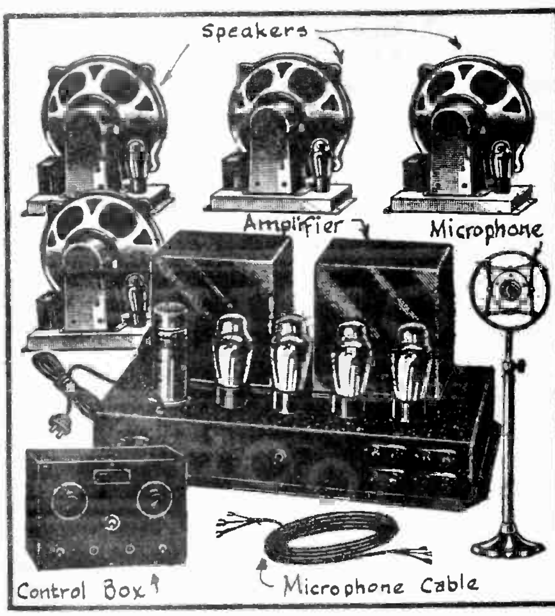

FIG. 1
Units Comprising a P. A. Amplifying System.

YOU WILL FIND THE UNITS AS DESCRIBED IN THIS LESSON TO BE ESPECIALLY SUITABLE FOR PUBLIC ADDRESS WORK, SO THAT YOU CAN IMMEDIATELY PUT THIS KNOWLEDGE TO WORK FOR YOU IN THIS PARTICULAR FIELD OF RADIO.

CLASSIFICATION OF AMPLIFIERS

A.F. AMPLIFIERS, AS COMMONLY USED, ARE CLASSIFIED INTO TWO GENERAL GROUPS, NAMELY AS CLASS A AND CLASS B AMPLIFIERS.

A "CLASS A" AMPLIFIER IS AN AMPLIFIER IN WHICH THE GRID BIAS AND THE EXITING GRID VOLTAGE ARE SUCH THAT THE PLATE CURRENT THROUGH THE TUBE FLOWS AT ALL TIMES. THE IDEAL CLASS "A" AMPLIFIER IS ONE IN WHICH

THE ALTERNATING COMPONENT OF THE PLATE CURRENT IS AN EXACT REPRODUCTION OF THE WAVE FORM OF THE ALTERNATING GRID VOLTAGE AND THE PLATE CURRENT FLOWS DURING 360 ELECTRICAL DEGREES OF THE CYCLE. THE CHARACTERISTICS OF A CLASS A AMPLIFIER ARE LOW EFFICIENCY AND OUTPUT, TOGETHER WITH LOW DISTORTION. THIS TYPE IS GENERALLY EMPLOYED WHERE FIDELITY OR QUALITY OF REPRODUCTION IS MORE DESIRABLE THAN POWER.

A "CLASS B" AMPLIFIER IS AN AMPLIFIER IN WHICH THE GRID BIAS IS APPROXIMATELY EQUAL TO THE CUT-OFF VALUE SO THAT THE PLATE CURRENT IS APPROXIMATELY ZERO WHEN NO EXITING GRID VOLTAGE IS APPLIED AND SO THAT THE PLATE CURRENT IN EACH TUBE FLOWS DURING APPROXIMATELY ONE-HALF OF EACH CYCLE WHEN AN EXITING GRID VOLTAGE IS PRESENT. THE IDEAL CLASS B AMPLIFIER IS ONE IN WHICH THE ALTERNATING COMPONENT OF PLATE CURRENT IS AN EXACT REPLICA OF THE ALTERNATING GRID VOLTAGE FOR THE HALF CYCLE WHEN THE GRID IS POSITIVE WITH RESPECT TO THE BIAS VOLTAGE AND THE PLATE CURRENT FLOWS DURING 180 ELECTRICAL DEGREES OF THE CYCLE. THE CHARACTERISTICS OF A CLASS B AMPLIFIER ARE MEDIUM EFFICIENCY AND OUTPUT BUT WITH SOMEWHAT MORE DISTORTION THAN IS OBTAINED WITH CLASS A AMPLIFIERS. CLASS B AMPLIFIERS ARE GENERALLY EMPLOYED WHEN HIGH POWER OUTPUTS ARE DESIRED AND WHEN SOME QUALITY OF REPRODUCTION CAN BE SACRIFICED.

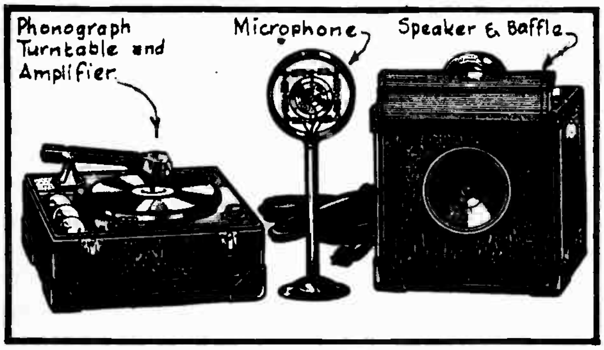

FIG. 2
A Portable Public Address System.

MODIFICATIONS OF THESE TWO CLASSES ARE ALSO EMPLOYED AND THESE WILL BE BROUGHT TO YOUR ATTENTION IN LATER LESSONS WHERE WE TREAT AMPLIFIERS MORE TECHNICALLY THEN IN THE PRESENT LESSON.

IN DESCRIBING THE VARIOUS SAMPLE AMPLIFIERS, IT IS LOGICAL TO COMMENCE WITH THE SMALLER AMPLIFIERS OF RELATIVELY LOW POWER OUTPUT AND THEN GRADUALLY ADVANCE THROUGH THE MORE ELABORATE DESIGNS OF HIGH OUTPUT POWER RATING. SMALL AMPLIFIERS ARE GENERALLY ASSOCIATED WITH PORTABLE EQUIPMENT, SO LET US CONSIDER ONE OF THESE UNITS FIRST.

A PORTABLE PUBLIC ADDRESS SYSTEM

IN FIG. 2 YOU ARE SHOWN THE VARIOUS UNITS WHICH ARE USED TOGETHER TO FORM A TYPICAL PORTABLE PUBLIC ADDRESS SYSTEM WHICH IS TO BE OPERATED FROM A 110 VOLT A.C. POWER SUPPLY. IN THIS PARTICULAR EXAMPLE, THE CARRYING CASE OPENS AND DIVIDES INTO TWO PARTS –– ONE CONTAINING THE SPEAKER AND SERVING AS ITS BAFFLE, WHILE THE OTHER CONTAINS THE PHONOGRAPH EQUIPMENT AND THE AMPLIFIER. THE MICROPHONE IS OF THE DOUBLE-BUTTON CARBON TYPE AND MOUNTED IN A SUITABLE STAND. CABLES OF SUFFICIENT LENGTH ARE SUPPLIED SO THAT THE VARIOUS UNITS CAN BE INTERCONNECTED PROPERLY ALTHOUGH CONSIDERABLY SEPARATED FROM EACHOTHER AND SO THAT THE AMPLIFIER CAN BE CONNECTED TO THE POWER SUPPLY.

IN SOME INSTANCES, EVEN TWO SPEAKERS ARE USED –– EACH BEING MOUNTED IN ONE-HALF OF THE CARRYING CASE SO THAT THE TWO SPEAKERS CAN BE PLACED INDEPENDENTLY AT THE MOST DESIRED LOCATIONS. PORTABLE EQUIPMENT OF THIS TYPE IS ILLUSTRATED IN FIG. 3.

SO MUCH FOR THE GENERAL DESCRIPTION OF A TYPICAL PORTABLE AMPLIFYING SYSTEM AND NOW LET US LOOK AT THE CIRCUIT DIAGRAM OF SUCH A UNIT.

IN FIG. 4 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A THREE-TUBE AMPLIFIER WHICH IS SUITABLE FOR PORTABLE USE WHERE AN A.C. POWER SUPPLY IS AVAILABLE. THE TUBES USED IN THIS CASE ARE A TYPE 57 IN THE INPUT STAGE AND A 59 OPERATED AS A POWER PENTODE IN THE OUTPUT STAGE, WHILE AN 80 SERVES AS THE RECTIFIER IN THE POWER PACK.

THE PARTICULAR CIRCUIT AS HERE ILLUSTRATED IS DESIGNED TO HANDLE TWO DYNAMIC SPEAKERS, WHOSE FIELD COILS ARE ENERGIZED BY THE "B" CURRENT WHICH IS SUPPLIED TO THE AMPLIFIER BY THE POWER PACK. THE TWO FIELD COILS, YOU WILL OBSERVE, ARE CONNECTED IN SERIES, EACH HAVING A D.C. RESISTANCE RATING OF 1250 OHMS. THE 25,000 OHM RESISTOR WHICH IS CONNECTED BETWEEN HIGH B+ AND THE METAL CHASSIS OR B- SERVES AS A BLEEDER RESISTOR FOR THE SYSTEM.

UPON TURNING YOUR ATTENTION TO THE INPUT END OF THIS AMPLIFIER, YOU WILL SEE THAT A DOUBLE-BUTTON CARBON MICROPHONE, ENERGIZED BY TWO SERIES CONNECTED #6 DRY CELLS, IS CONNECTED TO THE PRIMARY WINDING OF THE INPUT

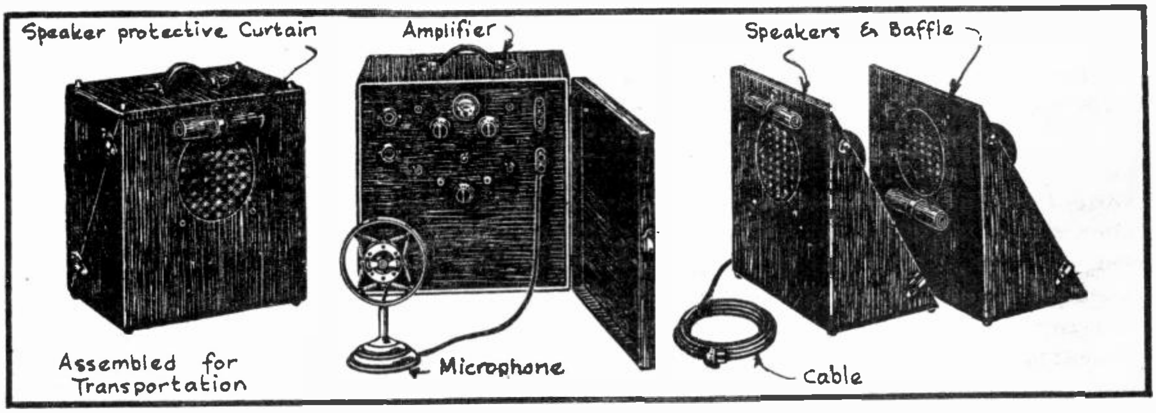

FIG. 3
Portable P. A. System With Two Speakers.

OR MICROPHONE TRANSFORMER. A SWITCH IN THE CENTER-LEG OF THE MICROPHONE CIRCUIT OFFERS A MEANS WHEREBY THE MICROPHONE CIRCUIT CAN BE INTERRUPTED WHEN NOT IN USE.

THE IMPEDANCE OF THE MICROPHONE TRANSFORMER'S PRIMARY WINDING IS MATCHED TO THE RESISTANCE RATING OF THE MICROPHONE, WHILE ITS SECONDARY WINDING IS MATCHED TO THE GRID CIRCUIT OF THE 57 TUBE INTO WHICH IT FEEDS. A .5 MEGOHM POTENTIOMETER IS CONNECTED ACROSS THE SECONDARY WINDING OF THIS TRANSFORMER TO SERVE AS A VOLUME CONTROL AND IS INTERCONNECTED WITH THE MICROPHONE CIRCUIT SWITCH SO THAT THE MICROPHONE CIRCUIT WILL BE INTERRUPTED AUTOMATICALLY WHEN THE VOLUME CONTROL IS AT ITS POSITION OF MINIMUM VOLUME. THE .5 MEGOHM FIXED RESISTOR WHICH IS CONNECTED BETWEEN THE CONTROL GRID OF THE 57 TUBE AND GROUND SERVES AS A FIXED LEAK FOR THE GRID OF THIS TUBE.

THE 57 TUBE IS COUPLED TO THE 59 THROUGH RESISTANCE-CAPACITY COUPLING AND THE 10,000 OHM RESISTOR IN THE PLATE CIRCUIT OF THE 57 TUBE, TOGEHTER WITH THE .5 MFD. CONDENSER, IS USED AS A FILTER TO PREVENT MOTORBOATING. THE 59 IS USED IN THE CONVENTIONAL PENTODE MANNER AND THE PRI-

MARY WINDINGS OF THE TWO OUTPUT TRANSFORMERS ARE CONNECTED IN PARALLEL IN THE PLATE CIRCUIT OF THIS POWER TUBE. NOW LET US FOLLOW THE SIGNAL THROUGH FROM THE MICROPHONE TO THE SPEAKERS.

AS THE SOUND WAVES ACT UPON THE MICROPHONE, THE MICROPHONE CURRENT WILL VARY ACCORDINGLY AS YOU ALREADY LEARNED IN YOUR PREVIOUS LESSON AND VOLTAGE CHANGES OF CORRESPONDING FREQUENCY WILL THRU INDUCTION APPEAR ACROSS THE SECONDARY WINDING OF THE MICROPHONE TRANSFORMER, AS WELL AS ACROSS THE ENDS OF THE VOLUME CONTROL POTENTIOMETER. THE SETTING OF THE POTENTIOMETER ARM DETERMINES WHAT PERCENTAGE OF THE AVAILABLE SIGNAL VOLTAGE IS TO BE APPLIED ACROSS THE CONTROL GRID CIRCUIT OF THE 57 TUBE.

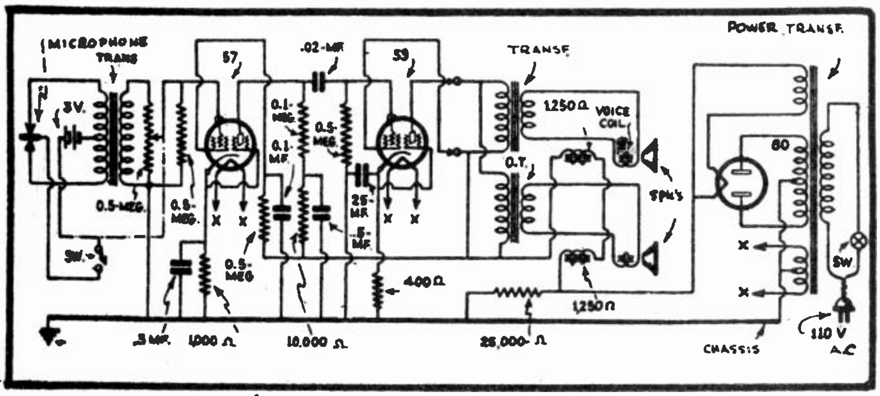

FIG. 4
Circuit Diagram of a Portable Amplifier.

THE 57 TUBE OPERATES AS AN A.F. AMPLIFIER, SO THAT THE PLATE CURRENT VARIATIONS WILL PRODUCE VOLTAGE CHANGES OF SIGNAL FREQUENCY ACROSS THE LOAD RESISTOR AND WHICH ARE APPLIED TO THE GRID CIRCUIT OF THE 59 THROUGH THE .02 MFD. COUPLING CONDENSER. THESE SIGNAL VOLTAGE CHANGES UPON BEING APPLIED TO THE GRID OF THE 59 TUBE, PRODUCE VARIATIONS IN THE PLATE CURRENT OF THIS SAME TUBE AND WHICH ARE ALSO OF THE SIGNAL FREQUENCY AND THUS CORRESPONDING VOLTAGE CHANGES ARE INDUCED INTO THE VOICE COIL CIRCUIT OF BOTH SPEAKERS SO THAT THE ORIGINAL SOUNDS WHICH ARE PRODUCED IN FRONT OF THE MICROPHONE ARE FAITHFULLY REPRODUCED BY THE SPEAKERS.

THE AMPLIFIER, WHOSE CIRCUIT DIAGRAM APPEARS IN FIG. 4, WILL DELIVER A MAXIMUM POWER OUTPUT OF APPROXIMATELY 3 TO $3\frac{1}{2}$ WATTS. ALTHOUGH THE PORTABLE AMPLIFIER JUST DESCRIBED OFFERS ONLY A RELATIVELY SMALL POWER OUTPUT, YET THERE ARE PORTABLE AMPLIFIERS IN USE WHOSE POWER OUTPUT IS QUITE HIGH.

A 10 WATT AMPLIFIER

IN FIG. 5 YOU ARE SHOWN THE CONSTRUCTIONAL ARRANGEMENT FOR AN AMPLIFIER WHICH IS RATED AT 6 WATTS BUT IN ACTUAL OPERATION WILL PROVIDE AN UNDISTORTED POWER OUTPUT OF 10 WATTS WITHOUT "FORCING" AND A MAXIMUM OR PEAK OUTPUT OF ABOUT 14 WATTS. THE TUBES USED ARE A 57 IN THE INPUT STAGE, A 56 IN

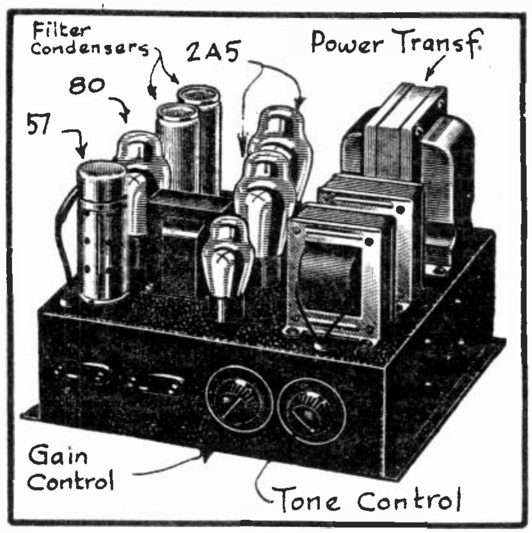

FIG. 5
A 10 Watt Amplifier.

THE INTERMEDIATE STAGE AND FOLLOWED BY A POWER STAGE EMPLOYING TWO 2A5's IN PUSH-PULL. AN 83 TUBE IS USED AS THE RECTIFIER.

THE CIRCUIT DIAGRAM OF THIS SAME AMPLIFIER APPEARS IN FIG. 6 AND AS YOU WILL OBSERVE, THE 57 TUBE IS BEING USED AS A PENTODE AMPLIFIER SIMILARILY AS IN THE PORTABLE AMPLIFIER WHOSE CIRCUIT DIAGRAM APPEARS IN FIG. 4 OF THIS LESSON. A .5 MEGOHM POTENTIOMETER SERVES AS A GRID LEAK FOR THE 57 TUBE, AS WELL AS ACTING AS THE VOLUME OR "GAIN CONTROL", AS IT IS FREQUENTLY CALLED. THE SECONDARY WINDING OF THE MICROPHONE TRANSFORMER (NOT SHOWN HERE) IS CONNECTED ACROSS THE INPUT TERMINALS.

THE 57 TUBE IS RESISTANCE-CAPACITY COUPLED TO THE 56 AND THIS LATTER TUBE IS COUPLED TO THE POWER STAGE THROUGH AN INPUT PUSH-PULL TRANSFORMER. TWO SECONDARY WINDINGS ARE PROVIDED ON THE OUTPUT TRANSFORMER OF THIS AMPLIFIER -- ONE OF THEM HAVING AN IMPEDANCE RATING OF 15 OHMS FOR SPEAKER VOICE COIL CONNECTION. THE 500 OHM SECONDARY WINDING IS PROVIDED WHEN IT IS DESIRED TO COUPLE THE OUTPUT OF THE AMPLIFIER TO A TRANSMISSION LINE AND WHICH WILL BE MORE FULLY EXPLAINED IN LATER LESSONS.

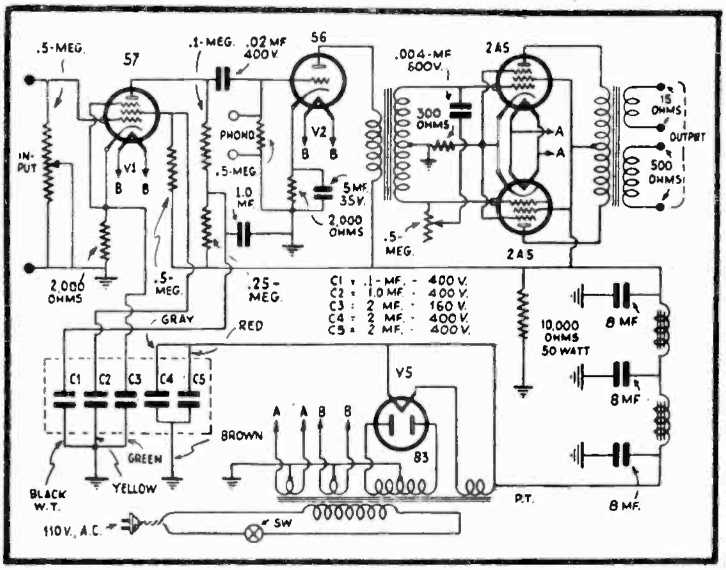

FIG. 6
Circuit Diagram of the 10 Watt Amplifier.

THE TONE CONTROL CONSISTS OF A .004 MFD. CONDENSER IN SERIES WITH A .5 MEGOHM POTENTIOMETER USED AS A RHEOSTAT AND CONNECTED ACROSS THE CONTROL GRID CIRCUIT OF THE 2A5 TUBES.

DUE TO THE HIGH GAIN OF THIS AMPLIFIER AND SINCE A PHONOGRAPH PICK-UP DELIVERS A GREATER SIGNAL VOLTAGE THEN DOES THE AVERAGE MICROPHONE, PROVISIONS ARE MADE FOR PLUGGING A PHONOGRAPH PICK-UP ACROSS THE .5 MEGOHM LEAK RESISTOR IN THE GRID CIRCUIT OF THE 56 TUBE, THEREBY ENTIRELY ELIMINATING THE 57 INPUT STAGE WHEN REPRODUCING PHONOGRAPH RECORDINGS. THE VOLUME CONTROL FOR PHONOGRAPH REPRODUCTION WILL IN THIS CASE HAVE TO BE MOUNTED AS A UNIT ON THE PHONOGRAPH PICK-UP AND AN IMPEDANCE MATCHING TRANSFORMER BEING PROVIDED WHOSE PRIMARY WINDING HAS AN IMPEDANCE RATING EQUAL TO THAT OF THE PICK-UP AND ITS VOLUME CONTROL, AND A SECONDARY WINDING WHOSE IMPEDANCE RATING MATCHES THE .5 MEGOHM LEAK RESISTOR OF THE 56 TUBE AND ACROSS WHICH IT IS TO BE CONNECTED.

A TYPE 83 TUBE IS USED AS THE RECTIFIER IN THE POWER PACK AND IN ALL OTHER RESPECTS THE AMPLIFIER FOLLOWS CONVENTIONAL CIRCUITS AND WITH WHICH YOU ARE BY NOW ALREADY FAMILIAR.

THE TWO FILTER CHOKES ARE EACH OF THE 30 HENRY TYPE AND THE SPEAKERS AS USED WITH THIS AMPLIFIER MUST BE OF THE A.C. TYPE IN WHICH THE FIELDS ARE ENERGIZED BY AN INDIVIDUAL POWER SUPPLY AT THE SPEAKER.

AS REGARDS THE POWER OUTPUT OF A.F. AMPLIFIERS, THE FACT SHOULD BE CONSIDERED THAT THE POWER OUTPUT RATINGS FOR THE PARTICULAR POWER TUBES BEING USED ARE GENERALLY QUITE CONSERVATIVE AND THAT IT IS GENERALLY POSSIBLE BY INCREASING THE PLATE VOLTAGE SLIGHTLY TO OBTAIN AN UNDISTORTED POWER OUTPUT OF APPROXIMATELY 20% GREATER THAN THAT FOR WHICH THE POWER TUBE IN QUESTION IS RATED BY THE TUBE MANUFACTURER.

A CLASS "A"-15 WATT AMPLIFIER

IN FIG. 7 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A CLASS "A" AMPLIFIER, WHOSE OUTPUT POWER IS RATED AT 15 WATTS. THIS CIRCUIT CONSISTS OF THREE PUSH-PULL STAGES AND WHICH RESULTS IN A UNIT OF EXCELLENT TONE QUALITY, IN THAT THE PUSH-PULL ARRANGEMENT BALANCES OUT ALL EVEN HARMONIC DISTORTION IN THE OUTPUT OF EACH STAGE.

NOTICE HOW TWO 57'S, OPERATING AS A PUSH-PULL STAGE, ARE PROVIDED AT THE INPUT. A PUSH-PULL TYPE A.F. CHOKE IS INCLUDED IN THE PLATE CIRCUIT OF THIS STAGE AND THE SIGNAL VOLTAGES AS PRODUCED ACROSS ITS EXTREMETIES ARE APPLIED TO THE GRIDS OF THE TWO 56 TUBES THROUGH THE COUPLING CONDENSERS C_1. THE TWO RESISTORS R_6 ACT AS GRID LEAKS FOR THE 56 TUBES, AND WHAT WE REALLY HAVE HERE IS IMPEDANCE COUPLING ABOUT WHICH YOU ALREADY STUDIED IN ONE OF YOUR FIRST LESSONS TREATING WITH AUDIO FREQUENCY AMPLICATION, ONLY THAT IN ADDITION, THE PUSH-PULL PRINCIPLE IS EMPLOYED.

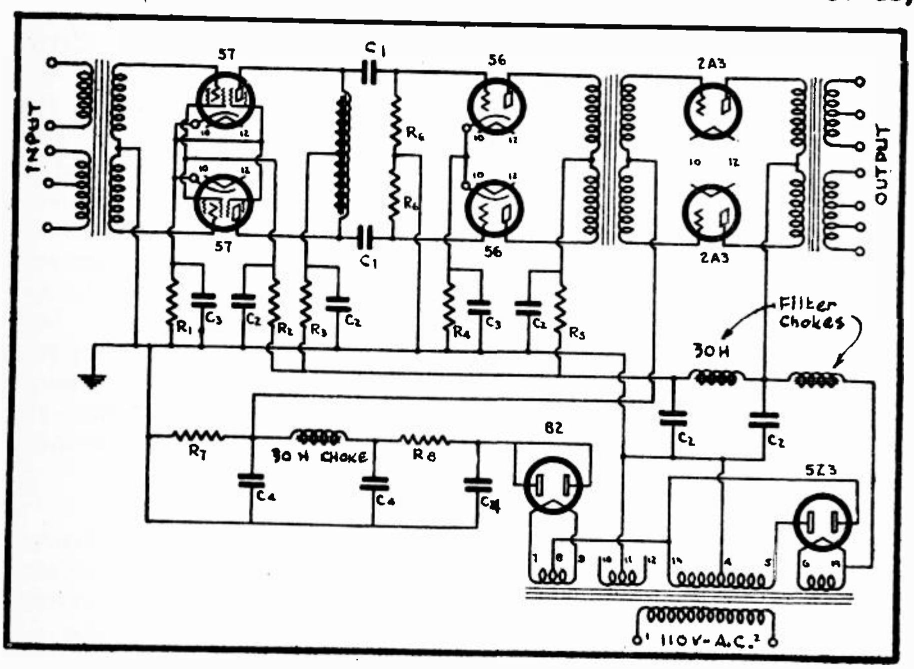

FIG. 7
A Class "A" – 15 Watt Amplifier.

THE PUSH-PULL STAGE WITH THE 56 TUBES IS COUPLED TO THE PUSH-PULL POWER STAGE EMPLOYING THE TYPE 2A3 TUBES. THE COUPLING TRANSFORMER USED IN THIS CASE IS SPECIALLY DESIGNED FOR THIS PURPOSE, BOTH OF ITS WINDINGS OFFERING A PUSH-PULL CIRCUIT.

TWO SECONDARY WINDINGS ARE FURNISHED ON THE OUTPUT TRANSFORMER AND EACH OF THESE IS TAPPED SO THAT A LARGE VARIETY OF OUTPUT IMPEDANCES ARE AVAILABLE IN ORDER TO PERMIT PRACTICALLY EVERY TYPE OF LOAD TO BE MATCHED. THIS PERMITS GROUPING OF MULTIPLE SPEAKERS IN ALL TYPES OF ARRANGEMENTS, AS WELL AS PROVIDING FASCILITIES FOR CONNECTING THE AMPLIFIER TO TRANSMISSION LINES OF VARIOUS DESIGNS. ALL OF THESE DETAILS WILL BE EXPLAINED

FULLY IN LATER LESSONS.

TWO SETS OF PRIMARY WINDINGS ARE PLACED ON THE INPUT TRANSFORMER OF THE AMPLIFIER SO THAT ANY TYPE OF MICROPHONE CIRCUIT, PRE-AMPLIFIER, RADIO TUNER WITH DETECTOR, OR PHONOGRAPH PICK-UP CAN BE PROPERLY MATCHED TO THE AMPLIFIER.

THE POWER PACK OF THIS AMPLIFIER IS UNIQUE IN DESIGN AND THEREFORE WARRANTS A MORE DETAILED EXPLANATION. THE 5Z3, FOR INSTANCE, SERVES AS THE RECTIFIER FOR THE ENTIRE AMPLIFIER, WHEREAS THE SOLE PURPOSE OF THE 82 TUBE IS TO FURNISH A FIXED BIAS VOLTAGE FOR THE TWO 2A3 TUBES.

BY LOOKING AT THE CIRCUIT OF THE 82 TUBE MORE CLOSELY, YOU WILL OBSERVE THAT THE CENTER TAP OF ITS FILAMENT WINDING IS CONNECTED TO ONE OF THE PLATES OF THE 5Z3. THE TWO PLATES OF THE 82 TUBE ARE TOGETHER CONNECTED TO GROUND OR B- THROUGH A RESISTANCE NETWORK AND SPECIAL FILTER CIRCUIT. THE CENTER TAP OF THE 5Z3'S HIGH VOLTAGE WINDING IS ALSO CONNECTED TO GROUND.

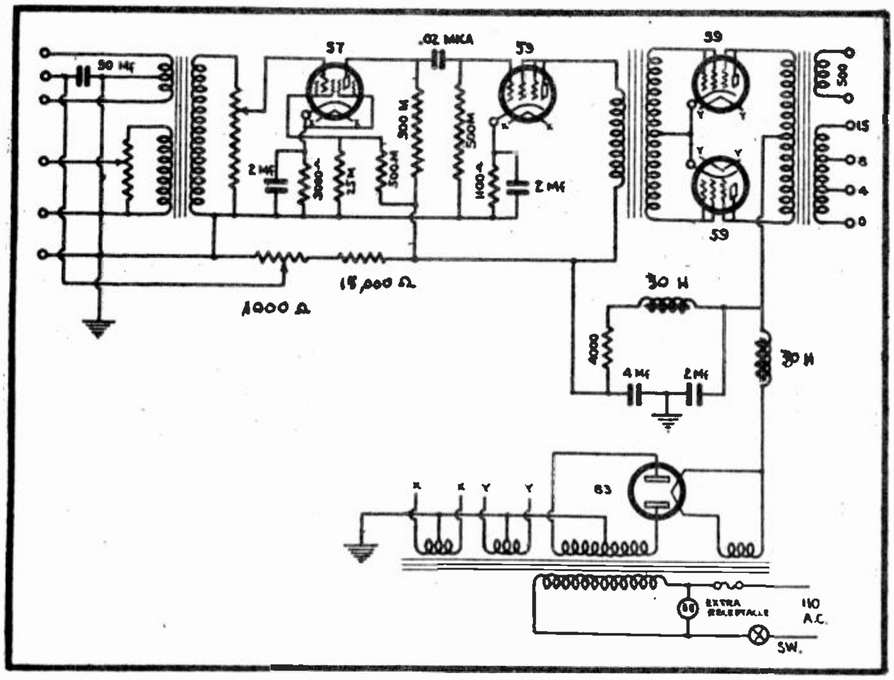

FIG. 8
Circuit Diagram of the 25 Watt Class "B" Amplifier.

NOW THEN, WHENEVER THE LEFT END OF THE POWER TRANSFORMER'S HIGH VOLTAGE WINDING IS POSITIVE, A POSITIVE POTENTIAL WILL ALSO BE APPLIED TO THE FILAMENT OF THE 82. SINCE AT THIS SAME INSTANT THE PLATES OF THE 82 ARE NEGATIVE WITH RESPECT TO THE FILAMENT DUE TO THEIR COMMON CONNECTION TO GROUND, NO CURRENT WILL FLOW THROUGH THE 82 TUBE. HOWEVER, WHENEVER THE LEFT END OF THE POWER TRANSFORMER'S HIGH VOLTAGE WINDING BECOMES NEGATIVE, THE FILAMENT OF THE 82 TUBE WILL BECOME NEGATIVE WITH RESPECT TO GROUND, AS WELL AS WITH RESPECT TO THE PLATES OF THE 82 TUBE, OR TO PUT IT ANOTHER WAY, THE PLATES OF THE 82 WILL NOW BE POSITIVE WITH RESPECT TO THE FILAMENT OF THIS SAME TUBE. UNDER THESE CONDITIONS, CURRENT WILL FLOW FROM GROUND, THROUGH THE 82 TUBE AND BACK TO THE HIGH VOLTAGE WINDING. IN OTHER WORDS, THE 82 TUBE FUNCTIONS AS A HALF-WAVE RECTIFIER AND PASSES CURRENT THROUGH RESISTOR R_7 ONLY FROM THE LEFT TOWARDS THE RIGHT. THE GRID RETURN CIRCUIT OF THE POWER STAGE BEING CONNECTED TO THE NEGATIVE END OF R_7 WHILE THE CENTER OF THE FILAMENT WINDING FOR THESE SAME TUBES IS GROUNDED, THE RESULTING VOLT DROP ACROSS R_7 WILL BE

APPLIED AS A BIAS VOLTAGE TO THE POWER STAGE.

THE CHOKE AND CONDENSERS C_4 SERVE AS A FILTER FOR THE CURRENT RECTIFIED BY THE 82 TUBE SO THAT THE BIAS VOLTAGE WILL BE FREE FROM RIPPLE. THE RESISTOR R_8 ACTS AS A CURRENT LIMITING RESISTOR FOR THIS CIRCUIT.

THE VALUES FOR THE DIFFERENT PARTS AS USED IN THE CIRCUIT OF FIG. 7 ARE AS FOLLOWS:

R_1 = 1500Ω - 1 WATT RESISTOR
R_2 = 250,000Ω - 1 WATT RESISTOR
R_3 = 20,000Ω - 2 WATT RESISTOR
R_4 = 1,300 Ω - 1 WATT RESISTOR
R_5 = 5,000 Ω - 2 WATT RESISTOR
R_6 = 100,000Ω - 1 WATT RESISTOR
R_7 = 15,000 Ω - 2 WATT RESISTOR
R_8 = 70,000 Ω - 2 WATT RESISTOR
C_1 = .1 MFD. 400 VOLT PAPER CONDENSER.
C_2 = 1 MFD. 1000 VOLT ELECTROLYTIC CONDENSER
(2-2MFD. ELECTROLYTICS OF 500 VOLTS IN SERIES).
C_3 = 2 MFD. 50 VOLT ELECTROLYTIC CONDENSER
C_4 = 10 MFD. 200 VOLT ELECTROLYTIC CONDENSER

A 25-WATT CLASS "B" AMPLIFIER

A CIRCUIT DIAGRAM OF AN AMPLIFIER, WHICH IS CAPABLE OF FURNISHING 25 WATTS OF AUDIO POWER, IS ILLUSTRATED FOR YOU IN FIG. 8. THIS CIRCUIT IS OF THE CLASS "B" TYPE AND EMPLOYS A TYPE 57 TUBE AS A PENTODE IN THE INPUT STAGE, THE 57 IS RESISTANCE-CAPACITY COUPLED TO A 59 TUBE WHICH IS USED AS A DRIVER WORKING INTO A PAIR OF 59'S OPERATING AS A CLASS "B" POWER STAGE. AN 83 IS USED AS THE RECTIFIER IN THE POWER PACK.

TWO SETS OF PRIMARY WINDINGS ARE SUPPLY ON THE INPUT TRANSFORMER SO THAT ANY TYPE OF MICROPHONE, RADIO TUNER, OR PHONOGRAPH PICK-UP CAN BE PROPERLY MATCHED TO THE INPUT CIRCUIT. THE OUTPUT TRANSFORMER IS ALSO PROVIDED WITH A LARGE ASSORTMENT OF SECONDARY IMPEDANCES SO AS TO ACCOMMODATE A LARGE VARIETY OF SPEAKER VOICE COIL CONNECTIONS, AS WELL AS A TRANSMISSION LINE.

RACK AND PANEL AMPLIFIER CONSTRUCTION

ALTHOUGH THERE IS NO FIXED RULE REGARDING THE GENERAL FORM OR SHAPE INTO WHICH AMPLIFIERS ARE BUILT, YET YOU WILL COMMONLY FIND IT TO BE THE CASE THAT AMPLIFIERS HAVING A POWER OUTPUT RATING OF 20 WATTS OR LESS ARE USUALLY BUILT ON A METAL CHASSIS BASE AS SHOWN IN FIG. 5, SO THAT THE UNIT RESEMBLES A CONVENTIONAL RADIO RECEIVER.

AMPLIFIERS OF OUTPUT RATINGS GREATER THAN 20 WATTS, FREQUENTLY THOUGH BY NO MEANS ALWAYS, ARE BUILT IN THE RACK AND PANEL FORM SUCH AS ILLUSTRATED IN FIG. 9.

IN THIS CASE, THE FRAME WORK IS MADE OF ANGLE IRON. THE DIFFERENT SECTIONS SUCH AS THE POWER PACK, AMPLIFIER, TUNER, ETC. ARE THEN MOUNTED ON SHELVES AS INDIVIDUAL UNITS, ONE ABOVE THE OTHER AS SHOWN IN FIG. 9. THE ARRANGEMENT IS GENERALLY SUCH THAT ANY ONE OF THE UNITS CAN BE REMOVED INDEPENDENTLY WITHOUT DISTURBING THE OTHERS WHENEVER REPAIRS ARE NECESSary.

An Amplifier for D.C. Power Supply

So far, all of the amplifiers which were described to you in this lesson are designed to be operated from a 110 volt A.C. power supply. In Fig. 10, however, you are shown the circuit diagram of a 6 watt Class "A" amplifier which is to be operated from a 110 volt D.C. line.

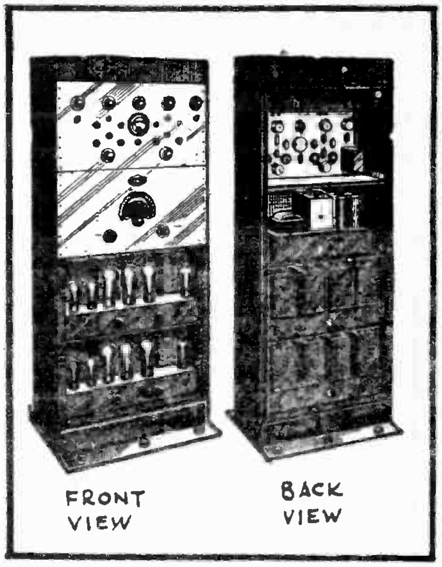

FIG. 9
Rack and Panel Amplifier.

In this circuit, a type 77 tube is used in the input circuit and it works into the second stage through resistance-capacity coupling and this is followed by a power stage containing two type 48 tubes connected in push-pull. By using a $22\frac{1}{2}$ volt battery to furnish the bias voltage for the power tubes, the power which would ordinarily be expended to produce a bias voltage by flowing through a bias resistor can be used to better advantage by making a high plate voltage possible and which in turn will bring about a greater power output.

The input transformer for this amplifier is supplied with primary windings of the proper design to accommodate a phonograph pick-up connection, as well as for a double-button carbon microphone.

Provisions are also made so that the microphone current can be obtained directly from the amplifier's circuits, being controlled by the setting of the 1000 ohm potentiometer.

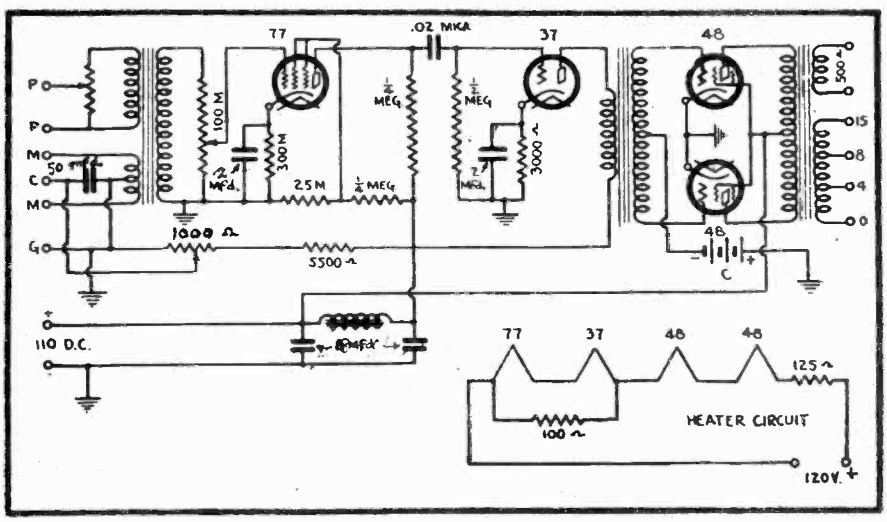

FIG. 10
Circuit Diagram of the 110 Volt D.C. Amplifier.

An A.C.-D.C. Amplifier

Quite often, a public address amplifier is required which is capable of operating either from an A.C. or a D.C. power supply. The one whose circuit diagram is illustrated in Fig. 11 will meet these demands. The tubes used are type 37's in

THE FIRST TWO STAGES AND A PAIR OF 43'S IN THE PUSH-PULL POWER STAGE. TWO 25Z5'S ARE CONNECTED IN PARALLEL IN THE POWER CIRCUIT. FROM WHAT YOU HAVE ALREADY LEARNED ABOUT AMPLIFIER CIRCUITS, AS WELL AS THE APPLICATION OF THE 25Z5 TUBE IN A.C.-D.C. RECEIVER CIRCUITS, THERE WILL BE NO NEED TO DISCUSS THIS CIRCUIT ANY FURTHER. IT IS WELL TO MENTION, HOWEVER, THAT THE OUTPUT POWER OF THE AMPLIFIER AS ILLUSTRATED IN FIG. 11 WOULD BE ONLY ABOUT 3 WATTS, BUT BY CONNECTING A 45 VOLT "B" BATTERY IN THE POSITIVE LEG OF THE FILTER CIRCUIT AT THE POINT MARKED WITH AN "X" AND CONNECTING ITS POSITIVE OR PLUS TERMINAL TO THE CHOKE, THE "B" VOLTAGE FOR THE CIRCUIT WILL BE INCREASED AND THEREBY MAKE AN OUTPUT POWER OF ABOUT 5 WATTS POSSIBLE.

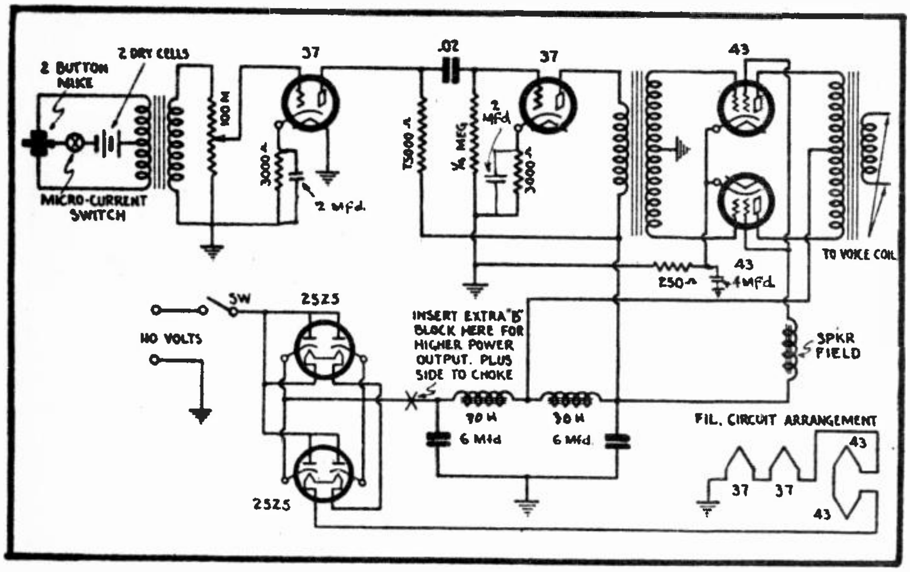

FIG. 11

Diagram of the A.C.-D.C. Amplifier.

A MOBILE SOUND SYSTEM

ANOTHER POPULAR FORM OF AMPLIFYING EQUIPMENT IS THAT DESIGNED FOR USE ON SOUND TRUCKS AND OTHER AUTOMOTIVE VEHICLES. AMPLIFIERS OF THIS TYPE ARE GENERALLY DESIGNED SO THAT A 6 VOLT STORAGE BATTERY (USUALLY THE CAR BATTERY) WILL FURNISH THE FILAMENT SUPPLY OF ALL TUBES, WHILE A DYNAMOTOR OPERATED FROM THE 6 VOLT BATTERY SUPPLIES THE NECESSARY "B" VOLTAGE. THESE DYNAMOTORS ARE SIMILAR TO THOSE WHICH WERE ALREADY DESCRIBED TO YOU IN YOUR LESSONS TREATING WITH AUTOMOBILE RECEIVERS.

A.F. AMPLIFYING EQUIPMENT, WHICH IS INTENDED TO BE USED ON AUTOMOTIVE VEHICLES, ARE GENERALLY REFERRED TO AS MOBILE SOUND SYSTEMS.

IN FIG. 12 YOU ARE SHOWN A CIRCUIT DIAGRAM OF A FOUR-TUBE

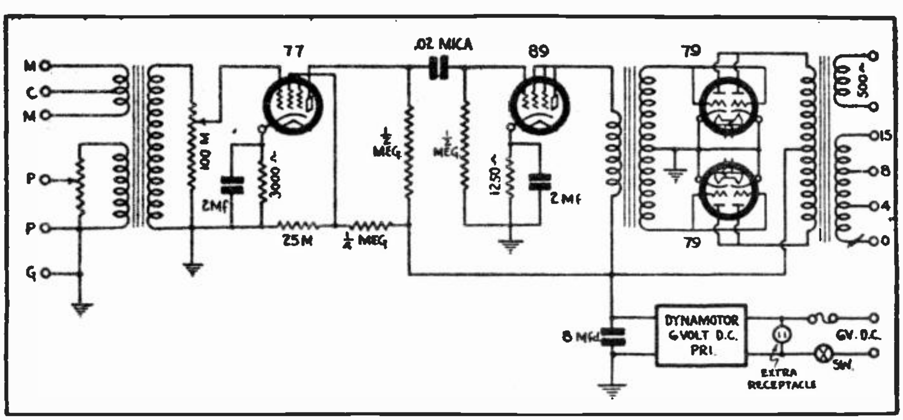

FIG. 12

Circuit Diagram of the Mobile Amplifier.

AMPLIFIER WHICH IS DESIGNED FOR MOBILE USE AND THE TUBES USED ARE A 77 IN THE INPUT STAGE, FOLLOWED BY AN 89 AND A PAIR OF 79'S IN THE PUSH-PUSH POWER STAGE. PROVISIONS ARE MADE FOR A DOUBLE-BUTTON CARBON MICROPHONE INPUT AND ALSO FOR A PHONOGRAPH PICK-UP INPUT. THE SECONDARIES OF THE OUTPUT TRANSFORMER OFFER IMPEDANCE MATCHING FASCILITIES FOR A LARGE VARIETY OF LOADS. A POWER OUTPUT OF APPROXIMATELY 12 WATTS IS AVAILABLE FROM THIS AMPLIFIER.

FIG. 13 WILL GIVE YOU SOME SUGGESTIONS AS TO HOW THE DIFFERENT UNITS OF THIS AMPLIFYING SYSTEM MAY BE MOUNTED ON A SEDAN.

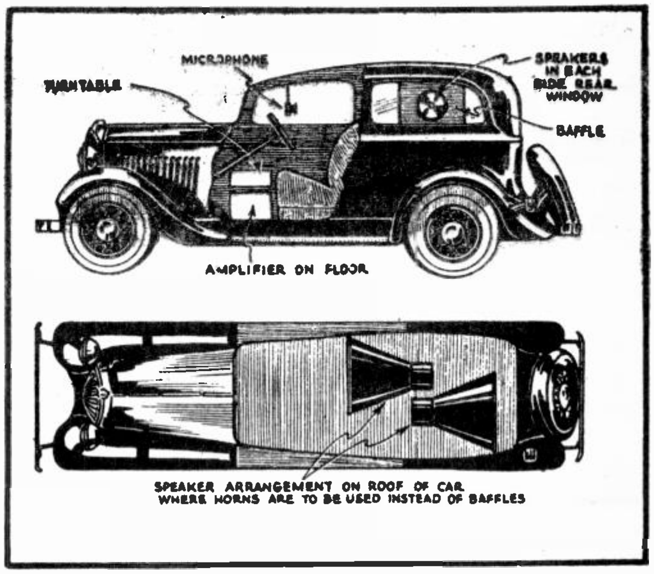

FIG. 13

Mounting Mobile Equipment.

HAVING COMPLETED THIS LESSON, YOU ARE NOW FAMILIAR WITH THE GENERAL CONSTRUCTION AND CIRCUIT FEATURES OF COMMONLY USED A.F. AMPLIFIERS FOR SOUND SYSTEMS AND YOU WILL FIND THIS KNOWLEDGE TO BE OF GREAT HELP TO YOU DURING YOUR STUDIES OF COMING LESSONS IN THIS SERIES WHERE AMPLIFYING SYSTEMS ARE EXPLAINED FROM A MORE TECHNICAL STANDPOINT THAN HERETOFORE.

IT IS WELL TO MENTION AT THIS TIME THAT THE SAME PLAN OF INSTRUCTION IS FOLLOWED THROUGHOUT YOUR ADVANCED SPECIALIZATION SUBJECTS AS IN YOUR FOUNDATIONAL TRAINING. THAT IS, YOU ARE FIRST PROPERLY FAMILIARIZED WITH THE VARIOUS COMPONENTS WHICH ARE USED TOGETHER IN ORDER TO FORM THE SYSTEM AND THEN WHEN YOU HAVE ACQUIRED THIS BASIC KNOWLEDGE, YOU ARE TAKEN IN LOGICAL STEPS THROUGH THE ANALYSIS OF THE ENGINEERING PROBLEMS WHICH ARE ASSOCIATED WITH THE SYSTEM. SUCH A WELL ORDERED PLAN, YOU NO DOUBT ALREADY REALIZE BY THIS TIME, PREVENTS THE POSSIBILITY OF OMITTING ANY DETAIL WHICH MAY NOT ALREADY BE CLEAR TO A STUDENT AND OFFERS THE STUDENT A TYPE OF TRAINING WHICH IS UNDERSTANDABLE AND EASY TO MASTER, WHILE AT THE SAME TIME MAKING THE INSTRUCTION SUFFICIENTLY TECHNICAL IN NATURE SO THAT OUR GRADUATES ARE QUALIFIED TO AVAIL THEMSELVES OF THE BETTER POSITIONS WHICH THE RADIO INDUSTRY HAS TO OFFER.

Examination Questions

Ans Mar 30, '41

LESSON NO. AS-2

The man who fails to pay the price
of success will succeed in paying the
penalty of failure. The man who does
not learn cannot earn.

1. - What is the essential difference between a Class A and a Class B amplifier?

2. - What is meant by a "Rack and Panel" design as applied to an amplifier?

3. - Illustrate by means of a diagram and explain how the bias voltage is produced for the power stage in the amplifier circuit shown in Fig. 7 of this lesson.

4. - For what reason are amplifier input transformers frequently supplied with several primary windings, or else with one primary winding having a number of taps?

5. - Why are several secondary windings, or else a secondary with a number of taps, frequently supplied on the output transformer of an amplifier?

6.- Draw a circuit diagram of an A.C. operated Class "A" amplifier.

7. - Draw a circuit diagram of an A.C. operated Class "B" amplifier.

8. - Explain in detail how the signal is passed through the amplifier from the microphone to one speaker in the circuit which you have drawn in answer to question #6 of this examination.

9. - Draw a circuit diagram of an A.C. operated portable amplifier having a double-button carbon microphone input only.

10.- Draw a circuit diagram of an amplifier suitable for installation on a sound truck or car.

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Amplifying Systems

LESSON NO. 3

SPEAKERS FOR SOUND SYSTEMS

HAVING CONSIDERED MICROPHONES AND AMPLIFIER CIRCUITS IN THE TWO PRECEDING LESSONS, THE NEXT LOGICAL UNIT OF THE SOUND SYSTEM TO BE BROUGHT TO YOUR ATTENTION WILL BE THE LOUD SPEAKER.

IN GENERAL PRINCIPLES, THE SPEAKERS AS USED FOR PUBLIC ADDRESS WORK AND OTHER SOUND SYSTEMS ARE PRACTICALLY THE SAME AS THOSE USED FOR RADIO RECEIVERS AND ABOUT WHICH YOU ALREADY LEARNED IN THE EARLIER LESSONS OF THIS COURSE. THERE ARE, HOWEVER, MANY SPECIAL FEATURES TO BE FOUND ON PUBLIC ADDRESS SPEAKERS AND ABOUT WHICH YOU MUST KNOW BEFORE GOING ANY FARTHER IN THIS WORK.

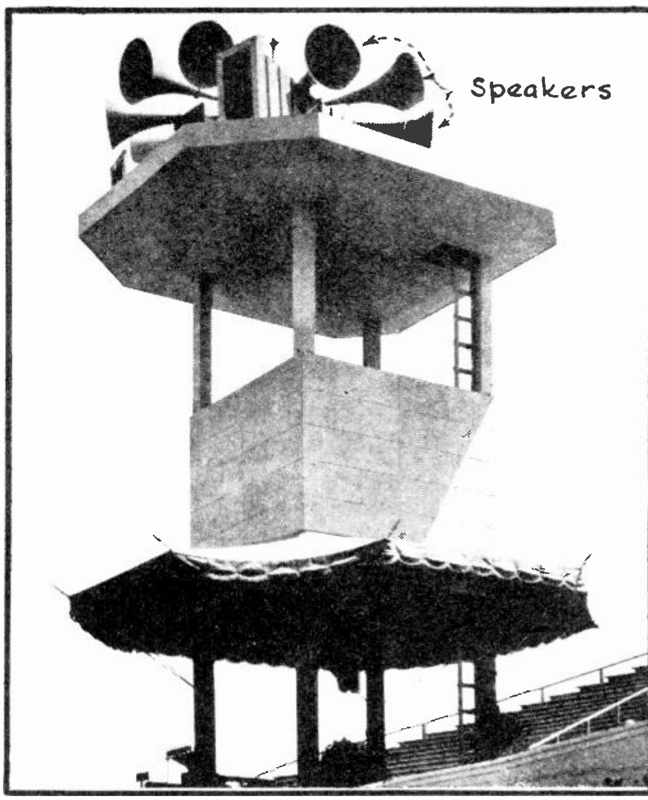

FIG. 1
A Typical Speaker Installation.

SPEAKERS, AS USED WITH PUBLIC ADDRESS (P.A.) SYSTEMS, CAN BE CLASSIFIED AS MAGNETIC, ELECTRODYNAMIC, CONE, HORN TYPE ETC. AND ALL OF THESE WILL BE DESCRIBED TO YOU IN THIS LESSON.

MAGNETIC SPEAKER WITH TRUMPET-TYPE HORN

FIRST, LET US LOOK AT FIG. 2. HERE YOU ARE SHOWN A MAGNETIC SPEAKER UNIT TOGETHER WITH A TRUMPET-TYPE HORN. SINCE A MAGNETIC SPEAKER UNIT IS BEING USED IN THIS INSTANCE, NO FIELD EXITING CURR-

ENT WILL BE NEEDED AS IS THE CASE WITH THE ELECTRODYNAMIC SPEAKER UNIT AND BECAUSE OF THIS, THE MAGNETIC TYPE SPEAKER ADAPTS ITSELF WELL FOR QUICK INSTALLATIONS.

FURTHERMORE, THIS TYPE OF SPEAKER IS LIGHT IN WEIGHT, EASILY CARRIED AND INSTALLED AND IS THEREFORE ADAPTABLE TO ALL KINDS OF TEMPORARY SOUND INSTALLATIONS. THIS SPEAKER HAS GOOD SOUND PROJECTING QUALITIES FOR OUTDOOR PURPOSES AND BY USING A SUFFICIENT NUMBER OF THEM, A CONSIDERABLE AREA CAN BE ADEQUATELY COVERED BY THE INSTALLATION.

THIS SPEAKER, HOWEVER, DOES NOT HAVE THE TONE QUALITY AS THOSE TO BE

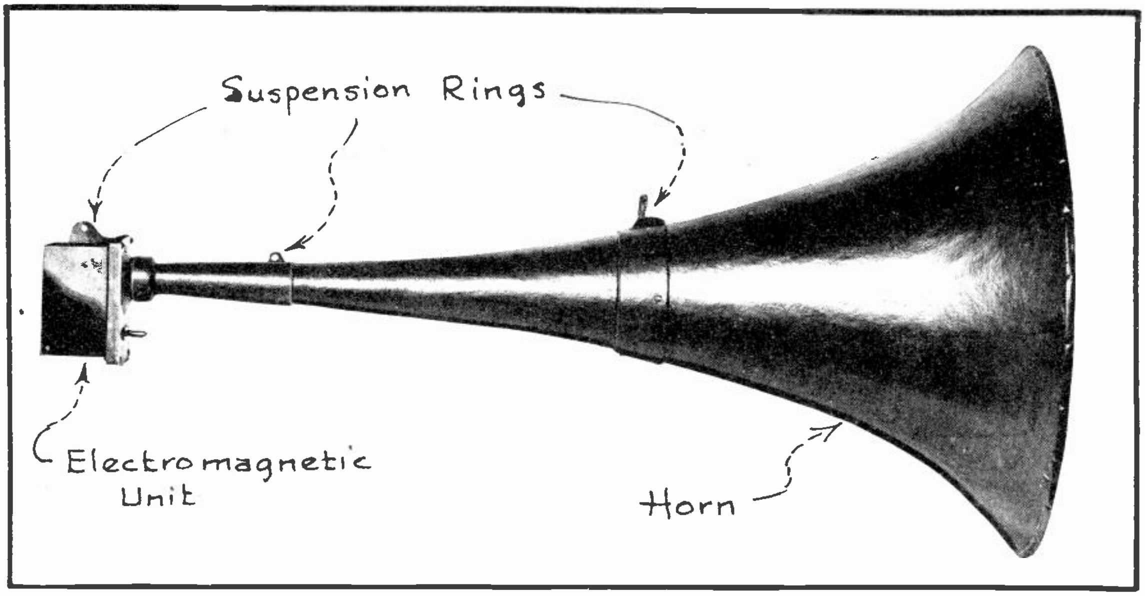

FIG. 2
Trumpet Type Horn For Public Address Systems.

SHOWN YOU LATER BUT THEN FOR GENERAL ANNOUNCING PURPOSES ETC., TONE QUALITY IS NOT AS ESSENTIAL AS WHEN REPRODUCING MUSIC.

THE HORN ILLUSTRATED IN FIG. 2 IS MANUFACTURED BY WRIGHT-DE COSTER INC. IT IS FINISHED IN BLACK WEATHER-PROOF DUCO AND WILL STAND ANY KIND OF WEATHER. ITS TOTAL LENGTH IS 3 FT. 9½ INCHES; IT HAS AN OPENING OF 20 IN. AT ITS BELL OR MOUTH AND WEIGHS 15 LBS.

THE MAGNETIC SPEAKER UNIT IS SHOWN IN FIG. 3, WHERE YOU WILL OBTAIN BOTH A FRONT AND INTERIOR VIEW. A DOUBLE MAGNET IS USED IN THIS CASE, SO AS TO ALLOW THE UNIT TO HANDLE A GREAT DEAL OF POWER WITHOUT REDUCING ITS EFFICIENCY. A POWER INPUT OF 1½ WATTS IS RECOMMENDED FOR THIS UNIT AND THIS SMALL WATTAGE MAKES IT POSSIBLE TO COVER A GREAT AREA, BY THE USE OF A NUMBER OF HORNS, WITHOUT THE

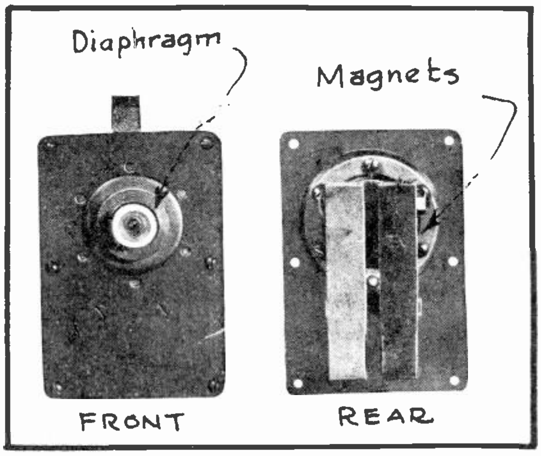

FIG. 3
Magnetic Speaker Unit for Trumpet Type Horn.

NECESSITY OF A VERY LARGE POWERFUL AMPLIFIER.

TRUMPET DYNAMIC UNITS

NOT ALL TRUMPET TYPE HORNS ARE FITTED WITH A MAGNETIC SPEAKER UNIT. IN FIG. 4, FOR INSTANCE, YOU ARE SHOWN THREE SIZES OF DYNAMIC UNITS AS MANUFACTURED BY THE RACON ELECTRIC CO. AND WHICH ARE DESIGNED TO BE USED WITH TRUMPET HORNS.

ALTHOUGH THIS DYNAMIC UNIT OPERATES UNDER THE SAME FUNDAMENTAL PRINCIPLES AS EXPLAINED TO YOU RELATIVE TO CONE-TYPE DYNAMIC SPEAKERS IN AN EARLIER LESSON, YET THE UNIT FOR THE HORN TYPE SPEAKER IS SOMEWHAT DIFFERENT IN CONSTRUCTION.

TO BEGIN WITH, THE HORN TYPE DYNAMIC UNIT USES A SMALL DIAPHRAGM. THIS DIAPHRAM IS MADE OF SOME LIGHT METAL, SUCH AS DURALUMINUM, HAVING A DIAMETER OF FROM FOUR TO SIX INCHES. THE DIAPHRAGM IS USUALLY SUSPENDED BY A CLOTH SUSPENSION, FASTENED AT SEVERAL POINTS AND QUITE OFTEN, A DOME-

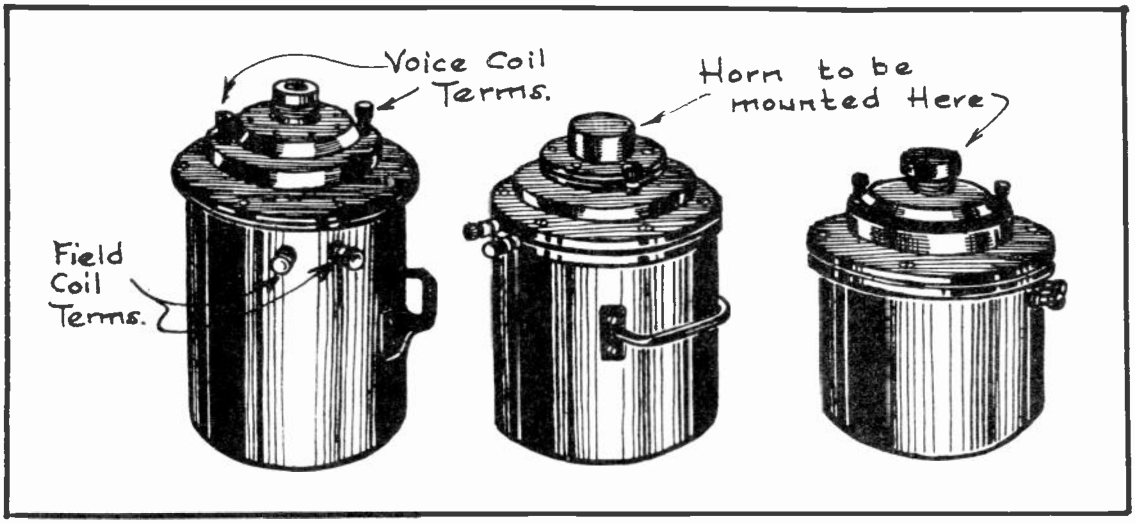

FIG. 4
Three Sizes of Trumpet Dynamic Units.

SHAPED DIAPHRAGM IS USED.

THE VOICE COIL IS WOUND WITH FINE COPPER OR ALUMINUM WIRE AND IT IS FASTENED TO THE DIAPHRAGM. THE DIAPHRAGM IS FREE TO MOVE UP AND DOWN WITH A PISTON LIKE MOTION WITH ITS MOVEMENT, HOWEVER, BEING MORE OR LESS RESTRICTED. FLEXIBLE LEADS ARE USED BETWEEN THE VOICE COIL AND THE BINDING POSTS, WHICH ARE MOUNTED ON THE OUTSIDE OF THE CASE.

THE CASE ITSELF IS MADE OF MAGNETIC STEEL, FORMING A PART OF THE MAGNETIC CIRCUIT OF THE FIELD, AND THE FIELD WINDINGS ARE HOUSED WITHIN THE CASE.

THIS TYPE OF SPEAKER UNIT MAY BE USED WITH A TRUMPET HORN OR ELSE WITH AN EXPONENTIAL HORN WHICH IS EXPLAINED LATER IN THIS LESSON. IT CANNOT, HOWEVER, BE USED SUCCESSFULLY WITH A PLAIN BAFFLE BOARD. DUE TO THE MANNER IN WHICH IT MUST BE USED WITH A HORN, IT CAN BE SEEN THAT THE

SPEAKER WILL BE HIGHLY DIRECTIONAL IN ITS PROPERTIES, SO AS TO CONCENTRATE THE SOUND WITHIN A LIMITED AREA.

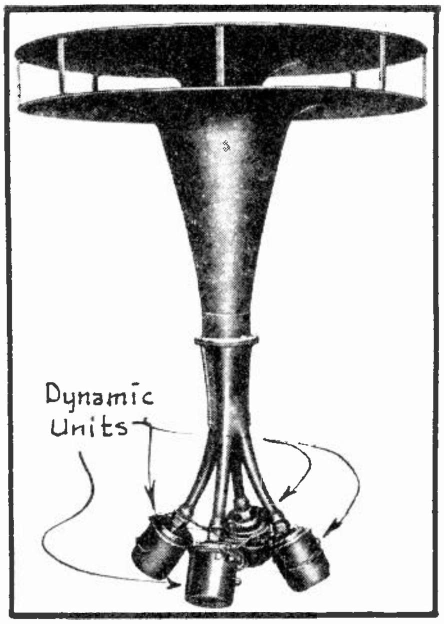

FIG. 5
The Radial Horn.

ALL OF THE DYNAMIC SPEAKER UNITS SHOWN YOU IN FIG. 4 ARE RATED AT A PEAK LOAD CAPACITY OF 50 WATTS BUT THE RECOMMENDED CAPACITY FOR CONTINUOUS OPERATION IS FROM 20 TO 25 WATTS. IN ALL THREE OF THE MODELS HERE ILLUSTRATED, THE VOICE COIL HAS AN IMPEDANCE RATING OF 15 OHMS AT 1000 CYCLES PER SECOND AND THE FIELD COIL IS DESIGNED TO BE EXITED BY A 6 TO 8 VOLT SUPPLY.

AS HAS ALREADY BEEN MENTIONED IN THIS LESSON, THE TRUMPET HAS HIGHLY DIRECTIONAL CHARACTERISTICS. THAT IS, IT WILL PROJECT THE SOUND OVER A CONSIDERABLE DISTANCE IN WHATEVER DIRECTION IT IS POINTED BUT IT WILL NOT DISTRIBUTE THE SOUND OVER ANY APPRECIABLE AREA TOWARDS EITHER SIDE OF ITS OPENING. FOR THIS LATTER REASON, IT IS THE COMMON PRACTICE WHEN USING THIS TYPE OF HORN AND WHERE THE AREA TO BE COVERED IS RATHER LARGE, TO ARRANGE SEVERAL OF THESE SPEAKERS AROUND A COMMON CENTER AND RADIATING OUTWARD IN ALL DIRECTIONS AS ILLUSTRATED IN FIG. 1 OF THIS LESSON.

SPECIAL TRUMPET DESIGNS

IN ORDER TO OVERCOME THE SHORT-COMING OF THE ORDINARY TRUMPET HORN AS REGARDS PROPER SOUND COVERAGE OVER AN APPRECIABLE AREA, SEVERAL MODIFICATIONS OF THIS TYPE OF SPEAKER WERE DEVISED. IN FIG. 5, FOR INSTANCE, YOU ARE SHOWN THE RADIAL HORN. THIS UNIT IS DESIGNED IN SUCH A MANNER THAT IT WILL PROJECT SOUND OVER 360° OR FROM A COMMON POINT EQUALLY IN ALL HORIZONTAL DIRECTIONS.

THIS HORN, IS THEREFORE PARTICULARLY ADAPTED FOR SOUND TRUCK USE, TOWER, AMUSEMENT PARK, OR WHERE COMPLETE CIRCUMFERENTIAL COVERAGE IS DESIRED.

THE CONSTRUCTION OF THE HORN IS SUCH THAT FOUR DYNAMIC UNITS WORK INTO IT SIMULTANEOUSLY AND IN THIS MANNER, A LARGE VOLUME OF SOUND CAN BE SATISFACTORILY HANDLED. ALSO OBSERVE THE DEFLECTION PLATES AS USED AT THE MOUTH OF THIS HORN SO AS TO RADIATE THE SOUND OUTWARD IN ALL DIRECTIONS. THIS HORN, OF COURSE, IS INTENDED FOR MOUNTING IN A VERTICAL POSITION THE SAME AS HERE ILLUSTRATED.

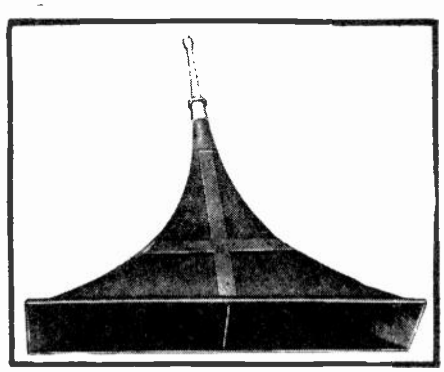

FIG. 6
The Flared Trumpet.

THE TRUMPET HORN WHICH IS SHOWN YOU IN FIG. 6 HAS ITS BELL FLARED SO THAT THE SOUND

WAVES AS THEY ARE EMITTED FROM IT ARE SPREAD OVER A LARGER AREA. THE COMPARATIVELY FLAT TOP AND BOTTOM SIDES OF THIS HORN AID CONSIDERABLY IN PREVENTING THE SOUND WAVES FROM BEING PROJECTED EITHER UPWARDS OR DOWNWARDS. THIS TYPE OF TRUMPET IS DESIGNED TO MEET SPECIAL CONDITIONS WHERE SPACE IS LIMITED AND IS EXCELLENT FOR SOUND-TRUCK USE, WHERE HEIGHT LIMITATIONS ARE IMPOSED.

IN FIG. 7 YOU ARE SHOWN WHAT IS KNOWN AS A FOUR-UNIT AIRPLANE HORN. THIS IS ALSO A SPECIAL TRUMPET TYPE DESIGN AND IS INTENDED FOR LONG-RANGE PROJECTION. PROVISIONS ARE MADE FOR CONNECTING FOUR DYNAMIC UNITS TO IT, SO THAT WHEN USED TOGETHER WITH AN AMPLIFIER OF HIGH AUDIO POWER OUTPUT, THE SOUND CAN BE SATISFACTORILY PROJECTED OVER A GREAT DISTANCE.

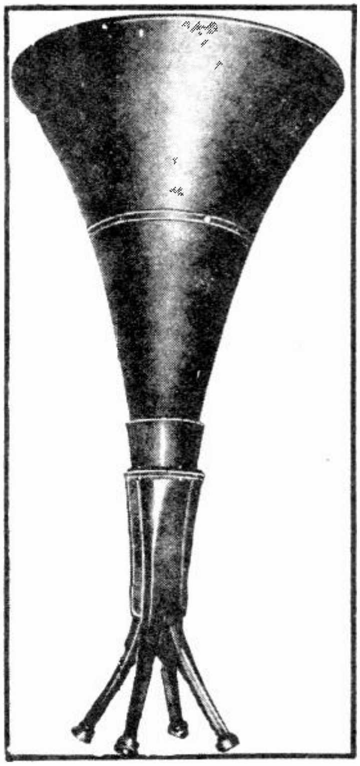

FIG. 7
Four Unit Airplane Horn.

THE EXPONENTIAL HORN

A DIFFERENT TYPE OF HORN IS SHOWN IN FIG.8 THIS IS KNOWN AS AN EXPONENTIAL HORN AND SOMETIMES THIS ENTIRE SPEAKER ASSEMBLY IS REFERRED TO AS AN "AIR-COLUMN SPEAKER". THIS LATER NAME WAS ORIGINATED FROM THE FACT THAT THIS HORN POSSESSES A LONG AIR COLUMN (DISTANCE FROM SPEAKER UNIT TO BELL OR MOUTH) AND THIS AIDS MATERIALLY IN BRINGING ABOUT A MORE FAITHFUL REPRODUCTION OF THE LOWER AUDIO FREQUENCIES.

AS AN EXAMPLE, YOU WILL FIND HORNS OF THIS TYPE HAVING AN AIR COLUMN APPROXIMATELY 10 FEET LONG AND WITH A BELL OPENING 30 x 40 INCHES IN CROSS-SECTION. THIS OPENING THEN GRADUALLY DECREASES IN SIZE TOWARD THE INPUT END OF THE HORN AT THE POINT WHERE THE SPEAKER UNIT IS ATTACHED.

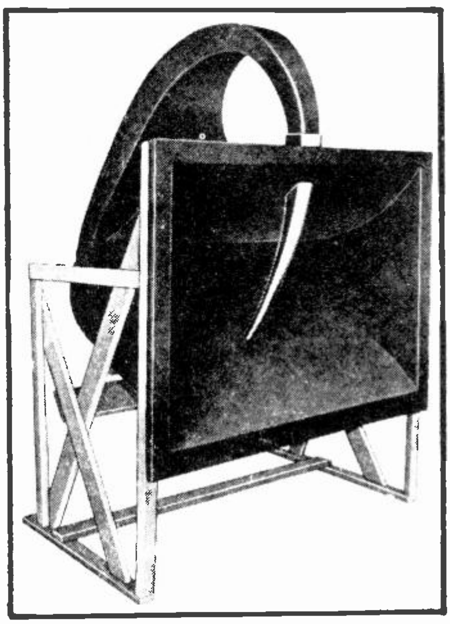

FIG. 8
The Exponential Horn

THE SAME DYNAMIC SPEAKER UNITS WHICH APPEAR IN FIG.4 OF THIS LESSON ARE USED WITH THE EXPONENTIAL TYPE HORN.

THE EXPONENTIAL HORN IS USED CONSIDERABLY IN TALKING PICTURE INSTALLATIONS AND WHEN USED WITH THE DYNAMIC SPEAKER UNIT AS ALREADY STATED, THE ASSEMBLY WILL FURNISH GOOD REPRODUCTION OF BOTH VOICE AND MUSIC BUT IT IS MORE EFFECTIVE IN THE REPRODUCTION OF THE LOWER FREQUENCIES THEN OF THE HIGHER FREQUENCIES.

HIGH-FREQUENCY REPRODUCERS

AVERAGE SPEAKERS DROP SHARPLY IN RESPONSE AT FREQUENCIES ABOVE 3000 CYCLES PER SECOND, WHEREAS HIGH FIDELITY AMPLIFIERS MAY SATISFACTORILY HANDLE FREQUEN-

CIES UP TO AROUND 17,000 CYCLES PER SECOND. HOWEVER, BY USING A HIGH-FREQUENCY SPEAKER IN ADDITION TO THE REGULAR SPEAKER, THIS DIFFICULTY CAN BE OVERCOME.

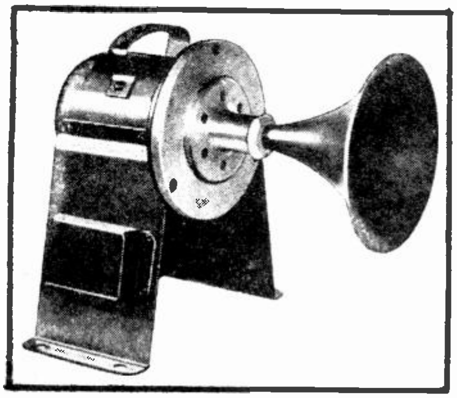

FIG. 9
A High Frequency Speaker.

WHENEVER A HIGH FREQUENCY REPRODUCER IS USED WITH A REGULAR SPEAKER, A SPECIAL FILTER SYSTEM IS ALSO EMPLOYED WHEREBY ONLY THE HIGH FREQUENCIES ARE PASSED ON TO THE HIGH FREQUENCY SPEAKER AND FOR WHOSE REPRODUCTION IT IS ESPECIALLY DESIGNED. CONSEQUENTLY, THE HIGH FREQUENCY SPEAKER REPRODUCES THE HIGHER FREQUENCIES FROM THE POINT WHERE THE REGULAR SPEAKER LEAVES OFF AND THE TWO BLEND TOGETHER SO AS TO COVER A LARGE FREQUENCY RANGE AND THEREBY PROVIDE HIGH FIDELITY PERFORMANCE.

THE NUMBER OF HIGH-FREQUENCY REPRODUCERS TO USE IN CONJUNCTION WITH LOW- FREQUENCY SPEAKERS DEPENDS ON THE INSTALLATION OR DISTRIBUTION OF SOUND, ALTHOUGH IT MAY USUALLY TAKE TWO LOW-FREQUENCY SPEAKERS FOR ONE OF THE NEW TYPE HIGH-FREQUENCY SPEAKERS IN ORDER TO ATTAIN A GOOD BALANCE OF TONE.

IN FIG. 9 YOU ARE SHOWN ONE OF THE NEW HIGH-FREQUENCY SPEAKERS. THE SPEAKER UNIT ITSELF IS OF THE DYNAMIC TYPE AND IT IS FITTED WITH A SMALL TRUMPET HORN. IT REQUIRES NO BAFFLE AND THE POWER INPUT TO THIS UNIT IS LIMITED TO FIVE WATTS.

HIGH FREQUENCY SPEAKERS OF THE CRYSTAL TYPE ARE ALSO BECOMING POPULAR AND THE ADVANTAGES OFFERED BY THEM ARE THAT THEY REQUIRE NO FIELD CURRENT, AND CAN BE CONNECTED DIRECTLY TO THE VOICE COIL TERMINALS OF ANY REGULAR DYNAMIC SPEAKER. THE MOVEMENT OF THIS SPEAKER CONSISTS OF FOUR SPECIALLY MATCHED PIEZO-ELECTRIC CRYSTALS THAT WILL ONLY RESPOND TO FREQUENCIES OVER 1500 CYCLES PER SECOND, THEREBY MAKING UNNECESSARY THE USE OF A FILTER SYSTEM.

CONE-DYNAMIC SPEAKERS

THE CONE-DYNAMIC SPEAKERS AS USED FOR PUBLIC ADDRESS WORK ARE IDENTICAL TO THOSE USED IN RADIO RECEIVERS WITH THE EXCEPTION THAT THEY ARE LARGER IN SIZE SO AS TO BE CAPABLE OF HANDLING GREATER AUDIO POWER WITHOUT RATTLING; THEY ARE USUALLY OF THE A.C. TYPE, HAVING THEIR INDIVIDUAL FIELD ENERGIZING SUPPLY AND THE WATTAGE FURNISHED THE FIELD COIL IS GENERALLY GREATER THAN THAT USED FOR RECEIVER TYPE CONE-DYNAMIC SPEAKERS.

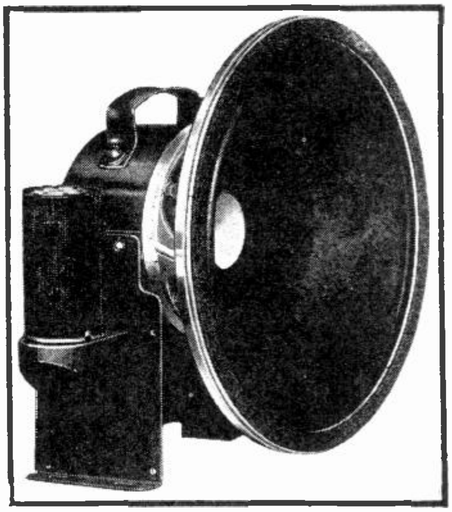

FIG. 10
Cone Dynamic Speaker.

IN FIG. 10 YOU ARE SHOWN A TYPICAL EXAMPLE OF A CONE-DYNAMIC SPEAKER AS USED FOR PUBLIC ADDRESS WORK. FREQUENTLY, SPEAKERS OF THIS TYPE ARE REFERRED TO AS AUDITORIUM SPEAKERS. OBSERVE IN THIS ILLUSTRATION THAT THIS

SPEAKER THROUGHOUT IS OF STURDIER CONSTRUCTION THAN THE ORDINARY CONE DYNAMICS.

THE QUESTION FREQUENTLY ARISES AS REGARDS THE CHOICE BETWEEN A TRUMPET TYPE SPEAKER OR A CONE-DYNAMIC PLACED EITHER WITHIN A HORN OR BEHIND A BAFFLE. THERE IS NO QUESTION BUT THAT FOR PROJECTING SOUND OVER A LONG DISTANCE, THE TRUMPET IS BEST, BUT WHERE GOOD REPRODUCTION IS DESIRED, THE CONE DYNAMIC UNIT IS PREFERABLE. HOWEVER, FOR BEST FREQUENCY RESPONSE, THE DYNAMIC CONE SHOULD BE USED ONLY WITH STRAIGHT BAFFLES OR WIDE-FLARE HORNS. THE REASON FOR THIS IS ILLUSTRATED IN FIG. 11.

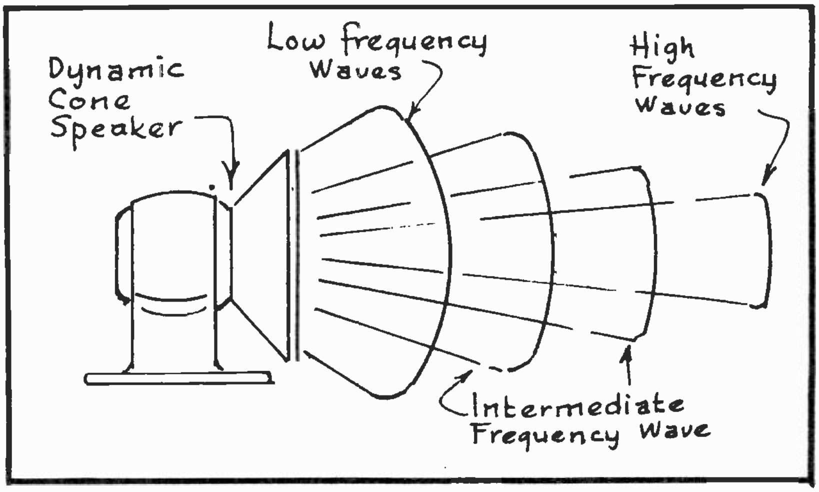

FIG. 11

Sound Emanations From Cone Dynamic Speaker

BY STUDYING FIG. 11 YOU WILL OBSERVE THE LOCATION AND SHAPE OF THE LOW-FREQUENCY SOUND WAVES AS THEY EMANATE FROM THE CONE. THE HIGH-FREQUENCY WAVES, YOU WILL NOTICE, ARE PROJECTED PRACTICALLY STRAIGHT AHEAD SO THAT THEY WILL REACH OUT OVER CONSIDERABLE DISTANCE. THE LOW-FREQUENCY WAVES, ON THE OTHER HAND, HAVE A NATURAL TENDENCY TO SPREAD OUTWARDS TOWARDS THE SIDES SHORTLY AFTER THEY LEAVE THE CONE SURFACE AND ARE NOT READILY PROJECTED FORWARD FOR ANY GREAT DISTANCE.

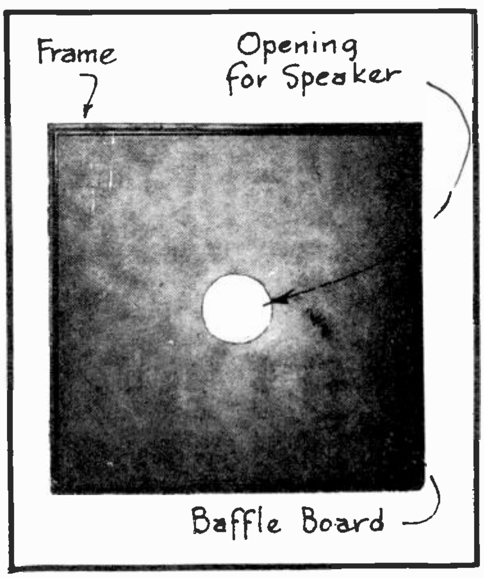

FIG. 12

Baffle for Cone Dynamic Speaker.

CONDITIONS BEING SUCH, IT IS CLEAR THAT IF THIS SPEAKER UNIT WERE MOUNTED TO A HORN OF TRUMPET DESIGN WHERE THE PROJECTION OF SOUND IS THE CHIEF CHARACTERISTIC, THE LOW-FREQUENCY WAVES WILL BE SQUASHED AND THEREBY DISTORTED BY THE RESTRICTION OFFERED BY THE SMALL END OF THE HORN. IN FACT, THESE LOW-FREQUENCY WAVES WOULD ACTUALLY BE LOST IN A HORN DESIGNED FOR THE PROJECTION OF SOUND UNLESS THE FLARE OR ANGLE OF THE HORN IS SO GREAT THAT IT IS USELESS AS A SOUND PROJECTING AND DIRECTING DEVICE.

THE HORNS AS USED WITH CONE-DYNAMIC SPEAKER UNITS ARE A COMPROMISE IN THAT THEY ARE FLARED CONSIDERABLY SO AS NOT TO RESTRICT THE LOW-FREQUENCY WAVES MATERIALLY AND YET AT THE SAME TIME ARE CONSTRUCTED TO PROVIDE REASONABLY GOOD SOUND PROJECTING QUALITIES. THESE VARIOUS HORN DESIGNS WILL BE DESCRIBED TO YOU IN

THE FOLLOWING PARAGRAPHS.

BAFFLES FOR CONE SPEAKERS

IN SOUND INSTALLATIONS WHERE IT IS NOT NECESSARY THAT THE SOUND WAVES BE DIRECTED PARTICULARLY WELL IN ANY GIVEN DIRECTION AND WHERE QUALITY OF REPRODUCTION IS MOST DESIRABLE, THEN A STRAIGHT BAFFLE CAN BE EMPLOYED IN CONJUNCTION WITH THE CONE-DYNAMIC SPEAKER UNIT.

A TYPICAL BAFFLE FOR THIS PURPOSE IS SHOWN YOU IN FIG. 12. THE ONE HERE ILLUSTRATED IS ESPECIALLY SUITABLE FOR A SPEAKER INSTALLATION IN DANCE HALLS, SKATING RINKS AND IN SOME THEATERS (IN ALL INSTANCES DEPENDING UPON THE ACOUSTIC PROPERTIES OF THE ROOM).

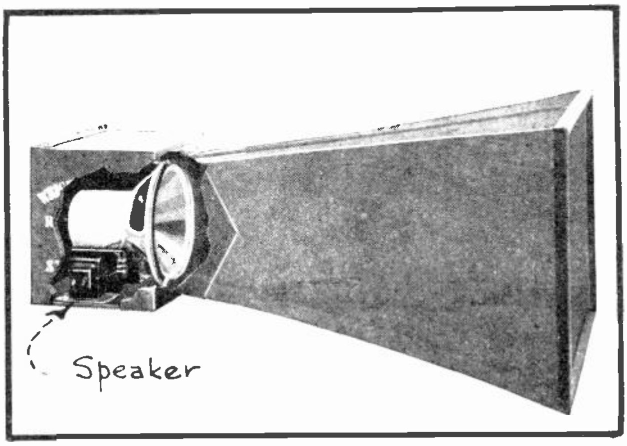

FIG. 13
Cone Speaker Mounted to Horn.

THE BAFFLE IN FIG. 12 IS MADE OF SOME SUCH NON-RESONANT MATERIAL AS CELOTEX OR FIRTEX WHICH IS 1" THICK AND ABOUT 4 FT. SQUARE. THIS MATERIAL IS MOUNTED IN A WOODEN FRAME AND A SHELF IS PROVIDED ON THE REAR SIDE OF THE BAFFLE TO SUPPORT THE SPEAKER UNIT.

THE USE OF HORNS WITH CONE SPEAKERS

IN CASES WHERE IT IS DESIRED THAT THE CONE SPEAKER PROJECT ITS SOUNDS IN A DEFINITE DIRECTION, THEN THE SPEAKER UNIT CAN BE MOUNTED TO A SPECIALLY DESIGNED HORN, SUCH AS PICTURED IN FIG. 13.

THE HORN SHOWN IN FIG. 13 HAS AN OVERALL OUTSIDE LENGTH OF 48" AND A BELL OPENING OF 30 x 21½ INCHES.

A FRONT VIEW OF THIS SAME HORN IS SHOWN IN FIG. 14 AND HERE THE BAFFLE OPENING FOR THE SPEAKER CONE CAN BE SEEN AT THE INNER END. IN THIS CASE, THE BAFFLE IS ONLY SLIGHTLY LARGER THAN ITS HOLE, WHICH ACCOMMODATES THE SPEAKER'S MOUTH. AS YOU WILL NOTE IN THIS ILLUSTRATION, BOTH SIDES OF THIS HORN ARE FLARED, WHICH ENABLES IT TO COVER A LARGE AREA. THE TOP OF THE HORN, ON THE OTHER HAND, IS PRACTICALLY FLAT, WHICH ADDS TO THE ADVANTAGE OF KEEPING THE SOUND OFF THE CEILING.

THIS TYPE HORN PROVIDES GOOD RESULTS IN THEATERS AND OTHER INDOOR INSTALLATIONS, WHERE THE SOUND IS TO BE DIRECTED TOWARD THE AUDIENCE AND KEPT AWAY FROM THE WALLS AND CEILING AS MUCH AS POSSIBLE. IT IS ALSO SUITABLE

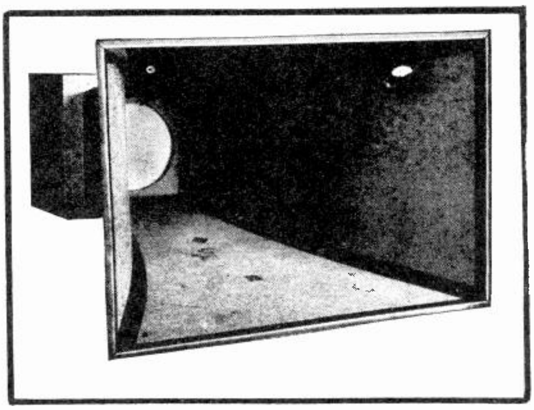

FIG. 14
Front View of Horn.

FOR OUTDOOR INSTALLATIONS, PROVIDED THAT THE DISTANCE TO BE COVERED IS NOT TOO GREAT. THAT IS, THIS HORN SPREADS THE SOUND OUT OVER A WIDE AREA BUT IS LIMITED AS TO THE DISTANCE COVERED.

IN FIG. 15 AN INTERESTING HORN DESIGN IS SHOWN, WHOSE CHIEF FEATURE IS TO PROJECT THE SOUNDS OVER A CONSIDERABLE DISTANCE. IT WILL NOT, HOWEVER, COVER AS BROAD AN AREA AS THE HORN WITH THE FLARED SIDES, WHICH IS SHOWN IN FIG. 14. BECAUSE OF THIS, IT WILL BE NECESSARY TO USE A GREATER NUMBER OF THE HORNS OF THE TYPE ILLUSTRATED IN FIG. 15, IN ORDER TO COVER THE SAME AREA AS IS POSSIBLE WITH THE HORN OF FIG. 14 BUT THE DISTANCE COVERED WILL BE GREATER.

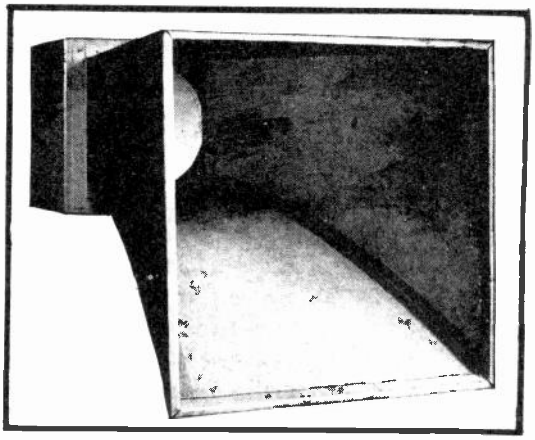

FIG. 15
Horn Design to Project Sound to Greater Distance.

THE HORN OF FIG. 15 CAN BE USED TO ADVANTAGE IN SOUND INSTALLATIONS MADE AT AIRPORTS, STADIUMS ETC. WHERE THE DISTANCE TO BE COVERED IS A VITAL FACTOR. FURTHERMORE, AN INSTALLATION IN LOCATIONS AS THIS OFFER THE REQUIRED SPACE, SO THAT SEVERAL OF SUCH SPEAKERS CAN BE CONVENIENTLY MOUNTED IN ORDER TO TAKE CARE OF A LARGE AREA.

NOT ONLY ARE THE HORN DESIGNS OF FIG. 14 AND 15 GOOD REPRODUCERS OF VOICE BUT OF MUSIC AS WELL. THE HORN OF FIG. 15 HAS AN OVERALL LENGTH OF 48 INCHES AND A BELL OPENING OF 23 x 22 INCHES.

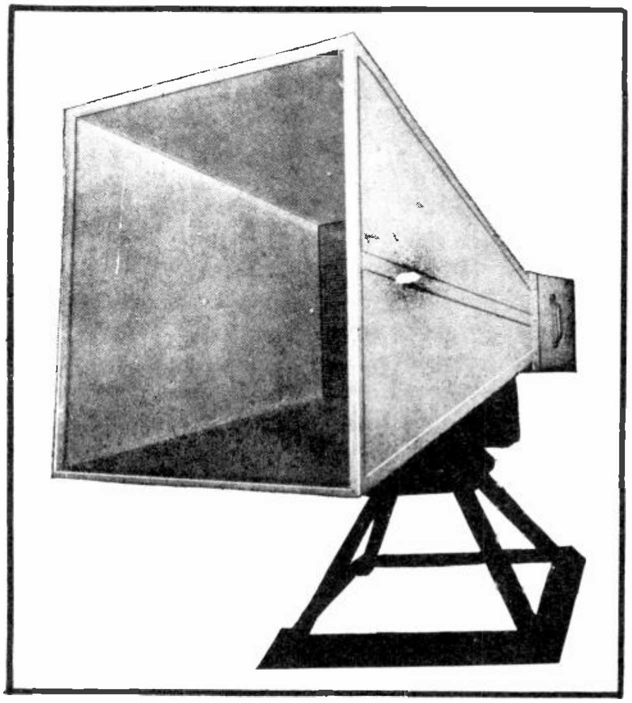

FIG. 16
Gigantic Speaker for Outdoor Use.

STILL ANOTHER TYPE OF HORN IS SHOWN IN FIG. 16 AND IT IS ESPECIALLY DESIGNED AND BUILT FOR OUTSIDE USE. THE HORN IS MADE OF THICK, STRONG, NON-RESONANT MATERIAL, REINFORCED WITH METAL. IT IS DOPED WITH A SPECIAL WATER-PROOFING MATERIAL WHICH WILL WITHSTAND THE SEVEREST KIND OF WEATHER AND ABUSE.

THE CONE TYPE ELECTRODYNAMIC SPEAKER UNIT, IS CONTAINED WITHIN A METAL WATER-PROOF COMPARTMENT AT THE SMALL END OF THE HORN. THE SPEAKER IN THIS CASE USES A WEATHER-PROOF CONE, WHICH IS PROTECTED BY A COPPER SCREEN. IT IS CLAIMED THAT THIS SPEAKER UNIT AND HORN COMBINATION CAN BE HEARD WITH EASE FOR A DISTANCE OF TWO OR THREE MILES, WHEN THE SPEAKER UNIT IS PROVIDED WITH AN OPERATING POWER OF 15 TO 30 WATTS.

This speaker can be mounted on top of an operator's room or tower and its mouth can be turned to any desired direction by the announcer. This horn is 7 ft. long and its height from the bottom of the base to the top of the horn is 6 ft. The width of the mouth is 4 ft. 1 inch and the width of the back is 16 inches. This gigantic speaker weighs about 480 lbs.

SPEAKER CONNECTIONS

For sound installations, where only a single speaker is used, we have practically the same problems to contend with as in the case of receivers. For instance, when using a dynamic speaker, the voice coil impedance should be matched to the impedance of the amplifier's output transformer secondary winding. That is to say, if the voice coil of the speaker being used has an impedance rating of 9 ohms, then the secondary winding of the output transformer, across whose terminals the voice coil is to be connected, must also have an impedance rating of 9 ohms. This you have already learned in your lessons pertaining to receivers.

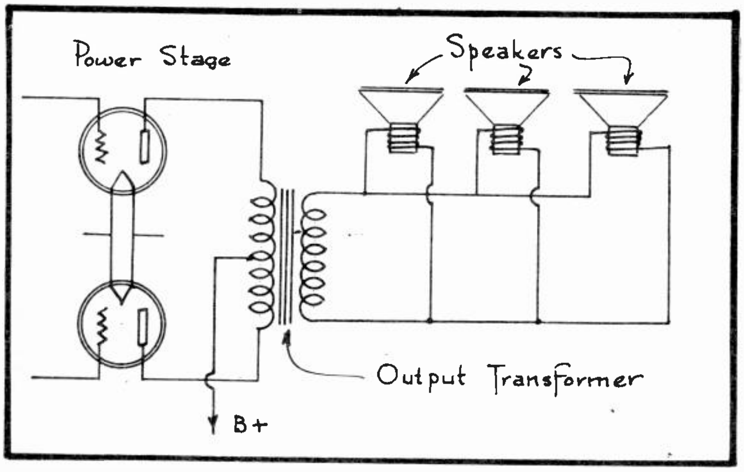

FIG. 17
Parallel-Connected Speakers.

In public address installations, it is the common practice to use more than one speaker and a variety of different speaker connections are being used in such cases to bring about the desired results. First, let us consider a parallel connection.

PARALLEL SPEAKER CONNECTION

In Fig. 17 you are shown one way in which three dynamic speakers may be connected in parallel. Assuming that each of the three speakers here used have a voice coil whose impedance rating is 9 ohms, then the total effective impedance of the three together will be equal to 1/3 of 9 or only 3 ohms. In other words, the total impedance of a parallel combination will in this instance be determined in the same manner as the total resistance of a parallel resistance combination — namely,

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ etc., or $\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}$ etc.

Since in the circuit of Fig. 17, the total impedance of the speaker voice coils amounts to 3 ohms, then the secondary winding of the output transformer here used must also have an impedance rating of 3 ohms. We then say that the impedances are "properly matched".

SERIES SPEAKER CONNECTION

Fig. 18 shows you how the same three speakers can be connected in

SERIES. HOWEVER, WITH THE SERIES CONNECTION, THE TOTAL IMPEDANCE OF THE SPEAKER VOICE COILS BECOMES EQUAL TO THE SUM OF THEIR INDIVIDUAL IMPEDANCES. IN OTHER WORDS, IF THE VOICE COIL IMPEDANCE OF EACH OF THE SPEAKERS IN FIG. 18 IS 9 OHMS, THEN THE THREE TOGETHER WILL OFFER AN IMPEDANCE OF 9+9+9=27 OHMS. (IN A SERIES CONNECTION $R=R_1+R_2+R_3$ ETC. OR $Z=Z_1+Z_2+Z_3$ ETC). THE SECONDARY WINDING OF THE OUTPUT TRANSFORMER FOR THIS ARRANGEMENT MUST THEREFORE, BE, 27 OHMS.

THEORETICALLY, THE DIVISION OF POWER BETWEEN THE PARALLEL OR SERIES SPEAKER ARRANGEMENT WILL BE THE SAME BUT IN ACTUAL PRACTICE, IT WILL BE MORE EVEN IN THE SERIES ARRANGEMENT, IN THAT THE CURRENT FLOW THROUGH EACH SPEAKER WILL IN THIS CASE BE THE SAME REGARDLESS OF THE LENGTHS OF CONNECTING WIRE USED BETWEEN THEM ETC. IN THE PARALLEL ARRANGEMENT, A SLIGHTLY HIGHER RESISTANCE IN ONE BRANCH WILL DEPRIVE THIS BRANCH OF THE PROPER PROPORTION OF POWER AND AT THE SAME TIME CAUSE AN EXCESS OF POWER TO BE IMPRESSED UPON THE OTHER SPEAKERS.

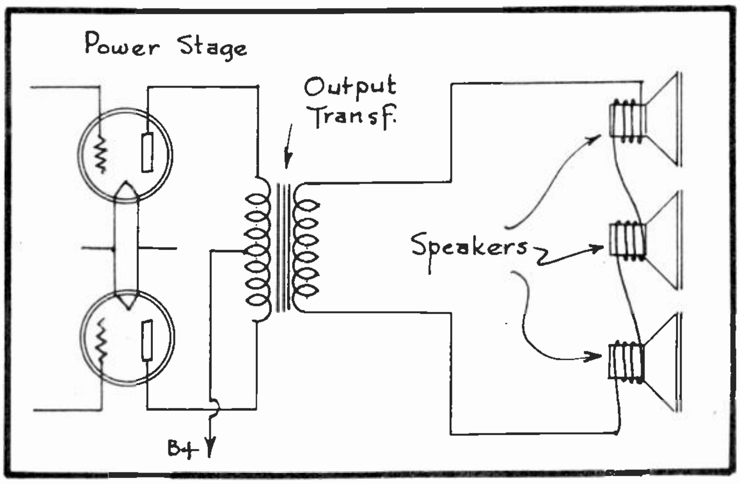

FIG. 18
Series-Connected Speakers.

IF A HIGH IMPEDANCE LOAD IS USED, SUCH AS A NUMBER OF MAGNETIC SPEAKERS AND HEADPHONES, THEN IF TOO MANY OF THESE ARE CONNECTED IN SERIES, THE TOTAL IMPEDANCE WILL BECOME SO HIGH AS TO BE IMPRACTICAL, HENCE A PARALLEL ARRANGEMENT WOULD HERE BE RESORTED TO. THEN ON THE OTHER HAND, IF LOW IMPEDANCE REPRODUCERS, SUCH AS DYNAMIC SPEAKERS ARE USED, WE FIND THAT IF TOO MANY OF THESE UNITS ARE CONNECTED IN PARALLEL, THE TOTAL IMPEDANCE WILL BECOME SO SMALL AS TO BE IMPRACTICABLE. THEREFORE, TO HAVE A SPEAKER LOAD WHOSE TOTAL IMPEDANCE IS NEITHER TOO HIGH NOR TOO LOW FOR PRACTICAL PURPOSES, A SERIES-PARALLEL ARRANGEMENT OF SPEAKERS IS USUALLY EMPLOYED.

SERIES-PARALLEL SPEAKER CONNECTION

A SERIES-PARALLEL CONNECTION OF SPEAKERS IS SHOWN YOU IN FIG. 19. HERE WE HAVE NINE SPEAKERS — THREE SPEAKERS ARE CONNECTED IN SERIES IN EACH GROUP AND THE THREE GROUPS ARE CONNECTED IN PARALLEL ACROSS THE SECONDARY WINDING OF THE OUTPUT TRANSFORMER.

IF EACH OF THE SPEAKERS HERE USED HAS A VOICE COIL IMPEDANCE OF 9 OHMS, THEN THE TOTAL IMPEDANCE OF EACH SERIES GROUP WILL BE 3 x 9 OR 27 OHMS. THEN SINCE THREE SUCH GROUPS OF 27 OHMS EACH ARE CONNECTED IN PARALLEL, THE TOTAL IMPEDANCE OF THE ENTIRE COMBINATION WILL BE 27 ÷ 3 OR 9 OHMS. THIS, YOU WILL NOTICE, IS THE SAME IMPEDANCE VALUE AS OFFERED BY ANY ONE OF THE SPEAKERS ALONE. THE SECONDARY WINDING OF THE OUTPUT TRANS-

FORMER WILL IN THIS CASE THEN HAVE TO BE RATED AT 9 OHMS.

TRANSMISSION LINES

ALL OF THE SPEAKER CIRCUITS SO FAR SHOWN YOU IN THIS LESSON ARE SUCH THAT THE VOICE COILS OF THE SPEAKERS ARE CONNECTED DIRECTLY ACROSS THE SECONDARY WINDING OF THE OUTPUT TRANSFORMER AND THE ENTIRE SPEAKER CIRCUIT IS THUS OF A LOW-IMPEDANCE ORDER. IF THE NATURE OF THE INSTALLATION IS SUCH THAT THE SPEAKERS ARE LOCATED AT A CONSIDERABLE DISTANCE FROM THE AMPLIFIER AND THEREBY REQUIRING WIRES OF CONSIDERABLE LENGTH BETWEEN THESE TWO POINTS, THEN WE RUN INTO DIFFICULTIES, WHEN USING SPEAKER CIRCUITS AS SO FAR ILLUSTRATED.

THE RUN OF WIRES BETWEEN THE OUTPUT OF THE AMPLIFIER AND THE SPEAKERS IS KNOWN AS THE TRANSMISSION LINE. IF THE TRANSMISSION LINE IS OF THE LOW-IMPEDANCE TYPE, AS WILL BE THE CASE IN THE CIRCUITS SO FAR ILLUSTRATED, WE HAVE THE FOLLOWING CONDITIONS TO CONTEND WITH:

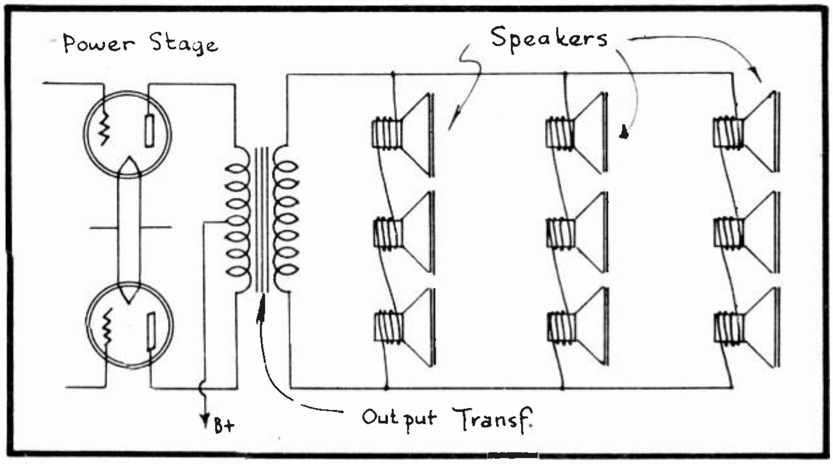

FIG. 19
Series-Parallel Connection of Speakers

THE CHARACTERISTICS OF A LOW-IMPEDANCE TRANSMISSION LINE (AROUND 8 TO 16 OHMS) ARE AS FOLLOWS:

(1) LOW VOLTAGE AND HIGH CURRENT.

(2) STRONG ELECTROMAGNETIC FIELDS AROUND THE WIRES WHICH MAY CAUSE FEED-BACK OR CROSS-TALK.

(3) D.C. RESISTANCE OF LINES (DUE TO LENGTH) IS APPRECIABLE AND RESULTS IN A LOSS OF POWER.

TO OVERCOME THESE UNDESIRABLE CONDITIONS, IT IS THE COMMON PRACTICE TO USE TRANSMISSION LINES OF HIGHER IMPEDANCE FOR INSTALLATIONS OF THE TYPE NOW BEING CONSIDERED AND SO THAT THE IMPEDANCES WILL THEREBY NOT BE MIS-MATCHED BETWEEN THE AMPLIFIER AND THE SPEAKERS, TWO SPECIAL IMPEDANCE-MATCHING TRANSFORMERS ARE USED IN THE MANNER ILLUSTRATED IN FIG. 20.

TRANSMISSION LINES OF HIGH-IMPEDANCE VALUES SUCH AS 5000 OHMS OR HIGHER HAVE THE FOLLOWING CHARACTERISTICS:-

(1) HIGH VOLTAGE AND LOW CURRENT.

(2) WEAK ELECTROMAGNET FIELDS.

(3) POWER LOST DUE TO CURRENT BEING OPPOSED BY D.C. RESISTANCE OF TRANSMISSION LINE NEGLIGIBLE.

(4) CAPACITIVE EFFECT BETWEEN THE TWO LINES APPRECIABLE.

THE FIRST THREE CHARACTERISTICS OF THE HIGH IMPEDANCE TRANSMISSION LINE ARE DESIRABLE, WHEREAS THE LAST MENTIONED CHARACTERISTIC IS HIGHLY UNDESIRABLE DUE TO THE BY-PASSING EFFECT OF THE HIGHER FREQUENCIES BETWEEN THE LINES.

IN ACTUAL INSTALLATION PRACTICE, A COMPROMISE IS THEREFORE MADE BETWEEN A LOW AND HIGH IMPEDANCE TRANSMISSION LINE AND RATINGS OF 200 TO 600 OHMS HAVE BEEN FOUND TO BE IDEAL. TRANSMISSION LINES OF 500 OHMS ARE MOST COMMONLY USED FOR PUBLIC ADDRESS WORK.

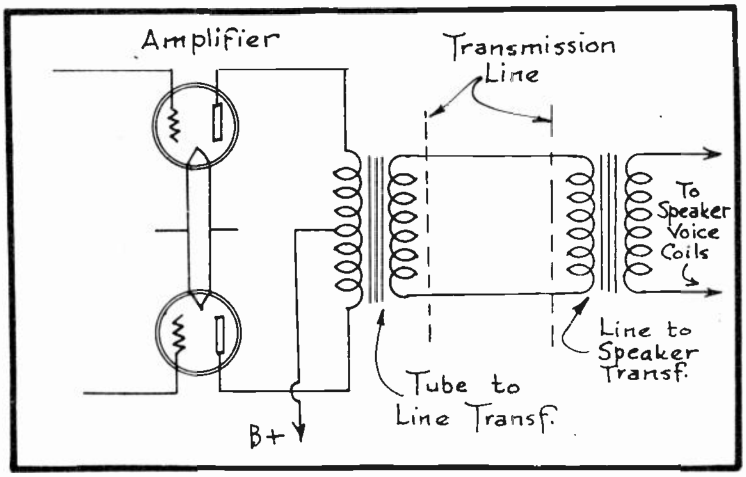

FIG. 20
Application of Transmission Line.

WITH THIS INFORMATION IN MIND, LET US RETURN TO FIG. 20. HERE WE FIND THAT IF A 500 OHM TRANSMISSION LINE IS BEING USED, THEN THE OUTPUT TRANSFORMER OF THE AMPLIFIER, OR THE "TUBE TO LINE TRANSFORMER" IN THIS CASE, WOULD HAVE A PRIMARY WINDING WHOSE IMPEDANCE IS MATCHED TO THE PLATE CIRCUIT OF THE POWER TUBES, WHEREAS ITS SECONDARY WINDING WOULD BE RATED AT 500 OHMS. THE "LINE TO SPEAKER TRANSFORMER", ON THE OTHER HAND, WILL IN THIS CASE HAVE A PRIMARY WINDING WHOSE IMPEDANCE RATING IS 500 OHMS TO MATCH THE SECONDARY OF THE PRECEDING TRANSFORMER AND THE SECONDARY WINDING WILL HAVE AN IMPEDANCE RATING TO CONFORM WITH THE TOTAL VOICE COIL IMPEDANCE CALLED FOR BY THE PARTICULAR SPEAKER COMBINATION.

MULTIPLE SPEAKER TRANSFORMERS

IN FIG. 21 YOU ARE SHOWN A GOOD METHOD OF CONNECTING A GROUP OF SPEAKERS TO A TRANSMISSION SYSTEM. IN THIS EXAMPLE, EACH SPEAKER HAS ITS INDIVIDUAL INPUT TRANSFORMER MOUNTED DIRECTLY AT THE SPEAKER AND THE PRIMARY WINDING OF THE INPUT TRANSFORMER OF EACH OF THE FIVE SPEAKERS BEING USED HAS AN IMPEDANCE RATING OF 2500 OHMS. SINCE FIVE OF THIS WINDINGS ARE CONNECTED IN PARALLEL ACROSS THE TRANSMISSION LINE, THEIR TOTAL OR COMBINED IMPEDANCE WILL BE 1/5 OF 2500 OHMS OR 500 OHMS. THIS COMBINED OR EFFECTIVE LOAD IMPEDANCE OF 500 OHMS WILL THEREFORE MATCH THE 500 OHM IMPEDANCE RATING OF THE AMPLIFIER TO LINE TRANSFORMER'S SECONDARY WINDING. THE SECONDARY WINDING OF EACH OF THE SPEAKER INPUT TRANSFORMERS WILL OF COURSE HAVE ITS IMPEDANCE MATCHED TO THAT OF THE VOICE COIL TO WHICH IT IS CONNECTED.

ANOTHER METHOD OF COUPLING A GROUP OF SPEAKERS HAVING INDIVIDUAL SPEAKER INPUT TRANSFORMERS TO THE TRANSMISSION LINE IS ILLUSTRATED FOR YOU IN FIG. 22. HERE THE PRIMARY WINDINGS OF THE SPEAKER INPUT TRANSFORM-

ERS ARE CONNECTED IN A SERIES-PARALLEL ARRANGEMENT. IF EACH OF THESE PRIMARY WINDINGS HAVE AN IMPEDANCE RATING OF 500 OHMS, THE TOTAL IMPEDANCE OF EACH SERIES GROUP WILL BE EQUAL TO 500+500 OR 1000 OHMS BUT SINCE TWO OF THESE SERIES GROUPS ARE CONNECTED IN PARALLEL, THEIR COMBINED EFFECTIVE IMPEDANCE WILL BE 1000÷2 OR 500 OHMS, WHICH IS THE SAME AS THAT OF ANY ONE OF THESE WINDINGS ALONE. THEREFORE, IN ORDER FOR THE ENTIRE SPEAKER CIRCUIT TO BE PROPERLY MATCHED TO THE SECONDARY WINDING OF THE AMPLIFIER TO LINE TRANSFORMER, THIS LATTER WINDING MUST HAVE AN IMPEDANCE RATING OF 500 OHMS.

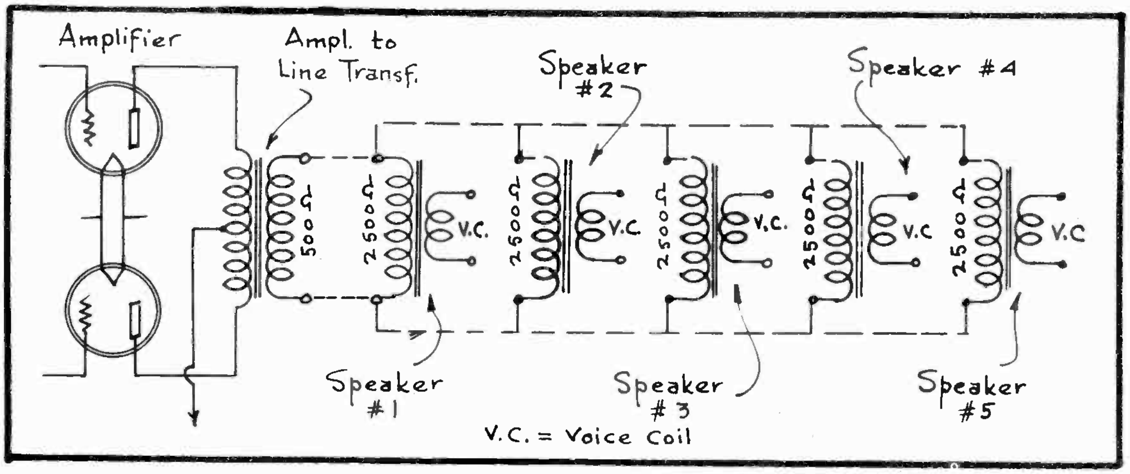

FIG. 21
A Five-Speaker System.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE DIFFERENT TYPES OF SPEAKERS AND HORNS, AS WELL AS THE VARIOUS METHODS OF CONNECTING MULTIPLE SPEAKERS TO THE AMPLIFIER OF A PUBLIC ADDRESS INSTALLATION.

IN THE FOLLOWING LESSON, YOU ARE GOING TO ENGAGE IN THE STUDY OF A MOST INTERESTING SUBJECT—NAMELY ACOUSTICS. HERE YOU WILL LEARN HOW SOUND AMPLIFYING EQUIPMENT CAN BE USED TO THE BEST ADVANTAGE IN THE MORE DIFFICULT INSTALLATIONS BY REDUCING ECHOES, REVERBERATION AND DEAD SPOTS TO A MINIMUM. NOT ONLY WILL YOU FIND THIS NEXT LESSON OF SPECIAL INTEREST BUT IT IS ALSO EXCEEDINGLY IMPORTANT IN THAT IT DEALS WITH A SUBJECT WHICH IS LITTLE UNDERSTOOD BY THE AVERAGE TECHNICIAN.

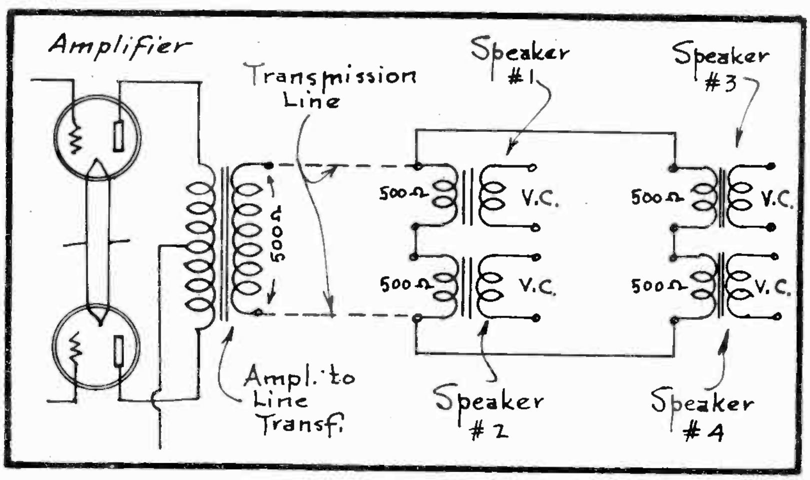

FIG. 22
Series- Parallel Speaker Connections.

Examination Questions

Ans Mar. 30

LESSON NO. AS-3

1. – For what type of sound system installation are trumpet type magnetic speakers best suited?

2. – Describe a dynamic speaker unit of the type suitable for use with a trumpet or exponential horn.

3. – What form of horn is best suited for a cone dynamic speaker? State the reason for your answer.

4. – Why are high frequency speakers used in some instances?

5. – Illustrate by means of a diagram how a group of three dynamic speakers may have their voice coils connected to the secondary winding of a single output transformer. (Indicate impedance values on your diagram.)

6. – What are the chief advantages of using a 500 ohm transmission line between the output of the amplifier and the speakers of a public address system?

7. – Draw a circuit diagram, showing how four speakers, having individual input transformers, may be connected to a common transmission line and show how the impedances are matched.

8. – What type of speaker installation would you prefer to use if faithfulness of reproduction is the most important characteristic desired?

9. – How do the cone dynamic speakers, as used for public address work, differ from this same type of speaker as used in conjunction with a radio receiver?

10. – Describe an exponential horn. What other name is sometimes used for a speaker employing an exponential horn?

Success Secrets

The man who thinks he has no chance destroys his chances by acknowledgment of self-defeat.

The world is filled with good brains which have missed the opportunity of training.

You say that you deserve success—then prove it.

Present your facts—show results, but don't rest your case with words.

Dishonesty doubles the journey to success.

A crooked path must always be longer than a straight one.

There's only one way that's right, and all the other ways are wrong.

Good ideas are only seeds. They must be planted and tilled before they can produce.

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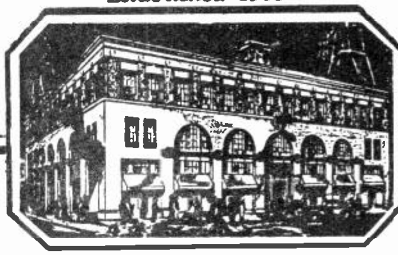

J. A. ROSENKRANZ, Pres.

Amplifying Systems

LESSON NO. 4

• ACOUSTICS •

ALTHOUGH AN EXCELLENT SOUND AMPLIFYING SYSTEM MAY BE DESIGNED AND CONSTRUCTED, YET THE INSTALLATION AS A WHOLE MAY BE A FAILURE IF THE ACOUSTIC CONDITIONS ARE NOT SATISFACTORY. THEREFORE, IF THE BEST OF RESULTS ARE TO BE EXPECTED FROM ANY SOUND SYSTEM, IT IS IMPERATIVE THAT THE ENGINEER IN CHARGE OF THE INSTALLATION WORK HAVE A GOOD UNDERSTANDING OF ACOUSTICS.

BY ACOUSTICS IS MEANT THE SCIENCE OF SOUND AND IN THIS LESSON WE SHALL TREAT THIS SUBJECT FROM AN ANGLE OF CLEAR AND INTELLIGIBLE REPRODUCTION. TO MAKE THIS POSSIBLE, THE SPEAKER MUST BE INSTALLED AT THE MOST ADVANTAGEOUS POSITIONS SO AS TO DISTRIBUTE THE SOUND OVER THE DESIRED AREA UNIFORMLY AND IF THE SYSTEM BE INSTALLED IN AN AUDITORIUM, HALL OR ANY OTHER SPACIOUS ENCLOSURE OR EVEN IN THE OPEN AIR FOR THAT MATTER, PROPER STEPS MUST BE TAKEN SO AS TO REDUCE ECHOES, REVERBERATION, DEAD SPOTS ETC.

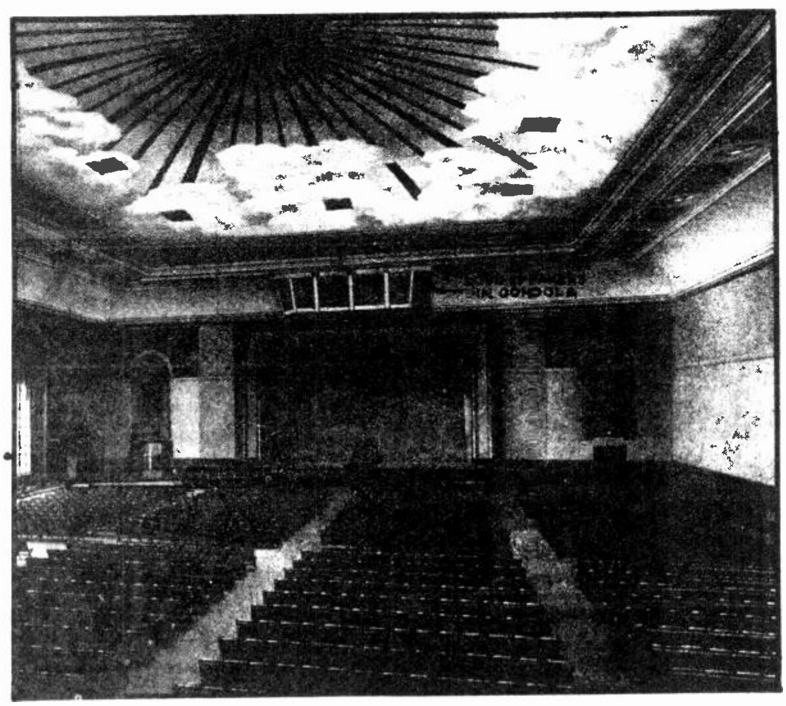

FIG. 1

An Auditorium Equipped With An Amplifying System.

FRANKLY, THE TASK OF CREATING THE PROPER ACOUSTIC CONDITIONS IS FREQUENTLY THE MOST DIFFICULT PROBLEM OF THE ENTIRE INSTALLATION AND ALTHOUGH THE RULES AND FORMULAS AS PRESENTED TO YOU IN THIS LESSON WILL BE OF GREAT HELP IN THE ACOUSTIC TREATMENT OF

HALLS, AUDITORIUMS, ETC., YET YOU SHOULD BEAR IN MIND THAT CONSIDERABLE EXPERIMENT MUST ALSO FREQUENTLY BE RESORTED TO DURING THE PROGRESS OF THE INSTALLATION WORK, IN ORDER TO BRING ABOUT THE DESIRED RESULTS.

REVERBERATION

No doubt, you have already experienced the difference which exists in sounds when heard in an empty room or auditorium as compared to the nature of sounds when produced in the same room or auditorium after it has been fully furnished or when a crowd of people is present. This is one of the acoustical conditions with which the sound engineer must deal.

Sound, you will recall, consists of vibrations of air or "waves", as we generally call them, and they are reflected readily whenever they strike bare walls or hard surfaces. In Fig. 2, for instance, we have a simple diagram which illustrates the different paths which sound waves may follow from the time they leave their source until they reach the ears of the listeners.

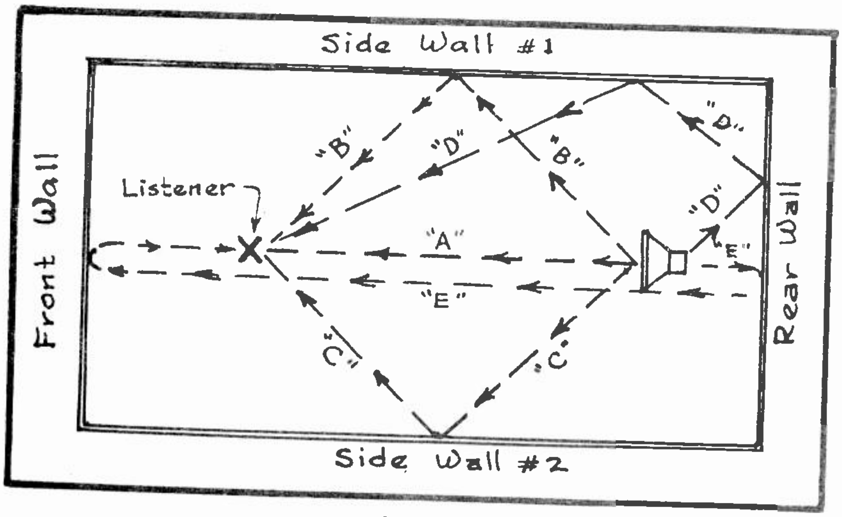

FIG. 2
Typical Paths Which Sound Waves May Travel in a Room.

Consider Fig. 2 as representing a hall, such as a dance hall or gymnasium and where the walls, floor, and ceiling are all bare and made of relatively hard finished material. Also visualize this hall as being empty of all furnishings and that the source of sound and one listener or observer are the only objects present.

First let us consider the path "A" in Fig. 2, which represents the most direct route by which sound waves may travel from the source to the listener. This is the most desirable sound path which we can have and will result in a faithful reproduction of the sound at the ears of the listener. However, when the listener is located at an appreciable distance from the source of the sound, large amounts of sound energy will reach him by way of the reflected paths. One of these paths, for example, is marked as "B" in Fig. 2 and in this case the sound travels towards side wall #1 and from which it is reflected towards the listener. We have a similar condition where the sound waves travel the route "C", strike side wall #2 and are then reflected towards the listener.

Another possible path is offered by route "E", where a sound wave is started towards the rear of the source, strikes the rear wall, and is reflected towards the observer, while some of it even passes the listener, strikes the front wall and is again reflected towards him so that he actually hears the sound coming from behind. These are just some of the paths which the sound waves may travel in a room of the type described,

YET ACTUALLY ANY NUMBER OF ADDITIONAL PATHS MAY ALSO BE OFFERED SUCH AS FLOOR REFLECTIONS, CEILING REFLECTIONS AND VARIED REFLECTIONS FROM ALL POSSIBLE ANGLES.

AS YOU WILL NO DOUBT NOW AGREE, A COMPLEX CONDITION EXISTS AND THE LISTENER IS LITERALLY "SWARMED" WITH A MULTITUDE OF SOUND WAVES STRIKING HIS EARS FROM ALL DIRECTIONS. SINCE SOUND WAVES TRAVEL THROUGH AIR AT A DEFINITE SPEED (APPROXIMATELY 1100 FT. PER SECOND) IT STANDS TO REASON THAT WHEN A GIVEN SOUND IS PRODUCED, CORRESPONDING WAVES WILL REACH THE LISTENER AT DEFINITE INTERVALS OVER A PERIOD OF TIME, DEPENDING UPON THE DISTANCE EACH OF THE MANY REFLECTED WAVES TRAVEL FROM THE SOURCE UNTIL THEY REACH THE EARS OF THE LISTENER. THIS RESULTS IN A CONDITION WHERE THE SOUND PERSISTS FOR SOME TIME AFTER IT HAS BEEN PRODUCED RATHER THAN TO DIE DOWN OR DISAPPEAR IMMEDIATELY AFTER THE SOUND IS STOPPED AT THE SOURCE. THIS TENDENCY FOR THE SOUND TO PERSIST OVER A DEFINITE PERIOD OF TIME AFTER IT HAS BEEN PRODUCED ORIGINALLY AND STOPPED AT THE SOURCE IS KNOWN AS REVERBERATION.

VARIOUS EFFECTS OF REFLECTIONS UPON OBSERVED SOUND

NOT ONLY WILL THE REFLECTION OF SOUND WAVES PRODUCE REVERBERATION BUT IN ADDITION, SEVERAL OTHER PRINCIPAL EFFECTS WILL RESULT FROM THIS CONDITION. FOR EXAMPLE, THE AVERAGE INTENSITY OF THE SOUND AS HEARD BY THE LISTENER WILL BE INCREASED SINCE THE SOUND ORIGINALLY RADIATED IN OTHER DIRECTIONS IS REFLECTED BACK TO THE LISTENER. ANOTHER INTERESTING FACT IS THAT SELECTIVE ABSORPTION OF CERTAIN REFLECTING SURFACES TEND TO REFLECT LOW FREQUENCIES MORE THAN THE HIGHER FREQUENCIES AND THIS WILL ALTER THE RELATIVE AMPLITUDES OF THE DIFFERENT FREQUENCY COMPONENTS OF THE SOUND.

SOUND REFLECTIONS AS JUST DESCRIBED WILL ALSO ALTER THE RELATIVE AMPLITUDE OF THE DIFFERENT FREQUENCY COMPONENTS OF THE SOUND DUE TO THE INTERFERENCE EFFECTS WHICH RESULT FROM THE FACT THAT THE PHASE WITH WHICH THE ENERGY TRAVELING ALONG THE DIFFERENT POSSIBLE PATHS COMBINES AND DEPENDS UPON THE FREQUENCY OF THE SOUND AND THE POSITION OF THE LISTENER.

REVERBERATION TIME

THE NUMBER OF SECONDS, OR FRACTION OF A SECOND, WHICH IS REQUIRED FOR THE SOUND TO DIE OUT AFTER THE SOURCE OF SOUND CEASES IS KNOWN AS THE REVERBERATION TIME AND IS MEASURED IN SECONDS. THE FORMULA FOR CALCULATING THE REVERBERATION TIME IS $T = \frac{.05V}{A}$; WHERE T = THE REVERBERATION TIME IN SECONDS; V = THE VOLUME OF THE ROOM OR AUDITORIUM; A = THE TOTAL UNITS OF ABSORPTION IN THE ROOM OR AUDITORIUM AND THE VALUE .05 IS A CONSTANT.

THE VALUE V TO USE FOR ANY GIVEN PROBLEM IS DETERMINED BY MULTIPLYING TOGETHER THE LENGTH OF THE ROOM OR HALL BY ITS WIDTH AND THEN MULTIPLYING THIS VALUE BY ITS HEIGHT. IF A BALCONY IS EMPLOYED IN THE ROOM IN QUESTION, THEN THE AVERAGE HEIGHT IS USED, DEDUCTIONS BEING MADE FOR THE FLOOR SPACE EXISTING BETWEEN ORCHESTRA AND BALCONY AND BETWEEN BALCONIES.

THE TOTAL UNITS OF ABSORPTION OR "A" OF THE FORMULA IS DETERMINED BY FIRST MEASURING THE SQUARE FOOTAGE OF EVERY TYPE OF MATERIAL USED IN THE SURFACE CONSTRUCTION OF THE ROOM AND MULTIPLYING IT BY ITS COEFFICIENT

OF ABSORPTION. THE VARIOUS PRODUCTS THUS OBTAINED FOR THE TOTAL ABSORPTION OF EACH TYPE OF SURFACE ARE THEN ADDED TOGETHER TO OBTAIN THE TOTAL ABSORPTION OF ALL OF THE VARIOUS TYPES OF SURFACES TOGETHER. THIS THEN, WILL BE THE ACTUAL ABSORPTION OF THE ENTIRE ROOM AND IS TO BE USED FOR THE VALUE "A" IN OUR FORMULA FOR CALCULATING THE REVERBERATION TIME.

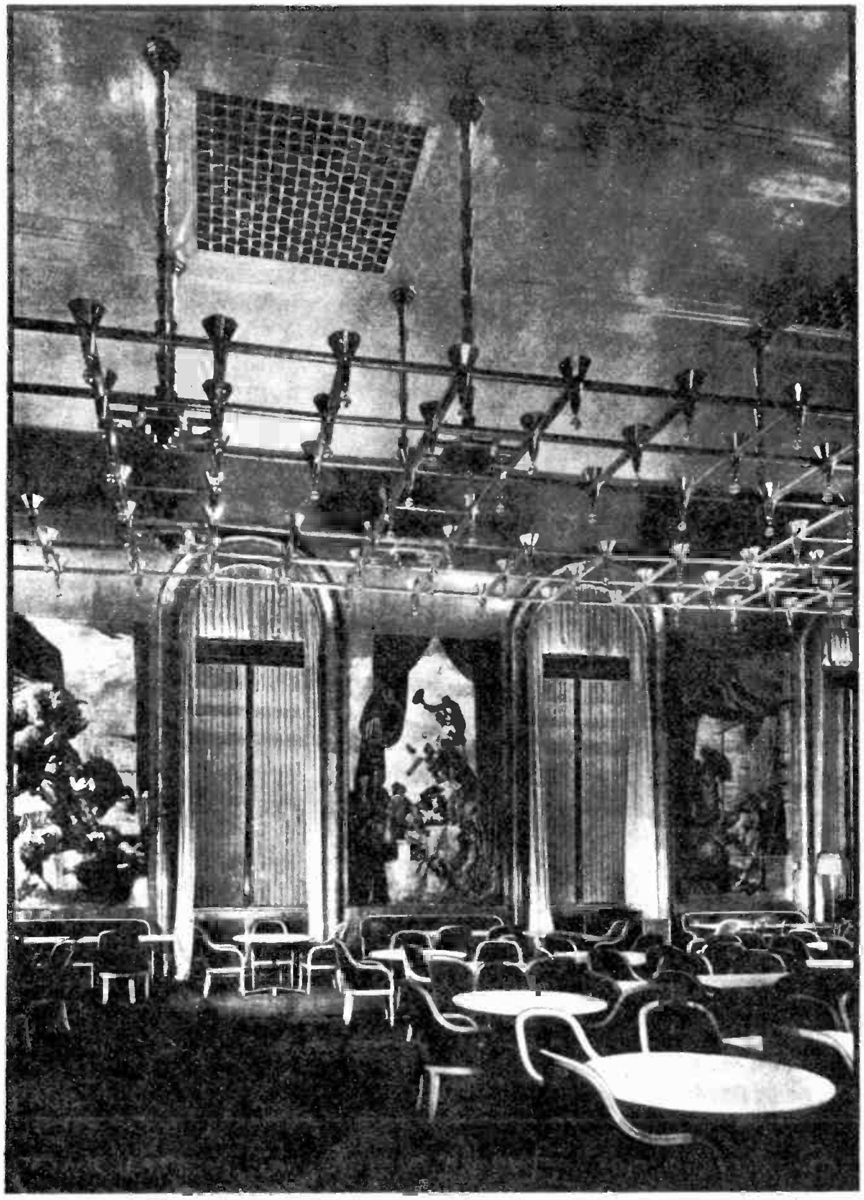

FIG. 3
A Dining Room With Sound Installation— Loud Speakers are Concealed Behind Grill in Ceiling.

THE COEFFICIENTS OF SOUND ABSORPTION HAVE BEEN DETERMINED FOR PRACTICALLY ALL MATERIALS AND YOU ARE GIVEN A LIST OF THEM IN TABLE I. IN THIS TABLE EACH SQUARE FOOT OF THE MATERIAL DESIGNATED IS RATED BY COMPARISON WITH ONE SQUARE FOOT OF OPEN WINDOW SPACE, WHICH IS ACCEPTED AS 100% ABSORPTIVE AND THEREFORE HAS A COEFFICIENT OF UNITY.

CALCULATIONS

TO ILLUSTRATE THE ACTUAL APPLICATION OF THE REVERBERATION TIME FORMULA, LET US WORK OUT A SPECIFIC PROBLEM.

IN FIG. 4 WE HAVE A TOP AND SIDE VIEW OF AN AUDITORIUM WHOSE ACOUSTIC CONDITIONS ARE TO BE ANALIZED. THE LENGTH OF THIS AUDITORIUM IS 75 FEET AND ITS WIDTH IS 55 FEET. THE AVERAGE HEIGHT IS 30 FT. THE TOTAL VOLUME OF THIS AUDITORIUM WILL THEN BE EQUAL TO 75 x 55 x 30 = 123,750 CUBIC FEET.

THE FLOOR SPACE WILL BE EQUAL TO APPROXIMATELY 75' x 55' = 4125 SQ. FEET. OF THIS TOTAL FLOOR SPACE, LET US SUPPOSE THAT 1000 SQUARE FEET

IS UTILIZED FOR AISLES WHICH LEAVES, 4125 MINUS 1000 OR ABOUT 3125 SQUARE FEET OF ACTUAL FLOOR SPACE TO ACCOMMODATE SEATS.

THE FLOOR SPACE FOR SEATS IN THIS PARTICULAR AUDITORIUM IS MADE OF UNFINISHED WOOD WHICH ACCORDING TO TABLE I HAS A COEFFICIENT OF ABSORPTION OF 0.061. THEREFORE, THE TOTAL ABSORPTION FOR THIS FLOOR SPACE IS EQUAL TO 0.061 x 3125 = 190.6 UNITS OF ABSORPTION. HOWEVER, SINCE SEATS ARE MOUNTED ABOVE THIS FLOOR SPACE, THEY WILL BE ABOUT 75% EFFECTIVE IN CANCELLING OUT FLOOR ABSORPTION BECAUSE THEY COVER THE GREATER PORTION OF THE FLOOR. THEREFORE, THE TOTAL FLOOR ABSORPTION WILL AMOUNT TO ONLY ABOUT 25% OF 190.6 OR APPROXIMATELY 48 UNITS.

A TOTAL OF 425 SEATS ARE PROVIDED IN THIS AUDITORIUM AND THEY ARE OF THE PARTLY UPHOLSTERED TYPE AND ACCORDING TO TABLE I, SEATS OF THIS TYPE EACH HAVE A COEFFICIENT OF ABSORPTION OF 1.6. THEREFORE, THE TOTAL ABSORPTION OF THE SEATS WILL AMOUNT TO 425 x 1.6=680 UNITS.

THE TOTAL AREA OF THE CEILING AND WALLS FOR THIS AUDITORIUM, WE SHALL ASSUME HAS THROUGH ACTUAL MEASUREMENT AND CALCULATION BEEN FOUND TO BE EQUAL TO 10,000 SQUARE FEET AND WHICH IN THE GREATER PARTS CONSISTS OF A PLASTER AND GLASS SURFACE. FROM TABLE I WE SHALL CHOOSE A COEFFICIENT OF ABSORPTION OF .03 FOR THIS SURFACE. THUS THE TOTAL ABSORPTION FOR THE WALLS AND CEILING BECOMES .03 x 10,000 = 300 UNITS.

THE STAGE FLOOR MEASURES 35' x 20' AND SO ITS TOTAL AREA BECOMES 35' x 20' = 700 SQUARE FEET. THIS FLOOR IS MADE OF VARNISHED WOOD WHICH ACCORDING TO TABLE I HAS A COEFFICIENT OF ABSORPTION OF .03 AND SO THE TOTAL ABSORPTION OF THE FLOOR IS 700 x .03=21 UNITS.

AS YOU WILL RECALL, 1000 SQUARE FEET OF THIS AUDITORIUM'S TOTAL FLOOR SPACE IS ALLOTED TO AISLES AND WHICH ARE COVERED WITH CARPET AND

TABLE I

COEFFICIENTS OF ABSORPTION

MATERIAL	UNITS PER SQUARE FOOT
OPEN WINDOW	1.00
PLASTER	.025 TO .034
CONCRETE	.015
BRICK SET IN PORTLAND CEMENT	.025
MARBLE	.01
GLASS, SINGLE THICKNESS	.027
WOOD SHEATHING	.061
WOOD, VARNISHED	.03
CORK TILE	.03
LINOLEUM	.03
CARPETS	.15 TO .29
CRETONNE CLOTH	.15
CURTAINS IN HEAVY FOLDS	.50 TO 1.00
HAIRFELT ½" (JOHNS-MANVILLE)	.31
HAIRFELT 1" (JOHNS-MANVILLE)	.59
FLAXLINUM ½"	.34
SABINITE ACOUSTICAL PLASTER	.21
ACOUSTI-CELOTEX, TYPE BB, PAINTED OR UNPAINTED	.70
ACOUSTI-CELOTEX, TYPE B, PAINTED OR UNPAINTED	.47
SANACOUSTIC TILE 1" ROCK WOOL FILLER	.74
NASHKOTE, TYPE A, 3/4" THICK	.27
INDIVIDUAL OBJECTS	
AUDIENCE, PER PERSON	4.7
PLAIN CHURCH PEWS LINEAR FT.	.18
UPHOLSTERED CHURCH PEWS PER LINEAR FT.	UP TO 1.6
PLAIN PLYWOOD AUDITORIUM CHAIRS, EACH	.24
PART UPHOLSTERED CHAIRS	1.6
COMPLETELY UPHOLSTERED CHAIRS	3.0

WHICH HAS A COEFFICIENT OF ABSORPTION OF 0.25. THE TOTAL ABSORPTION OF THE CARPET-COVERED AREA THUS AMOUNTS TO 1000 x .25 = 250 UNITS.

WE HAVE NOW ACCOUNTED FOR THE ABSORPTION OF EACH TYPE OF EFFECTIVE SURFACE EMPLOYED IN THIS AUDITORIUM. OUR NEXT STEP THEN, IS TO ADD TOGETHER ALL OF THESE VARIOUS UNITS. THUS WE HAVE:

WOOD FLOOR	48 UNITS
SEATS	680 UNITS
CEILING AND WALLS	300 UNITS
STAGE FLOOR	21 UNITS
CARPET FLOOR	250 UNITS
TOTAL	1299 UNITS

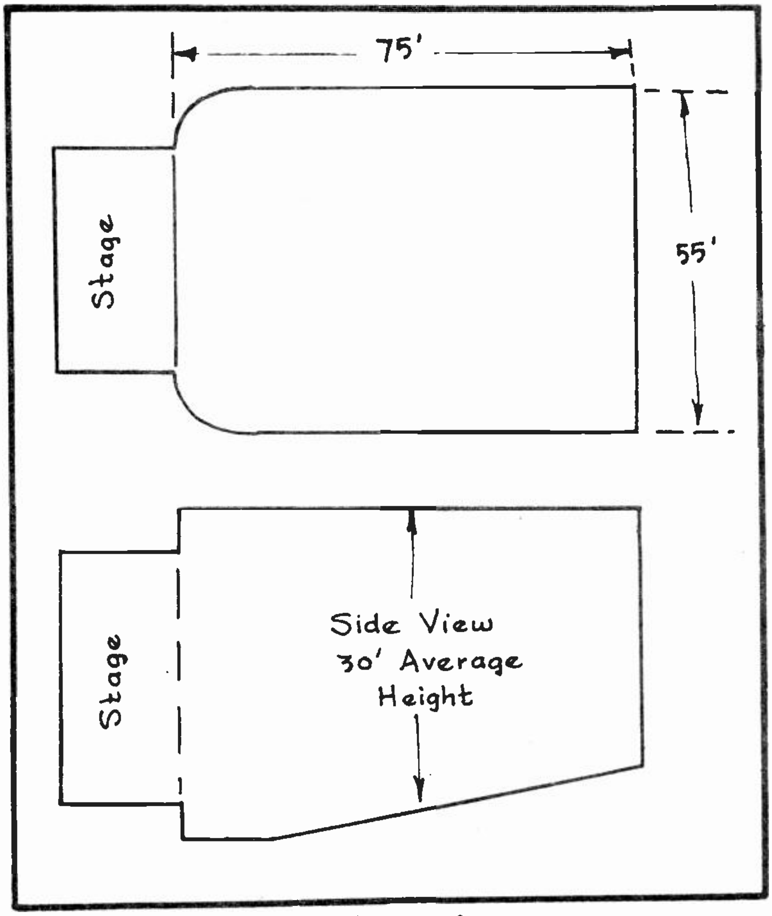

FIG. 4
Working Plan of Auditorium.

OUR TOTAL UNITS OF ABSORPTION OR "A" THUS BECOMES 1299 UNITS.

SUBSTITUTING THE VALUES NOW AVAILABLE IN OUR FORMULA $T = \frac{.05V}{A}$, WE HAVE $T = \frac{.05 \times 123,750}{1299} = \frac{6187.5}{1299} = 4.76$ SECONDS.

THIS BRINGS US UP TO THE POINT WHERE WE MUST TAKE INTO ACCOUNT THE OPTIMUM REVERBERATION TIME FOR ANY TYPE OF INSTALLATION. IN OTHER WORDS, WE MUST HAVE SOME SYSTEM WHEREBY WE CAN ASCERTAIN WHAT THE REVERBERATION SHOULD BE FOR ANY INSTALLATION SO THAT THE ACOUSTIC CONDITIONS WILL BE SATISFACTORY FROM THIS STANDPOINT. IN TABLE II YOU ARE GIVEN A LIST WHICH SPECIFIES THE OPTIMUM PERIODS OF REVERBERATION FOR ENCLOSURES OF VARIOUS VOLUMES.

BY REFERRING TO TABLE II AND COMPARING THE REVERBERATION TIME OF 4.76 SECONDS WHICH WE HAVE CALCULATED FOR OUR SAMPLE PROBLEM WITH THE VALUES GIVEN IN TABLE II, WE FIND THAT THE OPTIMUM PERIOD OF REVERBERATION FOR OUR AUDITORIUM OF 123,750 CUBIC FEET VOLUME SHOULD BE APPROXIMATELY 1.4 SECONDS. WE THUS NOTE THAT OUR CALCULATED VALUE OF 4.76 SECONDS IS RATHER HIGH FOR OPTIMUM CONDITIONS BUT WE MUST BEAR IN MIND THAT OUR CAL-

CULATIONS WERE BASED ON THE FACT THAT NO AUDIENCE IS PRESENT AND WHICH OF COURSE IS NOT A NORMAL CONDITION WHEN THE AUDITORIUM IS IN USE.

SINCE THE SEATING CAPACITY OF THE AUDITORIUM BEING CONSIDERED IS 425 PERSONS AND THE COEFFICIENT OF ABSORPTION PER PERSON IS 4.7 ACCORDING TO TABLE I, THEN THE TOTAL ABSORPTION AS OFFERED BY THE AUDIENCE AMOUNTS TO 425 x 4.7 = 1998 UNITS APPROXIMATELY. HOWEVER, THIS WILL SERVE TO JUST ABOUT CANCEL OUT THE ABSORPTIVE EFFECTS OF AN EQUAL NUMBER OF SEATS. SINCE, THE SEATS SUPPLIED 680 UNITS OF ABSORPTION, WE CAN FIND THE REVERBERATION WITH A FULL AUDIENCE IN THE FOLLOWING MANNER: $T = \frac{.05 \times 123,750}{1299 + (1998 - 680)}$

$\frac{6187.5}{1299 + 1318} = \frac{6187.5}{2617} = 2.4$ SECONDS. NOTICE THAT WITH A FULL AUDIENCE, THE REVERBERATION TIME APPROACHES THE OPTIMUM VALUE MUCH MORE CLOSELY THAN WHEN NO AUDIENCE IS PRESENT.

TABLE II				
OPTIMUM PERIODS OF REVERBERATION				
				SECONDS
BELOW 7,000 CUBIC FEET				1.0
7,000	TO	20,000		1.1
20,000	TO	45,000		1.2
45,000	TO	85,000		1.3
85,000	TO	145,000		1.4
145,000	TO	225,000		1.5
225,000	TO	330,000		1.6
330,000	TO	465,000		1.7
630,000	TO	835,000		1.9
835,000	TO	1,100,000		2.0

IN PRACTICE, IT IS NOT ADVISABLE TO ASSUME THE AUDIENCE AS FILLING THE AUDITORIUM TO ITS FULLEST CAPACITY. IT IS A BETTER POLICY TO CONSIDER THE ATTENDANCE AS BEING AN "AVERAGE VALUE", OR APPROXIMATELY 2/3 OF THE AUDITORIUM'S SEATING CAPACITY. THEN IF THE ACOUSTIC CONDITIONS OF THE AUDITORIUM ARE ARRANGED TO BE SATISFACTORY FOR THIS ATTENDANCE, THEY WILL ALSO BE CORRECT FOR FULL ATTENDANCE.

FOR INSTANCE, WITH 2/3 ATTENDANCE, THE TOTAL PERSONS IN THE AUDITORIUM WILL BE 2/3 OF 425 OR APPROXIMATELY 283 PERSONS. THIS AMOUNT OF PERSONS WILL ACCOUNT FOR AN ABSORPTION OF 283 x 4.7 = 1330 UNITS AND SINCE 142 SEATS ARE EMPTY, THEY WILL STILL HAVE THEIR ABSORPTION EFFECT. THEREFORE, THE EMPTY SEATS WILL PROVIDE AN ABSORPTION OF 142 x 1.6 = 227 UNITS.

THE TOTAL ABSORPTION OF THE AUDITORIUM WHEN 2/3 OF THE CAPACITY AUDIENCE IS PRESENT, THEN BECOMES:

WOOD FLOOR	48 UNITS
SEATS	227 UNITS
CEILING AND WALLS	300 UNITS
STAGE FLOOR	21 UNITS
CARPET	250 UNITS
PERSONS	1330 UNITS
TOTAL	2176 UNITS

SUBSTITUTING THIS VALUE IN OUR REVERBERATION TIME FORMULA, WE HAVE:

$T = \frac{.05 \times 123,750}{2176} = \frac{6187.5}{2176} = 2.8$ SECONDS

NOW THEN, UPON COMPARING OUR FINAL CALCULATED REVERBERATION TIME VALUE OF 2.8 SECONDS WITH THE OPTIMUM VALUE OF 1.4 SECONDS ALLOWABLE FOR

THE INSTALLATION, WE NOTE THAT OUR CALCULATED VALUE IS 2.8 MINUS 1.4 OR 1.4 SECONDS TOO HIGH.

BY THUS KNOWING THAT OUR REVERBERATION TIME FOR THE AUDITORIUM IS 1.4 SECONDS IN EXCESS TO WHAT IT SHOULD BE, WE CAN FIND THE ADDITIONAL UNITS OF ABSORPTION NECESSARY TO CORRECT THE CONDITION BY APPLYING THE FORMULA $T = \frac{.05V}{A}$ IN THE TRANSPOSED FORM $A = \frac{.05V}{T}$ AND THUS "T" IN THIS INSTANCE BECOMES 1.4 SECONDS AND "V" REMAINS AS 123,750 CUBIC FEET.

SUBSTITUTING THESE VALUES IN THE FORMULA $A = \frac{.05V}{T}$, WE HAVE

$A = \frac{.05 \times 123,750}{1.4} = \frac{6187.5}{1.4} = 4419$ UNITS (APPROXIMATELY). IN OTHER WORDS, 4419 ADDITIONAL UNITS OF ABSORPTION ARE NECESSARY IN ORDER TO REDUCE THE REVERBERATION TIME OF THE AUDITORIUM FROM ITS PRESENT VALUE OF 2.8 SECONDS TO THE OPTIMUM VALUE OF 1.4 SECONDS.

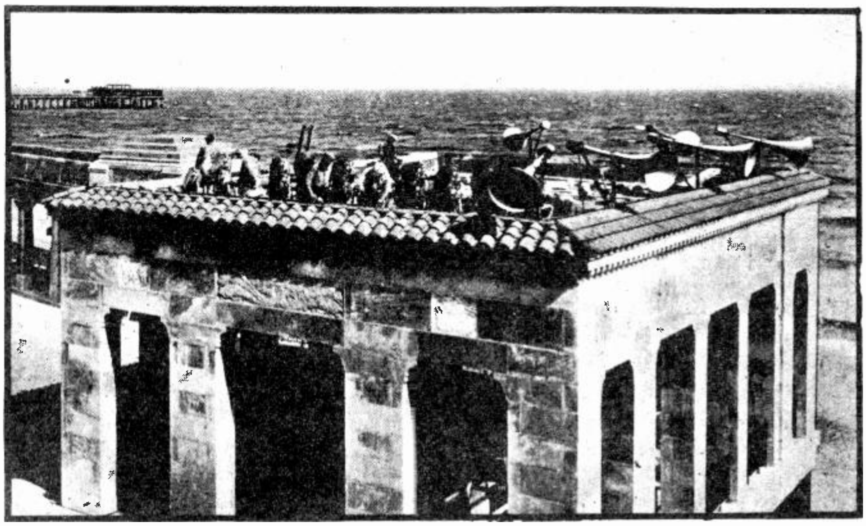

FIG. 5
An Installation of Speakers to Provide Programs on the Beach.

OUR NEXT STEP IS TO SELECT SOME STANDARD MATERIAL SUITABLE FOR ACOUSTIC TREATMENT AND WHOSE COEFFICIENT OF ABSORPTION IS KNOWN.

FOR THIS PARTICULAR AUDITORIUM, HEAVY CURTAINS ARRANGED IN FOLDS WOULD SUPPLY THE DESIRED ABSORPTION EFFECT WHILE AT THE SAME TIME SERVING AS AN ATTRACTIVE INTERIOR DECORATION FOR THE ROOM. BY REFERRING TO TABLE I, WE NOTE THAT CURTAINS ARRANGED IN HEAVY FOLDS HAVE A COEFFICIENT OF ABSORPTION ANYWHERE FROM ABOUT .50 TO 1.00. LET US ASSUME THAT WE CHOSE A TYPE OF CURTAIN WHOSE COEFFICIENT OF ABSORPTION IS 0.75. USING THIS MATERIAL, WE WOULD NEED $4419 \div .75 = 5892$ SQUARE FEET OF IT IN ORDER TO SUPPLY THE NECESSARY ADDITIONAL 4419 UNITS OF ABSORPTION.

THIS MATERIAL SHOULD BE PLACED ON THE SIDE AND REAR WALLS PARTICULARLY AND AT THE FRONT OF THE CEILING. THE STAGE WALLS SHOULD ALSO BE DRAPED TO ELIMINATE THE REVERBERATION AT THOSE POINTS WHICH WOULD REFLECT BACK TO THE MICROPHONE AND CREATE EFFECTS OF BOOMINESS.

A QUICK CHECK OF REVERBERATION TIME

A QUICKER METHOD OF CHECKING THE REVERBERATION TIME THAN THE PROCEDURE JUST OUTLINED IS TO STATION ONESELF AT SOME POINT IN THE AUDITORIUM BLOWING A WHISTLE HAVING A 512 CYCLE NOTE. THIS WHISTLE SHOULD BE

BLOWN AT AVERAGE INTENSITY FOR A PERIOD ABOUT AS LONG AS REQUIRED TO FILL THE AUDITORIUM WITH SOUND. AS SOON AS THE AUDITORIUM IS FILLED WITH SOUND, STOP BLOWING THE WHISTLE AND WITH A STOP WATCH MEASURE THE TIME ELAPSED FROM THE INSTANT YOU STOP BLOWING THE WHISTLE UNTIL THE SOUND DIES OUT COMPLETELY.

THIS TEST SHOULD BE REPEATED AT LEAST THREE TIMES AT ANY ONE LOCATION AND THE SAME PROCEDURE SHOULD BE CARRIED OUT AT VARIOUS DIFFERENT PLACES IN THE AUDITORIUM, ESPECIALLY UNDERNEATH BALCONIES, ON THE STAGE, IN RECESSES ALONG THE WALLS AND AT THE CENTER OF THE AUDITORIUM.

A RECORD SHOULD BE MADE FOR EACH "TIME PERIOD" AS OBTAINED WITH THIS TEST AND WHEN ALL OF THESE TIME MEASUREMENTS HAVE BEEN MADE, THEY SHOULD ALL BE ADDED TOGETHER AND THIS TOTAL DIVIDED BY THE NUMBER OF TESTS MADE. IN THIS MANNER, THE "AVERAGE TIME PERIOD OF REVERBERATION" IS OBTAINED.

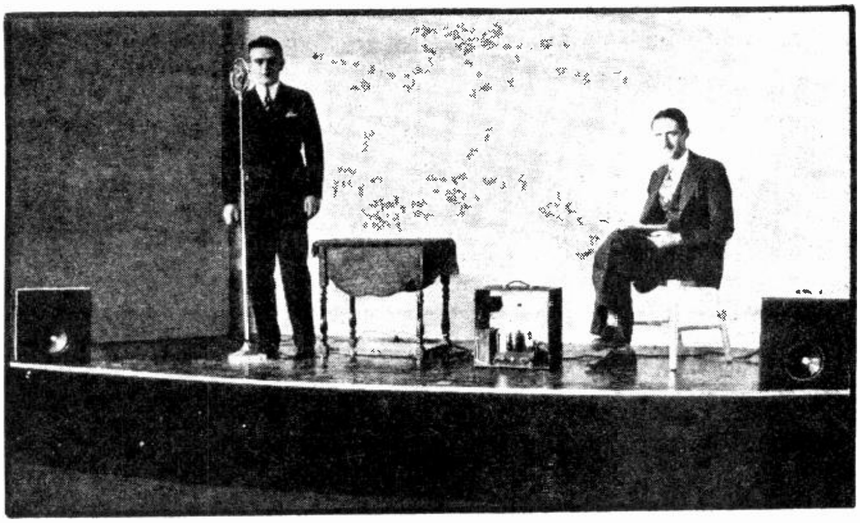

FIG. 6
Conducting Test During a Sound Installation.

THIS VALUE CAN THEN BE SUBTRACTED FROM THE OPTIMUM REVERBERATION PERIOD AS SPECIFIED IN TABLE II AND THIS REMAINDER SUBSTITUTED FOR THE VALUE "T" IN THE FORMULA $A = \frac{.05V}{T}$ IN ORDER TO DETERMINE THE NUMBER OF ABSORPTION UNITS NEEDED.

THE DESIRED MATERIAL CAN THEN BE SELECTED WITH WHICH TO "TREAT" THE WALLS ETC. AND BY DIVIDING THE TOTAL NUMBER OF ABSORPTION UNITS NEEDED BY THE COEFFICIENT OF ABSORPTION OF THE MATERIAL TO BE USED, THE TOTAL AMOUNT OF THIS MATERIAL REQUIRED CAN BE ASCERTAINED.

THIS MATERIAL CAN THEN BE DISTRIBUTED THROUGHOUT THE AVAILABLE SURFACES OF THE AUDITORIUM. THE REAR WALLS SHOULD BE TREATED IN PREFERENCE TO ALL OTHERS, AND THEN IN ORDER, BALCONY LEDGES, THE FRONT AND CENTER SECTIONS OF THE SIDE WALLS, STAGE AND FRONT SECTION OF CEILING.

DIRECTIONAL TYPE HORNS, SUCH AS DESCRIBED IN THE PREVIOUS LESSON, CAN BE USED TO ADVANTAGE IN KEEPING THE SOUND WAVES FROM STRIKING SURFACES WHICH TEND TO REFLECT THEM RATHER READILY AND IN THIS MANNER REDUCE REVERBERATION.

MATERIALS FOR ACOUSTIC TREATMENT

THE ACOUSTIC PROPERTIES OF BUILDINGS BEING CONSTRUCTED ARE MOST SATISFACTORILY CONTROLLED BY THE USE OF POROUS TILES AND PLASTERS, WHILE

DRAPES, RUGS, AND FELT ARE USED PRIMARILY FOR CORRECTIVE PURPOSES IN STRUCTURES ALREADY BUILT AND WHERE ACOUSTIC CORRECTIONS ARE TO BE MADE, OR WHERE IT IS DESIRED TO VARY THE ACOUSTIC PROPERTIES FROM TIME TO TIME.

INSTALLATION OF SPEAKERS

IN ADDITION TO THE ACOUSTIC CONDITION OF THE AUDITORIUM OR HALL BEING SATISFACTORY, IT IS ALSO IMPORTANT THAT THE PLACEMENT OF THE SPEAKERS BE CORRECT. FOR INSTANCE, WHERE HORN TYPE SPEAKERS ARE USED, THEIR LOCATION AND ANGLES MUST BE SUCH THAT MAXIMUM DISTRIBUTION OF THE SOUND WILL BE OBTAINED.

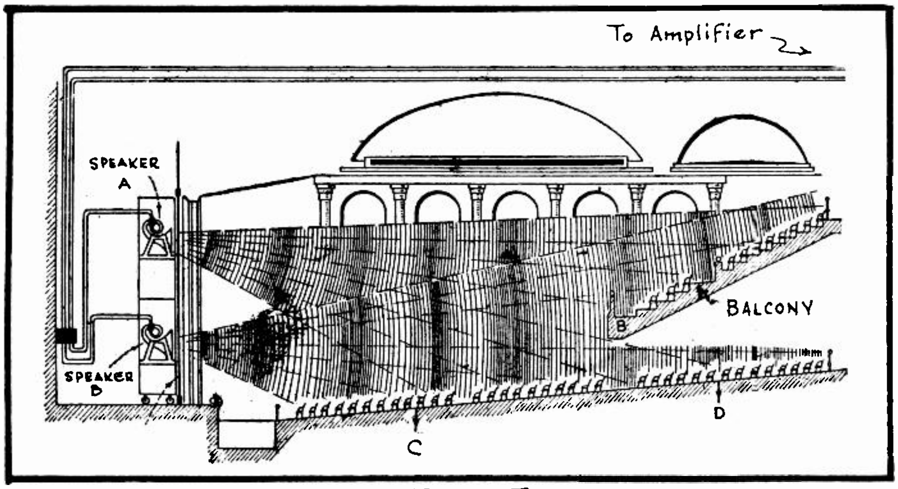

FIG. 7
The Effect of Proper Speaker Locations In a Theater or Auditorium.

IN FIG. 7, FOR EXAMPLE, YOU WILL SEE HOW TWO SPEAKERS FLOOD THE AUDITORIUM OF A THEATER WITH SOUND. NOTICE IN THIS ILLUSTRATION THAT IF SPEAKER "A" WERE USED ALONE, THEN THE PEOPLE OCCUPYING THOSE SEATS BETWEEN THE STAGE AND POINT "C" WOULD NOT BE SERVED PROPERLY BY HORN "A". FURTHERMORE, THIS SAME HORN WOULD NOT DELIVER SUFFICIENT SOUND TO THOSE PERSONS SEATED ON THE MAIN FLOOR BELOW THE BALCONY. SO YOU SEE, THIS SPEAKER IN ITSELF DOES NOT TAKE CARE OF THE ENTIRE AUDITORIUM.

BY INSTALLING THE ADDITIONAL SPEAKER "B" AND BY SETTING IT AT THE PROPER ANGLE, ITS SOUND WAVES CAN BE MADE TO SPREAD OUTWARD TO THOSE SEATS BELOW THE BALCONY, AS WELL AS TO THOSE SEATS BETWEEN POINT "C" AND THE STAGE. THE TWO SPEAKERS TOGETHER THEN, ARE ABLE TO FLOOD THE AUDITORIUM WITH SOUND, AS FAR AS HEIGHT AND THE DISTANCE TOWARD THE REAR OF THE AUDITORIUM ARE CONCERNED.

IN THE PREVIOUS LESSON ON SOUND AMPLIFIERS, YOU LEARNED THAT SOME SPEAKER HORNS ARE FLARED SO AS TO DIRECT THE SOUND WAVES UPWARD AND DOWNWARD AS THEY TRAVEL OUTWARDS FROM THE SPEAKER, WHEREAS OTHERS ARE FLARED IN SUCH A MANNER THAT THEY TEND TO SPREAD THE SOUND WAVES OUT TOWARD THE SIDES AND TO KEEP THEM AWAY FROM THE CEILING. EACH OF THESE HAVE THEIR INDIVIDUAL ADVANTAGES, DEPENDING UPON THE ACOUSTIC PROPERTIES OF THE ROOM IN WHICH THEY ARE INSTALLED.

ALWAYS BEAR IN MIND THAT WHEN HORN SPEAKERS ARE USED, THEY MUST BE CHOSEN WITH THE PROPER FLARE FOR INDOOR WORK AND SO DIRECTED THAT THE MINIMUM OF SOUND REACHES REAR OR SIDE WALLS THAT ARE NOT TREATED TO PREVENT REFLECTION OF SOUND WAVES. YOU WILL ALSO FIND IN PRACTICE THAT THE MOST

SUITABLE LOCATION AND ANGULAR POSITION OF THE SPEAKERS IS GENERALLY DETERMINED FROM THE RESULTS OF A SERIES OF SYSTEMATIC TESTS, IN WHICH THE SPEAKERS HAVE BEEN TEMPORARILY SET UP AT THE MOST ADVANTAGEOUS POINTS UNTIL THE BEST POSITION IS FOUND.

IT ISN'T ADVISABLE TO USE A GREATER NUMBER OF SPEAKERS THAN ABSOLUTELY NECESSARY IN ORDER TO PROVIDE SOUND DISTRIBUTION SINCE THE GREATER THE NUMBER OF SPEAKERS USED, THE MORE COMPLEX WILL BE THE SYSTEM NOT ONLY FROM THE STANDPOINT OF WIRING BUT ALSO FROM THE STANDPOINT OF PREVENTING THE SOUND WAVES FROM THE DIFFERENT UNITS CONFLICTING WITH EACHOTHER. OVER-DISTRIBUTION WILL ALSO OVER-EMPHASIZE ANY POOR ACOUSTICS. TOO FEW SPEAKERS, ON THE OTHER HAND, WILL RESULT IN INSUFFICIENT DISTRIBUTION OF THE SOUND SO THAT THE VOLUME THROUGHOUT THE AUDITORIUM MAY BE UNEVEN AND DEAD SPOTS MIGHT EXIST WHERE THE VOLUME OF SOUND MAY BE ABNORMALLY LOW.

PHASING SPEAKERS

WHEN MORE THAN ONE SPEAKER IS USED, THE PHASING OF ALL OF THE UNITS MUST BE UNIFORM, THAT IS, THE POLARITIES OF THE FIELDS AND VOICE COILS OF ALL THE SPEAKERS MUST BE SUCH THAT THE DIAPHRAGMS OF ALL OF THE SPEAKERS MOVE INWARDS AND OUTWARDS TOGETHER. IN OTHER WORDS, THEY MUST ALL MOVE OUTWARD AT THE SAME INSTANT AND ALL MOVE INWARD AT THE SAME INSTANT. SHOULD THE POLARITY OF ONE UNIT BE REVERSED SO THAT THE DIAPHRAGM OF ONE SPEAKER MOVES INWARD WHILE THAT OF THE OTHER MOVES OUTWARD, THEN THE AIR WILL BE COMPRESSED AROUND ONE SPEAKER WHILE THE AIR AROUND THE OTHER SPEAKER IS RAREFIED AND THIS WOULD RESULT IN A GOOD DEAL OF THE SOUND BEING BALANCED OUT BEFORE IT IS PROJECTED VERY FAR. IN ADDITION, SUCH A CONDITION WILL BRING ABOUT THE LOSS OF SOME FREQUENCIES AND THIS WILL PRODUCE DISTORTION.

SOME CONE UNITS HAVE THE VOICE COIL POLARITIES MARKED, THE POSITIVE SIDE BEING PAINTED RED AND THE NEGATIVE SIDE BLACK. THEREFORE WHEN CONNECTING ALL THE VOICE COILS IN PARALLEL, ALL OF THE RED TERMINALS ARE CONNECTED TOGETHER AND ALL OF THE BLACK TERMINALS ARE CONNECTED TOGETHER. SHOULD A SERIES CONNECTION BE USED, THEN CONNECT RED TO BLACK ETC. THE FIELD TERMINALS ARE ALSO MARKED PLUS AND MINUS AND SO THE PLUS TERMINALS OF ALL THE FIELD COILS SHOULD BE CONNECTED TO THE PLUS SIDE OF THE FIELD SUPPLY AND ALL OF THE NEGATIVE FIELD COIL TERMINALS TO THE NEGATIVE SIDE OF THE FIELD SUPPLY. REVERSING EITHER THE FIELD COIL OR VOICE COIL CONNECTIONS OF ONE OF THE SPEAKERS WILL THROW THAT UNIT OUT OF PHASE WITH THE OTHERS.

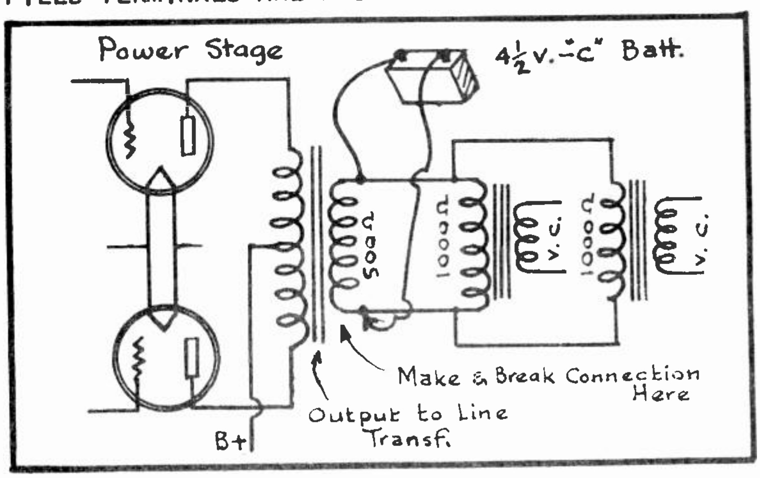

FIG. 8

A Speaker Phase Test

WHEN WORKING WITH A SPEAKER CIRCUIT OF THE TYPE ILLUSTRATED IN FIG. 8, A QUICK METHOD OF CHECKING THE PHASING OF THE SPEAKERS IS TO TURN ON THE FIELD SUPPLY FOR ALL THE SPEAKERS AND THEN MOMENTARILLY CONNECT A 4½ VOLT "C" BATTERY A-

CROSS THE SECONDARY TERMINALS OF THE OUTPUT TO LINE TRANSFORMER.

As THIS "C" BATTERY CONNECTION IS MADE BY ONE PERSON, ANOTHER SHOULD FEEL THE DIAPHRAGM OF EACH SPEAKER IN TURN AND NOTE IN WHICH DIRECTION THE DIAPHRAGM MOVES AS THE "C" BATTERY CONNECTION IS COMPLETED. THE DIAPHRAGMS OF ALL THE SPEAKERS SHOULD MOVE IN THE SAME DIRECTION AS THIS TEST IS MADE AND WHENEVER ONE OF THEM MOVES IN A REVERSE DIRECTION TO THAT OF THE OTHERS, EITHER ITS VOICE COIL CONNECTIONS OR FIELD COIL CONNECTIONS SHOULD BE REVERSED, WHICHEVER IS MOST CONVENIENT. IT IS IMPORTANT THAT THE "C" BATTERY CONNECTION BE COMPLETED FOR ONLY AN INSTANT AS EACH SPEAKER IS TESTED AND THE BATTERY CONNECTIONS SHOULD AT NO TIME BE REVERSED AS THE TEST IS IN PROGRESS.

IT IS ALSO OF UTMOST IMPORTANCE THAT THE MICROPHONE BE SO PLACED AS TO BE PROTECTED AGAINST ANY OF THE SPEAKER SOUND WAVES FROM ACTING UPON THE DIAPHRAGM OF THE MICROPHONE. SHOULD THIS OCCUR, THEN WE HAVE A CONDITION KNOWN AS "FEED-BACK" AND IT WILL CAUSE AN ANNOYING HOWLING SOUND TO BE EMITTED BY THE SPEAKERS.

answered Apr 22, 1941

Examination Questions

LESSON. NO. A.S.4

1. - WHAT DO YOU UNDERSTAND TO BE THE MEANING OF ACOUSTICS?

2. - WHAT IS REVERBERATION?

3. - WHAT IS MEANT BY REVERBERATION TIME?

4. - EXPLAIN IN DETAIL HOW THE REVERBERATION TIME OF AN AUDITORIUM MAY BE DETERMINED BY CALCULATION.

5. - WHAT DO WE MEAN BY THE COEFFICIENT OF ABSORPTION OF A MATERIAL?

6. - IF THE REVERBERATION TIME FOR A HALL OR AUDITORIUM HAS BEEN DETERMINED, HOW CAN YOU TELL TO WHAT EXTENT ACOUSTIC TREATMENT OR CORRECTION IS REQUIRED?

7. - WHEN CALCULATING THE REVERBERATION TIME OF AN AUDITORIUM ETC., WOULD YOU CONSIDER THE ROOM TO BE FILLED TO CAPACITY BY PERSONS? STATE THE REASON FOR YOUR ANSWER.

8. - DESCRIBE A QUICK METHOD FOR DETERMING THE REVERBERATION TIME OF A LARGE ROOM OR HALL.

9. - WHAT MAJOR CONDITIONS SHOULD BE CONSIDERED WITH RESPECT TO THE PLACEMENT OF SPEAKERS AND THE TYPE OF SPEAKER UNIT AND HORN TO USE?

10.- WHY IS THE PROPER PHASING OF SPEAKERS IMPORTANT WHEN A NUMBER OF SPEAKERS ARE USED? EXPLAIN HOW THIS WORK IS DONE.

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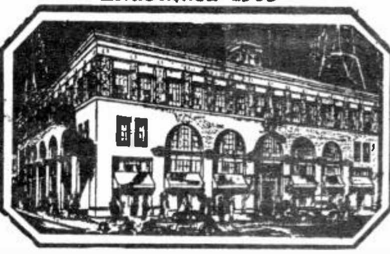

J. A. ROSENKRANZ, Pres.

Amplifying Systems

LESSON NO. 5

DIRECT-COUPLED AMPLIFIERS

IN ALL OF THE AUDIO AMPLIFER CIRCUITS WHICH YOU HAVE DEALT WITH SO FAR IN YOUR STUDIES THE VARIOUS STAGES WERE COUPLED TOGETHER EITHER THRU TRANSFORMERS, BY RESISTANCE CAPACITY COUPLING OR THROUGH SOME FORM OF IMPEDANCE COUPLING. AT ANY RATE, THERE WAS NO DIRECT CONNECTION BETWEEN THE PLATE OF ONE TUBE AND THE CONTROL GRID OF THE FOLLOWING TUBE. THE ONLY CONNECTION WHICH THESE TWO ELEMENTS HAD BETWEEN EACHOTHER WAS EITHER THRU MUTUAL INDUCTANCE OR THROUGH THE CAPACITY OFFERED BY A COUPLING CONDENSER.

IN THIS LESSON, HOWEVER, YOU ARE GOING TO BE SHOWN HOW THE VARIOUS STAGES OF AN A.F. AMPLIFIER CAN BE CONNECTED TOGETHER WITHOUT EMPLOYING EITHER OF THESE AND INSTEAD, TO USE A DIRECT CONNECTION. AMPLIFIERS WHICH EMPLOY THIS LATTER METHOD OF INTERCONNECTING OR COUPLING THE DIFFERENT STAGES ARE KNOWN AS DIRECT COUPLED AMPLIFIERS AND SOMETIMES THE NAME LOFTIN-WHITE IS ASSOCIATED WITH THEM.

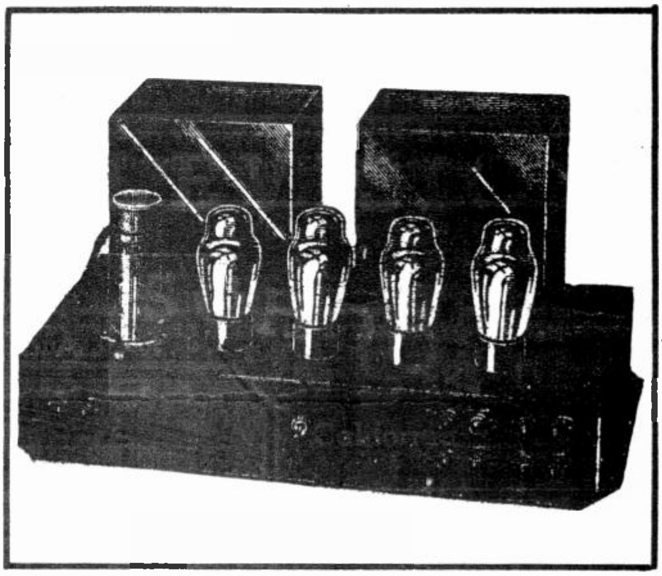

FIG. 1

An Amplifier Employing Direct-Coupling.

CIRCUIT ARRANGEMENT

IN FIG. 2 YOU ARE SHOWN THE FUNDAMENTAL CIRCUIT DIAGRAM OF A TYPICAL DIRECT COUPLED AMPLIFIER IN WHICH A TYPE -24 TUBE IS WORKING INTO A TYPE -45 TUBE. BY STUDYING THIS DIAGRAM CLOSELY, YOU WILL NOTICE THAT A GROUP OF SERIES RESISTORS CONSISTING OF R_2, R_3, R_4, R_5, R_6, AND R_7 ARE CONNECTED IN THE FORM OF A VOLTAGE DIVIDER ACROSS THE "B" SUPPLY. FOR THE PRESENT, WE SHALL NOT CONSIDER THE VALUES

OF THIS RESISTOR NETWORK AND SIMPLY ASSUME THAT THE VOLTAGES AVAILABLE AT THE DIFFERENT POINTS OF THIS CIRCUIT ARE AS NOTED ON THE DIAGRAM. IN THIS WAY, THE PREPARATORY EXPLANATION WILL BE SIMPLIFIED SOMEWHAT BEFORE WE ENTER INTO THE ACTUAL CALCULATIONS.

THE VOLTAGE IMPRESSED ACROSS THE ENTIRE B+ AND B- CIRCUIT IS 445 VOLTS AND THE PLATE OF THE POWER TUBE IS CONNECTED THROUGH ITS OUTPUT TRANSFORMER TO THE +445 VOLT TERMINAL.

THE ACTUAL PLATE VOLTAGE OF THIS TUBE, HOWEVER, IS NOT 445 VOLTS BECAUSE THE CENTER TAP OF ITS FILAMENT SHUNTING RESISTOR IS CONNECTED TO THE VOLTAGE DIVIDER AT A POINT CORRESPONDING TO A POTENTIAL OF +195 VOLTS. THE EFFECTIVE PLATE VOLTAGE AT ANY FILAMENT TYPE TUBE, YOU WILL RECALL, IS EQUAL TO THE DIFFERENCE IN VOLTAGE BETWEEN THE POTENTIALS APPLIED TO THE PLATE AND TO THE FILAMENT. THEREFORE, THE EFFECTIVE PLATE VOLTAGE AT THE POWER TUBE SOCKET IN THIS CASE ACTUALLY AMOUNTS TO ONLY 445 VOLTS MINUS 195 VOLTS OR 250 VOLTS.

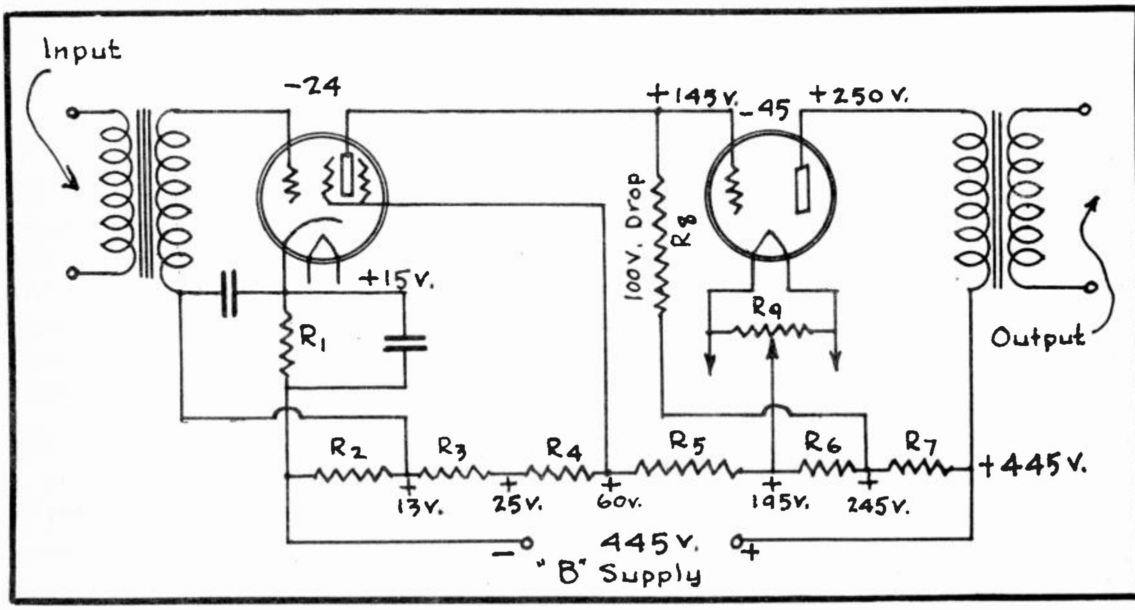

FIG. 2
A Typical Direct-Coupled Amplifier.

THE RESISTOR R_8 SERVES A DOUBLE PURPOSE. FOR EXAMPLE, FIRST IT WILL BE SEEN THAT THE PLATE CIRCUIT OF THE -24 AMPLIFIER TUBE IS CONNECTED TO THE +245 VOLT TAP THROUGH THE RESISTOR R_8. THE RESISTANCE VALUE OF R_8 IS SUCH THAT A DROP OF 100 VOLTS WILL BE DEVELOPED ACROSS ITS ENDS WHEN THIS TUBE IS DRAWING NORMAL PLATE CURRENT. THEREFORE, ONLY 245 VOLTS MINUS 100 VOLTS OR 145 VOLTS WILL BE IMPRESSED UPON THE PLATE OF THIS TUBE.

THIS VALUE OF 145 VOLTS, HOWEVER, IS NOT THE EFFECTIVE PLATE VOLTAGE OF THIS TUBE BECAUSE THIS TUBE'S PLATE CURRENT ALSO FLOWS THROUGH RESISTOR R_1 WHICH IS CONNECTED BETWEEN THIS TUBE'S CATHODE AND THE NEGATIVE "B" LINE. THE VALUE OF THIS RESISTOR AND THE PLATE CURRENT FLOWING THROUGH IT ARE SUCH THAT A VOLTAGE OF 15 VOLTS IS DEVELOPED ACROSS ITS ENDS — ITS UPPER END BEING POSITIVE WITH RESPECT TO ITS LOWER END AND AND FOR THIS REASON THE CATHODE OF THE -24 TUBE IS 15 VOLTS POSITIVE WITH

RELATION TO B-. THEREFORE, THE EFFECTIVE PLATE VOLTAGE UPON THE -24 TUBE IS EQUAL TO 145 VOLTS MINUS 15 VOLTS OR 130 VOLTS.

THE CONTROL GRID OF THE -24 TUBE IS CONNECTED TO THE +13 VOLT POINT OF THE VOLTAGE DIVIDER THROUGH THE SECONDARY WINDING OF THE TRANSFORMER. THE EFFECTIVE GRID BIAS VOLTAGE UPON THIS SCREEN-GRID TUBE, HOWEVER, IS NOT +13 VOLTS BECAUSE THE TUBE'S CATHODE IS AT A POTENTIAL OF +15 VOLTS AS WAS ALREADY STATED. IN OTHER WORDS, THE CATHODE POTENTIAL IS 2 VOLTS GREATER THAN THAT OF THE CONTROL GRID AND WHICH MEANS THAT THE CONTROL GRID IS ACTUALLY AT 2 VOLTS NEGATIVE POTENTIAL WITH RESPECT TO THE CATHODE OF THE SAME TUBE. SINCE IT IS ALWAYS THE DIFFERENCE IN POTENTIAL BETWEEN THE CONTROL GRID AND THE CATHODE WHICH DETERMINES THE EFFECTIVE GRID BIAS VOLTAGE, THE -24 TUBE IN THE CIRCUIT OF FIG. 2 IS IN REALITY BEING OPERATED WITH A BIAS OF -2 VOLTS.

THE SCREEN GRID OF THE -24 TUBE IS CONNECTED TO THE +60 VOLT TAP OF THE VOLTAGE DIVIDER BUT SINCE THE CATHODE POTENTIAL IS +15 VOLTS, THE EFFECTIVE SCREEN GRID VOLTAGE FOR THE -24 TUBE WILL BE ONLY 60 MINUS 15 OR 45 VOLTS.

NO DOUBT YOU HAVE BEEN WONDERING ABOUT THE VOLTAGE AS APPLIED TO THE GRID OF THE POWER TUBE. SINCE THE GRID OF THIS TUBE IS CONNECTED DIRECTLY TO THE PLATE OF THE PRECEDING TUBE, IT AT FIRST GLANCE APPEARS AS IF THE POWER TUBE'S GRID IS ALSO GOING TO HAVE A POTENTIAL OF +145 VOLTS IMPRESSED UPON IT AND SUCH A CONDITION WOULD BE ENTIRELY CONTRADICTORY TO ALL PRINCIPLES WHICH YOU HAVE SO FAR LEARNED.

THE TRUTH OF THE MATTER IS, HOWEVER, THAT THIS POWER TUBE IS ACTUALLY OPERATING AT A NEGATIVE GRID BIAS VOLTAGE OF 50 VOLTS. THE REASON FOR THIS IS THAT THE CENTER OF THE POWER TUBE'S FILAMENT IS SUBJECTED TO A "B" VOLTAGE OF +195 VOLTS SINCE THE CENTER TAP OF ITS FILAMENT SHUNTING RESISTOR IS CONNECTED TO A POINT OF THIS POTENTIAL. THEREFORE, EVEN THOUGH +145 VOLTS BE IMPRESSED UPON THIS TUBE'S GRID, THE EFFECTIVE VOLTAGE AS IMPRESSED ACROSS THE GRID AND FILAMENT OF THE POWER TUBE WILL BE 195 MINUS 145 OR 50 VOLTS. FURTHERMORE, SINCE THE FILAMENT OF THIS TUBE IS AT A POTENTIAL 50 VOLTS HIGHER THAN ITS GRID, THE GRID IS IN REALITY 50 VOLTS NEGATIVE WITH RESPECT TO ITS FILAMENT AND THUS A 50 VOLT NEGATIVE BIAS IS ACTUALLY APPLIED TO THE GRID CIRCUIT OF THIS TUBE.

SINCE RESISTOR R_8 IS INSTALLED IN THE PLATE CIRCUIT OF THE -24 TUBE, AS WELL AS IN THE GRID CIRCUIT OF THE POWER TUBE, ALL VOLTAGE CHANGES APPEARING ACROSS ITS EXTREMETIES DUE TO THE PLATE CURRENT VARIATIONS AT SIGNAL FREQUENCY PASSING THROUGH IT, THESE SAME SIGNAL VOLTAGES WILL BE APPLIED ACROSS THE GRID AND FILAMENT OF THE POWER TUBE AND THEREBY PERMIT THIS TUBE TO FUNCTION IN THE CONVENTIONAL MANNER.

DIRECT COUPLED AMPLIFIERS ARE RECOGNIZED FOR THEIR UNIFORM RESPONSE THROUGHOUT THE ENTIRE AUDIO FREQUENCY RANGE AND THIS IS DUE TO THE FACT THAT THE COUPLING BETWEEN STAGES DOES NOT DEPEND UPON THE SIGNAL VOLTAGE BEING "PASSED-ON" THROUGH THE PROPERTIES OF EITHER INDUCTANCE OR CAPACITY AND BOTH OF WHICH FAVOR CERTAIN FREQUENCY RANGES MORE OR LESS.

ONE OF THE DISADVANTAGES OF THIS TYPE OF CIRCUIT LIES IN THE FACT THAT A SOURCE OF RATHER HIGH "B" VOLTAGE IS REQUIRED IN ORDER THAT THE PROPER VOLTAGE DISTRIBUTION CAN BE OBTAINED THROUGHOUT THE CIRCUIT. THIS high "B" voltage requirement calls for a more expensive power transformer and filter chokes, as well as filter and bypass condensers which are capable of withstanding the high voltages to be handled.

CIRCUIT ARRANGEMENTS

Various arrangements are employed in practice in order to obtain direct coupling and now that you are familiar with the basic principles governing the circuits and operation of this type of amplifier, we shall proceed with a more detailed study of the various circuit designs employed in amplifiers of this type.

DIRECT COUPLED AMPLIFIER WITH COMMON CHOKE

In Fig. 3 you are shown the diagram of an interesting direct coupled amplifier circuit in which an A.F. choke is used as the load in the plate circuit of the first tube rather than a resistance. One of the advantages of using a choke for this purpose is that the D. C. resistance of a good choke of this type is much less than that of a resistance equivalent to the same loading effect, consequently the voltage drop across this choke due to the flow of plate current will be much less than that across a plate load resistor as would ordinarily be used for this purpose.

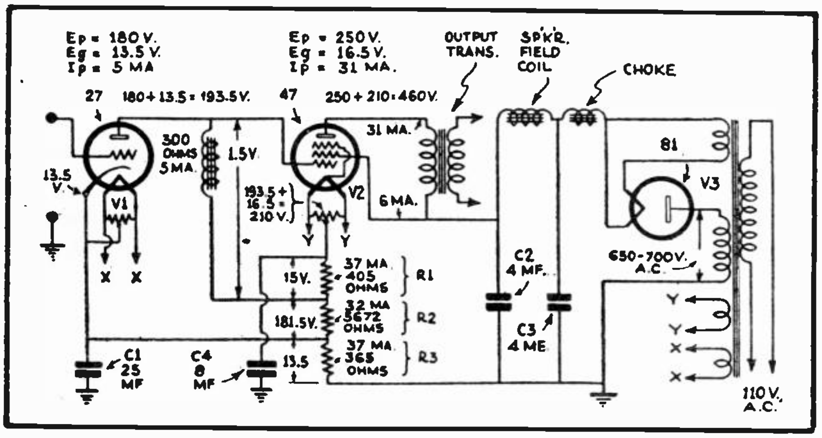

FIG. 3
Circuit of the Amplifier.

Although the A.F. choke should be of the best quality, yet when used in a circuit of this type, the frequency characteristic of the choke will be improved over to what it would be if the same unit were to be employed in a conventional circuit.

The design procedure for an amplifier of this type would be carried out in the following manner:

First, we make note of the operating characteristics under which the tubes of the circuit are to function, that is the plate voltage, bias voltage, plate current etc. which are all obtained by reference from tube data where the necessary specifications are given for operating the tubes to be used as amplifiers.

For the sake of a specific example, let us assume that the type -27 input tube is to be operated with a plate voltage of 180 volts and a bias

OF −13.5 VOLTS AND THAT UNDER THESE CONDITIONS THE TUBE WILL DRAW 5 MA. OF PLATE CURRENT. THE TYPE 47 POWER TUBE WE SHALL ASSUME IS TO BE OPERATED WITH A PLATE AND SCREEN VOLTAGE OF 250 VOLTS, A GRID BIAS OF −16.5 VOLTS AND THAT THE PLATE CURRENT AMOUNTS TO 31 MA. AND THE SCREEN CURRENT TO 6 MA.

NOW THEN, SINCE THE PLATE VOLTAGE FOR THE 27 TUBE IS TO BE 180 VOLTS AND THE BIAS −13.5 VOLTS, THE ACTUAL VOLTAGE WHICH MUST BE DELIVERED TO THE PLATE OF THIS TUBE SHOULD BE EQUAL TO 180+13.5 = 193.5 VOLTS. THEN IF THE D.C. RESISTANCE OF THE PLATE CIRCUIT CHOKE IS 300 OHMS AND THE PLATE CURRENT OF THE 27 TUBE IS 5 MA., THE VOLTAGE DROP ACROSS THIS CHOKE WILL BE EQUAL TO 300 x .005 = 1.5 VOLTS AND CONSEQUENTLY THE VOLTAGE AT THE INPUT END OF THIS CHOKE WILL BE 193.5 + 1.5 = 195 VOLTS.

SINCE THE BIAS VOLTAGE FOR THE 47 TUBE IS TO BE −16.5 VOLTS AND 1.5 VOLTS OF THIS AMOUNT IS ALREADY DEVELOPED ACROSS THE ENDS OF THE A.F. CHOKE, ONLY 16.5 MINUS 1.5 OR 15 VOLTS WILL HAVE TO BE FURNISHED BY THE VOLTAGE DROP ACROSS THE BIAS RESISTOR OR R_1. THE FILAMENT OF THE 47 TUBE MUST THEN BE AT A POSITIVE POTENTIAL AMOUNTING TO 195 PLUS 15 OR 210 VOLTS. THEN SINCE THE PLATE VOLTAGE OF THE 47 TUBE IS TO BE 250 VOLTS AND ITS FILAMENT IS GOING TO BE MAINTAINED AT A POTENTIAL OF 210 VOLTS, THEN THE VOLTAGE WHICH MUST BE AVAILABLE AT THE PLATE OF THE 47 TUBE WILL BE 250 + 210 = 460 VOLTS. THIS MEANS THAT A VOLTAGE OF 460 VOLTS MUST BE SUPPLIED AT THE OUTPUT OF THE POWER PACK'S FILTER SYSTEM. ALLOWING FOR THE REQUIRED VOLTAGE DROP ACROSS THE SPEAKER FIEL COIL WHICH IS BEING USED AS A SECOND FILTER CHOKE IN THIS CIRCUIT AND ALSO FOR THE VOLTAGE DROP ACROSS THE FIRST FILTER CHOKE, WE CAN ESTIMATE OUR REQUIRED "B" VOLTAGE ACROSS THE INPUT OF THE FILTER TO BE APPROXIMATELY 560 VOLTS. THEREFORE A TYPE −81 TUBE WITH ABOUT 650 TO 700 VOLTS APPLIED TO ITS PLATE WILL DELIVER THE NECESSARY "B" VOLTAGE AND CURRENT.

HAVING DETERMINED THESE VOLTAGE VALUES OF THE CIRCUIT, OUR NEXT JOB IS TO WORK OUT THE DESIGN FOR THE RESISTANCE NETWORK OR VOLTAGE DIVIDER SYSTEM. TO BEGIN WITH, THE BIAS VOLTAGE FOR THE 47 TUBE IS TO BE −16.5 VOLTS AND OF THIS AMOUNT 15 VOLTS IS TO BE FURNISHED BY THE VOLTAGE DROP ACROSS R_1 FOR REASONS ALREADY STATED. THE PLATE, AS WELL AS THE SCREEN CURRENT OF THE 47 TUBE MUST ALL FLOW THROUGH R_1 AND THEREFORE THE TOTAL CURRENT PASSING THROUGH THIS RESISTOR WILL AMOUNT TO 31 PLUS 6 OR 37 MA. THEN IF THE VOLTAGE DROP ACROSS R_1 IS TO BE 15 VOLTS FOR BIASING PURPOSES, ITS RESISTANCE VALUE ACCORDING TO OHM'S LAW WILL BE $R = \frac{E}{I} = \frac{15}{.037} = 405$ OHMS.

THE PLATE CIRCUIT OF THE −27 TUBE IS CONNECTED TO THE NEGATIVE END OF R_1 THROUGH THE A.F. CHOKE AND CONSEQUENTLY THE PLATE CURRENT FOR THIS TUBE WILL BE TAKEN OFF THE VOLTAGE DIVIDER SYSTEM AT THIS POINT. THIS MEANS THAT ONLY 37 MINUS 5 OR 32 MA. WILL FLOW THROUGH R_2. THEN SINCE THE NEGATIVE END OF R_1 IS AT A POTENTIAL OF 195 VOLTS AND THE CATHODE OF THE 27 TUBE IS TO BE MAINTAINED AT A POTENTIAL OF +13.5 FOR BIASING PURPOSES, THE VOLTAGE DROP REQUIRED ACROSS R_2 WILL BE 195 MINUS 13.5 OR 181.5 VOLTS. THEREFORE, THE RESISTANCE VALUE FOR R_2 WILL BE $R = \frac{E}{I} = \frac{181.5}{.032}$ = 5672 OHMS.

FINALLY, SINCE THE CATHODE OF THE 27 TUBE IS TO BE 13.5 VOLTS HIGHER THAN THE GROUND POTENTIAL FOR BIASING PURPOSES, THE VOLTAGE DROP A-

CROSS R_3 MUST BE 13.5 VOLTS. ALSO NOTICE THAT THE CIRCUIT ARRANGEMENT IS SUCH THAT THE PLATE CURRENT OF BOTH THE 47 AND 27 MUST FLOW THROUGH R_3 AND WHICH WILL AMOUNT TO 37 MA. THE RESISTANCE VALUE FOR R_3 IS THUS FOUND AS FOLLOWS: $R = \frac{E}{I} = \frac{13.5}{.037} = 365$ OHMS.

BEAR IN MIND THAT IN OUR PRESENT DISCUSSION WE ARE ONLY CONSIDERING THE DESIGN PROCEDURE WHICH MAKES DIRECT COUPLING POSSIBLE. IN THE ACTUAL AMPLIFIER IT WOULDN'T BE ADVISABLE TO OPERATE THE UNIT WITHOUT ANY BLEEDER CIRCUIT FOR THE POWER PACK AND WHICH WOULD REALLY BE THE CASE IN THE CIRCUIT OF FIG. 3. THIS CONDITION COULD BE OVERCOME IN FIG. 3, HOWEVER, SIMPLY BY CONNECTING A SUITABLE RESISTOR ACROSS THE POSITIVE AND NEGATIVE TERMINALS AT THE OUTPUT OF THE FILTER, CHOOSING ITS VALUE SO THAT THE BLEEDER CURRENT WILL BE NORMAL WHILE AT THE SAME TIME, THE POTENTIAL DIFFERENCE ACROSS ITS EXTREMETIES WILL BE OF THE PROPER MAXIMUM VALUE REQUIRED BY THE AMPLIFIER CIRCUIT IN QUESTION.

THREE DIRECT-COUPLET STAGES

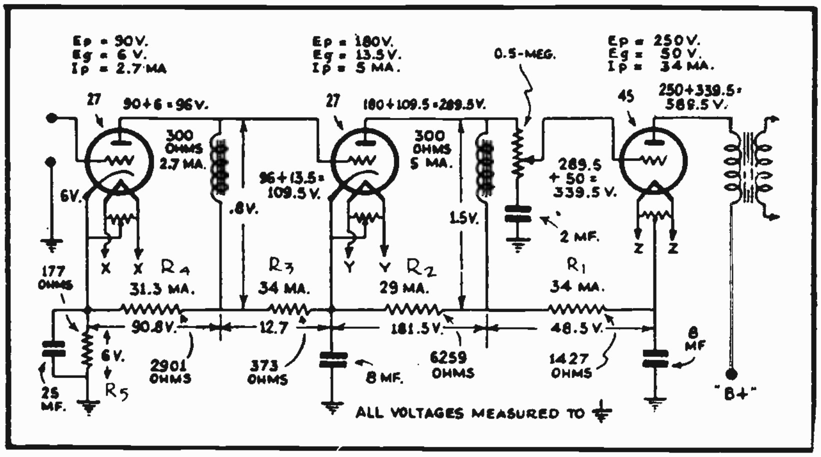

FIG. 4

Three Direct-Coupled Stages.

IN FIG. 4 YOU ARE SHOWN HOW THREE STAGES MAY BE CONNECTED TOGETHER BY DIRECT COUPLING AND HOW THE VOLUME MAY BE CONTROLLED IN SUCH A SYSTEM.

THE SAME GENERAL PROCEDURE IS APPLIED TO LAYING OUT THE DESIGN FOR A CIRCUIT OF THIS TYPE AS HAS ALREADY BEEN EXPLAINED REGARDING THE PRECEDING TWO-STAGE CIRCUIT. FOR INSTANCE, WE HAVE A SIMILAR RESISTANCE NETWORK FOR DISTRIBUTING THE VOLTAGE AND CURRENT IN THE PROPER MANNER TO THE VARIOUS CIRCUITS SO THAT EACH OF THE TUBES MAY OPERATE ACCORDING TO PRESCRIBED SPECIFICATIONS. THE VOLTAGES AND CURRENT REQUIRED BY EACH TUBE ARE NOTED DIRECTLY ABOVE THE CORRESPONDING TUBE. THE INPUT 27 TUBE, FOR INSTANCE, IS GOING TO EMPLOY A PLATE VOLTAGE OF 90 VOLTS AND A BIAS OF 6 VOLTS AND SO THE VOLTAGE AVAILABLE AT ITS PLATE MUST BE 90 PLUS 6 OR 96 VOLTS. SINCE THIS TUBE DRAWS 2.7 MA. OF PLATE CURRENT WHICH MUST FLOW THROUGH AN A.F. CHOKE OF 300 OHMS RESISTANCE, THE VOLTAGE DROP ACROSS THIS CHOKE WILL BE 300 TIMES .0027 = 0.8 VOLT.

THE SECOND 27 TUBE IS GOING TO REQUIRE A BIAS OF -13.5 AND SINCE THIS GRID IS AT A POSITIVE POTENTIAL OF 96 VOLTS THE SAME AS THE PLATE OF THE PRECEDING TUBE, ITS CATHODE POTENTIAL MUST BE 96 + 13.5 = 109.5 VOLTS. THE PLATE VOLTAGE FOR THIS SECOND 27 TUBE IS TO BE 180 VOLTS AND SO THE VOLTAGE AVAILABLE AT ITS PLATE MUST BE 180 + 109.5 = 289.5 VOLTS.

THE TYPE 45 TUBE IS TO BE OPERATED WITH A PLATE VOLTAGE OF 250 VOLTS

AND A BIAS OF 50 VOLTS, CONSEQUENTLY ITS FILAMENT POTENTIAL SHOULD BE 289.5 PLUS 50 = 339.5 VOLTS AND THE VOLTAGE AVAILABLE AT ITS PLATE MUST BE 339.5 PLUS 250 OR 589.5 VOLTS.

AS TO THE RESISTANCE NETWORK, NOTE THAT 34 MA. FLOW THROUGH R_1. OF THIS AMOUNT 5 MA. PASS THROUGH THE SECOND 27 TUBE SO THAT ONLY 34 MINUS 5 OR 29 MA. FLOW THROUGH R_2. THIS SAME 29 MA. CONTINUES FLOWING THROUGH R_3 BUT IN ADDITION THE PLATE CURRENT OF THE SECOND 27 TUBE IS RETURNED BY THE CATHODE SO THAT ACTUALLY 29 PLUS 5 OR 34 MA. FLOW THROUGH R_3. OF THIS AMOUNT 2.7 MA. IS USED BY THE INPUT 27 TUBE LEAVING ONLY 34 MINUS 2.7 OR 31.3 MA. FOR R_4. THIS 2.7 MA. WILL TOGETHER WITH THE 31.3 MA. FLOW THRU R_5 AND THEREFORE 31.3 PLUS 2.7 OR 34 MA. PASS THROUGH R_5.

SINCE A VOLT DROP OF 1.5 VOLTS IS PRODUCED ACROSS THE A.F. CHOKE IN THE PLATE CIRCUIT OF THE SECOND 27 TUBE, ONLY 50 MINUS 1.5 OR 48.5 VOLTS WILL HAVE TO BE PRODUCED ACROSS R_1 AND THEREFORE THE VALUE OF R_1 BECOMES $R = E/I = \frac{48.5}{.034} = 1427$ OHMS. (NOTICE THAT WITH RESPECT TO THE GRID CIRCUIT OF THE -45 TUBE, THE 1.5 VOLT DROP ACROSS THE 2ND A.F. CHOKE AND THE 48.5 VOLT DROP ACROSS R_1 ARE EFFECTIVELY IN SERIES, THE GRID-PLATE END OF THE SECOND A.F. CHOKE BEING AT A POTENTIAL OF 48.5 PLUS 1.5 OR 50 VOLTS LESS THAN THE FILAMENT POTENTIAL OF THE -45 TUBE. HENCE THE GRID OF THE 45 TUBE IS 50 VOLTS NEGATIVE WITH RESPECT TO ITS FILAMENT. THE VOLTAGE DROP ACROSS R_2 IS TO BE 291 VOLTS MINUS 109.5 VOLTS OR 181.5 VOLTS. THIS MEANS THAT THIS THIS RESISTOR MUST HAVE A VALUE OF 6259 OHMS ($R = \frac{E}{I} = \frac{181.5}{.029} = 6259$ OHMS).

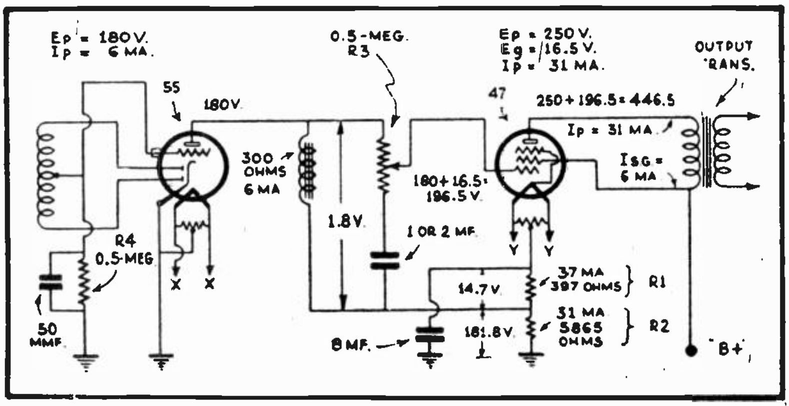

FIG. 5

Application of the -55 Tube.

THE VOLTAGE DROP ACROSS R_4 MUST BE 109.5 MINUS 96.8 OR 12.7 VOLTS AND SO ITS RESISTANCE VALUE WILL BE $R = \frac{E}{I} = \frac{12.7}{.034} = 373$ OHMS.

THE VOLTAGE DROP ACROSS R_4 WILL BE 96.8 MINUS 6 OR 90.8 VOLTS AND ITS RESISTANCE VALUE WILL THEN BE 2901 OHMS ($R = \frac{E}{I} = \frac{90.8}{.0313} = 2901$ OHMS). THE VOLT DROP ACROSS R_5 WILL BE EQUAL TO THE BIAS VOLTAGE WHICH IS TO BE APPLIED TO THE GRID OF THE INPUT 27 TUBE OR 6 VOLTS AND SINCE 34 MA. OF CURRENT PASSES THROUGH IT, THE RESISTANCE VALUE OF R_5 MUST BE $R = \frac{E}{I} = \frac{6}{.034} = 177$ OHMS.

NOTICE PARTICULARLY THE VOLUME CONTROL WHICH IS USED IN THIS CIRCUIT. THE POTENTIOMETER WHICH SERVES AS THE VOLUME CONTROL HAS ONE OF ITS ENDS CONNECTED TO THE PLATE END OF THE SECOND A.F. CHOKE, WHILE ITS OTHER END IS CONNECTED TO GROUND THROUGH A 2 MFD. CONDENSER AND THE ARM OF THIS

POTENTIOMETER IS CONNECTED TO THE GRID OF THE 45 TUBE. IN THIS WAY, THE BIAS VOLTAGE FOR THE 45 TUBE WILL NOT BE ALTERED AS THE POSITION OF THE VOLUME CONTROL IS CHANGED. THE AUDIO FREQUENCY CURRENTS, HOWEVER, WILL REACT THROUGH THIS VOLUME CONTROL CONDENSER AND THE POSITION OF THE POTENTIOMETER ARM WILL GOVERN THE PERCENTAGE OF ACTUAL SIGNAL VOLTAGE WHICH IS APPLIED TO THE GRID OF THE TUBE.

ALSO TAKE NOTE OF THE FACT THAT IN THE CIRCUIT OF FIG. 5, A SEPARATE FILAMENT WINDING IS USED FOR EACH STAGE SO AS TO AVOID HIGH POTENTIALS BETWEEN THE ELEMENTS OF THE TUBES.

A-55 TUBE DIRECT-COUPLED TO A POWER STAGE

IN FIG. 5 YOU ARE SHOWN HOW A TYPE 55 TUBE IS CONNECTED INTO A POWER OUTPUT STAGE BY MEANS OF DIRECT COUPLING. SINCE THE AMPLIFYING HALF OF THE 55 TUBE IS DIODE BIASED, THERE IS NO NEED FOR AN AUDIO BY-PASS CONDENSER AND THIS MAKES IT POSSIBLE TO REALIZE A BETTER TONE QUALITY.

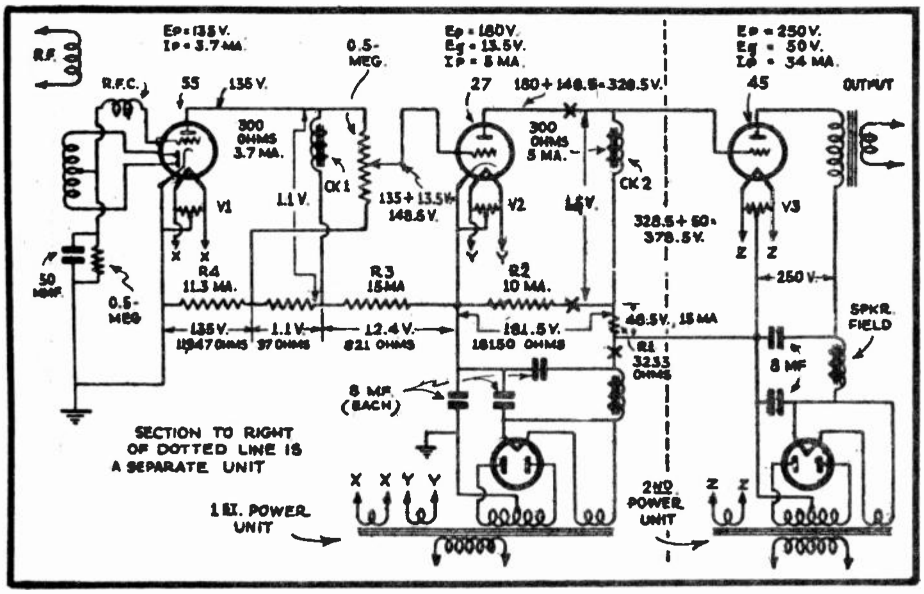

FIG. 6

Direct-Coupled Amplifier With Dual Power Packs.

IT SHALL BE NOTED HERE, HOWEVER, THAT IN MANY CASES THE VOLTAGE DROP ACROSS R_4, DUE TO THE RECTIFIED SIGNAL, MAY BE INSUFFICIENT TO PROPERLY BIAS THE TRIODE HALF OF THE 55 EXCEPT ON STRONG LOCAL STATIONS. FOR THIS REASON, THE PLATE VOLTAGE ON THE 55 TUBE SHOULD BE AS LOW AS POSSIBLE WITHOUT TOO MUCH SACRIFICE.

THE SAME PROCEDURE IS EMPLOYED FOR CALCULATING THE VARIOUS RESISTOR VALUES IN THIS CIRCUIT AS HAS ALREADY BEEN EXPLAINED AND SO THERE WILL BE NO NEED TO GO INTO FURTHER DETAILS REGARDING THIS MATTER.

ALL NECESSARY VALUES ARE NOTED ON THIS DIAGRAM SO THAT YOU SHOULD HAVE NO DIFFICULTY IN ANALYZING THIS CIRCUIT BY SIMPLY APPLYING THE PRINCIPLES WHICH HAVE ALREADY BEEN THOROUGHLY EXPLAINED.

DIRECT-COUPLED AMPLIFIER WITH DUAL POWER PACKS

DIRECT COUPLED AMPLIFIERS EMPLOYING MORE THAN TWO STAGES ORDINARILY OFFER A DISADVANTAGE FROM THE STANDPOINT THAT THE MAXIMUM "B" VOLTAGE MUST BE ABNORMALLY HIGH AND THEREBY NECESSITATES THE USE OF EXPENSIVE COMPONENTS IN THE POWER SUPPLY SYSTEM. IN FIG. 6, HOWEVER, YOU ARE SHOWN AN

INTERESTING THREE-STAGE DIRECT COUPLED AMPLIFIER CIRCUIT IN WHICH TWO POWER SUPPLIES CONSISTING OF STANDARD COMPONENTS ARE EMPLOYED.

HERE THE FIRST POWER UNIT IS EMPLOYED TO FURNISH THE NECESSARY POWER FOR THE FIRST TWO STAGES OF THE AMPLIFIER, AS WELL AS THE BIAS VOLTAGE FOR THE POWER TUBE. THE SECOND POWER UNIT IS THEREFORE ONLY CALLED UPON TO SUPPLY A "B" VOLTAGE OF 250 VOLTS AND THE FILAMENT VOLTAGE FOR ITS 80 RECTIFIER TUBE AND THE TYPE 45 POWER TUBE.

EVEN THOUGH A BLEEDER CURRENT FLOWS THROUGH THE SERIES OF RESISTANCES IN THE CIRCUIT OF FIG. 6 YET THIS DOES NOT COMPLICATE THE CALCULATIONS TO ANY APPRECIABLE EXTENT. THIS SIMPLY MEANS THAT THE DRAINED BLEEDER CURRENT MUST BE ADDED TO THE NORMAL TUBE CURRENT IN EACH CASE.

IN THE CIRCUIT OF FIG.6 FOR INSTANCE, A BLEEDER CURRENT OF 10 MA. IS BEING EMPLOYED AND THEREFORE THE 5 MA. PLATE CURRENT OF V_2 AND THE 10 MA. OF BLEEDER CURRENT FLOW THROUGH R_1 WHILE ONLY 10 MA. PASSES THROUGH R_2. A CLOSE STUDY OF FIG.6 WILL MAKE THIS DISTRIBUTION OF CURRENT PERFECTLY CLEAR IN THAT ALL VALUES ARE PLAINLY NOTED THEREON. THE REST OF THE VOLTAGE DISTRIBUTION CALCULATIONS FOLLOW THE SAME PROCEDURE AS ALREADY WERE SO FULLY EXPLAINED IN CONJUNCTION WITH THE PRECEDING EXAMPLES.

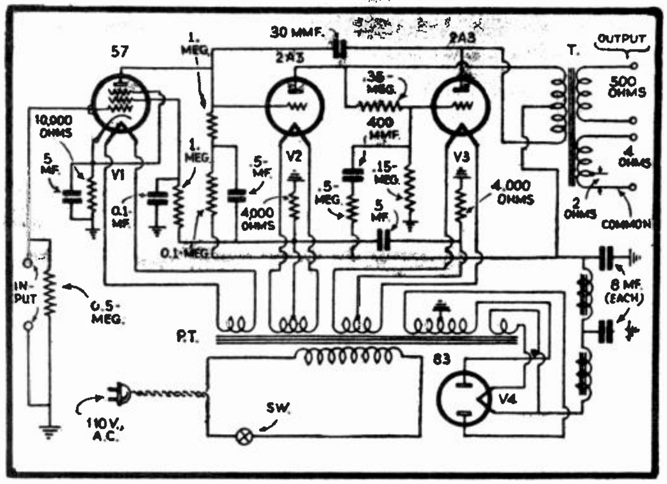

FIG. 7
A Four-Tube Direct-Coupled Amplifier.

THE VOLUME CONTROL FOR THIS CIRCUIT, YOU WILL NOTICE, CONSISTS OF A .5 MEGOHM POTENTIOMETER WHOSE EXTREMETIES ARE CONNECTED IN A MODIFIED PARALLEL ARRANGEMENT AROUND A.F. CHOKE "CK-1" SO THAT IT ALSO ACTS AS PART OF THE PLATE CIRCUIT LOAD FOR V_1 AS WELL AS PART OF THE GRID CIRCUIT OF V_2 AND FOR THIS REASON SIGNAL VOLTAGE VARIATIONS WILL APPEAR ACROSS BOTH THE CHOKE AND VOLUME CONTROL. THE SETTING OF THE POTENTIOMETER ARM THEREFORE DETERMINES WHAT PERCENTAGE OF THE AVAILABLE SIGNAL VOLTAGE VALUE IS APPLIED TO THE GRID OF V_2 AND IN THIS WAY THE VOLUME IS CONTROLLED.

WITH THE INFORMATION SO FAR GIVEN YOU, YOU SHOULD EXPERIENCE NO DIFFICULTY IN CALCULATING THE VOLTAGE AND CURRENT DISTRIBUTION IN AUDIO AMPLIFIERS OF THE DIRECT — COUPLED TYPE, REGARDLESS OF ANY MINOR DETAILS WHICH MAY DIFFER IN THE GENERAL CIRCUIT ARRANGEMENT. IN OTHERWORDS, EVEN, IF THE A.F. CHOKES AS USED IN THESE PARTICULAR CIRCUITS WERE TO BE REPLACED WITH RESISTORS, THE PROCEDURE FOR THE CALCULATIONS WOULD STILL BE THE SAME AS SO FAR DESCRIBED.

A FOUR-TUBE DIRECT-COUPLED AMPLIFIER

IN FIG.7 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A MODERN FOUR-TUBE

DIRECT-COUPLED AMPLIFIER AND IN WHICH THE TUBES USED ARE A 57 PENTODE INPUT, FOLLOWED BY A SPECIAL DIRECT-COUPLED PUSH-PULL ARRANGEMENT EMPLOYED A PAIR OF 2A3'S. AN 83 IS USED IN THE POWER PACK. THIS AMPLIFIER HAS AN OUTPUT RATING OF 10 WATTS.

NOTICE THAT IN THIS AMPLIFIER ALSO, A SEPARATE FILAMENT WINDING IS PROVIDED FOR EACH TUBE FOR THE SAME REASON AS ALREADY MENTIONED IN CONJUNCTION WITH THE CIRCUIT APPEARING IN FIG. 6 OF THIS LESSON. THE VOLUME CONTROL IS NOT INSTALLED IN THE AMPLIFIER ITSELF BUT IS INCLUDED IN A SEPARATE MIXER-CONTROL UNIT WHICH IS HOUSED IN A SEPARATE ENCLOSURE NOT SHOWN HERE. THE OUTPUT TERMINALS OF THIS CONTROL UNIT ARE TO BE CONNECTED ACROSS THE INPUT TERMINALS OF THE AMPLIFIER.

THE POWER STAGE IS RATHER UNUSUAL IN DESIGN. HERE THE PLATE RESISTANCE OF V_2 IS CONNECTED IN PARALLEL WITH THE PLATE-GRID RESISTORS (THE .35 MEG. AND .15 MEG. RESISTORS) AND BOTH OF WHICH TOGETHER ARE CONNECTED ACROSS B+ AND B- SO THAT THE "B" CURRENT WILL DIVIDE BETWEEN THESE TWO PATHS PROPORTIONATELY TO THEIR RESISTANCES. IF THE GRID OF V_2 IS DRIVEN POSITIVE BY A SIGNAL VOLTAGE, THEN THIS WILL DECREASE THE RESISTANCE THRU V_2 SO THAT THE PLATE CURRENT FLOW THROUGH IT INCREASES WITH RESPECT TO ITS NORMAL VALUE AND IN THIS WAY REDUCE THE VOLTAGE DROP ACROSS THE PLATE-GRID RESISTORS. THE REVERSE IS TRUE WHEN THE GRID OF V_2 IS DRIVEN NEGATIVE BY A SIGNAL AND THEREFORE WHENEVER THE GRID OF V_2 IS POSITIVE, THE GRID OF V_3 IS PROPORTIONATELY NEGATIVE AND VICE VERSA SO THAT PUSH-PULL OPERATION IS REALIZED.

RESISTANCE - COUPLED PUSH-PULL AMPLIFIER

IN FIG. 8 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN AMPLIFIER WHICH IS DIFFERENT IN DESIGN FROM ANY OF THE OTHERS WHICH WERE SO FAR SHOWN YOU. HERE YOU WILL OBSERVE, THAT PUSH-PULL PERFORMANCE IS OBTAINED IN TWO STAGES WITHOUT THE USE OF INTERSTAGE COUPLING TRANSFORMERS.

A TYPE 53 TUBE IS EMPLOYED AT THE INPUT OF THIS AMPLIFIER AND AS YOU WILL NOTICE FROM THE SYMBOL OF THIS TUBE, IT REALLY CONSISTS OF TWO HEATER TYPE TRIODES ENCLOSED IN A SINGLE GLASS BULB. FOR THE SAKE OF EXPLANATION, WE SHALL CALL THE LEFT HALF OF THIS TUBE THE "FIRST SECTION" AND THE RIGHT HALF THE "SECOND SECTION". THIS TUBE IS EMPLOYED IN A PHASE INVERSION CIRCUIT AND THIS SYSTEM OPERATES ON THE PRINCIPLES AS WILL NOW BE EXPLAINED.

IT IS A WELL KNOWN FACT THAT THE OUTPUT SIGNAL IN THE PLATE CIRCUIT OF A TUBE IS 180° OUT OF PHASE WITH THE INPUT SIGNAL; IN OTHER WORDS, THE AMPLIFYING TUBE REVERSES THE PHASE OF THE SIGNAL. NOW THEN REFERRING TO THE CIRCUIT OF FIG. 8, THE SIGNAL IS APPLIED TO THE GRID OF THE FIRST SECTION OF THE 53 — THE OUTPUT VOLTAGE APPEARING ACROSS THE PLATE CIRCUIT LOAD OF THIS FIRST TUBE SECTION AND IS TRANSFERRED THROUGH COUPLING CONDENSER C_3 THEREBY APPEARING ACROSS RESISTORS R_6 AND R_7 IN SERIES, AT THE SAME TIME ACTING UPON THE GRID OF THE UPPER 56 TUBE.

THAT PORTION OF THE SIGNAL VOLTAGE WHICH APPEARS ACROSS R_7 IS NOW TRANSFERRED TO THE GRID OF THE SECOND SECTION OF THE 53 AND IS INVERTED AND AMPLIFIED SO THAT THE SIGNAL VOLTAGE IN ITS PLATE CIRCUIT IS EQUAL AND OPPOSITE TO THAT ACROSS R_6 AND R_7.

THE VALUES OF R_6 AND R_7 HAVE BEEN SO CHOSEN AS TO MAKE THE VOLTAGES EQUAL IN BOTH HALVES OF THE TUBE.

THIS SECOND SIGNAL VOLTAGE IS THEN APPLIED TO THE GRID OF THE SECOND 56 TUBE BY WAY OF CONDENSER C_2. THUS THE 53 IS COUPLED TO TWO 56 TYPE TUBES IN PUSH-PULL WITHOUT THE USE OF A TRANSFORMER AND THEREBY ELIMINATING SOME OF THE CAUSES OF FREQUENCY DISCRIMINATION.

THIS SAME FUNCTION AS PERFORMED BY THE 53 TUBE COULD BE PERFORMED BY TWO ORDINARY TUBES BUT THE 53 HAS THE ADVANTAGE OF SAVING SPACE AND PARTS.

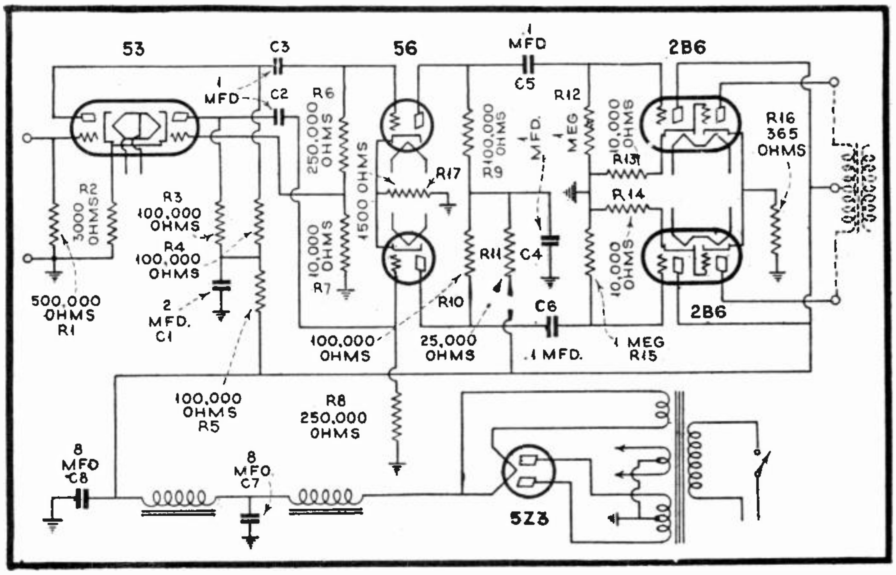

FIG. 8

The Resistance-Coupled Amplifier.

THE INTERMEDIATE STAGE EMPLOYING THE TWO 56 TUBES FEEDS INTO THE THIRD STAGE OF THE AMPLIFIER WHERE THE TWO 2B6 TUBES ARE USED. THESE 2B6 TUBES ARE OF THE TRIPLE-TWIN TYPE CONSISTING OF TWO HEATER TYPE TRIODE SECTIONS ENCLOSED IN A SINGLE GLASS BULB AND EACH OF THESE TUBES REALLY COMPRISES TWO STAGES DIRECTLY COUPLED.

THE PLATE LOAD OF THE FIRST SECTION IS IN THE CATHODE SIDE OF THE PLATE CIRCUIT. THE VOLTAGE ACROSS THIS RESISTOR IS APPLIED TO THE GRID OF THE SECOND SECTION WITHOUT ANY ADDITIONAL APPARATUS BECAUSE THE TWO ARE CONNECTED TOGETHER. THIS THEREFORE, IS ANOTHER FORM OF DISTORTIONLESS ENERGY TRANSFER.

THE ONLY COUPLING TRANSFORMER USED IN THIS ENTIRE AMPLIFIER IS THAT WHICH IS EMPLOYED TO COUPLE THE AMPLIFIER TO THE SPEAKER. THE OUTPUT OF THIS AMPLIFIER IS RATED AT 15 WATTS.

Examination Questions

LESSON NO. AS-5

"He is not only idle who does nothing, but he is idle who might be better employed."

Answered Apr 22/1941

1. – WHAT IS THE DISTINCTIVE FEATURE OF DIRECT-COUPLED AMPLIFIERS IN REGARDS TO THE CIRCUIT ARRANGEMENT?

2. – WHAT IS THE MOST OUTSTANDING FEATURE OF DIRECT- COUPLED AMPLIFIERS WITH RESPECT TO PERFORMANCE?

3. – WHAT IS ONE OF THE DISADVANTAGES OFFERED BY DIRECT-COUPLED AMPLIFIERS?

4. – DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES THE BASIC PRINCIPLES OF A DIRECT-COUPLED AMPLIFIER.

5. – EXPLAIN HOW THE CIRCUIT WHICH YOU HAVE DRAWN IN ANSWER TO QUESTION #4 OPERATES.

6. – WHY IS IT THAT ALTHOUGH THE PLATE OF A TUBE IS CONNECTED TO THE CONTROL GRID OF THE FOLLOWING TUBE THAT THIS SECOND TUBE IS STILL ABLE TO OPERATE WITH A NEGATIVE GRID BIAS?

7. – DRAW A CIRCUIT DIAGRAM OF A COMPLETE DIRECT-COUPLED AMPLIFIER.

8. – EXPLAIN IN DETAIL HOW YOU WOULD PROCEED IN DESIGNING A DIRECT-COUPLED AMPLIFIER WITH RESPECT TO THE PROPER VOLTAGE DISTRIBUTION AND ILLUSTRATE YOUR EXPLANATION BY MEANS OF A DIAGRAM.

9. – WHY IN THE CIRCUIT OF FIG. 8 IS THE 53 TUBE BEING EMPLOYED AS A PHASE-INVERTER?

10.– WHAT ADVANTAGE IS OFFERED BY A CIRCUIT, SUCH AS ILLUSTRATED IN FIG. 8, OVER THE MORE CONVENTIONAL AMPLIFIER CIRCUITS.

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Amplifying Systems

LESSON NO. 6

ALGEBRA I

Algebra is the continuation of arithmetic and is of great value in solving engineering problems.

It is the tool which enables us to perform rather complex calculations in a most systematic manner and to arrive at an answer with accuracy and in the shortest possible time.

A number of terms or expressions are used in connection with Algebra with which you are, perhaps, not yet familiar. It is therefore essential that these terms first be brought to your attention before we go into the exact mathematical processes as applied to Algebra.

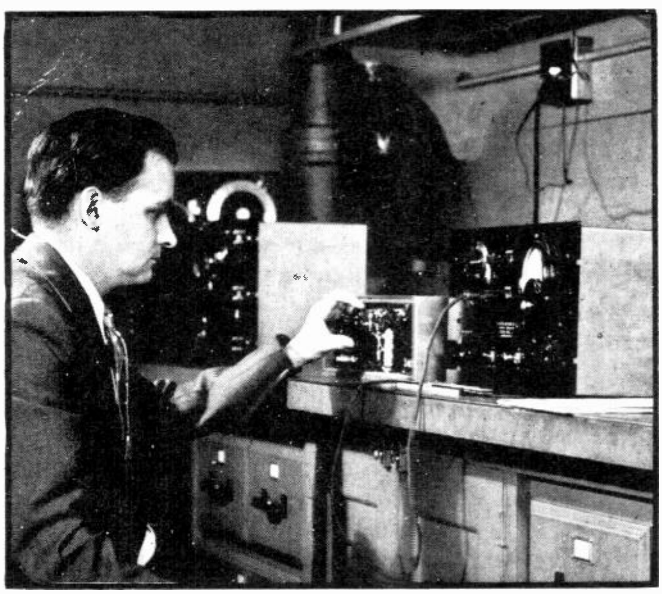

Fig. 1
A good knowledge of Mathematics is required by the Radio Engineer

ALGEBRAIC EXPRESSION

An algebraic expression is any expression that represents a number by means of the signs and symbols of Algebra. For instance, 3abc is an algebraic expression that tells us that the factors 3, a, b, and c are all to be multiplied together and could also be written in the form 3xaxbxc, where the sign (x) denotes the process of multiplication as you already learned in a previous lesson treating with Math-

EMATICS IN GENERAL.

FACTORS

IF WE SHOULD BE WORKING WITH AN ALGEBRAIC EXPRESSION SUCH AS 23 ACD, THEN 23, A, C, AND D ARE ALL CONSIDERED AS BEING THE FACTORS OF THIS ALGEBRAIC EXPRESSION. IN OTHER WORDS, THE VARIOUS INDIVIDUAL PARTS OF AN ALGEBRAIC EXPRESSION CONSTITUTE ITS FACTORS.

COEFFICIENT

SHOULD WE CONSIDER THE SAME EXPRESSION 23 ACD AGAIN, THEN ANY ONE OF ITS FACTORS OR ANY PRODUCT OF TWO OR MORE OF THEM IS CALLED THE CO-EFFICIENT OF THE REMAINING PART. FOR EXAMPLE, 23A MAY BE CONSIDERED AS BEING THE COEFFICIENT OF CD OR 23AC MAY BE CONSIDERED AS BEING THE COEFFICIENT OF D. AS A GENERAL RULE, HOWEVER, WE REFER TO THE NUMERICAL PART OF THE EXPRESSION ONLY AS BEING THE COEFFICIENT AND IN WHICH CASE IT IS CALLED THE NUMERICAL COEFFICIENT. WHENEVER NO NUMERICAL PART IS EXPRESSED, THEN IT IS UNDERSTOOD TO BE 1. FOR INSTANCE, 1 ACX IS THE SAME AS ACX.

POWER-EXPONENT

IF ALL THE FACTORS IN A PRODUCT ARE EQUAL AS $a.a.a.a$ THEN THE PRODUCT OF THE FACTORS IS CALLED A POWER OF ONE OF THEM. (THE PERIODS APPEARING BETWEEN THE SUCCESSIVE LETTERS "A" IN THIS CASE DENOTE THE PROCESS OF MULTIPLICATION AND ARE EQUIVALENT TO THE MORE COMMONLY USED SYMBOL FOR MULTIPLICATION X). THE FORM $a.a.a.a$ IS USUALLY WRITTEN AS a^4 AND THIS VALUE IS SPOKEN OF AS BEING a FOURTH POWER. THE SMALL NUMBER TO THE RIGHT AND ABOVE INDICATES HOW MANY TIMES a IS TAKEN AS A FACTOR. IN THE CASE OF a^4, a IS CALLED THE BASE AND 4 THE EXPONENT AND IT WOULD INDICATE THAT a IS TAKEN FOUR TIMES AS A FACTOR.

AS FURTHER EXAMPLES, LET US CONSIDER C^2 WHICH IS READ AS C SQUARE OR C SECOND POWER AND INDICATES THAT C IS TAKEN TWICE AS A FACTOR; C^3 IS READ AS C CUBE OR C THIRD POWER AND INDICATES THAT C IS TAKEN THREE TIMES AS A POWER; C^4 IS READ AS C FOURTH POWER AND INDICATES THAT C IS TAKEN FOUR TIMES AS A FACTOR; C^n IS READ AS C NTH POWER OR C EXPONENT "N" AND INDICATES THAT C IS TAKEN "N" TIMES AS A FACTOR.

WHEN NO EXPONENT IS WRITTEN, THEN THE EXPONENT IS UNDERSTOOD TO BE 1; THUS A IS THE SAME AS A^1.

A TERM

A TERM IN AN ALGEBRAIC EXPRESSION IS A PART OF THE EXPRESSION NOT SEPARATED BY A PLUS OR MINUS SIGN. THUS, IN THE EXPRESSION 4 AX + 3C −D, WE FIND THE TERMS TO BE 4 AX, 3C AND D.

IT IS CONVENIENT TO HAVE NAMES FOR ALGEBRAIC EXPRESSIONS HAVING DIFFERENT NUMBERS OF TERMS. FOR EXAMPLE, A MONOMIAL IS AN ALGEBRAIC EXPRESSION CONSISTING OF ONE TERM SUCH AS 3 XY; A BINOMIAL CONSISTS OF TWO TERMS SUCH AS $4AB^2 + 2X^3Y^2$ AND A TRINOMIAL CONSISTS OF THREE TERMS SUCH AS $2A^3B^2 - 3XY^3 + 8C^2D^6$. ANY ALGEBRAIC EXPRESSION OF TWO OR MORE TERMS (GENERALLY ABOVE THREE) IS CALLED A POLYNOMIAL OR A MULTINOMIAL. THE EXPRESSION $4A^2B^4 - 2XY^2 + 7C^2D - 10A^4$ WOULD BE A POLYNOMIAL OR A MULTINOMIAL.

TERMS THAT ARE EXACTLY THE SAME OR DIFFER ONLY IN THEIR COEFFICIENTS ARE CALLED LIKE TERMS OR SIMILAR TERMS, WHEREAS TERMS THAT DIFFER OTHERWISE THAN IN THEIR COEFFICIENTS ARE UNLIKE OR DISSIMILAR TERMS. THUS $6a^3x^2$, $-7a^3x^2$ AND $16a^3x^2$ ARE LIKE TERMS; WHILE $6ax^2$, $-7a^3x^2$ AND $16ayz$ ARE UNLIKE TERMS.

POSITIVE AND NEGATIVE NUMBERS

THE DEGREES OF TEMPERATURE INDICATED BY THE THERMOMETER SCALE, FOR EXAMPLE, ARE COUNTED IN TWO OPPOSITE DIRECTIONS FROM THE ZERO POINT AND WE USUALLY SPEAK OF A TEMPERATURE AS SO MANY DEGREES ABOVE OR BELOW ZERO. IN ALGEBRA, HOWEVER, WE EMPLOY A SYSTEM OF ABREVIATION TO STATE THE SAME THING AND WE DO THIS BY USING THE SIGNS + AND −.

ANY NUMBER PRECEDED BY THE + SIGN IS CALLED A POSITIVE NUMBER AND IS THEREFORE ABOVE A ZERO VALUE. ON THE OTHER HAND, ANY NUMBER PRECEDED BY THE − SIGN IS CALLED A NEGATIVE NUMBER AND IS THEREFORE BELOW A ZERO VALUE. THIS COULD BE ILLUSTRATED AS IS SHOWN YOU IN FIG. 2. THESE POSITIVE AND NEGATIVE NUMBERS, TOGETHER WITH ZERO, FORM THE SYSTEM CALLED ALGEBRAIC NUMBERS.

THE ABSOLUTE OR NUMERICAL VALUE OF A NUMBER IS THE VALUE WHICH IT HAS WITHOUT REFERENCE TO ITS SIGN. THUS, +5 AND −5 HAVE THE SAME ABSOLUTE VALUE 5.

ADDITION OF ALGEBRAIC NUMBERS

THE ADDITION OF ALGEBRAIC NUMBERS CAN BE DEMONSTRATED TO YOU GRAPHICALLY BY MEANS OF FIG. 2 AND WHICH WILL NO DOUBT HELP TO MAKE THIS CLEARER TO YOU.

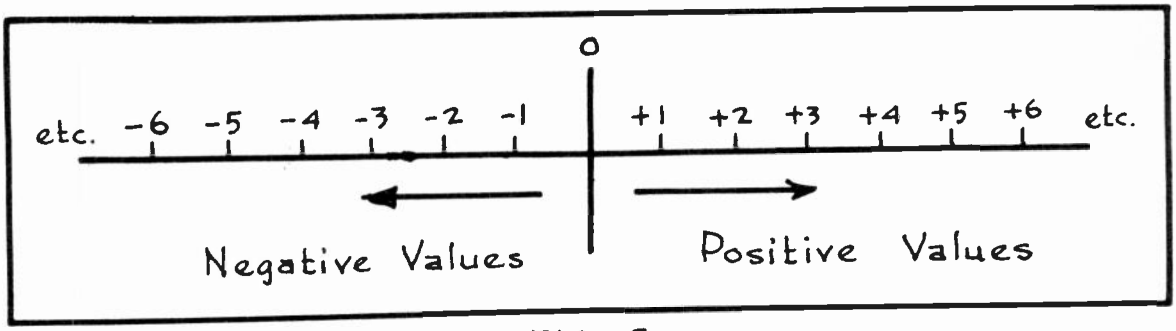

FIG. 2
Positive and Negative Numbers.

LET US SUPPOSE, FOR INSTANCE, THAT YOU ARE TO DETERMINE THE ALGEBRAIC SUM OF +3 AND +2. IN THIS CASE, WE WOULD START AT THE ZERO MARK IN FIG. 2 AND COUNT THREE DIVISIONS TOWARDS THE RIGHT WHICH WILL BRING US TO A VALUE OF +3. THEN IF WE SHOULD MOVE OVER TWO MORE DIVISIONS TOWARDS THE RIGHT FROM THIS MARK OF +3 OR ADD +2, AS IT WERE, THEN THIS WOULD BRING US TO THE +5 MARK. IN OTHER WORDS, THE ALGEBRAIC SUM OF +3 AND +2 IS +5.

NOW LET US SUPPOSE THAT WE ARE TO FIND THE ALGEBRAIC SUM OF +3 AND −2. IN THIS CASE, WE WOULD MOVE FROM ZERO TOWARDS THE RIGHT TO THE +3 MARK. THEN IF WE ARE TO ADD −2 TO THIS VALUE, WE WOULD MOVE BACK OR TO-

WARDS THE LEFT OF +3 FOR TWO DIVISIONS AND WHICH WOULD BRING US TO THE +1 MARK. THUS WE HAVE SHOWN THAT THE ALGEBRAIC SUM OF +3 AND −2 IS +1.

A CAREFUL CONSIDERATION OF THE FOREGOING EXPLANATION WILL DISCLOSE THE FOLLOWING RULE:

(1) THE ALGEBRAIC SUM OF TWO NUMBERS WITH LIKE SIGNS IS THE SUM OF THEIR ABSOLUTE VALUES, WITH THE COMMON SIGN PREFIXED.

THUS:−

$$\begin{array}{r} +4 \\ \underline{+3} \\ +7 \end{array} \qquad \begin{array}{r} -5 \\ \underline{-4} \\ -9 \end{array}$$

(2) THE ALGEBRAIC SUM OF TWO NUMBERS WITH UNLIKE SIGNS IS THE DIFFERENCE BETWEEN THEIR ABSOLUTE VALUES WITH THE SIGN OF THE ONE GREATER IN ABSOLUTE VALUE PREFIXED.

EXAMPLE:−

$$\begin{array}{r} +7 \\ \underline{-3} \\ +4 \end{array} \qquad \begin{array}{r} -3 \\ \underline{+5} \\ +2 \end{array}$$

WHENEVER IT IS NECESSARY TO ADD THREE OR MORE ALGEBRAIC NUMBERS, DIFFERING IN SIGNS, THEN FIND THE SUM OF THE POSITIVE NUMBERS AND THE SUM OF THE NEGATIVE NUMBERS BY RULE (1) AND THEN ADD THESE SUMS BY RULE (2).

EXAMPLE:− TO FIND THE SUM OF +3, +8, −6, −4, −10, +2 WE TAKE +3+8+2=+13 AND (−6) + (−4) + (−10) = −20, THEN +13 +(−20) = −7 THE SUM.

SUBTRACTION OF ALGEBRAIC NUMBERS

IN SUBTRACTION AS APPLIED TO ORDINARY ARITHMETIC, IT IS ASSUMED THAT THE MINUEND IS ALWAYS GREATER THAN THE SUBTRAHEND. HOWEVER, IN THE SUBTRACTION OF ALGEBRAIC NUMBERS WE NOT ONLY MAY HAVE THE SUBTRAHEND LARGER THAN THE MINUEND WHEN THE NUMBERS ARE POSITIVE BUT EITHER OR BOTH SUBTRAHEND AND MINUEND MAY BE NEGATIVE NUMBERS. THE RULES FOR SUBTRACTING ALGEBRAIC NUMBERS ARE AS FOLLOWS:

RULE :− THE SUBTRACTION OF ALGEBRAIC NUMBERS IS PERFORMED BY CONSIDERING THE SIGN OF THE SUBTRAHEND CHANGED AND PROCEEDING AS IN ADDITION OF ALGEBRAIC NUMBERS.

EXAMPLE:−

$$\begin{array}{r} +7 \\ \underline{+3} \\ +4 \end{array} \qquad \begin{array}{r} +4 \\ \underline{+6} \\ -2 \end{array} \qquad \begin{array}{r} -6 \\ \underline{-2} \\ -4 \end{array} \qquad \begin{array}{r} -3 \\ \underline{-7} \\ +4 \end{array} \qquad \begin{array}{r} -8 \\ \underline{+3} \\ -11 \end{array} \qquad \begin{array}{r} +7 \\ \underline{-2} \\ +9 \end{array}$$

ADDITION AND SUBTRACTION OF LITERAL ALGEBRAIC EXPRESSIONS

AS YOU ALREADY KNOW, IN ARITHMETIC WE CANNOT ADD OR SUBTRACT UNLIKE THINGS. FOR INSTANCE, WE ADD 5 BUSHELS, 8 BUSHELS, 10 BUSHELS AND OBTAIN 23 BUSHELS. SHOULD WE WISH TO ADD 10 BUSHELS TO 3 GALLONS THEN THE ONLY WAY THAT WE COULD WRITE THIS WOULD BE IN THE FORM 10 BUSHELS +3 GALLONS. IN OTHER WORDS, SINCE THESE ARE TWO DIFFERENT UNITS OF MEASUREMENT, THEY CANNOT BE COMBINED INTO ONE.

We have a similar condition to contend with in respect to the addition and subtraction of literal algebraic expressions. For instance, $6d + 4d + 7d = 17d$; or $4xy + 7xy + 8xy = 19xy$ etc. Whereas in the case of subtraction, we have $17a - 5a = 12a$ and $46x^3y^2 - 6x^3y^2 = 40x^3y^2$. Should we, however, wish to add two unlike algebraic expressions as $3a$ and $2b$, then the only way we can indicate this addition is thus, $3a + 2b$ but they cannot be combined into a single term.

The rule for the addition and subtraction of literal algebraic expressions is as follows: Rule:– Monomials which are alike or similar can be added or subtracted by adding or subtracting the coefficients. If the monomials are unlike, then the operations can only be indicated.

Examples of addition:

$$\begin{array}{r} (1) \\ +3\,abc \\ -6\,abc \\ +10\,abc \\ -16\,abc \\ -3\,abc \\ \hline -12\,abc \end{array} \qquad \begin{array}{r} (2) \\ -16\,xy^3 \\ +3\,xy^3 \\ -4\,xy^3 \\ -7\,xy^3 \\ +28\,xy^3 \\ \hline +4\,xy^3 \end{array} \qquad \begin{array}{c} (3) \\ 17\,ab \\ -3\,x \\ -4\,c^3 \\ +3\,a^2 \\ \hline 17\,ab - 3x - 4c^3 + 3a^2 \end{array}$$

Examples of subtraction:

$$\begin{array}{r} (1) \\ 4\,ax^2 \\ -6\,ax^2 \\ \hline 10\,ax^2 \end{array} \qquad \begin{array}{r} (2) \\ -21\,x^2y \\ 3\,x^2y \\ \hline -24\,x^2y \end{array} \qquad \begin{array}{c} (3) \\ 14\,ab \\ -6\,c \\ \hline 14\,ab + 6c \end{array}$$

The addition and subtraction of polynomials is similar to that of monomials. Simply write them so that like terms are in the same column and combine the terms in each column as with monomials.

Example of addition:

$$\begin{array}{rrr} +3\,ax^2 & +14y^2 & -3z \\ -7\,ax^2 & -16y^2 & +7z \\ +10\,ax^2 & -4y^2 & +9z \\ -7\,ax^2 & +10y^2 & -11z \\ \hline -ax^2 & +4y^2 & +2z \end{array}$$

Example of subtraction:

$$\begin{array}{rrr} 17\,xy^2 & -14\,c^2 & +4a \\ 10\,xy^2 & -5\,c^2 & -8a \\ \hline 7\,xy^2 & -9\,c^2 & +12a \end{array}$$

Terms with Unlike Coefficients

It often happens that we wish to add or subtract terms where the coefficients that are to be united are not all numerical. For example, add d^2x, e^2x, and cx by uniting the coefficients of x. Here the coefficients of x are d^2, e^2, and c. Since these are unlike terms, the addition can only be indicated; thus $d^2 + e^2 + c$. We may write the sum then of d^2x, e^2x and cx as $(d^2 + e^2 + c)\,x$. Similarly, the sum of $6x$, $5x$ and $2x$ may be written $(6+5+2)\,x$; although here the coefficients can actually be united and expressed as one symbol, thus $13x$.

Signs of Grouping

When a sign of grouping is preceded by a + or – sign, it indicates

THAT THE EXPRESSION ENCLOSED BY THE SIGN OF GROUPING IS TO BE ADDED TO OR SUBTRACTED FROM WHAT PRECEDES.

WHEN A PLUS SIGN PRECEDES A SIGN OF GROUPING, WE MAY REMOVE THE SIGN OF GROUPING WITHOUT MAKING ANY CHANGE IN SIGNS. THUS, $A+(B-C)= A+B-C$. WHEN PRECEDED BY A MINUS SIGN, THE SIGN OF GROUPING MAY BE REMOVED IF THE SIGNS WITHIN ARE CHANGED. THUS, $A-(B-C+D) = A - B + C - D$.

THE REASON FOR THIS CHANGE IS THE SAME AS FOR THE CHANGING OF THE SIGNS IN THE SUBTRAHEND WHEN SUBTRACTING.

WHEN THERE ARE SEVERAL SIGNS OF GROUPING, ONE WITHIN ANOTHER, THEY MAY BE REMOVED BY FIRST REMOVING THE INNERMOST ONE, AND THEN THE NEXT OUTER ONE, CONTINUING TILL ALL ARE REMOVED.

EXAMPLE #1:– SIMPLIFY $4x^2 - 5y^2 + x - [6x^2 - 3x - (y^2 - x)]$.

BEGINNING WITH THE INNER SIGN OF GROUPING, OR THE PARENTHESIS IN THIS CASE, OUR FIRST STEP IS AS FOLLOWS; $4x^2-5y^2+x-[6x^2-3x-y^2+x]$. THEN BY REMOVING THE BRACKETS WE HAVE; $4x^2 - 5y^2 + x - 6x^2 + 3x + y^2 - x$. THEN UPON COMBINING SIMILAR TERMS WE ARRIVE AT THE ANSWER OF $-2x^2-4y^2+3x$.

EXAMPLE #2:– SIMPLIFY $8-\{7-[4+(2-x)]\}$

SOLUTION: $8-\{7-[4+(2-x)]\}$
$= 8-\{7-[4+2-x]\}$
$= 8-\{7-4-2+x\}$
$= 8-7+4+2-x$
$= 7-x$ (ANSWER)

INSERTION OF SIGNS OF GROUPING

ANY TERMS OF A POLYNOMIAL MAY BE ENCLOSED IN A SIGN OF GROUPING PRECEDED BY A PLUS SIGN WITHOUT CHANGE OF SIGNS. THEY MAY BE ENCLOSED IN A SIGN OF GROUPING PRECEDED BY A MINUS SIGN, PROVIDED THE SIGN OF EACH TERM WITHIN IS CHANGED FROM – TO OR FROM + TO –.

EXAMPLE #1:– ENCLOSE THE LAST THREE TERMS IN THE EXPRESSION $ax + by + cd - e$ WITHIN PARENTHESES PRECEDED BY A + SIGN.

SOLUTION: $ax + by + cd - e = ax + (by + cd - e)$.

EXAMPLE #2:– ENCLOSE THE LAST THREE TERMS IN THE EXPRESSION $ax + by + cd - e$ WITHIN PARENTHESES PRECEDED BY A – SIGN.

SOLUTION: $ax + by + cd - e = ax - (-by - cd + e)$.

MULTIPLICATION

IN THE MULTIPLICATION AS APPLIED TO ALGEBRA, WE HANDLE POSITIVE NUMBERS IN THE SAME MANNER AS WHEN WORKING WITH REGULAR ARITHMETICAL VALUES AND WITH WHICH YOU ARE ALREADY FAMILIAR. FOR INSTANCE, IF WE WISH TO MULTIPLY 5 BY 3, WE CAN WRITE THIS IN THE FORM $5 \times 3 = 5 + 5 + 5 = 15$. ALGEBRAICLY, WE COULD ALSO WRITE THIS AS $(+5) \times (+3) = (+5) + (+5) + (+5) = +15$.

FROM THE PRECEDING CONSIDERATIONS, WE CAN ESTABLISH THE FOLLOWING RULES FOR FINDING THE PRODUCT OF TWO ALGEBRAIC NUMBERS:

(1) THE NUMERICAL PART OF THE PRODUCT IS THE PRODUCT OF THE ABSOLUTE VALUES OF THE MULTIPLICAND AND MULTIPLIER.

(2) THE SIGN OF THE PRODUCT IS PLUS WHEN THE SIGNS OF THE MULTIPLICAND AND MULTIPLIER ARE ALIKE, AND MINUS WHEN THEIR SIGNS ARE UNLIKE.

THIS IS CALLED THE LAW OF SIGNS IN MULTIPLICATION AND MAY BE STATED AS FOLLOWS:

$$+ \times + = +$$
$$- \times - = +$$
$$+ \times - = -$$
$$- \times + = -$$

CONTINUED PRODUCTS

TO FIND THE PRODUCT OF THREE OR MORE NUMBERS, WE FIND THE PRODUCT OF THE FIRST TWO, AND THEN MULTIPLY THIS PRODUCT BY THE THIRD AND SO ON TILL ALL THE NUMBERS HAVE BEEN USED. THE RULES FOR SIGNS IN MULTIPLICATION OF THIS TYPE ARE AS FOLLOWS:

(1) THE PRODUCT OF AN ODD NUMBER OF NEGATIVE FACTORS IS NEGATIVE.

(2) THE PRODUCT OF AN EVEN NUMBER OF NEGATIVE FACTORS IS POSITIVE.

(3) THE PRODUCT OF ANY NUMBER OF POSITIVE FACTORS IS POSITIVE.

THUS, $(-2)(-2)(-2)(-2)(-2) = -32$ WHILE $(-2)(-2)(-2)(-2)(-2)(-2) = +64$. THE FIRST OF THESE EQUALS $(-2)^5$ AND IS THEN READ "THE FIFTH POWER OF -2". THE SECOND OF THE PRECEDING EXPRESSIONS IS EQUAL TO $(-2)^6$.

TO STILL FURTHER ILLUSTRATE THIS POINT, LET US CONSIDER THE FOLLOWING EXAMPLES:

$$(-2)^2 = (-2)(-2) = 4 = 2^2$$
$$(-2)^3 = (-2)(-2)(-2) = -8 = -2^3$$
$$(-2)^4 = (-2)(-2)(-2)(-2) = 16 = 2^4$$
$$(-2)^5 = (-2)(-2)(-2)(-2)(-2) = -32 = -2^5$$
$$-2^5 = -(2)(2)(2)(2)(2) = -32$$
$$(-3)^2(-2)^3 = (-3)(-3)(-2)(-2)(-2) = -72$$
$$(4^2)(3^2) = 4 \times 4 \times 3 \times 3 = 144$$

LAW OF EXPONENTS

THE LAW OF EXPONENTS STATES THAT THE PRODUCT OF TWO OR MORE POWERS OF THE SAME BASE IS EQUAL TO THAT BASE AFFECTED WITH AN EXPONENT EQUAL TO THE SUM OF THE EXPONENTS OF THE POWER.

EXAMPLE:— MULTIPLY $14a^3b^2$ BY $-3a^4b^3$

$$\begin{array}{r} \text{SOLUTION:—}\quad 14\ A^3 B^2 \\ \underline{-\ 3\ A^4 B^3} \\ -42\ A^7 B^5 \end{array}$$

EXPLANATION:— SINCE THE MULTIPLIER IS COMPOSED OF THE FACTORS -3, A^4, AND B^3, THE MULTIPLICAND MAY BE MULTIPLIED BY EACH SUCCESSIVELY. IN EACH CASE, THE PRODUCT FOR ANY ONE OF THESE FACTORS IS OBTAINED BY MULTIPLYING A SINGLE FACTOR IN THE MULTIPLICAND BY IT. WE MULTIPLY BY -3, BY MULTIPLYING $14\ A^3 B^2$ BY -3 WHICH GIVES $-42\ A^3 B^2$. THIS IS MULTIPLIED BY A^4, BY MULTIPLYING THE A^3 BY A^4 WHICH GIVES $-42\ A^7 B^2$. THIS IS MULTIPLIED BY B^3 BY MULTIPLYING THE B^2 BY B^3 WHICH GIVES $-42\ A^7 B^5$ AS THE ANSWER.

THIS MULTIPLICATION PROCESS, YOU WILL NOTICE, IS CARRIED OUT BY DETERMING IN THE FOLLOWING ORDER:

(1) THE SIGN OF THE PRODUCT.
(2) THE COEFFICIENT OF THE PRODUCT.
(3) THE LETTERS OF THE PRODUCT.
(4) THE EXPONENTS OF THESE LETTERS.

THUS IN THE EXAMPLE JUST EXPLAINED, THE SIGN IS $+ \times - = -$; THE COEFFICIENT IS $14 \times 3 = 42$; THE LETTERS ARE a AND B; AND THE EXPONENTS ARE FOR A, $3+4 = 7$, AND FOR B, $2+3 = 5$.

NOW THAT YOU HAVE SEEN HOW WE MULTIPLY A MONOMIAL BY A MONOMIAL, LET US NEXT TURN OUR ATTENTION TO THE METHOD EMPLOYED FOR MULTIPLYING A POLYNOMIAL BY A MONOMIAL.

TO MULTIPLY A POLYNOMIAL BY A MONOMIAL

THE PRODUCT OF A POLYNOMIAL AND A MONOMIAL IS FOUND BY MULTIPLYING EACH TERM OF THE MULTIPLICAND BY THE MULTIPLIER AND TAKING THE ALGEBRAIC SUM OF THESE PARTIAL PRODUCTS.

EXAMPLE:— MULTIPLY $7\ AX^3 - 21\ AB^4 - 3\ X^2$ BY $2\ A^2 B^3 X^4$.

$$\begin{array}{l} \text{PROCESS:—}\quad 7AX^3 - 21AB^4 - 3X^2\ \text{(MULTIPLICAND)} \\ \qquad\qquad \underline{2A^2 B^3 X^4\ \text{(MULTIPLIER)}\qquad\qquad} \\ \qquad\qquad 14A^3 B^3 X^7 - 42A^3 B^7 X^4 - 6A^2 B^3 X^6\ \text{(ANSWER)} \end{array}$$

EXPLANATION:— FIRST MULTIPLY THE FIRST TERM OF THE MULTIPLICAND OR $7AX^3$ BY $2A^2 B^3 X^4$ IN THE SAME MANNER AS JUST EXPLAINED FOR MULTIPLYING A MONOMIAL BY A MONOMIAL. PLACE THIS RESULT AS THE FIRST TERM IN THE PRODUCT AND THEN MULTIPLY THE SECOND TERM OF THE MULTIPLICAND OR $-21\ AB^4$ BY $2A^2 B^3 X^4$, PLACING THIS RESULT AS THE SECOND TERM OF THE PRODUCT. FINALLY, MULTIPLY THE LAST TERM OF THE MULTIPLICAND OR $-3X^2$ BY $2A^2 B^3 X$ AND PLACE THIS RESULT AS THE THIRD TERM IN THE PRODUCT.

TO MULTIPLY A POLYNOMIAL BY A POLYNOMIAL

RULE:— TO MULTIPLY A POLYNOMIAL BY A POLYNOMIAL MULTIPLY EVERY TERM OF THE MULTIPLICAND BY EACH TERM OF THE MULTIPLIER, WRITE THE LIKE TERMS OF THE PARTIAL PRODUCTS UNDER EACHOTHER AND FIND THE ALGEBRAIC SUM OF THE PARTIAL PRODUCTS.

EXAMPLE:— MULTIPLY $x^2 + 3xy - 2y^2$ BY $2xy - 2y^2$

PROCESS:— $x^2 + 3xy - 2y^2$ (MULTIPLICAND)
$2xy - 2y^2$ (MULTIPLIER)
(STEP #1) $2xy^3 + 6x^2y^2 - 4xy^3$
(STEP #2) $-2x^2y^2 - 6xy^3 + 4y^4$
(STEP #3) $2xy^3 + 4x^2y^2 - 10xy^3 + 4y^4$ (ANSWER)

EXPLANATION:—

OBSERVE IN THE FOREGOING PROCESS THAT OUR FIRST STEP IS TO MULTIPLY THE ENTIRE MULTIPLICAND BY $2xy$ GIVING US $2xy^3 + 6x^2y^2 - 4xy^3$ AS SHOWN IN "STEP #1". THE NEXT STEP IS TO MULTIPLY THE ENTIRE MULTIPLICAND BY THE SECOND TERM OF THE MULTIPLIER $-2y^2$ IN ORDER TO OBTAIN THE RESULT $-2x^2y^2 - 6xy^3 + 4y^4$ IN "STEP #2". OBSERVE THAT THE TERMS OBTAINED IN STEP #2 ARE PLACED UNDER CORRESPONDING TERMS AS APPEAR IN STEP #1. IN STEP #3 WE ADD SIMILAR TERMS APPEARING IN STEPS #1 AND #2 AND OBTAIN OUR FINAL RESULT OR ANSWER OF $2xy^3 + 4x^2y^2 - 10xy^3 + 4y^4$.

NOW LET US CONSIDER THE MULTIPLICATION PROCESS WHEN THREE TERMS APPEAR IN BOTH THE MULTIPLIER AND MULTIPLICAND.

EXAMPLE:— MULTIPLY $3a^2 + 3b^2 + ab$ BY $b^3 - 2a^2b + ab^2$

PROCESS:— $3a^2 + 3b^2 + ab$ (MULTIPLICAND)
$b^3 - 2a^2b + ab^2$ (MULTIPLIER)
(STEP #1) $3a^2b^3 + 3b^5 + ab^4$
(STEP #2) $-6a^2b^3 \qquad -6a^4b - 2a^3b^2$
(STEP #3) $+a^2b^3 \qquad +3ab^4 \qquad +3a^3b^2$
$-2a^2b^3 + 3b^5 + 4ab^4 - 6a^4b + a^3b^2$ (ANSWER)

EXPLANATION:— THE FIRST STEP OR "STEP #1" OF THE FOREGOING PROCESS CONSISTS OF MULTIPLYING EACH TERM OF THE MULTIPLICAND BY THE FIRST TERM OF THE MULTIPLIER OR b^3 AND THIS GIVES US $3a^2b^3 + 3b^5 + ab^4$ AS THE PARTIAL PRODUCT IN "STEP #1". IN ORDER TO OBTAIN THE PARTIAL PRODUCT FOR "STEP #2", WE MULTIPLY EACH TERM OF THE MULTIPLICAND BY THE SECOND TERM OF THE MULTIPLIER OR $-2a^2b$ AND THIS GIVES US $-6a^2b^3 - 6a^4b - 2a^3b^2$ AS THE SECOND PARTIAL PRODUCT.

IT IS IMPORTANT THAT WE PLACE THE VARIOUS TERMS OF THE SECOND PARTIAL PRODUCT DIRECTLY BENEATH SIMILAR OR CORRESPONDING TERMS OF THE FIRST PARTIAL PRODUCT. IN OTHER WORDS, THE TERM $-6a^2b^3$ OF STEP #2 MUST BE DIRECTLY BELOW THE TERM $3a^2b^3$ OF STEP #1 AND SINCE THERE ARE NO TERMS HAVING THE COEFFICIENTS a^4b AND a^3b^2 IN THE PARTIAL PRODUCT OBTAINED IN STEP #1, THE TERMS $-6a^4b$ AND $-2a^3b^2$ OF STEP #2 MUST BE PLACED TO THE RIGHT OF THE LAST TERM APPEARING IN STEP #1.

TO OBTAIN THE PARTIAL PRODUCT APPEARING IN STEP #3 WE MULTIPLY EACH TERM OF THE MULTIPLICAND BY THE THIRD TERM OF THE MULTIPLIER OR $+ab^2$ AND THEREBY OBTAIN THE PARTIAL PRODUCT $a^2b^3 + 3ab^4 + 3a^3b^2$ AND WE PLACE THESE THREE TERMS DIRECTLY UNDER THE SIMILAR TERMS APPEARING IN THE PARTIAL PRODUCTS OBTAINED IN STEPS #1 AND #2. OUR FINAL STEP THEN IS TO ADD ALGEBRAICALLY THESE THREE PARTIAL PRODUCTS AND IN THIS WAY OBTAIN OUR FINAL PRODUCT OR ANSWER $-2a^2b^3 + 3b^5 + 4ab^4 - 6a^4b + a^3b^2$.

DIVISION

DIVISION IS THE INVERSE OF MULTIPLICATION. THAT IS, THE QUOTIENT MUST BE AN EXPRESSION THAT MULTIPLIED BY THE DIVISOR WILL GIVE THE DIVIDEND.

FROM THE LAW OF SIGNS AND THE LAW OF EXPONENTS IN MULTIPLICATION WE HAVE THE FOLLOWING RULES:

(1) IN DIVIDING, LIKE SIGNS GIVE A POSITIVE AND UNLIKE SIGNS GIVE A NEGATIVE SIGN FOR THE QUOTIENT.

(2) IN DIVIDING POWERS OF THE SAME BASE, THE EXPONENT OF THE QUOTIENT EQUALS THE EXPONENT OF THE DIVIDEND MINUS THE EXPONENT OF THE DIVISOR.

THIS APPLIES, BY DEFINITION OF THE POSITIVE INTEGRAL EXPONENT, ONLY WHEN THE EXPONENT OF THE DIVIDEND IS LARGER THAN THE EXPONENT OF THE DIVISOR. THUS $A^5 \div A^3 = A^2$; BUT WHEN THE EXPONENTS ARE EQUAL AND WE SUBTRACT, WE OBTAIN THE EXPONENT 0, WHICH IS MEANINGLESS.

IN DIVIDING THE SAME POWERS OF THE SAME BASE, THE QUOTIENT IS 1. THUS $A^3 \div A^3 = 1$ AND IN GENERAL $A^n \div A^n = 1$.

DIVISION OF ONE MONOMIAL BY ANOTHER

THE STEPS TO EMPLOY FOR THE DIVISION OF ONE MONOMIAL BY ANOTHER IS AS FOLLOWS:

(1) DETERMINE THE SIGN OF THE QUOTIENT
(2) DETERMINE THE COEFFICIENT
(3) DETERMINE LETTERS AND EXPONENTS.

REMEMBER THAT IN THE PROCESS OF DIVISION WE DIVIDE WHERE WE MULTIPLY IN MULTIPLICATION AND WE SUBTRACT EXPONENTS WHERE WE ADD EXPONENTS IN MULTIPLICATION.

EXAMPLE: – DIVIDE $25A^4X^5$ BY $-5A^2X^3$
PROCESS: – CARRIED OUT IN STEPS, THIS WOULD BE AS FOLLOWS:

$$25 \div -5 = -5$$
$$A^4 \div A^2 = A^2$$
$$X^5 \div X^3 = X^2$$
$$\text{THEREFORE} \quad 25A^4X^5 \div -5A^2X^3 = -5A^2X^2 \text{ (ANSWER)}$$

THE LAST OF THESE ABOVE LINES ONLY SHOULD BE WRITTEN DOWN IN PERFORMING THE WORK. THE FIRST THREE STEPS ARE MENTAL OPERATIONS AND ARE ONLY PLACED HERE FOR GUIDANCE.

THE DIVISION OF ONE MONOMIAL BY ANOTHER MAY ALSO BE PERFORMED AS A CANCELLATION. FOR EXAMPLE, IF WE RECALL THAT AN EXPRESSION LIKE $4A^2B^3$ MEANS 4A.A.B.B.B, WE MAY WRITE $16A^3B^5C^3 \div 4A^2B^3$ IN THE FORM

$$\frac{\cancel{4}\cdot 4\cdot \cancel{A}\cdot \cancel{A}\cdot A\cdot \cancel{B}\cdot \cancel{B}\cdot \cancel{B}\cdot B\cdot B\cdot C\cdot C\cdot C}{\cancel{4}\cdot \cancel{A}\cdot \cancel{A}\cdot \cancel{B}\cdot \cancel{B}\cdot \cancel{B}}$$

NOW BY CANCELLING THE FACTORS COMMON TO THE DIVIDEND AND DIVISOR (THAT IS CROSSING-OFF SIMILAR FACTORS) THE PRODUCT OF THE FACTORS REMAINING IN THE DIVIDEND IS THE QUOTIENT. THIS PROCESS IS TOO LONG FOR RAPID WORK WITH COMPUTATIONS OF THIS TYPE BUT IT MAY CLEAR UP POINTS INDIVISION INVOLVING ALGEBRA WHICH MAY AT FIRST TROUBLE A STUDENT.

DIVISION OF A POLYNOMIAL BY A MONOMIAL

EXAMPLE: – DIVIDE $24A^5Y^3 - 96A^5Y^6$ BY $8A^4Y^3$

PROCESS:– $8A^4Y^3 \overline{) \; 24A^5Y^3 - 96A^5Y^6}$

$$3A \quad - 12AY^3$$

RULE:– THE DIVISION IS PERFORMED BY DIVIDING EACH TERM OF THE DIVIDEND BY THE DIVISOR, BEGINNING AT THE LEFT.

EXPLANATION:– NOTICE THAT IN THE PROBLEM JUST PRESENTED, WE FIRST DIVIDE THE NUMBER 24 BY 8 WHICH GIVES US 3 AS THE FIRST NUMBER OF THE DIVISOR. WE THEN DIVIDE THE FIRST A^5 OF THE EXPRESSION $24A^5Y^3$ BY A^4 OF OUR DIVISOR WHICH GIVES US THE "A" TO FORM 3A AS THE FIRST EXPRESSION OF THE QUOTIENT. THEN BY DIVIDING $-96A^5Y^6$ OR THE SECOND EXPRESSION OF THE DIVIDEND BY THE DIVISOR $8A^4Y^3$ WE FIND THAT $-96 \div 8 = -12$; $A^5 \div A^4 = A$ AND $Y^6 \div Y^3 = Y^3$ AND OUR QUOTIENT THEN BECOMES $3A - 12AY^3$.

PRACTICE PROBLEMS

THE FOLLOWING IS A GROUP OF PRACTICE PROBLEMS WHICH WILL GIVE YOU THE OPPORTUNITY OF PUTTING INTO USE THE VARIOUS ALGEBRAIC PROCESSESS WHICH WERE EXPLAINED TO YOU IN THIS LESSON. YOU WILL ALSO FIND THE ANSWERS HERE GIVEN FOR EACH OF THESE PRACTICE PROBLEMS SO THAT YOU CAN CHECK YOUR OWN WORK.

WHEN YOU FEEL THAT YOU HAVE MASTERED THIS WORK AND SOLVED ALL OF THESE PRACTICE PROBLEMS SATISFACTORILY, THEN YOU ARE READY TO ANSWER THE EXAMINATION QUESTIONS WHICH APPEAR AT THE END OF THIS LESSON.

I FIND THE SUM IN THE FOLLOWING EXERCISES.

1. +7, –10, –13, +16, +25, –3 .... ANSWER =22
2. +3, +16, –21, –1, +2, +1 .... ANSWER = 0
3. 2X+3A+M, 2Y– 3A–M .... ANSWER =2X+2Y

II PERFORM THE FOLLOWING EXAMPLES IN SUBTRACTION.

1. FROM 3AX–4CD TAKE 10 AX–2CD .... ANSWER –7AX –2CD
2. FROM M^2–2MN + N^2 TAKE M^2+ 2MN + N^2.............. ANSWER –4 MN

III SIMPLIFY BY REMOVING THE SIGNS OF GROUPING AND UNITING THE LIKE TERMS IN THE FOLLOWING:

1. 4A +7B – (3A+2B) .... ANSWER=A+5B
2. 5–3X+(–18+2X) .... ANSWER= –13–X

IV FIND THE PRODUCT OF THE FOLLOWING:

1. 10 AB^2 AND $3A^3B$ .... ANSWER= $30A^4B^3$
2. $5B^2(5+6B^2-7B^4)$ ....ANSWER= $25B^2+30B^4-35B^6$

V FREE THE FOLLOWING SIGNS OF GROUPING AND SIMPLIFY

1. (A+B)(A–B) .... ANSWER=A^2-B^2
2. $(3X^2+AB)(3X^2-AB)$....................ANSWER= $9X^4-A^2B^2$

VI. PERFORM THE FOLLOWING PROCESSES OF DIVISION:

1. $18a^3b^2x$ BY $-3a^2bx$ ANSWER = $-6ab$
2. $-42a^3m^2y^3$ BY $7a^2m^2$ ANSWER = $-6ay^3$
3. $12a^3 + 3a^4 + 18a^5$ BY $3a^3$ ANSWER = $4 + a + 6a^2$
4. $24x^2y^2 - 8x^4y^5 - 24xy^2$ BY $8x$ ANSWER = $3xy^2 - x^3y^5 - 3y^2$

EXAMINATION QUESTIONS

answered April 22, 1941

LESSON NO. AS-6

1. - WHAT IS THE SUM OF $2a^2 - 4cd$, $-8a^2 - 7cd$, $-25a^2 + 16cd$?

2. - ADD $7x^2 - 9y^2 - 11xy$, $- 4xy - 11y^2 + 17x^2$.

3. - FROM $ax^2 + 3ay^2 - 4z^2$ SUBTRACT $2ax^2 + 3ay^2 - 4z^2$.

4. - TAKE $2x^3 - y^2$ FROM THE SUM OF $x^3 - 2xy + 3y^2$ AND $xy + 4y^2$.

5. - SIMPLIFY BY REMOVING THE SIGNS OF GROUPING AND UNITING THE LIKE TERMS IN THE FOLLOWING EXPRESSION:

$$a - 2b - [3a - (b - c) - 5c]$$

6. - COLLECT ALL THE COEFFICIENTS OF X IN THE FOLLOWING WITHIN PARENTHESES PRECEDED BY A MINUS (-) SIGN:

$$2cx - 4dx + 6ex - 2x$$

7. - MULTIPLY $5x + 4y$ BY $3x - 2y$.

8. - FREE THE FOLLOWING EXPRESSION OF SIGNS OF GROUPING AND SIMPLIFYING:

$$5(x^2 - ab) + 6(x^2 + ab)$$

9. - MULTIPLY $4x^3 - 3x^2y + 5xy^2 - 6y^3$ BY $5x + 6y$.

10. - DIVIDE $42a^3 - 14a^2 + 28a$ BY $7a$.

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LESSON NO. 7

ALGEBRA II

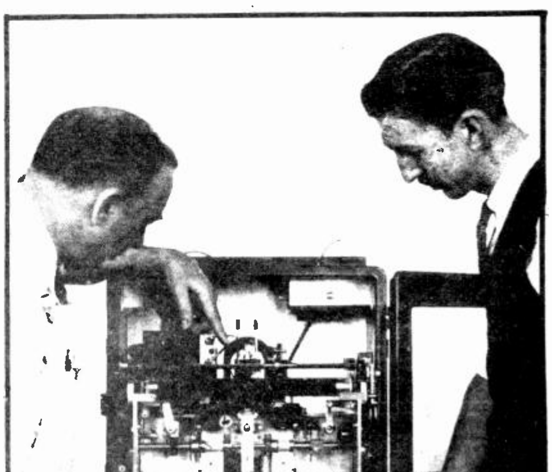
THIS LESSON IS A CONTINUATION OF THE PRECEDING ONE, THEREFORE IT IS IMPORTANT THAT YOU MASTER THE PAST LESSON BEFORE GOING AHEAD WITH THIS ONE. YOU WILL FIND THAT, TOGETHER, THESE TWO LESSONS TREATING WITH ALGEBRA WILL GIVE YOU A GOOD UNDERSTANDING OF THIS SUBJECT.

YOU ARE NOW PREPARED TO LEARN ABOUT FACTORS AND THE PROCESS OF FACTORING AS APPLIED TO ALGEBRAIC EXPRESSIONS.

FACTORS OF A POLYNOMIAL WHEN ONE FACTOR IS A MONOMIAL

BY LOOKING AT THE EXPRESSION $14ax + 28ay + 84az$, IT CAN READILY BE SEEN THAT EACH TERM OF THIS EXPRESSION CAN BE DIVIDED BY $14a$. THE QUOTIENT THUS BECOMING $x + 2y + 6z$.

IT THUS FOLLOWS THAT THE PRODUCT OF $x+2y+6z$ AND $14a$ IS $14ax+28ay+84az$ AND WE THEN SAY THAT $14a$ AND $x+2y+6z$ ARE THE FACTORS OF $14ax+28ay+84az$.



Mathematics Is Essential To The Laboratory Technician.

THE RULE THUS BECOMES: THE FACTORS OF A POLYNOMIAL SIMILAR TO THE FOREGOING ARE A MONOMIAL, CONTAINING ALL THAT IS COMMON TO EACH TERM OF THE POLYNOMIAL AND THE QUOTIENT FOUND BY DIVIDING THE POLYNOMIAL BY THE MONOMIAL.

EXAMPLE: FACTOR THE EXPRESSION $4a^2x-2ax^2+6a^2x^2$. BY INSPECTION IT WILL BE SEEN THAT THE MONOMIAL FACTOR IS $2ax$. THEN BY DIVIDING THE POLYNOMIAL $4a^2x-2ax^2+6a^3x^2$ BY $2ax$, WE OBTAIN $2ax-x+3ax$ WHICH IS

THE OTHER FACTOR. THE FACTORS ARE WRITTEN IN THE FORM $2AX(2A-X+3AX)$.

SQUARES AND SQUARE ROOTS OF MONOMIALS

BY THE PRINCIPLES OF MULTIPLICATION ALREADY GIVEN, THE SQUARE OF A MONOMIAL MAY BE FOUND AS FOLLOWS:

(1) THE SIGN IS ALWAYS PLUS.

(2) THE NUMERICAL COEFFICIENT IS THE SQUARE OF THE NUMERICAL CO-EFFICIENT OF THE MONOMIAL.

(3) THE EXPONENT OF ANY LETTER IS TWICE THE EXPONENT OF THE SAME LETTER IN THE MONOMIAL.

THUS $(5A^2B^3)^2 = 25A^4B^6$ AND $(-4A^3B^2D)^2 = 16A^6B^4D^2$.

THE SQUARE ROOT OF A MONOMIAL CAN BE FOUND BY DOING THE INVERSE PROCESSES TO THOSE FOR FINDING THE SQUARE OF A MONOMIAL. THE RULES FOR EXTRACTING THE SQUARE ROOT FOLLOW:

(1) THE SQUARE ROOT CAN BE FOUND OF A POSITIVE NUMBER ONLY.

(2) THE NUMERICAL COEFFICIENT IS THE SQUARE ROOT OF THE NUMERICAL COEFFICIENT OF THE MONOMIAL.

(3) THE EXPONENT OF ANY LETTER IS ONE-HALF THE EXPONENT OF THE SAME LETTER IN THE MONOMIAL.

IT THUS FOLLOWS THAT THE MONOMIAL OF WHICH THE SQUARE ROOT IS TO BE TAKEN MUST HAVE A NUMERICAL COEFFICIENT THAT IS A PERFECT SQUARE AND ALL THE EXPONENTS MUST BE EVEN NUMBERS. OTHERWISE, THE SQUARE ROOT CANNOT BE FOUND EXACTLY.

EXAMPLE: $\sqrt{16A^4B^2} = 4A^2B$ AND $\sqrt{225X^4Y^6Z^2} = 15X^2Y^3Z$ BUT $\sqrt{10A^4B^6}$ CAN ONLY BE EXPRESSED AS $\sqrt{10}A^2B^3$ AND $\sqrt{35A^3B}$ CANNOT BE FOUND EXACTLY.

THE SQUARE OF A BINOMIAL

THE EXPRESSION $(A+B)^2$ DENOTES THAT THE BINOMIAL $(A+B)$ IS TO BE SQUARED OR MULTIPLIED BY ITSELF. THIS CAN BE WORKED AS FOLLOWS:

$$\begin{array}{r} A + B \\ \underline{A + B } \\ A^2 + AB \\ \underline{+ AB + B^2} \\ A^2 + 2AB + B^2 \end{array}$$

THIS SAME WORK, HOWEVER, CAN BE GREATLY SIMPLIFIED BY APPLYING THE FOLLOWING RULES:

(1) THE SQUARE OF THE SUM OF TWO NUMBERS (OR LETTERS) EQUALS THE SQUARE OF THE FIRST PLUS TWICE THE PRODUCT OF THE FIRST BY THE SECOND PLUS THE SQUARE OF THE SECOND.

(2) THE SQUARE OF THE DIFFERENCE OF TWO NUMBERS EQUALS THE SQUARE OF THE FIRST MINUS TWICE THE PRODUCT OF THE FIRST BY THE SECOND PLUS THE SQUARE OF THE SECOND.

THE USE OF THESE PRINCIPLES WILL SAVE MUCH WORK IN MULTIPLICATION.

EXAMPLE 1: FIND THE VALUE OF $(cd+e)^2$

EXPLANATION: THE SQUARE OF THE FIRST TERM = $(cd)^2 = c^2d^2$.

TWICE THE PRODUCT OF THE FIRST BY THE SECOND = $2(cd)e = 2cde$.

THE SQUARE OF THE SECOND TERM = e^2.

THEREFORE, $(cd+e)^2 = c^2d^2+2cde+e^2$

EXAMPLE 2: $(2a+b^2)^2 = 4a^2+4ab^2+b^4$

EXAMPLE 3: $(2x^2-3y^3)^2 = 4x^4-12x^2y^3+9y^6$.

THE PRODUCT OF THE SUM OF TWO NUMBERS
BY THE DIFFERENCE OF THE SAME TWO NUMBERS

BY MULTIPLICATION $(a+b)(a-b) = a^2-b^2$.

SINCE "A" AND "B" ARE GENERAL NUMBERS, WE MAY USE THIS STATEMENT AS A FORMULA AND SO WRITE AT ONCE, WITHOUT ACTUAL MULTIPLICATION, THE PRODUCT OF THE SUM AND THE DIFFERENCE OF ANY TWO NUMBERS. THE FORMULA MAY BE TRANSLATED INTO WORDS AS FOLLOWS: THE PRODUCT OF THE SUM AND THE DIFFERENCE OF TWO NUMBERS EQUALS THE DIFFERENCE OF THEIR SQUARES.

EXAMPLE 1: $(2c+3b)(2c-3b) = 4c^2-9b^2$

EXAMPLE 2: $(16+2)(16-2) = 16^2-2^2 = 256-4 = 252$.

FACTORS OF THE DIFFERENCE OF TWO SQUARES

FROM A CONSIDERATION OF THE PRECEDING, IT IS EASILY SEEN THAT THE DIFFERENCE OF TWO SQUARES CAN BE FACTORED INTO TWO BINOMIAL FACTORS THAT ARE, RESPECTIVELY, THE SUM AND THE DIFFERENCE OF THE SQUARE ROOTS OF THESE SQUARES.

EXAMPLE 1: $4-a^2 = (2+a)(2-a)$

EXAMPLE 2: $16a^4-9y^2 = (4a^2+3y)(4a^2-3y)$.

THE PRODUCT OF TWO BINOMIALS HAVING ONE COMMON TERM

BY MULTIPLICATION, WE FIND THE FOLLOWING PRODUCTS:

(1) $(a+2)(a+3) = a^2+5a+6$

(2) $(a-2)(a-3) = a^2-5a+6$

(3) $(a+2)(a-3) = a^2-a-6$

(4) $(a-2)(a+3) = a^2+a-6$

(5) $(a+b)(a+c) = a^2+(b+c)a+bc$.

From an inspection of the foregoing, the truth of the following statements can be seen:

The product of two binomials, having one common term and the other terms unlike, is a trinomial consisting of the square of the common term, the algebraic sum of the unlike terms times the common term, and the product of the unlike terms.

Thus in (1) of the previous examples, the common term is "a" and the unlike terms are 2 and 3. The square of the common term is a^2. The algebraic sum of the unlike terms is $2+3 = 5$ and this times the common term is 5 times $a = 5a$. The product of the unlike terms is $2 \times 3 = 6$. Hence the result $(a+2)(a+3) = a^2+5a+6$.

Likewise in example (3), the square of the common term is a^2. The algebraic sum of the unlike terms is the sum of $+2$ and -3, or -1. This times the common term a is $-a$. The product of the unlike terms is 2 times $-3 = -6$. Hence the result $(a+2)(a-3) = a^2-a-6$.

TO FACTOR A TRINOMIAL INTO TWO BINOMIALS WITH ONE COMMON TERM

By further study of the algebraic manipulations as just explained, one can foresee the possibilities of factoring a trinomial into two binomials with one common term. The method of factoring such forms can best be seen by considering specific examples:

Example 1: Factor $a^2+9a+20$

By inspection, it will be seen that this trinomial has one term a^2, that is a perfect square. Therefore, a, the square root of a^2, is to be the common term of the factors if there are any. The unlike terms of the factor must have a product of $+20$ and a sum of $+9$. By inspection, it will be seen that $+5$ and $+4$ have such a product and sum. Hence the factors of $a^2+9a+20$ are $(a+5)(a+4)$.

Example 2: Factor a^2-a-20

As before, the common term is a. The unlike terms have a product of -20 and a sum of -1. The product being —, one of the terms will have to be − and the other +. The sum being −, shows that the larger in absolute value is −. This gives -5 and $+4$ as the numbers.

Hence $a^2-a-20 = (a-5)(a+4)$

Many trinomials that appear to be of the kind here considered cannot be factored in this way. For instance, x^2+7x+5 cannot be factored in this manner, for we can find no integral numbers which have a sum of 7 and a product of 5.

EQUATIONS

An EQUATION is a statement that wo expressions are equal in value.

Thus $A = \frac{1}{2}ab$ is an equation. So are $A = \pi r^2$; $V = 4/3\,\pi r^3$ and $3x+4 = 10$.

The part to the left of the equality sign is called the FIRST MEMBER of the equation, and the part to the right, the SECOND MEMBER.

If the area of a rectangle is 30 sq. ft. and the altitude is 4 ft. we have $36 = 4b$, where b stands for the base of the rectangle. Now it is easy to see that the statement, or equation is true if, and only if $b = 9$. In other words, $36 = 4 \times 9$. Such an equation as this, where the latter whose value we wish to find has a certain value, is called a CONDITIONAL EQUATION. That is, this equation is true on the condition that $b = 9$ and for no other value of b.

Not all statements of equality are conditional. For instance, $\frac{x^2-4}{x+2} = x-2$ is an equation; but x may have any value whatever and still make the equation true. Thus if $x = 3$, the equation becomes $\frac{9-4}{3+2} = 3-2$ or $1 = 1$. On the other hand, if $x=4$ we get $2=2$. Similarly, for any value we give x.

This kind of an equation is called an IDENTICAL EQUATION.

The number asked for in an equation or the letter standing for it is called the UNKNOWN NUMBER, the UNKNOWN QUANTITY, or briefly, the UNKNOWN. To SOLVE an equation is to find the value or values of the unknown that will make the equation true.

A large number of problems, that are solved by means of algebra, involve the equation in one form or another. This makes the equation the most important tool of algebra; in fact, it may be looked upon as a more or less complicated piece of machinery, with which the student should become familiar.

To become familiar with the mechanism of the equation and its applications requires time and drill in solving equations. Much of the work in solving equations is mechanical in that it does not require much thought in its performance. However, there is a reason for doing each step that is taken.

SOLUTION OF EQUATIONS

As already stated, to solve an equation is to determine the value or values of the unknown number or numbers in the equation. Let us now consider some simple equations and thereby work out some general methods of procedure in the solution.

Example 1: Find the value of x, if $x-5 = 3$. Here one readily sees by inspection that $x = 8$ but this does not help us any in solving a more complicated equation. If, however, we notice that in order to determine $x = 8$, 5 is added to each member of the given equation, we have a method of procedure that we can apply to another like problem. We have then the following solution:

Given equation,	$x-5 = 3$
Adding 5 to each member,	$x-5+5 = 3+5$
Collecting the terms,	$x = 8$

This process can be shortened as follows:

$$x-5 = 3$$
$$x = 3+5$$
$$x = 8$$

Example 2: Solve for x, if ---------- $x+3 = 10$
Solution: Given equation ---------- $x+3 = 10$
Subtracting 3 from each member ---------- $x+3-3 = 10-3$
Collecting the terms ---------- $x = 7$

Example 3: Solve for s, if ---------- $4s = 36$
Solution: Given equation, ---------- $4s = 36$
Dividing each member by 4, ---------- $s = 9$

Example 4: Solve for x, if ---------- $4x+5-7 = 2x+6$
Solution: Given equation ---------- $4x+5-7 = 2x+6$
Adding 7 to both members ---------- $4x+5 = 2x+6+7$
Subtracting 5 from both members ---------- $4x = 2x+6+7-5$
Subtracting 2x from both members ---------- $4x-2x = 6+7-5$
Collecting the terms ---------- $2x = 8$
Dividing both members by 2, ---------- $x = 4.$

Notice that when a term is added to or subtracted from both members of an equation, it is TRANSPOSED from one member to the other and its sign is changed. Now by this transposing, we can bring all the terms that contain the unknown into the FIRST MEMBER and all the others into the SECOND MEMBER. This gives a convenient form, for we wish finally to have an equation in which the form is:

Unknown = some number

Steps in solution: The solution of an equation that is in a simple form may then be carried out in the following three steps:

(1) Transpose all terms containing the unknown to the first member, and all other terms to the second member. In each case, change the sign of the term transposed.

(2) Collect the terms in each member

(3) Divide each member by the coefficient of the unknown.

It will be found later that there are other changes to be made in an equation that is not in a simple form, before these three steps are to be performed.

AXIOMS

An AXIOM is a truth that we accept without proof. The solutions of

THE EQUATIONS AND THE CHANGES MENTIONED IN THE PREVIOUS EXPLANATIONS SUGGEST THE FOLLOWING AXIOMS:

(1) IF EQUAL NUMBERS ARE ADDED TO EQUAL NUMBERS, THE SUMS ARE EQUAL.

(2) IF EQUAL NUMBERS ARE SUBTRACTED FROM EQUAL NUMBERS, THE REMAINDERS ARE EQUAL.

(3) IF EQUAL NUMBERS ARE MULTIPLIED BY EQUAL NUMBERS, THE PRODUCTS ARE EQUAL.

(4) IF EQUAL NUMBERS ARE DIVIDED BY EQUAL NUMBERS, THE QUOTIENTS ARE EQUAL.

(5) NUMBERS THAT ARE EQUAL TO THE SAME NUMBER OR EQUAL NUMBERS ARE EQUAL TO EACHOTHER.

(6) LIKE POWERS OF EQUAL NUMBERS ARE EQUAL.

(7) LIKE ROOTS OF EQUAL NUMBERS ARE EQUAL.

(8) THE WHOLE OF ANYTHING EQUALS THE SUM OF ALL ITS PARTS.

TESTING THE EQUATION

THE EQUATION PRESENTS THE FOLLOWING QUESTION: WHAT NUMBER, IF ANY, MUST THE UNKNOWN REPRESENT IN ORDER THAT THE TWO MEMBERS OF THE EQUATION SHALL BE EQUAL? THE SOLUTION OF THE EQUATION ANSWERS THIS QUESTION, BUT IT IS ALWAYS WELL TO TEST OR CHECK THE WORK. THIS MAY BE DONE BY SUBSTITUTING THE NUMBER OBTAINED FOR THE UNKNOWN IN PLACE OF THE UNKNOWN LETTER. IF THE TWO MEMBERS OF THE EQUATION THEN BECOME IDENTICAL, THE NUMBER SUBSTITUTED IS THE CORRECT ANSWER TO THE EQUATION.

EXAMPLE: SOLVE AND TEST: $47x-17 = 235-37x$
SOLUTION: GIVE EQUATION $47x-17 = 235-37x$
TRANSPOSING $47x+37x = 235+17$
COLLECTING TERMS $84x = 252$
DIVIDING BY THE COEFFICIENT OF X OR 84, $x = 3$
TESTING BY SUBSTITUTING 3 FOR X IN THE EQUATION, $141-17 = 235-111$

COLLECTING TERMS GIVES THE IDENTICAL EQUATION, $124 = 124$ WHICH PROVES THAT THE ANSWER $X = 3$ IS CORRECT.

EQUATIONS INVOLVING GROUPED TERMS

IF AN EQUATION HAS INDICATED MULTIPLICATIONS AND SIGNS OF GROUPING, IT IS USUALLY BEST TO PERFORM THE MULTIPLICATIONS AND REMOVE THE SIGNS OF GROUPING BEFORE PROCEEDING WITH THE SOLUTION OF THE EQUATION.

EXAMPLE I: FIND THE VALUE OF C FROM $4c+3\left[2c-4(c-2)\right] = 72-6c$

SOLUTION:

(1) GIVEN EQUATION $4c+3\left[2c-4(c-2)\right] = 72-6c$
(2) SIMPLIFYING $4c+3\left[2c-4c+8\right] = 72-6c$

(3) SIMPLIFYING $4c+6c-12c+24 = 72-6c$
(4) TRANSPOSING $4c+6c-12c+6c = 72-24$
(5) COLLECTING TERMS $4c = 48$
(6) DIVIDING BY THE COEFFICIENTS OF C, $c=12$

TEST: $48+3\left[24-4\ (12-2)\right]= 72-72$ OR $0 = 0$.

EXAMPLE 2: SOLVE FOR X IN THE FOLLOWING EQUATION:
$(1+3x)^2= (5-x)^2+4(1-x)(3-2x)$

SOLUTION:
(1) GIVEN EQUATION, $(1+3x)^2= (5-x)^2+4\ (1-x)(3-2x)$
(2) REMOVING PARENTHESIS, $1+6x+9x^2= 25-10x+x^2+12-20x+8x^2$
(3) TRANSPOSING, $9x^2-x^2-8x^2+6x+10x+20x = 25+12-1$
(4) COLLECTING TERMS, $36x = 36$
(5) DIVIDING BY 36, $x = 1$.

TEST: $(1+3)^2= (5-1)^2+ 4\ (1-1)(3-2)$
$4^2= 4^2+0$
$16 = 16$

EQUATIONS SOLVED BY THE AID OF FACTORING

THE EQUATIONS CONSIDERED SO FAR HAVE REDUCED TO A FORM IN WHICH A CERTAIN NUMBER OF TIMES THE UNKNOWN EQUALED SOME NUMBER. THUS $6x = 12$ IS SUCH A FORM. THEY ARE CALLED SIMPLE EQUATIONS.

ALL EQUATIONS DO NOT REDUCE TO SUCH A FORM AS THIS. FOR INSTANCE, WHEN THE EQUATION HAS BEEN REDUCED, WE MAY HAVE AN EQUATION IN WHICH THE SQUARE OF THE UNKNOWN EQUALS SOME NUMBER. THUS $x^2= 5$ IS SUCH A FORM. SUCH AN EQUATION IS CALLED A PURE QUADRATIC EQUATION.

AGAIN, WHEN THE EQUATION IS SIMPLIFIED AND REDUCED, WE MAY HAVE A FORM CONTAINING THE SQUARE AND THE FIRST POWER OF THE UNKNOWN EQUALING SOME NUMBER. THUS $x^2-5x = 24$ IS SUCH A FORM. SUCH AN EQUATION IS CALLED AN AFFECTED QUADRATIC.

SOME OF THESE FORMS OF EQUATIONS, TOGETHER WITH CERTAIN OTHER FORMS CAN BE SOLVED BY THE AID OF FACTORING.

EXAMPLE 1: SOLVE THE EQUATION $x^2-5x+6 = 0$

EXPLANATION: THIS EQUATION PRESENTS THE FOLLOWING QUESTION: FOR WHAT VALUES OF X DOES x^2-5x+6 EQUAL ZERO? IF WE FACTOR THE EXPRESSION IN THE FIRST MEMBER WE GET $(x-2)(x-3) = 0$. THE QUESTION NOW IS: FOR WHAT VALUES OF X DOES THE PRODUCT $(x-2)(x-3)$ HAVE THE VALUE ZERO? WE KNOW THAT THE PRODUCT OF TWO FACTORS IS ZERO IF EITHER, OR BOTH, FACTORS ARE ZERO AND NOT OTHERWISE. HENCE THE PRODUCT IS ZERO IF $x-2 = 0$, OR $x-3 = 0$. THUS, THE SOLUTION $x^2-5x+6 = 0$ DEPENDS UPON THE SOLUTION OF THE TWO SIMPLE EQUATIONS, $x-2 = 0$ AND $x-3 = 0$. THESE GIVE THE VALUES 2 AND 3 FOR X.

THAT THESE ARE THE VALUES OF X MAY BE TESTED BY SUBSTITUTING EACH ONE SEPARATELY IN THE EQUATION $x^2-5x+6 = 0$.

SUBSTITUTING $x = 2$, GIVES $4-10+6 = 0$, OR $0 = 0$

SUBSTITUTING $x = 3$, GIVES $9-15+6 = 0$, OR $0 = 0$

The values of the unknown number that satisfy the equation, that is, answer the question, are called ROOTS of the equation.

A quadratic equation having one unknown letter always has two roots.

Example 1: Solve the equation $x^2-25 = 0$

Solution:

(1) Given equation — — — — — — — — $x^2-25 = 0$
(2) Factoring — — — — — — — — — — $(x+5)(x-5) = 0$
(3) Putting each factor equal to zero. — — $x+5 = 0$ and $x-5 = 0$
(4) Transposing — — — — — — — — — $x = -5$ and $x = 5$

This same problem can also be solved in the following manner:

(1) Given equation — — — — — — — — — — — — $x^2-25 = 0$
(2) Transposing — — — — — — — — — — — — — $x^2 = 25$
(3) Taking the square root of each member of the equation. — — — — — — — — — — — — $x = \pm 5$

Here the sign $\pm$ is read "plus or minus" and it means that 5 is a plus as well as a minus quantity. It should be noted here that we are saying that 25 has the two square roots +5 and −5. Either of these is the square root of 25, for $(+5)^2 = 25$ and also $(-5)^2 = 25$. Hence both fulfill the definition of a square root, that is, one of the two equal factors into which a number may be divided.

We have the following rules of procedure when solving an equation by the aid of factoring.

(1) Simplify the equation as much as possible.
(2) Transpose all terms to the first member of the equation.
(3) Factor the expression in the first member.
(4) Equate each factor to zero
(5) Solve each of these equations.

FORMULAS

A formula as given usually stands solved for one letter in terms of several others. For example, considering the formula $T = ph + 2A$, we have T stated in terms of P, H, and A.

It often happens that one wishes to express H, for instance, in terms of T, P and A. To do this, it is only necessary to solve the formula as an equation and find the value of the particular letter desired in terms of the others.

Example: Solve the formula $T = PH+2A$ for each of the other letters.

Solution: Here there are three letters other than T and we shall solve for P, H, and A in turn.

(1) Given equation — — — — — — — — — — $T = PH+2A$
(2) Transposing — — — — — — — — — — — $-PH = -T+2A$
(3) Dividing by the coefficient of P which is −H and indicating the division we have: $P = \frac{T-2A}{H}$

(4) SOLVING STEP (2) FOR H WE HAVE — — — — — — — $\frac{T-2A}{P}$

(5) TO SOLVE FOR "A" TRANSPOSE STEP (1) AS FOLLOWS $-2A = -T+PH$

(6) DIVIDING BY THE COEFFICIENT OF "A" WHICH IS 2, WE OBTAIN — — — — — — — — — — $A = \frac{T-PH}{2}$

ALGEBRAIC FRACTIONS

YOU ARE ALREADY FAMILIAR WITH THE USE OF FRACTIONS AS APPLIED TO ARITHMETIC AND YOU WILL FIND THAT IN ALGEBRAIC EXPRESSIONS INVOLVING FRACTIONS, THE SAME PRINCIPLES ARE APPLIED AND THE SAME OPERATIONS PERFORMED AS IN ARITHMETIC.

REDUCTION OF A FRACTION TO ITS LOWEST TERMS

AS YOU WILL RECALL FROM YOUR PREVIOUS STUDIES OF ARITHMETIC, A FRACTION IS IN ITS LOWEST TERMS WHEN THERE IS NO FACTOR COMMON TO BOTH NUMERATOR AND DENOMINATOR. THE SAME APPLIES TO ALGEBRA. TO REDUCE AN ALGEBRAIC FRACTION TO ITS LOWEST TERMS, WE FIRST FACTOR EACH TERM OF THE FRACTION AND CANCEL THE COMMON FACTORS.

EXAMPLE 1: REDUCE $\frac{6x^2y^3}{12x^4y^4}$ TO ITS LOWEST TERMS

PROCESS: $\frac{6x^2y^3}{12x^4y^4} = \frac{\cancel{2}\cdot\cancel{3}\cdot\cancel{x}\cdot\cancel{x}\cdot\cancel{y}\cdot\cancel{y}\cdot\cancel{y}}{\cancel{2}\cdot 2\cdot\cancel{3}\cdot\cancel{x}\cdot\cancel{x}\cdot x\cdot x\cdot\cancel{y}\cdot\cancel{y}\cdot\cancel{y}\cdot y} = \frac{1}{2x^2y}$

EXAMPLE 2: REDUCE $\frac{x^2-y^2}{x^2+2xy+y^2}$ TO ITS LOWEST TERMS

PROCESS: $\frac{x^2-y^2}{x^2+2xy+y^2} = \frac{\cancel{(x+y)}(x-y)}{\cancel{(x+y)}(x+y)} = \frac{x-y}{x+y}$

EXAMPLE 3: $\frac{N^2+7N-30}{N^2-7N+12} = \frac{(N+10)\cancel{(N-3)}}{(N-4)\cancel{(N-3)}} = \frac{N+10}{N-4}$

THE LOWEST COMMON MULTIPLE

TO FIND THE LOWEST COMMON MULTIPLE OF A GROUP OF ALGEBRAIC EXPRESSIONS, THE FIRST STEP IS TO SEPARATE EACH TERM INTO ITS PRIME FACTORS. THIS DONE, THE LOWEST COMMON MULTIPLE IS FOUND BY TAKING EACH FACTOR THE GREATEST NUMBER OF TIMES IT IS FOUND IN ANY EXPRESSION.

EXAMPLE 1: FIND THE L.C.M. (LOWEST COMMON MULTIPLE) OF $12x^2y$, $16xy^3$ AND $24x^3y$

PROCESS:
$12x^2y = 2^2\cdot 3\cdot x^2\cdot y$
$16xy^3 = 2^4\cdot x\cdot y^3$
$24x^3y = 2^3\cdot 3\cdot x^3\cdot y$

THEREFORE L.C.M $= 2^4\cdot 3\cdot x^3\cdot y^3 = 48x^3y^3$

EXAMPLE 2: FIND THE L.C.M. OF $x^2+2xy+y^2$ AND x^2-y^2.

PROCESS:
$x^2+2xy+y^2 = (x+y)^2$
$x^2-y^2 = (x+y)(x-y)$

THEREFORE, L.C.M. $= (x+y)^2(x-y)$

THE LOWEST COMMON DENOMINATOR

THE METHOD OF FINDING THE LOWEST COMMON DENOMINATOR (L.C.D.) FOR A GROUP OF ALGEBRAIC FRACTIONS CAN BEST BE EXPLAINED BY MEANS OF THE FOLLOWING EXAMPLE:

EXAMPLE: CHANGE $\frac{X}{Y-2}$, $\frac{Z}{Y^2+4Y-12}$, AND $\frac{Y}{Y^2+6Y}$ TO FRACTIONS HAVING A L.C.D.

PROCESS: TO FIND THE L.C.D., PROCEED AS FOLLOWS:

$$Y-2 = Y-2$$
$$Y^2+4Y-12 = (Y+6)(Y-2)$$
$$Y^2+6Y = y(Y+6)$$

THEREFORE $\quad$ L.C.M.= $Y(Y+6)(Y-2)$

TO CHANGE THE GIVEN FRACTIONS TO FRACTIONS HAVING $Y(Y+6)(Y-2)$ AS AN L.C.D. WE HAVE:

(1) $\frac{X}{Y-2} = \frac{XY(Y+6)}{Y(Y+6)(Y-2)} = \frac{XY^2+6XY}{Y(Y^2+4Y-12} = \frac{XY^2+6XY}{Y^3+4Y^2-12Y}$

(2) $\frac{Z}{Y^2+4Y-12} = \frac{Z}{(Y+6)(Y-2)} = \frac{ZY}{Y(Y+6)(Y-2)} = \frac{ZY}{Y^3+4Y^2-12Y}$

(3) $\frac{Y}{Y^2+6Y} = \frac{Y}{Y(Y+6)} = \frac{Y(Y-2)}{Y(Y+6)(Y-2)} = \frac{Y(Y-Z)}{Y^3+4Y^2-12Y}$

ADDITION AND SUBTRACTION OF FRACTIONS

ALGEBRAIC FRACTIONS CAN BE ADDED OR SUBTRACTED AS IN ARITHMETIC BY FIRST REDUCING THEM TO FRACTIONS HAVING A COMMON DENOMINATOR AND THEN ADDING OR SUBTRACTING THE NUMERATORS. THE RESULT SHOULD THEN BE REDUCED TO ITS LOWEST TERMS.

EXAMPLE 1: FIND THE SUM OF $\frac{X}{A-X}$, $\frac{A}{A+X}$ AND $\frac{A^2+X^2}{A^2-X^2}$

PROCESS: L.C.D. = $A^2-X^2 = (A+X)(A-X)$
THEN

$$\frac{X}{A-X} = \frac{X(A+X)}{(A+X)(A-X)} = \frac{AX+X^2}{A^2-X^2}$$

$$\frac{A}{A+X} = \frac{A(A-X)}{(A+X)(A-X)} = \frac{A^2-AX}{A^2-X^2}$$

$$\frac{A^2+X^2}{A^2-X^2} = \frac{A^2+X^2}{(A+X)(A-X)} = \frac{A^2+X^2}{A^2-X^2}$$

THEN BY ADDING THE NUMERATORS, THE SUM OF THE FRACTIONS IS

$$\frac{2A^2+2X^2}{A^2-X^2}$$

EXAMPLE 2: FROM $\frac{A+X}{A^2-AX}$ TAKE $\frac{A+2X}{A^2-X^2}$

PROCESS: L.C.D. = $A(A+X)(A-X) = A^3-AX^3$

$$\frac{A+x}{A^2-Ax} = \frac{(A+x)(A+x)}{A(A+x)\ (A-x)} = \frac{A^2+2Ax+x^2}{A^3-Ax^2}$$

$$\frac{A+2x}{A^2-x^2} = \frac{A(A+2x)}{A(A+x)(A-x)} = \frac{A^2+2Ax}{A^3-Ax^2}$$

THEN BY SUBTRACTING THE NUMERATOR OF THE SECOND FRACTION FROM THE NUMERATOR OF THE FIRST, WE HAVE

$$\begin{array}{r} A^2+2Ax+x^2 \\ \underline{A^2+2Ax} \\ +x^2 \end{array}$$

THEREFORE OUR ANSWER IS $\frac{x^2}{A^3-Ax^2}$

MULTIPLICATION OF FRACTIONS

AS IN ARITHMETIC, THE PRODUCTS OF TWO OR MORE FRACTIONS IS THE PRODUCT OF THEIR NUMERATORS DIVIDED BY THE PRODUCT OF THEIR DENOMINATORS.

IF WE FIRST CANCEL ALL FACTORS COMMON TO BOTH THE NUMERATOR AND THE DENOMINATOR, THE RESULT WILL BE IN ITS LOWEST TERMS WHEN THE MULTIPLYING IS DONE.

EXAMPLE: PERFORM THE FOLLOWING PROBLEM OF MULTIPLICATION:

$$\frac{x-y}{x^2+2xy+y^2} \times \frac{x+y}{x^2-2xy+y^2} \times \frac{x^2-y^2}{x^3}$$

PROCESS: BY FACTORING THESE EXPRESSION WE OBTAIN:

$$\frac{x-y}{(x+y)(x+y)} \times \frac{x+y}{(x-y)(x-y)} \times \frac{(x+y)(x-y)}{x^3}$$

BY CANCELLING WE HAVE:

$$\frac{\cancel{x-y}}{\cancel{(x+y)}\cancel{(x+y)}} \times \frac{\cancel{x+y}}{\cancel{(x-y)}\cancel{(x-y)}} \times \frac{\cancel{(x+y)}\cancel{(x-y)}}{x^3} = \frac{1}{x^3}$$

DIVISION OF FRACTIONS

ONE FRACTION IS DIVIDED BY ANOTHER BY MULTIPLYING THE RECIPROCAL OF THE DIVISOR BY THE DIVIDEND. THE RECIPROCAL OF A NUMBER, YOU WILL RECALL, IS 1 DIVIDED BY THAT NUMBER. THE RECIPROCAL OF A FRACTION IS THEN THE FRACTION INVERTED.

EXAMPLE: DIVIDE $\frac{x^2-11x-26}{x^2-3x-18}$ BY $\frac{x^2-18x+65}{x^2-9x+18}$

PROCESS: GIVEN PROBLEM $\frac{x^2-11x-26}{x^2-3x-18} \div \frac{x^2-18x+65}{x^2-9x+18}$

INVERTING THE DIVISOR WE HAVE: $\frac{x^2-11x-26}{x^2-3x-18} \times \frac{x^2-9x+18}{x^2-18x+65}$

FACTORING AND CANCELLING WE HAVE: $\frac{(x-13)(x+2)}{(x-6)(x+3)} \times \frac{(x-3)(x-6)}{(x-13)(x-5)}$

$$= \frac{(x+2)(x-3)}{(x+3)(x-5)} = \frac{x^2-x-6}{x^2-2x-15}$$

EQUATIONS INVOLVING ALGEBRAIC FRACTIONS

THE EQUATIONS AS SO FAR PRESENTED TO YOU DID NOT INVOLVE FRACTIONS, SO THE STEP FOR YOU TO TAKE AT THIS TIME, WILL BE TO FAMILIARIZE YOURSELF WITH FRACTIONAL EQUATIONS.

WHEN AN EQUATION CONTAINS FRACTIONS, THESE MUST BE REMOVED. WE SPEAK OF THIS PROCESS AS "CLEARING THE EQUATION OF FRACTIONS". AN EQUATION CAN BE CLEARED OF FRACTIONS BY MULTIPLYING BOTH MEMBERS OF THE EQUATION BY THE LOWEST COMMON DENOMINATOR OF ALL THE FRACTIONS IN THE EQUATION.

EXAMPLE 1: SOLVE $\frac{x}{5} + \frac{x}{8} = 17 - \frac{x}{10}$

PROCESS: THE LOWEST COMMON DENOMINATOR IN THIS CASE WOULD BE 40. THEN BY MULTIPLYING EACH TERM BY 40, WE CAN CLEAR THE EQUATION OF FRACTIONS IN THE FOLLOWING MANNER:

$$\frac{x}{5} = \frac{8x}{40}$$

$$\frac{x}{8} = \frac{5x}{40}$$

$$17 = \frac{17}{1} = \frac{40 \times 17}{40} = \frac{680}{40}$$

$$-\frac{x}{10} = -\frac{4x}{40}$$

THUS BY USING THE NUMERATOR ONLY, THE DENOMINATORS BEING COMMON, WE HAVE — — — — — — — — — — $8x+5x = 680 - 4x$

TRANSPOSING TERMS — — — — $8x+5x+4x = 680$

COLLECTING TERMS — — — — — — — $17x = 680$

DIVIDING BY COEFFICIENT OF X OR 17 — — — $x = \frac{680}{17}$

$x = 40$

TEST IF $x=40$ IN THE EQUATION $\frac{x}{5} + \frac{x}{8} = 17 - \frac{x}{10}$ THEN BY SUBSTITUTING 40 FOR X IN THIS EQUATION WE HAVE $\frac{40}{5} + \frac{40}{8} = 17 - \frac{40}{10}$

$8 + 5 = 17-4$

$13 = 13$

EXAMPLE 2: IN THE EQUATION $S = \frac{E - IR}{0.220}$ SOLVE FOR I.

PROCESS: CLEARING OF FRACTIONS WE OBTAIN $0.220\ S = E-IR$

TRANSPOSING — — — — $IR = E - 0.220\ S$

DIVIDING BY COEFFICIENT OF I OR R WE HAVE: $I = \frac{E-0.220S}{R}$

PRACTICE PROBLEMS

THE FOLLOWING IS A SERIES OF PRACTICE PROBLEMS WHICH WILL GIVE YOU THE OPPORTUNITY OF BECOMING STILL MORE FAMILIAR WITH THE ALGEBRAIC PROCESSES EXPLAINED IN THIS LESSON BEFORE ANSWERING THE EXAMINATION QUESTIONS. THE ANSWERS TO THESE PROBLEMS ARE ALSO GIVEN HERE SO THAT YOU CAN CHECK YOUR OWN WORK.

I FIND THE PRODUCTS OF THE FOLLOWING WITHOUT ACTUAL MULTIPLICATION AND TEST BY ACTUAL MULTIPLICATION:

1. $(x+y)^2$ ______ ANSWER $= x^2+2xy+y^2$
2. $(3x+2y)^2$ ______ ANSWER $= 9x^2+12xy+4y^2$
3. $(3ax-4y)^2$ ______ ANSWER $= 9a^2x^2-24axy+16y^2$
4. $(2a^2y^3-3y)^2$ ______ ANSWER $= 4a^4y^6-12a^2y^4+9y^2$

II FIND THE PRODUCT OF THE FOLLOWING WITHOUT ACTUAL MULTIPLICATION AND TEST BY ACTUAL MULTIPLICATION:

1. $(2x+2y)(2x-2y)$ ______ ANSWER $= 4x^2-4y^2$
2. $(x^3+y^3)(x^3-y^3)$ ______ ANSWER $= x^6-y^6$
3. $(12x-13)(12x+13)$ ______ ANSWER $= 144x^2-169$
4. $(3x-y)(3x+y)$ ______ ANSWER $= 9x^2-y^2$

III FACTOR THE FOLLOWING AND TEST BY MULTIPLICATION:

1. $16-4y^2$ ______ ANSWER $= (4+2y)(4-2y)$
2. $36a^4-49b^2$ ______ ANSWER $= (6a^2-7b)(6a^2+7b)$
3. $1-9x^4$ ______ ANSWER $= (1+3x^2)(1-3x^2)$
4. 7^2-5^2 ______ ANSWER $= (7+5)(7-5)$
5. $b^2-7b+12$ ______ ANSWER $= (b-4)(b-3)$
6. x^2+2x-8 ______ ANSWER $= (x+4)(x-2)$
7. $x^2+15x+56$ ______ ANSWER $= (x+8)(x+7)$

IV SOLVE THE FOLLOWING EQUATIONS:

1. $7x-5 = x-23$ ______ ANSWER $= -3$
2. $2x-(5x+5) = 7$ ______ ANSWER $= -3$
3. $3(x+1) = -5(x-1)$ ______ ANSWER $= \frac{1}{4}$
4. $7x+19 = 5x+7$ ______ ANSWER $= -6$
5. GIVEN THE EQUATION $A = \pi AB$. SOLVE FOR A AND B ______ ANSWER $A = \frac{A}{\pi B}$, $B = \frac{A}{\pi a}$

V REDUCE THE FOLLOWING FRACTIONS TO THEIR LOWEST TERMS.

1. $\frac{125}{225}$ ______ ANSWER $= \frac{5}{9}$
2. $\frac{28a^3x^4}{35a^3x^5}$ ______ ANSWER $= \frac{4}{5x}$
3. $\frac{a^2-5a+6}{a^2-7a+10}$ ______ ANSWER $= \frac{a-3}{a-5}$

VI PERFORM THE FOLLOWING PROCESSES:

1. ADD $\frac{A-3}{3}$ AND $\frac{5+A}{6}$ ——— ANSWER = $\frac{3A-1}{6}$

2. FROM $\frac{4A+3X}{3A}$ TAKE $\frac{5A+2}{3}$ ——— ANSWER = $\frac{3X+2A-5A^2}{3A}$

3. ADD $\frac{3}{X-2}$, $\frac{4}{X-3}$ AND $\frac{7}{X^2-5X+6}$ ANSWER = $\frac{7X-10}{X^2-5X+6}$

4. MULTIPLY $\frac{3M}{CX}$ BY $\frac{C}{3}$ ——— ANSWER = $\frac{M}{X}$

5. FIND THE PRODUCT OF $\frac{3AB}{4CD} \times \frac{16C^2X^2}{21B^2} \times \frac{7D^3}{48X^2}$
ANSWER = $\frac{ACD^2}{B^2}$

6. DIVIDE $\frac{3X+Y}{9}$ BY $\frac{4X}{3}$ ——— ANSWER = $\frac{3X+Y}{12X}$

7. MULTIPLY $A^2+2AB+B^2$ BY $\frac{A}{A^2-B^2}$ —— ANSWER = $\frac{A^2+AB}{A-B}$

VII SOLVE THE FOLLOWING EQUATIONS FOR THE UNKNOWN "X" AND TEST THE RESULTS:

1. $\frac{X}{2} + \frac{X}{6} = \frac{10}{3}$ ——— ANSWER = 5

2. $\frac{2X}{3} - \frac{7X}{8} + \frac{5X}{18} + \frac{X}{24} = 4/9$ —— ANSWER = 4

3. $\frac{X+1}{2} + \frac{X+3}{4} = 2$ ——— ANSWER = 1

IN ORDER TO HANDLE QUICKLY AND ACCURATELY ALGEBRAIC PROBLEMS OF THE TYPES EXPLAINED, A GREAT DEAL OF PATIENT PRACTICE IS REQUIRED. ALTHOUGH MATHEMATICS OF THIS TYPE IS NOT ENECESSARY FOR THE ORDINARY MECHANICA, YET IT IS ESSENTIAL FOR THOSE WHO INTEND TO ENGAGE IN THE ENGINEERING FIELD IN A SUPERVISORY CAPACITY AND WHICH AFTER ALL SHOULD BE THE ULTIMATE GOAL OF EVERY NATIONAL GRADUATE. REMEMBER ALWAYS, IT REQUIRES ADDITIONAL CONCENTRATION ON THE PART OF THE STUDENT TO MASTER THIS WORK, BUT THE EFFORT MADE IN ACQUIRING THIS KNOWLEDGE WILL BE WELL WORTH WHILE.

Examination Questions

LESSON NO. AS- 7

> Faith is the essential condition of confidence, and confidence is the essential condition of success.

1. – Find the product $(2x+3y)^2$ without resorting to actual multiplication.

2. – Find the product of $(3x+4y)(3x-4y)$ without resorting to actual multiplication.

3. – Factor the expression $4a^4-16b^2$

4. – Factor the expression $x^2+7x+12$.

5. – Solve the following equation for x: $3x+4 = x+10$. Show the test or proof that your value for "x" is correct.

6. – Reduce the fraction $\frac{x^2+2x-8}{x^2-4x+4}$ to its lowest terms.

7. – Add $\frac{2a+5}{3}$ and $\frac{a-2}{6}$.

8. – From $\frac{3a+2}{b}$ take $\frac{7ab-10b}{b^2}$

9. – Find the product of $\frac{x^2-1}{x^2-4} \times \frac{x+2}{x-1}$

10.– Given the equation $V = 2\pi^2 R r^2$, solve for R.

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Amplifying Systems

LESSON NO. 8

EXPONENTS, POWERS, ROOTS AND LOGARITHMS

IN THIS LESSON YOU ARE GOING TO BE FAMILIARIZED WITH SOME OF THE MOST IMPORTANT MATHEMATICAL PROCESSES USED IN SOLVING ENGINEERING PROBLEMS AND IT IS THEREFORE ADVISABLE THAT YOU GIVE THIS LESSON YOUR UTMOST ATTENTION.

IN A PREVIOUS LESSON TREATING WITH MATHEMATICS YOU WERE ALREADY INTRODUCED TO EXPONENTS SO THAT WHAT YOU HAVE SO FAR LEARNED ABOUT THIS SUBJECT WILL AGAIN APPLY AT THIS TIME, ONLY THAT WE SHALL CARRY THIS ANALYSIS A LITTLE FURTHER THAN HERETOFORE.

LAW OF EXPONENTS IN MULTIPLICATION

THE LAW OF EXPONENTS AS APPLIED TO MULTIPLICATION WAS ALREADY GIVEN YOU PREVIOUSLY BUT IT IS ADVISABLE THAT IT BE BROUGHT TO YOUR ATTENTION AGAIN AT THIS TIME SO AS TO "TIE IN" WITH YOUR PRESENT STUDIES AND THEREFORE MAKE THE SUBJECTS AS PRESENTED IN THIS LESSON MORE UNDERSTANDABLE.

IN THE CASE OF MULTIPLICATION, YOU WILL RECALL, WE ADD EXPONENTS AND THIS CAN BE EXPRESSED IN SYMBOLS FOR ALL GENERAL CASES IN THE FOLLOWING MANNER:

$$A^m \cdot A^n = A^{m+n}$$

OR $A^3 \cdot A^4 = A^{3+4} = A^7$

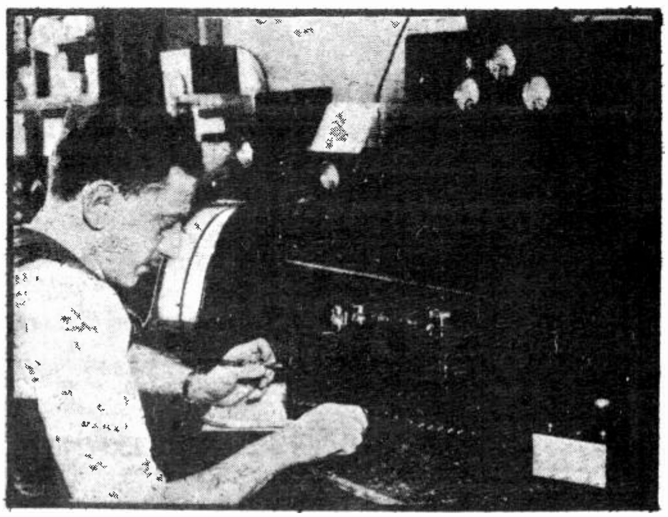

FIG. 1

Logarithms - Essential to Solve Design Problems in Amplifying Systems.

LAW OF EXPONENTS IN DIVISION

WHEN DIVIDING EXPRESSIONS INVOLVING EXPONENTS, THEN WE SUBTRACT EXPONENTS AND THIS CAN BE EXPRESSED IN SYMBOLS FOR ALL GENERAL CASES IN THE FOLLOWING MANNER:

$$A^{m} \div A^{m} = A^{m-n}$$

$$\text{OR} \quad A^{10} \div A^{2} = A^{10-2} = A^{8}$$

WHERE M IS GREATER THAN N. SHOULD M = N, THEN $A^{n} \div A^{n} = 1$.

POWER OF A POWER

IN ORDER TO FIND THE POWER OF A POWER, THE EXPONENTS ARE MULTIPLIED. FOR EXAMPLE, $(A^{m})^{n} = A^{mn}$. ILLUSTRATED NUMERICALLY, WE COULD HAVE: $(A^{8})^{4} = A^{8} \cdot A^{8} \cdot A^{8} \cdot A^{8} = A^{32}$.

POWER OF A PRODUCT

THE POWER OF A PRODUCT IS EQUIVALENT TO THE PRODUCT OF THE POWERS OF THE FACTORS. FOR EXAMPLE, $(ABCD)^{n} = A^{n} \cdot B^{n} \cdot C^{n} \cdot D^{n}$

$$\text{OR} \quad (4 \cdot 6 \cdot 8)^{4} = 4^{4} \cdot 6^{4} \cdot 8^{4}$$

$$\text{OR} \quad (3A^{2}X^{3}Y^{4})^{4} = 3^{4} \cdot (A^{2})^{4} \cdot (X^{3})^{4} \cdot (Y^{4})^{4} = 81A^{8}X^{12}Y^{16}$$

POWER OF A FRACTION

THE POWER OF A FRACTION IS EQUAL TO THE POWER OF THE NUMERATOR DIVIDED BY THE POWER OF THE DENOMINATOR.

EXAMPLE:

$$\left(\frac{A}{B}\right)^{m} = \frac{A^{m}}{B^{m}}$$

$$\text{OR} \quad \left(\frac{10}{5}\right)^{3} = \frac{10^{3}}{5^{3}} = \frac{10 \cdot 10 \cdot 10}{5 \cdot 5 \cdot 5} = \frac{1000}{125} = 8$$

$$\text{OR} \quad \left(\frac{3A^{3}B^{4}X}{2Y^{2}}\right)^{3} = \frac{3^{3}(A^{3})^{3} \cdot (B^{4})^{3} \cdot X^{3}}{2^{3}(Y^{2})^{3}} = \frac{27A^{9}B^{12}X^{3}}{8Y^{6}}$$

ROOT OF A POWER

IF WE TAKE THE ROOT OF A POWER, WE HAVE THE INVERSE OF FINDING THE POWER OF A POWER. THAT IS, THE INVERSE OF $(A^{m})^{n} = A^{mn}$ WOULD BE $\sqrt[n]{A^{m}} = A^{m \div n}$ OR $A^{\frac{m}{n}}$. A NUMERICAL EXAMPLE FOR FINDING THE ROOT OF A POWER WOULD BE AS FOLLOWS:

$$\sqrt[4]{4^{8}} = 4^{8 \div 4} = 4^{2} = 16$$

ANOTHER EXAMPLE FOLLOWS: FIND THE CUBE ROOT OF $3^{6}B^{9}X^{12}$

SOLUTION: $\sqrt[3]{3^{6}B^{9}X^{12}} = 3^{6 \div 3} \cdot B^{9 \div 3} \cdot X^{12 \div 3} = 3^{2}B^{3}X^{4}$

ZERO EXPONENT

ANY NUMBER OTHER THAN ZERO WHICH IS AFFECTED BY A ZERO EXPONENT IS EQUAL TO ONE.

EXAMPLES: $1^{0} = 1$; $5^{0} = 1$; $8^{0} = 1$; $A^{0} = 1$.

NEGATIVE EXPONENT

IN THE EXPLANATION PERTAINING TO THE LAW OF EXPONENTS IN DIVISION YOU WERE SHOWN THAT $A^m \div A^n = A^{m-n}$. WHEN M IS GREATER THAN N AS IN AN EXAMPLE SUCH AS $A^6 \div A^2 = A^4$, WE OBTAIN A POSITIVE EXPONENT BUT WHEN M IS LESS THAN N AS IN THE EXAMPLE $A^2 \div A^6 = A^{-4}$, WE OBTAIN A NEGATIVE EXPONENT.

IT IS ALSO TRUE THAT $A^2 \div A^6 = \frac{A^2}{A^6} = \frac{1}{A^4}$ AND THEREFORE $A^{-4} = \frac{1}{A^4}$.

SIMILARLY $A^{-n} = \frac{1}{A^n}$. RULE: A NUMBER AFFECTED BY A NEGATIVE EXPONENT EQUALS 1 DIVIDED BY THE SAME NUMBER AFFECTED BY A POSITIVE EXPONENT AND WHICH IS EQUAL IN ABSOLUTE VALUE TO THE NEGATIVE EXPONENT.

EXAMPLE: (1) $3^{-6} = \frac{1}{3^6} = \frac{1}{729}$

(2) $5^{-3} = \frac{1}{5^3} = \frac{1}{125}$

FRACTIONAL EXPONENT

IF WE APPLY THE LAW $\sqrt[n]{A^m} = A^{m \div n}$ WHEN M AND N HAVE ANY VALUES, THEN WE HAVE $\sqrt[n]{A^m} = A^{\frac{m}{n}}$ ALSO $\sqrt[n]{A} = A^{1 \div n} = A^{\frac{1}{n}}$.

BY DEFINITION THEN, A FRACTIONAL EXPONENT INDICATES A ROOT. THE DENOMINATOR IS THE INDEX OF THE ROOT AND THE NUMERATOR IS THE EXPONENT OF A POWER.

A FORM LIKE $A^{\frac{m}{n}}$ MEANS EITHER $\sqrt[n]{A^m}$ OR $(\sqrt[n]{A})^m$. IN OTHER WORDS, THE NUMBER "A" MAY BE RAISED TO THE "MTH" POWER AND THEN THE "NTH" ROOT TAKEN, OR ELSE THE "NTH" ROOT MAY BE TAKEN FIRST AND THEN THE RESULT RAISED TO THE "MTH" POWER.

THUS $8^{2/3} = \sqrt[3]{8^2} = \sqrt[3]{64} = 4$

OR $8^{2/3} = (\sqrt[3]{8})^2 = 2^2 = 4$

OTHER EXAMPLES OF FRACTIONAL EXPONENTS FOLLOW:

(1) $16^{1/2} = \sqrt{16} = 4$

(2) $64^{1/3} = \sqrt[3]{64} = 4$

(3) $32^{3/5} = (\sqrt[5]{32})^3 = 2^3 = 8$

(4) $4^{-3/2} = \frac{1}{4^{3/2}} = \frac{1}{\sqrt{4^3}} = \frac{1}{\sqrt{64}} = \frac{1}{8}$

IN ENGINEERING WORK, IT IS A COMMON PRACTICE TO WRITE LONG NUMBERS IN A SHORTER FORM WITH THE AID OF EXPONENTS. FOR EXAMPLE $10^3 = 1000$; $10^6 = 1,000,000$; $10^{-3} = .001$; $10^{-6} = .000001$ ETC.

LOGARITHMS

THE PROCESS OF MULTIPLICATION, DIVISION, RAISING TO POWERS AND EXTRACTING ROOTS OF ARITHMETICAL NUMBERS IS GREATLY SIMPLIFIED BY THE USE OF LOGARITHMS. MANY CALCULATIONS THAT ARE DIFFICULT OR EVEN IMPOSSIBLE BY ORDINARY ARITHMETICAL METHODS ARE SOLVED QUITE READILY BY MEANS OF LOGARITHMS. THIS WILL BECOME MORE APPARENT AS YOU PROGRESS THROUGH THIS LESSON.

DEFINITION

A LOGARITHM of a number is the exponent by which the base must be affected in order to produce that number. The logarithms of all the positive numbers to a given base are called a SYSTEM OF LOGARITHMS and the base is called the base of the system.

Although any base may be used in a system of logarithms, yet the base 10 is most commonly used because it offers the most convenient method to work with.

Let us consider the example $3^4 = 81$. In terms of logarithms this same expression can be interpreted as the logarithm of 81 to the base 3 is 4 and this would be written as $\log_3 81 = 4$. Note that the expression "Log" is an abreviation for "Logarithm" and is used most extensively. Oth er examples follow:

Expressed as Exponents		Expressed as Logarithms
$3^3 = 27$	———	$\log_3 3 = 27$
$3^4 = 81$	———	$\log_3 81 = 4$
$2^5 = 32$	———	$\log_2 32 = 5$
$10^3 = 1000$	———	$\log_{10} 1000 = 3$
$64^{1/3} = 4$	———	$\log_{64} 4 = 1/3$

Since logarithms to the base 10 are most extensively used in practice, let us therefore now consider this system in more detail.

LOGARITHMS TO THE BASE 10

When the base 10 is employed it has become the practice to omit the base and simply write the expressions in the following manner:

Log 10 .... = 1	Log 1 .... = 0
Log 100 ... = 2	Log 0.1 .. = −1
Log 1000... = 3	Log 0.01.. = −2
Log 10,000..= 4	Log 0.001..= −3
Log 100,000 = 5	Log 0.0001 = −4

In other words, when no base is expressed, it is understood to be 10.

As you will observe from the foregoing, the logarithm of any number between 10 and 100 is 1 plus a fraction; between 100 and 1000 the Log arithm is 2 plus a fraction; between 0.1 and 0.01 the logarithm is −1 mi nus a fraction or −2 plus a fraction.

As a general rule, the logarithm of a number consists of two parts, namely, a whole number and a fractional part. The whole number is called the CHARACTERISTIC and the fractional part is called the MANTISSA. The mantissas of the positive numbers arranged in order are called a TABLE OF LOGARITHMS.

The logarithm of 4976 consists of the characteristic 3 and some mantissa because 4976 lies between 1000 and 10,000. The logarithm of

36,572 IS 4 PLUS A FRACTION BECAUSE 36,572 LIES BETWEEN 10,000 AND 100,000. THE LOGARITHM OF 0.0432 IS −2 PLUS A FRACTION BECAUSE 0.0432 LIES BETWEEN 0.01 AND 0.1.

FROM THE EXAMPLES JUST GIVEN, YOU WILL READILY NOTE THAT MULTIPLYING A NUMBER BY 10 INCREASES ITS CHARACTERISTIC BY 1. WHEN USING THE BASE 10 IN A SYSTEM OF LOGARITHMS, THE CHARACTERISTIC CAN BE DETERMINED BY INSPECTION AND IT IS THEREFORE ONLY NECESSARY TO HAVE THE MANTISSA GIVEN IN A TABLE.

RULES FOR DETERMINING THE CHARACTERISTIC

FROM WHAT HAS JUST BEEN MENTIONED REGARDING THE CHARACTERISTICS IN A SYSTEM OF LOGARITHMS USING A BASE OF 10, YOU WILL READILY REALIZE THAT THE FOLLOWING RULES APPLY:

(1) FOR WHOLE NUMBERS, THE CHARACTERISTIC IS ONE LESS THAN THE NUMBER OF WHOLE NUMBER FIGURES AND IS POSITIVE.

(2) FOR DECIMALS, THE CHARACTERISTIC IS ONE MORE THAN THE NUMBER OF ZEROS IMMEDIATELY AT THE RIGHT OF THE DECIMAL POINT AND IS NEGATIVE.

(3) IN A NUMBER CONSISTING OF A WHOLE NUMBER AND A DECIMAL, CONSIDER THE WHOLE NUMBER PART AND APPLY RULE (1).

EXAMPLES: THE CHARACTERISTIC OF 472 IS 2 AS PER RULE (1); THE CHARACTERISTIC OF 36,743 IS 4 AS PER RULE (1); THE CHARACTERISTIC OF 0.034 IS −2 AS PER RULE (2) AND −4 FOR 0.000765 AS PER RULE (2); FOR 3.47 THE CHARACTERISTIC IS 0 AS PER RULE (3) AND FOR 463.89 IT IS 2 AS PER RULE (3).

THE MANTISSA

TO DETERMINE THE MANTISSA IS A MORE DIFFICULT TASK THAN DETERMINATION OF THE CHARACTERISTIC AND WE USE A TABLE TO DO SO. A FOUR PLACE TABLE OF LOGARITHMS IS GIVEN YOU UNDER THE HEADING TABLE I. BY EXAMINING THIS TABLE, YOU WILL OBSERVE THAT IT IS DIVIDED INTO A SERIES OF HORIZONTAL AND VERTICAL COLUMNS. THE FIRST VERTICAL COLUMN OF THE TABLE HAS THE LETTER N AT THE TOP AND WHICH IS AN ABREVIATION FOR "NUMBER". THE OTHER VERTICAL COLUMNS HAVE THE NUMBERS 0-1-2-3 ETC. AT THEIR TOP. BELOW THESE NUMBERED COLUMNS YOU WILL FIND NUMBERS MADE UP OF FOUR FIGURES. THESE NUMBERS ARE DECIMALS AND ARE THE MANTISSAS OF THE LOGARITHMS OF THE NUMBERS MADE UP OF THE FIGURES IN THE COLUMN HEADED N TOGETHER WITH THE HEAD OF ANOTHER COLUMN. SINCE THESE MANTISSAS TAKE CARE OF FOUR DECIMAL PLACES, THIS TABLE RECEIVES ITS CLASSIFICATION OF A "FOUR PLACE TABLE".

ANY NUMBER CONSISTING OF THREE FIGURES HAS ITS FIRST TWO FIGURES IN THE COLUMN HEADED N AND ITS THIRD FIGURE AT THE TOP OF ANOTHER COLUMN. FOR EXAMPLE IN THE CASE OF THE NUMBER 368 THE 36 IS FOUND IN THE COLUMN HEADED N AND THE 8 AT THE TOP OF ANOTHER COLUMN.

TO FIND THE MANTISSA OF A NUMBER CONSISTING OF THREE SIGNIFICANT FIGURES

YOU HAVE ALREADY BEEN SHOWN HOW THE CHARACTERISTIC OF A NUMBER IS

DETERMINED SO NOW LET US SEE HOW THE MANTISSA OF THE NUMBER IS FOUND FROM THE TABLE. AS OUR FIRST EXAMPLE, LET US CONSIDER A NUMBER WHICH HAS THREE SIGNIFICANT FIGURES SUCH AS 493 FOR INSTANCE.

TO DO THIS, WE FIRST LOOK IN THE COLUMN HEADED N FOR THE FIRST TWO FIGURES OF THE NUMBER 493 OR 49. THIS DONE, WE MOVE DIRECTLY TOWARDS THE RIGHT FROM 49 UNTIL WE COME TO THE VERTICAL COLUMN WHICH HAS THE THIRD FIGURE OF OUR NUMBER OR THE 3 AT ITS TOP. WE FIND IT TO BE "6928". IT SHOULD BE REMEMBERED, HOWEVER, THAT THIS VALUE OF "6928" FOR THE MANTISSA OF 493 IS A DECIMAL AND THESE FOUR FIGURES ARE REALLY THE FIRST FOUR FIGURES TO THE RIGHT OF THE DECIMAL POINT. HENCE THE MANTISSA FOR 493 IS ACTUALLY 0.6928.

REGARDLESS OF THE POSITION OF THE DECIMAL POINT IN THE NUMBER FOR WHICH THE MANTISSA IS BEING SOUGHT, THE MANTISSA STILL REMAINS 0.6928. FOR EXAMPLE, IF THE NUMBER IN QUESTION BE 493; 4.93; 49.3; OR 4930 THE MANTISSA WILL STILL BE 0.6928 BUT THE CHARACTERISTIC WILL OF COURSE BE DIFFERENT IN EACH CASE.

TABLE I
LOGARITHMS OF NUMBERS AND PROPORTIONAL PARTS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	1	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

TO FIND THE MANTISSA OF A NUMBER CONSISTING OF ONE OR TWO SIGNIFICANT FIGURES

When the number consists of one or two significant figures, the number is found in the column headed N and the mantissa to the right in the column headed zero. For example, the mantissa of 24 as per Table I is 0.3802. This is found by looking in the N column for the 24 and to the right under the 0 column.

The mantissa of 3 is 0.4771 and this is found from Table I by looking in the "N" column for the number 30 and to the right in the zero column.

TO FIND THE MANTISSA OF A NUMBER CONSISTING OF FOUR OR MORE SIGNIFICANT FIGURES

Table I, you will notice, is only direct reading for numbers having three significant figures, that is, numbers made up of three figures or a zero as the fourth figure such as 428 or 8790 etc. Our next step then will be to see how the mantissas can be found for numbers consisting of four or more significant figures. As an example, let us find the mantissa of the number 3965.

By inspection, you will readily realize that the number 3965 lies between 3960 and 3970 and therefore its mantissa must lie between the mantissas of 3960 and 3970. We then proceed as follows:

Mantissa of 3960 = 0.5977
Mantissa of 3970 = 0.5988

The difference between these two mantissas is equal to 0.5988−0.5977 = 0.0011 and this is spoken of as being the TABULAR DIFFERENCE. Now then, since an increase of 10 in the number (3960 to 3970) increases the mantissa by 0.0011, it is logical that an increase of 5 in the number (3960 to 3965) will increase the mantissa 5/10 as much or in our particular case 0.0011 x 0.5 = 0.00055. The mantissa for 3965 therefore becomes 0.5977 + 0.00055 = 0.59825 or 0.5982 (approximately). The process of determining the mantissa by the method just explained is known as INTERPOLATION.

The process of interpolation is simplified considerable by the section titled "Proportional Parts" in the right hand section of the logarithm table. For example, in the problem which we have just completed for finding the mantissa of the number 3965, we found that the mantissa was to be 5/10 as much as the mantissa for 3960 and so we look for the column headed 5 under "proportional parts" straight down until we come to the horizontal line corresponding to the number 39 in the N column and we find the number 5, which corresponds to the fourth decimal place. This means that we are to add 0.0005 to the mantissa of 3960 or 0.5977+0.0005= 0.5982 as the mantissa for 3965.

Now let us consider another example, namely to find the mantissa for the number 63,478 This number lies between 63,400 and 63,500 and from the table we thus obtain the following:

MANTISSA FOR 63,400 = 0.8021
MANTISSA FOR 63,500 = 0.8028

TABULAR DIFFERENCE = 0.8028 − 0.8021 = 0.0007.

THEN SINCE AN INCREASE OF 100 IN THE NUMBER INCREASES THE MANTISSA BY 0.0007 IT IS CLEAR THAT AN INCREASE IN THE NUMBER OF 78 OR 63400 TO 63478 WILL INCREASE THE MANTISSA 0.0007 x 0.78 = 0.000546 OR APPROXIMATELY 0.0005 TO THE NEAREST FOURTH DECIMAL PLACE. THEREFORE, THE MANTESSA FOR 63,478 IS EQUAL TO 0.8021 + 0.0005 OR 0.8026.

TO USE THE PROPORTIONAL PARTS SECTION OF THE TABLE IN WORKINGTHIS PROBLEM, WE WOULD LOOK IN THE "8" COLUMN (78 BEING VERY NEAR 80)AND DOWN THIS COLUMN TO A POINT CORRESPONDING TO 63 IN THE N COLUMN AND WHERE WE FIND "5". (THIS FIVE IS THE FOURTH DECIMAL PLACE). THEREFORE,WE ADD 0.0005 TO THE MANTISSA OF 63,400 OR 0.8021 + 0.0005 = 0.8026 AND WHICH CHECKS WITH THE PREVIOUS METHOD.

FINDING THE LOGARITHM OF A NUMBER

WHEN IT IS DESIRED TO FIND THE LOGARITHM OF A NUMBER IT IS ADVISABLE TO DETERMINE THE CHARACTERISTIC FIRST AND THEN THE MANTISSA.

EXAMPLE 1: FIND THE LOGARITHM OF 425.
PROCESS: THE CHARACTERISTIC = 2. (AS PER RULE I FOR CHARACTERISTICS)
THE MANTISSA = 0.6284 (AS PER TABLE)
THEREFORE, THE LOGARITHM OR LOG OF 425 = 2.6284.

EXAMPLE 2: FIND THE LOGARITHM OF 7543
PROCESS: THE CHARACTERISTIC = 3 (AS PER RULE I)
THE MANTISSA FOR 7540 = 0.8774
THE MANTISSA FOR 7550 = 0.8779
TABULAR DIFFERENCE = 0.8779−0.8774 = 0.0005
7543 IS GREATER THAN 7540 BY 3 AND SO
0.3x0.0005 = 0.00015 OR 0.0001. MANTISSA FOR
7543 = 0.8774 + 0.0001 = 0.8775
THEREFORE LOG 7543 = 3.8775.

EXAMPLE 3: FIND THE LOGARITHM OF 0.00042
THE CHARACTERISTIC = −4.
THE MANTISSA = 0.6232
THEREFORE LOG 0.00042 = $\bar{4}$.6232

NOTICE THAT IT IS NOT PERMISSIBLE TO PLACE THE MINUS SIGN BEFORE THE CHARACTERISTIC IN WRITING A NEGATIVE LOGARITHM FOR THIS WOULD INDICATE THAT BOTH CHARACTERISTIC AND MANTISSA ARE NEGATIVE WHEREAS THE MANTISSA SHALL ALWAYS BE POSITIVE. TO OVERCOME THIS DIFFICULTY, THENEGATIVE SIGN IS PLACED ABOVE THE CHARACTERISTIC AS WAS DONE IN EXAMPLE 3 WHICH WAS JUST EXPLAINED.

ANOTHER METHOD OF WRITING THE NEGATIVE LOGARITHM IS TO INCREASE THE CHARACTERISTIC BY 10 AND SUBTRACT 10 AT THE RIGHT OF THE MANTISSA. THUS THE LOGARITHM OF 0.00042 MAY BE WRITTEN AS $\bar{4}$.6232 OR 6.6232−10.

TO FIND THE NUMBER CORRESPONDING TO A LOGARITHM

IN ENGINEERING PRACTICE, NOT ONLY IS IT NECESSARY TO OFTEN FIND

THE LOGARITHM OF A NUMBER BUT IT IS ALSO FREQUENTLY NECESSARY TO FIND THE NUMBER CORRESPONDING TO A GIVEN LOGARITHM.

EXAMPLE: FIND THE NUMBER HAVING 3.4548 FOR A LOGARITHM.

PROCESS: SINCE THE DECIMAL OF THE LOGARITHM DOES NOT EFFECT THE MANTISSA, WE CAN DETERMINE ONLY THE FIGURES OF THE NUMBER WITH THE AID OF THE MANTISSA. THE DECIMAL POINT WILL BE DETERMINED LATER BY MEANS OF THE LOGARITHM'S CHARACTERISTIC.

THE NUMBER CORRESPONDING TO A MANTISSA OF 0.4548 AS PER THE LOG TABLE = 285. IN OTHER WORDS LOOK FOR THE MANTISSA 0.4548 OR "4548" IN THE LOG TABLE. TO THE LEFT OF THIS MANTISSA YOU WILL FIND THE NUMBER 28 IN THE N COLUMN AND AT THE TOP OF THE COLUMN IN WHICH THIS MANTISSA IS FOUND, THE NUMBER 5 APPEARS. THE NUMBER THEREFORE CONSISTS OF THE FIGURES 285 BUT AS YET THE POSITION OF THE DECIMAL POINT HAS NOT BEEN DETERMINED. IN THE GIVEN LOGARITHM 3.4548 WE HAVE A CHARACTERISTIC OF 3 AND WHICH ACCORDING TO THE RULE FOR CHARACTERISTICS MEANS THAT FOUR FIGURES MUST BE PLACED TO THE LEFT OF THE DECIMAL POINT. THIS MEANS THAT ONE ZERO MUST BE ANNEXED TO THE FIGURES 285 AND THE NUMBER THUS BECOMES 2850.

IN THE EXAMPLE JUST GIVEN YOU THE NUMBER COULD BE DETERMINED DIRECTLY FROM THE TABLE. NOW, HOWEVER, LET US SEE WHAT SHOULD BE DONE WHEN THE MANTISSA OF A GIVEN NUMBER IS NOT GIVEN EXACTLY IN THE TABLE. AS AN EXAMPLE, LET US FIND THE NUMBER CORRESPONDING TO THE LOGARITHM 2.4366.

UPON LOOKING IN TABLE I FOR THE MANTISSA 0.4366 OF THIS LOGARITHM YOU WILL OBSERVE THAT IT DOES NOT APPEAR HERE. THE NEAREST MANTISSA TO 0.4366 AS GIVEN IN THIS TABLE ARE 0.4362 AND 0.4378 AND BETWEEN WHICH 0.4366 LIES.

AS PER TABLE I, THE NUMBER CORRESPONDING TO THE LOGARITHM 2.4362 IS 273 AND THE NUMBER CORRESPONDING TO 2.4378 IS 274. THUS IT IS SEEN THAT AN INCREASE IN THE MANTISSA OF 0.4378-0.4362 = 0.0016 AND WHICH MAKES AN INCREASE OF 1 IN THE CORRESPONDING NUMBER (274-273 = 1). THE GIVEN MANTISSA 0.4366 IS 0.0004 LARGER THAN 0.4362. THEREFORE, THE REQUIRED NUMBER IS $\frac{0.0004}{0.0016} \times 1 = .25$ LARGER THAN 273 AND CONSEQUENTLY THE NUMBER CORRESPONDING TO THE LOGARITHM 2.4366 IS 273.25.

WHEN DEALING WITH THE TABULAR DIFFERENCE, FOR CONVENIENCE, IT IS PREFERABLE TO DROP THE DECIMAL POINT. THIS WILL RESULT IN THE FOLLOWING:

$\frac{4}{16} \times 1 = \frac{1}{4} = .25.$

THE RULES FOR FINDING THE NUMBER CORRESPONDING TO A GIVEN LOGARITHM CAN BE EXPRESSED AS FOLLOWS:

(1) WHEN THE MANTISSA OF THE GIVEN LOGARITHM IS EXACTLY GIVEN IN THE TABLE, THE FIRST TWO FIGURES OF THE NUMBER ARE FOUND TO THE LEFT OF THE GIVEN MANTISSA IN THE COLUMN HEADED N, AND THE THIRD FIGURE IS FOUND AT THE HEAD OF THE COLUMN IN WHICH THE MANTISSA IS GIVEN.

(2) WHEN THE MANTISSA OF THE GIVEN LOGARITHM IS NOT EXACTLY GIVEN

IN THE TABLE, FIND THE MANTISSA NEAREST THE GIVEN MANTISSA BUT SMALLER. THE FIRST THREE FIGURES OF THE NUMBER ARE THOSE CORRESPONDING TO THIS MANTISSA AND ARE FOUND BY RULE (1).

FOR ANOTHER FIGURE, DIVIDE THE DIFFERENCE BETWEEN THE MANTISSA FOUND AND THE GIVEN MANTISSA BY THE TABULAR DIFFERENCE. THE QUOTIENT IS THE OTHER FIGURE. ALWAYS DETERMINE THIS FIGURE TO THE NEAREST TENTH.

IN BOTH RULES (1) AND (2) PLACE THE DECIMAL POINT SO THAT THE RULES FOR DETERMING THE CHARACTERISTIC MAY BE APPLIED AND GIVE THE GIVEN CHARACTERISTICS.

AS FURTHER EXAMPLES, THE FOLLOWING ARE PRESENTED:

EXAMPLE 1: FIND THE NUMBER OF WHICH 2.8420 IS THE LOGARITHM. THE MANTISSA 0.8420 IS FOUND IN THE TABLE TO THE RIGHT OF 69 AND IN THE COLUMN HEADED 5; THEREFORE THE NUMBER CONSISTS OF THE FIGURES 695. THE DECIMAL POINT MUST BE PLACED SO AS TO GIVE A CHARACTERISTIC OF 2 WHEN THE RULE FOR CHARACTERISTIC IS APPLIED. CONSEQUENTLY, 695 IS THE NUMBER WHOSE LOGARITHM IS 2.8420.

EXAMPLE #2: FIND THE NUMBER WHOSE LOGARITHM IS 1.7624. THE MANTISSA NEAREST 0.7624 IS 0.7619 WHICH IS THE MANTISSA OF 578. THE TABULAR DIFFERENCE IS 8. THE DIFFERENCE BETWEEN THE MANTISSA FOUND (0.7619) AND THE GIVEN MANTISSA (0.7624) IS 5. THEN SINCE 5÷8 = 0.6 APPROXIMATELY, THE NUMBER CORRESPONDING TO THE LOGARITHM 1.7624 IS 57.86.

TO FIND THE PRODUCT OF TWO OR MORE FACTORS BY USING LOGARITHMS

THE RULE FOR FINDING THE PRODUCT OF TWO OR MORE FACTORS BY USING LOGARITHMS IS AS FOLLOWS: FIND THE SUM OF THE LOGARITHMS OF THE FACTORS. THE PRODUCT IS THEN THE NUMBER CORRESPONDING TO THIS SUM OF LOGARITHMS.

EXAMPLE: FIND THE PRODUCT OF 4.62 x 0.36 x 8.528

PROCESS: LOG 4.62 = 0.6646
LOG 0.36 = 1.5563
LOG 8.528 = 0.9308
LOG OF PRODUCT = 1.1517 THEREFORE THE PRODUCT IS EQUAL TO THE NUMBER CORRESPONDING TO THE LOGARITHM 1.1517 OR 14.18 (ANSWER)

TO FIND THE QUOTIENT OF TWO NUMBERS BY LOGARITHMS

TO FIND THE QUOTIENT OF TWO NUMBERS BY MEANS OF LOGARITHMS IS AS FOLLOWS: SUBTRACT THE LOGARITHMS OF THE DIVISOR FROM THE LOGARITHM OF THE DIVIDEND. THE QUOTIENT IS THE NUMBER CORRESPONDING TO THIS DIFFERENCE.

EXAMPLE 1: FIND THE QUOTIENT OF 42.65÷6.873

PROCESS: LOG 42.65 = 1.6299
LOG 6.873 = 0.8372
LOG OF QUOTIENT = 0.7927

THEREFORE, THE QUOTIENT IS EQUAL TO THE NUMBER CORRESPONDING TO THE LOGARITHM 0.7927 OR 6.204.

SOMETIMES WHEN SOLVING PROBLEMS BY MEANS OF LOGARITHMS YOU WILL FIND THAT THE ANSWER AS OBTAINED WITH LOGARITHMS DOES NOT CHECK EXACTLY

WITH THE ANSWER AS OBTAINED BY CONVENTIONAL CALCULATION. THE REASON FOR THIS IS THAT THE LOGARITHM METHOD IS ONLY AN APPROXIMATE METHOD, NEVERTHELESS IT IS SUFFICIENTLY ACCURATE FOR PRACTICAL PURPOSES—THE DIFFERENCE IN RESULTS BEING ONLY SLIGHT.

EXAMPLE 2: SOLVE THE FOLLOWING PROBLEM: $\frac{6.372 \times 0.6837 \times 4.362}{3.73 \times 0.4216 \times 36.65}$

OUR FIRST STEP IN AN EXAMPLE OF THIS TYPE IS TO FIND THE LOGARITHM OF THE NUMERATOR IN THE SAME MANNER AS WAS JUST EXPLAINED TO YOU REGARDING THE DETERMINING OF THE PRODUCT OF A SERIES OF NUMBERS BY MEANS OF LOGARITHMS. WE THUS OBTAIN THE FOLLOWING:

$$\begin{aligned} \log 6.372 &= 0.8042 \\ \log 0.6837 &= 9.8348 - 10 \\ \log 4.362 &= \underline{0.6397} \\ &\quad 11.2787 - 10 \\ \text{LOG OF NUMERATOR} &= 1.2787 \end{aligned}$$

THE NEXT STEP IS TO FIND THE LOGARITHM OF THE DENOMINATOR IN THE SAME MANNER AND THIS RESULTS IN THE FOLLOWING:

$$\begin{aligned} \log 3.73 &= 0.5717 \\ \log 0.4216 &= 9.6249 - 10 \\ \log 36.65 &= \underline{1.5641} \\ &\quad 11.7607 - 10 \\ \text{LOG OF DENOMINATOR} &= 1.7607 \end{aligned}$$

THE NEXT STEP IS TO DIVIDE THE NUMERATOR BY THE DENOMINATOR OF OUR GIVEN PROBLEM AND TO THIS WE FIRST SUBTRACT THE LOGARITHM OF THE DENOMINATOR FROM THE LOGARITHM OF THE NUMERATOR AS FOLLOWS:

$$\begin{aligned} \text{LOG OF NUMERATOR} &= 1.2787 \\ \text{LOG OF DENOMINATOR} &= \underline{1.7607} \\ \text{LOG OF QUOTIENT} &= \bar{1}.5180 \end{aligned}$$

THEREFORE, THE QUOTIENT IS EQUAL TO THE NUMBER CORRESPONDING TO THE LOGARITHM OF $\bar{1}.5180$ OR 0.3296. THE ANSWER TO THIS GIVEN PROBLEM IS THEREFORE 0.3296 (APPROXIMATELY).

TO FIND THE POWER OF A NUMBER BY LOGARITHMS

TO FIND THE POWER OF A NUMBER BY LOGARITHMS THE RULE IS AS FOLLOWS: MULTIPLY THE LOGARITHM OF THE NUMBER BY THE EXPONENT OF THE POWER. THE NUMBER CORRESPONDING TO THIS LOGARITHM IS THE REQUIRED POWER.

EXAMPLE 1: FIND THE VALUE OF $(2.378)^6$

PROCESS: LOG 2.378 = 0.3762

6 x LOG 2.378 = 2.2572 = LOG OF POWER.

THE NUMBER CORRESPONDING TO THE LOGARITHM 2.2572 = 180.8 AND THEREFORE $(2.378)^6$ = 180.8 (ANSWER).

EXAMPLE 2: FIND THE VALUE OF $(9.876)^{3/4}$

PROCESS: LOG 9.876 = 0.9946

3/4 OF LOG 9.876 = 0.9946 x 3/4 = 0.7460 = LOG $(9.876)^{3/4}$

THEREFORE $(9.876)^{3/4}$ = 5.571 (ANSWER)

TO FIND THE ROOT OF A NUMBER BY LOGARITHMS

THE RULE FOR FINDING THE ROOT OF A NUMBER BY LOGARITHMS IS AS FOLLOWS: DIVIDE THE LOGARITHM OF THE NUMBER BY THE INDEX OF THE ROOT. THE NUMBER CORRESPONDING TO THIS LOGARITHM IS THE REQUIRED ROOT.

EXAMPLE 1: FIND $\sqrt[5]{27.658}$

PROCESS: LOG 27.658 = 1.4418

$1/5$ LOG 27.658 = 0.2884 = LOG $\sqrt[5]{27.658}$

THEREFORE, $\sqrt[5]{27.658} = 1.943$

EXAMPLE 2: FIND $\sqrt[6]{0.008673}$

PROCESS: LOG 0.008673 = 7.9382 − 10

$$\log \sqrt[6]{0.008673} = 1/6 \text{ of } (7.9382-10)$$
$$= 1/6 \text{ of } (57.9382-60)$$
$$= \underline{9}.6564-10$$
$$= \bar{1}.6564$$

THEREFORE $\sqrt[6]{0.008673} = 0.4533$

NOTICE IN THIS EXAMPLE, THAT WHEN WE ARE TO DIVIDE A LOGARITHM WITH A NEGATIVE CHARACTERISTIC WHICH IS NOT A MULTIPLE OF THE DIVISOR, IT IS BEST TO FIRST ADD AND SUBTRACT SUCH A NUMBER OF TIMES 10 SO THAT AFTER DIVIDING THERE WILL BE A −10 AT THE RIGHT. THUS IN THE ABOVE, BEFORE DIVIDING (7.9382−10) BY 6, WE ADD AND SUBTRACT 50.

Examination Questions

LESSON AS-8

1\. – WHAT IS THE VALUE OF $(3A^2 B)^3$?

2\. – WHAT IS THE ROOT OF $\sqrt[4]{A^4 B^8 C^{12}}$?

3\. – WHAT IS THE LOGARITHM OF 315?

4\. – WHAT IS THE LOGARITHM OF 5445?

5\. – WHAT NUMBER HAS 2.6160 FOR A LOGARITHM?

6\. – FIND THE VALUE OF $(4.765)^5$ BY USING LOGARITHMS AND SHOW ALL YOUR WORK.

7\. – FIND THE PRODUCT OF 3.72 x 0.86 x 5.624 BY USING LOGARITHMS AND SHOW ALL YOUR WORK.

8\. – FIND THE QUOTIENT OF 63.47÷4.726 BY MEANS OF LOGARITHMS.

9\. – SOLVE THE FOLLOWING PROBLEM BY MEANS OF LOGARITHMS:

$$\frac{4.723 \times 0.4378 \times 3.427}{2.63 \times 0.3942 \times 38.73}$$

10\. – EXPRESS THE VALUE 3.5×10^7 AS A CONVENTIONAL NUMBER.

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Amplifying Systems

LESSON NO. A.S.-9

THE DECIBEL

In previous lessons, we referred to the gain and output of amplifiers considerable, speaking of these characteristics in terms of voltage and watts. For example, we may say that a certain amplifier offers a voltage gain of 270 and that it furnishes an output power of 5 watts.

Now let us make a comparison between two amplifiers of different power output ratings and analyze the situation with respect to the sound volume as perceived by the ear.

Amplifier #1 in Fig. 2 furnishes a power output of 5 watts and amplifier #2 of Fig.2 furnishes a power output of 10 watts. In other words, amplifier #2 supplies just TWICE the power output of amplifier #1, and upon first thought one might suppose that when operating at full volume, the sounds emitted by amplifier #2 would appear to the ear as being twice as loud as those from amplifier #1. Such, however, is not the case because our sense of hearing does not respond to different sound energies linearly or in direct proportion to the change in sound energies. Instead of this, our sense of hearing responds to different sound

Fig. 1
A.F. Amplifying Equipment In
Studio Control Room.

ENERGIES LOGARITHMICALLY OR TO PUT IT ANOTHER WAY, THE EAR'S RESPONSE IS PROPORTIONAL TO THE LOGARITHM OF THE CHANGE IN SOUND ENERGY.

IT THUS BECOMES APPARENT THAT IN ORDER TO EXPRESS THE RATIO OF POWERS OF EITHER ELECTRICAL OR SOUND ENERGIES WITH RESPECT TO THE RESPONSE OF THE EAR, A SPECIAL UNIT OF MEASUREMENT SHOULD BE USED AND SUCH IS THE CASE IN PRACTICE. THIS UNIT IS KNOWN AS THE DECIBEL AND IS GENERALLY ABBREVIATED AS "DB"; "DB" OR "DB". THE DECIBEL IS ALSO FREQUENTLY SPOKEN OF AS THE TRANSMISSION UNIT AND WHICH IS ABBREVIATED AS "TU".

OUR NEXT STEP WILL BE TO SEE HOW THE DECIBEL IS RELATED TO POWER RATIOS AND THIS IS EXPRESSED AS A FORMULA IN THE FOLLOWING MANNER:

$$\text{DECIBELS} = 10 \log_{10} \frac{P_1 \text{ (THE LARGER POWER)}}{P_2 \text{ (THE SMALLER POWER)}}$$

THIS FORMULA STATES THAT THE VALUE IN DECIBELS IS EQUAL TO 10 TIMES THE LOGARITHM OF THE POWER RATIO TO THE BASE 10. THE BASE 10 IS UNDERSTOOD AND THEREFORE FREQUENTLY OMITTED IN THE FORMULA. TO ILLUSTRATE THIS, LET US RETURN TO OUR EXAMPLE IN FIG. 2 AND SEE HOW THINGS WORK OUT.

THE POWER OUTPUT FOR AMPLIFIER #1 IS 5 WATTS AND THIS VALUE IS REPRESENTED AS P_2 IN THE FORMULA. THE POWER OUTPUT FOR AMPLIFIER #2 IS 10 WATTS AND THIS VALUE IS REPRESENTED AS P_1 IN THE FORMULA. SUBSTITUTING THESE VALUES IN THE FORMULA, WE HAVE:

$$\begin{aligned} \text{DECIBELS} &= 10 \log_{10} \frac{10}{5} \\ &= 10 \log 2 \\ &= 10 \times 0.3010 \\ &= 3 \text{ (APPROXIMATELY)} \end{aligned}$$

EXPLANATION: THE FIRST STEP IN THIS PROBLEM IS TO DIVIDE THE 10 BY

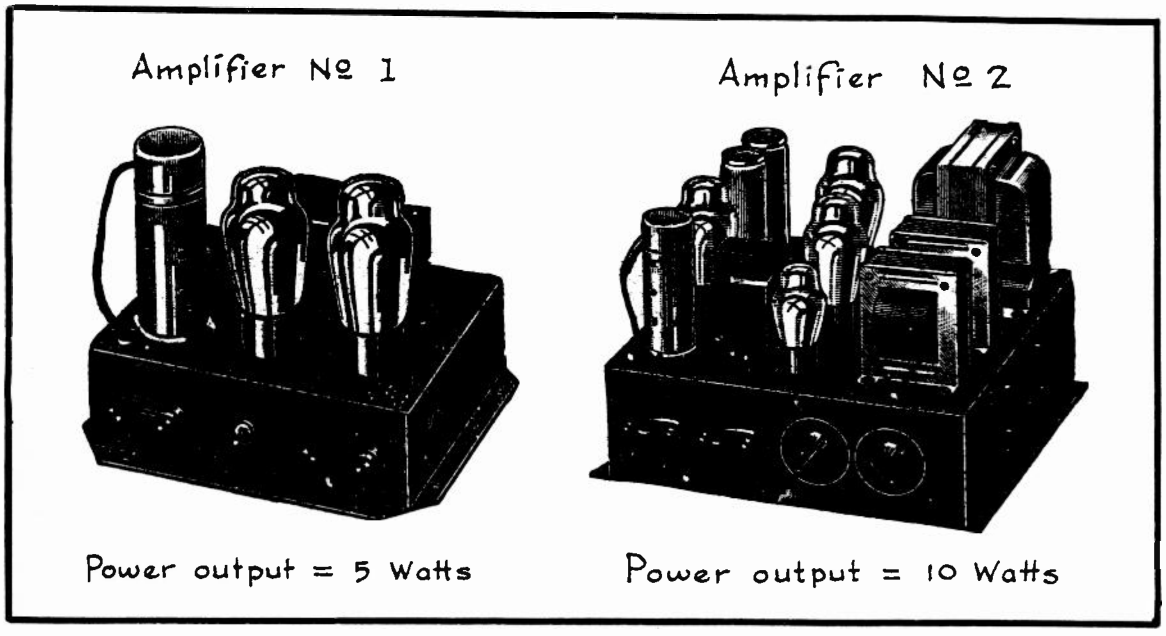

FIG. 2
A Comparison Between Amplifiers.

THE 5 AND THUS OBTAIN THE 2 IN THE SECOND LINE. WE THEN LOOK UP THE LOGARITHM OF 2 IN TABLE I OF THE PRECEDING LESSON, FINDING IT TO BE 0.3010 AND MULTIPLYING THIS BY 10 WE OBTAIN OUR ANSWER OF 3. THIS MEANS THAT AMPLIFIER #2 FURNISHES AN OUTPUT OF 3 DECIBELS OR 3 DB. GREATER THAN THAT OF AMPLIFIER #1.

THEORETICALLY, ONE DB. IS THE SMALLEST CHANGE IN SOUND ENERGY WHICH THE HUMAN EAR CAN RECOGNIZE BUT GENERALLY SPEAKING, IT REQUIRES A GOOD SENSE OF HEARING TO NOTICE SOUND ENERGY CHANGES OF 3 DB.

FROM THE PRECEDING EXPLANATION YOU WILL SEE THAT EVEN THOUGH THE POWER OUTPUT OF AMPLIFIER #2 IS TWICE THAT OF AMPLIFIER #1, YET AS FAR AS THE EAR IS CONCERNED, THERE WILL BE BUT SLIGHT DIFFERENCE IN THE SOUND INTENSITIES DELIVERED BY THESE TWO AMPLIFIERS.

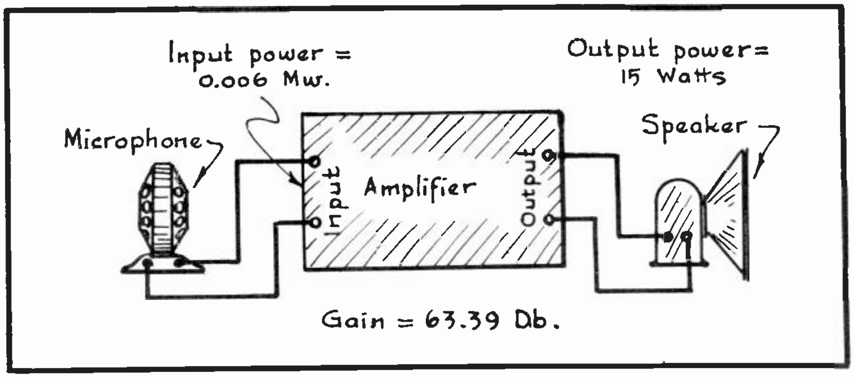

FIG. 3
Amplifier Gain.

IT IS IMPORTANT TO NOTE THAT THE DECIBEL IS A RELATIVE VALUE RATHER THAN AN ABSOLUTE VALUE. IN OTHER WORDS, WE CANNOT SPEAK OF AN AMPLIFIER AS HAVING AN OUTPUT OF SO MANY DB. BUT WE CAN SAY THAT A CERTAIN AMPLIFIER HAS AN OUTPUT OF SO MANY DB. MORE OR LESS THAN ANOTHER AMPLIFIER WITH WHICH A COMPARISON IS BEING MADE. IN LIKE MANNER, IF WE ASSIGN SOME ARBITRARY VALUE SUCH AS 10 MILLIWATTS, FOR EXAMPLE, AS A REFERENCE POINT AND COMPARE THE OUTPUT OF SEVERAL AMPLIFIERS TO THIS 10 MILLIWATT REFERENCE LEVEL, THEN WE CAN SAY THAT ONE OF THE AMPLIFIERS HAS 15 DB. OR 75 DB. GREATER OR LESS OUTPUT. THE 10 MILLIWATTS WOULD IN THIS CASE BE CONSIDERED AS THE "ZERO POWER LEVEL".

IN BROADCAST WORK IT HAS BECOME CUSTOMARY TO USE 6 MILLIWATTS OR 0.006 WATT AS THE ZERO LEVEL, WHEREAS 10 MILLIWATTS OR 0.010 WATT IS USED IN SOME TYPES OF TELEPHONE WORK.

GAIN EXPRESSED IN DECIBELS

IT HAS BECOME THE COMMON PRACTICE TO EXPRESS THE GAIN OF AMPLIFIERS IN TERMS OF DECIBELS AND AN EXAMPLE OF SUCH IS ILLUSTRATED IN FIG. 3. HERE LET US SUPPOSE THAT THE INPUT TO THE AMPLIFIER IS EQUAL TO 0.006 MILLIWATT OR 0.000006 WATT AND THAT THE OUTPUT POWER DELIVERED AT THE SPEAKER AMOUNTS TO 15 WATTS. SUBSTITUTING THESE VALUES INTO THE FORMULA $Db = 10 \log_{10} \frac{P_1}{P_2}$ WE WOULD HAVE $Db\ (GAIN) = 10 \log \frac{15}{0.000006} = 10 \log 2{,}500{,}000 = 10 \times 6.3971 = 63.39$. IN OTHER WORDS, THE GAIN OF THE AMPLIFYING SYSTEM IN FIG. 3 WOULD AMOUNT TO 63.39 DECIBELS OR 63.39 DB.

ATTENUATION

NOT ONLY IS THE DECIBEL ASSOCIATED WITH THE GAIN OF AMPLIFYING SYS-

TEMS BUT IT IS LIKEWISE USED IN CONNECTION WITH LOSSES IN AN AMPLIFYING SYSTEM. FOR EXAMPLE, IN THE SYSTEM ILLUSTRATED IN FIG. 4 THE AMPLIFIER IS PROVIDING AN OUTPUT OF 10 WATTS AND THE LINES BETWEEN THE AMPLIFIER AND THE SPEAKER ARE RESPONSIBLE FOR A POWER LOSS AMOUNTING TO 200 MILLIWATTS. THIS MEANS THAT THE ACTUAL POWER AVAILABLE AT THE SPEAKER WILL BE 10 MINUS 0.2 = 9.8 WATTS. EXPRESSED IN DECIBELS, THIS LINE LOSS WOULD FIGURE OUT AS FOLLOWS: $DB = 10 \log_{10} \frac{P_1}{P_2} = 10 \log \frac{10}{9.8} = 10 \times \log 1.02 = 10 \times 0.0086 = 0.08$ DB. LOSS IN THE TRANSMISSION LINE. THIS LOSS OF ENERGY IS COMMONLY SPOKEN OF AS ATTENUATION AND THIS MEANS THAT THE TRANSMISSION LINE IN THE SYSTEM OF FIG. 4 CAN BE SAID TO OFFER AN ATTENUATION AMOUNTING TO 0.08 DB.

IT IS ALSO CUSTOMARY TO REFER TO AN INCREASE IN POWER AS SO MANY "DB UP" AND LOSSES IN POWER AS SO MANY "DB DOWN".

THE DECIBEL AS RELATED TO VOLTAGE AND CURRENT CHANGES

SO FAR, YOU HAVE ONLY BEEN SHOWN HOW THE DECIBEL IS RELATED TO POWER RATIOS AND STRICTLY SPEAKING THE DECIBEL DEALS WITH POWER RATIOS ONLY. THERE ARE TIMES, HOWEVER, WHEN IT IS DESIRABLE TO DETERMINE A DB. GAIN OR ATTENUATION IN TERMS OF VOLTAGE CHANGES OR CURRENT CHANGES. FOR THIS, THE TWO FOLLOWING FUNDAMENTAL FORMULAS ARE AVAILABLE:

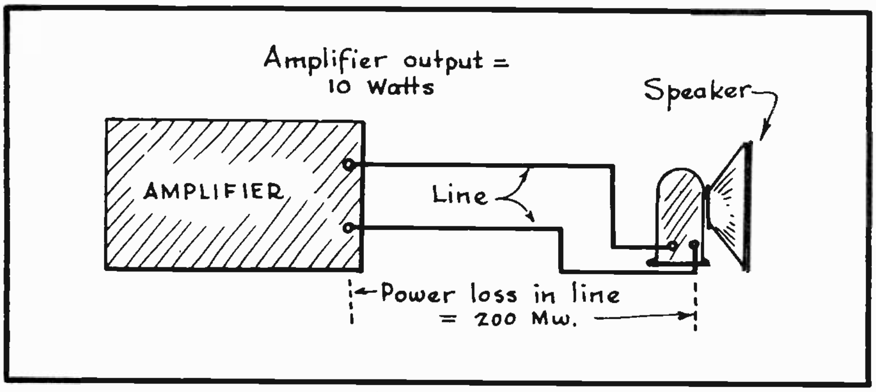

FIG. 4
Example of DB. Loss.

$$\text{DECIBELS} = 20 \log_{10} \frac{E_1 \text{ (THE LARGER VOLTAGE)}}{E_2 \text{ (THE SMALLER VOLTAGE)}}$$

$$\text{AND DECIBELS} = 20 \log_{10} \frac{I_1 \text{ (THE LARGER CURRENT)}}{I_2 \text{ (THE SMALLER CURRENT)}}$$

CARE MUST BE EXERCISED IN APPLYING THESE LATTER TWO FORMULAS, HOWEVER, BECAUSE THEY ARE ONLY CORRECT PROVIDED THAT THE IMPEDANCES ARE EQUAL ACROSS WHICH THESE TWO VOLTAGES ARE APPLIED OR THRU WHICH THESE TWO CURRENT VALUES FLOW.

IN THE EVENT THAT THE IMPEDANCES ARE NOT EQUAL THEN THE FOLLOWING FORMULAS SHOULD BE USED.

$$\text{DECIBELS} = 20 \log_{10} \frac{E_1 \div \sqrt{R_1}}{E_2 \div \sqrt{R_2}}$$

$$\text{AND DECIBELS} = 20 \log_{10} \frac{I_1 \sqrt{R_1}}{I_2 \sqrt{R_2}}$$

IF THE NATURE OF THE CIRCUIT IS SUCH THAT THE VOLTAGES IN QUESTION ARE APPLIED ACROSS A PURE RESISTANCE CIRCUIT OR THE CURRENTS IN QUESTION FLOW THROUGH A PURE RESISTANCE CIRCUIT, THEN R_1 AND R_2 IN THE PRECEDING FORMULAS WILL BE EXPRESSED IN OHMS RESISTANCE WHEREAS IF THE CIRCUITS BEING CONSIDERED INVOLVE INDUCTANCE, CAPACITY AND RESISTANCE OR ANY COMBINATION THEREOF, THEN R_1 AND R_2 OF THE FORMULAS WILL HAVE TO BE EXPRESSED IN TERMS OF EFFECTIVE IMPEDANCE.

NOW LET US PROCEED AND SEE HOW THIS LAST GROUP OF FORMULAS WOULD BE APPLIED IN PRACTICE. FIRST, WE SHALL CONSIDER PROBLEMS IN WHICH THE RESISTANCES OR IMPEDANCES ASSOCIATED WITH THE TWO VOLTAGE AND CURRENT VALUES ARE EQUAL.

CALCULATING THE VOLTAGE GAIN OF AN AMPLIFIER IN TERMS OF DECIBELS

IN FIG. 5 YOU ARE SHOWN THE ARRANGEMENT OF AN AMPLIFYING SYSTEM CONSISTING OF THREE AMPLIFYING UNITS, NAMELY, A PRE-AMPLIFIER, AN INTERMEDIATE AMPLIFIER AND A FINAL AMPLIFIER. THESE THREE UNITS ARE LOCATED IN DIFFERENT PARTS OF A STUDIO AND ARE INTERCONNECTED WITH A TRANSMISSION LINE. THE SIGNAL IS PASSED THROUGH EACH OF THESE UNITS IN TURN, AMPLIFIED

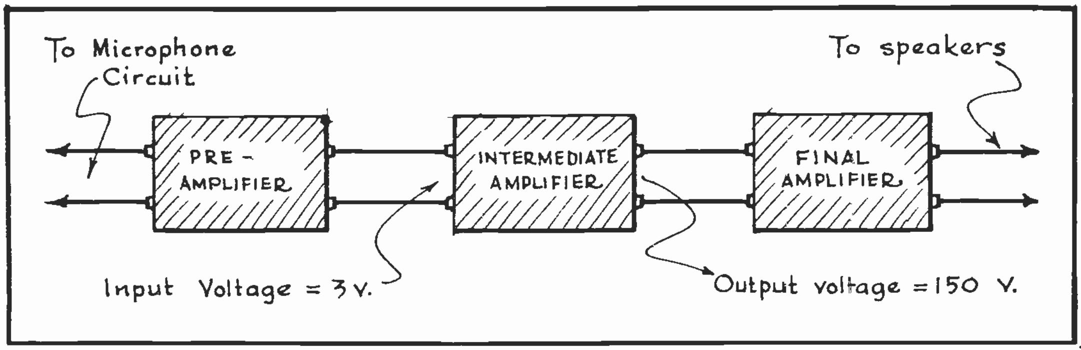

FIG. 5
A System of Amplifying Units.

BEFORE BEING PASSED ON TO THE NEXT AND UNTIL THE SIGNAL FINALLY REACHES THE SPEAKERS.

WE SHALL ASSUME THAT THE INPUT IMPEDANCE TO THE INTERMEDIATE AMPLIFIER IS EQUAL TO THE OUTPUT IMPEDANCE OF THIS SAME AMPLIFIER AND THAT THE SIGNAL VOLTAGE INPUT TO THE INTERMEDIATE AMPLIFIER AMOUNTS TO 3 VOLTS AND THE OUTPUT SIGNAL VOLTAGE FROM THIS SAME AMPLIFYING UNIT AMOUNTS TO 20 VOLTS. WITH THESE FACTS KNOWN, CALCULATE THE GAIN OF THIS INTERMEDIATE AMPLIFIER EXPRESSED IN DB. SINCE THE INPUT AND OUTPUT TERMINAL IMPEDANCES OF THIS INTERMEDIATE AMPLIFIER ARE EQUAL, THE FORMULA TO USE IN SOLVING THIS PROBLEM IS:

$\text{DECIBELS} = 20 \log_{10} \frac{E_1}{E_2}$ AND IN WHICH CASE THE VALUE FOR $E_1 = 150$ VOLTS AND THE VALUE FOR $E_2 = 3$ VOLTS. SUBSTITUTING THESE VALUES IN THE FORMULA, WE HAVE:

$$\text{DECIBELS} = 20 \log_{10} \frac{150}{3}$$

$$\text{Decibels} = 20 \log 50$$
$$= 20 \times 1.6990$$
$$= 33.98$$

In other words, the intermediate amplifier in Fig. 5 provides a gain of approximately 34 db.

APPLICATION OF THE DECIBEL TO CIRCUITS INVOLVING CURRENT CHANGES

In Fig. 6 we have a circuit in which a transmission line serves as the connecting link between the source of power and the load. Let us assume that under normal conditions 20 milliamperes flows through the transmission line and that the load is then increased to such a point that the current through the transmission line rises to a value of 70 milliamperes. The terminal impedance at each end of the transmission line is equal.

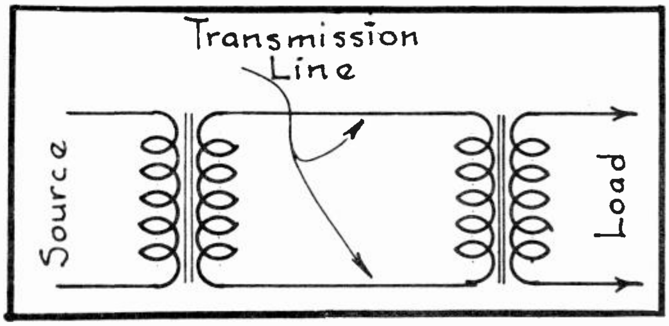

FIG. 6
A Problem in Changing Current Values.

The problem is to find the loss expressed in db resulting from the increased current flow through the transmission line of fixed resistance.

The formula to use in this case is:

$$\text{Decibels} = 20 \log_{10} \frac{I_1}{I_2}$$

and substituting the values of 70 for I_1 and 20 for I_2 we have:

$$\text{Decibels} = 20 \log_{10} \frac{70}{20}$$
$$= 20 \log 3.5$$
$$= 20 \times 0.5441$$
$$= 10.882$$

This means that if the current through the transmission line is increased from 20 to 70 milliamperes, we would realize a loss or attenuation of approximately 11 db.

CALCULATING GAIN INVOLVING DIFFERENT TERMINAL IMPEDANCES

So far, all of the sample problems dealing with gain and attenuation involving voltage or current changes were of the type in which the two resistances or impedances in question are equal. Now let us see how we would attack a problem where the impedances involved are not equal.

Problem: A certain amplifier has 1 volt applied to its input resistance of 15,000 ohms. A voltage of 50 appears across its output resistance of 4000 ohms. Find the voltage gain expressed in decibels.

FORMULA: $DB = 20 \log_{10} \frac{E_1 \div \sqrt{R_1}}{E_2 \div \sqrt{R_2}}$

WHERE $E_1 = 50$; $E_2 = 1$; $R_1 = 4000$ OHMS AND $R_2 = 15,000$ OHMS.

SUBSTITUTING THESE VALUES IN THE FORMULA WE HAVE:

$$\text{DECIBELS} = 20 \log \frac{50 \div \sqrt{4000}}{1 \div \sqrt{15,000}}$$
$$= 20 \log \frac{50 \div 63.24}{1 \div 122.48}$$
$$= 20 \log \frac{.79}{.0082}$$
$$= 20 \log 96.3$$
$$= 20 \times 1.9836$$
$$= 39.67$$

THUS WE HAVE DETERMINED THAT THE GAIN OF THIS PARTICULAR AMPLIFIER IS EQUIVALENT TO APPROXIMATELY 40 DECIBELS.

POWER RATIO IN TERMS OF DECIBELS

SO FAR, WE HAVE ONLY WORKED WITH PROBLEMS WHERE WE DETERMINED THE DECIBEL GAIN OR ATTENUATION IN TERMS OF THE VOLTAGE, CURRENT OR POWER RATIO. QUITE OFTEN, HOWEVER, IT IS DESIRED TO REVERSE THE PROCEDURE, THAT IS, TO DETERMINE WHAT POWER RATIO, FOR INSTANCE, IS NECESSARY IN ORDER TO BRING ABOUT A CERTAIN DB GAIN OR ATTENUATION. TO ILLUSTRATE THIS, LET US CONSIDER THE FOLLOWING SPECIFIC EXAMPLE.

PROBLEM: A CERTAIN CIRCUIT IS KNOWN TO OFFER A LOSS OR ATTENUATION OF 30 DB. WHAT POWER RATIO CORRESPONDS TO THIS LOSS?

SOLUTION: THE BASIC FORMULA TO APPLY IN THIS CASE IS $DB = 10 \log_{10} \frac{P_1}{P_2}$ AND TO SOLVE FOR THE RATIO $\frac{P_1}{P_2}$. TO DO THIS, IT IS NECESSARY TO FIRST TRANSPOSE THE GIVEN FORMULA SO THAT THE RELATION $\frac{P_1}{P_2}$ WILL APPEAR TO THE LEFT OF THE EQUALS SIGN. THIS IS ACCOMPLISHED BY FIRST WRITING THE FORMULA IN THE FORM $10 \log_{10} \frac{P_1}{P_2} = DB$. BY SUBSTITUTING THE VALUE OF 30 FOR DB. WE HAVE: $10 \log_{10} \frac{P_1}{P_2} = 30$. THE NEXT STEP IS TO DIVIDE THROUGH THE EQUATION BY 10 AND THUS OBTAIN $\frac{P_1}{P_2} = \text{ANTILOG } 3$ WHENCE $\frac{P_1}{P_2} = 1000$.

NOTICE THAT WE HAVE HERE USED THE EXPRESSION "ANTILOG". TO FIND THE ANTILOG OF A NUMBER IS JUST THE REVERSE PROCEDURE OF FINDING ITS LOGARITHM. FOR EXAMPLE, THE LOGARITHM OF 1000 IS 3 WHEREAS THE NUMBER CORRESPONDING TO THE LOGARITHM OF 3 OR THE ANTILOG OF 3 IS 1000.

VOLTAGE GAIN IN TERMS OF DECIBELS

SHOULD WE BE DEALING WITH A PROBLEM INVOLVING A VOLTAGE GAIN IN TERMS OF DB, THEN WE WOULD PROCEED IN THE MANNER AS ILLUSTRATED BY THE FOLLOW-

ING EXAMPLE: A CERTAIN AMPLIFIER IS KNOWN TO OFFER A GAIN OF 48 DB. WHAT IS THE VOLTAGE GAIN OF THIS AMPLIFIER, ASSUMING THE INPUT AND OUTPUT TERMINAL IMPEDANCES AS BEING EQUAL?

SOLUTION: THE FORMULA TO USE IN THIS CASE IS $DB = 20 \log_{10} \frac{E_1}{E_2}$ AND SUBSTITUTING THE VALUE 48 FOR DB WE HAVE $48 = 20 \log_{10} \frac{E_1}{E_2}$ AND WE SOLVE FOR THE RELATION $\frac{E_1}{E_2}$ IN THE FOLLOWING MANNER:

$$20 \log \frac{E_1}{E_2} = 48$$

DIVIDING BY 20 ——————— $\log \frac{E_1}{E_2} = 2.4$

$$\frac{E_1}{E_2} = \text{ANTILOG OF } 2.4$$

$\frac{E_1}{E_2} = 250.$ THAT IS TO SAY, THIS PARTICULAR AMPLIFIER WILL FURNISH A VOLTAGE GAIN OF APPROXIMATELY 250.

OVERALL GAIN OF AN AMPLIFYING SYSTEM

THE DECIBEL GREATLY SIMPLIFIES CALCULATING THE OVERALL GAIN OF AN AMPLIFYING SYSTEM IN WHICH A SERIES OF GAINS AND LOSSES ARE EXPERIENCED BETWEEN THE INPUT AND OUTPUT OF THE SYSTEM. THIS IS DUE TO THE FACT THAT THE SUCCESSIVE GAINS AND LOSSES IN THE SYSTEM WHEN EXPRESSED IN DECIBELS CAN BE ADDED ALGEBRAICALLY.

FOR EXAMPLE, IN FIG. 7 WE HAVE AN AMPLIFYING SYSTEM CONSISTING OF THREE AMPLIFYING UNITS INTERCONNECTED BY TRANSMISSION LINES. AMPLIFIER #1 SUPPLIES A GAIN OF 15 DB; AMPLIFIER #2 SUPPLIES A GAIN OF 35 DB AND AMPLIFIER #3 SUPPLIES A GAIN OF 20 DB. FURTHERMORE, THE TRANSMISSION LINE BETWEEN AMPLIFIER #1 AND AMPLIFIER #2 INTRODUCES A LOSS OF 6 DB AND THE TRANSMISSION LINE BETWEEN AMPLIFIER #2 AND AMPLIFIER #3 INTRODUCES A LOSS OF 5 DB.

TO CALCULATE THE OVERALL GAIN OF THIS SYSTEM, WE ADD THE DB VALUES OF THESE VARIOUS SECTIONS TOGETHER ALGEBRAICALLY, REMEMBERING THAT ALL GAINS ARE CONSIDERED AS POSITIVE DB VALUES AND ALL LOSSES AS NEGATIVE DB VALUES. THEREFORE, THE OVERALL GAIN OF THE SYSTEM IN FIG. 7 FROM THE INPUT OF THE FIRST AMPLIFIER TO THE OUTPUT OF THE FINAL AMPLIFIER WOULD BE WRITTEN IN THE FORM + 15 DB −6 DB + 35 DB −5 DB + 20 DB = +59 DB.

IT IS ALSO TRUE THAT IF THE GAIN OF EACH STAGE OF AN AMPLIFIER IS KNOWN IN TERMS OF DECIBELS, THEN THE OVERALL GAIN OF THE AMPLIFIER EXPRESSED IN DECIBELS WILL BE EQUAL TO THE SUM OF THE DB. GAIN OF THE VARIOUS STAGES.

FREQUENCY RESPONSE CURVES

WHEN CONSIDERING THE MERITS OF AN A.F. AMPLIFIER, IT IS IMPORTANT TO KNOW HOW MUCH IT AMPLIFIES EQUAL INPUT VOLTAGES THROUGHOUT THE AUDIO FREQUENCY RANGE. THIS TEST CAN BE MADE BY CONNECTING AN A.F. OSCILLATOR ACROSS THE INPUT TERMINALS OF THE AMPLIFIER AS SHOWN IN FIG. 8. SUCH AN

OSCILLATOR CAN BE MADE TO GENERATE AN AUDIO FREQUENCY SIGNAL OR NOTE OF ANY FREQUENCY DESIRED WITHIN ITS RANGE. THIS OSCILLATOR IS ADJUSTED IN TURN TO GENERATE A VARIETY OF DIFFERENT AUDIO SIGNALS AND THE SIGNAL VOLTAGE CAREFULLY MEASURED ACROSS THE INPUT TERMINALS OF THE AMPLIFIER BY MEANS OF THE VACUUM TUBE VOLTMETER. FOR EACH FREQUENCY SETTING, THE OSCILLATOR IS ADJUSTED SO THAT THE SAME VOLTAGE IS AVAILABLE ACROSS THE INPUT TERMINALS OF THE AMPLIFIER.

THE VACUUM TUBE VOLTMETER, WHICH IS CONNECTED ACROSS THE OUTPUT OF THE AMPLIFIER, IS USED TO MEASURE THE OUTPUT SIGNAL VOLTAGE AVAILABLE FOR EACH FREQUENCY SETTING OF THE A.F. OSCILLATOR. LET US SUPPOSE, FOR EXAMPLE, THAT THE CHARACTERISTICS OF THIS PARTICULAR AMPLIFIER UNDER TEST ARE SUCH THAT THE OUTPUT VOLTAGE IS 8 TIMES AS GREAT AS THE INPUT VOLTAGE WHEN A 100 CYCLE SIGNAL IS BEING PRODUCED, 80 TIMES AS GREAT WHEN A 1000 CYCLE SIGNAL IS BEING PRODUCED AND 150 TIMES AS GREAT WHEN A 5000 CYCLE

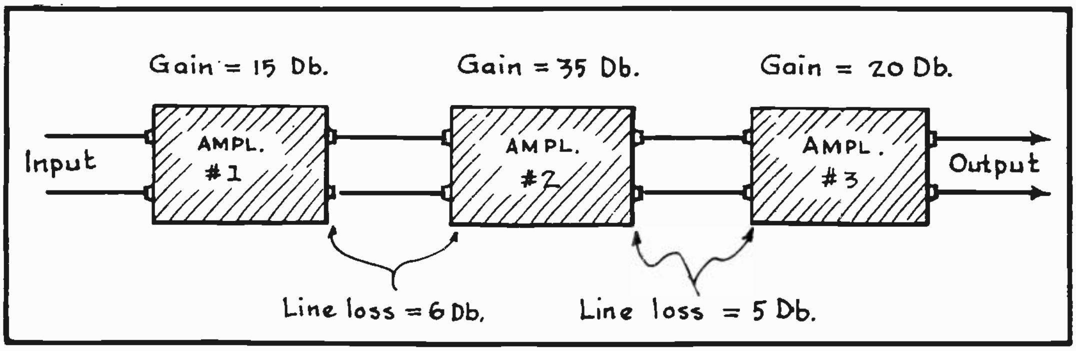

FIG. 7
Overall D.B. Gain

SIGNAL IS BEING PRODUCED. THESE FIGURES MEAN THAT THIS PARTICULAR AMPLIFIER HAS A VOLTAGE AMPLIFICATION OF 8 AT 100 CYCLES, A VOLTAGE AMPLIFICATION OF 80 AT 1000 CYCLES AND A VOLTAGE AMPLIFICATION OF 150 AT 5000 CYCLES. IN WORK DEALING WITH AUDIO FREQUENCIES, THE AMPLIFICATION AT 1000 CYCLES IS GENERALLY TAKEN AS A REFERENCE AND THE AMPLIFICATION AT ALL OTHER FREQUENCIES COMPARED TO THIS VALUE.

SINCE THE VOLTAGE AMPLIFICATION AT 1000 CYCLES IS 80 FOR THE PARTICULAR AMPLIFIER UNDER CONSIDERATION, THIS VALUE OF 80 WILL BE USED AS THE REFERENCE POINT. SINCE THE GAIN AT 100 CYCLES IS ONLY 8, THE RATIO BETWEEN THE 1000 CYCLE GAIN AND THIS VALUE BECOMES $\frac{80}{8} = 10$. EXPRESSED IN DECIBELS THIS WOULD BE EQUIVALENT TO 20 DB. WHICH IS SHOWN AS FOLLOWS:

$$\text{DB} = 20 \log_{10} \frac{80}{8} = 20 \times \log 10 = 20 \times 1 = 20.$$

THE 100 CYCLE AMPLIFICATION IS THEREFORE 20 DB. LESS THAN THE 1000 CYCLE AMPLIFICATION.

AT 5000 CYCLES THE VOLTAGE RATIO BECOMES $\frac{150}{80} = 1.87$ AND THIS WOULD BE EQUIVALENT TO A GAIN OF 5.43 DB. AS PER THE FOLLOWING CALCULATIONS:

$$\text{DB} = 20 \log \frac{150}{80} = 20 \log 1.87$$

$$Db = 20 \times 0.2718$$
$$= 5.43$$

THE IDEAL AMPLIFIER WOULD AMPLIFY ALL FREQUENCIES OF THE AUDIO FREQUENCY RANGE UNIFORMLY WELL. SUCH RESULTS, HOWEVER, ARE NOT REALIZED IN ACTUAL PRACTICE ALTHOUGH SOME VERY REMARKABLE RESULTS ARE BEING OBTAINED.

THE AMPLIFIER FOR WHICH THE CALCULATIONS HAVE JUST BEEN GIVEN HAS POOR CHARACTERISTICS IN THAT A DECIDED LOSS IS OBTAINED AT THE LOWER FREQUENCIES SO THAT THE LOW NOTES WOULD BE PRACTICALLY INAUDIBLE, WHILE ON THE OTHER HAND, THE HIGH NOTES WOULD BE ACCENTUATED CONSIDERABLY ABOVE THE NORMAL 1000 CYCLE LEVEL. IT THUS BECOMES OBVIOUS THAT THE DECIBEL IS OF GREAT VALUE IN EXPRESSING THE PERFORMANCE OF AMPLIFYING EQUIPMENT IN TERMS OF THE EFFECT UPON THE EARS OF THE LISTENER. IT IS CUSTOMARY TO PLOT FREQUENCY RESPONSE CURVES FOR AMPLIFIERS IN THE MANNER SHOWN YOU IN FIG. 9. HERE THE FREQUENCIES ARE LAID OFF HORIZONTALLY ON GRAPH PAPER WHICH IS RULED VERTICALLY ACCORDING TO A LOGARITHMICAL SCALE WHEREAS ITS HORIZONTAL LINES ARE RULED EQUIDISTANT APART TO DESIGNATE THE GAIN EXPRESSED IN DECIBELS.

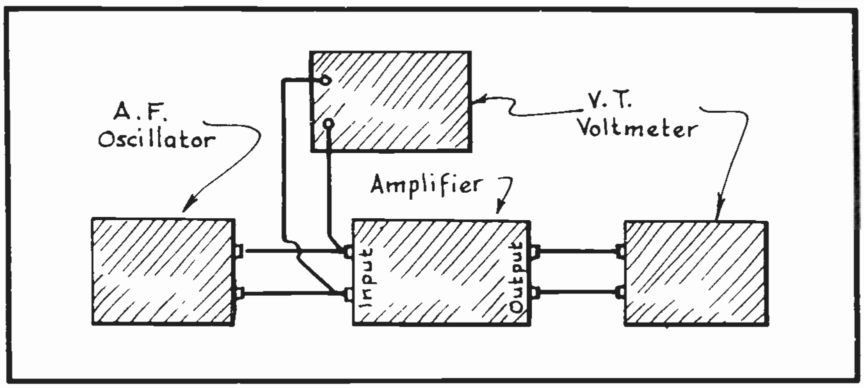

FIG. 8

Set-up for a Performance Test.

WHEN THE DB VALUES AT DIFFERENT FREQUENCIES HAVE BEEN OBTAINED BY THE TEST ILLUSTRATED IN FIG. 8, THEN CORRESPONDING POINTS ARE PLOTTED ON THE GRAPH PAPER AND CONNECTED TOGETHER WITH A CONTINUOUS LINE TO FORM A CURVE SIMILAR TO THAT SHOWN YOU IN FIG. 9.

THE CURVE IN FIG. 9 SHOWS THAT THE PARTICULAR AMPLIFIER FROM WHICH IT WAS PLOTTED OFFERED UNIFORM AMPLIFICATION THROUGHOUT THOSE FREQUENCIES EXTENDING FROM 100 TO 3000 CYCLES PER SECOND. IT DROPS GRADUALLY UNTIL THE 4000 CYCLE POINT IS REACHED AND THEN DROPS OFF ABRUPTLY AS A FREQUENCY OF 10,000 CYCLES IS APPROACHED. FROM 100 CYCLES DOWNWARD, THE GAIN INCREASES SLIGHTLY UNTIL A POINT CORRESPONDING TO 55 CYCLES IS REACHED AND THEN DROPS OFF RAPIDLY AT FREQUENCIES BELOW 55 CYCLES.

NOT ONLY ARE GRAPHS AS THIS USED FOR ILLUSTRATING THE PERFORMANCE OF AMPLIFIERS BUT THEY ARE ALSO EMPLOYED TO ILLUSTRATE THE PERFORMANCE OF VARIOUS UNITS WHICH ARE USED IN AUDIO FREQUENCY AMPLIFYING SYSTEMS SUCH AS MICROPHONES, SPEAKERS, A.F. TRANSFORMERS ETC.

ANOTHER PROBLEM INVOLVING DB GAIN

SO AS TO BE CERTAIN THAT YOU FULLY UNDERSTAND HOW TO FIGURE THE VOLTAGE GAIN EXPRESSED IN DECIBELS WHEN THE IMPEDANCES IN QUESTION ARE NOT EQUAL LET US CONSIDER ONE MORE PROBLEM. HERE IT IS: A CERTAIN AMPLIFIER

HAS AN INPUT IMPEDANCE OF 500,000 OHMS AND ACROSS WHICH A SIGNAL VOLTAGE OF 0.5 VOLT IS IMPRESSED. A SIGNAL VOLTAGE OF 30 VOLTS IS AVAILABLE ACROSS AN IMPEDANCE OF 7000 OHMS IN THE OUTPUT OF THIS AMPLIFIER. WHAT IS THE VOLTAGE GAIN OF THIS AMPLIFIER EXPRESSED AS DB?

SOLUTION: THE FORMULA TO USE HERE IS:

$$DB = 20 \log_{10} \frac{E_1 \div \sqrt{R_1}}{E_2 \div \sqrt{R_2}}$$

THE VALUE FOR $E_1 = 30$ VOLTS; $R_1 = 7000$ OHMS; $E_2 = 0.5$ VOLTS AND $R_2 =$ 500,000 OHMS. BY SUBSTITUTING THESE VALUES IN OUR FORMULA WE HAVE:

$$DB = 20 \log_{10} \frac{30 \div \sqrt{7000}}{0.5 \div \sqrt{500{,}000}}$$

$$DB = 20 \log_{10} \frac{30 \div 83.7}{0.5 \div 712}$$

$$DB = 20 \log_{10} \frac{0.358}{.0007}$$

$$DB = 20 \log 511$$

$$DB = 20 \times 2.7084$$

$$DB = 54 \text{ APPROXIMATELY.}$$

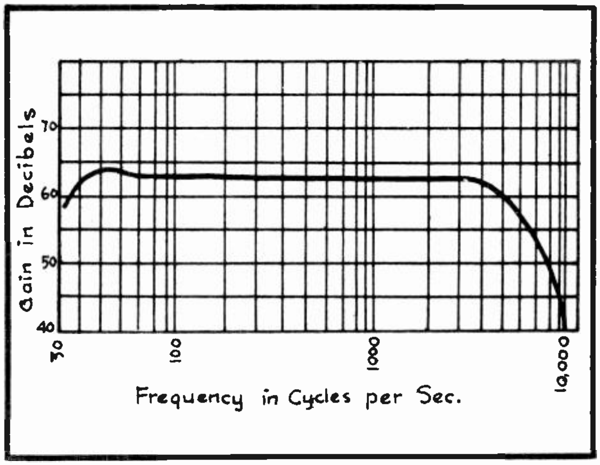

FIG. 9
A Frequency Response Curve.

THE VOLTAGE GAIN OF THIS AMPLIFIER WOULD BE EQUIVALENT TO APPROXIMATELY 54 DB.

THIS IS A VERY IMPORTANT LESSON AND YOU ARE URGED TO STUDY IT WITH UTMOST CARE. YOU WILL FIND COMPUTATIONS SUCH AS EXPLAINED IN THIS LESSON TO BE USED CONSIDERABLY IN LATER LESSONS OF THIS COURSE, AS WELL AS IN ENGINEERING WORK OUT IN THE INDUSTRY.

IN THE NEXT LESSON YOU ARE GOING TO BE TOLD ABOUT VARIOUS VOLUME CONTROL SYSTEMS AS USED IN AMPLIFIERS, AS WELL AS BEING MADE FAMILIAR WITH MIXERS, AND OTHER ALLIED SUBJECTS.

EXAMINATION QUESTIONS

LESSON NO. A.S.-9

1. - DEFINE THE DECIBEL.

2. - IF A CERTAIN AMPLIFIER AT ONE PARTICULAR TIME FURNISHES AN OUTPUT OF 3 WATTS AND THIS OUTPUT IS THEN INCREASED TO 12 WATTS, HOW MANY DECIBELS WILL THIS POWER INCREASE REPRESENT?

3. - WHAT IS MEANT BY THE EXPRESSION ATTENUATION?

4. - THE INPUT AND OUTPUT IMPEDANCES OF A CERTAIN AMPLIFIER ARE EQUAL. IF A SIGNAL VOLTAGE OF 2 VOLTS IS APPLIED TO THE INPUT OF THIS AMPLIFIER AND A SIGNAL VOLTAGE OF 100 APPEARS AT ITS OUTPUT, WHAT IS THE GAIN OF THIS AMPLIFIER EXPRESSED DB.?

5. - A CERTAIN CIRCUIT IS ARRANGED SO THAT BY OPENING A SWITCH ADDITIONAL RESISTANCE IS ADDED TO THE CIRCUIT AND BY CLOSING THE SWITCH, THE RESISTANCE OF THE CIRCUIT IS REDUCED. WHEN THIS SWITCH IS CLOSED, A CURRENT OF 100 MILLIAMPERES FLOWS THRU THE CIRCUIT AND WHEN THE SWITCH IS OPEN, A CURRENT OF 25 MILLIAMPERES OF CURRENT FLOWS THRU THE CIRCUIT. WHAT ATTENUATION EXPRESSED IN DB. IS OBTAINED WHEN THE SWITCH IS OPEN AS COMPARED WITH THE SWITCH IN THE CLOSED POSITION?

6. - A CERTAIN AMPLIFIER HAS 0.75 VOLTS APPLIED TO ITS INPUT RESISTANCE OF 20,000 OHMS. A SIGNAL VOLTAGE OF 75 APPEARS ACROSS ITS OUTPUT RESISTANCE OF 6000 OHMS. WHAT IS THE GAIN OF THIS AMPLIFIER EXPRESSED IN DB.?

7. - AN AMPLIFIER IS KNOWN TO FURNISH A GAIN OF 60 DB., AND AT WHICH TIME A SIGNAL VOLTAGE OF 30 VOLTS IS BEING DELIVERED. WHAT IS THE SIGNAL VOLTAGE INPUT TO THE AMPLIFIER AT THIS TIME? CONSIDER THE INPUT AND OUTPUT IMPEDANCES OF THIS AMPLIFIER TO BE EQUAL.

8. - A CIRCUIT IS KNOWN TO OFFER AN ATTENUATION OF 50 DB. WHAT POWER RATIO CORRESPONDS TO THIS LOSS?

9. - FOUR AMPLIFIERS ARE CONNECTED IN SERIES. AMPLIFIER #1 OFFERS A GAIN OF 20 DB; AMPLIFIER #2 A GAIN OF 50 DB; AMPLIFIER #3 A GAIN OF 80 DB AND AMPLIFIER #4 A GAIN OF 40 DB. THE TRANSMISSION LINE BETWEEN AMPLIFIERS #1 AND #2 INTRODUCES AN ATTENUATION OF 3 DB; THAT BETWEEN AMPLIFIERS #2 AND #3 AN ATTENUATION OF 5 DB; AND THAT BETWEEN AMPLIFIERS #3 AND #4 AN ATTENUATION OF 2 DB. WHAT IS THE OVERALL GAIN OF THIS COMPLETE AMPLIFYING SYSTEM?

10. - DRAW A FREQUENCY RESPONSE CURVE IN WHICH DECIBELS ARE PLOTTED AGAINST FREQUENCY AND EXPLAIN THE MEANING OF THIS CURVE.

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Amplifying Systems

LESSON NO. AS-10

ATTENUATION NETWORKS AND MIXERS

In high quality sound transmission circuits such as used for telephone lines, radio-broadcast sound equipment, public-address systems, talking picture apparatus etc., resistance networks known as ATTENUATORS are used extensively. These attenuators or PADS, as they are most generally called, offer a means whereby the energy which is being transmitted to a load at the far end of the line may be controlled in magnitude and in this way make possible an efficient transmission system from which the maximum output of energy with the least distortion may be obtained.

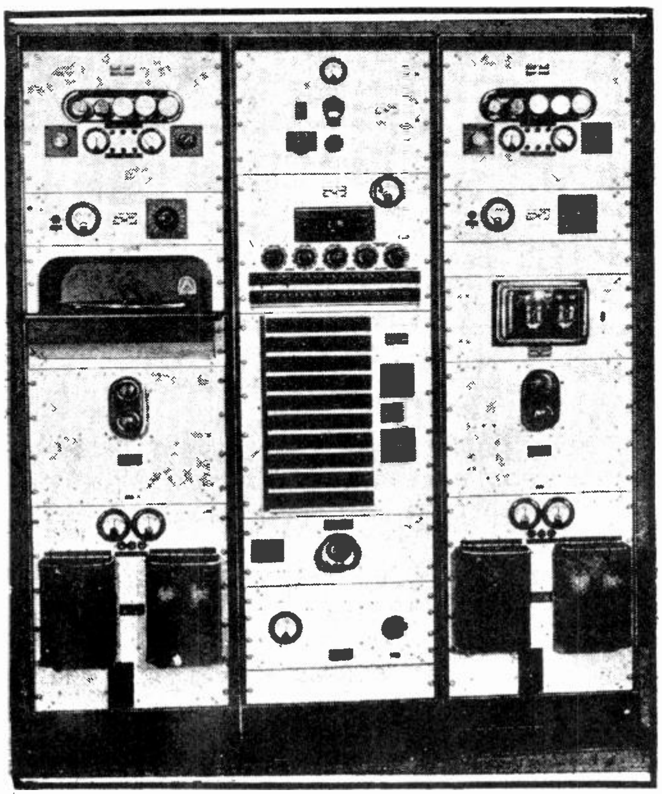

Fig. 1
A Two-Channel Sound And Centralized Radio System

When used, these pads are always in the transmission line between the source of energy and the load. The souree of energy may be any of the following:

(1) Output of a speech amplifier which is feeding another amplifier located at a remote point.

(2) Output of a low level amplifier such as a condenser microphone amplifier which is feeding a speech amplifier located at some distant point.

(3) OUTPUT OF A HIGH LEVEL POWER AMPLIFIER.

(4) OUTPUT OF MICROPHONE CIRCUITS ETC.

THE LOAD MAY CONSIST OF A TRANSMISSION LINE CARRYING THE ENERGY AND TERMINATING IN AN IMPEDANCE LOCATED AT THE FAR END OF THE LINE. THIS LOAD IMPEDANCE MIGHT CONSIST OF ANY OF THE FOLLOWING:

1. - PRIMARY SIDE OF A LINE-MATCHING TRANSFORMER (LINE TO LINE TRANSFORMER).
2. - INPUT CIRCUIT OF A SPEECH AMPLIFIER.
3. - LOUD SPEAKERS LOCATED AT DISTANT POINTS FROM AN AMPLIFIER.
4. - MIXING CIRCUITS ETC.

THE CHARACTERISTICS OF A PAD ARE SUCH AS TO IMPOSE A CONSTANT IMPEDANCE UPON THE TRANSMISSION LINE AND THEREBY CONTROLLING THE LEVEL (MAGNITUDE) OF THE ENERGY WHICH IS BEING TRANSMITTED TO THE LOAD AT THE FAR END OF THE LINE. THE PAD MAINTAINS THIS LEVEL BY INTRODUCING A LOSS IN ENERGY BETWEEN THE SOURCE AND THE LOAD AND AT THE SAME TIME CAUSING

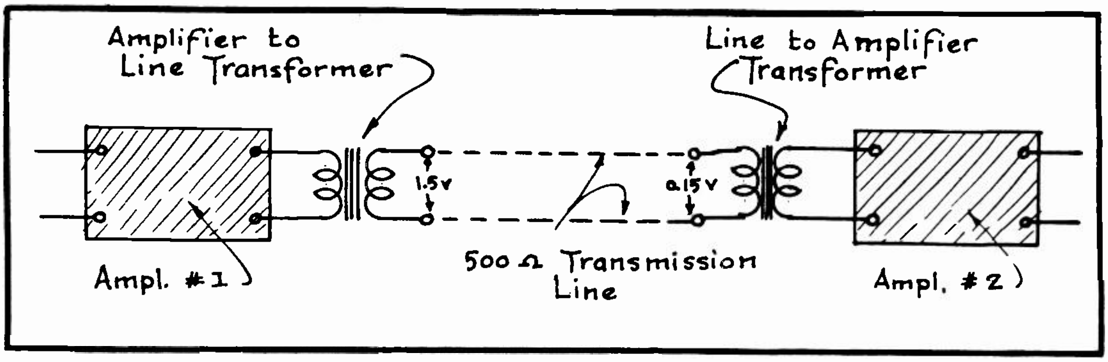

FIG. 2
Two Amplifiers Coupled by a Transmission Line.

NO IMPEDANCE MISMATCH TO THE IMPEDANCES BETWEEN WHICH IT IS WORKING, NAMELY, THE SOURCE IMPEDANCE AND THE LOAD IMPEDANCE.

A PRACTICAL PROBLEM

TO ILLUSTRATE THE APPLICATION OF A PAD AND AT THE SAME TIME EXPLAIN THE METHOD OF CALCULATING ITS VALUES, LET US CONSIDER THE FOLLOWING PRACTICAL EXAMPLE.

IN FIG. 2, THE SIGNAL ENERGY AS SUPPLIED AT THE OUTPUT OF AMPLIFIER #1 IS DELIVERED BY THE TRANSMISSION LINE TO AMPLIFIER #2 FOR FURTHER AMPLIFICATION. YOU WILL ALSO OBSERVE THAT IN ORDER TO BRING ABOUT PROPER MATCHING OF IMPEDANCES BETWEEN THESE TWO AMPLIFIERS ONE TRANSFORMER IS USED TO MATCH THE OUTPUT IMPEDANCE OF AMPLIFIER #1 TO THE TRANSMISSION LINE AND A SECOND TRANSFORMER IS USED TO MATCH THE TRANSMISSION LINE INTO THE INPUT IMPEDANCE OF AMPLIFIER #2.

SO AS TO HAVE A SPECIFIC PROBLEM WITH WHICH TO WORK, LET US ASSUME THAT THE SIGNAL VOLTAGE FURNISHED BY AMPLIFIER #1 AND AVAILABLE ACROSS THE SECONDARY TERMINALS OF THE AMPLIFIER, TO LINE TRANSFORMER AMOUNTS TO

1.5 VOLTS R.M.S. WE SHALL FURTHER ASSUME THAT THE OPERATING CHARACTERISTICS OF AMPLIFIER #2 ARE SUCH THAT IN ORDER NOT TO OVERLOAD ITS INPUT CIRCUIT, A VOLTAGE OF ONLY 0.15 VOLTS R.M.S. IS PERMISSIBLE ACROSS THE PRIMARY WINDING OF THE LINE TO AMPLIFIER TRANSFORMER. IN OTHER WORDS, THE CONDITIONS IN THIS PARTICULAR CASE ARE SUCH THAT 1.5 VOLTS IS AVAILABLE ACROSS THE SECONDARY TERMINALS OF THE AMPLIFIER TO LINE TRANSFORMER WHEREAS ONLY 0.15 VOLTS CAN BE TOLERATED ACROSS THE PRIMARY TERMINALS OF THE LINE TO AMPLIFIER TRANSFORMER AS POINTED OUT TO YOU IN FIG. 2.

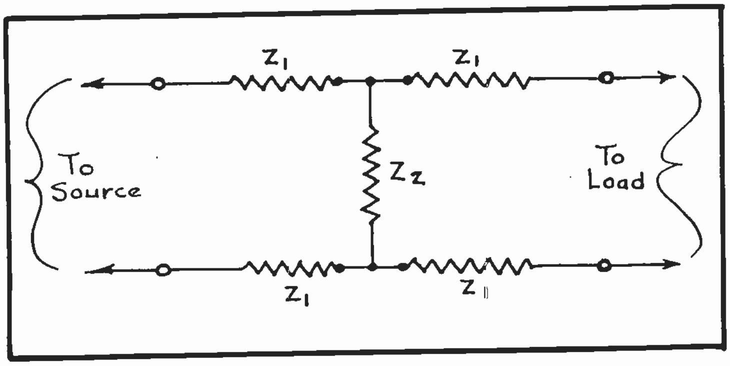

FIG. 3
The H- Pad.

OBVIOUSLY, IN ORDER TO PRODUCE THE REQUIRED LOSS IN SIGNAL VOLTAGE BETWEEN THE SOURCE AND LOAD ENDS OF THE TRANSMISSION LINE, IT IS NECESSARY TO INSTALL SOME FORM OF RESISTANCE NETWORK BETWEEN THESE TWO POINTS BUT AT THE SAME TIME NOT INTRODUCING ANY IMPEDANCE MISMATCH BETWEEN THE SOURCE AND THE LOAD.

AMOUNT OF ATTENUATION

THE FIRST STEP IN WORKING OUT THE DESIGN OF SUCH A RESISTANCE NETWORK IS TO DETERMINE TO WHAT EXTENT THE SIGNAL VOLTAGE MUST BE REDUCED SO AS TO PRODUCE THE REQUIRED ATTENUATION. FOR EXAMPLE, KNOWING THE VOLTAGES TO BE HANDLED AT BOTH ENDS OF THE LINE, THE CORRESPONDING VOLTAGE RATIO CAN BE CALCULATED IN THE FOLLOWING MANNER:

$$\frac{E_1}{E_2} = \frac{1.5}{0.15} = 10$$

IN OTHER WORDS, A VOLTAGE REDUCTION IN ACCORDANCE WITH A RATIO OF 10 TO 1 IS REQUIRED BETWEEN THE INPUT AND OUTPUT TERMINALS OF THE NETWORK WHICH IS TO BE DESIGNED FOR THE TRANSMISSION CIRCUIT IN FIG. 2.

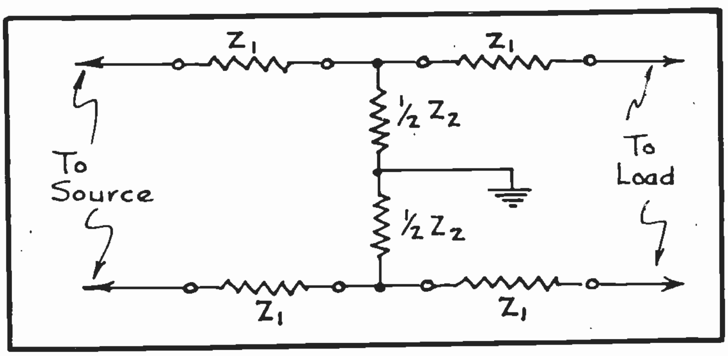

FIG. 4
H-Pad Balanced With Respect to Ground.

THE NEXT PROBLEM WHICH CONFRONTS US IS TO DETERMINE WHAT TYPE OF RESISTANCE NETWORK IS MOST SUITABLE FOR PRODUCING THIS LOSS IN THE TRANSMISSION SYSTEM AND YET NOT INTRODUCE ANY IMPEDANCE MISMATCH. IN COMMUNICATION CIRCUITS, TWO TYPES OF RESISTANCE NETWORKS ARE

USED FOR THIS PURPOSE AND THEY ARE CLASSIFIED AS (1) "H" TYPE PADS AND (2) "T" TYPE PADS.

THE H-PAD

THE "H-PAD" IS ILLUSTRATED FOR YOU IN FIG. 3 AND AS YOU WILL OBSERVE IT CONSISTS OF TWO SERIES CONNECTED RESISTORS Z_1 BEING INSTALLED IN EACH SIDE OF THE LINE AND ANOTHER RESISTOR Z_2 IS CONNECTED ACROSS THE LINE BETWEEN THE POINTS AT WHICH THE SERIES RESISTORS ARE UNITED. THE RESISTOR NETWORK THUS RESEMBLES THE LETTER H LAID ON ITS SIDE AND IS THEREFORE LOGICALLY NAMED AN "H-PAD". IT IS CUSTOMARY TO REFER TO THE VARIOUS RESISTORS Z_1 AS THE SERIES RESISTORS OR SERIES ARMS AND TO THE RESISTOR Z_2 AS THE SHUNT RESISTOR OR SHUNT ARM. IN SOME CASES, THE SHUNT ARM IS DIVIDED INTO TWO EQUAL PARTS AND WITH THE MID-POINT GROUNDED AS ILLUSTRATED IN FIG. 4. THIS LATTER CONNECTION ALSO BALANCES THE ENTIRE NETWORD WITH RESPECT TO GROUND BUT IS NOT ALWAYS USED.

FIG. 5 SHOWS YOU HOW THE CONVENTIONAL TYPE OF H-PAD IS CONNECTED

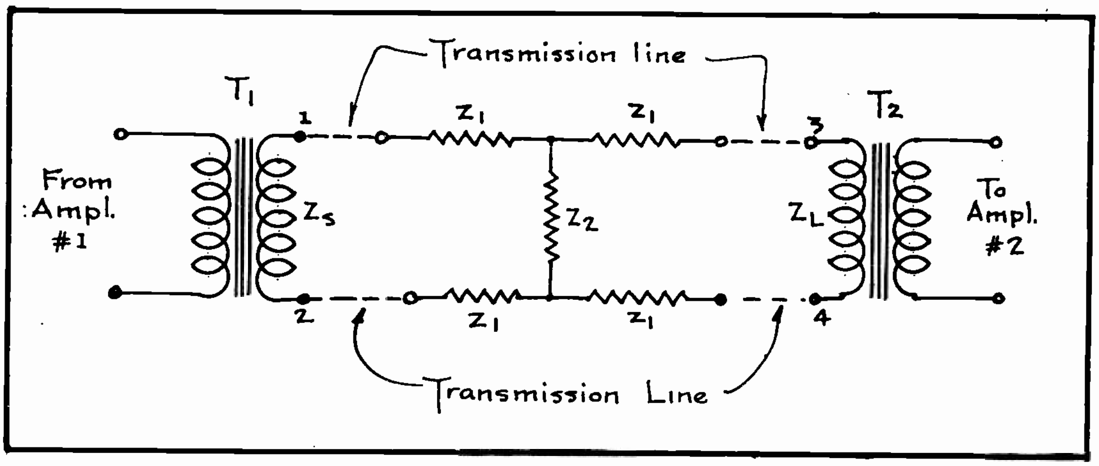

FIG. 5
Installation of the H-Pad In Transmission Circuit.

IN THE TRANSMISSION CIRCUIT. THE SECONDARY WINDING OF THE AMPLIFIER TO LINE TRANSFORMER (T_1) IS SPOKEN OF AS BEING THE SOURCE IMPEDANCE AND IS DESIGNATED ON THE DIAGRAM AS Z_S. THE PRIMARY WINDING OF THE LINE TO AMPLIFIER TRANSFORMER (T_2) IS SPOKEN OF AS BEING THE LOAD IMPEDANCE AND IS DESIGNATED ON THE DIAGRAM AS Z_L. IT IS IMPORTANT THAT Z_S AND Z_L BE EQUAL AND THE TRANSMISSION LINE IMPEDANCES MOST FREQUENTLY USED ARE 200 OHMS; 500 OHMS AND 600 OHMS. THE 500 OHM LINES ARE USED MOST.

IF AN ATTENUATOR OR PAD IS NOW INSERTED INTO THE TRANSMISSION LINE, IT MUST BE SO DESIGNED THAT ITS IMPEDANCE IN NO WAY UPSETS THE IMPEDANCE MATCH BETWEEN THE SOURCE AND LOAD AND WHICH HAS ALREADY BEEN ESTABLISHED. WE THEN FIND THAT WHEN THE PAD IS WORKING IN THE TRANSMISSION LINE, IF THE IMPEDANCE LOOKING INTO THE "SOURCE" FROM THE LINE EXACTLY EQUALS THE IMPEDANCE INTO THE "LOAD" FROM THE LINE THEN THE PAD IS SAID TO BE WORKING BETWEEN ITS "IMAGE IMPEDANCES". THIS CAN BE MADE STILL CLEARER BY AGAIN REFERRING TO FIG. 5. HERE, FOR INSTANCE, WHEN LOOKING INTO

THE 1 AND 2 TERMINALS, THE COMBINED OR RESULTANT IMPEDANCE OF THE PAD AND THE LOAD MUST EXACTLY EQUAL THE SOURCE IMPEDANCE. SIMILARLY, WHEN LOOKING INTO THE 3 AND 4 TERMINALS, THE COMBINED OR RESULTANT IMPEDANCE OF THE PAD AND THE SOURCE MUST EXACTLY EQUAL THE LOAD IMPEDANCE.

THE FORMULA FOR FINDING THE CORRECT VALUE OF THE SERIES RESISTANCE OR Z_1 OF AN H-PAD FOLLOWS:

$Z_1 = \frac{Z_o}{2}\left(\frac{K-1}{K+1}\right)$ WHERE K = THE VOLTAGE RATIO $\frac{E_1}{E_2}$ OR THE CURRENT RATIO $\frac{I_1}{I_2}$ AND Z_o = LOAD AND SOURCE IMPEDANCE.

RETURNING TO OUR PROBLEM OF DESIGNING A PAD FOR THE SYSTEM ILLUSTRATED IN FIG. 2, WE HAVE ASCERTAINED THE VOLTAGE RATIO OR K TO BE 10 AND THE IMPEDANCE OF THE TRANSMISSION LINE IS ALREADY KNOWN TO BE 500 OHMS. (THE LOAD AND SOURCE IMPEDANCE IN THIS CASE WOULD ALSO EACH BE 500 OHMS). THEREFORE, BY SUBSTITUTING THESE KNOWN VALUES IN THE FORMULA $Z_1 = \frac{Z_o}{2}\left(\frac{K-1}{K+1}\right)$ WE HAVE:

$$Z_1 = \frac{500}{2}\left(\frac{10-1}{10+1}\right)$$

$$Z_1 = 250\left(\frac{9}{11}\right)$$

$$Z_1 = 250 \times 0.82$$

$$Z_1 = 205 \text{ OHMS}$$

TO FIND THE VALUE OF THE SHUNT ARM OR Z_2 OF THE PAD, WE USE THE FORMULA $Z_2 = \frac{2Z_oK}{K^2-1}$

SO BY SUBSTITUTING VALUES IN THIS FORMULA WE HAVE:

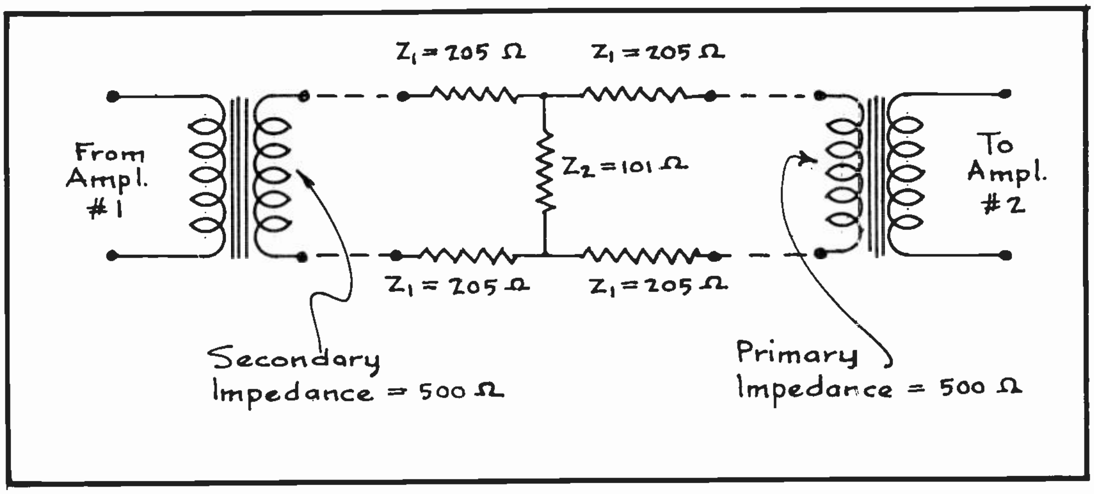

FIG. 6

The Complete H-Pad as Installed in the Line.

$$Z_2 = \frac{2 \times 500 \times 10}{10^2 - 1}$$

$$Z_2 = \frac{10,000}{100 - 1}$$

$$Z_2 = \frac{10,000}{99}$$

$$Z_2 = 101 \text{ OHMS}$$

THE PAD FOR THE SYSTEM OF FIG. 2 WILL NOW APPEAR AS SHOWN YOU IN FIG. 6 AND WHERE ALL VALUES ARE SPECIFIED.

DESIGNING A PAD FOR A GIVEN DB. ATTENUATION

SOMETIMES, THE NATURE OF THE PROBLEM IS SUCH THAT THE ATTENUATION WHICH IS TO BE OFFERED BY THE PAD IS EXPRESSED IN DECIBELS. AN EXAMPLE OF SUCH A PROBLEM FOLLOWS:

IT IS DESIRED TO DESIGN A 500 OHM TRANSMISSION LINE IN WHICH IS IN-

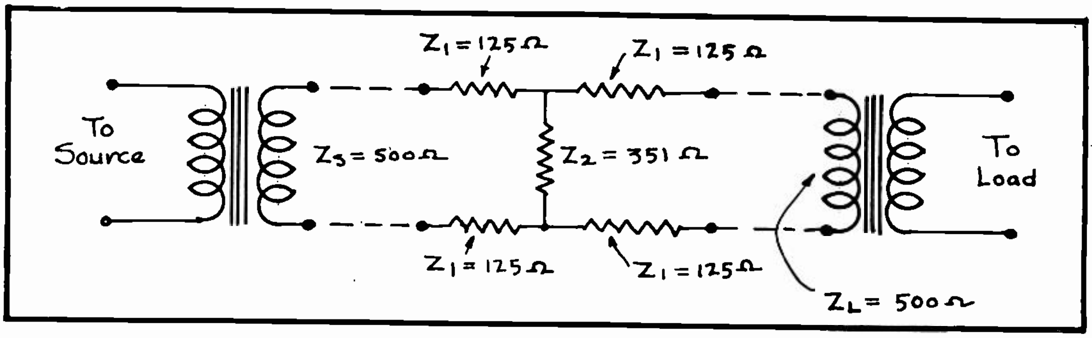

FIG. 7
The Pad Design For 10 Db. Attenuation.

CLUDED AN H-PAD FURNISHING AN ATTENUATION OF 10 DB. IN SUCH A CASE, WE WOULD USE AN AMPLIFIER TO LINE TRANSFORMER WHOSE SECONDARY IMPEDANCE IS RATED AT 500 OHMS AND CONNECT IT BETWEEN THE FIRST AMPLIFIER AND THE LINE. AT THE SAME TIME, WE WOULD USE A LINE TO AMPLIFIER TRANSFORMER WHOSE PRIMARY IMPEDANCE IS RATED AT 500 OHMS AND CONNECT IT BETWEEN THE LINE AND THE SECOND AMPLIFIER.

TO DESIGN THE PAD FOR THIS SAME TRANSMISSION CIRCUIT WE MUST FIRST DETERMINE THE VOLTAGE RATIO WHICH CORRESPONDS TO THE GIVEN ATTENUATION OF 10 DB. AND WE DO THIS BY USING THE FORMULA: $DB = 20 \log_{10} \frac{E_1}{E_2}$ AND TRANSPOSING IT SO AS TO SOLVE FOR $\frac{E_1}{E_2}$ IN THE FOLLOWING MANNER:

$$DB = 20 \log_{10} \frac{E_1}{E_2}$$

$$20 \log \frac{E_1}{E_2} = DB$$

DIVIDING BY 20 —— $\log \frac{E_1}{E_2} = \frac{DB}{20}$

$$\frac{E_1}{E_2} = \text{ANTILOG } \frac{DB}{20}$$

SINCE DB = 10 IN THIS PROBLEM

$$\frac{E_1}{E_2} = \text{ANTILOG } \frac{10}{20}$$

$$\frac{E_1}{E_2} = \text{ANTILOG } 0.5$$

$$\frac{E_1}{E_2} = 3.16$$

THIS CALCULATION SHOWS US THAT THE VOLTAGE RATIO OR $\frac{E_1}{E_2} = 3.16$ AND THIS RATIO, YOU WILL RECALL, IS EQUAL TO K IN THE PAD FORMULAS. TO FIND THE VALUE OF THE SERIES RESISTORS OR Z_1 OF THIS PAD WE AGAIN USE THE FORMULA:

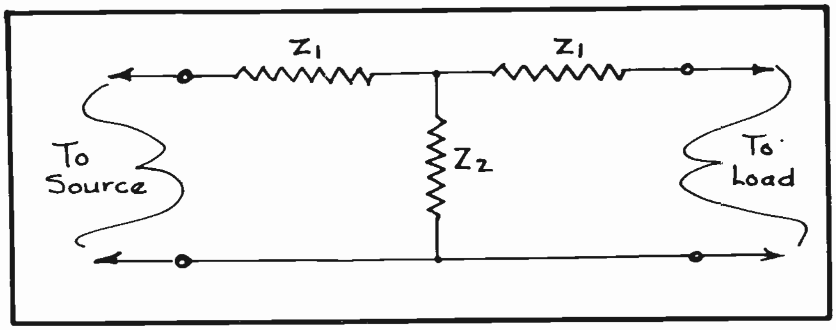

FIG. 8
The T- Pad.

$$Z_1 = \frac{Z_0}{2}\left(\frac{K-1}{K+1}\right)$$

$$Z_1 = \frac{500}{2}\left(\frac{3.16-1}{3.16+1}\right)$$

$$Z_1 = 250\left(\frac{2.16}{4.16}\right)$$

$$Z_1 = 250 \times 0.5$$

$$Z_1 = 125 \text{ OHMS.}$$

TO FIND THE VALUE OF THE SHUNT RESISTOR OR Z_2 WE PROCEED AS FOLLOWS:

$$Z_2 = \frac{2Z_0 K}{K^2 - 1}$$

$$Z_2 = \frac{2 \times 500 \times 3.16}{3.16^2 - 1}$$

$$Z_2 = \frac{3160}{9}$$

$$Z_2 = 351 \text{ OHMS.}$$

THE H-PAD TO SUPPLY A 10 DB ATTENUATION IN THE 500 OHM TRANSMISSION LINE WOULD HAVE THE SPECIFICATIONS NOTED IN FIG. 7.

THE T-PAD

THE T-PAD IS ILLUSTRATED FOR YOU IN FIG.8. IN THIS TYPE OF PAD THE TWO SERIES RESISTORS Z_1 ARE PLACED IN ONE SIDE OF THE LINE ONLY AND THE SHUNT RESISTOR Z_2 IS CONNECTED ACROSS THE LINE. THIS ARRANGEMENT OF RESISTORS THUS RESEMBLES THE LETTER "T" FROM WHICH IT DERIVES ITS NAME.

ALTHOUGH THE T-PAD WILL FURNISH THE REQUIRED ATTENUATION, YET WITH RESPECT TO THE H-PAD IT IS AN UNBALANCED NETWORK. ITS ONLY ADVANTAGE LIES IN THE SAVING IN COST OF TWO EXTRA RESISTORS AND THE H-PAD IS REALLY PREFERABLE.

THE DESIGN OF THE T-PAD MUST ALSO BE SUCH THAT IT DOES NOT UPSET

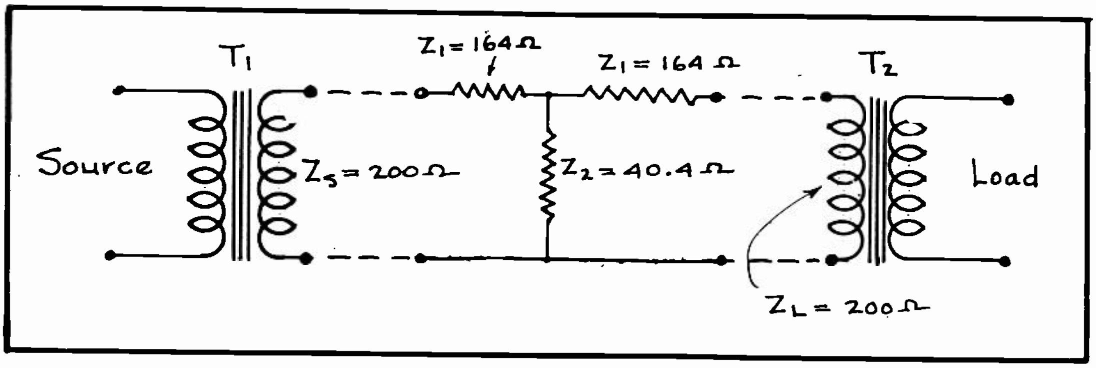

FIG. 9
Complete Design for the T- Pad.

THE IMPEDANCE MATCH OF THE TRANSMISSION CIRCUIT IN WHICH IT IS BEING USED AND SINCE TWO OF THE SERIES RESISTORS ARE ELIMINATED FROM THIS NETWORK AS COMPARED TO THE H-PAD, IT STANDS TO REASON THAT THE VALUES FOR Z_1 OF THE T-PAD MUST BE JUST TWICE AS GREAT AS FOR AN H-PAD CAPABLE OF SUPPLYING THE SAME ATTENUATION. THE VALUE FOR Z_2 OF A T-PAD WOULD BE THE SAME AS FOR THIS SAME RESISTOR IN AN H-PAD OF EQUAL ATTENUATION.

THESE CONDITIONS BEING TRUE, WE FIND THAT THE FORMULAS FOR CALCULATING THE VALUES OF Z_1 AND Z_2 OF A T-PAD ARE AS FOLLOWS:

$$Z_1 = Z_0\left(\frac{K-1}{K+1}\right)$$

AND $$Z_2 = \frac{2Z_0K}{K^2-1}$$

IN BOTH THESE FORMULAS Z_0 = LOAD AND SOURCE IMPEDANCE AND K = THE VOLTAGE OR CURRENT RATIO OF ATTENUATION THE SAME AS ALREADY PRESCRIBED FOR OUR H-PAD DESIGN FORMULAS.

TO ILLUSTRATE THE APPLICATION OF THESE T-PAD DESIGN FORMULAS, LET US WORK OUT THE VALUES FOR A PAD OF THIS TYPE TO SATISFY A GIVEN TRANSMISSION CIRCUIT.

A T-PAD DESIGN PROBLEM

PROBLEM: IT IS DESIRED TO INSTALL A T-PAD IN A 200 OHM TRANSMISSION LINE SO AS TO OBTAIN AN ATTENUATION OF 20 DB.

SOLUTION: THE FIRST STEP IS TO SELECT SUITABLE TRANSFORMERS FOR BOTH ENDS OF THE LINE SO THAT THE SOURCE IMPEDANCE AND LOAD IMPEDANCE WILL BOTH BE EQUAL TO 200 OHMS.

WE COMMENCE WORKING OUT THE DESIGN FOR THE PAD BY DETERMINING THE VOLTAGE RATIO REQUIRED AT THE ENDS OF THE LINE IN THE FOLLOWING MANNER:

$$DB = 20 \log_{10} \frac{E_1}{E_2}$$

$$\log \frac{E_1}{E_2} = \frac{DB}{20}$$

$$\frac{E_1}{E_2} = \text{ANTILOG } \frac{DB}{20}$$

$$\frac{E_1}{E_2} = \text{ANTILOG } \frac{20}{20}$$

$$\frac{E_1}{E_2} = \text{ANTILOG } 1$$

$$\frac{E_1}{E_2} = 10 = K \text{ OF THE PAD FORMULA}$$

TO DETERMINE THE VALUE FOR Z_1 OF THE PAD PROCEED AS FOLLOWS:

$$Z_1 = Z_0 \left(\frac{K-1}{K+1}\right)$$

$$Z_1 = 200\left(\frac{10-1}{10+1}\right)$$

$$Z_1 = 200\left(\frac{9}{11}\right)$$

$$Z_1 = 200 \times .82$$

$$Z_1 = 164 \text{ OHMS.}$$

WE ARE NOW READY TO DETERMINE THE VALUE FOR Z_2 OF THE PAD AND THIS IS DONE IN THE FOLLOWING MANNER:

$$Z_2 = \frac{2 Z_0 K}{K^2 - 1}$$

$$Z_2 = \frac{2 \times 200 \times 10}{10^2 - 1}$$

$$Z_2 = \frac{4000}{99}$$

$$Z_2 = 40.4 \text{ OHMS.}$$

HAVING OBTAINED THE NECESSARY VALUES, WE CAN NOW DRAW THE DIAGRAM FOR THIS TRANSMISSION CIRCUIT AS SHOWN IN FIG. 9 AND WHERE ALL VALUES ARE SPECIFIED.

SELECTION OF RESISTORS

NOT ONLY IS IT IMPORTANT THAT RESISTORS OF CORRECT VALUE BE USED IN AN ATTENUATION NETWORK BUT IT IS EQUALLY IMPORTANT THAT ONLY RESISTORS OF THE HIGHEST QUALITY BE SELECTED FOR THIS PURPOSE. FURTHERMORE, SO THAT THE IMPEDANCE OF THE PAD MAY BE UNIFORM THROUGHOUT THE ENTIRE BAND OF FREQUENCIES BEING HANDLED, IT IS NECESSARY THAT THE RESISTORS USED THEREIN BE OF THE NON-INDUCTIVE TYPE AND AT THE SAME TIME INTRODUCE A MINIMUM OF CAPACITY INTO THE CIRCUIT.

MIXERS

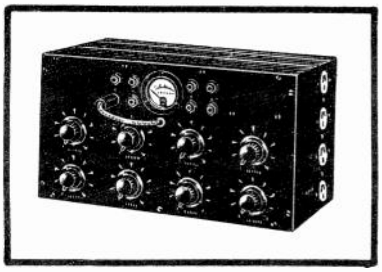

FIG. 10
A Typical Mixer.

IN PREVIOUS LESSONS, YOU HAVE ALREADY BEEN SHOWN HOW A SINGLE MICROPHONE OR PHONOGRAPH PICK-UP MAY BE CONNECTED TO THE INPUT OF AN AMPLIFIER. HOWEVER, FOR A GREAT MANY PURPOSES FOR WHICH A.F. AMPLIFIERS ARE USED IT IS NECESSARY TO FEED THE ENERGY FROM SEVERAL MICROPHONES, FROM SEVERAL PHONOGRAPH PICK-UPS, FROM A RADIO RECEIVER, OR A COMBINATION OF ANY OF THESE UNITS INTO THE INPUT OF A SINGLE AMPLIFIER. TO ACCOMPLISH THIS, WE EMPLOY A SPECIAL CIRCUIT ARRANGEMENT KNOWN AS A MIXER BETWEEN THE VARIOUS PICK-UP UNITS AND THE AMPLIFIER. YOU ARE SHOWN A TYPICAL MIXER IN FIG. 10 AND AS YOU WILL OBSERVE, IT CONSISTS ESSENTIALLY OF A CONTROL PANEL ON WHICH ARE MOUNTED A SERIES OF CONTROL KNOBS WHEREBY THE SIGNAL ENERGY FROM THE INDIVIDUAL PICK-UP UNITS CAN BE SET AT A DEFINITE LEVEL BEFORE BEING DELIVERED TO THE AMPLIFIER. QUITE OFTEN, A MILLIAMMETER IS ALSO FURNISHED FOR MEASURING THE MICROPHONE CURRENT.

IN CONSIDERING THE VARIOUS MIXER CIRCUITS WHICH ARE COMMONLY USED, WE SHALL START WITH THE MORE SIMPLE ARRANGEMENTS AND THEN GRADUALLY ADVANCE THROUGH THE MORE COMPLEX ARRANGEMENTS.

IN FIG. 11 YOU ARE SHOWN ONE METHOD WHEREBY THREE MICROPHONES MAY BE CONNECTED TO THE INPUT OF AN AMPLIFIER THROUGH A MIXING CIRCUIT. THE THREE MICROPHONES, FOR EXAMPLE, MAY BE LOCATED IN DIFFERENT SECTIONS OF A STUDIO PICKING UP THE PROGRAM. BY MEANS OF THE MIXING CIRCUIT AN OPERATOR BY LISTENING TO A MONITOR SPEAKER CAN ADJUST THE THREE POTENTIOMETERS SO THAT THE SIGNAL ENERGY FROM EACH MICROPHONE CAN BE REGULATED SO AS TO BLEND WITH THE SIGNAL PICK-UP OF THE OTHERS AND THEREBY FURNISH A WELL BALANCED SOURCE OF ENERGY TO THE AMPLIFIER. IN THIS WAY, WE CAN PREVENT THE SOUNDS AT ONE PART OF THE STUDIO FROM BEING LOST, SO TO SPEAK, AND AT THE SAME TIME PREVENT THE SOUNDS FROM THE OTHER PORTION OF THE STUDIO FROM BECOMING SO LOUD AS TO BE BLASTING IN EFFECT.

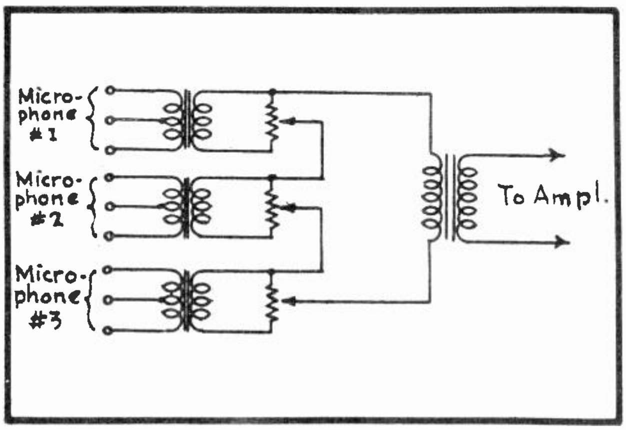

FIG. 11
Mixer Circuit For Three Microphones

BY STUDYING FIG. 11 MORE

CLOSELY YOU WILL NOTICE THAT AN IMPEDANCE MATCHING TRANSFORMER IS SUPPLIED FOR EACH MICROPHONE AND THAT A POTENTIOMETER IS CONNECTED ACROSS THE SECONDARY TERMINALS OF EACH OF THESE TRANSFORMERS. THE ENTIRE COMBINATION OF POTENTIOMETERS ARE CONNECTED IN A SERIES ARRANGEMENT AND TOGETHER CONNECTED ACROSS THE PRIMARY WINDING OF ANOTHER TRANSFORMER WHICH TRANSFERS THE SIGNAL ENERGY TO THE INPUT CIRCUIT OF THE AMPLIFIER.

A PICK-UP FADER CIRCUIT

FIG. 12 SHOWS YOU A "FADER CIRCUIT" TO BE USED IN CONJUNCTION WITH TWO PHONOGRAPH PICK-UP UNITS OPERATING ON INDIVIDUAL TURN-TABLES. THE FADER IS A SPECIAL FORM OF POTENTIOMETER, HAVING A CONNECTION AT THE CENTER OF ITS RESISTANCE ELEMENT AS WELL AS AT BOTH ENDS AND THE ARM CONNECTION. ONE END OF EACH PICK-UP WINDING IS CONNECTED TO THE CENTER TAP TERMINAL OF THE FADER'S RESISTANCE ELEMENT AND THE OTHER ENDS OF THE PICK-UP WINDINGS ARE CONNECTED TO OPPOSITE END TERMINALS OF THE FADER'S RESISTANCE ELEMENT.

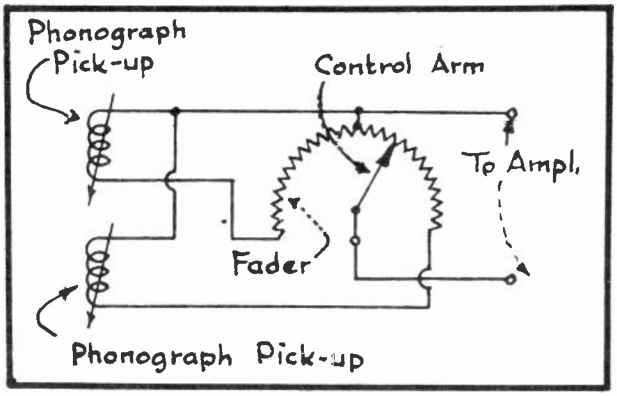

FIG. 12
Pick-up Fader Circuit.

THE ARM OF THE FADER IS CONNECTED TO ONE SIDE OF THE AMPLIFIER'S INPUT CIRCUIT, WHILE THE CENTER TAP OF THE RESISTANCE ELEMENT IS CONNECTED TO THE OTHER SIDE OF THE AMPLIFIER CIRCUIT. THE ACTUAL APPEARANCE OF THIS FADER IS SHOWN YOU IN FIG. 13.

THE RESISTANCE ELEMENT OF THIS FADER HAS A TAPERED CHARACTERISTIC SO THAT A GRADUAL AND SMOOTH DECREASE OR INCREASE IN VOLUME CAN BE OBTAINED AS THE CONTROL ARM IS ROTATED. BY CAREFULLY INSPECTING THE CIRCUIT DIAGRAM IN FIG. 12, IT CAN BE SEEN THAT BY ROTATING THE FADER ARM FROM ONE HALF OF THE RESISTOR TO THE OTHER HALF, THE OPERATOR CAN SWITCH FROM ONE PICK-UP UNIT TO THE OTHER AND THUS CHANGE PROGRAM RECORDS WITH A "FADING-AWAY" CHARACTERISTIC BETWEEN CHANGES SO THAT NO ABRUPT DIFFERENCE IN RECORDING IS PERCEPTIBLE TO THE LISTENER.

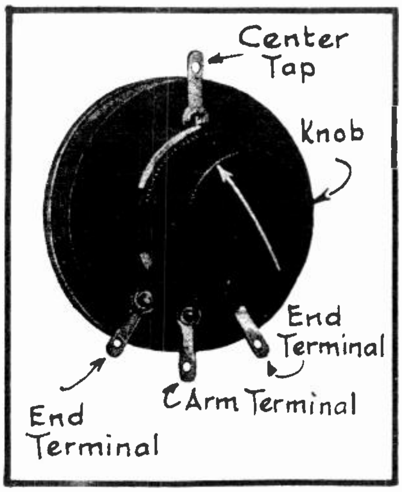

FIG. 13
The Fader.

CONSTANT IMPEDANCE VOLUME CONTROLS

ONE OF THE DISADVANTAGES OFFERED BY THE SIMPLE TYPES OF VOLUME CONTROLS AND MIXER CIRCUITS IS THAT THE IMPEDANCE OF THE CIRCUIT DOES NOT REMAIN CONSTANT FOR DIFFERENT SETTINGS OF THE VARIOUS POTENTIOMETERS AND AS A RESULT THE QUALITY WILL SUFFER TO A CERTAIN EXTENT. IT IS FOR THIS REASON THAT SPECIAL T-PAD VOLUME CONTROLS ARE NOW BEING EXTENSIVELY USED IN PLACE OF ORDINARY POTENTIOMETERS IN SOUND SYSTEMS WHERE THE BEST QUALITY OF REPRODUCTION IS REQUIRED.

AN EXAMPLE OF USING A T-PAD VOLUME CONtrol is shown you in Fig. 14 and the unit itself appears in Fig. 15. Volume controls of this type consist of three individual resistance elements with sliding contacts operating simultaneously across all of them and it is customary to draw them in symbol form as done in Fig. 14.

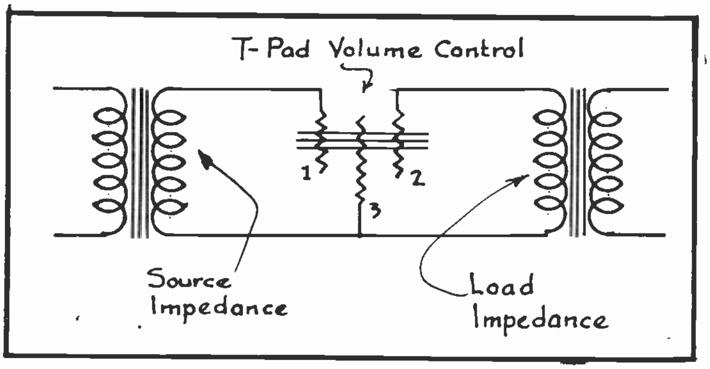

FIG. 14
Application of a T-Pad Volume Control.

The equivalent circuit of the T-pad volume control is the same as that of a T-type attenuator or T-pad about which you studied earlier in this lesson. In such a volume control it is possible to so proportion the resistances in legs 1 and 3 of Fig. 14 so as to have a proper impedance match for the load end of the circuit. The resistances across both the source and load remain constant with changes in position of the sliders.

Moving the arm upward on the resistances in Fig. 14 reduces the amount of resistance in legs 1 and 2 while increasing the resistance in leg 3. This permits greater energy transfer, less attenuation and greater volume. Moving the arm downward reverses these changes in resistance, decreasing the energy transfer and volume until a point of zero energy transfer is finally reached.

CONSTANT IMPEDANCE MIXERS

In Fig. 16 you are shown a mixer circuit employing four T-pad volume controls in order to control the energy supplied by four microphones. These four volume controls A-B-C and D are rated at 50 ohms each and connected across source impedances of equal value. These same four volume controls are effectively connected in series and together connected across a load impedance of 4 times 50 or 200 ohms and which transfers the signal energy to the amplifier by transformer action.

Although carbon microphones are here illustrated, the same system would be employed with a condenser or ribbon microphone only that the out-put of their respective pre-amplifiers would be connected to the volume controls through a line equipped with proper impedance matching transformers at both ends.

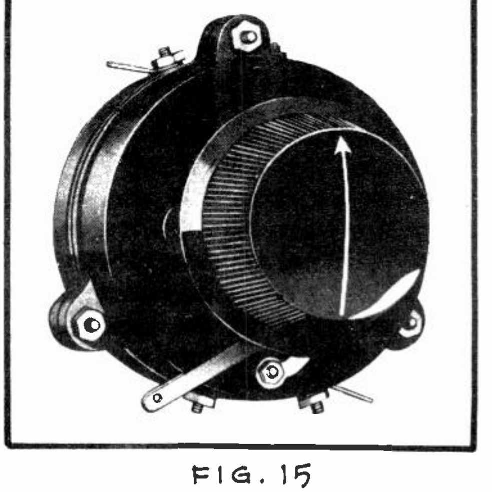

FIG. 15
The T-Pad Volume Control

In Fig. 17 you are shown a constant impedance mixer circuit employing T-pad volume controls and which takes care of feeding the energy from a radio tuner and detector, a microphone and a

PHONOGRAPH PICK-UP INTO THE INPUT OF THE AMPLIFIER. IN THIS PARTICULAR CASE, EACH OF THE VOLUME CONTROLS IS RATED AT 200 OHMS TO MATCH CORRESPONDING SOURCE IMPEDANCES AND SINCE THE THREE VOLUME CONTROLS ARE CONNECTED IN SERIES, THE LOAD IMPEDANCE ACROSS WHICH THEY ARE TOGETHER CONNECTED IS RATED AT 3 TIMES 200 OR 600 OHMS.

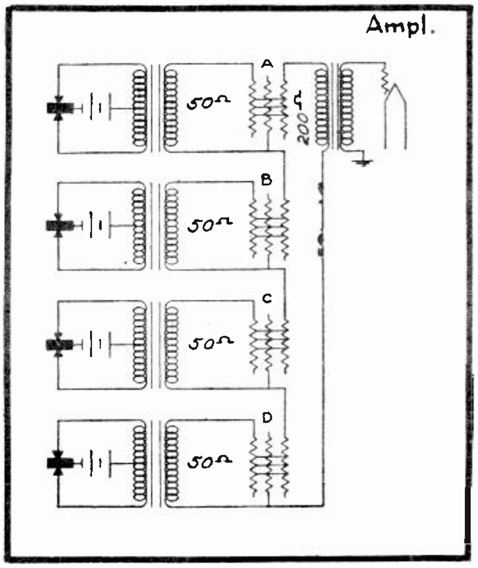

FIG. 16
Application of Constant Impedance Mixer.

MODIFIED CONSTANT IMPEDANCE MIXER

DUE TO THE HIGH COST OF T-PAD VOLUME CONTROLS AND IF THE NATURE OF THE INSTALLATION IS SUCH AT AN ABSOLUTELY CONSTANT IMPEDANCE VOLUME CONTROL IS NOT ESSENTIAL, THEN A MODIFIED CONSTANT IMPEDANCE MIXER CIRCUIT CAN BE ARRANGED AS ILLUSTRATED IN FIG. 18 WHERE FOUR L-PAD VOLUME CONTROLS ARE BEING USED. THESE VOLUME CONTROLS HAVE ONLY TWO RESISTANCE ELEMENTS ACROSS WHICH SLIDERS MOVE SIMULTANEOUSLY AND THEY MAINTAIN A FAIRLY CONSTANT IMPEDANCE ALTHOUGH NOT AS PERFECT AS THE T-PAD CONTROL. HOWEVER, SINCE THEY ARE NOT SO EXPENSIVE AS THE T-PAD CONTROL THEY ARE USED CONSIDERABLY.

EACH OF THE L-PAD VOLUME CONTROLS IN FIG. 18 ARE RATED AT 50 OHMS AND SINCE THEY ARE CONNECTED IN SERIES, THE LOAD IMPEDANCE CHOSEN IS 200 OHMS. THE GENERAL OUTER APPEARANCE OF THE L-PAD VOLUME CONTROL IS MUCH THE SAME AS THE T-PAD VOLUME CONTROL SHOWN IN FIG. 15.

DB. VOLUME CONTROLS

IN SOME A.F. AMPLIFYING EQUIPMENT YOU WILL FIND THE VOLUME CONTROL ARRANGED SOMEWHAT AS ILLUSTRATED IN FIG. 19. HERE THE CONTROL UNIT IS PROVIDED WITH TWELVE SWITCH POSITIONS INCLUDING AN "OFF" AND A "FULL-ON" POSITION. IN THE PARTICULAR ILLUSTRATION HERE SHOWN EACH OF THESE SWITCH POSITIONS REPRESENTS A LOSS OR ATTENUATION OF 2 DB. IN OTHER WORDS, WHEN IN THE POSITION FOR MINIMUM VOLUME, THIS VOLUME CONTROL WILL INTRODUCE AN ATTENUATION OF 20 DB. IN THE AMPLIFIER CIRCUIT. THE VOLUME CAN BE INCREASED OR REDUCED IN TEN STEPS, 2 DB. AT A TIME.

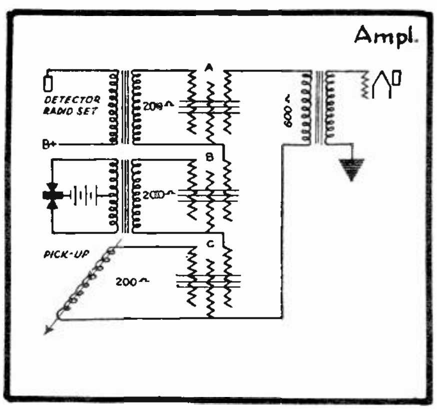

FIG. 17
Another Constant Impedance Mixer.

VOLUME CONTROLS OF THIS TYPE ARE ALSO KNOWN AS DECADE VOLUME CONTROLS AND IN SOME CASES YOU WILL FIND THE VOLUME CHANGES TO OCCUR IN 1 DB. STEPS, SOMETIMES IN 3 DB. STEPS ETC., DEPENDING UPON THE PARTICULAR REQUIREMENTS OF THE EQUIPMENT. THE MAXIMUM ATTENUATION EMPLOYED ALSO VARIES WITH DIFFERENT REQUIREMENTS.

A COMMON METHOD OF USING SUCH A DB. VOL-

UME CONTROL IN AN AMPLIFIER CIRCUIT IS ILLUSTRATED FOR YOU IN FIG. 20. HERE YOU WILL NOTE THAT THE GRID LEAK RESISTOR OF THE SECOND A.F. TUBE IS TAPPED AT INTERVALS SO THAT AS THE CONTROL ARM IS OPERATED THE EFFECTIVE GRID LEAK RESISTANCE FOR THE SECOND TUBE IS ALTERED.

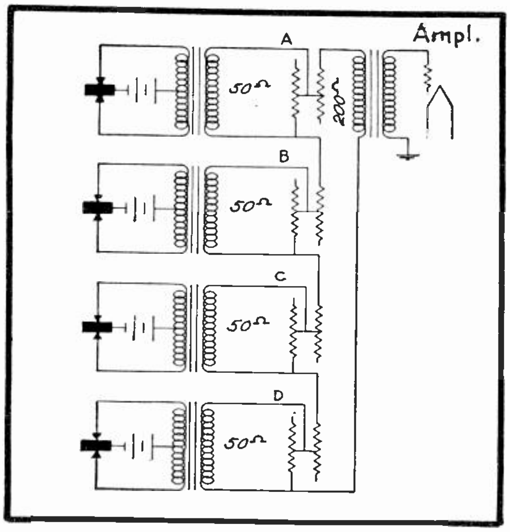

FIG. 18
Application of L-Pad Volume Control.

SO AS TO HAVE THE VOLUME CHANGES OCCUR IN DEFINITE DB. STEPS, IT IS OF COURSE NECESSARY THAT THE INDIVIDUAL RESISTOR SECTIONS OF THIS CONTROL HAVE THE PROPER VALUE. TO ILLUSTRATE HOW THESE VALUES ARE OBTAINED, LET US CONSIDER A SPECIFIC PROBLEM. HERE IT IS:

IT IS DESIRED TO CONSTRUCT A DECADE VOLUME CONTROL WHICH WILL FURNISH A MAXIMUM ATTENUATION OF 20 DB, AND TO HAVE THIS ATTENUATION OCCUR IN 10 STEPS OF 2 DB. CHANGE EACH. IN ADDITION, A POSITION OF MAXIMUM VOLUME (THE 0 POSITION) AND AN "OFF" POSITION ARE ALSO DESIRED.

THIS ARRANGEMENT WOULD APPEAR AS ILLUSTRATED IN FIG. 20 AND WE SHALL ASSUME THAT THE TOTAL GRID LEAK RESISTANCE FOR THIS PARTICULAR CIRCUIT IS TO BE 250,000 OHMS. THE SIGNAL VOLTAGE WHICH IS APPLIED TO THE GRID OF THE SECOND A.F. TUBE IN FIG. 20 WILL BE THAT VOLTAGE WHICH IS PRODUCED ACROSS THAT AMOUNT OF RESISTANCE USED IN ITS GRID LEAK CIRCUIT AND SINCE NO GRID CURRENT FLOWS IN A CIRCUIT SUCH AS THIS, THE SIGNAL VOLTAGE APPEARING ACROSS THE GRID CIRCUIT WILL BE PROPORTIONAL TO THE RESISTANCE INCLUDED IN THIS CIRCUIT.

YOU ARE ALREADY FAMILIAR WITH THE FORMULA $Db = 20 \log \frac{E_1}{E_2}$ WHERE E_1 = THE LARGER VOLTAGE AND E_2 = THE SMALLER VOLTAGE. THEN SINCE IN THIS PROBLEM THE VOLTAGE IS PROPORTIONAL TO THE RESISTANCE, IT IS ALSO TRUE THAT $Db = 20 \log \frac{R_1}{R_2}$ WHERE R_1 = THE LARGEST RESISTANCE VALUE OR THE TOTAL GRID LEAK RESISTANCE AND R_2 = THE GRID CIRCUIT RESISTANCE REQUIRED TO PRODUCE THE FIRST STEP OF ATTENUATION.

SINCE WE DESIRE TO SOLVE FOR R_2, WE CAN REARRANGE THE FORMULA $Db = 20 \log \frac{R_1}{R_2}$ AND APPLY IT IN THE FOLLOWING MANNER:

$$Db = 20 \log \frac{R_1}{R_2}$$

$$20 \log \frac{R_1}{R_2} = Db.$$

DIVIDING BY 20 —— $\log \frac{R_1}{R_2} = \frac{Db}{20}$

$$\frac{R_1}{R_2} = \text{ANTILOG } \frac{Db}{20}$$

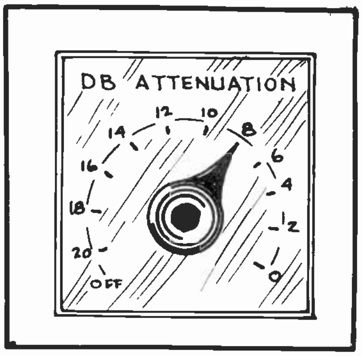

FIG. 19
The Decade Volume Control.

Since Db = 2 ------------- $\frac{R_1}{R_2}$ = antilog $\frac{2}{20}$

$$\frac{R_1}{R_2} = \text{antilog } 0.1$$

$$\frac{R_1}{R_2} = 1.259$$

Then since R_1 = 250,000 ohm $R_2 = \frac{250,000}{1.259}$ = 198,570 ohms. This means that the grid circuit resistance is to be reduced from 250,000 ohms to 198,570 ohms in order to provide the attenuation of 2 Db. Therefore, section "A" of the volume control will require a value of 250,000 minus 198,570 or 51,430 ohms.

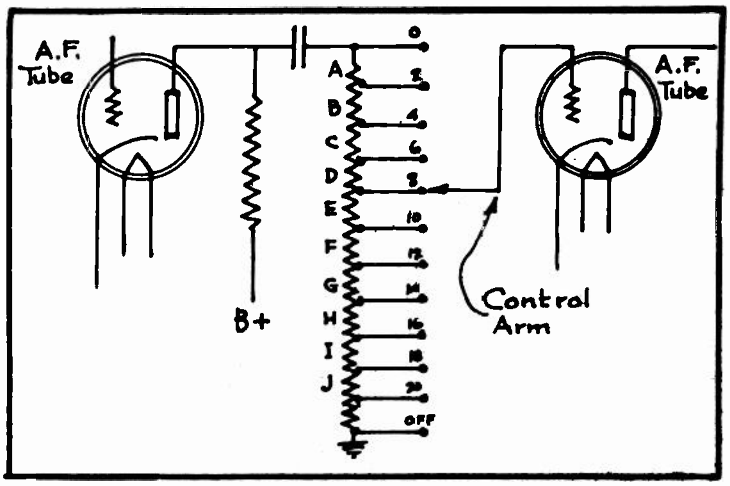

FIG. 20

Circuit Application of Db. Volume Control.

The values for the remaining sections of the volume control are determined in the following manner:

Section B = 198,570 minus $\frac{198,570}{1,259}$ = 198,570 minus 157,720 = 40,850 ohms.

Section C = 157,720 minus $\frac{157,720}{1.259}$ = 157,720 minus 125,274 = 32,446 ohms.

Section D = 125,274 minus $\frac{125,720}{1.259}$ = 125,274 minus 99,857 = 25,417 ohms.

Section E = 99,857 minus $\frac{99,857}{1.259}$ = 99,587 minus 79,314 = 20,273 ohms.

Section F = 79,314 minus $\frac{79,314}{1.259}$ = 79,314 minus 62,997 = 16,317 ohms

Section G = 62,997 minus $\frac{62,997}{1.259}$ = 62,997 minus 50,037 = 12,960 ohms.

Section H = 50,037 minus $\frac{50,037}{1.259}$ = 50,037 minus 39,743 = 10,294 ohms.

Section I = 39,743 minus $\frac{39,743}{1.259}$ = 39,743 minus 31,567 = 8,176 ohms.

Section J = 31,567 minus $\frac{31,567}{1.259}$ = 31,567 minus 25,073 = 6,494 ohms.

This leaves 250,000 minus 224,657 or 25,343 ohms for that portion of the resistance between the 20 Db. and the "off" position, and which would produce a rather noticeable thudding sound when the control passes through this position. In such a case, you can either add some more 2 Db. steps of attenuation or else reduce this last resistance section to 3,000 or 5,000 ohms and which will not materially affect the per-

FORMANCE OF THE SYSTEM.

THE RESISTORS USED FOR THIS PURPOSE SHOULD BE OF THE NON-INDUCTIVE TYPE AND INTRODUCE A MINIMUM OF CAPACITY IN THE CIRCUIT.

EXAMINATION QUESTIONS

LESSON NO. A. S.-10

1. - DRAW A DIAGRAM OF AN A.F. TRANSMISSION LINE CONNECTING TWO AMPLIFIERS TOGETHER AND SHOW HOW A T-PAD WOULD BE INCLUDED IN THIS LINE.

2. - DRAW A DIAGRAM OF AN A.F. TRANSMISSION LINE CONNECTING TWO AMPLIFIERS TOGETHER AND SHOW HOW AN H-PAD WOULD BE INCLUDED IN THIS LINE.

3. - IN A CERTAIN AMPLIFYING SYSTEM A SIGNAL VOLTAGE OF 2 VOLTS R.M.S. IS FURNISHED TO THE SOURCE END OF THE TRANSMISSION LINE. CONDITIONS ARE SUCH THAT ONLY 1 VOLT R.M.S. CAN BE TOLERATED AT THE LOAD END OF THE TRANSMISSION LINE. WORK OUT THE DESIGN FOR AN H-PAD WHICH WILL SUPPLY THE NECESSARY ATTENUATION IN THIS LINE AND DRAW A CIRCUIT DIAGRAM OF THE SYSTEM, INDICATING THE ELECTRICAL VALUES OF ALL PARTS USED.

4. - IT IS DESIRED TO DESIGN A 200 OHM TRANSMISSION LINE IN WHICH IS INCLUDED A T-PAD WHICH WILL FURNISH AN ATTENUATION OF 6 DB. WORK OUT THE DESIGN FOR THIS TRANSMISSION LINE AND INDICATE ALL ELECTRICAL VALUES OF THE PARTS USED ON A DIAGRAM.

5. - WHAT IS A "MIXER"?

6. - DRAW A DIAGRAM OF A MIXER CIRCUIT SHOWING HOW THREE MICROPHONES CAN BE WORKED INTO THE INPUT OF A SINGLE AMPLIFIER. CONVENTIONAL POTENTIOMETERS ARE TO BE USED.

7. - WHAT IS THE CHIEF ADVANTAGE WHICH IS OFFERED BY CONSTANT IMPEDANCE VOLUME CONTROLS?

8. - DRAW A DIAGRAM SHOWING HOW THREE T-PAD VOLUME CONTROLS MAY BE USED TO CONTROL THE VOLUME OF A RADIO TUNER AND DETECTOR, MICROPHONE, AND PHONOGRAPH PICK-UP, WHICH ARE ALL BEING WORKED INTO A SINGLE AMPLIFIER.

9. - DESCRIBE A "DECADE" OR "DB. VOLUME CONTROL".

10.- HOW WOULD YOU PROCEED TO DESIGN A DB. VOLUME CONTROL?

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Transmitters

LESSON NO. 1

• EARLY TRANSMITTERS •

In one of the first lessons which you studied and which is titled "Radio Communication", you learned in a general way what radio transmitters are expected to accomplish. You were also at that time introduced to the different sections which are incorporated in the typical transmitter and their respective duties.

All of these units, as well as many more, are now going to be explained to you in detail in the present series of lessons.

CLASSIFICATION OF TRANSMITTERS

We can classify radio transmitters into two general groups, namely, those which are used to send messages by means of the telegraphic code and those which are used for the transmission of voice and musical programs.

The code type transmitter was the first form of successful transmitter and is still being most extensively used in the handling of commercial traffic, by amateurs, etc. Code signals can be received successfully over greater distances than can voice or phone transmission but each type of transmission, of course, has its particular advantages.

Code transmitters are simpler than phone transmitters from the standpoint of both design and construction and therefore we shall study code transmitters first. Many of the components and principles, however, are the same in both types of transmitters so that what you learn by a study of one can

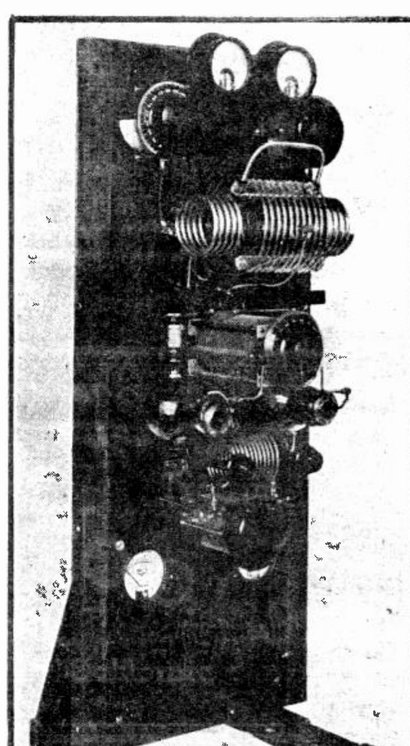

FIG. 1
A Typical Transmitter.

BE APPLIED EQUALLY WELL TO THE OTHER.

ALL MODERN TRANSMITTERS, WHETHER OF THE CODE OR PHONE TYPE, EMPLOY VACUUM TUBE OSCILLATORS BUT SINCE THE FIRST TRANSMITTERS DEPENDED UPON "SPARK OSCILLATORS", "ARC OSCILLATORS" ETC., IT WILL BE WELL FOR US TO CONSIDER THESE TYPES BRIEFLY BEFORE ENTERING THE STUDY OF THE MORE MODERN SYSTEMS. THIS WILL GIVE YOU A BETTER IDEA OF THE DEVELOPMENT AND ADVANCEMENT MADE IN THE FIELD OF TRANSMISSION.

THE SPARK TRANSMITTER

IN FIG. 2 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SIMPLE FORM OF COMMERCIAL TYPE SPARK TRANSMITTER.

HERE WE HAVE FIRST AN A.C. GENERATOR WHICH PRODUCES A VOLTAGE SOURCE HAVING A FREQUENCY OF APPROXIMATELY 500 CYCLES. THIS GENERATOR IS GENERALLY DRIVEN BY AN ELECTRIC MOTOR WHOSE ARMATURE SHAFT IS COUPLED TO THE ARMATURE SHAFT OF THE GENERATOR SO AS TO FORM A MOTOR-GENERATOR SET SIMILAR IN APPEARANCE TO THOSE ABOUT WHICH YOU STUDIED IN YOUR LESSONS PERTAINING TO BATTERY CHARGING EQUIPMENT.

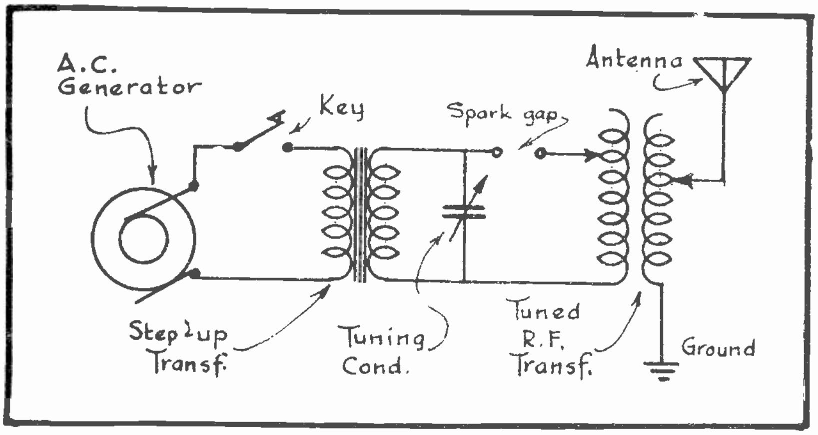

FIG. 2

A Simple Form of Spark Transmitter.

A TYPICAL KEY, AS USED WITH CODE TRANSMITTERS, IS ILLUSTRATED FOR YOU IN FIG. 3. THESE KEYS ARE GENERALLY KNOWN AS "TELEGRAPH KEYS" OR "WIRELESS KEYS" AND THEY CONSIST ESSENTIALLY OF A PAIR OF CONTACT POINTS WHICH ARE NORMALLY HELD IN AN OPEN POSITION BY SPRING TENSION. BY PRESSING DOWNWARD ON THE KNOB, WHICH IS MOUNTED ON THE END OF THE ARM, THE CONTACT POINTS ARE FORCED CLOSED IN ORDER TO COMPLETE THE CIRCUIT.

LATER ON YOU WILL BE GIVEN MORE COMPLETE INFORMATION REGARDING THE DIFFERENT TYPES OF KEYS AND THE TECHNIQUE OF USING THEM CORRECTLY. FOR THE PRESENT, LET US CONFINE OUR ATTENTION TO THE OPERATION OF THE CIRCUIT NOW UNDER CONSIDERATION.

RETURNING TO FIG. 2, WE FIND THAT WHEN THE KEY IS IN THE CLOSED POSITION, THE GENERATOR CIRCUIT THROUGH THE PRIMARY WINDING OF THE STEP-UP TRANSFORMER IS COMPLETE SO THAT A 500 CYCLE ALTERNATING CURRENT WILL FLOW THRU THIS WINDING.

BY INDUCTION, A MUCH HIGHER VOLTAGE WILL APPEAR ACROSS THE SECONDARY WINDING OF THE STEP-UP TRANSFORMER. IN THIS MANNER, A HIGH VOLTAGE IS APPLIED ACROSS THE TUNED OSCILLATOR CIRCUIT WHICH CONSISTS OF THE PRIMARY WINDING OF THE R.F. TRANSFORMER, THE TUNING CONDENSER AND THE SPARK GAP. THESE COMPONENTS OF THE TUNED R.F. CIRCUIT ARE ALL CONNECTED IN SERIES WITH EACHOTHER.

NOW THEN, NOTICE PARTICULARLY THAT THE SPARK GAP SERVES TO INTRODUCE AN OPEN CIRCUIT IN THE TUNED OSCILLATING CIRCUIT SO THAT NO OSCILLATING CURRENT WITH WHICH TO GENERATE RADIO FREQUENCY ENERGY FLOWS THROUGH THIS CIRCUIT AT THE TIME THE A.C. VOLTAGE BEGINS TO RISE TOWARDS ITS PEAK VALUE.

THE DISTANCE BETWEEN THE ELECTRODES OF THE SPARK GAP IS SO ADJUSTED THAT WHEN THE A.C. VOLTAGE REACHES A CRITICAL VALUE, THE CHARGE WHICH HAS BEEN BUILT UP ACROSS THE ELECTRODES OF THE SPARK GAP, AS WELL AS ACROSS THE TUNING CONDENSER PLATES, BECOMES SUFFICIENTLY GREAT TO OVERCOME THE RESISTANCE OF THE AIR GAP AND IT THEREFORE DISCHARGES ACROSS THE AIR GAP IN THE FORM OF A SPARK. WE THEN SAY THAT THE SPARK GAP "BREAKS DOWN".

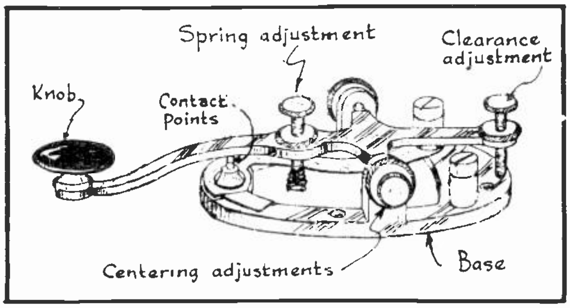

FIG. 3
A Telegraph Key.

THIS ACTION RESULTS IN A HIGH FREQUENCY OR OSCILLATING CURRENT BEING SET-UP IN THE TUNED HIGH FREQUENCY CIRCUIT OF THE TRANSMITTER. THIS CURRENT CONTINUES TO FLOW UNTIL THE VOLTAGE DROPS TO A VALUE LOW ENOUGH SO AS TO PERMIT THE RESISTANCE ACROSS THE SPARK GAP TO PREVENT ANY FURTHER FLOW OF CURRENT. THE VOLTAGE THEN COMMENCES TO BUILD UP AGAIN UNTIL ANOTHER SPARKING DISCHARGE OCCURS WITH ITS RESULTING FLOW OF RADIO FREQUENCY CURRENT THROUGH THE TUNED CIRCUIT AND AGAIN THIS RADIO FREQUENCY CURRENT DIES DOWN AS THE VOLTAGE DROPS IN VALUE. THIS CYCLE OF EVENTS CONTINUES IN THIS MANNER AS LONG AS THE KEY IS HELD CLOSED.

THE FREQUENCY OF OSCILLATION AS OCCURRING IN THIS CIRCUIT IS GOVERNED LARGELY BY THE TUNING CONSTANTS OF THIS SAME CIRCUIT AS DETERMINED BY THE CAPACITY OFFERED BY THE TUNING CONDENSER IN CONJUNCTION WITH THE INDUCTANCE VALUE OF THE R.F. TRANSFORMER'S PRIMARY WINDING. SO AS TO PROVIDE THE DESIRED TUNING RANGE, THE CONDENSER IS OF THE VARIABLE TYPE, WHILE THE PRIMARY WINDING OF THE R.F. TRANSFORMER IS GENERALLY SPACE-WOUND WITH LARGE DIAMETER BARE COPPER WIRE OR ELSE COPPER TUBING SO THAT THE COIL BECOMES SELF-SUPPORTING AND REQUIRES NO WINDING FORM. SPRING CLIPS ARE THEN USED AS ILLUSTRATED IN FIG. 4 SO THAT THE CONNECTIONS TO THE COIL CAN BE VARIED IN A CONVENIENT MANNER SO THAT AS MANY TURNS OF THE COIL AS NECESSARY CAN BE INCLUDED IN THE TUNED CIRCUIT IN ORDER TO OBTAIN THE DESIRED INDUCTANCE VALUE.

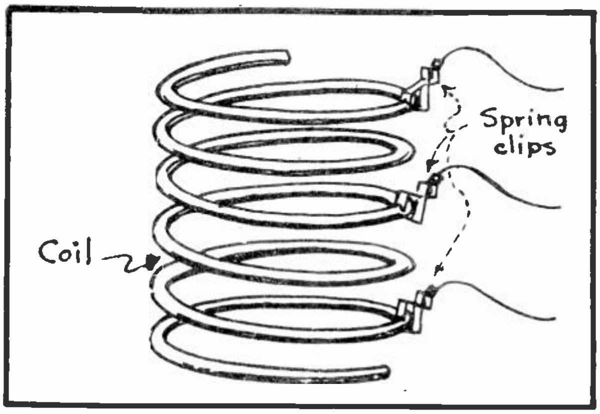

FIG. 4
A Variable-Inductance Coil.

SINCE THE SECONDARY WINDING OF THIS SAME R.F. TRANSFORMER IS INCLUDED IN THE ANTENNA CIRCUIT OF THE TRANSMITTER, WHILE AT THE SAME TIME BEING INDUCTIVELY COUPLED TO THE PRIMARY WINDING, IT IS CLEAR THAT THE ELECTRICAL OSCILLATIONS WHICH ORIGINATE IN THE TUNED CIRCUIT WILL BE TRANSFERRED BY INDUCTION TO THE SECONDARY WINDING. WITH THE OSCILLATING OR RADIO FREQUENCY CURRENT NOW FLOWING IN THE ANTENNA SYSTEM, IT WILL PRODUCE RADIO FREQUENCY WAVES WHICH ARE RADIATED OUT INTO SPACE.

SPARK GAPS

IN THE TRANSMITTER CIRCUIT OF FIG. 2 OF THIS LESSON, WE DEALT WITH A SIMPLE SPARK GAP CONSISTING OF TWO METAL BALLS SEPARATED BY AIR. A GAP AS THIS BECOMES QUITE HOT AFTER BEING IN CONTINUOUS OPERATION FOR SOME TIME AND THUS HAS A TENDENCY TO ARC. THIS ARCING EFFECT CAUSES THE AIR BETWEEN THE SPARK CONTACTS TO REMAIN A CONDUCTOR AND THIS WILL NOT PERMIT THE CONDENSER TO BE CHARGED TO ITS FULL CAPACITY. THAT IS, THE CONDENSER WILL DISCHARGE AT A POTENTIAL LOWER THAN DESIRED AND INSTEAD OF THE OSCILLATIONS IN THE CLOSED CIRCUIT BEING STOPPED AFTER THE AERIAL CIRCUIT HAS STARTED RADIATING ITS WAVES, WE FIND THAT THIS CONTINUAL ARCING ACROSS THE SPARK GAP ADDS EXTRA WAVES UPON THE ORIGINAL WAVE FORM, THEREBY PREVENTING TRANSMISSION OF "CLEAN CUT" WAVES.

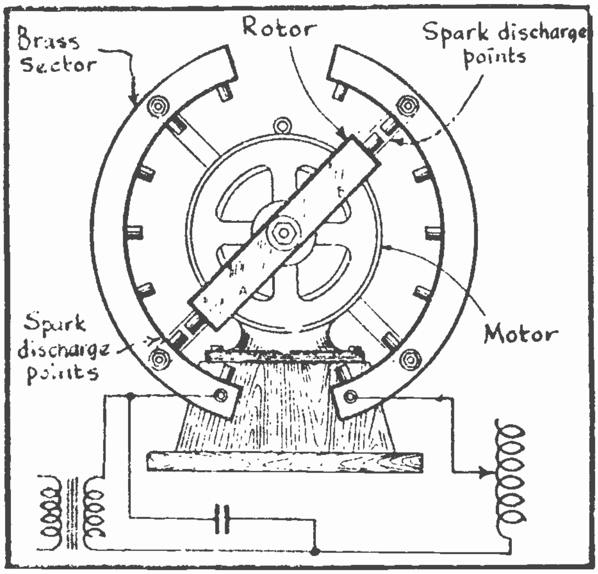

FIG.5
Non-Synchronous Discharger.

TO PREVENT THIS ILL EFFECT AND SO THAT MORE INTELLIGIBLE SIGNALS CAN BE TRANSMITTED, VARIOUS TYPES OF SPARK GAPS WERE DEVELOPED. IN FIG. 5 YOU WILL SEE A SPARK DISCHARGER, WHICH IS KNOWN AS A "NON-SYNCHRONOUS DISCHARGER." IN THIS CASE, A ROTOR ARM IS FIRMLY FASTENED AT THE CENTER TO THE ARMATURE SHAFT OF AN ELECTRIC MOTOR, SO THAT IT MUST ROTATE AS THE MOTOR'S ARMATURE SHAFT REVOLVES.

A SPARK DISCHARGE POINT IS FASTENED TO EACH END OF THIS ROTOR AND FOURTEEN OTHER SPARK DISCHARGE POINTS ARE FASTENED TO TWO STATIONARY BRASS SECTORS.

THE OSCILLATION CIRCUIT OF THE TRANSMITTER IS CONNECTED ACROSS THE DISCHARGER AS SHOWN AND WHEN THE ROTOR LINES UP WITH A PAIR OF STATIONARY ELECTRODES AS SHOWN IN FIG. 5, THEN THE SPARK CAN DISCHARGE ITSELF ACROSS THE TWO SPARK GAPS IN ORDER TO COMPLETE ITS CIRCUIT.

AS THE ROTOR REVOLVES, IT WILL CONTINUALLY BE CHANGING POSITIONS WITH RESPECT TO THE STATIONARY ELECTRODES, PERMITTING THE SPARK TO DISCHARGE THROUGH A DIFFERENT PAIR AS THE ROTOR REVOLVES. THIS PREVENTS OVER-HEATING OF THE CONTACT POINTS FOR ONE THING AND IN ADDITION, WE FIND THAT A MUSICAL PITCH IS PRODUCED AND THIS HELPS A GREAT DEAL IN "READING" THE CODE AT A RECEIVER, DUE TO ITS CLEARER AND MORE PRONOUNCED SIGNALS.

THE DRIVING MOTORS FOR SUCH DISCHARGERS GENERALLY RUN AT A SPEED OF FROM 1700 TO 3000 REVOLUTIONS PER MINUTE. THE REASON FOR CALLING THIS UNIT A "NON-SYNCHRONOUS" DISCHARGER

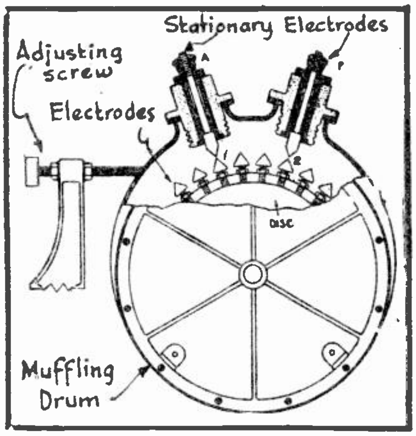

FIG. 6
Synchronous Rotary Discharger.

IS THAT THE SPEED OF THE MOTOR BEARS NO RELATION TO THE FREQUENCY OF THE CONDENSER CHARGING CURRENT. IN TRANSMITTERS USING A CURRENT OF 60 CYCLES IN THEIR HIGH VOLTAGE TRANSFORMER, THE ROTOR IS GENERALLY DRIVEN AT A SPEED WHICH WILL DELIVER FROM ABOUT 200 TO 300 SPARK DISCHARGES PER SECOND.

THE MOST POPULAR SPARK DISCHARGER IS SHOWN IN FIG. 6 AND THIS IS KNOWN AS A "SYNCHRONOUS" ROTARY SPARK DISCHARGER. IT CONSISTS OF A METAL DISC, WHICH IS FIRMLY KEYED AND LOCKED TO THE SHAFT OF THE ALTERNATOR. ON THE OUTER EDGE OF THIS DISC, YOU WILL FIND A NUMBER OF POINTED COPPER SPARK ELECTRODES BUT THE NUMBER OF THESE DISC ELECTRODES WILL ALWAYS BE EQUAL TO THE NUMBER OF FIELD POLES, WHICH ARE USED IN THE ALTERNATOR.

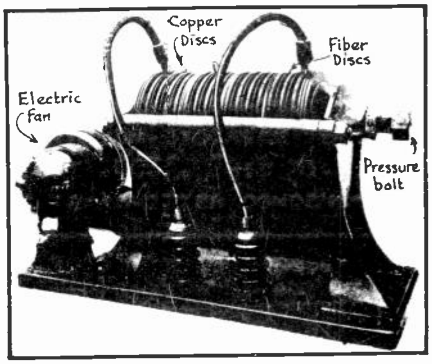

FIG. 7
Quenched Spark Discharger.

BECAUSE OF THE DISC BEING DRIVEN DIRECTLY BY THE ALTERNATOR, AS WELL AS HAVING SPARK ELECTRODES OF A NUMBER EQUAL TO THE NUMBER OF FIELD POLES WITHIN THE ALTERNATOR, WE FIND THAT THE DISCHARGE OF THE TRANSMITTER CONDENSER WILL BE ACCURATELY TIMED WITH THE ALTERNATIONS OF THE CHARGING CURRENT. IT IS FOR THIS REASON THAT THIS TYPE OF SPARK DISCHARGER IS REFFERED TO AS A "SYNCHRONOUS" DISCHARGER. THAT IS, ANY TWO THINGS, WHICH ARE PERFECTLY TIMED TO EACHOTHER, ARE SPOKEN OF AS BEING SYNCHRONIZED AND THIS OF COURSE IS THE CASE WITH THIS TYPE OF DISCHARGER.

TWO STATIONARY ELECTRODES ARE USED, AS SHOWN IN FIG. 6, AND THE OSCILLATING CIRCUIT OF THE TRANSMITTER IS CONNECTED ACROSS THESE TWO STATIONARY ELECTRODES. BY REGULATING THE ADJUSTING SCREW, LABELED IN FIG. 6, THE MUFFLING DRUM CAN BE SHIFTED ON ITS AXIS AND IN THIS WAY CAUSE THE STATIONARY CONTACTS TO ALTER THEIR POSITION SOMEWHAT IN RELATION TO THE DRIVEN DISC. THIS ADJUSTMENT PERMITS THE MOST FAVORABLE SPARKING POINT TO BE LOCATED AND RESULTS IN SYNCHRONOUS DISCHARGES, GIVING A CLEAR, MUSICAL SPARK NOTE.

BESIDES THIS ADJUSTMENT FOR PITCH, IT IS ALSO NECESSARY TO HAVE THE SPARK GAPS ADJUSTED SO AS TO GIVE THE SHORTEST POSSIBLE DISCHARGE GAP WITHOUT PERMITTING THE ELECTRODES TO TOUCH. THE MINIMUM DISTANCE BETWEEN THE STATIONARY AND REVOLVING POINTS SHOULD BE ABOUT .005". THIS WILL GIVE A CLEAR SPARK DISCHARGE AND WILL NOT SUBJECT THE TRANSMITTER CONDENSER TO

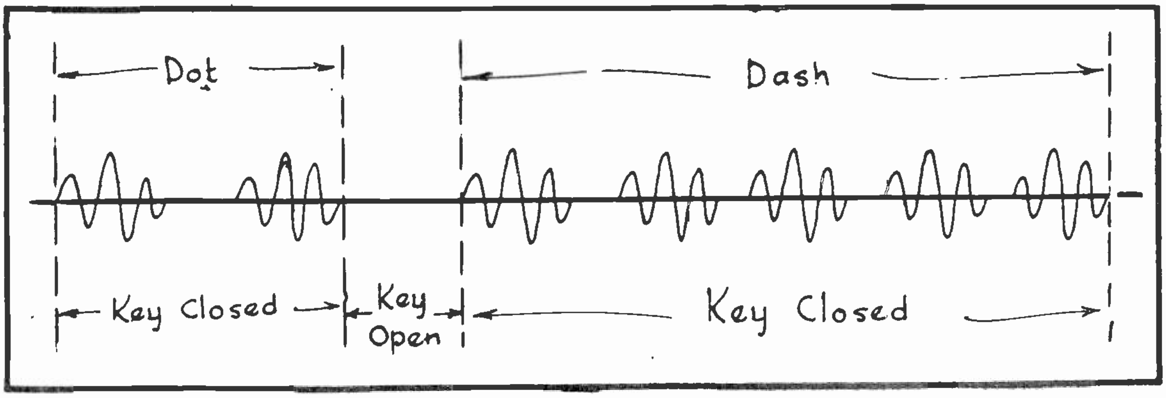

FIG. 8
Wave Radiation From Spark Transmitter.

AN ABNORMAL STRAIN.

SHOULD THE CIRCUIT OSCILLATION AT ANY ONE INSTANT BE SUCH AS TO FLOW INTO STATIONARY CONTACT "A", THEN THE SPARK WILL JUMP FROM THE CONTACT AT THE BOTTOM OF "A" OVER TO CONTACT #1 ON THE DISC. THENCE THROUGH THE DISC OVER TO ELECTRODE #2 AND ACROSS THE GAP TO STATIONARY CONTACT "B" AND IN THIS WAY RETURNING TO ITS ORIGIN. THE SYNCHRONOUS DISCHARGER IS CAPABLE OF HANDLING A LARGE AMOUNT OF POWER AND THEY HAVE BEEN SUCCESSFULLY OPERATED AT 500 KW.

IN SOME TRANSMITTERS, A "QUENCHED SPARK GAP" IS USED AND A PICTURE OF THIS TYPE GAP IS SHOWN IN FIG. 7. THIS DISCHARGER IS MAINLY USED IN THE LOWER POWER SPARK TRANSMITTERS, WHEREAS THE SYNCHRONOUS DISC DISCHARGER IS USED FOR THE SPARK TRANSMITTERS OF HIGHER POWER RATING.

THIS QUENCHED SPARK DISCHARGER CONSISTS OF A NUMBER OF COPPER DISCS SEPARATED FROM EACHOTHER BY SOME SUCH INSULATING MATERIAL AS FIBRE, MICANITE ETC. THESE COPPER AND INSULATING DISCS ARE PLACED IN AN IRON RACK AND AND COMPRESSED BY MEANS OF A PRESSURE BOLT. THE THICKNESS OF THE WASHERS OR INSULATING DISCS IS SUCH THAT THE SPACE BETWEEN THE COPPER SPARKING SURFACES OF A SINGLE SET OF COPPER DISCS DOES NOT EXCEED .01 INCH.

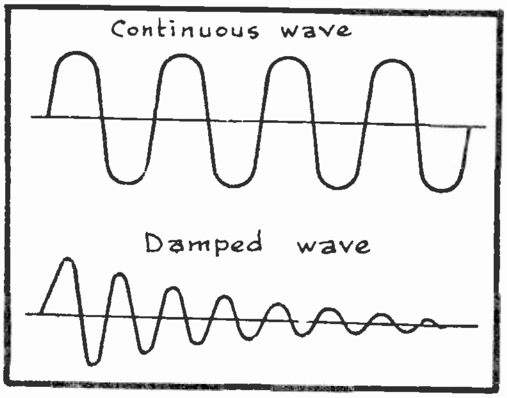

FIG.9
Continuous and damped waves.

THE INSULATING DISCS ARE ALSO SPECIALLY TREATED AND INSTALLED SO THAT THE DISCHARGE SURFACE IS AIRTIGHT AND THIS MAKES A NOISLESS DISCHARGE POSSIBLE, AT THE SAME TIME AIDING IN THE WORK OF QUENCHING OUT THE OSCILLATIONS IN THE OSCILLATING CIRCUIT.

A MOTOR-DRIVEN FAN OR BLOWER PROVIDES A DRAFT OF AIR OVER COOLING FLANGES OF THE SPARK DISCHARGER AND IN THIS WAY COOLS THE GAP.

WITH VERY LOOSE COUPLING BETWEEN THE COILS OF THE OSCILLATION OR R.F. TRANSFORMER, PRACTICALLY ANY TYPE OF SPARK GAP WILL PERMIT SATISFACTORY QUENCHING OF OSCILLATIONS, WHICH TEND TO CONTINUE IN THE OSCILLATOR CIRCUIT DURING THE RADIATION OF THE WAVE BUT THE QUENCHED SPARK DISCHARGER SHOWN IN FIG. 7 GIVES A SATISFACTORY QUENCHING RESULT, EVEN WHEN THE ANTENNA CIRCUIT IS CLOSELY COUPLED TO THE OSCILLATOR CIRCUIT AND THIS OF COURSE MAKES A GREATER ENERGY TRANSFER POSSIBLE WITH LESS POWER LOSS.

DUE TO THIS ADVANTAGE OF THE QUENCHED GAP, THE ANTENNA OSCILLATES AT BUT A SINGLE FUNDAMENTAL FREQUENCY AND WILL THEREFORE RADIATE A SINGLE WAVE, WITH NO ADDITIONAL WAVES SUPERIMPOSED UPON IT, BUT WHICH WOULD OTHERWISE OCCUR WITH THE SIMPLE FORM OF SPARK GAP.

THE RADIATED WAVE

NOW LET US CONSIDER THE NATURE OF THE SIGNAL WAVE WHICH IS RADIATED BY THE ORDINARY TYPE OF SPARK TRANSMITTER, SUCH AS SHOWN IN FIG. 2. A TYPICAL EXAMPLE OF SUCH WAVE RADIATIONS APPEAR IN FIG. 8.

Starting at the left of this drawing, we find that when the key is held closed for a short duration of time, a series of highly damped wave groups commence leaving the antenna. The longer that the key is held closed, the greater will be the number of these wave groups which leave the antenna during one depression of the key.

The number of peaks which appear in each group of a wave train is determined by the frequency of oscillation occurring in the transmitter circuit, whereas the separation between each of these wave groups in any one wave train is governed by the frequency of the A.C. input. That is, if a 500 cycle A.C. generator is working into the primary winding of the transmitters' step-up transformer, then twice this amount or 1000 wave groups per second will be radiated by the antenna.

The frequency of each of the highly damped wave groups is of radio frequency and are therefore inaudible and the number of wave groups radiated per second determine the audible frequency. Each wave train vibrates the headphone diaphragm at the receiver once so that the listener hears a muscial note. That is to say, if 1000 wave groups per second are being radiated, then the sound produced in the receiver headphones will be equivalent to a 1000 cycle musical note.

When the key is in the open position, no waves are radiated and therefore no sounds are heard at the receiver. With the key closed for a very short interval of time, the "dot" of the telegraphic code is formed and is heard in the receiver headphones as the short abrupt sound "dit". By closing the key for a longer period of time (about three times as long as that used to form the "dot") we produce the "dash" of the code which is heard in the headphones as the more drawn-out sound "dah". A proper combination of dots and dashes are used to form the letters of the alphabet — these are combined to spell words and thus the desired message is radiated into space.

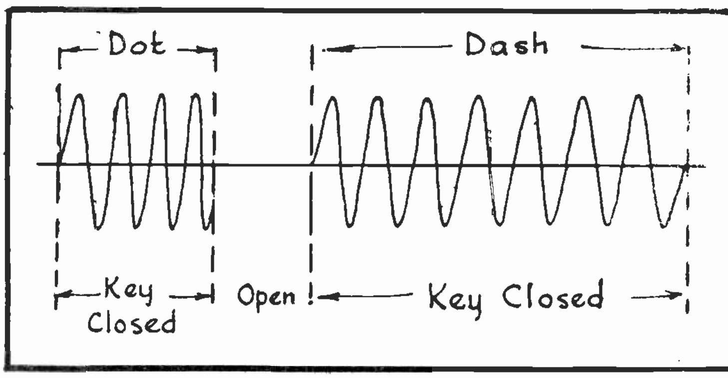

FIG. 10
C. W. Code Transmission.

Spark transmitters radiate a very highly damped form of wave and spread out over such a wide frequency band so that they can be heard all over the dial at the receiving end. Furthermore, they are very inefficient as regards the input power required and the actual output or radiation power obtained. Consequently, spark transmitters have been replaced with the more desirable type of transmitter which radiates a CONTINUOUS WAVE.

CONTINUOUS WAVES

Continous waves, you will recall from earlier studies, maintain a constant amplitude as illustrated in the upper portion of Fig. 9, while the damped waves start with a maximum amplitude which rapidly diminishes to a zero value as shown in the lower part of Fig. 9. It is the common practice

TO REFER TO CONTINUOUS WAVES SIMPLY AS C.W. WAVES.

CONTINUOUS WAVES CAN BE USED FOR THE TRANSMISSION OF MUSICAL BROADCAST PROGRAMS OR VOICE, AS WELL AS FOR CODE COMMUNICATION. ONE METHOD OF USING THESE C.W. WAVES FOR CODE TRANSMISSION IS ILLUSTRATED IN FIG. 10.

IN THIS CASE, THE KEY IS OPERATED SO AS TO START AND STOP THE WAVE PROPOGATION TO FORM THE "DOTS" AND "DASHES" OF THE CODE. ALTHOUGH RADIATION CEASES WHENEVER THE KEY IS OPEN YET THERE IS NO DAMPING EFFECT IN THE WAVE FORM.

THESE OSCILLATIONS ARE OF RADIO FREQUENCY AND THEREFORE FAR ABOVE AUDIBILITY. FOR THIS REASON, THEY CANNOT UNDER ORDINARY CONDITIONS BE HEARD AT THE RECEIVER. HOWEVER, TO MAKE THEM AUDIBLE, IT IS GENERALLY THE PRACTICE TO USE A SPECIAL OSCILLATOR AT THE RECEIVER AND WHICH IS KNOWN AS A BEAT OSCILLATOR.

THIS BEAT OSCILLATOR GENERATES RADIO FREQUENCY ENERGY AT CONTROLLED FREQUENCIES, THE SAME AS DOES THE OSCILLATOR OF A SUPERHETERODYNE RECEIVER. AS THE C.W. SIGNALS ARE PICKED UP AND AMPLIFIED BY THE RECEIVER, THE R.F. ENERGY GENERATED BY THE BEAT OSCILLATOR IS MADE TO HETERODYNE WITH THE INCOMING SIGNAL FREQUENCY TO PRODUCE THE INTERMEDIATE FREQUENCY, ONLY THAT IN THE CASE OF THE RECEPTION OF C.W. CODE SIGNALS, THE BEAT FREQUENCY IS IN THE AUDIBLE RANGE. THIS SUBJECT WILL BE EXPLAINED MORE THOROUGHLY IN A LATER LESSON.

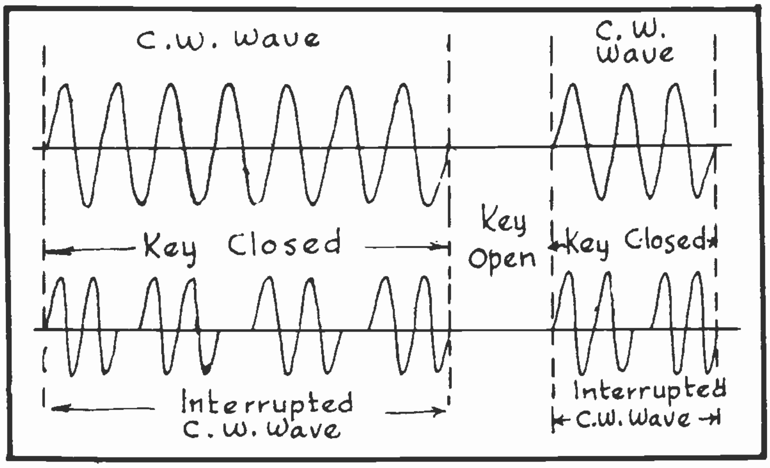

FIG. 11
The Interrupted C.W. Wave.

A STILL DIFFERENT TYPE OF CONTINUOUS WAVE IS THAT KNOWN AS THE INTERRUPTED CONTINUOUS WAVE AND WHICH IS ABREVIATED AS "I.C.W." IN THIS CASE, THE WAVE IS STILL OF THE CONTINUOUS TYPE BUT IS INTERRUPTED AT DEFINITE INTERVALS AS SHOWN IN THE LOWER PORTION OF FIG. 11. IN OTHER WORDS, DURING THE TIME THE KEY IS HELD CLOSED, A SERIES OF WAVES ARE RADIATED SOMEWHAT SIMILAR TO THE WAVE RADIATION FROM THE SPARK TRANSMITTER, ONLY THAT THE INDIVIDUAL WAVE GROUPS OF THE INTERRUPTED C.W. RADIATION ARE NOT DAMPED BUT OF CONSTANT AMPLITUDE.

WHILE THE KEY IS HELD CLOSED, THE CONTINUOUS WAVE IS INTERRUPTED AT A RATE CORRESPONDING TO AN AUDIBLE FREQUENCY, SAY FOR INSTANCE 500 TO 1000 TIMES PER SECOND. THE SIGNAL PRODUCED AT THE RECEIVER HEADPHONES, WHILE THE TRANSMITTER KEY IS HELD CLOSED, IS THEREFORE AUDIBLE. THEN BY CONTROLLING THE LENGTH OF TIME AT WHICH THE TRANSMITTER KEY IS HELD CLOSED, THE DOTS AND DASHES OF THE CODE ARE FORMED.

NOW THAT YOU ARE FAMILIAR WITH THE DIFFERENT WAVE FORMS AS RADIATED BY THE CODE TYPE TRANSMITTERS, LET US NEXT SEE HOW CONTINUOUS WAVES WERE PRODUCED BY THE EARLY TRANSMITTERS.

HIGH FREQUENCY GENERATORS

ONE OF THE METHODS WHICH HAS BEEN EMPLOYED FOR PRODUCING A CONTINUOUS OR INTERRUPTED CONTINUOUS WAVE FROM EARLY TRANSMITTERS WAS TO USE WHAT ARE KNOWN AS HIGH FREQUENCY GENERATORS.

A FUNDAMENTAL TYPE OF ALTERNATOR USED FOR THIS PURPOSE IS KNOWN AS THE "INDUCTOR TYPE". HERE THE ROTATING PART OF THE GENERATOR OR "INDUCTOR" CARRIES NO WINDINGS--INSTEAD, THE SURFACE OF THE IRON ROTOR IS SLOTTED SO AS TO FORM TEETH. AS THE ROTOR IS CAUSED TO REVOLVE, THE PASSAGE OF THE INDUCTOR TEETH ACROSS MAGNETIC POLES GENERATES AN ALTERNATING CURRENT. THIS PRINCIPLE WAS EMPLOYED IN THE ALEXANDERSON HIGH FREQUENCY ALTERNATORS WHICH WERE USED QUITE EXTENSIVELY BEFORE VACUUM TUBE TRANSMITTERS CAME INTO PROMINENCE.

ALEXANDERSON ALTERNATORS WERE CONSTRUCTED TO GENERATE FREQUENCIES AS HIGH AS 200 KC.

STILL OTHER TYPES OF HIGH FREQUENCY ALTERNATORS WHICH WERE USED WERE CONSTRUCTED MORE ALONG THE LINE OF THE COMMERCIAL ALTERNATORS. THAT IS, THEY CONSISTED OF A STATIONARY WINDING OR "STATOR" AND A REVOLVING WINDING OR ROTOR. HOWEVER, THE TWO WINDINGS ARE MADE PARTS OF TUNED OSCILLATORY CIRCUITS. DIFFERENT FREQUENCIES ARE GENERATED IN THE TWO WINDINGS AND THESE FREQUENCIES REACT WITH EACHOTHER TO PRODUCE BEAT FREQUENCIES OF TWICE, THREE TIMES AND FOUR TIMES THE ORIGINAL FREQUENCY. THE HIGHER FREQUENCIES CAN THEN BE USED FOR RADIATION PURPOSES.

IN FIG. 12 YOU WILL SEE A TYPICAL METHOD OF HOW A HIGH FREQUENCY GENERATOR CAN BE CONNECTED TO THE TRANSMITTER FOR CODE TRANSMISSION. HERE YOU WILL SEE THAT THE OUTPUT OF THE HIGH-FREQUENCY GENERATOR IS APPLIED ACROSS A CIRCUIT WHICH IS TUNED TO THE OUTPUT FREQUENCY OF THE GENERATOR. THIS CIRCUIT IS COUPLED TO THE TUNED ANTENNA CIRCUIT SO THAT A CONTINUOUS WAVE OF CORRESPONDING FREQUENCY CAN BE RADIATED. THE TRANSMITTER KEY IS CONNECTED IN THE FIELD CIRCUIT OF THE ALTERNATOR WHERE THE CURRENT VALUE IS RATHER SMALL.

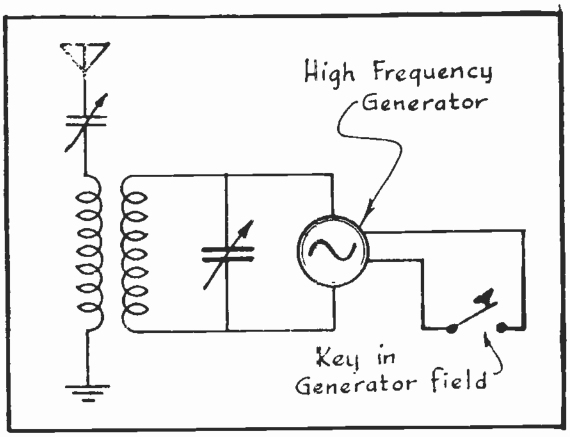

FIG. 12
Transmitter Circuit With High-Frequency Generator.

THE ARC TRANSMITTER

A SIMPLE ARC TRANSMITTER CIRCUIT IS ILLUSTRATED FOR YOU IN FIG. 13. THE SOURCE OF ELECTRICAL ENERGY IN THIS SYSTEM IS A DIRECT CURRENT GENERATOR WHICH FURNISHES AN E.M.F. OF 200 TO 1200 VOLTS, DEPENDING UPON ITS SIZE.

THE DIRECT CURRENT AS FURNISHED BY THE GENERATOR FLOWS FROM THE POSITIVE TERMINAL THROUGH THE CHOKE, WHOSE PURPOSE IS TO MAINTAIN THE CURRENT OF UNIFORM VALUE. THE CURRENT THEN FLOWS THROUGH THE ARC JUST AS IN AN ORDINARY ARC LAMP AND RETURNS TO THE NEGATIVE GENERATOR TERMINAL. A TUNED CIRCUIT CONSISTING OF AN INDUCTANCE L_1 AND THE CONDENSER C_1 ARE ALSO CONNECTED ACROSS THE ELECTRODES OF THE ARC.

Due to the presence of the choke in the generator circuit, the total current furnished to both the arc and the tuned circuit remains constant in value. At the time the circuit commences to operate, condenser C_1 is not charged and therefore a large portion of the generator current flows into the condenser plates, charging them. Therefore, less current will now flow through the arc because the generator current tends to maintain a constant value.

This decrease in current through the arc causes the voltage across it, as well as across the tuned circuit, to rise until the condenser C_1 is fully charged.

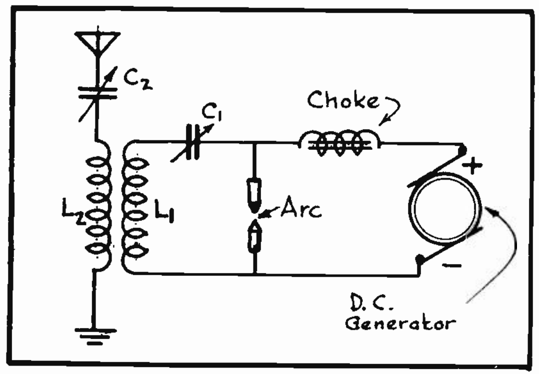

FIG. 13
Simple Arc Transmitter.

As soon as the condenser C_1 is fully charged, the current through the arc increases to its normal value and therefore the voltage across the arc will drop. However, since condenser C_1 is still fully charged, its voltage value will be higher than that of the arc and it therefore discharges across the arc. A charge then commences to build up again on condenser C_1 preparatory for another discharge and this cycle of events repeats itself as long as the D.C. voltage is applied.

Since the discharge occurs through a tuned oscillatory circuit consisting of C_1 and L_1, the oscillations produced occur at a frequency determined by the inductive value of L_1 in conjunction with the capacitive value of C_1.

These oscillations are then transferred to the tuned antenna circuit by means of electromagnetic induction and are thus radiated into space.

To key transmitters of this type, the method illustrated in Fig. 14 can be employed. Here you will see that the key is connected in series with the solenoid winding of the back-shunt relay and a low voltage D.C. supply. At the time the key is held closed, the resulting current flow through the solenoid winding of the relay will attract the contact blade towards the left so that it will touch contact #1. This will serve to connect the arc circuit to the tuned antenna circuit so

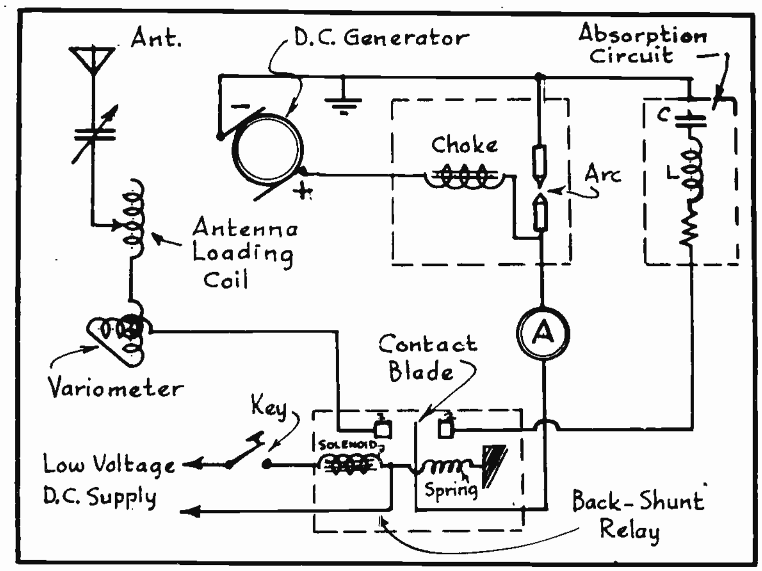

FIG. 14
The Arc Transmitter.

THAT ITS OSCILLATIONS MAY RADIATE A CONTINUOUS WAVE FROM THE ANTENNA.

WHEN THE KEY IS RELEASED, THE SOLENOID LOSES ITS ATTRACTION SO THAT THE CONTACT BLADE OF THE RELAY IS OVERCOME BY THE SPRING TENSION AND THERE FORE CLOSES THE CIRCUIT THROUGH CONTACT #2. THIS WILL DISCONNECT THE ANTENNA CIRCUIT FROM THE SYSTEM AND AT THE SAME TIME WILL CONNECT THE ABSORPTION CIRCUIT ACROSS THE ARC. THE ABSORPTION CIRCUIT IS ALSO A RESONANCE CIRCUIT AND PERMITS CONTINUED OSCILLATION TO OCCUR IN THE TRANSMITTER BUT PREVENTS RADIATION. THUS BY PROPERLY OPERATING THE KEY, THE DESIRED INTERRUPTIONS CAN BE PRODUCED IN THE TRANSMITTED CONTINUOUS WAVE TO FORM THE LETTERS OF THE CODE.

ALTHOUGH ALL MODERN TRANSMITTERS EMPLOY VACUUM TUBE CIRCUITS RATHER THAN THE SYSTEMS DESCRIBED IN THIS LESSON, YET THIS LESSON SHOULD HAVE SERVED ITS PURPOSE OF FAMILIARIZING YOU WITH THESE EARLIER CIRCUITS SUFFICIENTLY SO THAT YOU WILL AT LEAST HAVE SOME IDEA AS TO THEIR CONSTRUCTION AND OPERATION IN THE EVENT THAT YOU SHOULD AT SOME TIME OR OTHER HEAR ABOUT THEM.

THERE IS NO NEED TO DESCRIBE THESE EARLIER TRANSMITTERS IN FURTHER DETAIL AND SO IN THE NEXT LESSON, WE WILL START RIGHT IN WITH THE MODERN VACUUM TUBE TRANSMITTER CIRCUITS. YOU WILL FIND THE STUDIES TO FOLLOW TO BE UP TO DATE AND COMPLETE IN EVERY RESPECT.

Answered July 18 1941

Examination Questions

LESSON NO. T-1

> It is well for a man to respect his own vocation whatever it is, and to think himself bound to uphold it, and to claim for it the respect it deserves.

1. – DRAW A DIAGRAM OF A SIMPLE SPARK TRANSMITTER AND EXPLAIN HOW IT OPERATES.

2. – DESCRIBE A "QUENCHED SPARK GAP" AND EXPLAIN THE REASON FOR USING IT.

3. – MAKE A SIMPLE DRAWING OF A SYNCHRONOUS DISCHARGER AND EX PLAIN HOW IT OPERATES.

4. – WHAT IS THE DIFFERENCE BETWEEN AN INTERRUPTED CONTINUOUS WAVE AND THE TYPE OF WAVE RADIATED BY A SIMPLE SPARK TRAN SMITTER WHEN SENDING CODE SIGNALS?

5. – BY WHAT METHODS MAY CONTINUOUS WAVES BE GENERATED?

6. – DRAW A DIAGRAM OF A SIMPLE ARC TRANSMITTER CIRCUIT AND EX PLAIN HOW IT OPERATES.

7. – FOR WHAT TYPE OF RADIO COMMUNICATION ARE CONTINOUS WAVES ADAPTED?

8. – WHAT IS THE DIFFERENCE BETWEEN A "SYNCHRONOUS DISCHARGER" AND A "NON-SYNCHRONOUS DISCHARGER" AS USED IN A SPARK TRANS MITTER?

9. – HOW DOES A TELEGRAPH KEY ENABLE THE "DOTS" AND DASHES" OF THE CODE TO BE FORMED WHEN OPERATING A TRANSMITTER WHICH RADIATES AN INTERRUPTED CONTINUOUS WAVE?

10. – WHY IS A BEAT NOTE OSCILLATOR USED IN CONJUNCTION WITH A RECEIVER WHEN LISTENING TO C.W. CODE SIGNALS?

NOTICE:– BE SURE TO NUMBER ALL OF YOUR EXAMINATION PAPERS FOR THE ADVANCED LESSON GROUPS TO CORRESPOND WITH THE LESSON NUMBER APPEARING AT THE TOP OF THE EXAMINATION PAGE IN EACH OF THESE LESSONS. FOR EXAMPLE, THE NUMBER OF THIS LESSON IS T-1. THIS IS IMPORTANT.

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Los Angeles, California

Transmitters

LESSON NO. 2

• VACUUM TUBE OSCILLATORS •

You have already been told that modern transmitters employ vacuum tube oscillators in order to generate the radio frequency energy which is to be used for radiating continuous waves and in this lesson, you are going to be shown how such oscillators function and the methods of using them in transmitter circuits.

PRODUCING OSCILLATIONS

Our first step will be to see how electrical oscillations can be produced in a vacuum tube circuit and in Figure 2 you are shown the fundamental circuit of an inductive feed-back type oscillator. Here, you will notice, that we have a small plate coil connected in series with the plate circuit of the tube and at the same time closely coupled to the grid coil of the same tube so that there is mutual inductance between these two coils.

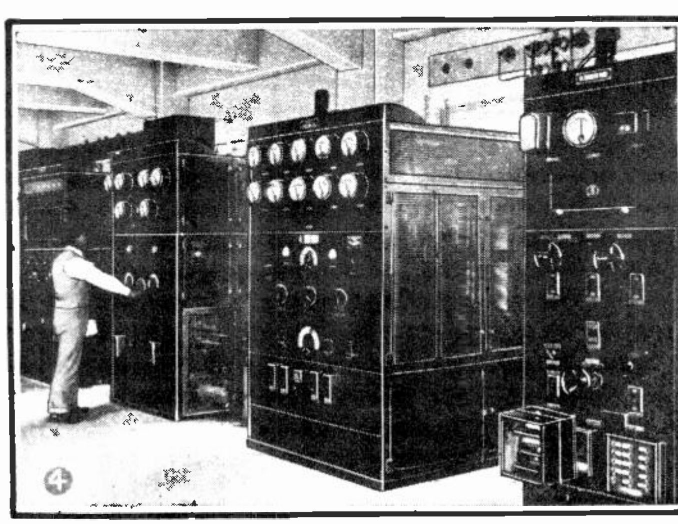

FIG. 1
Engineer at Work Adjusting a Transmitter.

When it is desired to set this system in operation, the first step taken is to close the filament circuit so that the current furnished by the "A" supply can heat up the filament. The resulting electron emission will permit plate current to flow through the circuit.

This plate current must all flow through the plate coil and in doing so, a magnetic field is established around it. However, it is important to note that

Before this plate current reaches its peak value, a certain length of time is required and during which period the resulting magnetic field produced by the plate coil is undergoing an expanding impulse. .

Since the plate and grid coils are inductively coupled, the expanding field of the plate coil will cut through the turns of the grid coil and in so doing induce an E.M.F. in the grid coil. If conditions are such that the upper end of the grid winding at this particular instant becomes positive while its lower end becomes negative, then the grid of the tube will have a positive charge impressed upon it. This in turn will cause the flow of plate current to increase.

This increasing plate current causes a still greater expansion of the magnetic field around the plate coil, which results in a still greater induction in the grid coil and the application of a still higher positive potential upon the grid of the tube. This causes a further increase in the plate current and the application of still higher positive potentials upon the grid. This building-up process continues in this way up to a certain point and which is dependent upon the characteristics of the tube as well as the resistance of the circuit.

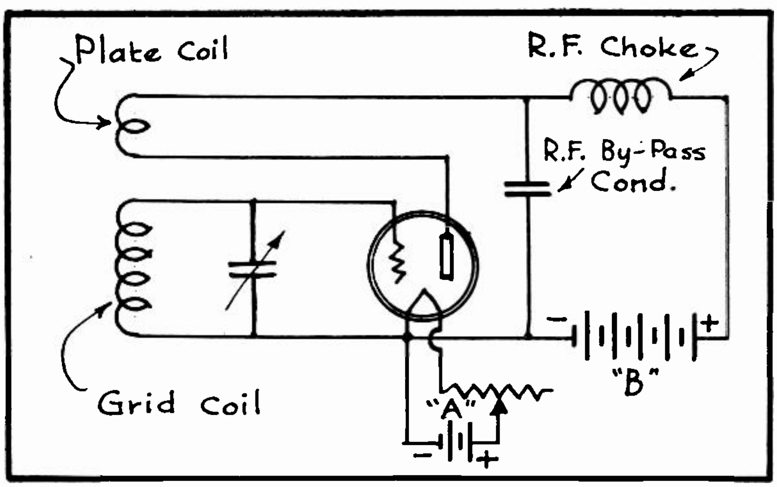

FIG. 2
A Fundamental Oscillator Circuit.

Finally, the plate current will stop increasing and herefore the magnetic field of the plate coil no longer continues to expand. At this time, no voltage can be induced in the grid winding and the voltage at the grid thus drops to zero. This brings about a reduction in the plate current and a collapse of the magnetic field. Since the lines of force are now moving in a direction opposite to their former direction of travel, the polarity of the grid coil will at this time be reversed, that is, its upper end will now be negative and its lower end positive. This means that a negative voltage will now be applied to the grid and thereby reduce the flow of plate current still more.

The plate current will continue to decrease in this manner, dropping below its normal value until a point is finally reached at which no further decrease takes place and the grid potential remains constant for an instant. The current then commences to increase again and the cycle as just described will repeat itself, continuing in this manner indefinitely as long the operating voltages are applied to the tube.

Although the "B" supply furnishes a direct current, yet when the tube is in a state of oscillation, the plate current rises and falls with re-

SPECT TO THE NORMAL PLATE CURRENT (THE NORMAL PLATE CURRENT IS THAT PLATE CURRENT VALUE WHICH FLOWS WHEN NO "SIGNAL" VOLTAGE IS APPLIED TO THE GRID). THIS NORMAL PLATE CURRENT VALUE THEREFORE IS EQUIVALENT TO THE ZERO LINE OR LEVEL IN THE WAVE FORM OF A TRUE ALTERNATING CURRENT. IT IS CUSTOMARY TO REFER TO THE RISES AND FALLS IN PLATE CURRENT AS THE A.C. COMPONENT OF THE PLATE CURRENT AND IT IS OBVIOUS THAT IF A CURRENT OF THIS TYPE PASSES THROUGH THE PRIMARY WINDING OF A TRANSFORMER, A.C. VOLTAGES WILL THROUGH INDUCTION APPEAR ACROSS THE SECONDARY TERMINALS. THE A.C. COMPONENT OF AN OSCILLATOR'S PLATE CURRENT CAN THEREFORE PRODUCE THE SAME RESULTS AS A CONVENTIONAL ALTERNATING CURRENT.

IN FIG. 3 YOU ARE SHOWN A GROUP OF CURVES WHICH ILLUSTRATE CLEARLY HOW AN ALTERNATING E.M.F. WHEN APPLIED TO THE GRID OF THE OSCILLATOR TUBE CAN PRODUCE AN A.C. COMPONENT OF STILL GREATER MAGNITUDE IN THE PLATE CIRCUIT AND IT IS IMPORTANT TO REMEMBER THAT THE A.C. GRID VOLTAGE AS APPLIED TO THE GRID OF THE OSCILLATOR TUBE IS OBTAINED FROM THE TRANSFER OF PLATE ENERGY TO THE GRID CIRCUIT.

IT IS REALLY THE ABILITY OF A VACUUM TUBE TO AMPLIFY WHICH ENABLES IT TO FUNCTION AS AN OSCILLATOR. IN OTHER WORDS, SINCE THE POWER REQUIRED BY THE INPUT OF AN AMPLIFIER IS MUCH LESS THAN THE AMPLIFIED OUTPUT, THE AMPLIFIER TUBE CAN BE MADE TO SUPPLY ITS OWN INPUT. IT IS ALSO TRUE THAT AT THE TIME THE CIRCUIT GOES INTO OSCILLATION, THE R.F. ENERGY AS FURNISHED BY THE PLATE CIRCUIT TO THE GRID CIRCUIT IS GREAT ENOUGH SO AS TO REDUCE THE GRID CIRCUIT LOSSES TO ZERO.

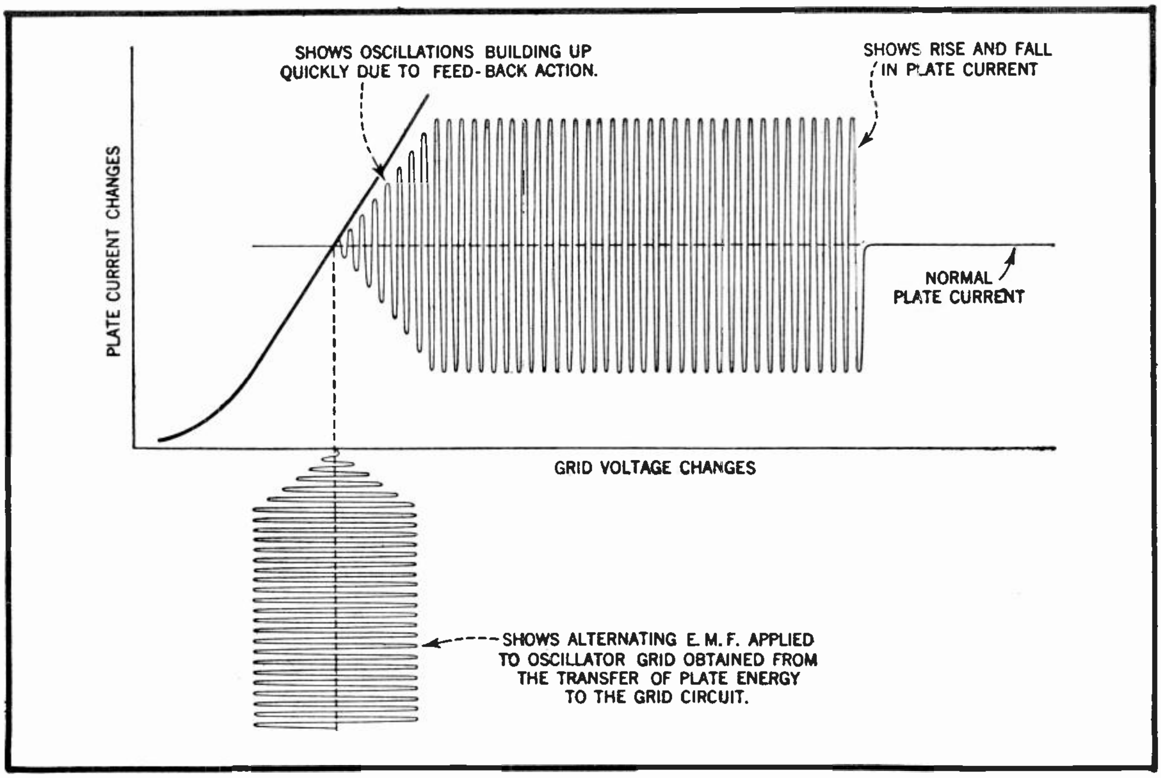

FIG. 3

Curves Showing How High-Frequency A.C. is Generated by the Oscillator Circuit.

OBSERVE IN FIG. 3 THAT THE OSCILLATIONS BUILD UP QUITE RAPIDLY UNTIL THE FINAL AMPLITUDE IS REACHED AND THAT WHEN ONCE IN OPERATION, THE WAVE FORM IS CONTINUOUS AND OF CONSTANT AMPLITUDE AND IT IS THIS FEATURE WHICH PERMITS THE VACUUM TUBE OSCILLATOR TO PRODUCE A CONTINUOUS WAVE. THE FREQUENCY OF OSCILLATION, OR THE FREQUENCY AT WHICH THE PLATE CURRENT RISES AND FALLS IS GOVERNED BY THE CAPACITIVE AND INDUCTIVE VALUES AS USED IN THE TUNED CIRCUIT (THE GRID CIRCUIT IN THE CASE OF FIG.2).

IN PRACTICE, SEVERAL FUNDAMENTAL OSCILLATOR CIRCUITS ARE EMPLOYED AND THESE SHALL NOW BE EXPLAINED IN THEIR PROPER ORDER.

THE HARTLEY OSCILLATOR

IN FIG. 4 YOU ARE SHOWN WHAT IS KNOWN AS A "SHUNT-FEED" HARTLEY OSCILLATOR. BY STUDYING THIS DIAGRAM CAREFULLY, YOU WILL OBSERVE THAT WE HAVE FIRST A COIL OR INDUCTANCE L AND A VARIABLE CONDENSER C WHICH TOGETHER FORM THE TUNING CIRCUIT. THE UPPER END OF COIL L IS CONNECTED TO THE GRID OF THE TUBE AND THE LOWER END OF THIS SAME COIL IS CONNECTED TO THE PLATE OF THE TUBE THRU THE COUPLING CONDENSER C_2. THE FILAMENT CIRCUIT AND B— ARE CONNECTED TO COIL L AT A POINT BETWEEN ITS END CONNECTIONS AND THIS RESULTS IN THE UPPER SECTION OF COIL L BEING INCLUDED IN THE GRID CIRCUIT AND THE LOWER SECTION OF L BEING INCLUDED IN THE PLATE CIRCUIT OF THE SAME TUBE. THEN SINCE THESE TWO SECTIONS ARE PARTS OF THE SAME WINDING, WE HAVE THE GRID AND PLATE CIRCUITS OF THIS TUBE SO COUPLED THAT OSCILLATIONS CAN BE PRODUCED AS ALREADY EXPLAINED RELATIVE TO FIG. 2.

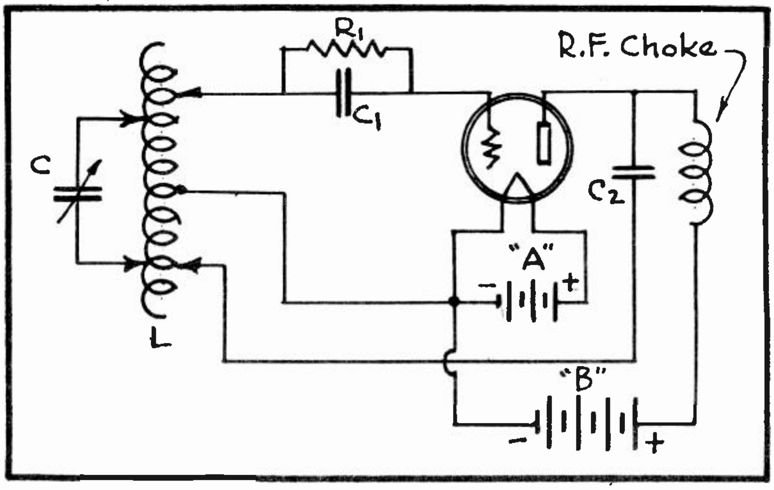

FIG. 4
Shunt-Feed Hartley Oscillator

THE CONNECTIONS AT COIL L WHICH ARE INDICATED BY MEANS OF THE ARROW HEADS INDICATE THAT THESE CONNECTIONS ARE SUBJECT TO CHANGE AT THE TIME THE OSCILLATOR IS BEING ADJUSTED FOR OPERATION. IT IS CUSTOMARY TO WIND COIL L WITH COPPER TUBING SO THAT A SPACE-WOUND, SELF-SUPPORTING COIL IS OBTAINED AND TO USE CLIP CONNECTIONS AT THOSE POINTS WHICH ARE INDICATED BY THE ARROW HEADS IN FIG. 4.

THE R.F. CHOKE PROVIDES A HIGH IMPEDANCE TO RADIO FREQUENCY CURRENTS IN THE "B" CIRCUIT OF THIS TUBE AND THEREBY FORCES THE R.F. ENERGY THRU CONDENSER C_2 INTO THE LOWER SECTION OF COIL L.

THE PURPOSE OF THE CONDENSER C_1 AND THE LEAK RESISTOR R_1 AS USED IN THIS CIRCUIT IS TO KEEP THE AVERAGE POTENTIAL OF THE GRID NEGATIVE WITH RESPECT TO THE FILAMENT. CONDENSER C_1 OFFERS PRACTICALLY NO OPPOSITION TO THE HIGH FREQUENCY CURRENTS SO THAT R.F. VOLTAGES CAN BE APPLIED THRU IT

AND IMPRESSED UPON THE GRID OF THE TUBE. EACH TIME THAT THE INSTANTANEOUS GRID POTENTIAL IS POSITIVE, ELECTRONS ARE ATTRACTED TO THE GRID AND PERMITTED TO FLOW THROUGH THE GRID CIRCUIT BY BEING SHUNTED AROUND C_1 THRU RESISTOR R_1. SINCE THIS GRID CURRENT FLOW THROUGH R_1 IS ALWAYS IN THE SAME DIRECTION, THE RESULTING VOLT DROP ACROSS R_1 CAN BE USED AS A BIAS VOLTAGE FOR THE TUBE — THE GRID BEING NEGATIVE WITH RESPECT TO THE FILAMENT.

THE SERIES-FEED HARTLEY OSCILLATOR

THE "SERIES-FEED" HARTLEY OSCILLATOR IS ILLUSTRATED IN FIG. 5. THIS CIRCUIT IN GENERAL IS QUITE SIMILAR TO THE HARTLEY CIRCUIT OF FIG. 4 BUT IT DIFFERS IN THAT IN THE SERIES-FEED SYSTEM, THE LOWER SECTION OF COIL L IS USED TO COMPLETE THE CONNECTION BETWEEN B- AND A-. IN OTHER WORDS, IN THE SERIES-FEED SYSTEM, THE LOWER SECTION OF COIL L IS IN SERIES WITH THE "B" CIRCUIT. THIS BEING TRUE, WE HAVE HERE ANOTHER CASE WHERE THE GRID AND PLATE CIRCUITS ARE CLOSELY COUPLED SO THAT OSCILLATION CAN BE PRODUCED. THE PURPOSE OF CONDENSER C_2 IS TO PROVIDE A SHUNTING PATH AROUND THE "B" SUPPLY SO THAT NONE OF THE RADIO FREQUENCY ENERGY WILL BE COMPELLED TO FLOW THROUGH THE "B" SUPPLY.

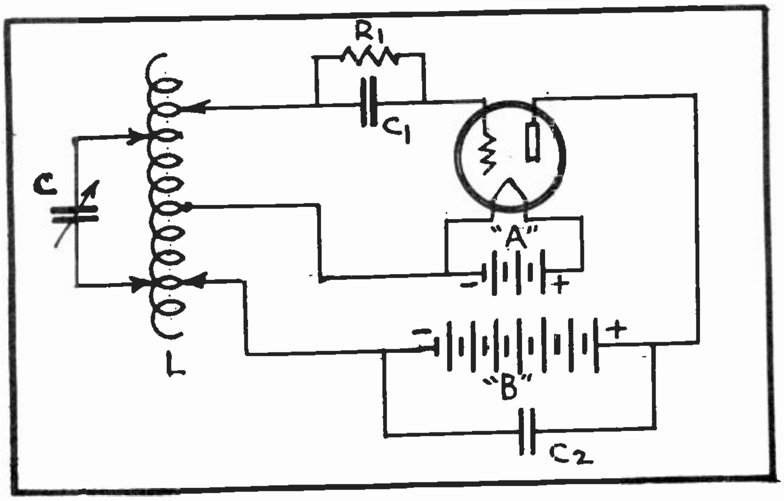

FIG. 5
Series-Feed Hartley Oscillator.

THE COLPITTS CIRCUIT

IN THE OSCILLATORS AS SO FAR DESCRIBED, FEED-BACK WAS ACCOMPLISHED THROUGH INDUCTIVE COUPLING BETWEEN THE PLATE AND GRID CIRCUITS OF THE OSCILLATOR TUBE. IN ADDITION TO THIS METHOD, IT IS ALSO POSSIBLE TO OBTAIN THIS FEED-BACK BY UTILIZING CAPACITY COUPLING BETWEEN THE PLATE AND GRID CIRCUITS OF THE TUBE. A CIRCUIT OF THIS TYPE IS SHOWN YOU IN FIG. 6 AND IT IS KNOWN AS THE COLPITTS SYSTEM.

BY STUDYING FIG. 6 CAREFULLY, YOU WILL OBSERVE THAT THE TWO SERIES CONNECTED CONDENSERS C_1 AND C_2 ARE TOGETHER CONNECTED ACROSS COIL L. IT IS ALSO TRUE THAT CONDENSERS C_2 AND C_3 ARE EFFECTIVELY CONNECTED IN SERIES AND TOGETHER SHUNTED ACROSS THE "B" SUPPLY. THE GRID CONDENSER C_4 AND LEAK RESISTOR R_1 FUNCTION IN THE SAME MANNER AS ALREADY EXPLAINED RELATIVE TO THE PRECEDING CIRCUITS.

WITH THESE POINTS IN MIND, LET US NOW SEE HOW THIS SYSTEM OPERATES:

AT THE TIME THE FILAMENT CIRCUIT IS COMPLETED, ELECTRON EMISSION TAKES PLACE AND PLATE CURRENT COMMENCES TO FLOW. THE R.F. CHOKE IN THE PLATE CIRCUIT OPPOSES ANY FLOW OF RADIO FREQUENCY CURRENT THROUGH IT AND FORCES THE R.F. ENERGY THROUGH CONDENSERS C_3 AND C_2 WHICH ARE CONNECTED IN

SHUNT WITH THE "B" CIRCUIT AND THEREFORE VOLTAGE DROPS OF CORRESPONDING VARIATION APPEAR ACROSS THE PLATES OF CONDENSER C_2. THE METHOD OF CONNECTION BETWEEN C_1—C_2 AND L ARE SUCH THAT IF A VOLTAGE DROP OR DIFFERENCE OF POTENTIAL IS ESTABLISHED ACROSS THE PLATES OF C_2, A VOLTAGE DROP OR DIFFERENCE OF POTENTIAL MUST ALSO APPEAR ACROSS CONDENSER C_1 AND WHICH WILL RESULT IN A VOLTAGE DIFFERENCE BETWEEN THE FILAMENT AND GRID ACROSS WHICH IT IS CONNECTED. THIS CHANGE IN THE VOLTAGE DIFFERENCE BETWEEN THE FILAMENT AND GRID WILL PRODUCE A CORRESPONDING CHANGE IN THE PLATE CURRENT AND WHICH IN TURN WILL BRING ABOUT A FURTHER CHANGE IN GRID POTENTIAL DUE TO THE CORRESPONDING VOLTAGE CHANGES WHICH APPEAR ACROSS C_2 AND C_1 ON ACCOUNT OF THE FEED-BACK. SINCE THE A.C. COMPONENT OF THE PLATE CIRCUIT IS BEING UTILIZED FOR FEED-BACK, ALTERNATING-POTENTIAL VARIATIONS ARE BEING APPLIED TO THE GRID AND THE PHASE RELATION IN THE CIRCUITS IS SUCH THAT SELF-SUSTAINED OSCILLATIONS RESULT.

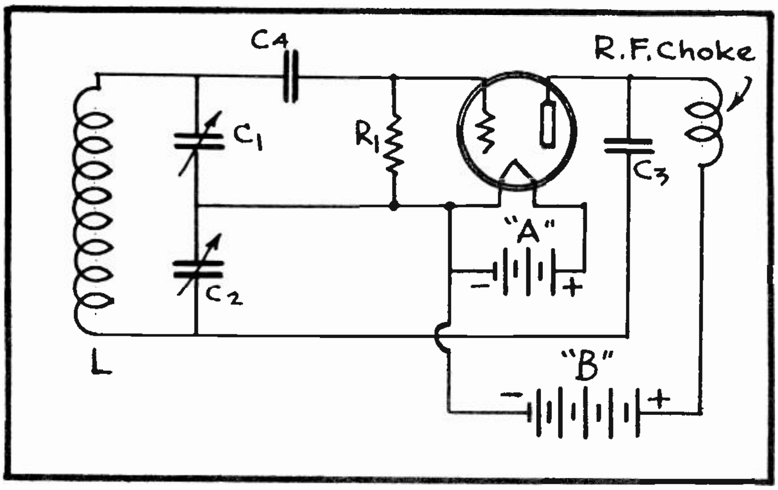

FIG. 6
The Colpitts Oscillator.

THE FEED-BACK EFFECT IS INFLUENCED BY THE CAPACITY OF CONDENSERS C_1 AND C_2 AND THE FREQUENCY OF OSCILLATION IS DETERMINED BY THE INDUCTANCE VALUE OF COIL L IN CONJUNCTION WITH THE CAPACITIVE VALUES OF CONDENSERS C_1 AND C_2.

THE TUNED-PLATE, TUNED-GRID OSCILLATOR

IN FIG.7 YOU ARE SHOWN A TUNED- PLATE, TUNED-GRID OSCILLATOR AND WHICH ALSO MAKES USE OF A CAPACITIVE FEED-BACK SYSTEM. IN THIS CASE, ONE TUNED CIRCUIT CONSISTING OF L_1 AND C_1 IS CONNECTED ACROSS THE GRID CIRCUIT AND ANOTHER TUNED CIRCUIT CONSISTING OF L_2 AND C_2 IS CONNECTED IN THE PLATE CIRCUIT.

WHEN THESE TWO CIRCUITS ARE TUNED TO RESONANCE WITH EACHOTHER, R.F. ENERGY OF THIS SAME FREQUENCY IS REJECTED BY THE TUNED PLATE CIRCUIT AND SOME IF IT IS FORCED THROUGH THE TUBE'S GRID-PLATE CAPACITY AND THUS APPLIED TO THE GRID. VOLTAGE CHANGES THUS IMPRESSED UPON THE TUBE'S GRID AT RADIO FREQUENCIES WILL CAUSE CORRESPONDING VARIATIONS IN PLATE CURRENT AND SINCE THE OUTPUT POWER OF THE TUBE IS MUCH GREATER THAN THE INPUT POWER REQUIRED TO PRODUCE IT, CONTINUOUS OSCILLATIONS CAN BE GENERATED THE SAME AS ALREADY EXPLAINED RELATIVE TO THE SYSTEMS PREVIOUSLY DESCRIBED.

THE R.F. CHOKE AND CONDENSER C_4 ARE USED IN THE CIRCUIT OF FIG.7 SO THAT THERE WILL BE NO TENDENCY FOR R.F. ENERGY TO PASS THROUGH THE "B" SUPPLY. THE GRID CONDENSER C_3 AND THE LEAK RESISTOR R_1 FUNCTION IN THE SAME MANNER AS ALREADY EXPLAINED FOR THESE SAME UNITS EARLIER IN THIS LESSON.

THE MEISSNER CIRCUIT

IN THE MEISSNER CIRCUIT WHICH IS ILLUSTRATED IN FIG.8 WE HAVE THREE

COILS INDUCTIVELY COUPLED. COIL L_1 IS INCLUDED IN THE GRID CIRCUIT AND INDUCTIVELY COUPLED TO THE ANTENNA COIL, WHILE COIL L_2 IS INCLUDED IN THE PLATE CIRCUIT AND ALSO INDUCTIVELY COUPLED TO THE ANTENNA COIL. NEITHER L_1 NOR L_2 IS TUNED — THE FREQUENCY OF OSCILLATION IN THIS CIRCUIT BEING CONTROLLED BY TUNING THE ANTENNA CIRCUIT.

IN THIS CIRCUIT RADIO FREQUENCY ENERGY IN THE PLATE CIRCUIT IS INDUCED FROM COIL L_2 INTO THE ANTENNA COIL WITH WHICH IT IS COUPLED AND THE ANTENNA COIL IN TURN INDUCES VOLTAGES OF CORRESPONDING FREQUENCY INTO THE GRID COIL L_1 WITH WHICH IT IS COUPLED. IN THIS MANNER REGENERATION AND OSCILLATION IS PRODUCED.

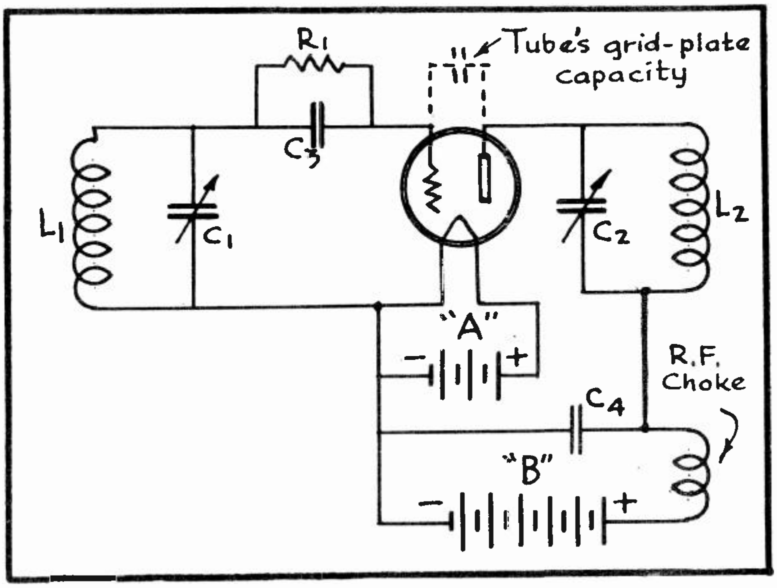

FIG. 7
Tuned-Plate, Tuned-Grid Oscillator.

THE "TNT" CIRCUIT

THE CIRCUITS AS SO FAR DESCRIBED ARE THE FUNDAMENTAL OSCILLATOR CIRCUITS BUT IN PRACTICE YOU WILL FIND THAT IN ADDITION TO THESE, A NUMBER OF MODIFICATIONS OF THESE FUNDAMENTAL CIRCUITS ARE EMPLOYED. IN FIG. 9, FOR INSTANCE, WE HAVE WHAT IS KNOWN AS THE "T.N.T." CIRCUIT.

BY STUDYING FIG. 9 CAREFULLY, YOU WILL OBSERVE THAT THE TUNING CIRCUIT IS HERE INCLUDED IN THE PLATE CIRCUIT OF THE TUBE AND CONSISTS OF THE COIL L_1 AND THE CONDENSER C_1. THE GRID COIL L_2 IS SO CONSTRUCTED THAT ITS INDUCTANCE TOGETHER WITH ITS DISTRIBUTED CAPACITY AND THE ADDITIONAL CAPACITY INTRODUCED BY THE GRID CIRCUIT WIRING PERMITS IT TO RESONATE BROADLY AT THE OPERATING FREQUENCY. THE GRID-PLATE CAPACITY OF THE TUBE PROVIDES THE NECESSARY FEED-BACK THE SAME AS IN THE TUNED-GRID, TUNED-PLATE OSCILLATOR — THE ONLY DIFFERENCE BEING THAT THE GRID COIL IS NOT TUNED BY A CONDENSER.

THE ELECTRON-COUPLED OSCILLATOR

FIG. 10 SHOWS YOU HOW A SCREEN GRID TUBE OF THE HEATER TYPE IS USED IN AN ELECTRON-COUPLED OSCILLATOR CIRCUIT. THE SCREEN GRID, CATHODE AND CONTROL GRID ARE CONNECTED IN A HARTLEY CIRCUIT SO AS TO GENERATE THE OSCILLATIONS. THE AMPLIFIED R.F. ENERGY IS TAKEN FROM THE TUNING CIRCUIT WHICH IS CONNECTED IN SERIES WITH THE PLATE. IN OTHER WORDS, THIS ARRANGEMENT SERVES AS AN OSCILLATOR AS WELL AS AN R.F. AMPLIFIER SO THAT THE R.F. ENERGY IN ADDITION TO BEING GENERATED CAN ALSO BE AMPLIFIED BY THE SAME TUBE.

ALTHOUGH BATTERIES ARE SHOWN AS SUPPLYING THE "B" VOLTAGES, AND ALSO THE "A" VOLTAGE IN THESE DIFFERENT OSCILLATOR CIRCUITS, YET YOU MUST BEAR IN MIND THAT THE OSCILLATOR CIRCUIT ARRANGEMENT REMAINS THE SAME REGARD-

LESS OF THE TYPE OF POWER SUPPLY BEING USED. THE DIFFERENT POWER SUPPLIES AS USED WITH TRANSMITTERS AND ALSO COMPLETE TRANSMITTER CIRCUIT DIAGRAMS TOGETHER WITH THEIR PROPER POWER SUPPLIES WILL ALL BE BROUGHT TO YOUR ATTENTION AT THE PROPER TIME IN THE COURSE.

TWO-TUBE OSCILLATORS

SOMETIMES, IT IS DESIRED TO OBTAIN A GREATER POWER OUTPUT FROM AN OSCILLATOR THAN CAN BE SUPPLIED FROM A SINGLE TUBE OF THE TYPE AVAILABLE. IN SUCH CASES, IT IS THEREFORE THE PRACTICE TO USE TWO TUBES TO FUNCTION SIMULTANEOUSLY AS OSCILLATORS AND IN THIS WAY FURNISH APPROXIMATELY TWICE THE POWER OUTPUT OF A SINGLE TUBE. ONE METHOD IS TO CONNECT THE TWO OSCILLATOR TUBES IN PARALLEL, THAT IS, USING THE SAME FUNDAMENTAL OSCILLATOR CIRCUIT AS WITH A SINGLE TUBE BUT TO CONNECT TOGETHER THE GRIDS, THE PLATES AND THE FILAMENTS OF TWO SIMILAR TUBES.

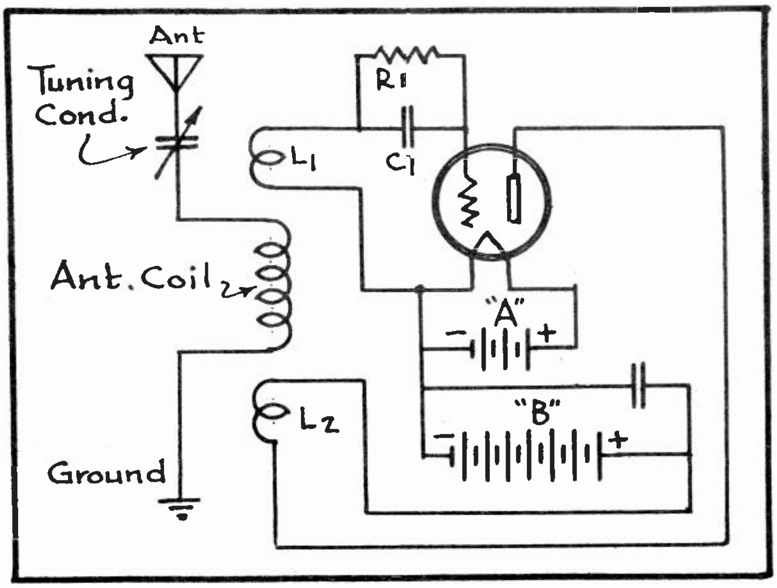

FIG. 8
The Meissner Circuit.

A PARALLEL OSCILLATOR CONNECTION, HOWEVER, IS NOT ALTOGETHER DESIRABLE IN THAT THIS ARRANGEMENT ALSO PLACES THE GRID-PLATE CAPACITIES OF THE TWO TUBES IN PARALLEL AND IN THIS WAY INCREASES THE FEED-BACK. WHEN TWO TUBES ARE TOGETHER INVOLVED IN THIS WAY THE FEED-BACK IS NOT EASILY CONTROLLED.

IF TWO OSCILLATOR TUBES ARE WANTED, THEN IT IS BETTER TO CONNECT THEM IN A PUSH-PULL ARRANGEMENT. THE PUSH-PULL CIRCUIT IN THIS CASE WILL HAVE THE SAME CHARACTERISTICS AS A PUSH-PULL TUBE CONNECTION IN AUDIO AMPLIFIERS. IN OTHER WORDS, THE PUSH-PULL OSCILLATOR CONNECTION ALSO PROVIDES US WITH ABOUT TWICE THE POWER OUTPUT OF A SINGLE TUBE AND IN ADDITION PLACES THE GRID-PLATE CAPACITIES OF THE TWO TUBES EFFECTIVELY IN SERIES.

IN THIS MANNER, WE ARE THEREFORE ABLE TO REALIZE A GREATER POWER OUTPUT AND AT THE SAME TIME REDUCE THE GRID-PLATE CAPACITY SO THAT FEED-BACK CAN BE READILY CONTROLLED. IT IS FOR THESE REASONS THAT THE PUSH-PULL CONNECTION IS MOST USED WHERE DUAL OSCILLATOR TUBES ARE EMPLOYED.

THE PUSH-PULL OSCILLATOR

A SIMPLE FORM OF PUSH-PULL OSCILLATOR IS SHOWN YOU IN FIG. 11 AND WHICH YOU WILL NO DOUBT READILY RECOGNIZE AS BEING BASED ON THE T.N.T. CIRCUIT.

Coil L_1 of the plate tuned circuit is center-tapped and connected to B+, while its extremeties are each connected to one of the oscillator tube plates. The R.F. choke L_2 which is connected across the grids of the two tubes is also center-tapped, the center tap being connected to B- and the electrical center of the filament circuit through the blocking condenser C_2 and the leak resistor R_1. The purpose of the condenser C_3 is to serve as a high frequency by-pass around the B supply.

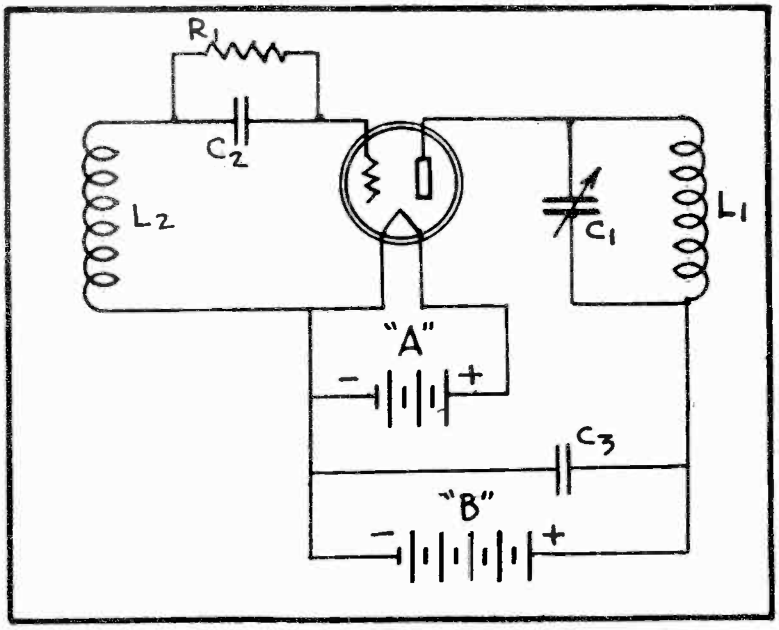

FIG. 9
The "T.N.T." Circuit.

From what you have already learned in this lesson concerning an oscillator circuit of this type when using a single tube in conjunction with what you already know about push-pull operation, you should have no difficulty whatever in acquiring an intelligent understanding of the circuit presented in Fig. 11.

THE TUNED-PLATE, TUNED-GRID, PUSH-PULL OSCILLATOR

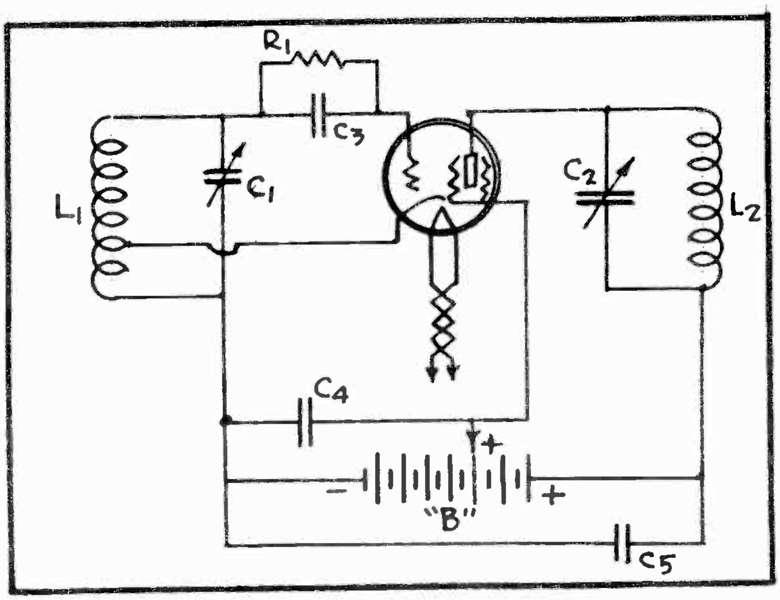

FIG. 10
The Electron-Coupled Oscillator.

In Fig. 12 you will see how two tubes can be operated in a push-pull arrangement by using the tuned-plate, tuned-grid oscillator principle. Here, the grid coil L_1 is center tapped and tuned by condenser C_1 — the center tap is connected to B- and the electrical center of the filament circuit through the blocking condenser C_3 and the leak resistor R_1. The plate coil L_2 is also center tapped and tuned by condenser C_2 — the center tap being connected to B+. The other connections

AND CIRCUIT COMPONENTS ARE SELF-EXPLANATORY BY THIS TIME.

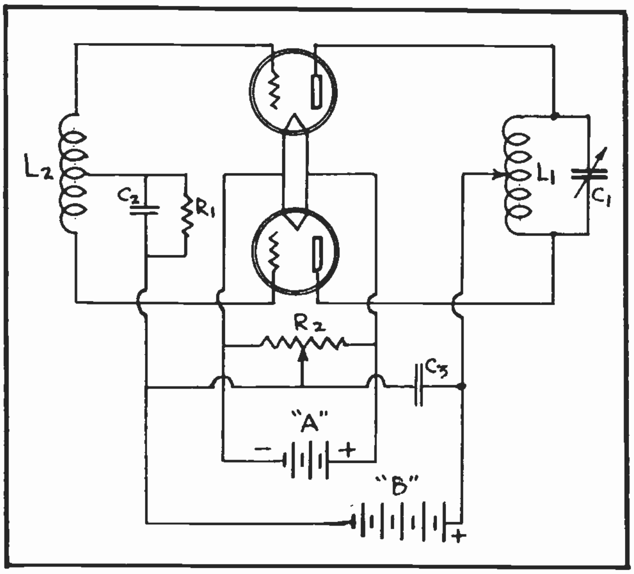

FIG. 11

The Push-Pull Oscillator.

WHEN PUSH-PULL OSCILLATOR TUBES ARE USED, THE T.N.T. AND TUNED-PLATE, TUNED-GRID ARRANGEMENTS ARE MOST GENERALLY EMPLOYED, HOWEVER, THE HARTLEY AND COLPITTS SYSTEM CAN ALSO BE APPLIED IN A PUSH-PULL CIRCUIT.

THE PUSH-PULL HARTLEY CIRCUIT

FOR YOUR INFORMATION YOU ARE SHOWN IN FIG. 13 A HARTLEY OSCILLATOR CIRCUIT IN WHICH TWO TUBES ARE USED IN PUSH-PULL. HERE THE BASIC PUSH-PULL ARRANGEMENT IS USED AND IN ADDITION THE COUPLING CONDENSERS C_2 AND C_3 ARE CONNECTED BETWEEN THE GRIDS OF THE TUBES AND OPPOSITE ENDS OF THE PLATE COIL L_1. THESE CONDENSERS ARE USED TO PERMIT FEED-BACK AND THEIR POINT OF CONNECTION TO L_1 IS VARIABLE SO THAT MORE OR LESS OF COIL L_1 CAN BE INCLUDED IN THE FEED-BACK CIRCUIT FOR BOTH TUBES. DUE TO THE MANY CONNECTIONS WHICH ARE NECESSARY AT COIL L_1 WHEN USING THIS CIRCUIT, THE COIL IN THIS CASE BECOMES QUITE CUMBERSOME AND AWKWARD TO HANDLE.

OTHER THAN THE FEED-BACK CONNECTIONS AT THE COIL L_1 THE CIRCUIT IN GENERAL DIFFERS VERY LITTLE FROM THE OTHER PUSH-PULL CIRCUITS SHOWN YOU IN THIS LESSON.

THE PUSH-PULL COLPITTS CIRCUIT

THE PUSH-PULL COLPITTS CIRCUIT IS SHOWN YOU IN FIG. 14. HERE THE CONDENSERS C_1 AND C_2 WHICH TOGETHER TUNE THE CIRCUIT MUST BE EITHER INDIVIDUAL CONDENSERS OR ELSE A SPLIT STATOR CONDENSER. THE VARIABLE GRID CONDENSERS C_3 AND C_4 ARE USED TO FURNISH A CONTROL OF GRID EXITATION.

THE REMAINING FEATURES OF THIS CIRCUIT FOLLOW THE

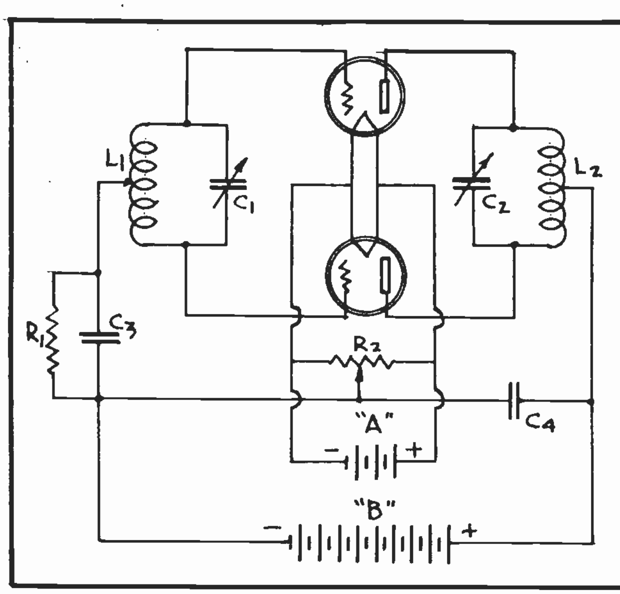

FIG. 12

The Tuned-Plate, Tuned Grid Push-Pull Oscillator.

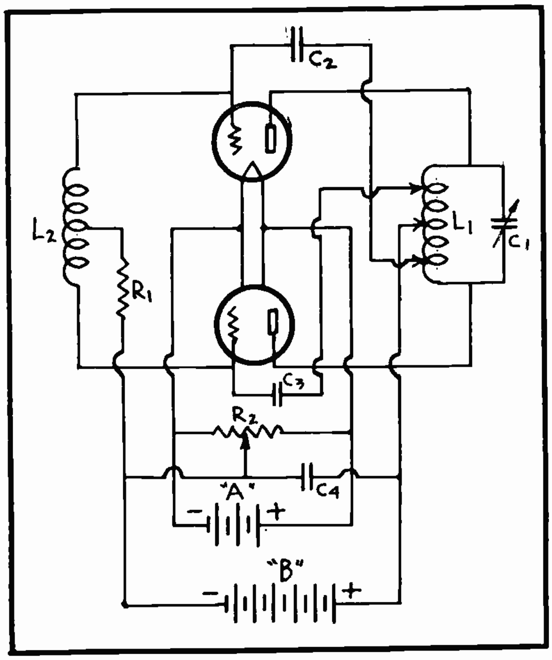

FIG. 13
The Push-Pull Hartley Circuit.

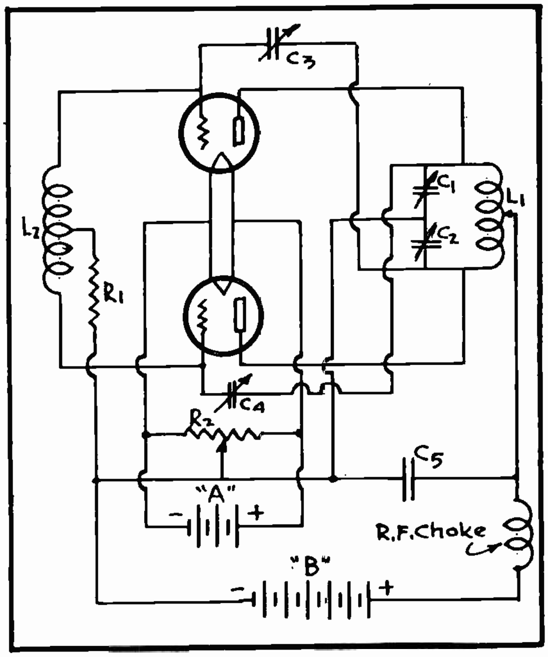

FIG. 14
The Push-Pull Colpitts Circuit.

SAME DESIGN PRINCIPLES AS THE OTHERS SO FAR DESCRIBED IN THIS LESSON AND THERE IS THEREFORE NO NEED FOR REPEATING THIS INFORMATION AT THE PRESENT TIME.

IN THIS LESSON YOU HAVE HAD THE OPPORTUNITY OF BECOMING ACQUAINTED WITH THE BASIC OSCILLATOR CIRCUITS AS USED IN TRANSMITTERS FOR BOTH CODE AND PHONE TRANSMISSION. IN THE FOLLOWING LESSON YOU ARE GOING TO CONTINUE YOUR TRANSMITTER STUDIES BY APPLYING THESE FUNDAMENTAL OSCILLATOR CIRCUITS TO LOW-POWER CODE TRANSMITTERS AND WHERE YOU WILL ALSO BE GIVEN COMPLETE CONSTRUCTIONAL DATA AS WELL AS THE ELECTRICAL VALUES OF THE PARTS USED AND CORRECT PROCEDURE FOR OPERATING SUCH TRANSMITTERS. YOU WILL THEN ADVANCE IN LOGICAL STEPS THROUGH YOUR CODE STUDIES, THE APPLICATION OF R.F. AMPLIFICATION TO TRANSMITTERS, MODULATION SYSTEMS ETC. SO THAT BY THE TIME YOU COMPLETE THIS SERIES OF LESSONS TREATING WITH TRANSMITTERS, YOU WILL HAVE A MOST THOROUGH KNOWLEDGE OF THIS DIVISION OF THE RADIO FIELD.

Answered 7/18/41

LESSON NO. T-2

Study and understudy. After you have really mastered your job and know more about it than anyone else, study the job of the man ahead. Be an understudy. Be prepared for opportunity

1. - Draw a diagram of a fundamental vacuum tube oscillator circuit and explain how oscillation is produced.

2. - Draw a diagram of a shunt-feed Hartley oscillator and explain how it operates.

3. - Draw a diagram of the Colpitts oscillator and explain how it operates.

4. - Draw a diagram of a tuned-plate, tuned-grid oscillator and explain how it operates.

5. - Draw a diagram of the T.N.T. oscillator circuit and explain how it operates.

6. - What advantages are obtained by employing two tubes in a push-pull oscillator circuit and why is this arrangement preferable to parallel connected oscillator tubes?

7. - Draw a diagram of a tuned-plate, tuned-grid push-pull oscillator and explain how it operates.

8. - What is the difference between the series-feed Hartley oscillator and the shunt-feed Hartley oscillator?

9. - Why in oscillator circuits is it customary to connect a by-pass condenser across the B power supply circuit?

10.- Draw a diagram of the Meissner oscillator circuit and explain how it operates.

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Transmitters

LESSON NO. 3

• LOW-POWER TRANSMITTERS •

WITH WHAT YOU HAVE LEARNED IN THE PREVIOUS LESSON ABOUT VACUUM TUBE OSCILLATORS, YOU ARE NOW IN A POSITION TO STUDY ABOUT LOW-POWER TRANSMITTERS IN THEIR COMPLETE FORM AND THE CORRECT METHOD OF OPERATING THEM. IT IS NO MORE BUT LOGICAL THAT WE START THIS STUDY WITH THE SIMPLER CIRCUITS INVOLVING AN OSCILLATOR STAGE ONLY AND THEN GRADUALLY ADVANCE THROUGH THE MORE COMPLEX SYSTEMS IN WHICH A GREATER NUMBER OF TUBES ARE EMPLOYED.

YOU WILL ALSO FIND THAT FOR THE PRESENT, ONLY CODE-TRANSMITTERS ARE BEING CONSIDERED IN THAT THESE TRANSMITTERS MAKE USE OF MORE SIMPLE CIRCUIT DESIGNS THAN DO THE PHONE TRANSMITTERS WHICH ARE DESCRIBED IN LATER LESSONS.

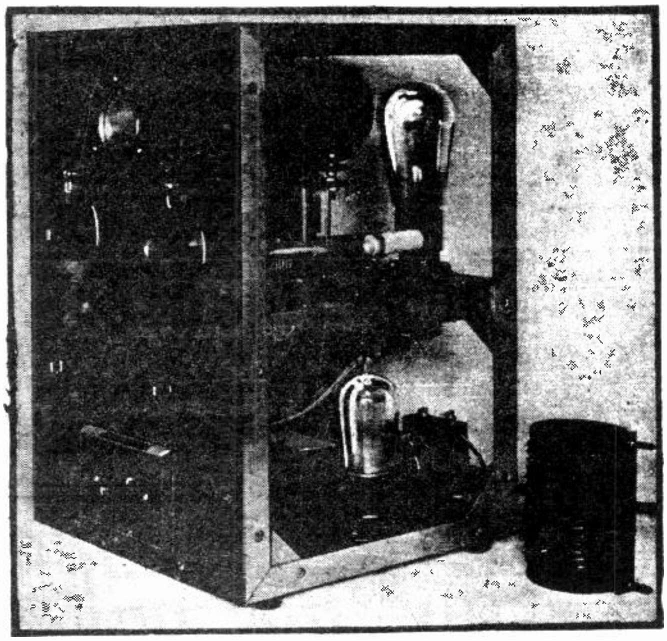

FIG. 1
An Attractive Low-Power Transmitter.

WE WANT YOU TO UNDERSTAND CLEARLY, THAT THE CONSTRUCTIONAL DATA AS FURNISHED IN THESE LESSONS IS OFFERED SOLELY FOR INSTRUCTIONAL PURPOSES AND THAT IT IS UNLAWFUL TO OPERATE ANY OF THIS TRANSMITTING EQUIPMENT WITHOUT FIRST HAVING PASSED THE REQUIRED EXAMINATION AND RECEIVED A LICENSE FROM THE FEDERAL COMMUNICATIONS COMMISSION (FORMERLY KNOWN AS THE FEDERAL RADIO COMMISSION) TO

OPERATE AN AMATEUR STATION.

LATER IN THIS COURSE, YOU WILL RECEIVE MORE SPECIFIC DATA AS TO THE REQUIREMENTS FOR QUALIFYING FOR SUCH A LICENSE.

A ONE-TUBE TRANSMITTER

IN FIG.2 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES AND GENERAL LAY OUT OF A LOW-COST, LOW-POWER TRANSMITTER. THIS TRANSMITTER, YOU WILL OBSERVE, REQUIRES BUT A SINGLE TUBE, OPERATING AS AN OSCILLATOR. IN THE PARTICULAR ILLUSTRATION HERE SHOWN A TYPE -45 TUBE IS BEING USED. THIS TUBE WILL FUNCTION SPLENDIDLY WHEN FILAMENT AND "B" VOLTAGES ARE SUPPLIED BY THE POWER PACK WHICH IS DESCRIBED LATER IN THIS LESSON.

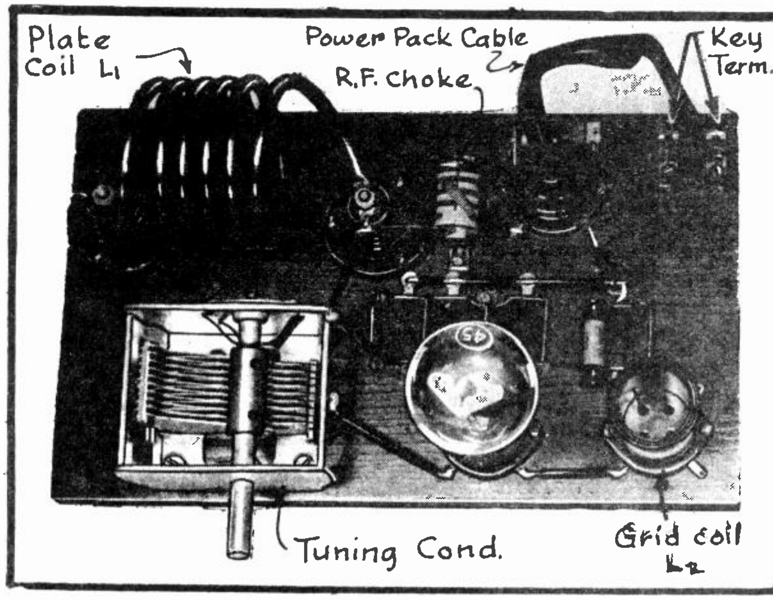

FIG.2
The One Tube Transmitter.

FOR BATTERY OPERATION, A TYPE 30 TUBE CAN BE USED WITH 90 VOLTS ON THE PLATE OR ELSE A TYPE -71A OR AN -01A WITH 180 VOLTS ON THE PLATE. FOR A STILL GREATER POWER OUTPUT AND WHEN A SUITABLE A.C. POWER PACK IS AVAILABLE, THEN A TYPE -10 TUBE CAN BE USED WITH 500 VOLTS APPLIED TO THE PLATE.

THE CIRCUIT DIAGRAM OF THIS PARTICULAR TRANSMITTER APPEARS IN FIG.3 AND IS HERE SHOWN USING A TYPE-45 TUBE. BY INSPECTING THIS DIAGRAM CLOSELY, YOU WILL READILY REALIZE HOW IT RESEMBLES THE BASIC OSCILLATOR CIRCUITS WHICH WERE SHOWN YOU IN THE PREVIOUS LESSON.

THE TUNING CIRCUIT OF THIS TRANSMITTER CONSISTS OF THE PLATE COIL L_1 ACROSS WHICH A CONVENTIONAL RECEIVER TYPE VARIABLE CONDENSER OF .00035 MFD. RATING IS CONNECTED.

COIL L_1 IS WOUND OF 1/4" DIAMETER SOFT COPPER TUBING, A PIPE OR DRY CELL APPROXIMATELY 2 3/8" IN DIAMETER BEING USED AS THE WINDING FORM. AFTER THE WINDING HAS BEEN COMPLETED, THE FORM IS REMOVED AND THE ENDS OF THE COIL ARE FLATTENED AND DRILLED SO AS TO FIT OVER THE MACHINE SCREWS IN THE STAND-OFF INSULATORS AS SHOWN IN FIG. 2.

ALL PARTS OF THIS TRANSMITTER ARE MOUNTED ON A WOODEN BOARD AND CAN BE LOCATED QUITE EASILY DIRECT FROM FIG. 2. THE STAND-OFF INSULATORS FOR SUPPORTING COIL L_1 ARE MOUNTED DIRECTLY BEHIND THE TUNING CONDEN

SER AND THE DISTANCE BETWEEN THE TWO INSULATORS IS 5" AS MEASURED BETWEEN CENTERS.

So THAT THIS TRANSMITTER CAN BE OPERATED IN EITHER THE 20; 40 OR 80 METER BANDS IN WHICH AMATEURS MAY CONDUCT CODE COMMUNICATION, THREE DIFFERENT COILS ARE USED FOR L_1. THE SPECIFICATIONS FOR THIS SET OF THREE PLATE COILS ARE AS FOLLOWS:

80 METER BAND	14 TURNS
40 METER BAND	6 TURNS
20 METER BAND	4 TURNS

THE GRID COIL L_2 IS ALSO WOUND AS A SET OF THREE TO COVER THE 20; 40 AND 80 METER BANDS — EACH BEING WOUND ON A STANDARD FOUR-PRONG PLUG-IN COIL FORM OF 1¼" DIAMETER. THE SPECIFICATIONS FOR THE GRID COIL FOLLOW:

80 METER BAND, 50 TURNS
40 METER BAND, 15 TURNS
20 METER BAND, 6 TURNS

ALL OF THESE GRID COILS ARE WOUND WITH #30 B&S DOUBLE COTTON COVERED MAGNETIC WIRE. GRID COIL L_2 IS INSERTED IN THE FOUR-HOLE SOCKET WHICH IS MOUNTED DIRECTLY TO THE RIGHT OF THE TUBE IN FIG. 2.

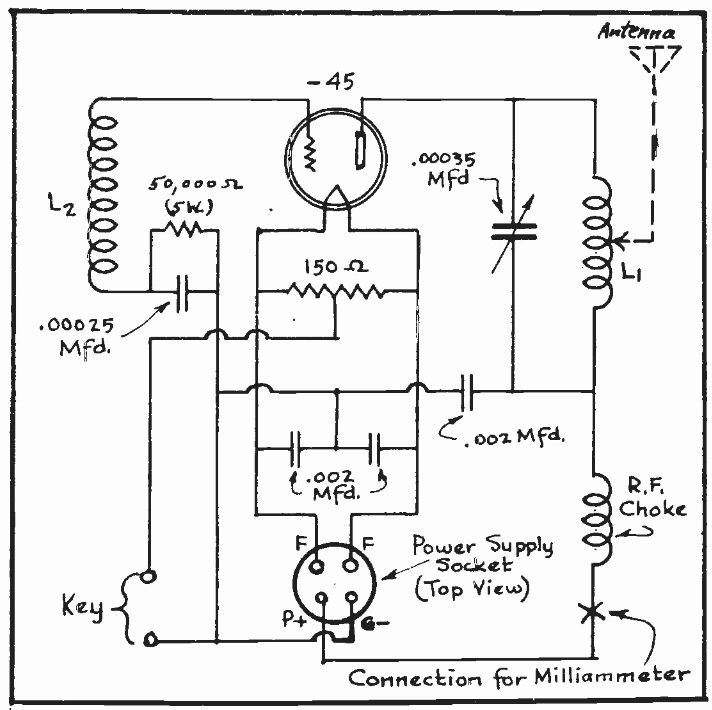

FIG. 3
Circuit Diagram of the Transmitter.

NOTICE IN FIG. 3 THAT A 150 OHM CENTER-TAPPED FILAMENT RESISTOR IS CONNECTED ACROSS THE FILAMENT CIRCUIT AND THAT ITS CENTER TAP SERVES AS THE B- CONNECTION. YOU WILL ALSO OBSERVE IN THIS SAME DIAGRAM THAT THE TERMINALS FOR THE KEY ARE SO PLACED THAT THE KEY WILL BE CONNECTED IN SERIES WITH THE NEGATIVE SIDE OF THE "B" CIRCUIT AND IN THIS WAY PROVIDE A MEANS WHEREBY THE PLATE CIRCUIT CAN BE COMPLETED OR INTERRUPTED TO FORM THE DOTS AND DASHES OF THE CODE.

THE VARIOUS BY-PASS CONDENSERS WHICH ARE USED MAY BE OF THE TYPE SUITABLE FOR RECEIVERS BUT SHOULD HAVE A MICA DIELECTRIC. THE PURPOSE OF THE TWO SERIES CONNECTED .002 MFD. CONDENSERS WHICH ARE CONNECTED ACROSS THE FILAMENT CIRCUIT IS TO PROVIDE A HIGH FREQUENCY PATH FROM THE FILAMENT TO B- SO THAT THE HIGH FREQUENCY CURRENTS WON'T HAVE TO PASS THRU THE FILAMENT RESISTOR OR KEY.

A STANDARD SHORT-WAVE R.F. CHOKE MAY BE USED IN THIS CIRCUIT BUT

IT IS IMPORTANT THAT IT BE CAPABLE OF PASSING 100 MILLIAMPERES.

THE CIRCUITS ARE ALL WIRED WITH HEAVY BUS BAR AND THE LEADS ARE MADE AS SHORT AS POSSIBLE SO THAT THE RESISTANCE OF THE VARIOUS CIRCUITS WILL BE REDUCED TO A MINIMUM.

THE POWER PACK

THIS TRANSMITTER IS CONNECTED TO ITS POWER PACK BY MEANS OF A FOUR-WIRE CABLE AND THROUGH A PLUG AND SOCKET CONNECTION — THE SOCKET BEING MOUNTED ON THE TRANSMITTER AND THE CABLE WITH PLUG TO THE POWER PACK. THE CORRESPONDING POWER PACK IS SHOWN IN FIG. 4 AND ITS CIRCUIT DIAGRAM IN FIG. 5.

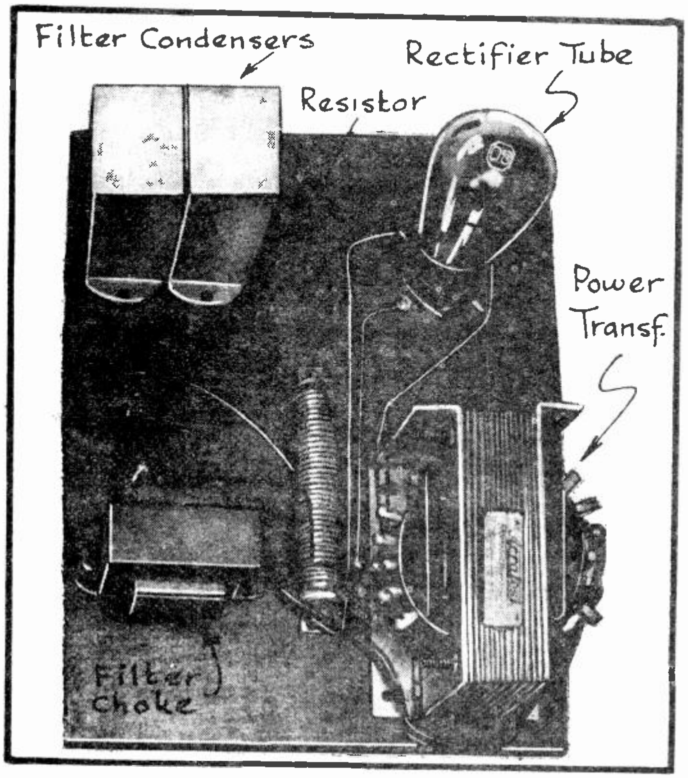

FIG. 4
The Power Pack.

YOU WILL IMMEDIATELY REALIZE THAT THIS POWER PACK FOLLOWS THE SAME CONVENTIONAL DESIGN AS USED IN A.C. RECEIVERS AND THERE IS THEREFORE NO PARTICULAR NEED FOR OFFERING ANY ADDITIONAL EXPLANATIONS REGARDING IT.

THE ANTENNA

IN A LATER LESSON YOU WILL BE GIVEN COMPLETE INSTRUCTIONS REGARDING TRANSMITTER ANTENNA SYSTEMS BUT IN ORDER THAT THE TRANSMITTER WHICH IS NOW BEING DESCRIBED WILL NOT BE INCOMPLETE, THE ANTENNA DATA RELATED THERETO SHALL NOW BE GIVEN.

THE ANTENNA WHICH IS TO BE USED WITH THIS TRANSMITTER IS OF THE MOST SIMPLE TYPE AND SO THAT THE TRANSMITTER MAY BE OPERATED ON EITHER THE 20; 40 OR 80 METER BANDS, ITS DIMENSIONS SHOULD CORRESPOND WITH THE DIAGRAM WHICH HAS BEEN PREPARED FOR YOU IN FIG. 6. HERE YOU WILL OBSERVE THAT THE TOTAL LENGTH OF THE ANTENNA FROM INSULATOR TO INSULATOR AMOUNTS TO 133 FT. AND THE WIRE USED FOR THIS PURPOSE IS A #14 B&S SOLID, ENAMELED WIRE.

THE "FEEDER" WHICH CORRESPONDS TO THE LEAD-IN ON A RECEIVING TYPE ANTENNA IS TAKEN OFF FROM A POINT 18 FT — 7 INCHES FROM THE CENTER OF THE ELEVATED WIRE OR FLAT-TOP. A HEAVY RUBBER-COVERED COPPER WIRE MAY BE USED AS THE FEEDER AND ITS LENGTH IS NOT CRITICAL. IT SHOULD, HOWEVER, RUN AT RIGHT ANGLES TO THE FLAT TOP FOR AT LEAST THE FIRST 30% OF ITS LENGTH.

NO GROUNDING SYSTEM IS USED IN CONJUNCTION WITH THIS TRANSMITTER

AND ITS ANTENNA.

SO MUCH FOR THE CONSTRUCTIONAL FEATURES OF THE TRANSMITTER. YOUR NEXT STEP WILL BE TO LEARN HOW THIS TRANSMITTER IS TO BE TUNED AND ADJUSTED SO THAT IT WILL OPERATE CORRECTLY AND IN THE PROPER FREQUENCY BAND. FOR THIS WORK, MOST AMATEUR OPERATORS USE A UNIT WHICH IS KNOWN AS A MONITOR AND SO THIS WILL BE DESCRIBED TO YOU NEXT, AFTER WHICH YOU WILL BE SHOWN HOW IT IS USED IN ORDER TO ADJUST THE TRANSMITTER.

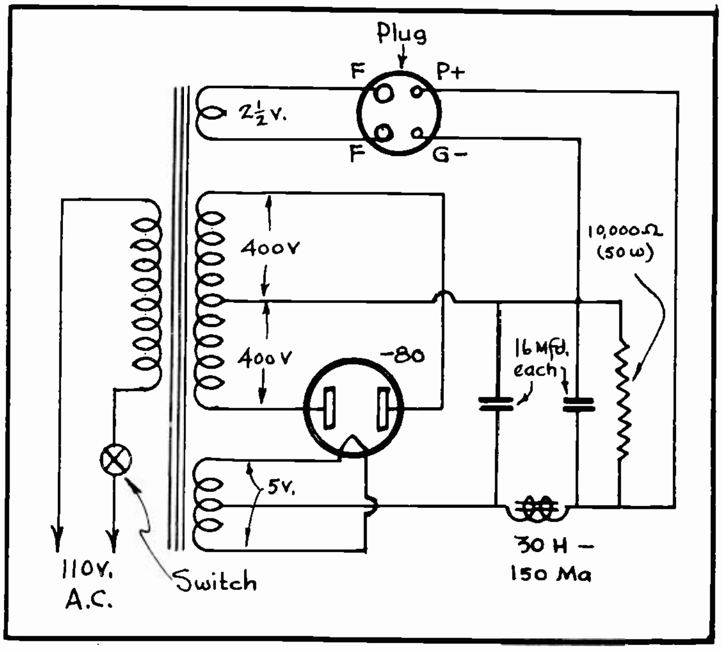

FIG. 5

Diagram of the Power Pack.

THE MONITOR

AN EXTERNAL VIEW OF A TYPICAL MONITOR IS SHOWN YOU IN FIG. 7, WHILE THE INTERNAL CONSTRUCTION OF THIS SAME UNIT IS SHOWN IN FIG. 8.

THE MONITOR IS IN REALLITY A SMALL ONE-TUBE, TOTALLY SHIELDED REGENERATIVE RECEIVER. THE PARTICULAR MONITOR HERE SHOWN USES A TYPE 30 TUBE AND THE TWO SERIES CONNECTED DRY CELLS FOR THE "A" BATTERY, AS WELL AS THE SMALL SIZE 45 VOLT "B" BATTERY, ARE ALL CONTAINED DIRECTLY IN THE SHIELD CAN TOGETHER WITH THE COIL, TUNING CONDENSER AND THE OTHER MISCELLANEOUS PARTS.

THE CIRCUIT DIAGRAM OF THIS MONITOR IS PRESENTED TO YOU IN FIG. 9 AND BY STUDYING THIS DIAGRAM YOU WILL SEE HOW SIMPLE IN CONSTRUCTION IT REALLY IS.

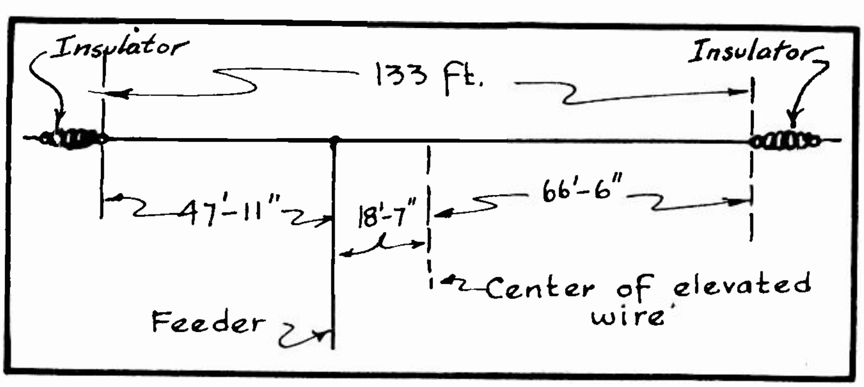

FIG. 6

The Antenna Dimensions.

SO THAT THIS MONITOR MAY ALSO COVER THE 20–40 AND 80 METER BANDS IN WHICH THIS TRANSMITTER IS TO BE OPERATED, IT IS ALSO PROVIDED WITH THREE SETS OF COILS — ONE FOR EACH BAND.

THE PLATE

AND GRID COIL FOR EACH COIL SET ARE BOTH WOUND TOGETHER ON A CONVENTIONAL PLUG-IN TYPE COIL FORM — THE WINDINGS BEING ARRANGED AS ILLUSTRATED IN FIG. 10. BOTH WINDINGS FOR ALL THREE WAVE BANDS ARE WOUND WITH #30 B&S DOUBLE COTTON- COVERED WIRE AND THE WINDING SPECIFICATIONS FOLLOW:

FIG. 7
Front View of the Monitor.

WAVE BAND	GRID COIL	PLATE COIL
80 METER	43 TURNS	20 TURNS
40 METER	15 TURNS	10 TURNS
20 METER	7 TURNS	7 TURNS

IN ALL CASES, NO SPACING IS TO BE ALLOWED BETWEEN THE GRID AND PLATE WINDINGS.

THE MONITOR POSSESSES TWO IMPORTANT CHARACTERISTICS, NAMELY, (1) IT OFFERS A MEANS OF LISTENING TO THE STATION TRANSMITTER'S SIGNAL AT LOW VOLUME AND OF THE SAME TONE AND CHARACTERISTIC AS WILL THESE SAME SIGNALS BE HEARD AT A DISTANT RECEIVING STATION. (2) THE MONITOR ALSO FUNCTIONS AS A MINIATURE TRANSMITTER SO THAT ITS SIGNAL CAN BE PICKED UP BY THE STATION RECEIVER.

CALIBRATING THE MONITOR

THE NEXT STEP IS TO CALIBRATE THE MONITOR AND THIS IS ACCOMPLISHED IN THE MANNER AS WILL NOW BE DESCRIBED.

FIRST, A GOOD SHORT-WAVE RECEIVER SHOULD BE AVAILABLE. AFTER THE RECEIVER HAS BEEN OPERATED FOR SOME TIME, ONE WILL BE FAMILIAR WITH THE LOCATION OF THE DIFFERENT AMATEUR BANDS WITH RESPECT TO THE RECEIVER'S DIAL SETTINGS. HAVING LOCATED ONE OF THESE AMATEUR BANDS IN THIS WAY, THE NEXT STEP IS TO TUNE IN SEVERAL COMMERCIAL AND GOVERNMENT STATIONS WHICH OPERATE CLOSEST TO BOTH ENDS OF THE PARTICULAR AMATEUR BAND IN QUESTION. THE FREQUENCY OF THESE STATIONS CAN BE DETERMINED BY CONSULTING A RADIO CALL BOOK IN WHICH ALL COMMERCIAL STATIONS ARE LISTED TOGETHER WITH THEIR FREQUENCY ASSIGNMENTS.

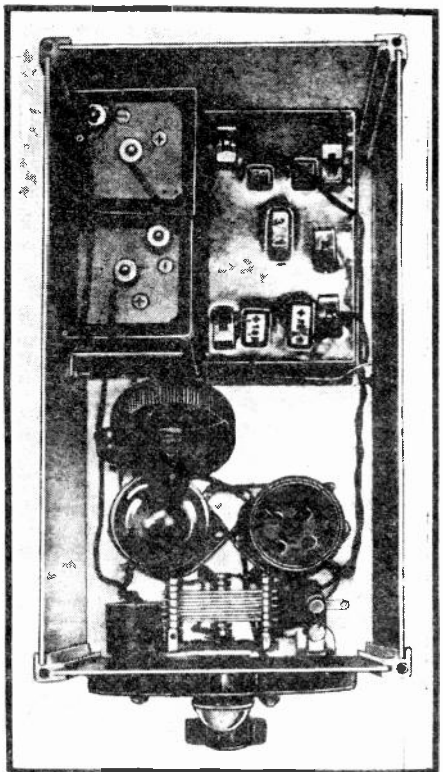

FIG. 8
Internal View of the Monitor.

THESE STATIONS ARE GENERALLY REFERRED TO AS "MARKER STATIONS" BY AMATEURS. WITH ONE OF THESE MARKER STATIONS LOCATED, THE MONITOR IS PLACED NEAR THE RECEIVER AND PUT INTO OPERATION, USING THE PROPER COIL FOR THE BAND IN QUESTION. THE MONITOR IS THEN TUNED SO THAT ITS SIGNAL IS AUD-

IBLE AT THE RECEIVER AND AT A FREQUENCY REASONABLY CLOSE TO THAT AT WHICH THE FIRST MARKER STATION WAS TUNED IN. THIS DONE, THE MARKER STATION IS TUNED INACCURATELY ON THE RECEIVER AND THE MONITOR DIAL IS THEN ROTATED CAREFULLY SO THAT THE MONITOR SIGNAL FREQUENCY WILL BE ADJUSTED TO ZERO BEAT WITH THE SIGNAL COMING FROM THE MARKER STATION. THE DIAL SETTING OF THE MONITOR IS THEN CAREFULLY NOTED AND THEN PLOTTED ON GRAPH PAPER WHICH IS RULED OFF IN TERMS OF DIAL SETTINGS AND KILOCYCLES AS SHOWN IN FIG. 11.

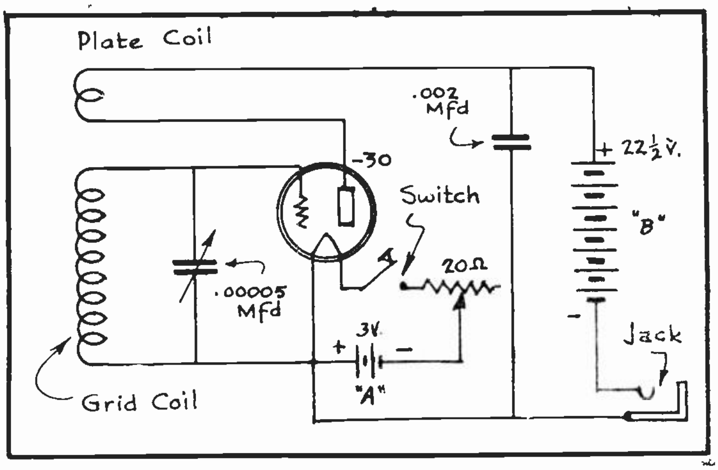

FIG. 9
Circuit Diagram of the Monitor.

THIS SAME PROCEDURE SHOULD BE REPEATED FOR EACH AVAILABLE MARKER STATION AND WHEN ALL THE CORRESPONDING MONITOR DIAL SETTINGS HAVE THUS BEEN PLOTTED ON THE GRAPH, A CONTINUOUS LINE IS DRAWN THROUGH THESE POINTS AND THIS RESULTS IN THE CALIBRATION CURVE FOR THE MONITOR. FROM THIS CURVE THE CORRESPONDING FREQUENCY FOR EACH DIAL SETTING OF THE MONITOR CAN BE DETERMINED WITH A REASONABLE AMOUNT OF ACCURACY. ONE SUCH CURVE MUST BE PLOTTED FOR EACH OF THE MONITOR COILS WHICH ARE USED. A SIMILAR SET OF CALIBRATION CURVES CAN AT THE SAME TIME BE PLOTTED FOR THE RECEIVER.

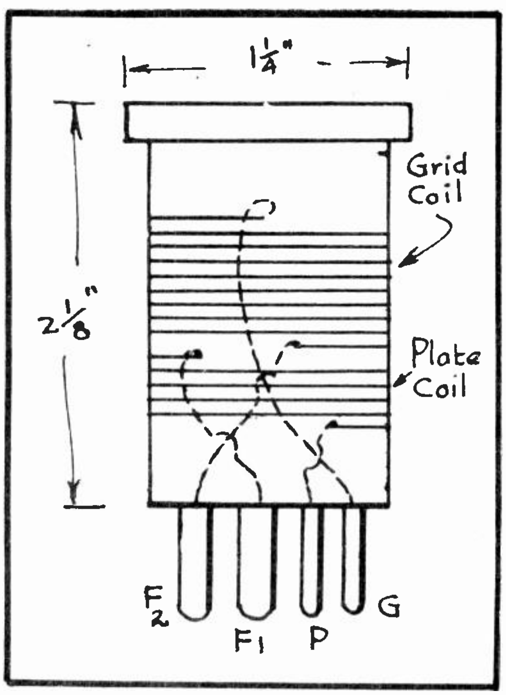

FIG. 10
The Monitor Coil.

IT IS TO BE UNDERSTOOD THAT THE MONITOR SIGNAL IS PICKED UP BY THE RECEIVER THROUGH RADIATION WHEN THE MONITOR IS PLACED REASONABLY CLOSE TO THE RECEIVER AND THAT NO WIRED CONNECTIONS ARE USED BETWEEN THESE TWO UNITS. SHOULD THE SHIELDING OF THE MONITOR BE TOO NEAR PERFECT, THEN SOMETIMES HOLES ARE DRILLED THROUGH THE SHIELDING SO THAT THE PROPER SIGNAL PICK-UP CAN BE OBTAINED.

TUNING THE TRANSMITTER

WHEN TUNING THE TRANSMITTER PREPARATORY TO GOING ON THE AIR, THE FIRST STEP IS TO INSTALL THE PROPER SET OF COILS FOR THE BAND TO BE USED AND THE TRANSMITTER IS FOR THE TIME BEING DISCONNECTED FROM THE ANTENNA FEEDER. NOW TUNE IN THE BAND WITH THE RECEIVER AND LOCATE A POINT WELL WITHIN THE BAND WHICH IS COMPARATIVELY CLEAR. THE MON

ITOR IS NOW ADJUSTED FOR THIS SAME FREQUENCY BY REFERENCE TO ITS CALIBRATION CURVE.

A MILLIAMMETER HAVING A RANGE FROM 0 TO 100 MA. IS CONNECTED IN SERIES WITH THE TRANSMITTER'S PLATE LEAD AT THE POINT MARKED WITH AN "X" IN FIG. 3. THE OPERATING MONITOR IS PLACED WITHIN A REASONABLE DISTANCE FROM THE TRANSMITTER AND ITS DIAL SETTING LEFT AT THE SAME POSITION WHICH HAS JUST PREVIOUSLY BEEN DETERMINED. THE NEXT STEP IS TO TURN THE TRANSMITTER DIAL UNTIL THE NEEDLE OF THE MILLIAMMETER DROPS TO A MINIMUM POSITION.

SOMEWHERE IN THAT PORTION OF THE DIAL WHERE A MINIMUM READING IS OBTAINED, A WHISTLE SHOULD BE HEARD IN THE EARPHONES WHICH ARE CONNECTED TO THE MONITOR. THE NUMBER OF TURNS USED ON THE GRID COIL SHOULD BE SUCH THAT THE MILLIAMMETER WILL READ MINIMUM AT THE LOW FREQUENCY END OF THE DIAL — IF IT DOESN'T, TURNS CAN BE ADDED TO OR TAKEN OFF THIS COIL.

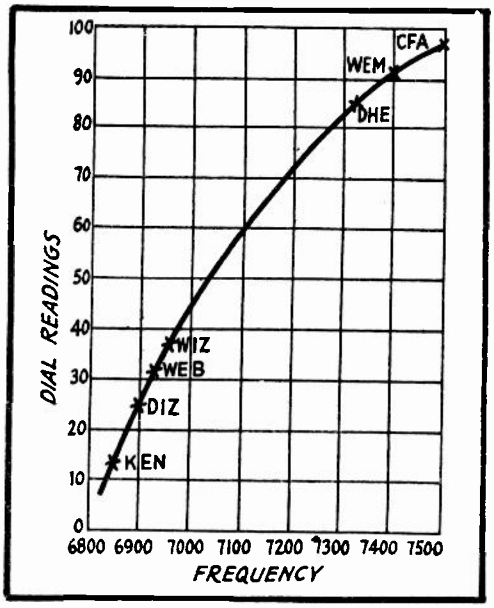

FIG. 11
A Calibration Curve.

WITH THE GRID COILS PROPERLY ADJUSTED, RETUNE THE TRANSMITTER FOR ZERO BEAT WITH THE MONITOR AND CLIP THE ANTENNA UNTO THE PLATE COIL, AT A POINT CORRESPONDING TO ONE TURN FOR THE 20, TWO TURNS FOR THE 40 AND FIVE TURNS FOR THE 80 METER COIL AS COUNTED FROM THE "COLD" OR PLATE BLOCKING CONDENSER END OF THIS COIL. ANY FINAL ADJUSTMENT IN TUNING CAN THEN BE MADE SO THAT THE TRANSMITTER FREQUENCY WILL BE THE SAME AS THAT FOR WHICH THE MONITOR IS TUNED. THE ANTENNA CAN BE CLIPPED ONTO THE PLATE AS NEAR THE HOT END AS POSSIBLE BUT WHICH STILL PERMITS SENDING A GOOD CLEAN NOTE.

FOR THE PARTICULAR ANTENNA SPECIFICATIONS WHICH WERE GIVEN FOR THIS TRANSMITTER, THE TRANSMITTER WILL OPERATE AT PEAK EFFICIENCY AT 3575 KC. IN THE 80 METER BAND AND ALSO AT THE HARMONIC 7150 KC. IN THE 40 METER BAND AND AT 14,300 KC. IN THE 20 METER BAND.

AFTER THE TRANSMITTER IS OPERATING PROPERLY AT THE CORRECT FREQUENCY, THE MONITOR CAN BE USED WITH THE HEADPHONES SO THAT THE OPERATOR CAN AT ALL TIMES "LISTEN-IN" AND CHECK UP ON THE QUALITY OF HIS TRANSMISSION.

A PUSH-PULL TRANSMITTER

THE SAME BASIC DESIGN AS JUST DESCRIBED RELATIVE TO THE ONE-TUBE TRANSMITTER CAN ALSO BE APPLIED TO A LOW-POWER PUSH-PULL TRANSMITTER. THE CONSTRUCTIONAL FEATURES OF THIS PUSH-PULL TRANSMITTER ARE SHOWN IN FIG. 12, WHERE YOU WILL SEE THE TRANSMITTER ITSELF, AS WELL AS THE POWER PACK.

THE CIRCUIT DIAGRAM OF THE PUSH-PULL TRANSMITTER APPEARS IN FIG.

13. AND BY STUDYING BOTH FIGS 12 AND 13 YOU WILL NOTICE THAT A PAIR OF TYPE-45 RECEIVER TUBES ARE EMPLOYED.

FROM WHAT YOU HAVE ALREADY LEARNED ABOUT TRANSMITTERS OF SIMILAR TYPE, THIS CIRCUIT IS SELF-EXPLANATORY. THE PLATE COIL TOGETHER WITH THE .0005 MFD. VARIABLE CONDENSER CONSTITUTES THE TUNING CIRCUIT AND THE SPECIFICATIONS FOR WINDING THIS COIL FOR THE 80; 40 AND 20 METER ARMATEUR BANDS FOLLOWS:

ALL THREE COILS ARE WOUND OF 1/4" DIAMETER SOFT COPPER TUBING AND ARE 2 3/8" IN DIAMETER. THE NUMBER OF TURNS USED ARE 12 FOR THE 80 METER BAND, 6 FOR THE 40 METER BAND AND 4 FOR THE 20 METER BAND. THE CENTER TAP CONNECTION TO THESE COILS CAN BE MADE BY MEANS OF A CLIP.

THE GRID COILS ARE ALL WOUND ON BAKELITE TUBING OF 1" DIAMETER AND WITHOUT ANY SPACING BETWEEN TURNS. EACH OF THESE GRID COILS IS FITTED WITH THREE PRONGS WHICH FIT INTO CORRESPONDING JACK-HOLES WHICH ARE MOUNTED IN A STRIP OF BAKELITE AND PLACED ON THE BASEBOARD OF THE TRANSMITTER. THIS GRID COIL CONSTRUCTION IS CLEARLY ILLUSTRATED IN FIG. 14.

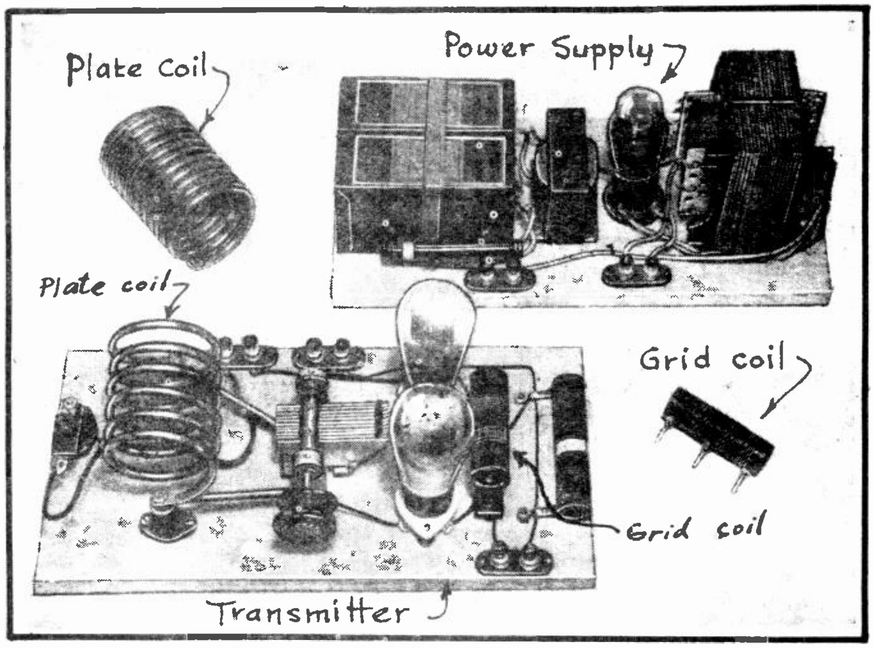

FIG. 12

The Push-Pull Transmitter and Power Supply.

EACH OF THESE GRID COILS IS WOUND IN TWO SECTIONS WITH A SPACE OF 9/16" BETWEEN SECTIONS. THE DATA FOR THESE COILS TO COVER THE THREE BANDS USED ARE AS FOLLOWS:

BAND	NO. OF TURNS	SIZE OF WIRE
80 METER	78	36 D.S.C.
40 METER	42	26 D.S.C.
20 METER	16	26 D.S.C.

THE SAME ANTENNA SYSTEM IS USED WITH THIS PUSH-PULL TRANSMITTER AS HAS BEEN RECOMMENDED FOR THE ONE-TUBE TRANSMITTER EARLIER IN THIS LESSON, ONLY THAT THE FEEDER IS CONNECTED TO THE PLATE COIL THROUGH A .001 MFD. MICA-DIELECTRIC FIXED CONDENSER.

THE POWER PACK FOR THIS TRANSMITTER IS DESIGNED TO FURNISH A "B"

VOLTAGE OF 400 VOLTS AND A TYPE -83 TUBE IS USED AS THE RECTIFIER. THE DIAGRAM FOR THIS POWER PACK APPEARS IN FIG. 15.

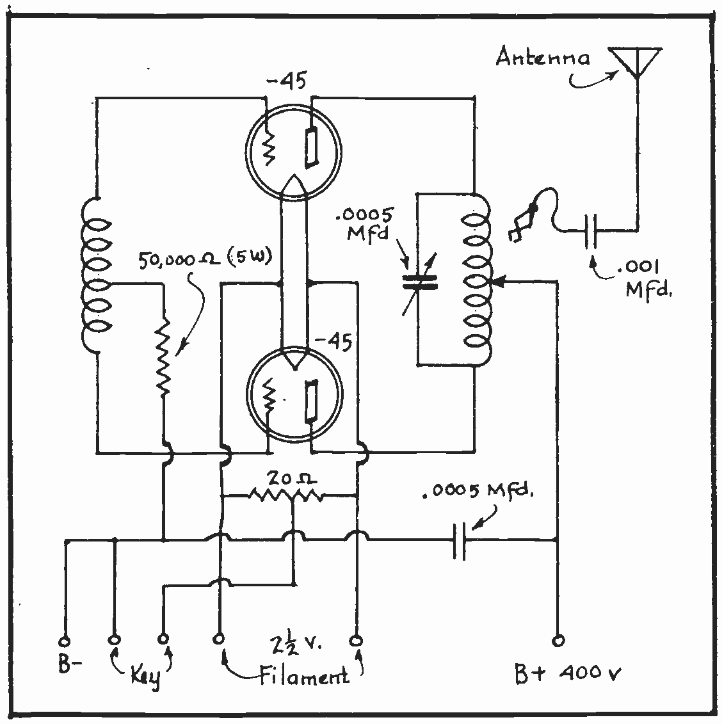

FIG. 13
Circuit of the Push-Pull Transmitter.

TO PREPARE THIS TRANSMITTER FOR OPERATION, THE SAME GENERAL PROCEDURE IS FOLLOWED AS HAS ALREADY BEEN EXPLAINED RELATIVE TO THE ONE-TUBE TRANSMITTER EARLIER IN THIS LESSON.

ANOTHER PUSH-PULL TRANSMITTER

IN FIG. 16 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF A TRANSMITTER WHICH EMPLOYS A PAIR OF TYPE -10 TUBES IN A PUSH-PULL, TUNED-PLATE, TUNED-GRID CIRCUIT. THIS TRANSMITTER CAN ALSO BE CONSTRUCTED ON A WOODEN BASEBOARD THE SAME AS THE OTHERS ALREADY DESCRIBED IN THIS LESSON.

THE POWER PACK FOR THIS TRANSMITTER USES A PAIR OF TYPE -81 TUBES AS RECTIFIERS AND DUE TO THE HIGH VOLTAGE BEING HANDLED, GREAT CARE SHOULD BE TAKEN IN SELECTING FILTER CONDENSERS FOR THIS POWER PACK. THE FIRST FILTER CONDENSER AT THE INPUT END OF THE FILTER, FOR EXAMPLE, SHOULD BE RATED AT 1000 VOLTS D.C. OR HIGHER, AS SHOULD ALSO THE CENTER FILTER CONDENSER. A RATING OF APPROXIMATELY 750 VOLTS D.C. IS REQUIRED FOR THE FILTER CONDENSER WHICH IS PLACED AT THE OUTPUT END OF THE FILTER. THE FILTER CHOKES SHOULD EACH BE CAPABLE OF CARRYING 150 MILLIAMPERES AS SHOULD ALSO THE SHORT-WAVE R.F. CHOKE (R.F.C.). THE POWER TRANSFORMER IS TO BE EQUIPPED WITH A PRIMARY WINDING DESIGNED FOR THE LINE VOLTAGE BEING USED, TWO 7½ VOLT SECONDARIES, AND A 1100 VOLT CENTER-TAPPED SECONDARY.

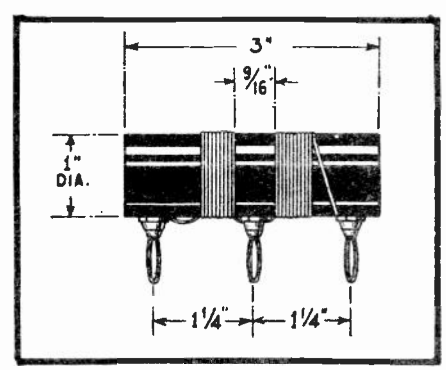

FIG. 14
Details of the Grid Coil.

COILS L_1 AND L_2 OF THE TRANSMITTER CIRCUIT ARE IDENTICAL FOR EACH WAVE BAND AND THE SAME WINDING SPECIFICATIONS CAN BE USED AS ALREADY SPECIFIED FOR THE PLATE COIL L_1 AS USED IN THE TRANSMITTER WHOSE CIRCUIT DIAGRAM APPEARS IN FIG. 3 OF THIS LESSON. THE CENTER TAP CONNECTION AT EACH OF THESE

COILS CAN BE MADE BY MEANS OF GOOD CLIPS HAVING STRONG SPRINGS.

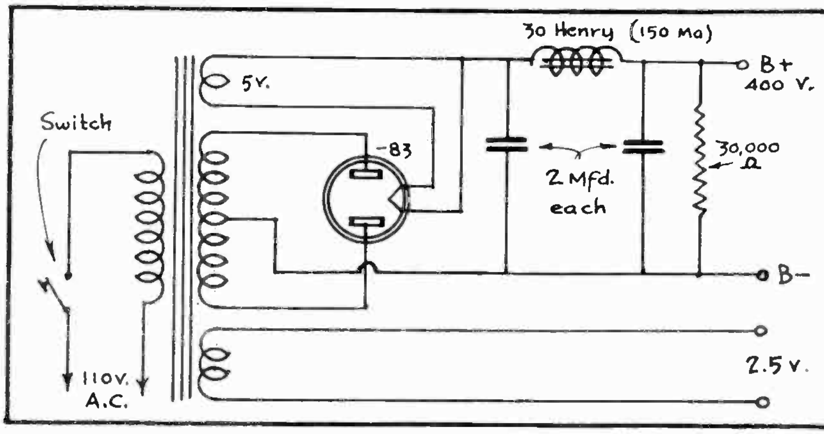

FIG. 15
Power Pack For the Push-Pull Transmitter.

THE ANTENNA SYSTEM WHICH IS ILLUSTRATED TOGETHER WITH THE TRANSMITTER CIRCUIT IN FIG. 16 IS KNOWN AS A ZEPPELIN ANTENNA AND ITS DIMENSIONS SHOULD BE AS FOLLOWS: LENGTH OF FLAT TOP BETWEEN INSULATORS = 133 FT.; LENGTH OF FEEDERS = 45 FT. THE TWO FEEDER WIRES SHOULD BE SEPARATED ABOUT 10 INCHES WITH GOOD LIGHTWEIGHT SPREADERS WHICH HAVE BEEN PREVIOUSLY BOILED IN PARAFFINE. THE TWO ANTENNA COILS "L" SHOULD EACH BE WOUND WITH THE SAME SIZE COPPER TUBING AS USED FOR COILS L_1 AND L_2. APPROXIMATELY 5 TURNS WOUND IN A $2\frac{1}{3}$" DIAMETER COIL WILL BE SATISFACTORY FOR EACH OF THE ANTENNA COILS. ONE OF THESE ARE MOUNTED AT EACH END OF L_1 AND PROVISIONS MADE SO THAT THE COUPLING AT THESE POINTS CAN BE VARIED.

TO ADJUST THIS TRANSMITTER FOR OPERATION, ALL THAT IS NECESSARY IS TO ADJUST THE TWO TUNING CONDENSERS C_1 AND C_2 FOR THE PROPER FREQUENCY

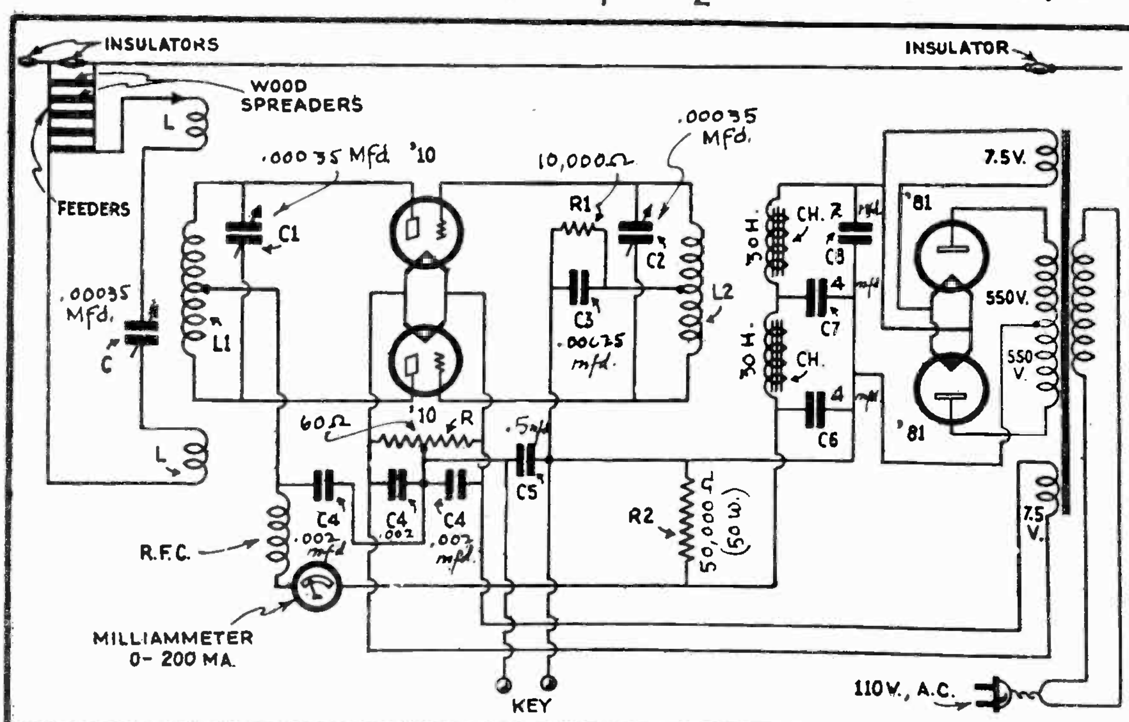

FIG. 16
A Push-Pull Tune-Plate, Tuned-Grid Transmitter.

AS CHECKED WITH THE MONITOR — THE MILLIAMMETER WILL AT THIS TIME SHOW A LOW READING OF AROUND 40 TO 60 MILLIAMPERES. THEN WITH THE ANTENNA CONNECTED UP, THE ANTENNA CONDENSER IS ADJUSTED UNTIL THE READING ON THE MILLIAMMETER IS MAXIMUM.

IN THE NEXT LESSON YOU ARE GOING TO RECEIVE CODE INSTRUCTION AND SUGGESTIONS REGARDING THE CORRECT MANNER OF OPERATING THE TRANSMITTER KEY. YOU WILL THEN PROGRESS IN LOGICAL STEPS, LEARNING ABOUT CRYSTAL-CONTROLLED OSCILLATORS, AMPLIFYING SYSTEMS FOR TRANSMITTERS, MORE ELABORATE METHODS OF ADJUSTING TRANSMITTERS ETC.

Examination Questions

LESSON NO. T-3

1. — DRAW A CIRCUIT DIAGRAM OF A COMPLETE LOW-POWER TRANSMITTER TOGETHER WITH ITS POWER-PACK.

2. — EXPLAIN THE OPERATION OF THE SYSTEM WHICH YOU HAVE DRAWN IN ANSWER TO THE PRECEDING QUESTION.

3. — DRAW A CIRCUIT DIAGRAM OF A MONITOR AND EXPLAIN ITS OPERATING PRINCIPLES.

4. — EXPLAIN HOW YOU WOULD PROCEED IN ORDER TO CALIBRATE A MONITOR WHICH HAS JUST BEEN CONSTRUCTED?

5. — EXPLAIN HOW YOU WOULD ADJUST THE TRANSMITTER ILLUSTRATED IN FIGS. 2 AND 3 OF THIS LESSON PREPARATORY TO GOING ON THE AIR.

6. — HOW ARE THE TUNED WINDINGS OF THESE LOW-POWER TRANSMITTERS GENERALLY CONSTRUCTED?

7. — DRAW A COMPLETE CIRCUIT DIAGRAM OF A TRANSMITTER USING PUSH-PULL OSCILLATOR TUBES AND A TUNED-PLATE, TUNED-GRID CIRCUIT.

8. — EXPLAIN HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE CIRCUIT DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #7 OF THIS EXAMINATION.

9. — WHAT ARE SOME OF THE MOST IMPORTANT THINGS TO CONSIDER IN SELECTING THE PARTS WHICH ARE TO BE USED IN A TRANSMITTER?

10. — IN WHAT PART OF A LOW-POWER TRANSMITTER CIRCUIT IS IT CUSTOMARY TO CONNECT THE KEY?

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Transmitters

LESSON NO. 4

MASTERING THE CODE

PART I

IN THE PRECEDING LESSON, YOU WERE TOLD ABOUT THE CONSTRUCTIONAL FEATURES AND METHOD OF SETTING UP SOME SIMPLE TRANSMITTERS PREPARATORY TO OPERATION. SINCE THESE TRANSMITTERS ARE ALL DESIGNED TO RADIATE THEIR MESSAGES BY MEANS OF THE TELEGRAPHIC CODE, IT IS NATURALLY NECESSARY THAT THE OPERATOR OF SUCH A TRANSMITTER BE THOROUGHLY FAMILIAR WITH THIS CODE. THIS THEN WILL BE YOUR NEXT STEP.

FURTHERMORE, SHOULD IT BE YOUR DESIRE TO QUALIFY EITHER AS AN AMATEUR OPERATOR, AS A COMMERCIAL OPERATOR, OR AS AN UNLIMITED BROADCAST OPERATOR, THEN YOU WILL BE REQUIRED TO PASS A CODE EXAMINATION IN THE PRESENCE OF AN EXAMINER WHO IS AUTHORIZED BY THE FEDERAL COMMUNICATIONS COMMISSION.

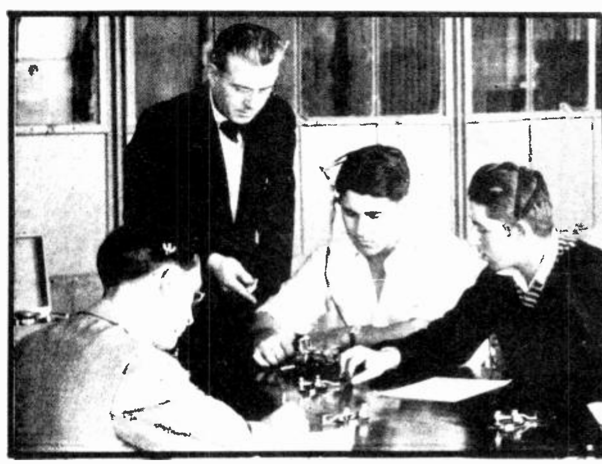

FIG. I
A Group of National Students Learning the Code.

IT IS ADVISABLE THAT YOU QUALIFY FOR AN AMATEUR'S LICENSE FIRST SINCE THIS DOES NOT CALL FOR SUCH A HIGH CODE SPEED OR AS COMPLETE TECHNICAL KNOWLEDGE AS DO THE REQUIREMENTS FOR LICENSE HOLDERS OF HIGHER RANK. IN ADDITION, THE EXPERIENCE WHICH YOU WILL ACQUIRE AS AN AMATEUR OPERATOR WILL BE OF A TREMENDOUS HELP IN PREPARING YOU TOWARDS BECOMING A COMMERCIAL OPERATOR LATER ON.

APPLICANTS FOR AN AMATEUR'S LICENSE ARE EXPECTED TO TRANSMIT AND RECEIVE AT LEAST 10 WORDS PER MINUTE IN THE CONTINENTAL CODE — FIVE CHARACTERS TO THE WORD. THIS, THEREFORE, SHOULD BE YOUR FIRST GOAL TOWARDS MASTERING THE CODE.

The complete International Morse Code (Continental Code), as well as the conventional signals, are all listed for you in TABLE I in a handy reference form. Study this table carefully so as to have a good idea of its contents but for the present don't attempt to memorize the code, especially in the form in which it is presented here. This table is to serve chiefly as a reference for future use.

TABLE I

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be used for all general public service radio communication

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Separation signal	• — • • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

By glancing through Table I, you will note that the letters of the alphabet, numbers, punctuation, and miscellaneous conventional signals all consist of dots and dashes arranged in a definite manner. It is not advisable to think of these letters or code groups in terms of dots and dashes but rather in terms of their equivalent sounds. For example, you should think of a dot as the sound "dit" and of a dash as the sound "dah". Thus the letter A should register in your mind as the sounds "dit dah" rather than dot dash, the letter B as "dah dit dit dit" instead of dash dot dot dot etc.

The logical method of learning the code is to learn the alphabet first, for the time being forgetting all about the numbers, punctuation etc. Furthermore, it is also advisable that you start learning the code by actual use of the key right from the start. In this way, you will at the very beginning become accustomed to thinking of the alphabetical letters in terms of their equivalent sounds and which is of utmost importance.

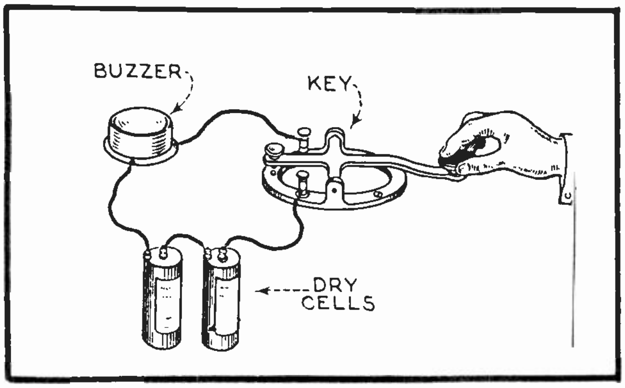

FIG. 2
The Buzzer Practice Set.

Before describing to you the routine to follow in order to master the code in the easiest and quickest possible manner, some suggestions will first be given so that you can construct suitable code-practice equipment.

A BUZZER-TYPE CODE PRACTICE SET

In Fig. 2 you are shown the constructional features of a buzzer-type code practice set. This assembly, you will observe, consists of a regular telegraph key (as used with radio transmitters) connected in series with two #6 series-connected dry cells and an ordinary buzzer as used for call systems.

Each time the key is depressed, the buzzer will emit its characteristic sound and thus by proper manipulation of the key, the buzzer sounds can be produced as the dit dah's of the code.

THE AUDIO-OSCILLATOR CODE PRACTICE SET

The audio oscillator code practice set whose diagram appears in Fig. 3 is by far preferable to the buzzer practice set. This arrangement is nothing more than a simple audio oscillator, consisting essentially of a type -30 tube, an old A.F. transformer, a 20 ohm rheostat, an "A" supply of two series-connected #6 dry cells and a $22\frac{1}{2}$ volt "B" battery. A set of headphones and a key are connected in series with the plate circuit as here shown so that each time that the key is depressed, a signal will be heard in the headphones which greatly resembles that as heard from a receiver when a signal is tuned in.

Sometimes, the "B" battery can be eliminated and the plate circuit

CONNECTED DIRECTLY TO THE "A" PLUS TERMINAL. THE SIGNAL WILL UNDER THESE CONDITIONS NATURALLY BE WEAKER BUT FREQUENTLY STILL STRONG ENOUGH FOR THIS USE. IF YOU WISH, YOU CAN TRY THIS LATTER CONNECTION BEFORE INVESTING IN A 22½ VOLT "B" BATTERY.

THE PRACTICE SET AS ILLUSTRATED IN FIG.3 IS QUITE INEXPENSIVE, NEVERTHELESS IT WILL SERVE ITS PURPOSE MOST ADMIRABLY. THE VARIOUS PARTS CAN ALL BE MOUNTED ON A WOODEN BASE-BOARD, FAHNESTOCK CLIPS BEING USED FOR THE EXTERNAL CONNECTIONS TO THE HEADPHONES ETC.

ALTHOUGH MORE ELABORATE CODE-PRACTICE SETS CAN BE CONSTRUCTED THAN THOSE HERE DESCRIBED, YET THE FEW ADDITIONAL FEATURES OBTAINED THEREFROM HARDLY WARRANTS A GREATER EXPENSE SINCE AFTER ALL, THIS ARRANGEMENT IS ONLY GOING TO BE USED FOR A LIMITED TIME. IT IS ADVISABLE TO PURCHASE A REASONABLY GOOD KEY FOR THE CODE PRACTICE SET SO THAT IT WILL ALSO BE SUITABLE FOR THE TRANSMITTER LATER ON. THE REMAINING PARTS WILL ALSO BE USEFUL AGAIN LATER ON, EITHER IN THE SHORT-WAVE RECEIVER OF THE STATION OR IN THE MONITOR ETC.

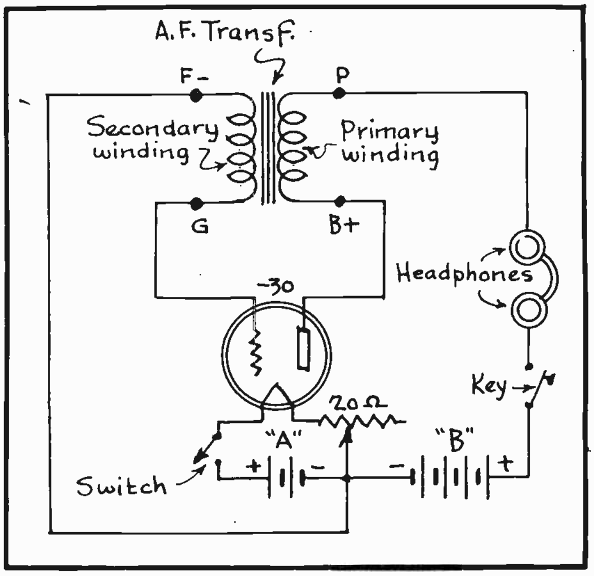

FIG. 3
The Audio-Oscillator Code Practice Set.

SO MUCH FOR THE CONSTRUCTIONAL FEATURES OF THE CODE-PRACTICE SET. NOW LET US PROCEED WITH THE HANDLING OF THE KEY.

MOUNTING THE KEY

THE CONVENTIONAL KEYS ARE PROVIDED WITH A BASE OFFERING PROVISIONS FOR FASTENING THE KEY DOWN FIRMLY UPON THE TOP OF A TABLE WITH WOOD SCREWS. THIS IS IMPORTANT SO THAT THE KEY WILL NOT JUMP AROUND WHILE IT IS BEING OPERATED. IF NO TABLE IS AVAILABLE UPON WHICH THE KEY CAN BE MOUNTED, THEN THE NEXT BEST THING IS TO FASTEN THE KEY UPON A LARGE FLAT BOARD WHICH CAN BE PLACED ON TOP OF A TABLE AND STILL NOT PERMIT THE KEY TO SHIFT ITS POSITION WHILE IT IS BEING OPERATED.

THE CORRECT POSITION FOR THE KEY IS APPROXIMATELY EIGHTEEN INCHES FROM THE EDGE OF TABLE WHICH FACES THE OPERATOR AND APPROXIMATELY IN LINE WITH THE OPERATOR'S RIGHT SHOULDER. THIS POSITION OF THE KEY WILL PERMIT THE OPERATOR'S ELBOW TO REST ON THE TABLE AND WHICH IS IMPORTANT TOWARDS GOOD KEY MANIPULATION.

ADJUSTING THE KEY

THE BEGINNER IS URGED TO USE A CONVENTIONAL KEY IN PREFERENCE TO

THE HIGH-SPEED "VIBROPLEX" AND "DOUBLE-ACTION" KEYS WHICH ARE INTENDED PRIMARILY FOR THE EXPERIENCED OPERATOR. THE CONSTRUCTIONAL DETAILS OF THE CONVENTIONAL OR STANDARD KEY ARE CLEARLY ILLUSTRATED IN FIG. 4 AND HERE YOU WILL NOTICE THAT THREE SETS OF ADJUSTMENTS ARE PROVIDED. THESE ADJUSTMENTS ARE AS FOLLOWS: (1) A SCREW AND LOCKING NUT FOR ADJUSTING THE SPRING TENSION. (2) A SCREW AND LOCKING NUT FOR ADJUSTING THE CLEARANCE BETWEEN THE CONTACT POINTS OF THE KEY WHEN IN ITS NORMAL POSITION. (3) THE TWO SCREWS AND LOCKS, THE ADJUSTMENT OF WHICH PERMITS CENTERING THE ARM CONTACT OVER THE STATIONARY CONTACT, AS WELL AS SIDE-PLAY OF THE ARM.

WITH THE CONTACT POINTS PROPERLY LINED UP, THE SPRING TENSION SHOULD BE ADJUSTED. THE CORRECT TENSION VARIES WITH DIFFERENT OPERATORS, BUT FOR THE BEGINNER A FAIRLY HEAVY SPRING ADJUSTMENT IS MOST DESIRED. THE CLEARANCE ADJUSTMENT SHOULD BE SO REGULATED THAT A VERTICAL MOVEMENT OF THE KNOB EQUIVALENT TO APPROXIMATELY 1/16" IS NECESSARY IN ORDER TO CLOSE THE CONTACT POINTS OR A CLEARANCE BETWEEN THE POINTS OF ABOUT 1/32" OR SLIGHTLY MORE. THE ADJUSTMENTS AS HERE GIVEN ARE ONLY AVERAGE AND CAN BE VARIED TO BEST SUIT THE INDIVIDUAL OPERATOR SO AS TO PERMIT HIM TO SEND THE CLEAREST SIGNALS POSSIBLE.

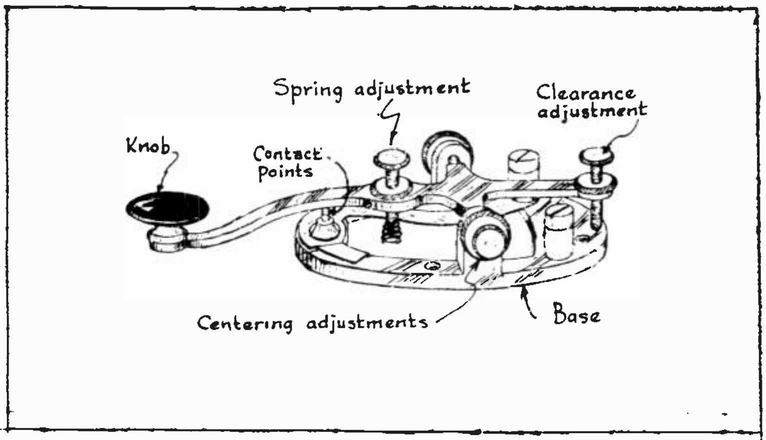

FIG. 4
Details of the Key.

MANIPULATING THE KEY

THE CORRECT METHOD OF GRASPING THE KEY IS ILLUSTRATED FOR YOU IN FIG. 5. NOTE THAT THE KEY IS NOT HELD TIGHTLY AND THAT THE HAND IS PERMITTED TO REST LIGHTLY ON THE KEY. THE THUMB SHOULD BE HELD AGAINST THE LEFT SIDE OF THE KEY, WHEREAS THE FIRST AND SECOND FINGERS SHOULD BE BENT SLIGHTLY AND SHOULD HOLD THE MIDDLE AND RIGHT SIDES OF THE KNOB RESPECTIVELY. OBSERVE IN FIG. 5 THAT THESE THREE FINGERS ARE PARTLY ON TOP OF THE KNOB WHILE THE REMAINING TWO FINGERS ARE ENTIRELY FREE OF THE KEY.

WHEN OPERATING THE KEY, THE ELBOW SHOULD BE RESTED ON THE TABLE AND A WRIST MOTION USED TO WORK THE KEY. DO NOT USE FINGER MOTION NOR THE WHOLE ARM. THE WRIST SHOULD AT ALL TIMES BE HELD ABOVE THE TABLE AND THE FINGERS WHICH GRASP THE KEY SHOULD NEVER LEAVE THE KEY WHILE SENDING.

SINCE THE CODE IS MADE UP OF DIFFERENT COMBINATIONS OF DOTS AND DASHES, IT IS IMPORTANT THAT THE INDIVIDUAL DOTS AND DASHES BE OF THE CORRECT LENGTH AND THAT THE PROPER TIME INTERVAL OR SPACING BE ALLOWED BETWEEN PARTS OF THE SAME LETTER, BETWEEN LETTERS OF THE SAME WORD ETC. IF THIS IS NOT DONE, THEN UTTER CONFUSION WOULD RESULT ON THE PART OF THE PERSON WHO IS RECEIVING YOUR SIGNALS.

HERE ARE THE RULES WHICH YOU MUST FOLLOW:

(1) A DASH IS EQUAL IN LENGTH TO THREE DOTS.

(2) THE SPACE BETWEEN PARTS OF THE SAME LETTER IS EQUAL TO ONE DOT.

(3) THE SPACE BETWEEN TWO LETTERS IS EQUAL TO THREE DOTS.

(4) THE SPACE BETWEEN TWO WORDS IS EQUAL TO FIVE DOTS.

MEMORIZING GROUPS

NOW FOR THE ACTUAL MEMORIZING OF THE CODE. AS HAS BEEN STATED BEFORE, WE START WITH THE ALPHABET BUT IT ISN'T ADVISABLE TO LEARN THE LETTERS IN THE SAME ORDER IN WHICH THEY APPEAR IN THE ALPHABET. SUCH A PROCEDURE WOULD COMPLICATE THINGS CONSIDERABLY AND MAKE YOUR LEARNING OF THE CODE QUITE DIFFICULT.

A BETTER PLAN IS TO DIVIDE THE ALPHABET INTO GROUPS, SO THAT YOU START WITH THE SIMPLER LETTERS AND THEN GRADUALLY ADVANCE THROUGH THE MORE DIFFICULT ONES. BY GLANCING THROUGH THE ALPHABET IN TABLE I, YOU WILL FIND THAT THE LETTERS T-M AND O ARE ALL DASH LETTERS, WHEREAS THE LETTERS E-I-S AND H ARE ALL DOT LETTERS. THEREFORE, IT IS NO MORE BUT LOGICAL TO MEMORIZE THESE SIMPLER LETTERS FIRST. THE VARIOUS CODE GROUPS ARE ALL ARRANGED FOR YOU IN TABLE II IN THEIR ORDER OF SIMPLICITY AND WHICH IS THE SAME ORDER IN WHICH YOU SHOULD MEMORIZE THEM.

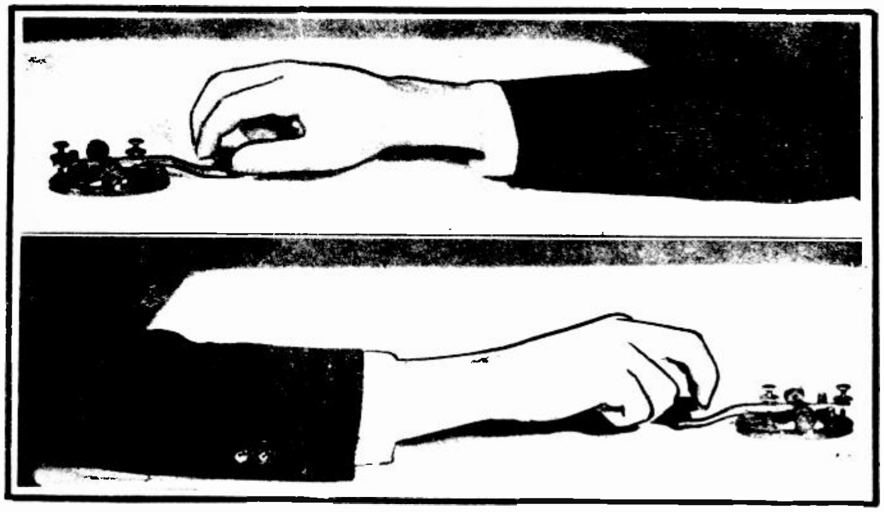

FIG. 5
Two Views Showing the Correct Position of Hand, Wrist and Elbow When Sending.

START WITH MEMORIZING GROUP #1 FIRST, PRACTICE THE SENDING OF THE LETTERS T, M AND O DILIGENTLY UNTIL YOU ARE ABLE TO SEND ANY ONE OF THESE SMOOTHLY AND WITHOUT ANY EFFORT AND SO THAT THERE WILL BE NO HESITATION ON YOUR PART IN SENDING EITHER OF THESE THREE LETTERS REGARDLESS OF THE ORDER IN WHICH YOU SEND THEM.

PRACTICE EXERCISE #1

AFTER YOU HAVE MASTERED THESE THREE LETTERS, YOUR NEXT TASK WILL BE TO SEND THEM IN THE CODE GROUPS AS PRESENTED TO YOU IN THIS PRACTICE EXERCISE. NOTICE THAT THE FOLLOWING CODE GROUPS ARE MADE UP OF VARIOUS COMBINATIONS OF THE DASH LETTERS T, M AND O. IN ADDITION TO SENDING THESE LETTERS CORRECTLY, IT IS ALSO IMPORTANT THAT YOU WATCH YOUR SPACING IN THE FOLLOWING GROUPS, BOTH BETWEEN LETTERS AND BETWEEN GROUPS.

TABLE II

MEMORIZING GROUPS

GROUP #1

T	DAH
M	DAH DAH
O	DAH DAH DAH

GROUP #2

E	DIT
I	DIT DIT
S	DIT DIT DIT
H	DIT DIT DIT DIT

GROUP #3

A	DIT DAH
N	DAH DIT
D	DAH DIT DIT

GROUP #4

W	DIT DAH DAH
J	DIT DAH DAH DAH
B	DAH DIT DIT DIT

GROUP #5

R	DIT DAH DIT
F	DIT DIT DAH DIT
L	DIT DAH DIT DIT

GROUP #6

U	DIT DIT DAH
V	DIT DIT DIT DAH
K	DAH DIT DAH

GROUP #7

C	DAH DIT DAH DIT
G	DAH DAH DIT
Q	DAH DAH DIT DAH

GROUP #8

Y	DAH DIT DAH DAH
Z	DAH DAH DIT DIT
P	DIT DAH DAH DIT
X	DAH DIT DIT DAH

GROUP #9

1	DIT DAH DAH DAH DAH
2	DIT DIT DAH DAH DAH
3	DIT DIT DIT DAH DAH
4	DIT DIT DIT DIT DAH
5	DIT DIT DIT DIT DIT

GROUP #10

6	DAH DIT DIT DIT DIT
7	DAH DAH DIT DIT DIT
8	DAH DAH DAH DIT DIT
9	DAH DAH DAH DAH DIT
0	DAH DAH DAH DAH DAH

GROUP #11

PERIOD	DIT DIT DIT DIT DIT DIT
INTERROGATION	DIT DIT DAH DAH DIT DIT
BREAK OR DOUBLE DASH	(=) DAH DIT DIT DIT DAH
ERROR	DIT DIT DIT DIT DIT DIT DIT DIT

GROUP #12

WAIT	DIT DAH DIT DIT DIT
END OF MESSAGE	DIT DAH DIT DAH DIT
END OF TRANSMISSION	DIT DIT DIT DAH DIT DAH

TWO-LETTER CODE GROUPS

TT MM OO MO OM TT MM MT MO TM TO MO TM OT MT OM TM TO
OT TM OM MT OT MT OM OT MT OM TM MM TT MO OM OO MM TT

THREE-LETTER CODE GROUPS

TOM	MOO	OTO	TOM	OMO	MOO	TTM	OMO	MMT	MMT	OTM
TMO	TOO	MTM	MOM	TOM	TMO	MTM	MOT	TMT	TOO	OOM
TMT	TOT	OOM	OOT	NTO	TOM	MOM	TOM	MTM	OOT	MTO

FOUR-LETTER CODE GROUPS

TOMO	TMTM	OTOT	MMOT	MOTO	MTMT	MOMO	TMTO	MOTT	OTOM	MOTO
MTTM	MTOC	TMOT	TOTO	OMTO	MTOM	OOTT	OMTM	TOOM	OMOT	TOTO
OMOT	TOOM	MOOT	OTTO	OMOT	TOTO	MTOM	MOTM	MOOT	TMOO	MTOM

FIVE-LETTER CODE GROUPS

TOTOM	MTMOT	TOTTO	OTTOM	MOTMT	MMOOT	MTOMT	TOMOT	OTOMO	TMOTO	TOMMT
OOMTT	TMOTM	MOTTM	OMOTT	OMOTO	MTOMT	TOMOT	TOTOO	MOTOO	MMTOT	OTTOM
MOTOT	OMMOT	TOMOT	TMOTO	MTOMT	TMOTM	OTMOT	MOTOT	MOTTM	TOMTO	MOTOM

WHILE PERFORMING THESE PRACTICE EXERCISES, SEND SLOWLY AT FIRST. IT IS MORE IMPORTANT THAT YOUR SENDING BE CLEAN-CUT AND ACCURATELY SPACED THAN IT IS TO ACQUIRE SPEED. YOU WILL DEVELOPE GREATER SENDING SPEED AUTOMATICALLY WITH CONTINUED PRACTICE AND EXPERIENCE.

AT FIRST YOU MIGHT FIND THIS WORK TO BE SOMEWHAT OF A STRAIN, CAUSING YOU TO BECOME MENTALLY FATIGUED IN A RELATIVELY SHORT TIME. FOR THIS REASON, IT IS NOT ADVISABLE THAT YOU STUDY THE CODE FOR A LONGER PERIOD THAN 20 MINUTES AT ONE SITTING SO AS NOT TO BECOME OVER-TIRED. THEN AFTER A SUITABLE PERIOD OF RELAXATION, YOU CAN CONTINUE YOUR STUDIES AGAIN AS YOU SEE FIT.

NOW THAT YOU ARE THOROUGHLY FAMILIAR WITH THE STRAIGHT DASH LETTERS YOU CAN COMMENCE MEMORIZING THE STRAIGHT DOT LETTERS E, I, S AND H AS THEY APPEAR IN GROUP #2 OF TABLE II, BUT BY ALL MEANS DON'T EVEN ATTEMPT TO LEARN GROUP #2 UNTIL YOU ARE ABSOLUTELY CERTAIN OF GROUP #1. OBSERVE CAREFULLY IN GROUP #2 THAT E IS DIT, I IS DIT DIT, S IS DIT DIT DIT AND H IS DIT DIT DIT DIT. WHEN YOU HAVE LEARNED THESE FOUR LETTERS THOROUGHLY, YOU CAN CONTINUE WITH PRACTICE EXERCISE #2.

PRACTICE EXERCISE # 2

THIS SECOND PRACTICE EXERCISE CONSISTS OF VARIOUS GROUPINGS OF THE LETTERS E, I, S, AND H. HERE TOO YOU MUST BE VERY CAREFUL OF YOUR SPACING BETWEEN LETTERS AS WELL AS THE SPACING BETWEEN GROUPS.

TWO-LETTER GROUPS

EI	EH	SH	SI	IH	SS	II	HI	HS	EH	ES	IS
SE	IE	HH	EE	HE	EI	ES	IE	HE	SH	IS	SE
HH	EE	HI	IE	IH	SS	EH	HE	SI	ES	SH	IE

THREE-LETTER GROUPS

SIS	SIE	ISI	ESH	HIH	ESE	EIE	ESE	ISH	HIS
HEN	IEI	ISI	EIE	SIH	HEH	ISE	IHI	SHE	ESI
ISE	EHS	IHI	ESI	HEH	HIS	EIE	IEI	NEH	HEN

FOUR-LETTER GROUPS

SISE	ISIS	HSEI	ISHE	EHIS	SISE	ESHE	SHEE	HIHI	SEIS
HESE	HISI	EIEI	SIES	ISHE	SHIS	SHIE	HEHE	ISHI	ESEH
ESIS	ESEH	HISE	EHSI	SIHE	ESHI	SHEE	HISH	EISH	HIHI

FIVE-LETTER GROUPS

ESEES	ESHIE	SISSE	ESSES	HISII	HESHE	SHIHI	ESHIS	IHESI	SHISE
ISHIE	HHIHE	HEESE	SESHE	IHIHE	IIEEI	SHEIE	ISHIE	SHHSE	HISES
EHIES	SHEHI	HIHIE	IESEH	IIHIH	ESEHI	SESSE	ESEEH	ISEHS	SEESE

UPON COMPLETION OF PRACTICE EXERCISE #2, YOU ARE READY TO SEND CODE GROUPS WHICH CONTAIN LETTERS FROM BOTH MEMORIZING GROUPS #1 AND #2 USED IN VARIOUS COMBINATIONS. NOW YOU WILL HAVE TO WATCH YOURSELF PARTICULARLY IN YOUR SPACING BETWEEN THE LETTERS OF A GROUP AND BETWEEN GROUPS, OTHERWISE THE CHARACTERS OF THE DIFFERENT LETTERS WILL HAVE A TENDENCY TO RUN TOGETHER AND IN THIS WAY BECOME CONFUSING TO THE LISTENER.

IT IS ALSO ADVISABLE THAT YOU DEVELOPE THE HABIT NOW OF MAKING THE ERROR SIGN EACH TIME THAT YOU MAKE A MISTAKE IN KEYING AND THEN IMMEDIATELY SEND THE SIGNAL AGAIN CORRECTLY.

PRACTICE EXERCISE #3

THIS THIRD PRACTICE EXERCISE INCLUDES CODE GROUPS CONTAINING LETTERS OF THE STRAIGHT DASH AND THE STRAIGHT DOT TYPE AS EXTRACTED FROM MEMORIZING GROUPS #1 AND #2 OF TABLE II.

TETES	TEHOS	ESOTI	EMHIT	EOHSI	HISME	EMITO	IHEME
ISTEM	THIOM	OMITH	HOHOE	HOSEM	OEIST	TIHME	ISOIM
STEITH	EHOIM	SETOI	HOSME	TSEMO	MISSI	MSETH	OMSIT

PRACTICE EXERCISE #4

BY THE TIME YOU HAVE REACHED THIS POINT OF THE LESSON, YOU HAVE LEARNED SEVEN LETTERS OF THE ALPHABET WELL AND WITH THESE SEVEN LETTERS YOU CAN ALREADY COMMENCE SPELLING OUT SIMPLE WORDS. THIS WILL MAKE YOUR CODE STUDIES STILL MORE INTERESTING. THE WORDS WHICH YOU ARE NOW TO SPELL FOLLOW:

IT	SET	HOT	TOO	HIM	MEET	TOTEM	MITES	ITEMS	MET
HE	MET	NET	THE	SIT	MESS	TOSS	MEMO	THEME	MEMO
ME	TEE	SIM	SOT	HIS	MOST	HOIST	OTTO	SOME	HEM

MEMORIZING GROUP #3

THE NEXT THREE LETTERS WHICH YOU ARE TO ADD TO YOUR CODE LIST ARE THE "A", THE "N" AND THE "D". BY REFERRING TO MEMORIZING GROUP #3 IN TABLE II YOU WILL NOTE THAT THESE ARE YOUR FIRST LETTERS WHICH ARE A

COMBINATION OF THE DOT AND THE DASH. IN OTHER WORDS, "A" IS DIT DAH, "N" IS DAH DIT AND "D" IS DAH DIT DIT. THE THING TO DO NOW IS TO LEARN THESE THREE LETTERS THOROUGHLY SO THAT YOU CAN SEND EITHER ONE OF THEM WITHOUT HESITATION. WHEN YOU ARE SURE OF THESE THREE LETTERS THEN YOU CAN PROCEED WITH PRACTICE EXERCISE #5.

PRACTICE EXERCISE #5

THIS FIFTH PRACTICE EXERCISE CONSISTS OF CODE GROUPS CONTAINING THE LETTERS T–M–O–E–I–S–H–A–N–D WHICH YOU HAVE SO FAR LEARNED. PRACTICE SENDING ALL OF THESE WITH ACCURACY AND AS SMOOTHLY AS POSSIBLE.

FIVE-LETTER CODE GROUPS

AISHD	DANAS	NINES	DISOM	SMITE	IDSNT	ANOMI
SAMES	DODOS	MISAD	NATID	DITES	MEDIN	OTDIN
DIDAN	ONSET	SNADS	TADAN	SEDNI	INISE	NADAT
MIDAS	MANDA	HDTAN	ADANE	NTMOA	NEADS	AIDIS
OTESA	DIDSN	ENTAH	NEATS	NANED	MADIN	HEOAD
ANDAD	ADNAD	ODONA	OSTEA	SANDS	IMONA	ESINI

TWO AND THREE-LETTER WORDS

TO	THE	ODE	MAD	ATE	SIN	TAN	DIN	SOT
IT	AND	ODD	TEE	TIT	TEN	SET	AID	DIE
AS	TOT	NED	SAT	EAT	TEA	NAT	DEN	TAT

SIMPLE FOUR-LETTER WORDS

THEM	TEND	SODA	ITEM	MOTE	NINE	MOTH	NAME
DATE	NAME	SOME	EAST	INTO	IDEA	MOAN	TEST
HOME	IDES	EASE	EDEN	SAND	MATE	EDIT	TIDE

SIMPLE FIVE-LETTER WORDS

DIDOS	MAIDS	TEEMS	MEANS	HINTS	NAMES	TEAMS
DINES	STINT	DATES	SMASH	DEANS	SODAS	AIDES
STAND	ASHES	DANES	MITES	SAINT	DOMES	MAINS

THE NEXT THREE LETTERS FOR YOU TO LEARN ARE THE W – J AND THE B WHICH ARE INCLUDED IN GROUP #4 OF TABLE II. THE LETTER W, YOU MUST REMEMBER, IS DIT DAH DAH, J IS DIT DAH DAH DAH AND B IS DAH DIT DIT DIT. STAY WITH THESE THREE LETTERS UNTIL YOU LEARN THEM THOROUGHLY AND THEN GO AHEAD WITH PRACTICE EXERCISE #6.

PRACTICE EXERCISE #6

THE FIRST PART OF THIS EXERCISE CONSIST OF CODE GROUPS CONTAINING IN VARIOUS COMBINATIONS ALL OF THE LETTERS WHICH YOU HAVE LEARNED SO FAR, INCLUDING THE LAST THREE LETTERS W–J–B. THE SECOND PART OF THIS EXERCISE SUGGEST SIMPLE BUT COMPLETE SENTENCES WHICH YOU CAN SEND BY USING THE LETTERS WHICH YOU KNOW AT THIS TIME. IT IS IMPORTANT THAT YOU GIVE THIS PARTICULAR EXERCISE YOUR FULLEST ATTENTION.

CODE GROUPS

IWAWE	JABEW	DIJOW	TWIBE	ESIBN	JASBI	TOWID
SHEJD	SEJOW	OBJSI	EWABD	DBEBI	ISHWJ	DBIDJ
NTOJW	OWESJ	JANDB	ANJEB	MIWAD	BADIJ	ATJJS
BIJEW	EJMWD	JASWB	SWEBT	WAIBJ	BOSWE	WISDJ

SIMPLE SENTENCES

THIS JOB IS TO BE DONE BY THE BEST MAN.

JAMES IS TO MEET SAM BETWEEN TEN AND NOON.
THE SAME MAN WAS TO BE SENT AT THIS TIME.
JOHN AND SAM WENT DOWN TOWN AT NINE A.M.
TOM WAITED TO SEE THAT THE BAT WAS SENT HOME.
JOE SAID HE WAS NOT A BAD MAN.
JIM BOASTED THAT HE DID NOT OWE DAN.
WE JOINED BOTH ENDS AND WAITED.

MEMORIZING GROUP #5

THE NEXT THREE LETTERS WHICH YOU ARE TO LEARN ARE THE R, THE F AND THE L AS GIVEN IN MEMORIZING GROUP #5 OF TABLE II. NOTICE THAT R IS DIT DAH DIT, F IS DIT DIT DAH DIT, AND L IS DIT DAH DIT DIT. LEARN THESE THREE LETTERS THOROUGHLY AND THEN PROCEED WITH PRACTICE EXERCISE #7.

PRACTICE EXERCISE #7

THIS PRACTICE EXERCISE CONSITS OF CODE GROUPS CONTAINING ALL OF THE LETTERS WHICH YOU HAVE LEARNED SO FAR AND INCLUDING THE LETTERS R, F, AND L. IN ADDITION, YOU ARE ALSO AT THIS TIME GIVEN SOME MORE PRACTICE SENTENCES EMPLOYING THESE NEW LETTERS.

THE CODE GROUPS

RARIR	DAFIN	LFRWE	FELWI	TLOFR	IRERT
LELIL	SBLJW	JBARL	DWETW	RIRAR	SLOWE
RFWLB	NWJDB	NRWJT	TRIRE	JOLIB	RFLWJ
TRFLE	BSJWD	RASIR	LJWBL	BRFLW	LFRHM
ITEMS	FEFOS	REFIL	WJBER	FRWJB	IJWFS

SIMPLE SENTENCES

THE WATER IS FINE.
THE OWNER OF THE HORSE SAW IT STOLEN.
THERE WILL BE A ROW WHEN JIM FINDS WE ARE LATE.
ATTEND TO THE JOINT BETWEEN THE WINDOWS.
I SEE THAT THE FLOW IS FROM BOTH EAST AND WEST.
THAT INDIAN IS NOT A BAD MAN.
THE BEST THREE ARE TO BE SENT WITH JOHN.
HE WILL HAVE ONE HORSE AND WE WILL WANT TWO.
BETWEEN THE TWO OF THEM IT WILL BE FINE.

SOME SPECIAL SUGGESTIONS

ALTHOUGH IT IS PREFERABLE THAT YOU START YOUR CODE STUDIES BY ACTUALLY USING A KEY, YET THIS DOES NOT MEAN THAT YOU SHOULD NEGLECT YOUR CODE STUDIES JUST BECAUSE YOU DON'T AT PRESENT HAVE A CODE PRACTICE SET AVAILABLE. IF SUCH BE THE CASE, YOU CAN START LEARNING THE CODE BY GOING THROUGH ALL THE EXERCISES PRESCRIBED IN THIS LESSON BY PRODUCING THE CODE CHARACTERS WITH YOUR MOUTH. FOR EXAMPLE, FOR THE LETTER "A" SIMPLY UTTER THE SOUNDS DIT DAH, FOR THE LETTER "S" UTTER THE SOUNDS DIT DIT DIT JUST AS YOU WOULD MAKE THEM IF YOU HAD A CODE PRACTICE SET. EVEN THIS ROUTINE, WILL HELP YOU TREMENDOUSLY IN THE TASK OF LEARNING CODE AND THEREBY ENABLE YOU TO BE JUST THAT FAR AHEAD WHEN YOU HAVE ACCESS TO A CODE PRACTICE SET AND THUS MAKE YOUR PROGRESS THROUGH THIS WORK JUST THAT MUCH MORE RAPID.

IT IS ALSO GOOD PRACTICE TO HAVE SOME OTHER PERSON SEND THE DIFFERENT LETTERS OR CODE GROUPS TO YOU SO THAT YOU CAN ADAPT YOURSELF TO THE RECEPTION OF CODE. THESE "SIGNALS" CAN BE SENT TO YOU EITHER BY WORD OF MOUTH OR ELSE BY SOME OTHER PARTY SENDING THEM TO YOU WITH THE KEY WHILE YOU LISTEN-IN ON THE HEADPHONES OF YOUR CODE PRACTICE SET. YOU WILL CONTINUE YOUR CODE WORK IN THE NEXT LESSON.

Examination Questions

stripped

LESSON NO. T-4

1. — HOW MUCH TIME HAVE YOU SPENT SO FAR IN THE STUDY OF THE CODE?
2. — ARE YOU USING A CODE PRACTICE SET WITH WHICH TO LEARN THE CODE?
3. — AT THE PRESENT TIME, HOW MANY CODE LETTERS CAN YOU TRANSMIT WITHOUT REFERRING TO YOUR TEXT?
4. — DRAW A CIRCUIT DIAGRAM OF A CODE PRACTICE SET EMPLOYING A VACUUM TUBE AND EXPLAIN HOW IT IS USED.
5. — WHAT IS THE MEANING OF • —— • ?
6. — HOW WOULD YOU MAKE THE LETTER B BY MEANS OF THE CODE? INDICATE THIS ON YOUR PAPER BY THE PROPER ARRANGEMENT OF DOTS AND DASHES.
7. — WHAT IS THE CORRECT RELATION BETWEEN THE LENGTH OF A DOT AND THE LENGTH OF A DASH.
8. — TRANSCRIBE THE FOLLOWING SENTENCE INTO CODE BY PLACING THE PROPER ARRANGEMENT OF DOTS AND DASHES ON YOUR PAPER, BEING SURE TO INDICATE THE CORRECT SPACING BETWEEN THE LETTERS OF ANY ONE WORD AND BETWEEN WORDS. HERE IS THE SENTENCE: THE WATER IS FINE.
9. — WHAT IS THE CORRECT SPACING BETWEEN THE LETTERS OF A WORD AND BETWEEN WORDS OF A SENTENCE?
10. — TRANSCRIBE INTO CODE THE FOLLOWING SENTENCE: THE OWNER OF THE HORSE SAW IT STOLEN.

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LESSON NO. 5

MASTERING THE CODE

PART II

GUIDED BY THE PRECEDING LESSON, YOU SHOULD BY THIS TIME BE CAPABLE OF BOTH SENDING AND RECEIVING WELL ALL THOSE LETTERS OF THE ALPHABET WHICH ARE INCLUDED IN THE FIRST FIVE MEMORIZING GROUPS IN TABLE II OF THE PREVIOUS LESSON. SINCE YOU WILL AGAIN HAVE NEED FOR THIS SAME TABLE IN THE PRESENT LESSON, IT IS ADVISABLE THAT YOU OPEN THE PREVIOUS LESSON AT THE PAGE UPON WHICH TABLE II APPEARS AND IN THIS WAY HAVE IT HANDY FOR REFERENCE AS YOU CONTINUE YOUR CODE STUDIES ACCORDING TO THE INSTRUCTIONS WHICH WILL NOW BE GIVEN.

YOU ARE AT THE PRESENT TIME PREPARED TO LEARN THOSE LETTERS WHICH ARE INCLUDED IN MEMORIZING GROUP #6, NAMELY, U-V AND K. THE U, YOU WILL OBSERVE, IS DIT DIT DAH; THE V IS DIT DIT DIT DAH AND THE K. IS DAH DIT DAH.

WHEN YOU HAVE LEARNED THESE THREE NEW LETTERS THOROUGHLY, PROCEED BY DILIGENTLY PRACTICING THE FOLLOWING CODE GROUPS.

DON'T BE CONTENT BY GOING THROUGH THE FOLLOWING CODE GROUPS ONLY ONCE BUT PRACTICE THEM REPEATEDLY SEVERAL TIMES SO THAT ALL OF THE LETTERS WILL REGISTER IN YOUR MIND WITHOUT ANY HESITATION.

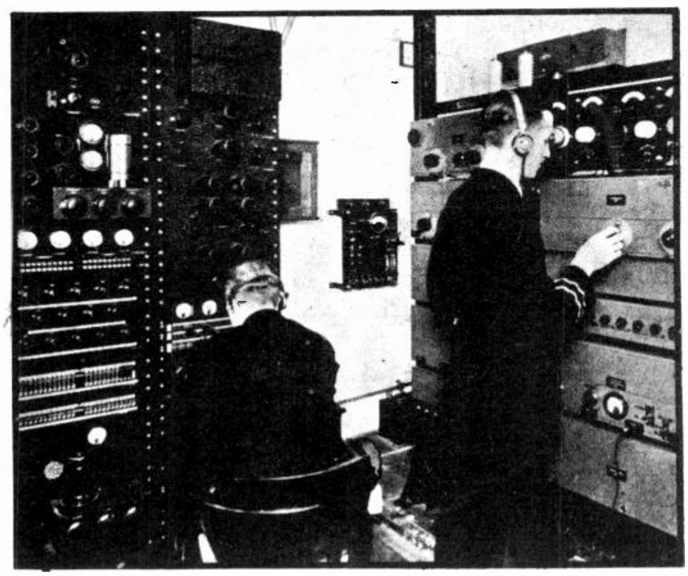

FIG. 1
Commercial Operating Offers Many Opportunities to the Trained Man.

RURUF	RFLUV	KIULR	IUSVH	SEARU	IRULU
VIVOR	FLOSD	KERIF	FAVOR	ULRUL	EKIKU
NIFAO	SLHUT	KINKS	MUVIK	VMKOR	DOVES
SUFLU	KESIK	ERIFS	FELTU	KIKOR	VEVIR
UFRKU	LHUTV	IVMKO	VISOR	VEVFS	UEVIK
FDLEL	THISF	KESTI	ITSEK	FSIHT	LELDF

MEMORIZING GROUP #7

MEMORIZING GROUP #7 CONTAINS THE THREE LETTERS C, G AND Q. AS YOU WILL HAVE NOTICED BY THIS TIME, THE LETTERS WHICH YOU ARE NOW LEARNING ARE OF A MORE COMPLEX STRUCTURE THAN THOSE WHICH YOU LEARNED FIRST AND IT WILL THEREFORE REQUIRE A LITTLE MORE TIME AND PRACTICE IN ORDER FOR YOU TO MASTER THEM.

THE FIVE-LETTER CODE GROUPS WHICH FOLLOW, OFFER YOU SPLENDID PRACTICE IN SENDING AND RECEIVING THE LETTERS C, G AND Q AS WELL AS SOME OF THE OTHERS WHICH ARE INCLUDED IN THE MORE ADVANCED MEMORIZING GROUPS.

CUCKO	FLRQG	LOGOQ	CRUFL	GURQE	GVGUK
QURFQ	RFVUL	LQFGC	CEGIQ	QUQUE	CGQRU
GVQLR	QURCG	CVKLC	QUOGO	QUACK	GKVUG
VOTES	QUART	GUGGO	LFULG	RUCFL	KGIQC
GFRKG	QFCKL	RGFQV	KLGCV	CFLGR	FLUGF
KICKS	CLGQF	GKLFR	GRUCQ	FLUGF	RVQCF
LUCGQ	FORKE	QGFLC	TCMQG	GQMCT	EKROF

WHEN SENDING WORDS OR CODE GROUPS WHICH CONTAIN THE LETTERS C, Q, V, L AND J YOU MUST BE PARTICULARLY CAREFUL WITH THE SPACING WITHIN THE LETTER. FOR EXAMPLE, THE LETTER C CAN BE INCORRECTLY SENT SO AS TO SOUND ALMOST THE SAME AS TR, AS NN, OR AS KE. SIMILAR CONFUSION CAN ALSO RESULT BY INCORRECT SPACING WITHIN OTHER LETTERS. THEREFORE, IF YOU FIND YOURSELF HAVING ACQUIRED ANY SUCH UNDESIRABLE HABITS OF SENDING, IT IS OF UTMOST IMPORTANCE THAT YOU CORRECT THIS CONDITION NOW BEFORE THESE HABITS BECOME TOO STRONG AND INCREASINGLY DIFFICULT TO CORRECT.

MEMORIZING GROUP #8

THE FINAL GROUP OF LETTERS WHICH YOU ARE TO LEARN ARE INCLUDED IN MEMORIZING GROUP #8 AND THESE ARE Y, Z, P AND X. THESE LETTERS ARE FORMED IN THE FOLLOWING MANNER: Y IS DAH DIT DAH DAH; Z IS DAH DAH DIT DIT; P IS DIT DAH DAH DIT AND X IS DAH DIT DIT DAH. A NUMBER OF PRACTICE CODE GROUPS WHICH CONTAIN THE LETTERS Y, Z, P AND X, AS WELL AS OTHERS FOLLOW:

YOYOY	YACHT	XADNQ	SGQEH	JAWZX	ZLFRZ
CXZQG	YESTZ	ZONIC	BJXEZ	XUXZC	PAPPA
ZINCS	WAXIW	IZSGL	PAYER	YUSTX	FZQRV
BYZER	ZILOZ	FETQX	FLUXZ	YTZIZ	CEXIG
BUZIX	ZEZIZ	GIRLS	GAGIC	PLAXR	SHZXY
XUXVK	BJKRV	ZINCQ	YCZCX	XEXQR	GWJBX
XTXEX	TOXIG	JAXIJ	DALYP	GIXOT	XBJWG

A GENERAL REVIEW

AFTER YOU HAVE LEARNED THE LETTERS OF MEMORIZING GROUP #8 THOROUGHLY

IT IS ADVISABLE THAT YOU CONDUCT A CAREFUL REVIEW OF EVERYTHING WHICH YOU HAVE SO FAR LEARNED ABOUT THE CODE. WHEN YOU HAVE DONE THIS, THEN PRACTICE SENDING AND RECEIVING THE MORE DIFFICULT TYPES OF WORDS WHICH APPEAR IN THE FOLLOWING LIST: GYNECOLOGY, MISSISSIPPI, NECESSITATE, NECESSITOUS, LEGUMINOUS, GYROSCOPE, GLAGITIOUSNESS, CONSCIENTIOUSNESS, AMBIGUOUSLY, ABERRATION, ENFRANCHISEMENT, GRADILOQUENTLY, HERBINOROUS, ISOSCELES, JUVENESCENCE, KALEIDOSCOPIC, LOXODROMICS, MUTINOUSNESS, MYTHOLOGICALLY, ORCHIDACEOUS, PARALLELOPIPED, RECRIMINATORY, RHAPSODICALLY, SILHOUETTE, SOLIDUNGALATE, TERRAQUEOUS, VENTUROUSNESS, XYLOPHONE, XYLOPYROGRAPHY, ZYMURGY.

QUITE OFTEN, LONG WORDS WHICH CONTAIN COMBINATIONS OF LETTERS WHICH ARE NOT USED FREQUENTLY HAVE A TENDENCY TO CAUSE HESITATION AND INACCURACY. WHEN SENDING SUCH A WORD AND YOU MAKE A MISTAKE, THEN TRY YOUR BEST TO REMAIN CALM RATHER THAN BECOME CONFUSED — SIMPLY MAKE THE ERROR SIGN AND PROCEED TO SEND THE WORD AGAIN CORRECTLY.

ON THE OTHER HAND, IF YOU ARE RECEIVING A CODE GROUP, WORD, OR MESSAGE AND YOU FIND THAT YOU CANNOT IMMEDIATELY RECOGNIZE A GIVEN LETTER, THEN DO NOT WASTE VALUABLE TIME BY VAINLY TRYING TO RECALL THAT LETTER BUT SIMPLY SKIP THAT LETTER AND BE READY TO CATCH THE NEXT ONE. IF YOU SHOULD PAUSE FOR TOO GREAT A LENGTH OF TIME ON A SINGLE LETTER, SEVERAL OTHER LETTERS MAY ALREADY BE SENT TO YOU WHILE YOU ARE STILL CONTEMPLATING UPON THE FIRST. THE RESULT IS THAT YOU MAY MISS AN ENTIRE WORD AND THE TRUE MEANING OF A MESSAGE ALL ON ACCOUNT OF ONE LETTER. IT IS MUCH MORE PREFERABLE TO MISS A LETTER AND SATISFACTORILY RECEIVE THE REMAINDER OF THE MESSAGE CORRECTLY.

IN THE FOLLOWING PRACTICE SENTENCES YOU WILL FIND A LARGE VARIETY OF LETTERS USED IN MANY DIFFERENT COMBINATIONS. PRACTICE SENDING THESE SENTENCES SEVERAL TIMES.

PRACTICE SENTENCES

1. – MANY OF THE COUNTRY TOWNS ARE INSTALLING NEW OR ADDITIONAL PLANTS TO REPLACE OBSOLETE AND INEFFICIENT SETS WHICH HAVE BEEN IN USE FOR MANY YEARS PAST THEIR EFFECTIVE LIFE OWING TO THE RECENT STRINGENT CONDITIONS.

2. – HE REPORTS TO A SUPERIOR AND THE DEFENDANT IS TRIED BY A COURT COMPOSED OF THE SUPERINTENDENT AND TWO DISINTERESTED PARTIES.

3. – THE INSPECTOR DOES NOT HAVE A REGULAR SCHEDULE SO NO ONE KNOWS WHEN TO EXPECT HIM.

4. – THIS WILL TAKE CARE OF BOTH DUST AND MOISTURE THAT ARE HIDING TO DO DAMAGE LATER.

5. – MARKING IS BY MEANS OF HOLES IN WHICH STEEL PINS ARE FITTED.

6. – NOW THAT THE ITINERARY OF A WORN OUT ENGINE HAS BEEN TRACED THROUGH ITS REJUVINATION PROCESS AND BACK TO WORK AGAIN WE CAN GO ON TO THE OTHER UNITS.

7. — THE LIGHT BEAM IS ADJUSTED SO THAT IT PASSES THROUGH THE NEGATIVE AND FALLS ON THE PLATE OF THE PHOTO ELECTRIC CELL.

8. — A SPRING SUSPENSION IS EMPLOYED AT ONE END OF EACH STRIP TO KEEP THE STRIP TAUT.

9. — THE FIRST IMPORTANT POINT FOR CONSIDERATION IS THAT OF BONDING BETWEEN THE VARIOUS METALLIC MEMBERS OF AN AUTOMOBILE EQUIPPED WITH A RADIO SET.

10.— TO SECURE THE MOST PERFECT REPRODUCTION AT ALL TIMES IT IS NECESSARY THAT THE RECEIVER BE CAPABLE OF HANDLING EVERY LOUD PASSAGE OR PEAK THAT COMES IN WITHOUT OVERLOADING OR DISTORTING.

YOU WILL DERIVE EXCELLENT PRACTICE BY SENDING PARAGRAPHS WHICH ARE PRINTED IN NEWSPAPERS, MAGAZINES ETC. AND IF POSSIBLE HAVE SOME OTHER PARTY SEND YOU THESE MESSAGES BY CODE SO THAT YOU CAN PRACTICE RECEIVING AS WELL. AN EXCELLENT METHOD OF OBTAINING RECEIVING PRACTICE IS TO LISTEN TO AMATEUR OR COMMERCIAL TRAFFIC WHERE CODE IS BEING EMPLOYED. YOU CAN ALWAYS FIND SOME STATION IN THIS WAY WHICH IS TRANSMITTING CODE AT A MODERATE SPEED SUITABLE FOR A BEGINNER. AT FIRST, YOU MAY ONLY BE ABLE TO PICK OUT A FEW LETTERS BUT WITH CONTINUED PRACTICE YOU WILL FIND YOURSELF RECEIVING MORE LETTERS AND GRADUALLY SHORT WORDS AND FINALLY COMPLETE SENTENCES. IT IS REALLY SURPRISING HOW MANY PERSONS HAVE LEARNED THE CODE WITH NO HELP OTHER THAN INSTRUCTIONS AS THESE, A CODE PRACTICE SET AND A SHORT-WAVE RECEIVER.

NUMERALS

UP TO THIS TIME YOUR CODE STUDIES HAVE BEEN DEVOTED SOLELY TO THE LETTERS OF THE ALPHABET USED IN VARIOUS ARRANGEMENTS. YOUR NEXT STEP WILL BE TO LEARN THE NUMERALS BUT BY ALL MEANS DON'T EVEN ATTEMPT TO LEARN THE NUMERALS UNTIL YOU FEEL ABSOLUTELY CERTAIN OF YOUR ABILITY TO HANDLE THE ALPHABET SATISFACTORILY.

COMMENCE YOUR STUDY OF THE NUMERALS WITH MEMORIZING GROUP #9 AND WHICH CONSISTS OF THE NUMBERS 1 TO 5 INCLUSIVE. NOTE IN PARTICULAR THAT ALL OF THE NUMBERS CONTAIN FIVE CHARACTERS AND THAT A VERY DEFINITE ARRANGEMENT IS USED. FOR INSTANCE, THE NUMBER 1 IS MADE UP OF ONE DIT FOLLOWED BY FOUR DAHS; THE NUMBER TWO IS MADE UP OF TWO DITS FOLLOWED BY THREE DAH'S ETC. IN OTHER WORDS, THE NUMBER OF DITS USED IN SUCCESSION OF EACH OF THE FIRST FIVE NUMBERS IS INDICATIVE OF THE NUMBER. THIS IS A SIMPLE RELATION, WHICH WHEN NOTED, WILL HELP YOU TO REMEMBER THESE NUMERALS.

WHEN YOU HAVE BOTH SENT AND RECEIVED THE FIRST FIVE NUMERALS SO THAT YOU CAN SEND THEM IN ANY ORDER WITHOUT HESITATION, THEN CONTINUE WITH THE FOLLOWING EXERCISE.

13121	24351	42432	14245	24214	23325
52513	52134	13413	45521	31452	23453
45132	34152	45321	12345	32245	11234
23245	34512	13412	42324	32452	32341
52321	34252	51234	51423	34145	21234
32452	41434	15152	43212	51425	55321
11452	35421	52113	32451	22133	15243

NUMBER AND LETTER GROUPS

The next step is to practice the following groups which contain combinations of the first five numerals and the letters T, M, O, E, I, S, and H. When copying code groups of this nature great care must be exercised so as not to mistake a I for an I or an O for zero. For this reason, it is customary to place a dot in the middle of a zero when copying code so that it will not later be read as the letter O. In the case of the letter I either be sure to place cross bars at each of its extremeties or else write it in the script form "I" so as not to later read it as the number I. Here is the practice exercise:

SI324	H2ITO	04I53	I432H	5255I	20I53
T4245	SIE45	E5532	EI342	42T35	4E32I
45234	T4H5T	42I38	3345I	E245I	T342I
T3H2I	52423	43I5I	32TI4	4I32S	3SI42
5I34M	I034M	5HI34	I534M	E32I5	H4232

MEMORIZING GROUP #10

The numbers 6 to 0 are contained in memorizing group #10. These numbers follow a sequence which is reversed to that of the numbers I to 5 in that the dahs come first and are followed by the dits while zero consists of five dahs produced one after the other. A practice exercise containing the numbers 6 to 0 in various combinations follows:

67890	60097	99680	80997	87979	78786
67897	66078	79680	89679	88776	77896
66867	97860	77889	88769	98760	86908
69798	79680	86668	86908	69798	79680
67789	78608	67780	78676	78907	99870
09876	60708	89760	69886	87606	98076

The following exercise will furnish you with excellent practice involving all ten of the numbers. Apply yourself conscientiously to this work and do not rush through it.

33220	32603	67513	48965	42823	39824
72823	85789	31764	44693	97680	79606
01801	44693	97680	79606	84725	68410
84736	97439	78261	78696	72654	67671
37601	87427	92121	43295	42690	46743
46821	63891	87462	12814	42391	84765
09875	45121	58798	95864	32165	51232
90001	70663	37680	79805	02370	35506
52436	89706	50362	44551	87294	75613
46789	32176	42638	23578	77654	46803

A REVIEW EXERCISE

A good review exercise follows. By performing this exercise you will have an opportunity to use all of the letters in the alphabet as well as all ten numerals.

3HOWS	6G14J	V3LUJ	4S3XA	QOS37	429DO
Y64UT	3K403	F390G	W6FMO	7MOHS	56NQR
52RNL	PQ6HT	KOH41	P78BC	8NOR5	78ANY
1D9EV	103AX	TOM59	Y23ZU	BE752	2280K

WHEN YOU HAVE REACHED THIS STAGE OF YOUR CODE STUDIES, YOU SHOULD BE ABLE TO SEND ANY FORM OF LETTER, WORD OR NUMBER COMBINATION WITH EASE AND ACCURACY. HOWEVER, IT TAKES A GREAT DEAL OF PATIENT PRACTICE AND EARNEST STUDY IN ORDER TO BE ABLE TO DO THIS.

HAVING MASTERED THIS PART OF THE WORK, YOU ARE NOW READY TO LEARN THE MOST USED PUNCTUATION MARKS AND SPECIAL ABREVIATIONS WHICH APPEAR IN MEMORIZING GROUPS #11 AND #12. THESE CONSIST OF THE PERIOD; THE INTERROGATION OR QUESTION MARK; THE BREAK OR DOUBLE DASH; THE ERROR SIGN WHICH YOU SHOULD ALREADY HAVE BEEN USING AS PER PREVIOUS INSTRUCTIONS; THE WAIT SIGN; THE END OF MESSAGE AND THE END OF TRANSMISSION SIGNS. IN ADDITION, YOU CAN ALSO AT THIS TIME LEARN THE SIGNS FOR "RECEIVED O.K." (DIT DAH DIT) AND "INVITATION TO TRANSMIT (GO AHEAD)" WHICH APPEARS AS DAH DIT DAH IN YOUR COMPLETE CODE TABLE I IN THE PREVIOUS LESSON.

IN ORDER TO QUALIFY FOR AN AMATEUR'S LICENSE THIS COMPLETES YOUR CODE KNOWLEDGE AS FAR AS TABLE I OF THE PREVIOUS LESSON IS CONCERNED. TO BECOME THOROUGHLY QUALIFIED AS A COMMERCIAL OPERATOR, HOWEVER, YOU SHOULD ALSO LEARN THE REMAINING PORTIONS OF THIS SAME TABLE I BUT THIS CAN BE DONE GRADUALLY OVER A PERIOD OF TIME AND AS YOU BECOME MORE EXPERIENCED IN THIS LINE OF WORK.

THE "Q" CODE

NOW IN ADDITION TO THE MORSE CODE, WE ALSO HAVE WHAT IS KNOWN AS THE "Q" CODE. THIS "Q" CODE IS NOTHING MORE THAN A SERIES OF ABREVIATIONS WHICH HAS BEEN DEVISED FOR USE IN INTERNATIONAL RADIO COMMUNICATIONS. THIS "Q" CODE APPEARS IN TABLE I OF THIS LESSON AND AS YOU WILL OBSERVE, EACH OF THE ABREVIATIONS STARTS WITH THE LETTER Q AND FROM WHICH IT DERIVES THE SIGNIFICANT NAME "Q-CODE".

THESE VARIOUS ABREVIATIONS HAVE THE MEANINGS AS SPECIFIED IN THE "ANSWER" COLUMN OF TABLE I. WHENEVER ANY OF THESE ABREVIATIONS IS FOLLOWED BY A QUESTION MARK, THEN ITS MEANING BECOMES AS SPECIFIED IN THE "QUESTION COLUMN" OF TABLE I. FOR EXAMPLE, IF YOU SUSPECT THAT THE SIGNALS BETWEEN YOU AND THE PARTY WITH WHOM YOU ARE COMMUNICATING ARE BEING SUBJECTED TO INTERFERENCE, THEN YOU WOULD SEND THE SIGNAL QRM. IF SUCH BE THE CASE, THEN THE OTHER PARTY CAN ANSWER YOUR QUESTION BY SIMPLY SENDING THE ABBREVIATION QRM, WHICH MEANS THAT HE IS BEING INTERFERED WITH.

YOU WILL ALSO OBSERVE IN TABLE I THAT THE DIFFERENT TYPES OF WAVE FORMS ARE REFERRED TO AS WAVES OF TYPE A1, A2, A3 AND B. THESE PARTICULAR ABREVIATIONS HAVE THE FOLLOWING MEANING:

TYPE A1 WAVES ARE UNMODULATED CONTINUOUS WAVES WHICH ARE VARIED BY TELEGRAPHIC KEYING; TYPE A2 WAVES ARE CONTINUOUS WAVES WHICH ARE MODULATED AT AUDIBLE FREQUENCY AND WITH WHICH IS COMBINED TELEGRAPHIC KEYING; TYPE A3 WAVES ARE CONTINUOUS WAVES WHICH ARE MODULATED BY SPEECH OR BY MUSIC; TYPE B WAVES ARE DAMPED WAVES.

TABLE I

THE Q CODE

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is ....
QRB	At what approximate distance are you from my station?	The approximate distance between our stations is ...... nautical miles (or ...... kilometers).
QRC	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the .... private company (or by the government administration of ....).
QRD	Where are you going?	I am going to ......
QRE	What is the nationality of your station?	The nationality of my station is ....
QRF	Where do you come from?	I come from ....
QRG	Will you indicate to me my exact wave length in meters (or frequency in kilocycles)?	Your exact wave length is ...... meters (or .... kilocycles).
QRH	What is your exact wave length in meters (frequency in kilocycles)?	My exact wave length is .... meters (frequency .... kilocycles).
QRI	Is my tone bad?	Your tone is bad.
QRJ	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy. Or, (I am busy with ......). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Must I increase power?	Increase power.
QRP	Must I decrease power?	Decrease power.
QRQ	Must I send faster?	Send faster (...... words per minute).
QRS	Must I send more slowly?	Send more slowly (........ words per minute).
QRT	Must I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Must I send a series of V's?	Send a series of V's.
QRW	Must I advise .... that you are calling him?	Please advise .... that I am calling him.
QRX	Must I wait? When will you call me again?	Wait until I have finished communicating with .... I will call you immediately (or at .... o'clock).
QRY	Which is my turn?	Your turn is No. .... (or according to any other indication).
QRZ	By whom am I being called?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSC	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD	Is my keying bad?	Your keying is bad. Your signals are unreadable.
QSE	Are my signals distinct?	Your signals run together.
QSF	Is my automatic transmission good?	Your automatic transmission fades out.
QSG	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ	What is the charge to be collected per word for .... including your internal telegraph charge?	The charge to be collected per word for .... is .... francs, including my internal telegraph charge.
QSK	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at .... (o'clock).
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN	Can you receive me now? Must I continue to listen?	I can not receive you now. Continue to listen.
QSO	Can you communicate with .... directly (or through the intermediary of ....)?	I can communicate with .... directly (or through the intermediary of ......).

Abbreviation	*Question*	*Answer*
QSP	Will you relay to .... free of charge?	I will relay to .... free of charge.
QSQ	Must I send each word or group once only?	Send each word or group once only.
QSR	Has the distress call received from .... been attended to?	The distress call received from .... has been attended to by ....
QSU	Must I send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B?	Send on .... meters (or on .... kilocycles), waves of Type A1, A2, A3 or B. I am listening for you.
QSV	Must I shift to the wave of .... meters (or of .... kilocycles), for the balance of our communications, and continue after having sent several V's?	Shift to wave of .... meters (or of ... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW	Will you send on .... meters (or on .. kilocycles) waves of Type A1, A2, A3 or B?	I will send on .... meters (or .... kilocycles) waves of Type A1, A2, A3 or B. Continue to listen.
QSX	Does my wave length (frequency) vary?	Your wave length (frequency) varies.
QSY	Must I send on the wave of .... meters (or .... kilocycles) without changing the type of wave?	Send on the wave of .... meters (or .... kilocycles) without changing the type of wave.
QSZ	Must I send each word or group twice.	Send each word or group twice.
QTA	Must I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my word count?	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you or for ....
QTD	Is the word-count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE	What is my true bearing? (or) What is my true bearing relative to?	Your true bearing is .... degrees (or) Your true bearing relative to .... is .... degrees at .... (o'clock).
QTF	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on the bearings taken by the radiocompass stations which I control is .... latitude .... longitude.
QTG	Will you transmit your call signal for one minute on a wave length of .... meters (or .... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for one minute on the wave length of .... meters (or .... kilocycles) in order that you may take my radiocompass bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is .... latitude .... longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots (or .... kilometres) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).
QTP	Are you going to enter dock (or port)?	I am going to enter dock (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is ....
QTU	What are the hours during which your station is open?	My station is open from .... to ....
QUA	Have you news of .... (call sign of the mobile station)?	Here is news of .... (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for .... (place of observation)?	Here is the information requested ....
QUC	What is the last message received by you from .... (call sign of the mobile station)?	The last message received by me from .... (call sign of the mobile station) is ....
QUD	Have you received the urgency signal sent by .... (call sign of the mobile station)?	I have received the urgency signal sent by .... (call sign of the mobile station) at .... (time).
QUF	Have you received the distress signal sent by .... (call sign of the mobile station)?	I have received the distress signal sent by .... (call sign of the mobile station) at .... (time).

Abbreviation	Question	Answer
QUG	Are you being forced to alight in the sea (or to land)?	I am forced to alight (or land) at .... (place).
QUH	Will you indicate the present barometric pressure at sea level?	The present barometric pressure at sea level is .... (units).
QUJ	Will you indicate the true course for me to follow, with no wind, to make for you?	The true course for you to follow, with no wind, to make for me is .... degrees at .... (time).

TABLE II

ABBREVIATIONS MORE ESPECIALLY USED IN AIRCRAFT RADIO SERVICE

Abbreviation	Question	Answer
QAA.............	At what time do you expect to arrive at ......?	I expect to arrive at ...... at ...... (o'clock).
QAB.............	Are you en route to......?..............	I am en route to ...... or Go to ......
QAC.............	Are you returning to......?..............	I am returning to ...... or Return to....
QAD.............	At what time did you leave ...... ? (place of departure).	I left ...... (place of departure) at ...... (o'clock).
QAE.............	Have you news of ...... (call signal of the aircraft station)?	I have no news of ...... (call signal of the aircraft station).
QAF.............	At what time did you pass......?.........	I passed ...... at ...... (o'clock).
QAH.............	What is your height?....................	My height is ...... meters (or according to any other indication).
QAI.............	Has any aircraft signaled in my neighborhood?	No aircraft has signaled in your neighborhood.
QAJ.............	Must I look for another aircraft in my neighborhood?	Look for another aircraft in your neighborhood (or) Look for ...... (call signal of the aircraft station) which was flying near ...... (or in the direction of ......) at ...... (o'clock).
QAK.............	On what wave are you going to send the meteorological warning messages?	I am going to send the meteorological warning messages on wave length of ...... meters (or ...... kilocycles).
QAL.............	Are you going to land at ......?..........	I am going to land at ...... or Land ......
QAM.............	Can you give me the latest meteorological message concerning weather for ...... (place of observation)?	Here is the latest meteorological message concerning weather for ...... (place of observation).
QAN.............	Can you give me the latest meterological message concerning surface wind for ...... (place of observation)?	Here is the latest meteorological message concerning surface wind for ...... (place of observation).
QAO.............	Can you give me the latest meteorological message concerning upper wind for ...... (place of observation)?	Here is the latest meteorological message concerning upper wind for ...... (place of observation).
QAP.............	Must I continue to listen for you (or for ......) on ...... meters (or ...... kilocycles?	Continue to listen for me (or for ......) on ...... meters (or ...... kilocycles).
QAQ.............	Will you hasten the reply to message No. ...... (or in accordance with any other indication)?	I hasten the reply to message No. ...... (or in accordance with any other indication).
QAR.............	Must I reply to ...... for you?.........	Reply to ...... for me.
QAS.............	Must I send message No. ...... (or in accordance with any other indication) to ......?	Send message No. ...... (or in accordance with any other indication) to ......
QAT.............	Must I continue to send.................	Listen before sending; you are interfering; or Listen before sending; you are sending at the same time as ......
QAU.............	What is the last message received by you from ......?	The last message received by me from ...... is ......
QAV.............	Are you calling me?...................... or Are you calling ...... (call signal of the aircraft station?	I am calling you or I am calling ...... (call signal of the aircraft station).
QAW.............	Must I cease listening until ...... (o'clock)?.	Cease listening until ...... (o'clock).
QAX.............	Have you received the urgent signal sent by ...... (call signal of the aircraft station)?	I received the urgent signal sent by ...... call signal of the aircraft station) at ...... (o'clock).
QAY.............	Have you received the distress signal sent by ...... (call signal of the aircraft station)?	I received the distress signal sent by ...... (call signal of the aircraft station) at ...... (o'clock).
QAZ.............	Can you receive in spite of the storm?	I can no longer receive. I am going off watch because of the storm.

TABLE III

Miscellaneous Abbreviations

Abbreviation	*Meaning*
C	Yes.
N	No.
P	Indicator of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	All after .... (to be used after a note of interrogation to ask for a repetition).
AB	All before .... (to be used after a note of interrogation to ask for a repetition).
AL	All that has just been sent (to be used after a note of interrogation to ask for a repetition).
BN	All between .... (to be used after a note of interrogation to ask for a repetition).
BQ	A reply to an RQ
CL	I am closing my station.
CS	Call sign (to be used to ask for a call sign or to have one repeated).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DF	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DL	Your bearing at .... (time) was .... degrees in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at .... (time).
DP	Beyond 50 miles, the possible error of bearing may amount to two degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is two-way, what is your approximate direction in degrees in relation to this station?
DZ	Your bearing is reciprocal (to be used only by the control station of a group of direction-finding stations when it is addressing other stations of the same group).
ER	Here .... (to be used before the name of the mobile station in the sending of route indications).
GA	Resume sending (to be used more specially in the fixed service).
JM	If I may transmit, send a series of dashes. To stop my transmission, send a series of dots [not to be used on 500 kc/s (600 m)].
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	I resume transmission (to be used more especially in the fixed service).
OK	Agreed.
RQ	Designation of a request.
SA	Indicator preceding the name of an aircraft station (to be used in the sending of particulars of flight).
SF	Indicator preceding the name of an aeronautical station.
SN	Indicator preceding the name of a coast station.
SS	Indicator preceding the name of a ship station (to be used in sending particulars of voyage).
TR	Indicator used in sending particulars concerning a mobile station.
UA	Are we agreed?
WA	Word after .... (to be used after a note of interrogation to request a repetition).
WB	Word before .... (to be used after a note of interrogation to request a repetition).
XS	Atmospherics.
YS	Your service message.
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADR	Address (to be used after a note of interrogation to request a repetition).
CFM	Confirm (or I confirm).
COL	Collate (or I collate).
ITP	Stops (punctuation) count.
MSG	Telegram concerning the service of the ship (to be used as a prefix).
NIL	I have nothing for you (to be used after an abbreviation of the Q code to mean that the answer to the question put is negative).
PBL	Preamble (to be used after a note of interrogation to request a repetition).
REF	Referring to .... (or Refer to ....).
RPT	Repeat (or I repeat) (to be used to ask for or to give repetition of all or part of the traffic the relative particulars being sent after the abbreviation).
SIG	Signature (to be used after a note of interrogation to request a repetition).
SVC	Indicator of service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a note of interrogation to request a repetition).

TABLE II, YOU WILL NOTICE, IS ALSO A Q CODE BUT APPLIED PARTICULARLY TO AIRCRAFT RADIO SERVICE.

MISCELLANEOUS ABBREVIATIONS

THE MISCELLANEOUS ABBREVIATIONS WHICH APPEAR IN TABLE III HAVE BEEN ADOPTED BY UNIVERSAL AGREEMENT AND SHOULD THEREFORE NOT BE EMPLOYED IN OTHER THAN THE MEANINGS SPECIFIED NOR SHOULD OTHER THAN THE SPECIFIED ABBREVIATION BE EMPLOYED TO CONVEY ANY MEANING LISTED IN THIS TABLE.

THE AUDIBILITY SCALE

BY AGAIN REFERRING TO TABLE I OF THIS LESSON AND "LOOKING-UP" THE MEANING FOR THE ABREVIATION QSA, YOU WILL FIND THIS ABBREVIATION TO BE USED TO SPECIFY SIGNAL STRENGTH IN TERMS OF NUMBERS EXTENDING FROM 1 TO 5. THIS NUMBERING SYSTEM HAS THE FOLLOWING MEANING:

QSA1 = HARDLY PERCEPTIBLE, UNREADABLE
QSA2 = WEAK, READABLE NOW AND THEN
QSA3 = FAIRLY GOOD, READABLE BUT WITH DIFFICULTY
QSA4 = GOOD, READABLE
QSA5 = VERY GOOD, PERFECTLY READABLE.

IN AMATEUR WORK, THE "R" SYSTEM OF INDICATING AUDIBILITY IS ALSO NOW BEING USED EXTENSIVELY. THE "R SYSTEM" FOLLOWS:

R1 = FAINT SIGNALS, JUST AUDIBLE
R2 = WEAK SIGNALS, BARELY AUDIBLE
R3 = WEAK SIGNALS, COPIABLE (IN ABSENCE OF ANY DIFFICULTY)
R4 = FAIR SIGNALS, READABLE
R5 = MODERATELY STRONG SIGNALS
R6 = STRONG SIGNALS
R7 = GOOD STRONG SIGNALS (SUCH AS COPIABLE THROUGH INTERFERENCE)
R8 = VERY STRONG SIGNALS; CAN BE HEARD SEVERAL FEET FROM PHONES
R9 = EXTREMELY STRONG SIGNALS.

IN THIS LESSON YOU HAVE BEEN GIVEN A GREAT DEAL OF INFORMATION REGARDING THE CODE AND INFORMATION OF THE TYPE WHICH WILL REQUIRE STUDY OVER A CONSIDERABLE PERIOD OF TIME IN ORDER FOR YOU TO LEARN IT. DO NOT EXPECT TO LEARN THIS ALL AT ONCE BUT LEARN A FEW OF THE ABBREVIATIONS AT A TIME, STARTING WITH THOSE WHICH OBSERVATION AND LISTENING EXPERIENCE WILL SHOW YOU TO BE THE MOST IMPORTANT AND MOST USED. IN DUE TIME, YOU WILL FIND YOURSELF TO REMEMBER QUITE A NUMBER OF THEM.

SO THAT YOUR LESSONS MAY BE KEPT AS INTERESTING AS POSSIBLE, YOU ARE GOING TO HAVE A COMPLETE CHANGE OF SUBJECT MATTER IN YOUR NEXT LESSON. THIS FOLLOWING LESSON IS GOING TO TELL YOU ALL ABOUT CRYSTAL CONTROLLED OSCILLATORS AS USED IN TRANSMITTERS AND AFTER WHICH YOU WILL LEARN ABOUT AMPLIFYING STAGES AS USED IN TRANSMITTERS, POWER SUPPLIES, SPECIAL KEY CIRCUITS, ANTENNA SYSTEMS ETC.

THIS TECHNICAL INSTRUCTION WILL THEN BE FOLLOWED BY A COMPLETE EXPLANATION REGARDING THE TECHNIQUE OF CONDUCTING RADIO COMMUNICATION BY MEANS OF THE CODE, THE CORRECT PROCEDURE FOR HANDLING MESSAGES ETC.

Examination Questions

LESSON NO. T-5

> Men may learn from past experience but bemoaning lost yesterdays is worse than futile when the calender is filled with priceless tomorrows.

1. – AT THE TIME OF ANSWERING THIS EXAMINATION, HOW MANY CODE LETTERS CAN YOU TRANSMIT WITHOUT REFERRING TO YOUR TEXT?

2. – WHAT PARTICULAR PRECAUTIONS SHOULD BE EXERCISED WHEN SENDING THE LETTERS C, Q, V, L AND J?

3. – WHEN COPYING CODE, WHY IS IT ADVISABLE TO SKIP A LETTER IF YOU CAN'T REMEMBER IT AT THE TIME?

4. – HOW IS THE NUMBER 9 PRODUCED BY MEANS OF THE CODE?

5. – WHEN COPYING CODE, WHAT PRECAUTIONS ARE TAKEN SO THAT A ZERO IS NOT READ FROM THE WRITTEN COPY AS THE LETTER O?

6. – WHEN COPYING CODE, WHAT PRECAUTIONS ARE TAKEN SO THAT THE LETTER I IS NOT MISTAKEN FOR THE NUMERAL 1?

7. – WHAT IS THE MEANING OF THE ABBREVIATION QRX?

8. – SHOW BY MEANS OF THE PROPER ARRANGEMENT OF DOTS AND DASHES HOW YOU WOULD MAKE THE QUESTION MARK BY MEANS OF THE CODE.

9. – IF YOU SHOULD SEND SOMEONE THE SIGNAL ABBREVIATION QSA FOLLOWED BY A QUESTION MARK AND THEY SENT YOU AN ANSWER OF QSA5, WHAT WOULD THIS ANSWER INDICATE?

10. – EXPLAIN WHAT TYPES OF WAVES ARE INDICATED BY THE FOLLOWING ABBREVIATIONS: TYPE A1, A2, A3 AND B.

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RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

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Transmitters

LESSON NO. 6

CRYSTAL-CONTROLLED OSCILLATORS

AS YOU WILL RECALL FROM YOUR PREVIOUS STUDIES CONCERNING VACUUM TUBE OSCILLATOR CIRCUITS OF THE SIMPLE TYPE, IT IS OF UTMOST IMPORTANCE THAT SUCH CIRCUITS BE CAREFULLY TUNED SO THAT THE TRANSMITTER WILL OPERATE ON THE CORRECT FREQUENCY. HOWEVER, IN SPITE OF THE FACT THAT SUCH AN OSCILLATOR CIRCUIT IS PROPERLY ADJUSTED FOR A GIVEN FREQUENCY, YET CONDITIONS ARISE IN PRACTICE WHICH MAY CAUSE THE OSCILLATOR TO CHANGE ITS FREQUENCY ON ITS OWN ACCORD. WHENEVER ANY SUCH FREQUENCY VARIATION OCCURS DURING THE COURSE OF OPERATION WE SAY THAT THE OSCILLATOR IS UNSTABLE OR THAT THE TRANSMITTER IS SUBJECT TO "FREQUENCY INSTABILITY".

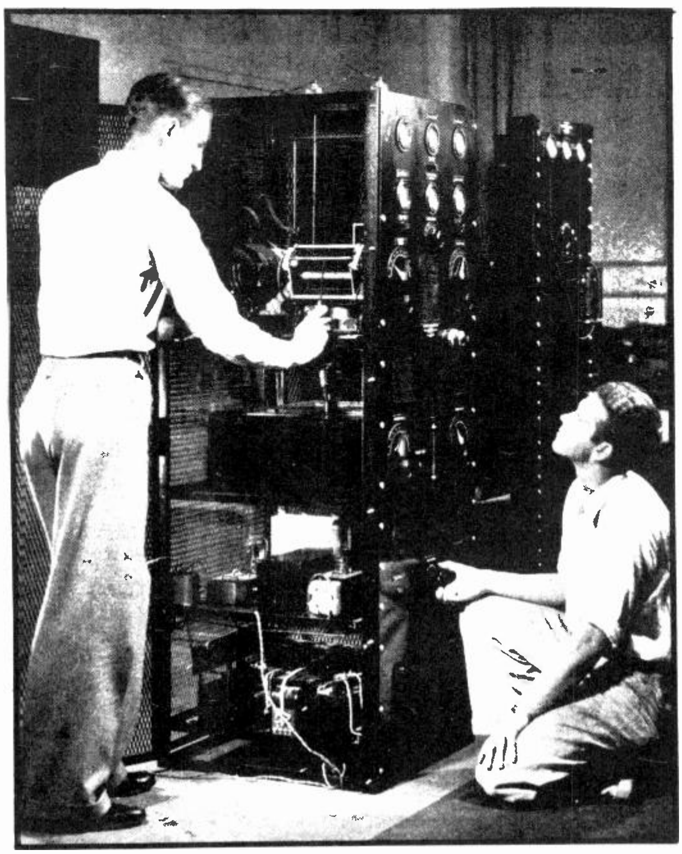

FIG. 1
Students Conducting Tests On One of Nationals Crystal-Controlled Transmitters.

THE REASON WHY SIMPLE OR SELF-CONTROLLED OSCILLATORS ARE SUBJECT TO FREQUENCY INSTABILITY CAN BE EXPLAINED IN THE FOLLOWING MANNER: THE FREQUENCY TO WHICH AN OSCILLATOR CIRCUIT IS TUNED IS GOVERNED CHIEFLY BY THE INDUCTANCE VALUE OF THE COIL AND THE CAPACITIVE VALUE OF THE CONDENSER WHICH ARE USED IN

THE TUNING CIRCUITS. IN THE CASE OF THE TUNED GRID CIRCUIT, THE CAPACITANCE OF THIS CIRCUIT IS ALSO SHUNTED BY THE INPUT CAPACITY OF THE TUBE AND THIS INPUT CAPACITY IS A FUNCTION OF THE PLATE LOAD AND THE GRID-PLATE CAPACITY OF THE TUBE. EXPRESSED AS A FORMULA THIS WOULD BE:

$$C_i = C_{gf} + C_{gp}\left(\frac{\mu R_o}{R_o + R_p} + 1\right)$$

WHERE C_i = INPUT CAPACITY; C_{gf} = GRID-FILAMENT CAPACITY; C_{gp} = GRID-PLATE CAPACITY; μ = AMPLIFICATION FACTOR OF THE TUBE; R_o = OUTPUT LOAD RESISTANCE AND R_p = THE TUBE'S PLATE RESISTANCE.

BY STUDYING THIS FORMULA CAREFULLY, YOU WILL NOTICE THAT ANY CHANGE IN THE PLATE RESISTANCE, IN THE GRID-PLATE CAPACITY, OR THE OUTPUT LOAD WILL PRODUCE A CHANGE IN THE GRID-FILAMENT CAPACITY AND WHICH IN TURN IS CAPABLE OF DETERMINING THE FREQUENCY AT WHICH THE CIRCUIT OSCILLATES. IT IS ALSO TRUE THAT CHANGES IN FILAMENT TEMPERATURE, IN C BIAS, OR IN PLATE VOLTAGE WILL AFFECT THE PLATE RESISTANCE OF THE TUBE AND THEREBY CHANGE ITS RELATION TO THE LOAD RESISTANCE. CHANGES OF THIS NATURE WILL ALSO AFFECT THE FREQUENCY OF THE OSCILLATOR'S OUTPUT. IT IS INTERESTING TO NOTE THAT THE SMALLER THE PLATE LOAD, THE LARGER WILL BE THE GRID-PLATE CAPACITY; AND THE GREATER THE PLATE RESISTANCE OF THE TUBE, THE MORE WILL THE GENERATED FREQUENCY DEPEND UPON THESE FACTORS.

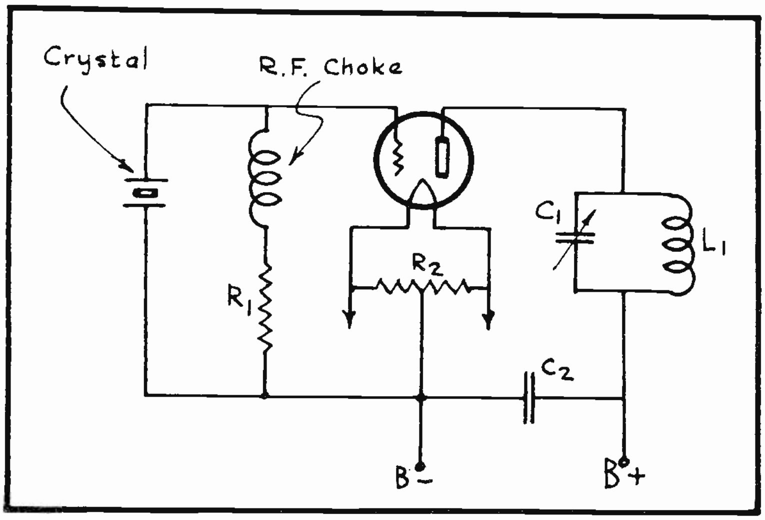

FIG. 2
Application of the Crystal.

IMPROVING STABILITY

ONE METHOD OF MAKING THE OSCILLATOR FREQUENCY MORE INDEPENDENT FROM THE TUBE CHARACTERISTICS IS TO USE A RATHER LARGE FIXED INPUT CAPACITY TO THE NORMAL GRID-FILAMENT CAPACITY SO THAT CHANGES IN THE LATTER ARE UNIMPORTANT. IN THIS WAY, BY SHUNTING A FAIRLY LARGE CAPACITY ACROSS THE GRID AND FILAMENT, THE TOTAL EFFECTIVE INPUT CAPACITY WILL BE INCREASED TO SUCH AN EXTENT THAT SMALL CHANGES IN THE INTERNAL CAPACITY OF THE TUBE WILL HAVE RATHER LITTLE EFFECT UPON THE TUNING.

A STILL DIFFERENT METHOD WHICH IS COMMONLY USED TO IMPROVE THE FREQUENCY STABILITY OF AN OSCILLATOR IS TO USE A TUNING CONDENSER OF RATHER LARGE CAPACITY AND A COIL OF PROPORTIONATELY LOWER INDUCTANCE — IN OTHER WORDS, A HIGH CAPACITY — LOW INDUCTANCE TUNING CIRCUIT.

IN THE SMALLER TRANSMITTERS WHERE THE OSCILLATOR IS COUPLED DIRECTLY TO THE ANTENNA SYSTEM WITHOUT ANY STAGE OF AMPLIFICATION BETWEEN THE OSCILLATOR AND THE ANTENNA, IT IS ALSO A COMMON OCCURRENCE FOR ANY CHANGE IN THE CAPACITY OF THE ANTENNA AS CAUSED BY SWAYING IN THE WIND ETC. TO REACT BACK UPON THE OSCILLATOR CIRCUIT AND IN THIS WAY ALTER THE FREQUEN-

QUENCY WHICH IS BEING GENERATED BY THE OSCILLATOR.

THE CRYSTAL OSCILLATOR

IN MODERN TRANSMITTERS WHICH ARE REQUIRED TO POSSESS EXCELLENT FREQUENCY STABILITY, THE USUAL RESONANT CIRCUIT IN THE OSCILLATOR TUBE'S GRID CIRCUIT IS REPLACED WITH A QUARTZ CRYSTAL AND WHOSE CHARACTERISTICS ARE SUCH THAT THE VARIATIONS IN FREQUENCY ARE PRACTICALLY NEGLIGIBLE EVEN WHEN SOME OF THE OTHER CIRCUIT CONSTANTS ARE VARIED APPRECIABLY. OSCILLATORS WHICH EMPLOY SUCH A CRYSTAL IN ORDER TO INSURE FREQUENCY STABILITY ARE KNOWN AS CRYSTAL CONTROLLED OSCILLATORS.

IN FIG. 2 YOU ARE SHOWN A DIAGRAM OF AN OSCILLATOR CIRCUIT IN WHICH A CRYSTAL IS EMPLOYED. HERE YOU WILL OBSERVE THAT WE HAVE A TRIODE OSCILLATOR TUBE HAVING A TUNING CIRCUIT CONSISTING OF C_1 AND L_1 INSTALLED IN ITS PLATE CIRCUIT. THE CRYSTAL, ON THE OTHER HAND IS CONNECTED ACROSS THE GRID CIRCUIT OF THIS TUBE AND IS SHUNTED BY THE LEAK RESISTOR R_1 AND THE R.F. CHOKE WHICH ARE CONNECTED TOGETHER IN SERIES.

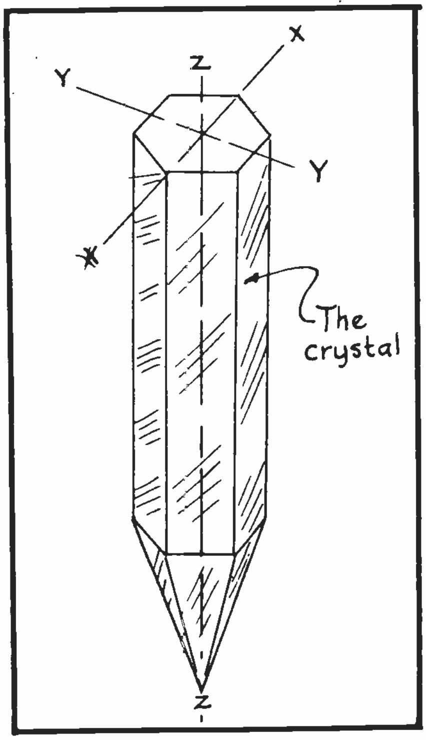

FIG. 3
The Crystalline Structure.

THE CRYSTAL IS SO CONSTRUCTED THAT IT WILL PERMIT THE CIRCUIT TO OSCILLATE AT ONLY ONE PARTICULAR FREQUENCY. BY PROPER ADJUSTMENT OF THE PLATE CIRCUIT, THE FEED-BACK ENERGY WILL BE IMPRESSED UPON THE GRID CIRCUIT THROUGH THE GRID-PLATE CAPACITY OF THE TUBE AND THEREBY CAUSE THE CIRCUIT TO OSCILLATE.

WHEN TUNING AN OSCILLATOR OF THIS TYPE, THE PROCEDURE IS AS FOLLOWS: THE ANTENNA (LOAD) IS DISCONNECTED AND WITH A MILLIAMMETER CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE OSCILLATOR, CONDENSER C_1 IS ADJUSTED UNTIL THE MILLIAMMETER READING DROPS SUDDENLY AND WHICH SHOWS THAT OSCILLATION HAS COMMENCED. CONDENSER C_1 IS THEN FURTHER ADJUSTED UNTIL THE MILLIAMMETER OFFERS A MINIMUM READING AND WHICH SHOWS THAT THE PLATE CIRCUIT IS NOW TUNED TO RESONANCE WITH THE CRYSTAL-CONTROLLED GRID CIRCUIT. HOWEVER, IF THE OSCILLATOR IS PERMITTED TO OPERATE IN THIS CONDITION, ANY SLIGHT CHANGE IN THE CIRCUIT CONSTANTS MAY CAUSE THE CRYSTAL TO STOP OSCILLATING. FOR THIS REASON, CONDENSER C_1 IS ADJUSTED FOR A FREQUENCY WHICH IS A TRIFLE HIGHER THAN THE SETTING WHICH HAS JUST BEEN DETERMINED — THE CRYSTAL NEVERTHELESS CONTINUES TO OSCILLATE AT ITS NATURAL FREQUENCY IN SPITE OF THIS SLIGHT ALTERATION IN PLATE CIRCUIT TUNING. IN FACT, FOR SEVERAL DEGREES OF THE PLATE TUNING CONDENSER, THE OSCILLATOR'S OUTPUT FREQUENCY IS THAT OF THE CRYSTAL AND IN THIS MANNER CHANGES IN THE PLATE RESISTANCE OF THE TUBE, POWER SUPPLY VOLTAGES ETC., WILL HAVE RELATIVELY SMALL EFFECT ON CONTROLLING THE FREQUENCY AT WHICH THE CIRCUIT OSCILLATES.

NOW THAT YOU ARE IN A GENERAL WAY FAMILIAR WITH THE MANNER IN WHICH I

THE CRYSTAL IS USED IN AN OSCILLATOR CIRCUIT, YOU WILL NO DOUBT BE INTERESTED IN LEARNING MORE ABOUT THE CONSTRUCTIONAL FEATURES OF THE CRYSTAL AND THE PROPERTIES WHICH IT POSSESSES THAT ENABLES IT TO CONTROL THE FREQUENCY OF THE OSCILLATOR. THIS THEN WILL BE OUR NEXT STEP.

PIEZO-ELECTRIC PROPERTIES

ALL CRYSTALS WHICH ARE SUITABLE FOR CONTROLLING THE FREQUENCY OF AN OSCILLATOR POSSESS WHAT ARE KNOWN AS PIEZO – ELECTRIC PROPERTIES. QUITE A NUMBER OF CRYSTALLINE SUBSTANCES HAVE PIEZO-ELECTRIC PROPERTIES AND AMONG THESE WE FIND QUARTZ, TOURMALINE, ROCHELLE SALTS AND SEVERAL OTHERS BUT OF ALL THESE QUARTZ IS USED EXCLUSIVELY IN CRYSTAL CONTROLLED OSCILLATORS. THE EXTENSIVE USE OF QUARTZ IS PRIMARILY DUE TO ITS COMPARATIVELY LOW COST, MECHANICAL RUGGEDNESS, AND LOW TEMPERATURE COEFFICIENT.

IN FIG. 3 YOU ARE SHOWN THE GENERAL SHAPE OF A NATURAL QUARTZ CRYSTAL. NOTICE, THAT ITS CROSS-SECTION IS A HEXAGON OR SIX-SIDED FIGURE AND THAT IT HAS THREE MAJOR AXES, NAMELY, THE X AXIS, THE Y AXIS AND THE Z AXIS.

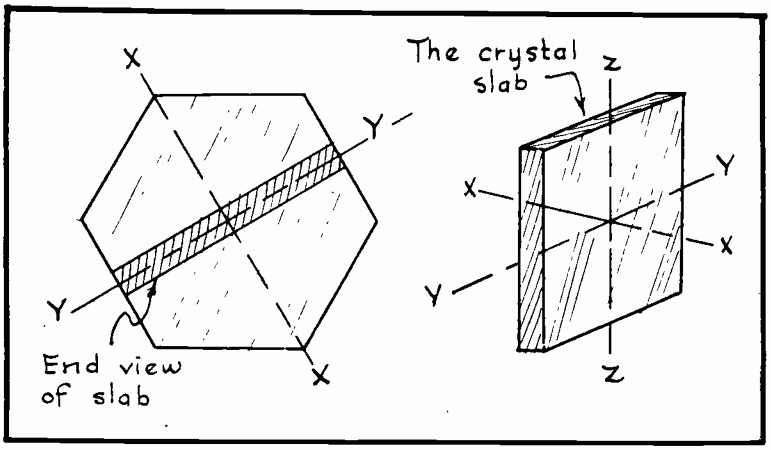

FIG. 4
The "X Cut" or "Curie-Cut" Crystal.

THE X AXIS PROJECTS THROUGH OPPOSITE CORNERS OF THE HEXAGON CROSS-SECTION AND IT IS KNOWN AS THE "ELECTRICAL AXIS". WITH A HEXAGON FIGURE, IT IS OF COURSE APPARENT THAT THREE SUCH X AXES EXIST.

THE Y AXIS PROJECTS THROUGH THE CENTER OF THE CROSS-SECTION AND IS PERPENDICULAR TO OPPOSITE SIDES OF THE FIGURE. THE Y AXIS IS KNOWN AS THE "MECHANICAL AXIS" AND FOR THE ONE CRYSTALLINE STRUCTURE, THERE ARE THREE SUCH Y AXES.

THE Z AXIS IS KNOWN AS THE "OPTICAL AXIS" AND IT PROJECTS LONGITUDINALLY THROUGH THE CENTER OF THE STRUCTURE.

THE ILLUSTRATION IN FIG. 3, YOU WILL RECALL, IS THE NATURAL SHAPE OF THE QUARTZ CRYSTAL BUT FOR USE IN THE TRANSMITTER, THE CRYSTALS ARE GENERALLY CUT FROM THE ORIGINAL STRUCTURE SO THAT THE FINISHED UNIT IS A SQUARE-SHAPED SLAB.

THERE ARE TWO METHODS OF CUTTING A FLAT SECTION OR SLAB FOR TRANSMITTER USE FROM THE ORIGINAL CRYSTAL STRUCTURE. ONE OF THESE METHODS RESULTS IN WHAT IS KNOWN AS AN "X-CUT" OR "CURIE-CUT" CRYSTAL WHILE THE OTHER METHOD OF CUTTING RESULTS IN WHAT IS KNOWN AS A "Y-CUT" OR "30° – CUT" CRYSTAL.

THE "X-CUT" CRYSTAL

FIG. 4 SHOWS YOU HOW AN "X-CUT" OR "CURIE-CUT" CRYSTAL IS OBTAINED.

AT THE LEFT OF FIG. 4 YOU ARE LOOKING AT THE CROSS-SECTION OF THE ORIGINAL CRYSTAL AS SEEN FROM ABOVE, AND HERE THE EDGE OF THE SLAB FACES UPWARD AND IS INDICATED BY THE SHADED AREA IN THIS ILLUSTRATION. THE FLAT SIDES OF THE CRYSTAL SLAB WILL THEREFORE IN THIS INSTANCE BE PARALLEL TO THE Y AXIS AND PERPENDICULAR TO THE X AXIS. AFTER THE FINAL CRYSTAL HAS BEEN CUT FROM THE ORIGINAL STRUCTURE IN THIS MANNER, IT WILL APPEAR AS ILLUSTRATED AT THE RIGHT OF FIG. 4 AND HERE AGAIN ITS AXIS HAVE BEEN INDICATED FOR YOUR CONVENIENCE.

IN THE X-CUT CRYSTAL, WE FIND THAT ANY MECHANICAL STRESSES WHICH ARE APPLIED ALONG THE Y OR MECHANICAL AXIS WILL PRODUCE ELECTRICAL CHARGES ON THE FLAT SIDES OF THE SLAB. FURTHERMORE, IF THE DIRECTION OF THESE STRESSES IS CHANGED FROM TENSION TO COMPRESSION OR VICE VERSA, THEN THE POLARITY OF THE CHARGES ON THE FLAT SIDES OF THE CRYSTAL IS REVERSED.

THE REVERSE OF THIS PROCESS IS ALSO TRUE. THAT IS, IF ELECTRICAL CHARGES ARE PLACED ON THE FLAT SIDES OF THE CRYSTAL BY APPLYING A VOLTAGE ACROSS THESE FACES, THEN A MECHANICAL STRESS WILL BE PRODUCED IN THE DIRECTION OF THE Y-AXIS. THIS CHARACTERISTIC BY MEANS OF WHICH THE ELECTRICAL AND MECHANICAL PROPERTIES ARE RELATED IN A CRYSTAL IS KNOWN AS THE PIEZO-ELECTRIC EFFECT AND IT IS A NATURAL CHARACTERISTIC OF THE SUBSTANCE.

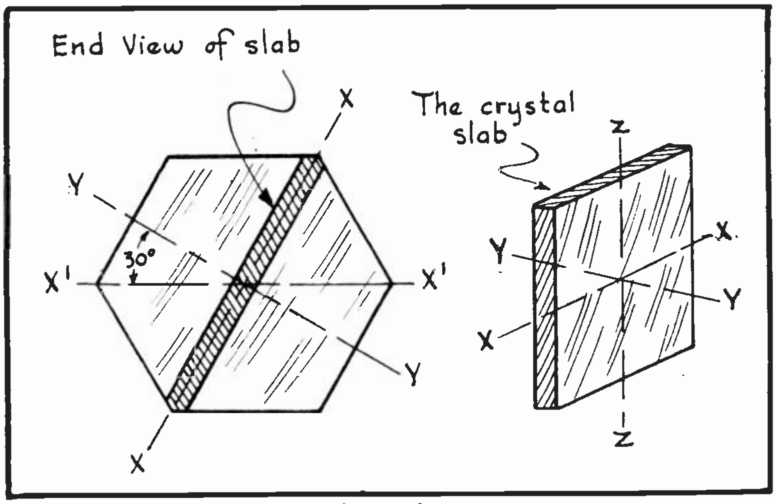

FIG. 5
The "Y Cut" or "30°-Cut" Crystal.

THE "Y-CUT" CRYSTAL

FIG. 5 SHOWS YOU HOW A "Y-CUT" OR "30°-CUT" CRYSTAL IS OBTAINED FROM THE ORIGINAL CRYSTALLINE STRUCTURE. HERE YOU ARE AGAIN SHOWN A TOP VIEW OF THE ORIGINAL CRYSTAL'S STRUCTURE AT THE LEFT AND WITH THE EDGE OF THE FINAL SLAB INDICATED BY THE SHADED AREA. THE Y-CUT CRYSTAL YOU WILL HERE OBSERVE HAS ITS FLAT SIDES PARALLEL WITH THE X AXIS AND PERPENDICULAR TO THE Y AXIS. THE FINISHED Y-CUT CRYSTAL SLAB IS SHOWN AT THE RIGHT OF FIG. 5 WITH ITS AXIS INDICATED FOR YOUR CONVENIENCE.

WITH THE Y-CUT CRYSTAL, WE FIND THAT WHEN MECHANICAL STRESSES ARE APPLIED ACROSS ITS FACES, THEN ELECTRICAL CHARGES WILL BE ESTABLISHED ALONG ITS X AXIS AND VICE VERSA.

EFFECT OF THE CRYSTAL'S RESONANT FREQUENCY

CONTINUING OUR INVESTIGATION OF THE PIEZO-ELECTRIC PROPERTIES OF QUARTZ CRYSTALS WE NEXT COME TO THE POINT WHERE WE CONSIDER THE BEHAVIOR OF THE CRYSTAL WHEN SUBJECTED TO A.C. VOLTAGES.

WHENEVER AN A.C. VOLTAGE IS APPLIED ACROSS A QUARTZ CRYSTAL IN SUCH A DIRECTION THAT THERE IS A COMPONENT OF ELECTRICAL STRESS IN THE DIRECTION OF AN ELECTRICAL AXIS, THEN ALTERNATING MECHANICAL STRESSES WILL BE PRODUCED IN THE DIRECTION OF THE Y AXIS. THESE STRESSES WILL CAUSE THE CRYSTAL TO VIBRATE AND IF THE FREQUENCY OF THE APPLIED A.C. VOLTAGE IS NEAR THE NATURAL MECHANICAL VIBRATING FREQUENCY OF THE CRYSTAL, THEN A CONDITION OF MECHANICAL RESONANCE WILL EXIST IN THE CRYSTAL AND THE AMPLITUDE OF THE VIBRATIONS WILL THEREFORE BE RELATIVELY LARGE. IT IS ALSO INTERESTING TO NOTE THAT THE CURRENT WHICH IS DRAWN AT THE RESONANT FREQUENCY BY THE CRYSTAL DUE TO THE VIBRATIONS IS EQUAL TO THE SAME VALUE OF CURRENT WHICH IS DRAWN BY A CIRCUIT CONSISTING OF RESISTANCE, INDUCTANCE, AND CAPACITY.

FREQUENCY OF CRYSTALS

IN PRACTICE, BOTH X AND Y—CUT CRYSTALS ARE USED — EACH HAVING ITS INDIVIDUAL CHARACTERISTICS AND THEREFORE BEST ADAPTED FOR DIFFERENT USES. FOR A GIVEN FREQUENCY, AN X-CUT PLATE IS THICKER THAN A Y—CUT PLATE; THE X—CUT PLATE HAS BUT ONE MAJOR FREQUENCY OF OSCILLATION WHICH IS DETERMINED BY ITS THICKNESS, WHEREAS A Y—CUT PLATE SOMETIMES HAS TWO — A KILOCYCLE OR TWO APART; AS A GENERAL RULE, THE Y—CUT PLATE OSCILLATES MORE READILY, ALTHOUGH WHEN PROPERLY GROUND AND MOUNTED, CRYSTALS OF EITHER CUT WILL OSCILLATE PROPERLY IN A WELL—DESIGNED CIRCUIT.

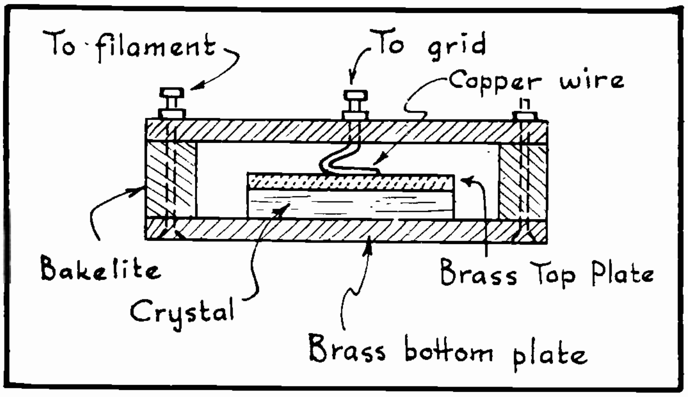

FIG. 6
A Typical Crystal Holder.

AS HAS ALREADY BEEN STATED, THE THICKNESS OF THE CRYSTAL DETERMINES AT WHICH FREQUENCY THE OSCILLATOR WILL OSCILLATE. THE APPROXIMATE FORMULAS WHICH EXPRESS THE RELATION BETWEEN THE THICKNESS AND FREQUENCY OF A CRYSTAL SLAB ARE AS FOLLOWS:

FOR AN X—CUT CRYSTAL $f \times t = 112.6$ WHEREAS FOR THE Y—CUT PLATE THE FORMULA BECOMES $f \times t = 77.0$. IN BOTH OF THESE FORMULAS, f = THE FREQUENCY EXPRESSED IN KILOCYCLES, t = THICKNESS OF THE PLATE EXPRESSED IN INCHES AND THE VALUES 112.6 AND 77.0 ARE CONSTANTS IN THE RESPECTIVE FORMULAS. EITHER OF THESE TWO FORMULAS CAN BE TRANSPOSED ALGEBRAICALLY SO THAT EITHER THE FREQUENCY OR THICKNESS OF THE CRYSTAL CAN BE DETERMINED IN TERMS OF THE OTHER FACTOR. THAT IS TO SAY FOR THE X—CUT CRYSTAL $f = \frac{112.6}{t}$ OR $t = \frac{112.6}{f}$ WHEREAS FOR THE Y—CUT CRYSTAL $f = \frac{77}{t}$ OR $t = \frac{77}{f}$.

SINCE THE THICKNESS OF A CRYSTAL IS INVERSELY PROPORTIONAL TO ITS FREQUENCY, IT IS OBVIOUS THAT THE CRYSTAL SLABS BECOME VERY THIN AND FRAGIL WHEN GROUND FOR THE HIGHER FREQUENCIES (3500 KC. OR HIGHER). IT IS FOR THIS REASON THAT FOR TRANSMITTERS OPERATING AT FREQUENCIES HIGHER THAN 3500 KC., IT IS GENERALLY ALTHOUGH NOT ALWAYS THE PRACTICE TO EMPLOY AN

OSCILLATOR CIRCUIT WHOSE FREQUENCY OF OSCILLATION IS ONLY ONE-HALF THAT OF THE CARRIER WAVE WHICH IS RADIATED. THE CARRIER OF HIGHER FREQUENCY IN SUCH A CASE IS OBTAINED BY INCLUDING A SPECIAL CIRCUIT KNOWN AS A "FREQUENCY DOUBLER" BETWEEN THE OSCILLATOR AND THE ANTENNA SYSTEM. THESE FREQUENCY DOUBLERS ARE EXPLAINED IN DETAIL IN A LATER LESSON.

CRYSTAL MOUNTINGS

THE MAJORITY OF TRANSMITTER CRYSTALS ARE APPROXIMATELY 1" SQUARE, PERFECTLY FLAT AND THE TWO MAJOR SURFACES ARE PARALLEL. WHEN IN USE, THE CRYSTAL IS ENCASED IN A HOLDER AND OF WHICH THERE ARE A NUMBER OF DIFFERENT TYPES.

A SIMPLE FORM OF CRYSTAL HOLDER IS SHOWN YOU IN FIG. 6. HERE THE CRYSTAL IS LAID FLAT BETWEEN TWO BRASS PLATES WHICH ARE APPROXIMATELY 1/16" THICK. THE SURFACE AREA OF THE TOP PLATE IS FREQUENTLY MADE THE SAME AS THAT OF THE CRYSTAL, ALTHOUGH IT IS ALSO A COMMON PRACTICE TO MAKE THE UPPER PLATE CIRCULAR IN SHAPE AND SOMEWHAT SMALLER IN DIAMETER THAN THE CRYSTAL. THE BOTTOM PLATE IS GENERALLY MADE LARGE ENOUGH SO AS TO SERVE AS A BASE FOR THE ENTIRE CRYSTAL ASSEMBLY.

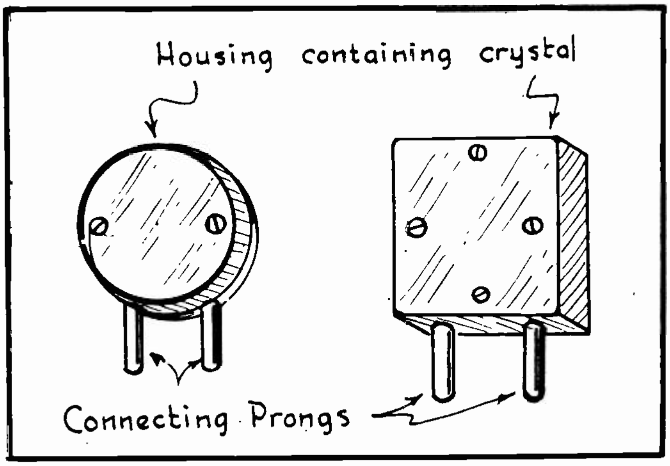

FIG. 7
Two Popular Crystal Holders.

THE CRYSTAL IS ENCLOSED IN A BOX MADE OF SOME SUCH INSULATING MATERIAL AS BAKELITE AND TERMINALS ARE PROVIDED WHEREBY THE BRASS PLATES OF THE ASSEMBLY CAN BE CONNECTED TO THE TRANSMITTER CIRCUIT. A LIGHT LEAF OF SPRING BRASS OR A SMALL SPIRAL OF FINE COPPER WIRE IS GENERALLY EMPLOYED FOR COMPLETING THE ELECTRICAL CONNECTION TO THE TOP PLATE OF THE CRYSTAL ASSEMBLY.

TWO POPULAR CRYSTAL HOLDERS OF THE COMMERCIAL TYPE ARE ILLUSTRATED IN FIG. 7. ONE OF THESE CONSISTS OF A BOX-SHAPED CRYSTAL CONTAINER WHILE THE OTHER IS ROUND. BOTH UNITS, HOWEVER, ARE FITTED WITH A PAIR OF PRONGS WHEREBY THE CRYSTAL CAN BE CONNECTED IN THE OSCILLATOR CIRCUIT BY SIMPLY INSERTING THE CRYSTAL HOLDER INTO A SUITABLE SOCKET.

IN SOME CRYSTAL UNITS YOU WILL ALSO FIND THAT THE TOP BRASS PLATE OF THE ASSEMBLY DOES NOT LIE FLAT UPON THE UPPER SURFACE OF THE CRYSTAL BUT THAT THERE IS AN AIR GAP OF APPROXIMATELY ONE-THOUSANDTH OF AN INCH BETWEEN THE TOP PLATE AND THE UPPER SURFACE OF THE CRYSTAL. THIS AIR SPACE PERMITS A SLIGHT ADJUSTMENT OF THE FREQUENCY SINCE A SLIGHT CHANGE IN THIS SPACING WILL AFFECT THE FREQUENCY.

TEMPERATURE CONTROL

THE FREQUENCY OF A CRYSTAL IS ALSO AFFECTED MATERIALLY BY THE TEMP

ERATURE OF THE CRYSTAL AND THEREFORE IF THE FREQUENCY STABILITY OF THE OSCILLATOR IS TO BE AT ITS BEST, IT IS NECESSARY THAT THE TEMPERATURE OF THE CRYSTAL BE MAINTAINED AT A CONSTANT VALUE. THIS IS KNOWN AS TEMPERATURE CONTROL AND SINCE THIS FEATURE MAKES THE TRANSMITTER MORE EXPENSIVE TO BUILD, IT IS EMPLOYED ONLY IN TRANSMITTERS OF HIGHER QUALITY.

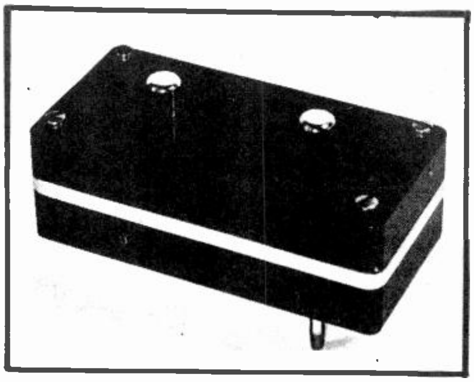

FIG. 8
The Crystal Oven.

THE TEMPERATURE COEFFICIENT OF AN X-CUT CRYSTAL IS NEGATIVE, WHICH MEANS THAT THE FREQUENCY GOES DOWN WITH A RISING TEMPERATURE. THE TEMPERATURE COEFF. OF Y-CUT CRYSTAL IS POSITIVE AND WHICH MEANS THAT THE FREQUENCY INCREASES WITH A RISING TEMPERATURE. IN EITHER CASE, THE FREQUENCY OF THE OSCILLATOR WILL "CREEP" IF THE TEMPERATURE OF THE CRYSTAL CHANGES DURING OPERATION.

SO AS TO MAINTAIN THE TEMPERATURE OF THE CRYSTAL AT A CONSTANT VALUE, THE CRYSTAL IS PLACED IN A CRYSTAL OVEN. AN EXTERNAL VIEW OF A TYPICAL CRYSTAL OVEN IS SHOWN YOU IN FIG. 8, WHILE THE INTERNAL CONSTRUCTION OF THE SAME UNIT IS SHOWN IN FIG. 9.

THE PARTICULAR CRYSTAL OVEN HERE SHOWN IS DESIGNED TO ACCOMMODATE TWO CRYSTALS. BY STUDYING FIG. 9 CAREFULLY, YOU WILL NOTE THAT WE HAVE HERE FIRST A BOTTOM PIECE WHICH IS MOLDED OF A HEAT-RESISTING MATERIAL KNOWN AS DUREZ. WITHIN THE CHAMBER OF THIS BOTTOM PIECE ARE CONTAINED TWO WIRE HEATER ELEMENTS AND A THERMOSTAT. THESE HEATER ELEMENTS ARE CONNECTED ACROSS A VOLTAGE SOURCE OF 10 TO 12 VOLTS. A SET OF THERMOSTATICALLY OPERATED POINTS ARE CONNECTED IN THIS HEATER CIRCUIT AND IN THIS MANNER THE TEMPERATURE WITHIN THE CHAMBER IS KEPT CONSTANT. THE THERMOSTAT OF THIS PARTICULAR UNIT IS ADJUSTABLE AND MAY BE SET FOR TEMPERATURES BETWEEN 35 AND 50 DEGREES CENTIGRADE (95 AND 122 DEGREES FAHRENHEIT).

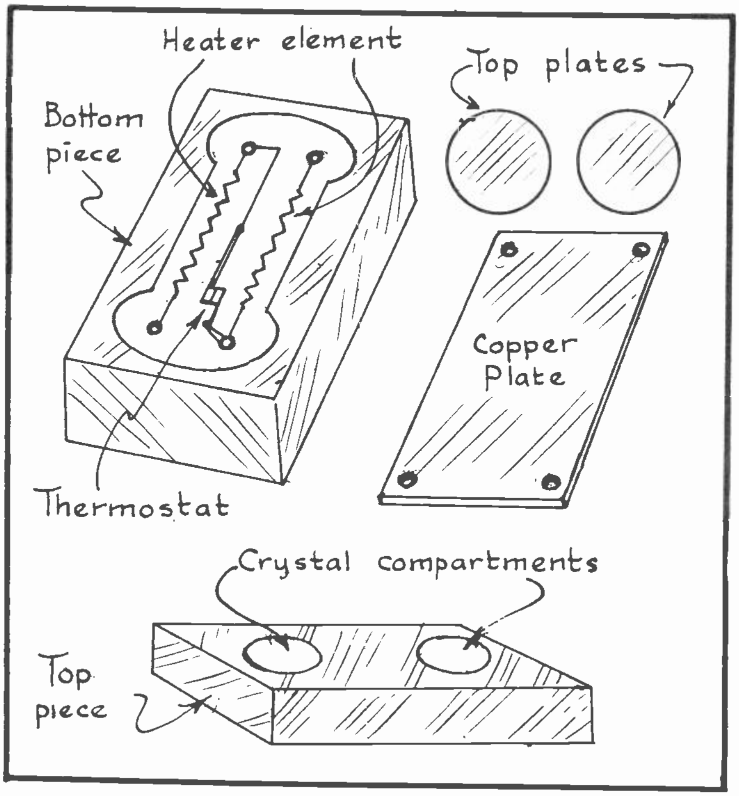

FIG. 9
Details of the Crystal Oven.

A HEAVY COPPER PLATE IS PLACED OVER

THIS HEATING CHAMBER AND AT THE SAME TIME SERVES AS THE BOTTOM PLATE FOR THE CRYSTAL HOLDER. THE HEAT DISTRIBUTION OVER THIS ENTIRE PLATE IS UNIFORM BECAUSE OF THE HIGH THERMAL CONDUCTIVITY OF COPPER AND THE THICKNESS OF THE PLATE.

THE TOP PIECE OF THIS OVEN HAS COMPARTMENTS FOR TWO CRYSTALS. THE TWO DISCS WHICH ARE SHOWN IN FIG. 9 ARE THE TOP PLATES FOR THE CRYSTAL HOLDER AND ARE MADE OF MONEL METAL. CONNECTIONS TO THE HEATER ARE MADE BY MEANS OF TWO PLUGS ON THE BOTTOM PLATE OF THE HOLDERS AND CONNECTION TO THE TOP PLATES IS MADE BY SLIPPING A GRID CLIP OVER THE CAP STUDS WHICH PROJECT FROM THE TOP OF THE CASE.

SOME OF THE CRYSTAL OVENS ARE EVEN MORE ELABORATE IN DESIGN THAN THE ONE ILLUSTRATED IN FIGS. 8 AND 9. FOR INSTANCE, IN SOME CASES, THE CRYSTAL IS HOUSED WITHIN A HEATED CHAMBER WHICH IS HEAT-INSULATED FROM AN OUTER CASING AND WHICH SERVES AS AN ENCLOSURE FOR THE ENTIRE ASSMEBLY. QUITE OFTEN, A THERMOMETER IS ALSO USED AS A PART OF THE CRYSTAL OVEN EQUIPMENT WHEREBY THE OPERATOR CAN AT ALL TIMES ASCERTAIN THE TEMPERATURE AT WHICH THE CRYSTAL IS OPERATING.

APPLICATIONS OF THE CRYSTAL

THERE ARE A NUMBER OF METHODS IN WHICH A CRYSTAL CAN BE APPLIED IN AN OSCILLATOR CIRCUIT. IN FIG.2, FOR EXAMPLE, YOU WERE SHOWN HOW A CRYSTAL CAN BE EMPLOYED IN A CIRCUIT IN WHICH A TRIODE IS EMPLOYED.

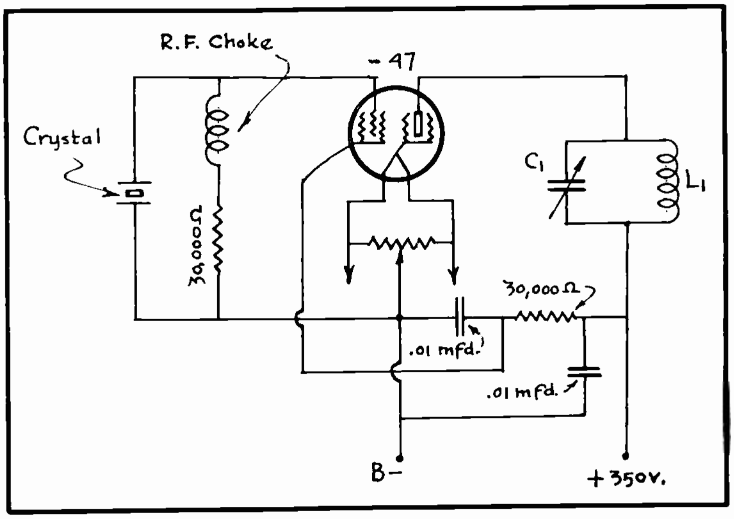

FIG. 10
Pentode Crystal Controlled Oscillator

FIG. 10 SHOWS YOU A CIRCUIT IN WHICH A PENTODE TUBE IS USED AS THE OSCILLATOR, TOGETHER WITH CRYSTAL CONTROL FEATURES. THE TUBE HERE SHOWN IS A TYPE 47.

IN FIG. 11 YOU WILL SEE HOW A CRYSTAL MAY BE EMPLOYED WHEN TWO OSCILLATOR TUBES ARE CONNECTED IN PUSH-PULL. THE TUBES USED IN THIS PARTICULAR ILLUSTRATION ARE ALSO BOTH OF THE PENTODE TYPE.

THE POWER WHICH CAN BE OBTAINED FROM A CRYSTAL OSCILLATOR WILL DEPEND UPON THE TYPE OF OSCILLATOR TUBE USED, THE PLATE VOLTAGE AND THE AMPLITUDE OF THE R.F. VOLTAGE WHICH IS DEVELOPED AS A RESULT OF THE CRYSTAL'S MECHANICAL VIBRATION. IN THE EVENT THAT THE FEED-BACK VOLTAGE IS TOO GREAT, THE MECHANICAL STRAIN IMPOSED UPON THE CRYSTAL AS A RESULT OF THE VIBRATION WILL CAUSE THE CRYSTAL TO HEAT CONSIDERABLY AND MAY IN DUE

TIME CAUSE THE CRYSTAL TO CRACK AND THEREBY BECOME RUINED.

ONE OF THE ADVANTAGES OF USING A PENTODE AS AN OSCILLATOR IN CRYSTAL CONTROLLED TRANSMITTERS IS THAT THIS TYPE OF TUBE HAS A RELATIVELY LOW GRID-PLATE CAPACITY AND THEREFORE HAS A TENDENCY TO REDUCE THE FEED-BACK SOMEWHAT. IN ADDITION, PENTODES ARE CAPABLE OF DELIVERING FAIRLY LARGE POWER OUTPUTS WITH A SMALL EXITING GRID VOLTAGE.

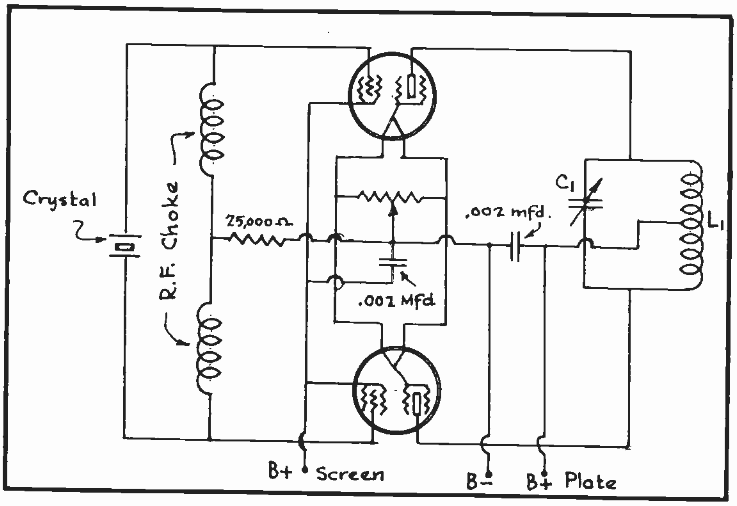

FIG. 11
The Push-Pull Crystal Oscillator.

IT IS INTERESTING TO NOTE THAT FOR A GIVEN APPLIED PLATE VOLTAGE, HEATING OF THE CRYSTAL WILL BE LESS WITH A PENTODE THAN WITH A TRIODE AS THE OSCILLATOR TUBE. THIS BEING THE CASE, IT IS EQUALLY TRUE THAT FOR THE SAME AMPLITUDE OF CRYSTAL VIBRATION, HIGHER PLATE VOLTAGES CAN BE USED WITH THE PENTODE WITH ITS RESULTING INCREASED POWER OUTPUT.

FIG. 12 SHOWS YOU HOW A 2A5 HEATER TYPE TUBE MAY BE USED IN A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT AND AS YOU WILL OBSERVE THE BASIC DESIGN OF THIS CIRCUIT IS SIMILAR TO OTHERS WHICH APPEAR IN THIS LESSON ONLY THAT THE CATHODE CIRCUIT SERVES TO COMPLETE THE B- CIRCUIT.

GRINDING CRYSTALS

ALTHOUGH CRYSTALS CAN BE PURCHASED WHICH ARE ALREADY ACCURATELY GROUND FOR THE FREQUENCY DESIRED, YET ONE CAN ALSO PURCHASE BLANK CRYSTALS WHICH ARE CUT TO SIZE BUT NOT SUBJECTED TO THE FINAL GRINDING PROCESS WHICH DETERMINES THEIR RESONANT FREQUENCY. NO DOUBT YOU WILL BE INTERESTED IN KNOWING HOW BLANK CRYSTALS ARE GROUND AND SO THIS WILL NOW BE EXPLAINED.

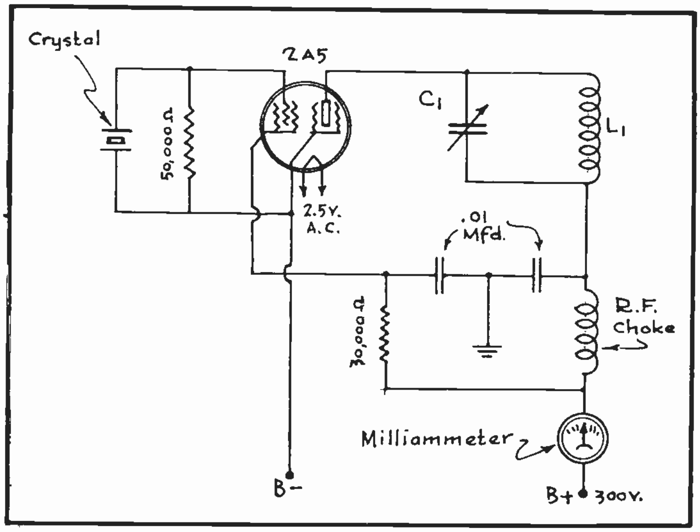

FIG. 12
A Heater-Type Pentode Crystal Oscillator.

TO BEGIN WITH, THE APPROXIMATE THICKNESS

OF THE CRYSTAL FOR THE FREQUENCY DESIRED CAN BE DETERMINED FROM THE FORMULAS WHICH WERE GIVEN EARLIER IN THIS LESSON. AS THE GRINDING PROCESS PROCEEDS, THIS THICKNESS CAN BE CHECKED WITH AN ACCURATE MICROMETER CALIPER. THIS SAME INSTRUMENT CAN ALSO BE EMPLOYED AS A MEANS FOR CHECKING THE THICKNESS FOR UNIFORMITY AND IN THIS WAY AVOID GRINDING BUMPS AND HOLLOW AREAS IN THE SURFACES OF THE CRYSTAL.

THE GRINDING PROCESS IS GENERALLY ACCOMPLISHED BY ROTATING THE FLAT SURFACES OF THE CRYSTAL IN IRREGULAR SPIRALS ON A PIECE OF PLATE GLASS AND ON WHOSE SURFACE HAS BEEN SMEARED A MIXTURE OF #102 CARBORUNDUM AND WATER OR KEROSENE.

SO THAT THE CRYSTAL SURFACES WILL BE GROUND ABSOLUTELY FLAT, IT IS ESSENTIAL THAT AN EVEN PRESSURE BE APPLIED OVER THE WHOLE AREA OF THE CRYSTAL. THIS CAN BEST BE ACCOMPLISHED BY STICKING THE CRYSTAL TO A PERFECTLY FLAT PIECE OF THIN BRASS OR A TO A GLASS MICROSCOPE SLIDE, WHICH SERVES AS A PRESSURE PLATE. BY MOISTENING THE CRYSTAL SURFACE WITH KEROSENE IT CAN BE MADE TO ADHERE TO THE BRASS OR GLASS SLIDE SUFFICIENTLY WELL FOR THIS PURPOSE. THIS WILL PERMIT ONE TO APPLY THE PRESSURE OF THE FINGERS TO THE PRESSURE PLATE AS THE EXPOSED SURFACE OF THE CRYSTAL IS MOVED OVER THE GRINDING COMPOUND.

AS THE GRINDING PROCESS PROGRESSES, THE CRYSTAL SHOULD BE CHECKED FOR ITS FREQUENCY OF OSCILLATION BY CONNECTING IT IN A TEST OSCILLATOR CIRCUIT AND LISTENING TO THE SIGNAL IN A RECEIVER WHOSE DIAL HAS BEEN ACCURATELY CALIBRATED. IN THE EVENT THAT THE CRYSTAL SHOULD STOP OSCILLATING DURING THE GRINDING PROCESS THEN ITS EDGES SHOULD BE GROUND CAREFULLY UNTIL OSCILLATION RESUMES.

AS THE FREQUENCY COMES WITHIN A FEW KILOCYCLES OF THE DESIRED VALUE, ANY FURTHER GRINDING MUST BE DONE WITH EXTREME CARE, USING A FINER GRADE OF CARBORUNDUM POWDER SUCH AS GRADES FF AND FFF FOR THE FINAL GRINDING.

SO FAR, ALL OF THE TRANSMITTER CIRCUITS WHICH WERE EXPLAINED TO YOU EMPLOYED NOTHING MORE THAN AN OSCILLATOR STAGE IN THE TRANSMITTER PROPER. IN THE FOLLOWING LESSON, HOWEVER, YOU ARE GOING TO BE SHOWN HOW THE OUTPUT OF THE OSCILLATOR CAN BE AMPLIFIED BY ADDING SOME AMPLIFYING STAGES TO THE CIRCUIT AND IN THIS WAY MAKE GREATER POWER OUTPUTS POSSIBLE.

Examination Questions

LESSON NO. T-6

Answered Nov 13, 1941

> Setbacks never whip a fighter, they only sharpen his faculties. The more he fights the better he becomes. So roll up your sleaves and give Life the greatest battle it ever had.

1. – WHAT IS THE REASON FOR USING A QUARTZ CRYSTAL IN THE OSCILLATOR CIRCUIT OF A TRANSMITTER?

2. – EXPLAIN THE PIEZO-ELECTRIC EFFECT.

3. – DESCRIBE IN DETAIL AN X-CUT CRYSTAL.

4. – DESCRIBE IN DETAIL A Y-CUT CRYSTAL.

5. – WHAT FACTORS DETERMINE AT WHAT FREQUENCY A QUARTZ CRYSTAL WILL RESONATE?

6. – DESCRIBE HOW A CRYSTAL MAY BE MOUNTED IN A TRANSMITTER.

7. – DESCRIBE A TYPICAL CRYSTAL OVEN AND EXPLAIN THE REASON FOR ITS USE.

8. – DRAW A CIRCUIT DIAGRAM OF A CRYSTAL CONTROLLED OSCILLATOR.

9. – EXPLAIN HOW YOU WOULD ADJUST THE OSCILLATOR WHOSE CIRCUIT YOU HAVE DRAWN IN ANSWER TO QUESTION #8 AND ALSO EXPLAIN IN DETAIL HOW THIS CIRCUIT FUNCTIONS.

10. – WHAT PRECAUTIONS MUST BE TAKEN IN THE DESIGN OF A CRYSTAL CONTROLLED OSCILLATOR AS REGARDS THE FEED-BACK VOLTAGE?

RADIO - TELEVISION

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NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO. T-7

OSCILLATOR-AMPLIFIER TRANSMITTERS

IN THE PREVIOUS LESSON YOU WERE TOLD THAT IF AN OSCILLATOR WITHOUT CRYSTAL CONTROL FEATURES IS COUPLED DIRECTLY TO THE ANTENNA SYSTEM, THE OSCILLATOR MAY NOT ONLY BE SUBJECT TO CHANGING ITS FREQUENCY BECAUSE OF CHANGING CONDITIONS WHICH ORIGINATE IN ITS OWN CIRCUIT BUT THAT CHANGES IN THE RESONANT FREQUENCY OF THE ANTENNA CIRCUIT CAUSED BY SWINGINGWIRES ETC. MAY ALSO CAUSE THE OSCILLATOR TO UNDERGO A SHIFT IN FREQUENCY. THIS LAST MENTIONED CONDITION CAN BE ELIMINATED, HOWEVER, BY PLACING A STAGE OF RADIO FREQUENCY AMPLIFICATION BETWEEN THE OSCILLATOR AND THE ANTENNA CIRCUIT AND WHEN USED FOR THIS PURPOSE, THIS R.F. STAGE IS GENERALLY CALLED A BUFFER. BESIDES SERVING AS A BUFFER, THIS R.F. STAGE PROVIDES ANOTHER ADVANTAGE AND THAT IS THAT IT AMPLIFIES THE OSCILLATOR'S OUTPUT SO THAT GREATER RADIO FREQUENCY ENERGY CAN BE SUPPLIED TO THE ANTENNA SYSTEM.

THE CRYSTAL CONTROLLED OSCILLATOR ON THE OTHER HAND, HAS SUCH EXCELLENT FREQUENCY STABILITY SO THAT IF IT BE COUPLED DIRECTLY TO THE ANTENNA SYSTEM, ITS FREQUENCY WILL REMAIN CONSTANT EVEN THOUGH THE CHARACTERISTICS OF THE ANTENNA CIRCUIT MAY VARY SOMEWHAT DURING OPERATION. THE CRYSTAL OSCILLATOR, HOWEVER, IS A LOW-POWER DEVICE AND THEREFORE IT IS DESIRABLE TO BUILD UP ITS OUTPUT POWER TO A HIGHER LEVEL BY MEANS OF ONE OR MORE STAGES OF RADIO FREQUENCY AMPLIFICATION WHICH ARE PLACED BETWEEN THE OSCILLATOR AND THE ANTENNA.

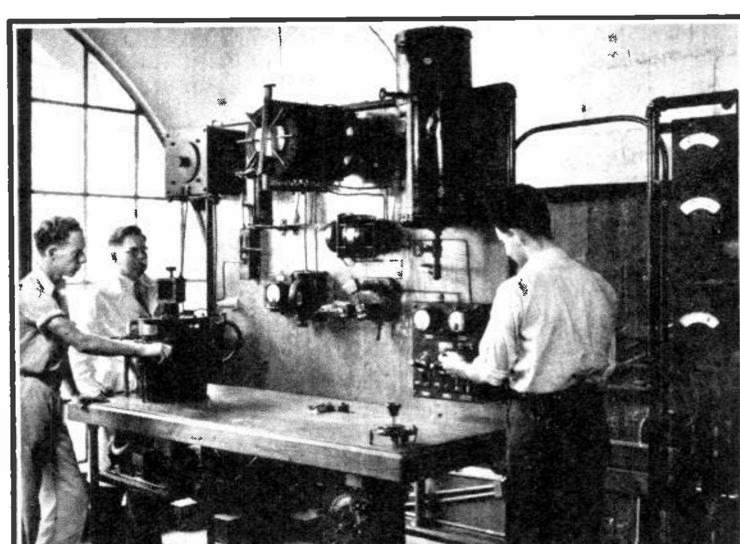

FIG. 1
SPARK TRANSMITTER INSTALLED
AT NATIONAL

THUS YOU WILL SEE THAT REGARDLESS OF WHETHER THE OSCILLATOR BE SELF-TUNING OR HAS ITS FREQUENCY CONTROLLED BY MEANS OF A CRYSTAL, A RADIO FREQUENCY AMPLIFYING SYSTEM BETWEEN THE OSCILLATOR AND THE ANTENNA IS DESIRABLE.

EFFECT OF ANTENNA UPON OSCILLATOR

BEFORE WE GO INTO DETAILS CONCERNING THE R.F. STAGES THEMSELVES AS EMPLOYED IN TRANSMITTERS, LET US FIRST SEE JUST HOW IT IS THAT THE ANTENNA MAY INFLUENCE THE TUNING OF A SIMPLE OSCILLATOR.

A GLANCE AT THE TYPICAL SINGLE-TUBE TRANSMITTER DIAGRAM IN FIG.2 WILL SHOW THAT THE ANTENNA IS ENERGIZED BY THE SECONDARY OF AN R.F.TRANSFORMER, THE PRIMARY BEING IN THE PLATE CIRCUIT OF THE TUBE. THE INDUCTANCE OF THE ANTENNA SYSTEM IS TUNED BY THE VARIABLE CONDENSER WHICH IS CONNECTED ACROSS THE SECONDARY COIL. YOU WILL ALSO OBSERVE THAT THE DISTRIBUTED CAPACITANCE OF THE FEEDERS MAY BE CONSIDERED AS BEING IN PARALLEL WITH THIS CAPACITANCE.

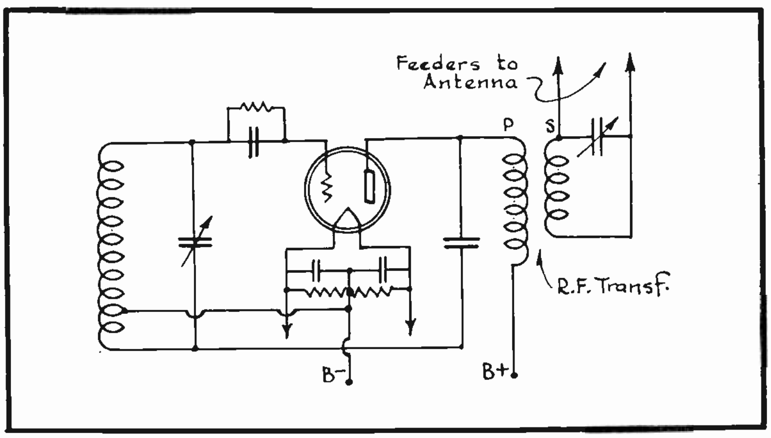

FIG. 2
A Single Tube Hartley Transmitter.

JUST AS ANY CHANGE IN THE DIELECTRIC SPACING BETWEEN THE PLATES OF A CONDENSER CAUSES A CHANGE IN CAPACITANCE, SO ANY CHANGE IN SPACING BETWEEN THE TWO FEEDER WIRES DUE TO WIND, FOR EXAMPLE, WILL CAUSE A CHANGE IN CAPACITANCE WHICH WILL CHANGE THE RESONANT FREQUENCY OF THE SYSTEM. SINCE A RESONANT CONDITION IN A SECONDARY COIL IS "REFLECTED" BACK INTO THE PRIMARY CIRCUIT, THIS SWING IN ANTENNA RESONANCE MAY CAUSE THE OSCILLATOR TO VARY IN FREQUENCY.

SO YOU SEE AN R.F. AMPLIFIER IN THIS CASE REALLY SERVES A DUAL PURPOSE, NAMELY, TO BOOST THE OUTPUT AND AT THE SAME TIME TENDING TO STABILIZE FREQUENCY.

R.F. AMPLIFIER DESIGN PRACTICE

THERE ARE SEVERAL METHODS OF COUPLING THE OSCILLATOR TUBE TO THE BUFFER STAGE AND WHICH DIFFERS FROM THE INTER-STAGE CIRCUITS USED IN RECEIVING SETS ONLY IN THE TYPE OF EQUIPMENT USED AND IN MINOR DETAILS. THE OBJECTIVES OF THE ENGINEER IN DESIGNING ANY VACUUM TUBE AMPLIFIER, WHETHER IT BE FOR A RECEIVER, A SPEECH AMPLIFIER, OR FOR A RADIO TRANSMITTER ARE:

1. TO PLACE IN THE PLATE CIRCUIT OF THE TUBE A SUITABLE IMPEDANCE SO THAT THE ALTERNATE RISE AND FALL OF PLATE CURRENT WILL CAUSE AN ALTERNATE RISE AND FALL IN THE I TIMES Z VOLTAGE DROP, THUS

PROVIDING AN ALTERNATING OUTPUT VOLTAGE.

2. TO PROVIDE SOME MEANS OF APPLYING THIS SIGNAL VOLTAGE TO THE GRID OF THE NEXT TUBE AND AT THE SAME TIME BLOCKING FROM THIS GRID THE HIGH POSITIVE PLATE POTENTIAL.

3. TO CONNECT THE GRID TO A POINT OF THE CORRECT BIAS POTENTIAL THROUGH A RESISTOR OR INDUCTOR OF SUFFICIENT IMPEDANCE. AN ADDITIONAL OBJECTIVE, IF THE AMPLIFIER IS TO BE OF THE TUNED RADIO FREQUENCY TYPE IS:

4. TO CONTROL FREQUENCY BY PLACING A RESONANT CIRCUIT IN GRID CIRCUIT, PLATE CIRCUIT, OR BOTH. SUCH A TUNED CIRCUIT IN A TRANSMITTER IS USUALLY CALLED A "TANK CIRCUIT."

IT IS INTERESTING TO NOTE IN THE FOLLOWING REPRESENTATIVE INTER-

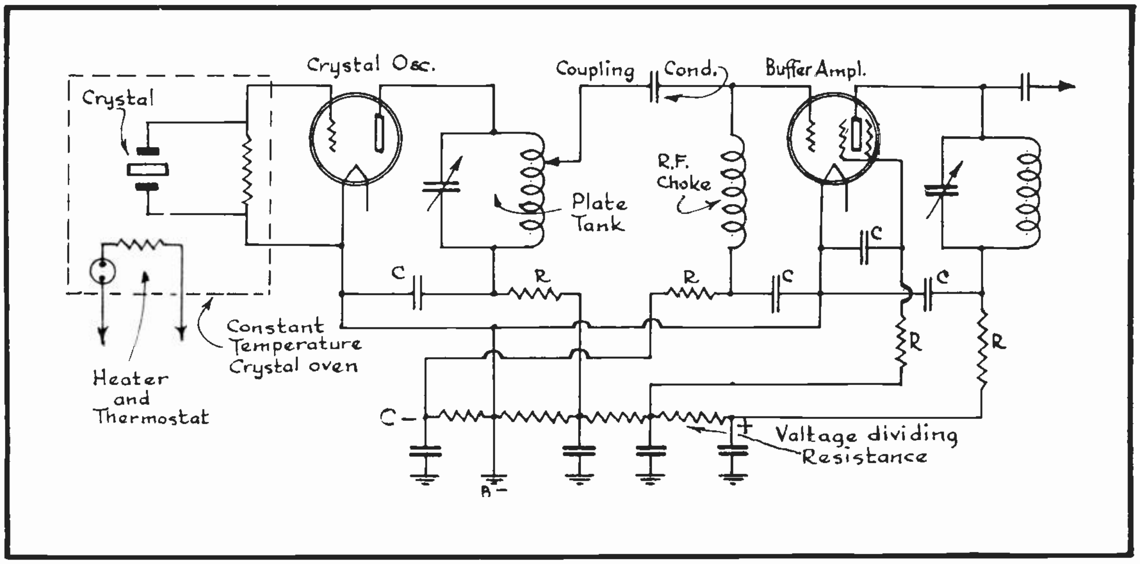

FIG. 3
Oscillator and Buffer Amplifier Circuit.

STAGE COUPLING CIRCUITS HOW THE ABOVE OBJECTIVES ARE ATTAINED.

APPLICATION OF THE BUFFER AMPLIFIER

FIG. 3, FOR INSTANCE, SHOWS THE OSCILLATOR AND BUFFER STAGES OF A WIDELY USED 20-40 KW COMMERCIAL CODE TRANSMITTER. THE PARALLEL-RESONANT TANK CIRCUIT OF THE OSCILLATOR PROVIDES ADEQUATE PLATE CIRCUIT IMPEDANCE AND AIDS IN TUNING THE SYSTEM, WHILE CAPACITANCE COUPLING LEADS THE RADIO FREQUENCY POWER TO THE GRID OF THE AMPLIFIER TUBE. THE COUPLING CONDENSER SHOULD BE A HIGH QUALITY MICA CONDENSER WITH A VOLTAGE RATING AT LEAST 2 OR 3 TIMES THE DC VOLTAGE APPEARING ACROSS IT. THIS VOLTAGE, YOU WILL NOTE, IS THE SUM OF THE OSCILLATOR PLATE VOLTAGE AND THE AMPLIFIER GRID BIAS BECAUSE THE PLATE IS MORE POSITIVE THAN GROUND WHILE THE GRID IS MORE NEGATIVE THAN GROUND. THE D.C. BIAS VOLTAGE IS APPLIED TO THE GRID OF THE AMPLIFIER TUBE THROUGH AN R.F. CHOKE WHICH EFFECTIVELY PREVENTS THE HIGH FREQUENCY SIGNALS FROM PASSING TO GROUND THROUGH THE BIAS SUPPLY.

You will also observe in Fig. 3 that a variable tap connection on the tank coil is used to pass the energy on to the amplifier stage. By means of this tap the energy which is delivered to the grid circuit of the amplifier from the oscillator can be controlled and thus prevent overloading the amplifier tube. The nearer this tap is to the plate end, the greater will be the exiting voltage delivered to the amplifier.

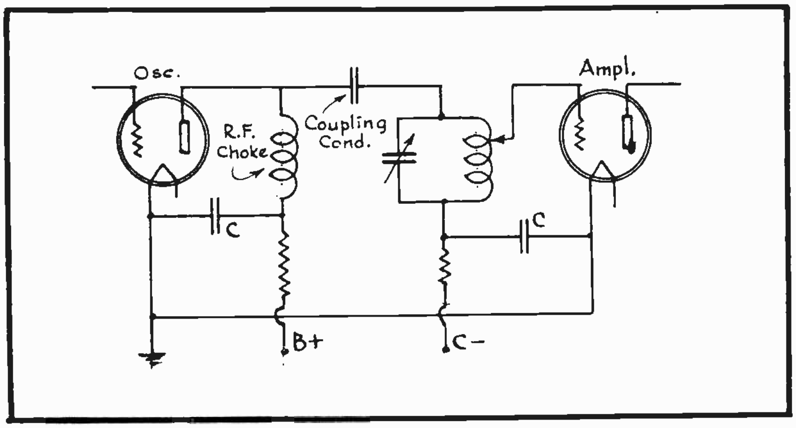

FIG. 4
Untuned Plate-Tuned Grid Circuit.

The blocking resistors marked "R" and the by-pass condensers "C" prevent any undesirable coupling between the two tubes through the power supply. In spite of the fact that in this complete transmitter nine heavy duty tubes follow the two tubes shown, the frequency generated by the crystal oscillator will not vary from a given value by more than 1 part in 4000. Factors contributing to this excellent frequency stability are:

1. Location of the crystal in an oven where temperature is kept at 45 degrees, C. to an accuracy of 0.25 degree, C. (Centigrade)
2. Use of a buffer amplifier.
3. Use of a separate power supply for oscillator and buffer tubes.
4. Careful shielding.

COUPLING UNTUNED PLATE TO TUNED GRID CIRCUIT

The system of Fig. 4 is similar in operating characteristics to that of Fig. 3. The R.F. choke coil in this case acts as the plate circuit impedance and the coupling condenser carries the signal from plate to grid circuit, while a tuned grid circuit connects the grid to the proper negative potential. In this circuit, the grid of the amplifier tube is connected to a tap

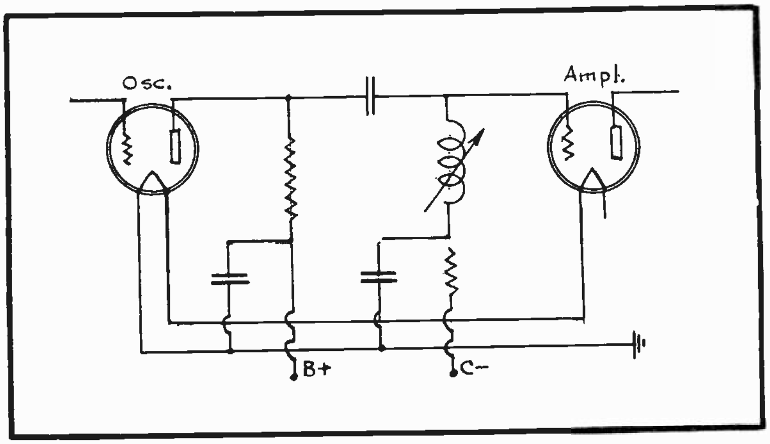

FIG. 5
Distributed Capacitance Tunes Variable Inductance.

ON THE TUNED GRID WINDING SO THAT THE SIGNAL VOLTAGE MAY BE REDUCED IF THE TUBE IS OVERLOADED.

NO TUNING CONDENSER USED

IN SOME CASES, ESPECIALLY AT HIGH LEVELS OF R.F. VOLTAGE WHICH TEND TO BREAK DOWN THE CONDENSER DIELECTRIC, TUNED CIRCUITS EMPLOY ONLY THE CAPACITIES SUPPLIED BY TUBES, LEADS AND THE COIL ITSELF AND ARE ADJUSTED BY VARYING THE CIRCUIT INDUCTANCE. AN EXAMPLE OF THIS IS ILLUSTRATED IN FIG.5 WHERE YOU ARE SHOWN THE INTERSTAGE COUPLING IN A 50 WATT SHORT-WAVE TELEPHONE TRANSMITTER DESIGNED FOR AIRCRAFT USE.

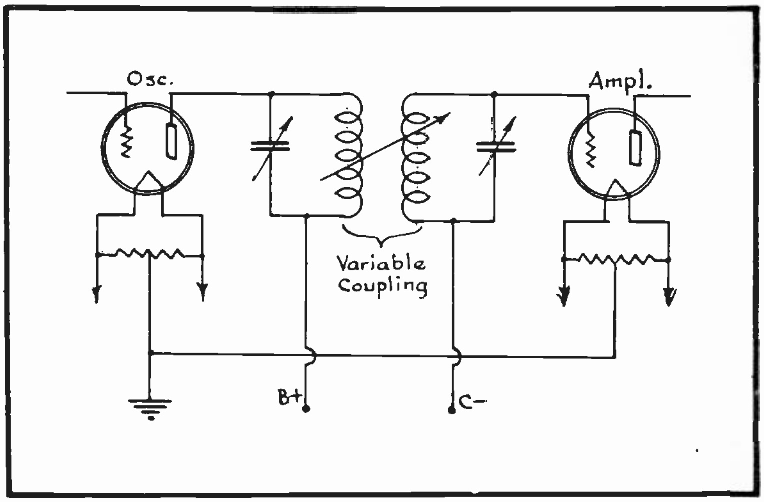

FIG.6
Inductive Coupling.

TRANSFORMER COUPLING

TRANSFORMER COUPLING BETWEEN STAGES HAS THE ADVANTAGE THAT, IF COUPLING IS SUFFICIENTLY LOOSE, IT IS SOMEWHAT MORE EFFICIENT AT THE HIGHER FREQUENCIES THAN IS CAPACITY COUPLING. MAXIMUM EFFICIENCY IS OBTAINED BY USING DIRECT INDUCTIVE COUPLING AS IN FIG. 6 AND VARYING THE COUPLING UNTIL OPTIMUM RESULTS ARE OBTAINED, OR BY USING AN UNTUNED TRANSMISSION LINE, INDUCTIVELY COUPLED TO THE TANK COILS AT BOTH ENDS AS SHOWN IN FIG. 7. IN PRACTICE, THE NUMBER OF TURNS ON THE SMALLER COILS IS VARIED UNTIL THE PROPER COUPLING IS REACHED. THIS SYSTEM, WHICH IS ALSO KNOWN AS "LINK COUPLING", IS ADVANTAGEOUS WHEN THE TWO TUBES ARE TO BE MOUNTED AT SOME DISTANCE FROM EACH OTHER. FOR FREQUENCIES ABOVE 1500 KC., TWO TO FIVE TURNS ARE USED ON EACH OF THE TRANSMISSION LINE COILS AND THE TRANSMISSION LINE MAY BE A TWISTED PAIR SEVERAL FEET LONG.

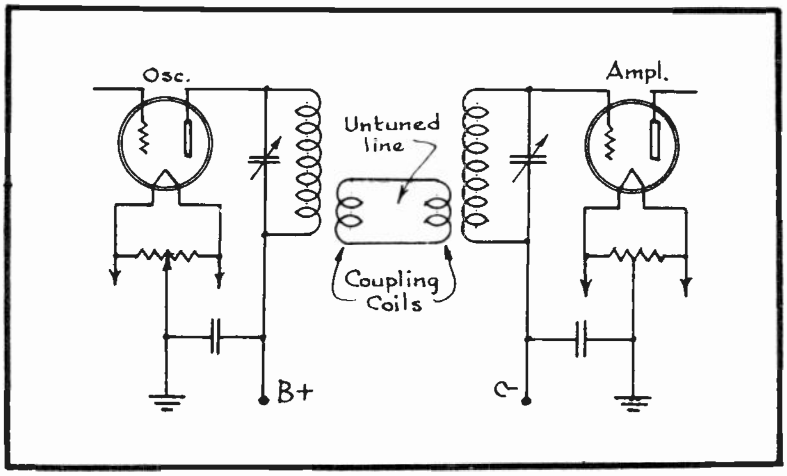

FIG.7
Link Coupling.

PUSH-PULL CIRCUITS ARE ESPECIALLY SUITABLE FOR R.F. AMPLIFIERS, WHEN IN THE STAGE FOLLOWING THE OSCILLATOR OR IN SUCCEEDING STAGES OF

THE TRANSMITTER. WHEN DRIVEN BY A SINGLE TUBE, EITHER TRANSFORMER OR CAPACITY COUPLING CAN BE EMPLOYED AS SHOWN IN THE CIRCUITS OF FIGS. 8 AND 9. IN FIG. 8, WHERE TRANSFORMER COUPLING IS USED, YOU WILL OBSERVE A MARKED RESEMBLANCE TO THE AUDIO FREQUENCY CIRCUITS ABOUT WHICH YOU STUDIED IN PREVIOUS LESSONS. THE THEORY OF OPERATION IS THE SAME, THE DIFFERENCE BEING THAT IN THIS CASE RADIO FREQUENCY TRANSFORMERS ARE USED WITH BOTH PRIMARY AND SECONDARY COILS TUNED BY VARIABLE CONDENSERS, WHILE IN THE CASE OF AUDIO SYSTEMS, WE WERE WORKING WITH IRON-CORE A.F. TRANSFORMERS.

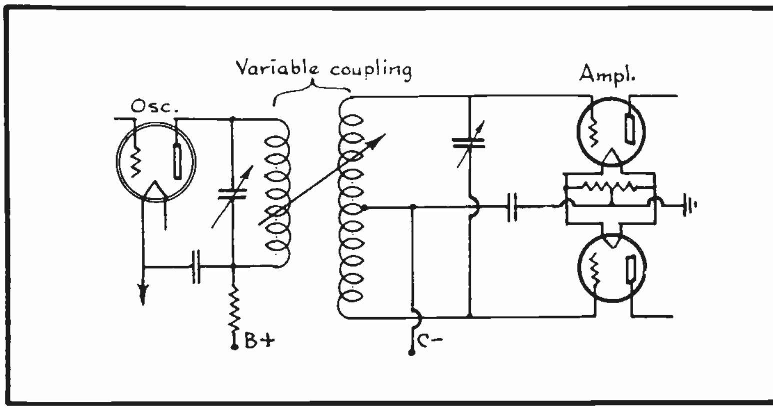

FIG. 8
Single Driver Push-Pull Ampl.

IN FIG. 9 IS SHOWN CAPACITY COUPLING. THE PLATE COIL IS TAPPED AT THE CENTER POINT, THUS BECOMING AN AUTO-TRANSFORMER WITH THE HALF NEXT TO THE PLATE ACTING AS THE PRIMARY AND THE OTHER HALF ACTING AS THE SECONDARY. THE R.F. VOLTAGES AT THE LOWER END OF THE COIL WILL BE EQUAL TO, BUT OPPOSITE IN SIGN (POLARITY) TO THE R.F. VOLTAGES AT THE PLATE AND CAN THEREFORE BE USED TO ENERGIZE THE GRID OF THE LOWER PUSH-PULL TUBE. THIS COUPLING METHOD IS THE SAME AS THAT EMPLOYED IN THE CIRCUIT OF FIG. 3 IN THIS LESSON ONLY THAT IT IS ADAPTED TO THE PUSH-PULL SYSTEM.

FIG. 10 SHOWS TWO METHODS OF COUPLING WHICH ARE SATISFACTORY FOR APPLICATION WHEN BOTH DRIVER AND DRIVEN STAGES ARE BALANCED CIRCUITS. THE TWO CAPACITORS SHOWN IN EACH PLATE TANK OF THESE TWO CIRCUITS ARE A SINGLE "SPLIT STATOR" VARIABLE CONDENSER.

OCCASIONALLY IT IS NECESSARY TO COUPLE A PUSH-PULL STAGE TO A SINGLE TUBE WHICH FOLLOWS IT. IN SUCH A CASE INDUCTIVE COUPLING IS ADVISABLE AND EITHER OF THE TWO CIRCUITS SHOWN IN FIG. 11 WILL BE FOUND SATISFACTORY. IT IS ALSO WELL TO MENTION AT THIS TIME THAT WHEN AN UNTUNED TRANSMISSION LINE IS USED, THEN THE COILS OF THIS LINE SHOULD BE SPACED AS FAR AS POSSIBLE FROM THAT PART OF THETHE TANK COIL WHICH IS CONNECTED TO THE GRID OR PLATE. IN THIS MANNER, UNDESIRABLE CAPACITY

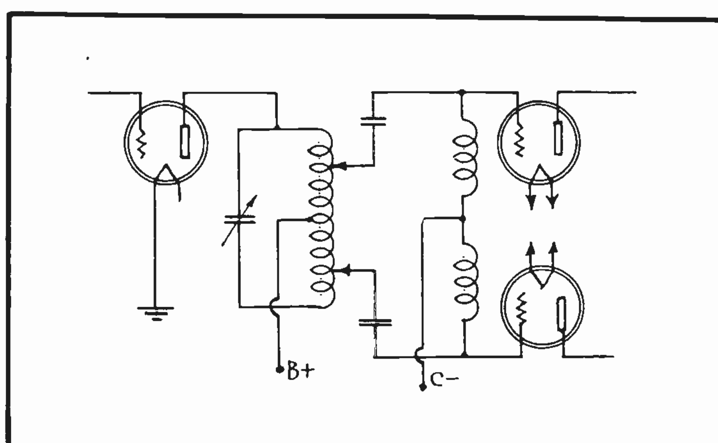

FIG. 9
Capacitance Coupling Between Single Driver and Push-Pull Amplifier.

EFFECTS ARE AVOIDED.

NEUTRALIZING R.F. AMPLIFIERS

As has already been outlined, a vacuum tube will act as an oscillator whenever a part of the power in the plate circuit is fed back into the grid circuit in such a way as to make the tube self-exciting. A problem which always enters the picture when a three element tube is used as a radio frequency amplifier is feed-back through the grid-plate capacity. In a tetrode or pentode the screen grid acts as an electrostatic shield which effectively prevents oscillation, but in a triode amplifier, it is necessary to nullify the feed-back through the inter-electrode capacitance by feeding back a neutralizing voltage which is equal to, but 180 degrees out of phase with the voltage causing the tube to oscillate. The two systems most commonly used are shown in Fig.12. In circuit "A" of Fig.12 the A.C. component of plate current flowing through section "X" induces by mutual induction a neutralizing voltage in section "Y"

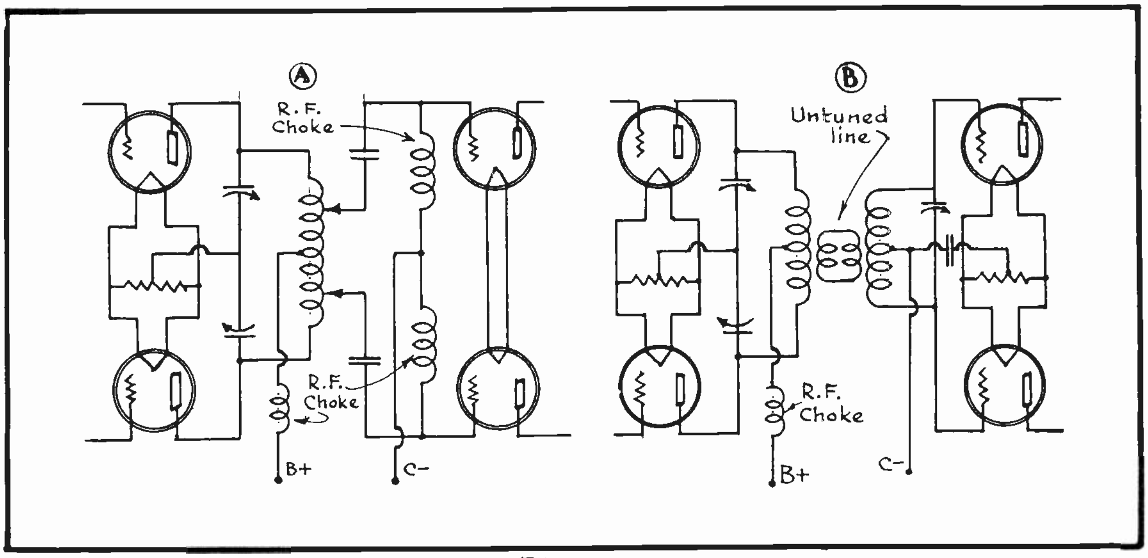

FIG.10
Interstage Coupling Between Push-Pull Amplifier.

which is led to the grid through the small condenser "C", to neutralize the voltage which appears across the grid and plate.

In "B" of Fig. 12 a split-stator tuning condenser is used with its rotor grounded and connected to the filament. The neutralizing voltage is obtained as a voltage drop across the lower section of the condenser and is fed to the grid through the neutralizing condenser "C".

Push-pull stages, as well as single amplifiers, require neutralizing. Fig. 13-A, for example, uses the principle of Fig. 12-A adapted to the balanced circuit, while Fig. 13-B is similar in principle to Fig.12-B. The use of the split-stator condenser in Figs. 12-B and 13-B renders greater frequency stability at very high frequencies than does the use of the tapped coil and it is therefore more popular in short wave work.

As a general rule, the tap on the tank coil should be at the center. Correct neutralization will then be obtained when the neutralizing

CONDENSER HAS A CAPACITY ABOUT EQUAL TO THE GRID-PLATE CAPACITY OF THE TUBE. IT IS EVIDENT, THEN, THAT THE VALUE OF THIS CAPACITANCE DEPENDS UPON THAT OF THE TUBE USED.

ALL BY-PASS CONDENSERS AND SUNDRY PARTS NOT ACTIVELY TAKING PART IN THE PROCESS OF NEUTRALIZATION ARE OF THE USUAL VALUES.

THE PROCEDURE TO BE FOLLOWED IN NEUTRALIZING AN R.F. STAGE IS NOT ESPECIALLY DIFFICULT. IT IS THE SAME REGARDLESS OF THE TYPE OF CIRCUIT EMPLOYED AND IS CARRIED OUT IN THE FOLLOWING STEPS:

1. DISCONNECT PLATE VOLTAGE FROM TUBE.

2. WITH THE FILAMENT LIGHTED, FEED THE GRID IN THE NORMAL WAY FROM THE OUTPUT OF THE PRECEDING TUBE.

3. COUPLE A RESONANCE INDICATOR (SEE YOUR LESSON NO.51.) INDUCTIVELY TO THE PLATE TANK COIL.

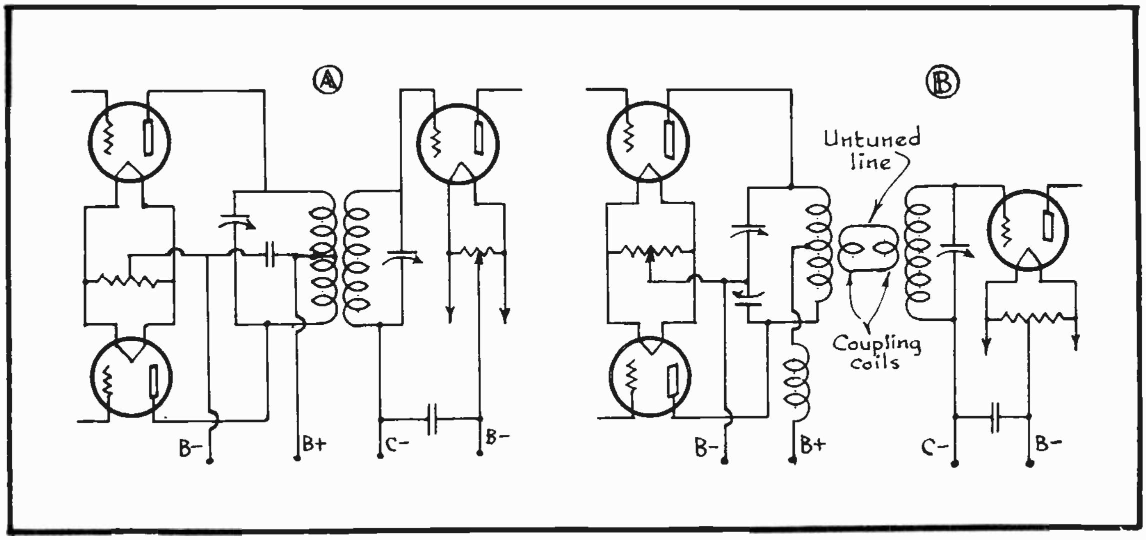

FIG. 11
Single Tubes Driven By Push-Pull Stages.

4. SET THE RESONANCE INDICATOR AT THE FREQUENCY ON WHICH THE TRANSMITTER IS TO OPERATE, AND TUNE THE PLATE CIRCUIT TO RESONANCE.

5. NOW ADJUST THE NEUTRALIZING CONDENSER TO THAT POSITION WHICH CAUSES MINIMUM R.F. PLATE CURRENT AS INDICATED BY THE RESONANCE INDICATOR. THIS INDICATION SHOULD BE VIRTUALLY ZERO.

6. THE LAST STEP HAS PROBABLY DETUNED THE DRIVER TANK, SO GO BACK AND RETUNE THIS STAGE.

7. NOW COME BACK TO THE STAGE BEING NEUTRALIZED, TUNE ITS TANK TO RESONANCE, AND NEUTRALIZE ONCE MORE. THIS WORKING BACK AND FORTH BETWEEN THESE TWO STAGES IS NECESSARY BECAUSE ANY CHANGE IN ONE CIRCUIT HAS A TENDENCY TO UPSET THE OTHER.

8. WHEN THE RESONANCE INDICATOR GIVES NO INDICATION WITH THE PLATE

TANK TUNED TO THE RESONANT FREQUENCY, WE KNOW THAT THE SIGNAL CARRIED THROUGH THE NEUTRALIZING CONDENSER IS EQUAL, AND OPPOSITE IN PHASE, TO THE SIGNAL CARRIED THROUGH THE GRID-PLATE CAPACITY OF THE TUBE, AND THE STAGE IS NEUTRALIZED.

9. NOW RESTORE PLATE VOLTAGE TO THE TUBE AND THE STAGE IS READY TO OPERATE.

SCREEN-GRID AMPLIFIERS

IN FIG. 14 YOU ARE SHOWN THE BASIC AMPLIFIER CIRCUIT FOR A TRANSMITTER WHEN SCREEN-GRID TUBES ARE USED. THE CIRCUIT AT THE LEFT OF FIG. 14 SHOWS YOU HOW A TETRODE IS USED FOR THIS PURPOSE, WHILE THE CIRCUIT AT THE RIGHT OF THIS SAME ILLUSTRATION SHOWS YOU HOW THE PENTODE IS EMPLOYED. THE EXACT VOLTAGES WHICH ARE TO BE APPLIED TO THE ELEMENTS OF THESE TUBES NATURALLY DEPEND UPON THE OPERATING CHARACTERISTICS OF THE

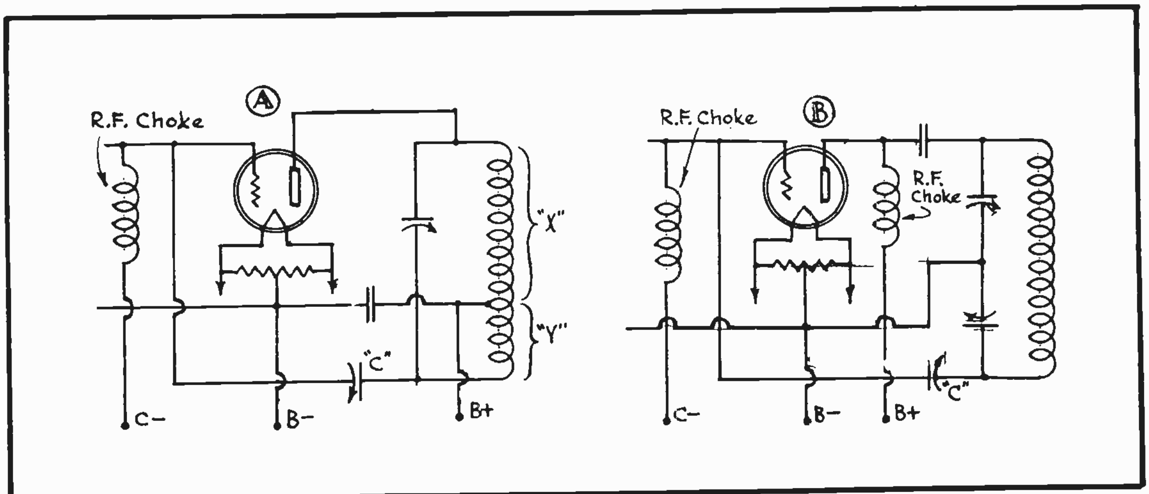

FIG. 12
Two Methods of Neutralizing.

TUBES IN QUESTION. IN A LATER LESSON, YOU WILL BE FURNISHED WITH COMPLETE DATA OF THIS NATURE PERTAINING TO TRANSMITTER TUBES.

SINCE THE TETRODE AND PENTODE TUBES BOTH HAVE INTERNAL SHIELDS, NO REGENERATIVE FEED-BACK CAN BE PASSED THROUGH THESE TUBES WHEN THEY ARE USED PROPERLY AND FOR THIS REASON NO NEUTRALIZING PROVISIONS NEED BE MADE. HOWEVER, IT IS IMPORTANT THAT THE INPUT AND OUTPUT CIRCUITS OF THE TUBE BE SUFFICIENTLY ISOLATED SO THAT STRAY MAGNETIC OR CAPACITIVE COUPLING CANNOT TAKE PLACE BETWEEN THEM. FOR THIS SAME REASON, IT IS FREQUENTLY THE PRACTICE IN DESIGNING CIRCUITS OF THIS TYPE TO SHIELD THE INPUT AND OUTPUT CIRCUITS OF THE TUBE.

TRANSMITTING CONDENSERS

YOU ARE BY THIS TIME ALREADY QUITE FAMILIAR WITH THE GENERAL CONSTRUCTIONAL FEATURES OF THE R.F. TRANSFORMERS AND COILS USED IN THE TUNING CIRCUITS OF TRANSMITTERS — THAT IS, THAT THESE WINDINGS ARE GENERALLY MADE OF COPPER TUBING OR LARGE-SIZE COPPER WIRE SO THAT LOSSES CAN BE REDUCED TO A MINIMUM. YOU WERE ALSO SHOWN WHAT PRECAUTIONS ARE TAKEN SO THAT THESE WINDINGS ARE WELL-INSULATED FROM ALL SURROUNDING BODIES BY

USING LARGE HIGH-QUALITY INSULATORS AS SUPPORTS. HOWEVER, LITTLE HAS AS YET BEEN MENTIONED ABOUT THE TUNING CONDENSERS AS USED IN TRANSMITTERS AND SO IT WILL BE WELL TO CONSIDER THIS POINT NEXT.

IN FIG. 15 YOU ARE SHOWN TWO TYPICAL VARIABLE CONDENSERS AS USED IN HIGH-POWER TRANSMITTERS FOR TUNING PURPOSES. FUNDAMENTALLY, THESE CONDENSERS ARE THE SAME AS THOSE USED IN RECEIVERS, IN THAT THEY ALSO CONSIST OF A STATOR PLATE GROUP AND A ROTOR PLATE GROUP — IN FACT, FOR LOW POWER TRANSMITTERS GOOD RECEIVER TYPE TUNING CONDENSERS CAN BE USED SATISFACTORILY. IN THE CASE OF HIGH-POWER TRANSMITTERS, HOWEVER, SOME REFINEMENTS ARE MADE IN THE CONSTRUCTION OF THE TUNING CONDENSERS AS WILL BE APPARANT FROM AN INSPECTION OF FIG. 15.

TO BEGIN WITH, REGULAR TRANSMITTING CONDENSERS ARE CONSTRUCTED WITH GREATER PRECISION THAN ARE THE CONVENTIONAL RECEIVER TYPE CONDENSERS. YOU WILL ALSO OBSERVE IN FIG. 15 THAT GREATER SPACING IS ALLOWED BETWEEN THE

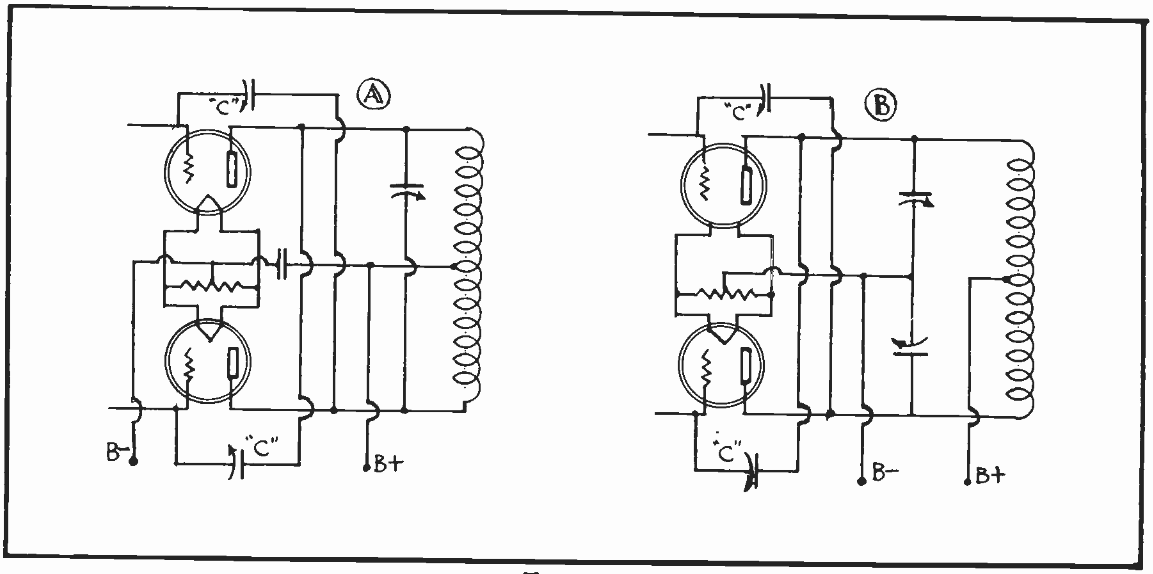

FIG. 13
Neutralization of Push-Pull Stages.

PLATES OF THE UNIT — THIS IS DONE SO THAT THERE WILL BE NO POSSIBILITY OF THE HIGH VOLTAGES ENCOUNTERED IN TRANSMITTERS FROM CAUSING ARCING BETWEEN THE PLATES.

THE FRAMES, AS WELL AS ALL PARTS OF THE TRANSMITTING CONDENSER, ARE CONSTRUCTED OF HEAVY MATERIAL SO THAT THE ENTIRE UNIT WILL BE ASSURED OF GREATER RIGIDITY AND FREEDOM FROM VIBRATION — ALL OF WHICH PLAY AN IMPORTANT PART IN MAKING A STEADY SIGNAL POSSIBLE. THE BEST OF INSULATION, SUCH AS ISOLANTITE, IS ALSO GENERALLY USED SO THAT THE UNIT MAY OPERATE AT UTMOST EFFICIENCY.

THE CONDENSER WHICH IS SHOWN IN THE UPPER PORTION OF FIG. 15 IS OF THE SPLIT-STATOR TYPE, SUCH AS USED IN SEVERAL OF THE CIRCUITS WHICH ARE ILLUSTRATED IN THIS LESSON. IN CONDENSERS OF THIS TYPE A SINGLE SHAFT HAS ALL OF THE ROTOR PLATES OF THE ENTIRE UNIT ATTACHED TO IT. THE STATOR PLATES, HOWEVER, ARE CONNECTED TOGETHER IN SUCH A MANNER AS TO FORM TWO SEPARATE GROUPS — EACH GROUP HAVING ITS OWN TERMINAL CONNECTION. IN

EFFECT, THIS ARRANGEMENT WOULD BE THE SAME AS TWO SECTIONS OF A RECEIVER

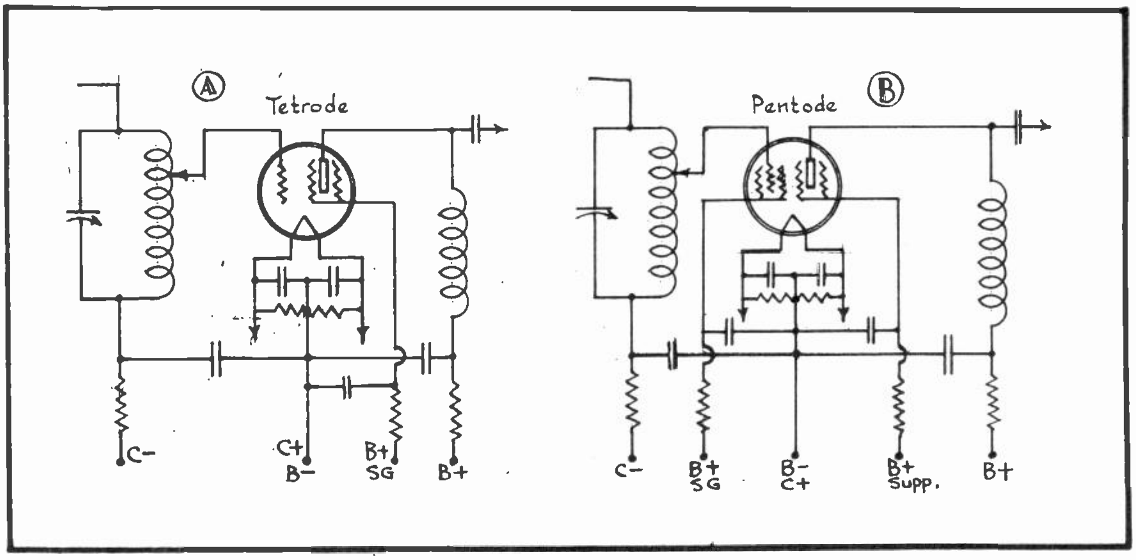

FIG. 14
Application of Screen Grid Amplifiers.

TYPE GANG CONDENSER CONNECTED IN SERIES.

BY USING A SPLIT STATOR CONDENSER IN A TRANSMITTER, THE ROTOR AND CONTROL SHAFT CAN AT ALL TIMES BE MAINTAINED AT GROUND POTENTIAL EVEN WHEN THE CONDENSER IS EMPLOYED IN THE PLATE CIRCUIT OF A TUBE. THIS IS CLEARLY ILLUSTRATED IN FIG. 10 OF THIS LESSON, WHERE YOU WILL FIND THE ROTOR PLATES OF THE SPLIT-STATOR CONDENSER CONNECTED TO THE ELECTRICAL CENTER OF THE FILAMENT CIRCUIT. THIS ARRANGEMENT ALSO ELIMINATES THE PROBABILITY OF R.F. BURNS THROUGH THE CONDENSER HANDLE AND AT THE SAME TIME GREATLY REDUCES HAND-CAPACITY EFFECTS.

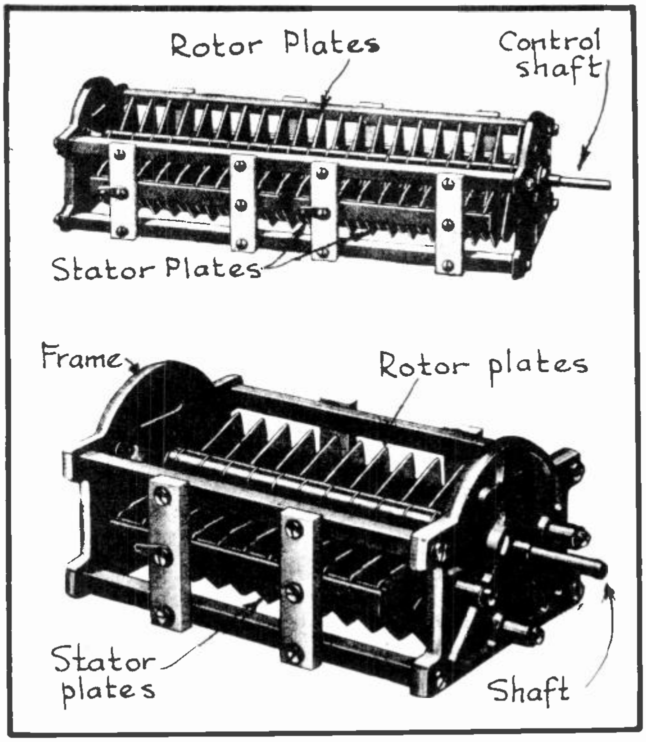

FIG. 15
Typical Transmitter Tuning Condensers.

IN THE NEXT LESSON YOU ARE GOING TO CONTINUE YOUR STUDIES OF R.F. AMPLIFIERS AS USED IN TRANSMITTERS BY LEARNING THE PROPER PROCEDURE, FOR TUNING SUCH AMPLIFIERS. YOU WILL ALSO FIND THIS NEXT LESSON TO FURNISH YOU WITH COMPLETE INSTRUCTIONS REGARDING FREQUENCY MULTIPLIERS, POWER AMPLIFIERS, ETC.

GRADUALLY, YOU ARE LEARNING MORE AND MORE ABOUT TRANSMITTERS AND WHEN YOU HAVE COMPLETED THIS SERIES OF LESSONS, YOU WILL HAVE A MOST THOROUGH KNOWLEDGE OF THIS SUBJECT.

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EXAMINATION QUESTIONS

LESSON NO. T-7

1. – Explain how the swinging of a transmitter antenna may affect an oscillator not employing crystal control and which is coupled directly to the antenna system. How may this trouble be remedied?

2. – What is a "buffer amplifier"?

3. – Why in the circuit of Fig. 3 is a "tap connection" used between the plate circuit of the oscillator and the grid circuit of the buffer amplifier?

4. – Draw a circuit diagram which illustrates how link coupling may be used between two stages of a transmitter.

5. – Draw a circuit diagram showing how a split-stator tuning condenser may be used in a transmitter circuit.

6. – Describe the constructional features of a split-stator condenser and explain what advantages are obtained thru its use.

7. – Draw a circuit diagram which illustrates the neutralizing system of a transmitter's R.F. amplifier and in which a single triode is employed.

8. – Explain in detail how you would go about the task of neutralizing an R.F. stage of a transmitter.

9. – Draw a circuit diagram of a push-pull R.F. stage for a transmitter using a pair of triodes and also show the neutralizing circuit which may be employed in this case.

10.– Explain in detail the operation of the circuit which is illustrated in Fig. 9 of this lesson.

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Transmitters

LESSON NO. 8

TUNING AMPLIFIERS - APPLICATION OF FREQUENCY MULTIPLIERS

In previous lessons you were told how to go about the task of tuning the oscillator of a transmitter whether it be of the simple self-tuning type or crystal controlled and now that you are familiar with the applications of R.F. amplifiers in transmitters, our next step will be to go into the details concerning the procedure which should be followed in order to tune such amplifiers correctly.

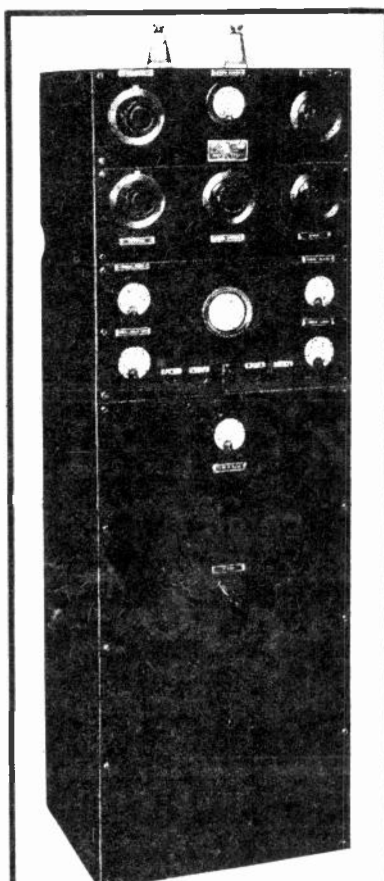

FIG.1
A 100-Watt Transmitter.

TUNING THE AMPLIFIER

Before commencing to tune the R.F. amplifier, it is necessary that it be properly neutralized, assuming that triodes are being used. Should the amplifier in question employ tubes of the screen-grid type, then it is of course necessary that the circuit arrangement be such that there is no possibility of feedback between its output and input circuits. With these conditions taken care of, we proceed to tune the amplifier as shall now be explained.

First disconnect the plate voltage from the amplifier, set the oscillator into operation and carefully adjust it to the frequency at which the transmitter is to operate. The correct method for adjusting the oscillator has already been explained in previous lessons.

With the oscillator adjusted for the proper frequency, the next step is to make further adjustments so that maximum energy will

BE TRANSFERRED FROM THE OSCILLATOR'S OUTPUT TO THE GRID CIRCUIT OF THE AMPLIFIER WHICH IT IS DRIVING. ONE METHOD OF DETERMINING THE EXITATION POWER WHICH IS BEING DELIVERED BY THE OSCILLATOR TO THE R.F. STAGE, OR FROM ANY DRIVER STAGE TO THE FOLLOWING STAGE FOR THAT MATTER, IS TO CONNECT A D.C. MILLIAMMETER IN SERIES WITH THE GRID RETURN CIRCUIT OF THE AMPLIFIER STAGE WHICH IS RECEIVING THIS EXITING ENERGY. WHEN EMPLOYING THIS METHOD, WE FIND THAT THE GREATER THE EXITATION ENERGY BEING RECEIVED BY THIS CIRCUIT, THE GREATER WILL BE THE RECTIFIED GRID CURRENT WHICH IS INDICATED BY THE METER.

THE EXACT MANNER IN WHICH SUCH A MILLIAMMETER IS TO BE CONNECTED IN THE GRID CIRCUIT OF THE AMPLIFIER WILL NATURALLY DEPEND UPON THE CIRCUIT ARRANGEMENT OF THE PARTICULAR AMPLIFIER IN QUESTION. IN FIGS. 2, 3 AND 4 YOU ARE SHOWN SOME TYPICAL CIRCUITS IN WHICH THE MILLIAMMETER CONNECTIONS ARE ILLUSTRATED IN ORDER TO MEASURE THE RECTIFIED GRID CURRENT IN THE AMPLIFIER STAGE. BY FAMILIARIZING YOURSELF THOROUGHLY WITH THESE CONNECTIONS IN PARTICULAR, YOU SHOULD HAVE NO DIFFICULTY IN APPLYING THE SAME METHOD TO ANY OTHER SIMILAR CIRCUIT WHICH MAY DIFFER IN CERTAIN RESPECTS. THE DRIVER STAGE IN ANY OF THESE CIRCUITS MAY BE EITHER AN OSCILLATOR OR ANOTHER STAGE OF R.F. AMPLIFICATION PRECEDING THE R.F. STAGE IN WHICH THE ADJUSTMENTS ARE AT THE TIME BEING MADE. NOTICE ALSO IN FIGS. 2, 3 AND 4 THAT THE POLARITY OF THE MILLIAMMETER IS INDICATED AND THE CIRCUIT CONNECTIONS SHOULD BE MADE ACCORDINGLY.

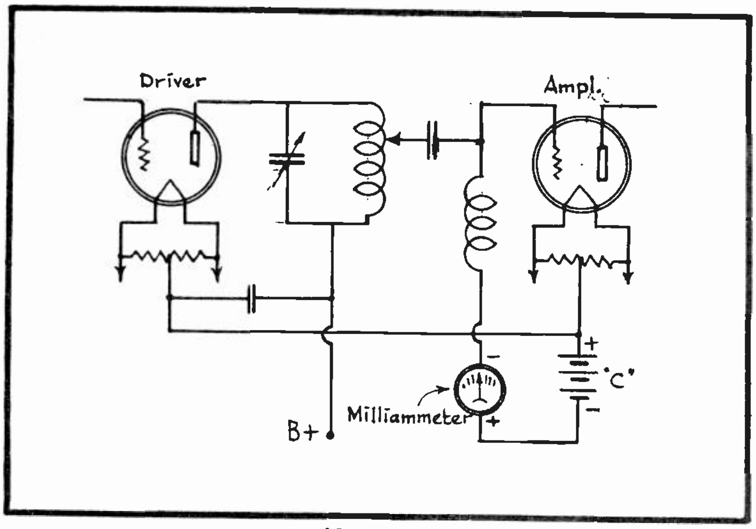

FIG. 2
Milliammeter Connection.

WITH THE MILLIAMMETER PROPERLY CONNECTED IN THE CIRCUIT, THE DRIVER STAGE TUNING CIRCUIT SHOULD BE ADJUSTED FOR MAXIMUM GRID CURRENT. THE COUPLING BETWEEN THE DRIVER STAGE AND THE AMPLIFIER SHOULD THEN ALSO BE ADJUSTED FOR MAXIMUM GRID CURRENT. IN THE EVENT THAT TRANSFORMER COUPLING IS EMPLOYED, THE COUPLING BETWEEN THE TWO STAGES CAN BE ADJUSTED BY VARYING THE DISTANCE AND ANGLE OF COUPLING OR BOTH BETWEEN THE PRIMARY AND SECONDARY WINDINGS OF THE TRANSFORMER.

IF THE CIRCUIT ARRANGEMENT IS SUCH THAT A TAP CONNECTION IS USED BETWEEN THE OUTPUT OF THE DRIVER TUBE AND THE INPUT OF THE AMPLIFIER AS IN FIGS. 2 AND 3, THEN THE POSITION OF THE TAP CONNECTION ON ITS COIL SHOULD BE ALTERED UNTIL MAXIMUM GRID CURRENT IS INDICATED IN THE AMPLIFIER CIRCUIT. SHOULD SUCH A TAP CONNECTION BE USED IN A PUSH-PULL ARRANGEMENT, THEN BOTH TAPS SHOULD BE CHANGED SIMULTANEOUSLY AND IN SUCH A MANNER SO THAT EACH TAP WILL BE THE SAME NUMBER OF TURNS FROM THE CENTER OF THE COIL.

WHEN LINK COUPLING IS USED, THE DEGREE OF COUPLING CAN BE CHANGED

BY MOVING THE TRANSMISSION LINE COUPLING COILS CLOSER TO THE TANK COILS WITH WHICH THEY ARE COUPLED OR ELSE TO CHANGE THE NUMBER OF TURNS USED ON THE COUPLING COILS.

WHENEVER, THE COUPLING IS CHANGED, REGARDLESS OF THE TYPE USED, THE DRIVER CIRCUIT SHOULD BE RETUNED TO RESONANCE BECAUSE ANY CHANGE IN THE DEGREE OF COUPLING IS LIKELY TO DETUNE THE PLATE TANK CIRCUIT OF THE DRIVER STAGE. IN THE EVENT THAT A TANK CIRCUIT (TUNING CIRCUIT) IS ALSO USED IN THE GRID CIRCUIT OF THE AMPLIFIER STAGE WHICH IS BEING ADJUSTED, AS IS THE CASE IN FIG. 4, FOR INSTANCE, THEN THIS CIRCUIT SHOULD ALSO BE RETUNED WHENEVER ANY CHANGES ARE MADE IN COUPLING SO THAT MAXIMUM GRID CURRENT WILL BE INDICATED BY THE MILLIAMMETER.

WITH THESE ADJUSTMENTS COMPLETED, THE PLATE TANK CIRCUIT OF THE AMPLIFIER SHOULD BE SET APPROXIMATELY AT RESONANCE AND WITH THE EXITING VOLTAGE AS SUPPLIED BY THE OUTPUT OF THE OSCILLATOR OR PRECEDING AMPLIFIER STAGE BEING APPLIED TO THE GRID CIRCUIT OF THE R.F. STAGE WHICH IS BEING ADJUSTED, YOU CAN PROCEED TO CONNECT THE PLATE VOLTAGE TO THE R.F. TUBE AND TUNE ITS PLATE TANK CIRCUIT TO RESONANCE. A CONDITION OF RESONANCE WILL BE INDICATED BY A PRONOUNCED DIP OF THE NEEDLE OF A D.C. MILLIAMMETER WHICH IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE AMPLIFIER BEING ADJUSTED. THIS TUNING ADJUSTMENT FOR MINIMUM PLATE CURRENT SHOULD BE MADE QUICKLY BECAUSE IF THIS PLATE TANK CIRCUIT IS PERMITTED TO REMAIN FAR REMOVED FROM RESONANCE FOR AN APPRECIABLE LENGTH OF TIME WHILE THE PLATE CIRCUIT IS COMPLETE, THE RESULTING HIGH PLATE CURRENT MAY DAMAGE THE TUBE.

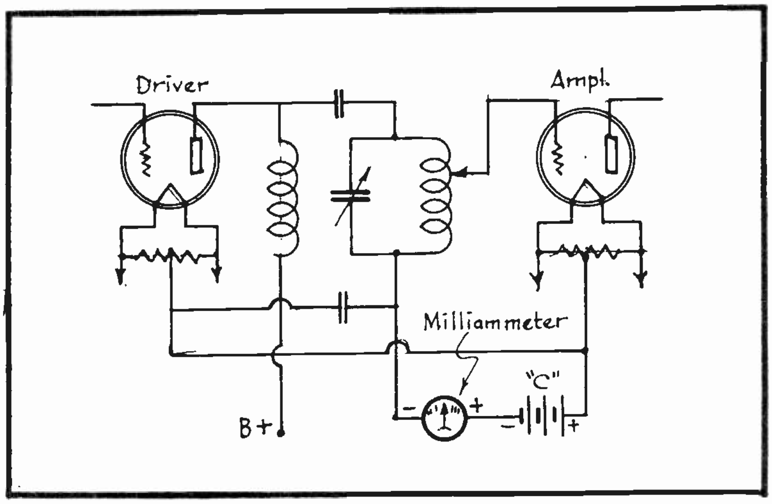

FIG.3
Milliammeter Connection When Using Tuned-Grid Circuit.

AFTER THIS TANK CIRCUIT HAS BEEN TUNED FOR MINIMUM PLATE CURRENT, THE OUTPUT LOAD CIRCUIT MAY BE CONNECTED TO THE AMPLIFIER. THIS OUTPUT LOAD MAY BE THE GRID CIRCUIT OF A FOLLOWING STAGE OF R.F. AMPLIFICATION OR ELSE THE ANTENNA CIRCUIT, DEPENDING UPON THE PARTICULAR TRANSMITTER CIRCUIT IN QUESTION. UPON CONNECTING THE LOAD, THE PLATE CURRENT READING OF THE AMPLIFIER WILL INCREASE SOMEWHAT AND SINCE ITS TANK CIRCUIT MAY BE DETUNED SOMEWHAT AT THE TIME THE LOAD IS APPLIED, IT SHOULD BE AGAIN CAREFULLY ADJUSTED FOR MINIMUM PLATE CURRENT. THE MINIMUM PLATE CURRENT AT THIS TIME, HOWEVER, WILL NOT BE AS LOW AS THAT WHICH WAS OBTAINED BEFORE THE LOAD WAS CONNECTED. THE COUPLING AT THE OUTPUT END OF THIS AMPLIFIER STAGE SHOULD BE ADJUSTED SO THAT THE PLATE CURRENT DRAWN BY THE AMPLIFIER TUBE WILL BE NEAR THE NORMAL PLATE CURRENT VALUE FOR WHICH THE TUBE IS RATED.

IF ANOTHER AMPLIFIER STAGE FOLLOWS, ITS CIRCUIT SHOULD BE ADJUSTED IN THE SAME MANNER AS HAS JUST BEEN EXPLAINED. ON THE OTHER HAND, IF THE ANTENNA CIRCUIT IS FED BY THIS AMPLIFIER, THEN THE ANTENNA CIRCUIT SHOULD BE ADJUSTED AS DESCRIBED IN THE NEXT LESSON. YOU WILL ALSO BE SHOWN LATER IN THIS LESSON HOW DUMMY ANTENNAS ARE ARE SOMETIMES USED FOR THE PRELIMINARY TUNING OF AMPLIFIERS.

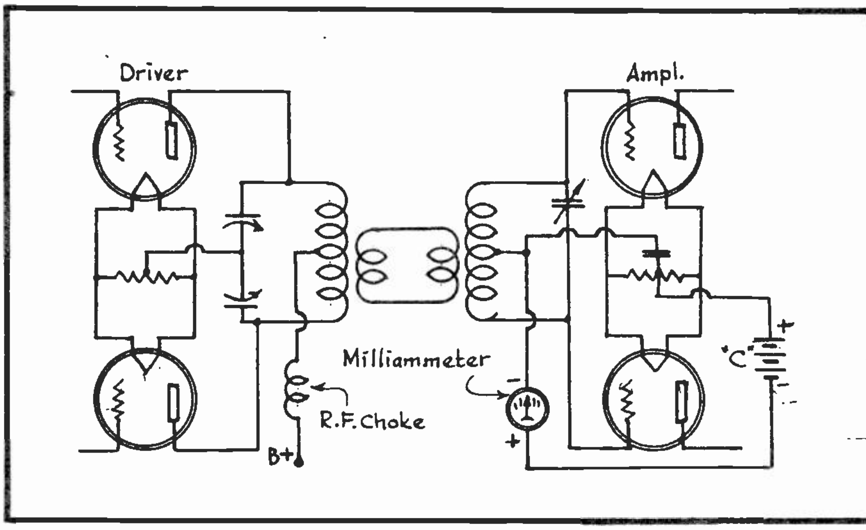

FIG. 4
Milliammeter Connections In Push-Pull Circuit.

FREQUENCY MULTIPLIERS

IN BROADCAST TRANSMITTERS, THE OPERATING FREQUENCY IS SUFFICIENTLY LOW SO THAT THE CRYSTAL AS USED IN ITS OSCILLATOR CIRCUIT CAN BE MADE THICK ENOUGH TO POSSESS THE REQUIRED MECHANICAL STRENGTH TO INSURE LONG LIFE. IN SUCH A CASE, IT IS PRACTICAL TO DESIGN ALL OF THE R.F. STAGES, AS WELL AS THE ANTENNA CIRCUIT, TO RESONATE AT THE SAME FREQUENCY AS THAT FOR WHICH THE OSCILLATOR IS TUNED AND WHICH IN TURN IS GOVERNED BY THE FREQUENCY FOR WHICH THE CRYSTAL HAS BEEN GROUND. HOWEVER, IN THOSE SHORT-WAVE TRANSMITTERS WHICH RADIATE THEIR ENERGY AT VERY HIGH FREQUENCIES (APPROXIMATELY 7 MEGACYCLES OR OVER), IT HAS BECOME THE COMMON PRACTICE TO OPERATE THE OSCILLATOR AT A RELATIVELY LOW FREQUENCY AND WITH WHICH A CRYSTAL OF SUFFICIENT THICKNESS TO INSURE STRENGTH CAN BE USED. THIS FUNDAMENTAL FREQUENCY AS GENERATED BY THE OSCILLATOR IS THEN DOUBLED

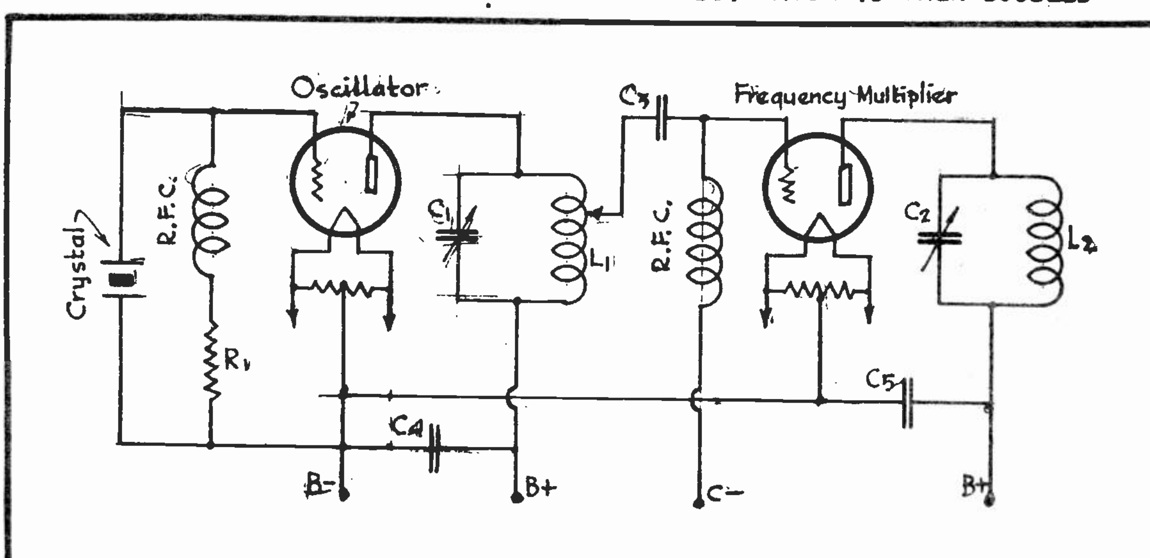

FIG. 5
Application of the Frequency Multiplier.

or tripled by means of special circuits which are known as FREQUENCY MULTIPLIERS or "harmonic generators".

Fig. 5 shows you a typical example of how a frequency multiplier is used in conjunction with a crystal controlled oscillator. For the sake of explanation, let us assume that the crystal is ground for a frequency of 3500 Kc. The plate tank circuit of this oscillator, consisting of C_1 and L_1, will in this case also be tuned to resonance at 3500 Kc. This oscillator frequency of 3500 Kc. will be applied across the grid circuit of the frequency multiplier tube through coupling condenser C_3.

The circuits employed in the frequency multiplier stage are exactly the same as those of a conventional amplifier and the only real difference is that the tube is being operated at a higher negative grid bias voltage than ordinarily. Under these conditions, a relatively strong harmonic output will appear in the plate circuit of the frequency multiplier tube. The second harmonic will be most prominent and in our particular example this would be equal to a frequency of twice 3500 Kc. or 7000 Kc. The plate tank circuit of this frequency multiplier stage is therefore tuned to a frequency of 7000 Kc. so that it will resonate at the second harmonic and thereby be capable of transferring maximum energy at this harmonic frequency to the following circuit.

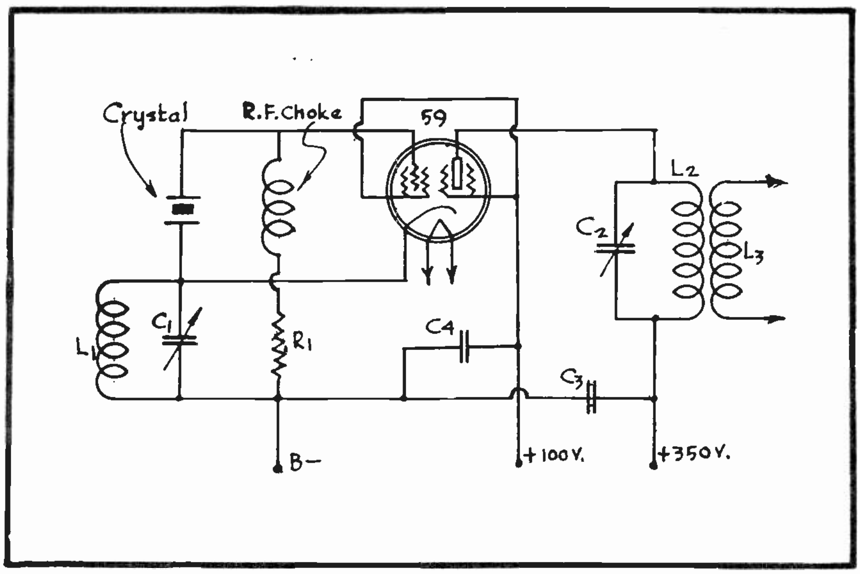

FIG. 6
The Tri-Tet Circuit.

Since the original frequency has in this particular case been doubled, the frequency multiplier in this instance would be logically called a FREQUENCY DOUBLER.

Although it is true that a frequency multiplier can be designed to deliver a harmonic which is higher than the second harmonic of the frequency applied across its input circuit, yet it is equally true that the plate efficiency of a frequency multiplier is appreciably less than that of a straight amplifier and decreases rapidly as the plate circuit is tuned to a harmonic higher than the second. It is for this reason that most frequency multipliers are designed to function as DOUBLERS. Sometimes, however, another doubler follows the first so that the frequency can be doubled once more and thus become four times that of the original oscillator or fundamental frequency.

GRID BIAS FOR AMPLIFIERS

In order to realize good plate efficiency from a power amplifier

TUBE, IT IS NECESSARY THAT THE GRID BIAS VOLTAGE UNDER OPERATING CONDITIONS BE GREATER THAN THAT WHICH IS ACTUALLY REQUIRED IN ORDER TO "CUT-OFF" THE PLATE CURRENT WHEN THE AMPLIFIER IS NOT RECEIVING ANY EXITING R.F. ENERGY. A STRAIGHT AMPLIFIER TUBE SHOULD BE OPERATED WITH A BIAS VOLTAGE WHICH IS EQUAL TO APPROXIMATELY TWICE THE "CUT-OFF" BIAS FOR THE TUBE BEING USED. THE CUT-OFF BIAS FOR A GIVEN TUBE IS GENERALLY GIVEN IN THE SPECIFICATIONS WHICH ARE ISSUED BY THE TUBE MANUFACTURER BUT IN THE CASE OF TRIODES IS APPROXIMATELY EQUAL TO THE PLATE VOLTAGE AT WHICH THE TUBE IS BEING OPERATED DIVIDED BY ITS AMPLIFICATION FACTOR. IN THE CASE OF A FREQUENCY MULTIPLIER, THIS TUBE SHOULD BE OPERATED WITH A GRID BIAS VOLTAGE CONSIDERABLY ABOVE DOUBLE CUT-OFF AND EXITED WITH A CORRESPONDINGLY GREATER R.F. VOLTAGE — IN FACT, THE DRIVING POWER REQUIRED FOR GOOD DOUBLING EFFICIENCY IS ABOUT TWO OR THREE TIMES THAT WHICH IS NECESSARY FOR EFFICIENT STRAIGHT AMPLIFICATION.

THERE ARE SEVERAL METHODS WHEREBY THE BIAS VOLTAGE MAY BE OBTAINED FOR THE R.F. AMPLIFIER IN A TRANSMITTER. ONE METHOD IS TO USE BATTERIES AS A "C" SUPPLY AND IN SUCH CASES A BANK OF REGULAR "B" BATTERIES ARE USED, ONLY THAT THEY ARE EMPLOYED IN THE CIRCUIT AS "C" BATTERIES. ALTHOUGH BATTERIES PROVIDE A RELATIVELY CONSTANT BIAS VOLTAGE REGARDLESS OF WHETHER THE AMPLIFIER IS BEING EXITED OR NOT, YET THE GRID CURRENT WHICH FLOWS WHEN THE TRANSMITTER IS IN OPERATION HAS A CHARGING EFFECT AND IN THIS MANNER TENDS TO INCREASE THE BATTERY VOLTAGE. THIS EFFECT IS MORE NOTICEABLE AS THE BATTERIES AGE AND THEIR INTERNAL RESISTANCE INCREASES.

ANOTHER METHOD OF OBTAINING A GRID BIAS VOLTAGE IS TO USE THE GRID LEAK METHOD AS HAS ALREADY BEEN EXPLAINED RELATIVE TO OSCILLATORS. THIS METHOD IS BOTH ECONOMICAL AS REGARDS THE SAVING IN COST OF BATTERIES AND IN ADDITION OFFERS THE DESIRABLE FEATURE OF REGULATING THE BIAS VOLTAGE IN ACCORDANCE WITH THE AMOUNT OF EXITING ENERGY AVAILABLE AND IN THIS WAY MOST EFFICIENT AMPLIFIER OPERATION IS REALIZED UNDER VARYING CONDITIONS OF OPERATION. THIS SAME METHOD ALSO OFFERS A DISADVANTAGE, HOWEVER, IN THAT IN CASE EXITATION SHOULD CEASE FOR SOME REASON OR OTHER, NO BIAS VOLTAGE WILL BE PRODUCED AND THE RESULTING INCREASE IN PLATE CURRENT MAY DAMAGE THE TUBE.

QUITE OFTEN, A COMBINATION OF GRID LEAK AND BATTERY BIAS IS USED AND IN WHICH CASE SUFFICIENT BATTERY VOLTAGE IS EMPLOYED TO SAFEGUARD THE TUBE IN CASE OF A LACK OF EXITATION AND THE ADDITIONAL BIAS VOLTAGE IS FURNISHED BY THE LEAK. UNDER SUCH CONDITIONS, THE BATTERY VOLTAGE AND THE VOLTAGE DROP PRODUCED ACROSS THE LEAK RESISTOR BY THE FLOW OF GRID CURRENT ARE EFFECTIVELY CONNECTED IN SERIES, THEREFORE, THE ACTUAL OR EFFECTIVE BIAS VOLTAGE WILL BE EQUAL TO THE SUM OF THE BATTERY VOLTAGE PLUS THE VOLT DROP ACROSS THE LEAK RESISTOR.

THE BIAS VOLTAGE MAY ALSO BE OBTAINED FROM THE TRANSMITTER'S POWER PACK OR ELSE FROM A BIAS RESISTOR WHICH IS INCLUDED IN THE CATHODE CIRCUIT OF THE TUBE THE SAME AS IN RECEIVERS. CIRCUIT DIAGRAMS WHICH ARE YET TO BE SHOWN YOU WILL ILLUSTRATE THESE DIFFERENT BIASING METHODS CLEARLY.

TUNING FREQUENCY MULTIPLIERS

IN THE TUNING OF FREQUENCY MULTIPLIERS, THE GENERAL PROCEDURE IS

MUCH THE SAME AS THAT OF TUNING STRAIGHT AMPLIFIERS AND IS DONE IN THE FOLLOWING MANNER:

FIRST THE PLATE VOLTAGE SOURCE IS DISCONNECTED FROM THE FREQUENCY MULTIPLIER TUBE AND THE GRID CIRCUIT IS THEN ADJUSTED FOR MAXIMUM GRID CURRENT IN THE SAME WAY AS ALREADY DESCRIBED RELATIVE TO STRAIGHT AMPLIFIERS. THE PLATE VOLTAGE IS THEN APPLIED TO THIS TUBE AND THE PLATE TANK CIRCUIT IS ADJUSTED SO AS TO RESONATE AT THE SECOND HARMONIC FREQUENCY AND WHICH IS INDICATED BY THE DIP IN PLATE CURRENT THE SAME AS WHEN TUNING A STRAIGHT AMPLIFIER TO RESONANCE WITH THE FUNDAMENTAL. IN THE CASE OF THE FREQUENCY MULTIPLIER, HOWEVER, THIS DIP IS NOT QUITE SO PRONOUNCED AS WHEN TUNING A STRAIGHT AMPLIFIER.

WITH THESE ADJUSTMENTS PROPERLY MADE, THE LOAD MAY BE CONNECTED AND THE OUTPUT COUPLING AND LOAD CIRCUITS ADJUSTED FOR MAXIMUM OUTPUT, IN KEEPING WITH THE PLATE CURRENT RATING OF THE TUBE. GENERALLY, IT IS ADVISABLE THAT THIS PLATE CURRENT BE SLIGHTLY LOWER THAN THAT FOR WHICH THE TUBE IS RATED, ESPECIALLY IF THE PLATE OF THE TUBE HAS A TENDENCY TO BECOME RED — THIS IS DUE TO THE INEFFICIENCY AT WHICH A FREQUENCY MULTIPLIER TUBE OPERATES. WITH ALL OF THESE ADJUSTMENTS TAKEN CARE OF, A LITTLE EXPERIMENTING CAN BE DONE AS REGARDS VARYING THE BIAS VOLTAGE OF THE FREQUENCY MULTIPLIER TUBE UNTIL MAXIMUM OUTPUT IS OBTAINED.

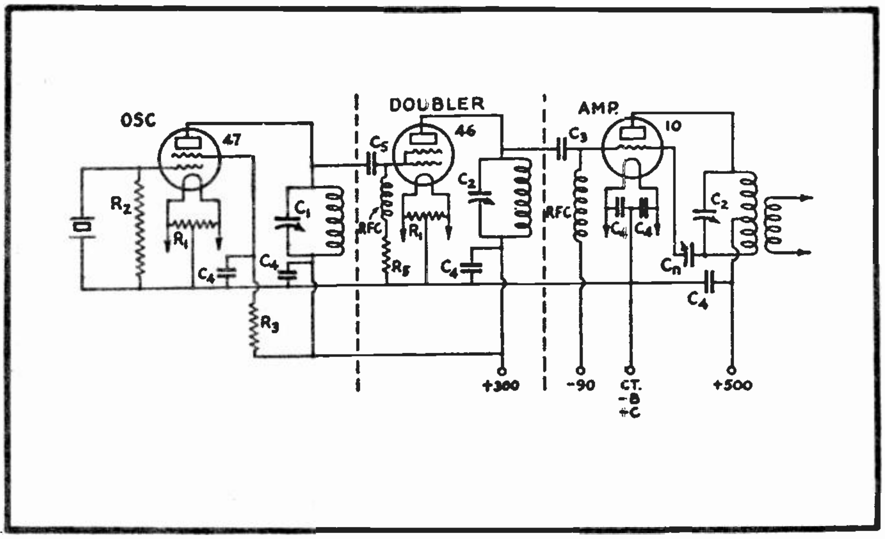

FIG.7
Low-Power Three-Tube Transmitter.

THE TRI-TET PRINCIPLE

IN FIG. 6 YOU ARE SHOWN A CIRCUIT DIAGRAM WHICH IS SO ARRANGED THAT A SINGLE TUBE CAN FUNCTION SIMULTANEOUSLY AS A CRYSTAL CONTROLLED OSCILLATOR AND AS A STRAIGHT AMPLIFIER OR A FREQUENCY MULTIPLIER. AS SUCH, THE TRANSMITTER CAN BE OPERATED AT TWO DIFFERENT FREQUENCIES EVEN THOUGH ONLY A SINGLE CRYSTAL IS EMPLOYED. THE TUBE USED IN THIS PARTICULAR CASE IS A TYPE 59 RECEIVER POWER TUBE, HOWEVER, THE SAME PRINCIPLE CAN ALSO BE EMPLOYED WITH SOME REGULAR TRANSMITTING TYPE TUBES SO THAT GREATER POWER OUTPUTS CAN BE REALIZED.

HERE THE CRYSTAL, R.F. CHOKE, AND LEAK RESISTOR R_1 ARE CONNECTED ACROSS THE GRID CIRCUIT OF THE TUBE WHILE THE TUNING CIRCUIT CONSISTING OF L_1 AND C_1 ARE CONNECTED IN THE CATHODE CIRCUIT OF THE SAME TUBE. THE

VALUES OF L_1 AND C_1 ARE SO CHOSEN THAT THIS CIRCUIT WILL RESONATE AT THE FREQUENCY OF THE CRYSTAL.

THE TUNING CIRCUIT CONSISTING OF L_2 AND C_2 IS INSTALLED IN THE PLATE CIRCUIT OF THE SAME TUBE AND ITS VALUES ARE SO CHOSEN THAT THIS CIRCUIT WILL ALSO BE TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY. UNDER THESE CONDITIONS, THIS PORTION OF THE CIRCUIT WILL FUNCTION AS A STRAIGHT AMPLIFIER.

IN ORDER TO FURNISH AN OUTPUT FREQUENCY OF TWICE THAT OF THE CRYSTAL, IT IS ONLY NECESSARY TO CHANGE THE VALUES OF L_2 AND C_2 SO THAT THIS TUNING CIRCUIT WILL RESONATE AT THE SECOND HARMONIC OF THE FUNDAMENTAL. THE TRANSMITTER WILL THEREFORE FUNCTION AS A "TRI-TET".

COMPLETE TRANSMITTER CIRCUITS

SO FAR, WE HAVE ONLY CONSIDERED THE INDIVIDUAL SECTIONS OF MULTI-TUBE TRANSMITTERS, THEREFORE, THE NEXT STEP FOR US TO TAKE IS TO LOOK AT SOME TYPICAL TRANSMITTER CIRCUITS AS A WHOLE AND IN WHICH THESE DIFFERENT SECTIONS HAVE ALL BEEN COMBINED TO FORM A COMPLETE TRANSMITTER UNIT. THE POWER PACKS AND KEY CIRCUITS ARE NOT BEING CONSIDERED AT THE PRESENT TIME, SINCE THEY ARE FULLY EXPLAINED IN LATER LESSONS.

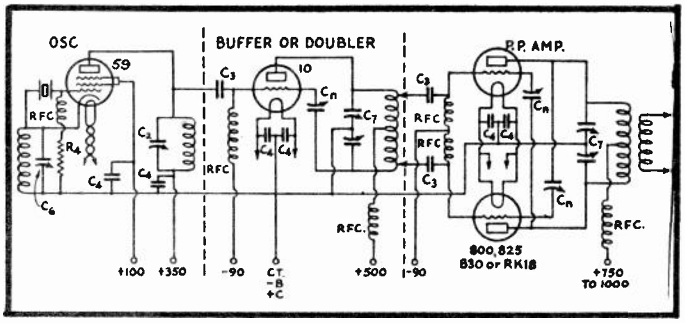

FIG. 8
Transmitter With Push-Pull Power Amplifier.

IN FIG. 7, FOR INSTANCE, YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A TRANSMITTER IN WHICH THREE TUBES ARE EMPLOYED. THIS IS A TRANSMITTER OF COMPARATIVELY LOW POWER OUTPUT AND CALLS FOR A POWER PACK WHICH OFFERS A MAXIMUM "B" VOLTAGE OF ONLY 500 VOLTS. THE TUBES USED IN THIS TRANSMITTER, YOU WILL OBSERVE, ARE A TYPE 47 AS A CRYSTAL CONTROLLED OSCILLATOR, A 46 AS A FREQUENCY DOUBLER AND BUFFER AND A TYPE 10 AS THE FINAL AMPLIFIER.

WHEN WORKING "STRAIGHT", THE TUNING CIRCUITS OF ALL THREE TUBES ARE TUNED TO THE SAME FREQUENCY, THAT IS, TO THE FREQUENCY OF THE CRYSTAL. WHEN "DOUBLING", THE TUNING CIRCUIT OF THE OSCILLATOR IS STILL TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY BUT THE TUNING CIRCUITS OF THE DOUBLER AND AMPLIFIER ARE BOTH TUNED TO RESONANCE WITH THE SECOND HARMONIC OF THE OSCILLATOR FREQUENCY.

A STILL DIFFERENT CIRCUIT DESIGN APPEARS IN FIG. 8. HERE A TYPE 59 TUBE IS USED IN A TRI-TET OSCILLATOR CIRCUIT AND WHICH IS FOLLOWED BY A BUFFER OR DOUBLER STAGE IN WHICH A TYPE 10 TUBE IS EMPLOYED. THE POWER AMPLIFIER CONTAINS TWO TUBES CONNECTED IN PUSH-PULL AND WHICH MAY BE OF THE TYPE 800, 825, 830 OR RK18 TRANSMITTER TUBES. EACH OF THESE FOUR TUBE TYPES HAS A POWER OUTPUT RATING OF 50 WATTS AND THEREFORE AN ARRANGEMENT AS THIS WILL PROVIDE A TRANSMITTER OF HIGHER POWER OUTPUT THAN WILL THE CIRCUIT OF FIG. 7.

WHEN THE TRANSMITTER OF FIG. 8 IS OPERATED "STRAIGHT", ALL TUNING

CIRCUITS ARE TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY BUT WHEN "DOUBLING", THE PLATE CIRCUIT OF THE OSCILLATOR, DOUBLER TUBE AND FINAL AMPLIFIER STAGE ARE ALL TUNED TO THE SECOND HARMONIC OF THE CRYSTAL FREQUENCY.

IN FIG. 9 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A TRANSMITTER IN WHICH A 47 TUBE IS USED IN THE CRYSTAL CONTROLLED OSCILLATOR CIRCUIT, A 50 WATT 800, 825, 830 OR RK18 IN THE BUFFER OR DOUBLER STAGE AND A 100 WATT 860 TUBE IN THE FINAL STAGE. THIS TRANSMITTER CAN BE OPERATED ON THREE DIFFERENT FREQUENCIES AND USING BUT A SINGLE CRYSTAL BY CARRYING OUT THE FOLLOWING PLAN:

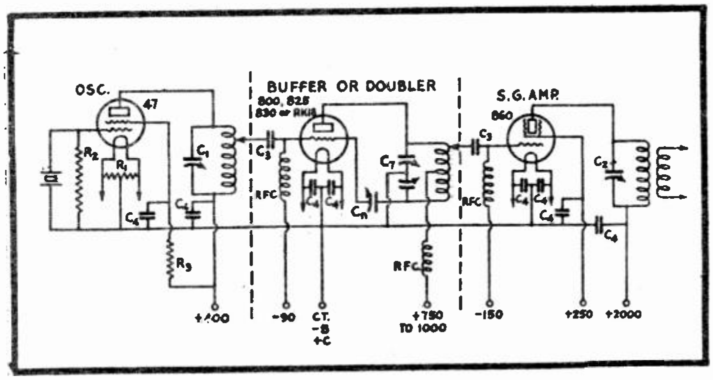

FIG. 9
Application of Screen Grid Tube as Final Amplifier.

WHEN OPERATED STRAIGHT, ALL TUNING CIRCUITS ARE TUNED TO THE FREQUENCY OF THE CRYSTAL. FOR THE SECOND BAND, THE FIRST AMPLIFIER STAGE CAN BE OPERATED AS A DOUBLER BY BEING TUNED TO THE SECOND HARMONIC AND IN WHICH CASE THE FINAL STAGE WOULD ALSO BE TUNED TO THE SECOND HARMONIC. FOR OPERATING ON THE THIRD BAND, THE FINAL AMPLIFIER STAGE IS ALSO OPERATED AS A DOUBLER SO THAT IT WILL AMPLIFY THE SECOND HARMONIC AS APPLIED TO ITS INPUT CIRCUIT FROM THE PRECEDING DOUBLER STAGE.

THE VALUES FOR THE DIFFERENT PARTS WHICH ARE USED IN THE CIRCUITS ILLUSTRATED IN FIGS. 7, 8 AND 9 ARE LISTED FOR YOU IN TABLE I.

TABLE I

C_1 = .00025 MFD. VARIABLE CONDENSER
C_2 = .0001 MFD. VARIABLE CONDENSER
C_3 = .0001 MFD. FIXED MICA CONDENSER
C_4 = .002 MFD. FIXED MICA CONDENSER
C_5 = .00005 MFD. FIXED MICA CONDENSER
C_6 = .00035 MFD. VARIABLE CONDENSER
C_7 = .0001 MFD. SPLIT-STATOR CONDENSER (BOTH SECTIONS IN SERIES).
C_n = NEUTRALIZING CONDENSER WHOSE CAPACITY AT MID-POSITION IS APPROXIMATELY EQUAL TO THE GRID-PLATE CAPACITY OF THE TUBE WITH WHICH IT IS BEING USED.
R_1 = 20 OHMS, CENTER-TAPPED.
R_2 = 10,000 OHMS
R_3 = 50,000 OHMS
R_4 = 100,000 OHMS
R_5 = 5000 OHMS.

DETAILED SPECIFICATIONS REGARDING THE TUNED COILS APPEAR IN A LATER LESSON.

DUMMY ANTENNAS

While preliminary adjustments are being made on a transmitter, it is advisable to use a DUMMY ANTENNA instead of the regular radiating antenna. In this way, the transmitter will not produce any interference while it is being adjusted.

A variety of dummy antenna circuits are available and in Fig. 10 you are shown three of them. For instance, at "A" of Fig. 10 you are shown a dummy antenna circuit which consists of the coil L and the variable condenser C which are connected in series with a resistor and a radio frequency ammeter. This constitutes a tuning circuit and whose constants are so chosen that this circuit can be tuned to the same frequency as furnished by the output of the transmitter. Therefore, if this dummy antenna circuit is coupled to the output tank circuit of the transmitter, it will

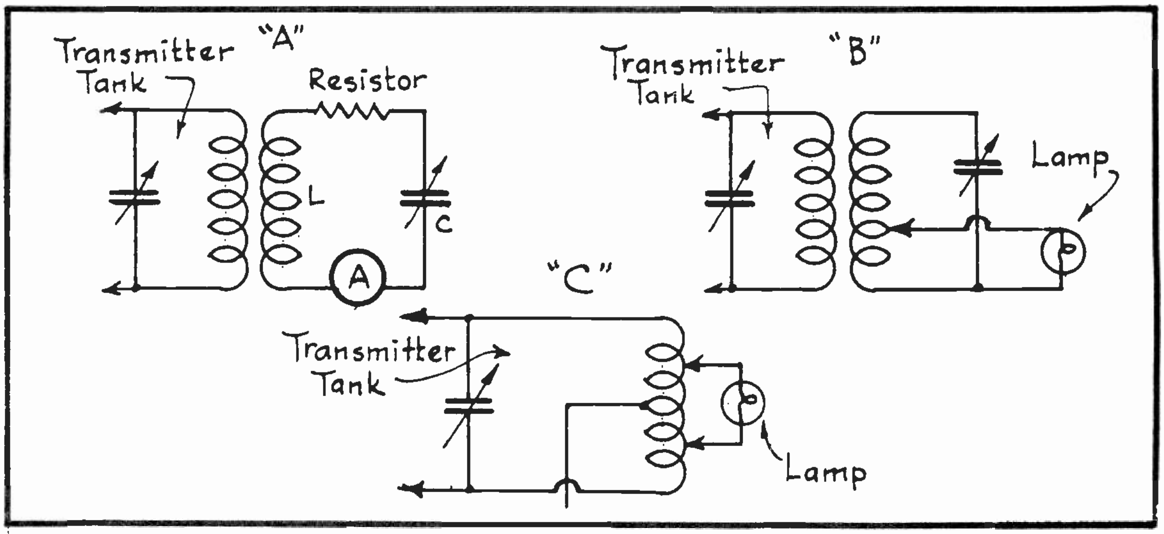

FIG. 10
Typical Dummy Antenna Circuits.

serve as a load in which the output energy of the transmitter can be dissipated just as though a regular antenna were used only that no appreciable radiation of this energy will occur. The value of this resistor is so chosen that the power which is dissipated by it is approximately equivalent to the output power of the transmitter in question.

If the resistor thus used is of the non-inductive type and its resistance value known, then by observing the current flow indicated by the radio frequency ammeter, the approximate power output can be determined by applying the formula $W = I^2R$. However, at high frequencies, the skin-effect becomes a most noticeable factor and for this reason the output power when measured in this manner is not altogether accurate.

Incandescent lamps are also used considerably in dummy antenna systems, and illustrations "B" and "C" of Fig. 10 illustrate this method. When using lamps in this manner, a lamp should be chosen whose watt rating is approximately the same as the power output of the transmitter, for in this way the lamp will be permitted to operate at about its normal brilliancy when the system is in operation.

A PAIR OF LEADS ARE USED WITH WHICH TO CONNECT THE LAMP EITHER TO THE TUNED ABSORPTION CIRCUIT AS AT "B" OF FIG. 10 OR DIRECTLY TO THE TRANSMITTER TANK AS AT "C". THE NUMBER OF COIL TURNS ACROSS WHICH THE LAMP IS TO BE CONNECTED SHOULD BE VARIED, AS SHOULD ALSO THE TUNING OF THE DUMMY ANTENNA CIRCUIT AND ITS COUPLING WITH THE TRANSMITTER, UNTIL THE GREATEST OUTPUT IS OBTAINED FOR A GIVEN PLATE INPUT. THIS GREATEST OUTPUT IS INDICATED BY THE MAXIMUM BRILLIANCE AT WHICH THE LAMP LIGHTS.

IN THE NEXT LESSON, YOU ARE GOING TO BE TOLD ABOUT THE DIFFERENT TYPES OF ANTENNA SYSTEMS WHICH ARE BEING USED IN CONJUNCTION WITH MODERN TRANSMITTERS. YOU WILL ALSO HAVE THE OPPORTUNITY AT THIS TIME OF BECOMING ACQUAINTED WITH THE FORMULAS FOR DESIGNING SUCH ANTENNA SYSTEMS, THE VARIOUS METHODS OF COUPLING THE ANTENNA SYSTEMS TO TRANSMITTERS AND THE CORRECT PROCEDURE FOR ADJUSTING THESE CIRCUITS SO THAT THE MAXIMUM SIGNAL ENERGY AS SUPPLIED AT THE OUTPUT OF THE TRANSMITTER CAN BE RADIATED INTO SPACE.

NO DOUBT YOU REALIZE BY THIS TIME THAT THE SAME SYSTEMATIC METHOD IS BEING EMPLOYED IN PRESENTING THE SUBJECT OF TRANSMITTERS TO YOU AS HAS BEEN USED THROUGHOUT THE ENTIRE PERIOD OF YOUR TRAINING UP TO THE PRESENT TIME. THIS PREVENTS EVEN THE SLIGHTEST DETAILS FROM PASSING YOU BY UNOTICED AND MAKES YOUR STUDIES MOST COMPLETE AS WELL AS UNDERSTANDABLE.

BY ACQUIRING A THOROUGH KNOWLEDGE OF ALL THE BASIC TRANSMITTER SYSTEMS AS THEY ARE NOW BEING BROUGHT TO YOU, YOU WILL FIND THE MORE COMPLEX TRANSMITTER CIRCUITS AS INCLUDED IN THE MORE ADVANCED LESSONS OF THIS SERIES TO BE READILY MASTERED. ALSO REMEMBER THAT EVEN THOUGH NOTHING AS YET HAS BEEN MENTIONED REGARDING RADIO-TELEPHONE OR BROADCAST TRANSMITTERS, YET ALL OF THE INFORMATION WHICH IS BEING GIVEN YOU NOW APPLIES EQUALLY WELL TO EVERY TYPE OF TRANSMITTER IN USE.

Examination Questions

Ans Jan 21, 1942

LESSON NO. T - 8

Every man who believes in himself, no matter who he be, stands on a higher level than the wobbler.

1. – Explain in detail how you would proceed to tune an R.F. amplifier stage of a transmitter.

2. – Make a diagram which illustrates how you can determine by means of a D.C. milliammeter the degree of exitation which is being delivered to the grid circuit of an R.F. amplifier in a transmitter.

3. – Describe the different methods whereby the coupling between the different stages of a transmitter may be varied.

4. – Why is it so important that the plate tank circuit of an amplifier in a transmitter be tuned approximately to resonance before applying the plate voltage to the tube which is used in this stage?

5. – What is a frequency multiplier or harmonic generator as used in transmitters?

6. – Explain in detail how you would proceed to tune a frequency-doubler stage in a transmitter, assuming that the input frequency for this same stage is 4000 Kc.

7. – Describe the different methods which may be used to furnish the grid bias voltage for the R.F. amplifier tubes of a transmitter.

8. – What are the essential differences in the design of a straight R.F. amplifier and a frequency multiplier?

9. – Draw a diagram of a "Tri-tet" circuit and explain how it operates and also how you would adjust it so that its output frequency will be twice the frequency for which the crystal is ground.

10. – Draw a circuit diagram of a practical dummy antenna; explain the reason for its use and also the method of using it in actual practice.

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Transmitters

LESSON NO. 9

TRANSMITTING ANTENNAS

THE ANTENNA IS A MOST IMPORTANT PART OF THE TRANSMITTING EQUIPMENT AND MUST BE CORRECTLY DESIGNED AND CONSTRUCTED IN ORDER FOR THE TRANSMITTER TO PERFORM AT ITS BEST. IT IS THEREFORE ESSENTIAL THAT YOU BE THOROUGHLY INFORMED OF ALL THE DIFFERENT ANTENNA SYSTEMS OF STANDARD DESIGN WHICH ARE USED IN PRACTICE AND THE METHOD OF CORRECTLY ADJUSTING THEM FOR MAXIMUM EFFICIENCY.

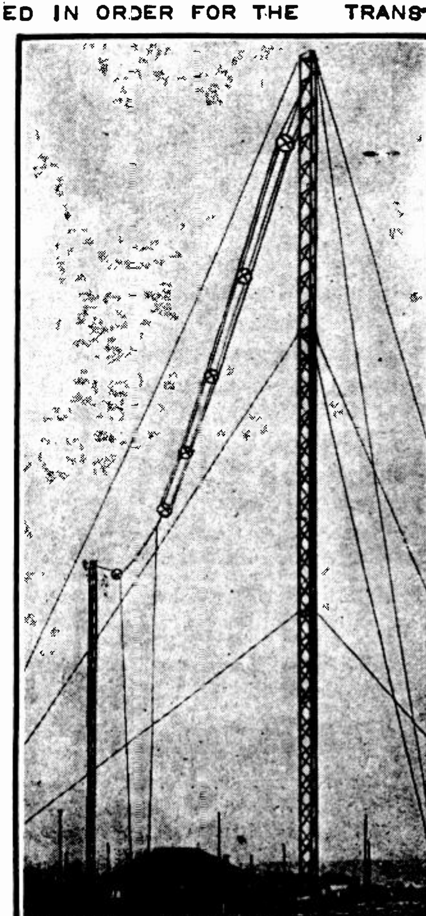

FIG. 1
Antenna of a High-Power Short-Wave Station.

THERE ARE TWO BASIC TYPES OF ANTENNAS WHICH ARE USED WITH TRANSMITTERS AND THEY ARE KNOWN AS THE MARCONI ANTENNA AND THE HERTZ ANTENNA. THOSE ANTENNAS WHICH EMPLOY THE GROUND AS A PART OF THE SYSTEM ARE CLASSIFIED AS MARCONI ANTENNAS, WHEREAS THOSE ANTENNAS WHICH OPERATE ENTIRELY INDEPENDENTLY OF THE GROUND ARE CLASSIFIED AS HERTZ ANTENNAS.

MARCONI ANTENNA SYSTEMS

IN FIG. 2 YOU ARE SHOWN THE THREE FUNDAMENTAL FORMS IN WHICH THE MARCONI ANTENNA SYSTEMS ARE CONSTRUCTED. AT THE LEFT OF FIG. 2, FOR INSTANCE, YOU ARE SHOWN THE VERTICAL TYPE MARCONI ANTENNA AND IN WHICH CASE THE RADIATING PORTION OF THE ANTENNA WIRE IS SUSPENDED VERTICALLY — ONE OF ITS ENDS BEING INSULATED AND THE OTHER END BEING GROUNDED THROUGH THE ANTENNA CIRCUIT OF THE TRANSMITTER. AN INVERTED "L" TRANSMITTER ANTENNA APPEARS AT THE CENTER OF FIG. 2 AND THIS SYSTEM YOU WILL READILY OBSERVE IS THE SAME AS THE RECEIVING TYPE INVERTED "L",

ONLY THAT THE TRANSMITTER IS INSERTED IN THE FEEDER-WIRE RATHER THAN THE RECEIVER. FINALLY AT THE RIGHT OF FIG. 2 YOU WILL SEE AN INVERTED "L" ANTENNA WITH WHICH A COUNTERPOISE IS USED INSTEAD OF THE GROUND CONNECTION AND IN THIS CASE THE TRANSMITTER IS CONNECTED TO THE FEEDER BETWEEN THE HORIZONTAL OR FLAT-TOP PORTION OF THE ANTENNA AND THE COUNTERPOISE. IN ADDITION TO THESE BASIC DESIGNS OF THE MARCONI SYSTEM, YOU WILL ALSO FIND MODIFICATIONS USED SUCH AS THE "T" TYPE ANTENNA ETC. BUT WHICH HAVE THE SAME GENERAL APPEARANCE AS ANTENNAS OF CORRESPONDING DESIGN AS USED WITH RECEIVERS AND WHICH WERE ALREADY DESCRIBED TO YOU IN PREVIOUS LESSONS. IT IS EQUALLY TRUE THAT INSTEAD OF USING ONLY A SINGLE FLAT-TOP CONDUCTOR, YOU WILL ALSO FIND CASES WHERE SEVERAL SUCH WIRES ARE RUN PARALLEL TO EACHOTHER AND TOGETHER CONNECTED TO THE FEEDER OF THE SYSTEM.

HERTZ ANTENNA SYSTEMS

IN FIG. 3 YOU ARE SHOWN THREE FUNDAMENTAL FORMS OF HERTZ ANTENNAS

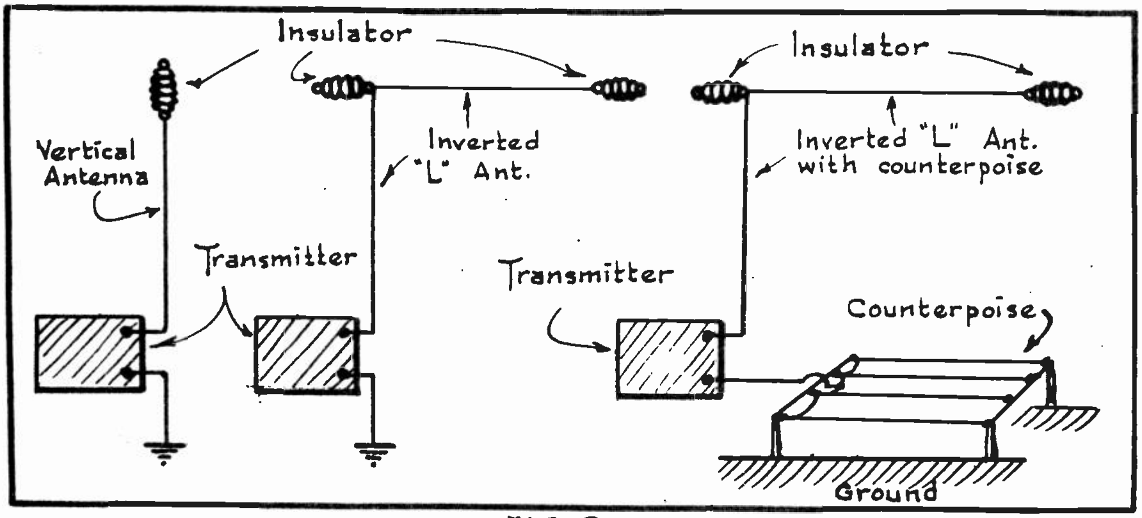

FIG. 2

Three Fundamental Forms of Marconi Type Antennas.

WHICH ARE COMMONLY USED. FOR EXAMPLE, AT THE LEFT OF FIG. 3 WE AGAIN HAVE THE VERTICAL ANTENNA ONLY THAT IN THIS CASE IT IS COMPLETELY INSULATED FROM GROUND AND THE TRANSMITTER FEEDS INTO THE SYSTEM AS HERE SHOWN. AT THE CENTER OF FIG. 3 ONE FORM OF HORIZONTAL ANTENNA IS SHOWN AND WITH WHICH NO GROUND CONNECTION IS USED. THE UNGROUNDED ANTENNA AT THE RIGHT OF FIG. 3 IS ALSO OF THE HORIZONTAL TYPE AND IN GENERAL APPEARANCE RESEMBLES THE DOUBLET ANTENNA AS USED WITH SHORT-WAVE RECEIVERS.

YOU WILL ALSO FIND VARIOUS MODIFICATIONS USED AS REGARDS THE HERTZ ANTENNA SYSTEMS BUT BY HAVING THESE FUNDAMENTAL PRINCIPLES IN MIND, YOU ARE NOW PREPARED TO ENTER A MORE DETAILED STUDY OF THESE DIFFERENT SYSTEMS. OUR FIRST STEP IN THIS DIRECTION WILL BE TO INVESTIGATE THE THEORY OF RADIATION A LITTLE MORE THOROUGHLY.

RADIATION

TRANSMITTING ANTENNA SYSTEMS FORM AN OSCILLATORY CIRCUIT IN THE SAME MANNER AS HAS ALREADY BEEN PREVIOUSLY EXPLAINED RELATIVE TO RECEIVER ANTENNAS AND THEREFORE BY PROPERLY COUPLING THE ANTENNA SYSTEM TO THE

OUTPUT OF A TRANSMITTER, THE HIGH FREQUENCY ENERGY WHICH IS GENERATED AND AMPLIFIED BY THE TRANSMITTER CAN CAUSE CURRENTS OF RADIO FREQUENCY TO FLOW IN THE ANTENNA CIRCUIT.

FROM YOUR PREVIOUS STUDIES, YOU WILL RECALL THAT WHENEVER AN ELECTRIC CURRENT FLOWS THROUGH A CONDUCTOR, ELECTROMAGNETIC LINES OF FORCE WILL ENCIRCLE THE CONDUCTOR AND THIS IS ALSO THE CASE IN OUR ANTENNA SYSTEM AS ILLUSTRATED AT THE LEFT OF FIG.4. THEN SINCE THIS ANTENNA CURRENT IS CHANGING ITS DIRECTION OF FLOW AT A VERY HIGH FREQUENCY, THE RESULTING MAGNETIC FIELD WILL BUILD UP AND COLLAPSE AT A TREMENDOUS SPEED.

WHENEVER A CONDUCTOR IS CARRYING A CURRENT AT A RATHER LOW FREQUENCY SUCH AS A 60 CYCLE CURRENT, FOR EXAMPLE, THEN ALL OF THE ENERGY WHICH IS STORED IN THE MAGNETIC FIELD AROUND THE CONDUCTOR IS RETURNED TO THE CONDUCTOR AS THE FIELD COLLAPSES. HOWEVER, WHEN A CONDUCTOR IS CARRYING A CURRENT OF VERY HIGH FREQUENCY THEN THIS CONDITION IS NO LONGER TRUE FOR UNDER SUCH CIRCUMSTANCES NOT ALL OF THE ENERGY STORED IN THE MAGNETIC FIELD IS RETURNED TO THE CONDUCTOR. INSTEAD, SOME OF IT ESCAPES IN THE

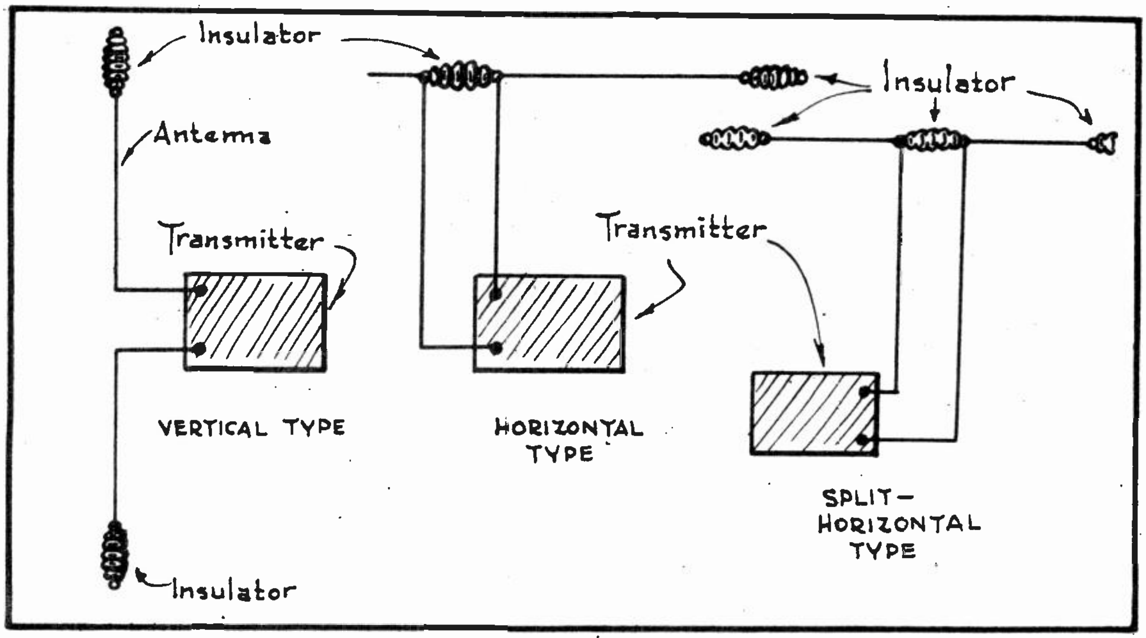

FIG. 3
Three Fundamental Types of Hertz Antenna.

FORM OF MAGNETIC WAVES AND WE THEN SAY THAT ENERGY HAS BEEN "RADIATED".

IN ADDITION TO THE FORMATION OF ELECTROMAGNETIC LINES OF FORCE AROUND AN ANTENNA SYSTEM, IT IS EQUALLY TRUE THAT ELECTROSTATIC LINES OF FORCE ARE ALSO PRODUCED AS ILLUSTRATED AT THE RIGHT OF FIG.4. THIS CAN BE BETTER VISUALIZED BY CONSIDERING THE HORIZONTAL FLAT-TOP AS ONE PLATE OF A CONDENSER AND THE GROUND AS THE OTHER PLATE. THE AIR SPACE BETWEEN THEM SERVES AS THE DIELECTRIC OF THE CONDENSER. BY CONSIDERING THIS ARRANGEMENT IN THIS MANNER, IT CAN READILY BE SEEN THAT THE HIGH FREQUENCY VOLTAGE OUTPUT OF THE TRANSMITTER WILL CONTINUALLY MAINTAIN A POTENTIAL DIFFERENCE BETWEEN THE AERIAL AND GROUND. THAT IS, SOMETIMES THE VOLTAGE OF THE AERIAL WILL BE GREATER THAN THAT OF GROUND AND SOMETIMES IT WILL BE LESS. IN EFFECT, WE HAVE A CONDENSER WHICH IS BEING

CHARGED FIRST IN ONE DIRECTION AND THEN IN ANOTHER.

WHENEVER A CONDENSER IS CHARGED, ELECTROSTATIC LINES OF FORCE WILL EXTEND THROUGH THE DIELECTRIC FROM ONE PLATE TO THE OTHER AND THUS FORM AN ELECTROSTIC FIELD. IN THIS SAME MANNER, AN ELECTROSTATIC FIELD IS PRODUCED IN THE ANTENNA SYSTEM AS PICTURED AT THE RIGHT OF FIG.4 AND IT IS CONTINUALLY VARYING IN INTENSITY AND POLARITY IN ACCORDANCE WITH THE RADIO FREQUENCY ENERGY WHICH IS FED TO THE ANTENNA FROM THE TRANSMITTER. THUS YOU WILL NOW SEE THAT BOTH AN ELECTROMAGNETIC FIELD AND AN ELECTROSTATIC FIELD ARE ESTABLISHED AROUND THE ANTENNA. IT IS CUSTOMARY TO SPEAK OF THE ELECTROMAGNETIC FIELD SIMPLY AS THE "MAGNETIC FIELD" AND THE ELECTROSTATIC FIELD AS THE "ELECTRIC FIELD". THESE TWO FIELDS TOGETHER CONSTITUTE THE ELECTROMAGNETIC WAVES.

VOLTAGE AND CURRENT DISTRIBUTION OF ANTENNAS

AN ANTENNA WHICH HAS NO "LUMPED" INDUCTANCE OR CAPACITY BUT DEPENDS

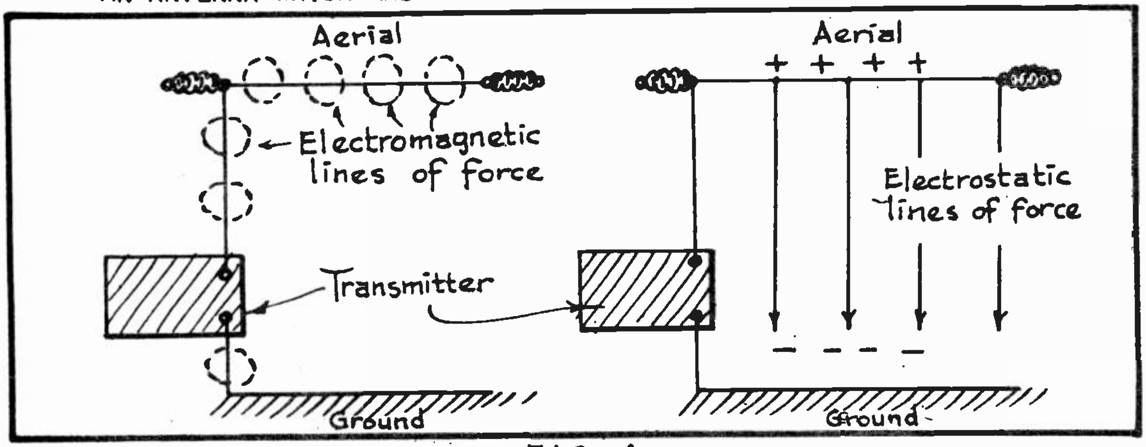

FIG. 4

Establishing Electromagnetic and Electrostatic Fields.

RATHER ON ITS DISTRIBUTED INDUCTANCE AND CAPACITY IS GENERALLY SPOKEN OF AS A "LINEAR OSCILLATORY CIRCUIT". A PECULIARITY OF SUCH A LINEAR CIRCUIT IS THAT WHEN IT IS EXITED AT ITS RESONANT FREQUENCY, THE CURRENT OR VOLTAGE AS MEASURED THROUGHOUT ITS LENGTH WILL HAVE DIFFERENT VALUES AT DIFFERENT POINTS. FOR EXAMPLE, IF THE WIRE HAPPENS TO BE SUSPENDED IN FREE SPACE BETWEEN INSULATORS AND WITH BOTH ENDS OPEN CIRCUITED AS IN THE HERTZ, THEN WHEN IT IS EXITED AT ITS RESONANT FREQUENCY, THE CURRENT WILL BE MAXIMUM AT THE CENTER AND ZERO AT THE ENDS AS ILLUSTRATED BY THE CURRENT CURVE IN FIG.5. IT IS ALSO OF INTEREST TO NOTE AT THIS TIME THAT AN ANTENNA OF THIS TYPE HAS A NATURAL TENDENCY TO RADIATE WAVES WHOSE WAVELENGTH IS EQUAL TO TWICE THAT OF THE LENGTH OF THE ANTENNA AND THE ANTENNA IS THEREFORE LOGICALLY NAMED A "HALF-WAVE ANTENNA".

THE VOLTAGE DISTRIBUTION IN THIS SAME ANTENNA OF FIG.5 IS JUST OPPOSITE TO THAT OF THE CURRENT DISTRIBUTION. IN OTHER WORDS, THE VOLTAGE WILL BE MAXIMUM AT THE ENDS AND ZERO AT THE CENTER AS SHOWN BY THE VOLTAGE CURVE IN FIG. 5. THE POINTS AT WHICH THE CURRENT OR VOLTAGE REACHES A MAXIMUM VALUE ARE CALLED ANTI-NODES OR LOOPS WHEREAS THE POINTS OF ZERO CURRENT ARE CALLED NODES.

THE REASON WHY THE CURRENT AND VOLTAGE VALUES DISTRIBUTE THEMSELVES

ACCORDING TO FIG.5 IS DUE TO THE FACT THAT THE TRAVELLING WAVES ON THE WIRE ARE REFLECTED WHEN THEY REACH AN END. THE WAVES WHICH ARE REFLECTED FROM AN END ARE KNOWN AS THE REFLECTED WAVES, WHEREAS THOSE TRAVELLING TOWARDS THE SAME END ARE KNOWN AS THE INCIDENT WAVES. IT IS THUS OBVIOUS THAT AS SUCCEEDING WAVES TRAVEL TOWARDS THE SAME END OF THE WIRE, THE INCIDENT WAVES MEET THE REFLECTED WAVES AND DUE TO THIS MEETING, THE CURRENTS ADD UP AT THE CENTER AND THE VOLTAGES CANCEL OUT AT THE CENTER. AS THE OPERATION OF THE SYSTEM CONTINUES WITH ITS REPEATED REACTION BETWEEN THE INCIDENT AND REFLECTED WAVES, THE EFFECT OF A "STANDING WAVE" IS PRODUCED IN THE SYSTEM.

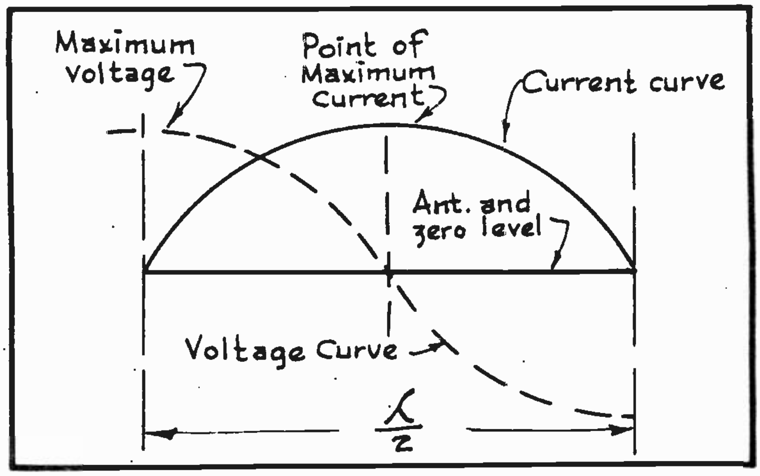

FIG. 5
Voltage and Current Distribution.

HARMONIC OPERATION OF ANTENNAS

THE VOLTAGE AND CURRENT DISTRIBUTION AS PICTURED IN FIG.5 ASSUMES THAT THE ANTENNA IS BEING OPERATED AT ITS FUNDAMENTAL FREQUENCY. HOWEVER, IT IS ALSO POSSIBLE FOR AN ANTENNA TO OPERATE AT HARMONICS OF THE FUNDAMENTAL. IN FIG.6, FOR EXAMPLE, WE HAVE THE SAME ANTENNA SYSTEM AS WAS USED RELATIVE TO FIG.5 ONLY THAT IT IS NOW BEING OPERATED AT ITS SECOND HARMONIC INSTEAD OF AT ITS FUNDAMENTAL. WE THUS FIND THAT WHILE THERE WAS ONLY ONE POINT OF MAXIMUM CURRENT WITH FUNDAMENTAL OPERATION, THERE ARE TWO SUCH POINTS WHEN OPERATING AT THE SECOND HARMONIC.

IN FIG.7 YOU ARE SHOWN THE CONDITIONS AS THEY EXIST WHEN OPERATING THE SAME ANTENNA AT THE THIRD HARMONIC. AT THIS TIME THERE ARE THREE POINTS OF MAXIMUM CURRENT. IT IS THUS CLEAR THAT THE NUMBER OF POINTS OF MAXIMUM CURRENT AND MAXIMUM VOLTAGE ARE IN ACCORDANCE WITH THE ORDER OF THE HARMONIC AT WHICH THE SYSTEM IS BEING OPERATED.

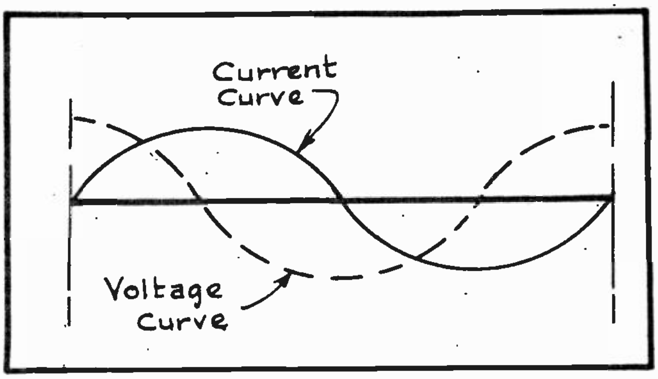

FIG. 6
Operation at Second Harmonic.

IT IS INTERESTING, AS WELL AS IMPORTANT, TO NOTE THAT A HERTZ ANTENNA MAY BE OPERATED AT THE FUNDAMENTAL FREQUENCY OR A HARMONIC FREQUENCY WHICH IS EITHER ODD OR EVEN. THE MARCONI ANTENNA, ON THE OTHER HAND, CAN BE OPERATED ONLY AT ITS FUNDAMENTAL OR HARMONICS THAT ARE ODD MULTIPLES OF THE FUNDAMENTAL FREQUENCY.

HAVING ADDED THIS AMOUNT

OF INFORMATION TO YOUR INCREASING KNOWLEDGE OF TRANSMITTER ANTENNAS, YOU ARE NOW PREPARED TO LEARN SOMETHING ABOUT "RADIATION RESISTANCE" AND THE PROCEDURE TO BE FOLLOWED IN THE DESIGN OF ANTENNA SYSTEMS.

RADIATION RESISTANCE

ALTHOUGH RADIATION WILL OCCUR FROM ANY CONDUCTOR THROUGH WHICH A HIGH-FREQUENCY CURRENT IS FLOWING, YET THE RADIATION IS GREATEST WHEN THE ANTENNA IS RESONATED TO THE FREQUENCY OF THE CURRENT. THE ENERGY WHICH IS ACTUALLY RADIATED BY AN ANTENNA IS EQUIVALENT TO THE ENERGY DISSIPATED WHEN CURRENT FLOWS THROUGH A RESISTANCE AND IN THE CASE OF ANTENNAS, THIS EQUIVALENT RESISTANCE IS KNOWN AS THE RADIATION RESISTANCE. IN REALLITY, THE RADIATION RESISTANCE IS A FICTITIOUS QUANTITY IN THAT IT IS EQUAL IN VALUE TO AN IMAGINARY RESISTANCE WHICH WHEN INSERTED IN SERIES WITH THE ANTENNA WILL CONSUME THE SAME AMOUNT OF POWER AS IS ACTUALLY RADIATED.

THE AVERAGE RADIATION RESISTANCE OF A HERTZ ANTENNA WHEN OPERATING AT ITS FUNDAMENTAL FREQUENCY IS APPROXIMATELY 70 OHMS AND FOR A MARCONI ANTENNA WHEN OPERATING AT ITS FUNDAMENTAL FREQUENCY IT IS APPROXIMATELY 35 OHMS.

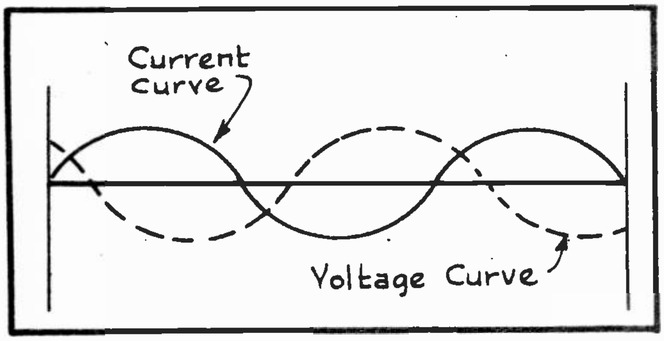

FIG. 7
Operation at Third Harmonic.

THE APPROXIMATE ANTENNA POWER IN WATTS CAN BE CALCULATED BY MULTIPLYING ITS ASSUMED RADIATION RESISTANCE EXPRESSED IN OHMS BY THE SQUARE OF THE MAXIMUM CURRENT (THAT IS, THE CURRENT AT THE CENTER OF A FUNDAMENTAL HERTZ ANTENNA AND THIS CURRENT VALUE SHOULD BE EXPRESSED IN AMPERES.)

SO MUCH FOR THE THEORY REGARDING ANTENNAS. NOW LET US PROCEED WITH THE CONSTRUCTIONAL DETAILS CONCERNING THESE SYSTEMS.

CALCULATING LENGTH OF HERTZ ANTENNAS

THEORETICALLY, THE NATURAL WAVELENGTH OF A FREELY SUSPENDED WIRE AS USED BY THE HERTZ SYSTEM IS EQUAL TO TWICE THE ACTUAL LENGTH OF THE WIRE. IN ACTUAL PRACTICE, HOWEVER, THE NATURAL WAVELENGTH OF THE WIRE WILL BE SOMEWHAT GREATER THAN ITS PHYSICAL LENGTH. THIS IS PRIMARILY DUE TO THE FACT THAT THE WIRE IS NOT ACTUALLY ISOLATED IN SPACE BUT IS IN PROXIMITY TO OTHER BODIES SUCH AS INSULATORS, ANTENNA MASTS, GUY WIRES ETC. AND ALL OF WHICH TEND TO INCREASE THE DISTRIBUTED CAPACITY TOGETHER WITH A RESULTING INCREASE IN THE WAVELENGTH OF THE SYSTEM.

FOR THE AVERAGE WELL CONSTRUCTED SYSTEM, THE NATURAL WAVELENGTH WILL BE BETWEEN 2.07 AND 2.1 TIMES THE PHYSICAL LENGTH OF THE WIRE. SOME HANDY FORMULAS FOR CALCULATING THE LENGTH OF THE RADIATING PORTION OF A HERTZ ANTENNA FOR ANY FREQUENCY DESIRED FOLLOW:

LENGTH IN FEET = 1.56 X DESIRED NATURAL WAVELENGTH EXPRESSED IN METERS.

LENGTH IN METERS = 0.475 X DESIRED NATURAL WAVELENGTH EXPRESSED IN METERS.

$$\text{LENGTH IN FEET} = \frac{468,000}{\text{FREQUENCY IN Kc.}}$$

$$\text{LENGTH IN METERS} = \frac{142,500}{\text{FREQUENCY IN Kc.}}$$

THE REQUIRED LENGTH OF WIRE REQUIRED SHOULD BE MEASURED ACCURATELY AND PREFERABLY WITH A GOOD STEEL TAPE, YARD STICK, OR METER STICK.

IT SHOULD ALSO BE REMEMBERED THAT THE HERTZ ANTENNA DOES NOT NECESSARILY HAVE TO BE CUT TO A LENGTH WHICH IS EQUAL TO HALF THE WAVELENGTH DESIRED. IT IS ALSO PERMISSIBLE TO HAVE THE ANTENNA LENGTH SO THAT IT WILL BE EQUAL TO A HALF WAVELENGTH MULTIPLIED BY ANY WHOLE NUMBER. HOWEVER, IT IS IMPORTANT TO NOTE THAT THE LENGTH OF THE ANTENNA ALWAYS MUST BE SUCH THAT IT WILL ACCOMMODATE A DEFINITE NUMBER OF HALF-WAVES. NO LESSER PORTION OF A WAVE SHOULD BE LEFT OVER.

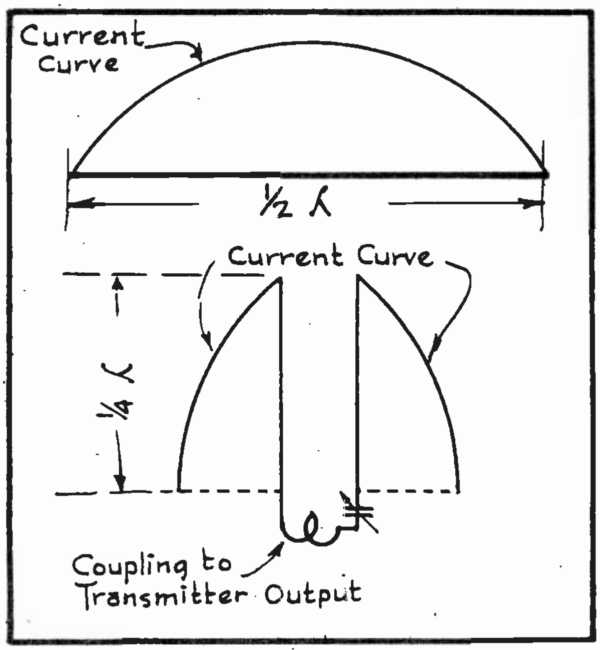

FIG. 8

A Quarter-Wave Feeder.

THE FACT THAT THE ANTENNA CAN BE MADE TO OPERATE AT HARMONICS OF ITS FUNDAMENTAL IS QUITE ADVANTAGEOUS IN THAT THIS FEATURE MAKES IT POSSIBLE TO EFFICIENTLY OPERATE A GIVEN TRANSMITTER AND ANTENNA COMBINATION AT MORE THAN ONE FREQUENCY.

FEEDERS FOR THE HERTZ ANTENNA

HAVING DETERMINED THE LENGTH OF ANTENNA WIRE WHICH IS TO BE SUSPENDED HORIZONTALLY IN SPACE, OUR NEXT PROBLEM WILL BE TO TRANSFER THE SIGNAL ENERGY FROM THE TRANSMITTER TO THE RADIATING PART OF THE ANTENNA AND FOR THIS PURPOSE, WE USE A SYSTEM OF WIRES WHICH ARE KNOWN AS FEEDERS OR TRANSMISSION LINES. TWO GENERAL TYPES OF TRANSMISSION LINES ARE USED IN CONJUNCTION WITH HERTZ TYPE ANTENNAS AND THEY ARE CLASSIFIED AS TUNED OR RESONANCE LINES AND AS UNTUNED OR APERIODIC LINES.

THE TUNED TYPE OF TRANSMISSION LINE SHALL BE EXPLAINED FIRST.

TUNED TRANSMISSION LINES

THE THEORY OF A TUNED TRANSMISSION LINE FOR A HALF-WAVE ANTENNA IS ILLUSTRATED IN FIG. 8. IN THE UPPER PORTION OF THIS ILLUSTRATION THE HALF-WAVE ANTENNA IS SHOWN TOGETHER WITH ITS CORRESPONDING CURRENT CURVE WHEN OPERATING AT THE FUNDAMENTAL. NOW IF WE SHOULD TAKE A SIMILAR WIRE

AND FOLD IT IN HALF SO THAT EACH HALF WOULD BE ¼ WAVE LENGTH LONG AS SHOWN IN THE LOWER ILLUSTRATION OF FIG. 8 WE WOULD HAVE A QUARTER-WAVE TRANSMISSION LINE. UNDER THESE CONDITIONS, THE CURRENTS FLOWING IN EACH SIDE OF THE TWO-WIRE LINE WILL OPPOSE EACHOTHER AND THEREBY RESULTING IN A CANCELLATION OF THE FIELDS AROUND THE WIRES. FOR THIS REASON THE TRANSMISSION LINE WILL TAKE NO PART IN RADIATION AND SERVES ONLY TO CARRY THE ENERGY FROM THE TRANSMITTER TO THE RADIATING PORTION OF THE ANTENNA.

THE COUPLING COIL AND VARIABLE CONDENSER, WHICH SERVE BOTH AS A MEANS FOR TUNING THE SYSTEM AS WELL AS COUPLING THE ANTENNA TO THE TRANSMITTER, ARE CONNECTED AT THE POINT WHERE THE HALF-WAVE WIRE HAS BEEN FOLDED. FURTHERMORE, SINCE THE TRANSMITTER ENERGY IS FED INTO THE TRANSMISSION LINE AT A POINT WHERE THE LINE HAS BEEN "FOLDED" AND WHICH CORRESPONDS TO THE POINT OF MAXIMUM CURRENT, THIS PARTICULAR LINE IS SAID TO BE CURRENT FED.

WHEN CURRENT FEEDING IS USED IN THIS MANNER, SERIES TUNING SHOULD BE USED FOR THE TRANSMISSION LINE AND THIS IS ILLUSTRATED IN FIG. 8 AND ALSO IN THE ILLUSTRATION AT THE LEFT OF FIG. 9. IT IS THE MORE COMMON PRACTICE TO EMPLOY TWO TUNING CONDENSERS IN THE SERIES ARRANGEMENT AS SHOWN IN FIG. 9. SERIES TUNING OF THE TRANSMISSION LINE HAS NO EFFECT ON THE CURRENT DISTRIBUTION IN THE SYSTEM.

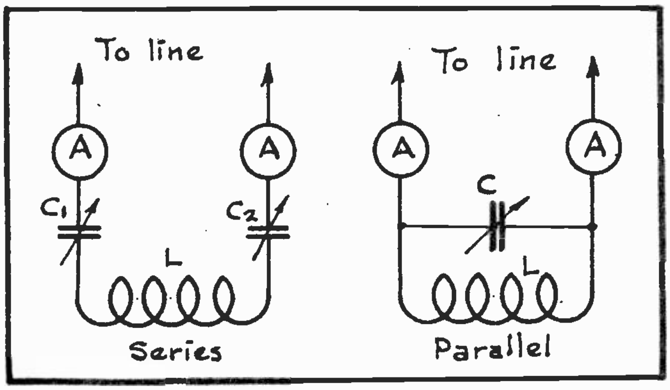

FIG. 9
Series and Parallel Feeder Tuning.

IN THE ANTENNA WHICH IS SHOWN IN THE UPPER PORTION OF FIG. 10 THREE HALF-WAVES ARE IMPOSED UPON IT AND UPON FOLDING THIS ANTENNA AT ITS MIDPOINT TO FORM A FEEDER OR TRANSMISSION LINE, WE HAVE AN ARRANGEMENT AS PICTURED IN THE LOWER SECTION OF FIG. 10. HERE WE FIND THAT UPON FOLDING THE WIRE AT ITS MIDPOINT, THE TWO OUTER HALF-WAVES ARE SIMPLY FOLDED BACK — ONE HALF-WAVE REMAINING FOR EACH OF THE FEEDER WIRES. THE THIRD HALF-WAVE WHICH APPEARS BETWEEN THE OUTER TWO AT THE TOP OF FIG. 10 IS REPLACED WITH A PARALLEL TUNING CIRCUIT WHICH IS TUNED TO THE FUNDAMENTAL OF ONE OF THESE HALF-WAVELENGTHS. THUS THE THREE HALF-WAVELENGTHS ARE STILL ACCOUNTED FOR IN THE TRANSMISSION LINE.

BY EMPLOYING THE PARALLEL TUNING CIRCUIT IN A TRANSMISSION LINE OF THIS TYPE, IT ACTS AS A PHASE REVERSER, THEREBY BRINGING THE CURRENTS IN THE TWO WIRES INTO PHASE-OPPOSITION SO THAT NO RADIATION CAN RESULT THRUOUT THE LENGTH OF THIS TRANSMISSION LINE. FROM A FURTHER STUDY OF THE TRANSMISSION LINE AS PICTURED IN THE LOWER SECTION OF FIG. 10, YOU WILL NOTICE THAT IF THE COIL OF THIS TUNING CIRCUIT IS COUPLED TO THE OUTPUT TANK OF A TRANSMITTER, THE R.F. ENERGY WILL BE FED INTO THE TRANSMISSION LINE AT A POINT OF ZERO CURRENT BUT WHICH AT THE SAME TIME CORRESPONDS TO A POINT OF MAXIMUM VOLTAGE AS YOU LEARNED FROM FIG. 5. CONDITIONS BEING SUCH, WE THEN SAY THAT HERE IS A CASE WHERE WE HAVE VOLTAGE FEED TO THE TRANSMISSION LINE.

A HANDY RULE TO REMEMBER IS THAT IN OPEN-ENDED TRANSMISSION LINES WHERE THE LENGTH OF EACH TRANSMISSION WIRE IS AN ODD NUMBER OF QUARTER-WAVES LONG, CURRENT FEED IS REQUIRED IN CONJUNCTION WITH SERIES TUNING. ON THE OTHER HAND, IF THE LENGTH OF EACH WIRE OF THE TRANSMISSION LINE IS AN EVEN NUMBER OF QUARTER-WAVES LONG, THEN VOLTAGE FEED TOGETHER WITH PARALLEL TUNING IS REQUIRED.

THE TWO WIRES OF THE TRANSMISSION LINE SHOULD BOTH BE EQUAL IN LENGTH AND SHOULD BE RUN PARALLEL TO EACHOTHER THROUGHOUT THEIR LENGTH AND WITH A SEPARATION OF 3" TO 12" BETWEEN THEM. IT IS ALSO DESIRABLE THAT THE LENGTH OF THE TRANSMISSION LINE BE AN EXACT MULTIPLE OF A QUARTER WAVELENGTH, HOWEVER, EVEN IF THIS ISN'T EXACT, THE TUNING CIRCUIT IN THE LINE OFFERS A MEANS OF LOADING THE FEEDERS SO AS TO COMPENSATE FOR DIFFERENCES BETWEEN A QUARTER WAVELENGTH AND THE ACTUAL LENGTH OF THE WIRES.

HAVING CONSIDERED THE METHOD OF COUPLING THE ANTENNA TRANSMISSION LINE TO THE TRANSMITTER, OUR NEXT STEP WILL BE TO CONNECT THE OTHER END OF THIS TRANSMISSION LINE TO THE ANTENNA.

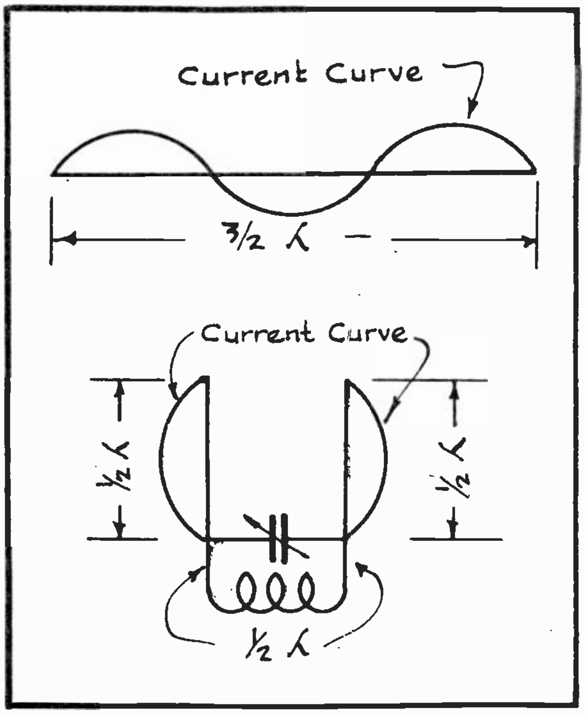

FIG. 10
Voltage-Feed Line.

THE ZEPPELIN ANTENNA

IN FIG. 11 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES OF ONE FORM OF HERTZ ANTENNA WHICH IS KNOWN AS A ZEPPELIN ANTENNA OR SIMPLY AS A "ZEPP" ANTENNA. THE CONSTRUCTIONAL DATA AS HERE FURNISHED WILL SET THE FUNDAMENTAL FREQUENCY OF THE ANTENNA AT 3550 KC. BUT WITH THE AID OF THE TUNING ARRANGEMENT WHICH IS ALSO PROVIDED, THIS SYSTEM CAN BE ADJUSTED FOR A FUNDAMENTAL FREQUENCY ANYWHERES BETWEEN 3500 AND 3600 KC. IN ADDITION THIS SAME ANTENNA CAN BE OPERATED AT ITS HARMONICS OF 7000 AND 14000 KC. AND IS THEREFORE SUITABLE FOR AMATEUR USE. THE TRANSMISSION LINE OF THIS ANTENNA IS BOTH SERIES TUNED AND PARALLEL TUNED — PARALLEL TUNING BEING MOST EFFECTIVE FOR 3500 KC. AND SERIES TUNING FOR THE 7000 AND 14,000 KC. BANDS. THE CONDENSERS C_1 AND C_2 MAY BE OF .00035 MFD. RATING. MORE DETAILS REGARDING THE ANTENNA-TRANSMITTER COUPLING METHODS ARE GIVEN IN A LATER LESSON.

SINCE THE ZEPPELIN ANTENNA IS OF THE HALF-WAVE TYPE, THERE IS ALWAYS A VOLTAGE LOOP AT ITS END AND SINCE THE TRANSMISSION LINE IS CONNECTED TO THE ANTENNA AT THIS POINT, THE ANTENNA IS SAID TO BE VOLTAGE FED. THE ANTENNA MAY BE ANY NUMBER OF HALF WAVES LONG AND THE LENGTH OF THE FEEDER IS USUALLY AN ODD MULTIPLE OF A QUARTER WAVELENGTH. SERIES TUNING IS RECOMMENDED WHEN THE FEEDERS HAVE A LENGTH BETWEEN ONE-QUARTER AND THREE-EIGHTS OF A WAVELENGTH WHEREAS FOR FEEDERS MUCH LESS THAN A QUARTER

WAVELENGTH LONG OR FOR LENGTHS FROM APPROXIMATELY THREE-EIGHTS UPTO ONE HALF WAVELENGTH, PARALLEL TUNING IS DESIRED.

A CENTER-FEED ANTENNA

THE ZEPPELIN ANTENNA, YOU WILL RECALL IS VOLTAGE FED, SO NOW LET US SEE HOW A "CURRENT FEED" ARRANGEMENT WOULD LOOK. ONE SUCH ARRANGEMENT IS ILLUSTRATED IN FIG. 12.

HERE THE ANTENNA IS ONE-HALF WAVELENGTH LONG AND THEREFORE THE CURRENT DISTRIBUTION WILL BE AS HERE SHOWN, THAT IS, WITH A CURRENT LOOP AT THE CENTER. THUS IF THIS ANTENNA IS TO BE CURRENT FED IT CAN BE CUT AT THE CENTER AND A FEEDER WIRE CONNECTED TO EACH OF THE RESULTING ANTENNA WIRES.

IN A SYSTEM OF THIS TYPE IT IS ALSO NECESSARY THAT THE LENGTH OF THE FEEDER WIRES BE SUCH THAT A CURRENT LOOP WILL ALSO OCCUR AT THEIR INPUT ENDS SO THAT THE PHASE RELATION THROUGHOUT THE SYSTEM MAY BE CORRECT. FOR THIS REASON, EACH WIRE OF THE FEEDER IS MADE ONE-HALF WAVELENGTH LONG. THIS ALSO PERMITS SERIES TUNING, WHEREAS IF THE FEEDERS SHOULD ONLY BE ONE-QUARTER WAVELENGTH LONG IT WOULD BE NECESSARY TO INSTALL A PHASE REVERSER IN THE FORM OF A PARALLEL TUNING CIRCUIT AT THEIR INPUT END.

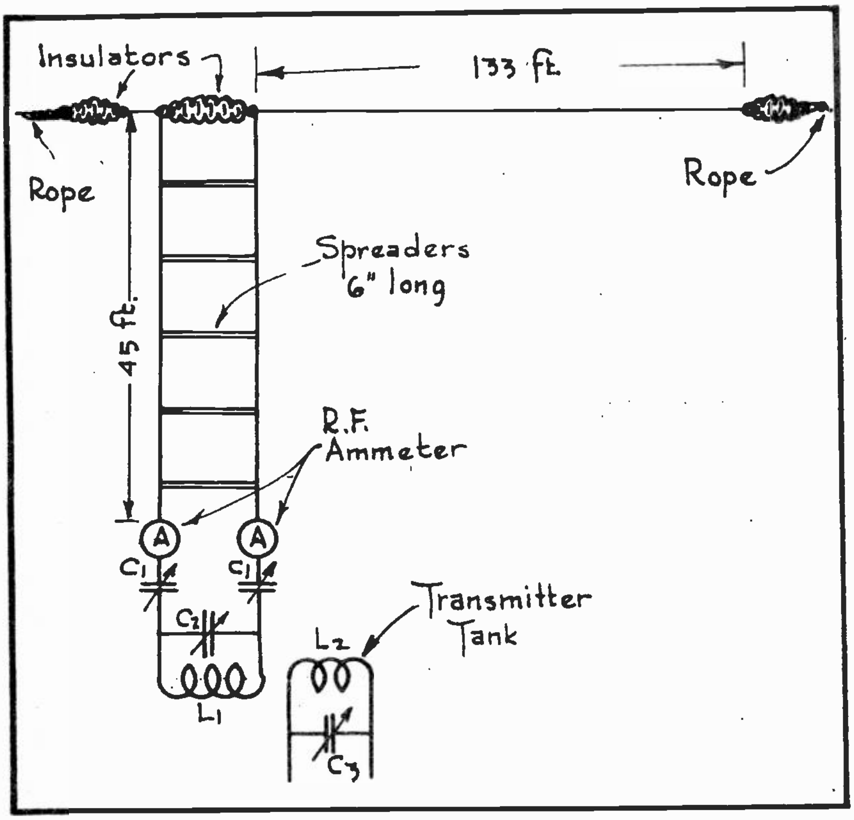

FIG. 13
The Zeppelin Antenna.

IN FIG. 13 YOU ARE SHOWN HOW THIS PRINCIPLE MAY BE EMPLOYED IN PRACTICE. THE PARTICULAR DESIGN HERE ILLUSTRATED IS INTENDED FOR AMATEUR USE AND HAS A FUNDAMENTAL FREQUENCY OF 7100 KC. IT MAY ALSO BE OPERATED AT ITS SECOND HARMONIC OR 14,200 KC. AND AT THE FOURTH HARMONIC OR 28,400 BOTH OF WHICH ARE IN AN AMATEUR BAND. A COMBINATION OF SERIES AND PARALLEL TUNING IS BEING USED IN THIS EXAMPLE, PARALLEL TUNING BEING EMPLOYED FOR THE 7100 KC. AND 28,400 KC. BANDS AND SERIES TUNING FOR THE 14,200 KC. BAND. IT MAY ALSO BE OPERATED ON THE 3500 KC. BAND WITH PARALLEL TUNING.

ALTHOUGH THE ANTENNA IN FIG. 13 IS A CENTER-FEED SYSTEM, YET THIS

DOES NOT NECESSARILY MEAN THAT IT IS CURRENT-FED. FOR INSTANCE, AT 7100 KC. WHERE THE ANTENNA IS A HALF-WAVE LONG, IT IS CURRENT FED BUT WHEN OPERATING AT 14,200 KC. AND HIGHER EVEN HARMONICS, IT IS VOLTAGE FED. IN THIS LATTER CASE THIS ANTENNA IN REALLITY BECOMES TWO ZEPPELIN ANTENNAS PLACED END TO END AND WHEN OPERATING AT 3500 KC., ONLY ONE HALF OF THE ANTENNA IS ACTUALLY USED.

TUNING THE ANTENNA SYSTEM

HAVING SO FAR CONSIDERED THE CONSTRUCTIONAL DETAILS OF TUNED TRANSMISSION LINES AS USED WITH ANTENNA SYSTEMS, OUR NEXT STEP WILL BE TO INVESTIGATE THE PROPER PROCEDURE OF TUNING THE ANTENNA WHEN PUTTING THE TRANSMITTER ON THE AIR. THE SYSTEMS ILLUSTRATED IN FIGS. 11 AND 12 SHALL BE USED AS AN EXAMPLE.

THE FIRST STEP IS TO PLACE THE TRANSMITTER IN OPERATION AND TO ADJUST IT THROUGHOUT FOR OPERATION AT THE DESIRED FREQUENCY. ASSUMING THAT SERIES TUNING IS TO BE EMPLOYED, SET THE ANTENNA'S PARALLEL TUNING CONDENSER AT ITS POSITION OF MINIMUM CAPACITY AND THE SERIES CONDENSERS AT THEIR POSITION OF MAXIMUM CAPACITY.

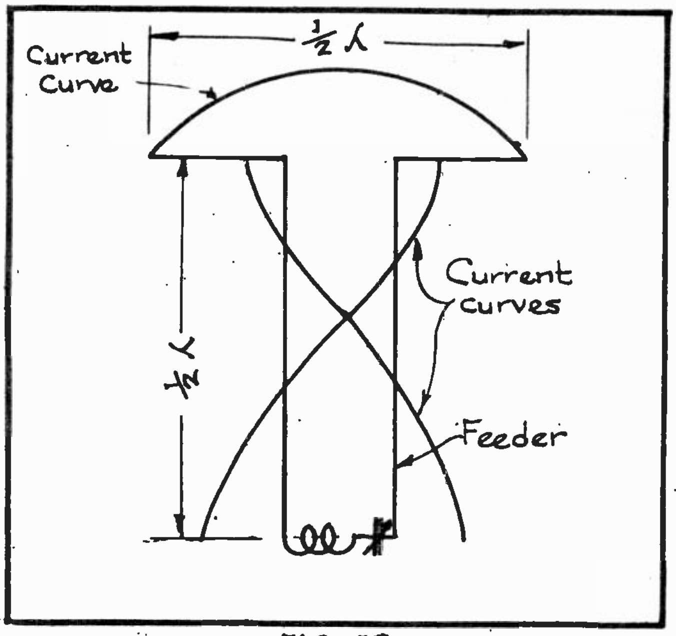

FIG. 12
A Current-Fed Antenna.

COUPLE THE ANTENNA COUPLING COIL TO THE TANK COIL IN THE OUTPUT CIRCUIT OF THE TRANSMITTER AND SIMULTANEOUSLY TURN BOTH SERIES CONDENSERS OUT OF MESH VERY SLOWLY, CAREFULLY WATCHING THE ANTENNA AMMETERS AS YOU DO SO. CONTINUE THIS ADJUSTMENT UNTIL THESE AMMETERS INDICATE MAXIMUM CURRENT AND AT WHICH TIME THE ANTENNA SYSTEM WILL BE TUNED TO RESONANCE WITH THE FREQUENCY FOR WHICH THE TRANSMITTER IS ADJUSTED. IF TWO POINTS OF MAXIMUM CURRENT ARE INDICATED BY THE AMMETERS, LOOSEN THE COUPLING SLIGHTLY BETWEEN THE ANTENNA COUPLING COIL AND THE TRANSMITTER TANK COIL.

IN THE EVENT THAT PARALLEL TUNING OF THE ANTENNA'S TRANSMISSION LINE IS BEING EMPLOYED, THEN SET THE SERIES TUNING CONDENSERS, AS WELL AS THE PARALLEL TUNING CONDENSER AT THEIR POSITION OF MAXIMUM CAPACITY. THEN SLOWLY DECREASE THE CAPACITY OF THE PARALLEL CONDENSER UNTIL THE ANTENNA AMMETERS OFFER A MAXIMUM READING.

AS AN ADDITIONAL CHECK WHEN TUNING THE ANTENNA, YOU WILL FIND THAT THE PLATE CURRENT OF THE FINAL TUBE WILL INCREASE AS THE ANTENNA CIRCUIT IS TUNED NEARER TO RESONANCE.

UNTUNED TRANSMISSION LINES

In addition to the tuned transmission lines as so far described, transmission lines of the untuned type are also used. The untuned line offers the advantage that no standing waves appear upon it and it can therefore be made any length. However, the design and construction of the untuned line is much more critical than is that of the tuned line.

The main thing to be taken into consideration with respect to the untuned transmission line is that if it is terminated in an impedance which is equal to the characteristic impedance of the line or to the "surge impedance" as it is sometimes called, then no reflection will occur and no standing waves will be present on the line. Under these conditions, the transmission line can be made any length, no radiation will occur from the transmission line and practically all of the R.F. power which is fed into the line will be delivered to the antenna.

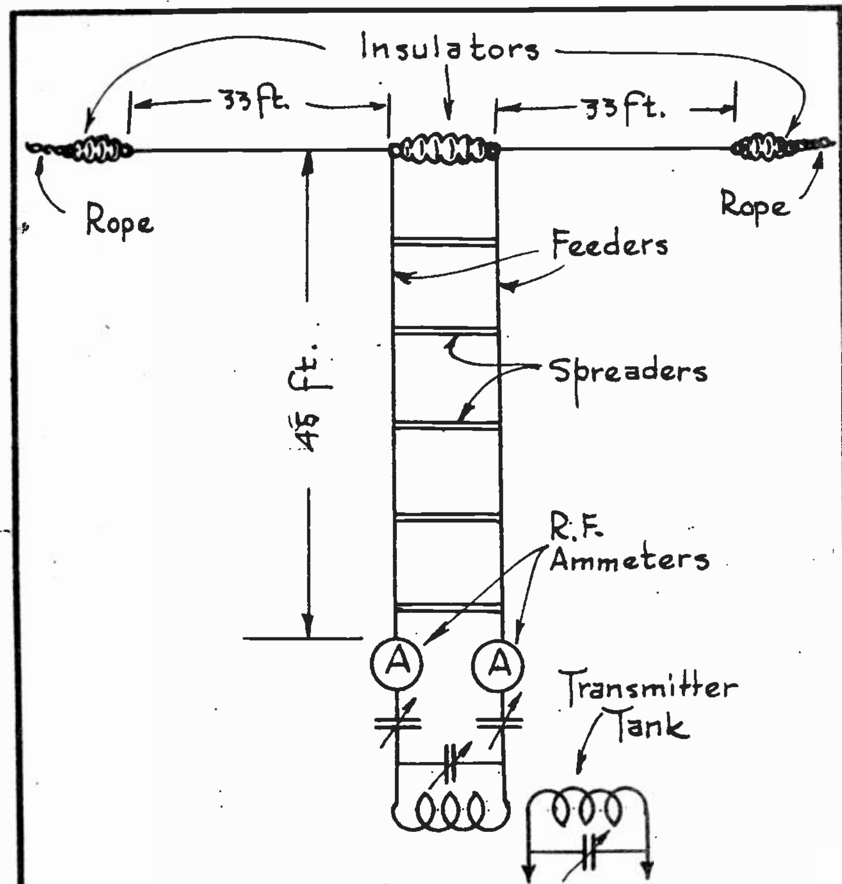

FIG. 13

A Typical Center-Feed Antenna System.

The surge or characteristic impedance of a two-wire transmission line is expressed by the following formula:

$$Z = 276 \log_{10} \frac{B}{A}$$

where Z = characteristic impedance; 276 is a constant; B = spacing between the wires in inches and A = the radius of the transmission line wire expressed in inches. A characteristic impedance of 600 ohms has through experiment been found to be most practical for this purpose.

In Fig. 14 you are shown how a 600 ohm untuned transmission line is used with a two-wire, matched-impedance antenna system. In this arrangement the transmission line itself may be of any length but the dimensions L-A-B and C are of utmost importance. Also observe in Fig. 14 that the transmission line spreads apart or is "fanned" at its upper end. This is done with the intention of having a gradually increasing impedance at

SPECIAL NOTICE

During the process of printing Transmitter Lesson #9 an omission occurred on page 13.

Following the formula $A(\text{meters}) = \frac{150.00}{F} \times K_1$ on this page the text here given was omitted:

In these formulas also, the frequency F is expressed in kilocycles and the value for K_1 is a constant which varies with the frequency in the following manner: For frequencies below 3000 Kc., $K_1 = 0.25$; for frequencies between 3000 and 28,000 Kc., $K_1 = 0.24$ and for frequencies above 28,000 Kc., $K_1 = 0.23$.

The dimension "B" of the antenna system is determined by applying either one of the following formulas:

$$B\ (\text{feet}) = \frac{147,600}{F \text{ in Kc.}}$$

$$B\ (\text{meters}) = \frac{45,000}{F \text{ in Kc.}}$$

THIS END OF THE LINE SO THAT ITS IMPEDANCE AT THE ANTENNA END WILL BE EQUAL TO THE IMPEDANCE OF SECTION "A" OF THE ANTENNA.

PROVIDED THAT THE CHARACTERISTIC IMPEDANCE OF THE TRANSMISSION LINE IS FIXED AT 600 OHMS, WE PROCEED TO WORK OUT THE DESIGN FOR THIS ANTENNA SYSTEM IN THE MANNER AS SHALL NOW BE EXPLAINED:

FIRST WE DETERMINE THE LENGTH OF THE ANTENNA BY APPLYING THE FOLLOWING FORMULA:

$$L\ (\text{FEET}) = \frac{492{,}000}{F} \times K \quad \text{OR} \quad L\ (\text{METERS}) = \frac{150{,}000}{F} \times K.$$

IN THIS FORMULA F = FUNDAMENTAL FREQUENCY OF THE ANTENNA SYSTEM EXPRESSED IN KILOCYCLES AND K IS A CONSTANT WHICH IS DEPENDENT UPON THE FREQUENCY IN THE FOLLOWING ORDER: FOR FREQUENCIES BELOW 3000 Kc., K = 0.96; FOR FREQUENCIES BETWEEN 3000 Kc. AND 28,000 Kc., K = 0.95 AND FOR FREQUENCIES ABOVE 28,000 Kc., K = 0.94.

THE NEXT STEP IS TO DETERMINE THE DIMENSION "A" OF FIG. 14 AND FOR THIS, EITHER OF THE FOLLOWING TWO FORMULAS CAN BE APPLIED:

$$A\ (\text{FEET}) = \frac{492{,}000}{F} \times K_1$$

$$A\ (\text{METERS}) = \frac{150{,}000}{F} \times K_1$$

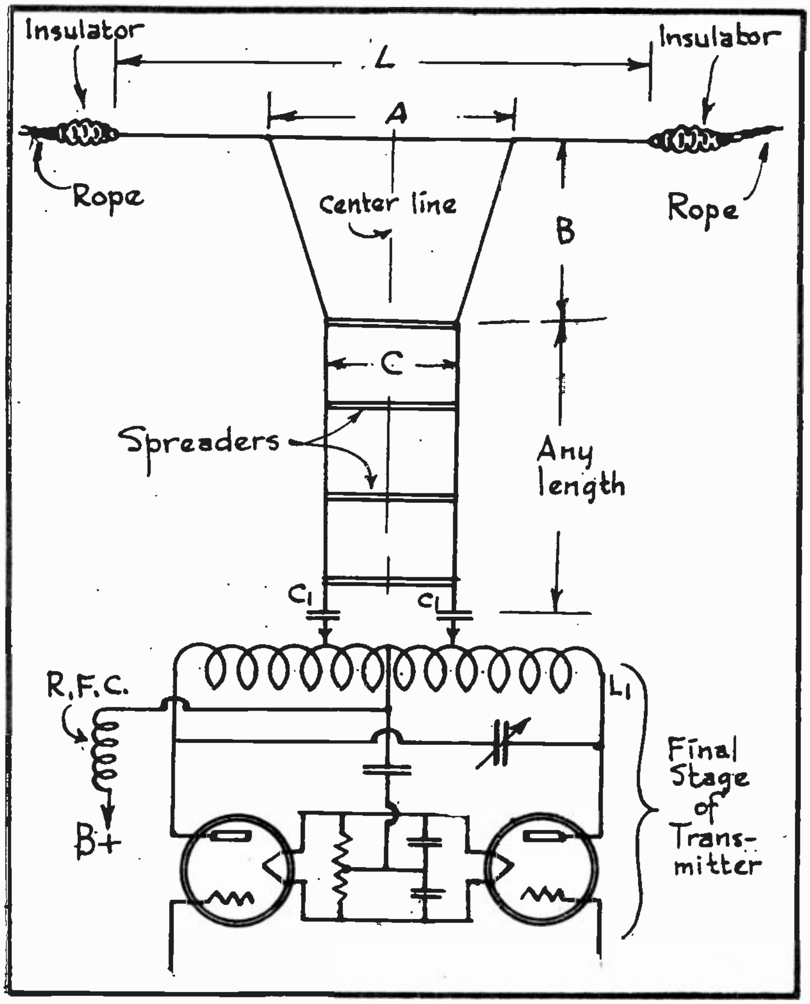

FIG. 14

Two-Wire Matched-Impedance Antenna.

THE FINAL STEP IS TO DETERMINE THE DIMENSION "C" OF THE SYSTEM, THAT IS, THE SPACING TO BE ALLOWED BETWEEN THE FEEDER WIRES AND FOR THIS WE USE THE FORMULA $C = 75 \times D$, WHERE C = THE DISTANCE BETWEEN THE WIRES; D = THE DIAMETER OF THE WIRE AND THE NUMBER 75 IS A CONSTANT. IF "D" IS EXPRESSED IN INCHES, THEN C WILL ALSO BE EXPRESSED IN INCHES, WHEREAS IF "D" IS EXPRESSED IN MILLIMETERS, THEN C WILL ALSO BE EXPRESSED IN MILLIMETERS. IN THIS SYSTEM, IT IS ESPECIALLY NECESSARY THAT THE SPACING BETWEEN THE TWO WIRES OF THE TRANSMISSION LINE

BE KEPT CONSTANT THROUGHOUT THEIR ENTIRE LENGTH AND THAT THEY ALSO BE KEPT TAUT. IT IS ALSO IMPORTANT THAT SECTION "B" OF THE LINE BE RUN STRAIGHT AWAY FROM THE ANTENNA AND THE TWO HALVES OF DIMENSION "A" SHOULD BE EQUIDISTANT FROM THE EXACT CENTER OF THE ANTENNA'S FLAT TOP.

FIG. 14 ALSO SHOWS YOU HOW THE UNTUNED TRANSMISSION LINE MAY BE COUPLED TO THE TRANSMITTER'S PLATE CIRCUIT TANK THROUGH THE FIXED CONDENSERS C_1. THESE TWO CONDENSERS C_1 MAY EACH HAVE A VALUE OF .002 MFD. AND THE TWO WIRES OF THE LINE SHOULD BE CLIPPED ON THE TRANSMITTER TANK COIL AN EQUAL NUMBER OF TURNS FROM EACH SIDE OF ITS CENTER. STARTING FROM THE CENTER OF THE COIL, THESE CLIPS CAN TOGETHER BE MOVED OUTWARD ONE TURN AT A TIME UNTIL THE TUBES ARE DRAWING THEIR NORMAL PLATE CURRENT.

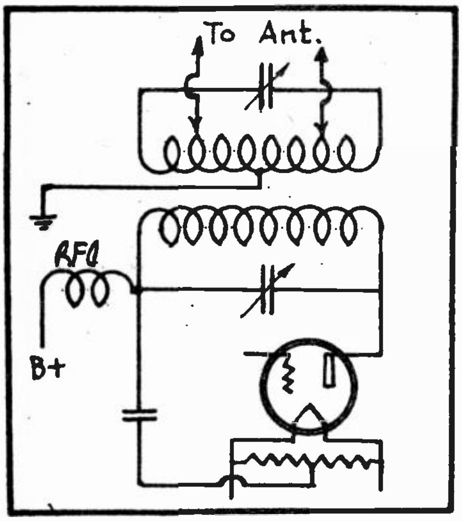

FIG. 15
Untuned line Coupled to Single-Tube Output.

IF ONLY A SINGLE TUBE IS USED IN THE FINAL STAGE OF THE TRANSMITTER, THEN IT CAN BE COUPLED TO THE TRANSMISSION LINE AS ILLUSTRATED IN FIG. 15.

SINGLE-WIRE FEED

IN FIG. 16 YOU ARE SHOWN A SINGLE-WIRE ANTENNA FEED AND IN WHICH CASE THE TRANSMISSION LINE CONSISTS OF ONLY A SINGLE WIRE INSTEAD OF TWO WIRES. IN A SYSTEM AS THIS, THE LENGTH OF THE ANTENNA IS DETERMINED AS ALREADY PREVIOUSLY DESCRIBED, THAT IS, BY EMPLOYING THE FORMULA $L(\text{FEET}) = \frac{492{,}000}{F} \times K$.

THE DIMENSION "D" OR THE DISTANCE FROM THE CENTER OF THE ANTENNA TO THE POINT AT WHICH THE FEEDER IS TAPPED TO IT IS FOUND BY MULTIPLYING THE LENGTH L BY 0.14.

IN AN ANTENNA OF THIS TYPE THE FEEDER MUST RUN AT RIGHT ANGLES TO THE ANTENNA FOR A DISTANCE WHICH IS AT LEAST EQUAL TO 1/3 THE LENGTH OF THE ANTENNA AND SHARP BENDS SHOULD BE AVOIDED IN THE FEEDER THROUGHOUT ITS LENGTH.

INVERTED "L" ANTENNA

TO DETERMINE THE LENGTH OF AN INVERTED "L" ANTENNA FOR A TRANSMITTER IS A RATHER SIMPLE PROCEDURE IN THAT THE NATURAL WAVELENGTH OF THIS TYPE OF ANTENNA IS APPROXIMATELY 4.2 TIMES ITS ACTUAL LENGTH. THE LENGTH CONSIDERED IN THIS CASE IS THE TOTAL LENGTH FROM THE OPEN END OF THE ANTENNA TO THE GROUND CONNECTION OR COUNTERPOISE. FOR EXAMPLE, IF THE FREQUENCY OF A TRANSMITTER IS 1250 KC. AND WHICH IS EQUIVALENT TO 240 METERS; THEN THE TOTAL LENGTH OF THE ANTENNA SYSTEM SHOULD BE $\frac{240}{4.2} = 57.14$ METERS. EXPRESSED IN FEET, THIS LENGTH IS EQUAL TO 57.14 x 3.28 = 187.42 FT. APPROXIMATELY.

SINCE IT IS CUSTOMARY TO INCLUDE A TUNING CIRCUIT IN SERIES WITH THIS TYPE OF ANTENNA AS ILLUSTRATED IN YOUR FIRST LESSON OF THE TRANSMITT-

ER SERIES, THE LENGTH OF THE TOTAL ANTENNA NEED NOT BE CALCULATED TO AN EXTREME ACCURACY. THIS TUNING CIRCUIT WILL PERMIT ANY NECESSARY ADJUSTMENT FOR TUNING THE ANTENNA CIRCUIT TO RESONANCE IN THE EVENT THAT THE LENGTH ITSELF DOES NOT RESONATE TO THE FREQUENCY.

SUGGESTIONS FOR CONSTRUCTION

ALL ANTENNA ERECTION JOBS SHOULD BE SO PLANNED THAT THE ELECTRICAL JOINTS IN THE SYSTEM WILL BE KEPT DOWN TO A MINIMUM. THE SAME PRECAUTIONS SHOULD BE EXERCISED IN SUSPENDING THE ANTENNA WIRE IN AS CLEAR A SPACE AS POSSIBLE AS HAVE ALREADY BEEN EXPLAINED RELATIVE TO RECEIVER TYPE ANTENNAS AND BOTH ENDS OF THE ANTENNA WIRE SHOULD BE ANCHORED IN SUCH A MANNER THAT IT WILL BE PREVENTED FROM SWAYING IN THE WIND. IN THIS CASE ALSO, A PULLEY AND WEIGHT ARRANGEMENT ARE FREQUENTLY USED TO TAKE UP ANY SLACK IN THE SYSTEM. A #12 B&S GAUGE HARD-DRAWN ENAMELLED COPPER WIRE FOR BOTH THE ANTENNA AND TRANSMISSION LINES WILL MEET MOST INSTALLATIONS OF THE AVERAGE TYPE.

WHENEVER ANY JOINTS ARE NECESSARY, THEY SHOULD BE MECHANICALLY TIGHT AND THOROUGHLY SOLDERED. IN THE CASE OF TWO-WIRE TRANSMISSION LINES, THE SPREADERS MAY CONSIST OF WOODEN DOWELS WHICH HAVE BEEN BOILED IN PARAFFIN AND THEY CAN BE ATTACHED TO THE WIRES BY DRILLING SMALL HOLES THRU THE ENDS OF THE DOWELS AND THEN BINDING THEM TO THE WIRES OF THE LINE.

ONLY THE BEST INSULATORS SHOULD BE USED, PYREX ELECTRICAL-RESISTANT GLASS INSULATORS BEING PREFERRED, ALTHOUGH GLAZED PORCELAIN INSULATORS CAN ALSO BE USED. THESE INSULATORS ARE SIMILAR IN APPEARANCE TO THOSE USED WITH RECEIVING ANTENNAS ONLY THAT THEY ARE LARGER. TRANSMITTER INSULATORS OF 12" LENGTH ARE FREQUENTLY USED FOR TRANSMITTERS OF MODERATE POWER, WHEREAS STATIONS OF LESSER POWER USE SMALLER INSULATORS AND SOMETIMES TWO SMALL INSULATORS CONNECTED IN SERIES.

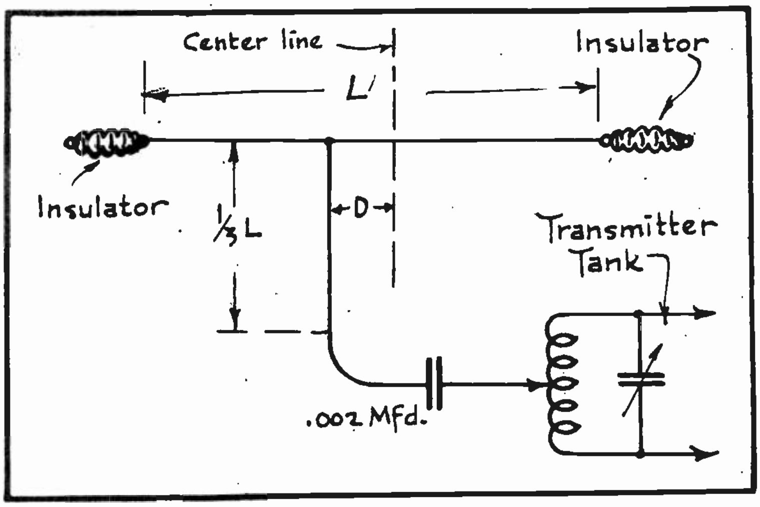

FIG. 16
Single-Wire Antenna Feed.

FOR HIGH FREQUENCY TRANSMITTERS, HERTZ ANTENNAS ARE USED MOST EXTENSIVELY ALTHOUGH MARCONI ANTENNAS ARE ALSO USED TO A CERTAIN EXTENT IN WORK OF THIS TYPE. LATER IN THE COURSE YOU WILL RECEIVE STILL MORE INSTRUCTIONS REGARDING ANTENNAS OF SPECIAL TYPES.

Due Jan 23, 1942

Examination Questions

LESSON NO. T-9

> A business may be ever so successful, but it is never so sure—never se cure, until it holds its old friends by Service and increases its circle of New Friends on the basis of Satisfaction.

1. – WHAT IS THE ESSENTIAL DIFFERENCE BETWEEN THE HERTZ TYPE ANTENNA AND THE MARCONI TYPE ANTENNA?

2. – EXPLAIN THE CURRENT AND VOLTAGE DISTRIBUTION ON A HERTZ ANTENNA WHILE IT IS BEING OPERATED AT ITS FUNDAMENTAL FREQUENCY.

3. – WHAT IS MEANT BY "RADIATION RESISTANCE"?

4. – IF YOU INTEND TO DESIGN AN INVERTED L (MARCONI ANTENNA) FOR A TRANSMITTER WHOSE OPERATING FREQUENCY IS 1500 KC., WHAT SHOULD BE THE TOTAL LENGTH OF THE ANTENNA?

5. – SHOULD YOU BE CALLED UPON TO CONSTRUCT A HERTZ ANTENNA FOR A TRANSMITTER OPERATING AT 6000 KC., HOW LONG WOULD YOU MAKE THE FLAT-TOP OF THE ANTENNA, THAT IS, THE RADIATING PART OF THE ANTENNA?

6. – WHAT EFFECT DOES A PARALLEL TUNING CIRCUIT IN AN ANTENNA FEEDER HAVE UPON THE CURRENT DISTRIBUTION IN THE SYSTEM?

7. – WHAT IS MEANT BY A "CURRENT-FED" ANTENNA TRANSMISSION LINE?

8. – WHAT IS MEANT BY A "VOLTAGE-FED" ANTENNA?

9. – EXPLAIN IN DETAIL HOW YOU WOULD PROCEED TO TUNE AN ANTENNA SYSTEM IN WHICH A TWO-WIRE TRANSMISSION LINE IS USED IN CONJUNCTION WITH SERIES TUNING.

10. – WHAT FACTS ARE TO BE CONSIDERED IN WORKING OUT THE DESIGN FOR AN UNTUNED, TWO-WIRE TRANSMISSION LINE FOR A HERTZ ANTENNA?

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Transmitters

LESSON NO. 10

POWER SUPPLY FOR TRANSMITTERS

IN ONE OF THE EARLY LESSONS OF THIS COURSE YOU WERE INSTRUCTED IN THE PRINCIPLES INVOLVED IN THE POWER SUPPLY CIRCUIT OF THE RECEIVING SET. THE SAME GENERAL PLAN IS USED IN LAYING OUT THE POWER SUPPLY SECTION OF THE TRANSMITTER, THE CHIEF DIFFERENCES BEING DUE TO THE LARGER CURRENT AND HIGHER VOLTAGE REQUIREMENTS OF THE LATTER. WHILE THE APPARATUS USED IS NOT AT ALL COMPLICATED, STILL THE OPERATION OF THE WHOLE TRANSMITTER DEPENDS UPON THE CARE AND PRECISION WITH WHICH THIS UNIT IS DESIGNED AND INSTALLED. NO TRANSMITTER CAN BE ANY BETTER THAN ITS POWER SUPPLY.

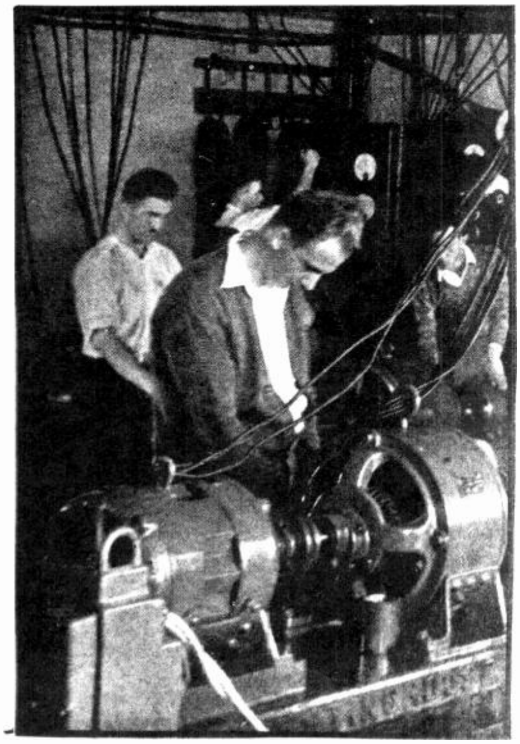


FIG. I

Section of National's Power Room.

POWER SUPPLY FROM A.C. SOURCE

WE SHALL FIRST CONSIDER THOSE SYSTEMS IN WHICH THE SOURCE OF ENERGY IS AN ALTERNATING CURRENT LINE, EITHER SINGLE PHASE, TWO PHASE, OR THREE PHASE. THERE ARE, IN EACH OF THESE SYSTEMS, FIVE MAJOR PARTS, NAMELY:

1. THE POWER TRANSFORMER WHICH STEPS THE LINE VOLTAGE UP TO A HIGHER VALUE.

2. THE FILAMENT TRANSFORMERS WHICH STEP THE LINE VOLTAGE DOWN TO THE PROPER VALUE. IN TRANSMITTERS, THE FILAMENT TRANSFORMERS ARE SELDOM COMBINED WITH THE HIGH VOLTAGE TRANSFORMER AS IN THE RECEIVING SET.

3. THE RECTIFIER WHICH CHANGES THE

HIGH AC VOLTAGE TO A PULSATING DC.

4. THE FILTER WHICH CHANGES THE PULSATING DC OUTPUT OF THE RECTIFIER TO A CONSTANT DC.

5. THE VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS NEEDED BELOW THE HIGH DC OUTPUT OF THE FILTER SYSTEM.

YOUR LESSON #59 PRESENTED IN DETAIL THE DESIGN AND CONSTRUCTION OF POWER TRANSFORMERS SUCH AS ARE USED IN CONJUNCTION WITH THERMIONIC RECTIFIER TUBES TO PRODUCE THE HIGH DC POTENTIAL WHICH, AFTER BEING FILTERED, ENERGIZES THE PLATE AND OTHER "B" CIRCUITS OF THE TRANSMITTER.

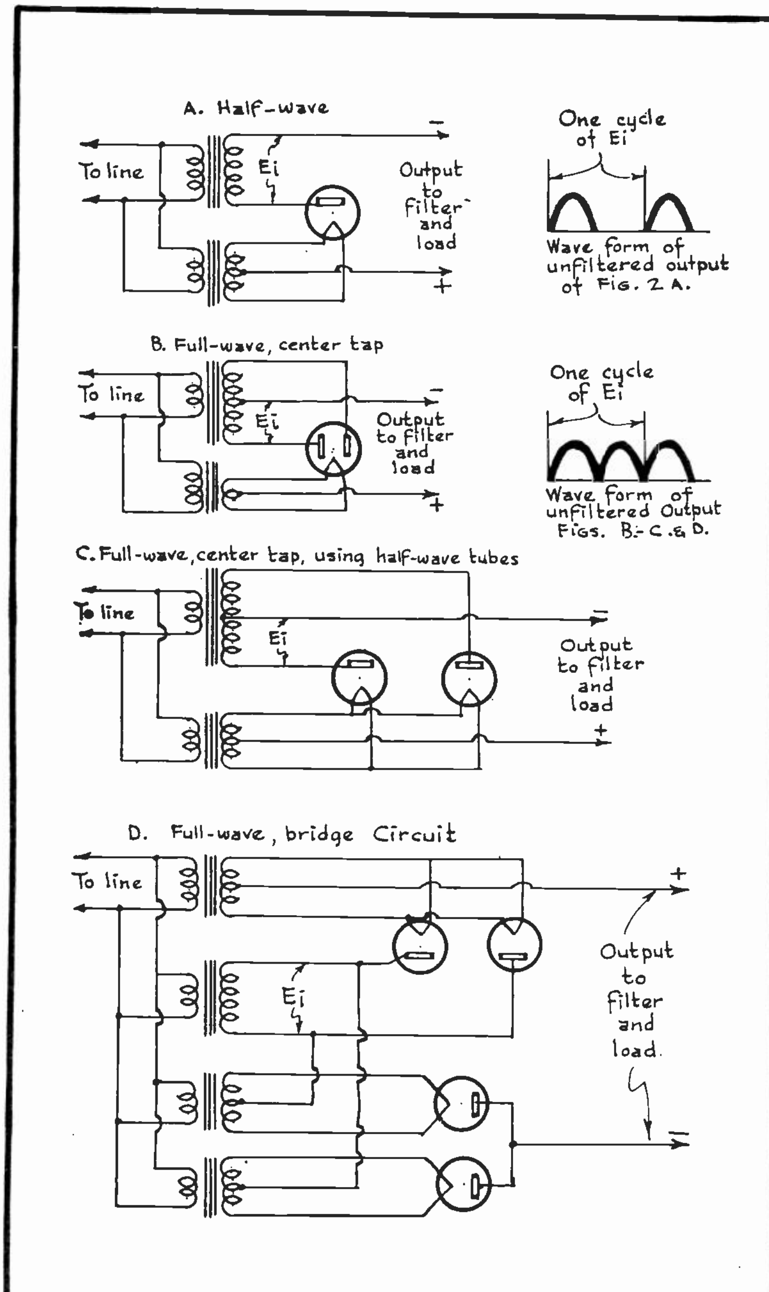


FIG. 2

Single-Phase Rectifier Circuits.

SINGLE-PHASE RECTIFIER CIRCUITS

THE CIRCUITS OF FIG. 2 IN THE PRESENT LESSON SHOWS YOU A NUMBER OF TYPICAL RECTIFYING SYSTEMS FOR A SINGLE-PHASE LINE. THE FIRST CIRCUIT (A) IS NOT OFTEN USED IN COMMERCIAL TRANSMITTERS BECAUSE OF THE DIFFICULTY OF FILTERING THE HALF-WAVE OUTPUT. HOWEVER, IT DOES HAVE ITS APPLICATION IN THE AMATEUR TRANSMITTER WHERE COST IS A LIMITING FACTOR. THE FAMILIAR CIRCUIT OF FIG. 2B IS USED EXTENSIVELY IN SUPPLYING THE SPEECH - INPUT AMPLIFIERS OF THE BROADCAST TRANSMITTER, BUT IS LIMITED TO THIS SERVICE BECAUSE THE FULL-WAVE RECTIFIER TUBES COMMERCIALLY AVAILABLE ARE NOT CAPABLE OF MEETING THE HIGH CURRENT AND VOLTAGE REQUIREMENTS OF THE OTHER SECTIONS OF THE TRANSMITT-

ER. (OF COURSE THIS LAYOUT CAN BE, AND OFTEN IS, USED IN LOW POWERED AMATEUR RIGS.)

THE HIGH VOLTAGE TUBES ARE ALL HALF-WAVE RECTIFIERS. TWO ARE CONNECTED AS IN FIG. 2C WHEN THE FULL-WAVE CENTER-TAP CIRCUIT IS TO BE USED WITH AN AC VOLTAGE PER PLATE OF OVER 500 VOLTS, EFFECTIVE VALUE, WHICH IS THE MAXIMUM RATING OF THE TYPE 83 FULL-WAVE RECTIFIER.

FOUR RECTIFIER TUBES ARE REQUIRED IN THE BRIDGE CIRCUIT OF FIG. 2D, AND THREE SEPARATE FILAMENT TRANSFORMERS MUST BE PROVIDED. TO OFFSET THIS, HOWEVER, TWICE AS MUCH VOLTAGE CAN BE OBTAINED FROM THE BRIDGE CIRCUIT AS FROM THE CENTER-TAP SYSTEM WITHOUT EXCEEDING THE PEAK-INVERSE-VOLTAGE RATING OF THE TUBES. A CAREFUL INSPECTION OF THIS CIRCUIT WILL SHOW THAT IT IS THE FAMILIAR BRIDGE CIRCUIT OF FIG. 7, LESSON NO. 13, AND FIG. 6, OF LESSON NO. 50, WITH THE OXIDE RECTIFIERS REPLACED BY VACUUM TUBES.

VOLTAGE DOUBLER

WHEN A HIGH VOLTAGE IS NEEDED AND THE CURRENT DRAIN IS TO BE RATHER SMALL, A HALF-WAVE VOLTAGE DOUBLER RECTIFIER CAN BE USED TO ADVANTAGE. FIG. 3 SHOWS THIS SYSTEM.

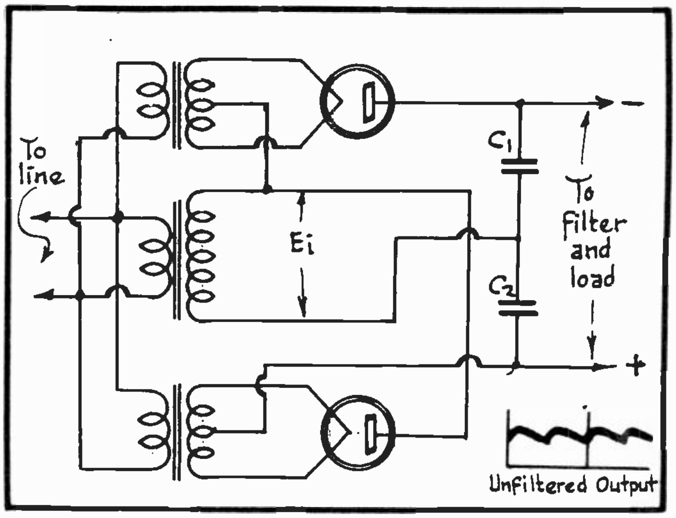


FIG. 3
Voltage Doubler.

A D.C. OUTPUT VOLTAGE NEARLY TWICE THE R.M.S. OR EFFECTIVE VOLTAGE OF THE TRANSFORMER IS PRODUCED BY ALTERNATELY CHARGING THE TWO CONDENSERS C1 AND C2 TO THE FULL VOLTAGE OF THE TRANSFORMER. SINCE THESE TWO CONDENSERS ARE IN SERIES SO FAR AS THE OUTPUT CIRCUIT IS CONCERNED, THE TOTAL VOLTAGE IS TWICE THE VOLTAGE ACROSS EITHER ONE. (SEE FIG. 12 OF LESSON #29.)

POLYPHASE SYSTEMS

BECAUSE MOST OF THE ALTERNATING CURRENT DISTRIBUTION SYSTEMS IN COMMON USE ARE TWO AND THREE PHASE SYSTEMS, TWO AND THREE PHASE RECTIFIER CIRCUITS ARE OFTEN USED IN SUPPLYING THE TRANSMITTER WITH ITS PLATE CURRENT.

THE TWO-PHASE SYSTEM

A TWO-PHASE SYSTEM IS AN ALTERNATING-CURRENT SYSTEM ENERGIZED BY TWO SEPARATE E.M.F.'S WHICH ARE EQUAL IN VALUE BUT WHICH DIFFER IN PHASE BY NINETY ELECTRICAL DEGREES. A SINGLE ALTERNATING-CURRENT GENERATOR HAVING TWO SEPARATE WINDINGS IS USED TO ENERGIZE SUCH A SYSTEM. TRANSFORMERS IN SUCH A DISTRIBUTION SYSTEM MUST HAVE TWO WINDINGS ON BOTH PRIMARY AND SECONDARY WITH A SEPARATE MAGNETIC CIRCUIT FOR EACH "PHASE", AS THE E.M.F.'S ARE CALLED, OR ELSE TWO TRANSFORMERS MUST BE USED. THE GREEK

LETTER ϕ(PHI) IS FREQUENTLY USED TO DESIGNATE PHASE.

TWO-PHASE MOTORS ARE PROVIDED WITH TWO SETS OF COILS JUST AS ARE THE GENERATORS, AND WHEN A LAMP LOAD IS CARRIED BY A TWO-PHASE SYSTEM, THE LAMPS ARE DIVIDED INTO TWO "PHASE GROUPS", ONE BEING CONNECTED TO ONE PHASE AND THE OTHER GROUP BEING CONNECTED TO THE OTHER PHASE AS SHOWN IN FIG. 4.

WHEN THE TWO PHASES ARE INTERCONNECTED AS SHOWN IN FIG.5, A TWO-PHASE, THREE-WIRE SYSTEM RESULTS. NOTE THAT THE VOLTAGE BETWEEN THE "OUTSIDE" WIRES IS 1.41 (OR THE SQUARE-ROOT OF TWO) TIMES THE PHASE-VOLTAGE. THIS IS THE RESULTANT VOLTAGE OBTAINED BY ADDING THE TWO PHASE-VOLTAGES AT A PHASE-DISPLACEMENT OF 90°. THE CURRENT IN THE COMMON OR NEUTRAL WIRE WILL BE 1.41 TIMES THE "LINE CURRENT" IN EITHER OUTSIDE WIRE.

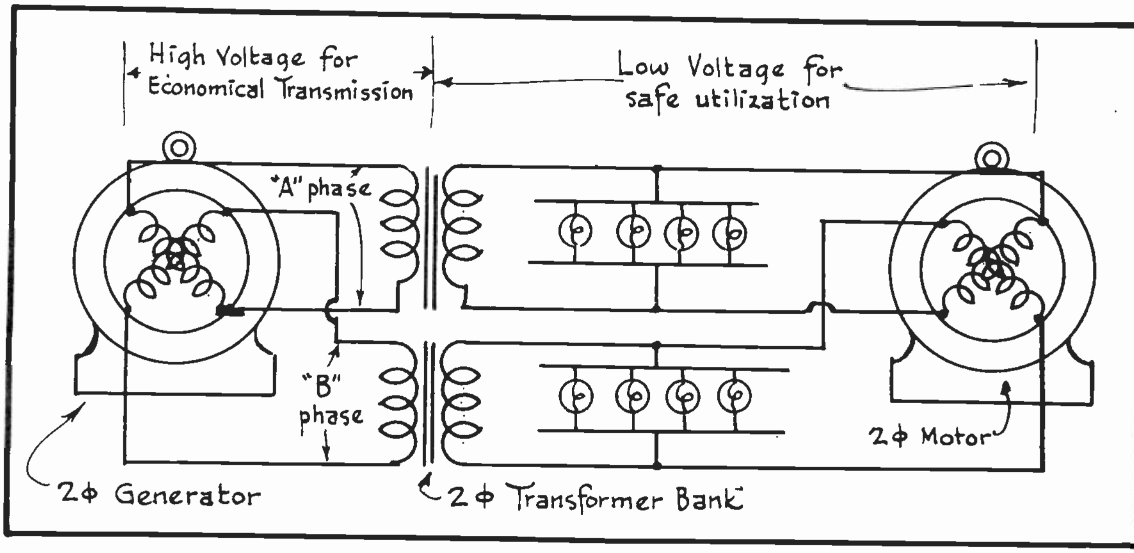


FIG. 4
A Two-Phase, Four-Wire System.

TWO METHODS OF REPRESENTING THE TWO PHASE SYSTEM GRAPHICALLY ARE SHOWN IN FIG. 6. THE DOTTED LINE OF THE VECTOR DIAGRAM SHOWS THE VOLTAGE BETWEEN THE OUTSIDE WIRES OF THE TWO-PHASE, THREE-WIRE SYSTEM AS THE VECTORIAL SUM OF THE TWO PHASE-VOLTAGES.

THE THREE-PHASE SYSTEM

A THREE-PHASE SYSTEM IS ENERGIZED BY THREE SEPARATE E.M.F.'S, EQUAL IN VOLTAGE BUT DIFFERING IN PHASE BY ONE-HUNDRED-TWENTY ELECTRICAL DEGREES. THIS IS GRAPHICALLY ILLUSTRATED IN FIG. 7.

THREE WIRES ONLY ARE REQUIRED TO CARRY THREE-PHASE ENERGY. THE PHASE WINDINGS OF THE GENERATOR ARE CONNECTED TO THE LINE WIRES EITHER IN STAR AS IN FIG. 8A, OR IN DELTA AS IN FIG. 8B. IN THE STAR-CONNECTED CIRCUIT THE LINE VOLTAGE E_L IS 1.73 (OR THE SQUARE ROOT OF THREE) TIMES THE PHASE VOLTAGE E_{PH}. WHEN A DELTA CONNECTION IS EMPLOYED, THE LINE VOLTAGE EQUALS THE PHASE VOLTAGE.

THREE-PHASE SYSTEMS ARE FAR MORE COMMON THAN SINGLE-OR TWO-PHASE

SYSTEMS FOR THE FOLLOWING REASONS: THE COST OF COPPER FOR THE THREE-PHASE DISTRIBUTION SYSTEM IS LESS; AN A.C. GENERATOR TAPPED FOR THREE-PHASE OUTPUT DELIVERS 50% MORE POWER THAN THE SAME GENERATOR TAPPED FOR SINGLE-PHASE OUTPUT, AND 6% MORE POWER THAN WHEN TAPPED FOR TWO-PHASE; AND IN ADDITION THREE-PHASE MOTORS ARE SELF-STARTING AND MORE ECONOMICAL THAN SINGLE-PHASE MOTORS. IN THE CASE OF THE RECTIFIER, THE OUTPUT OF

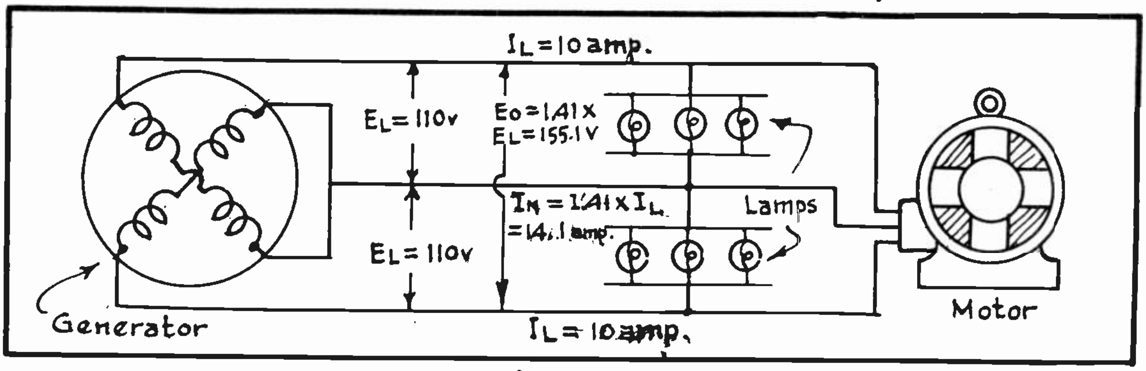


FIG. 5
Two-Phase, Three-Wire System.

THE THREE-PHASE RECTIFIER REQUIRES MUCH LESS FILTERING THAN EITHER SINGLE OR TWO-PHASE.

ANY PHASE OF A POLYPHASE LINE CAN BE USED TO ENERGIZE A SINGLE-PHASE LOAD.

THREE-PHASE CURRENT DISTRIBUTION

THE CURRENT DISTRIBUTION IN THE THREE-PHASE SYSTEM IS ESPECIALLY INTERESTING. TO BEGIN WITH WE FIND THAT IN THE STAR CONNECTION, THE CURRENT IN EACH LINE WIRE IS THE SAME AS THE CURRENT IN EACH PHASE COIL. THIS IS OBVIOUSLY TRUE BECAUSE EACH LINE IS CONNECTED TO A SINGLE COIL. IN THE DELTA CONNECTION, HOWEVER, BECAUSE EACH LINE IS FED BY TWO PHASE-COILS, THE LINE CURRENT IS THE VECTORIAL SUM OF THE TWO PHASE CURRENTS OR 1.73 TIMES THE PHASE CURRENT OF ONE COIL.

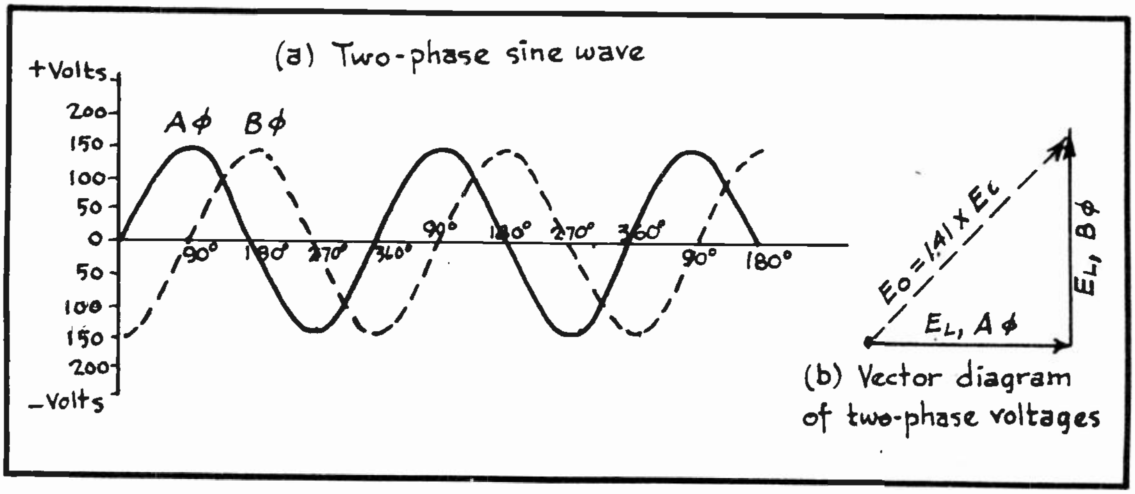


FIG. 6
Graphical Representation of Two φ Systems.

The four transformer connections in general use on three phase lines are: The DELTA-DELTA (Fig. 9A), the DELTA-STAR (Fig. 9B) the STAR-STAR (Fig. 9C), and the STAR-DELTA (Fig. 9D).

Usually three separate single phase transformers are employed, but in rectifier circuits it is quite common to use a specially constructed three-phase transformer. The voltage transformation obtained depends upon the connection used, for example, if E_p is Primary Voltage, E_s is Secondary Voltage, and N is Turns Ratio then:

In Delta-Delta	E_s equals E_p times N
In Delta-Star	E_s equals E_p times N times 1.73
In Star-Star	E_s equals E_p times N
In Star-Delta	E_s equals E_p times N divided by 1.73.

Thus we have a simple and convenient means for obtaining different output voltages.

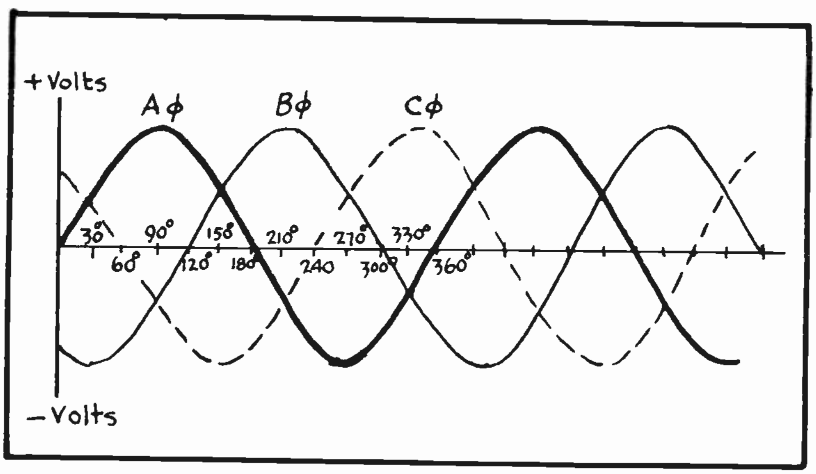


FIG. 7
Three-Phase Sine Wave.

TYPICAL TWO-PHASE CIRCUITS

Although two-phase circuits are seldom encountered, nevertheless, we show in Fig. 10 some rectifier hook-ups which are energized by this type of system.

THREE-PHASE RECTIFIERS

The three-phase rectifying circuits as usually employed use a delta-star transformer connection for obtaining the high voltage supply, as shown in Fig. 11. This is done primarily because the center of the star-connected secondary forms a convenient negative load terminal. A primary delta connection is used because by so doing the voltage transformation is increased by 1.73. The three-phase, half-wave circuit, you will see by referring back to Fig. 2A, is essentially three single-phase, half-wave rectifiers with each leg of the star secondary forming one phase. Note that the wave-form of the unfiltered output more nearly approaches a constant D.C. than the output of any of the single-phase rectifiers.

By using two three-phase, half-wave rectifiers connected in parallel, as shown in Fig. 12A, it is possible to obtain an output wave with a very small ripple. This is accomplished by arranging the polarities of the two star secondaries so that when the output voltage of one three-phase unit is at a minimum, the output of the other is at a maximum. The interphase reactor, whose center tap is connected to the negative output terminal, acts as a balance coil which enables each three-phase unit to operate independently. The three-phase, full-wave rectifier circuit of

FIG. 12B HAS THE ADVANTAGE THAT ONLY ONE THREE-PHASE SECONDARY IS REQUIRED, AND THE INTERPHASE REACTOR CAN BE DISPENSED WITH. TO PARTIALLY OFFSET THIS, FOUR SEPARATE FILAMENT SECONDARIES ARE REQUIRED. THE OUTPUT WAVE HAS THE SAME FORM AS THAT OF CIRCUIT 12A.

IN ALL OF THE PRECEDING CIRCUITS, IF MERCURY-VAPOR RECTIFIER TUBES ARE USED, SWITCHES SHOULD BE SO INSTALLED THAT THE FILAMENT TRANSFORMERS CAN BE CONNECTED TO THE LINE FROM 40 SECONDS TO ONE MINUTE BEFORE THE HIGH-VOLTAGE TRANSFORMERS ARE TURNED ON. THE FILAMENT SHOULD ALWAYS BE ALLOWED TO COME UP TO FULL OPERATING TEMPERATURE BEFORE THE PLATE VOLTAGE IS APPLIED.

A COMPARISON BETWEEN THESE RECTIFIER CIRCUITS, AS GIVEN BY TABLE I IS INTERESTING.

TABLE I

FIGURE	MAX. PERMISSIBLE INPUT VOLTS (E_i) EFFECTIVE VALUE	D.C. OUTPUT IGNORING DROP IN TUBE AND FILTER	MAX. PERMISSIBLE D.C. OUTPUT CURRENT
2B AND 2C	.353 M.P.I.V.	.85 E_i	.66 M.P.P.C.
2D	.7 M.P.I.V.	.85 E_i	.66 M.P.P.C.
3	1.14 M.P.I.V.	1.7 E_i	.33 M.P.P.C.
11	.41 M.P.I.V.	1.17 E_i	.84 M.P.P.C.
12A	.41 M.P.I.V.	1.17 E_i	2.00 M.P.P.C.
12B	.41 M.P.I.V.	2.34 E_i	1.00 M.P.P.C.

NOTE: M.P.I.V. = MAXIMUM PEAK INVERSE VOLTAGE AT RECTIFIER TUBE.
M.P.P.C. = MAXIMUM PERMISSIBLE PLATE CURRENT OF RECTIFIER TUBE.

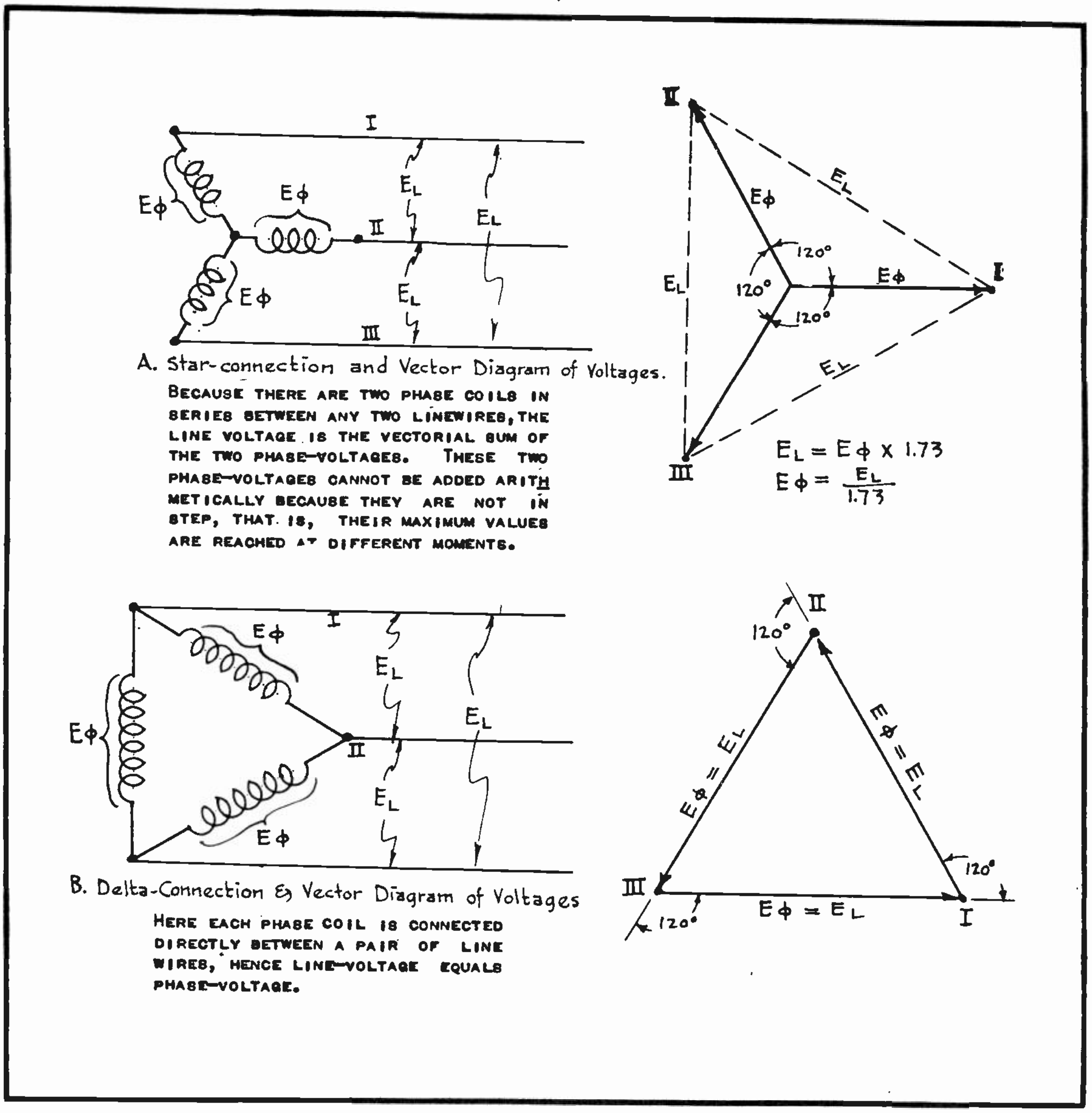
VOLTAGE REGULATION

ALTHOUGH THE EXPRESSION "VOLTAGE REGULATION" IS ALSO QUITE OFTEN USED IN CONNECTION WITH THE POWER PACK OF RECEIVERS YET IT IS STILL MORE FREQUENTLY EMPLOYED RELATIVE TO THE POWER SUPPLY OF TRANSMITTERS. THIS TERM IS USED TO INDICATE THE CHANGE IN TERMINAL VOLTAGE OF A PLATE-SUPPLY SYSTEM WITH DIFFERENT LOAD CURRENTS.

THE WINDINGS OF TRANSFORMERS, FILTER CHOKES ETC. AS USED IN POWER SUPPLY SYSTEMS ALL HAVE A CERTAIN AMOUNT OF RESISTANCE AND THEREFORE AS THE LOAD CURRENT THROUGH THESE WINDINGS INCREASES, THE VOLTAGE DROP ACROSS THEM WILL ALSO INCREASE AND CONSEQUENTLY THE OUTPUT TERMINAL VOLTAGE WILL DECREASE WITH ANY APPRECIABLE INCREASE IN LOAD CURRENT.

BESIDES THE OHMIC RESISTANCE OF THESE WINDINGS, OTHER FACTORS SUCH AS THE GENERAL BEHAVIOR OF THE FILTER UNDER OPERATING CONDITIONS ALSO AFFECT THE VOLTAGE REGULATION OF THE POWER SUPPLY SYSTEM. OBVIOUSLY, THE LESS VARIATION WHICH OCCURS WITH CHANGES IN LOAD CURRENT, THE BETTER WILL BE THE VOLTAGE REGULATION OF THE SYSTEM.

IT IS CUSTOMARY TO EXPRESS THE VOLTAGE REGULATION OF A POWER SUPPLY



A. Star-connection and Vector Diagram of Voltages.
BECAUSE THERE ARE TWO PHASE COILS IN SERIES BETWEEN ANY TWO LINEWIRES, THE LINE VOLTAGE IS THE VECTORIAL SUM OF THE TWO PHASE-VOLTAGES. THESE TWO PHASE-VOLTAGES CANNOT BE ADDED ARITHMETICALLY BECAUSE THEY ARE NOT IN STEP, THAT IS, THEIR MAXIMUM VALUES ARE REACHED AT DIFFERENT MOMENTS.

B. Delta-Connection & Vector Diagram of Voltages
HERE EACH PHASE COIL IS CONNECTED DIRECTLY BETWEEN A PAIR OF LINE WIRES, HENCE LINE-VOLTAGE EQUALS PHASE-VOLTAGE.

FIG. 8
Three-Phase, Three-Wire Systems.

SYSTEM AS A PERCENTAGE. GOOD PLATE VOLTAGE SUPPLIES WILL HAVE A REGULATION OF 10% OR LESS AND THIS FACTOR IS DETERMINED IN THE FOLLOWING MANNER: FIRST THE OUTPUT VOLTAGE OF THE PLATE POWER SUPPLY IS MEASURED AT NO LOAD, THAT IS, WITH NONE OF THE TRANSMITTER TUBES DRAWING ANY "B" CURRENT. THIS DONE, THE OUTPUT VOLTAGE OF THE PLATE POWER SUPPLY IS MEASURED AT NORMAL LOAD, THAT IS, WITH THE TRANSMITTER DRAWING ITS NORMAL

AMOUNT OF "B" CURRENT. WE THEN SUBTRACT THE "NORMAL LOAD" VOLTAGE FROM THE "NO LOAD" VOLTAGE AND DIVIDE THIS DIFFERENCE BY THE NO LOAD VOLTAGE. THIS RESULTING QUOTIENT WILL BE THE VOLTAGE REGULATION EXPRESSED AS A DECIMAL FRACTION.

TO MORE CLEARLY ILLUSTRATE THIS MATTER LET US CONSIDER THE FOLLOWING EXAMPLE: WE SHALL ASSUME THAT THE OUTPUT TERMINAL VOLTAGE OF A CERTAIN PLATE POWER SUPPLY IS 2000 VOLTS AT NO LOAD AND 1800 VOLTS AT NORMAL LOAD. THE CORRESPONDING VOLTAGE REGULATION OF THIS SYSTEM WILL THEN BE

$$\frac{2000 - 1800}{2000} = .1 = 10\%.$$

THE VOLTAGE REGULATION OF A TRANSMITTER'S POWER SUPPLY IS A VERY IMPORTANT ITEM AND THIS IS PARTICULARLY TRUE OF RADIO-TELEGRAPH TRANSMITTERS WHERE THE "B" CURRENT WHICH IS DRAWN IS BEING CONTINUALLY VARIED IN INTENSITY DURING THE PROCESS OF KEYING. WERE POOR REGULATION TO EXIST, THE "B" VOLTAGES AT THE TUBES WOULD BE SUBJECT TO CONSIDERABLE VARIATION WHEN KEYING.

FILTERS

THE FILTER CIRCUITS AS USED IN THE PLATE SUPPLY SYSTEM FOR TRANS-

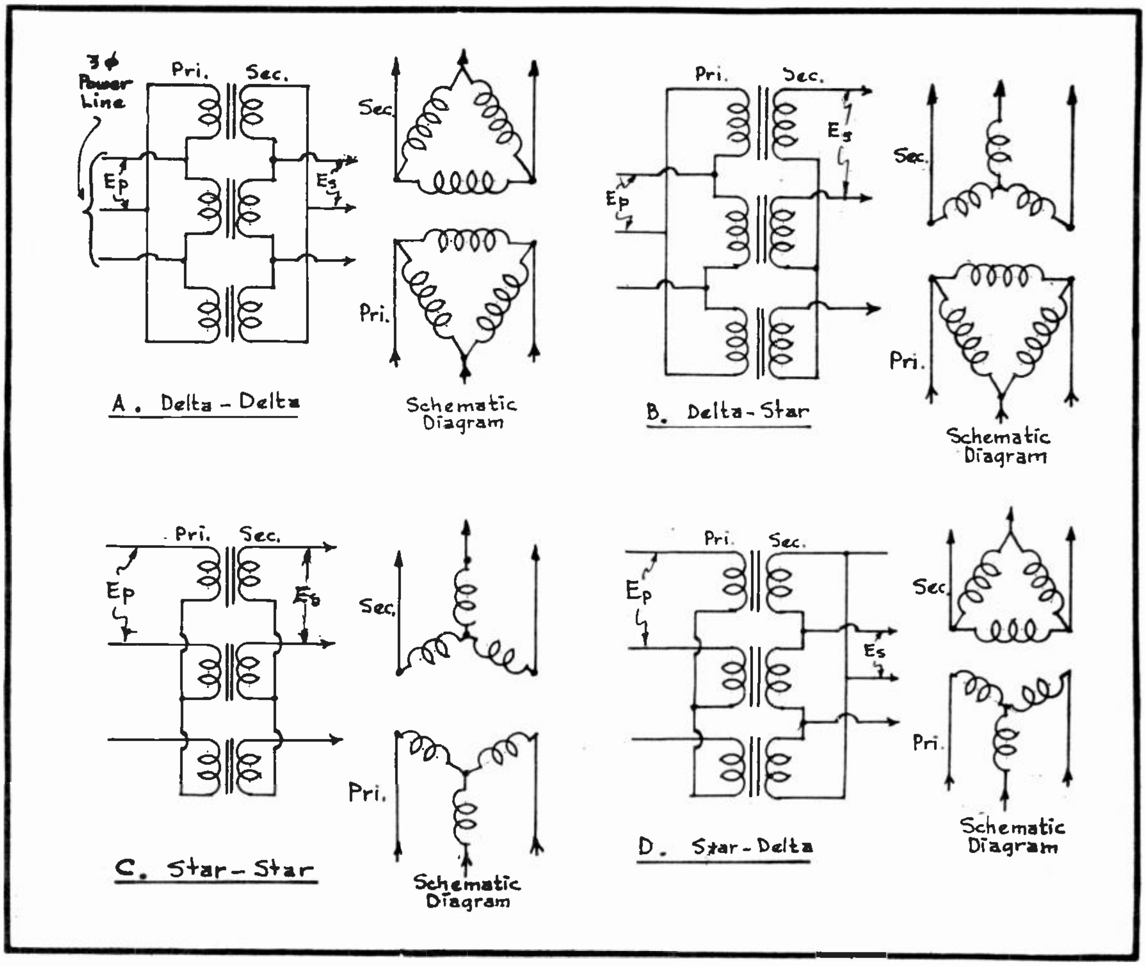


FIG. 9

Three-Phase Transformer Connections.

MITTERS FOLLOW THE SAME GENERAL DESIGN PRINCIPLES AS THOSE ALREADY DESCRIBED TO YOU RELATIVE TO RECEIVERS. THE ESSENTIAL DIFFERENCE BETWEEN THE RECEIVER AND TRANSMITTER FILTER LIES IN THE FACT THAT IN THE TRANSMITTER THE CONSTRUCTION OF THE FILTER MUST BE SUCH THAT THE SYSTEM CAN CARRY THE LARGER CURRENTS AND HANDLE THE HIGHER VOLTAGES SATISFACTORILY.

THE FILTER CONDENSERS AS USED WITH TRANSMITTERS MAY BE OF THE WET ELECTROLYTIC, DRY ELECTROLYTIC, PAPER, OR OIL IMPREGNATED PAPER TYPE. THE ELECTROLYTIC CONDENSERS OF BOTH TYPES HAVE A DISADVANTAGE IN THAT THEY ARE SELDOM CAPABLE OF WITHSTANDING D.C. VOLTAGES HIGHER THAN 500 VOLTS PEAK VALUE, HOWEVER, IT IS POSSIBLE TO CONNECT TWO OR MORE OF THESE CONDENSERS IN SERIES SO THAT THE SERIES COMBINATION MAY TAKE THE PLACE OF A SINGLE CONDENSER IN A CIRCUIT OF RATHER HIGH VOLTAGE. IT IS OF COURSE TO BE UNDERSTOOD THAT A SERIES CONDENSER ARRANGEMENT AS THIS WILL REDUCE

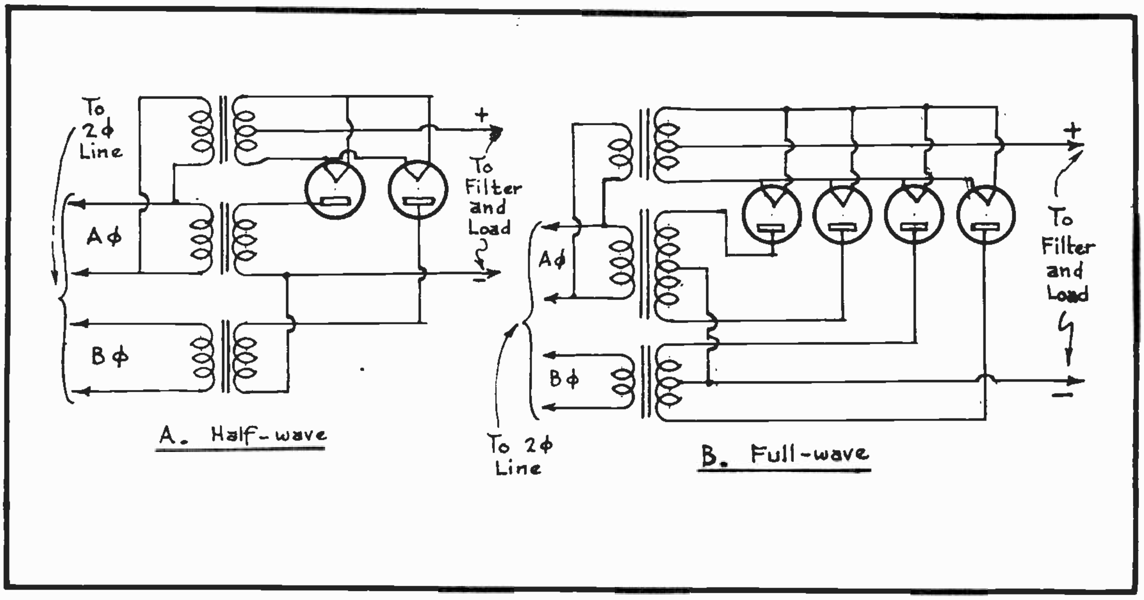


FIG. 10
Two-Phase Rectifier Circuit.

THE OVER-ALL CAPACITY OF THE ARRANGEMENT ACCORDINGLY.

IN FIG. 13 YOU ARE SHOWN A TYPICAL PAPER DIELECTRIC TYPE TRANSMITTING CONDENSER WHICH IS RATED FOR A CAPACITY OF 2 MFD. AND A D.C. WORKING VOLTAGE OF 2000 VOLTS. NOTICE HOW THE TERMINALS ARE SUPPORTED ON SPECIAL STAND-OFF INSULATORS SO THAT THE HIGH VOLTAGES CAN BE HANDLED PROPERLY. CONDENSERS AS THIS CAN BE OBTAINED TO WITHSTAND D.C. VOLTAGES AS HIGH AS 4000 VOLTS.

OIL IMPREGNATED PAPER DIELECTRIC CONDENSERS WILL STAND VOLTAGES STILL HIGHER THAN WILL THOSE OF THE PLAIN PAPER TYPE. THE OIL FREQUENTLY USED FOR THIS PURPOSE IS KNOWN AS PYRANOL AND IT HAS A HIGH DIELECTRIC STRENGTH AS WELL AS OTHER DESIRABLE PROPERTIES WHICH PERMIT THE CONSTRUCTION OF EFFICIENT CONDENSERS.

RIPPLE VOLTAGE

AS YOU WILL RECALL FROM YOUR PREVIOUS STUDIES CONCERNING FILTERS,

THE OUTPUT OF THE CONVENTIONAL FILTER IS NOT ABSOLUTELY UNIFORM IN VALUE BUT STILL HAS IMPOSED UPON IT A CERTAIN AMOUNT OF A.C. VOLTAGE AND WHICH IS GENERALLY REFERRED TO AS RIPPLE VOLTAGE. THE EXTENT OF RIPPLE WHICH IS PRESENT IN THE OUTPUT OF A FILTER IS GENERALLY EXPRESSED AS A PERCENTAGE AND WHICH IS EQUAL IN VALUE TO THE EFFECTIVE VALUE OF THE RIPPLE VOLTAGE DIVIDED BY THE D.C. VOLTAGE. THIS PERCENTAGE OF RIPPLE OFFERS A PRACTICAL MEANS OF COMPARING THE PERFORMANCE OF VARIOUS FILTER CIRCUITS. EXPERIENCE HAS SHOWN THAT A RIPPLE OF 5% OR LESS IS SATISFACTORY AND 1% IS DESIRABLE FOR A C.W. TRANSMITTER WHEREAS FOR RADIOTELEPHONY THE RIPPLE SHOULD NOT EXCEED 0.25% SO THAT THE HUM LEVEL WILL NOT BE OBJECTIONABLE.

OBVIOUSLY, THE PERCENT RIPPLE IS AFFECTED BY THE INDUCTANCE AND CAPACITIVE VALUES WHICH ARE USED IN THE FILTER CIRCUIT. FOR A SIMPLE SINGLE SECTION FILTER SUCH AS ILLUSTRATED AT "A" IN FIG. 15 AND WHICH IS GENER-

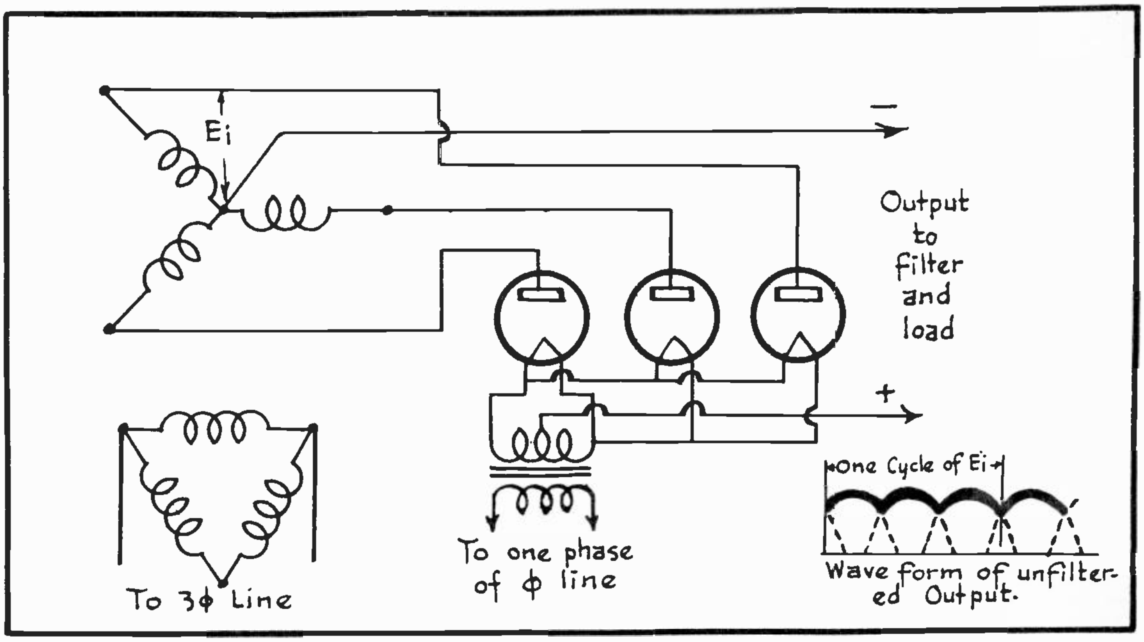


FIG. 11
Three-Phase, Half-Wave Rectifier.

ALLY SUFFICIENT IF A RIPPLE OF 5% CAN BE TOLERATED, THE FOLLOWING RELATION HOLDS GOOD:

$$\% \text{ RIPPLE} = \frac{100}{L\,C}$$ WHERE L IS EXPRESSED IN HENRYS AND C IN MFDS.

BY TRANSPOSITION, WE HAVE $LC = \frac{100}{\% \text{ RIPPLE}}$ AND FROM WHICH THE LC FACTOR CAN BE OBTAINED. THIS DONE, WE CAN SELECT A PRACTICAL CONDENSER RATING AND DETERMINE THE CORRESPONDING INDUCTANCE RATING FOR THE CHOKE OR VICE VERSA.

FOR A TWO SECTION FILTER SUCH AS THAT WHICH IS ILLUSTRATED AT "B" OF FIG. 15 THE RELATION BECOMES AS FOLLOWS: $\% \text{ RIPPLE} = \frac{650}{L_1 L_2 (C_1 + C_2)^2}$.

IN THIS CASE ALSO, A SUITABLE COMBINATION OF L_1; L_2; C_1 AND C_2 CAN BE DETERMINED TO SATISFY THE FORMULA.

IT IS ALSO WELL TO POINT OUT THIS TIME THAT FOR FILTER SYSTEMS WHICH OPERATE AT HIGH VOLTAGE A CHOKE INPUT FILTER IS PREFERABLE TO A CONDENSER INPUT FILTER. A CHOKE INPUT FILTER OFFERS AS ITS CHIEF CHARACTERISTICS GOOD VOLTAGE REGULATION AND A COMPARATIVELY LOW RECTIFIER TUBE PEAK CURRENT.

THE OPTIMUM VALUE FOR THE INPUT CHOKE INDUCTANCE OF THE FILTER IS

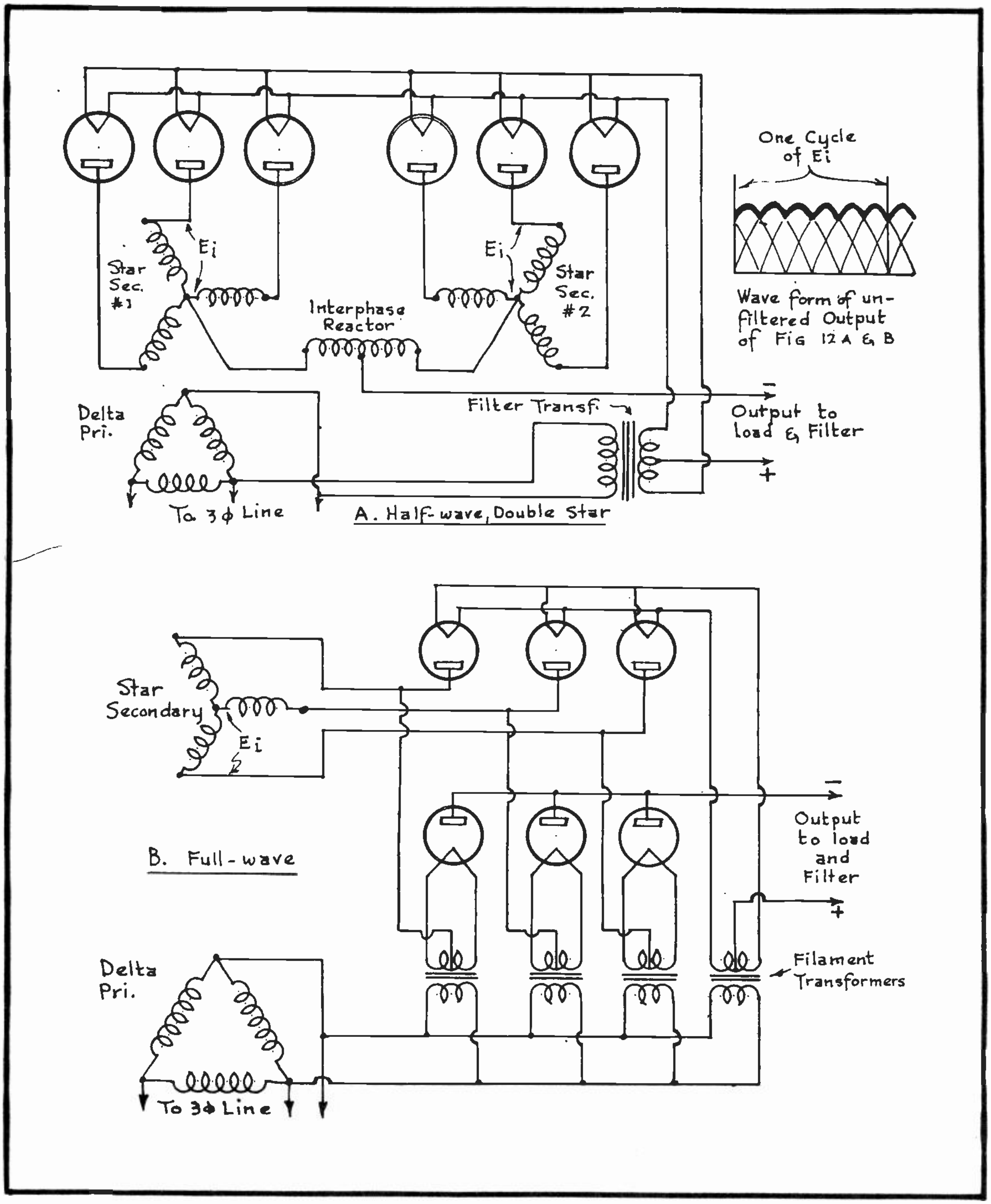


FIG. 12

Three-Phase Rectifier Circuits.

FOUND BY USING THE FOLLOWING FORMULA: $L_{opt.} = \frac{\text{FULL LOAD RESISTANCE}}{500}$ WHERE

L = INDUCTANCE OF CHOKE EXPRESSED IN HENRYS; THE FULL LOAD RESISTANCE IN OHMS IS EQUAL TO THE OUTPUT VOLTAGE DIVIDED BY THE TOTAL LOAD CURRENT IN AMPERES AND 500 IS A CONSTANT.

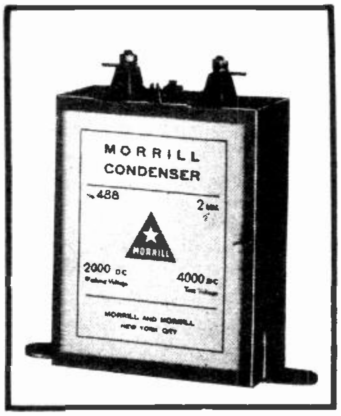


FIG. 13
A Transmitter Condenser.

THE CRITICAL VALUE FOR THIS SAME INPUT CHOKE INDUCTANCE IS FOUND BY USING THE FORMULA:

$$L_{crit.} = \frac{\text{RESISTANCE OF BLEEDER IN OHMS.}}{1000}$$

BY INSPECTING THESE TWO FORMULAS, YOU WILL NOTE THAT TWO DIFFERENT CHOKE VALUES WILL BE OBTAINED, NAMELY THE OPTIMUM AND THE CRITICAL VALUES. ALTHOUGH A CHOKE HAVING THE CRITICAL INDUCTANCE CAN BE USED FOR THIS PURPOSE, YET IT WOULD BE STILL MORE PREFERABLE TO USE A "SWINGING CHOKE" WHOSE INDUCTANCE VALUE VARIES FROM NO LOAD TO FULL LOAD BETWEEN THE LIMITS ESTABLISHED BY THE OPTIMUM AND CRITICAL INDUCTANCE VALUES.

IN THE "B" POWER SUPPLY A BLEEDER RESISTOR IS DESIRABLE THE SAME AS IN RECEIVERS. IT IS A COMMON PRACTICE TO SELECT A BLEEDER RESISTANCE OF SUCH VALUE THAT IT WILL PASS A CURRENT OF ABOUT 10% OR LESS OF THE FULL LOAD CURRENT.

GENERATORS

SO FAR IN THIS LESSON YOU WERE ONLY SHOWN HOW AN EXISTING A.C. POWER SUPPLY CAN BE UTILIZED FOR OPERATING TRANSMITTERS BUT IN ADDITION TO THIS METHOD YOU WILL ALSO FIND GENERATORS AND MOTOR-GENERATORS USED EXTENSIVELY. IN LESSON #39 OF YOUR FOUNDATIONAL TRAINING YOU WERE ALREADY TOLD ABOUT THE OPERATING PRINCIPLES OF THE A.C. GENERATOR AND SO IF NECESSARY, IT IS ADVISABLE THAT YOU REVIEW LESSON #39 AT THIS TIME BEFORE CONTINUING WITH THE PRESENT LESSON REGARDING D.C. GENERATORS, MOTOR-GENERATOR SETS, CONVERTERS ETC.

FIG. 14
Oil-Filled Condensers

THE D.C. GENERATOR

BY TAKING THE SIMPLE A.C. GENERATOR WHICH WAS SHOWN YOU IN LESSON #39 AND MAKING SOME MINOR CHANGES, A D.C. GENERATOR CAN BE PRODUCED. FOR EXAMPLE, BY LOOKING AT FIG. 16 OF THE PRESENT LESSON YOU WILL SEE A LOOP PLACED IN A MAGNETIC FIELD BUT INSTEAD OF USING TWO COLLECTOR RINGS, WE ARE ONLY USING ONE AND EVEN THIS IS CUT IN HALF, SO THAT ITS ENDS ARE SEPARATED FROM EACHOTHER. WE DON'T REFER TO THIS AS A

COLLECTOR RING NOW BUT WE CALL IT A COMMUTATOR AND EACH HALF OR SECTION OF THE COMMUTATOR IN FIG. 16 IS REFERRED TO AS A COMMUTATOR SEGMENT.

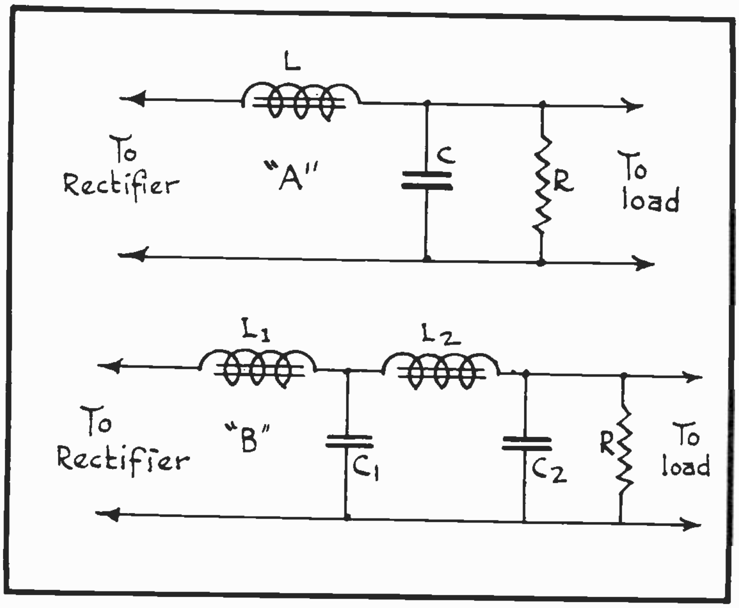


FIG. 15
Typical Filter Circuits.

SEGMENT A OF THIS COMMUTATOR IS CONNECTED TO THE END OF THE LOOP ON SIDE E AND SEGMENT B IS CONNECTED TO THE LOOP END ON SIDE F. NOW THEN, WITH THE LOOP BEING ROTATED IN THE DIRECTION AS INDICATED, BY SOME MECHANICAL FORCE, SIDE F WILL BE CUTTING LINES OF FORCE IN A DOWNWARD DIRECTION AND SIDE E WILL BE CUTTING THEM IN AN UPWARD DIRECTION, AND AS A RESULT, THE INDUCED OR GENERATED CURRENT WITHIN THE LOOP WILL FLOW FROM SIDE F TOWARDS AND INTO COMMUTATOR SEGMENT B. BRUSH D IS AT THIS TIME MAKING CONTACT WITH SEGMENT B AND SO THIS GENERATED CURRENT FLOWS THROUGH BRUSH D AND OVER THE EXTERNAL CIRCUIT. THIS SAME CURRENT THEN FLOWS FROM THE EXTERNAL CIRCUIT INTO BRUSH C, THROUGH WHICH IT ENTERS COMMUTATOR SEGMENT A AND SIDE E OF THE LOOP. SO HERE AGAIN WE HAVE A COMPLETE CIRCUIT WITH THE GENERATED CURRENT FLOWING OVER THE EXTERNAL CIRCUIT FROM BRUSH D TO BRUSH C, AND BRUSH D IS AT THIS TIME THE (+) BRUSH AND C IS THE (−) BRUSH. WITHIN THE LOOP, THE CURRENT IS FLOWING FROM SEGMENT A TOWARD SEGMENT B.

ACTION TAKING PLACE AFTER ROTATING THE D.C. GENERATOR LOOP 180°

AFTER THE LOOP HAS BEEN ROTATED A HALF REVOLUTION OR 180°, THE LOOP WILL COME TO THE POSITION AS PICTURED IN FIG. 17 AND HERE YOU WILL SEE THAT THE COMMUTATOR SEGMENTS, TOGETHER WITH THE LOOP, HAVE CHANGED THEIR POSITIONS WITH RESPECT TO THE BRUSHES. THAT IS, SEGMENT A IS MAKING CONTACT WITH BRUSH D, JUST THE OPPOSITE TO THE POSITIONS OCCUPIED IN FIG. 16.

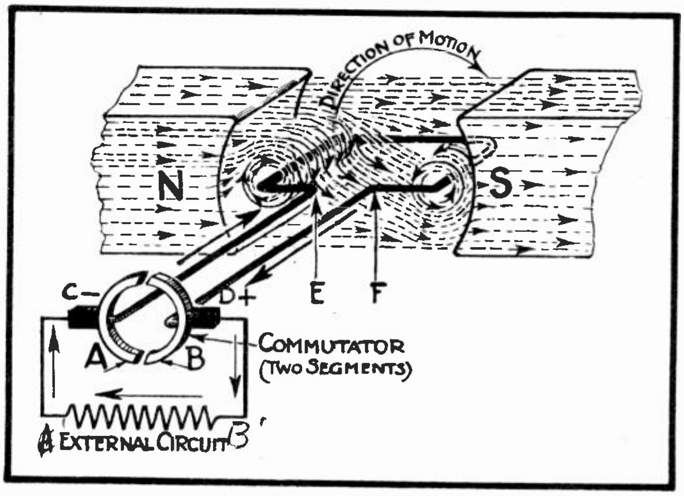


FIG. 16
The Simple D.C. Generator.

NOW IN FIG. 17, SIDE E OF THE LOOP WILL BE CUTTING LINES OF FORCE IN A DOWNWARD

DIRECTION, WHILE SIDE F IS CUTTING THEM IN AN UPWARD DIRECTION AND AS A RESULT, THE GENERATED CURRENT ON SIDE E WILL FLOW TOWARD AND INTO COMMUTATOR SEGMENT A, THENCE THROUGH BRUSH D OVER THE EXTERNAL CIRCUIT AND THROUGH BRUSH C INTO COMMUTATOR SEGMENT B AND THUS BACK INTO SIDE F OF THE COIL.

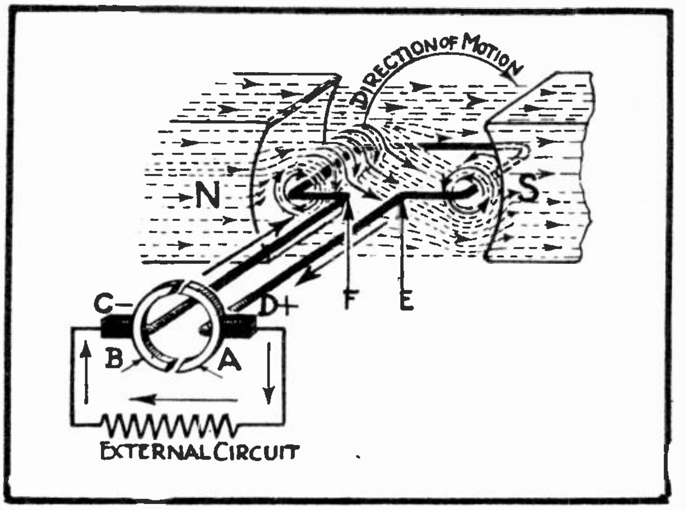


FIG. 17
Current Flow over External Circuit.

A DIRECT CURRENT SENT OVER THE EXTERNAL CIRCUIT

NOTICE ESPECIALLY IN FIG. 17 HOW THE GENERATED CURRENT FLOWS OVER THE EXTERNAL CIRCUIT FROM BRUSH D TO BRUSH C AND THIS, YOU WILL NOTICE, IS THE SAME DIRECTION THAT IT FLOWED IN FIG. 16. NOW TAKE A LOOK AT THE LOOP ITSELF IN FIG. 17 AND YOU WILL SEE THAT WITHIN THE LOOP, THE GENERATED CURRENT IS FLOWING FROM SEGMENT B TOWARD SEGMENT A AND THIS FLOW IS IN THE OPPOSITE DIRECTION TO WHICH THE CURRENT WAS FLOWING WITHIN THE LOOP IN FIG. 16. THIS SHOWS YOU THAT ALTHOUGH AN ALTERNATING CURRENT IS ACTUALLY GENERATED IN THE LOOP, YET THE COMMUTATOR ARRANGEMENT MAKES IT POSSIBLE TO SEND A DIRECT CURRENT OVER THE EXTERNAL CIRCUIT. THUS BRUSH D IS A POSITIVE AND BRUSH C IS A NEGATIVE BRUSH IN BOTH OF THESE ILLUSTRATIONS AND THEIR POLARITY NEVER REVERSES BUT REMAINS THE SAME.

BY USING BUT A SINGLE LOOP OR INDUCTOR IN EITHER A D.C. OR A.C. GENERATOR, IT IS EVIDENT THAT THE DELIVERED CURRENT WILL BE VERY IRREGULAR IN ITS FLOW, FOR THERE ARE PERIODS WHEN THE LOOP IS IN A STRAIGHT UP AND DOWN POSITION, AT WHICH INSTANT NO CURRENT IS GENERATED AT ALL. THEREFORE, TO OBTAIN A MORE UNIFORM AND USEABLE CURRENT OUTPUT FOR PRACTICAL PURPOSES, WE USE MANY INDUCTORS OR LOOPS, ARRANGING THEM ON AN IRON FORM OR CORE AND WE CALL THIS ENTIRE REVOLVING UNIT OF THE GENERATOR, THE ARMATURE. THEN IN ORDER TO GENERATE HIGHER VOLTAGES, WE USE COILS MADE UP OF SEVERAL TURNS OF WIRE INSTEAD OF THE LOOPS OF A SINGLE TURN.

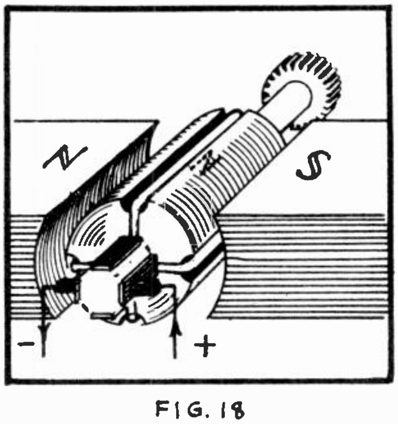


FIG. 18
Motor Details.

ELECTRIC MOTORS

WHILE YOU HAVE THESE GENERATOR PRINCIPLES WELL IN MIND LET US NEXT BECOME BETTER ACQUAINTED WITH ANOTHER IMPORTANT UNIT, WHOSE OPERATING PRINCIPLES ARE CLOSELY RELATED TO THE ELECTRICAL GENERATOR. THIS OTHER UNIT IS THE ELECTRIC MOTOR AND A D.C. MOTOR IS SHOWN IN SIMPLIFIED FORM BOTH IN FIGURES 18 AND 19. THE MOTOR'S PURPOSE IS TO CONVERT ELECTRICAL ENERGY OR POWER INTO MECHANICAL POWER.

IN FIGS. 18 AND 19 WE HAVE TWO MAGNETS,

with an armature supported between them. This armature consists of a laminated iron core, having four slots cut along its length and the inductors or wire loops are firmly held in these slots. The ends of the loops are connected to the segments of the commutator as shown. Two brushes are installed, so as to make contact with two opposite commutator segments and in this way, they will connect the ends of ONE of the armature loops across the external circuit or power supply, which in this case happens to be a battery.

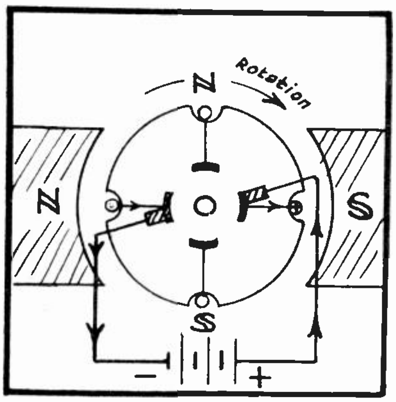


FIG. 19
Simple D.C. Motor

With the armature in the position shown in Fig. 19, the flow of battery current through this loop or coil will cause it to act as an electromagnet, with the upper portion of the armature becoming a north pole and the lower portion a south pole, just as shown in Fig. 19. The vertical loop in Fig. 19 is dead at this time, as no current is flowing through it.

Due to this polarization of the armature, the "S" field magnet of the motor will exert an attractive force upon the "N" section of the armature, while at this same time, the "N" field magnet will exert an attractive force upon the "S" section of the armature. Furthermore, the "N" field magnet and the "N" section of the armature tend to repel eachother and the same is true in respect to the "S" polarities. It thus becomes obvious that this magnetic reaction will cause the armature to rotate in a clockwise direction as indicated by the arrow in Fig. 19.

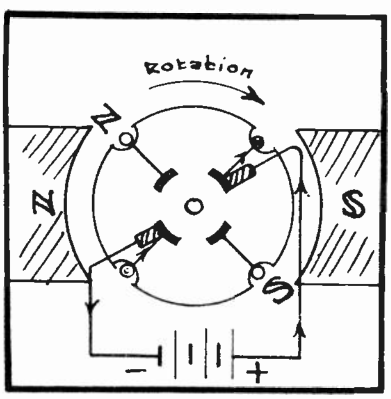


FIG. 20
Commutator Action.

Were it not for the commutator, we would find that after the armature has rotated one quarter revolution from the position pictured in Fig. 19, the north section of the armature would come directly under the influence of the "S" field magnet and the South section of the armature would come directly next to the "N" field magnet. The magnetic attraction would now be so strong as to hold the armature stationary.

To prevent this undesirable condition, we make use of the commutator and the brushes are placed in such a position so as to make contact with a different pair of commutator segments before the armature has completed its quarter revolution, from the position shown in Fig. 19. This is clearly shown in Fig. 20, where you will notice that the commutator segments of the armature coil begin to come in contact with the brushes soon enough, so that the north and south sections of the armature are still near the pole pieces at the instant that this particular armature coil sets up its magnetic field. This means that the like magnetic poles will exert a violent repelling force toward one another and before the armature poles come directly under the face of the field magnets of opposite polarity, the commutator will already have caused current to stop flowing

THROUGH THE COIL IN QUESTION AND TO HAVE PERMITTED THE CURRENT TO NOW FLOW THROUGH THE ARMATURE COIL WHICH WAS FORMERLY DEAD.

THE NEW COIL WILL NOW BECOME THE WORKING COIL AND THUS ANOTHER ROTATIVE IMPULSE IS FURNISHED THE ARMATURE AND JUST BEFORE THESE NEW ARMATURE POLES COME DIRECTLY UNDER THE INFLUENCE OF FIELD MAGNETS OF OPPOSITE POLARITY, THE BRUSHES WILL AGAIN SEND CURRENT THROUGH ANOTHER PAIR OF COMMUTATOR SEGMENTS. THIS ACTION CONTINUES ON IN THIS WAY AND THE ARMATURE KEEPS ON REVOLVING CONSTANTLY AS LONG AS IT IS FURNISHED WITH AN ELECTRIC CURRENT.

THE ROTATION, AS PRODUCED BY ONLY TWO ARMATURE LOOPS, WILL NOT BE UNIFORM BUT THIS CONDITION CAN BE OVERCOME BY USING A GREATER NUMBER OF ARMATURE COILS AND COMMUTATOR SEGMENTS AND THIS YOU WILL FIND TO BE THE CASE IN COMMERCIAL ELECTRIC MOTORS.

MOTOR AND GENERATOR CONSTRUCTION

IN FIG. 21, YOU WILL SEE A PHOTOGRAPH OF A D.C. MOTOR, WITH A SECTION OF THE HOUSING CUT AWAY SO THAT ITS INNER PARTS ARE EXPOSED TO VIEW. NOTICE CAREFULLY IN THIS ILLUSTRATION HOW THE PARTS, WHICH WE HAVE BEEN DISCUSSING, APPEAR ON THE ACTUAL UNIT AND THAT THE FIELD MAGNETS OR POLES ARE ELECTROMAGNETS PROVIDED WITH A WINDING.

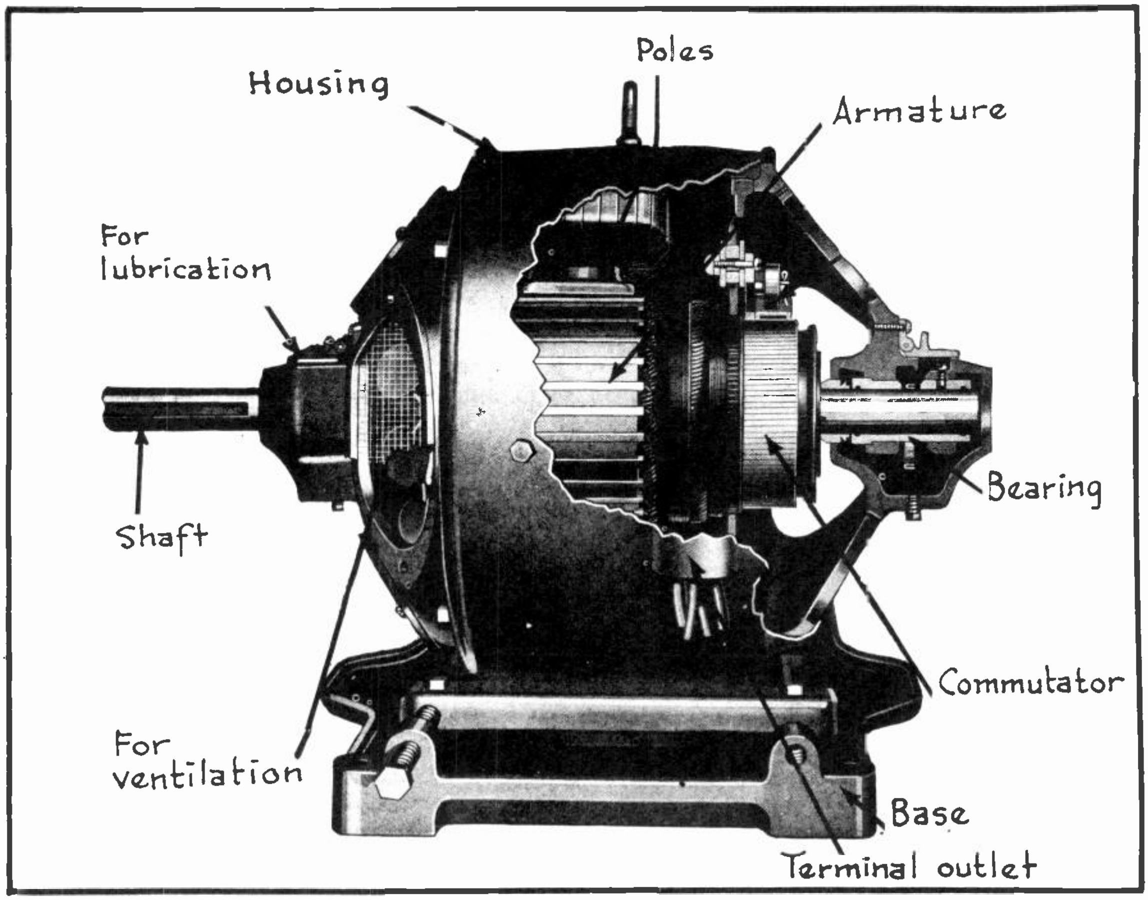


FIG. 21
A Direct Current Motor

SHOULD YOU OPEN UP A DIRECT CURRENT GENERATOR, YOU WOULD FIND ITS INTERNAL CONSTRUCTION TO BE PRACTICALLY THE SAME AS THAT OF THE MOTOR SHOWN IN FIG. 21. IN FACT, BY PASSING A DIRECT CURRENT FROM SOME OUTSIDE SOURCE THROUGH A D.C. GENERATOR, YOU WOULD FIND THAT THE GENERATOR ARMATURE WOULD REVOLVE THE SAME AS THAT OF A MOTOR. THEN AGAIN, SHOULD YOU DRIVE THE ARMATURE OF A MOTOR BY SOME MECHANICAL MEANS YOU WOULD FIND THAT IT WOULD TO A CERTAIN EXTENT ACT AS A GENERATOR OF ELECTRIC CURRENT.

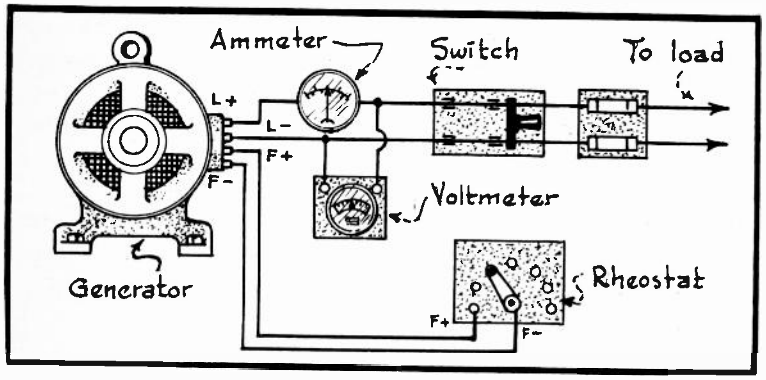


FIG. 22

Typical Generator Control Unit.

THE MOTOR, HOWEVER, CAN GENERATE BUT LITTLE CURRENT WHILE ON THE OTHER HAND A PLAIN GENERATOR WHEN OPERATED AS A MOTOR DOES NOT PRODUCE THE REQUIRED MECHANICAL POWER IN ORDER TO HANDLE HEAVY LOADS AS DOES THE MOTOR. EACH, THEREFORE, IS ESPECIALLY DESIGNED TO FULFILL A DEFINITE PURPOSE.

THERE ARE OF COURSE MANY TYPES OF ELECTRIC MOTORS AND GENERATORS AND TO MASTER ALL OF THE MORE COMPLICATED TYPES, REQUIRE SPECIAL STUDY. YOU ARE BEING TRAINED AS A RADIO SPECIALIST AND NOT AS A MOTOR OR GENERATOR EXPERT. CONSEQUENTLY, THERE IS NO NEED FOR YOU TO STUDY MOTORS, GENERATORS ETC. IN TOO GREAT DETAIL BUT YOU SHOULD BE FAMILIAR WITH THIS TYPE OF EQUIPMENT, WHICH YOU MAY BE CALLED UPON TO USE IN YOUR RADIO WORK.

OPERATING GENERATORS

THE CORRECT METHOD OF OPERATING GENERATORS AND MOTORS IS AN IMPORTANT MATTER AND ONE WHICH YOU CANNOT AFFORD TO OVERLOOK. A TYPICAL CONTROL CIRCUIT FOR A GENERATOR IS SHOWN IN FIG. 22 AND THE GENERATOR SHOULD BE OPERATED ACCORDING TO THE METHODS OUTLINED IN THE FOLLOWING PHARAGRAPHS.

TO START THE GENERATOR, BE SURE THAT THE LINE SWITCH IS OPEN AND THAT THE RHEOSTAT CONTROL SWITCH IS TURNED TO THAT POSITION, WHICH OFFERS MAXIMUM RESISTANCE. THIS POINT IS MARKED ON THE RHEOSTAT IN A SELF-EXPLAINING MANNER.

NOW START THE GENERATOR ARMATURE IN MOTION BY PUTTING ITS DRIVING UNIT INTO OPERATION. THIS DRIVING UNIT MAY BE AN ELECTRIC MOTOR, A GASOLINE ENGINE, ETC. AS SOON AS THE GENERATOR ARMATURE HAS COME UP TO ITS FULL RUNNING SPEED, GRADUALLY TURN THE RHEOSTAT

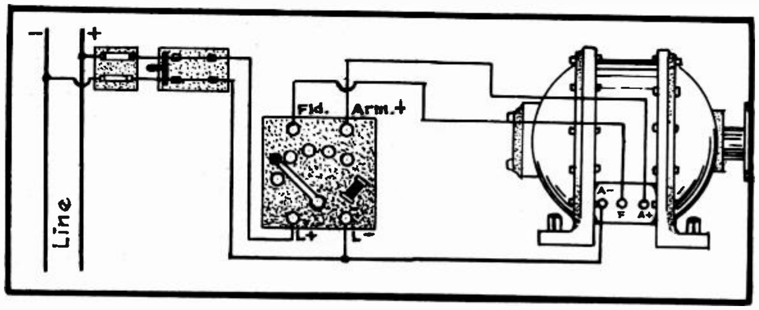


FIG. 23

Typical Motor Control

CONTROL KNOB IN THE DIRECTION INDICATED THEREON, UNTIL THE VOLTAGE OF THE GENERATOR COMES UP TO ITS NORMAL VALUE. THIS DONE, CLOSE THE LINE SWITCH, CAREFULLY WATCHING THE VOLTMETER AND AMMETER DURING THIS PROCESS AND MAKE A FURTHER ADJUSTMENT OF THE RHEOSTAT IF NECESSARY, IN ORDER TO BRING THE GENERATOR TO THE REQUIRED OUTPUT.

IN A GREAT DEAL OF THE MODERN GENERATING EQUIPMENT, NO HAND OPERATED LINE SWITCH IS USED BETWEEN THE GENERATOR AND ITS LOAD. IN SUCH A CASE, THIS LINE SWITCH WILL BE REPLACED WITH AN AUTOMATICALLY OPERATING CIRCUIT BREAKER, WHICH AUTOMATICALLY CONNECTS THE GENERATOR TO THE LOAD AS SOON AS THE GENERATOR VOLTAGE COMES UP TO THE REQUIRED POINT.

IN ORDER TO SHUT DOWN THIS GENERATOR, COMMENCE BY TURNING THE RHEOSTAT CONTROL KNOB SO AS TO REDUCE THE GENERATOR OUTPUT. IF AN AUTOMATIC CIRCUIT BREAKER IS USED, IT WILL DISCONNECT THE GENERATOR FROM THE LOAD AT THE PROPER TIME BUT IF NONE IS USED, THEN YOU WILL HAVE TO INTERRUPT THE CIRCUIT WITH THE HAND OPERATED SWITCH BUT NOT UNTIL THE GENERATOR VOLTAGE IS QUITE LOW. ANY OTHER GENERATOR SWITCH, WHICH MIGHT BE USED, CAN NOW BE OPENED AND THE DRIVING MACHINE CAN THEN BE SHUT DOWN.

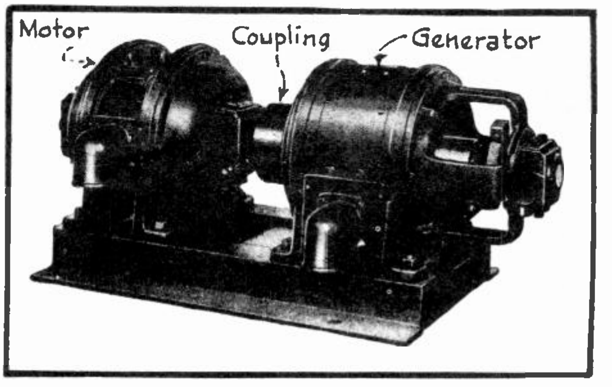


FIG. 24

A Motor Generator Set.

OPERATING MOTORS

ON MANY OF THE SMALLER ELECTRIC MOTORS, ALL THAT MUST BE DONE, IN ORDER TO START THEM, IS TO TURN "ON" A SWITCH. MANY OF THE LARGER MOTORS, HOWEVER, ARE EQUIPPED WITH A STARTING SWITCH OR CONTROL, WHICH ENABLES THE MOTOR TO PICK UP ITS LOAD WITHOUT DRAWING AN EXCESSIVE AND INJURIOUS STARTING CURRENT, AS WELL AS OFFERING A MEANS WHEREBY THE SPEED OF THE MOTOR CAN BE CONTROLLED.

A COMMONLY USED MOTOR CONTROL CIRCUIT IS SHOWN IN FIG. 23. TO START UP SUCH A MOTOR, FIRST SEE TO IT THAT THE CONTROL OF THE STARTING RHEOSTAT IS IN THE "OFF" POSITION AND THEN CLOSE THE MAIN OR LINE SWITCH. NOW GRADUALLY TURN THE RHEOSTAT CONTROL TOWARD THE HIGH OR RUNNING POSITION, PAUSING AT EACH CONTACT FOR A FEW SECONDS AND WAITING FOR THE MOTOR ARMATURE TO PICK UP SPEED OR ACCELERATE UNTIL THE HANDLE REACHES ITS LIMIT OF TRAVEL.

IN ORDER TO STOP THE MOTOR, ALL THAT IS NECESSARY IS TO OPEN THE LINE SWITCH. MOST OF THE STARTING RHEOSTATS ARE SO MADE AS TO CAUSE THE CONTROL ARM TO RETURN TO ITS "OFF" POSITION AUTOMATICALLY. NO ATTEMPT SHOULD BE MADE TO FORCE THE OPERATING ARM OF AN AUTOMATIC STARTING RHEOSTAT BACK TO ITS "OFF" POSITION.

THE MOTOR-GENERATOR

SO FAR, WE HAVE CONSIDERED THE MOTOR AND GENERATOR AS TWO SPEARATE UNITS BUT IN RADIO TRANSMITTING PRACTICE, YOU WILL GENERALLY FIND THE TWO USED TOGETHER IN A COMBINATION, WHICH WE REFER TO AS A MOTOR-GENERATOR. A

TYPICAL MOTOR-GENERATOR SET IS SHOWN IN FIG. 24 AND AS YOU WILL OBSERVE, IT CONSISTS OF A SEPARATE MOTOR AND GENERATOR MOUNTED ON THE SAME BASE, WHILE THEIR ARMATURE SHAFTS ARE COUPLED TOGETHER BY SOME SEMI-FLEXIBLE TYPE COUPLING DEVICE.

ALTHOUGH MOUNTED SO AS TO FORM A SINGLE UNIT, YET FROM AN ELECTRICAL STANDPOINT, THEY ARE ENTIRELY INDEPENDENT FROM EACHOTHER. THE MOST COMMON PRACTICE IS TO USE AN A.C. MOTOR, WHICH IS CONNECTED TO THE A.C. POWER LINES AND THIS MOTOR IN TURN SERVES AS THE DRIVING FORCE TO ROTATE THE GENERATOR ARMATURE. THE GENERATOR IS GENERALLY OF THE D.C. TYPE AND IN THIS WAY, A D.C. SUPPLY FOR THE TRANSMITTER CAN BE GENERATED READILY, EVEN THOUGH THE TRANSMITTER BE LOCATED IN A DISTRICT, WHOSE ONLY POWER SUPPLY IS OF THE A.C. VARIETY.

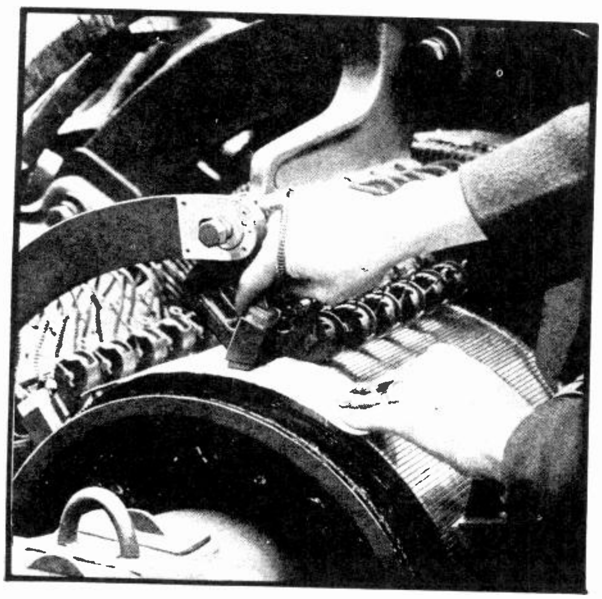


FIG. 25
Sanding the Commutator.

IT IS OF COURSE NOT ALWAYS ESSENTIAL TO USE THIS A.C.-D.C. COMBINATION AS JUST MENTIONED AND THIS SET WOULD STILL BE CLASSIFIED AS A MOTOR-GENERATOR, EVEN THOUGH THE MOTOR WERE OF THE A.C. TYPE DRIVING AN A.C. GENERATOR. THEN TOO, YOU WILL FIND CASES WHERE A SINGLE A.C. MOTOR IS DRIVING TWO OR THREE D.C. GENERATORS, ALL OF WHICH ARE MOUNTED ON A COMMON BASE AND WITH THE ARMATURE SHAFTS ALL CONNECTED END TO END WITH FLEXIBLE COUPLINGS. COMPOUND UNITS AS THIS WOULD STILL BE CLASSIFIED AS MOTOR-GENERATORS.

AS FAR AS THE CONTROL METHODS FOR OPERATING MOTOR-GENERATORS ARE CONCERNED, THEY ARE PRACTICALLY THE SAME AS THOSE OUTLINED FOR THE MOTORS AND GENERATORS SEPARATELY. THAT IS, THE MOTOR PORTION OF THE MOTOR GENERATOR SET IS TREATED AS THOUGH IT WERE AN INDEPENDENT MOTOR AND THE GENERATOR OR GENERATORS, WHICH ARE DRIVEN BY IT, ARE TREATED AS THOUGH THEY WERE INDEPENDENT — IN FACT, THEY ARE.

CARE OF MOTORS AND GENERATORS

ALTHOUGH THESE VARIOUS MOTORS AND GENERATORS MAY APPEAR TO YOU AS BEING RUGGED UNITS OF BRUTE STRENGTH WHEN COMPARED TO GENERAL RADIO EQUIPMENT, YET DON'T BY ANY MEANS OVERLOOK THE FACT THAT THESE MOTORS AND GENERATORS DEMAND AND SHOULD HAVE THE SAME CAREFUL ATTENTION AS THAT GIVEN TO ANY OTHER IMPORTANT PART OF THE TRANSMITTER. A FAILURE OF THEIR OPERATION MEANS THE FAILURE OF THE WHOLE TRANSMITTER.

SINCE MOTORS AND GENERATORS ARE SO MUCH ALIKE IN THEIR CONSTRUCTION, MANY OF THE MINOR TROUBLES WILL BE FOUND TO BE COMMON IN BOTH THESE CLOSELY ASSOCIATED UNITS.

PERIODIC LUBRICATION IS OF UTMOST IMPORTANCE IN ALL TYPES OF MACHINERY

AND MOTORS AND GENERATORS ARE NO EXCEPTIONS. SPECIAL OIL CHAMBERS OR WELLS ARE PROVIDED IN THE BEARING ENDS OF THE UNITS HOUSING AND IT IS ADVISABLE TO SEE THAT THESE ARE ADEQUATELY SUPPLIED WITH THE TYPE OF LUBRICANT RECOMMENDED BY THE MANUFACTURES, EACH TIME BEFORE THE UNIT IS PUT INTO OPERATION.

ANY OIL, WHICH MAY OVERFLOW FROM THE BEARINGS, SHOULD BE WIPED AWAY IMMEDIATELY AND NO DIRT OR DUST SHOULD BE PERMITTED TO ACCUMULATE ANY-WHERES UPON THE UNIT. COMPRESSED AIR OFFERS THE BEST MEANS WITH WHICH TO BLOW OUT DUST OR DIRT FROM A MOTOR OR GENERATOR.

AFTER MOTORS OR GENERATORS HAVE BEEN IN OPERATION FOR SOME TIME, THE COMMUTATOR GENERALLY BECOMES SOMEWHAT ROUGH AND BURNT-LOOKING AND CONTINUOUS SPARKING WILL BE NOTICED BETWEEN THE BRUSHES AND THE COMMUTA-TOR. TO REMEDY THIS CONDITION, HOLD THE ROUGH SIDE OF A PIECE OF #00 SAND PAPER AGAINST THE COMMUTATOR WHILE THE ARMATURE IS REVOLVING, AS SHOWN IN FIG. 25, AND THIS WILL SMOOTH DOWN SLIGHTLY ROUGH SUR-FACES. EMERY CLOTH OR EMERY PAPER SHOULD NEVER BE USED FOR THIS PUR-POSE.

IN EXTREME CASES OF COMMUT-ATOR WEAR, SANDING WILL BE FOUND TO BE INSUFFICIENT AND IN SUCH A CASE, IT BECOMES NECESSARY TO DISMANTEL THE UNIT AND "MACHINE-DOWN" THE COMMU-TATOR IN A LATHE.

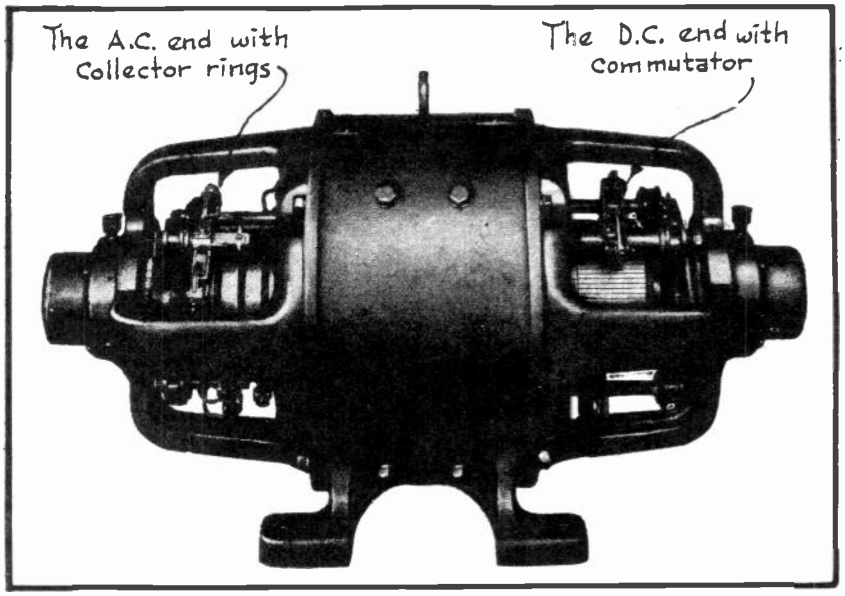


FIG. 26

A Synchronous Converter. Showing the A.C. and D.C. Ends.

BRUSHES IN EITHER A MOTOR OR GENERATOR SHOULD FIT WELL IN THEIR HOLDERS. THIS FIT SHOULD NOT BE LOOSE ENOUGH SO AS TO PERMIT THE BRUSH TO BE JARRED ABOUT AND YET NOT TIGHT ENOUGH SO AS TO PREVENT THE BRUSH SPRINGS FROM EXERTING THEIR FULL FORCE TOWARD PRESSING THE BRUSHES A-GAINST THE COMMUTATOR. THE EDGE OF THE BRUSHES, WHICH RIDES ON THE COMMU-TATOR, SHOULD BE SMOOTH AND MAKING CONTACT ACROSS ITS ENTIRE SURFACE AGAINST THE COMMUTATOR. IN THE CASE OF STICKING BRUSHES, THIS MAY BE FOUND TO BE DUE TO GREASE AND DIRT HAVING ACCUMULATED BETWEEN THE BRUSH AND BRUSH HOLDER AND SHOULD THIS BE TRUE, THESE FOREIGN MATERIALS CAN BE RE-MOVED BY WASHING THE BRUSH AND HOLDER WITH GASOLINE WHILE THE MACHINE IS AT REST — DON'T USE KEROSENE.

IN DUE TIME, THE BRUSHES WILL DECREASE IN LENGTH BECAUSE OF WEAR AND IF THE BRUSHES ARE MATERIALLY SHORTENED BY THIS CAUSE, THEY SHOULD

BE REPLACED WITH NEW ONES OF THE SAME SIZE AND TYPE AS THOSE ORIGINALLY USED IN THE MACHINE AT THE TIME OF ITS CONSTRUCTION.

A GENERAL CHECK-UP SHOULD BE MADE NOW AND THEN, IN ORDER TO INSURE THAT ALL ELECTRICAL CONNECTIONS ARE SECURE AND IN FIRST CLASS CONDITION.

CONVERTERS

NOW ANOTHER POWER UNIT, WHICH IS USED IN RADIO WORK, IS THE ROTARY CONVERTER — SOMETIMES CALLED THE SYNCHRONOUS CONVERTER. THIS UNIT CONSISTS OF A SINGLE ARMATURE, HAVING A.C. COLLECTOR RINGS AT ONE END AND A D.C. COMMUTATOR AT THE OTHER END AND THE SAME ARMATURE WINDING IS USED FOR BOTH ENDS.

ITS PURPOSE IS TO MAKE USE OF AN ALTERNATING CURRENT POWER SUPPLY WHICH IS CONNECTED TO THE A.C. END OF THE UNIT AND THUS DRIVES THE ARMATURE AS AN A.C. MOTOR. THIS REVOLVING OF THE ARMATURE AT THE SAME TIME GENERATES AN ELECTRIC CURRENT AND BY MEANS OF THE COMMUTATOR AT THE OTHER END OF THE UNIT,A DIRECT CURRENT WILL BE DELIVERED FROM IT. IN OTHER WORDS, THE ROTARY CONVERTER IS MADE TO USE AN A.C. SUPPLY, IN ORDER TO PRODUCE A D.C. OUTPUT.

IN THIS RESPECT, THE ROTARY CONVERTER SERVES THE SAME PURPOSE AS A MOTOR-GENERATOR SET BUT FOR RADIO PURPOSES,THE MOTOR-GENERATOR SET IS MOST COMMONLY USED BECAUSE IT DOESN'T INTRODUCE THE A.C. LINE VOLTAGE VARYING CHARACTERISTICS INTO THE D.C. OUTPUT, AS IS THE CASE WITH A ROTARY CONVERTER.

INSTEAD OF SUPPLYING THE CONVERTER WITH AN A.C. SUPPLY IN ORDER TO PRODUCE A D.C. OUTPUT, IT IS EQUALLY TRUE THAT WE CAN HAVE A CONVERTER IN WHICH WE PROVIDE A D.C. SUPPLY AND RECEIVE AN A.C. OUTPUT IN RETURN. THE UNIT THEN BECOMES WHAT IS CORRECTLY CALLED AN INVERTED ROTARY OR SYNCHRONOUS CONVERTER AND ONE SUCH UNIT IS SHOWN YOU IN FIG.26.

IN GENERAL APPEARANCE AND CONSTRUCTION,THE ROTARY CONVERTER AND THE INVERTED ROTARY CONVERTER ARE THE SAME AND THE ONLY DIFFERENCE IS THAT THEIR OUTPUT AND INPUT CHARACTERISTICS ARE REVERSED. FIG.26 SHOWS YOU CLEARLY HOW THE A.C. COLLECTOR RINGS ARE MOUNTED ON ONE END OF THE ARMATURE, WHILE THE D.C. COMMUTATOR IS MOUNTED ON THE OTHER END.

THE INVERTED ROTARY CONVERTER IS ESPECIALLY ADAPTABLE IN SUCH LOCALITIES WHERE A D.C. POWER SUPPLY IS PROVIDED BUT WHERE A.C. RADIO EQUIPMENT HAS TO BE OPERATED. IN FACT, INVERTED ROTARY CONVERTERS ARE NOW BEING MARKETED AT A REASONABLE PRICE, WHICH WILL OPERATE AT 32, 115, OR 230 VOLTS D.C., IN ORDER TO PRODUCE AN OUTPUT OF 110 VOLTS-60 CYCLE A.C., WITH WHICH TO OPERATE RADIO EQUIPMENT.

THE GENERAL CARE, OPERATION AND INSPECTION OF CONVERTERS IS MUCH THE SAME AS OUTLINED FOR YOU IN OUR DISCUSSION OF MOTORS AND GENERATORS.

THE DYNAMOTOR

STILL ANOTHER POWER UNIT IS KNOWN AS THE DYNAMOTOR. THIS DEVICE IS

SIMILAR TO THE CONVERTER IN THAT IT USES A SINGLE ARMATURE, WITH A COMMUTATOR AT ONE END AND COLLECTOR RINGS AT THE OTHER END. THE A.C. AND D.C. PORTION OF THE UNIT MAKE USE OF THE SAME FIELD WINDING, THE SAME AS IN THE CONVERTER BUT THE BIG DIFFERENCE BETWEEN THE DYNAMOTOR AND CONVERTER IS THAT THE DYNAMOTOR HAS TWO SETS OF ARMATURE WINDINGS.

THESE TWO INDEPENDENT ARMATURE WINDINGS, HOWEVER, ARE WOUND TOGETHER IN THE SAME SLOTS BUT ARE THOROUGHLY INSULATED FROM EACHOTHER. ONE OF THE WINDINGS IS CONNECTED TO THE COLLECTOR RINGS, WHEREAS THE OTHER IS CONNECTED TO THE COMMUTATOR. DUE TO THE USE OF SEPARATE WINDINGS THERE IS LESS NEED FOR FILTERING THE D.C. OUTPUT BECAUSE THE A.C. LINE CHARACTERISTICS ARE NOT CARRIED OVER INTO THE D.C. OUTPUT, AS MUCH AS IS THE CASE WHERE THE SAME ARMATURE WINDING IS COMMON TO BOTH THE A.C. AND D.C. PARTS OF THE UNIT, AS FOUND IN THE CONVERTER. LESS INTERFERENCE IS ALSO EXPERIENCED WITH THE DYNAMOTOR THAN WITH THE CONVERTER.

THIS IS A VERY IMPORTANT LESSON AND A GREAT DEAL OF WORK HAS BEEN COVERED HEREIN. IT IS THEREFORE NECESSARY THAT YOU MASTER THIS LESSON THOROUGHLY AND IF NECESSARY TO STUDY IT EVEN A SECOND OR THIRD TIME.

THE DETAILS CONCERNING THE CONSTRUCTION AND OPERATING CHARACTERISTICS OF TRANSMITTER TYPE RECTIFIER TUBES, AS WELL AS THE PRACTICAL OPERATION OF POWER MACHINERY RELATING TO TRANSMITTERS, WILL BE THOROUGHLY EXPLAINED IN LATER LESSONS OF THIS TRANSMITTER SERIES.

IN THE LESSON IMMEDIATELY FOLLOWING, YOU ARE GOING TO HAVE THE OPPORTUNITY OF STUDYING ABOUT THE CONSTRUCTIONAL FEATURES AND CORRECT METHODS OF OPERATING RADIO-TELEGRAPH TRANSMITTERS IN THEIR COMPLETE FORM.

THIS COMING LESSON WILL ANSWER FOR YOU THE MANY QUESTIONS WHICH WOULD PERHAPS ARISE IN YOUR MIND IF YOU WERE PLACED BEFORE A RADIO- TELEGRAPH TRANSMITTER AND TOLD TO OPERATE IT. THIS BEING THE CASE, YOU CAN READILY SEE THAT THIS COMING LESSON IS NOT GOING TO BE ESPECIALLY INTERESTING BUT ALSO OF GREAT TECHNICAL VALUE.

Examination Questions

LESSON NO. T-10

Feb 11, 1942

"Its the easiest thing in the world for a man to deceive himself."

1. – NAME THE VARIOUS COMPONENTS WHICH CONSTITUTE THE POWER SUPPLY OF THE CONVENTIONAL TRANSMITTER AND EXPLAIN HOW THESE VARIOUS UNITS DIFFER FROM THE CORRESPONDING UNITS AS USED IN RADIO RECEIVERS.

2. – DRAW A CIRCUIT DIAGRAM OF A TWO-PHASE, THREE-WIRE ELECTRICAL SYSTEM AND DESCRIBE ITS ELECTRICAL CHARACTERISTICS, THAT IS, THE VOLTAGE AND CURRENT DISTRIBUTION ETC.

3. – WHAT IS AN OUTSTANDING ADVANTAGE OF USING A THREE-PHASE RECTIFIER SYSTEM FOR A TRANSMITTER?

4. – EXPLAIN WHAT IS MEANT BY THE VOLTAGE REGULATION OF A POWER SUPPLY AND DESCRIBE HOW IT MAY BE DETERMINED.

5. – HOW MAY THE PERCENT OF RIPPLE OF A POWER SUPPLY BE DETERMINED?

6. – DRAW A CIRCUIT DIAGRAM OF A RECTIFYING SYSTEM EMPLOYING A THREE-PHASE, FULL-WAVE ARRANGEMENT.

7. – ILLUSTRATE BY MEANS OF SCHEMATIC DIAGRAMS THE FOLLOWING THREE-PHASE TRANSFORMER CONNECTIONS:
(1) STAR-STAR CONNECTION; (2) DELTA-STAR CONNECTION;
(3) DELTA-DELTA CONNECTION; (4) STAR-DELTA CONNECTION.

8. – EXPLAIN THE OPERATING PRINCIPLES OF A D.C. GENERATOR AND ILLUSTRATE YOUR EXPLANATION BY MEANS OF A DIAGRAM.

9. – DRAW A CIRCUIT DIAGRAM OF A MOTOR CONTROL CIRCUIT AND EXPLAIN HOW YOU WOULD OPERATE THIS SYSTEM.

10.– DRAW A CIRCUIT DIAGRAM OF A GENERATOR CONTROL CIRCUIT AND EXPLAIN HOW YOU WOULD OPERATE THIS SYSTEM.

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RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO. T-11

RADIO TELEGRAPH TRANSMITTERS

UP TO THIS TIME IN YOUR TRANSMITTER STUDIES, YOU HAVE CENTERED YOUR ENTIRE ATTENTION UPON SPECIFIC SECTIONS OF RADIO TELEGRAPH TRANSMITTERS AND NOW THAT YOU ARE WELL ACQUAINTED WITH THESE VARIOUS PARTS, THE NEXT LOGICAL STEP WILL BE TO STUDY TRANSMITTERS OF THIS TYPE AS A WHOLE. WE SHALL NATURALLY START WITH THE MORE SIMPLE MULTI-TUBE TRANSMITTERS AND GRADUALLY ADVANCE THROUGH THE MORE COMPLEX EQUIPMENT.

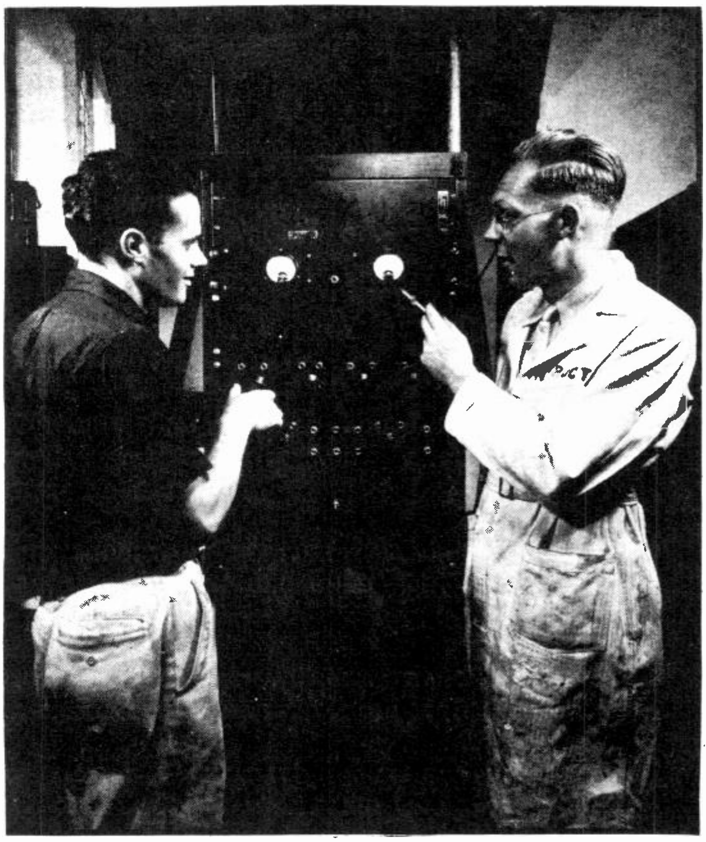

FIG. 1
TUNING NATIONAL'S TRANSMITTER.

A BATTERY OPERATED TRANSMITTER

IN FIG. 2 YOU ARE SHOWN A FRONT AND REAR VIEW OF AN EFFICIENT LOW-POWER BATTERY-OPERATED TRANSMITTER AND THE CIRCUIT DIAGRAM OF THIS SAME UNIT APPEARS IN FIG. 3. THIS TRANSMITTER, YOU WILL OBSERVE, CONSISTS OF A PUSH-PULL, TUNED-GRID, TUNED-PLATE OSCILLATOR STAGE IN WHICH A PAIR OF TYPE 30 TUBES ARE EMPLOYED. THE POWER AMPLIFIER IS ALSO OF PUSH-PULL DESIGN AND USES A PAIR OF TYPE -33 TUBES.

COIL L_2 ACTS AS AN AUTO-TRANSFORMER AND FURNISHES SUFFICIENT STEP-UP OF R.F. VOLTAGE TO SWING THE PENTODE GRIDS FOR MAXIMUM EXCITATION. AT THE SAME TIME IT SERVES AS A COUPLING

BETWEEN THE OSCILLATOR AND AMPLIFIER AND ALSO SERVES AS A PART OF THE TUNING SYSTEM IN THE PLATE CIRCUIT OF THE OSCILLATOR.

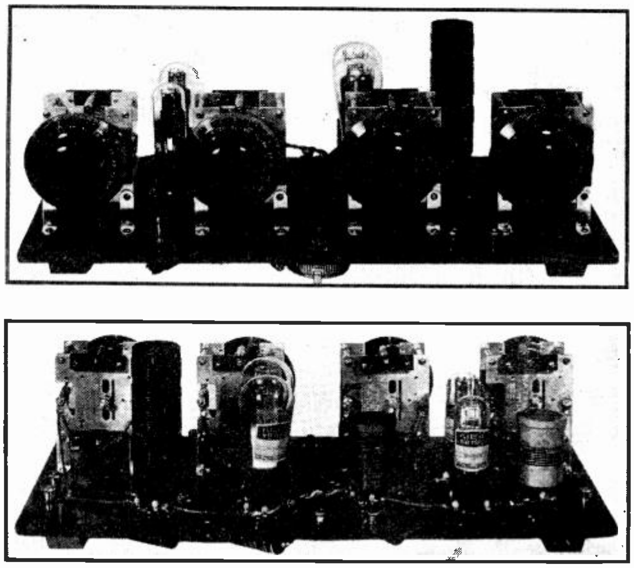

FIG. 2

Front and Back Views of a Battery-Operated Transmitter.

THE NEUTRALIZING CAPACITIES C_7 AND C_8 IN THE POWER AMPLIFIER CIRCUIT ARE MADE BY ATTACHING 4" LENGTHS OF RUBBER COVERED HOOK-UP WIRE TO EACH GRID AND PLATE SOCKET TERMINAL. EACH GRID WIRE IS TWISTED WITH THE PLATE WIRE OF THE OPPOSITE TUBE AND WHEN SUFFICIENT CAPACITY FOR NEUTRALIZATION HAS BEEN OBTAINED IN THIS MANNER, THE REMAINING WIRE IS CUT-OFF. IT IS IMPORTANT THAT THE OPEN ENDS OF THESE WIRES DO NOT MAKE CONTACT AS THIS WOULD SHORT CIRCUIT THE "B" AND "C" BATTERIES.

ALL OTHER CONSTRUCTIONAL FEATURES OF THIS TRANSMITTER WILL BE OBVIOUS UPON STUDYING FIGS. 2 AND 3 CAREFULLY. DATA CONCERNING THE ELECTRICAL VALUES OF THE VARIOUS PARTS USED IN THIS CIRCUIT FOLLOWS:

C_1-C_2-C_3-C_4	350 MMFD. VARIABLE CONDENSERS.
C_5-C_6-C_9-C_{10}	200 MMFD. FIXED CONDENSERS.
R_1	10,000 OHM CARBON RESISTOR.
R_2	2 OHM RHEOSTAT
RFC	SHORT-WAVE TRANSMITTING TYPE R.F. CHOKES.
K	TELEGRAPH KEY.
SW	SWITCH

TABLE I

COIL SPECIFICATIONS					
BAND	L_1 TURNS	L_2 TURNS	X TURNS	L_3 TURNS	L_4 TURNS
1715 Kc	26	40	26	40	12
3500 Kc	14	30	14	30	10
7000 Kc	8	18	8	18	9
14000 Kc	4	10	4	10	7

COILS L_1 AND L_2 ARE BOTH WOUND ON TYPE R-39 NATIONAL COIL FORMS. L_1 IS CENTER-TAPPED AND L_2 IN ADDITION TO BEING CENTER TAPPED ALSO HAS TWO ADDITIONAL TAPS AS SPECIFIED IN TABLE I. THE AMPLIFIER PLATE COIL L_3 AND THE ANTENNA COUPLING COILS L_4 ARE WOUND ON THE SAME BAKELITE FORM WHICH IS 5" LONG AND WHOSE INSIDE DIAMETER IS SUCH AS TO FIT SNUGLY OVER A TUBE

BASE TO WHICH IT IS CEMENTED. ALL OF THE COILS ARE WOUND WITH #20 B&S ENAMELED WIRE. THE COILS FOR THE 7000 AND 14,000 KC. BANDS ARE SINGLE SPACED WHILE ALL OTHERS ARE CLOSE-WOUND.

THE COUPLING BETWEEN COILS L_3 AND L_4 SHOULD BE VARIED UNTIL THE BEST RESULTS ARE OBTAINED BY EXPERIMENT.

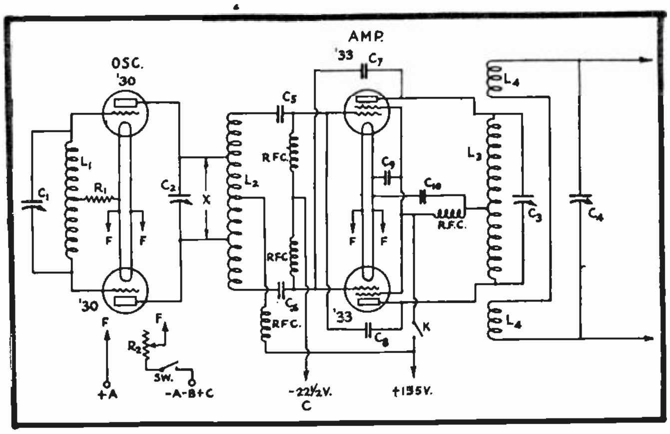

FIG. 3

Diagram of Battery-Operated Transmitter.

A MEDIUM POWER TRANSMITTER

THE COMPLETE CIRCUIT DIAGRAM FOR AN A.C.- OPERATED OSCILLATOR- AMPLIFIER TRANSMITTER APPEARS IN FIG. 4. THIS TRANSMITTER IS EQUIPPED WITH A TYPE 59 TUBE OPERATING AS A TRI-TET OSCILLATOR FEATURING CRYSTAL CONTROL, AND A TYPE 210 TUBE IS USED IN THE POWER AMPLIFIER STAGE. SEPARATE POWER PACKS ARE USED FOR THE OSCILLATOR AND AMPLIFIER STAGE.

THE POWER PACK FOR THE OSCILLATOR NEEDS ONLY TO FURNISH A "B" SUPPLY OF ABOUT 15 MA. AND THEREFORE FOR THIS PURPOSE AN ORDINARY RECEIVER TYPE POWER SUPPLY CAN BE USED. THIS USE OF A SEPARATE POWER SUPPLY FOR THE OSCILLATOR PERMITS THE OSCILLATOR TO OPERATE ABSOLUTELY STEADY IN THAT IT IS ENTIRELY UNAFFECTED BY KEYING OF THE AMPLIFIER. THE "B" VOLTAGES AT THE OUTPUT OF THIS POWER PACK ARE ADJUSTED FOR THE VOLTAGES DESIGNATED ON THE DIAGRAM BY MEANS OF THE SLIDING TAPS ON THE VOLTAGE DIVIDER.

THE POWER PACK FOR THE AMPLIFIER HERE USED MUST BE CAPABLE OF FURNISHING A "B" SUPPLY OF 100 MA. AT 450 VOLTS. TO MEET THIS DEMAND. THIS POWER TRANSFORMER SHOULD DEVELOP 600 VOLTS ACROSS EACH SIDE OF THE CENTER TAP AND TWO TYPE-81 TUBES OR A SINGLE 5Z3 MAY BE USED AS THE RECTIFIER. A SEPARATE TRANSFORMER IS USED FOR FURNISHING THE FILAMENT SUPPLY FOR THE

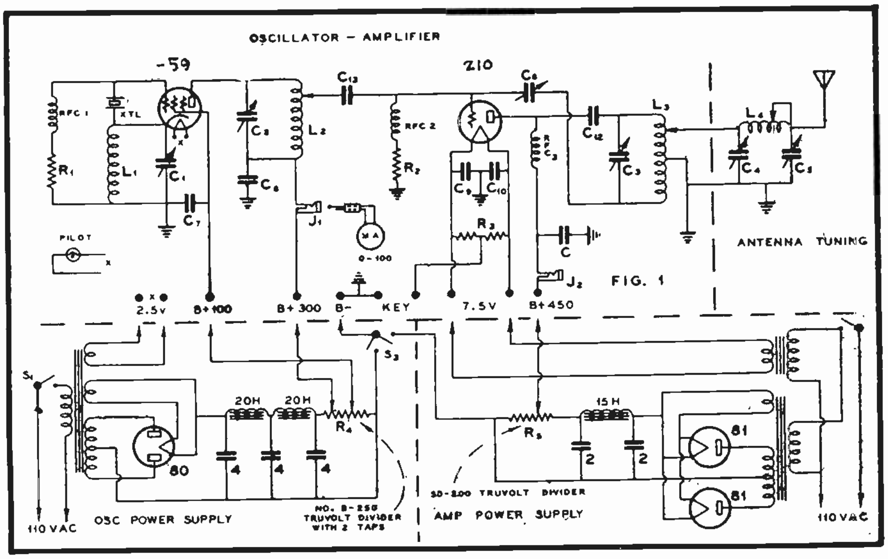

FIG. 4

The A.C. Operated Transmitter.

THE 210 TUBE. SWITCH S_3 IS PROVIDED SO THAT THE B- CIRCUITS CAN BE INTERRUPTED DURING PERIODS OF RECEPTION. IN THIS WAY THE TUBE FILAMENTS ARE PERMITTED TO REMAIN HOT AND THUS PERMIT THE TRANSMITTER TO COME INTO INSTANT OPERATION AS SOON AS THE "B" CIRCUIT IS COMPLETED.

THE PARTS VALUES FOR THE CIRCUIT OF FIG.4 ARE GIVEN TO YOU IN TABLE II.

TABLE II

C_1–C_2–C_3–	140 MMFD VARIABLE CONDENSERS.
C_4	500 MMFD. " "
C_5	220 MMFD. " "
C_6	50 MMFD DOUBLE SPACED NEUTRALIZING CONDENSER
C_7–C_8–C_9–C_{10} –C_{11}	.005 MFD. 1000 VOLT MICA CONDENSERS
C_{12}	.005 MFD. 2500 VOLT MICA CONDENSER
C_{13}	.00025 MFD. 1000 VOLT MICA CONDENSER
R_1	50,000 OHM 2 WATT
R_2	10,000 OHM NON-INDUCTIVE 100 WATT
R_3	60 OHM WIRE-WOUND AND CENTER TAPPED
R_4	25,000 OHM DIVIDER WITH TWO SLIDER TAPS
R_5	20,000 OHM DIVIDER WITH TWO SLIDER TAPS
RF_1 – RF_2	8 MH. CHOKES
RF_3	5 MH. HEAVY DUTY CHOKES
J_1–J_2	SINGLE CLOSED CIRCUIT JACKS WITH ONE PHONE PLUG
0–100 MA	0–100 MILLIAMMETER
XTAL	CRYSTAL FOR FREQUENCIES BEING USED

THE COIL DATA FOR THIS SAME TRANSMITTER FOLLOWS:

FOR 40 METERS:

L_1	16 TURNS #20 D.C.C.
L_2	19 TURNS #20 D.C.C. TAPPED AT 14TH TURN
L_3	14 TURNS #14 BARE

FOR 80 METERS:

L_2	30 TURNS #20 D.C.C. TAPPED AT 20TH TURN
L_3	25 TURNS #14 BARE

FOR BOTH BANDS L_1 AND L_2 MAY BE WOUND ON 4 PRONG PLUG-IN FORMS OF 1 3/4" DIAMETER, WHEREAS FORMS OF 2½" DIAMETER AND WHICH ARE SUPPORTED BY STAND-OFF INSULATORS ARE TO BE USED FOR L_3 AND L_4. THE TURNS ARE SPACED EQUAL TO THE DIAMETER OF THE WIRE. L_4 SHOULD CONSIST OF 25 TURNS OF #14 BARE COPPER WIRE.

IN THE PARTICULAR TRANSMITTER WHICH IS ILLUSTRATED IN FIG.4, THE OSCILLATOR AND AMPLIFIER ARE BUILT AS ONE UNIT, THE ANTENNA TUNING ARRANGEMENT AS ANOTHER AND EACH OF THE POWER SUPPLIES IS AN INDIVIDUAL UNIT AND WIRED TO THE TRANSMITTER PROPER. THE JACK ARRANGEMENT PERMITS THE USE OF A SINGLE MILLIAMMETER FOR MEASURING THE PLATE CURRENT OF EITHER THE OSCILLATOR OR THE AMPLIFIER.

TUNING THE TRANSMITTER

THE TUNING OF THIS TRANSMITTER IS CARRIED OUT IN THE FOLLOWING MANNER:

FOR OPERATION ON THE CRYSTAL FREQUENCY, USE THE CORRESPONDING COIL COMBINATION, SHORT OUT THE L_1 SOCKET, CONNECT THE MILLIAMMETER TO JACK J_1, TURN ON BOTH POWER PACKS, LEAVING THE TRANSMITTER KEY IN THE OPEN POSITION SO THAT NO CURRENT IS APPLIED TO THE PLATE OF THE POWER AMPLIFIER.

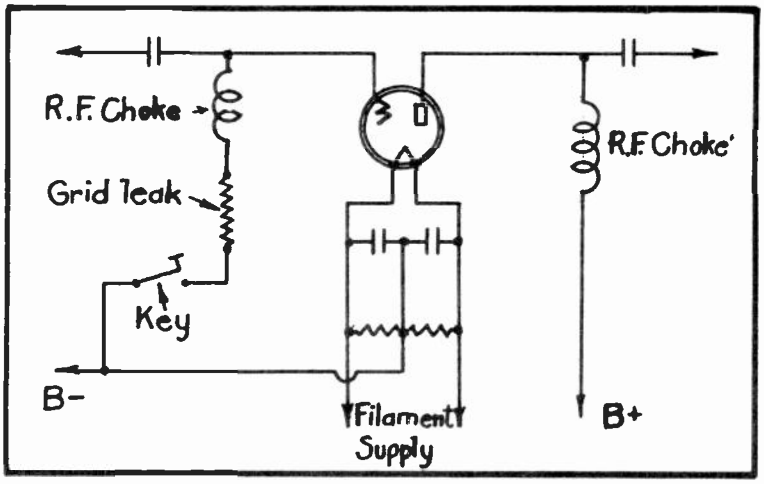

FIG. 5

Grid-leak Keying.

TURN C_6 AND C_3 TO ZERO. TUNE C_2 FOR MINIMUM PLATE CURRENT — A CRITICAL SPOT WILL BE FOUND BUT THE CONDENSER SHOULD BE SET FOR A LITTLE LOWER CAPACITY THAN THE MINIMUM REQUIRES. TOUCH A NEON TUBE TO THE TOP OF L_3 AND TUNE C_3 FOR MAXIMUM GLOW. NOW TURN IN C_6 SLOWLY (MAKING A SLIGHT READJUSTMENT ON C_2 TO KEEP THE OSCILLATOR STABLE) AND ROCK C_3 BACK AND FORTH UNTIL THE GLOW DISAPPEARS AND CANNOT BE OBTAINED WITH ANY SETTING OF C_3. THE AMPLIFIER TUBE IS THEN NEUTRALIZED.

SWITCH THE MILLIAMMETER TO J_2, PRESS THE KEY (WITH THE AERIAL OFF) AND TUNE C_3 SHARPLY FOR MINIMUM PLATE CURRENT.

IN ORDER TO "DOUBLE" THE CRYSTAL FREQUENCY, USE THE 40 METER COIL COMBINATION AND TUNE C_1 AND C_2 FOR MINIMUM PLATE CURRENT AS INDICATED WHEN THE MILLIAMMETER IS INSERTED IN JACK J_1. TUNE C_3 FOR MINIMUM PLATE CURRENT AS INDICATED WHEN THE MILLIAMMETER IS INSERTED IN JACK J_2.

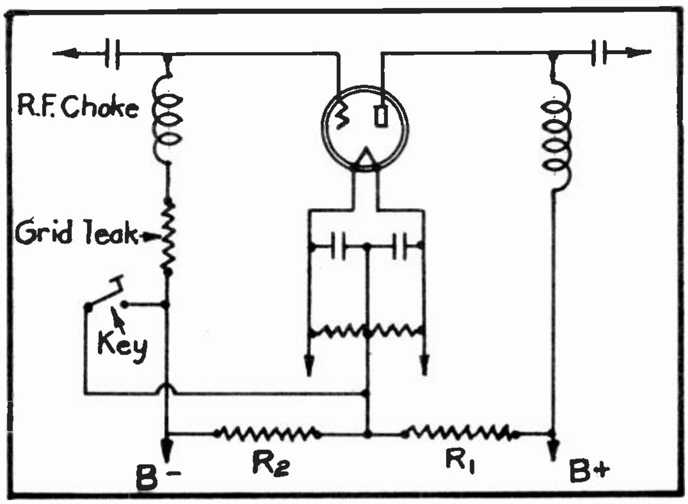

FIG. 6

Blocking Grid With Bias Voltage.

TO ADJUST THE ANTENNA COUPLING CIRCUIT MAKE THE CLIP CONNECTION TO L_3 EXPERIMENTALY AND THE TAP CONNECTION AT L_4 SHOULD BE MADE SO THAT APPROXIMATELY ONE-HALF OF THIS WINDING WILL BE USED. UPON ROTATING C_4 RAPIDLY, WITH C_5 ABOUT HALF IN, A DIP SHOULD BE NOTICED IN THE PLATE CURR-

ENT OF THE POWER AMPLIFIER TUBE. CONTINUE BY ADJUSTING C_5, JUGGLING IT AGAINST C_4 UNTIL THE AMPLIFIER TUBE IS SAFELY LOADED AND AN ANTENNA AMMETER OR FLASHLIGHT LAMP SHOWS A MAXIMUM INDICATION. A 2.5 VOLT PILOT LIGHT FURNISHES A GOOD BRILLIANT INDICATION WITH THE PLATE LOAD ABOUT 65 MA. AT 450 VOLTS.

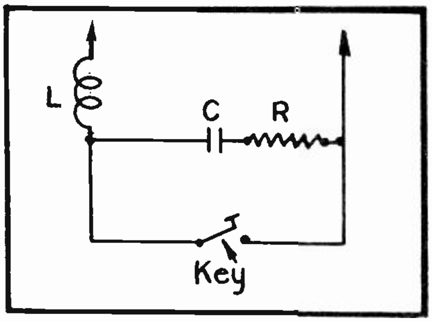

FIG. 7
A Key Filter.

METHODS OF KEYING

BEFORE WE GO INTO DETAILS CONCERNING THE MORE POWERFUL COMMERCIAL TRANSMITTERS THERE ARE SOME IMPORTANT FACTS WHICH WE MUST CONSIDER REGARDING SPECIAL TYPES OF KEYING CIRCUITS WHICH ARE EMPLOYED IN CODE TRANSMITTERS OF MORE ELABORATE DESIGN.

AS YOU WILL HAVE NOTICED FROM THE TRANSMITTER CIRCUITS WHICH WERE SHOWN YOU SO FAR, IT HAS BECOME THE GENERAL PRACTICE TO INCLUDE THE KEY IN THE TRANSMITTER CIRCUIT IN SUCH A MANNER THAT THE "B" CIRCUIT OF A TUBE IS SUCCESSIVELY COMPLETED AND INTERRUPTED IN ORDER TO FORM THE CHARACTERS OF THE CODE. SINCE YOU HAVE ALREADY HAD THE OPPORTUNITY OF INSPECTING MANY CIRCUITS OF THIS TYPE WE SHALL NOT SPEND ANY MORE TIME UPON THEM NOW.

GRID-LEAK KEYING

A SOMEWHAT DIFFERENT KEYING METHOD IS ILLUSTRATED IN FIG. 5. THIS METHOD PERMITS THE PLATE CIRCUIT OF THE TUBE TO BE COMPLETE AT ALL TIMES, AND THE KEY SIMPLY BREAKS THE D.C. GRID RETURN CIRCUIT.

WHEN THE KEY IS IN THE OPEN POSITION THE GRID RETURN CIRCUIT IS ALSO OPEN AND THIS CONDITION WILL CAUSE ELECTRONS TO ACCUMULATE ON THE GRID TO SUCH AN EXTENT THAT THE NEGATIVE CHARGE WILL BECOME GREAT ENOUGH TO BLOCK THE TUBE AND THEREBY PREVENT ANY FURTHER PASSAGE OF PLATE CURRENT THROUGH IT. WHEN USED, THIS METHOD IS MORE SUCCESSFUL WHEN KEYING THE GRID LEAK CIRCUIT OF A TUBE WHICH HAS A HIGH AMPLIFICATION RATHER THAN ONE HAVING A LOW AMPLIFICATION FACTOR. THE REASON FOR THIS IS THAT A LOWER BLOCKING VOLTAGE IS REQUIRED FOR A HIGH-MU TUBE THAN FOR A LOW-MU TUBE. IT IS ALSO IMPERATIVE THAT GOOD INSULATION BE USED IN THE KEY WHEN EMPLOYING THIS SYSTEM, OTHERWISE SOME OF THE ELECTRON CHARGE MAY LEAK OFF THE GRID AND THEREBY PERMIT SOME PLATE CURRENT TO FLOW EVEN THOUGH THE KEY BE OPEN. ANY SUCH RESULTING RADIATION WHICH OCCURS DURING SPACES IN KEYING IS CALLED A "BACK-WAVE" AND IS OF COURSE UNDESIRABLE.

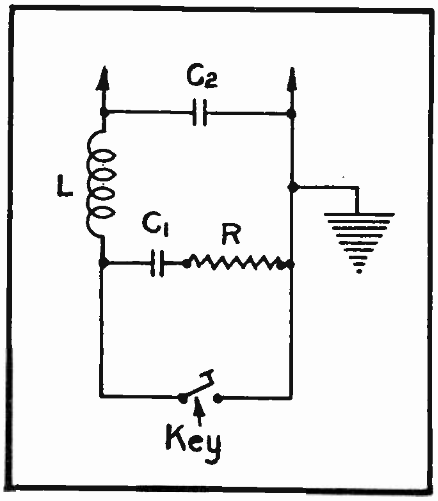

FIG. 8
Another Key Filter.

ANOTHER BLOCKED-GRID KEYING METHOD

IN FIG. 6 YOU ARE SHOWN A CIRCUIT WHICH ALSO HAS THE KEY INSTALLED IN THE

GRID RETURN CIRCUIT BUT INSTEAD OF DEPENDING UPON THE TUBE TO BLOCK ON ACCOUNT OF AN EXCESSIVE ELECTRON ACCUMULATION WHEN THE GRID RETURN CIRCUIT IS INTERRUPTED, THE CIRCUIT OF FIG. 6 ACTUALLY APPLIES A DEFINITE SURPLUS BIAS VOLTAGE TO THE TUBE'S GRID SO THAT THE TUBE IS ABSOLUTELY ASSURED OF BLOCKING.

BY STUDYING FIG.6 CLOSELY, YOU WILL OBSERVE THAT THE BLOCKING BIAS IS OBTAINED FROM THE PLATE SUPPLY THROUGH A VOLTAGE DIVIDER. THE CENTER-TAP OF THE TUBE'S FILAMENT IS CONNECTED TO THE JUNCTION OF R_1 AND R_2 AND THE GRID RETURN IS CONNECTED TO THE NEGATIVE SIDE OF THE POWER SUPPLY. THEREFORE, WHEN THE KEY IS OPEN, THE VOLTAGE DROP ACROSS R_2 IS APPLIED AS BIAS TO THE GRID OF THE TUBE. THIS SERVES AS ADDITIONAL BIAS, CAUSING THE TUBE TO BLOCK WHEN THE KEY IS OPEN.

UPON CLOSING THE KEY, R_2 IS SHORT-CIRCUITED, THEREBY REDUCING THE BIAS VOLTAGE THE PROPER AMOUNT SO THAT THE TUBE CAN OPERATE NORMALLY. RESISTOR R_1 MAY BE THE REGULAR BLEEDER RESISTOR FOR THE POWER SUPPLY AND R_2 CAN IN THE MAJORITY OF CASES HAVE A VALUE OF ABOUT ONE-HALF THAT OF R_1.

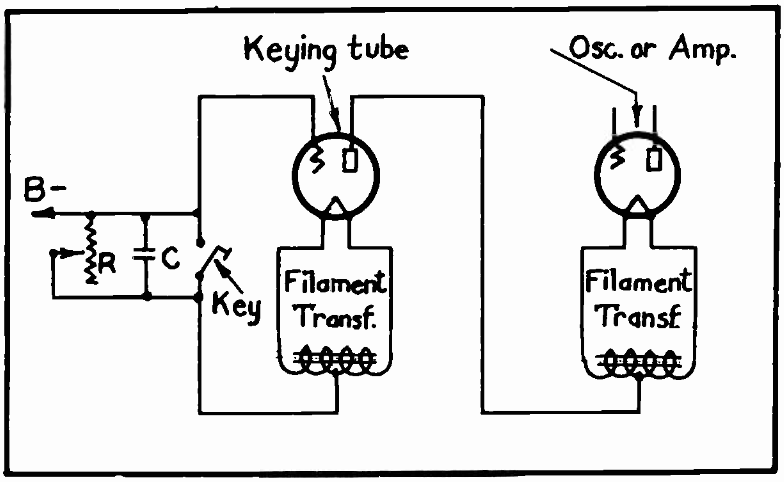

FIG. 9
The Vacuum Tube Keying Method.

IN MULTI-STAGE TRANSMITTERS EMPLOYING AMPLIFIERS OF HIGH POWER OUTPUT, IT IS GENERALLY THE PRACTICE TO INSTALL THE KEY IN ONE OF THE LOW-POWER AMPLIFIER STAGES PRECEDING THE FINAL STAGE. IN SUCH A CASE, EVEN THOUGH THE FINAL POWER AMPLIFIER IS AT ALL TIMES OPERATING, YET IT RECEIVES NO EXITATION NOR DELIVERS ANY POWER OUTPUT EXCEPT WHEN THE KEY IS DEPRESSED IN THE INTERMEDIATE STAGE. HOWEVER, WHEN USING THIS METHOD, IT IS IMPORTANT THAT ALL TUBES FOLLOWING THE KEYED STAGE SHOULD BE FURNISHED WITH A SUFFICIENT BIAS VOLTAGE SO AS TO CUT OFF THE PLATE CURRENT THROUGH THESE TUBES WHEN NO EXITATION IS PRESENT. IF THIS IS NOT DONE, EXCESSIVE PLATE CURRENT FLOWING THROUGH THE FINAL TUBES MAY DAMAGE THEM.

AS A RULE IN MULTI-STAGE TRANSMITTERS, THE KEY IS NOT INSTALLED IN THE OSCILLATOR CIRCUIT SO THAT THE OSCILLATOR MAY REMAIN IN OPERATION CONTINUOUSLY DURING THE KEYING PROCESS.

WHEN KEYING IN AN INTERMEDIATE STAGE, THERE IS ALSO LESS POSSIBILITY FOR BACK-WAVES BEING EMITTED AND ALSO "KEY CLICKS" BECOME LESS BOTHERSOME.

KEYING TROUBLES

IN THE ELEMENTARY TYPE OF KEYING CIRCUITS WITH WHICH YOU ARE NOW FAMILIAR, A CERTAIN FORM OF INTERFERENCE IS SOMETIMES PRODUCED AND WHICH

MAKES ITS PRESENCE KNOWN AS CLICKING OR THUMPING SOUNDS IN NEARBY RECEIVERS EVEN THOUGH THESE RECEIVERS BE TUNED TO FREQUENCIES FAR REMOVED FROM THE OPERATING FREQUENCY OF THE TRANSMITTER IN QUESTION. THIS DISTURBANCE IS KNOWN AS "KEY CLICKS".

THESE KEY CLICKS ARE GENERALLY CAUSED BY STRAY OSCILLATIONS OF SHORT DURATION THAT ARE PRODUCED BY THE RAPID STARTING AND STOPPING OF POWER OUTPUT DURING THE PROCESS OF KEYING. THESE STRAY OSCILLATIONS OR "TRANSIENT OSCILLATIONS", AS THEY ARE FREQUENTLY CALLED, DO NOT HAVE A DEFINITE FREQUENCY AND SPREAD OVER A CONSIDERABLE PORTION OF THE FREQUENCY SPECTRUM. FORTUNATELY, THESE INTERFERRING RADIATIONS DO NOT TRAVEL FAR FROM THE TRANSMITTER BUT NEVERTHELESS THEY ARE EXTREMELY ANNOYING TO THE OPERATORS OF NEARBY RECEIVERS.

THESE TRANSIENT OSCILLATIONS CAN BE PREVENTED BY SLOWING UP THE RATE AT WHICH THE POWER IS APPLIED TO THE TRANSMITTER BUT CARE MUST BE EXERCISED SO THAT THIS SLOWING UP IS NOT CARRIED OUT TO AN EXTREME DEGREE, OTHERWISE THE KEYING WILL NOT BE CLEAR.

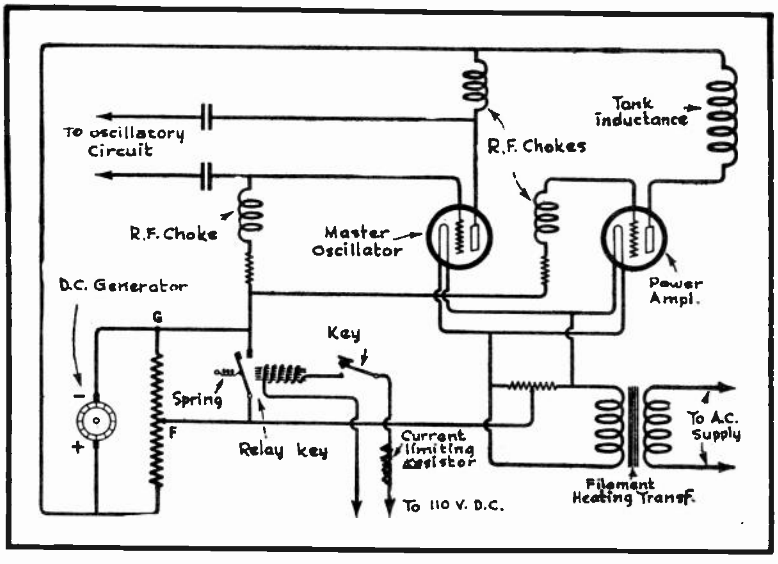

FIG. 10

Application of the Relay Key.

APPLICATION OF KEY FILTER

ONE METHOD OF PREVENTING KEY CLICKS IS TO RETARD THE OTHERWISE SUDDEN APPLICATION OF POWER TO THE TRANSMITTER AND THIS CAN BE ACCOMPLISHED BY THE FILTER SYSTEM WHICH IS ILLUSTRATED IN FIG. 7. THIS FILTER, YOU WILL OBSERVE, CONSISTS OF AN INDUCTANCE CONNECTED IN SERIES WITH THE KEY CIRCUIT. AN INDUCTANCE, YOU WILL RECALL, HAS A NATURAL TENDENCY OF OPPOSING ANY SUDDEN CHANGE IN CURRENT FLOW WHICH PASSES THROUGH IT.

THE INTRODUCTION OF THE INDUCTANCE IN THE KEY CIRCUIT, HOWEVER, IS LIKELY TO CAUSE SPARKING AT THE KEY CONTACTS AND TO PREVENT THIS A CONDENSER C AND RESISTOR R ARE CONNECTED ACROSS THE KEY AS ALSO SHOWN IN FIG. 7. QUITE OFTEN, THE RESISTANCE HERE USED IS OF THE VARIABLE TYPE SO AS TO PERMIT ADJUSTMENT.

THE VALUE OF THE INDUCTANCE ORDINARILY NEEDS BE ONLY OF A RELATIVELY SMALL VALUE, RANGING FROM A LARGE R.F. CHOKE OF AROUND 10 MILLIHENRYS UP TO AN IRON CORE CHOKE OF A FEW HENRYS INDUCTANCE. THIS VALUE CAN BE DETERMINED BY EXPERIMENT — THE INDUCTANCE SHOULD JUST BE SUFFICIENT TO PREVENT CLICKS AND NO MORE. THE CONDENSER AS USED HERE SHOULD ORDINARILY HAVE A CAPACITY OF FROM 0.25 TO 1 MFD. AND IF VARIABLE, A MAXIMUM RESIS-

TANCE OF 50 TO 100 OHMS.

IT ALSO FREQUENTLY HAPPENS THAT OSCILLATIONS ORIGINATE IN THE KEY CIRCUIT AND TRAVEL OVER THE POWER LINES. SUCH OSCILLATIONS CAN BE PREVENTED FROM BECOMING BOTHERSOME BY USING THE ARRANGEMENT SHOWN IN FIG. 8. HERE YOU WILL OBSERVE THAT THE INDUCTANCE, CONDENSER, AND RESISTOR COMBINATION IS STILL RETAINED AND THAT AN ADDITIONAL CONDENSER C_2 IS ALSO CONNECTED ACROSS THE LINES LEADING TO THE KEY. THE VALUE FOR C_2 IS APPROXIMATELY 0.1 MFD.

THAT SIDE OF THE LINE WHICH IS CONNECTED TO THE LOW POTENTIAL SIDE OF THE TRANSMITTER (GENERALLY B–) IS INDICATED IN FIG. 8 BY THE GROUND SYMBOL. TO USE THESE FILTER CIRCUITS TO THE BEST ADVANTAGE THE FILTER SHOULD BE INSTALLED AS CLOSE AS POSSIBLE TO THE KEY.

IT IS ALSO DESIRABLE TO INSTALL AN INTERFERENCE ELIMINATING FILTER BETWEEN THE POWER SUPPLY OF THE TRANSMITTER AND THE POWER LINE FROM WHICH IT IS OPERATED. FILTERS OF THIS TYPE WERE ALREADY DESCRIBED TO YOU IN AN EARLIER LESSON TREATING WITH RADIO INTERFERENCE.

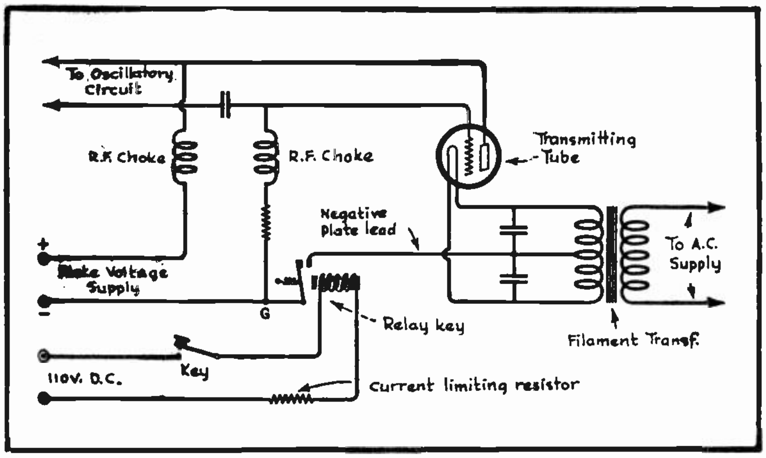

FIG. 11

Another Application of the Relay Key.

THE VACUUM TUBE KEYING METHOD

IN FIG. 9 YOU ARE SHOWN AN ARRANGEMENT IN WHICH A VACUUM TUBE IS USED TO REPLACE THE INDUCTANCE-CAPACITY FILTER IN THE KEYING CIRCUIT. HERE YOU WILL OBSERVE THAT A SPECIAL TUBE KNOWN AS THE "KEYING TUBE" IS SO PLACED IN THE CIRCUIT THAT ALL "B" CURRENT FLOWING THROUGH THE TUBE TO BE KEYED MUST ALSO FLOW THROUGH THE KEYING TUBE IN ORDER TO REACH THE LOW POTENTIAL SIDE OF THE CIRCUIT OR B–.

THE KEY IS INSTALLED IN THE GRID CIRCUIT OF THE KEYING TUBE IN SUCH A MANNER THAT WHEN THE KEY IS IN THE OPEN POSITION, THE FLOW OF PLATE CURRENT THROUGH R WILL CAUSE A VOLTAGE DROP OF SUFFICIENT MAGNITUDE ACROSS IT AND WHICH WHEN APPLIED AS A GRID BIAS TO THE KEYING TUBE WILL CAUSE THIS TUBE TO BLOCK AND THEREBY PREVENT ANY FURTHER PASSAGE OF PLATE CURRENT THROUGH EITHER THE KEYING TUBE OR THE ACTUAL TRANSMITTER TUBE WHICH IS BEING KEYED.

WHEN THE KEY IS CLOSED, RESISTOR R WILL BE SHORT CIRCUITED AND THUS REMOVE THE BIAS VOLTAGE FROM THE KEYING TUBE. THIS TUBE THEN ACTS LIKE A RESISTANCE OF LOW VALUE AND THUS PERMITS THE PLATE CURRENT OF THE TUBE WHICH IS BEING KEYED TO FLOW THROUGH IT. WHEN LARGER CURRENTS ARE BEING

HANDLED, SEVERAL KEYING TUBES ARE FREQUENTLY CONNECTED IN PARALLEL. THIS METHOD OF KEYING ALSO ASSISTS IN THE SUPPRESSION OF ANY TRANSIENT RADIATION WHICH ORIGINATES FROM THE KEYING PROCESS.

THE RELAY KEY

IN TRANSMITTERS OF HIGHER POWER RATING THE KEY ITSELF IS NOT GENERALLY INCLUDED IN THE CIRCUIT IN WHICH THE ACTUAL KEYING IS DONE. INSTEAD, A SPECIAL RELAY KEY IS USED AND THE CIRCUIT IN FIG. 10 SHOWS YOU ONE TYPICAL METHOD IN WHICH THIS IS DONE.

BY STUDYING FIG. 10 CLOSELY, YOU WILL OBSERVE THAT THE KEY RELAY CONSISTS OF AN IRON CORE AROUND WHICH IS PLACED A WINDING. THIS WINDING IS CONNECTED IN SERIES WITH THE REGULAR KEY AND A SEPARATE VOLTAGE SOURCE AND WHICH IN THE CASE OF FIG. 10 IS A 110 VOLT D.C. SUPPLY. A RESISTOR LIMITS THE FLOW OF CURRENT THROUGH THE RELAY COIL.

THIS RELAY KEY IS ALSO PROVIDED WITH AN ARMATURE OR PIVOTED ARM AND ON WHOSE EXTREMETY IS ATTACHED A CONTACT POINT. ANOTHER CONTACT POINT REMAINS STATIONARY.

A SPRING NORMALLY HOLDS THE ARMATURE OF THE RELAY KEY IN THE POSITION SHOWN IN FIG. 10 AND AT WHICH TIME THE CONTACT POINTS ARE SEPARATED.

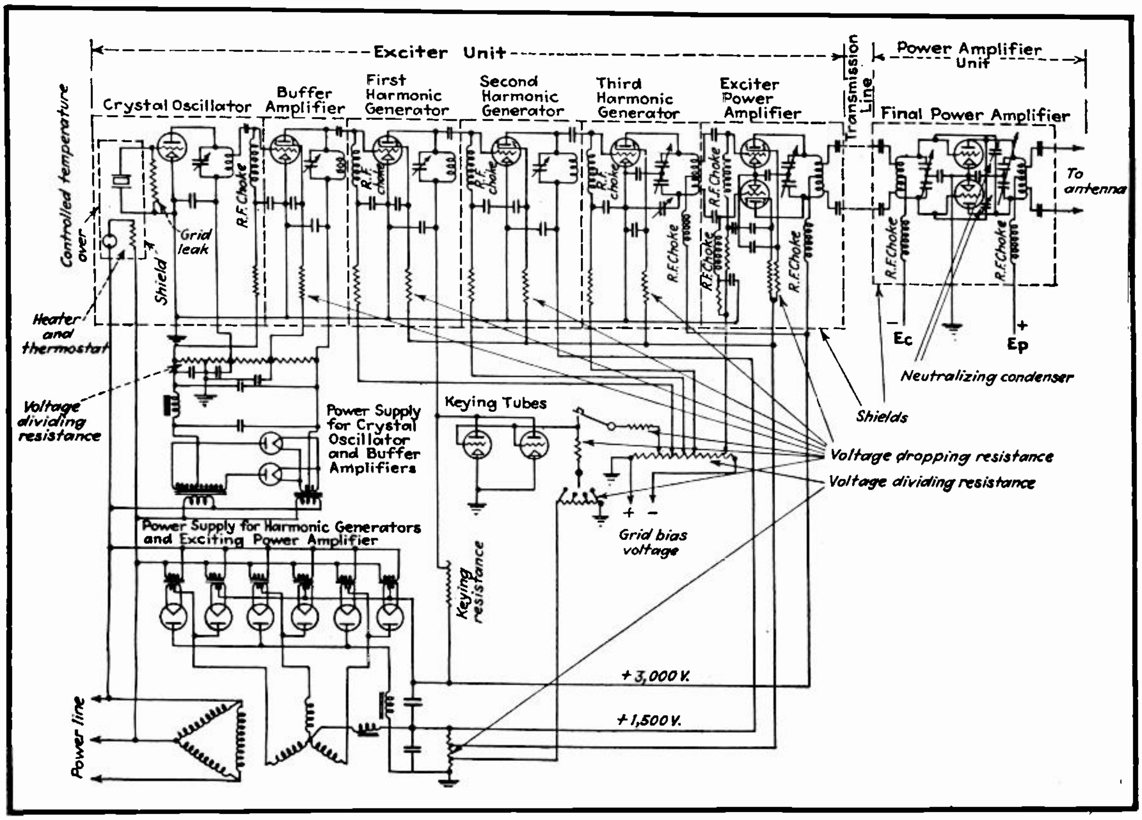

FIG. 12

Circuit Diagram of a 20-40 KW. R.C.A. Short-Wave Code Transmitter.

WHEN THE HAND KEY IS CLOSED, DURING SENDING, THE CIRCUIT THROUGH THE RELAY COIL IS COMPLETED AND THE RESULTING MAGNETIC FIELD THEREBY ESTABLISHED CAUSES THE RELAY ARMATURE TO BE PULLED TOWARDS THE IRON CORE, RESISTING THE SPRING TENSION AND IN THIS WAY CLOSES THE CONTACT POINTS OF THE RELAY. THESE RELAY CONTACT POINTS AT THIS TIME COMPLETE THE KEYING CIRCUIT OF THE TRANSMITTER.

UPON OPENING THE HAND KEY, THE MAGNETIC FIELD OF THE RELAY KEY COLLAPSES AND SPRING TENSION CAUSES THE CONTACTS OF THE RELAY KEY TO SEPARATE. THUS BY OPERATING THE HAND KEY IN THE CONVENTIONAL MANNER, THE RELAY KEY AUTOMATICALLY TAKES CARE OF KEYING THE TRANSMITTER CIRCUIT.

THE ARRANGEMENT IN FIG. 10 IS SUCH THAT WHEN THE KEY IS OPEN, THE VOLTAGE DROP APPEARING ACROSS RESISTOR SECTION G-F IS APPLIED AS A BIAS VOLTAGE TO THE TRANSMITTER TUBES HERE SHOWN. THE BIAS VOLTAGE AT THIS TIME IS GREAT ENOUGH TO BLOCK THE TUBES. UPON CLOSING THE HAND KEY, THE CLOSING OF THE RELAY CONTACTS SHORT CIRCUITS THE BIASING RESISTOR AND PERMITS THE TUBES TO FUNCTION NORMALLY.

ANOTHER APPLICATION OF THE RELAY KEY IS SHOWN YOU IN FIG. 11. HERE THE RELAY CONTACTS CONTROL THE COMPLETION AND INTERRUPTION OF BOTH THE NEGATIVE LEAD OF THE PLATE CIRCUIT AND THE TUBE'S GRID RETURN CIRCUIT. THE HAND KEY CONTROLS THE OPERATION OF THE RELAY KEY IN THE SAME MANNER, AS HAS ALREADY BEEN DESCRIBED.

A HIGH-POWER SHORT-WAVE COMMERCIAL CODE TRANSMITTER

IN FIG. 12 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A HIGH-POWER SHORT WAVE COMMERCIAL CODE TRANSMITTER WHICH IS DESIGNED TO OPERATE WITHIN A FREQUENCY RANGE OF 6670 KC. TO 21,500 KC. AT ITS LOWER FREQUENCY LIMIT IT IS CAPABLE OF FURNISHING AN OUTPUT OF 50 KW. AND AT ITS HIGHEST FREQUENCY SETTING AN OUTPUT OF 23 KW.

THIS TRANSMITTER IS DIVIDED INTO TWO DISTINCT PARTS, NAMELY, AN EXITER UNIT WHICH CONTAINS THE CRYSTAL OSCILLATOR, BUFFER AMPLIFIER, FREQUENCY MULTIPLIERS (HARMONIC GENERATORS) AND A POWER AMPLIFIER WHICH FURNISHES A POWER OUTPUT OF 1 KW. THE SECOND UNIT CONSISTS OF THE FINAL POWER AMPLIFIER AND IT IS CONNECTED TO THE OUTPUT OF THE EXITER UNIT BY A SHORT TRANSMISSION LINE.

BY USING THIS TWO-UNIT TYPE OF CONSTRUCTION, THE SHIELDING BETWEEN THE FINAL POWER AMPLIFIER AND THE CIRCUITS OF LOWER POWER LEVELS IS GREATLY SIMPLIFIED.

A 7½ WATT TRIODE IS USED IN THE CRYSTAL-CONTROLLED OSCILLATOR CIRCUIT. THIS IS FOLLOWED BY A 75 WATT SCREEN-GRID BUFFER AMPLIFIER AND THEN IN TURN BY A 75 WATT SCREEN-GRID FREQUENCY DOUBLER, A 75 WATT SCREEN GRID FREQUENCY DOUBLER (THE SECOND DOUBLER), A 500 WATT SCREEN-GRID TUBE WHICH IS USED AS A THIRD HARMONIC GENERATOR IF THE OUTPUT FREQUENCY IS IN EXCESS OF 12,000 KC. AND OTHERWISE AS A POWER AMPLIFIER AND FINALLY TWO 500 WATT SCREEN-GRID TUBES IN A PUSH-PULL ARRANGEMENT AT THE OUTPUT OF THE EXITER UNIT.

FOR FREQUENCIES BELOW 12,000 KC. THE CRYSTAL IS GROUND SO THAT THE

OSCILLATOR FREQUENCY WILL BE ONE-FOURTH THAT OF THE FREQUENCY TO BE TRANSMITTED AND TWO DOUBLERS ARE USED. FOR FREQUENCIES ABOVE 12,000 KC. THE CRYSTAL WILL PERMIT THE OSCILLATOR TO OPERATE AT ONE-EIGHTH THE FREQUENCY TO BE TRANSMITTED AND THREE DOUBLERS ARE AT THIS TIME USED.

NOTICE CAREFULLY IN THE CIRCUIT OF FIG. 12 THAT THE VARIOUS SECTIONS OF THE TRANSMITTER PROPER FOLLOW THE SAME GENERAL DESIGNS AS WERE DESCRIBED TO YOU IN DETAIL IN PREVIOUS LESSONS. ALSO OBSERVE HOW EACH OF THE VARIOUS STAGES ARE FULLY SHIELDED FROM EACHOTHER AS INDICATED BY THE DOTTED LINES.

THREE SEPARATE "B" POWER SUPPLIES ARE USED WITH THIS TRANSMITTER AND TWO OF WHICH ARE SHOWN IN THE CIRCUIT OF FIG. 12. THE CRYSTAL OSCILLATOR AND BUFFER AMPLIFIER RECEIVE THEIR "B" SUPPLY FROM A SINGLE PHASE CENTER-TAPPED RECTIFIER USING TYPE 866 MERCURY-VAPOR RECTIFIER TUBES. THE OUTPUT OF THIS RECTIFIER IS EQUIPPED WITH A FILTER AND VOLTAGE DIVIDING SYSTEM.

THE REMAINDER OF THE EXITER RECEIVES ITS "B" SUPPLY FROM A THREE PHASE FULL-WAVE RECTIFIER USING SIX TYPE 872 MERCURY-VAPOR RECTIFIER TUBES. THE OUTPUT OF THIS RECTIFIER IS ALSO EQUIPPED WITH A FILTER AND DIVIDER SYSTEM SO THAT VOLTAGES OF 3000; 1500; AND LESSER VOLTAGES MAY BE OBTAINED. THE GRID BIAS VOLTAGES FOR THE EXITER ARE OBTAINED BY CONNECTING THE OUTPUT OF A 1000 VOLT MOTOR-GENERATOR ACROSS THE + AND — TERMINALS OF THE GRID BIAS VOLTAGE DIVIDING RESISTANCE, ALTHOUGH A RECTIFYING SYSTEM MAY BE USED.

THE POWER-AMPLIFIER UNIT HAS ITS "B" SU-

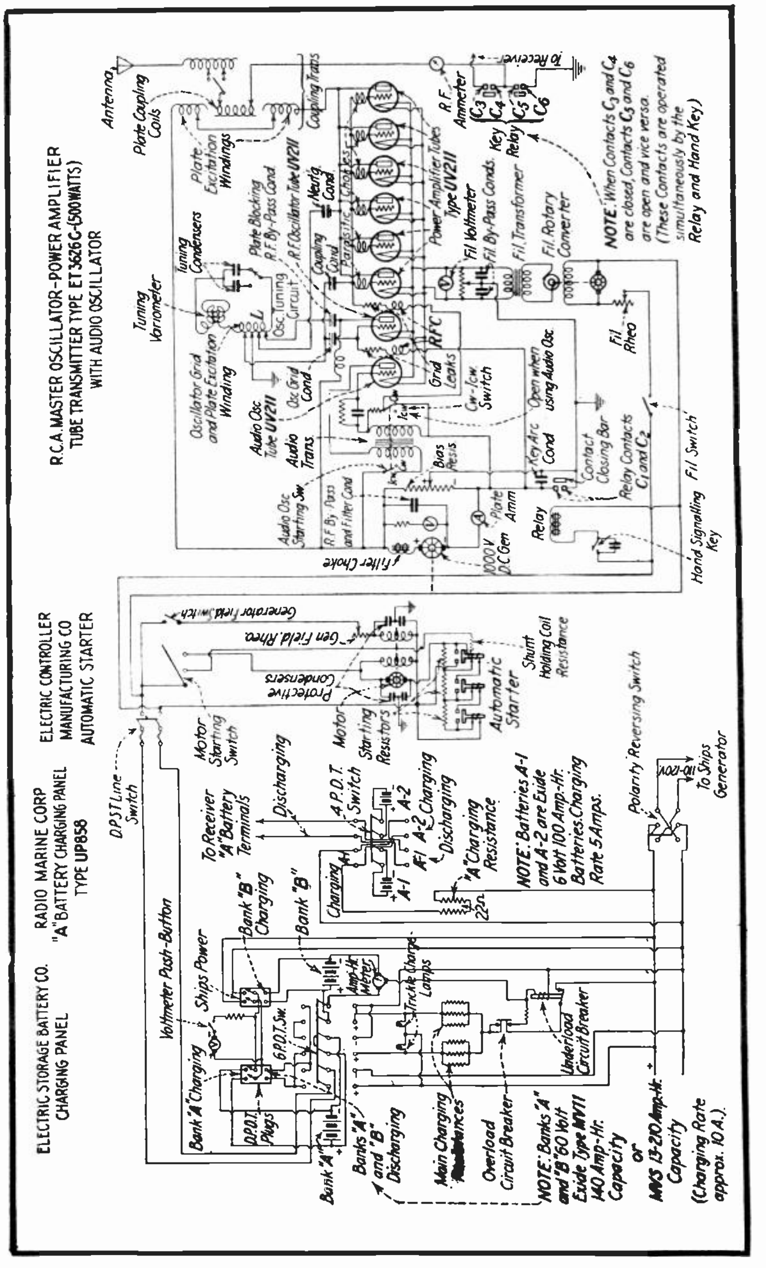

FIG. 13

A Transmitter Designed for Marine Use.

PPLY FURNISHED BY A SEPARATE SUPPLY NOT SHOWN IN FIG. 12 BUT WHICH CONSISTS OF A THREE-PHASE FULL-WAVE RECTIFIER USING TYPE 869 MERCURY-VAPOR TUBES AND DELIVERING A DIRECT CURRENT OUTPUT OF 8 AMPS. AT 12,000 VOLTS. TWELVE RECTIFIER TUBES ARE EMPLOYED, BEING OPERATED IN PARALLEL PAIRS. YOU WILL RECEIVE TRANSMITTER TUBE DATA IN A LATER LESSON.

THE METHOD OF KEYING THIS TRANSMITTER IS RATHER INTERESTING. BY REFERRING TO FIG. 12 AGAIN, YOU WILL OBSERVE THAT THE KEYING IN THIS CASE IS DONE IN THE FIRST DOUBLER STAGE BY REDUCING THE PLATE VOLTAGE SUPPLIED TO THE DOUBLER TUBE TO THE POINT WHERE THE OUTPUT IS INSUFFICIENT TO BRING THE INSTANTANEOUS GRID POTENTIAL OF THE SUCCEEDING TUBE ABOVE CUT-OFF.

THE KEYING UNIT CONSISTS OF TWO 50-WATT TUBES IN PARALLEL AND THE PLATES OF WHICH ARE FED IN PARALLEL WITH THE PLATE OF THE FIRST DOUBLER TUBE THROUGH A COMMON RESISTANCE FROM THE 3000 VOLT POWER SUPPLY. WHEN THE KEY IS CLOSED, A NEGATIVE BIAS EXCEEDING THE CUT-OFF VALUE IS PLACED ON THE GRIDS OF THE KEYING TUBES SO THAT THE KEYING UNIT DRAWS NO CURRENT AND ALLOWS NORMAL VOLTAGE TO BE APPLIED TO THE PLATE OF THE DOUBLER TUBE.

WHEN THE KEY IS OPEN, A SLIGHTLY POSITIVE VOLTAGE IS APPLIED TO THE GRIDS OF THE KEYING TUBES, CAUSING THESE TUBES TO DRAW A LARGE PLATE CURRENT THROUGH THE SERIES RESISTANCE AND THUS REDUCES TO A VERY LOW VALUE THE POTENTIAL WHICH IS APPLIED TO THE PLATE OF THE DOUBLER TUBE.

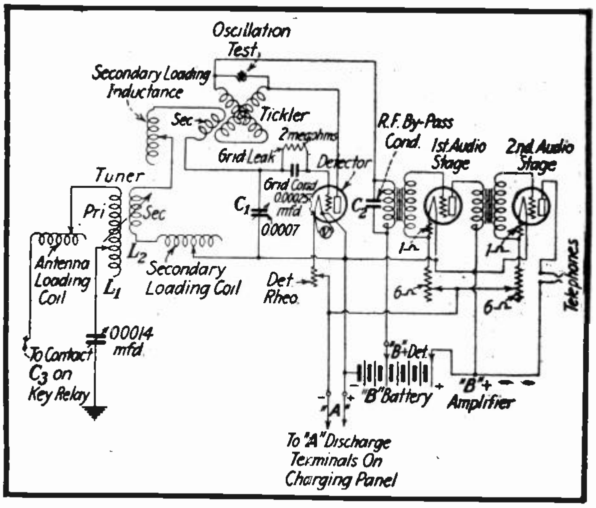

FIG. 14
The Receiver Diagram.

A COMPLETE MARINE TRANSMITTER

IN FIG. 13 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF A TRANSMITTER WHICH WAS DESIGNED FOR MARINE USE. THE CIRCUIT DIAGRAM OF THE RECEIVER WHICH IS USED WITH THIS SAME TRANSMITTER APPEARS IN FIG. 14.

THE TRANSMITTER IS OF THE MASTER-OSCILLATOR-POWER-AMPLIFIER TYPE AND IS DESIGNED FOR A POWER OUTPUT OF 500 WATTS AND AFFORDS BOTH CW AND ICW TRANSMISSION. IT IS DESIGNED TO OPERATE ON TWO-WAVELENGTH RANGES, ONE WHICH EXTENDS FROM 1250 TO 2500 METERS AND THE OTHER FROM 600 AND 1250 METERS.

THE POWER SUPPLY

THE AUXILIARY POWER SUPPLY CONSISTS OF TWO 60 VOLT STORAGE BATTERIES WITH A SWITCHING ARRANGEMENT WHEREBY THEY CAN BE CONNECTED IN PARALLEL OR SERIES FOR EITHER CHARGING OR DISCHARGING PURPOSES. OVERLOAD AND

UNDERLOAD CIRCUIT BREAKERS ARE ALSO SUPPLIED SO AS TO PROTECT THE BATTERIES IN CASE A SHORT CIRCUIT OCCURS OR ELSE IF THE CHARGING VOLTAGE DECREASES BEYOND A CERTAIN POINT.

UPON PLACING THE 6 P.D.T. CHARGING SWITCH IN THE "DOWN POSITION" AND THE POLARITY REVERSING SWITCH IN THE PROPER POSITION, CURRENT AS FURNISHED BY THE SHIP'S D.C. GENERATOR WILL FLOW THROUGH THE UNDERLOAD CIRCUIT BREAKER, OVERLOAD CIRCUIT BREAKER, MAIN CHARGING RESISTANCES, THRU THE BATTERY BANKS "A" AND "B", THROUGH THE AMPERE-HOUR METER AND BACK TO THE NEGATIVE SIDE OF THE LINE. THE BATTERIES ARE CONNECTED IN PARALLEL DURING THIS TIME.

AS THE CHARGE PROGRESSES THE AMPERE-HOUR METER READS IN A COUNTER-CLOCKWISE DIRECTION UNTIL ITS HAND REACHES A VERTICAL POSITION AND AT WHICH TIME IT CLOSES A SMALL CONTACT AND SHORT-CIRCUITS THE HOLDING COIL OF THE UNDERLOAD CIRCUIT BREAKER, OPENING THE CHARGING CIRCUIT.

WHEN THE BATTERIES ARE FULLY CHARGED, THE OVERLOAD CIRCUIT BREAKER CAN BE OPENED SO AS TO DISCONNECT THE MAIN CHARGING RESISTANCES. BY LEAVING THE 6 P.D.T. SWITCH IN THE CHARGING POSITION AT THIS TIME, THE BATTERIES CAN STILL BE SUPPLIED WITH A SMALL TRICKLE CHARGE THROUGH TWO SMALL LAMPS. THIS KEEPS THE BATTERIES IN A GOOD CONDITION WHEN NOT IN USE.

THE 4 P.D.T. SWITCH WHICH IS LOCATED AT THE RIGHT OF THE 6 P.D.T. CHARGING SWITCH PERMITS EITHER ONE OF THE TWO "A" BATTERIES FOR THE RECEIVER TO BE CHARGED WHILE THE OTHER IS IN USE.

WITH THE 6 P.D.T. SWITCH PLACED IN THE UPWARD POSITION, THE ENTIRE CHARGING SYSTEM IS DISCONNECTED AND THE TWO 60 VOLT BANKS ARE CONNECTED IN SERIES SO AS TO SUPPLY AN E.M.F. OF 120 VOLTS. THIS VOLTAGE MAY BE APPLIED TO THE MOTOR STARTER AND GENERATOR BY CLOSING THE D.P.S.T. LINE SWITCH AT THE TOP.

BY PLACING THE 6 P.D.T. SWITCH IN THE DOWNWARD POSITION THE SHIP'S GENERATOR CAN BE USED TO OPERATE THE MOTOR STARTER AND GENERATOR, AT THE SAME TIME CHARGING THE BATTERIES.

THE MOTOR STARTER AND MOTOR GENERATOR

BY CLOSING THE MOTOR STARTING SWITCH, THE VOLTAGE FROM THE SHIP'S D.C. LINE OR ELSE FROM THE BATTERIES IS APPLIED TO THE MOTOR AND GENERATOR UNITS. CURRENT WILL THEN FLOW THROUGH THE MOTOR ARMATURE, STARTING RESISTANCES AND MOTOR FIELD. NO CURRENT WILL FLOW THROUGH THE GENERATOR FIELD UNTIL THE GENERATOR FIELD SWITCH IS CLOSED.

THE CURRENT WHICH IS NOW FLOWING THROUGH THE MOTOR ARMATURE AND STARTING RESISTANCES ALSO FLOWS THROUGH THE FIRST PLUNGER COIL OF THE AUTOMATIC STARTER. AFTER A FEW SECONDS THIS PLUNGER RISES AND SHORT CIRCUITS THE FIRST RESISTANCE WHICH ALLOWS MORE CURRENT TO FLOW INTO THE ARMATURE. THE SECOND PLUNGER COIL THEN BECOMES ENERGIZED AND AFTER A FEW SECONDS IT ALSO RISES AND SHORT-CIRCUITS THE SECOND RESISTANCE, ALLOWING MORE CURRENT TO FLOW INTO THE ARMATURE. THE THIRD PLUNGER COIL THEN BECOMES ENERGIZED AND AFTER A FEW SECONDS SHORT-CIRCUITS THE THIRD AND FINAL RESISTANCE WHICH ALLOWS THE FULL CURRENT TO FLOW THRU THE MOTOR ARMATURE. THE THIRD PLUNGER IS ALSO PROVIDED WITH A SHUNT HOLDING COIL WHICH KEEPS

THE PLUNGER IN AN UPWARD POSITION DURING THE TIME THAT THE MOTOR IS OPERATING.

WITH THE MOTOR FIELD AND ARMATURE NOW FULLY EXITED AND RUNNING AT FULL SPEED, THE GENERATOR FIELD SWITCH MAY BE CLOSED TO EXITE THE GENERATOR FIELD. THE DIRECT-DURRENT GENERATOR WILL GENERATE AN E.M.F. OF 1,000 VOLTS AND WHICH MAY BE REGULATED BY VARYING THE GENERATOR FIELD RHEOSTAT UNTIL THE DESIRED VOLTAGE IS OBTAINED. THIS GENERATOR FIELD SWITCH SHOULD NOT BE CLOSED UNTIL THE TUBE FILAMENTS ARE LIGHTED. A FILTER IS INSTALLED AT THE OUTPUT OF THIS GENERATOR SO AS TO FURNISH A D.C. SUPPLY FREE FROM RIPPLE.

THE TRANSMITTER

UPON CLOSING THE FILAMENT SWITCH, A D.C. SUPPLY IS FURNISHED THE ROTARY CONVERTER AND THIS UNIT IN TURN CAUSES AN ALTERNATING CURRENT TO FLOW THROUGH THE PRIMARY WINDING OF THE FILAMENT TRANSFORMER. A STEP-DOWN RATIO IS OFFERED BY THIS TRANSFORMER SO THAT A FILAMENT VOLTAGE OF 10 VOLTS WILL BE APPLIED TO THE FILAMENTS OF THE TRANSMITTER TUBES. THIS VOLTAGE IS CONTROLLED BY THE FILAMENT RHEOSTAT.

UPON OPERATING THE HAND KEY, THE RELAY KEY CONTROLS THE TRANSMITTER. WITH THE KEY IN THE OPEN POSITION, A HIGH NEGATIVE BIAS VOLTAGE, FURNISHED BY THE RESISTOR WHICH IS CONNECTED ACROSS THE D.C. GENERATOR, CAUSES THE TRANSMITTER TUBES TO BLOCK AND RADIATION CEASES.

BY CLOSING THE KEY, THE "B" CIRCUIT OF THE TRANSMITTER AND THE ANTENNA CIRCUIT TO THE TRANSMITTER ARE COMPLETED AND AT THE SAME TIME, THE EXCESS BIAS VOLTAGE IS REMOVED FROM THE TUBES AND THE RECEIVER IS DISCONNECTED FROM THE RECEIVER.

WITH THE CW-ICW SWITCH IN THE CW POSITION AND THE AUDIO-OSCILLATOR NOT OPERATING, CONTINUOUS WAVE (CW) SIGNALS WILL BE RADIATED. FOR ICW SIGNALLING, THE CW-ICW SWITCH IS CLOSED TO THE ICW POSITION. THIS CLOSES THE AUDIO-OSCILLATOR STARTING SWITCH CAUSING THE AUDIO OSCILLATOR TO OPERATE. THE OUTPUT OF THIS AUDIO OSCILLATOR MODULATES THE CONTINUOUS WAVES GENERATED BY THE R.F. OSCILLATOR AND THIS RESULTS IN THE EMISSION OF AN INTERRUPTED CONTINUOUS WAVE (ICW). A STANDARD MARCONI ANTENNA IS USED WITH THIS TRANSMITTER.

OPERATING PROCEDURE

TO PREPARE THIS TRANSMITTER FOR OPERATION, THE PROCEDURE IS AS FOLLOWS: TURN THE FIELD AND FILAMENT RHEOSTATS TO THEIR LOWEST VOLTAGE POSITION. CLOSE THE MAIN LINE SWITCH AND PRESS THE "START" BUTTON AND PERMIT THE MOTOR GENERATOR TO COME UP TO SPEED. ADJUST FILAMENT VOLTAGE FOR A FILAMENT E.M.F. OF 10 VOLTS. WHEN TUBE FILAMENTS ARE HOT, ADJUST GENERATOR-FIELD RHEOSTAT FOR A PLATE VOLTAGE OF 1,000 VOLTS.

NEXT THROW THE WAVE-RANGE TRANSFER SWITCH TO THE POSITION FOR THE WAVE-RANGE DESIRED. THEN SET THE "EXITER TUNING" AND "RANGE SWITCH" TO THE WAVELENGTH DESIRED. SET THE CW-ICW SWITCH TO THE CW POSITION.

NOW ADJUST THE ANTENNA INDUCTANCE SWITCHES TO RANGE DESIRED AND ADJUST THE PROPER "ANTENNA TUNING KNOB" FOR A MAXIMUM READING ON THE

RADIATION METER WHILE PRESSING THE "TEST" PUSH BUTTON. THE SET IS NOW TUNED AND THE TELEGRAPH KEY MAY BE OPERATED FOR THE TRANSMISSION OF SIGNALS.

TO SHUT DOWN THE TRANSMITTER, PRESS THE "STOP" BUTTON.

THE RECEIVER AS USED WITH THIS TRANSMITTER EMPLOYS DESIGN PRINCIPLES WITH WHICH YOU ARE ALREADY FAMILIAR AND FOR THIS REASON IT IS NOT NECESSARY TO OFFER A DESCRIPTIVE EXPLANATION REGARDING IT.

EXAMINATION QUESTIONS

LESSON NO. T-11

1. - DRAW A COMPLETE CIRCUIT DIAGRAM OF AN OSCILLATOR - AMPLIFIER C.W. TRANSMITTER TOGETHER WITH ITS POWER SUPPLY.

2. - EXPLAIN IN DETAIL HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #1.

3. - DRAW A CIRCUIT DIAGRAM OF A KEYING CIRCUIT WHOSE OPERATION IS BASED UPON BLOCKING WITH BIAS VOLTAGE THE GRID OF THE TUBE WHICH IS BEING KEYED AND EXPLAIN HOW THIS SYSTEM FUNCTIONS.

4. - DRAW A CIRCUIT DIAGRAM OF A KEY FILTER; EXPLAIN THE REASON FOR USING IT.

5. - DRAW A CIRCUIT DIAGRAM WHICH SHOWS HOW A KEYING TUBE MAY BE USED IN THE TRANSMITTER AND EXPLAIN HOW THIS SYSTEM OPERATES.

6. - WHAT ARE THE ADVANTAGES OF USING A RELAY KEY IN TRANSMITTERS OF HIGHER POWER RATING?

7. - DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES HOW A RELAY KEY MAY BE USED IN A TRANSMITTER CIRCUIT AND EXPLAIN HOW THIS PARTICULAR SYSTEM OPERATES.

8. - DESCRIBE SOME OF THE MORE IMPORTANT FEATURES WHICH MAY BE FOUND IN A COMMERCIAL TRANSMITTER DESIGNED FOR MARINE USE.

9. - WHAT IS THE GENERAL PROCEDURE FOR OPERATING A TRANSMITTER SUCH AS YOU HAVE DESCRIBED IN ANSWER TO QUESTION 8?

10. - WHAT IS THE ADVANTAGE OF USING A SEPARATE POWER SUPPLY FOR THE OSCILLATOR OF AN OSCILLATOR-AMPLIFIER TRANSMITTER?

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Transmitters

LESSON NO. 12

MESSAGE HANDLING AND OPERATING REGULATIONS

HAVING BY THIS TIME FAMILIARIZED YOURSELF WITH THE CONSTRUCTION AND OPERATION OF CODE TRANSMITTERS, AS WELL AS WITH THE CODE ITSELF, YOU ARE NOW PREPARED TO LEARN ABOUT THE PROCEDURE WHICH IS USED IN THE HANDLING OF MESSAGES WITH THIS METHOD.

TO BEGIN WITH, CLEAR AND DISTINCT SENDING AT A MODERATE SPEED IS MUCH PREFERRED OVER ERRATIC SENDING AT AN EXCESSIVE SPEED.

CALLING A STATION

THE PROCEDURE FOR CALLING A STATION IS AS FOLLOWS: FIRST, DETERMINE WHETHER OR NOT THE STATION TO BE CALLED IS ALREADY COMMUNICATING WITH SOME OTHER STATION. THIS IS DETERMINED BY "LISTENING IN" FOR A SHORT PERIOD ON THE FREQUENCY AT WHICH THE STATION TO BE CALLED OPERATES. BY DOING THIS, UNNECESSARY INTERFERENCE IS AVOIDED. IF THE TRANSMITTING FREQUENCY OF THE STATION TO BE CALLED IS NOT ALREADY KNOWN, THEN IT CAN

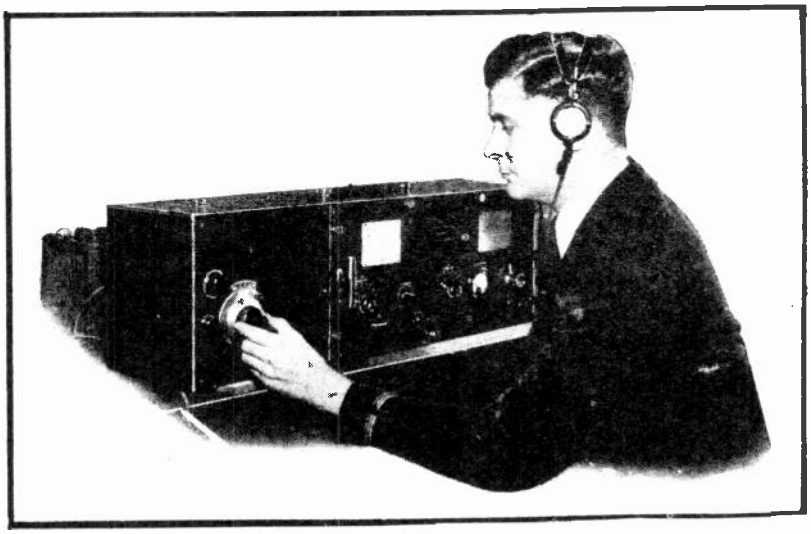


FIG. 1

Opportunities and Adventure Await the Commercial Operator.

BE DETERMINED FROM A "CALL BOOK" IN WHICH ALL STATIONS ARE LISTED.

HAVING THUS DETERMINED THAT THE STATION TO BE CALLED IS NOT ALREADY COMMUNICATING, THE NEXT STEP IS TO SEND THREE TIMES IN SUCCESSION THE CALL LETTERS OF THE STATION YOU ARE CALLING. THIS SHOULD BE FOLLOWED BY THE SIGNAL "DE" (FROM OR — • • •) TRANSMITTED ONCE AND THEN SEND THREE TIMES IN SUCCESSION THE CALL LETTERS OF YOUR STATION (THE CALLING STATION).

FOR EXAMPLE, LET US SUPPOSE THAT YOU ARE THE OPERATOR OF STATION WXOH AND DESIRE TO COMMUNICATE WITH STATION WCNR. THIS BEING THE CASE YOU WOULD TRANSMIT AS FOLLOWS:

WCNR WCNR WCNR DE WXOH WXOH WXOH

IT IS OF COURSE IMPORTANT THAT THE STATION MAKING THE CALL TRANSMIT ON THE FREQUENCY AT WHICH THE STATION BEING CALLED KEEPS WATCH.

IT THE STATION BEING CALLED (STATION WCNR IN OUR CASE) DOES NOT ANSWER THE FIRST CALL, THEN TWO MINUTES MUST ELAPSE BEFORE CALLING AGAIN. IF THE SECOND CALL IS NOT ANSWERED, THEN TWO MINUTES MUST ELAPSE BEFORE THE THIRD CALL IS MADE. IF NO RESPONSE IS RECEIVED FROM THE THIRD CALL, THEN FIFTEEN MINUTES SHOULD ELAPSE BEFORE CALLING IS RESUMED. IT IS OF UTMOST IMPORTANCE THAT THE CALLING OPERATOR DOES NOT INTERFERE WITH COMMUNICATIONS BEING EXCHANGED BETWEEN OTHER STATIONS.

ANSWERING A CALL

IN ANSWERING A CALL, THE STATION BEING CALLED SHOULD REPLY BY TRANSMITTING NOT MORE THAN THREE TIMES THE CALL SIGNAL OF THE CALLING STATION, FOLLOWED BY THE WORD "DE" (FROM) AND THEN ITS OWN CALL SIGNAL AND THE LETTER K WHICH IS THE SIGNAL TO GO AHEAD. FOR EXAMPLE, STATION WCNR WOULD ANSWER STATION WXOH IN THE FOLLOWING MANNER: WXOH WXOH WXOH DE WCNR K.

TO ACKNOWLEDGE THE ANSWER, THE CALLING STATION (WXOH) NOW CALLS STATION WCNR AGAIN AS FOLLOWS: WCNR DE WXOH AND PROCEEDS WITH THE MESSAGE.

IF FOR SOME REASON OR OTHER, THE STATION BEING CALLED IS UNABLE TO RECEIVE THE MESSAGE, THEN AT THE TIME OF ACKNOWLEDGING THE CALL, THE WAIT SIGNAL SHOULD BE GIVEN IN PLACE OF THE LETTER K AND THIS SHOULD BE FOLLOWED BY A NUMBER INDICATING IN MINUTES THE PROBABLE DURATION OF THE WAIT OR ANY FURTHER EXPLANATION IF NECESSARY.

TRANSMITTING A RADIOGRAM

IN FIG. 2 YOU ARE SHOWN A TYPICAL EXAMPLE OF A RADIOGRAM AS IT IS PREPARED ON SHIPBOARD PREPARATORY TO TRANSMISSION. A MESSAGE AS THIS CAN BE DIVIDED INTO FOUR DISTINCT PARTS OR SECTIONS, NAMELY, AS THE PREAMBLE, ADDRESS, TEXT, AND SIGNATURE. IN FIG. 3 YOU ARE SHOWN HOW THIS DIVISION IS MADE.

WHEN SENDING A MESSAGE OF THIS TYPE THE BREAK SIGNAL (— ••• —) IS

TRANSMITTED TO SEPARATE THE ADDRESS FROM THE TEXT AND THE TEXT FROM THE SIGNATURE. THE MESSAGE IS TERMINATED WITH THE SIGNAL . — . — . AFTER WHICH THE CALLING STATION GIVES HIS LETTERS AND ASKS THE STATION BEING CALLED TO ACKNOWLEDGE RECEIPT OF THE MESSAGE.

THE COMPLETE TRANSMISSION OF THIS PARTICULAR MESSAGE WOULD PROGRESS AS FOLLOWS — ASSUMING THAT STATION WXOH IS CALLING WCNR:

WCNR WCNR WCNR DE WXOH WXOH WXOH
(STATION WCNR ANSWERING.) WXOH WXOH WXOH DE WCNR K
WCNR DE WXOH
P 2 R 16 RADIO 88 SANTA BARBARA 10.35 A.M.
TO: C.H. TAYLOR 33 SOUTH AVE DENVER (COLO) — . . . —
EXPECT TO ARRIVE PIER 13 NEWYORK SATURDAY
LOVE — . . . —
CLARA . — . — . WXOH — . —

IF THE RECEIVING STATION DOES NOT ACKNOWLEDGE RECEIPT OF THE MESSAGE, THE MESSAGE IS NOT CONSIDERED AS BEING SENT AT ALL. THEREFORE, UPON RECEIVING THE MESSAGE JUST DESCRIBED, STATION WCNR WOULD ACKNOWLEDGE THE FACT IN THE FOLLOWING MANNER:

WCNR DE WXOH No 2 . — . — . —

NOTICE THAT IN THIS ACKNOWLEDGEMENT THE RADIOGRAM IS ACKNOWLEDGED BY ITS NUMBER (No.2); THE SIGNAL . — . MEANS THAT THE MESSAGE WAS RECEIVED O.K.; AND THE FINAL K OR — . — MEANS FOR THE CALLING STATION TO GO AHEAD. THE CALLING STATION WXOH THEN REPLIES AS FOLLOWS: WCNR DE WXOH . . . — . — (TRANSMISSION FINISHED OR CONCLUSION OF CORRESPONDENCE).

THE EXPRESSION P 2 R 16 WHICH APPEARS IN THE PREAMBLE OF THIS MESSAGE INDICATES THAT THIS IS THE SECOND RADIOGRAM OF THE ORDINARY PAID TYPE SENT AND THAT IT CONSISTS OF 16 WORDS ACCORDING TO THE CABLE — COUNT SYSTEM. SOMETIMES THE LETTER W IS USED TO INDICATE "NUMBER OF WORDS" —

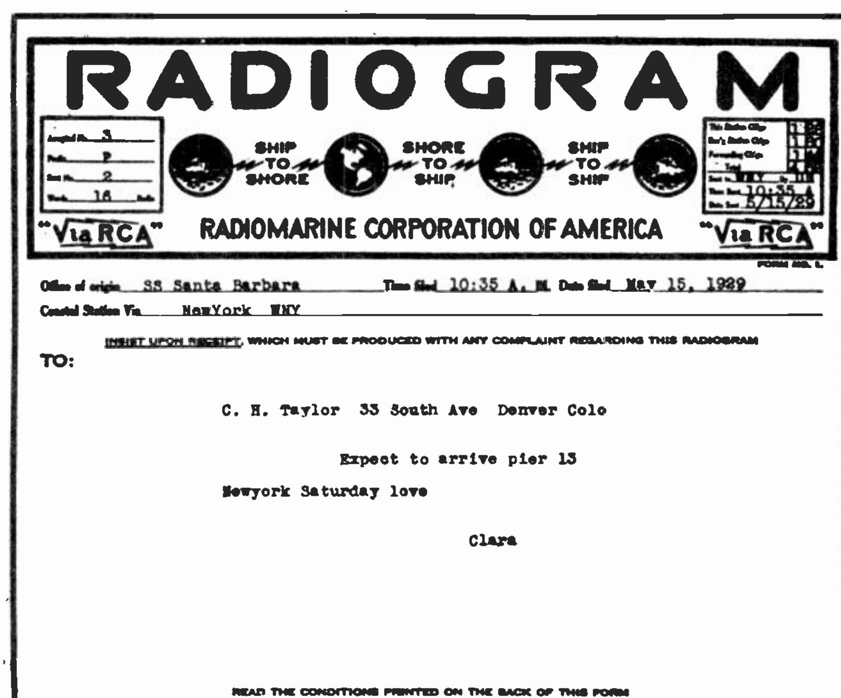


FIG. 2
A Radiogram Originating on Shipboard.

THUS W 16.

CERTAIN CLASSES OF RADIOGRAMS ARE INDICATED BY THE FOLLOWING CONVENTIONAL SIGNS WHICH ARE TRANSMITTED IN THE PREAMBLE AND AGAIN AS THE FIRST ITEM OF THE ADDRESS. SUCH SIGNS ARE COUNTED AND CHARGED FOR IN THE ADDRESS AS ONE WORD. THESE SIGNS ARE AS FOLLOWS:

RP, AND THE AMOUNT PREPAID —— RADIOGRAMS WITH PREPAID REPLY.
POST —— RADIOGRAMS TO BE DELIVERED BY MAIL.
TC —— COLLATED RADIOGRAMS (FOR VERIFICATION PURPOSES ONLY).
PR —— RADIOGRAMS TO BE POSTED AS REGISTERED LETTERS.
EXPRESS —— RADIOGRAMS FOR SPECIAL DELIVERY WHEN THE COST OF DELIVERY IS TO BE COLLECTED FROM THE ADDRESSEE.
XP —— RADIOGRAMS FOR SPECIAL DELIVERY IN THE COUNTRY OF THE COAST STATION THROUGH WHICH THE MESSAGE IS SENT, WHEN THE COST OF THE SPECIAL DELIVERY IS PREPAID.
JOUR —— RADIOGRAMS NOT TO BE DELIVERED DURING THE NIGHT TIME.
NUIT —— RADIOGRAMS TO BE DELIVERED AT NIGHT TIME IF RECEIVED THEN.
TR —— RADIOGRAMS TO BE CALLED FOR AT A TELEGRAPH OFFICE.
GP —— RADIOGRAMS TO BE CALLED FOR AT A POST OFFICE.
TM, AND THE FIGURE REPRESENTING THE NUMBER OF ADDRESSES —— RADIOGRAMS WITH MULTIPLE ADDRESSES.

PC —— RADIOGRAMS WITH ACKNOWLEDGEMENT OF RECEIPT BY TELEGRAPH.
PCP —— RADIOGRAMS WITH ACKNOWLEDGEMENT OF RECEIPT BY POST.
CR —— RADIOGRAMS OF ACKNOWLEDGEMENT OF "PC" OR "PCP" RADIOGRAMS.
D —— RADIOGRAMS TO BE GIVEN PRIORITY OVER THE LAND TELEGRAPH SYSTEM, THAT IS, URGENT MESSAGES.
ST —— PAID SERVICE ADVICES.
OL —— OCEAN LETTERS.
GOVT —— RADIOGRAMS ON UNITED STATES GOVERNMENT BUSINESS.
PRESSE —— RADIOGRAMS CONTAINING PRESS NEWS.

PREAMBLE: –	P 2 R 16 RADIO SS SANTA BARBARA 10.35 A.M.
ADDRESS: –	TO: C.H. TAYLOR 33 SOUTH AVE DENVER (COLO)
TEXT: –	EXPECT TO ARRIVE PIER 13 NEWYORK SATURDAY LOVE
SIGNATURE: –	CLARA

FIG. 3
Components of the Message.

IN FIG. 4 YOU ARE SHOWN AN EXAMPLE OF A TYPICAL "REPLY PREPAID" RADIOGRAM.

THE CABLE-COUNT SYSTEM

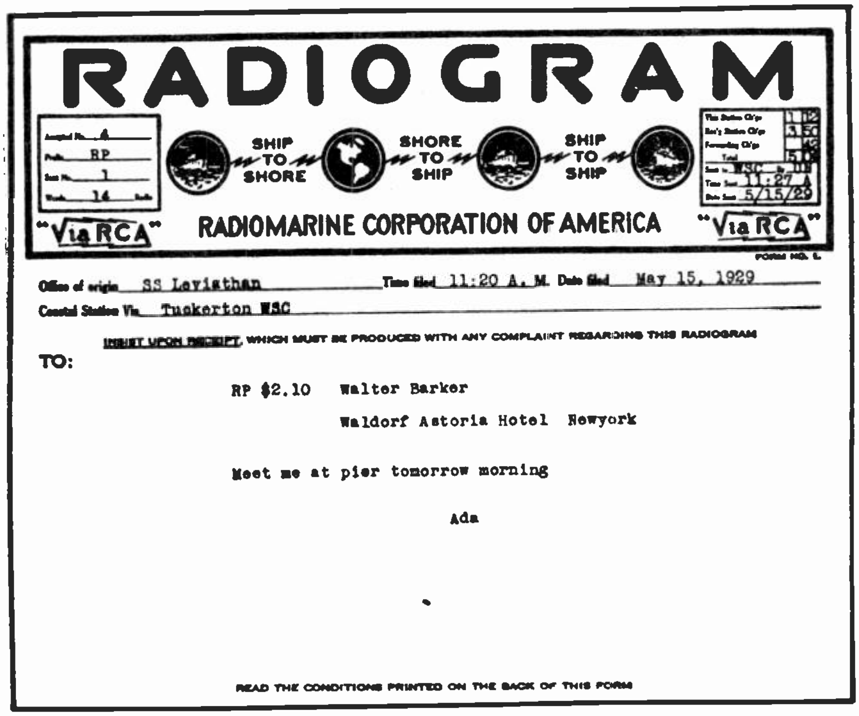
IN COUNTING THE WORDS CONTAINED IN A RADIOGRAM AND FOR WHICH A CHARGE IS MADE, THE CABLE-COUNT SYSTEM IS USED. THIS SYSTEM PROVIDES THAT ALL WORDS IN THE ADDRESS, TEXT, AND SIGNATURE MUST BE COUNTED AND CHARGED FOR.

IN THIS SYSTEM, MESSAGES ARE DIVIDED INTO THREE DISTINCT CLASSES AS FOLLOWS: (1) PLAIN LANGUAGE; (2) CODE LANGUAGE; AND (3) CIPHER LANGUAGE.

IN THE CASE OF PLAIN-LANGUAGE, THE MESSAGES MUST BE WRITTEN ENTIRELY IN PLAIN LANGUAGE AND THE WORDS ARE COUNTED ON THE BASIS OF 15 CHARACTERS TO THE WORD. ANY FRACTIONAL PART OF 15 CHARACTERS IS ALSO COUNTED AS 1 WORD. NUMBERS UP TO 5 IN A GROUP ARE COUNTED AS ONE WORD AND NUMBERS OVER 5 IN A GROUP ARE COUNTED AS TWO WORDS.

EXAMPLES:

BUILDING	1 WORD
PARENTHESIS	1 WORD
UNCONSTITUTIONAL	2 WORDS
6,742	1 WORD
358	1 WORD
247,956	2 WORDS



RADIOGRAM

Accepted No. 4
Prefix RP
Sent No. 1
Words 14

SHIP TO SHORE — SHORE TO SHIP — SHIP TO SHIP

This Station Ch'gs 1.12
Sen'g Station Ch'gs 3.50
Forwarding Ch'gs .48
Total 5.10
Sent to WSC By DB
Time Sent 11:27 A
Date Sent 5/15/29

"Via RCA" RADIOMARINE CORPORATION OF AMERICA "Via RCA"

FORM NO. 1

Office of origin SS Leviathan Time filed 11:20 A. M. Date filed May 15, 1929

Coastal Station Via Tuckerton WSC

INSIST UPON RECEIPT, WHICH MUST BE PRODUCED WITH ANY COMPLAINT REGARDING THIS RADIOGRAM

TO:

RP $2.10 Walter Barker
Waldorf Astoria Hotel Newyork

Meet me at pier tomorrow morning

Ada

READ THE CONDITIONS PRINTED ON THE BACK OF THIS FORM

FIG. 4

A "Reply Prepaid" Radiogram.

CODE LANGUAGE CONSISTS OF PRONOUNCEABLE WORDS BUT WHICH HAVE NO DIRECT MEANING AND WHICH DO NOT EXCEED 10 CHARACTERS IN LENGTH. EXAMPLES OF CODE LANGUAGE ARE AS FOLLOWS; NRTOSU = 1 WORD; X-RAY = 2 WORDS.

IF THE CODE WORDS ARE NON-PRONOUNCEABLE OR ELSE PRONOUNCEABLE BUT EXCEED 10 CHARACTERS IN LENGTH THEN THEY ARE COUNTED ACCORDING TO THE CIPHER RATE. CIPHER LANGUAGE IS COUNTED AT THE RATE OF 5 LETTERS TO THE WORD AND MAY BE MADE UP OF ANY COMBINATION OF LETTERS OR FIGURES SUCH AS: ARSQO = 1 WORD; PNOSJR = 2 WORDS; H 4T3 = 4 WORDS.

WHEN SENDING RADIOGRAMS, THE WORD STREET, ROAD, PARK, OR SQUARE IS ALWAYS COUNTED AS ONE WORD ASIDE FROM ITS DESIGNATOR IN THE ADDRESS. HYPHENATED OR COMPOUND WORDS ARE COUNTED AS SO MANY SEPARATE WORDS, DEPENDING ON THE NUMBER OF PARTS.

NAMES OF PLACES SUCH AS NEW YORK, NEW LONDON ETC. ARE COUNTED AS ONE

WORD' IN THE ADDRESS AND TWO WORDS IN THE TEXT.

IF NEW YORK IS WRITTEN AS NEWYORK OR NEW LONDON IS WRITTEN AS NEWLONDON ETC. THEN THEY ARE COUNTED AS ONE WORD IN THE TEXT. SUCH NAMES, HOWEVER, SHOULD BE WRITTEN AS TWO SEPARATE WORDS IN THE ADDRESS.

RADIO COMPASS BEARINGS

OPERATORS OF MOBILE STATIONS ARE OFTEN REQUIRED TO OBTAIN A RADIO COMPASS BEARING. THE UNITED STATES GOVERNMENT HAS DRAWN UP THE FOLLOWING REGULATIONS REGARDING RADIO COMPASS BEARINGS: ALL RADIO COMPASS COMMUNICATIONS ARE TO BE HANDLED ON THE 800 METER WAVELENGTH. SHIPS ARE NOW EQUIPPED WITH THIS ADDITIONAL OPERATING WAVELENGTH FOR RADIO COMPASS EXCLUSIVELY. WHEN A COMPASS BEARING IS DESIRED, THE RADIO OPERATOR OF THE SHIP CALLS THE NEAREST COMPASS BEARING CONTROL STATION ON 800 METERS AND SENDS THE "Q" CODE SIGNAL QTE FOLLOWED BY THE QUESTION MARK (. . — — . .) AND WHICH SIGNIFIES THAT HIS SHIP DESIRES A COMPASS BEARING.

FOR EXAMPLE, IF YOU WERE THE OPERATOR ON THE SS SANTA BARBARA WHOSE CALL SIGNAL IS WXOH AND THE CAPTAIN OF THE VESSEL REQUESTED YOU TO OBTAIN A COMPASS BEARING FROM THE CAPE JUNE COMPASS BEARING STATION WHOSE CALL SIGNAL IS RNO, THEN YOUR PROCEDURE WOULD BE AS FOLLOWS:

RNO RNO RNO DE WXOH WXOH WXOH — . . . — QTE . . — — . . . — . — . — . — (THIS WOULD BE INTERPRETED AS WXOH CALLING RNO; BREAK; WHAT IS MY TRUE BEARING?; END OF MESSAGE; GO AHEAD.)

STATION RNO WOULD THEN RESPOND AS FOLLOWS:

WXOH DE RNO — . — STATION WXOH WOULD THEN CONTINUE AS FOLLOWS: RNO DE WXOH — . . . — QTE . . — — . . WXOH MO WXOH MO WXOH MO (THIS ALTERNATION OF WXOH AND MO SHOULD BE SENT FOR A PERIOD OF NOT MORE THAN 50 SECONDS, SENDING SLOWLY AND PROLONGING THE DASHES.) THEN PROCEED WITH . — . — . — . — RNO WILL THEN PROCEED TO TRANSMIT THE BEARING IN THE FOLLOWING MANNER: WXOH DE RNO — . . . — QTE CAPE JUNE 130 CAPE NEW HALL 115 SEAL BEACH 095 AT 0127 . — . — . — . — (THESE BEARINGS OF COURSE WILL DEPEND UPON THE PARTICULAR POSITION OF THE MOBILE STATION AT THE TIME IN QUESTION).

AFTER THE BEARING HAS BEEN TRANSMITTED BY THE COMPASS BEARING STATION, THE MOBILE STATION REPEATS THE FIGURES TO THE BEARING STATION FOR VERIFICATION AND THIS IS DONE AS FOLLOWS:

RNO DE WXOH — . . . — 130 115 095 0127 . . — — . . . — . —. — . — RNO THEN RESPONDS: WXOH DE RNO . — . . . . . — . —

STANDARD TIME

ANOTHER IMPORTANT SUBJECT WITH WHICH THE RADIO OPERATOR SHOULD BE FAMILIAR IS THAT TREATING WITH THE DIFFERENT TIME SYSTEMS WHICH ARE USED. THE THREE SYSTEMS WHICH ARE USED FOR THIS PURPOSE ARE EASTERN STANDARD TIME (EST), PACIFIC TIME (PT) AND GREENWICH MEAN TIME (GMT).

THERE IS A DIFFERENCE OF FIVE HOURS BETWEEN GREENWICH MEAN TIME AND EASTERN STANDARD TIME, AND A DIFFERENCE OF EIGHT HOURS BETWEEN GREENWICH MEAN TIME AND PACIFIC STANDARD TIME. THAT IS TO SAY, WHEN IT IS 2 A.M. GREENWICH MEAN TIME, IT IS 9 P.M. EASTERN STANDARD TIME AND 6 P.M. PACIFIC STANDARD TIME.

IN FIG. 5 YOU ARE SHOWN A STANDARD TIME CHART WHICH YOU SHOULD FIND TO BE BOTH INTERESTING AND HELPFUL. IT IS OF INTEREST TO NOTE THAT TIME CHANGES 1 HOUR WITH EACH 15 DEGREES DIFFERENCE IN LONGITUDE. FOR EXAMPLE, WHEN IT IS 2 A.M. IN LONDON (GMT), IT IS 9 P.M. IN NEW YORK (EST) AND 6 P.M. IN SAN FRANCISCO (PST).

TWENTY-FOUR-HOUR TIME SYSTEM

RADIOTELEGRAMS ARE FILED ON THE BASIS OF THE 24-HOUR SYSTEM. IN THIS SYSTEM THE HOURS FOR THE ENTIRE CALENDER DAY ARE COUNTED FROM 0 TO 23 STARTING AT MIDNIGHT. THIS PERMITS THE ABREVIATIONS A.M. AND P.M. TO BE ELIMINATED AND INCREASES THE ACCURACY. THE MINUTES 01 TO 59 ARE INDICATED AFTER THE HOURS, THUS 2:15 P.M. WOULD BE 1415; 5:37 A.M. WOULD BE 0537; 11:59 P.M. WOULD BE 2359 ETC.

THE DISTRESS SIGNAL

THE "DISTRESS SIGNAL", AS YOU WILL RECALL FROM PREVIOUS INSTRUCTIONS, IS SOS OR • • • — — — • • • AND WHICH MEANS THAT THE MOBILE STATION IN QUESTION IS THREATENED BY GRAVE AND IMMENENT DANGER AND REQUESTS IMMEDIATE ASSISTANCE.

THE INTERNATIONAL CALLING AND DISTRESS FREQUENCY IS 500 KC., WHILE IN THE GREAT LAKES REGION OF THE UNITED STATES A FREQUENCY OF 410 KC. IS USED FOR THIS PURPOSE.

THE OPERATOR IS NOT PERMITTED TO GIVE THE DISTRESS SIGNAL EXCEPT BY AUTHORITY OF THE

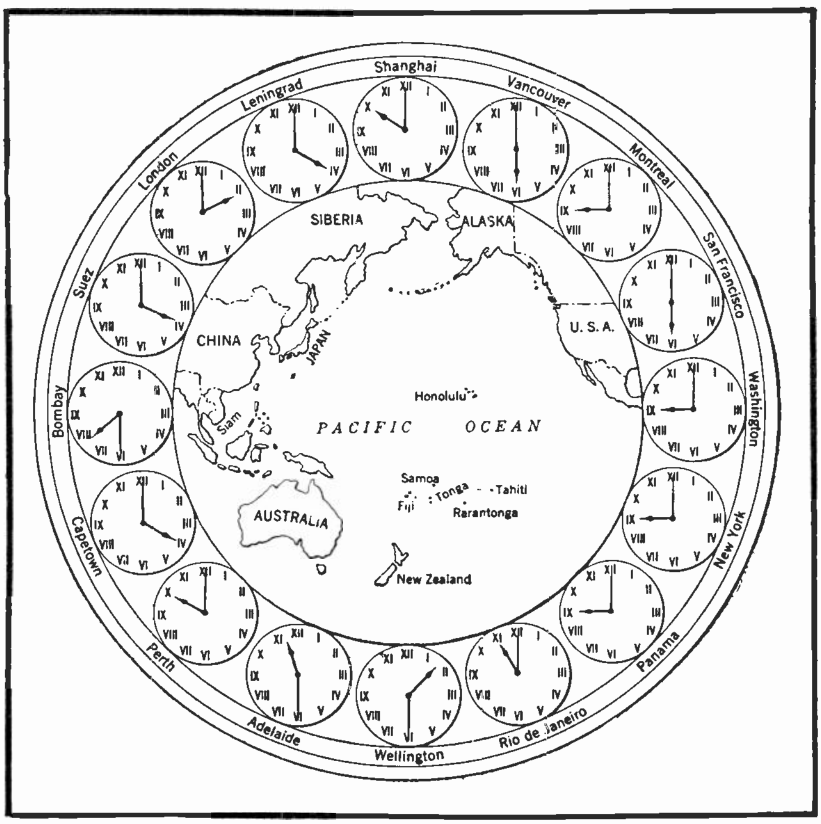


FIG. 5
Standard Time Chart.

MASTER OR PERSON IN CHARGE OF THE SHIP, AIRCRAFT, OR MOBILE STATION.

IN GIVING THE DISTRESS SIGNAL, THE PROCEDURE IS AS FOLLOWS: TRANSMIT THE DISTRESS SIGNAL THREE TIMES IN SUCCESSION, FOLLOWED BY THE WORD DE AND THEN THE CALL SIGNAL OF THE MOBILE STATION IN DISTRESS ALSO SENT THREE TIMES.

THIS CALL SHOULD NOT BE ADDRESSED TO ANY PARTICULAR STATION AND IT IS REQURED THAT ALL LAND OR MOBILE STATIONS CEASE ALL TRANSMISSION CAPABLE OF INTERFERING WITH THE DISTRESS CALLS OR MESSAGES AND THEY MUST LISTEN ON THE WAVE USED FOR THE DISTRESS CALL. THE DISTRESS CALL HAS ABSOLUTE PRIORITY OVER ALL OTHER TRANSMISSIONS.

THE DISTRESS MESSAGE FOLLOWING THE DISTRESS CALL SHOULD INCLUDE THE NAME OF THE SHIP OR OTHER MOBILE UNIT IN DISTRESS, INFORMATION CONCERNING ITS POSITION AND THE NATURE OF THE DISTRESS AND THE KIND OF ASSISTANCE DESIRED.

THE DISTRESS CALL AND MESSAGE SHOULD BE REPEATED AT INTERVALS UNTIL AN ANSWER IS RECEIVED. THESE INTERVALS, HOWEVER, SHOULD BE OF SUFFICIENT LENGTH SO AS TO PERMIT STATIONS ANSWERING THE CALL TO PLACE THEIR TRANSMITTER IN OPERATION.

IF THE STATION IN DISTRESS RECEIVES NO ANSWER TO THE DISTRESS CALL WHEN TRANSMITTING IT AT 500 KC., THEN THE CALL AND MESSAGE MAY BE REPEATED ON ANY OTHER AVAILABLE WAVE ON WHICH ATTENTION MIGHT BE ATTRACTED.

STATIONS WHICH RECEIVE A DISTRESS MESSAGE FROM A MOBILE STATION IN THEIR IMMEDIATE VICINITY MUST AT ONCE ACKNOWLEDGE RECEIPT THEREOF AND EXERCISE SPECIAL PRECAUTIONS SO AS NOT TO INTERFERE WITH THE TRANSMISSION OF THE ACKNOWLEDGEMENTS OF RECEIPT OF THE SAME MESSAGE SENT BY OTHER STATIONS. IF THERE IS GOOD REASON THAT SOME OTHER STATION IS LOCATED STILL NEARER TO THE STATION IN DISTRESS, THEN PREFERENCE SHOULD BE GIVEN TO THE NEARER STATION FOR ANSWERING THE CALL BUT YET TO BE READY TO SEND AN ACKNOWLEDGEMENT IF OTHERS FAIL TO DO SO.

TO ACKNOWLEDGE RECEIPT OF A DISTRESS MESSAGE THE PROCEDURE IS AS FOLLOWS: TRANSMIT THREE TIMES THE CALL SIGNAL OF THE STATION IN DISTRESS, FOLLOWED BY THE WORD DE, THE CALL SIGNAL OF THE STATION ACKNOWLEDGING RECEIPT (THREE TIMES), GROUP R R R, DISTRESS SIGNAL. IF THE ACKNOWLEDGING STATION IS ALSO MOBILE, THEN IT SHOULD ALSO INCLUDE ITS NAME AND POSITION AS A PART OF ITS ACKNOWLEDGEMENT.

A SHIP WHICH RECEIVES A DISTRESS MESSAGE MAY TRANSMIT THE MESSAGE IF THE SHIP IN DISTRESS IS NOT ITSELF IN A POSITION TO DO SO OR IF THE MASTER OF THE VESSEL JUDGES THAT FURTHER HELP IS NECESSARY. ALL COMMUNICATIONS RELATING TO DISTRESS MESSAGES MUST BE DELIVERED IMMEDIATELY TO THE MASTER OF THE SHIP.

THE RADIOTELPHONE DISTRESS SIGNAL IS THE SPOKEN EXPRESSION MAYDAY. THIS IS SPOKEN THREE TIMES FOLLOWED BY THE NAME OF THE STATION SPOKEN THREE TIMES.

THE AUTOMATIC ALARM SIGNAL

THE AUTOMATIC ALARM SIGNAL IS USED TO ANNOUNCE THAT A DISTRESS CALL WILL FOLLOW IMMEDIATELY. THE ALARM SIGNAL IS COMPOSED OF A SERIES OF 12 DASHES SENT IN ONE MINUTE, THE DURATION OF EACH DASH BEING 4 SECONDS AND THE DURATION OF THE INTERVAL BETWEEN TWO DASHES, 1 SECOND.

THE URGENT SIGNAL

THE URGENT SIGNAL IS X X X SENT SEVERAL TIMES BEFORE THE CALL LETTERS. IT IS USED TO INDICATE THAT THE CALLING STATION HAS A VERY URGENT MESSAGE CONCERNING THE SAFETY OF THE SHIP OR ANOTHER SHIP, OR THE SAFETY OF ANY PERSON ON BOARD THE SHIP OR IN SIGHT OF THE SHIP. THIS SIGNAL SHALL BE TRANSMITTED ONLY WITH THE AUTHORIZATION OF THE MASTER OR PERSON RESPONSIBLE FOR THE SHIP.

THE SAFETY SIGNAL

THE SAFETY SIGNAL CONSISTS OF THE GROUP T T T WHICH IS TRANSMITTED WITH THE LETTERS WELL SEPARATED, FOLLOWED BY THE WORD "DE" AND BY THE CALL SIGNAL OF THE STATION SENDING IT. THIS SIGNAL INDICATES THAT THE STATION SENDING IT IS ABOUT TO TRANSMIT A MESSAGE CONCERNING THE SAFETY OF NAVIGATION OR GIVING OTHER IMPORTANT INFORMATION RELATIVE TO METEOROLOGICAL WARNING MESSAGES.

THE SAFETY SIGNAL AND THE SAFETY MESSAGE SHALL BE SENT AT 500 KC. AND IF NECESSARY, ON THE NORMAL LISTENING WAVE OF SHIP AND AIRCRAFT STATIONS. IT SHALL BE SENT ONCE DURING THE FIRST SILENT PERIOD AND NEAR THE END OF THAT PERIOD. ALL STATIONS HEARING IT MUST CONTINUE TO LISTEN ON THE NORMAL SHIP CALLING WAVE OR ON THE AUTHORIZED AIRCRAFT STATION WAVE UNTIL THE MESSAGE PRECEDED BY THE SAFETY SIGNAL SHALL HAVE ENDED. THE TRANSMISSION OF THIS MESSAGE SHALL BEGIN IMMEDIATELY AFTER THE END OF THE SILENT PERIOD.

THE CQ SIGNAL

THE SIGNAL CQ IS THE SIGNAL OF INQUIRY. STATIONS DESIRING TO ENTER INTO COMMUNICATION WITH MOBILE STATIONS WITHOUT, HOWEVER, KNOWING THE NAMES OF MOBILE STATIONS WHICH ARE WITHIN THEIR RANGE OF ACTION, MAY USE THE SIGNAL OF THE STATION CALLED IN THE CALLING FORMULA, THIS FORMULA BEING FOLLOWED BY THE LETTER K.

IN REGIONS WHERE TRAFFIC IS HEAVY, THE USE OF THE CALL CQ FOLLOWED BY THE LETTER K IS FORBIDDEN EXCEPT IN COMBINATION WITH URGENT SIGNALS. THE CALL CQ NOT FOLLOWED BY THE LETTER K SHALL BE EMPLOYED FOR RADIOTELEGRAMS OF GENERAL INFORMATION, TIME SIGNALS, REGULAR METEOROLOGICAL INFORMATION, GENERAL SAFETY NOTICES, AND INFORMATION OF ALL KINDS INTENDED TO BE READ BY ANYONE WHO CAN RECEIVE THEM.

VARIOUS REGULATIONS

THE FOLLOWING ARE REGULATIONS OF VARIOUS TYPES AND WITH WHICH THE COMMERCIAL OPERATOR SHOULD BE FAMILIAR:

1. – TABLE I SPECIFIES THE TIME PERIODS DURING WHICH A RADIO WATCH MUST BE MAINTAINED ON ALL SHIPS WITHIN THE ZONES INDICATED. THESE ARE KNOWN AS "ZONES OF WATCH" AND IN TABLE I THE FIGURES INDICATE TIME ON THE 24-HOUR TIME SYSTEM. THE INTERNATIONAL LAW ALSO REQUIRES THAT ALL STATIONS IN MOBILE MARITIME SERVICE MUST LISTEN-IN ON THE DISTRESS WAVE FOR THREE MINUTES TWICE EACH HOUR, BEGINNING AT THE 15TH MINUTE AND AT THE 45TH MINUTE AFTER EACH HOUR, AND ALSO DURING THE TIME OF DISTRESS COMMUNICATIONS.

2. – TWO INTERNATIONAL SILENT PERIODS ARE TO BE OBSERVED PER HOUR. EACH OF THESE SILENT PERIODS SHOULD BE THREE MINUTES LONG, BEGINNING AT THE 15TH MINUTE AND AT THE 45TH MINUTE AFTER EACH HOUR GREENWICH MEAN TIME. DURING THESE PERIODS THE TRANSMITTER SHALL NOT BE USED.

3. – DURING TRANSMISSIONS "TO ALL STATIONS" OF TIME SIGNALS AND OF METEOROLOGICAL MESSAGES INTENDED FOR STATIONS OF THE MOBILE SERVICE, ALL STATIONS IN THAT SERVICE AND THE TRANSMISSIONS OF WHICH MIGHT INTERFERE WITH THE RECEPTION OF THE SIGNAL AND MESSAGES IN QUESTION, MUST KEEP SILENT IN ORDER TO PERMIT ALL STATIONS SO DESIRING TO RECEIVE THESE SIGNALS AND MESSAGES.

4. – NO PERSON RECEIVING OR ASSISTING IN RECEIVING ANY RADIO COMMUNICATION SHALL DIVULGE OR PUBLISH ITS CONTENTS OR ANY PART OF IT TO ANY PERSON OTHER THAN THE ADDRESSEE, HIS AGENT, OR ATTORNEY, OR MASTER OF THE SHIP ON WHICH THE MESSAGE IS SENT OR RECEIVED, OR IN RESPONSE TO A SUBPOENA ISSUED BY A COURT OF COMPETENT JURISDICTION, OR IN DEMAND OF OTHER LAWFUL AUTHORITY. FOR VIOLATING THIS LAW THE VIOLATOR MAY BE PUNISHED BY A FINE OF NOT MORE THAN $500 FOR EACH AND EVERY OFFENSE.

TABLE NO. I

ZONES OF WATCH SCHEDULE

Zones		Duration of hours of service Greenwich Mean Time	
		One operator ships	Two operator ships
A	Eastern Atlantic Ocean, Mediterranean, North Sea, Baltic	From 8 to 10h 12 to 14h 16 to 18h 20 to 22h	From 0 to 6h 8 to 14h 16 to 18h 20 to 22h
B	Indian Ocean, eastern Arctic Ocean	From 4 to 6h 8 to 10h 12 to 14h 16 to 18h	From 0 to 2h 4 to 10h 12 to 14h 16 to 18h 20 to 24h
C	China Sea, western Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 12 to 14h	From 0 to 6h 8 to 10h 12 to 14h 16 to 22h
D	Central Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 20 to 22h	From 0 to 2h 4 to 6h 8 to 10h 12 to 18h 20 to 24h
E	Eastern Pacific Ocean	From 0 to 2h 4 to 6h 16 to 18h 20 to 22h	From 0 to 2h 4 to 6h 8 to 14h 16 to 22h
F	Western Atlantic Ocean and Gulf of Mexico	From 0 to 2h 12 to 14h 16 to 18h 20 to 22h	From 0 to 2h 4 to 10h 12 to 18h 20 to 22h

5. – THE SHIP'S MASTER HAS THE RIGHT TO CENSURE ANY MESSAGES RECEIVED AND TRANSMITTED BY THE RADIO STATION ON SHIPBOARD.

6. – VESSELS PLYING 200 MILES OR MORE BETWEEN PORTS AND LICENSED TO CARRY,

OR CARRYING, FIFTY OR MORE PASSENGERS OR CREW SHALL BE EQUIPPED WITH RADIO APPARATUS AND BE IN CHARGE OF TWO OR MORE OPERATORS AND MAINTAIN A CONTINUOUS WATCH. EMERGENCY EQUIPMENT, INDEPENDENT OF THE SHIP'S MAIN SOURCE OF POWER SUPPLY, CAPABLE OF TRANSMITTING AND RECEIVING MESSAGES OVER A DISTANCE OF 100 MILES DAY OR NIGHT FOR A PERIOD OF AT LEAST FOUR HOURS, MUST BE PROVIDED.

7. - MAXIMUM POWER SHALL BE USED IN TRANSMITTING DISTRESS MESSAGES OR MESSAGES RELATED HERETO. IN ALL OTHER CLASSES OF RADIO CORRESPONDENCE ONLY THAT AMOUNT OF POWER NECESSARY TO INSURE RELIABLE COMMUNICATION SHALL BE USED. WHEN WITHIN 5 NAUTICAL MILES OF NAVAL OR MILITARY STATIONS THE TRANSFORMER INPUT SHALL NOT EXCEED $\frac{1}{2}$ KW AND WHEN WITHIN 15 MILES OF SUCH STATIONS THE TRANSFORMER INPUT SHALL NOT EXCEED 1 KW.

8. - SUPERFLUOUS SIGNALS ARE THOSE WHICH ARE UNNECESSARY IN CARRYING OUT EFFICIENT RADIO CORRESPONDENCE. THEY ARE FORBIDDEN.

9. - NO PERSON, FIRM, COMPANY OR CORPORATION WITHIN THE JURISDICTION OF THE UNITED STATES SHALL KNOWINGLY UTTER OR TRANSMITK OR CAUSE TO BE UTTERED OR TRANSMITTED, ANY FALSE OR FRAUDULENT SIGNAL OF DISTRESS OR COMMUNICATION RELATING THERETO.

10.- THE PRIORITY OF VARIOUS CLASSES OF RADIO COMMUNICATIONS FOLLOW THE ORDER AS HERE GIVEN.

(A) DISTRESS CALLS, DISTRESS MESSAGES, AND DISTRESS TRAFFIC.

(B) COMMUNICATIONS PRECEDED BY AN URGENT SIGNAL.

(C) COMMUNICATIONS PRECEDED BY THE SAFETY SIGNAL.

(D) COMMUNICATIONS RELATIVE TO RADIO COMPASS BEARINGS.

(E) ALL OTHER COMMUNICATIONS.

11. - ALL STATIONS ARE BOUND TO EXCHANGE RADIO COMMUNICATIONS OR SIGNALS WITH OTHER STATIONS REGARDLESS OF THE RADIO SYSTEM USED.

12. - IF IT IS NECESSARY TO COMMUNICATE WITH A FOREIGN VESSEL WHOSE CREW CANNOT UNDERSTAND ENGLISH, THEN THE COMMUNICATION SHOULD BE CONDUCTED BY MEANS OF THE INTERNATIONAL SIGNAL CODE AND THE INTERNATIONAL RADIOTELEGRAPH ABREVIATIONS.

13. - IN TABLE II YOU ARE GIVEN A HANDY REFERENCE TABLE OF ALL WAVE LENGTH ALLOCATIONS FOR VARIOUS PURPOSES.

14. - THE VIOLATIONS AND THEIR PENALTIES TO WHICH AN OPERATOR IS SUBJECT UNDER THE RADIO ACT OF 1927 ARE AS FOLLOWS:

AN OPERATOR'S LICENSE MAY BE SUSPENDED FOR A PERIOD NOT EXCEEDING TWO YEARS FOR: (A) FAILURE TO CARRY OUT THE LAWFUL ORDERS OF THE MASTER OF THE VESSEL ON WHICH HE IS EMPLOYED, (B) WILLFULLY DAMAGING OR PERMITTING RADIO APPARATUS TO BE DAMAGED, (C) TRANSMITTING SUPERFLUOUS RADIO COM

TABLE NO. II

WAVE-LENGTH ALLOCATIONS

Frequencies, kilocycles per second	Approximate wave lengths, meters	Services
10 to 100	30,000 to 3,000	Fixed services
100 to 110	3,000 to 2,725	Fixed services and mobile services
110 to 125	2,725 to 2,400	Mobile services
125 to 150[1]	2,400 to 2,000[1]	Maritime mobile services *open to public correspondence exclusively*
150 to 160	2,000 to 1,875	Mobile services a. Broadcasting b. Fixed services c. Mobile services
160 to 194	1,875 to 1,550	The conditions for use of this band are subject to the following regional arrangements: All regions where broadcasting stations now exist working on frequencies below 300 kilocycles per second (above 1,000 meters) } broadcasting Other regions { Fixed services / Mobile services Regional arrangements will respect the rights of other regions in this band a. Mobile service b. Fixed service c. Broadcasting
194 to 285	1,550 to 1,050	The conditions for use of this band are subject to the following regional arrangements: Europe { a. *Air* mobile service *exclusively*; b. *Air* fixed services *exclusively*; c. Within the band 250 to 285 kilocycles per second (1,200 to 1,050 meters). Fixed service *not open to public correspondence.*; d. Broadcasting within the band 194 to 224 kilocycles per second (1,550 to 1,340 meters) Other regions { a. Mobile services except commercial ship stations; b. Fixed *air* services *exclusively*; c. Fixed services *not open to public correspondence*
285 to 315	1,050 to 950	Radio beacons
315 to 350[2]	950 to 850[2]	*Air* mobile services *exclusively*
350 to 360	850 to 830	Mobile services *not open to public correspondence*
360 to 390	830 to 770	a. Radio compass service b. Mobile services, on condition that they do not interfere with radio compass service
390 to 460	770 to 650	Mobile services
460 to 485	650 to 620	Mobile services (*except damped waves and radiotelephony*)
485 to 515[3]	620 to 580[3]	Mobile services (distress, call, etc.)
515 to 550	580 to 545	Mobile services *not open to public correspondence (except damped waves and radiotelephony)*
550 to 1,300[4]	545 to 230[4]	Broadcasting: a. Broadcasting
1,300 to 1,500	230 to 200	b. Maritime mobile services, waves of 1,365 kilocycles per second (220 meters) exclusively
1,500 to 1,715	200 to 175	Mobile services
1,715 to 2,000	175 to 150	{ Mobile services Fixed services Amateurs
2,000 to 2,250	150 to 133	Mobile services and fixed services
2,250 to 2,750	133 to 109	Mobile services
2,750 to 2,850	109 to 105	Fixed services
2,850 to 3,500	105 to 85	Mobile services and fixed services
3,500 to 4,000	85 to 75	{ Mobile services Fixed services Amateurs
4,000 to 5,500	75 to 54	Mobile services and fixed services
5,500 to 5,700	54 to 52.7	Mobile services
5,700 to 6,000	52.7 to 50	Fixed services
6,000 to 6,150	50 to 48.8	Broadcasting
6,150 to 6,675	48.8 to 45	Mobile services
6,675 to 7,000	45 to 42.8	Fixed services
7,000 to 7,300	42.8 to 41	Amateurs
7,300 to 8,200	41 to 36.6	Fixed services
8,200 to 8,550	36.6 to 35.1	Mobile services
8,550 to 8,990	35.1 to 33.7	Mobile services and fixed services
8,900 to 9,500	33.7 to 31.6	Fixed services
9,500 to 9,600	31.6 to 31.2	Broadcasting
9,600 to 11,000	31.2 to 27.3	Fixed services
11,000 to 11,400	27.3 to 26.3	Mobile services
11,400 to 11,700	26.3 to 25.6	Fixed services
11,700 to 11,900	25.6 to 25.2	Broadcasting
11,900 to 12,300	25.2 to 24.4	Fixed services
12,300 to 12,825	24.4 to 23.4	Mobile services
12,825 to 13,350	23.4 to 22.4	Mobile services and fixed services
13,350 to 14,000	22.4 to 21.4	Fixed services
14,000 to 14,400	21.4 to 20.8	Amateurs
14,400 to 15,000	20.8 to 19.85	Fixed services
15,100 to 15,350	19.85 to 19.55	Broadcasting
15,350 to 16,400	19.55 to 18.3	Fixed services
16,400 to 17,100	18.3 to 17.5	Mobile services
17,100 to 17,750	17.5 to 16.9	Mobile services and fixed services
17,750 to 17,800	16.9 to 16.85	Broadcasting
17,800 to 21,450	16.85 to 14	Fixed services
21,450 to 21,550	14 to 13.9	Broadcasting
21,550 to 22,300	13.9 to 13.45	Mobile services
22,300 to 23,000	13.45 to 13.1	Mobile services and fixed services
23,000 to 28,000	13.1 to 10.7	Not reserved
28,000 to 30,000	10.7 to 10	Amateurs and experimental
30,000 to 56,000	10 to 5.35	Not reserved
56,000 to 60,000	5.35 to 5	Amateurs and experimental
Above 60,000	Below 5	Not reserved

[1] The wave of 143 kilocycles per second (2,100 meters) is the calling wave for mobile stations using long continuous waves.

[2] The wave of 333 kilocycles per second (900 meters) is the international calling wave for air services.

[3] The wave of 500 kilocycles per second (600 meters) is the international calling and distress wave. It may be used for other purposes on condition that it will not interfere with call signals and distress signals.

[4] Mobile services may use the band 550 to 1,300 kilocycles per second (545 to 230 meters) on condition that this will not cause interference with the services of a country which uses this band exclusively for broadcasting.

NOTE.—It is recognised that short waves (frequencies from 6,000 to 23,000 kilocycles per second approximately—wave lengths from 50 to 13 meters approximately) are very efficient for long-distance communications. It is recommended that, as a general rule, this band of waves be reserved for this purpose, in services between fixed points.

MUNICATIONS OR SIGNALS OR RADIO COMMUNICATIONS CONTAINING PROFANE OR OBSCENE WORDS OR LANGUAGE, (D) WILLFULLY OR MALICIOUSLY INTERFERING WITH ANY RADIO COMMUNICATIONS OR SIGNALS, (E) ANY IMPROPER ALTERATION OF THE SERVICE RECORD ON THE LICENSE, OR THE FORGERY OF MASTERS' OR EMPLOYERS' SIGNATURES THEREON OR (F) VIOLATION OF ANY PROVISION OF ANY ACT OR TREATY BINDING ON THE UNITED STATES WHICH THE SECRETARY OF COMMERCE OR THE COMMISSION IS AUTHORIZED BY THE RADIO ACT OF 1927 TO ADMINISTER, OR OF ANY REGULATION MADE BY THE COMMISSION OR THE SECRETARY OF COMMERCE UNDER ANY SUCH ACT OR TREATY.

ANY OPERATOR FAILING OR REFUSING TO OBSERVE OR VIOLATING ANY RULE, REGULATION, RESTRICTION, OR CONDITION MADE OR IMPOSED BY THE LICENSING AUTHORITY UNDER THE AUTHORITY OF THE RADIO ACT OF 1927 OR OF ANY INTERNATIONAL RADIO CONVENTION OR TREATY RATIFIED OR ADHERED TO BY THE UNITED STATES, IN ADDITION TO ANY OTHER PENALTIES PROVIDED BY LAW, UPON CONVICTION THEREOF BY A COURT OF COMPETENT JURISDICTION, SHALL BE PUNISHED BY A FINE OF NOT MORE THAN $500 FOR EACH AND EVERY OFFENSE.

ANY OPERATOR WHO SHALL VIOLATE ANY PROVISION OF THE RADIO ACT OF 1927, OR SHALL KNOWINGLY MAKE ANY FALSE OATH OR AFFIRMATION IN ANY AFFIDAVIT REQUIRED OR AUTHORIZED BY THE RADIO ACT OF 1927, OR SHALL KNOWINGLY SWEAR FALSELY TO A MATERIAL MATTER IN ANY HEARING AUTHORIZED BY THE ACT, UPON THE CONVICTION THEREOF IN ANY COURT OF COMPETENT JURISDICTION SHALL BE PUNISHED BY A FINE OF NOT MORE THAN $5000 OR BY IMPRISONMENT FOR A TERM OF NOT MORE THAN FIVE YEARS, OR BOTH, FOR EACH AND EVERY SUCH OFFENSE.

15. — EVERY SHIP STATION WHOSE RADIO SERVICE IS ON THE VERGE OF BEING CLOSED BY REASON OF ITS ARRIVAL IN PORT MUST NOTIFY THE NEAREST LAND STATION. A CONSTANT RADIO WATCH SHALL BE MAINTAINED WHEN ENTERING ANY PORT OF CALL, BEGINNING EIGHT HOURS BEFORE ARRIVAL.

16. — BROADCASTING TRANSMITTERS ARE PERMITTED BY LAW TO HAVE A FREQUENCY DEVIATION NOT IN EXCESS OF 50 CYCLES, PLUS OR MINUS.

17. — WHEN IT IS NECESSARY TO MAKE TEST SIGNALS IN ORDER TO ADJUST THE APPARATUS BEFORE PROCEEDING WITH A CALL OR TRANSMISSION, THEN THE SIGNALS MUST NOT BE MADE FOR MORE THAN ABOUT 10 SECONDS AND THEY MUST BE COMPOSED OF A SERIES OF V'S FOLLOWED BY THE CALL SIGNAL OF THE SENDING STATION.

IF A STATION SENDS TEST SIGNALS AT THE REQUEST OF ANOTHER STATION TO PERMIT THE LATTER TO ADJUST ITS RECEIVING APPARATUS, THESE SIGNALS MUST LIKEWISE BE COMPOSED OF A SERIES OF V'S IN WHICH THE CALL SIGNAL OF THE TRANSMITTING STATION SHALL APPEAR SEVERAL TIMES.

TESTS AND ADJUSTMENTS IN ANY STATION MUST BE CONDUCTED SO AS NOT TO INTERFERE WITH THE SERVICE OF OTHER STATIONS ENGAGED IN AUTHORIZED CORRESPONDENCE. THE TEST AND ADJUSTMENT SIGNALS MUST BE CHOSEN SO THAT NO CONFUSION CAN BE PRODUCED WITH A SIGNAL, ABBREVIATION ETC. OF SPECIAL MEANING DEFINED BY THE REGULATIONS.

ANY STATION TRANSMITTING FOR TESTS, ADJUSTMENTS, OR EXPERIMENTS, MUST DURING THE COURSE OF THESE TRANSMISSIONS SEND ITS CALL SIGNALS AT FREQUENT INTERVALS.

AMATEUR RULES AND REGULATIONS

For those who are interested in operating an amateur station, the following rules and regulations are pointed out. It is to be noted that those rules here given apply particularly to amateur operation and were therefore not given earlier in this lesson where commercial operating was of primary consideration. It is, however, advisable that even the amateur operator be familiar with ALL of the rules and regulations which have been presented in this lesson.

1. — The term "amateur" when used without further descriptive words means a person interested in radio technique solely with a personal aim and without accepting payment for handling messages of any kind.

2. — The various bands which are set aside for amateur use are designated as such in Table II of this lesson.

3. — In the United States none other than citizens of this country may obtain an amateur station license and no station may be operated on premises which are controlled by an alien.

4. — All amateur operators are required to keep an accurate "log" (record) of all communications in which they engage and are obliged to make it available to authorized government representatives upon demand. This log must specify the date and time of all transmissions; the name of the person operating the transmitter at that time; the station called; nature of transmission; the frequency band used; the location of the transmitter at each transmission if it is of the portable type; and the input power to the final amplifier stage.

5. — The maximum input power allowed for an amateur station is 1 Kw. This means a maximum of 1 Kw. to the plate circuit of the final amplifier.

6. — An amateur station may not broadcast any form of entertainment.

7. — If an amateur station causes interference with broadcast reception on receivers of modern design, the station is required to observe a silent period (called "quiet hours") from 8:00 P.M. to 10:30 P.M. local time and on Sundays during an additional period extending from 10:30 A.M. until 1 P.M.

8. — Amateurs in different countries must confine their exchange to communications having to do with their experiments and/or to remarks of such a nature that they would not be sufficiently important to send by public telegraph or cable service. Unless special arrangements have been made between governments of the two countries concerned, third-party messages (that is, messages addressed to or from some person other than either of the amateurs concerned in the contact) may not be handled.

9. — In the event that the operator of an amateur station should here a distress signal being transmitted from a ship or aircraft, then

HE SHOULD CEASE ALL TRANSMISSION CAPABLE OF INTERFERING WITH THE SIGNALS OF THE DISTRESSED SHIP, OR STATIONS COMMUNICATING WITH IT. THE OPERATOR SHOULD CONTINUE TO LISTEN UNTIL IT IS APPARENT THAT THE SHIP IS RECEIVING ASSISTANCE.

IF NO ONE SEEMS TO ANSWER THE SHIP, FULL PARTICULARS SHOULD IMMEDIATELY BE CONVEYED BY LAND LINE TO THE NEAREST GOVERNMENT OR COMMERCIAL STATION. EVERYTHING POSSIBLE SHOULD BE DONE TO BRING ASSISTANCE TO THE DISTRESSED SHIP WITHOUT RISKING RADIO INTERFERENCE TO THOSE IN A POSITION TO AID.

IF YOU INTEND TO ENGAGE IN COMMERCIAL OPERATING OR TO BECOME ACTIVE IN THE FIELD OF BROADCASTING, THEN YOU SHOULD STUDY THIS LESSON WITH SPECIAL CARE BECAUSE QUESTIONS CONCERNING THE SUBJECT MATTER CONTAINED HEREIN ARE ASKED IN THE GOVERNMENT EXAMINATIONS WHICH QUALIFY YOU FOR AN OPERATOR'S LICENSE. EVEN THOUGH YOU DO NOT SELECT ANY OF THESE PARTICULAR FIELDS FOR SPECIALIZATION, IT IS MOST ADVISABLE THAT YOU HAVE A CLEAR KNOWLEDGE OF THIS MATTER, FOR YOU NEVER CAN TELL BUT THAT YOU MIGHT HAVE NEED FOR IT SOME TIME IN THE FUTURE, EVEN THOUGH YOU MAY NOT REALIZE IT NOW.

WITHOUT A DOUBT, YOU ARE GOING TO FIND THE FOLLOWING LESSON TO BE OF SPECIAL INTEREST IN THAT YOU WILL AT THAT TIME COMMENCE YOUR STUDY OF RADIO TELEPHONE TRANSMITTERS, WHICH PERMIT THE TRANSMISSION OF VOICE BY MEANS OF RADIO. HOWEVER, BEFORE CONTINUING WITH THE NEXT LESSON, FIRST MAKE SURE THAT YOU HAVE A PERFECT UNDERSTANDING OF EVERYTHING WHICH HAS BEEN COVERED UP UNTIL NOW REGARDING CODE TRANSMITTERS BECAUSE THE MAJORITY OF THESE SAME PRINCIPLES ARE AGAIN GOING TO BE EMPLOYED IN YOUR PHONE TRANSMITTER STUDIES WHICH ARE NOW TO COME. SINCE IT WILL BE ASSUMED THAT YOU ARE ALREADY WELL INFORMED CONCERNING THE SUBJECTS OF PREVIOUS LESSONS, NONE OF THESE SHALL BE REPEATED IN THE FOLLOWING LESSONS. THEREFORE, IF THERE IS ANY DOUBT WHATEVER IN YOUR MIND REGARDING ANY ONE OF THESE SUBJECTS, IT IS ADVISABLE BEFORE CONTINUING WITH YOUR ADVANCED WORK THAT YOU REVIEW YOUR PREVIOUS TRANSMITTER LESSONS VERY CAREFULLY — ESPECIALLY THOSE WHICH TREAT WITH OSCILLATORS, AMPLIFIERS, ANTENNA SYSTEMS, AND POWER SUPPLIES.

Ans Feb 21, 1942

Examination Questions

LESSON NO. T-12

A business may be ever so successful, but it is never so sure -- never secure, until it holds its old friends by Service and increases its circle of New Friends on the basis of Satisfaction.

1. – What is the general routine which is to be followed when calling a station?

2. – If you were an operator aboard ship, how would you obtain a radio compass bearing?

3. – How would you answer a call from another station previous to the transmission of the actual message?

4. – Explain the relation between Eastern Standard Time, Pacific Standard Time, and Greenwich Mean Time.

5. – Explain in detail how a Radiogram should be transmitted.

6. – If you were an operator aboard ship, how would you send the distress signal?

7. – Explain in detail the twenty-four-hour time system.

8. – What is meant by the expression "zones of watch"?

9. – What is the law regarding the secrecy of messages which are handled by radio communication?

10.– State the order of priority of various classes of radio communication.

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Transmitters

LESSON NO. 13

RADIO · TELEGRAPH · TRANSMITTERS

YOUR TRANSMITTER STUDIES UP TO THE PRESENT TIME HAVE TREATED EXCLUSIVELY WITH CODE TRANSMITTERS, BUT COMMENCING WITH THIS LESSON YOU ARE GOING TO BE TOLD A GREAT DEAL ABOUT TRANSMITTERS WHICH ARE SUITABLE FOR THE TRANSMISSION OF BOTH VOICE AND MUSIC. TRANSMITTERS OF THIS TYPE ARE GENERALLY CLASSIFIED AS RADIO TELEPHONE TRANSMITTERS AND FREQUENTLY FOR THE SAKE OF CONVENIENCE REFERRED TO SIMPLY AS "PHONE TRANSMITTERS".

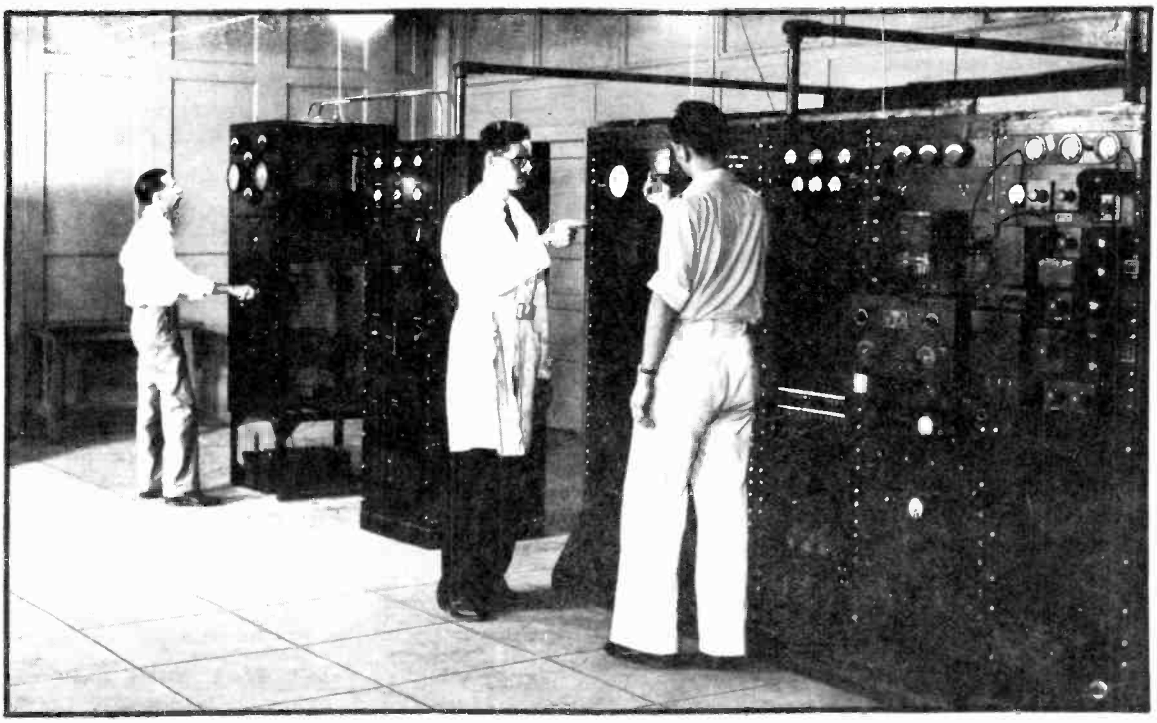

FIG.1
A Section of National's Transmitter Room.

IT IS IMPORTANT THAT YOU BEAR IN MIND THAT THE RADIO FREQUENCY SECTION OF PHONE TRANSMITTERS IS FUNDAMENTALLY THE SAME AS THAT OF A CODE TRANSMITTER. IN BOTH CASES, THIS SECTION OF THE TRANSMITTER GENERATES AND AMPLIFIES RADIO FREQUENCY ENERGY SO THAT THE NECESSARY ELECTROMAGNETIC WAVES MAY BE RADIATED IN ORDER TO CARRY THE MESSAGE OR PROGRAM THROUGH SPACE. THIS MEANS THAT EVERYTHING WHICH YOU HAVE LEARNED SO FAR CONCERNING TRANSMITTERS IS GOING TO BE OF GREAT VALUE TO YOU IN THE STUDIES WHICH ARE NOW TO COME.

THERE ARE OF COURSE SOME RADICAL DIFFERENCES BETWEEN CODE AND PHONE TRANSMITTERS BUT THESE SHALL ALL BE POINTED OUT TO YOU AS WE ADVANCE THRU THIS MOST INTERESTING PART OF YOUR TRANSMITTER STUDIES.

MODULATION

IN FIG. 2 YOU ARE SHOWN A BLOCK DIAGRAM OF A TYPICAL RADIO TELEPHONE TRANSMITTER. AS YOU WILL OBSERVE, THE OSCILLATOR, R.F. AMPLIFIER, POWER AMPLIFIER AND THE ANTENNA ARE PLACED IN THIS SYSTEM IN THE SAME MANNER AS YOU FOUND THEM IN CODE TRANSMITTERS. THIS SECTION OF THE PHONE TRANSMITTER IS SO CONSTRUCTED THAT WHEN NO SOUNDS ARE BEING PICKED UP BY THE MICROPHONE, A CONTINUOUS TYPE WAVE WILL BE RADIATED BY THE ANTENNA SYSTEM. THIS IS KNOWN AS THE CARRIER WAVE.

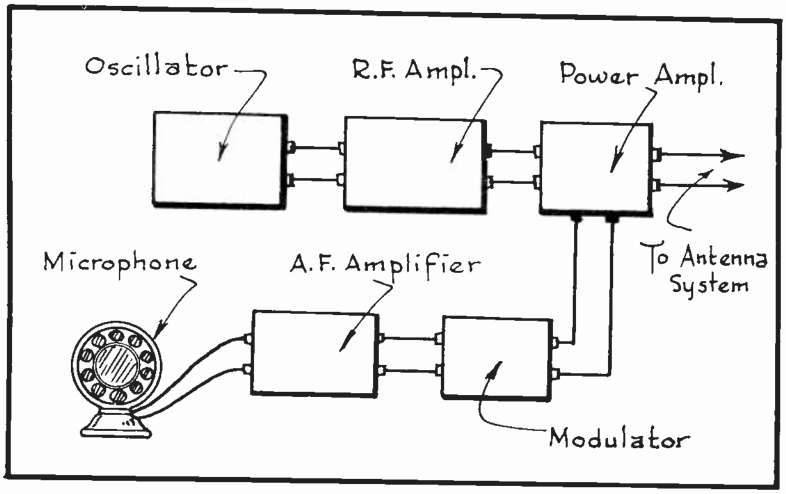

FIG. 2
Block Diagram of a Typical Radio Telephone Transmitter.

WHENEVER SOUND WAVES ACT UPON THE MICROPHONE, THEN THESE ARE CONVERTED TO ELECTRICAL IMPULSES IN THE USUAL WAY AND ARE AMPLIFIED BY THE A.F. AMPLIFIER. THE TASK OF THE MODULATOR IS TO UTILIZE THE AMPLIFIED A.F. SIGNALS IN SUCH A MANNER THAT THE R.F. WAVE-FORM AT THE OUTPUT OF THE TRANSMITTER WILL HAVE EITHER ITS FREQUENCY OR AMPLITUDE VARIED IN ACCORDANCE WITH THE AUDIO WAVE-FORM AS FURNISHED BY THE A.F. AMPLIFIER. THIS PROCESS OF VARYING THE R.F. WAVE-FORM OF THE TRANSMITTER EITHER IN FREQUENCY OR AMPLITUDE AT AN AUDIO FREQUENCY RATE IS KNOWN AS MODULATION.

ALTHOUGH MODULATION CAN BE ACCOMPLISHED BY VARYING EITHER THE FREQUENCY OR AMPLITUDE OF THE R.F. WAVE AT AN AUDIO FREQUENCY RATE, YET COMMERCIALLY ONLY "AMPLITUDE MODULATION" IS USED IN MODERN RADIO TELEPHONE EQUIPMENT.

THE MODULATED WAVE

IN FIG.3 YOU ARE SHOWN WHAT HAPPENS TO THE CARRIER WAVE WHEN AMP-

LITUDE MODULATION TAKES PLACE. NOTICE AT THE RIGHT OF FIG. 3 HOW THE CARRIER FREQUENCY IS OF THE PURE C.W. (CONTINUOUS) TYPE AND OF CONSTANT AMPLITUDE AT THAT TIME WHEN NO MODULATION OCCURS.

WHEN MODULATION OCCURS, THE CARRIER FREQUENCY STILL REMAINS CONSTANT BUT THE AMPLITUDE OF THIS WAVE-FORM INCREASES AND DECREASES IN ACCORDANCE WITH THE AUDIO FREQUENCY VARIATIONS. WE THEN HAVE A CONDITION AS PICTURED IN THAT PORTION OF FIG. 3 WHERE MODULATION IS SHOWN AS TAKING PLACE.

THE EXTENT OR AMOUNT THAT THE CARRIER WAVE IS CHANGED DURING THE PROCESS OF MODULATION IS EXPRESSED AS A PERCENTAGE AND IS COMMONLY REFERRED TO AS THE PERCENTAGE OF MODULATION.

THE CARRIER WAVE NORMALLY HAS A CERTAIN VALUE OR AMPLITUDE AND WHEN "FULL MODULATION" OR 100% MODULATION OCCURS, WE HAVE A CONDITION AS PICTURED AT "A" OF FIG. 4. IN THIS CASE, WE FIND THAT WHEN THE POSITIVE PEAK OF THE AUDIO WAVE REACHES ITS MAXIMUM VALUE, THE PEAKS OF THE CARRIER WAVE BECOME DOUBLE THE VALUE REACHED WHEN NO MODULATION IS OCCURING. ALSO, WHEN THE OTHER HALF OF THE AUDIO WAVE REACHES A MAXIMUM VALUE IN A NEGATIVE DIRECTION, THE CARRIER-WAVE PEAKS ARE REDUCED TO ZERO.

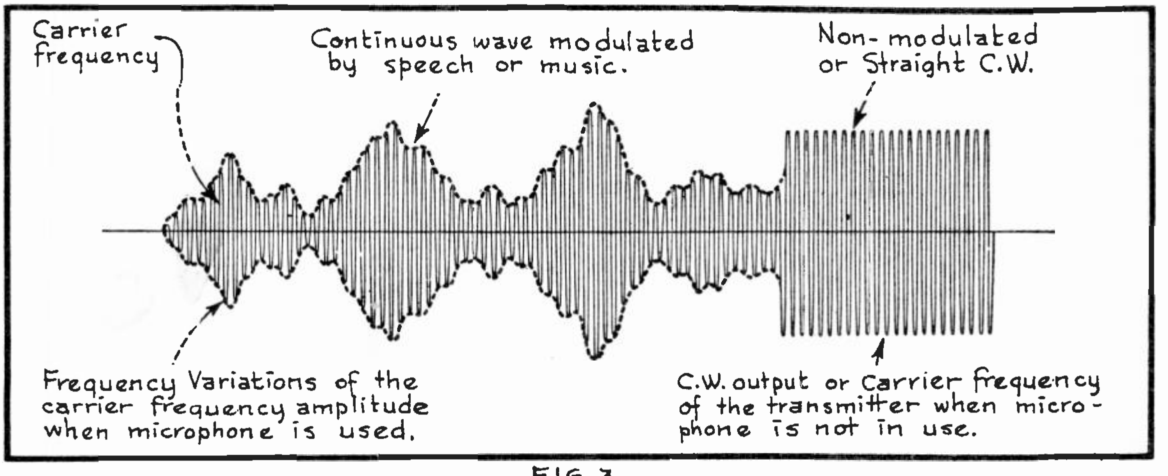

FIG. 3
Modulating the Carrier Frequency.

THE CONDITION OF 100% MODULATION IS IDEAL AND IS STRIVED FOR IN ALL HIGH QUALITY TRANSMITTERS.

WHENEVER THE CARRIER-WAVE IS LESS THAN 100% MODULATED, THEN WE HAVE A CONDITION SOMEWHAT AS THAT ILLUSTRATED AT "B" OF FIG. 4. HERE YOU WILL OBSERVE THAT THE PEAKS OF THE CARRIER-WAVE NO LONGER BECOME EQUAL TO TWICE THEIR UN-MODULATED AMPLITUDE WHEN THE A.F. WAVE IS AT ITS POSITIVE MAXIMUM VALUE, NOR IS THE CARRIER WAVE REDUCED TO ZERO WHEN THE A.F. WAVE IS AT ITS NEGATIVE MAXIMUM VALUE.

THE REPRODUCTION OF THE SOUNDS AT THE RECEIVER IS GREATLY AFFECTED BY THE EXTENT TO WHICH THE CARRIER-WAVE IS MODULATED. FOR INSTANCE, AS FAR AS THE RECEIVER IS CONCERNED, A 10-WATT CARRIER MODULATED 100% IS PRACTICALLY AS EFFECTIVE AS A 40-WATT CARRIER WHICH IS MODULATED ONLY 50%.

AT "C" OF FIG. 4 YOU ARE SHOWN WHAT OCCURS WHEN "OVER-MODULATION" TAKES PLACE. WHEN THIS HAPPENS, WE FIND THAT WHEN THE POSITIVE PEAK OF THE AUDIO WAVE REACHES ITS MAXIMUM VALUE, THE PEAKS OF THE CARRIER WAVE BECOME MORE THAN DOUBLE THE VALUE REACHED WHEN NO MODULATION OCCURS. FURTHERMORE, WHEN THE OTHER HALF OF THE AUDIO WAVE REACHES A MAXIMUM VALUE IN A NEGATIVE DIRECTION, THE NEGATIVE PEAK OF THE ENVELOPE IS CUT OFF ENTIRELY. THIS THEN IS A CASE OF UNSYMMETRICAL MODULATION IN THAT THE AVERAGE AMPLITUDE IS NO LONGER THE SAME AS THE UNMODULATED AMPLITUDE AND DISTORTION RESULTS EVEN THOUGH THE MODULATING SIGNAL BE A PURE TONE. OVER-MODULATION, THEREFORE, IS UNDESIRABLE.

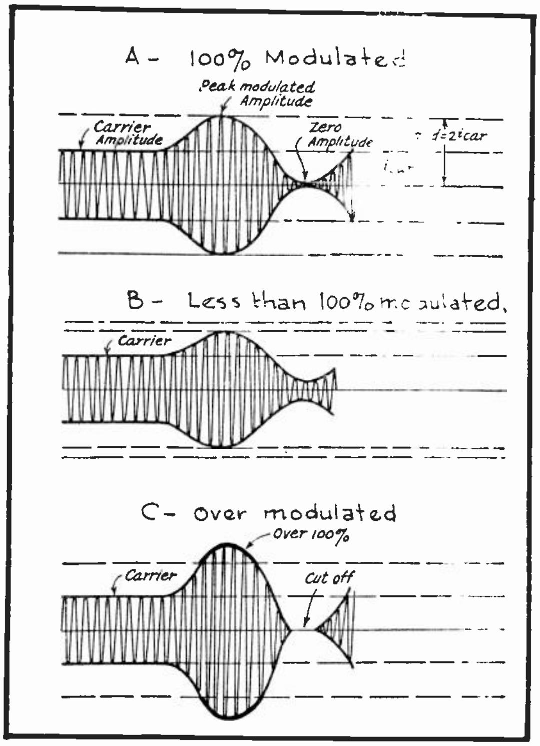

FIG. 4
Various Degrees of Modulation.

THE PERCENTAGE OF MODULATION(M) CAN BE CALCULATED WITH THE AID OF THE FOLLOWING FORMULA:

$$M = \frac{I \text{ MODULATED} - I \text{ CARRIER}}{I \text{ CARRIER}} \times 100$$

WHERE "I MODULATED" IS THE PEAK-CURRENT VALUE AT THE MAXIMUM AMPLITUDE OF THE MODULATED WAVE AND "I CARRIER" IS THE PEAK-CURRENT VALUE OF THE CARRIER AMPLITUDE.

THE EXPRESSION MODULATION FACTOR IS ALSO FREQUENTLY USED. THIS VALUE IS EQUAL TO THE PERCENTAGE OF MODULATION DIVIDED BY 100 — THAT IS, SIMPLY WITH THE PERCENT SIGN REMOVED AND THE DECIMAL POINT MOVED TWO PLACES TOWARDS THE LEFT. IN OTHER WORDS, A MODULATION PERCENTAGE OF 100% IS EQUIVALENT TO A MODULATION FACTOR OF 1; A MODULATION PERCENTAGE OF 50% IS EQUIVALENT TO A MODULATION FACTOR OF 0.5 ETC.

SIDE BANDS

WHEN DEALING WITH MODULATED WAVE-FORMS, WE MUST IN ADDITION TO THE CARRIER FREQUENCY ALSO CONSIDER THE "SIDE-BAND FREQUENCIES". FOR EXAMPLE, STANDARD BROADCAST TRANSMITTERS ARE CAPABLE OF HANDLING AUDIO FREQUENCIES UP TO 5000 CYCLES PER SECOND. ALTHOUGH IT IS TRUE THAT FOR HIGH FIDELITY RECEPTION, A.F. SIGNALS OF STILL HIGHER FREQUENCY WOULD BE REQUIRED, YET THESE HIGHER FREQUENCIES ARE NOT ABSOLUTELY ESSENTIAL FOR SATISFACTORY RESULTS.

AT ANY RATE, ASSUMING THAT AN AUDIO FREQUENCY OF 5000 CYCLES IS BEING HANDLED BY A CERTAIN TRANSMITTER, THIS WOULD MEAN THAT IN ADDITION TO THE CARRIER FREQUENCY, OUR MODULATED WAVE-FORM WOULD ALSO CONSISTS OF TWO SIDE-BAND COMPONENTS EXTENDING 5000 CYCLES ON EACH SIDE OF THE CARRIER FREQUENCY.

IN FIG. 5, FOR INSTANCE, WE HAVE ONE CURVE ILLUSTRATING AN AUDIO FREQUENCY OF 5000 CYCLES BESIDE ANOTHER CURVE WHICH REPRESENTS A STATION'S CARRIER FREQUENCY OF 800 KC. OR 800,000 CYCLES. THE LOWER SIDE-BAND FRE-

QUENCY WOULD THEN BE EQUAL TO 800,000 MINUS 5,000 OR 795,000 CYCLES. THE HIGHER SIDE-BAND FREQUENCY IN THIS SAME INSTANCE WOULD BE EQUAL TO 800,000 PLUS 5,000 OR 805,000 CYCLES.

THE INTERACTION BETWEEN THESE THREE DISTINCT FREQUENCIES PRODUCES THE RESULTANT AMPLITUDE CHANGE IN THE OUTPUT WAVE-FORM, CHANGING IT TO THE SHAPE DESIGNATED AS THE "RESULTANT MODULATED WAVE-FORM" IN FIG. 5. THIS RESULTANT WAVE SHAPE AT EACH POINT REPRESENTS THE INSTANTANEOUS SUM OF THE CARRIER, LOWER SIDE-BAND, AND HIGHER SIDE BAND FREQUENCIES.

ALTHOUGH IT IS TRUE THAT THE BAND WIDTH OCCUPIED BY THE SIDE BANDS IN THIS PARTICULAR CASE AMOUNTS TO 5,000 PLUS 5,000 OR 10,000 CYCLES, YET THE ACTUAL RESULTANT FREQUENCY DUE TO THE INTERACTIONS JUST EXPLAINED IS 5,000 CYCLES AND THE RECEIVER'S SPEAKER UNIT WILL THEREFORE RESPOND TO THIS 5000 CYCLE FREQUENCY AND REPRODUCE THE CORRESPONDING TONE.

THE MODULATION FACTOR CAN ALSO BE DETERMINED IN TERMS OF THE SIDE-BAND AND CARRIER FREQUENCIES BY APPLYING THE FOLLOWING FORMULA:

$$\text{MODULATION FACTOR} = \frac{I_1 + I_2}{I_C}$$

WHERE I_1 = PEAK-CURRENT VALUE OF THE LOWER SIDE-BAND FREQUENCY; I_2 = PEAK-CURRENT VALUE OF THE UPPER SIDE-BAND FREQUENCY; AND I_C = PEAK-CURRENT VAL- OF THE CARRIER FREQUENCY.

METHODS OF MODULATION

NOW THAT YOU ARE FAMILIAR WITH THE GENERAL THEORY PERTAINING TO THE MODULATED WAVE-FORM, YOU WILL NEXT BE INTERESTED IN LEARNING JUST EXACTLY HOW MODULATION IS ACCOMPLISHED.

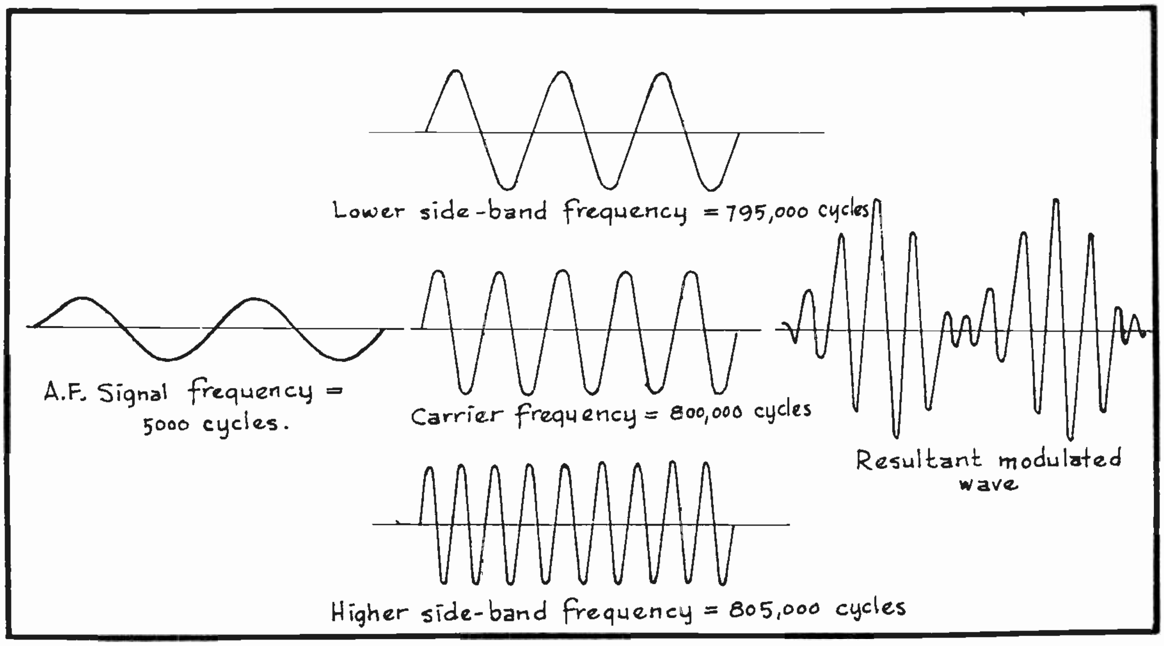

FIG. 5
The Carrier and Side-Band Frequency Relation.

THERE ARE TWO GENERAL TYPES OF MODULATION SYSTEMS WHICH ARE USED, NAMELY, PLATE MODULATION AND GRID MODULATION. PLATE MODULATION WAS INVENTED BY R.A. HEISING AND THEREFORE THIS METHOD IS ALSO KNOWN AS THE "HEISING MODULATION SYSTEM". THE HEISING SYSTEM SHALL BE EXPLAINED TO YOU FIRST.

THE HEISING MODULATING SYSTEM

IN FIG. 6 YOU ARE SHOWN THE BASIC HEISING MODULATING SYSTEM. BY STUDYING THIS CIRCUIT CAREFULLY YOU WILL NOTE THAT AN IRON CORE CHOKE COIL, CALLED THE "PLATE REACTOR", IS CONNECTED BETWEEN B+ AND THE PLATE OF BOTH THE R.F. AMPLIFIER AND THE MODULATOR TUBE. THEREFORE, THE PLATE CURRENT WHICH IS DRAWN BY BOTH OF THESE TUBES MUST FLOW THROUGH THIS SAME REACTOR.

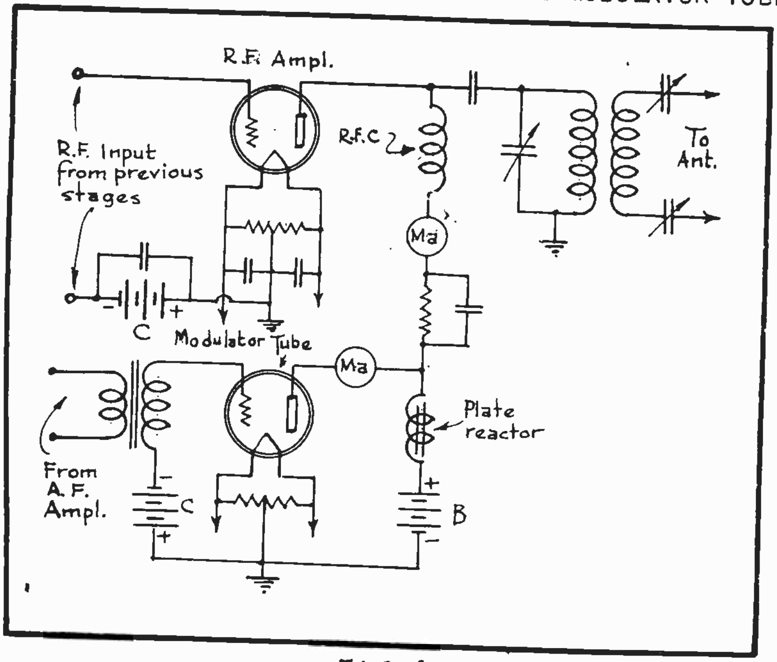

FIG. 6
The Basic Heising Modulating System.

AT THE TIME THAT THE MODULATOR TUBE IS NOT IN USE, THE PLATE CURRENT FLOWING THRU THE R.F. AMPLIFIER WILL VARY ABOVE AND BELOW ITS NORMAL VALUE AT A RADIO FREQUENCY RATE IN ACCORDANCE WITH THE FREQUENCY WHICH IS GENERATED BY THE TRANSMITTER'S OSCILLATOR. THE GRID CIRCUIT OF THE MODULATOR TUBE, ON THE OTHER HAND, IS EXITED AT AN AUDIO FREQUENCY RATE IN ACCORDANCE WITH THE AMPLIFIED SIGNAL ENERGY AS FURNISHED BY THE MICROPHONE AND A.F. AMPLIFIER. THEREFORE, THE PLATE CURRENT WHICH FLOWS THROUGH THIS TUBE WILL VARY ABOVE AND BELOW ITS NORMAL VALUE AT THE AUDIO FREQUENCY RATE ALREADY MENTIONED.

DUE TO THE HIGH SELF-INDUCTANCE OF THE PLATE REACTOR, IT TENDS TO MAINTAIN THE TOTAL CURRENT WHICH FLOWS THROUGH IT AT A PRACTICALLY CONSTANT VALUE. IN OTHER WORDS, WHENEVER, THE CURRENT FLOWING THRU THIS REACTOR TENDS TO INCREASE, ADDITIONAL LINES OF FORCE WILL SPREAD OUT AROUND IT AND WILL CUT THROUGH THE TURNS OF THE WINDING, PRODUCING A COUNTER-ELECTROMOTIVE FORCE WHICH AUTOMATICALLY RETARDS THE FLOW OF CURRENT. SHOULD THE CURRENT FLOW THROUGH THE REACTOR TEND TO DECREASE WITH RESPECT TO ITS NORMAL VALUE, THEN THE COLLAPSING EFFECT OF THE LINES OF FORCE WOULD INDUCE A REACTANCE VOLTAGE ACROSS THIS COIL, TENDING TO INCREASE THE FLOW OF CURRENT. IN THIS MANNER, THE CURRENT WHICH IS PASSED BY THE REACTOR REMAINS VERY NEARLY CONSTANT IN VALUE.

TO FURTHER ILLUSTRATE THIS POINT, LET US LOOK AT FIG.7. HERE YOU

ARE SHOWN IN A MORE SIMPLIFIED FORM THE RELATION BETWEEN THE R.F. AMPLIFIER AND MODULATOR TUBE, AS WELL AS THEIR CONNECTION TO THE "B" CIRCUIT.

AS A PRACTICAL EXAMPLE, LET US ASSUME THAT THE NORMAL PLATE CURRENT PASSING THROUGH THE REACTOR AMOUNTS TO 100 MA. AND THAT THIS CURRENT DIVIDES EQUALLY BETWEEN THE PLATE CIRCUITS OF THE AMPLIFIER AND MODULATOR TUBES, 50 MA. FLOWING THROUGH EACH TUBE.

NOW LET US SUPPOSE THAT AN AUDIO SIGNAL CAUSES A POSITIVE CHARGE TO BE APPLIED TO THE GRID OF THE MODULATOR TUBE AT ONE PARTICULAR INSTANT AND THAT THIS CHARGE IS SUFFICIENT TO CAUSE THE PLATE CURRENT THROUGH THIS TUBE TO INCREASE FROM 50 TO 60 MA. SINCE THE REACTOR TENDS TO MAINTAIN THE TOTAL "B" CURRENT AT 100 MA., THE INCREASE IN CURRENT THROUGH THE MODULATOR TUBE WILL BRING ABOUT A CORRESPONDING DECREASE IN THE CURRENT FLOWING THROUGH THE AMPLIFIER TUBE. IN OTHER WORDS, ONLY 100 MINUS 60 OR 40 MA. WILL AT THIS TIME BE AVAILABLE FOR THE AMPLIFIER TUBE.

AT THE NEXT INSTANT, LET US ASSUME THAT THE AUDIO SIGNAL CAUSES A NEGATIVE CHARGE TO BE APPLIED TO THE GRID OF THE MODULATOR TUBE, AND THAT THIS CHARGE IS SUFFICIENT TO CAUSE THE PLATE CURRENT THROUGH THIS TUBE TO DROP DOWN TO 20 MA. THE REACTOR IN THIS CASE WILL STILL TEND TO MAINTAIN A TOTAL CURRENT FLOW OF 100 MA. AND SO 100 MINUS 20 OR 80 MA. WILL AT THIS TIME FLOW THROUGH THE R.F. AMPLIFIER TUBE.

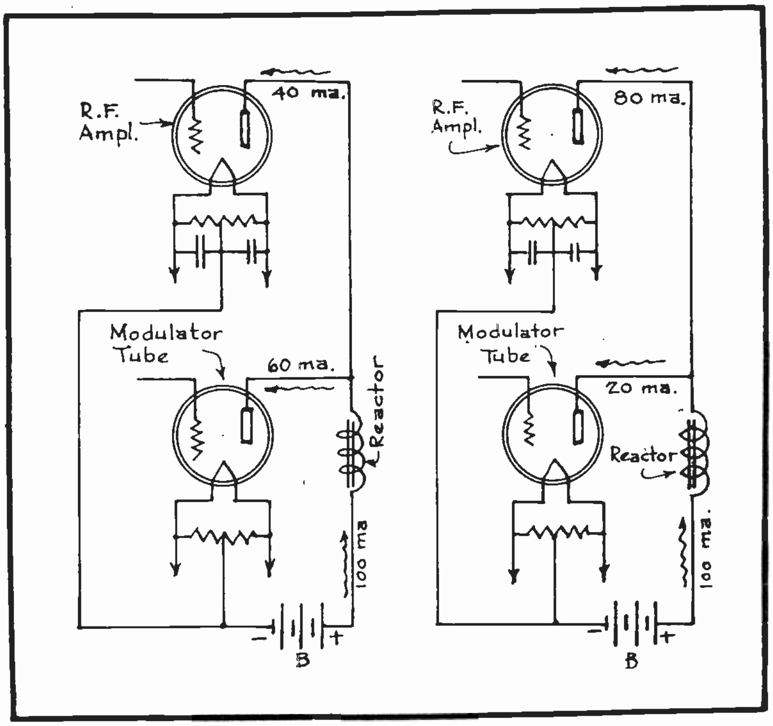

FIG. 7
Diagrammatic Explanation of the "Constant Current" Principle.

BY FOLLOWING THIS SAME TREND OF THOUGHT, IT CAN BE SEEN THAT BY APPLYING A FLUCTUATING VOLTAGE OF AUDIO FREQUENCY TO THE GRID OF THE MODULATOR TUBE, THE PLATE CURRENT THROUGH THE R.F. AMPLIFIER TUBE WILL VARY CORRESPONDINGLY. AT THE SAME TIME, HOWEVER, THE R.F. AMPLIFIER IS HAVING ITS PLATE CURRENT VARIED AT A RADIO FREQUENCY RATE DUE TO THE EXITING VOLTAGE WHICH IS BEING APPLIED ACROSS ITS GRID CIRCUIT. THE NET RESULT IS THAT THE AMPLITUDE OF THE CARRIER WAVE IS INCREASED AND DECREASED WITH RESPECT TO ITS NORMAL VALUE IN ACCORDANCE WITH THE A.F. SIGNAL WHICH IS HANDLED BY THE MODULATOR TUBE. THE MODULATOR TUBE, YOU

WILL NOTICE, OPERATES UPON THE SAME PRINCIPLE AS A POWER TUBE OF AN A.F. AMPLIFIER.

THE HEISING SYSTEM OF MODULATION, AS JUST EXPLAINED, IS ALSO FREQUENTLY REFERRED TO AS THE "CONSTANT-CURRENT SYSTEM" OF MODULATION AND FROM WHAT YOU HAVE ALREADY LEARNED ABOUT THIS METHOD, YOU CAN READILY SEE HOW THIS CLASSIFICATION ALSO APPLIES TO THIS METHOD OF MODULATION.

A TRANSFORMER-COUPLED MODULATOR

IN FIG. 8 YOU ARE SHOWN A SOMEWHAT DIFFERENT CIRCUIT IN ORDER TO OBTAIN PLATE MODULATION. THIS CIRCUIT IS ESSENTIALLY THE SAME AS THAT OF FIG.6 WITH THE EXCEPTION THAT THE PLATE REACTOR IS REPLACED WITH A MODULATION TRANSFORMER. THE PRIMARY WINDING OF THIS TRANSFORMER IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE MODULATOR TUBE, WHILE THE SECONDARY WINDING OF THIS SAME TRANSFORMER IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE R.F. AMPLIFIER TUBE.

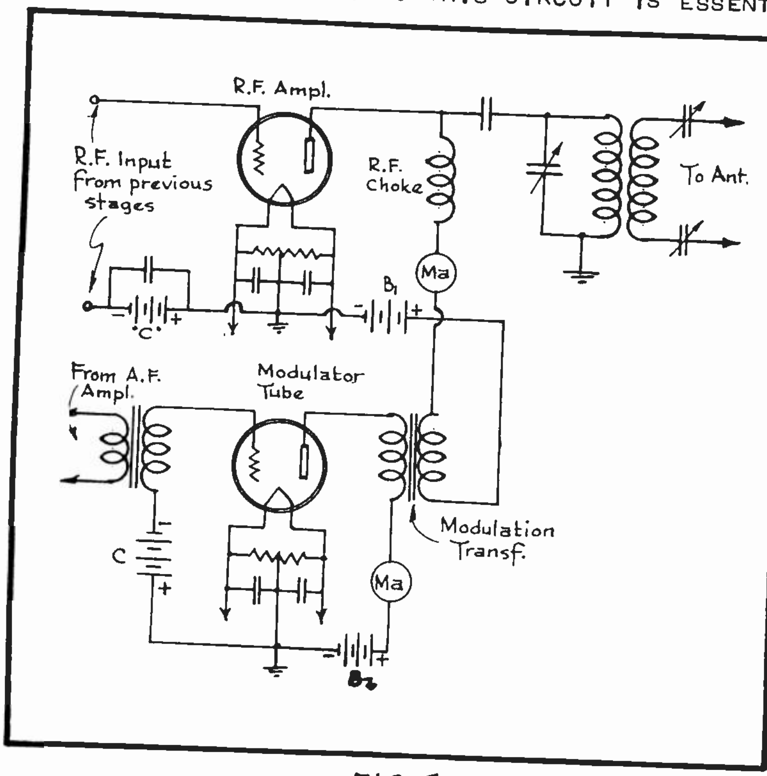

FIG. 8
Application of the Modulation Transformer.

IN THIS MANNER, A.F. SIGNAL VOLTAGES CAN BE INDUCED INTO THE SECONDARY WINDING THROUGH WHICH THE R.F. AMPLIFIER TUBE IS DRAWING ITS PLATE CURRENT. AT TIMES, THE A.F. SIGNAL VOLTAGE APPEARING IN THIS WINDING WILL BE EFFECTIVELY ADDED TO THE PLATE VOLTAGE AS APPLIED TO THE R.F. TUBE AND THEREBY CAUSE ITS PLATE CURRENT TO INCREASE CORRESPONDINGLY. AT OTHER TIMES, THE A.F. SIGNAL VOLTAGE APPEARING ACROSS THE SECONDARY WINDING OF THE MODULATION TRANSFORMER WILL BE OF OPPOSITE SIGN TO THAT OF THE APPLIED PLATE VOLTAGE AND IN THIS WAY REDUCE THE FLOW OF PLATE CURRENT THROUGH THE R.F. AMPLIFIER TUBE.

SO HERE AGAIN, WE HAVE A SUBTRACTION FROM AND AN ADDING TO THE RADIO FREQUENCY CURRENT VARIATIONS THROUGH THE PLATE CIRCUIT OF THE R.F. AMPLIFIER, SO THAT THIS OCCURS AT AN AUDIO FREQUENCY RATE AND FURNISHES US WITH A MODULATED WAVE-FORM.

A PUSH-PULL MODULATOR

QUITE OFTEN, INSTEAD OF USING ONLY A SINGLE MODULATOR TUBE AS SO FAR SHOWN, A PAIR OF MODULATOR TUBES ARE CONNECTED IN A PARALLEL, PUSH-PULL, OR A CLASS "B" ARRANGEMENT. WHEN THIS IS DONE, THE MODULATION CIRCUIT, HOWEVER, REMAINS TRUE TO FORM AS A STUDY OF THE PUSH-PULL MODULATOR IN FIG. 9 WILL SOON DISCLOSE.

GRID MODULATION

IN FIG. 10 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SYSTEM WHICH IS KNOWN AS GRID BIAS MODULATION OR SIMPLY AS GRID MODULATION.

BY STUDYING THIS DIAGRAM CAREFULLY, YOU WILL OBSERVE THAT THE CIRCUIT FOR THE MODULATOR TUBE IS THE SAME AS THAT EMPLOYED IN THE OTHER CIRCUITS SO FAR SHOWN YOU. HOWEVER, THE SECONDARY WINDING OF THE MODULATION TRANSFORMER IS CONNECTED IN SERIES WITH THE GRID BIAS CIRCUIT OF THE R.F. AMPLIFIER.

WHEN NO A.F. SIGNAL VOLTAGES ARE BEING HANDLED BY THE MODULATOR TUBE, A STEADY BIAS VOLTAGE IS APPLIED TO THE GRID CIRCUIT OF THE R.F. AMPLIFIER AND THEREFORE THIS TUBE WILL AMPLIFY THE CARRIER FREQUENCY IN THE CUSTOMARY MANNER.

AT THE TIME THAT THE MODULATOR TUBE IS HANDLING A.F. SIGNALS, VOLTAGES OF CORRESPONDING FREQUENCY WILL BE INDUCED INTO THE SECONDARY WINDING OF THE MODULATION TRANSFORMER. THESE SECONDARY VOLTAGE VARIATIONS WILL ALTERNATELY BE ADDED TO AND SUBTRACTED FROM THE BIAS VOLTAGE WHICH IS NORMALLY APPLIED TO THE R.F. AMPLIFIER TUBE — DEPENDING UPON THE POLARITY OF THE INDUCED VOLTAGE AT ANY PARTICULAR INSTANT.

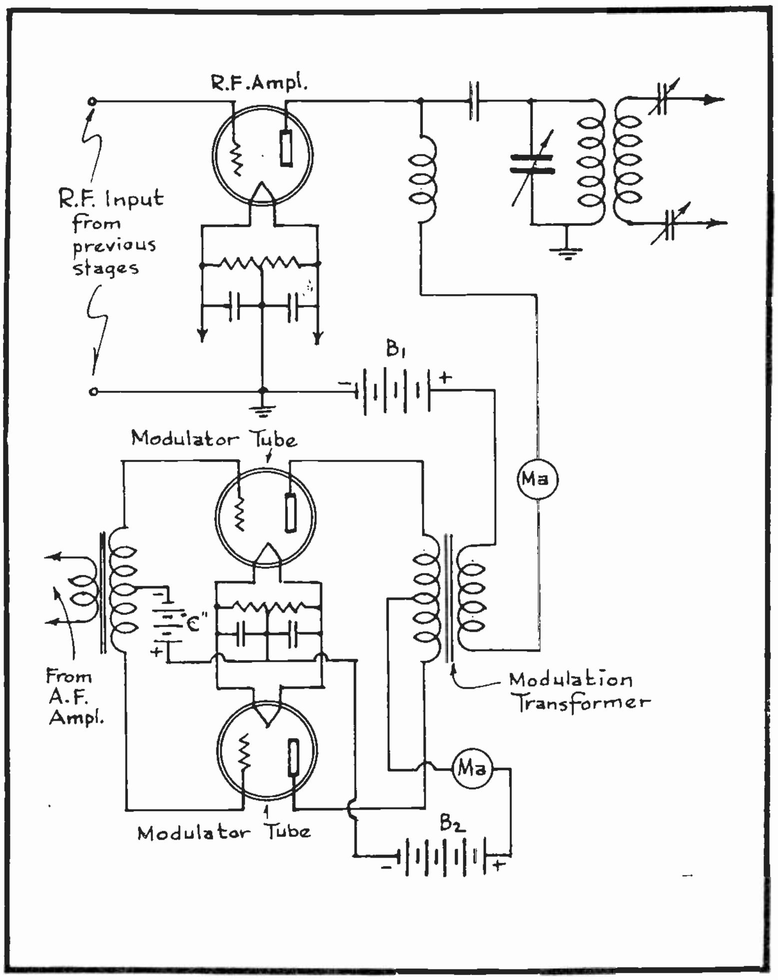

FIG. 9
Application of Push-Pull Modulator Tubes.

THUS IT IS CLEAR

THAT THE BIAS VOLTAGE OF THE R.F. AMPLIFIER WILL VARY AT AN AUDIO FREQUENCY RATE AND IN ACCORDANCE WITH THE OUTPUT OF THE MODULATOR TUBE. THEREFORE, A CORRESPONDING VARIATION IN THE PLATE CURRENT THROUGH THE R.F. AMPLIFIER WILL ALSO OCCUR AND THE NET RESULT IS THAT THE R.F. CURRENT VARIATIONS WHICH ARE ALSO HANDLED BY THE R.F. AMPLIFIER WILL HAVE THEIR AMPLITUDE (INTENSITY) VARIED AT AN AUDIO FREQUENCY RATE. THUS MODULATION HAS TAKEN PLACE AND A MODULATED WAVE OF CORRESPONDING PATTERN WILL BE RADIATED BY THE ANTENNA SYSTEM.

LOW LEVEL AND HIGH LEVEL MODULATION

IN ALL OF THE MODULATION SYSTEMS WHICH WERE SHOWN YOU SO FAR IN THIS LESSON, THE FINAL R.F. STAGE OF THE TRANSMITTER WAS MODULATED. WHEN SUCH IS THE CASE, THE SYSTEM IS GENERALLY REFERRED TO AS EMPLOYING HIGH LEVEL MODULATION. WHEN THIS IS DONE, ALL R.F. STAGES PRECEDING THE STAGE IN WHICH MODULATION OCCURS MAY BE STRAIGHT R.F. AMPLIFIERS OF RATHER HIGH GAIN AND NEED NOT NECESSARILY BE LINEAR IN THEIR OPERATING CHARACTERISTICS. FOR HIGH LEVEL MODULATION, PLATE MODULATION IS MOST EXTENSIVELY USED.

IN SUCH CIRCUIT ARRANGEMENTS WHERE AN R.F. STAGE PREVIOUS TO THE FINAL STAGE OF THE TRANSMITTER IS MODULATED, THEN THE SYSTEM IS SAID TO BE OF THE LOW LEVEL MODULATION TYPE. WHEN SUCH IS THE CASE, EITHER PLATE OR GRID MODULATION CAN BE USED. THIS ARRANGEMENT ALSO PERMITS THE USE OF AN AUDIO AMPLIFIER OF LESS POWER OUTPUT THAN DOES HIGH LEVEL MODULATION BUT IT IS EQUALLY TRUE THAT WHEN LOW LEVEL MODULATION IS EMPLOYED, ALL STAGES OF THE TRANSMITTER FOLLOWING THAT IN WHICH MODULATION OCCURS MUST BE LINEAR AMPLIFIERS SO THAT THE MODULATED CARRIER FREQUENCY CAN BE AMPLIFIED SATISFACTORILY.

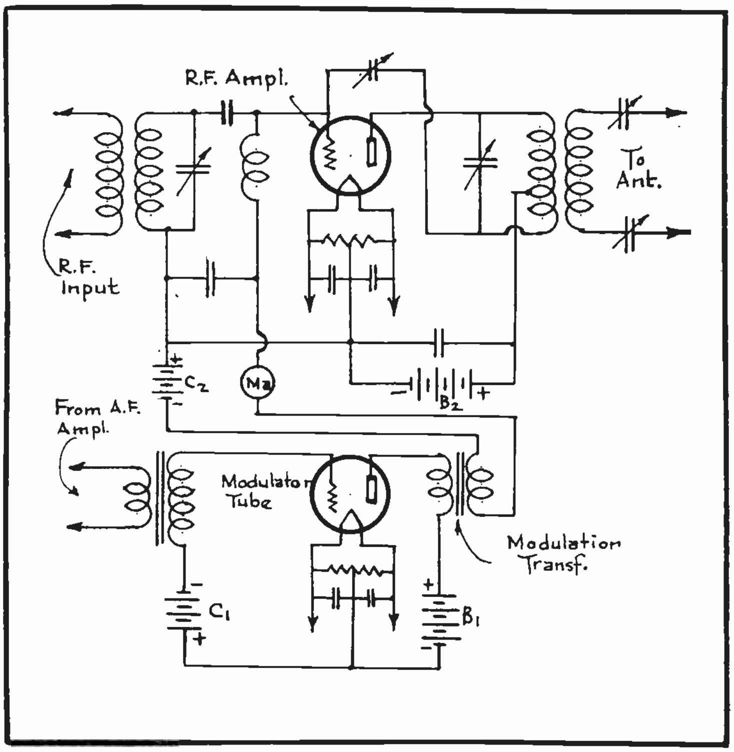

FIG. 10
Grid Modulation.

CLASSES OF MODULATORS AND AMPLIFIERS

AS YOU HAVE ALREADY BEEN SHOWN, THE MODULATOR IS ESSENTIALLY AN AUDIO-FREQUENCY AMPLIFIER AND THEREFORE ITS BASIC DESIGN FOLLOWS CONSIDERABLY THAT OF THE CONVENTIONAL A.F. AMPLIFIERS WITH WHICH YOU ARE ALREADY FAMILIAR. SIMILARLY, MODULATORS MAY ALSO BE OF EITHER ONE OF TWO BASIC TYPES THAT

IS, A CLASS A OR CLASS B TYPE, THE SAME AS REGULAR A.F. AMPLIFIERS. WITH THIS RESPECT THERE ARE ALSO CERTAIN MODIFICATIONS, THE SAME AS WE FIND THEM IN GENERAL A.F. AMPLIFIER PRACTICE.

IN TRANSMITTER PRACTICE, WE ALSO DEAL WITH A THIRD DISTINCTIVE CLASS, NAMELY CLASS C, AND WHICH IS CONFINED TO THE R.F. SECTION OF THE EQUIPMENT. SO THAT YOU WILL HAVE A CLEAR MENTAL CONCEPTION CONCERNING THE DIFFERENCES BETWEEN THESE THREE DISTINCT CLASSES OF AMPLIFIERS, IT WILL BE WELL THAT WE COMPARE THEIR CHARACTERISTICS BRIEFLY AT THIS TIME.

CLASS "A" AMPLIFIERS

A CLASS "A" AMPLIFIER, YOU WILL RECALL, IS DESIGNED IN SUCH A MANNER THAT THE PLATE OUTPUT WAVE SHAPES ARE ESSENTIALLY THE SAME AS THOSE OF THE EXITING GRID VOLTAGE. ITS NEGATIVE GRID BIAS VOLTAGE IS SO CHOSEN THAT THE PLATE CURRENT IS THE SAME WITH AND WITHOUT GRID EXITATION. ALSO THE ALTERNATING GRID EXITATION VOLTAGE AND THE LOAD RESISTANCE ARE SUCH AS TO MAKE ITS DYNAMIC CHARACTERISTICS ESSENTIALLY LINEAR.

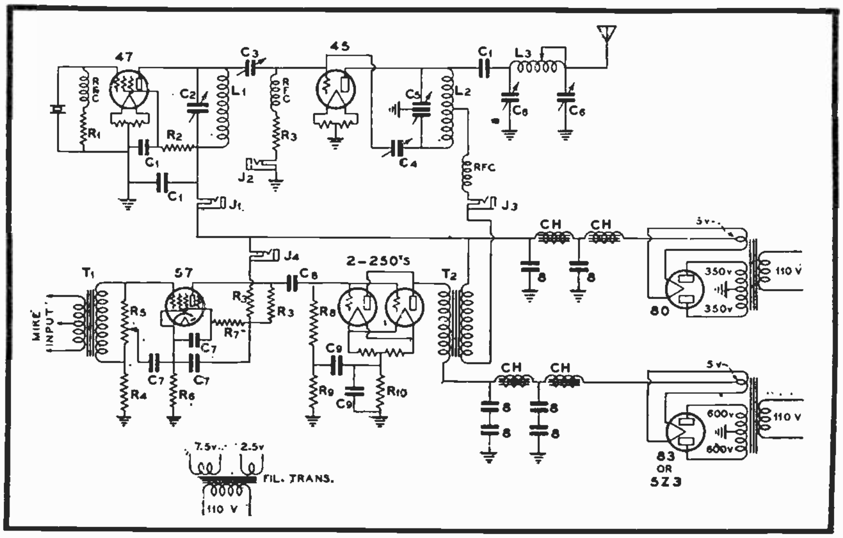

FIG. 11.
A 15-Watt Phone Transmitter.

BY DEFINITION THE TERM "LINEAR" REFERS TO A RELATION BETWEEN ELECTRICAL QUANTITIES WHICH IS SUCH THAT A CHANGE IN ONE IS ACCOMPANIED BY AN EXACTLY PROPORTIONAL CHANGE IN ANOTHER. "LINEAR AMPLIFICATION", ON THE OTHER HAND, IS AMPLIFICATION OF SUCH A NATURE THAT THE SIGNAL OUTPUT VOLTAGE AT ANY FREQUENCY AND ANY VALUE IS DIRECTLY PROPORTIONAL TO THE INPUT VOLTAGE. A CLASS "A" AMPLIFIER OPERATES ON THE STRAIGHT PORTION OF THE PLATE CURRENT—GRID VOLTAGE CHARACTERISTIC CURVE.

NOT ONLY ARE CLASS "A" AMPLIFIERS RESTRICTED TO A.F. AMPLIFIERS AND MODULATORS BUT THEY MAY BE USED AS R.F. AMPLIFIERS AS WELL.

CLASS "B" AMPLIFIERS

IN CLASS "B" AMPLIFIERS A PUSH—PUSH ARRANGEMENT OF TUBES IS GENERALLY EMPLOYED AND THIS SYSTEM OPERATES AT THE LOWER PORTION OF THE PLATE CURRENT—GRID VOLTAGE CHARACTERISTIC CURVE AND WITH SUFFICIENT BIAS VOLTAGE APPLIED SO THAT A VERY SMALL PLATE CURRENT FLOWS AT THE TIME NO SIGNAL VOLTAGE EXITES THE GRID CIRCUIT. ALTHOUGH THIS SYSTEM WILL NOT FUNCTION SATISFACTORILY AS AN A.F. AMPLIFIER WHEN ONLY A SINGLE

TUBE IS USED, YET IN A RADIO FREQUENCY AMPLIFIER, EITHER A SINGLE OR A TWO-TUBE ARRANGEMENT MAY BE OPERATED UNDER CLASS "B" CHARACTERISTICS, ALTHOUGH A TWO-TUBE CIRCUIT IS PREFERABLE IN EITHER CASE.

WHEN A TUBE IS OPERATING AS A CLASS B AMPLIFIER, THE OUTPUT POWER IS PROPORTIONAL TO THE SQUARE OF THE GRID-EXITATION VOLTAGE AND CONSEQUENTLY CAUSES THE OUTPUT TO RESEMBLE A LINEAR CHARACTERISTIC. CLASS "B" AMPLIFIERS ARE THEREFORE ALSO FREQUENTLY CLASSIFIED AS LINEAR AMPLIFIERS. THE PLATE EFFICIENCY OF THE CLASS B AMPLIFIER IS HIGHER THAN THE PLATE EFFICIENCY OF A CLASS A AMPLIFIER BECAUSE NO D.C. PLATE CURRENT FLOWS WHEN THE GRID EXITING VOLTAGE IS REMOVED. IT IS FOR THIS REASON THAT A CLASS B AMPLIFIER IS ALWAYS USED IN THE AMPLIFICATION OF MODULATED WAVES WHEN PLATE EFFICIENCY IS OF IMPORTANCE.

CLASS "C" AMPLIFIERS

A CLASS C AMPLIFIER IS PRACTICALLY THE SAME AS A CLASS B AMPLIFIER WITH THE EXCEPTION THAT IN THE CASE OF THE CLASS C AMPLIFIER, THE BIAS VOLTAGE IS ADJUSTED TO A POINT FAR BEYOND THE CUT-OFF ON THE PLATE CURRENT-GRID VOLTAGE CHARACTERISTIC CURVE. GENERALLY, THE NEGATIVE BIAS USED IS BETWEEN ONE AND ONE-HALF TO TWICE THE CUT-OFF BIAS VOLTAGE.

THE CLASS C AMPLIFIERS MUST RECEIVE A CONSIDERABLE GREATER GRID EXITATION IN ORDER TO OVERCOME THE HEAVY NEGATIVE BIAS IF SUITABLE PLATE-CURRENT PEAKS ARE TO BE PRODUCED IN THE OUTPUT CIRCUIT. FOR THIS REASON, CLASS C AMPLIFIERS ARE USED ONLY IN TRANSMITTING CIRCUITS BECAUSE OF THE RELATIVELY HIGHER GRID VOLTAGES THAT MAY BE PRODUCED IN THESE CIRCUITS. ALSO THE USE OF A CLASS C AMPLIFIER PROVIDES A HIGH EFFICIENCY IN THE CONVERSION OF DIRECT-CURRENT PLATE-SUPPLY POWER TO ALTERNATING-CURRENT ENERGY BUT RESULTS IN A NON-LINEAR RELATION BETWEEN THE APPLIED VOLTAGE AND THE POWER OUTPUT. THE OUTPUT OF THE CLASS C AMPLIFIER VARIES ESSENTIALLY AS THE SQUARE OF THE PLATE VOLTAGE WITHIN LIMITS.

NOW THAT YOU ARE FAMILIAR WITH THE VARIOUS SECTIONS OF RADIO TELEPHONE TRANSMITTERS AND THE MANNER IN WHICH THEY OPERATE, YOU WILL NEXT BE INTERESTED IN STUDYING CIRCUITS OF THIS TYPE AS A WHOLE RATHER THAN IN PART. FOR THIS REASON, THE COMPLETE CIRCUITS OF TYPICAL TRANSMITTERS OF THIS TYPE ARE ILLUSTRATED AND EXPLAINED TO YOU IN THE FOLLOWING PAGES.

A 15-WATT PHONE TRANSMITTER

IN FIG. 11 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF A PHONE TRANSMITTER WHICH FURNISHES A 15-WATT CARRIER. THIS TRANSMITTER YOU WILL OBSERVE, CONSISTS OF A 47 CRYSTAL CONTROLLED OSCILLATOR, FOLLOWED BY A FINAL AMPLIFIER IN WHICH A TYPE 45 TUBE IS USED.

THE A.F. CHANNEL CONSISTS OF THE MICROPHONE CIRCUIT FEEDING INTO A 57 TUBE OPERATING AS AN A.F. AMPLIFIER AND WHICH IS FOLLOWED BY A PAIR OF 250'S CONNECTED IN PARALLEL. PLATE MODULATION IS EMPLOYED.

THE ELECTRICAL VALUES FOR THE VARIOUS PARTS USED IN THIS TRANSMITTER ARE AS FOLLOWS: C_1= .006 MFD; C_2= 100 MMFD.; C_3= 25 MMFD.;

C_4= 25 MMFD; C_5= 40 MMFD. SPLIT-STATOR VARIABLE; C_6;= 350 MMFD; C_7= 1 MMFD; C_8= .01 MFD; C_9= 1 MFD; R_1= 30,000 OHMS, 5 WATT; R_2= 30,000 OHMS, 2 WATT; R_3= 50,000 OHMS, 5 WATT; R_4 AND R_5= 1/4 MEG; R_8= 500,000 OHMS; R_9= 25,000 OHMS; R_{10}= 400 OHMS; 10 WATT; T_1= MICROPHONE MATCHING INPUT TRANSFORMER; T_2= 2:1 STEP-UP TRANSFORMER OF FAIRLY HEAVY CONSTRUCTION; CH = 30 HENRY FILTER CHOKES RATED AT 100 MA.

THIS TRANSMITTER IS TUNED AND NEUTRALIZED IN THE SAME MANNER AS HAS ALREADY BEEN EXPLAINED IN PREVIOUS LESSONS AND BEFORE TURNING ON THE POWER FOR THE MODULATOR.

A 50-WATT GRID-MODULATED PHONE TRANSMITTER

THE CIRCUIT DIAGRAM WHICH APPEARS IN FIG. 12 IS THAT OF A 50-WATT, GRID-MODULATED PHONE TRANSMITTER. HERE WE HAVE A 47 CRYSTAL OSCILLATOR, FOLLOWED BY A 46 BUFFER AND A PAIR OF PARALLEL CONNECTED 211 E'S IN THE FINAL STAGE. IN THE A.F. SECTION, A 56 TUBE IS USED AT THE INPUT, FOLLOWED BY ANOTHER 56 IN THE INTERMEDIATE STAGE, AND A PAIR OF 45'S CONNECTED IN PUSH-PULL OPERATING AS MODULATORS.

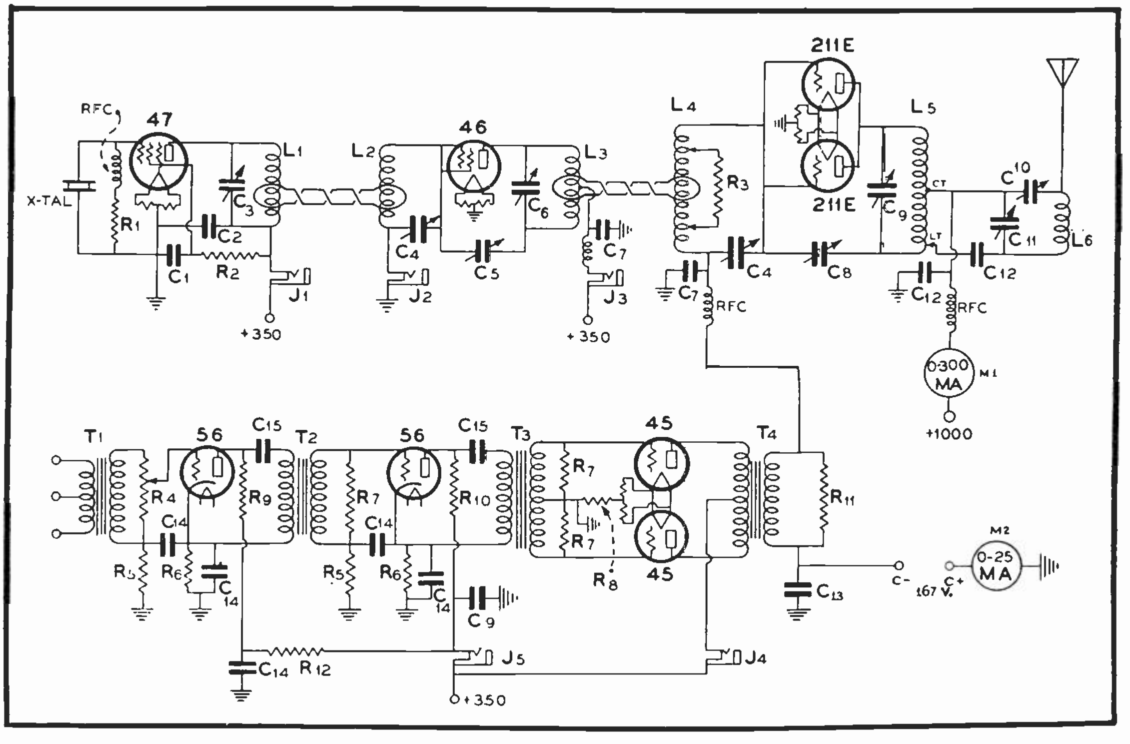

FIG. 12.
The 50 Watt Phone Transmitter.

THE ELECTRICAL VALUES FOR THE PARTS USED IN THIS CIRCUIT ARE LISTED IN TABLE 1.

THE CHIEF PURPOSE OF R_3 IN THIS CIRCUIT IS TO STABILIZE THE LOAD ON THE BUFFER STAGE WHILE R_{11} SERVES THE SAME PURPOSE FOR THE MODULATORS.

A 1000-Watt Transmitter

The circuit diagram for a 1000 watt Radio Telephone transmitter appears in Fig. 13. In this case a 59 tube is used in a Tri-tet oscillator circuit and followed in turn by a 59 buffer, a 210 buffer, an HK 354 buffer-driver stage and a final power stage with a pair of HK 354's.

TABLE I

LIST OF PARTS

R-1—15,000 to 50,000 ohms.
R2—50,000 ohms.
R3—20,000 ohms, 25 watts non-inductive.
R4—200,000 ohm potentiometer.
R5—.1 meg.
R6—2500 ohms.
R7—200,000 ohms.
R8—1000 ohms.
R9—30,000 ohms
R9—30,000 ohms.
R10—20,000 ohms.
R11—3,000 ohms.
R12—20,000 ohms.
C1—.01ufd.
C2—.006 ufd.
C3—100 uufd. variable.
C4—100 uufd. variable.
C5—50 uufd. variable.
C6—100 uufd. variable.
C7—.001 ufd.
C8—100 uufd. variable.
C9—150 uufd. variable.
C10—350 uufd. variable.
C11—350 uufd. variable.
C12—.006 ufd.
C-13—2 ufd.
C14—1 ufd.
C15—.25 ufd.
T1—Mike to grid transformer.
T2—Triode plate to grid transformer.
T3—Triode plate to PP grids.
T4—Class B input transformer, 2 to 1 or 3 to 1 step-down.

The A.F. system is rather conventional in design and plate modulation is used.

This same transmitter is also so arranged that CW code transmission can be employed. For this purpose, the keying relay shorts out the coupling link between the driver stage and the final amplifier. Since the final amplifier uses grid-leak bias for reasons of economy and flexibility, it is necessary to provide a means of preventing excessive plate current with the key up. This is accomplished with the aid of a second relay which is actuated by the rectified grid current through the grid leak and which cuts in the 1500 ohms of cathode bias whenever the excitation fails.

The electrical values for the various parts used in this transmitter are given in Table II.

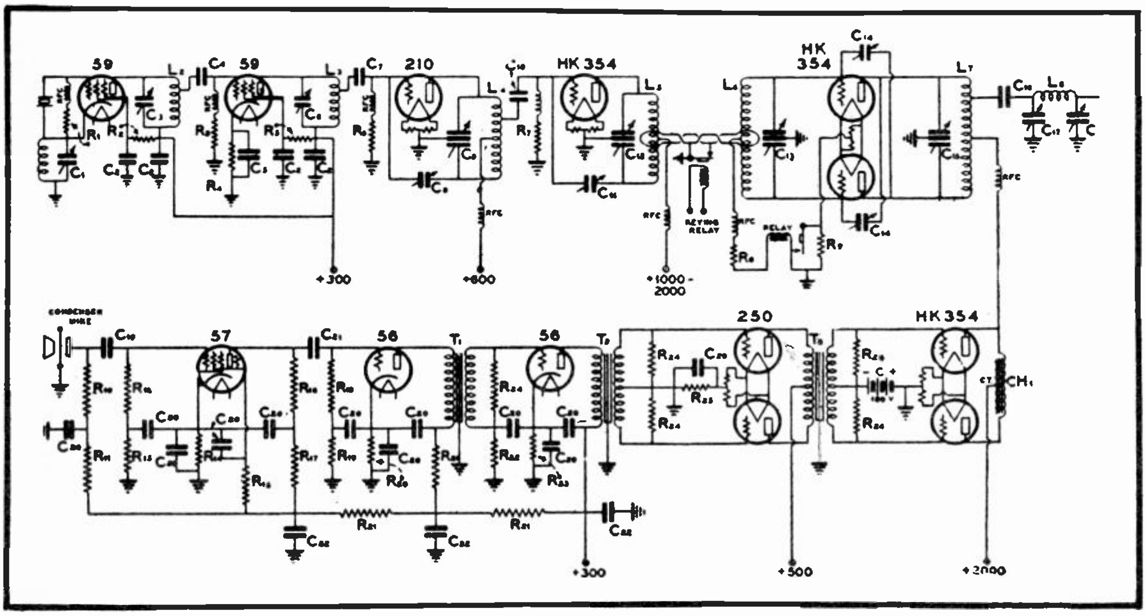

FIG. 13

The 1000-Watt Transmitter.

ALSO NOTICE IN THE CIRCUIT OF FIG. 13 THAT A CONDENSER MICROPHONE IS USED AND THAT ALL AMPLIFICATION WHICH IS NECESSARY FOR ITS SATISFACTORY OPERATION IS INCLUDED IN THE A.F. CHANNEL. ALSO OBSERVE HOW THE MODULATION CHOKE IS CENTER TAPPED AND CONNECTED TO THE PLATES OF THE MODULATOR TUBES IN THE SAME MANNER AS THE PRIMARY WINDING OF AN OUTPUT PUSH-PULL TRANSFORMER.

TABLE II

LIST OF PARTS

C1—140 mmf. Hammarlund Condenser.
C2—.01 mfd. C3—50 mmf. Hammarlund.
C4—.00025. C5—.0001. C6—50 mmf. Hammarlund.
C7—.00025. C8—22 mmf. Neutralizing.
C9—100 mmf. split stator. C10—.00025.
C11—15 mmf. neutralizing. C12—100 mmf. split stator.
C13—100 mmf. split stator. C14—15 mmf. neutralizing.
15—100 mmf. split stator. C16—.001.
C17—250 mmf. C18—250 mmf. C19—.001.
C20—1 mfd. C21—.01 mfd. C22—8mfd.
R1, R2, R3, R5, R17, R19—50,000 ohms.
R4—1000 ohms. R6, R7—15,000 ohms.

R8—25,000 ohms. R9—1500 ohms.
R10—10 megohms. R11—5 megohms.
R12—½ megohm. R13—¼ megohm.
R14—750 ohms. R15—½ megohm.
R16—¼ megohm. R18—¼ megohm.
R20—2500 ohms. R21—20,000 ohms.
R22—¼ megohm. R23—2500 ohms.
R24—1 megohm. R25—750 ohms.
R26—10,000 ohms.
T1—Triode Plate to Grid.
T2—Push-Pull Input. T3—Class B Input, 1:1 for 354's; 2:1 for 357's.
Ch—Class B Output Choke, 92 henries.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE CONSTRUCTIONAL FEATURES AND OPERATING PRINCIPLES OF RADIO TELEPHONE TRANSMITTERS. THIS HAS SUPPLIED YOU WITH THE BASIC KNOWLEDGE CONCERNING THESE CIRCUITS SO THAT YOU WILL BE BETTER ABLE TO UNDERSTAND THE VARIOUS TRANSMITTER DESIGN PROBLEMS WHICH WILL BE PRESENTED TO YOU IN A LESSON SOON TO COME.

IN THE LESSON IMMEDIATELY TO FOLLOW, YOU WILL BE GIVEN THE OPERATING CHARACTERISTICS AND OTHER ENGINEERING DATA PERTAINING TO THE MORE COMMON TRANSMITTER TUBES AND WHICH YOU WILL FIND TO BE OF GREAT VALUE.

Answered Mar 22, 1942

EXAMINATION QUESTIONS

LESSON NO. 13

In all your self-development, have a definite purpose in view. What is the good of a wonderful character if it does not accomplish something besides its own development?

1. - EXPLAIN IN DETAIL WHAT IS MEANT BY THE EXPRESSION "AMPLITUDE MODULATION".

2. - MAKE A DIAGRAMMATIC ILLUSTRATION OF A WAVE-FORM WHICH IS MODULATED 100% AND EXPLAIN IN DETAIL THE FULL MEANING OF THE DRAWING.

3. - WHAT IS MEANT BY THE EXPRESSION "MODULATION FACTOR"?

4. - DESCRIBE IN DETAIL THE SIDE-BAND FREQUENCIES WHICH EXIST IN THE WAVE-FORM WHICH IS RADIATED BY A BROADCAST TRANSMITTER.

5. - HOW CAN THE PERCENTAGE OF MODULATION BE DETERMINED?

6. - DRAW A CIRCUIT DIAGRAM OF A HEISING MODULATION SYSTEM USING A PLATE REACTOR AND EXPLAIN IN DETAIL HOW THIS SYSTEM OPERATES.

7. - DRAW A CIRCUIT DIAGRAM OF A GRID MODULATION SYSTEM AND EXPLAIN IN DETAIL HOW THIS SYSTEM OPERATES.

8. - DESCRIBE FULLY THE OPERATING CHARACTERISTICS OF A CLASS "C" AMPLIFIER.

9. - WHAT IS THE EFFECT OF OVER-MODULATION UPON RECEPTION?

10. - DRAW A COMPLETE CIRCUIT DIAGRAM OF A RADIO-TELEPHONE TRANSMITTER AND EXPLAIN THE OPERATION OF THE VARIOUS UNITS OR SECTIONS WHICH ARE INCLUDED IN IT.

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

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Transmitters

LESSON NO. 14

• TRANSMITTER TUBES •

IN FUNDAMENTAL DESIGN, TRANSMITTING TUBES ARE THE SAME AS RECEIVER TUBES, THAT IS, TRANSMITTING TUBES OF THE TRIODE TYPE ALSO CONSIST OF A FILAMENT, PLATE AND GRID; TRANSMITTING TUBES OF THE TETRODE TYPE ALSO CONSIST OF A FILAMENT, CONTROL GRID, PLATE, AND SCREEN GRID THE SAME AS THE CORRESPONDING RECEIVER TUBE ETC. IN FACT, AS YOU HAVE ALREADY LEARNED, IF THE POWER HANDLING REQUIREMENTS ARE NOT TOO HIGH, RECEIVING TYPE TUBES CAN BE MADE TO SERVE AS TRANSMITTER TUBES AND THIS PRACTICE IS BEING USED SATISFACTORILY IN THOUSANDS OF AMATEUR TRANSMITTERS.

IN SPITE OF THIS SIMILARITY, THERE IS ALSO A RADICAL DIFFERENCE BETWEEN THE RECEIVER AND TRANSMITTER TUBES BUT THIS DIFFERENCE EXISTS LARGELY IN CONSTRUCTIONAL DETAILS SO AS TO ENABLE THE TRANSMITTER TUBES TO HANDLE LARGER POWERS.

OUR FIRST STEP IN THIS LESSON WILL BE TO POINT OUT THE MORE IMPORTANT CONSTRUCTIONAL FEATURES OF THE VARIOUS DISTINCTIVE TYPES OF TRANSMITTER TUBES AND THIS WILL BE FOLLOWED BY DATA CONCERNING THE OPERATING CHARACTERISTICS OF SOME OF THE TRANSMITTER TUBES WHICH ARE MOST COMMONLY USED IN PRACTICE.

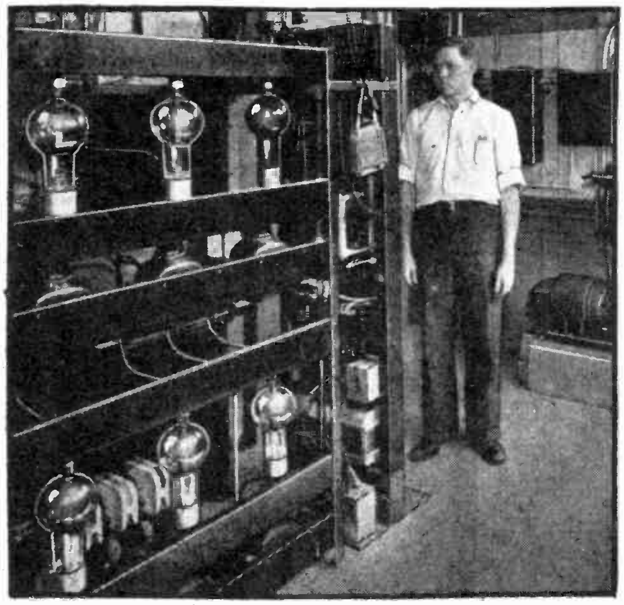

FIG. 1

Bank of Rectifier Tubes In a Short-Wave Broadcast Station.

CONSTRUCTIONAL FEATURES

IN FIG. 2 YOU ARE SHOWN THE TYPE 800 TUBE. THIS TUBE IS A

TRIODE OF RATHER LOW POWER RATING BUT DESIGNED PRIMARILY FOR OPERATION IN HIGH FREQUENCY CIRCUITS. THE MOST INTERESTING FEATURE OF THIS TUBE IS THAT THE GRID AND PLATE CONNECTIONS ARE MADE AT TWO METAL CAPS WHICH ARE PLACED ON THE CREST OF THE GLASS BULB. THIS FORM OF CONSTRUCTION REDUCES THE GRID–PLATE CAPACITY OF THE TUBE AND ITS CONNECTING CIRCUITS AND WHICH IS OF VITAL IMPORTANCE IN CIRCUITS OPERATING AT HIGH FREQUENCIES. AT THE SAME TIME, GOOD INSULATIVE PROPERTIES ARE ALSO INTRODUCED BY THIS ARRANGEMENT.

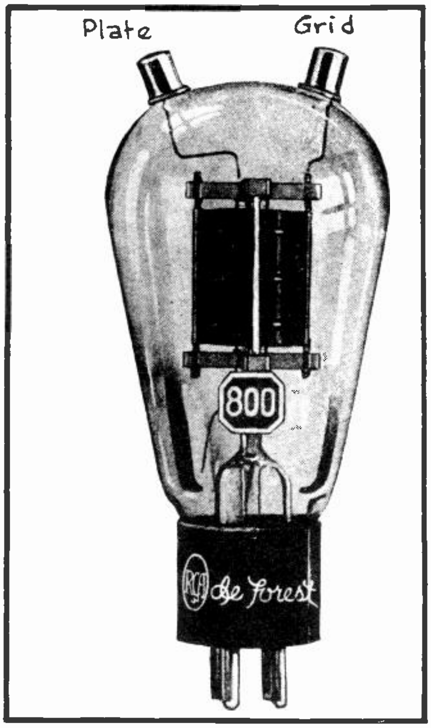

FIG. 2
The Type 800 Tube.

A FOUR–PRONG BASE IS USED IN THIS CASE, THE TWO LARGER ONES TAKING CARE OF THE FILAMENT CONNECTIONS WHILE THE TWO SMALLER ONES ARE BLANK. THE OVER–ALL HEIGHT OF THIS TUBE IS 6 3/8" WHILE THE MAXIMUM DIAMETER OF ITS GLASS BULB IS 2 11/16".

50 WATT TUBES

THE CONSTRUCTIONAL FEATURES OF A TYPICAL 50 WATT TUBE ARE SHOWN IN FIG. 3, WHERE THE 203–A IS USED AS THE EXAMPLE. THIS TUBE IS ALSO A TRIODE AND FITTED WITH FOUR BASE PRONGS OF THE SHORT TYPE. IN THIS CASE, ALL OF THE ELEMENTS ARE CONNECTED TO THE BASE PRONGS IN THE USUAL WAY. THE OVERALL HEIGHT OF THIS TUBE IS 7 7/8" AND ITS MAXIMUM DIAMETER IS 2 5/16".

A STILL DIFFERENT FORM OF TUBE CONSTRUCTION IS SHOWN IN FIG. 4, WHERE A 50 WATT TUBE APPEARS AT THE LEFT AND A 150 WATT TUBE AT THE RIGHT. HERE THE GLASS BULB IS OF MAXIMUM DIAMETER AT THE APPROXIMATE CENTER AND REDUCED AT EACH END. BOTH OF THESE TUBES ARE OF THE TRIODE TYPE AND HAVE THEIR FILAMENT CONNECTIONS MADE AT THE BASE PRONGS, WHILE THE GRID CONNECTION IS MADE AT A CAP AT THE UPPERMOST END OF THE TUBE AND THE PLATE CONNECTION AT THE METAL CAP WHICH IS PROVIDED AT THE SIDE OF THE LOWER PORTION OF THE GLASS BULB. THIS FORM OF CONSTRUCTION ALSO PERMITS WIDE SEPARATION BETWEEN THE GRID AND PLATE CIRCUIT WIRING AS WELL AS GOOD INSULATIVE PROPERTIES. THE APPROXIMATE OVERALL HEIGHT OF A TUBE OF THIS TYPE IS 8 3/4" AND ITS MAXIMUM BULB DIAMETER IS 4 1/4".

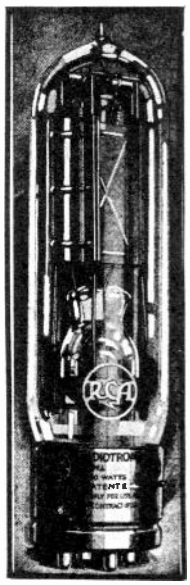

FIG. 3
The 203-A

THE 204–A

IN FIG. 5 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES OF THE 204–A, WHICH IS RATED AT 250 WATTS. THIS TUBE IS FITTED WITH A THREE–PRONG BASE AND A METAL CAP CONNECTION AT THE OPPOSITE END. THE TWO OUTER AND LARGER BASE PRONGS ARE FOR THE FILAMENT CONNECTIONS WHILE THE CENTER PRONG OF THIS GROUP IS FOR THE GRID CONNECTION. THE PLATE CONNECTION IS MADE AT THE METALLIC CAP.

THIS TUBE IS TO BE FITTED IN SPECIAL END MOUNTINGS AND WHICH ARE ALSO SHOWN IN FIG.5. IT MAY BE MOUNTED EITHER IN A VERTICAL POSITION WITH THE FILAMENT END UP OR IN A HORIZONTAL POSITION WITH THE PLATE IN A VERTICAL PLANE (ON EDGE). YOU WILL ACQUIRE SOME IDEA AS TO THE SIZE OF THIS TUBE FROM ITS DIMENSIONS AND WHICH ARE AS FOLLOWS: OVERALL HEIGHT = $14\frac{1}{4}$" ; MAXIMUM DIAMETER = $4\frac{1}{16}$".

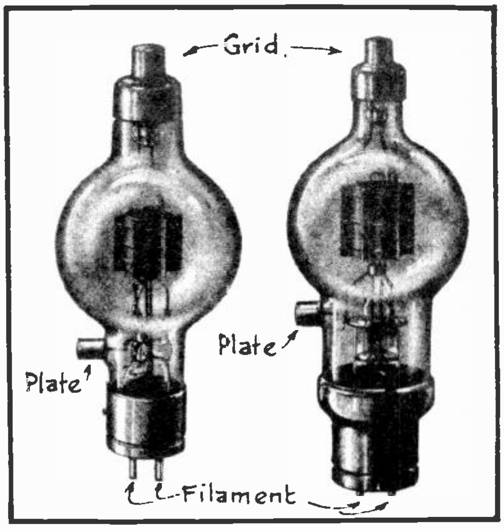

FIG. 4
Another Form of Tube Construction.

1 KW. TUBES

A PICTURE OF THE 206 APPEARS IN FIG. 6 AND WHICH YOU WILL NOTE IS MOUNTED SOMEWHAT THE SAME AS THE 204-A, WITH THE EXCEPTION THAT THE GRID CONNECTION IS BROUGHT OUT AT THE SIDE OF THE GLASS ENCLOSURE.

ANOTHER 1000 WATT TUBE, THE 851, IS SHOWN IN FIG.7. THIS ALSO HAS A THREE PRONG BASE AND A CAP CONNECTION. THE TWO LARGE BASE PRONGS ARE FOR THE FILAMENT AND THE SMALLER CENTRALLY LOCATED ONE IS FOR THE GRID. THE PLATE CONNECTION IS MADE AT THE METAL CAP AT THE OPPOSITE END OF THE TUBE. THIS TUBE IS MOUNTED SIMILARLY TO THAT METHOD WHICH IS ILLUSTRATED FOR THE 204-A AND THE 206 TUBES. THE OVERALL LENGTH OF THE 851 IS $17\frac{1}{2}$" AND ITS MAXIMUM DIAMETER IS $6\frac{1}{8}$".

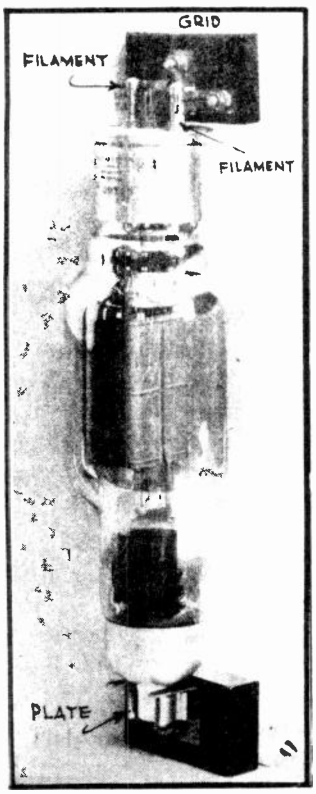

FIG.5
The 204-A

THE EXPLANATIONS AS SO FAR GIVEN SHOULD HAVE SERVED TO GIVE YOU SOMEWHAT OF AN IDEA REGARDING THE GENERAL SHAPE AND APPEARANCE OF TRANSMITTER TUBES. TO ILLUSTRATE EVERY SINGLE TYPE OF TRANSMITTER TUBE WOULD NOT ONLY BE UNNECESSARY BUT ALSO A WASTE OF TIME. THE ONES SHOWN ARE TYPICAL OF THOSE WHICH YOU WILL FIND IN THE INDUSTRY, AS IN APPEARANCE THEY NEARLY ALL FOLLOW THE SAME SHAPE AS THOSE WHICH HAVE BEEN ILLUSTRATED.

OUR NEXT STEP WILL BE TO CONSIDER SOME OF THE DESIGN FEATURES OF TRANSMITTER TUBES.

DETAILS OF DESIGN

TRANSMITTER TUBES OF HIGHER POWER RATING MUST BE DESIGNED AND CONSTRUCTED WITH UTMOST CARE AND PRECISION.

THE ELECTRON EMITTER IN TUBES OF THIS TYPE IS NEARLY ALWAYS A TUNGSTEN FILAMENT. OXIDE-COATED AND THORIATED-TUNGSTEN FILAMENTS ARE CONFINED PRACTICALLY EXCLUSIVELY TO TUBES OF SMALLER SIZE.

THE REASON FOR USING TUNGSTEN FILAMENTS IS

THAT WHEN THE ELECTRONS TRAVEL FROM THE EMITTER TO THE PLATE OF THE TUBE, THEY COLLIDE WITH ANY REMAINING TRACES OF GAS MOLECULES, BREAKING THEM UP INTO SMALL POSITIVE PARTICLES KNOWN AS POSITIVE IONS AND SMALL NEGATIVE PARTICLES KNOWN AS NEGATIVE IONS. WHEN HIGH PLATE VOLTAGES ARE USED, THE POSITIVE IONS TRAVEL TOWARDS THE EMITTER WITH SUCH TERRIFIC SPEED THAT THE IMPACT UPON STRIKING THE EMITTER IS SUFFICIENT TO STRIP THE THORIUM LAYER OFF THE EMITTER.

THE FILAMENT CURRENT AS DRAWN BY THE LARGER TRANSMITTER TUBES IS GENERALLY QUITE HIGH SO THAT ADEQUATE ELECTRON EMISSION MAY BE OBTAINED. WHEN USING SOME OF THE LARGER TUBES, IT IS CUSTOMARY TO PLACE A RESISTANCE IN SERIES WITH THE FILAMENT WHEN THE FILAMENT CIRCUIT IS FIRST CLOSED, SO AS TO LIMIT THE RUSH OF CURRENT THAT WOULD OTHERWISE FLOW BECAUSE OF THE LOW RESISTANCE OF THE COLD FILAMENT. SHOULD THIS STARTING RESISTANCE NOT BE EMPLOYED, THE INITIAL FILAMENT CURRENT IN THE LARGER TUBES WOULD BURN OUT FUSES OR PERHAPS DAMAGE THE TUBE ITSELF.

TO PREVENT TRACES OF GAS WITHIN TRANSMITTER TUBES IS ONE OF THE MOST DIFFICULT PROBLEMS ENCOUNTERED IN THEIR MANUFACTURE. ALTHOUGH IT IS TRUE THAT THE AIR AND TRACES OF GAS CAN BE REMOVED QUITE READILY FROM THE GLASS ENVELOPE, YET THE EXHAUSTING OF GAS STILL INCLUDED IN THE METALLIC PARTS AND OTHER GLASS SUPPORTING MEMBERS IS EXTREMELY DIFFICULT.

THE GAS IS DRIVEN OUT OF THE METAL STRUCTURE WITHIN THE TUBE BY HEATING THE METAL TO A HIGH TEMPERATURE BEFORE PLACING IT IN THE TUBE AND THE PUMPING IS CARRIED OUT WITH THE ENTIRE TUBE IN AN OVEN THAT IS HEATED TO A TEMPERATURE JUST BELOW THE SOFTENING POINT OF THE GLASS. FINALLY, WHILE THE PUMP IS STILL IN OPERATION, THE METAL PARTS ARE BROUGHT UP TO TEMPERATURES ABOVE THOSE WHICH WOULD OCCUR DURING THE NORMAL OPERATION OF THE TUBE. SOME OF THE LARGER TUBES REQUIRE AS LONG AS 24 HOURS OF CONTINUOUS PUMPING IN ORDER TO REMOVE THE GASES WHICH WOULD ORDINARILY BE HELD BY THE VARIOUS PARTS WHICH ARE ENCLOSED IN THE GLASS ENVELOPE.

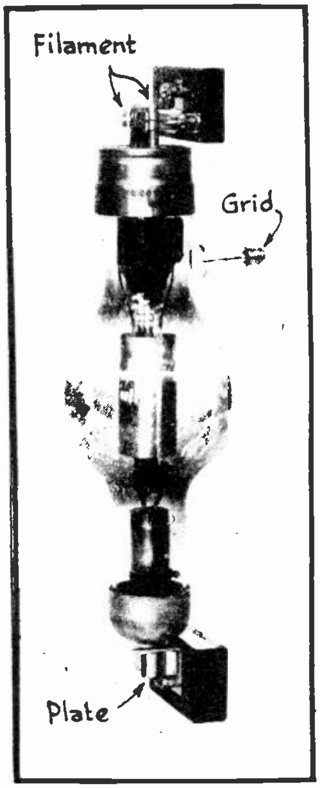

FIG. 6
The 206

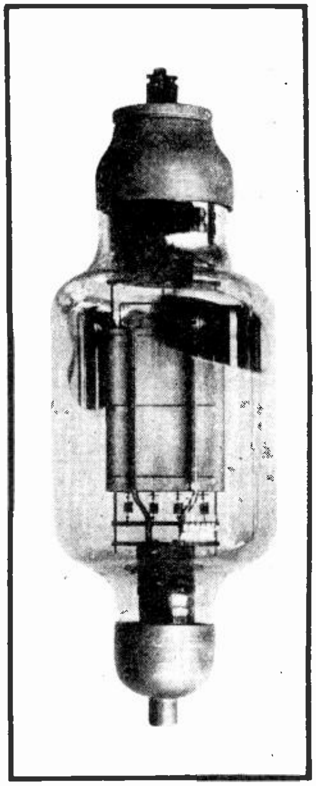

FIG. 7
The 851

THE MATERIALS WHICH ARE SELECTED FOR THE GRIDS AND PLATES MUST BE SELECTED WITH SPECIAL CARE DUE TO THE HIGH TEMPERATURES AT WHICH THESE ELEMENTS FREQUENTLY OPERATE WHEN IN USE. THE GRIDS ARE GENERALLY MADE OF TUNGSTEN ALTHOUGH MOLYBDENUM IS ALSO USED. THE PLATES IN AIR-COOLED TUBES

ARE GENERALLY MADE OF MOLYBDENUM BUT TANTALUM IS ALSO USED.

WHEN TRANSMITTER TUBES ARE IN OPERATION, THEY GENERATE CONSIDERABLE HEAT. THIS HEAT ORIGINATES PRIMARILY AT THE FILAMENT AND PLATE, THE PLATES FREQUENTLY BECOMING RED HOT, ALTHOUGH THIS IS ALSO TRUE OF THE GRIDS IN SOME CASES. SO AS TO PERMIT ADEQUATE RADIATION OF THIS HEAT TO THE SURROUNDING AIR AND THEREBY PREVENT TUBE HEATING OF AN INJURIOUS MAGNITUDE, IT IS CUSTOMARY TO SUPPLY THE TUBE WITH A GLASS ENVELOPE OF CONSIDERABLE SIZE. THE GREATER THE AREA OF THE GLASS IN CONTACT WITH THE SURROUNDING AIR, THE MORE EFFICIENT WILL BE THE COOLING.

TO FASCILITATE COOLING OF THE TUBES THEY SHOULD BE INSTALLED IN SUCH A MANNER THAT THEY WILL BE EXPOSED FREELY TO THE SURROUNDING AIR RATHER THAN BEING CRAMPED IN CLOSE QUARTERS. AN EXAMPLE OF SUCH A TUBE INSTALLATION IS SHOWN IN FIG. 8. ALSO NOTICE IN THIS ILLUSTRATION THAT BEAD INSULATION IS USED ON THE HIGH VOLTAGE CONDUCTORS LEADING TO THE TUBES.

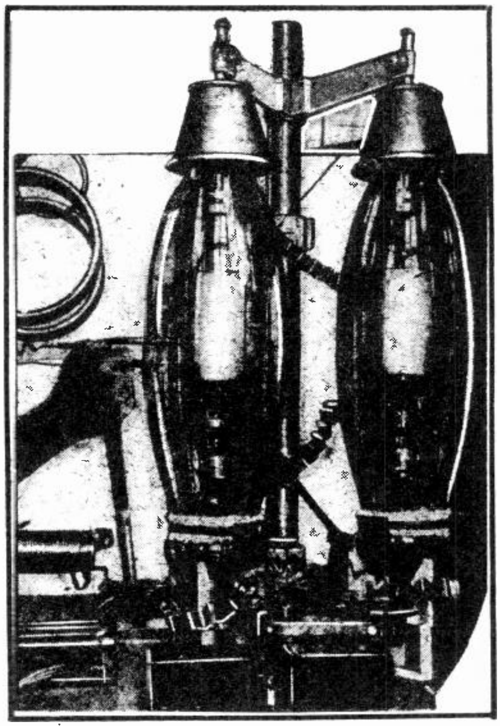

FIG. 8
A Typical High Power Tube Installation.

QUITE OFTEN TO PROVIDE STILL BETTER TUBE COOLING, A DRAFT OF AIR IS CIRCULATED AROUND THEM. THIS CAN BE ACCOMPLISHED WITH THE AID OF LARGE FANS OR BLOWERS WHICH FORCE A DRAFT OF AIR AROUND THE TUBES WHILE THEY ARE IN OPERATION.

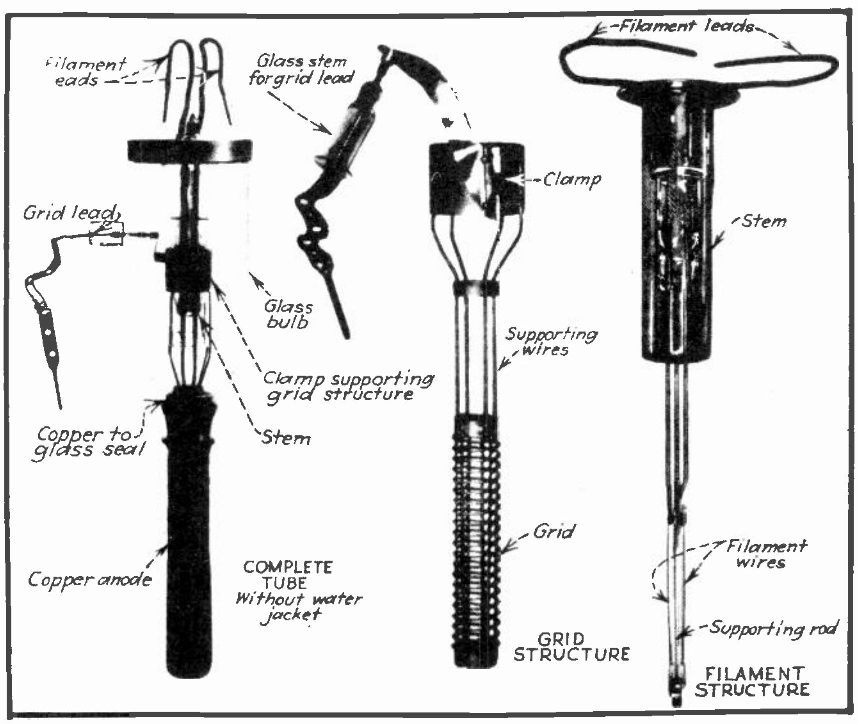

FIG. 9
A Water-Cooled Tube.

WATER-COOLED TUBES

FOR MOST OF THE TUBES OF VERY HIGH POWER RATING, AS USED IN BROADCAST STATIONS, AIR cooling is not sufficient to keep the tube temperatures at a safe value. In such cases, water is used as the cooling medium. To use water for this purpose, the tube must be specially designed and an example of such a water-cooled tube is shown you in Fig. 9.

Here the tube is shown at the left in an assembled condition, whereas the grid structure is shown in detail at the center and the filament structure at the right.

This tube uses a hollow, tubular shaped, plate (anode) which is closed at its lower end. The filament structure is inserted in the space within the center of the grid structure and these two structures are together inserted into the hollow plate. The upper portion of the tube is sealed in a glass envelope.

When in use, the plate end of the tube is inserted into a special jacket through which cooling water is circulated, and which at the same time serves as the tube holder. This is illustrated in Fig. 10.

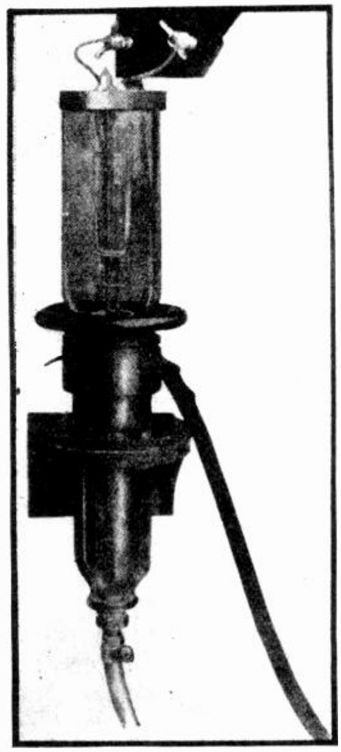

FIG. 10
Water-Cooled Tube Mounted in Jacket.

Sufficient space is provided between the inside of the jacket and the copper plate so as to permit a column of water to circulate freely around the plate for the extraction of heat generated at this point. Hose connections lead the water into and out of the jacket and a special gasket between the tube and the jacket prevents leakage.

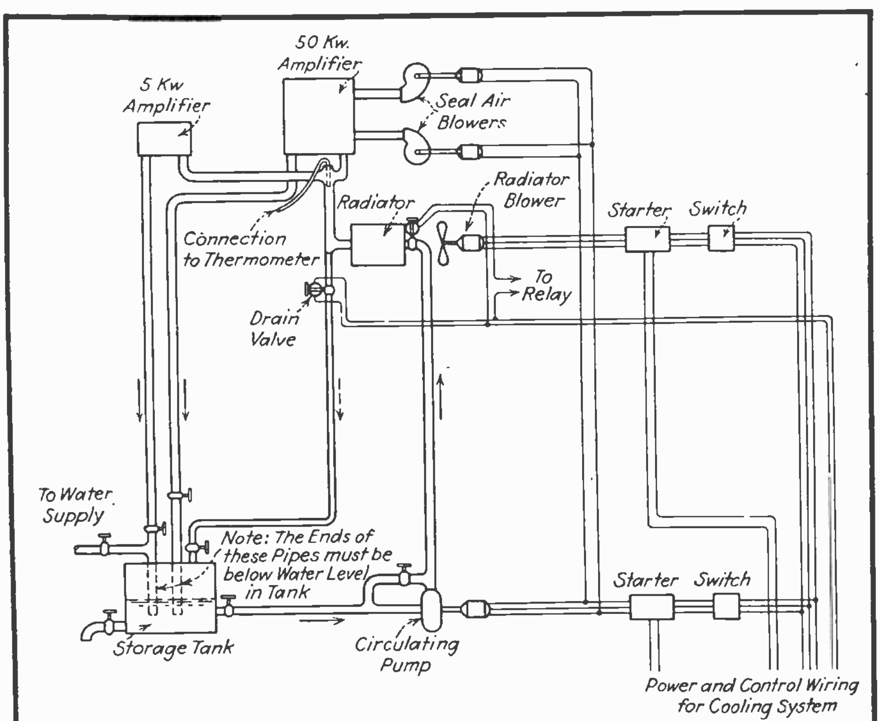

FIG. 11
A Typical Water-Cooling System.

A typical water-cooling system as used with a 50 Kw broadcast transmitter is shown in Fig. 11. As you will observe, this system consists of a

STORAGE TANK FROM WHICH THE COOLING WATER IS DRAWN AND FORCED BY THE PRESSURE OF A PUMP THROUGH A RADIATOR, THROUGH THE TUBE JACKETS, AND BACK TO THE STORAGE TANK.

THE RADIATOR IS SIMILAR IN CONSTRUCTION TO AN AUTOMOBILE RADIATOR ONLY THAT IT IS LARGER IN SIZE. A FAN WHICH IS DRIVEN BY AN ELECTRIC MOTOR FORCES AIR THROUGH THE RADIATOR SO AS TO COOL THE WATER BEFORE CIRCULATING IT AROUND THE TUBES. A BANK OF COOLING FANS OF THIS TYPE ARE SHOWN YOU IN FIG. 12. HERE THE AIR IS TAKEN IN FROM OUTSIDE THE BUILDING THROUGH LOUVRES AND FORCED BY THE FANS THROUGH THE RADIATORS WHICH ARE LOCATED DIRECTLY IN FRONT OF THEM.

IN THE SYSTEM OF FIG. 11 ADDITIONAL ELECTRICALLY DRIVEN AIR BLOWERS ALSO FORCE A DRAFT OF AIR AROUND THE TUBES OF THE 50 KW. AMPLIFIER TO STILL FURTHER AID IN THE PROCESS OF COOLING.

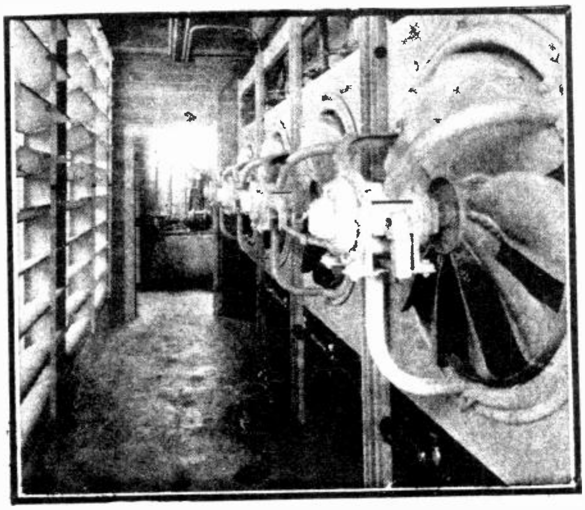

FIG. 12
Cooling Fans and Radiator System.

IN THE LARGE TUBES, ABOUT TWO OR THREE GALLONS OF WATER PER MINUTE IS PUMPED PAST THE PLATE (ANODE). A CIRCUIT BREAKER IS FREQUENTLY INSTALLED BETWEEN THE WATER CIRCULATING SYSTEM AND THE ELECTRICAL CIRCUITS AND IS SET TO OPEN IN CASE THE WATER SUPPLY SHOULD FAIL FOR ANY REASON.

THE TEMPERATURE OF THE WATER IS USUALLY MEASURED AFTER IT HAS PASSED THE HOT ANODE AND AT THIS POINT IS SELDOM PERMITTED TO EXCEED 70° CENTIGRADE (158° FAHRENHEIT). BECAUSE OF THE HIGH PLATE POTENTIAL REQUIRED BY SUCH TUBES, THE PLATE IS CAREFULLY INSULATED FROM THE WATER TANK AND THEMETAL TUBING WHICH IS NORMALLY GROUNDED. BY USING A FAIRLY LONG RUBBER HOSE TO CONNECT THE WATER JACKET TO THE WATER SOURCE AND ALSO BY USING PUREWATER IN THE CI CULATORY SYSTEM, THE INSULATION RESISTANCE IS BUILT UP TO THE ORDER OF SEVERAL HUNDREDS OF THOUSANDS OF OHMS, THIS RESISTANCE IS BETWEEN THE HIGH POTENTIAL ANODE WHICH IS IN DIRECT CONTACT WITH THE WATER, AND THE COOLING SYSTEM, AND IN TURN, THE GROUND.

ANOTHER "TRICK" WHICH IS RESORTED TO IN ORDER TO FASCILITATE THE COOLING OF TRANSMITTER TUBES IS TO BLACKEN THE PLATE SO AS TO INCREASE THE RATE OF HEAT RADIATION. ALSO IN SOME OF THE TRANSMITTER TUBES SPECIAL BUILT-IN FEATURES SUCH AS R.F. CHOKES WILL BE FOUND AND WHICH HAVE BEEN PLACED THEREIN WITH THE INTENTION OF REDUCING PARASITIC OSCILLATIONS.

TUBE OPERATING CHARACTERISTICS

NOW THAT YOU ARE FAMILIAR WITH THE CONSTRUCTIONAL FEATURES OF THE DIFFERENT DISTINCTIVE TYPES OF TRANSMITTER TUBES, YOU WILL NEXT BE INTERESTED IN LEARNING HOW THE OPERATING CHARACTERISTICS OF THESE TUBES COMPARE WITH THOSE AS USED IN RECEIVERS.

TABLE I

TRANSMITTING TUBES

TRIODES

Type	Nominal R.F. Output (watts)[1]	Fil. Volts (E_f)	Fil. Amps. (I_f)	Max. Plate Volts[2] (E_b)	Max. Plate Ma. (I_p)	Neg. Grid Bias Volts[3] (E_c)	Max. Grid Ma. (I_c)	Grid Driving Power (watts)	Safe Plate Dissipation (watts)	Amp. Factor (μ)	Interelectrode Capacitances ($\mu\mu$fd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Grid Leak (ohms)
45	10	2.5	1.50	400	50	180		2.0	10	3.5	5.0	8.0	3.0	50,000
46	10	2.5	1.75	400	50	180[4] 22[5]		2.0	10	5.6 30.0				50,000 1,000
59	10	2.5‡	2.0	400	50	135[6] 22[7]		3.0 2.0	10	6.0 30.0				25,000 1,000
843	10	2.5‡	2.5	425	40	90	7.5		15	7.7	5.0	6.0	5.0	10,000
10	15	7.5	1.25	500	60	135	15	3.0	15	8.0	4.0	7.0	3.0	10,000
841	15	7.5	1.25	500	60	30	20	2.0	15	30.0	5.0	8.0	3.0	5,000
801*	25	7.5	1.25	600	65	150	15	4.5	20	8	4.5	6	1.5	10,000
800*	50	7.5	3.25	1000	75	135	25	5.0	35	15.0	2.8	2.5	1.0	10,000
825*	50	7.5	3.25	1000	75	180		5.0	40	10.0	2.0	3.0	1.0	10,000
830	50	10.0	2.15	750	110	180	18	5.0	40	8.0	4.9	9.9	2.2	10,000
RK-18*	50	7.5	2.5	1000	85	135	15	4.0	40	18.0	3.8	5.0	2.0	10,000
304-A*	85	7.5	3.25	1250	100	200	20	8	50	11	2	2.5	0.7	10,000
203-A	100	10.0	3.25	1250	175	100	60	14.0	100	25.0	6.5	14.5	5.5	10,000
211	100	10.0	3.25	1250	175	200	50	14.0	100	12.0	8.0	15.0	7.0	15,000
242-A	100	10.0	3.25	1250	150	150	50	14.0	100	12.5	6.5	13.0	4.0	15,000
852*	100	10.0	3.25	3000	100	350	40	20.0	100	12.0	2.0	3.0	1.0	10,000
354*	150	5	7.75	3000	175	275	40	15.0	150	11.0	9.0	3.7	0.4	10,000
150T*	200	5	10.0	3000	200	300	25	15.0	150	12.0				10,000
F-108-A*	200	10.0	11.0	3000	200	350	50	25.0	175	12.0	3.0	7.0	2.0	15,000
204-A	350	11.0	3.85	2500	275	250	80	60.0	250	25.0	18.0	17.0	3.0	10,000
849	450	11.0	5.0	2500	350	300	125	75.0	300	19.0	17.0	33.5	3.0	10,000
831*	500	71.0	10.0	3000	350	300	100	75.0	400	14.5	3.8	4.0	1.5	10,000
F-100*	500	11.0	25.0	2000	500	300		75.0	500	14.0	4.0	10.0	2.0	10,000

TETRODES AND PENTODES

Type	Nominal R.F. Output (watts)[1]	Fil. Volts (E_f)	Fil. Amps. (I_f)	Max. Plate Volts[2] (E)	Max. Screen Volts (E)	Neg. Grid Bias Volts (E)	Max. Plate Ma.[2] (I_p)	Max. Grid Ma. (I_c)	Grid Driving Power (watts)	Safe Screen Dissipation (watts)	Safe Plate Dissipation (watts)	Interelectrode Capacitances ($\mu\mu$fd.) Grid to Cathode	Grid to Plate	Plate to Cathode
41	5	6.3‡	0.4	300	100	22	40		1.0					
42	10	6.3	0.7	400	100	45	50		2.0					
47	10	2.5	1.75	400	100	45	50		2.0			8.6	1.2	13.0
2A5	10	2.5‡	1.75	400	100	45	50		2.0					
89	10	6.3‡	0.4	400	100	45	40		2.0					
59	10	2.5‡	2.0	400	100	45	50		2.0					
844	5	2.5‡	2.5	500	150	10	30	5	1.0	3	15	10.0	0.07	8.5
865*	15	7.5	2.0	750	150	75	60	15	2.5	3	15	10.0	0.05	7.5
254-A*	20	5.0	3.25	750	175	90	60		3.0	5	20	4.6	0.1	9.4
254-B*	25	7.5	3.25	750	150	135	75		3.0	5	25	11.2	0.085	5.4
282-A*	50	10.0	3.0	1000	250	150	100		5.0	5	70	12.2	0.2	6.8
RK-20*	50	7.5	3.0	1000	300	75	85		3.0	10	40	11.0	0.01	9.5
850	100	10.0	3.25	1250	150	150	175	40	10.0	10	100	17.0	0.2	26.0
860*	100	10.0	3.25	3000	250	200	100	40	15.0	10	100	8.5	0.05	9.0
861*	540	11.0	10.0	3500	500	200	350	100	50.0	35	400	17.0	0.1	13.0

[1] Conservative rating based on normal plate input and operating conditions. The actual output will depend upon the efficiency and the power supplied to the tube plate.
[2] Maximum recommended values, unmodulated d.c. With modulation, d.c. plate voltage should be 25 to 30 per cent lower.
[3] Recommended value for operation as oscillator or Class-C power amplifier.
[4] With outer grid connected to plate.
[5] With grids connected together.
[6] Grids Nos. 2 and 3 connected to plate.
[7] Grids Nos. 1 and 2 connected together; grid No. 3 connected to plate.
‡ Indirectly-heated cathode.
* Especially designed for very high-frequency use.

IN TABLE I, FOR EXAMPLE, YOU ARE GIVEN THE OPERATING CHARACTERISTICS OF THE TRIODES, TETRODES AND PENTODES WHICH ARE MOST EXTENSIVELY USED FOR AMATEUR AND MEDIUM POWER COMMERCIAL TRANSMITTERS. THESE TRIODES ARE SUITABLE AS OSCILLATORS AND POWER AMPLIFIERS. THE TETRODES AND PENTODES WHICH ARE DESIGNED PARTICULARLY FOR TRANSMITTERS ARE INTENDED TO BE USED PRIMARILY AS OSCILLATORS AND RADIO FREQUENCY POWER AMPLIFIERS AND CAN BE USED WITHOUT NEUTRALIZATION. THE OPERATING CHARACTERISTICS OF THE MORE POPULAR RECTIFIER TUBES APPEAR IN TABLE II.

A PAIR OF THE LARGER RECTIFIER TUBES ARE SHOWN YOU IN FIG. 13 WHERE THE 217-C APPEARS AT THE LEFT AND THE 218 AT THE RIGHT. BOTH OF THESE TUBES ARE OF THE HALF-WAVE TYPE. THE OPERATING CHARACTERISTICS OF THE 217-C ARE AS FOLLOWS: FILAMENT VOLTAGE = 10; FILAMENT CURRENT = 3.25 AMPS; PEAK INVERSE VOLTAGE;= 7500 VOLTS MAXIMUM; PEAK PLATE CURRENT =0.6 AMP. MAXIMUM. THE OPERATING CHARACTERISTICS OF THE 218 ARE AS FOLLOWS: FILAMENT VOLTAGE = 11; FILAMENT CURRENT = 14.75 AMPS; PEAK INVERSE VOLTS = 50,000 MAXIMUM; PEAK PLATE CURRENT = 0.75 AMP. MAXIMUM.

THE RECTIFIER TUBES OF LARGER SIZE CAN ALSO BE OF THE AIR-COOLED OR WATER-COOLED TYPE THE SAME AS ALREADY EXPLAINED FOR TRANSMITTER TUBES IN GENERAL.

TUBES OF HIGHER RATING

NOW THAT TABLE I HAS FAMILIARIZED YOU WITH THE OPERATING CHARACTERISTICS OF TRANSMITTER TUBES OF MODERATE SIZE, LET US NEXT TAKE A GLANCE AT THE SPECIFICATIONS OF THE LARGER, WATER-COOLED TUBES. AS AN EXAMPLE, LET US USE THE 848.

WHEN OPERATING AS A PLATE-MODULATED "CLASS C" R.F. POWER AMPLIFIER,

TABLE II

RECTIFIER TUBES

Type No.	Fil. Volts	Fil. Amps.	Max. Voltage per plate (a.c. r.m.s.)	Max. Inverse Peak Voltage	Max. D.C. Output Current (ma.)	Max. Peak Current (ma.)	Type
1	6.3*	0.3	350	1000	50	400	Half-wave M.V.
1-V	6.3*	0.3	350		50		Half-wave H.V.
84	6.3*	0.5	225		50		Full-wave H.V.
12Z3	12.6*	0.3	250		60		Half-wave H.V.
25Z5	25.0*	0.3	125		100		H.V. Voltage-Doubler[1]
80	5.0	2.0	350 400 550[2]		125 110 135		Full-wave H.V.
82	2.5	3.0	500	1400	125	400	Full-wave M.V.
5Z3	5.0	3.0	500		250		Full-wave H.V.
83	5.0	3.0	500	1400	250	800	Full-wave M.V.
81	7.5	1.25	700		85		Half-wave H.V.
RK19	7.5*	2.5	1250	3500		600	Full-wave H.V.
866	2.5	5.0		7500		600	Half-wave M.V.
866-A	2.5	5.0		10,000		600	Half-wave M.V.
872	5.0	10.0		7500		2500	Half-wave M.V.

H.V. — High Vacuum. M.V. — Mercury Vapor.
* Indirectly-heated cathode.

[1] Two independent rectifiers in one bulb.
[2] Only with input choke of at least 20 henrys to filter.

THE 848 HAS THE FOLLOWING CHARACTERISTICS; FILAMENT VOLTAGE = 22 VOLTS A.C. OR D.C.; FILAMENT CURRENT=52 AMPS; D.C. PLATE VOLTAGE = 9000 VOLTS; GRID VOLTAGE = -4000 VOLTS (APPROXIMATELY); POWER OUTPUT = 6000 WATTS (APPROXIMATELY).

WHEN WORKING WITH HIGH POWER TUBES OF THIS KIND, THEIR APPLICATION TO THE TRANSMITTER CIRCUIT FROM AN ELECTRICAL STANDPOINT IS PRACTICALLY THE SAME AS ALREADY DESCRIBED TO YOU IN PREVIOUS LESSONS RELATIVE TO TRANSMITTER TUBES OF MEDIUM POWER RATING. THE ONLY ESSENTIAL DIFFERENCES ENCOUNTERED WHEN USING THE HIGHER POWER TUBES IS THE COOLING MEDIUM USED, THE USE OF A POWER SUPPLY OF HIGHER OUTPUT ABILITY, THE EXERCISING OF GREATER PRECAUTIONS IN THE ARRANGEMENT AND DESIGN OF THE CIRCUIT SO THAT THE VERY HIGH VOLTAGES AND POWERS CAN BE HANDLED WITH SAFETY. YOU WILL BE TOLD MORE ABOUT THE USE OF THESE TUBES OF HIGH POWER RATING IN YOUR STUDIES WHICH TREAT WITH BROADCAST TRANSMITTERS.

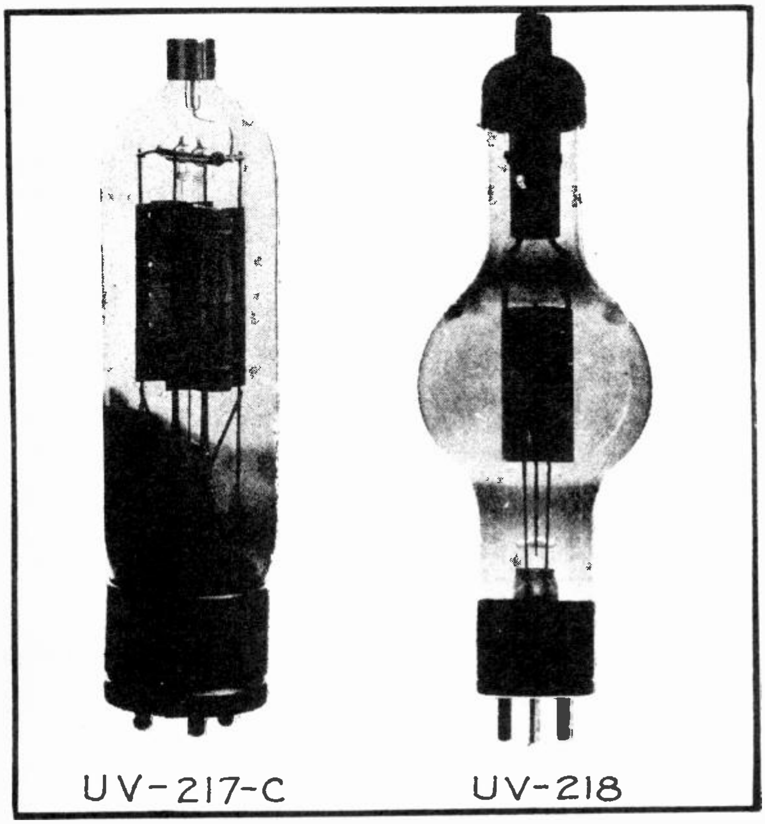

FIG. 13
Typical Rectifier Tubes

ANOTHER IMPORTANT POINT WHICH IT WILL BE WELL TO REMEMBER REGARDING TRANSMITTER TUBES IS THAT THEIR POWER OUTPUT RATING AS SPECIFIED BY THE MANUFACTURERS IS A MORE OR LESS AVERAGE VALUE AND THAT THE POWER OUTPUT REALIZED IN ACTUAL PRACTICE IS GOVERNED LARGELY BY THE DESIGN OF THE PARTICULAR CIRCUIT IN WHICH THE TUBE IS USED.

TUBE DATA FOR MODULATORS

IN TABLES III AND IV OF THIS LESSON, YOU ARE FURNISHED WITH ADDITIONAL TUBE DATA WHICH SPECIFIES THE CHARACTERISTICS FOR OPERATING SOME OF THE MORE POPULAR TUBES AS CLASS A AMPLIFIERS AND MODULATORS, AS WELL AS CLASS B MODULATORS.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD GENERAL KNOWLEDGE OF THE CONSTRUCTION AND OPERATING CHARACTERISTICS OF TYPICAL TRANSMITTER TUBES. PERHAPS YOU MAY STILL BE WONDERING JUST EXACTLY HOW ALL OF THE TUBE DATA AS PRESENTED IN THIS LESSON IS APPLIED TO THE ACTUAL DESIGN OF TRANSMITTER EQUIPMENT. THESE DETAILS, HOWEVER, WILL ALL BE TAKEN CARE OF IN LESSONS WHICH YOU WILL RECEIVE A LITTLE LATER ON.

BEFORE WE GO INTO THE VARIOUS TRANSMITTER DESIGN CALCULATIONS, HOWEVER, THERE IS STILL ONE MORE IMPORTANT MATTER FOR US TO CONSIDER AND

TABLE III

TYPICAL CLASS-A AMPLIFIER AND MODULATOR OPERATING DATA

Type Tube	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma., I_b	Neg. Grid Volts,[1] E_c	Load Imp.,[2] Ohms	Audio Output,[3] Watts
50	7.5	500	50	100	7500	5.5
2A3 (P.P.)[4]	2.5	300	80	62	3000	15.0
211, 242A, 276A	10.0	1000	65	52	7000	10.0
845	10.0	1000	75	150	7500	23.0
284A	10.0	1250	60	228	10,000	41.5
849	11.0	2000 2500 3000	125 110 100	75 104 132	12,000 12,000 20,000	42.5 81.0 100.0

With exception noted, ratings are for a single tube. For tubes in parallel multiply I_b and Output Watts by number used, and divide Load Impedance by number used. For 2 tubes in push-pull, multiply I_b, Load Impedance and Output Watts by 2, taking peak audio grid voltage twice bias value.
[1] Peak audio grid voltage equal to bias value for single tube or tubes in parallel.
[2], [3] To be used in determining Class-C amplifier operating conditions.
[4] Two tubes in push-pull. Peak audio grid voltage twice bias value.

TABLE IV

TYPICAL CLASS-B MODULATOR OPERATING DATA

Class-B Tubes (2)	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma. (Max.), I_b	Neg. Grid Volts, E_c	Load Imp., Ohms [1]	Tube Output, Watts	Input Trans. Turns Ratio (Pri.:Sec.)	Driver Tubes (P.P.)	Driver Plate Volts
46	2.5	400	108	0	7000	25	3:1	45	225
59	2.5	400	124	0	6000	28	3:1	45	225
841	7.5	500	108	13.5	8000	29	5:1	45	250
210*	7.5	600	153	67	8000	57.5	1.6:1	45	250
800	7.5	1000	164	55	12,500	100	1:1	2A3	250
RK18	7.5	1000	164	45	12,000	100	2:1	45	250
830-B*	10.0	1000	280	33	10,000	190	1:1.4	2A3	250
203-A*	10.0	1000	366	40	5800	240	1.6:1	2A3	250

Ratings are for 2 tubes, Class-B.
* Graphite anode types.
[1] Plate-to-plate. Use this load impedance and Output Watts for determining Class-C stage coupling and operating conditions

THAT IS THE CONSTRUCTIONAL FEATURES AND OPERATION OF RECEIVERS WHICH ARE PARTICULARLY SUITABLE FOR COMMUNICATION STATIONS. THIS, THEREFORE, IS THE SUBJECT MATTER TO BE DISCUSSED WITH YOU IN THE NEXT LESSON. AT THIS TIME YOU WILL ALSO HAVE THE OPPORTUNITY OF LEARNING ABOUT CRYSTAL FILTERS AS USED IN RECEIVERS, ABOUT BEAT-NOTE OSCILLATORS FOR C.W. CODE RECEPTION AND OTHER INTERESTING FEATURES OF COMMERCIAL STATION EQUIPMENT.

THIS AMOUNT OF ADDITIONAL INFORMATION WILL GIVE YOU THE BACK-GROUND WHICH IT IS NECESSARY FOR YOU TO HAVE IN ORDER TO DERIVE THE FULLEST VALUE FROM THE LESSONS WHICH ARE TO FOLLOW.

YOU WILL ALSO NO DOUBT BE INTERESTED IN KNOWING AT THIS TIME THAT AFTER YOU HAVE COMPLETED YOUR STUDIES PERTAINING TO THE DESIGNING FACTORS AS APPLIED TO TRANSMITTER CIRCUITS, YOU WILL ENGAGE IN AN EXTENSIVE STUDY OF BROADCAST TRANSMITTERS AND ALL OF THE STUDIO AND CONTROL ROOM EQUIPMENT WHICH IS ASSOCIATED WITH THESE HIGHLY INTERESTING SYSTEMS.

Answered March 23, 1942

LESSON NO. T-14

"The man who watches the clock usually remains one of the hands."

1. – WHAT ARE THE CHIEF CONSTRUCTIONAL DIFFERENCES BETWEEN THE CONVENTIONAL RECEIVER AND TRANSMITTER TUBES?

2. – WHAT IS THE OBJECT OF KEEPING THE GRID AND PLATE TERMINALS WIDELY SEPARATED ON SOME OF THE TRANSMITTER TUBES?

3. – HOW DOES THE SIZE OF A TUBE'S GLASS ENVELOPE AFFECT THE OPERATION OF THE TUBE?

4. – ILLUSTRATE BY MEANS OF A SKETCH AND DESCRIBE FULLY THE CONSTRUCTIONAL FEATURES OF A TYPICAL WATER-COOLED TRANSMITTER TUBE.

5. – DRAW A DIAGRAM OF A TYPICAL TUBE-COOLING SYSTEM WHICH IS SUITABLE FOR A BROADCAST TRANSMITTER AND EXPLAIN IN DETAIL HOW IT OPERATES.

6. – WHAT ARE THE OPERATING CHARACTERISTICS OF THE TYPE 204-A TUBE?

7. – WHAT SPECIAL FEATURE IS SOMETIMES INCORPORATED IN THE FILAMENT CIRCUIT OF HIGH POWER TRANSMITTER TUBES IN ORDER TO PREVENT TOO MUCH FILAMENT CURRENT BEING DRAWN BEFORE THE FILAMENT TEMPERATURE COMES UP TO NORMAL?

8. – WHAT MATERIAL IS GENERALLY USED FOR THE CONSTRUCTION OF THE FILAMENT IN THE LARGER TRANSMITTER TUBES AND WHY IS THIS PARTICULAR MATERIAL SELECTED?

9. – DESCRIBE SOME OF THE MOST COMMONLY USED METHODS OF MOUNTING OR SUPPORTING TRANSMITTER TUBES.

10. – HOW MAY AIR-COOLING OF TRANSMITTER TUBES BE ACCOMPLISHED?

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LESSON NO. 15

COMMUNICATION RECEIVERS AND SPECIAL SYSTEMS

YOU HAVE ALREADY LEARNED A GREAT DEAL ABOUT STANDARD-WAVE BROADCAST, SHORT-WAVE, AND ALL-WAVE RECEIVERS AS USED BY THE AVERAGE RADIO LISTENER AND EXPERIMENTER. THERE ARE, HOWEVER, A NUMBER OF FEATURES INCORPORATED IN COMMUNICATION TYPE RECEIVERS AS USED BY COMMERCIAL OPERATORS AND ABOUT WHICH YOU HAVE AS YET NOT BEEN TOLD. THESE ADDITIONAL RECEIVER FEATURES CONSIST OF BEAT-NOTE OSCILLATORS, CRYSTAL FILTERS ETC. THESE, THEREFORE, ARE ALL EXPLAINED IN THIS LESSON.

IN FIG. 1 YOU ARE SHOWN A FRONT VIEW OF A TYPICAL COMMUNICATION TYPE RECEIVER, WHILE A BIRD'S-EYE-VIEW OF THE SAME UNIT, WHEN REMOVED FROM THE METAL CABINET, IS SHOWN YOU IN FIG. 2. LATER IN THIS LESSON YOU WILL HAVE THE OPPORTUNITY OF STUDYING THE CIRCUITS OF THIS RECEIVER BUT FIRST IT IS NECESSARY THAT YOU BECOME FAMILIAR WITH THE OPERATION AND USE OF THE BEAT-NOTE OSCILLATOR.

BEAT-NOTE RECEPTION

FROM WHAT YOU HAVE ALREADY LEARNED ABOUT RADIO TRANSMISSION AND RECEPTION, YOU REALIZE THAT IF A TRANSMITTER WERE TO RADIATE AN UNMODULATED CONTINUOUS WAVE, NO RESULTING SIGNAL WOULD BE HEARD IN THE ORDINARY RECEIVER EVEN THOUGH THE RECEIVER BE ACCURATELY TUNED TO THE TRANSMITTER FREQUENCY. THE REASON FOR THIS IS THAT THE TRANSMITTED WAVE IS BEYOND THE FREQUENCY OF AUDIBILITY.

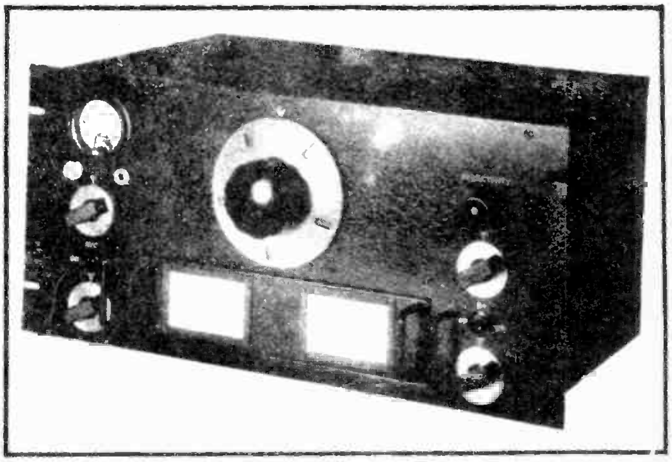

FIG. 1
The National "HRO" Communications Type Receiver.

THE ONLY METHOD WHEREBY THE CONTINUOUS WAVE CAN ORDINARILY TRANSMIT A SIGNAL WHICH IS AUDIBLE IS TO MODULATE THE CARRIER FREQUENCY (C.W.) AT AN AUDIO

FREQUENCY RATE. THIS WILL ENABLE THE DETECTOR OF THE RECEIVER TO SEPARATE THE AUDIO COMPONENT FROM THE CARRIER WAVE FORM SO THAT THE DESIRED SIGNAL CAN BE HEARD.

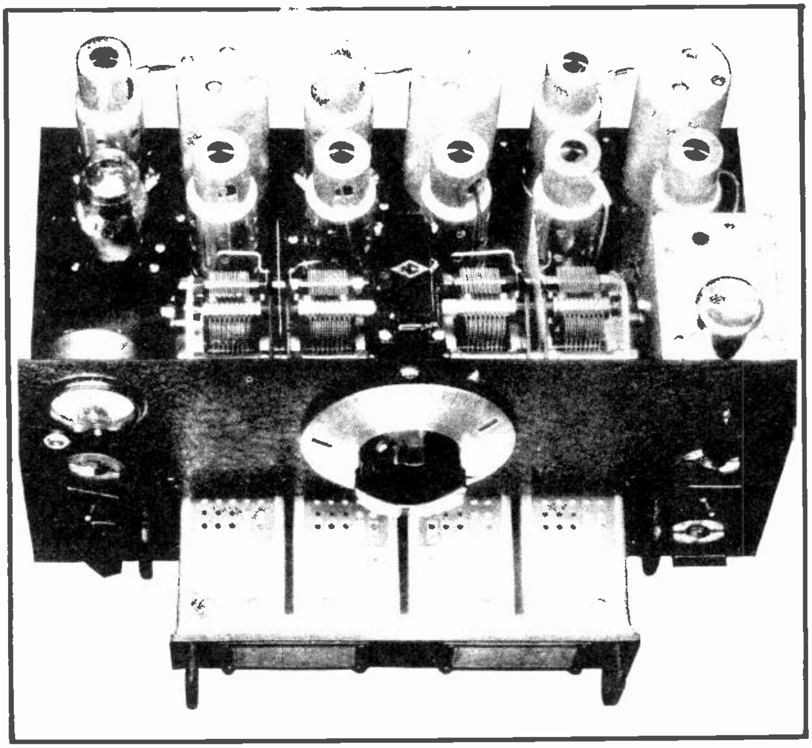

FIG. 2
The National Receiver Removed from the Cabinet

IN THE CASE OF CODE COMMUNICATION, HOWEVER, THE TRANSMISSION OF AN UNMODULATED CONTINUOUS WAVE IS USED EXTENSIVELY. WHEN THIS IS DONE, THE WAVE RADIATION WILL BE SIMILAR TO THAT ILLUSTRATED IN FIG. 3. HERE YOU WILL OBSERVE THAT THE DOT OF THE CODE IS FORMED BY HOLDING THE KEY CLOSED FOR A SHORT DURATION, WHILE THE DASH IS FORMED BY HOLDING THE KEY CLOSED FOR A SLIGHTLY LONGER PERIOD. WHEN THE KEY IS OPEN, THE WAVE RADIATION CEASES ALTOGETHER.

BY STUDYING FIG. 3 CLOSELY, YOU WILL NOTE THAT THE FREQUENCY OF THE WAVE FORM IN EACH GROUP IS OF RADIO FREQUENCY AND OF CONSTANT AMPLITUDE AND FOR THIS REASON SIGNALS WHICH ARE TRANSMITTED IN THIS MANNER WOULD ORDINARILY BE INAUDIBLE.

UPON CARRYING OUR INVESTIGATION OF THIS PRINCIPLE A LITTLE FARTHER, WE NEXT COME TO THE POINT WHICH IS ILLUSTRATED IN FIG.4. HERE WE ARE ILLUSTRATING AT THE CENTER A CONTINUOUS SIGNAL WAVE HAVING A FREQUENCY OF 7,205 KC. (7,205,000 CYCLES PER SECOND) AND WHICH YOU WILL IMMEDIATELY REALIZE AS BEING INAUDIBLE.

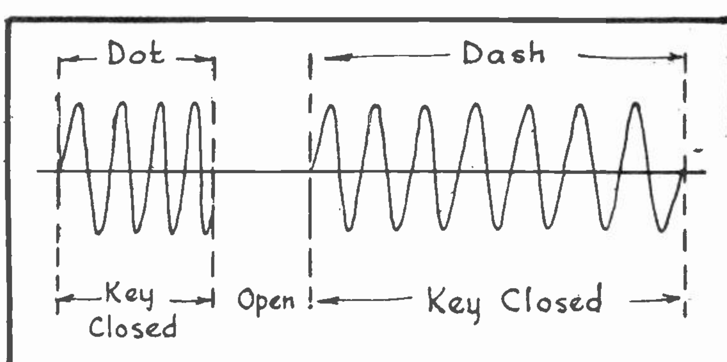

FIG. 3
C. W. Code Transmission.

DIRECTLY ABOVE THIS 7,205 KC. SIGNAL WAVEFORM, WE HAVE ILLUSTRATED ANOTHER WAVE FORM WHICH IS GENERATED BY AN OSCILLATOR WHICH IS LO-

CATED AT THE RECEIVER. THIS PARTICULAR OSCILLATOR ALSO PRODUCES A CONTINUOUS WAVE FORM BUT ITS FREQUENCY IN THE PARTICULAR CASE ILLUSTRATED IS 7,200 KC. OR 7,200,000 CYCLES PER SECOND.

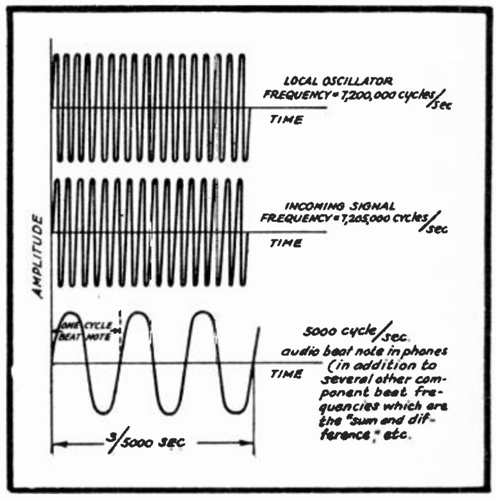

FIG. 4
Producing a Beat-Note By Means of the Heterodyne Principle.

NOW IF WE WERE TO TUNE IN ON THE RECEIVER THE 7,205 KC SIGNAL AND COUPLE TO THIS SAME RECEIVER CIRCUIT THE OUTPUT OF THE LOCAL OSCILLATOR WHOSE FREQUENCY IS 7,200 KC., THEN THROUGH HEATERODYNE ACTION, A BEAT-FREQUENCY WOULD BE PRODUCED IN THE SAME MANNER AS IN A SUPERHETERODYNE RECEIVER. THE BEAT-FREQUENCY IN THIS PRESENT CASE, HOWEVER, WILL BE EQUAL TO THE ARITHMETICAL DIFFERENCE BETWEEN 7,205 KC. AND 7,200 OR 7,205 MINUS 7,200 = 5KC. OR 5000 CYCLES PER SECOND. IN THIS INSTANCE, YOU WILL NOTE THAT THE BEAT FREQUENCY IS OF AN AUDIO FREQUENCY WHILE THE BEAT OR INTERMEDIATE FREQUENCY AS PRODUCED IN THE SAME MANNER IN AN ORDINARY SUPERHETERODYNE RECEIVER IS TOO HIGH TO BE AUDIBLE.

FROM THE EXPLANATION AS SO FAR GIVEN, IT WILL BE APPARENT THAT C.W. CODE TRANSMISSION CAN BE ATTAINED IF THE SIGNAL IS USED AT THE RECEIVER IN SUCH A MANNER SO AS TO PRODUCE A BEAT NOTE OF AUDIBLE FREQUENCY.

C.W. RECEPTION WITH REGENERATIVE RECEIVER

AMATEUR RADIO OPERATORS USE REGENERATIVE RECEIVERS QUITE EXTENSIVELY FOR C.W. CODE RECEPTION, A CIRCUIT OF SUCH DESIGN BEING ILLUSTRATED IN FIG. 5. TO ACCOMPLISH THIS, THE REGENERATION CONTROL OF THE RECEIVER IS ADVANCED FAR ENOUGH SO THAT THE DETECTOR CIRCUIT IS ADJUSTED TO THE POINT OF SELF-OSCILLATION. WHEN THIS IS DONE, THE FREQUENCY WHICH IS DUE TO THIS LOCAL SOURCE OF OSCILLATION WILL HETERODYNE WITH THE INCOMING SIGNAL FREQUENCY SO THAT A BEAT FREQUENCY WILL APPEAR IN THE PLATE CIRCUIT OF THE DETECTOR. FOR EXAMPLE, IF THE INCOMING SIGNAL FREQUENCY IS 3000 KC. AND THE SELF-SUSTAINED OSCILLATION IN THE DETECTOR CIRCUIT HAS A FREQUENCY OF 3001 KC., THEN THE

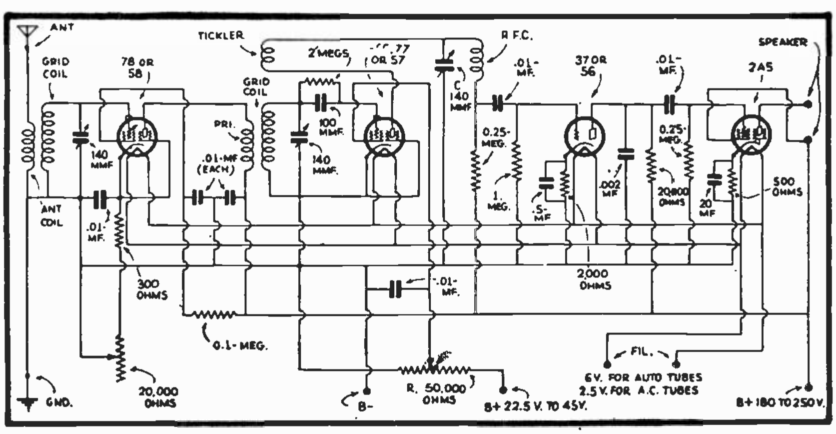

FIG. 5
A Four-Tube Regenerative Receiver.

beat frequency appearing in the plate circuit of the detector will have a frequency of 1Kc. or 1000 cycles per second and which when reproduced by the headphones or speaker will be an audible note.

Since the oscillations in the receiver are continuous and without interruption, while the continuous wave of the incoming signal enters in the form of successive trains with interruptions between them, the rate at which the beat note occurs, as well as the length of each beat note, will be dependant upon the time interval between the various wave groups which are radiated by the transmitter and the length of each wave group with respect to time. Thus the characters of the code are heard as the familiar dit-dah sounds.

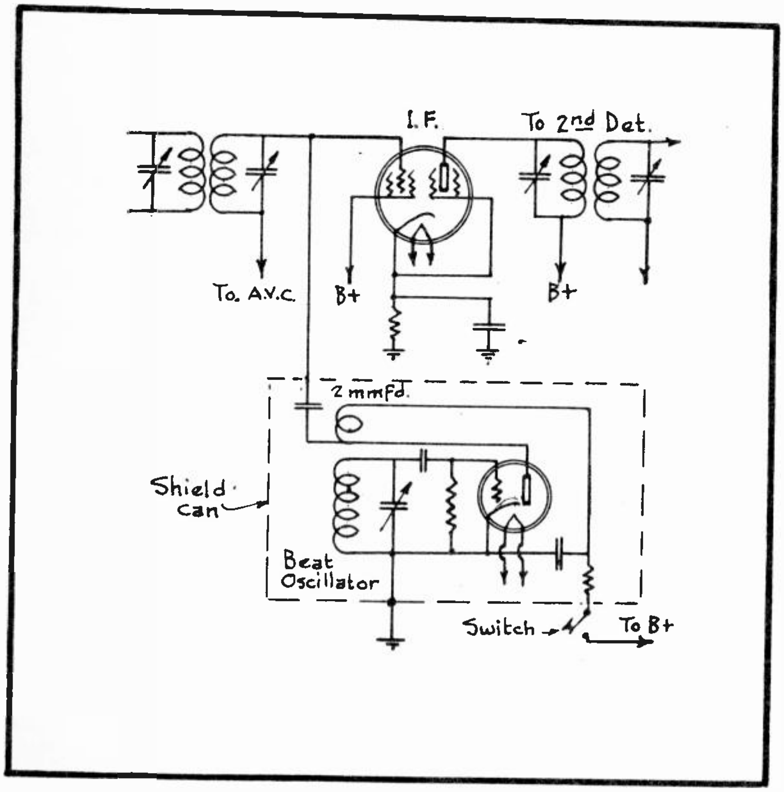

FIG. 6
Application of the Beat-Oscillator.

When a detector of a receiver operates both as a detector and an oscillator as just described, the method is generally referred to as the AUTODYNE method of beat reception.

THE BEAT OSCILLATOR

Most communication type receivers are of superheterodyne design and so as to make the reception of C.W. code signals possible in this case, a second oscillator is incorporated into the receiver. This second oscillator is then coupled to the circuits of the receiver in some such manner as illustrated in Fig.6. An oscillator which is used for this purpose is known as a BEAT OSCILLATOR or a C.W. OSCILLATOR.

A C.W. oscillator, as this, is constructed the same as a conventional oscillator such as used in superheterodyne receivers in order to aid in producing the I.F. frequency. The C.W. oscillator differs from the regular oscillator of the superheterodyne, however, in that its tuning circuit is designed so that the frequency as generated by the C.W. oscillator will be from one to two kilocycles higher or lower than the frequency to which the I.F. amplifier of the receiver is tuned.

By referring to Fig.6, you will note that the C.W. oscillator is fully shielded from the rest of the receiver circuits and its output is loosely coupled through a 2 mmfd. condenser to the control grid circuit of the I.F. tube which precedes the second detector of the receiver. A

SWITCH IS INCLUDED IN THE PLATE CIRCUIT OF THE BEAT OSCILLATOR SO AS TO PREVENT THIS UNIT FROM OPERATING AT ALL TIMES EXCEPT DURING THE RECEPTION OF C.W. SIGNALS.

QUITE OFTEN, THE C.W. OSCILLATOR IS COUPLED TO THE SECOND DETECTOR OF THE RECEIVER IN SOME SUCH MANNER AS ILLUSTRATED IN FIG.7.

OPERATION OF THE SYSTEM

ASSUMING THAT C.W. SIGNALS ARE BEING RECEIVED AT A FREQUENCY OF 7000 KC. WHEN USING SUCH A SYSTEM AND THE SUPERHETERODYNE IN QUESTION HAS AN INTERMEDIATE FREQUENCY OF 465 KC., THEN THE OPERATION OF THE COMPLETE SYSTEM WOULD BE AS FOLLOWS:

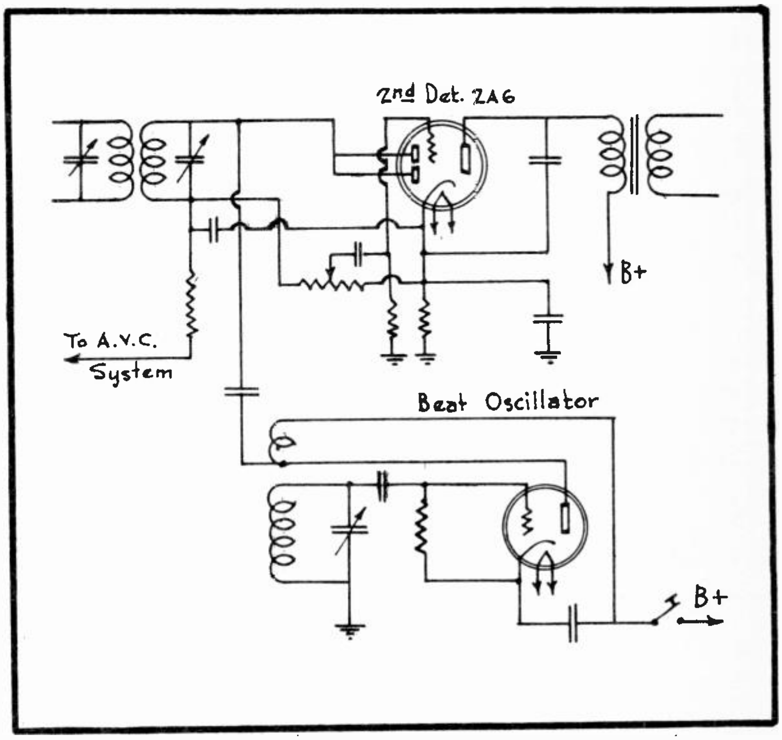

FIG.7.
Beat Oscillator Coupled to Second Detector

THE INPUT R.F. AND FIRST DETECTOR CIRCUITS WOULD BE TUNED TO 7000 KC. THE REGULAR OSCILLATOR OF THE RECEIVER WOULD AT THE SAME TIME BE TUNED TO A FREQUENCY OF 7000 PLUS 465 OR 7,465 KC. THE RESULTING HETERODYNE ACTION PRODUCES A BEAT FREQUENCY OF 465 KC WHICH IS AMPLIFIED BY THE I.F. AMPLIFIER. ASSUMING THAT A 1000 CYCLE (1KC.) SIGNAL NOTE IS TO BE PRODUCED, THE C.W. OSCILLATOR WOULD BE TUNED TO A FREQUENCY OF 465 PLUS 1 OR 466 KC. THE RESULTING HETERODYNE ACTION BETWEEN THE 465 AND THE 466 KC. FREQUENCY WILL CAUSE A BEAT FREQUENCY OF 1 KC. OR 1,000 CYCLES TO APPEAR IN THE OUTPUT CIRCUIT OF THE TUBE AT WHOSE INPUT THE TWO FREQUENCIES ARE SIMULTANEOUSLY APPLIED. THE 1,000 CYCLE BEAT IS OF AUDIO FREQUENCY AND IS THEN FURTHER AMPLIFIED AND REPRODUCED AS THE EQUIVALENT SOUND BY THE SPEAKER OR HEADPHONES.

EVEN THOUGH THE OUTPUT OF THE C.W. OSCILLATOR BE APPLIED TO THE INPUT OF THE FINAL I.F. TUBE OF A SUPERHETERODYNE, THE FOLLOWING SINGLE I.F. TRANSFORMER IS SUFFICIENTLY BROAD TUNING SO AS TO PERMIT THE 1000 KC. SIGNAL TO PASS THROUGH SATISFACTORILY.

BESIDES MAKING C.W. CODE RECEPTION POSSIBLE, THE C.W. OSCILLATOR ALSO ASSISTS IN LOCATING THE MODULATED SIGNALS FROM DISTANT STATIONS. THIS IS ACCOMPLISHED BY THE HETERODYNING ACTION BETWEEN THE SIGNAL FREQUENCY AND THAT OF THE C.W. OSCILLATOR. THUS WITH A BEAT NOTE BEING AUD-

IBLE, IT IS AN INDICATION THAT A STATION IS BEING TUNED IN. THE C.W. OSCILLATOR CAN THEN BE SWITCHED OFF AND THE RECEIVER VERY SLOWLY AND CAREFULLY TUNED SO THAT THE STATION SIGNALS WILL COME THROUGH IN THE BEST MANNER POSSIBLE.

SINGLE-SIGNAL RECEIVERS

ANOTHER INTERESTING FEATURE WHICH YOU WILL FIND IN SOME OF THE MORE ELABORATE COMMUNICATION TYPE RECEIVERS IS A QUARTZ CRYSTAL WHICH IS INCLUDED IN THE I.F. AMPLIFIER.

ALTHOUGH IT IS TRUE THAT THE SUPERHETERODYNE TYPE OF RECEIVER AFFORDS EXCELLENT SELECTIVITY AS FAR AS THE RECEPTION OF BROADCAST PROGRAMS ARE CONCERNED, YET FOR THE RECEPTION OF C.W. CODE SIGNALS, ESPECIALLY IN THE HIGHER FREQUENCY BANDS WHICH ARE RATHER CROWDED, THE CONVENTIONAL SUPERHETERODYNE IS NOT AS SELECTIVE AS WOULD BE DESIRED.

THE CUSTOMARY I.F. AMPLIFIER OF THE AVERAGE SUPERHETERODYNE WILL PASS A BAND OF FREQUENCIES WHICH IS FROM 5 TO 10 KC. WIDE.

A VARIETY OF COMBINATIONS OF SIGNAL FREQUENCIES WITH WHICH THE R.F. OSCILLATOR OF THE RECEIVER MAY BEAT, MAY BE SUCH THAT SIGNALS VARYING BY 2 KC. ABOVE AND BELOW THE RESONANT FREQUENCY OF THE I.F. AMPLIFIER MAY FIND THEIR WAY THROUGH THE I.F. AMPLIFIER AND THEREBY CAUSE INTERFERENCE UNLESS THE I.F. AMPLIFIER BE TUNED VERY SHARP. ANY ONE OF THESE FREQUENCIES WHICH FIND THEIR WAY THROUGH THE I.F. AMPLIFIER MAY HETERODYNE WITH THE FREQUENCY GENERATED BY THE C.W. OSCILLATOR AND THEREBY CAUSE A MOST DISTURBING INTERFERENCE. TO PREVENT THIS, A QUARTZ CRYSTAL IS USED TO MAKE THE CIRCUIT VERY SHARP TUNING AND PERMIT ONLY THE DESIRED FREQUENCY TO PASS THROUGH THE I.F. AMPLIFIER

A QUARTZ CRYSTAL, YOU WILL RECALL, POSSESSESS PIEZO-ELECTRIC CHARACTERISTICS AND BECAUSE OF THIS FACT PERMITS ONLY CURRENTS TO FLOW THRU

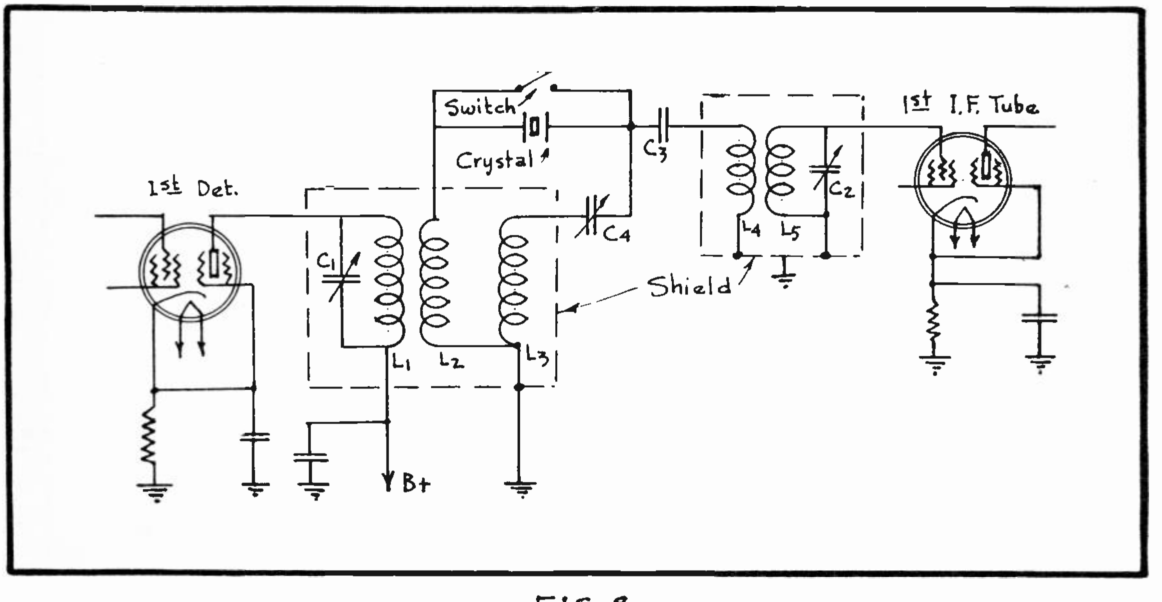

FIG. 8
Application of the Quartz Crystal I.F. Filter.

IT WHOSE FREQUENCY IS IDENTICAL TO THAT FOR WHICH THE CRYSTAL IS GROUND. THIS BEING THE CASE, IT CAN BE READILY SEEN THAT A CRYSTAL OF THIS TYPE WOULD SERVE ADMIRABLY AS A VERY SELECTIVE FILTER IN A RECEIVER CIRCUIT. WHEN USED FOR THIS PURPOSE, THE CRYSTAL IS INSTALLED IN THE RECEIVER CIRCUIT IN A MANNER SOMEWHAT AS ILLUSTRATED IN FIG. 8.

IN THIS CIRCUIT, THE TUNED CIRCUIT CONSISTING OF L_1 AND C_1 IS IN REALLITY THE PRIMARY HALF OF THE FIRST I.F. TRANSFORMER, WHILE THE TUNED CIRCUIT CONSISTING OF L_5 AND C_2 IS IN REALLITY THE SECONDARY HALF OF THE FIRST I.F. TRANSFORMER. HOWEVER, INSTEAD OF THESE TWO HALVES OF THE TRANSFORMER BEING PLACED TOGETHER IN THE SAME SHIELD CAN IN THE USUAL WAY, THEY ARE PLACED IN SEPARATE SHIELD CANS AND COUPLING BETWEEN THEM IS ACCOMPLISHED THROUGH THE VARIOUS COUPLING COILS IN CONJUNCTION WITH THE CRYSTAL FILTER. THE CRYSTAL IS GROUND FOR THE FREQUENCY FOR WHICH THE I.F. AMPLIFIER IS DESIGNED.

THE SPLIT WINDINGS L_2 AND L_3 ARE INDUCTIVELY COUPLED TO L_1 AND THEREBY PROVIDE AN INPUT CIRCUIT TO THE CRYSTAL FILTER. THE OUTPUT OF THE CRYSTAL FILTER IS IN TURN COUPLED TO COIL L_5 THROUGH C_3 AND L_4.

AT RESONANCE, L_1 AND L_2, AND L_4 AND L_5 ARE MATCHED IMPEDANCES. THE PURPOSE OF COIL L_3 AND CONDENSER C_4 IS TO NEUTRALIZE THE CAPACITY OF THE CRYSTAL HOLDER PLATES.

COILS L_2 AND L_3 HAVE INDUCED IN THEM E.M.F'S WHICH ARE 180° OUT OF PHASE. THEREFORE, WHEN C_4 EQUALS THE CAPACITY OF THE CRYSTAL HOLDER PLATES, ANY CURRENTS WHICH THESE PLATES MIGHT BYPASS THROUGH THEIR CAPACITY ARE CANCELLED OUT BY CURRENTS IN OPPOSITE PHASE FED THROUGH C_4. CONSEQUENTLY, ONLY THE SIGNAL E.M.F.'S ARE PASSED BY THE CRYSTAL FREE TO REACH THE INPUT CIRCUIT OF THE I.F. AMPLIFIER.

SINCE THE CONDENSER C_4 AFFECTS THE CIRCUIT AS JUST EXPLAINED, IT

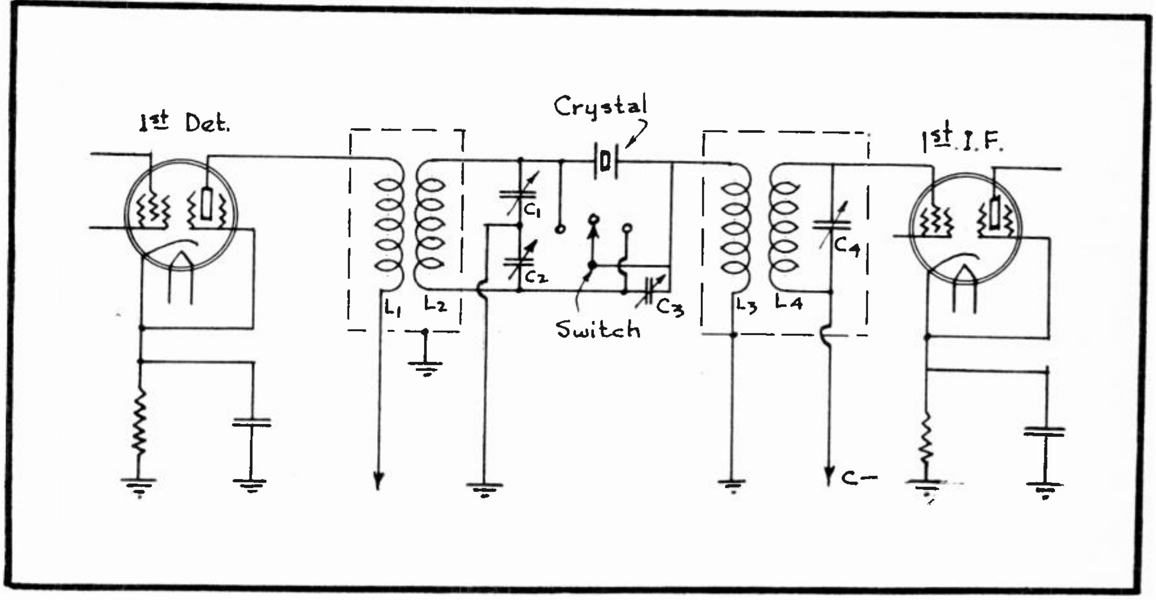

FIG. 9
Another Crystal-Filter Circuit.

CAN READILY BE SEEN THAT THE SETTING OF THIS CONDENSER GOVERNS THE SELECTIVITY OF THE CRYSTAL AND BY THIS METHOD THE BAND PASSED THROUGH THE CRYSTAL CAN BE WIDENED SLIGHTLY.

IN SUPERHETERODYNE RECEIVERS IN WHICH A CRYSTAL FILTER IS EMPLOYED, THE VOLTAGE GAIN OF AN INTERFERRING SIGNAL MAY BE REDUCED AS MUCH AS 97% WHEN THE CIRCUIT IS ADJUSTED APPROXIMATELY 1000 CYCLES OFF THE RESONANT FREQUENCY, WHEREAS IN A SUPERHETERODYNE RECEIVER NOT EQUIPPED WITH A CRYSTAL FILTER, THE INTERFERING SIGNAL MAY BE REDUCED ONLY AS MUCH AS 5% UNDER THE SAME CONDITION OF OPERATION.

THE SHARP TUNING CHARACTERISTIC OF THE CRYSTAL FILTER MAKES ITS USE DESIRABLE FOR THE RECEPTION OF C.W. CODE SIGNALS BUT THIS SAME FEATURE WHEN USED FOR THE RECEPTION OF BROADCAST PROGRAMS WILL MAKE THE FAITHFUL REPRODUCTION OF THE MUSICAL SCALE IMPOSSIBLE. BY THE ADJUSTMENT OF C_4 IN THE CIRCUIT OF FIG.8, HOWEVER, THE WIDTH OF BAND PASSED BY THE CRYSTAL FILTER CAN BE INCREASED TO THE POINT NECESSARY TO PASS THE SPEECH FREQUENCIES SATISFACTORILY. A SWITCH IS ALSO GENERALLY ALWAYS FURNISHED WHEREBY THE CRYSTAL CAN BE SHORT-CIRCUITED AT WILL AND ITS SHARP TUNING CHARACTERISTICS THEREBY BE REMOVED FROM THE CIRCUIT.

ANOTHER BASIC CRYSTAL FILTER CIRCUIT IS SHOWN IN FIG.9. HERE THE SECONDARY CIRCUIT OF THE INPUT TRANSFORMER SUPPLIES A VARIABLE PARALLEL IMPEDANCE AND IS IN SERIES WITH THE CRYSTAL. THIS VARIABLE PARALLEL IMPEDANCE EFFECTS VARIATION IN THE EFFECTIVE RESISTANCE IN THE CRYSTAL CIRCUIT, THEREBY VARYING THE SELECTIVITY IN ACCORDANCE WITH THE PRINCIPLES OF RESONANT CIRCUITS.

THE APPLIED VOLTAGE IS PROPORTIONAL TO THE PARALLEL IMPEDANCE, INCREASING AS THE EFFECTIVE RESISTANCE INCREASES, SO THAT THE EFFECTIVE SENSITIVITY OF THE RECEIVER FOR A SINGLE-FREQUENCY SIGNAL IS BUT LITTLE AFFECTED OVER A CONSIDERABLE BAND WIDTH.

MINIMUM SELECTIVITY OCCURS WITH THE PARALLEL CIRCUIT TUNED TO RESONANCE, AT WHICH TIME IT IS PURELY RESISTIVE, AND MAXIMUM SELECTIVITY OCCURS WHEN THE PARALLEL CIRCUIT IS TUNED SO AS TO BE CONSIDERABLY REACTIVE. THE CRYSTAL IS CONNECTED IN A BRIDGE CIRCUIT THROUGH AN ADJUSTABLE CONDENSER SO AS TO PROVIDE COUNTER-VOLTAGE OF CONTROLLABLE PHASE AND SO AS TO MODIFY THE RESONANCE CURVE AND SHIFT THE ANTI-RESONANT FREQUENCY OF THE CRYSTAL, THEREBY GIVING PARTICULAR REJECTION FOR AN UNWANTED SIGNAL, IN ADDITION TO THE SHARPLY PEAKED RESPONSE GIVEN FOR THE DESIRED SIGNAL.

IN THE CIRCUIT OF FIG.9 THE OUTPUT TRANSFORMER OF THE FILTER CONSISTS OF THE TUNED CIRCUIT L_4-C_4 WHICH IS CLOSELY COUPLED TO THE UNTUNED COIL L_3 THE NUMBER OF TURNS USED ON COIL L_3 ARE CONSIDERABLE LESS THAN THAT USED ON COIL L_4. THE REASON FOR THIS IS THAT THIS TURNS-RATIO AFFORDS THE PROPER IMPEDANCE MATCH BETWEEN THE CRYSTAL FILTER AND THE INPUT CIRCUIT TO THE 1ST I.F. TUBE.

NOW THAT YOU ARE FAMILIAR WITH THE OPERATION AND APPLICATION OF C.W. OSCILLATORS AND CRYSTAL FILTERS, LET US NEXT LOOK AT THE COMPLETE CIRCUIT OF COMMUNICATION OR PROFESSIONAL TYPES OF RECEIVERS WHICH MAKE USE OF THESE FEATURES.

A SEVEN–TUBE SUPERHETERODYNE

IN FIG. 10 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SEVEN–TUBE SUPERHETERODYNE WHICH BY MEANS OF A BAND–SWITCH PROVIDES THE THREE FOLLOWING FREQUENCY RANGES: (1) FROM 540 TO 1700 KC.; (2) FROM 1650 TO 4300 KC.; AND (3) FROM 5.5 TO 18 MEGACYCLES. IN OTHER WORDS, THIS WOULD BE CLASSIFIED AS AN ALL–WAVE RECEIVER.

THE TUBES USED ARE A 78 IN THE TUNED R.F. PRE–SELECTOR STAGE; A 6A7 AS THE FIRST DETECTOR AND OSCILLATOR; A 78 AS AN I.F. AMPLIFIER; A 75 AS A COMBINATION SECOND DETECTOR, TRIODE A.F. AMPLIFIER AND A.V.C. TUBE; A 42 AS THE POWER OUTPUT TUBE; AN 80 AS THE RECTIFIER; AND A 78 AS AN ELECTRON COUPLED C.W. OR BEAT OSCILLATOR.

OTHER INTERESTING FEATURES OF THIS SAME RECEIVER INCLUDE A SWITCH WHICH PERMITS AUTOMATIC VOLUME CONTROL TO BE USED OR NOT AT THE WILL OF THE OPERATOR. A "STAND–BY" SWITCH IS ALSO FURNISHED AND WHICH WHEN CLOSED TO THE "RECEIVE POSITION" PERMITS NORMAL RECEPTION, WHEREAS WHEN OPEN OR IN THE "SEND POSITION", THE PLATE SUPPLY TO THE R.F. SECTION OF THE RECEIVER IS CUT–OFF AND THEREBY PREVENTS OPERATION OF THE RECEIVER WHILE THE LOCAL TRANSMITTER IS ON THE AIR BUT YET DOES NOT PERMIT THE FILAMENTS OF THE RECEIVER'S TUBES TO COOL SO THAT THE SET CAN COME INTO INSTANT USE WHEN RECEPTION IS TO BE RESUMED.

A SPECIAL JACK IS PROVIDED IN THE OUTPUT CIRCUIT WHICH PERMITS THE INSERTION OF HEADPHONES IN THE CIRCUIT AND AT THE SAME TIME CUTS OUT THE SPEAKER THE INSTANT THAT THE PHONES ARE PUT INTO USE. A SWITCH IS ALSO PROVIDED FOR TURNING "ON" AND "OFF" THE BEAT OSCILLATOR.

THE POTENTIOMETER WHICH IS INCLUDED IN THE CATHODE CIRCUIT OF THE

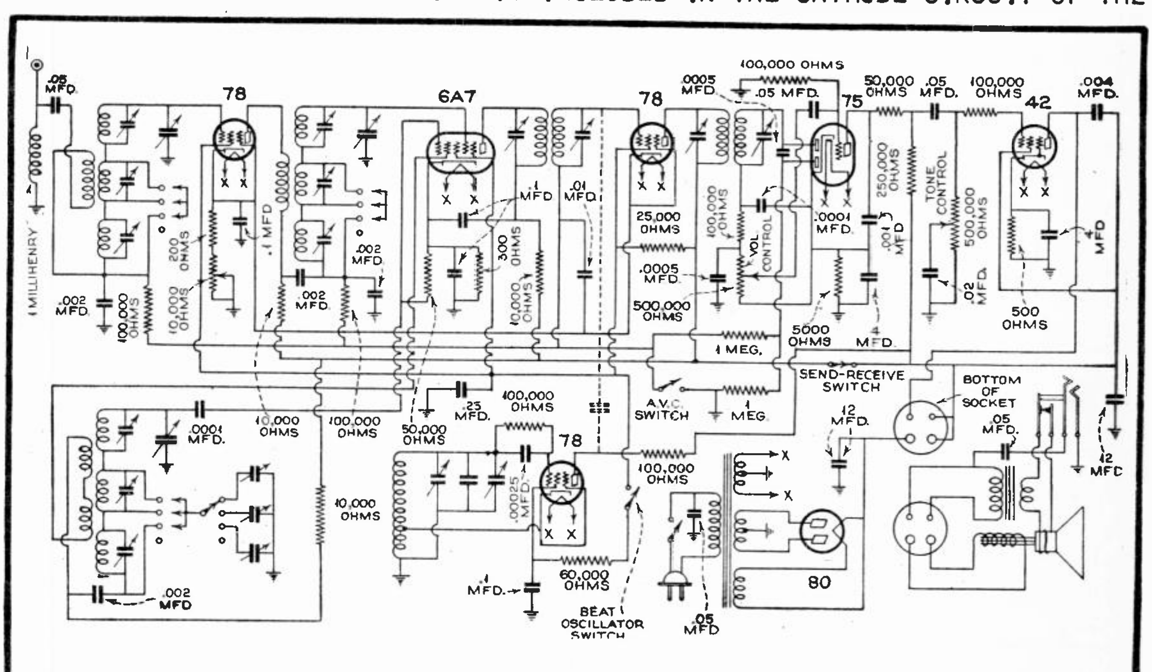

FIG. 10

A 7-Tube Professional Model Receiver.

R.F. TUBE SERVES AS A SENSITIVITY CONTROL, AND WHICH IS USED AS A VOLUME CONTROL WHEN THE A.V.C. SYSTEM IS NOT BEING USED. THE REGULAR VOLUME CONTROL IS INCORPORATED IN THE A.F. CIRCUIT OF THE 75 TUBE.

THE NATIONAL "HRO" CIRCUIT

IN FIG. 11 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF THE NATIONAL "HRO" COMMUNICATION TYPE RECEIVER AND WHOSE PICTURE APPEARS IN FIG. 1 AND 2 OF THIS LESSON. BY STUDYING FIG. 11 CAREFULLY, YOU WILL OBSERVE THAT THIS RECEIVER EMPLOYS BOTH A C.W. OSCILLATOR AND A CRYSTAL FILTER, AS WELL AS MANY OTHER INTERESTING FEATURES.

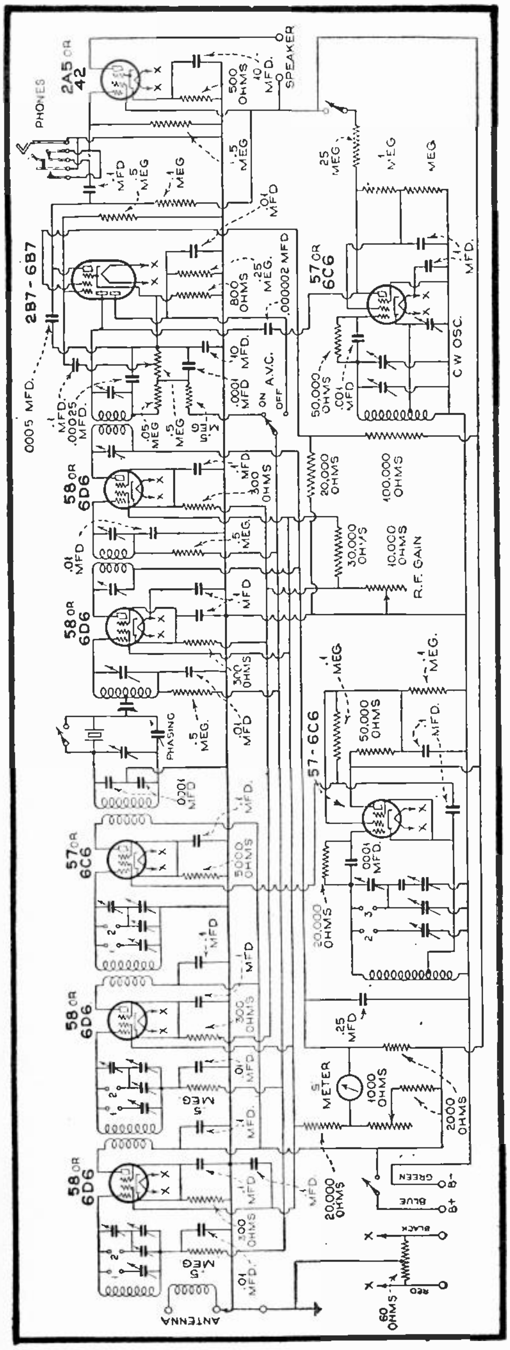

FIG.11

Circuit Diagram of the National "HRO" Receiver.

THE POWER PACK FOR THIS RECEIVER IS AN INDEPENDENT UNIT, HOUSED SEPARATELY FROM THE RECEIVER AND IS CONNECTED TO THE RECEIVER THROUGH THE HEATER AND "B" TERMINALS WHICH APPEAR IN THE LOWER LEFT HAND CORNER OF FIG. 11.

THE SWITCH WHICH APPEARS IN THE B+ LEAD IN FIG. 11 IS A "STAND-BY" SWITCH AND SERVES THE SAME PURPOSE AS THE EQUIVALENT SWITCH IN THE CIRCUIT OF FIG. 10. A SWITCH IS ALSO HERE PROVIDED SO THAT THE A.V.C. ACTION CAN BE USED OR NOT AS DESIRED. A SENSITIVITY OR R.F. GAIN CONTROL IS SUPPLIED IN THE FORM OF A 10,000 OHM RHEOSTAT WHICH IS CONNECTED IN SERIES WITH THE CATHODE CIRCUITS OF SOME OF THE R.F. TUBES AND B-, WHILE THE REGULAR VOLUME CONTROL IS IN THE FORM OF A .5 MEG. POTENTIOMETER IN THE A.F. CIRCUIT OF THE 2B7 OR 6B7 TUBE. PROVISIONS ARE ALSO MADE FOR THE USE OF EITHER A LOUD SPEAKER OR HEADPHONES.

A SHUNTING SWITCH FOR THE CRYSTAL IS ALSO FURNISHED AND WHICH PERMITS THE CRYSTAL TO BE EXCLUDED FROM THE CIRCUIT WHEN THIS SWITCH IS CLOSED AND THUS MAKE BROADCAST RECEPTION POSSIBLE.

THE PHASING CONDENSER WHICH IS ALSO INCLUDED IN THE CRYSTAL CIRCUIT OFFERS A MEANS OF WIDENING SOMEWHAT THE FREQUENCY BAND PASSED SO THAT SPEECH CAN BE RECEIVED SATISFACTORILY EVEN WHEN THE CRYSTAL IS BEING USED.

NINE TUBES ARE USED IN THIS RECEIVER AND THEY MAY BE EITHER OF THE

2.5 OR 6.3 VOLT SERIES. TWO STAGES OF TUNED RADIO FREQUENCY AMPLIFICATION ACT AS A PRE-SELECTOR AHEAD OF THE FIRST DETECTOR.

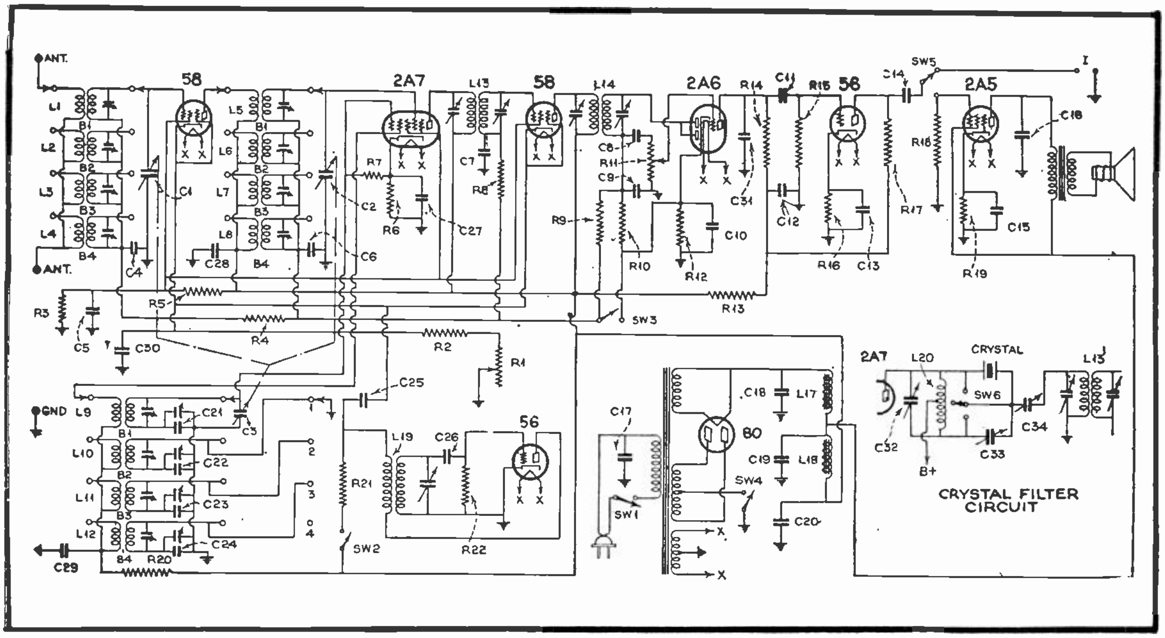

FIG. 12

An 8-Tube Communications Type Receiver.

A SET OF FOUR PLUG-IN COILS ARE USED TO AFFORD FULL BAND COVERAGE AND THEY ARE CONTAINED IN A HANDY DRAWER WHICH CAN BE WITHDRAWN FROM THE CABINET AS SHOWN IN FIG. 2 OF THIS LESSON.

THE "S" METER IS USED AS A MEANS FOR INDICATING THE STRENGTH OF THE SIGNAL WHICH IS BEING RECEIVED.

TABLE I

1—Gen-Ral Coil Kit No. 34 consisting of:
- 1—multi-wave unit—18 to 1.5 megacycles.
- 1—LCX 200D-V-M 507 kc. series wound i.f. unit, input—top grid.
- 1—LCX200D-V-M 507 kc. series wound i.f. unit, output—bottom grid.
- 1—Heterodyne Oscillator—507 kc.

1—Reliance 140 mmfd. band-spread condenser, type 2K140.

C4, C6, C7, C27—.05 mfd., 200 volt.
C5, C8, C10, C11—.01 mfd., 200 volt.
C9—.0001 mfd. mica condensers.
C12, C17—1. mfd. 400 volt.
C13—5. mfd. 25 volt.
C14, C16—.01 mfd. 400 volt.
C15—10. mfd. 25 volt.
C18, C19, C20—8 mfd. 450 volt. Screw type mounting.
C25—.1 mfd., 200 volt.
C26—.00025 mfd. mica condenser.
C28, C29—.10 mfd., 400 volt.
C30—.2 mfd., 200 volt.
C31—.001 mfd. mica condensers.

R1—25,000 ohm volume control with taper.
R2—150 ohm 1 watt carbon resistor.
R3—40,000 ohm 1 watt carbon resistor.
R4, R8, R14—250,000 ohm 1/3 watt carbon resistor.
R5—13,000 ohm 2 watt carbon resistor.
R6—200 ohm 1/3 watt carbon resistor.
R7—25,000 ohm 1/3 watt carbon resistor.
R9—1,000,000 ohm 1/3 watt carbon resistor.
R10—200,000 ohm 1/3 watt carbon resistor.
R11—500,000 ohm pot. type volume control.
R12—5,000 ohm 1/3 watt carbon resistor.
R13, R17, R21, R22—50,000 ohm 1/3 watt carbon resistor.
R15, R18—500,000 ohm 1/3 watt carbon resistor.
R16—3,000 ohm 1/3 watt carbon resistor.
R19—500 ohm 1 watt carbon resistor.
R20—20,000 ohm 1 watt carbon resistor.

AN 8-TUBE RECEIVER

IN FIG. 12 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN EIGHT-TUBE RECEIVER WHICH FEATURES A COIL SWITCHING ARRANGEMENT FOR COVERING THE DIFFERENT WAVE-BANDS, A TUNED R.F. INPUT USING A TYPE -58 TUBE, A 2A7 OPERATING AS THE FIRST DETECTOR AND R.F. OSCILLATOR, AND A 56 TUBE OPERATING AS THE BEAT-NOTE OSCILLATOR, FOR C.W. CODE RECEPTION.

THE CRYSTAL FILTER, WHICH IS OPTIONAL WITH THIS CIRCUIT, IS SHOWN IN THE LOWER RIGHT HAND CORNER OF THE DIAGRAM. THE ELECTRICAL VALUES FOR THE VARIOUS PARTS AS USED IN THIS CIRCUIT ARE LISTED FOR YOU IN TABLE I OF THIS LESSON.

SWITCH SW_2 OFFERS A MEANS OF CUTTING IN AND OUT THE BEAT-OSCILLATOR, SW_3 PERMITS THE USE OR REJECTION OF A.V.C.

action, SW_4 is the stand-by switch, SW_5 permits the use of headphones when in the position here illustrated and the headphones are connected across the terminals at "I".

A special type of tuning condenser is used with this circuit so as to obtain continuous band-spread features. This condenser consists of a three-gang condenser having a capacity rating of 140 mmfd. per section. Mounted on this same condenser frame is another three-gang condenser of 33 mmfd. per section and operated by a common shaft. The main condenser control is handled in the usual way and the smaller condenser gang adjusted for the desired band-spread effect.

Answered March 23, 1942

Examination Questions

Lesson No. T-15

1. - What are some of the more important features which are found in communication type receivers and which are not found in the conventional type of all-wave receiver?

2. - Explain in detail how the reception of C.W. code signals may be accomplished.

3. - How is it possible to receive C.W. code signals with a regenerative type receiver?

4. - Draw a circuit diagram which illustrates how a beat-oscillator may be applied to a superheterodyne receiver for the reception of C.W. code signals. Explain in detail how this system operates.

5. - Draw a circuit diagram which illustrates the use of a crystal filter circuit in a superheterodyne receiver and explain fully how this system operates.

6. - Draw a complete circuit diagram of a communications type receiver and point out the more important features which it offers.

7. - What is the object of incorporating a "stand-by switch" in the circuit of a communication type receiver?

8. - For what other purpose may a beat-oscillator be used other than for the reception of C.W. code signals? Explain.

9. - What is the chief advantage which is obtained through the use of a crystal filter in a communication type receiver?

10. - What would be the disadvantage of using a crystal filter circuit in a superheterodyne receiver of the broadcast type?

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Transmitters

LESSON NO. 16

TRANSMITTER DESIGN PROBLEMS.

MANY OF THE PROBLEMS WHICH ARE ASSOCIATED WITH THE DESIGN OF TRANSMITTERS ARE HANDLED IN THE SAME MANNER AS HAS ALREADY BEEN DESCRIBED TO YOU IN PREVIOUS LESSONS TREATING WITH RECEIVERS AND AMPLIFIERS. FOR EXAMPLE, THE DESIGNING OF TUNED CIRCUITS, VOLTAGE DISTRIBUTION SYSTEMS IN THE FORM OF RESISTANCE NET-WORKS, A.F. AMPLIFIERS, ETC., WOULD BE CARRIED OUT ACCORDING TO THE SAME ROUTINE OF CALCULATION REGARDLESS IF THE SYSTEM OR CIRCUIT IN QUESTION BE EMPLOYED IN A RADIO RECEIVER, A PUBLIC- ADDRESS AMPLIFIER, OR IN A TRANSMITTER. THIS BEING THE CASE, WE SHALL NOT TREAT DESIGN PROBLEMS OF THIS NATURE IN THIS LESSON.

THE FIRST TYPE OF PROBLEM WHICH WE SHALL NOW CONSIDER IS THAT OF CALCULATING THE OUTPUT IMPEDANCE OF A MODULATING AMPLIFIER.

CALCULATING OUTPUT IMPEDANCE OF MODULATING AMPLIFIER

IN FIG. 2 WE HAVE THE FUNDAMENTAL OUTPUT CIRCUIT OF A MODULATING AMPLIFIER AND WHICH YOU WILL NOTE CONSISTS OF C_1, L_1, AND R_1. WHEN THIS CIRCUIT IS TUNED TO RESONANCE WITH THE OPERATING FREQUENCY, THE INDUCTIVE AND CAPACITIVE REACTANCE IN THE CIRCUIT WILL PRACTICALLY CANCEL EACHOTHER.

FIG.1
Adjusting a Transmitter.

WHEN SERIES RESONANCE HAS THUS BEEN ESTABLISHED, WE FIND THAT WITH RESPECT TO THE ASSOCIATED CIRCUITS, MAXIMUM IMPEDANCE WILL OCCUR IN THE PLATE CIRCUIT AND ACROSS WHICH THE SIGNAL VOLTAGE IS DEVELOPED, AND AT THE SAME TIME MINIMUM PLATE CURRENT WILL FLOW THROUGH THE TUBE.

UNDER THE CONDITIONS HERE DESCRIBED, THE OUTPUT IMPEDANCE OF THE CIRCUIT WITH RESPECT TO THE TUBE CAN BE DETERMINED APPROXIMATELY BY APP-

LYING THE FORMULA $Z = \frac{X_L^2}{R}$ WHERE X_L IS THE INDUCTIVE REACTANCE OF COIL L_1 AT THE FREQUENCY BEING HANDLED AND R_1 THE TOTAL RESISTANCE OF THE CIRCUIT.

FOR EXAMPLE, ASSUMING THAT THE CIRCUIT WILL NORMALLY OPERATE AT A FREQUENCY OF 1000 KC., THAT THE INDUCTANCE VALUE OF L_1 = 160 MICROHENRIES, THAT R_1 = 30 OHMS AND THAT THE TUNING CONDENSER IS SET FOR A CAPACITY OF 0.000158 MFD. WHEN TUNED TO RESONANCE, THEN THE IMPEDANCE OF THIS CIRCUIT WILL WORK OUT IN THE FOLLOWING MANNER:

$$X_L = 2\pi f L = 2 \times 3.14 \times 1{,}000{,}000 \times 0.000160 = 1004.8 \text{ OHMS (APPROXIMATELY)}$$

THEN $$Z = \frac{X_L^2}{R} = \frac{1004.8^2}{30} = \frac{1{,}009{,}623.04}{30}$$

$$Z = 33{,}654 \text{ OHMS (APPROXIMATELY)}$$

IN ORDER TO REALIZE THE MAXIMUM OF LINEAR AMPLIFICATION FROM THE MODULATING STAGE, THE OUTPUT IMPEDANCE OF THIS TUBE'S CIRCUIT AT THE FREQUENCY OF OPERATION SHOULD BE EQUAL TO THE PLATE IMPEDANCE OF THE TUBE OR SOME VALUE GREATER THAN THIS AMOUNT UP TO AS MUCH AS TWICE THE PLATE IMPEDANCE OF THE TUBE.

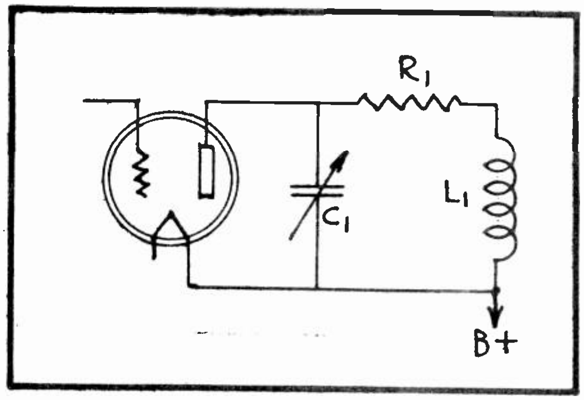


FIG. 2
The Fundamental Circuit.

AFTER WORKING OUT THE OUTPUT IMPEDANCE OF THE TUBE AS JUST EXPLAINED AND IT IS FOUND THAT THE IMPEDANCE IS TOO LOW WITH RESPECT TO THE PLATE IMPEDANCE, THEN THE OUTPUT IMPEDANCE CAN BE INCREASED AS NECESSARY BY ADDING MORE TURNS TO THE COIL, OR ELSE BY WORKING OUT THE DESIGN SO THAT THE RESISTANCE OF THE CIRCUIT IS REDUCED WITHOUT A REDUCTION IN THE INDUCTIVE REACTANCE. ON THE OTHER HAND, IF THE OUTPUT IMPEDANCE VALUE TURNS OUT TO BE TOO HIGH, THEN THE NUMBER OF TURNS ON THE COIL CAN BE REDUCED OR ELSE THE RESISTANCE OF THE CIRCUIT INCREASED. IN OTHER WORDS, THE CONSTANTS OF THE CIRCUITS CAN BE VARIED UNTIL THE PROPER COMBINATION IS ARRIVED AT SO THAT THE OUTPUT IMPEDANCE WILL PROPERLY MATCH THE PLATE IMPEDANCE OF THE TUBE FOR BEST OPERATION AT THE FREQUENCY WHICH IS TO BE HANDLED.

REFLECTED RESISTANCE

IN THE ACTUAL TRANSMITTER, THE LOAD IS NOT QUITE SO SIMPLY ARRANGED AS THAT WHICH IS ILLUSTRATED IN FIG. 2 BECAUSE THE OUTPUT CIRCUIT OF THE TUBE IS GENERALLY COUPLED TO ANOTHER CIRCUIT IN SOME SUCH MANNER AS ILLUSTRATED IN FIG.3, WHERE WE HAVE AN INDUCTIVELY COUPLED CIRCUIT.

BY STUDYING FIG.3 CLOSELY, YOU WILL OBSERVE THAT HERE WE HAVE THE PRIMARY COIL L_1 INDUCTIVELY COUPLED TO THE SECONDARY COIL L_2 AND WITH THE MUTUAL INDUCTANCE BETWEEN THEM REPRESENTED BY M. COIL L_1 IS TUNED BY CON

DENSER C_1 WHILE COIL L_2 IS TUNED BY CONDENSER C_2. IN THE SECONDARY CIRCUIT R_2 REPRESENTS THE LOAD RESISTANCE IN WHICH THE RADIO FREQUENCY POWER IS TO BE DISSIPATED.

WHEN BOTH OF THESE CIRCUITS ARE TUNED TO RESONANCE, THE ENTIRE SECONDARY CIRCUIT IN FIG. 3 MAY BE REDUCED TO THE EQUIVALENT CIRCUIT WHICH IS PICTURED IN FIG. 2 AND IN WHICH CASE, THE SECONDARY CIRCUIT WITH ITS RESISTANCE R_2 IS REPLACED BY L_1 AND AN EQUIVALENT RESISTANCE R_1. THIS PROCEDURE IS KNOWN AS "REFLECTING" THE RESISTANCE INTO THE PRIMARY CIRCUIT AND IT SIMPLIFIES CONSIDERABLY THE IMPEDANCE CALCULATIONS.

THE REASON AS TO WHY THIS LOAD RESISTANCE CAN BE REFLECTED BACK INTO THE PRIMARY CIRCUIT CAN BE EXPLAINED AS FOLLOWS: DUE TO THE ACTION OF THE TRANSFORMER, THE CURRENT WHICH FLOWS THROUGH R_2 IS OF SUCH A VALUE AS TO INDUCE BACK INTO THE PRIMARY CIRCUIT A VOLTAGE OF SUCH VALUE AND PHASE ANGLE THAT THIS REINDUCED VOLTAGE IS EQUIVALENT TO THE VOLTAGE DROP WHICH WOULD OCCUR IN A RESISTANCE OF THE PROPER VALUE IF IT WERE REALLY THERE.

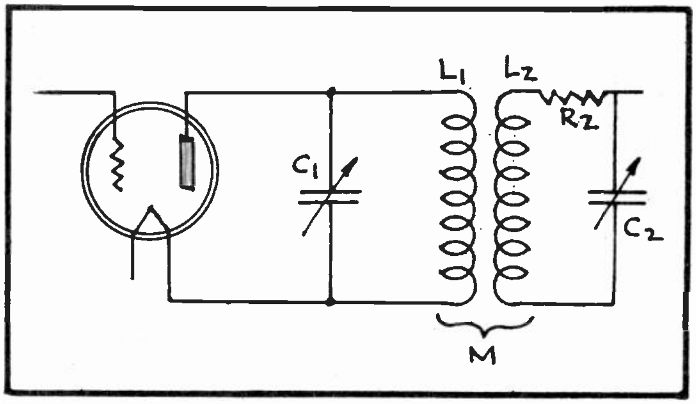


FIG. 3
Inductively Coupled Load.

THE NUMERICAL VALUE OF THE REFLECTED RESISTANCE R_1 CAN BE DETERMINED IN THE FOLLOWING MANNER: $R_1 = \frac{X_M^2}{R_2}$

WHERE X_M = THE MUTUAL REACTANCE OF THE PRIMARY AND SECONDARY OF THE TRANSFORMER AND R_2 = THE LOAD RESISTANCE.

IN ORDER TO CALCULATE THE IMPEDANCE OF THE EQUIVALENT CIRCUIT, THE SAME FORMULAS AND PROCEDURES ARE USED AS ALREADY EXPLAINED RELATIVE TO THE FUNDAMENTAL CIRCUIT IN FIG. 2. THE ONLY DIFFERENCE IS THAT R IN THE FORMULA $Z = \frac{X_L^2}{R}$ WILL NOW BE EQUAL TO THE REFLECTED RESISTANCE PLUS THE RESISTANCE OF COIL L_1.

DETERMINING GRID EXITATION POWER

IN ORDER TO DERIVE THE GREATEST POSSIBLE POWER OUTPUT FROM AN AMPLIFIER TUBE, IT IS NECESSARY THAT THE PROPER EXITATION BE APPLIED TO ITS GRID. IN PRACTICE, IT WORKS OUT THAT THE POWER REQUIRED TO PROPERLY OPERATE THE GRID OF AN AMPLIFIER TUBE BE APPROXIMATELY EQUAL TO ONE-TENTH THE POWER OUTPUT OF THE SAME TUBE. THAT IS TO SAY, IF THE POWER OUTPUT OF A CERTAIN TUBE IS RATED AT 100 WATTS, THEN APPROXIMATELY 10 WATTS OF POWER SHOULD BE AVAILABLE TO EXITE ITS GRID. THIS THEN MEANS THAT THE DRIVER TUBE MUST BE CAPABLE OF FURNISHING THE REQUIRED 10 WATTS OF POWER TO THE GRID CIRCUIT OF THE TUBE WHICH IT IS DRIVING AND THE TYPE OF DRIVER TUBE AND ITS OPERATION IN THE CIRCUIT MUST THEREFORE BE SELECTED ACCORDINGLY.

DETERMINING GRID EXITATION VOLTAGE

A PRACTICAL METHOD OF DETERMINING THE GRID EXITATION AVAILABLE IS

ILLUSTRATED FOR YOU IN FIG.4. HERE TWO RADIO-FREQUENCY AMMETERS ARE CONNECTED IN THE CIRCUIT AS SHOWN. WHEN THESE TWO METERS INDICATE INDENTICAL VALUES, THEN THE GRID EXITATION VOLTAGE AVAILABLE (E_G) IS DETERMINED WITH THE AID OF THE FOLLOWING FORMULA : $E_G = IX_L$.

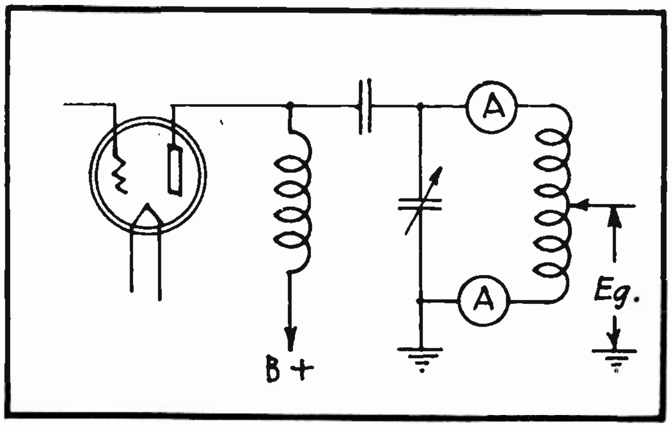


FIG. 4
Determining Grid Exitation Voltage.

IN THE EVENT THAT THE CIRCUIT ARRANGEMENT IS SUCH AS SHOWN IN FIG.5 AND IN WHICH THE GRID EXITATION VOLTAGE IS EQUAL TO THE VOLTAGE DEVELOPED ACROSS THE CONDENSER C_2, THEN WITH THE RADIO-FREQUENCY AMMETER INSTALLED IN THE CIRCUIT AS SHOWN AND THE CIRCUIT TUNED TO RESONANCE, THE GRID EXITATION VOLTAGE WILL BE FOUND FROM THE RELATION $E_G = IX_C$ WHERE I = THE CURRENT INDICATED BY THE METER AND X_C = THE CAPACITIVE REACTANCE OF CONDENSER C_2 AT THE RESONANT FREQUENCY.

APPLICATION OF GRAPHS

THE STATIC AND DYNAMIC CHARACTERISTICS OF A VACUUM TUBE CAN ALSO BE USED TO GOOD ADVANTAGE IN WORKING OUT THE DESIGN OF A TRANSMITTER'S AMPLIFIER WITH RESPECT TO THE GRID EXITATION. THIS METHOD SHALL NOW BE EXPLAINED AS IT WOULD BE APPLIED TO THE CIRCUIT WHICH IS ILLUSTRATED IN FIG. 6.

THIS PARTICULAR CIRCUIT IS A BALANCED PUSH-PULL LINEAR AMPLIFIER AND THE POWER TUBES WHICH ARE USED ARE A PAIR OF WESTERN ELECTRIC TYPE W.E. 279A AND EACH OF WHICH HAS A RATED POWER OUTPUT OF 1 KW. (1000 WATTS). ALTHOUGH THE RATING OF THESE PARTICULAR TUBES IS 1KW YET THEY ARE CAPABLE OF HANDLING A PEAK LOAD OF 2 KW. WITHOUT OVERLOADING.

WHEN ARRANGED IN A BALANCED PUSH-PULL CIRCUIT AS HERE ILLUSTRATED, EACH TUBE WILL HANDLE ONE-HALF OF THE TOTAL POWER OUTPUT. IN OTHER WORDS, IF THE CIRCUIT CONSTANTS AND DESIGN ARE SUCH THAT 1000 WATTS IS TO BE HANDLED BY THE POWER STAGE, THEN EACH OF THESE TUBES WILL DISSIPATE APPROXIMATELY 500 WATTS IN

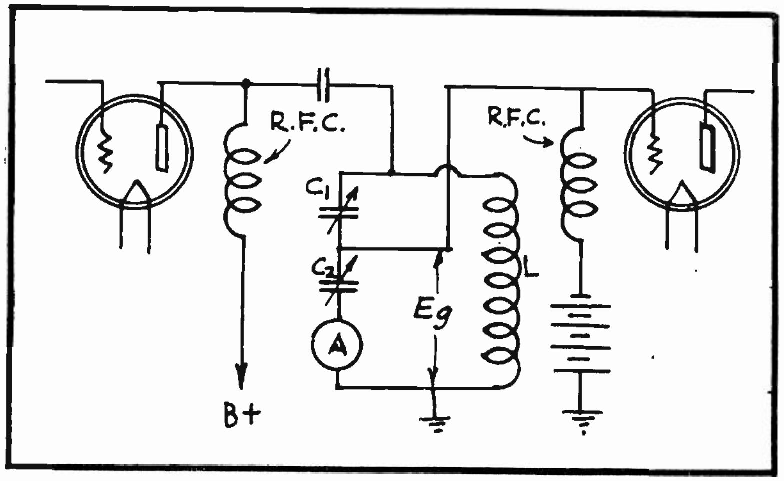


FIG. 5
Another Method of Determining Grid Exitation Voltage.

THIS CIRCUIT, THAT IS TO SAY, 1000 WATTS OF CARRIER OR UNMODULATED POWER. HOWEVER, AT 100 PER CENT MODULATION, THE MODULATED PEAK POWER WILL BE FOUR TIMES THE CARRIER POWER OR 4 X 1000 = 4000 WATTS AND FOR THIS REASON IT IS NECESSARY THAT THESE TUBES BE CAPABLE OF HANDLING THESE SWINGS WITHOUT OVERLOADING. THIS THEY ARE CAPABLE OF DOING ACCORDING TO THE MANUFACTURERS' SPECIFICATIONS.

THE NEXT STEP WILL BE TO REFER TO THE STATIC CHARACTERISTIC CURVE OF THE WE. 279A TUBE WHICH APPEARS IN FIG.7. THIS YOU WILL RECOGNIZE AS BEING THE PLATE CURRENT-GRID VOLTAGE CURVE WHEN OPERATING AT ITS NORMAL PLATE POTENTIAL OF 3,000 VOLTS AND A GRID BIAS OF 275 VOLTS ACCORDING TO THE MANUFACTURER'S SPECIFICATIONS.

THE DYNAMIC CHARACTERISTIC CURVES OF TWO W.E. 279A TUBES WHEN OPERATING IN PUSH-PULL IS SHOWN YOU IN FIG.8. THE CHARACTERISTICS OF THE

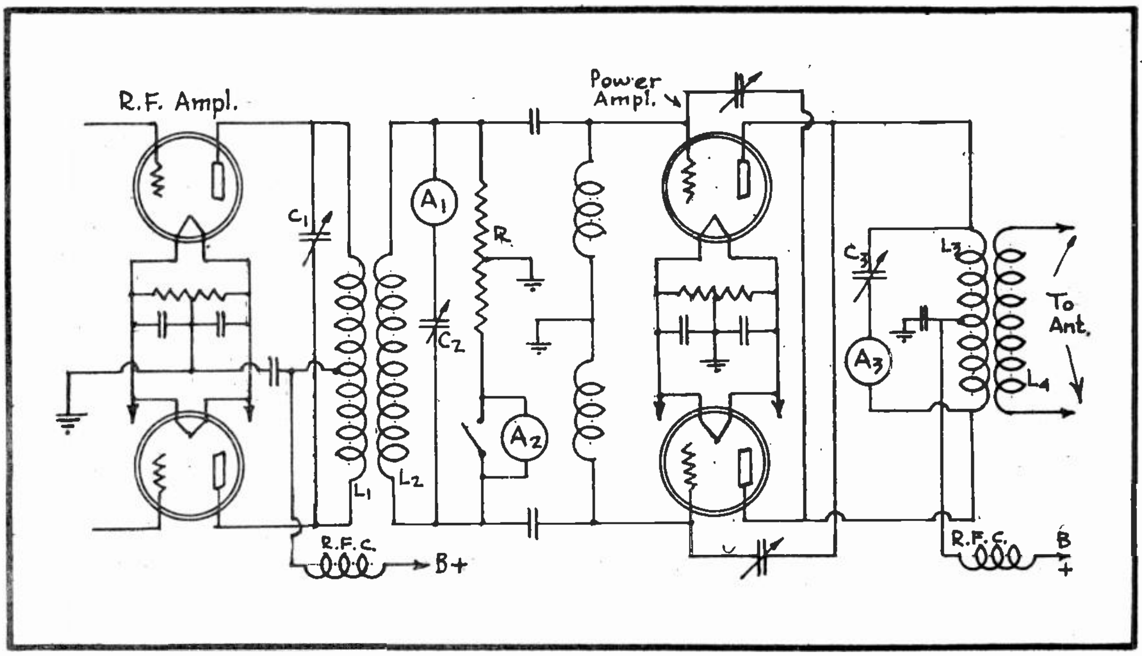


FIG. 6
A Push-Pull Linear Amplifier.

TUBES ARE HERE ILLUSTRATED WHEN OPERATING INTO A LOAD IMPEDANCE OF APPROXIMATELY 3,500 OHMS.

THE UPPER DOTTED CURVE IN THE GRAPH OF FIG.8 REPRESENTS THE APPROXIMATE EFFICIENCY OF THE TUBES WITH RELATION TO THE EXITATION VOLTAGE AND THE LOWER DOTTED CURVE REPRESENTS THE VALUE OF THE TANK POWER IN THE LOAD CIRCUIT C_3 L_3 OF FIG.6.

BY APPLYING A NEGATIVE GRID BIAS OF APPROXIMATELY 275 VOLTS AND A PLATE POTENTIAL OF SLIGHTLY OVER 3000 VOLTS TO THESE TUBES, WE FIND THAT THE TUBES WILL BE BIASED ALMOST TO THE POINT OF PLATE CURRENT CUT-OFF (CLASS B) AND IN THE PLATE LOAD CIRCUIT WILL APPEAR A POWER OUTPUT EQUAL TO THE SQUARE OF THE INPUT GRID VOLTAGE.

IF 100% MODULATION IS USED, THEN THE PEAK OUTPUT WILL BE FOUR TIMES

GREATER THAN THE UNMODULATED CARRIER POWER.

AS WAS STATED PREVIOUSLY, EACH OF THESE POWER TUBES IS EXPECTED TO DELIVER AN UNMODULATED CARRIER OUTPUT OF 500 WATTS OR 1000 WATTS FOR THE TWO TUBES TOGETHER. FOR THIS REASON THE GRID EXITATION POWER MUST BE APPROXIMATELY 1/10 OF THE OUTPUT POWER OR 50 WATTS PER TUBE AND 100 WATTS ACROSS THE GRIDS OF BOTH TUBES. THIS TOTAL GRID EXITATION OF 100 WATTS MUST BE DISSIPATED BY RESISTOR R OF THE CIRCUIT IN FIG.6.

SINCE THE POWER TUBES OF THIS SAME CIRCUIT ARE BIASED AT 275 VOLTS, A GRID EXITATION VOLTAGE OF APPROXIMATELY 265 VOLTS MUST BE APPLIED TO EACH OF THEM IN ORDER TO REALIZE THEIR FULL RATED OUTPUT. THIS MEANS A TOTAL EXITATION VOLTAGE OF 2 TIMES 265 OR 530 VOLTS FOR THE TWO TUBES AND WHICH MUST BE DEVELOPED ACROSS THE EXTREMITIES OF RESISTOR R.

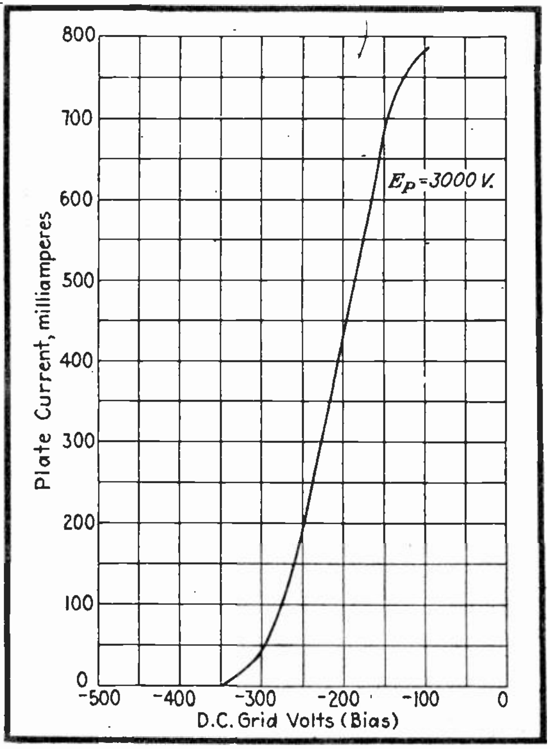


FIG.7
Static Characteristic Curve of the W.E. 279 A.

ASSUMING THAT THE TOTAL RESISTANCE OF R IS 2400 OHMS, WE CAN DETERMINE THE WATTAGE WHICH IS DISSIPATED ACROSS IT BY INSERTING A RADIO-FREQUENCY AMMETER IN SERIES WITH IT AS INDICATED BY A_2 IN FIG.6. THE RADIO-FREQUENCY DRIVE OR INPUT TO THIS CIRCUIT IS THEN VARIED UNTIL THE AMMETER A_2 OFFERS A READING WHICH WHEN SQUARED AND MULTIPLIED BY THE RESISTANCE OF R OR 2400 OHMS WILL BE EQUAL TO APPROXIMATELY 100 WATTS. FOR EXAMPLE, WHEN THIS AMMETER OFFERS A READING OF 0.21 AMP., THEN I^2R = 0.21x0.21x2400= 105.84 WATTS. THEREFORE, WHEN AMMETER A_2 READS 0.21 AMP. THE PROPER GRID EXITATION EXISTS. THE CORRESPONDING GRID EXITATION VOLTAGE IN THIS CASE WILL BE E = I x R = 0.21 x 2400 = 504 VOLTS, AND WHICH CHECKS CLOSE ENOUGH TO OUR DESIRED VALUES FOR PRACTICAL PURPOSES.

IT IS TO BE UNDERSTOOD THAT THE VARIOUS VALUES AS SO FAR DETERMINED WILL NOT MAKE SATISFACTORY OPERATION POSSIBLE, UNLESS THE LOAD IMPEDANCE C_3 L_3 IN FIG.6 BE OF THE CORRECT IMPEDANCE TO MATCH THE OUTPUT TUBES. IN OTHER WORDS, THE GRAPHS AND DATA WHICH WE HAVE USED IN MAKING THE CALCULATIONS FOR THE CIRCUIT OF FIG.6, HAVE ASSUMED L_3 C_3 AS PROVIDING A LOAD IMPEDANCE OF APPROXIMATELY 14,000 OHMS (4 TIMES 3500 = 14,000) AT THE OPERATING FREQUENCY OF 1000 KC.

SHOULD THIS CIRCUIT BE OPERATED WITH TOO LOW A LOAD IMPEDANCE, THEN THE EXCESSIVE POWER WHICH IS DEVELOPED WILL BE DISSIPATED IN THE TUBE RATHER THAN IN THE LOAD AND THEREBY CAUSE THE TUBE TO OVERHEAT AS WELL AS TO BECOME OVERLOADED. AT THE SAME TIME, THE LOW-LOAD IMPEDANCE MAY CAUSE THE MODULATION PERCENTAGE TO BECOME TOO HIGH AND THUS CAUSE AUDIO-FREQUENCY DISTORTION.

ON THE OTHER HAND, IF THE LOAD IMPEDANCE IS TOO HIGH THEN THE INSUFFICIENT POWER WHICH WILL BE DEVELOPED ACROSS IT WILL CAUSE THE MODULATION PERCENTAGE TO BE TOO LOW.

CALCULATING LOAD IMPEDANCE FOR POWER AMPLIFIERS

ALTHOUGH FOR GENERAL CONDITIONS, THE LOAD IMPEDANCE FOR POWER AMPLIFIERS IS SET AT A VALUE EQUAL TO TWICE THE PLATE IMPEDANCE OF THE TUBE AT THE FREQUENCY BEING HANDLED, YET THIS FACTOR CAN BE DETERMINED WITH STILL GREATER ACCURACY BY APPLYING THE CALCULATIONS AS WILL NOW BE EXPLAINED.

IN FIG. 9, FOR INSTANCE, YOU ARE SHOWN A FAMILY OF CHARACTERISTIC CURVES FOR THE TYPE -10 TUBE, EACH FOR A DIFFERENT GRID BIAS VALUE. THE NORMAL BIAS VOLTAGE FOR THIS TUBE IS -30 VOLTS. THE PROPER GRID SWING FOR THIS TUBE WILL THEN BE PLUS OR MINUS 30 VOLTS WITH RESPECT TO THE NORMAL BIAS OR A TOTAL GRID SWING OF TWICE THE BIAS VOLTAGE OF 30 OR 60 VOLTS.

THE EXTENT OF THE PLATE VOLTAGE SWING AS EXPERIENCED IN THIS CASE CAN BE DETERMINED BY DRAWING A STRAIGHT LINE THROUGH THE NORMAL OPERATING POINT IN THE GRAPH OF FIG. 9 AND EXTENDING THIS LINE SO THAT IT WILL INTERSECT THE CURVE $E_c = 0V$ AT SOME ARBITRARY POINT. THIS SAME LINE IS ALSO EXTENDED TO THE CURVE $E_c = -60V$. VERTICAL LINES ARE THEN RULED THROUGH THESE POINTS OF INTERSECTION ON THE $E_c = 0V$ AND THE $E_c = -60V$. CURVES. UPON DOING THIS, IT WILL BE NOTED THAT THESE POINTS CORRESPOND TO PLATE VOLTAGES (E_p) OF 230 AND 548 VOLTS RESPECTIVELY. THESE SAME POINTS ALSO CORRESPOND TO PLATE CURRENT VALUES OF 36 MA. AND 6 MA. RESPECTIVELY.

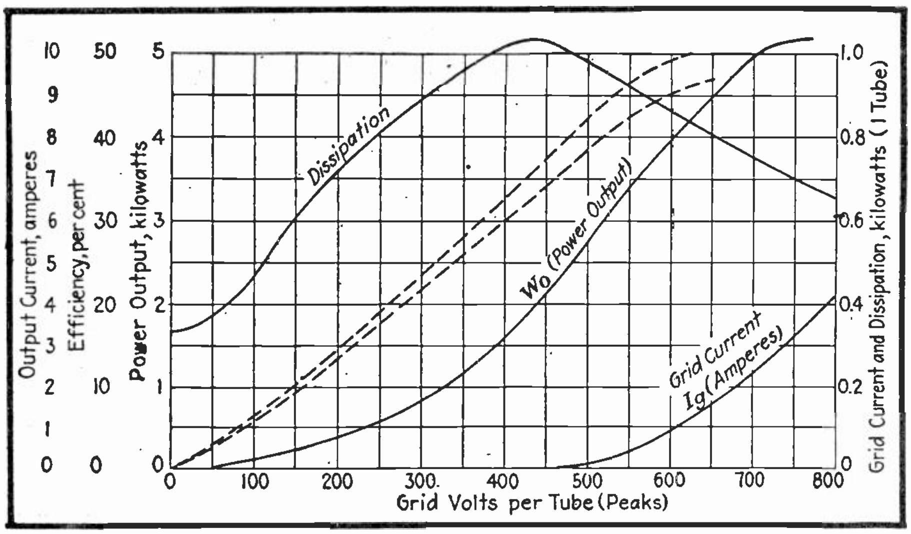


FIG. 8

Dynamic Characteristic Curves of Two W.E. 279A Tubes Operating in Push-Pull.

BY THUS KNOWING THE TOTAL PLATE VOLTAGE SWING E_s AS BEING 548 MINUS 230 OR 318 VOLTS, THE MAXIMUM PLATE CURRENT AS BEING 36 MA. AND THE MINIMUM PLATE CURRENT AS BEING 6 MA., THEN LOAD IMPEDANCE MAY BE CALCULATED BY APPLYING THE FORMULA: $Z_O = \frac{E_S}{I_{P\,MAX} - I_{P\,MIN}}$ WHERE E_S = TOTAL PLATE VOLTAGE SWING; I_{PMAX} = MAXIMUM PLATE CURRENT EXPRESSED IN AMPERES AND I_{PMIN} = MINIMUM PLATE CURRENT EXPRESSED IN AMPERES.

BY SUBSTITUTING INTO THIS FORMULA THE VALUES WHICH WE HAVE SO FAR

DETERMINED, WE HAVE $Z_o = \frac{318}{0.036 - 0.006} = \frac{318}{0.030} = 10,600$ OHMS.

NOTICE PARTICULARY IN THIS CASE THAT THE LOAD IMPEDANCE WHEN WORKED OUT IN THIS MANNER CHECKS FAVORABLY WITH THE LOAD IMPEDANCE WHEN ASSUMING THE LOAD IMPEDANCE TO BE EQUAL TO TWICE THE PLATE IMPEDANCE OF THE TUBES. THAT IS TO SAY, THE TYPE -10 TUBE AT A PLATE VOLTAGE OF 400 VOLTS AND A GRID BIAS OF -30 VOLTS HAS A PLATE IMPEDANCE OF APPROXIMATELY 5000 OHMS AND TWICE 5000 OHMS = 10,000 OHMS AS THE RECOMMENDED LOAD IMPEDANCE.

HAVING DETERMINED THE LOAD IMPEDANCE AS JUST EXPLAINED, WE CAN ALSO PROCEED TO DETERMINE THE POWER OUTPUT OF THE SAME TUBE UNDER THESE SAME CONDITIONS OF OPERATION BY APPLYING THE FORMULA: Po IN WATTS = $\frac{(E_{MAX} - E_{MIN}) \times (I_{MAX} - I_{MIN})}{8}$. WHENCE Po = $\frac{(548-230) \times (0.036-0.006)}{8}$ = 1.192 WATTS.

THE PERCENT DISTORTION CAN ALSO BE DETERMINED FROM THE FACTS WHICH ARE NOW AVAILABLE BY APPLYING THE FORMULA:

$$\text{\% DISTORTION (2ND HARMONIC.)} = \frac{\frac{1}{2}(I_{MAX.} + I_{MIN.}) - I_{NORMAL}}{I_{MAX} - I_{MIN}} \times 100$$

THUS IN OUR PARTICULAR EXAMPLE, DISTORTION = $\frac{\frac{1}{2}(0.036+0.006)-0.018}{0.036-0.006} \times 100 = \frac{\frac{1}{2}(0.042)-0.018}{0.03} \times 100 = \frac{0.021-0.018}{0.03} \times 100 = \frac{0.003}{0.03} \times 100 = 10\%$.

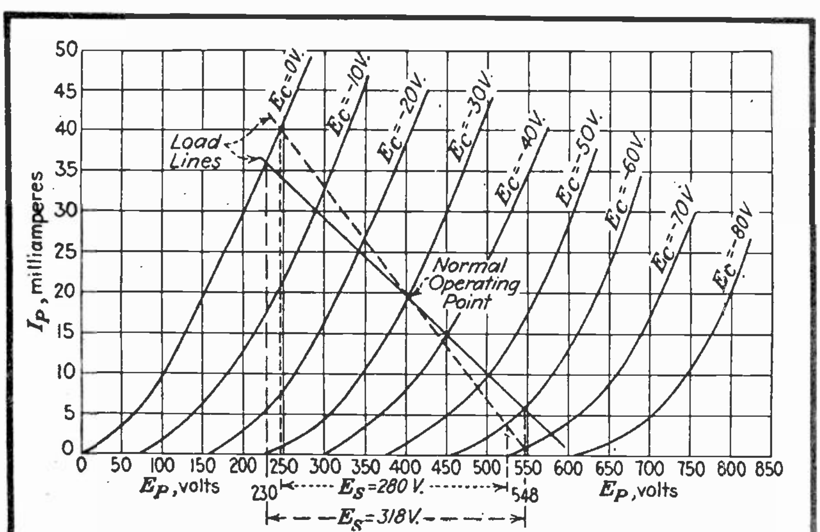


FIG. 9
Load-line Impedance Determination.

NOW LET US SEE WHAT WOULD HAPPEN IF OUR ARBITRARY LOAD LINE IN FIG. 9 SHOULD HAVE OCCUPIED ANOTHER POSITION, SUCH AS INDICATED BY THE DOTTED LINE, FOR EXAMPLE. THE POINTS WHERE THIS DOTTED LINE INTERSECTS THE Ec=0V AND THE Ec=-60V. CURVES CORRESPONDS RESPECTIVELY TO THE FOLLOWING PLATE VOLTAGE AND CURRENT VALUES: 525 VOLTS AT 4 MA.; AND 245 VOLTS AT 41 MA.

UPON CALCULATING THE LOAD IMPEDANCE IN THIS CASE, WE HAVE:

$$Z_o = \frac{E_S}{I_{PMAX} - I_{PMIN}} = \frac{525-245}{0.041-0.004} = \frac{280}{0.037} = 7,600 \text{ OHMS.}$$

DETERMINING THE POWER FROM Po = $\frac{(E_{MAX}-E_{MIN}) \times (I_{MAX}-I_{MIN})}{8} = \frac{(525-245) \times (0.041-0.004)}{8}$

= 1.3 WATTS (APPROX.)

SECOND HARMONIC DISTORTION = $\frac{\frac{1}{2}(I_{MAX} + I_{MIN.}) - I_{NORMAL}}{I_{MAX} - I_{MIN.}}$ X 100 =

$\frac{\frac{1}{2}(0.041 + 0.004) - 0.018}{0.041 - 0.004}$ X 100 = $\frac{0.0045}{0.037}$ X 100 = 12% APPROX.

BY COMPARING THESE TWO LOAD LINES IN FIG. 9 TOGETHER WITH THEIR CORRESPONDING CALCULATIONS WE NOTE THAT WITH THE DOTTED LINE, THE POWER OUTPUT IS SOMEWHAT GREATER AS IS ALSO THE PERCENTAGE OF HARMONIC DISTORTION. UPON DRAWING A NUMBER OF LOAD LINES ON THE GRAPH OF FIG. 9 AND WORKING OUT THE CALCULATIONS AS JUST EXPLAINED THE MOST DESIRED COMBINATION BETWEEN THE LOAD IMPEDANCE AND PERCENTAGE OF SECOND HARMONIC DISTORTION CAN BE ARRIVED AT.

THIS METHOD OF CALCULATING THE PROPER LOAD IMPEDANCE CAN BE APPLIED TO SOLVE PROBLEMS OF THIS NATURE IN ALL TYPES OF AUDIO, RADIO-FREQUENCY, OR POWER-AMPLIFIER SYSTEMS.

DETERMINING OPERATING CONDITIONS FOR PLATE MODULATION

IN FIG. 10 YOU ARE SHOWN THE SKELETON DIAGRAM OF A CLASS-A MODULATOR "CHOKE-COUPLED" TO THE PLATE CIRCUIT OF A CLASS C AMPLIFIER ACCORDING TO THE HEISING SYSTEM OF MODULATION.

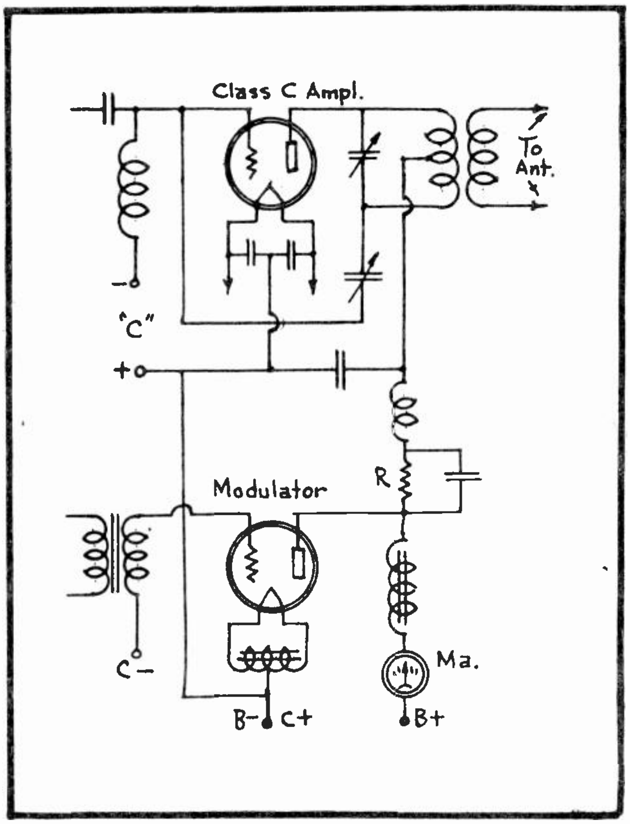


FIG. 10
The Modulation Circuit.

IN ORDER THAT 100 % MODULATION MAY BE OBTAINED IN THIS CASE, THE CLASS C AMPLIFIER'S D.C. INPUT POWER SHOULD BE TWICE THE MODULATOR'S RATED MAXIMUM UNDISTORTED POWER OUTPUT. THIS D.C. INPUT IS EQUAL TO THE CLASS C AMPLIFIER'S MEAN (AVERAGE) D. C. PLATE VOLTAGE AND PLATE CURRENT. IT IS ALSO TRUE THAT THE MEAN PLATE VOLTAGE DIVIDED BY THE PLATE CURRENT WILL RESULT IN THE MODULATING IMPEDANCE AND WHICH IN THIS CASE SHOULD EQUAL THE MODULATOR'S RATED LOAD IMPEDANCE.

THE FOLLOWING RELATIONS ALSO APPLY IN CIRCUITS OF THIS TYPE: $I_B = \sqrt{\frac{P_O}{R_P}}$ AND $E_B = \frac{P_O}{I_B}$ WHERE I_B = MEAN D.C. CURRENT TO R.F. AMPLIFIER PLATE EXPRESSED IN AMPERES; P_O = UNMODULATED D.C. POWER INPUT TO R.F. STAGE AND WHICH IS EQUAL TO TWICE THE MODULATOR POWER OUTPUT EXPRESSED IN WATTS; R_P = OPTIMUM LOAD RESISTANCE FOR MODULATOR EXPRESSED IN OHMS AND E_B = MEAN

D.C. PLATE VOLTAGE OF R.F. AMPLIFIER.

AS A PRACTICAL EXAMPLE, LET US CONSIDER A TYPE 845 TUBE OPERATING AS A CLASS A MODULATOR WITH A PLATE SUPPLY OF 1000 VOLTS AT 75 MA. WE SHALL FURTHER ASSUME THAT THE POWER OUTPUT OF THIS TUBE IS 23 WATTS FOR A LOAD RESISTANCE OF 7500 OHMS. THE MEAN PLATE CURRENT FOR THE CLASS C R.F. AMPLIFIER IS THEN DETERMINED AS FOLLOWS:

$I_B = \sqrt{\frac{Po}{R_P}} = \sqrt{\frac{2 \times 23}{7500}} = 0.078$ AMP. = 78 MA. THE MEAN D.C. PLATE VOLTAGE FOR THE CLASS C AMPLIFIER IS SOLVED AS: $E_B = \frac{Po}{I_B} = \frac{2 \times 23}{0.078} = 590$ VOLTS.

THE PLATE VOLTAGE DROP FOR THE CLASS C AMPLIFIER IS THEREFORE 1000 MINUS 590 = 410 VOLTS AND WHICH MUST BE DEVELOPED ACROSS RESISTOR R IN FIG. 10. THE VALUE OF RESISTOR R IS DETERMINED BY APPLYING OHM'S LAW IN THE FORM $R = \frac{E}{I} = \frac{410}{0.078} = 5256$ OHMS. THE WATTAGE WHICH THIS SAME RESISTOR MUST DISSIPATE IS EQUAL TO E x I = 410 X 0.078 = 32 WATTS. AS A MATTER OF SAFETY, THE RESISTOR USED SHOULD NOT BE RATED AT LESS THAN 50 WATTS.

FROM THESE CALCULATIONS, IT HAS BEEN DETERMINED THAT THE CLASS C AMPLIFIER TUBE SHOULD BE SELECTED FROM THE STANDPOINT OF BEING CAPABLE OF OPERATING SATISFACTORILY WITH A PLATE INPUT OF APPROXIMATELY 78 MA. AT APPROXIMATELY 590 OR 600 VOLTS.

IN THE EVENT THAT TRANSFORMER COUPLING IS USED BETWEEN THE MODULATOR AND THE CLASS C AMPLIFIER, THEN THE TURNS RATIO OF THE MODULATION TRANSFORMER MUST BE CALCULATED SO AS TO MATCH THE MODULATING IMPEDANCE OF THE CLASS C AMPLIFIER TO THE REQUIRED LOAD IMPEDANCE OF THE MODULATOR. THIS IS ACCOMPLISHED IN THE FOLLOWING MANNER:

A CERTAIN CLASS B MODULATOR HAS A POWER OUTPUT OF 100 WATTS WITH 1000 VOLTS APPLIED TO THE PLATES OF THE TWO TUBES AND OPERATES INTO A SUITABLE LOAD IMPEDANCE OF 14,000 OHMS. TWO SIMILAR TUBES ARE USED IN THE CLASS C AMPLIFIER, ALSO BEING OPERATED AT A PLATE VOLTAGE OF 1000 VOLTS AND WITH AN AVERAGE D.C. POWER INPUT OF TWICE THE MODULATOR'S RATED MAXIMUM OUTPUT OR 2 x 100 = 200 WATTS.

THE PLATE CURRENT FOR THE CLASS C AMPLIFIER IS THEN SOLVED FOR IN THE FOLLOWING MANNER:

$$I_B = \frac{Po}{E_B} = \frac{2 \times 100}{1000} = 0.2 \text{ AMP.} = 200 \text{ MA.}$$

THE MODULATING IMPEDANCE OF THE CLASS C AMPLIFIER IS $Z_M = \frac{E_B}{I_B} = \frac{1000}{0.2} = 5000$ OHMS.

THIS MEANS THAT THE MODULATION TRANSFORMER MUST PROPERLY MATCH THE MODULATOR'S LOAD IMPEDANCE OF 14,000 OHMS TO THE CLASS C AMPLIFIER'S MODULATING IMPEDANCE OF 5000 OHMS. THE CORRESPONDING TRANSFORMER TURNS RATIO WILL BE EQUAL TO THE SQUARE ROOT OF THE PRIMARY-SECONDARY IMPEDANCE RATIO

OR TURNS RATIO $= \sqrt{\frac{14,000}{5000}} = \sqrt{2.8} = 1.6$ TO 1 OR 1 TO 0.62.

THIS SAME METHOD OF CALCULATION IS EMPLOYED WHETHER THE MODULATOR BE OF THE CLASS A OR CLASS B TYPE. IT IS ALSO IMPORTANT IN THIS CASE THAT THE TRANSFORMER WINDINGS BE CAPABLE OF CARRYING THE NECESSARY CURRENT WITHOUT SATURATING THE CORE.

CHECKING THE MODULATION

A SIMPLE METHOD OF CHECKING THE MODULATION OF A TRANSMITTER IS TO APPLY A CONSTANT MODULATING FREQUENCY TO THE CARRIER AND NOTE THE INCREASE IN ANTENNA CURRENT. IF THE CARRIER IS MODULATED 100%, THE ANTENNA CURRENT WILL RISE TO APPROXIMATELY 1.23 TIMES THE CARRIER VALUE.

THE CIRCUIT DIAGRAM OF A MODULOMETER APPEARS IN FIG. 11. THIS DEVICE IS USED FOR DETERMINING THE PERCENTAGE OF MODULATION IN THE FOLLOWING MANNER: COIL L_2 IS COUPLED TO THE OUTPUT CIRCUIT OF THE TRANSMITTER. THE R.F. CURRENT WHICH PASSES THROUGH THIS CIRCUIT CAUSES A VOLTAGE DROP ACROSS RESISTOR R_1 AND WHICH IS DIRECTLY PROPORTIONAL TO THE CURRENT THROUGH THE RESISTOR.

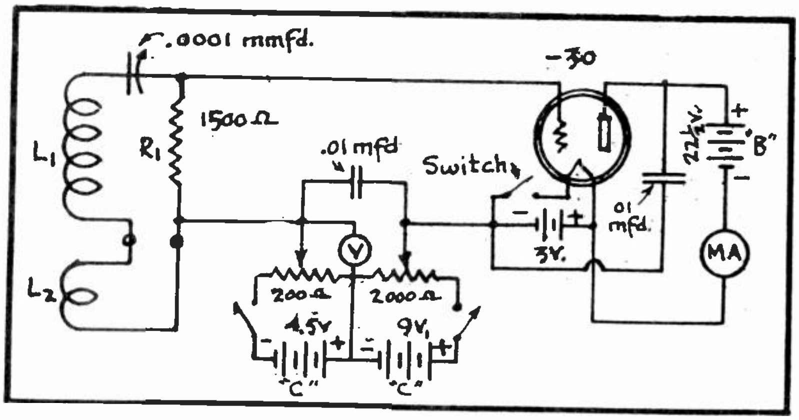


FIG. 11
Circuit of the Modulometer.

VARIATIONS IN THE AMPLITUDE OF THE R.F. CURRENT WILL THEREFORE CAUSE PROPORTIONATE VARIATIONS IN THE R.F. VOLTAGE ACROSS RESISTOR R_1 AND THE POSITIVE HALF CYCLES OF THIS VOLTAGE IS MEASURED BY THE PEAK VOLTMETER (VACUUM TUBE VOLTMETER) WHICH IS INCORPORATED IN THE MODULOMETER.

DURING THE TIME OF CONDUCTING THIS TEST, THE TRANSMITTING ANTENNA IS REPLACED WITH A DUMMY ANTENNA AND THE COUPLING IS SO ADJUSTED THAT THE MODULATED AMPLITUDE OF THE VOLTAGE ACROSS R_1 IS 5 OR 6 VOLTS. THE GAIN CONTROL OF THE SPEECH AMPLIFIER IS THEN SET AT ZERO SO THAT THE CARRIER IS UNMODULATED AND A SECOND MEASUREMENT IS MADE. THE PERCENTAGE OF MODULATION IS THEN DETERMINED FROM THE RELATION $M = \frac{E\ MOD. - E\ CAR.}{E\ CAR.} \times 100$

WHERE M IS THE PERCENTAGE OF MODULATION, EMOD. IS THE VOLTAGE WITH MODULATION AND ECAR IS THE VOLTAGE OF THE UNMODULATED CARRIER.

THE COIL L_1 AND CONDENSER C_1 ARE SO CHOSEN THAT THIS CIRCUIT CAN BE TUNED TO THE CARRIER FREQUENCY OF THE TRANSMITTER. THE COUPLING OR PICK-UP COIL L_2 MAY CONSIST OF TWO OR THREE TURNS OF LAMP CORD OF ANY CONVENIENT SIZE.

Answered May 19, 1942

Examination Questions

LESSON NO. T-16

Men are so inclined to content themselves with what is most common, that it is necessary to continually study and nourish in his mind the things which are beautiful and perfect.

1. – WHAT APPROXIMATE RELATION EXISTS BETWEEN THE OUTPUT POWER OF AN AMPLIFIER TUBE AND THE GRID EXITATION POWER FOR THE SAME TUBE? 1/10

2. – WHAT PROCEDURE CAN BE USED IN ORDER TO DETERMINE THE APPROXIMATE GRID EXITING VOLTAGE NECESSARY IN ORDER THAT A CERTAIN AMPLIFIER TUBE MAY DELIVER ITS RATED OUTPUT POWER?

3. – HOW WOULD YOU GO ABOUT THE TASK OF DETERMINING THE OUTPUT IMPEDANCE OF A MODULATING AMPLIFIER?

4. – WHAT IS MEANT BY "REFLECTED RESISTANCE"?

5. – EXPLAIN IN DETAIL HOW THE PROPER LOAD IMPEDANCE FOR A POWER AMPLIFIER MAY BE DETERMINED WITH THE AID OF A FAMILY OF CHARACTERISTIC CURVES CORRESPONDING TO THE SAME TUBE.

6. – EXPLAIN HOW THE PERCENTAGE OF SECOND HARMONIC DISTORTION AT THE OUTPUT OF AN AMPLIFIER MAY BE DETERMINED.

7. – IN ORDER TO REALIZE 100% MODULATION WHEN USING THE HEISING SYSTEM OF MODULATION, WHAT RELATION SHOULD EXIST BETWEEN THE CLASS C AMPLIFIER'S D.C. INPUT POWER AND THE MODULATOR'S RATED MAXIMUM UNDISTORTED POWER OUTPUT?

8. – WHAT METHOD MAY BE EMPLOYED IN ORDER TO DETERMINE THE PERCENTAGE OF MODULATION REALIZED WITH A CERTAIN TRANSMITTER?

9. – IF THE HEISING SYSTEM OF MODULATION IS TO BE EMPLOYED BY USING A MODULATION TRANSFORMER, WHAT STEPS SHOULD BE TAKEN IN ORDER TO DETERMINE THE CORRECT TURNS RATIO FOR THIS TRANSFORMER?

10. – IF THE LOAD IMPEDANCE OF A TRANSMITTER'S POWER AMPLIFIER IS OF TOO LOW A VALUE FOR THE TUBES USED, HOW WILL THIS AFFECT THE OPERATION OF THE TRANSMITTER? HOW WILL THE OPERATION OF THE SAME TRANSMITTER BE AFFECTED IN THE EVENT THAT THE LOAD IMPEDANCE IS OF TOO HIGH A VALUE?

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO 17

· STUDIO AND CONTROL-ROOM EQUIPMENT ·

WITH THIS LESSON YOU ARE GOING TO COMMENCE YOUR STUDY OF BROADCAST TRANSMITTERS AND ASSOCIATED STATION EQUIPMENT. THE STUDIO END OF THE SYSTEM SHALL BE CONSIDERED FIRST.

FIG. 2 SHOWS YOU IN A SIMPLIFIED FORM HOW THE STUDIO IS RELATED TO THE OTHER MAJOR UNITS OF THE BROADCAST TRANSMITTER. HERE YOU WILL OBSERVE THAT A NUMBER OF STUDIO MICROPHONES FEED INTO A MIXER AND FROM HERE THE SOUND ENERGY IS DELIVERED TO THE A.F. AMPLIFYING EQUIPMENT WHICH IS LOCATED IN THE CONTROL ROOM. IN THE TRANSMITTER ROOM THIS A.F. ENERGY IS STILL FURTHER AMPLIFIED TO THE VALUE NECESSARY FOR PROPER MODULATION AND FROM THE TRANSMITTER THE MODULATED R.F. ENERGY IS FED INTO THE ANTENNA.

NUMEROUS MODIFICATIONS OF THIS TYPICAL ARRANGEMENT ARE USED BY DIFFERENT STATIONS. FOR EXAMPLE, IN MANY CASES YOU WILL FIND THE MICROPHONES OPERATING DIRECTLY INTO A PRE-AMPLIFIER AND THE A.F. SIGNALS DELIVERED FROM THESE SMALL AMPLIFIERS TO THE MIXER WHICH IS IN SUCH INSTANCES LOCATED IN THE CONTROL ROOM.

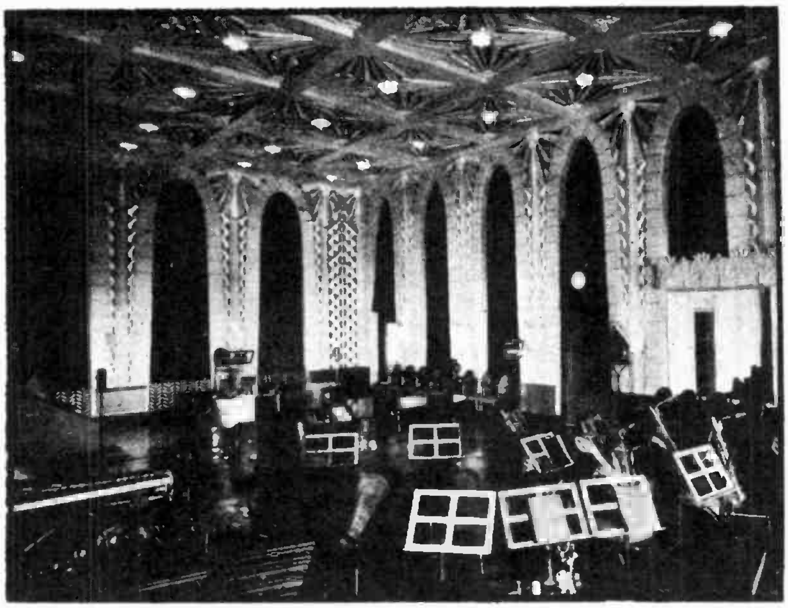


FIG. I
Main Studio of a Broadcast Station.

IN FIG.2 YOU ARE ALSO SHOWN HOW PROGRAMS ARE HANDLED BY REMOTE CONTROL. THIS, YOU WILL NOTE, IS ACCOMPLISHED BY PLACING THE NECESSARY MICROPHONES AND MIXER AT THE POINT WHERE THE PROGRAM ORIGINATES — AN AUDITORIUM IN THIS particular case. The A.F. energy is then amplified at this same location and the output terminals of this amplifier carry the amplified A.F. signals to the control room of the station over special telephone lines. These signals are then passed through the equalizer and from here on, the program is handled in the same manner as already explained.

Also observe in Fig. 2 that a separate telephone system is included between the station and the distant origin of the program so that the operators at both points can maintain private communication between themselves regarding the handling of the program.

From this brief explanation, you should now have a general idea of the entire broadcast system. In the instruction which is to follow you will have the opportunity of studying each unit in detail, as well as all accessory equipment such as the relays, volume indicators, monitoring devices etc. which for the sake of clarity and simplicity have been omitted from Fig. 2.

STUDIO ARRANGEMENT

In Fig. 3 you are shown an artist's cut-away sketch of the NATIONAL BROADCASTING STUDIOS and which is part of the training equipment in our school. This studio arrangement is typical of that used by the better broadcasting stations of this country and consequently our students have the opportunity of working under the same conditions as would exist in any of the larger stations.

You will no doubt be interested in knowing that NATIONAL SCHOOLS also conduct the NATIONAL SCHOOL OF BROADCASTING and which is devoted ex-

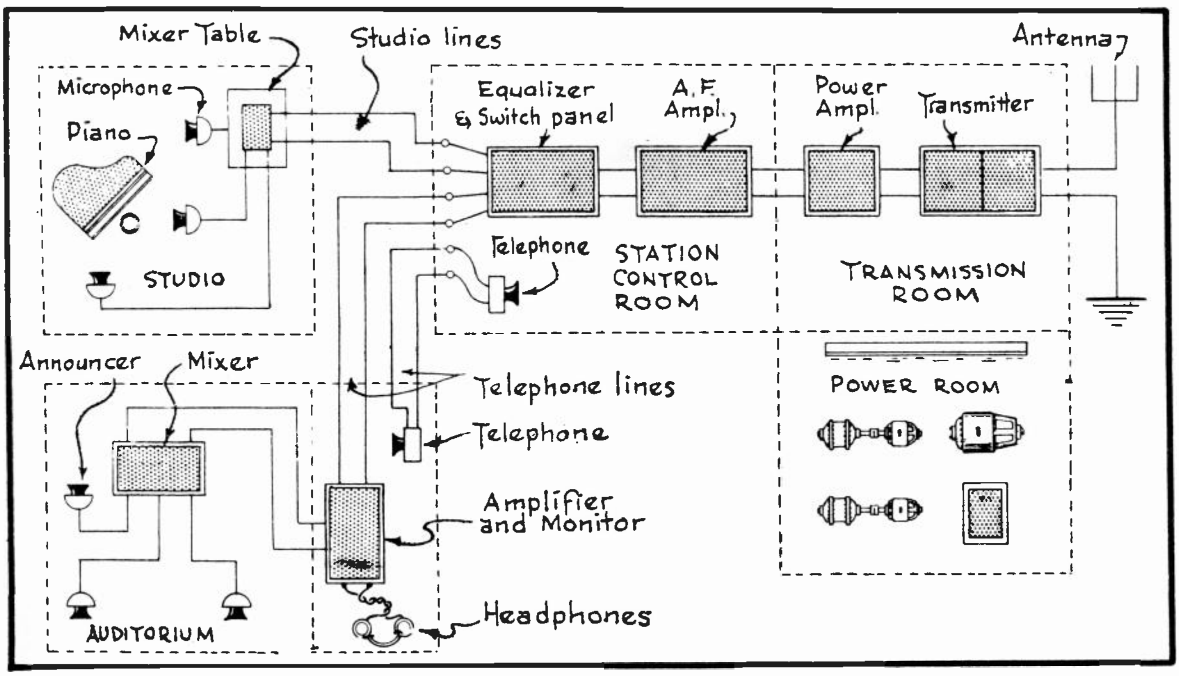


FIG. 2

Typical Arrangement of a Broadcast Station.

CLUSIVELY TO THE TRAINING OF ARTISTS AND OTHER TALENTED PERSONS SO THAT THEY MAY DEVELOP FOR RADIO USE THEIR TALENTS IN THE FIELD OF SINGING, DRAMATICS, ANNOUNCING, CONTINUITY WRITING, ETC. VARIED TYPES OF PROGRAMS WHICH ORIGINATE IN OUR STUDIOS ARE RELEASED ON REGULAR SCHEDULE BY ONE THE MAJOR BROADCASTING STATIONS OF LOS ANGELES.

WHILE THE STUDENTS OF OUR BROADCASTING SCHOOL USE OUR STUDIOS TO THEIR PARTICULAR ADVANTAGE, YET THIS IS OF MUTUAL BENEFIT TO THE RADIO STUDENTS OF OUR TECHNICAL SCHOOL WHO ARE PRIVELEDGED TO ACT AS STUDIO TECHNICIANS, MONITORING MEN, AND STATION TECHNICIANS, IN ADDITION TO GAINING THE MOST VALUABLE EXPERIENCE OF SERVICING ALL THIS EQUIPMENT.

BY AGAIN REFERRING TO FIG. 3 YOU WILL NOTE THAT THE STUDIOS CONSIST OF SEVERAL DEPARTMENTS AND WHICH IS TRUE IN THE MAJORITY OF STATIONS. THE MAIN STUDIO, FOR INSTANCE, IS LOCATED AT "A" — THIS IS A LARGE STUDIO IN WHICH ORIGINATE ALL MAJOR PROGRAMS INVOLVING A NUMBER OF PERSONS.

AT "B", "C" AND "D" WE HAVE THREE SMALLER STUDIOS WHICH ARE USED FOR THE BROADCASTING OF PROGRAMS INVOLVING A MINIMUM OF STUDIO EQUIPMENT AND

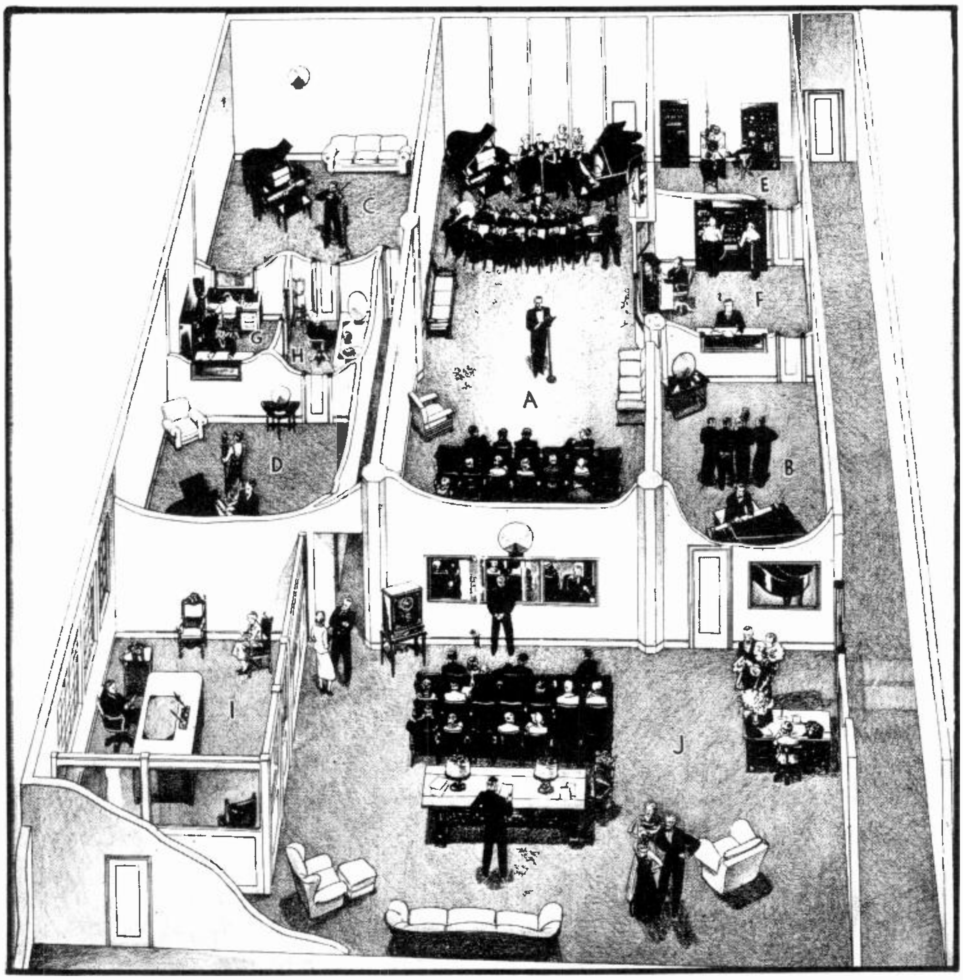


FIG. 3
The National Broadcasting Studios.

IN WHICH ONLY A LIMITED NUMBER OF PERSONS PARTICIPATE. THE SMALLER STUDIOS AS THIS ARE BEST ADAPTED FOR VOICE AND INSTRUMENTAL SOLOIST, SPEAKERS, ETC.

THE TELEVISION STUDIO IS LOCATED AT "E" AND CONTROL ROOMS ARE LOCATED AT BOTH "F" AND "G". SPECIALLY DESIGNED WINDOWS, WHICH ARE INSTALLED IN THE WALLS OF THE CONTROL ROOMS, ENABLE THE CONTROL ROOM OPERATORS TO OBTAIN A FULL VIEW OF THE ACTIVITIES IN ALL OF THE STUDIOS.

AN AUDITION ROOM IS LOCATED AT "H", THE DIRECTOR'S OFFICE AT "I" AND THE RECEPTION ROOM. AT "J". WINDOWS ARE PROVIDED SO THAT THE AUDIENCE IN ROOM "J" CAN WATCH THE ACTIVITIES IN STUDIOS "A" AND "B" AND AT THE SAME TIME HEAR THE PROGRAMS THROUGH SPEAKERS WHICH ARE INSTALLED IN THE RECEPTION ROOM.

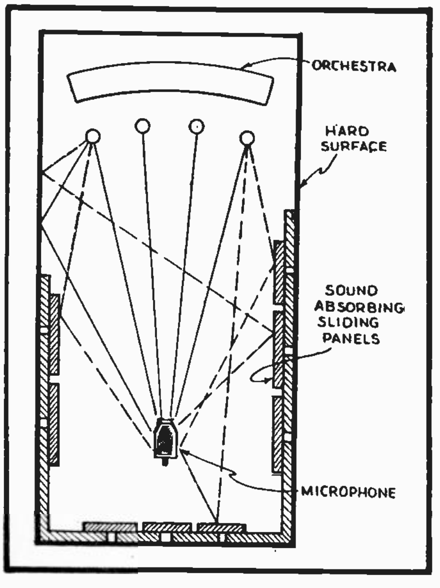


FIG. 4
A "Live and Dead end" Studio.

STUDIO ACOUSTICS

IN THE DESIGN OF BROADCAST STUDIOS, THE ACOUSTIC CONDITIONS ARE OF THE GREATEST IMPORTANCE. FROM WHAT YOU HAVE ALREADY LEARNED IN A PREVIOUS STUDY OF ACOUSTICS, YOU WILL RECALL THAT SOME WALL SURFACES REFLECT SOUND WAVES READILY WHILE OTHERS HARDLY REFLECT SOUND WAVES AT ALL. THOSE SURFACES WHICH REFLECT SOUND WAVES READILY ARE GENERALLY REFERRED TO AS "LIVE" SURFACES WHILE THOSE WHICH DO NOT REFLECT SOUND WAVES READILY ARE REFERRED TO AS "DEAD" SURFACES.

ALL OF THE INSTRUCTION WHICH HAS BEEN GIVEN YOU IN THE LESSON TITLED "ACOUSTICS" OF THE LESSON SERIES TREATING WITH AMPLIFYING SYSTEMS APPLIES TO STUDIO TECHNIQUE EQUALLY AS WELL AS IT DOES TO ACOUSTIC CONDITIONS IN GENERAL. THEREFORE, IF NECESSARY, IT IS ADVISABLE THAT YOU REVIEW YOUR LESSON ON ACOUSTICS AT THIS TIME.

IN STUDIO PRACTICE WE FIND THAT IF THE WALL SURFACES SURROUNDING THE MICROPHONE ARE TOO LIVE, THEN EXCESSIVE REVERBERATION WILL BRING ABOUT UNDESIRABLE ECHOING CONDITIONS AND CAUSE THE SOUND REPRODUCTION TO APPEAR AS THOUGH THE PROGRAM ORIGINATED IN A LARGE AND EMPTY HALL. ON THE OTHER HAND, IF THE WALL SURFACES ARE TOO DEAD, THEN THE REPRODUCTION OF MUSICAL SELECTIONS INVOLVING A LARGE VARIETY OF FREQUENCIES WILL LOOSE SOME OF ITS SPARKLING EFFECT OR BRILLIANCE AND THUS BECOME DULLER THAN IS ADVISABLE.

SO AS TO MEET ALL OF THESE EXTREME CONDITIONS SATISFACTORILY, MOST OF THE LARGER STUDIOS ARE OF THE LIVE END-DEAD END TYPE. AN EXAMPLE OF SUCH A DESIGN IS ILLUSTRATED IN FIG. 4.

IN STUDIOS OF THE LIVE END-DEAD END TYPE, ONE END OF THE STUDIO HAS ITS WALLS FINISHED WITH A HARD, SOUND-REFLECTING SURFACE, WHILE THE DEAD

END OF THE STUDIO HAS ITS WALLS FINISHED WITH A SOUND-ABSORBING MATERIAL. IN SOME CASES, THE NECESSARY SOUND REFLECTION IS OBTAINED BY USING A HARD PLASTER FINISH ON THE WALLS AND CEILING, WHEREAS THE NECESSARY SOUND ABSORBING CHARACTERISTICS CAN BE OBTAINED BY FINISHING THE WALLS AT THE OPPOSITE END OF THE STUDIO WITH ROCK WOOL AND MONK'S CLOTH.

FIG. 5
Interior of one of the Smaller Studios.

IT IS ALSO THE PRACTICE IN SOME INSTANCES TO FURNISH THIS SOUND ABSORPTION WITH A TAPERING CHARACTERISTIC. THAT IS, THE HARDEST AND BEST REFLECTING SURFACE IS PLACED AT ONE END OF THE STUDIO AND THE WALL SURFACES ARE THEN APPLIED SO THAT THEIR DEGREE OF ABSORPTION IS GRADUALLY INCREASED AS THE OPPOSITE END OF THE STUDIO IS APPROACHED — THE DEAD END OFFERING THE MAXIMUM AMOUNT OF ABSORPTION.

FOR DIFFERENT TYPES OF PROGRAMS, A VARYING AMOUNT OF SOUND REFLECTION AND ABSORPTION IS DESIRED AND TO SATISFY THESE CONDITIONS, DIFFERENT POSITIONS IN THE STUDIOS FOR THE MICROPHONES AND ARTISTS ARE TRIED UNTIL THE DESIRED EFFECT IS OBTAINED.

IT IS ALSO A COMMON PRACTICE TO FURNISH THE LARGER STUDIOS WITH SLIDING PANELS OR SCREENS MADE OF SOUND ABSORBING OR SOUND REFLECTING MATERIAL IN THE MANNER SHOWN IN FIG. 4. WITH THIS ARRANGEMENT, THE ACOUSTIC CONDITIONS OF THE STUDIO CAN BE ALTERED CONVENIENTLY SO AS TO BE BEST ADAPTED TO ANY PARTICULAR TYPE OF PROGRAM AND STUDIO SET-UP.

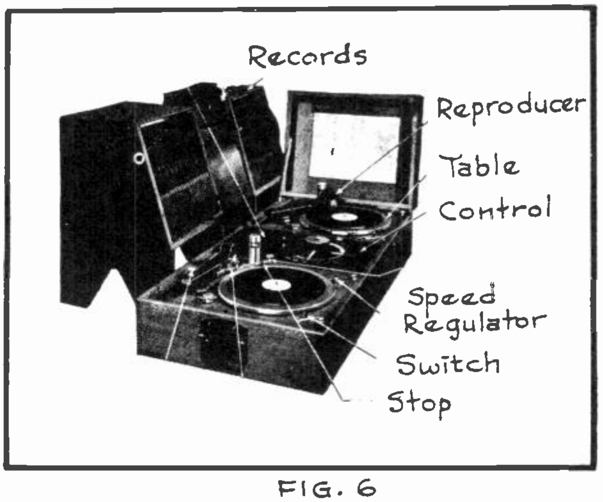


FIG. 6
A Turntable Set.

MICROPHONE PLACEMENT

ANOTHER IMPORTANT PROBLEM WITH WHICH THE STUDIO TECHNICIAN MUST COPE IS "MICROPHONE PLACEMENT". THIS CONSISTS OF PLACING THE MICROPHONE OR GROUP OF MICROPHONES IN THE MOST ADVANTAGEOUS POSITION FOR THE DESIRED PICK-UP.

IN THE CASE OF MICROPHONE

PLACEMENT, WE HAVE SOUND REFLECTION TO CONTEND WITH THE SAME AS ALREADY DESCRIBED RELATIVE TO SPEAKERS AS USED WITH SOUND AMPLIFYING EQUIPMENT. PROVIDED THAT THE SOUNDS ARE NOT COMPARABLE IN INTENSITY, THE TIME LAG BETWEEN THE ORIGINAL AND REFLECTED SOUNDS IS OF NO GREAT IMPORTANCE. HOWEVER, IF THE ORIGINAL AND REFLECTED SOUND INTENSITIES ARE COMPARABLE, THEN IT IS ADVISABLE TO MAINTAIN A SHORT TIME LAG.

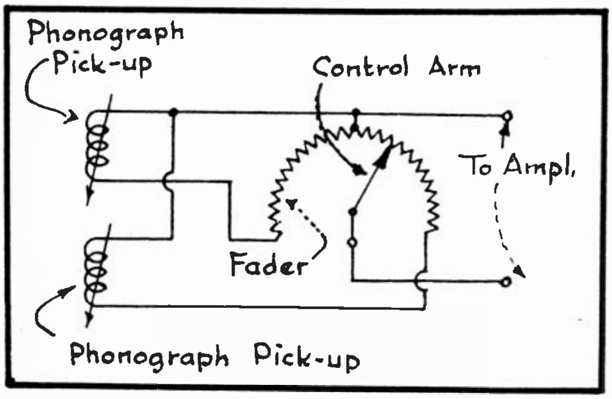


FIG. 7
The Pick-up Fader Circuit.

THE MORE LIVE THE SURROUNDINGS ABOUT THE MICROPHONE, THE SHORTER WILL BE THE TIME LAG AND THIS WILL CAUSE THE REPRODUCTION TO APPEAR AS TINNY. SHOULD THE TIME LAG BE TOO LONG, THEN THE REPRODUCTION WILL TAKE ON A HOLLOW SOUND EFFECT. WHEN A LIVE AND DEAD END STUDIO IS EMPLOYED FOR THE PRODUCTION OF A LARGE PROGRAM IT IS CUSTOMARY TO PLACE THE MICROPHONE OR MICROPHONES IN THE DEAD END OF THE STUDIO AND THE ORCHESTRA IN THE LIVE END OF THE STUDIO AS POINTED OUT IN FIG. 4.

SINCE STUDIO SET-UPS OF THIS NATURE INVOLVE INSTRUMENTS OR VOICES OF DIFFERING QUALITY AND FREQUENCY RANGE, IT IS IMPORTANT THAT THE VARIOUS INDIVIDUALS BE ARRANGED AROUND THE MICROPHONE OR MICROPHONES IN SUCH A MANNER THAT THE SOUND REPRODUCTION AS EMITTED FROM THE LOUD SPEAKER BE WELL BALANCED AND NATURAL IN EFFECT. FOR EXAMPLE, THE WAVES OF CERTAIN FREQUENCIES ARE REFLECTED MORE READILY THAN THOSE OF OTHER FREQUENCIES AND SO THAT CERTAIN SOUNDS DO NOT OVER-POWER OTHERS, THE MORE INTENSIVE SOUND PRODUCERS ARE PLACED FARTHER AWAY FROM THE MICROPHONE.

ANOTHER EFFECT THAT SOMETIMES CAUSES TROUBLE IS THAT WHEN SEVERAL MICROPHONES ARE USED TO PICK UP THE SAME PROGRAM, THE SOUNDS WHICH ARE PRIMARILY INTENDED FOR ONE MICROPHONE ALSO ACT UPON SOME OF THE OTHER MICROPHONES AT SLIGHTLY DIFFERENT TIME INTERVALS AND VOLUMES. WHEN SUCH A CONDITION EXISTS, A SORT OF ECHOING SENSATION APP

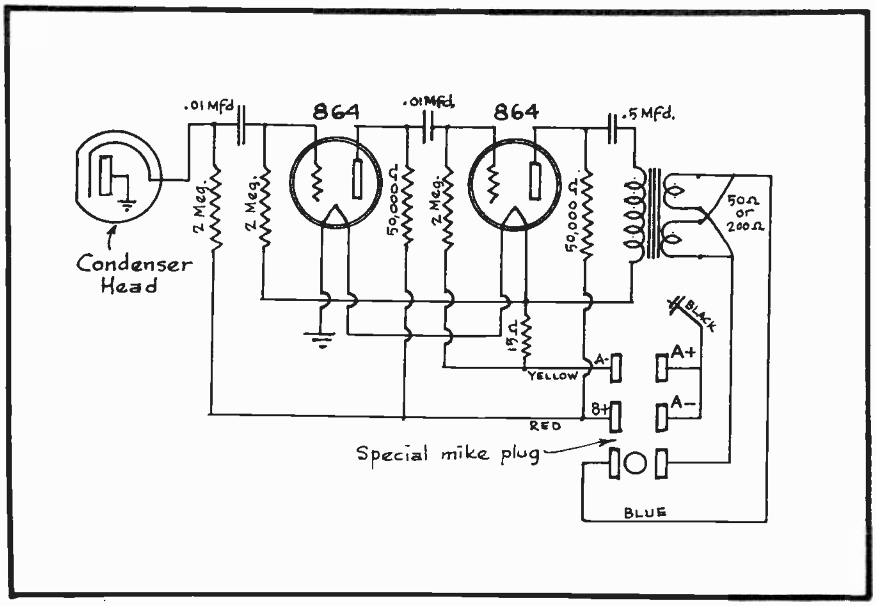


FIG. 8
The Microphone Head Amplifier.

EARS AT THE LOUDSPEAKER, SIMILAR TO THAT EXPERIENCED WHEN THE MICROPHONE IS PLACED IN HIGHLY REFLECTING SURROUNDINGS.

PROPER MICROPHONE PLACEMENT AND THE ADJUSTMENT OF ACOUSTICAL CONDITIONS FOR LARGE STUDIO PRESENTATIONS IS AN ART REQUIRING A SKILL WHICH CAN ONLY BE OBTAINED THROUGH EXTENSIVE EXPERIENCE IN THIS WORK. THIS JOB IS GENERALLY HANDLED BY WHAT ARE KNOWN AS "PRODUCTION MEN" AND WHO ARE HIGHLY SPECIALIZED IN THIS WORK. SINCE THIS IS NOT ALTOGETHER THE WORK OF THE ENGINEER, WE SHALL NOW LEAVE THIS SUBJECT AND TURN OUR ATTENTION TO THE MORE TECHNICAL DETAILS OF THE BROADCAST STATION.

MICROPHONES

THE MICROPHONES AS USED IN BROADCAST STATIONS ARE OF THE HIGHEST QUALITY AND MAY BE OF THE CARBON, CONDENSER, RIBBON, DYNAMIC, OR CRYSTAL TYPE. ALL OF THESE VARIOUS MICROPHONES WERE ALREADY DESCRIBED TO YOU IN A PREVIOUS LESSON OF THE SERIES TREATING WITH AMPLIFYING SYSTEMS AND IT IS THEREFORE NOT NECESSARY TO REPEAT THIS INFORMATION AT THE PRESENT TIME. WE MIGHT POINT OUT, HOWEVER, THAT OF ALL THE MICROPHONE TYPES AVAILABLE, THE CONDENSER AND RIBBON TYPES ARE AT THE PRESENT TIME MOST EXTENSIVELY USED FOR BROADCAST PURPOSES, ALTHOUGH THE DYNAMIC AND CRYSTAL TYPES ARE GAINING IN POPULARITY.

ELECTRICAL EQUIPMENT

BESIDES THE MICROPHONE EQUIPMENT, PROVISIONS ARE ALSO MADE IN MOST BROADCAST STATIONS FOR RELEASING ELECTRICAL TRANSCRIPTION PROGRAMS OVER THE AIR. AN ELECTRICAL TRANSCRIPTION IS A RECORDED COMMERCIAL PROGRAM AND IS EQUIVALENT TO A PHONOGRAPH RECORD OF HIGH QUALTIY.

IN ORDER TO REPRODUCE THESE RECORDINGS, THE STATION EQUIPMENT MUST INCLUDE A SET OF TURN TABLES AND PICK-UP DEVICES AND AN EXAMPLE OF WHICH APPEARS IN FIG. 6. THIS EQUIPMENT IS GENERALLY USED IN PAIRS SO THAT AS THE PROGRAM PROGRESSES AND ONE RECORD IS FINISHED, THE FOLLOWING RECORD CAN BE

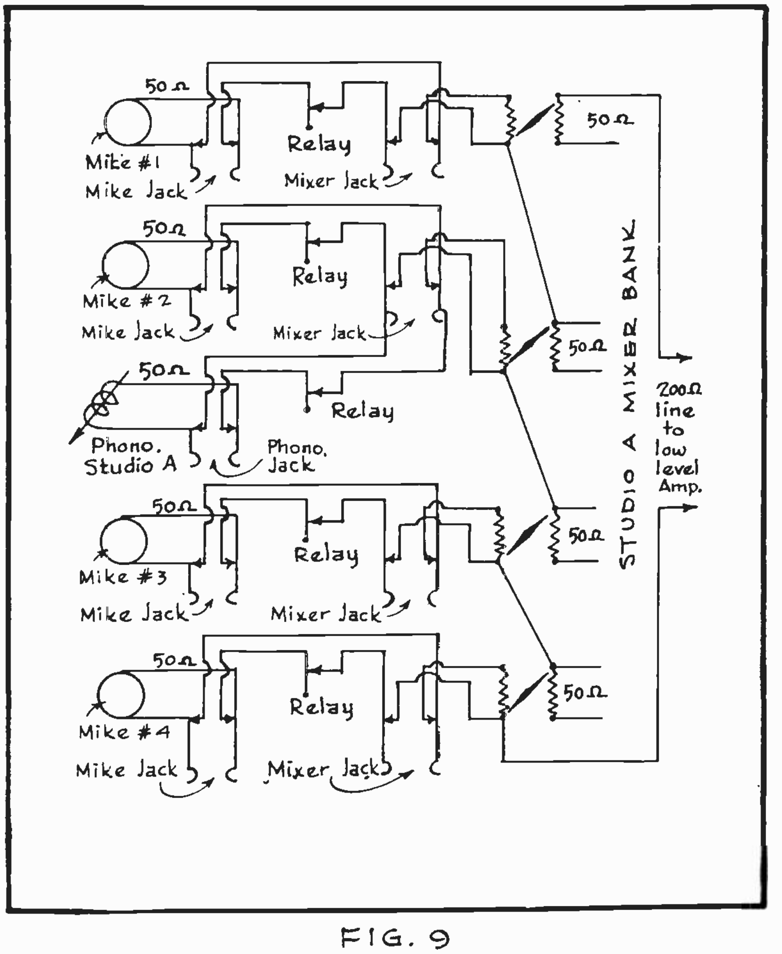


FIG. 9
The Typical Mixer Circuit.

STARTED AND BLENDED INTO THE PRECEDING ONE WITHOUT ANY NOTICEABLE INTERRUPTION. A FADER IS MOUNTED BETWEEN THESE TWO TABLES TO PERMIT THE PROPER SWITCHING OF RECORDS AND THIS CONTROL IS ILLUSTRATED IN FIG.7. THE OPERATION OF THIS FADER CIRCUIT HAS ALREADY BEEN EXPLAINED TO YOU IN A PREVIOUS LESSON TREATING WITH AMPLIFYING SYSTEMS.

TRANSCRIPTION RECORDINGS ARE MADE AT ONE OF TWO SPEEDS, NAMELY 33 R.P.M. AND 78 R.P.M. THE 78 R.P.M. RECORDS ARE GENERALLY 12" IN DIAMETER AND CAPABLE OF PLAYING FOR 5 MINUTES. THE 33 R.P.M. RECORDINGS ARE 16" IN DIAMETER AND ARE CAPABLE OF PLAYING CONTINUOUSLY FOR 15 MINUTES.

ELECTRICAL TRANSCRIPTION PROGRAMS ARE USUALLY OF SHORT DURATION, AT THE MOST LASTING FOR 15 MINUTES. THIS BEING THE CASE, A SINGLE 33 R.P.M. RECORD WILL HANDLE THE ENTIRE PROGRAM WITHOUT THE NEED OF CHANGING RECORDS.

WHEN THE STATION IS EQUIPPED WITH APPARATUS FOR THE REPRODUCTION OF ELECTRICAL TRANSCRIPTIONS, THIS SAME EQUIPMENT CAN ALSO BE USED FOR THE REPRODUCTION OF ORDINARY PHONOGRAPH RECORDINGS FOR TRANSMISSION PURPOSES.

AT THE PRESENT TIME WE SHALL NOT GO INTO DETAILS REGARDING THE PROCESSES INVOLVED IN MAKING THESE RECORDINGS IN THAT THIS IS FULLY COVERED IN LESSONS TREATING WITH SOUND PICTURES. THIS ALSO APPLIES TO THE REFINED TYPES OF PICK-UP HEADS.

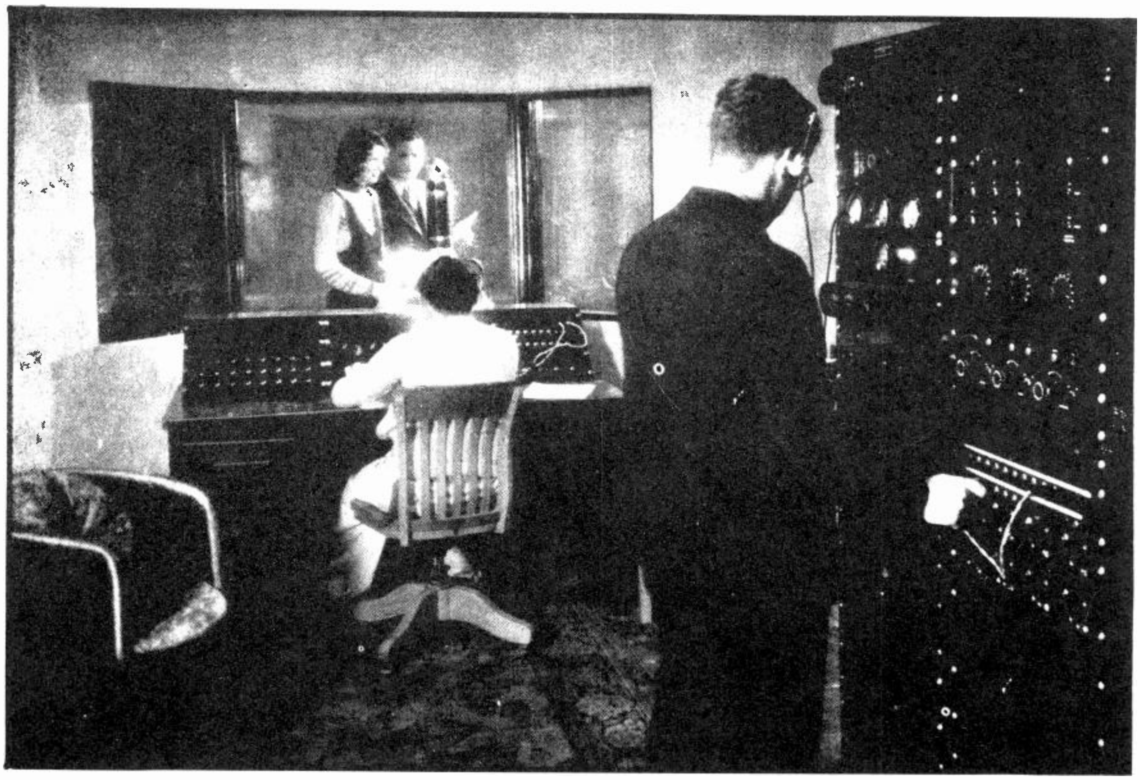


FIG. 10

National's Broadcast Control Room.

ASSUMING THAT CONDENSER MICROPHONES ARE BEING USED IN THE STUDIO, EACH OF THESE MICROPHONES WILL BE FITTED WITH A HEAD OR PRE-AMPLIFIER SIMILAR TO THAT WHICH IS ILLUSTRATED IN FIG.8. EACH OF THESE PRE-AMPLIFIERS IS FITTED WITH AN OUTPUT TRANSFORMER WHICH MATCHES THE INPUT IMPEDANCE OF THE MIXER AND THE HEAD AMPLIFIER OUTPUT OF EACH MICROPHONE IS CONNECTED TO THE MIXER THROUGH A SEPARATE CABLE AND CONDUIT WIRING SYSTEM. THE BATTERY LEADS FOR THE VARIOUS HEAD AMPLIFIERS ARE ALSO FREQUENTLY INCORPORATED INTO THE SAME MICROPHONE CABLE TOGETHER WITH THE A.F. LINE.

FOR THE HEAD AMPLIFIER WHICH IS ILLUSTRATED IN FIG.8 AND WHICH IS USED IN OUR STUDIOS, A 6 VOLT STORAGE BATTERY IS USED FOR THE "A" SUPPLY AND THREE SERIES CONNECTED 45 VOLT "B" BATTERIES FOR THE B SUPPLY. THE WIRING FROM THE CONTROL ROOM TO THE STUDIOS IS CARRIED IN CONDUIT AND THE CONNECTION BETWEEN THE VARIOUS MICROPHONE CABLES AND THE CONTROL ROOM CIRCUITS ARE COMPLETED THROUGH SPECIAL PLUG AND SOCKETS, THE ARRANGEMENT OF WHICH COINCIDES WITH THAT ILLUSTRATED IN FIG.8.

THE OUTPUTS OF THESE VARIOUS HEAD-AMPLIFIERS AND THE OUTPUT OF THE PHONOGRAPH PICK-UP CIRCUIT ARE THEN ALL CONNECTED TO THE MIXER IN SOME SUCH ARRANGEMENT AS ILLUSTRATED IN FIG.9. IT IS OF COURSE ESSENTIAL THAT ALL OF THESE COUPLING DEVICES, AS WELL AS THE MIXER CONTROLS, ALL BE PROPERLY MATCHED WITH RESPECT TO IMPEDANCE AS HAS ALREADY BEEN ADEQUATELY EXPLAINED TO YOU IN PREVIOUS LESSONS.

YOU WILL ACQUIRE A STILL CLEARER CONCEPTION OF THE ACTUAL APPEARANCE OF THE CONTROL ROOM EQUIPMENT BY REFERRING TO FIG. 10. HERE YOU ARE SHOWN A SECTION OF THE CONTROL ROOM IN OUR SCHOOL BROADCASTING STATION. THE MIXER DESK APPEARS AT THE CENTER, WITH THE OPERATOR SEATED IN FRONT OF IT AND IN SUCH A POSITION THAT HE MAY THRU SPECIALLY DESIGNED WINDOWS OBTAIN A FULL VIEW OF THE PERFORMERS IN FRONT OF THE STUDIO MICROPHONES. THE AMPLIFYING EQUIPMENT IS SHOWN AT THE RIGHT, BEING ATTENDED BY A TECHNICIAN.

IN FIG. 11 YOU ARE SHOWN THE MIXER PANEL REMOVED FROM ITS MOUNTING AS TESTS ARE BEING CONDUCTED BY A STUDENT. THIS WILL SERVE TO FAMILIARIZE YOU WITH THE GENERAL APPEARANCE OF THE INTERNAL CONSTRUCTION AND WIRING OF THIS ASSEMBLY.

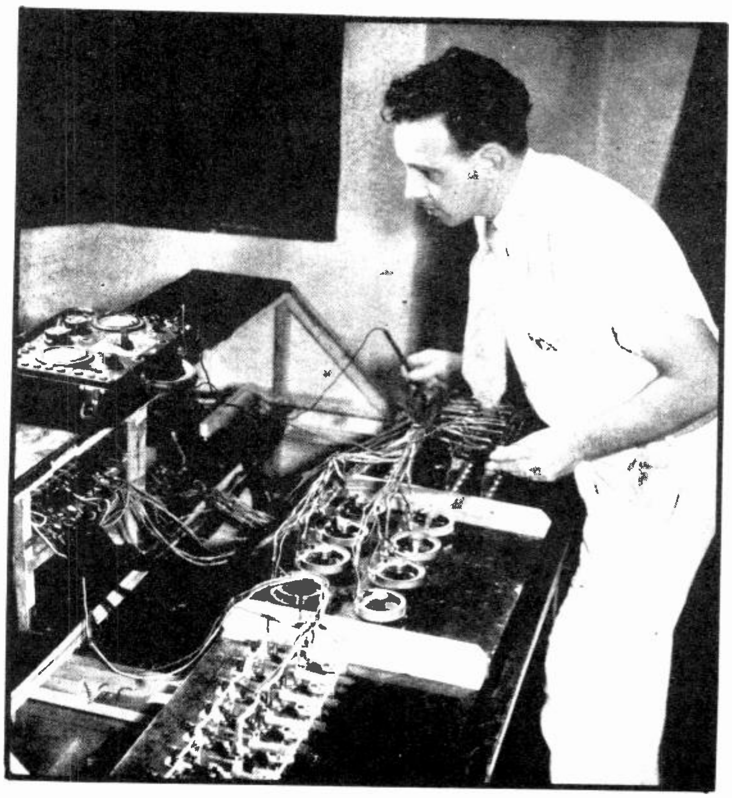


FIG. II
Testing the Mixer in the Broadcast Control Room.

BY AGAIN REFERRING TO FIG.9 YOU WILL NOTE THAT THE 50 OHM LINE FROM EACH OF THE MICROPHONES AND THE PHONOGRAPH PICK-UP UNITS FEED THROUGH A SYSTEM OF JACKS AND RELAYS TO THE INPUTS OF THE VARIOUS L-PAD VOLUME CONTROLS. THESE VARIOUS JACKS, RELAYS, AND VOLUME CONTROLS CONSTITUTE A PART OF THE MIXER PANEL.

THE LOW-LEVEL AMPLIFIER

THE OUTPUT OF THE MIXER FEEDS INTO THE INPUT OF THE LOW LEVEL AMPLIFIER THROUGH A 200 OHM LINE. A CIRCUIT DIAGRAM OF THE LOW LEVEL AMPLIFIER IS SHOWN IN FIG.12. THIS LOW LEVEL AMPLIFIER CONSISTS OF THREE STAGES EMPLOYING TYPE 112A TUBES. IN THE GRID CIRCUIT OF THE SECOND STAGE OF THIS LOW LEVEL AMPLIFIER IS LOCATED A GAIN OR VOLUME CONTROL BY MEANS OF WHICH THE OVER-ALL GAIN OF THIS AMPLIFIER CAN BE CONTROLLED. LOW LEVEL OR LOW GAIN AMPLIFIERS AS THIS MAKE IT POSSIBLE TO AMPLIFY THE AUDIO FREQUENCY ENERGY IN A MOST STABLE MANNER. THAT IS TO SAY, THIS SYSTEM IS NOT NEARLY SO SUSCEPTIBLE TO FEED-BACK TROUBLES AND OSCILLATION AS ARE AMPLIFIERS OF HIGH GAIN PER STAGE. YOU WILL ALSO OBSERVE IN FIG.12 THAT JACKS ARE FURNISHED SO THAT THE PLATE AND FILAMENT CURRENT IN THE VARIOUS STAGES OF THIS AMPLIFIER CAN BE MEASURED WITH A MINIMUM OF EFFORT.

THE FILAMENT CIRCUIT OF THE LOW LEVEL AMPLIFIER IS CONNECTED ACROSS A 6 VOLT STORAGE BATTERY, WHILE THE B SUPPLY FOR THIS SAME AMPLIFIER IS OBTAINED FROM THE SAME B POWER SUPPLY AS THAT USED FOR THE HIGH LEVEL AMPLIFIER. THE USE OF A BATTERY FILAMENT SUPPLY IN ALL OF THESE LOW LEVEL STAGES REDUCES THE POSSIBILITY OF HUM PICK-UP TO A MINIMUM. THIS IS IMPORTANT IN THAT ANY HUM OR OTHER EXTRANEOUS NOISE WHICH ORIGINATES IN THE LOW LEVEL AMPLIFIER, OR OTHER INPUT EQUIPMENT, WILL BE GREATLY MAGNIFIED BY THE TIME IT IS PASSED THROUGH THE FOLLOWING SECTIONS OF THE EQUIPMENT

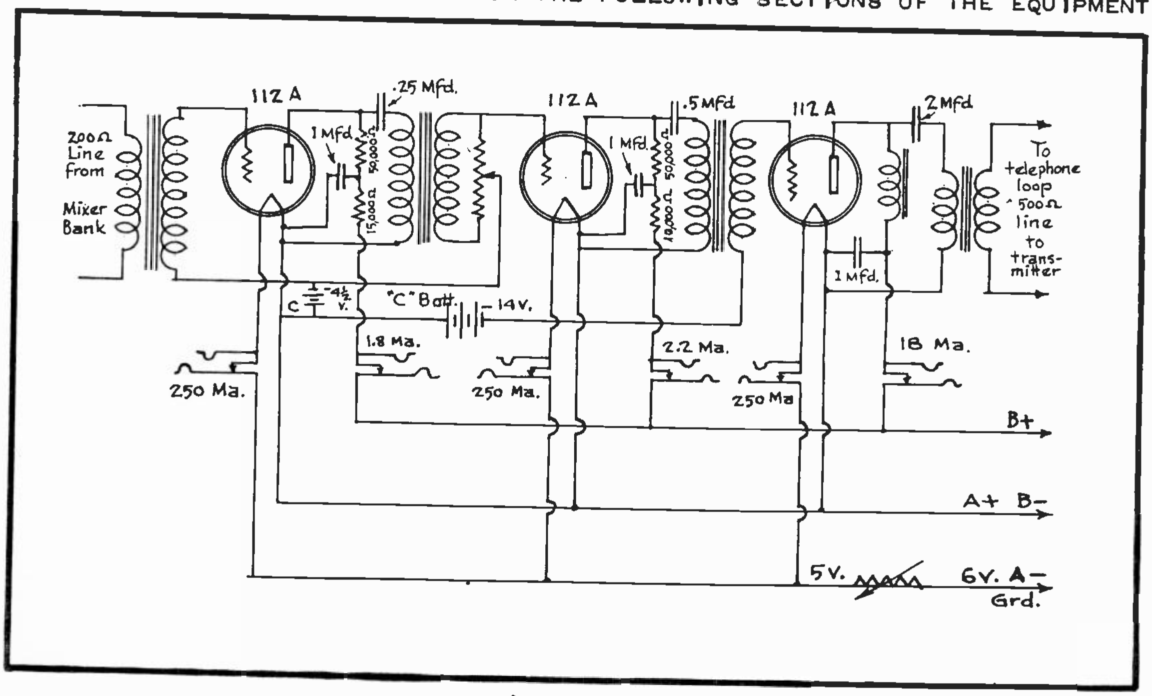


FIG. 12
The Low-level Amplifier.

IT IS ALSO A COMMON PRACTICE TO MOUNT THE TUBES OF THE LOW LEVEL AMPLIFIER IN RUBBER CUSHIONED SOCKETS AND FREQUENTLY TO PROVIDE A COVERING OVER THESE TUBES SO AS TO GUARD AGAINST ANY POSSIBLE CONDITION OF MICROPHONISM.

THE HIGH-LEVEL AMPLIFIER

THE OUTPUT OF THE LOW LEVEL AMPLIFIER IN FIG.12 IS SO ARRANGED THAT IT MAY BE CONNECTED THROUGH A 500 OHM TRANSMISSION LINE TO THE INPUT OF THE A.F. AMPLIFYING EQUIPMENT WHICH IS LOCATED UPSTAIRS IN THE TRANSMITTER ROOM. THIS SAME OUTPUT IS ALSO SO ARRANGED THAT IT CAN BE FED INTO THE SPECIAL TELEPHONE LINE LEADING TO ONE OF THE MAJOR BROADCASTING STATIONS OF LOS ANGELES FOR THE RELEASE OF SPECIAL PROGRAMS. THE THIRD POSSIBILITY

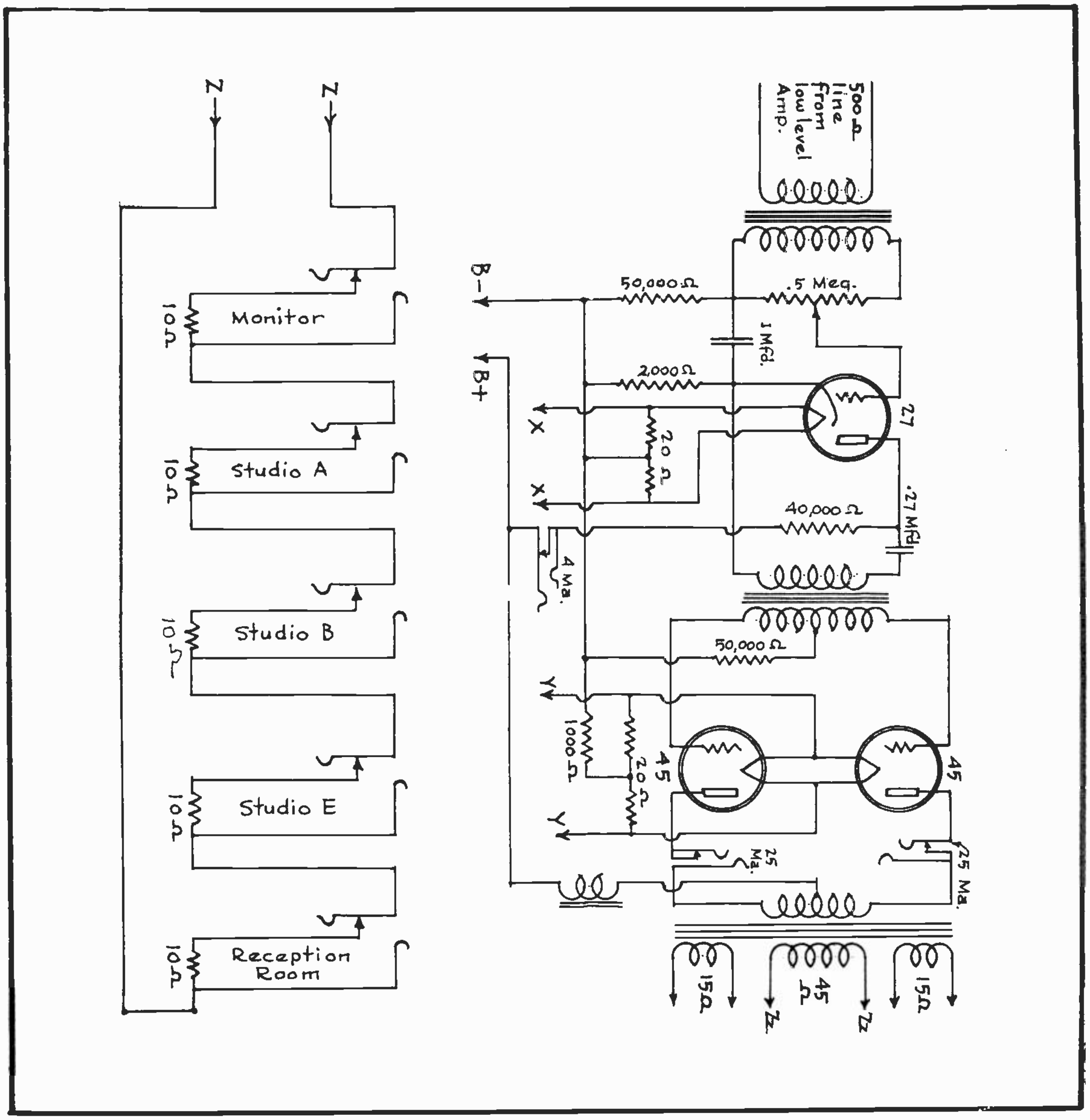


FIG. 13
The High-Level Amplifier.

IS TO CONNECT THE OUTPUT OF THE LOW LEVEL AMPLIFIER TO THE INPUT OF THE HIGH LEVEL AMPLIFIER WHICH IS ALSO INCLUDED IN THE STUDIO CONTROL ROOM. THIS INTER-AMPLIFIER CONNECTION IS MADE THROUGH A 500 OHM LINE.

THE CIRCUIT DIAGRAM OF THE HIGH LEVEL AMPLIFIER IS SHOWN IN FIG. 13 AND THIS UNIT, YOU WILL OBSERVE, CONSISTS OF ONE STAGE EMPLOYING A 27 TUBE AND WHICH IS FOLLOWED BY A PUSH-PULL STAGE IN WHICH A PAIR OF 45'S ARE EMPLOYED. THE INPUT OF THIS HIGH LEVEL AMPLIFIER IS ALSO EQUIPPED WITH A MASTER GAIN CONTROL. THE AUDIO TRANSFORMERS WHICH ARE HERE USED ARE OF THE BEST QUALITY TO INSURE GOOD PERFORMANCE.

ALSO NOTICE IN FIG. 13 THE EXTENSIVE USE OF JACKS FOR THE INSERTION OF A MILLIAMMETER FOR TAKING CURRENT READINGS. YOU WILL ALSO OBSERVE IN THIS SAME ILLUSTRATION THAT PROVISIONS ARE MADE FOR CONNECTING THE VOICE COILS OF FIVE DIFFERENT DYNAMIC SPEAKERS TO THE OUTPUT OF THE HIGH LEVEL AMPLIFIER. THE MONITOR SPEAKER IS MOUNTED IN THE CONTROL ROOM SO AS TO OFFER A MEANS OF CHECKING UP ON THE REPRODUCTION OF THE PROGRAM. ANOTHER SPEAKER IS PLACED IN THE RECEPTION ROOM AND ONE SPEAKER IN EACH OF THE THREE SMALLER STUDIOS. ALL OF THESE SPEAKERS ARE CONNECTED IN SERIES.

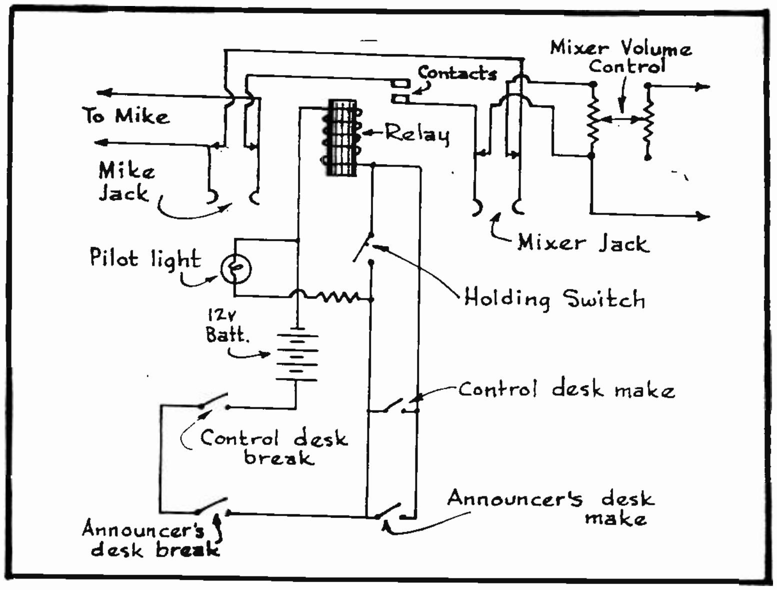


FIG. 14

Details of Microphone Control Circuit.

THE 10 OHM RESISTORS WHICH ARE CONNECTED ACROSS EACH OF THE SPEAKER JACKS ARE CONNECTED IN SERIES WHEN THE SPEAKERS ARE NOT IN USE BUT EACH OF THEM IS AUTOMATICALLY DISCONNECTED FROM THE CIRCUIT AT THE TIME THE SPEAKER IS PLUGGED INTO THE SAME JACK. THIS ARRANGEMENT PERMITS THE SPEAKER CIRCUIT TO MAINTAIN A PRACTICALLY CONSTANT IMPEDANCE VALUE REGARDLESS OF THE NUMBER OF SPEAKERS USED AT ANY ONE TIME. THE SPEAKER FIELDS ARE ENERGIZED BY A 12 VOLT STORAGE BATTERY.

ALTHOUGH THE OUTPUT OF THIS HIGH LEVEL AMPLIFIER ISN'T OF ANY VERY GREAT VALUE, YET IT IS SUFFICIENT FOR THE USE TO WHICH IT IS BEING SUBJECTED. FURTHERMORE, IT IS TO BE REMEMBERED THAT THE GREATER AMOUNT OF AUDIO FREQUENCY AMPLIFICATION OCCURS IN THE MORE POWERFUL AUDIO AMPLIFYING SYSTEM WHICH IS LOCATED IN THE TRANSMITTER ROOM. ALL OF THE AMPLIFYING EQUIPMENT THROUGHOUT IS BUILT ACCORDING TO A RACK AND PANEL DESIGN AS WILL BE APPARENT FROM AN INSPECTION OF FIG. 10, AND WHICH IS THE STANDARD PRACTICE IN ALL BROADCASTING STATIONS.

NATURALLY, YOU WILL NOT FIND THE SAME AMPLIFIER CIRCUITS AS THOSE ILLUSTRATED IN THIS LESSON TO BE USED IN THE CONTROL ROOM OF EVERY STA-

TION. THESE CIRCUITS, YOU WILL REALIZE, MAY VARY CONSIDERABLY AND FOLLOW ANY OF THE VARIETY OF AUDIO AMPLIFIER CIRCUITS WHICH WERE EXPLAINED TO YOU IN PREVIOUS LESSONS. NEVERTHELESS, THE CIRCUITS WHICH ARE PRESENTED TO YOU IN THIS LESSON ARE TYPICAL OF THIS EQUIPMENT.

A BATTERY CHARGER OF THE TUNGAR BULB TYPE IS ALSO USED AS A PART OF THIS CONTROL ROOM EQUIPMENT AND A SWITCH IS PROVIDED IN THE STORAGE BATTERY CIRCUIT SO THAT THESE BATTERIES CAN BE CONVENIENTLY CONNECTED TO THE CHARGER WHENEVER NECESSARY.

THE RELAY SYSTEM

IN FIG. 14 YOU ARE SHOWN IN A MORE DETAILED FORM THE MICROPHONE CONTROL CIRCUIT AND IN WHICH THE APPLICATION OF THE RELAY SYSTEM IS MORE CLEARLY ILLUSTRATED.

AS YOU WILL OBSERVE IN THIS DIAGRAM, THE MICROPHONE CIRCUIT THROUGH THE MIKE JACK, RELAY CONTACTS, MIXER JACK, AND MIXER VOLUME CONTROL CORRESPONDS TO THIS SAME SECTION OF THE CIRCUIT IN THE COMPLETE MIXER SYSTEM WHICH APPEARS IN FIG. 9 OF THIS LESSON.

IN ADDITION, YOU WILL SEE IN FIG. 14 HOW THE WINDING OF THE RELAY IS CONNECTED IN SERIES WITH A 12-VOLT STORAGE BATTERY THROUGH A SERIES OF SWITCHES SO THAT THE MICROPHONE CAN BE CUT IN OR OUT OF THE CIRCUIT BY OPERATING SWITCHES WHICH ARE LOCATED EITHER AT THE CONTROL DESK OR AT THE ANNOUNCER'S DESK. A SMALL PILOT LIGHT, MOUNTED BEHIND A RED GLASS BULLS'-EYE ON THE PANEL OF THE CONTROL DESK, LIGHTS UP WHENEVER THIS MICROPHONE IS IN USE AND IN SOME INSTANCES A SIMILAR SIGNAL LIGHT IS LOCATED AT THE ANNOUNCER'S DESK.

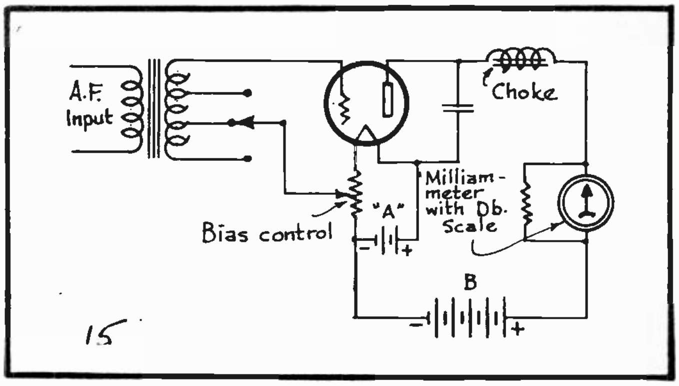


FIG. 15
Application of the V.T. Voltmeter as a Volume Indicator.

VOLUME INDICATORS

IN ORDER SO THAT THE CONTROL ROOM OPERATOR MAY KNOW AT ALL TIMES THE EXACT PROGRAM LEVEL, A METER CALIBRATED IN DECIBELS IS MOUNTED ON THE CONTROL DESK DIRECTLY IN FRONT OF THE OPERATOR. THERE ARE VARIOUS WAYS IN WHICH THIS PROGRAM LEVEL CAN BE ASCERTAINED AND ONE METHOD IS ILLUSTRATED IN FIG. 15. BY REFERRING TO FIG. 15 YOU WILL OBSERVE HOW THE PRINCIPLES OF A VACUUM TUBE VOLTMETER CAN BE USED FOR THIS PURPOSE, WITH THE EXCEPTION THAT THE CUSTOMARY MILLIAMMETER SCALE IN THIS CASE IS REPLACED WITH A SCALE WHICH IS CALIBRATED IN DECIBELS. FROM WHAT YOU HAVE ALREADY LEARNED ABOUT VACUUM TUBE VOLTMETERS, YOU ARE FAMILIAR WITH THEIR PRINCIPLE OF OPERATION AND ALSO REALIZE THAT VERY LITTLE ENERGY IS TAKEN FROM THE CIRCUIT UNDER TEST IN ORDER TO ACTUATE THE INDICATOR.

A POPULAR METHOD OF CONNECTING SUCH A DB. METER TO THE EQUIPMENT IS

IS TO CONNECT IT ACROSS THE 500 OHM LINE BETWEEN THE HIGH AND LOW LEVEL AMPLIFIER. THE INPUT TRANSFORMER OF THE UNIT ILLUSTRATED IN FIG.15 IS TAPPED AND PROVIDED WITH A SWITCH SO THAT THE INSTRUMENT CAN BE MADE TO READ DIFFERENT INPUT LEVELS. THE ARM POSITIONS ARE IN THIS CASE ALSO MARKED IN DECIBELS AND THE ACTUAL DB. LEVEL IS EQUAL TO THE ALGEBRAIC SUM OF THE DB. INDICATION ON THE SWITCH AND THE DB. READING ON THE METER.

THE POINT OF ZERO DB. ON THE METER SCALE IS SOMEWHERES NEAR THE CENTER OF THE SCALE AND THE POINTS IMMEDIATELY BELOW AND ABOVE IT ARE MARKED IN POSITIVE AND NEGATIVE VALUES.

A STILL DIFFERENT TYPE OF DB. VOLUME INDICATOR CONSISTS OF A MILLIAMMETER MOVEMENT WHICH IS FITTED WITH A COPPER-OXIDE RECTIFIER SO AS TO BE SUITABLE FOR TAKING A.C. MEASUREMENTS. THIS LATTER TYPE OF VOLUME INDICATOR IS USED A GREAT DEAL SINCE IT IS NOT AS EXPENSIVE AS THE V.T. VOLTMETER TYPE, REQUIRES NO AUXILIARY EQUIPMENT, AND CAN THEREFORE BE CONSTRUCTED IN A MORE COMPACT FORM AND AT THE SAME TIME IS CONVENIENT TO USE.

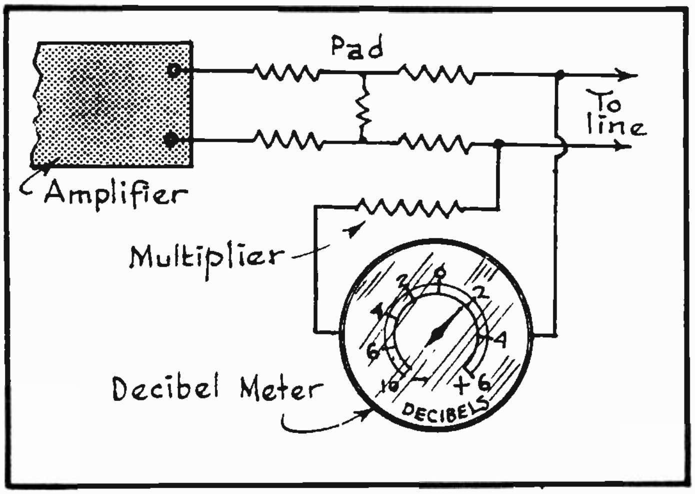


FIG 16
Application of the D.B. Meter.

WHEN USING THE COPPER OXIDE TYPE METER, MULTIPLIER'S ARE GENERALLY CONNECTED IN SERIES WITH THE METER AND THE AMPLIFIER LINE ACROSS WHICH THE METER IS CONNECTED. THE INSTRUMENT THEN FUNCTIONS AS A PEAK-READING VOLTMETER, ONLY THAT THE SCALE IS CALIBRATED IN DECIBELS. WITH THIS ARRANGEMENT, THE IMPEDANCE OF THE METER CIRCUIT IS SUFFICIENTLY HIGH SO THAT WHEN CONNECTED ACROSS THE A.F. LINE, IT DOES NOT NOTICEABLY AFFECT THE PROGRAM LEVEL.

ALTHOUGH IT IS A RATHER COMMON PRACTICE TO CONNECT THE VOLUME INDICATOR DIRECTLY ACROSS THE A.F. LINE WITH ADEQUATE RESISTANCE IN SEREIS SO AS TO PREVENT THE INSTRUMENT FROM ABSORBING A PROHIBITIVE AMOUNT OF ENERGY, YET THIS METHOD OFFERS A DISADVANTAGE IN THAT THE METER READING IS AFFECTED BY CHANGES IN THE FREQUENCY HANDLED BY THE LINE.

TO OVERCOME THIS, THE VOLUME INDICATOR IS FREQUENTLY CONNECTED ACROSS THE OUTPUT END OF A PAD WHICH IS INSTALLED BETWEEN THE OUTPUT OF THE AMPLIFIER AND THE LINE AS ILLUSTRATED IN FIG.16. IN THIS MANNER, THE IMPEDANCE ACROSS THE METER CIRCUIT IS KEPT PRACTICALLY CONSTANT AT ALL FREQUENCIES AND THEREFORE RESULTS IN A MORE ACCURATE INDICATION.

IT IS ALSO POSSIBLE TO CONNECT THE VOLUME INDICATOR ACROSS THE INPUT END OF THE PAD BUT WHEN THIS IS DONE, THE METER READING WILL BE

HIGHER THAN THE ACTUAL LINE LEVEL BY THE VALUE OF THE PAD.

DUPLICATE EQUIPMENT

IN ORDER TO PREVENT A LENGTHY INTERRUPTION IN A BROADCAST PROGRAM IN CASE OF THE FAILURE OF ONE OF THE UNITS, IT HAS BECOME THE PRACTICE TO DUPLICATE STATION EQUIPMENT. FOR EXAMPLE, IN FIG. 17 YOU ARE SHOWN IN DIAGRAM FORM A SERIES OF STUDIO AMPLIFIERS WHICH ARE CONNECTED TOGETHER THROUGH JACKS. THUS IT BECOMES OBVIOUS THAT IF AMPLIFIER #2 SHOULD SUDDENLY BECOME INOPERATIVE WHILE A PROGRAM IS IN PROGRESS, IT IS ONLY NECESSARY TO CONNECT AMPLIFIER #1 TO AMPLIFIER #3 DIRECT BY MEANS OF PATCH CORDS AND THUS ELIMINATE AMPLIFIER #1 ENTIRELY. THE GAIN OF THE

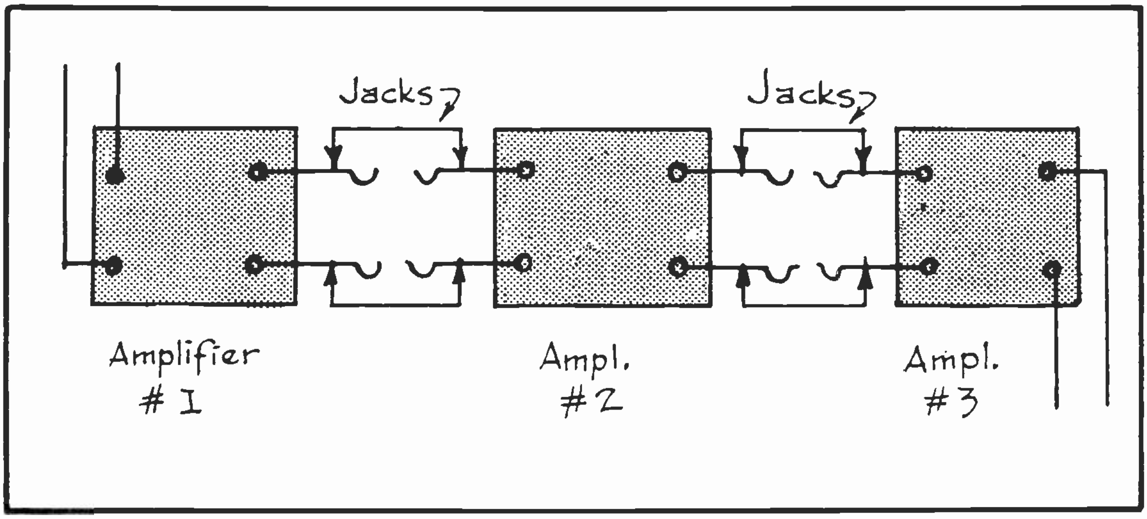


FIG. 17
Jack Connection of Amplifiers.

AMPLIFIERS IN USE CAN THEN BE TURNED UP TO A HIGHER LEVEL TO MAKE UP FOR THE LOSS OF AMPLIFIER #2. (A PATCH CORD IS NOTHING MORE THAN A FLEXIBLE INSULATED WIRE WITH A JACK PLUG ATTACHED TO EACH OF ITS ENDS).

FROM THIS LESSON YOU WILL HAVE OBTAINED A GOOD UNDERSTANDING OF THE EQUIPMENT WHICH IS RELATED TO THE BROADCAST STUDIO. IN THE NEXT LESSON, YOU WILL CONTINUE YOUR STUDY OF BROADCAST STATIONS BY LEARNING ABOUT ALL OF THAT EQUIPMENT WHICH IS LOCATED BETWEEN THE CONTROL ROOM APPARATUS AND THE ANTENNA SYSTEM. THIS WILL INCLUDE EQUALIZERS, BROADCAST TRANSMITTERS, SPEECH INPUT EQUIPMENT AND ALL OTHER APPARATUS WHICH IS DIRECTLY RELATED TO THE TRANSMITTER SECTION OF THE BROADCAST STATION.

Examination Questions

LESSON NO. T-17

Cooperation is the foundation upon which every successful business is built. To SUCCEED - COOPERATE!

answer June 1, 19(4)

1. - WHAT EQUIPMENT IS GENERALLY INCLUDED IN A TYPICAL STUDIO CONTROL ROOM?

2. - DRAW A FLOOR PLAN OF THE STUDIOS AND CONTROL ROOM OF A TYPICAL BROADCAST STATION AND LABEL CLEARLY THE VARIOUS SECTIONS OF THE SYSTEM.

3. - WHAT IS MEANT BY A LIVE END-DEAD END STUDIO?

4. - WHAT ARE SOME OF THE MORE IMPORTANT THINGS TO BE CONSIDERED WITH RESPECT TO MICROPHONE PLACEMENT IN A BROADCAST STUDIO?

5. - DESCRIBE A MIXER AS USED WITH RADIO BROADCASTING?

6. - DESCRIBE A LOW-LEVEL AMPLIFIER AND MENTION SOME OF THE MORE IMPORTANT REASONS FOR ITS USE IN CONNECTION WITH RADIO BROADCASTING.

7. - NAME SOME OF THE VARIOUS MATERIALS WHICH ARE USED FORTHE THE ACOUSTIC TREATMENT OF BROADCAST STUDIOS.

8. - DESCRIBE A TYPICAL VOLUME INDICATOR AND EXPLAIN HOW IT MAY BE USED IN RADIO BROADCASTING.

9. - WHAT IS MEANT BY AN ELECTRICAL TRANSCRIPTION AND WHAT EQUIPMENT IS REQUIRED IN THE BROADCAST STATION IN ORDER TO PRESENT PROGRAMS OF THIS TYPE?

10. - DRAW A COMPLETE CIRCUIT DIAGRAM OF ALL THE EQUIPMENT USED IN THE STUDIOS AND CONTROL ROOM OF A TYPICAL BROADCAST STATION AND ALSO SHOW HOW THESE VARIOUS UNITS ARE ALL CONNECTED TOGETHER FROM THE MICROPHONES UP TO THE LINES LEADING TO THE TRANSMITTER ROOM.

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO. 18

• BROADCAST TRANSMITTERS •

IN THE PREVIOUS LESSON YOU LEARNED ABOUT THE CONTROL ROOM EQUIPMENT AS USED IN THE TYPICAL BROADCAST STATION, AND SHOULD NOW BE THOROUGHLY FAMILIAR WITH THE MANNER IN WHICH THE AUDIBLE SIGNALS ARE HANDLED FROM THE TIME THEY ORIGINATE IN THE MICROPHONE CIRCUIT UNTIL THEY FINALLY REACH THE CIRCUIT WHICH LEADS FROM THE CONTROL ROOM TO THE TRANSMITTER. THE NEXT LOGICAL STEP, THEREFORE, IS TO LEARN HOW THESE SAME SIGNALS ARE PASSED THROUGH THE TRANSMITTER CIRCUITS PREPARATORY TO THE RADIATION OF THE MODULATED CARRIER WAVE.

AS YOU HAVE ALREADY LEARNED, THE OUTPUT OF THE STUDIO CONTROL ROOM AMPLIFIER IS GENERALLY CONNECTED TO THE INPUT END OF THE TRANSMITTER EQUIPMENT THROUGH A TRANSMISSION LINE AS ILLUSTRATED IN FIG.1. A TELEPHONE LINE IS ALSO CONNECTED BETWEEN THESE TWO LOCATIONS SO THAT THE OPERATORS CAN COMMUNICATE WITH EACHOTHER WHENEVER NECESSARY. THE LENGTH OF THIS TRANSMISSION LINE WILL NATURALLY VARY ACCORDING TO THE LAYOUT OF THE STATION IN QUESTION -- IN SOME OF THE SMALLER STATIONS THE LENGTH OF THIS LINE MAY ONLY AMOUNT TO A FEW FEET WHILE IN THE CASE OF REMOTE STUDIOS, THIS TRANSMISSION LINE MAY BE SEVERAL MILES IN LENGTH.

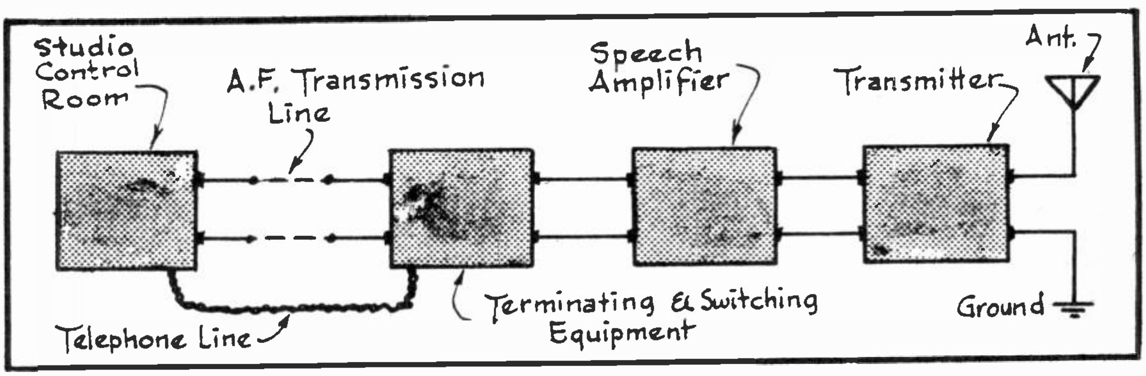


FIG. 1
Arrangement of Broadcast Transmitter Equipment.

EQUALIZERS

LONG TRANSMISSION LINES HAVE A NATURAL CHARACTERISTIC OF PRODUCING A LOSS OF THE HIGHER FREQUENCIES DUE TO THE CAPACITY EFFECT BETWEEN THE CONDUCTORS OF SUCH LINES. IF SUCH A CONDITION WERE PERMITTED TO EXIST, THE LOWER AUDIO FREQUENCIES WOULD BE TOO STRONG IN PROPORTION TO THE HIGHER FREQUENCIES AND THEREBY RESULT IN THE REPRODUCTION OF A PROGRAM WHICH IS NOT IDENTICAL IN QUALITY TO THE ORIGINAL SOUNDS AS PRODUCED IN THE STUDIO. TO OVERCOME THIS DIFFICULTY, EQUALIZERS ARE INSERTED IN THE TRANSMISSION LINE.

IN FIG.2 YOU ARE SHOWN HOW A PARALLEL-RESONANCE EQUALIZER MAY BE INSTALLED IN A TRANSMISSION LINE. THIS EQUALIZER CONSISTS OF A CONDENSER C CONNECTED ACROSS THE ENDS OF AN INDUCTANCE L TO FORM A RESONANT CIRCUIT. THIS RESONANT CIRCUIT IS THEN CONNECTED ACROSS THE TRANSMISSION LINE WITH A VARIABLE RESISTANCE R IN SERIES. AS YOU WILL READILY REALIZE WE HAVE HERE A PARALLEL-RESONANCE CIRCUIT.

TO BETTER ILLUSTRATE THE EFFECT OF THIS EQUALIZER, LET US ASSUME THAT THE NATURAL CHARACTERISTIC OF A CERTAIN TRANSMISSION LINE IS SUCH THAT MOST OF THE FREQUENCIES ABOVE 6000 CYCLES ARE ATTENUATED DUE TO THE DISTRIBUTED CAPACITY BETWEEN THE WIRES OF THE LINES. NOW IF THE PARALLEL-RESONANCE EQUALIZER OF FIG.2 WERE ADJUSTED TO RESONATE AT 6000 CYCLES AND CONNECTED ACROSS THE LINE AS SHOWN IN FIG. 2, IT WILL OFFER A MAXIMUM IMPEDANCE TO ENERGY OF THIS FREQUENCY AND CONSEQUENTLY VERY LITTLE ENERGY AT THE HIGHER FREQUENCIES WILL BE LOST THROUGH THIS CIRCUIT. IN OTHER WORDS, THE FEEBLE ENERGY ORDINARILY DEVELOPED ACROSS IT AT THE 6000 CYCLE FREQUENCY WILL BE INCREASED BY THE E.M.F. DEVELOPED ACROSS THIS HIGH IMPEDANCE.

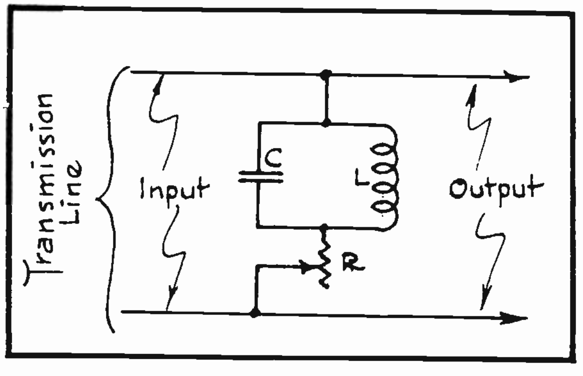


FIG. 2
A Parallel-Resonance Equalizer.

FREQUENCIES BELOW THE RESONANT FREQUENCY OF THIS EQUALIZER WILL BE BY-PASSED THROUGH THIS CIRCUIT AND THUS SHUNTED ACROSS THE LINE. THE FARTHER THAT THE FREQUENCY IN QUESTION IS REMOVED FROM THE RESONANT FREQUENCY, THE GREATER WILL BE THE SHUNTING EFFECT AND THIS CAN TO A CERTAIN EXTENT BE CONTROLLED BY THE VALUE OF THE RESISTANCE USED AT R IN FIG.2.

THUS IT CAN BE SEEN THAT BY INCREASING THE TRANSMISSION OF ENERGY AT THE HIGHER FREQUENCIES AND REDUCING IT AT THE LOWER FREQUENCIES, THE OVERALL FREQUENCY CHARACTERISTIC OF THE LINE WILL BECOME MORE UNIFORM.

A SERIES-RESONANCE EQUALIZER IS ILLUSTRATED IN FIG.3. HERE A CONDENSER, INDUCTANCE, AND RESISTANCE ARE ALL CONNECTED IN SERIES AND TOGETHER CONNECTED ACROSS THE TRANSMISSION LINE. THE SERIES-RESONANCE EQUALIZER FUNCTIONS IN JUST THE REVERSE MANNER AS THE PARALLEL- RESONANCE UNIT IN THAT IT OFFERS A MINIMUM IMPEDANCE TO THE FREQUENCY AT WHICH IT RESONATES. THIS BEING TRUE, IT CAN BE SEEN THAT THE SERIES-RESONANCE EQUALIZER OPERATES AS A LOW IMPEDANCE OR ATTENUATING DEVICE.

THE CHARACTERISTICS OF THE SERIES-RESONANCE EQUALIZER BEST ADAPT IT AS A MEANS FOR ATTENUATING SOME LOWER FREQUENCY WHICH IS TOO STRONG IN RELATION TO ALL OF THE OTHER FREQUENCIES BEING HANDLED AND THEREFORE PREDOMINATES TO AN OBJECTIONABLE EXTENT. THUS THE SERIES-RESONANCE EQUALIZER ALSO MAKES THE FREQUENCY CHARACTERISTIC OF THE TRANSMISSION LINE MORE UNIFORM.

ALTHOUGH IT IS POSSIBLE TO PLACE THE EQUALIZER AT ANY POINT OF THE TRANSMISSION LINE, YET IT IS PERFERABLE TO PLACE IT AT THE OUTPUT END, THAT IS, THE END OF THE LINE WHICH IS CONNECTED TO THE TRANSMITTER EQUIPMENT. THIS LOCATION OF THE EQUALIZER PERMITS THE NECESSARY ADJUSTMENT TO BE MADE AT THAT POINT OF THE SYSTEM WHERE THE QUALITY OF TRANSMISSION IS MOST IMPORTANT AND WHERE IT IS ACTUALLY JUDGED. THIS SAME ARRANGEMENT IS ALSO MORE EFFECTIVE IN ATTENUATING ANY NOISE WHICH MAY BE PICKED UP BY THE LINE.

THE FREQUENCY RUN

IN ORDER TO DETERMINE THE FREQUENCY CHARACTERISTIC OF A TRANSMISSION LINE, A TEST IS MADE AND WHICH IS COMMONLY CALLED A FREQUENCY RUN. A TYPICAL SET-UP FOR A TRANSMISSION LINE FREQUENCY RUN IS ILLUSTRATED IN FIG.4.

BY STUDYING FIG.4 CAREFULLY YOU WILL NOTE THAT AT THE INPUT END OF THE LINE WE HAVE EITHER A PHONOGRAPH PICK-UP OR ELSE AN AUDIO OSCILLATOR WORKING INTO AN AMPLIFIER AND THIS AMPLIFIER IS IN TURN CONNECTED TO THE TRANSMISSION LINE THROUGH A PAD. IN THE EVENT THAT A PHONOGRAPH INPUT IS USED FOR THIS TEST, SPECIAL "FREQUENCY RECORDS" ARE EMPLOYED. RECORDS OF THIS TYPE ARE MADE SPECIFICALLY FOR TESTING PURPOSES AND WILL FURNISH A VARIETY OF KNOWN TONES OR FREQUENCIES. THE AUDIO OSCILLATOR YOU ARE ALREADY FAMILIAR WITH.

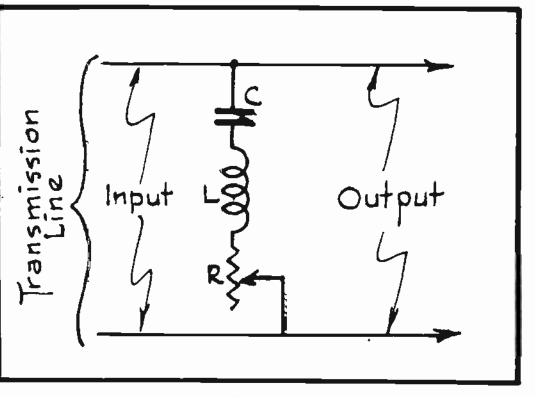


FIG.3
A Series-Resonance Equalizer

BY APPLYING A KNOWN FREQUENCY TO THIS END OF THE LINE, THE VOLUME IS ADJUSTED SO THAT A CONVENIENT READING APPEARS ON THE VOLUME INDICATOR #1 AT THIS LOCATION.

THE OTHER END OF THE TRANSMISSION LINE FEEDS INTO THE EQUALIZER, WHICH IS FOLLOWED BY AN AMPLIFIER AND ACROSS WHOSE OUTPUT ANOTHER VOLUME INDICATOR (#2) IS CONNECTED. WITH A CERTAIN FREQUENCY APPLIED TO THE INPUT END OF THE TRANSMISSION LINE, AS ALREADY EXPLAINED, THE READING OF VOLUME INDICATOR #2 IS NOTED.

A SIGNAL OF A DIFFERENT FREQUENCY IS THEN APPLIED TO THE LINE AND THE EQUIPMENT AT THIS END OF THE LINE IS ADJUSTED SO THAT VOLUME INDICATOR #1 OFFERS THE SAME READING AS BEFORE. THE READING OF VOLUME INDICATOR #2 IS THEN NOTED. THE SAME TEST IS REPEATED FOR AS MANY DIFFERENT FREQUENCIES AS DESIRED -- IT IS COMMON TO MAKE THIS TEST AT 100; 1,000; 3,000; AND 5,000 CYCLES, ALTHOUGH A MUCH GREATER VARIETY OF FREQUENCIES

CAN BE EMPLOYED IF ONE SO CHOOSES.

FROM THE DATA WHICH IS OBTAINED FROM THIS FREQUENCY RUN, A FREQUENCY RESPONSE CURVE SIMILAR TO THAT SHOWN IN FIG. 5 CAN BE PLOTTED. THE EQUALIZER VALUES CAN THEN BE ADJUSTED AS FOUND NECESSARY IN ORDER TO FLATTEN OR STRAIGHTEN OUT THIS CURVE SO THAT REASONABLY UNIFORM FREQUENCY CHARACTERISTICS CAN BE ATTAINED FROM THE LINE.

THE SET UP FOR MAKING THE FREQUENCY RUN IS NOT ALWAYS EXACTLY LIKE THAT WHICH IS ILLUSTRATED IN FIG. 4. SOMETIMES, THE LINE OUTPUT, AFTER BE... EQUALIZED, IS CONNECTED TO A SUITABLE LINE-TERMINATING COIL AND THE ...UT OF WHICH IS PASSED THROUGH A PAD. THE LEVEL AT THE OUTPUT OF THE ... CAN THEN BE MEASURED WITH A SENSITIVE THERMOCOUPLE TYPE D.B. METER.

WHENEVER A TRANSMISSION LINE AS THIS IS OF EXCESSIVE LENGTH, BOOSTER AMPLIFIERS ARE INSERTED AT INTERVALS. SUCH BOOSTERS, WHEN USED, ARE USUALLY INSERTED EVERY 10 OR 20 MILES AND THEY SERVE NOT ONLY TO MAINTAIN

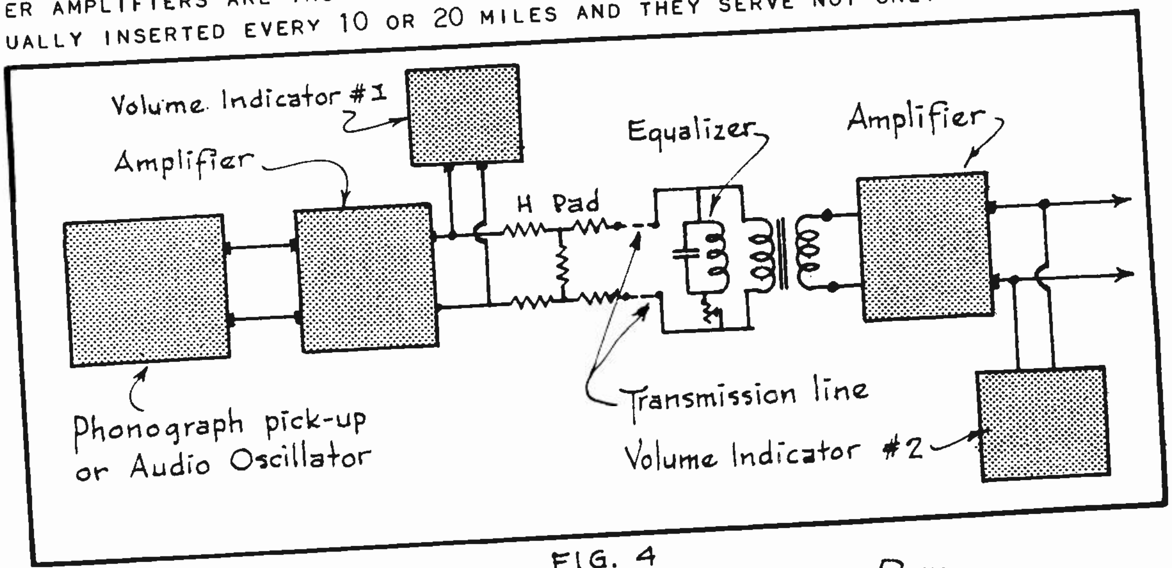


FIG. 4
Set-up for a Transmission Line Frequency Run.

THE PROGRAM LEVEL AT A DESIRED POINT WITH RESPECT TO ATTENUATION DUE TO THE LONG LINES BUT ALSO PERMIT MAINTAINING THE PROGRAM LEVEL WELL ABOVE THE LINE NOISE.

REMOTE CONTROL EQUIPMENT

THE EQUIPMENT USED FOR REMOTE CONTROL BROADCASTS IS QUITE SIMILAR TO THAT EMPLOYED IN THE STUDIO AND STUDIO CONTROL ROOM, WITH THE EXCEPTION THAT IT IS USUALLY OF PORTABLE DESIGN. THIS APPARATUS CONSISTS ESSENTIALLY OF AN AMPLIFIER, MIXER, VOLUME INDICATOR, AND A BATTERY POWER SUPPLY. CARBON MICROPHONES ARE USED CONSIDERABLY FOR THIS PURPOSE DUE TO THEIR PORTABILITY AND HIGH OUTPUT, ALTHOUGH WHERE CONDITIONS PERMIT, APPARATUS OF STILL MORE ELABORATE DESIGN IS USED.

IN CERTAIN INSTANCES, SUCH AS WHERE A DANCE ORCHESTRA BROADCASTS REGULARLY, NO MIXER OR VOLUME INDICATOR IS USED AND THE ANNOUNCER HIMSELF PLACES THE EQUIPMENT IN OPERATION AT THE TIME THE PROGRAM GOES ON

THE AIR. UNDER THESE CONDITIONS, NO STATION OPERATOR NEED BE SENT TO THE ORIGIN OF THE REMOTE BROADCAST.

IN THIS LAST MENTIONED CASE, IT IS ALSO THE USUAL PRACTICE TO FEED A CONSIDERABLE OUTPUT FROM THE AMPLIFIER INTO THE SPECIAL PROGRAM TELEPHONE LINE LEADING TO THE STATION SO AS TO SATISFACTORILY COVER UP THE NORMAL LINE NOISE.

BROADCAST TRANSMITTERS

BROADCASTING STATIONS OF SMALL AND MODERATE SIZE USUALLY HAVE THEIR STUDIOS AND ALL TRANSMITTING EQUIPMENT LOCATED ON THE SAME PREMISES AND WHICH SIMPLIFIES THE SYSTEM CONSIDERABLY. MANY OF THE MORE POWERFUL STATIONS, HOWEVER, HAVE THEIR STUDIOS LOCATED IN A METROPOLITAN CITY SO AS TO BE CONVENIENT FOR THE ARTISTS, EXECUTIVES, PUBLICITY STAFF ETC. WHO ARE ASSOCIATED WITH THE STATION. SINCE NEARBY BUILDINGS AND OTHER STEEL STRUCTURES HAVE A TENDENCY TO REDUCE THE EFFICIENCY OF RADIATION, THE TRANSMITTERS OF SUCH STATIONS ARE USUALLY LOCATED AT SOME DISTANCE OUTSIDE OF THE CONGESTED SECTION OF THE CITY AND THE PROGRAMS ARE CARRIED FROM THE STUDIO TO THE TRANSMITTER BUILDING OVER SPECIAL TELEPHONE LINES. IN FACT, SEVERAL OF SUCH TRANSMISSION LINES ARE GENERALLY SUPPLIED BETWEEN THE STUDIO AND TRANSMITTER TO FASCILITATE THE HANDLING OF PROGRAMS, AS WELL AS TO INSURE UNINTERRUPTED SERVICE IF ONE OF THE LINES SHOULD DEVELOPE TROUBLE. IN ADDITION TO THE PROGRAM LINES, PRIVATE TELEPHONE LINES ARE ALSO INCLUDED BETWEEN THE STUDIO AND THE TRANSMITTING QUARTERS SO THAT THE OPERATING PERSONNEL AT BOTH POINTS CAN MAINTAIN CONTINUAL COMMUNICATION BETWEEN EACHOTHER.

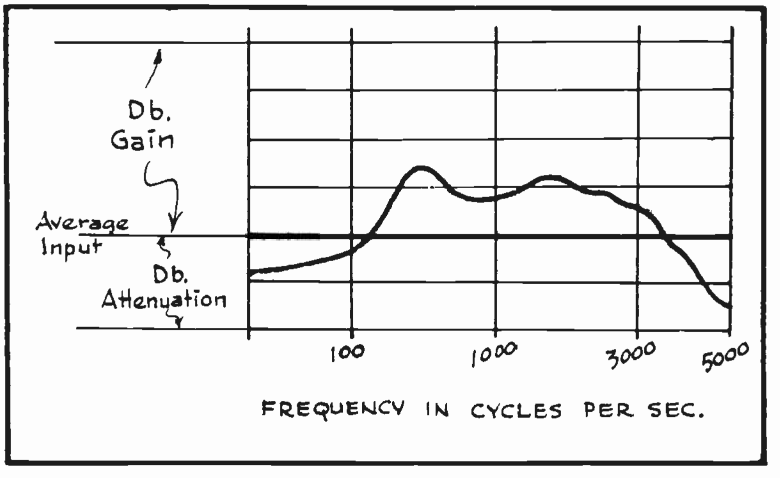


FIG. 5.
A Frequency Response Curve

THE FIRST PIECE OF EQUIPMENT WHICH IS IMMEDIATELY ASSOCIATED WITH THE TRANSMITTER IS THE SWITCHING EQUIPMENT AS POINTED OUT IN FIG.1 OF THIS LESSON. SINCE MOST STATIONS ARE EQUIPPED TO FEED THE MICROPHONES FROM SEVERAL STUDIOS INTO THE TRANSMITTER EQUIPMENT, AS WELL AS HAVING PROGRAM LINES LEADING TO VARIOUS SOURCES FOR REMOTE CONTROL AND CHAIN HOOK-UPS, THE SWITCHING EQUIPMENT AT THE STATION OFFERS A CONVENIENT MEANS OF CONNECTING THE DESIRED LINE TO THE APPARATUS FOR ANY PARTICULAR PROGRAM. THIS SWITCHING EQUIPMENT IS SIMILAR IN APPEARANCE AND OPERATION TO A SWITCHBOARD AS USED FOR TELEPHONE SERVICE. IMPEDANCE MATCHING DEVICES, EQUALIZERS AND ASSOCIATED LINE TERMINATING EQUIPMENT IS ALSO INSTALLED AT THIS POINT.

FOLLOWING THIS PART OF THE TRANSMITTER EQUIPMENT WE HAVE THE SPEECH

AMPLIFIER AND THE PURPOSE OF WHICH IS TO ACCEPT THE COMPARATIVELY FEEBLE A.F. ENERGY COMING OVER THE LINE AND AMPLIFY IT TO THE EXTENT NECESSARY IN ORDER TO PROPERLY MODULATE THE TRANSMITTER. AFTER THE SPEECH AMPLIFIER COMES THE TRANSMITTER ITSELF.

SO THAT YOU MAY OBTAIN A PERFECTLY CLEAR PICTURE OF THE ENTIRE BROADCAST STATION EQUIPMENT COMPLETE FROM THE MICROPHONE TO THE ANTENNA, WE SHALL USE A WESTERN ELECTRIC 1 KW. BROADCAST TRANSMITTER AS A PRACTICAL EXAMPLE.

SPEECH INPUT EQUIPMENT

THE SPEECH INPUT EQUIPMENT FOR THIS TRANSMITTER APPEARS IN FIG. 6. THIS APPARATUS, YOU WILL OBSERVE, CONSISTS OF A DYNAMIC MICROPHONE FEEDING INTO A LOW-LEVEL SPEECH AMPLIFIER.

TRANSFORMER COUPLING IS USED THROUGHOUT THIS LOW-LEVEL SPEECH AMPLIFIER AND SO AS TO PREVENT SATURATING THE CORE OF THESE TRANSFORMERS, THE PLATE CURRENT FOR THE TWO TUBES USED IN THIS AMPLIFIER IS CARRIED BY PLATE LOAD RESISTORS R_p AND ONLY THE ALTERNATING OR SIGNAL VOLTAGES CAN REACT THROUGH THE CONDENSERS C_B AND THUS BECOME EFFECTIVE AT THE PRIMARY WINDING OF THE FOLLOWING A.F. TRANSFORMER. THE CORES OF HIGH-GRADE TRANSFORMERS SATURATE VERY READILY AND THEREFORE THE CIRCUIT ARRANGEMENT AS HERE USED IS NECESSARY.

THE OUTPUT OF THE LOW-LEVEL SPEECH AMPLIFIER IS FED INTO THE INPUT OF THE HIGH-LEVEL SPEECH AMPLIFIER THROUGH AN ATTENUATING DEVICE IN THE

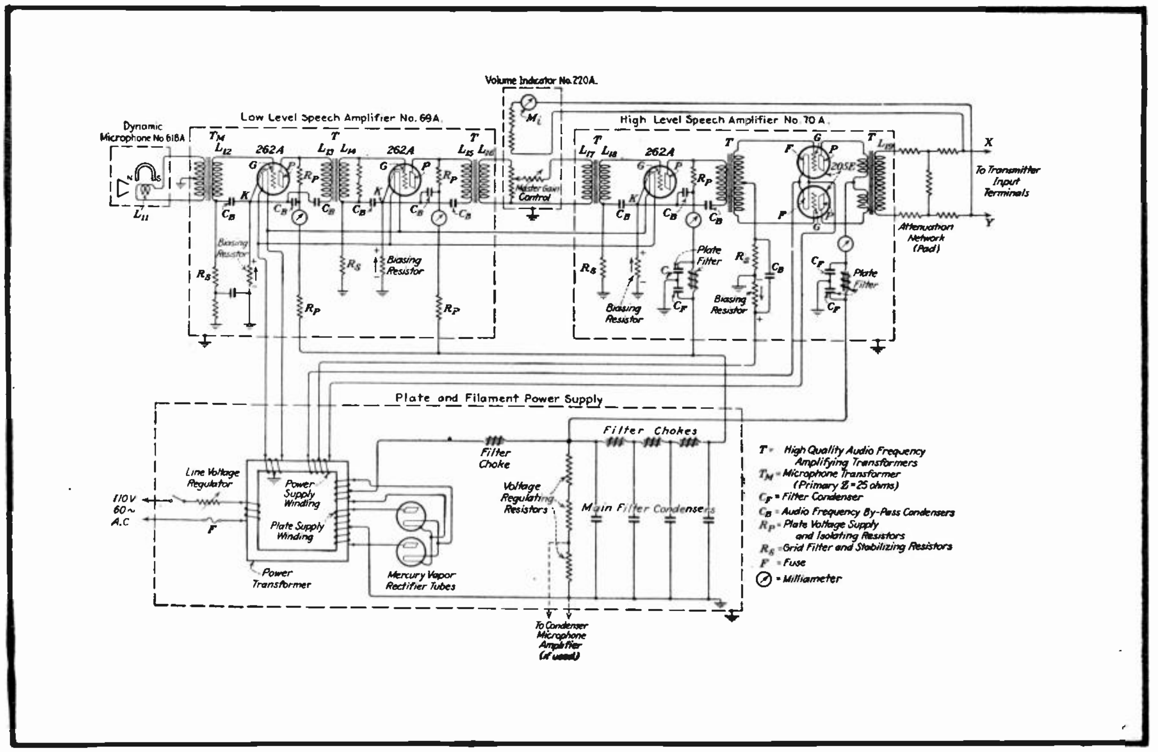


FIG. 6

Diagram of Western Electric Speech Amplifier.

FORM OF A MASTER GAIN CONTROL. THIS GAIN CONTROL IS IN REALLITY A DB. VOLUME CONTROL EQUIPPED WITH 18 STEPS AND 2 DB. PER STEP. THE VOLUME INDICATOR MAKES IT POSSIBLE FOR THE OPERATOR TO KNOW AT WHAT POSITION TO PLACE THE MASTER GAIN CONTROL FOR ANY GIVEN OCCASSION.

THE PUSH-PULL POWER STAGE OF THE HIGH-LEVEL SPEECH AMPLIFIER BY MEANS OF AN OUTPUT TRANSFORMER IS CONNECTED TO A 5 DB. ATTENUATION NET-WORK OF THE H-PAD TYPE AND WHICH IN TURN HAS ITS OUTPUT CONNECTED TO A 500 OHM LINE LEADING TO THE TRANSMITTER. A VOLUME INDICATOR OF THE COPPER-OXIDE RECTIFIER TYPE IS CONNECTED THROUGH A MULTIPLIER RESISTANCE ACROSS THE OUTPUT OF THE ATTENUATION NET-WORK.

ALSO NOTE IN FIG.6 THAT THIS SPEECH AMPLIFYING EQUIPMENT HAS ITS INDIVIDUAL PLATE AND FILAMENT POWER SUPPLY APART FROM THE POWER SUPPLY OF THE TRANSMITTER.

THE TRANSMITTER

IN FIG.7 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF THE 1 KW.WESTERN ELECTRIC BROADCAST TRANSMITTER INTO WHICH THE SPEECH AMPLIFYING EQUIPMENT OF FIG.6 OPERATES. BY STUDYING THE DIAGRAM IN FIG.7 CLOSELY, YOU WILL NOTE THAT THE LINE FROM THE SPEECH AMPLIFYING EQUIPMENT IS CONNECTED ACROSS THE PRIMARY WINDING OF TRANSFORMER T_{14} AND WHOSE SECONDARY WINDING IS CONNECTED IN THE GRID CIRCUIT OF THE TRANSMITTER'S THIRD AMPLIFIER SECTION (THE MODULATED R.F. AMPLIFIER). THIS CIRCUIT CONNECTION WILL IMMEDIATELY INFORM YOU OF THE FACT THAT GRID-MODULATION IS USED IN THIS PARTICULAR TRANSMITTER.

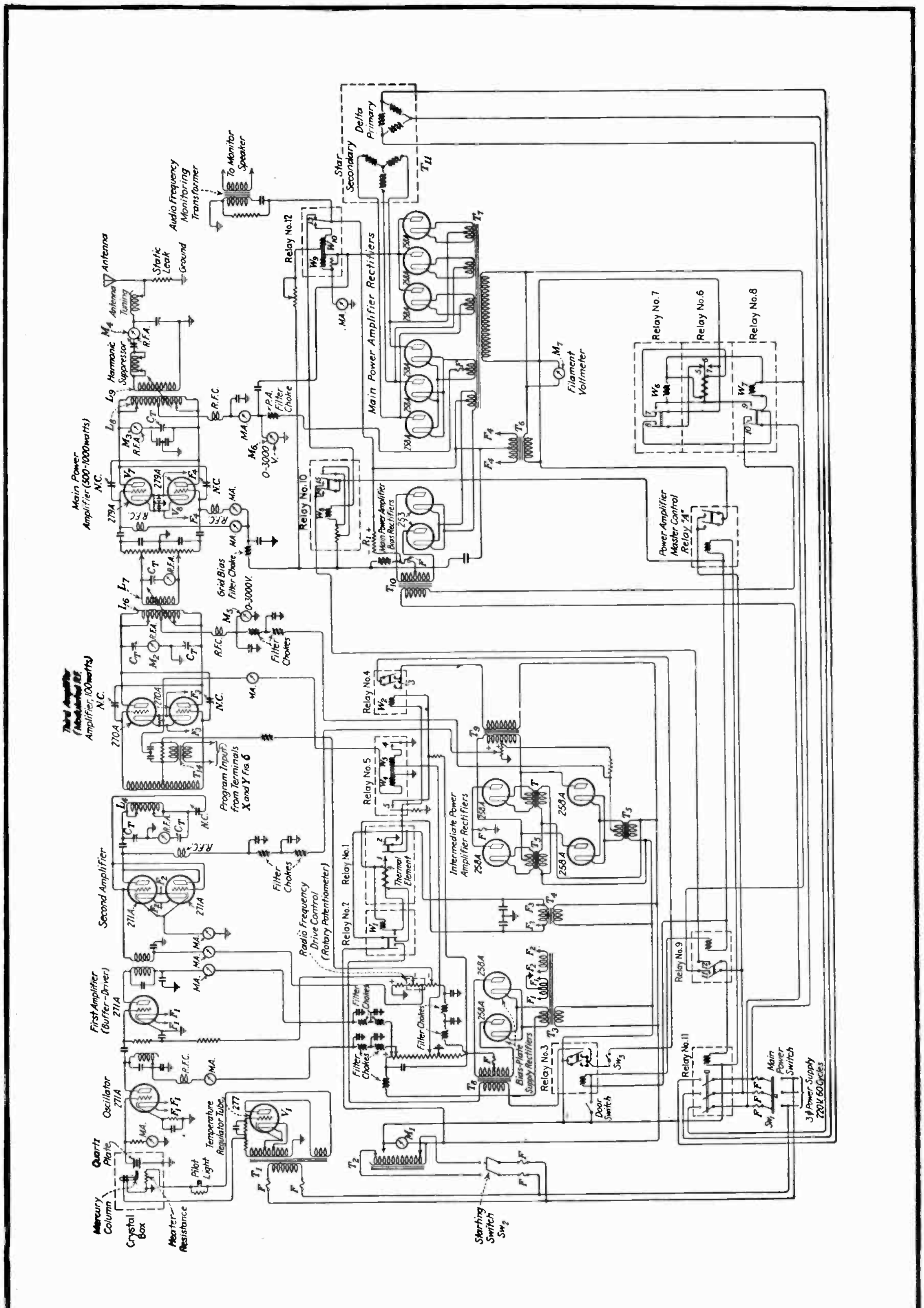
THIS TRANSMITTER IS CONSTRUCTED IN TWO DISTINCT SECTIONS, INDEPENDENT OF EACHOTHER. ONE SECTION INCLUDES ALL THAT EQUIPMENT FROM THE OSCILLATOR UP TO THE MODULATED R.F. STAGE IN WHICH THE TWO 270-A TUBES ARE USED. THE OUTPUT OF THIS AMPLIFIER IS 100 WATTS AND IT MAY THEREFORE ACTUALLY BE OPERATED AS A 100 WATT TRANSMITTER BY CONNECTING ITS OUTPUT TO AN ANTENNA SYSTEM. THE 1000 WATT MAIN POWER AMPLIFIER IS AN ENTIRELY SEPARATE UNIT.

POWER CONTROL AND PROTECTION CIRCUITS

FROM WHAT YOU HAVE ALREADY LEARNED IN PREVIOUS LESSONS ABOUT TRANSMITTERS, YOU WILL BE FAMILIAR WITH THE OPERATION OF THE VARIOUS SECTIONS OF THE ASSEMBLY ILLUSTRATED IN FIG.7. THE SYSTEM OF RELAYS,HOWEVER, WHICH IS USED IN THIS INSTALLATION,IS SOMEWHAT DIFFERENT THAN ANY OF THOSE WHICH HAVE BEEN SHOWN YOU UP TO THIS TIME AND FOR THIS REASON WILL NOW BE EXPLAINED IN DETAIL.

THE OPERATION OF THE POWER-CONTROL AND PROTECTION CIRCUITS OF THIS TRANSMITTER IS AS FOLLOWS:

THE MAIN SWITCH SW_1 CONNECTS A THREE-PHASE 220-VOLT 60-CYCLE SOURCE TO THE VARIOUS CIRCUITS OF THE TRANSMITTER AND IS CLOSED WHEN THE TRANSMITTER IS IN OPERATION. THESE CIRCUITS, WITH THE EXCEPTION OF THE TRANSFORMER T_1, WILL, HOWEVER, NOT BE ENERGIZED BY THE CLOSING OF THIS SWITCH. THE TRANSFORMER T_1 MUST BE CONSTANTLY ENERGIZED IN ORDER TO OPER-



F I G. 7

Diagram of Western Electric Broadcast Transmitter.

ATE THE TEMPERATURE-CONTROL CHAMBER OF THE CRYSTAL BOX TO MAINTAIN A CONSTANT-OPERATING FREQUENCY. THE PRIMARY WINDING IS, THEREFORE, PERMANENTLY CONNECTED ACROSS THE ALTERNATING-CURRENT LINE. IF THIS SWITCH IS LEFT OPEN FOR A CONSIDERABLE TIME THE TEMPERATURE IN THE CRYSTAL CHAMBER WILL BE ALTERED, AND A FREQUENCY DEVIATION OF SEVERAL HUNDRED CYCLES MAY RESULT. THIS TRANSFORMER SUPPLIES THE FILAMENT, PLATE, AND BIAS VOLTAGES FOR THE ARGON REGULATOR TUBE V_1.

THE NEXT SWITCH TO BE CLOSED IS Sw_2. THIS SUPPLIES AN ALTERNATING-CURRENT VOLTAGE ACROSS AN AUTOTRANSFORMER T_2. A TAPPED PORTION OF THIS TRANSFORMER CONNECTS TO A ROTARY SWITCH FOR THE PURPOSE OF SELECTING THE PROPER ALTERNATING-CURRENT VOLTAGE TO BE DELIVERED TO THE OPERATING CIRCUITS. THIS PROVIDES THE PROPER FLEXIBILITY NECESSARY TO MAINTAIN THE DESIRED VOLTAGE TO THE LOAD CIRCUITS TO COMPENSATE FOR LINE-VOLTAGE CHANGES. THIS VOLTAGE MUST BE MAINTAINED AT 220 VOLTS AS INDICATED BY THE ALTERNATING-CURRENT LINE VOLTMETER M_1. ANY VARIATION IN THE SUPPLY-LINE VOLTAGE MAY THEN BE REGULATED BY THE ROTARY SWITCH TO THE REQUIRED VALUE.

THE AUTOTRANSFORMER VOLTAGE EXCITES THE PRIMARY WINDINGS OF THE FILAMENT-LIGHTING TRANSFORMERS T_3, T_4, AND T_5 AND THE MASTER-CONTROL RELAY A WHICH CLOSES AND EXCITES THE PRIMARY WINDINGS OF THE FILAMENT TRANSFORMERS T_6 AND T_7 FOR THE POWER AMPLIFIER AND RECTIFIER TUBES, RESPECTIVELY.

CONNECTED ACROSS THE SECONDARY WINDING OF THE FILAMENT TRANSFORMER T_4 IS A RESISTANCE UNIT WHICH BECOMES HEATED WHEN THE WINDING IS ENERGIZED. THIS UNIT (AND ITS ASSOCIATED CONTACTS) IS KNOWN AS A THERMAL OR HEATER-ELEMENT TIME-DELAY RELAY, (RELAY 1). THIS RESISTANCE IS LOCATED VERY CLOSE TO AN ALLOY STRIP (THERMAL ELEMENT) WHICH, WHEN HEATED, BEGINS TO EXPAND OWING TO THE EFFECT OF HEAT ON THE METAL. AS THIS METAL STRIP EXPANDS SUFFICIENTLY IT FINALLY MAKES CONTACT WITH THE TERMINAL 1 ON THE UNIT AND ENERGIZES ANOTHER RELAY COIL WINDING W_1 OF RELAY 2. THE MAGNETIZED WINDING OF THIS COIL ATTRACTS TWO METAL CONTACT STRIPS WHICH, WHEN CLOSED, OPEN UP THE CONNECTION TO THE HEATER UNIT OF RELAY 1 AND CLOSE THE CIRCUIT LEADING TO THE PRIMARY WINDING OF THE TRANSFORMER T_8. THIS TRANSFORMER SUPPLIES THE PLATE VOLTAGE TO THE OSCILLATOR AND BUFFER-AMPLIFIER STAGES ONLY AND ALSO SUPPLIES THE NEGATIVE BIAS TO THE GRIDS OF THE FIRST AMPLIFIER AND MODULATING RADIO-FREQUENCY AMPLIFIER STAGES. IT IS IMPORTANT TO NOTE, HOWEVER, THAT RELAY 2 CANNOT BE ACTUATED UNLESS RELAY 3 IS ALSO CLOSED. THE LATTER CAN ONLY BE OPERATED WHEN ALL DOOR SWITCHES ARE CLOSED BY TIGHTLY LOCKING ALL COMPARTMENT DOORS.

SINCE THE HEATING RESISTANCE UNIT OF RELAY 1 IS OPEN-CIRCUITED, THE HEATING EFFECT UPON THE METAL STRIP WILL BE DECREASED AND CONSEQUENTLY WILL CAUSE THE STRIP TO RETURN BACK TO ITS NORMAL POSITION. THIS CLOSES THE BACK CONTACTS 2 AND COMPLETES THE CIRCUIT THROUGH THE RELAY 4, WINDING W_2. THIS CLOSES THE CONTACT 3 ON THIS RELAY AND EXCITES THE PRIMARY WINDING OF THE PLATE-VOLTAGE TRANSFORMER T_9. IT IS ASSUMED, OF COURSE, THAT THE PLATE-SUPPLY SWITCH Sw_3 AND THE DOOR-SWITCH RELAY 3 HAVE BEEN PREVIOUSLY CLOSED.

THE OVERLOAD RELAY 5 OF THE TRANSMITTER CONSISTS OF TWO COILS, NAMELY, THE OVERLOAD-COAL WINDING W_4 AND THE OPERATING WINDING W_5. THE OVER

LOAD COIL IS CONNECTED IN SERIES WITH THE CENTER TAPPED FILAMENT RETURN LEAD TO GROUND WHICH COMPLETES THE PLATE-CURRENT CIRCUIT FOR THE MODULATED RADIO-FREQUENCY AMPLIFIER TUBES. IF AN ABNORMAL FLOW OF PLATE CURRENT SHOULD RESULT IN THESE TUBES DUE TO EXCESSIVE MODULATION PEAKS OR LINE-VOLTAGE SURGES, THE WINDING W_4 OF RELAY 5 WILL BE ENERGIZED SUFFICIENTLY TO DRAW OVER THE CONTACTORS AND CLOSE THE CIRCUITS 4 AND 5. THIS ACTION WILL SHORT-CIRCUIT THE WINDING OF RELAY 4 THEREBY DEMAGNETIZING IT AND RELEASING THE CONTACTS 3 ON THE RELAY 4. THUS THE PRIMARY WINDING OF THE PLATE-SUPPLY TRANSFORMER T_9 WILL BE OPENED AND THE HIGH VOLTAGE TO THE MODULATED AMPLIFIER TUBES WILL BE DISCONNECTED.

A SMALL OVERLOAD RESET PUSH-BUTTON (NOT SHOWN) IS PROVIDED TO OPEN THE WINDING W_5 SO THAT THE SHORT CIRCUIT WILL BE REMOVED FROM THE WINDING W_2 ON RELAY 4 AND THEREBY REESTABLISH THE PLATE VOLTAGE TO THE MODULATED AMPLIFIER TUBES.

WHEN THE MASTER CONTROL RELAY A IS CLOSED, THE PRIMARY WINDING OF THE FILAMENT TRANSFORMERS T_6 AND T_7 ARE EXCITED AS STATED BEFORE. AT THE SAME TIME, HOWEVER, ANOTHER THERMAL TIME-DELAY RELAY 6 IS HEATED, SINCE IT IS CONNECTED ACROSS THE PRIMARY WINDINGS OF THE TWO FILAMENT TRANSFORMERS T_6 AND T_7. THIS RESULTS IN THE EXPANSION OF THE THERMAL ELEMENT AND THE CLOSING OF CONTACTS 6 AND 7; AND THIS ALLOWS CURRENT TO FLOW THROUGH THE WINDING W_6 WHICH ENERGIZES RELAY 7. WHEN THIS RELAY IS ENERGIZED, THE CONTACT 7 IS OPENED AND THE HEATER WINDING OF RELAY 6 IS BROKEN, THUS ALLOWING THE THERMAL ELEMENT TO CONTRACT AND REESTABLISH CONNECTIONS 5 AND 6 ON RELAY 6. AT THE SAME TIME, HOWEVER, THE CONTACT 8 IS CLOSED WHICH ALLOWS A CURRENT TO FLOW THROUGH THE WINDING W_7. THIS MAGNETIZES RELAY 8 AND CLOSES THE CONTACTS 9 AND 10. THE CLOSING OF THESE CONTACTS ALLOWS AN ALTERNATING CURRENT TO FLOW THROUGH THE PRIMARY WINDING OF THE TRANSFORMER T_{10} AND ESTABLISH A VOLTAGE BETWEEN THE TWO PLATES OF THE ASSOCIATED MERCURY-VAPOR RECTIFIER TUBES. THIS RESULTS IN A CURRENT FLOW THROUGH THE RESISTANCE R_1 WHICH DEVELOPS A VOLTAGE DROP ACROSS IT. THIS DROP IS USED TO SUPPLY THE BIAS OF -275 VOLTS TO THE GRIDS OF THE TWO POWER-AMPLIFIER TUBES V_7 AND V_8. THIS IS, OF COURSE, PROVIDED THAT THE RELAY 9 IS ALSO CLOSED BY HAVING ALL DOOR SWITCHES LOCKED. OTHERWISE CONTACT 11 WILL BE OPEN AND NO CURRENT WILL PASS THROUGH T_{10}.

AS SOON AS THE GRID-BIAS VOLTAGE IS DEVELOPED ACROSS THE RESISTANCE R_1, A CURRENT WILL PASS THROUGH THE GRID-BIAS RELAY 10 BECAUSE IT IS CONNECTED DIRECTLY ACROSS THE RESISTOR THROUGH CONTACTS 13. THIS ACTUATES THE RELAY WINDING W_8 BY MAGNETIZING THE IRON CORE AND CLOSING THE CONTACTS 14 AND 15. IN SERIES WITH THESE CONTACTS IS A LARGE SOLENOID CONTACTOR, RELAY 11, WHICH BECOMES ENERGIZED AND DRAWS OVER THREE CONTACTORS TO CLOSE THE THREE-PHASE ALTERNATING-CURRENT SUPPLY TO THE HIGH-VOLTAGE TRANSFORMER T_{11}. THIS ACTION SUPPLIES THE ALTERNATING-CURRENT HIGH VOLTAGE TO THE PLATES OF THE MAIN POWER-AMPLIFIER, MERCURY-VAPOR RECTIFIER TUBES, WHERE IT IS THEN RECTIFIED TO THE DESIRED DIRECT-CURRENT POTENTIAL OF 3,000 VOLTS FOR THE PLATE SUPPLY.

ALL CIRCUITS SHOULD NOW BE EXCITED AND THE PROPER PLATE, BIAS, AND FILAMENT VOLTAGES SHOULD BE APPLIED. THESE VOLTAGES MAY NOW BE PROPERLY CHECKED BY THE FILAMENT VOLTMETER M_7 AND THE DIRECT-CURRENT VOLTMETERS M_5 AND M_6. ALL PLATE AND RADIO-FREQUENCY CURRENTS MAY ALSO THEN BE CHECKed by the various plate milliammeters MA, and by the radio-frequency ammeters RFA, in the respective circuits.

In the W.E. installation only one milliammeter is used to obtain the plate and grid-current readings for several of the low-power stages in the 100-watt unit. This is accomplished by a number of resistance shunts and a rotary-selector switch which transfers the meter into the desired circuit. In Fig. 7 this switch and the associated shunts are omitted, but individual meters are inserted in their proper places to simplify circuit analysis.

All plate and power-supply circuits are suitably protected by fuses and overload circuit breakers as illustrated in the diagram. Two overload relays 5 and 12 are provided in the 100-watt and power amplifier units to enable the operator quickly to reestablish transmitter operation in the event of a circuit breaker "tripping" owing to excessive modulation peaks, line-voltage surges, or temporary condenser flashovers due to dust accumulation.

The overload-coil winding W_9 of relay 12 is connected in series with the negative terminal of the 3,000-volt rectifier and ground. If an excessive value of current flows through this coil the core is magnetized sufficiently to pull the relay arm over and break the contacts 13. This opens the winding W_8 on relay 10 and releases the contact arm of the relay, which breaks contacts 14 and 15 and opens relay 11. This disconnects the three-phase supply to the power transformers and cuts off the high-voltage supply to the power-amplifier tubes. The winding W_{10} on the overload relay 12 serves to hold the arm in this position until it is desired to reestablish the plate voltage.

A push-button reset switch (not shown) is connected in series with winding W_{10} to break this circuit when it is desired to release the arm back to its normal position, thereby reestablishing contacts 13, 14, and 15 and again energizing winding W_8 of relay 10.

OPERATING THE TRANSMITTER

From previous lessons treating with transmitters, you already learned the general procedure for adjusting a transmitter preparatory to operation. Nevertheless, you should find the following specific information regarding the operation and adjusting of the Western Electric transmitter illustrated in Fig. 7 to be both interesting and highly instructive. The procedure in this particular case is as follows:

All plate, filament, and bias voltages must be carefully adjusted to their required values in accordance with their class of operation.

The crystal oscillator uses a type 271-A tube and operates with a plate potential of 130 volts at a plate current of 7 ma. and a grid current of 0.3 ma. The first amplifier uses a type 271-A tube and operates with a plate potential of 300 volts and draws a plate current of 6 ma.

The second amplifier stage consists of two 271-A cathode-heater

TUBES, IN SERIES OR PARALLEL. THESE TUBES OPERATE AT A PLATE POTENTIAL OF 350 VOLTS, A PLATE CURRENT OF 12 MA., AND A GRID BIAS OF -75 VOLTS. THE THIRD AMPLIFIER OR MODULATING RADIO FREQUENCY STAGE USES TWO 270-A TUBES (350 WATTS EACH) OPERATING AS A CLASS C AMPLIFIER AT A PLATE POTENTIAL OF 3,000 VOLTS, A TOTAL PLATE CURRENT OF 125 MA., AND A GRID BIAS OF -250 VOLTS. THESE TUBES ARE ADJUSTED TO A 100-WATT OUTPUT.

THE FINAL, OR POWER AMPLIFIER, STAGE USES TWO TYPE 279-A TUBES (RATED AT 1,200 WATTS EACH) OPERATING AS A CLASS B AMPLIFIER WITH A PLATE POTENTIAL OF 3,000 VOLTS, A TOTAL PLATE CURRENT OF 0.25 AMP., AND A GRID BIAS OF -275 VOLTS.

THE FILAMENTS OF THE ENTIRE TRANSMITTER ARE ALTERNATING CURRENT OPERATED THROUGH THE MEDIUM OF SINGLE PHASE POWER TRANSFORMERS. THE FILAMENT OPERATING VOLTAGE OF THE 271-A TUBES IS 5 VOLTS; AND THE 270-A AND 279-A TUBES ARE ALL OPERATED AT 10 VOLTS.

THE HIGH VOLTAGE RECTIFIER TUBES ARE W.E. TYPE 258-A HAVING A MAXIMUM INVERSE-PEAK POTENTIAL OF 6,500 VOLTS. THE GRID BIAS RECTIFIER TUBES ARE W.E. TYPE 253-A HAVING A MAXIMUM INVERSE-PEAK POTENTIAL OF 3,500 VOLTS. ALL RECTIFIERS ARE OF THE MERCURY VAPOR TYPE. TYPE 253-A TUBES ARE USED IN THIS TRANSMITTER IN THE RECTIFIER UNIT, AND TYPE 258-A TUBES ARE USED IN THE PLATE SUPPLY RECTIFIER UNITS. THE FILAMENT VOLTAGE OF BOTH TYPES IS 2.5 VOLTS. THE PEAK CURRENT OF TYPE 253-A IS 500 MA.; OF TYPE 258-A 1.1 AMP.

USE THE CRYSTAL-OXCILLATOR BOX CORRESPONDING TO THE NEWLY ASSIGNED FREQUENCY. THIS BOX IS ADJUSTED TO WITHIN 25 CYCLES OF THE ASSIGNED FREQUENCY BY THE WESTERN ELECTRIC COMPANY. CARE MUST BE TAKEN THAT THE MERCURY COLUMN IN THE BOX IS FREE TO RISE. THIS MAY BE ASSURED BY SLIGHTLY TAPPING THE REAR EDGE OF THE BOX ON A TABLE.

INSERT A NEW ARGON HEATER REGULATOR TUBE BUT LEAVE THE PLATE VOLTAGE FOR THIS UNIT DISCONNECTED UNTIL ITS FILAMENT HAS BEEN HEATED FOR SEVERAL MINUTES. THEN CLOSE THE PLATE VOLTAGE SUPPLY SWITCH. A PILOT LIGHT WILL SHOW THAT THE HEATER UNIT IN THE CRYSTAL BOX IS BEING PROPERLY HEATED. IT WILL TAKE AT LEAST 2 HOURS BEFORE THE BOX TEMPERATURE IS CORRECT AND THE PILOT LIGHT GOES OUT.

CONNECT COILS, CONDENSERS, AND LINKS TO CORRESPOND TO THE DESIRED FREQUENCY.

CLOSE ALL DOOR SWITCHES BY CLOSING DOORS, AND PLACE THE MASTER SWITCH IN STARTING POSITION. VARIOUS TIME DELAY RELAYS WILL CLOSE IN GRADUAL SUCCESSION BUT ONLY AFTER THE BIAS RECTIFIER TUBES ARE IN OPERATION. THIS PREVENTS ANY POSSIBILITY OF THE PLATE VOLTAGE BEING APPLIED BEFORE THE BIASING CIRCUIT IS COMPLETED.

THE FIRST AMPLIFIER, OR BUFFER STAGE, REQUIRES NO TUNING ADJUSTMENTS OR NEUTRALIZATION BECAUSE OF ITS APERIODICALLY TUNED PLATE CIRCUIT TRANSFORMER. THIS TRANSFORMER EFFECTIVELY COVERS THE BROADCAST FREQUENCIES OF FROM 500 TO 1,200 KILOCYCLES. A VARIABLE RESISTANCE CONTROLS THE BIAS VOLTAGE ON THE GRID OF THIS TUBE AND ALSO IS THE MAIN RA

RADIO FREQUENCY DRIVE CONTROL FOR THE SUCCEEDING AMPLIFIER TUBES.

PREPARE THE SECOND RADIO FREQUENCY AMPLIFIER FOR NEUTRALIZING BY OPENING THE THIRD AMPLIFIER PLATE SUPPLY SWITCH AND CLOSING THE SECOND AMPLIFIER PLATE SUPPLY SWITCH.

CLOSE THE HIGH VOLTAGE SUPPLY SWITCH ON THE 100 WATT SECTION OF THE TRANSMITTER PANEL AND NOTE THE PLATE CURRENT READING OF THE MILLIAMMETER. ADJUST THE TUNING CONDENSERS WHICH ARE CONNECTED ACROSS L_4 UNTIL THE PLATE MILLIAMMETER SHOWS A MAXIMUM DROP. THIS IS A PRELIMINARY TUNING ADJUSTMENT BEFORE NEUTRALIZING AND, SHOULD DIFFICULTY BE ENCOUNTERED IN THE ADJUSTMENT, THE NEUTRALIZING CONDENSER SHOULD BE SHIFTED SLIGHTLY. IT WAS ASSUMED THAT THE NEUTRALIZING CONDENSER WAS APPROXIMATELY ONE FOURTH ENGAGED.

THE SECOND STAGE IS NOW READY FOR NEUTRALIZING, BUT IT IS ADVISABLE TO PROCEED FIRST WITH THE NEUTRALIZATION OF THE THIRD AMPLIFIER TO SIMPLIFY MATTERS.

TO NEUTRALIZE THE THIRD AMPLIFIER OPEN THE HIGH VOLTAGE SUPPLY SWITCH AND OPEN DOORS. SET THE NEUTRALIZING CONDENSERS ON THE THIRD AMPLIFIER STAGE SO THAT THEY ARE A LITTLE LESS THAN ONE HALF ENGAGED. INSERT A THERMOGALVANOMETER AND THERMO-COUPLE INTO THE PLATE MESH CIRCUIT C_7L_6. CLOSE THE PANEL DOORS AND ADJUST THE RADIO FREQUENCY DRIVE TO A MINIMUM POSITION AND LOOSEN THE MAGNETIC COUPLING OF L_6L_7. CLOSE THE HIGH VOLTAGE SUPPLY SWITCH AND BEGIN TO VARY THE THIRD AMPLIFIER TUNING CONDENSERS ACROSS L_6 UNTIL THE RADIO FREQUENCY AMMETER IN THIS MESH CIRCUIT READS MAXIMUM. IF NO READING IS OBTAINED, INCREASE THE RADIO-FREQUENCY DRIVE. ALSO VARY THE MESH TUNING CONDENSERS. AN EXCESSIVE READING WILL REQUIRE AN INCREASE IN THE CAPACITY OF THE NEUTRALIZING CONDENSERS UNTIL THE READING DROPS TO A LOW VALUE. CONTINUE TO INCREASE THE RADIO FREQUENCY DRIVE BUT KEEP ADJUSTING THE NEUTRALIZING CONDENSERS SO THAT THE MESH CURRENT DOES NOT EXCEED 3/4 AMP.

BOTH THE SECOND AND THIRD AMPLIFIER TUNING CONDENSERS MUST THEN BE VARIED UNTIL A MAXIMUM CURRENT IS INDICATED IN THE RADIO FREQUENCY MESH CIRCUIT AMMETER. THEN VARY THE THIRD AMPLIFIER NEUTRALIZING CONDENSERS UNTIL THE RADIO FREQUENCY AMMETER IN THE MESH CIRCUIT READS ZERO.

THE SECOND AMPLIFIER MAY NOW BE NEUTRALIZED BY OPENING THE HIGH VOLTAGE SUPPLY SWITCH AND REDUCING THE RADIO FREQUENCY DRIVE TO A MINIMUM. OPEN THE PLATE SUPPLY SWITCH TO THE SECOND AMPLIFIER AND CLOSE THE PLATE SWITCH TO THE THIRD AMPLIFIER. CLOSE THE HIGH-VOLTAGE SUPPLY SWITCH AND VARY THE RADIO FREQUENCY DRIVE TOGETHER WITH THE NEUTRALIZING CONDENSER UNTIL THE RADIO FREQUENCY AMMETER IN THE THIRD AMPLIFIER MESH CIRCUIT READS ABOUT 3/4 AMP. ADJUST THE SECOND AND THIRD AMPLIFIER TUNING CONDENSERS UNTIL THE THIRD AMPLIFIER RADIO FREQUENCY MESH METER M_4 READS A MAXIMUM. THEN VARY THE SECOND AMPLIFIER NEUTRALIZING CONDENSER UNTIL THIS METER READS MINIMUM.

THE RADIO FREQUENCY DRIVE SHOULD THEN BE INCREASED TO A MAXIMUM AND THE SECOND AMPLIFIER NEUTRALIZING CONDENSER ADJUSTED UNTIL NO READING IS OBTAINED AT THE RADIO FREQUENCY METER IN THE THIRD AMPLIFIER

MESH CIRCUIT.

THE POWER AMPLIFIER STAGE MAY NOW BE NEUTRALIZED BY OPENING ITS PLATE SUPPLY CIRCUIT AND REDUCING THE MAGNETIC COUPLING BETWEEN L_8 AND L_9 AND INCREASING THE CAPACITY OF THE POWER STAGE NEUTRALIZING CONDENSERS TO ABOUT ONE FOURTH CAPACITY. APPLY THE PLATE VOLTAGE BY CLOSING THE HIGH VOLTAGE SWITCH ON THE 100 WATT UNIT. INCREASE THE RADIO FREQUENCY DRIVE AND VARY THE POWER AMPLIFIER TUNING CONDENSER ACROSS L_8 UNTIL THE RADIO FREQUENCY AMMETER M_3 IN THE PLATE MESH $C_T L_8$ READS ABOUT $1\frac{1}{2}$ TO 2 AMP. INCREASE THE CAPACITY OF THE NEUTRALIZING CONDENSERS UNTIL THE READING OF THE POWER AMPLIFIER RADIO FREQUENCY AMMETER IN THE C_T L_8 MESH READS AT, OR VERY NEARLY, ZERO.

THE ENTIRE TRANSMITTER MAY NOW BE TUNED FOR MAXIMUM EFFICIENCY BY ADJUSTING THE VARIOUS AMPLIFIER STAGES TO THE PROPER LOAD AND RESONANT CONDITIONS. ALL STAGES WITH THE EXCEPTION OF THE FIRST AMPLIFIER AND ANTENNA CIRCUITS INDICATE A RESONANT CONDITION WHEN A MINIMUM PLATE CURRENT IS OBTAINED IN THE TUBE WHOSE TUNED CIRCUIT IS BEING ADJUSTED. GREAT CARE SHOULD BE TAKEN IN TUNING THE SECOND AND THIRD AMPLIFIER SO THAT THEY WILL NOT BE RESONANT TO THE SECOND HARMONIC FREQUENCY OF THE CARRIER.

NO TUNING ADJUSTMENTS ARE NECESSARY IN THE FIRST AMPLIFIER CIRCUITS, SINCE ALL CONDENSERS AND COILS ARE OF THE FIXED OR UNTUNED VARIETY. THE SECOND AMPLIFIER CIRCUIT IS TUNED FOR A MAXIMUM DIP IN THE PLATE CURRENT BY VARYING THE CONDENSERS C_T ACROSS L_4. THE THIRD AMPLIFIER OUTPUT CIRCUIT IS THEN ADJUSTED FOR THE DESIRED INPUT TO THE POWER AMPLIFIER TUBES.

OPEN THE PLATE SUPPLY VOLTAGE OF THE 1000 WATT UNIT (POWER AMPLIFIER STAGE), AND INSERT THE FULL POWER INPUT RESISTANCE ACROSS THE GRIDS OF THE POWER AMPLIFIER TUBES. CLOSE THE PLATE SUPPLY VOLTAGE OF THE 100 WATT UNIT AND TUNE CONDENSERS C_T ACROSS L_8 UNTIL THE RADIO FREQUENCY AMMETER IN THIS MESH READS A MAXIMUM VALUE. ADJUST THE RADIO FREQUENCY DRIVE SO THAT THIS METER DOES NOT EXCEED 1.5 AMP. VARY THE COUPLING OF $L_6 L_7$, AND ADJUST THE POWER AMPLIFIER INPUT CONTROL CONDENSER C_T ACROSS L_7 UNTIL THE RADIO FREQUENCY AMMETER IN THE $C_T L_6$ CIRCUIT READS A MINIMUM. INCREASE THE COUPLINGS OF $L_6 L_7$ AND THE RADIO FREQUENCY DRIVE UNTIL THE RADIO FREQUENCY AMMETER IN THE $C_T L_7$ CIRCUIT READS ABOUT 1 AMP. AND THE RADIO FREQUENCY AMMETER IN THE $C_T L_6$ CIRCUIT DROPS BETWEEN 0.8 AND 1.3 AMP. THE PLATE CURRENT OF THE THIRD AMPLIFIER STAGE AT THIS POINT SHOULD READ BETWEEN 125 AND 165 MA. THEN ADJUST C_T ACROSS L_6 FOR A MINIMUM PLATE CURRENT READING IN THIS STAGE.

BEFORE PROCEEDING WITH THE OUTPUT TUNING OF THE POWER AMPLIFIER STAGE, IT WILL BE NECESSARY TO ADJUST THE RADIO FREQUENCY DRIVE SO THAT THE GRIDS OF THE POWER AMPLIFIER TUBES RECEIVE THE PROPER EXCITATION. THIS IS ACCOMPLISHED BY INSERTING A RADIO FREQUENCY AMMETER IN SERIES WITH THE RESISTANCES (2,400 OHMS) WHICH ARE ACROSS THE POWER AMPLIFIER GRIDS. ASSUMING 100 WATT EXCITATION, THE RADIO FREQUENCY DRIVE IS INCREASED UNTIL THE RADIO FREQUENCY AMMETER IN THE RESISTANCE CIRCUIT READS A LITTLE LESS THAN 0.22 AMP. THUS, $W = I^2 R$ OR APPROXIMATELY 100 WATTS. ACCURATE POWER AMPLIFIER GRID EXCITATION MAY THUS BE OBTAINED FOR ANY POWER UP TO 1,000 WATTS IN THIS TRANSMITTER.

The output circuit of the power amplifier may then be tuned as follows. Adjust the harmonic suppression coil to the reactance value which will offer a minimum impedance to the desired carrier frequency and a maximum impedance to the second harmonic frequency. This value is obtained by referring to the calibration chart accompanying the transmitter. Close the power amplifier plate supply circuit. The plate current in this circuit should read very nearly 0.3 amp.

Vary the radio frequency drive until the radio frequency ammeter in the $C_T L_8$ mesh reads approximately 2 amp. At this point recheck the third amplifier plate current by varying C_T across L_6 until the plate current in this stage is of minimum value.

Vary C_T across L_8 for maximum current in the $C_T L_8$ radio frequency mesh. Increase the output coupling slightly, and vary the antenna tuning condenser in series with the harmonic suppression coil until the radio frequency ammeter in the plate mesh reads a minimum.

Increase the coupling $L_8 L_9$, and vary the radio frequency drive until all meter readings in the power amplifier output circuit correspond with the required manufacturer's ratings for a given power output.

When the transmitter has been properly tuned and neutralized as described, the proper monitoring level may be determined for the amount of power to be used.

The complete adjustment of the radio and audio frequency circuits are carried on into a dummy antenna load having a resistance of approximately the same value as that of the antenna. This permits the thorough testing of all the circuits to insure their compliance with the rigid requirements of the licensing authority before connecting the transmitter to the antenna or radiating system, thereby greatly reducing interference during the test hour periods.

Slight retuning of the output coupling circuits must again be made when the antenna circuit is connected for program radiation.

Although the tank circuits are tuned to resonance when adjusted for a maximum dip in the plate current reading as indicated by the direct current milliammeter, the full power output cannot be secured unless the tuning adjustments are slightly altered. In reality the circuit is not detuned but merely changed from a maximum impedance to a unity power factor condition. This is particularly important if the circuit is adjusted by the inductive reactance X_L since the resistive component of the inductance L prevents an absolute adjustment to these conditions. If, however, the tank circuit is tuned by a condenser, as in Fig. 7, the capacitive reactance may be more easily adjusted so that the combined reactances are equal, thereby resulting in a unity power factor condition. This adjustment gives a greater transfer of power because the load circuit resistance will decrease, thereby reducing the power dissipation, due to the resistance, and giving more useful power output. Modulation and frequency measurements must then be made to insure the proper percentage of modulation and frequency stabilization in accordance with the requirements of the Federal licensing authority.

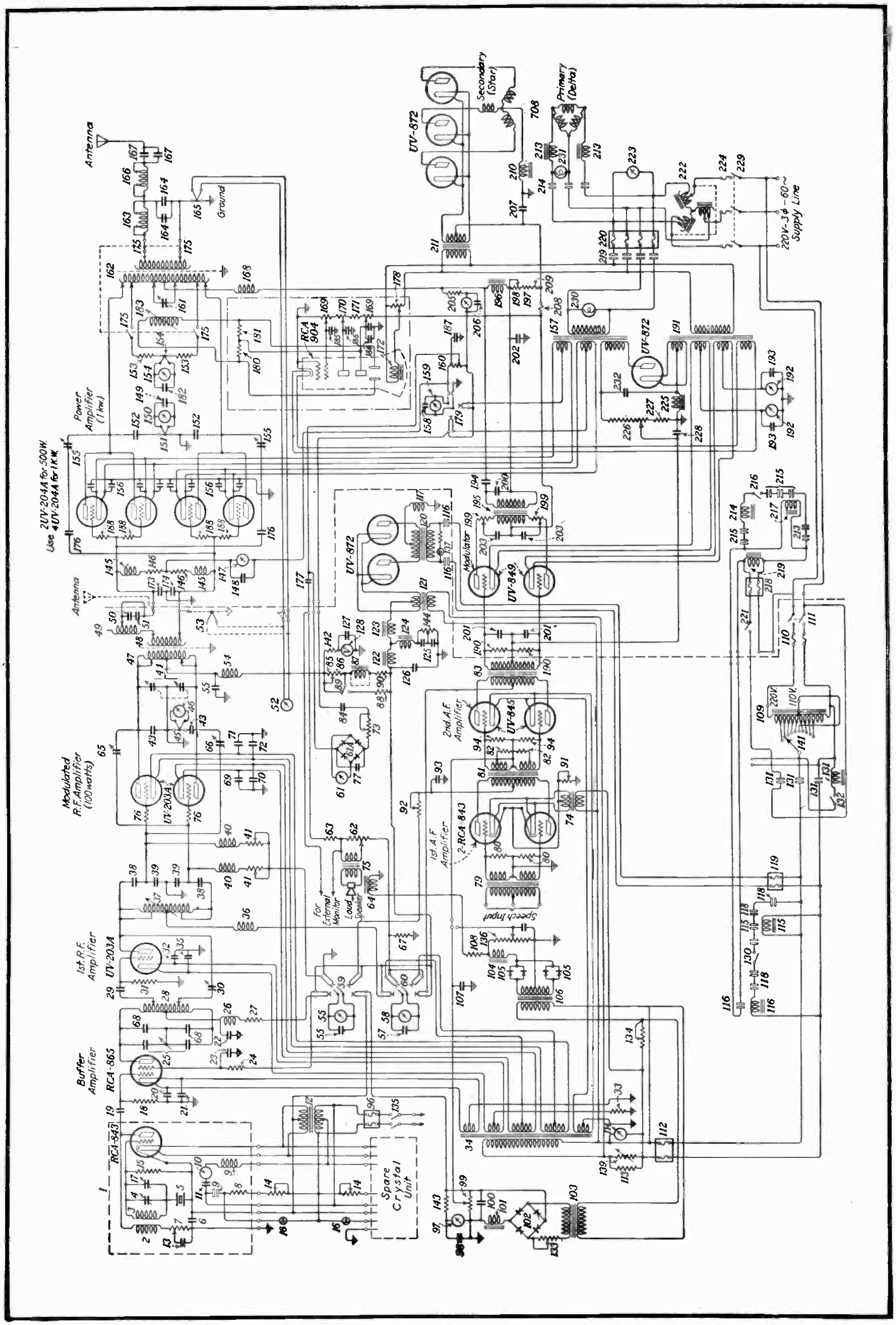


FIG. 8
R.C.A. Victor 1-Kw. Broadcast Transmitter.

1	Crystal oscillator unit.
2	Oscillator plate inductance.
3	Oscillator grid inductance.
4	Oscillator tank circuit capacity, 0.000365 mf.
5	Quarts plate.
6	By-pass condenser, 0.01 mf., 2,000-volt rating.
7	Plate feed-back resistance, 1,000 ohm, 3 watts.
8	Crystal heater resistances, 500 ohms.
9	Heater control relay.
10	Mercury thermo-regulator.
11	Relay condenser, 0.2 mf., 300-volt rating.
12	Filament transformer, 50 or 60 cycles.
13	By-pass condenser, 0.01 mf., 2,000-volt rating.
14	Heater control resistance, 500 ohms, 60 watts.
15	Oscillator grid leak resistance, 1 meg-ohm, 1 watt.
16	Heater indicator lamp.
17	Frequency vernier capacity, 0.00007 mf.
18	Buffer amplifier grid resistance, 100,000 ohms, 1 watt.
19	Coupling capacity, 0.00004 mf., 5,000-volt rating.
20–23	By-pass condenser, 0.01 mf., 2,000-volt rating.
24	Screen grid resistance, buffer amplifier, 50,000 ohms, 44 watts.
25	Split stator tank circuit capacity, 0.00048 mf. each section.
26	Plate choke coil.
27	Plate resistance, 15,000 ohms, 100 watts.
28	Plate inductance.
29	Blocking condenser, 0.001 mf., 5,000-volt rating.
30	Neutralizing condenser, 0.000034 mf.
31	Grid resistance, 2,000 ohms, 5 watts.
32	By-pass condenser, 0.01 mf., 2,000-volt rating.
33	Biasing resistance, 100 ohms, 5 watts.
34	Filament transformer.
35	By-pass condenser, 0.01 mf., 2,000 volt rating.
36	R.F. choke coil.
37	Plate inductance.
38	Coupling condenser.
39	By-pass condenser.
40	R.F. choke coil.
41	Power amplifier grid leak resistance, 20,000 ohms, 75 watts.
42	Spare crystal unit. Same as 5.
43	Tank circuit by-pass condenser.
44	Tank circuit tuning condenser, 0.00022 mf.
45	Thermocouple, 0 to 5 amp.
46	R.F. ammeter, 0 to 5 amp.
47	R.F. transformer.
48	Antenna coupling coil.
49	Loading inductance.
50–51	Antenna series capacity, 0.001 mf.
52	Antenna radio-frequency ammeter.
53	Thermocouple for antenna r.f. ammeter (not shown).
54	R.F. choke coil.
55	Meter by-pass condenser, 0.01 mf.
56	D-c. milliammeter, 0 to 150 ma.
57	Meter by-pass condenser, 0.01 mf.
58	D-c. milliammeter, 0 to 500 ma.
59–60	Meter switch.
61	Modulation indication meter, 0 to 1.5 ma.
61A	Modulation indication meter Rectox rectifier units.
62	Loud-speaker volume-control potentiometer, 500 ohms, 50 watts.
63	Monitor resistances, 30 ohms, 20 watts.
64	Monitoring loud-speaker.
65–66	Neutralizing condenser, 0.000056 mf.
67	Bleeder resistance, 25 ohms, 25 watts.
68	Condenser for buffer amplifier tank.
69–72	By-pass condenser, 0.01 mf., 2,000-volt rating.
73	Modulation indicator adjustable resistance, 10,000 ohms, 75 watts.
74	Filament transformer.
75	Loud-speaker input transformer.
76	Grid resistance, 100 ohms, 5 watts.
77	By-pass condenser, 0.01 mf., 2,000-volt rating.
78	A.F. amplifier and modulator (not separately numbered on diagram).
79	Audio-input transformer.
80	Audio-input load resistance, 9,000 ohms, 1 watt.
81	Interstage coupling transformer.
82	Load resistance, 15,000 ohms, 3 watts.
83	Modulator interstage coupling transformer.
84	Blocking condenser, 2 mf., 2000 volt rating.
85, 86	Amplifier feed resistance.
87	Modulator reactor.
88	Shunt reactor resistance.
89	Power changing switch.
90	Power-amplifier plate resistance, 2,500 ohms with 10 taps, 200 watts.
91	Biasing resistance, 750 ohms, 100 watts. Variable.
92	Plate feed resistance.
93	By-pass condenser, 4 mf., 1,000-volt d-c. rating.
94	Grid resistance, 100,000 ohms, 3 watts.
95	Power equipment (not separately numbered on diagram).
96	Cartridge-type fuses, 6 amp., 250 volts.
97	D-c. voltmeter, 0 to 500 volts.
98	Meter by-pass condenser, 0.01 mf.
99	Potentiometer, 3,500 ohms, 50 watts.
100	Filter condenser, 18 mf., 1,000-volt rating.
101	Filter choke coil.
102	Rectox rectifier unit.
103	Rectifier transformer.
104	Filter choke coil.
105	Rectox rectifier units.
106	Rectifier transformer.
107	Filter condenser. electrolytic type. 200 mf., 50-volt rating.
108	Voltage divider resistance section, 40 ohms, 100 watts.
109	Autotransformer.
110	Cartridge-type fuses, 30 amp., 250 volts.
111	Line switch.
112	Cartridge-type fuses, 10 amp., 250 volts.
113	Section of regulating resistance, 10 ohms, 100 watts.
114	Filament voltmeter. 150 volts, A.c.
115	Time-delay relay. Dash-pot type.
116	Plate contactor.
117	D-c. overload relay, dash-pot type.
118	Door switches.
119	Cartridge-type fuses, 20 amp., 250 volts.
120	Plate-supply power transformers.
121	Filament transformer.
122–124	Filter choke coil.
125	Filter condenser, 2 mf., 1,500-volt d-c. rating.
126	Filter condenser, 10 mf., 1,000-volt d-c. rating.
127	By-pass condenser, 0.01 mf.
128	Plate voltmeter, 0 to 1,500 volts.
129	Electrolytic condenser, 200 mf., 50-volt rating.
130	Plate-voltage switch.
131	Filament contactor.
132	Transmitter starting switch.
133	Rectox regulator resistance.
134	Regulator resistance for T103 and T106.
135	Crystal-heater switch.
136	Biasing potentiometer, 5,000 ohms, 50 watts.
137	Plate-voltage indicator light.
138	Spare-crystal indicator light.
139	Filament rheostat, 10 ohms, 75 watts. Adjustable.
140	Meter panel lights.
141	Line-voltage switch.
142	Voltmeter multiplier for 0 to 1,500-volt meter.
143	Voltmeter multiplier for 0 to 500-volt meter.
144	Filter resistance, 500,000 ohms, 3 watts.
145	R.F. choke coil.
146	Grid resistance, 2,000 ohms, 60 watts.
147	D.c. ammeter, 0 to 300 ma.
148	By-pass condenser, .01 mf.
149	By-pass condenser, 0.01 mf.
150	R.F. ammeter, 0 to 8 amp.
151	External thermocouple for 0- to 8-amp. meter.
152	Power-amplifier tank circuit condenser.
153	Phantom antenna resistance, twelve 220-ohm units in series.
154	Phantom antenna ammeter, 0 to 1 amp.
155	Variable condenser, 0.00011 mf.
156	By-pass condenser, 0.01 mf., 2,000-volt rating.
157	Filament and bias rectifier transformer.
158	By-pass condenser, 0.01 mf.
159	Power-amplifier plate ammeter, 0 to 1 amp.
160	Biasing resistance, 150 ohms, 200 watts.
161	Variable tank-circuit capacity, 0.00022 mf.
162	R.F. transformer.
163	Harmonic suppression inductance.
164	Antenna-coupling condenser.
165	Antenna ammeter thermocouple.
166	Antenna loading inductance.
167	Antenna condenser.
168	R.F. choke coil.
169	Potentiometer, 100,000 ohms.
170	Potentiometer, 350,000 ohms.
171	Separating resistance.
172	Cathode-ray sweep-circuit coils
173	Grid tuning condenser.
174	Grid tuning condenser.
175	Phantom antenna switch.
176	Neutralising condenser, 0.0001 mf.
177	Monitor blocking condenser, 28 mf., 1,000-volt d-c. rating.
178	Potentiometer, 2,300 ohms.
179	Meter switch.
180–181	Coupling-coil balancing resistance.
182	By-pass condenser, 0.01 mf.
183	Coupling coil for cathode-ray modulator indicator.
184	By-pass condenser, 0.001 mf., 5,000-volt rating.
185	By-pass condenser, 0.01 mf., 2,000-volt rating.
186	By-pass condenser, 0.01 mf., 2,000-volt rating.
187	Power-supply filter condenser, 10 mf., 1,000-volt rating.
188	Power-amplifier grid resistance, 100 ohms, 5 watts.
189	Modulator (not separately numbered on diagram).
190	Secondary stabilising resistances.
191	Filament transformer.
192	Plate ammeter, 0 to 300 ma.
193	By-pass condenser, 0.01 mf.
194	Blocking condenser, 6 mf., 2,000-volt rating.
195	Modulation output transformer.
196	Modulation reactor.
197, 198	Plate-feed resistances.
199	Modulation plate resistance, 100 ohms, 30 watts.
200	Secondary shunt condenser.
201, 202	Secondary by-pass condenser.
203	Primary by-pass condenser.
204	Power equipment (not separately numbered on diagram).
205	Voltmeter and multiplier, 0 to 5,000 volts, d.c.
206	By-pass condenser, 0.01 mf.
207	Filter condenser, two 3.5-mf. units, 3,000-volt rating.
208, 209	Fuse, 1 amp., 2,000 volts.
210	Filter choke coil.
211	Filament transformer.
212	Plate power transformers, 3.75-kva. rating.
213	Overload relays, oil dashpot, time-delay relay.
214	Plate contactor.
215	Door interlocking switches.
216	Plate ON switch.
217	Time-delay relay, oil-dashpot type.
218	Fuses, 6 amp., 250 volts.
219	Filament contactor.
220	Fuses, 6 amp., 250 volt.
221	Filament switch.
222	Autotransformer.
223	Line voltmeter, 0 to 250 volts a.c.
224	Fuses, 20 amp., 250 volts.
225	Bias filter choke coil.
226	Bias potentiometer, 125 ohms.
227	Bias resistance, 200 ohms, 200 watts.
228	Bias filter condenser, 200 mf., 200 volts, electrolytic type.
229	Line switch, three-pole single-throw variety.
230, 231	Indicator lamp.
232	Bias filter condenser.
233	Panel lights.

TABLE I

Parts of R.C.A. Victor Broadcast Transmitter.

R.C.A. VICTOR BROADCAST TRANSMITTERS

IN FIG 8 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN R.C.A. VICTOR BROADCAST TRANSMITTER WHICH IS RATED AT I KW. AND A REFERENCE INDEX FOR THE VARIOUS PARTS OF THIS TRANSMITTER APPEARS IN TABLE 1.

THIS TRANSMITTER CONSISTS OF TWO SELF-CONTAINED UNITS,NAMELY, A 100 WATT TRANSMITTER UNIT AND A 1000 WATT AMPLIFIER UNIT. IF SO DESIRED, THE ANTENNA SYSTEM CAN BE CONNECTED AS INDICATED BY THE DOTTED LINES AND THE UNIT THUS OPERATED AS A 100 WATT TRANSMITTER AND WITHOUT THE USE OF THE POWER AMPLIFIER UNIT.

FROM WHAT YOU HAVE ALREADY LEARNED ABOUT TRANSMITTERS, AND AIDED BY TABLE 1, YOU SHOULD BE ABLE TO ANALYZE FOR YOURSELF THE VARIOUS DETAILS OF THIS CIRCUIT. IT WILL BE WELL TO MENTION AT THIS POINT, HOWEVER, THAT THE R.C.A. 904 TUBE WHICH IS USED WITH THIS EQUIPMENT IS A CATHODE-RAY TUBE ACTING AS A MODULATION INDICATOR. FOR THE PRESENT,DON'T WORRY ABOUT THE OPERATION OF THIS TYPE OF MODULATION INDICATOR,AS YOU WILL RECEIVE COMPLETE INSTRUCTIONS REGARDING CATHODE-RAY TUBES AND ALL OF THEIR VARIOUS APPLICATIONS IN LATER LESSONS WHICH ARE INCLUDED INTHE "ELECTRONICS SERIES".

OPERATING POWER

THE DETERMINATION OF THE OPERATING POWER OR OUTPUT POWER IS A PROBLEM WHICH ARISES FREQUENTLY WITH RESPECT TO TRANSMITTER EQUIPMENT. TO ASCERTAIN THIS VALUE, THE FOLLOWING FORMULA CAN BE USED: OUTPUT POWER IN WATTS= PLATE VOLTS X PLATE CURRENT EXPRESSED IN AMPERES X F.

THE FACTOR F IS A CONSTANT AND HAS THE FOLLOWING VALUE:

FOR TRANSMITTERS USING HIGH-LEVEL MODULATION

MAXIMUM RATED CARRIER POWER OF TRANSMITTER (WATTS)	FACTOR "F"
100	0.50
250-1,000	0.60
2,500-50,000	0.65

FOR TRANSMITTERS USING LOW-LEVEL MODULATION

MAXIMUM PERCENTAGE OF MODULATION	FACTOR "F"
75-85	0.40
86-100	0.33

FOR TRANSMITTERS USING GRID-BIAS MODULATION IN LAST RADIO STAGE

MAXIMUM PERCENTAGE OF MODULATION	FACTOR "F"
75-85	0.27
86-100	0.22

TO ILLUSTRATE THE USE OF THIS DATA, LET US CONSIDER A PRACTICAL PROBLEM: A CERTAIN TRANSMITTER EMPLOYS LOW-LEVEL MODULATION AND MODULATES THE CARRIER FREQUENCY AT 80%. THE PLATE VOLTAGE OF THE FINAL R.F AMPLIFYING TUBE IS 2500 VOLTS AND DRAWS A PLATE CURRENT OF 275 MA. THE FACTOR F IN THIS CASE WOULD BE APPROXIMATELY 0.40 AND BY SUBSTITUTING VALUES IN THE OUTPUT POWER FORMULA WE HAVE:

OUTPUT POWER IN WATTS = 2500 X .275 X 0.40 = 275 WATTS.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW BE THOROUGHLY FAMILIAR WITH BROADCAST TRANSMITTERS AND THEIR RELATED EQUIPMENT.

YOU MUST REMEMBER, OF COURSE, THAT NOT ALL BROADCAST STATIONS ARE DESIGNED EXACTLY ALIKE BUT THOSE INSTALLATIONS, WHICH WERE EXPLAINED TO YOU IN THESE LESSONS, ARE TYPICAL EXAMPLES. THEREFORE, BY HAVING A GOOD UNDERSTANDING OF THESE PARTICULAR ONES AND AIDED BY ALL OF THE ADDITIONAL KNOWLEDGE WHICH YOU NOW HAVE ABOUT TRANSMITTERS IN GENERAL, IT SHOULD BE A SIMPLE MATTER FOR YOU TO FULLY ACQUAINT YOURSELF WITH THE EQUIPMENT USED IN ANY CONVENTIONAL STATION.

AGAIN LET US REMIND YOU THAT EVEN IF YOU DO NOT INTEND TO SPECIALIZE IN ANY ONE OF THE MANY FIELDS WHICH INVOLVE TRANSMITTERS, YOU OWE IT TO YOURSELF TO GET AS MUCH OUT OF THIS SERIES OF LESSONS AS YOU POSSIBLY CAN.

NATIONAL HAS TRIED ESPECIALLY HARD TO MAKE THIS COURSE AS COMPLETE AS POSSIBLE SO THAT EACH AND EVERY STUDENT WILL HAVE AN EQUAL OPPORTUNITY TO SUCCEED IN THIS GREAT INDUSTRY. TO BE SUCCESSFUL IN THIS DAY AND AGE A MAN MUST HAVE A GOOD GENERAL KNOWLEDGE OF THE ENTIRE FIELD IN WHICH HE IS ACTIVE, AND IN ADDITION, HE MUST HAVE A MOST THOROUGH UNDERSTANDING OF THE SUBJECT WHICH HE SELECTS AS HIS PARTICULAR BRANCH OF SPECIALIZATION. FROM BEGINNING TO END, THIS COURSE HAS BEEN CAREFULLY PLANNED TO MEET THIS CONDITION AND WE URGE YOU TO MAKE THE MOST OF THE OPPORTUNITIES WHICH NATIONAL IS SO EAGER TO EXTEND TO YOU.

ans June 31, 1942

Examination Questions

LESSON NO. T-18

> Education is the practical preparation of the individual in order to face and dominate the obstacles on the road to success.

1. - (A) MAKE A SIMPLE DIAGRAM WHICH ILLUSTRATES THE RELATION BETWEEN THE VARIOUS UNITS OR SECTIONS WHICH TOGETHER CONSTITUTE A TYPICAL BROADCAST STATION. (B) EXPLAIN THE PURPOSE OF EACH OF THESE UNITS.

2. - DRAW A CIRCUIT DIAGRAM OF A SERIES-RESONANCE EQUALIZER. DESCRIBE HOW IT IS USED, AND EXPLAIN HOW IT OPERATES.

3. - DRAW A CIRCUIT DIAGRAM OF A PARALLEL-RESONANCE EQUALIZER. DESCRIBE HOW IT IS USED, AND EXPLAIN HOW IT OPERATES.

4. - EXPLAIN HOW REMOTE-CONTROL BROADCASTS ARE GENERALLY HANDLED.

5. - MAKE A DRAWING OF THE TYPICAL SET-UP FOR MAKING A FREQUENCY RUN ON AN A.F. TRANSMISSION LINE.

6. - DESCRIBE THE PROCESSES WHICH ARE INVOLVED WHEN MAKING SUCH A FREQUENCY RUN.

7. - WHAT DOES A FREQUENCY RESPONSE CURVE INDICATE?

8. - WHAT ARE SOME OF THE MORE IMPORTANT PROTECTIVE DEVICES WHICH ARE USED IN THE LARGER BROADCAST TRANSMITTERS?

9. - IN WHAT WAYS DOES THE CONVENTIONAL BROADCAST TRANSMITTER DIFFER FROM THE ORDINARY PHONE-TYPE COMMERCIAL TRANSMITTER?

10 - EXPLAIN IN DETAIL HOW THE OPERATING POWER OF A BROADCAST TRANSMITTER CAN BE DETERMINED.

NATIONAL SCHOOLS

LOS ANGELES CALIFORNIA

ESTABLISHED 1905 J. A. ROSENKRANZ, *President*

RADIO DIVISION

SPECIAL EXAMINATION #9

Dear Student:

Having by this time completed eighteen lessons treating with Radio Transmitters, you should now have a good understanding of this subject.

Since answering your last special examination, you have learned a great deal concerning the power supply for transmitters, constructional features and operation of radio-telegraph transmitters, handling radio messages, transmitter tubes, communication receivers, and broadcast transmitters.

Due to the outstanding importance of these subjects, as well as those which were discussed with you during the first nine lessons of the Transmitter Series, it is advisable that you review this entire series of Transmitter Lessons with special care.

Upon the completion of this intensive review, answer fully the following questions which are based upon all of the transmitter lessons which you have studied thus far, and send them to us for correction.

You will find this set of examination questions to serve as a good guide for conducting your review and I am confident that you will do your utmost to receive a splendid grade on this examination.

Sincerely yours,

J. A. Rosenkranz

President

EXAMINATION QUESTIONS

1. - Draw a complete circuit diagram of a commercial type radio-telegraph transmitter.

2. - Explain the procedure for operating the transmitter whose diagram you have drawn in answer to question #1.

3. - What Greenwich Mean Time corresponds to an Eastern Standard Time of 11 p.m.?

(over)

4. - DRAW A COMPLETE CIRCUIT DIAGRAM OF A THREE-PHASE, HALF-WAVE RECTIFIER THAT IS SUITABLE FOR A TRANSMITTER'S "B" SUPPLY.

5. - DRAW A DIAGRAM OF A CRYSTAL FILTER CIRCUIT AS USED IN A RECEIVER AND EXPLAIN ITS OPERATION IN DETAIL.

6. - DRAW A CIRCUIT DIAGRAM SHOWING HOW A BEAT OSCILLATOR MAY BE COUPLED TO THE SECOND DETECTOR OF A SUPERHETERODYNE RECEIVER AND EXPLAIN IN DETAIL HOW THE COMPLETE SYSTEM OPERATES.

7. - WHAT IS THE OBJECT OF PROVIDING A SHORT-CIRCUITING SWITCH FOR THE CRYSTAL FILTER OF A RECEIVER?

8. - WHAT ARE THE OPERATING CHARACTERISTICS OF A TYPE 204A TRANSMITTER TUBE?

9. - WHAT ARE THE OPERATING CHARACTERISTICS OF A TYPE 866 TUBE?

10. - DRAW A COMPLETE CIRCUIT DIAGRAM OF THE EQUIPMENT WHICH YOU WOULD EXPECT TO FIND IN THE STUDIOS AND CONTROL ROOM OF A TYPICAL BROADCAST STATION.

11. - DESCRIBE THE EQUIPMENT AND CIRCUITS WHICH YOU WOULD EXPECT TO FIND IN THE TRANSMITTER ROOM OF A TYPICAL BROADCAST STATION.

12. - WHAT IMPORTANT FACTS SHOULD BE CONSIDERED IN LAYING OUT THE DESIGN OF A PHONE TRANSMITTER?

13. - DRAW A COMPLETE CIRCUIT DIAGRAM OF A PHONE TRANSMITTER EMPLOYING THE HEISING SYSTEM OF MODULATION.

14. - EXPLAIN IN DETAIL THE OPERATION OF THE CIRCUIT WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #13.

15. - DRAW A CIRCUIT DIAGRAM OF A PHONE TRANSMITTER EMPLOYING GRID BIAS MODULATION.

16. - EXPLAIN IN DETAIL THE OPERATION OF THE CIRCUIT WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #15.

17. - EXPLAIN WHAT IS MEANT BY "MODULATION PERCENTAGE" AND ALSO EXPLAIN HOW THIS VALUE CAN BE DETERMINED.

18. - WHAT IS THE GENERAL PROCEDURE FOR TUNING A TRANSMITTER WHICH DOES NOT EMPLOY ANY FREQUENCY-MULTIPLIER STAGES?

19. - WHAT IS THE GENERAL PROCEDURE FOR TUNING A TRANSMITTER WHICH DOES EMPLOY ONE OR MORE FREQUENCY-MULTIPLIER STAGES?

20. - WHAT ARE SOME OF THE MORE IMPORTANT PRECAUTIONS WHICH SHOULD BE EXERCISED WHEN OPERATING ANY RADIO TRANSMITTER?

NATIONAL SCHOOLS
LOS ANGELES CALIFORNIA
ESTABLISHED 1905 J. A. ROSENKRANZ, *President*

RADIO DIVISION

SPECIAL EXAMINATION #8

Dear Student:

You are at the present time engaged in an intensive study of Radio Transmitters wherein many new and important principles are being explained. The knowledge of transmitters which you are now acquiring is going to be especially valuable to you if you intend to ultimately specialize in radio broadcasting, in any of the many applications of commercial operating, or in television.

Even if you do not plan to specialize in any field of radio which involves transmitters, you should not deny yourself this additional training. A thorough study of this subject will broaden your knowledge of radio in general and will also familiarize you with many facts which may be of tremendous value to you at some later time even though you may not realize it now.

The questions in this examination are based on the first nine lessons of the Transmitter Series. I therefore suggest that you review these nine lessons carefully, and then answer the following questions to the best of your ability.

Sincerely yours,

J. A. Rosenkranz
President

EXAMINATION QUESTIONS

1. - Draw a circuit diagram of a spark transmitter and explain how it operates.

2. - What is the difference between a Y-cut crystal and an X-cut crystal?

3. - How would you designate the completion of a transmitted message by means of code?

4. - What is the difference between a series-feed oscillator and a shunt feed oscillator?

5. - Draw a complete circuit diagram of a radio-telegraph transmitter consisting of a push-pull oscillator stage only, using two type 10 tubes. The circuit of the power pack for A-C operation is also to be included in this diagram.

(over)

6. - DRAW A CIRCUIT DIAGRAM OF A HARTLEY OSCILLATOR AND EXPLAIN HOW IT OPERATES.

7. - DRAW A CIRCUIT DIAGRAM OF A MONITOR WHICH IS SUITABLE FOR AMATEUR USE. EXPLAIN HOW YOU WOULD CALIBRATE IT AND HOW YOU WOULD USE IT FOR ADJUSTING AN AMATEUR TRANSMITTER.

8. - WHAT IS THE MEANING OF THE SIGNAL ABBREVIATION "QSO"?

9. - DRAW A CIRCUIT DIAGRAM OF A CRYSTAL-CONTROLLED OSCILLATOR AND EXPLAIN HOW IT OPERATES.

10. - DRAW A CIRCUIT DIAGRAM OF A COMPLETE CODE-TRANSMITTER COMPRISING A TRI-TET OSCILLATOR, FOLLOWED BY ONE DOUBLER STAGE AND A FINAL POWER STAGE.

11. - DESCRIBE IN DETAIL HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #10.

12. - DESCRIBE THE DIFFERENT TYPES OF COUPLING WHICH ARE PRACTICAL IN THE R-F STAGES OF A TRANSMITTER.

13. - UPON WHAT FACTORS DOES THE RESONANT FREQUENCY OF A QUARTZ CRYSTAL DEPEND?

14. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF A SPLIT-STATOR TUNING CONDENSER AND MENTION THE ADVANTAGES OF USING SUCH A UNIT IN A TRANSMITTER.

15. - EXPLAIN IN DETAIL HOW YOU WOULD WORK OUT THE DESIGN FOR A HERTZ ANTENNA.

16. - EXPLAIN HOW A FREQUENCY MULTIPLIER OF A TRANSMITTER OPERATES.

17. - MAKE A SKETCH OF A ZEPPELIN ANTENNA AND EXPLAIN FULLY HOW YOU WOULD ADJUST SUCH AN ANTENNA SYSTEM TO RESONANCE WITH THE FREQUENCY AT WHICH THE TRANSMITTER IS OPERATING?

18. - WHAT IS THE ADVANTAGE OF USING FREQUENCY MULTIPLIER STAGES IN A TRANSMITTER?

19. - EXPLAIN HOW YOU WOULD PROCEED TO DESIGN AN UNTUNED TRANSMISSION LINE FOR A TRANSMITTER ANTENNA SYSTEM.

20. - DRAW A CIRCUIT DIAGRAM OF AN ELECTRON-COUPLED OSCILLATOR AND EXPLAIN HOW IT OPERATES.

Practical-Technical

TRAINING IN RADIO AND TELEVISION

ESTABLISHED 1905

J. A. ROSENKRANZ, Pres.

NATIONAL SCHOOLS

LOS ANGELES, CALIFORNIA

EXPERIMENT LESSON NO. FG-1

BASIC RADIO EXPERIMENTS

The experimental and practical work, which you are now ready to begin, is one of the most important and interesting phases of your study. As you no doubt realize,it is highly important that you master thoroughly the basic principles governing the operation of radio receivers, in order to become a fully trained and qualified technician. It is for this reason that we furnish you with a complete series of experimental kits, together with this special series of Experiment Lessons.

As you continue with this phase of your Training, you will receive complete instructions with each individual kit, showing you exactly how each apparatus should be constructed and how to perform the various experiments related thereto. This does not mean that you must confine your studies to these experiments alone. On the contrary, you should always be on the lookout for new methods of experimentation, as in this way you will acquire experience which will be of tremendous value to you. At the same time, you will successfully overcome the "fear" that most beginners experience when they face their first radio service job.

The experiments which you will perform are in progressive order, and in accord with our method of teaching which has been time-tested by years of experience in the field of technical education. Therefore, it is important that you follow our instructions carefully and perform these experiments exactly as presented. Under no conditions, should you skip any of the experiments, regardless of how simple they might appear to you, for in performing even the most simple experiment you will learn something new and valuable.

YOUR FIRST KIT OF PARTS

The first kit consists of the following parts:

1 - Eight-prong socket
1 - Grid cap for metal tube
1 - .00025 mf mica condenser
1 - 500,000 ohm carbon resistor
1 - Input push-pull transformer
1 - Headset (headphones)
20 feet of push-back wire for connections

Remember, too, that as you advance through the series of construction projects and experiments, the kits become more elaborate,and contain more parts. Thus, you progress into the advanced experimental and constructional work step by step.

When you receive a kit, your first action should be to carefully examine the parts received, so as to become thoroughly familiar with them. Then, with this equipment before you, you should read this lesson very carefully.

The TUBE SOCKET is a very simple item, so we will say very little about it, except to make this observation. Some sockets are equipped with many terminals that are placed quite close to each other. When mounting such sockets on the metal chassis, be careful that the mounting screws or nuts do not touch any of the socket terminals and thus ground them.

The GRID CAP is also very simple and therefore needs little explanation. When soldering your connections be sure that they form solid and neat unions. Poorly soldered connections will increase the resistance and may cause serious difficulties.

Now, for the MICA CONDENSER and the CARBON RESISTOR. In some cases, you will find the electrical value marked on these units in some such form as .00025 mf or 1000 ohms. However, it is the more general practice among radio parts manufacturers to indicate the electrical value of the unit by means of a color-code.

It is advisable that you learn the color code, which has been adopted by all leading radio manufacturers. This code is known as the "RMA code" -- RMA being the abbreviation for Radio Manufacturer's Association. It is applied by giving a fixed value to each color, so that combining the several colors will result in the total value of the resistor or condenser. The numerical equivalents of the different colors used in the "code" are as follows:

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

The value of a resistor is determined by noting the colors in the following order: The body, the end, and a dot or stripe. The last color indicates the number of ciphers (zeros) to be added to the first two numbers. The method of "coding" resistors is illustrated in Fig. 1.

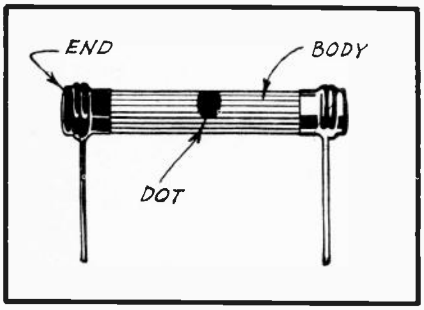


FIG. 1
COLOR-CODED RESISTOR

A 500,000-ohm resistor has a green body (5), a black end-color (0), and a yellow stripe or dot. The yellow stripe or dot means that we are to add 4 ciphers to numbers ascertained previously. Our numerical values thus take the form 5-0-0000, giving us the figure 500,000 ohms. In the same way, a resistor with a red body, green end-color and an orange dot, would have the value of 2-5-000, or 25,000 ohms. A resistor with a green body, black end-color, and a black dot or stripe would have a value of 5-0, or 50 ohms. Note carefully in the latter example, that we do not add any ciphers beyond the first two figures, because the black dot or stripe indicates zero, showing us that no ciphers are to be added.

CONDENSER VALUES are indicated by the same color code, but you must remember that when dealing with condensers, the values are expressed in micromicrofarads (mmf). When reading the color code of condensers, the condenser is held in such a position that the trade-mark is right side up, as in Fig. 2. The values of the colors are then read from left to right. For example, if a condenser has a red, green and brown dot (in reading order) its value is 2-5-0 = 250 mmf or .00025 mf.

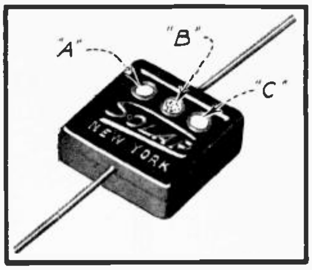


FIG. 2
COLOR-CODED CONDENSER

THE INPUT PUSH-PULL TRANSFORMER

The input push-pull transformer is the small transformer contained in your first kit. This transformer consists of a primary and secondary winding placed on a laminated steel core. The primary winding is easily recognized by the fact that it is provided with only two terminals. The secondary is wound over the primary and has three terminals --- one for each of the two ends and one for the center-tap.

In the illustrations of this transformer, appearing in this lesson, the terminals of the primary are placed on one side and those of the secondary on the other side. This is not always the case, as some transformers have all five terminals on one side while others use flexible insulated wires instead of terminals.

It is a very simple matter to identify the terminals of these transformers. We do this in the following manner: Connect one lead of your headphones to the positive terminal of a $1\frac{1}{2}$-volt dry cell. Then, connect one of your test leads to the other headphone tip and attach your other test lead to the negative terminal of the battery. You can then test the windings of the transformer by touching the test points to the various terminals of the transformer. If you hear a "click" as the test points are brought into contact with two terminals, it shows that the circuit is complete. You will find three of the terminals to indicate a complete circuit between themselves -- these are the secondary terminals. The two remaining terminals are connected to the ends of the primary winding.

By using the same headphone test, it is also a simple matter to determine which of the three inter-connected terminals is the center-tap. Contacting the terminals which are connected to the ends of the winding will produce a more faint "click" in the headphones than will contact between the center-tap and either end-terminal. Having thus definitely identified the ends of the winding, the remaining terminal of the group is connected to the center-tap.

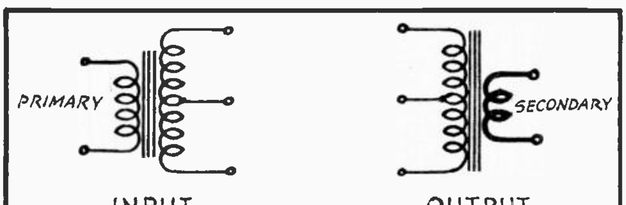


FIG. 3
PUSH-PULL TRANSFORMER

OUTPUT PUSH-PULL TRANSFORMERS are also equipped with one group of three terminals and one group of two terminals. However, upon inspecting the transformer more closely you will see that one winding consists of a much larger wire-size than the other. The larger wire-size is used for the secondary winding of the output push-pull transformer. Fig. 3 shows the difference between an input and an output push-pull transformer.

With these instructions you will have no difficulty in identifying the terminals of "push-pull" transformers.

TESTING THE HEADPHONES

Let us now examine the headphones. Notice first that the metal head-band can be bent to fit your head, and that you can also fit the phones to your ears by sliding them up or down upon the rod.

Now unscrew from one phone unit that part (the cap) which contacts your ear. IMPORTANT -- do not remove any nuts or screws from the unit during this process as otherwise the entire assembly will fall apart.

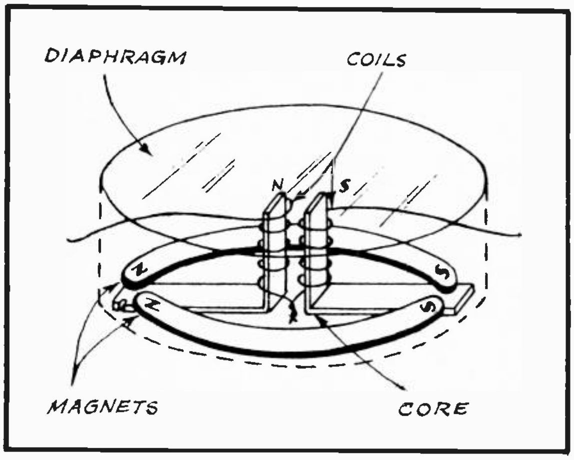


FIG. 4
TYPICAL HEADPHONE CONSTRUCTION

Slide (do not lift) the diaphragm off the phone, and you will notice that two small coils of very fine wire are wound upon steel cores. Now slide the diaphragm back into position on the phone very slowly; notice that there is a very small clearance between the ends of the cores and the diaphragm, and that it is magnetically attracted by them. This attraction is caused by two small permanent magnets touching the lower parts of the iron cores.

Fig. 4 shows you the inner construction of an earphone (headphone) in a simplified form. Notice how the poles of the magnet are placed (S with S and N with N). This makes one core-end a south pole and the other core-end a north pole. Therefore, a magnetic field will be established between both cores, causing the diaphragm to be attracted.

The headphone coils are made of many turns of very fine wire. As a general rule, the wire used in each coil offers a resistance of 500 ohms. Taking into consideration the fact that the two coils in each phone unit are connected in series, the total resistance of the four coils used in the headset is 2,000 ohms.

By studying Fig. 4 and the headphones, you will notice that current will flow in opposite directions through the two coils. Therefore, the outer end of one of the coils will be of a north polarity, while the outer end of the other coil will be of a south polarity.

When the headphones are connected to a receiver, a pulsating signal current flows through the coils. As a result, there will be a constant change in the intensity of the magnetic field, and the attraction on the diaphragm will vary accordingly. Thus, the movement of the diaphragm produces sound waves which reach our ear.

If you stop to think, you will reach the following conclusion: The current should flow through the phone windings in such a direction that the magnetic field produced by the current will be added to that caused by the magnets. Thus, the sound waves will be stronger and the magnetism will be retained by the permanent magnets for a longer period of time. To prevent the current from demagnetizing the magnets, manufacturers generally color-code the phone leads for identification purposes.

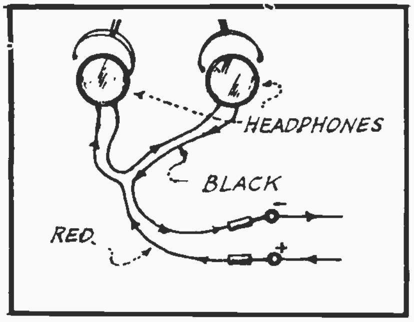


FIG. 5
HEADPHONE CONNECTIONS

Fig. 5 shows you how the headphones are connected to the circuit. Notice that the red lead is connected to the positive side of the circuit and the black lead to the negative side. However, when the polarity of the circuit is unknown, the headphones will still function regardless of the connections as to polarity.

AN EXPERIMENTAL TELEPHONE

Let us now use our headphones to form a simple telephone system as illustrated by the drawing appearing in Fig. 6. Observe that the phones are connected together with a long piece of wire. For this purpose you may use the hook-up wire sent to you in this kit. When disconnecting the regular leads from the phone during this experiment be careful not to damage the units.

The length of "line" between the two phones should not be too great. Just enough wire should be used so that one phone may be placed in one room and the other phone in another room. The object is to listen at one phone unit while another person speaks into the other phone unit. The latter unit will at this time function as a microphone. ("Cupping" one of your hands around the "microphone" will assist in focusing the sound waves toward its diaphragm.)

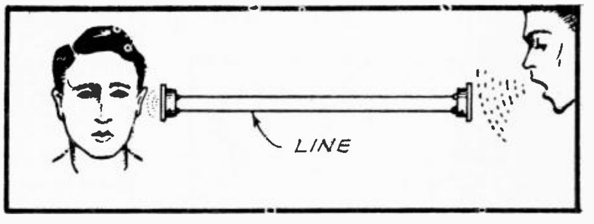


FIG. 6
SIMPLE TELEPHONE CIRCUIT

Fig. 7 is a side view of an earphone. As you can see, the diaphragm completes the magnetic circuit produced by the magnets. By talking into this phone at close range, the sound waves will act upon the diaphragm, causing it to vibrate vigorously.

The movement of the diaphragm, illustrated by the dotted lines in Fig. 7, deflects the magnetic field and thus generates a small voltage that causes a tiny current to flow through the coils. This phenomenon is described fully in the regular lessons of your course, and corresponds to the same principle which makes possible the operation of generators, transformers, etc., by the fluctuation of a magnetic field.

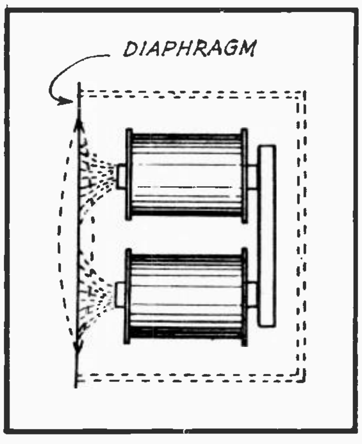


FIG. 7
MAGNETIC INFLUENCE
UPON THE DIAPHRAGM

Having connected your phones as shown in Fig. 6, the weak signals generated in the coils of the one are used as a microphone pass to the other, where they reproduce the original sound uttered into the "microphone." When the phones are connected in this way, they can be used interchangeably as the microphone or reproducer.

While conducting this experiment, you must bear in mind that the phones were not constructed to serve as a microphone and should therefore not be expected to operate efficiently, as a regular microphone. However, using them in this experiment does demonstrate clearly the principle of telephony. If you have a small battery or dry cell handy, try connecting it in series with this system -- you will find it to increase the volume considerably. In any case, the phone being used as the microphone must be held directly in front of the mouth and you must talk into it loudly so as to cause the diaphragm to vibrate vigorously.

DIRECT OR ALTERNATING CURRENT

We will now use the headphones in a more practical manner. First, we shall use them to determine whether a circuit is passing an a-c or d-c current. With the help of the headphones, this is a simple matter.

Keeping in mind the manner in which the headphone functions, you can readily see that the only effect on the diaphragm, when connecting the phones to a d-c circuit, will be a slight "click" as the circuit is closed or opened. This is true because d-c current is of constant intensity.

However, when the phones are connected to an a-c circuit, a constant hum will be produced, because the current is constantly changing its intensity. This hum will be of the same frequency as the a-c current. In other words, if the a-c is of the 50 or 60 cycle type -- the more common frequencies -- the diaphragm will vibrate rapidly and reproduce the low tone of that frequency.

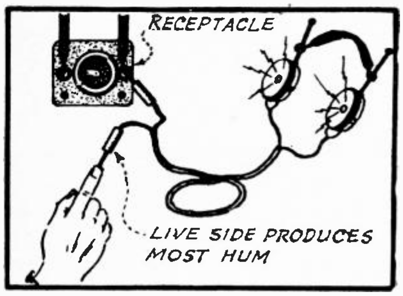


FIG. 8
IDENTIFYING THE "LIVE-SIDE" OF THE LINE

Fig. 8 illustrates a practical way of performing this test, and at the same time serves to show us which is the "live-side" of any wiring system.

> **CAUTION**
> It is important that you be on a DRY wooden floor while conducting the experiment illustrated in Fig. 8. This is necessary to avoid a dangerous electrical shock. For the same reason, be careful not to contact both sides of the lighting circuit with your hands.

In almost all a-c lines, as well as many d-c lines, one side of the circuit is permanently connected to a ground, either at the power house or at the distribution transformers. The object of this connection to ground is to protect the system against electrical discharges and lightning, by dissipating any excess voltage directly to ground. This will result in the least amount of damage to the system or equipment. The ungrounded side is usually called the "live-side" of the circuit.

It is often necessary to determine which side of the line is grounded and which is the live side, as when connecting an outlet plug or lamp receptacle to the system. If this is not done correctly, it is quite probable that any handling of the equipment, as when turning a lamp on or off, will result in an electric shock.

To conduct the "line test", proceed as follows: Connect the headphones into the lighting system as illustrated in Fig.8. That is, touch one of the phone tips with one of your fingers. Touch the other phone tip alternately to both sides of the line, without touching this tip. If you hear a loud hum when the line is contacted in this way, it indicates that alternating current is energizing the circuit, and that you are touching the "live side" of the system. The phones are so sensitive that you need not be actually grounded when performing this test.

If no hum is heard at all, the circuit is of the d-c type. The live side in this case is the one which produces a definite "click" in the headphones.

IMPORTANT: The headphones should never be connected directly across a power line unless a .00025 mf condenser is connected in series so as to reduce the current. By no means should you connect your phones directly to an a-c line, as this is certain to cause the magnets to lose their polarity and thus damage them beyond repair.

A good way to avoid this form of damage to your phones, when using them in a radio circuit operating at voltages exceeding 45 volts, is to connect a .05 mf condenser in series with them -- thereby allowing only the audio signals to pass through them and rejecting the d-c. Never connect the phones across the primary or secondary winding of a power transformer, as the current circulating through them is then of the a-c type and may destroy the polarity of the magnets.

CONTINUITY TESTS

Another application of the headset is its use in conducting continuity tests. That is, determining whether or not a circuit, or part of a circuit, is complete. In this way, the windings of transformers, chokes, coils, condensers and other radio parts can be checked. Because of their sensitivity, the phones are also useful in ascertaining the condition of high-ressitance coils, high-value resistors, etc.

Fig. 9 shows the method of using a dry cell in series for this purpose. (This cell may be of the flashlight type.) Note that the contact on top of the cell is connected to the positive lead of the phones. The other phone terminal is used as a test lead, as is also the wire which is connected to the metal can (negative terminal) of the dry cell.

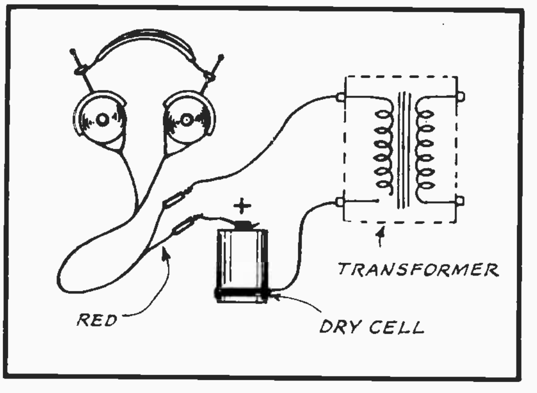


Fig. 9
Headphone Continuity Test

Note that a "click" is heard in the phones, when bringing your test leads in contact with each other. This also happens when the circuit is completed through a coil, resistor, or any radio part that permits the flow of d-c. Fig. 9 shows that the winding under test is open; therefore, no "click" is heard.

TESTING RADIO PARTS FOR CONTINUITY

R-F TRANSFORMERS: By means of the continuity test just described, you can determine the condition of a coil, and also identify the ends of the secondary and primary windings. To do this, simply touch one of the test leads to a terminal, and then with the free lead, touch one terminal after another until you hear a "click" in the phones. The "click" indicates that these two terminals are connected together by a winding. These circuits are of low resistance; therefore, the sound produced will be about the same as that experienced when touching the leads together.

A-F TRANSFORMERS: By applying the continuity test to a-f transformers, you can determine the condition of the primary or secondary winding, locate shorts between either winding and the core, distinguish the primary from the secondary, or identify the terminals of the unit.

For this test, connect one test lead to one of the lugs or terminals and touch the other lead to each of the other terminals in successive order. When contacting in this manner the terminals corresponding to the ends of the winding, you will hear a soft but definite "click." Do this repeatedly, so that you may get an idea of the audible effects obtained under such circumstances.

You can proceed to identify the terminals of the other windings in the same way -- notice particularly if the "click" is strong or weak. As a general rule,the primary winding produces a louder "click" due to its lesser resistance.

If the transformer is of the input push-pull type,a louder click will be produced when testing through the primary winding. When testing through an output push-pull transformer,the secondary will produce a much louder click then the primary. If any of the windings are open, there will be no click whatsoever.

Sometimes, you may come across a transformer which apparently tests normal; however, if the circuit is kept intact for a while, you may hear rasping sounds, indicating a defective winding. When the windings are in good condition, the click will be heard only at the instant that the circuit is closed or opened.

The final test is to determine the probability of current-leakage between the windings and the core. To conduct this test, simply touch one of your leads to the core, and with the other lead touch the various terminals, one at a time. If the insulation is perfect between both windings and the core, no click will be heard in the headphones. If the click is anywhere near as loud as the one heard when testing between the ends of either the primary or secondary, it indicates current-leakage through the insulation. Such a transformer is either entirely unserviceable or else will cause noisy (raspy) reception.

CHOKES: Test across the terminals. If the winding is in good condition, a strong click will be heard in the phones. Also, test between the core and the windings, checking for imperfect insulation as already explained relative to a-f transformers.

R-F CHOKES: Test across the terminals. This should produce a loud click.

RHEOSTATS, RESISTORS, ETC: Place your test leads across the resistor or rheostat. The intensity of the click should be in accordance with the resistance value of the part being tested. High-resistance units produce a slight click, whereas low-resistance units produce a louder click.

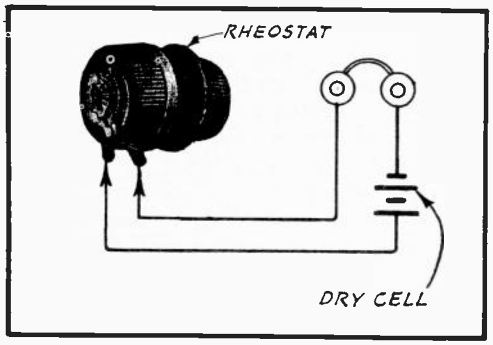


FIG. 10
CHECKING A RHEOSTAT

When testing rheostats and resistors in general, connect them as in Fig. 10. Turn the control-arm slowly, listening for noises in the phones. A noisy unit may either be shorted or simply dirty.

LIGHTNING ARRESTORS: Connect your test leads across the terminal posts of the lightning arrestor and listen for a click. If you do hear a click, it indicates that the arrestor is defective, for there should be no flow of current whatsoever when conducting this test. When performing this test, be certain that the arrestor is in no way connected to the circuit which it is intended to protect.

RADIO TUBES: This test does not permit us to determine whether or not the tube is in working order, but it does enable us to test the filament, and to determine if any internal short circuits exist within the tube.

To conduct such a test, remove the tube from the socket, and place a test point on one of the base prongs. With the other lead, alternately touch the other prongs. If no click is heard, change the first test lead to the next prong and repeat the test. Normally, a complete circuit should be available through the filament,but no click should be heard when testing between either of these two terminals and the other prongs. If, however, no click is heard when testing across the two prongs of the filament, the test indicates that this element is open.

VARIABLE CONDENSERS: To test a variable condenser, disconnect it from its circuit and place one of the test leads on the terminal of a stationary plate-group and touch the other one to the terminal of the rotor plates. (The rotor plates are generally grounded to the frame, in which case the frame is considered as the terminal for the rotor plates.) No sound whatsoever should be heard in the phones upon completing the connections in this manner. If a sound is heard, you can be sure that a stationary plate is touching a rotor plate or else a stationary plate is contacting the frame. Inspect the plates carefully; straightening bent plates will usually correct this defect.

Now, leave your test leads connected as described above, and turn the rotor plates slowly. You will hear crackling sounds in the phones, in case some of them are out of line or are dusty or dirty. If everything is in perfect order, you will hear no noises of any kind.

TESTING CONDENSERS

Condensers cannot be tested accurately with the headphones. However, since we have shown you in this lesson how to test various other circuit components, we may as well go a step farther and discuss the more reliable but simple condenser tests.

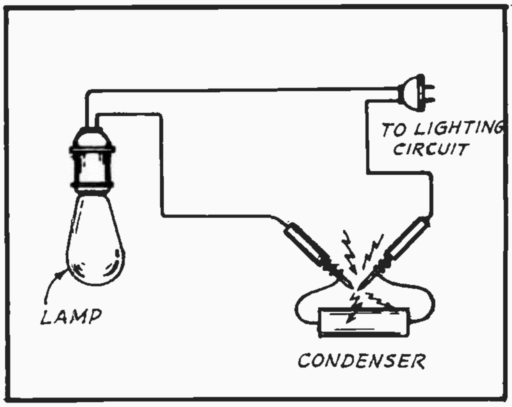


FIG. 11
TESTING A CONDENSER

FIXED CONDENSERS: The best way to test condensers of this type is to use line-current, either a-c or d-c. For this purpose, we connect a pair of test leads in series with a lamp of the same voltage as the line (see Fig. 11). The condenser under test is connected between the test leads. If the line-current is d-c, the lamp should not light. Also, if the line-current is a-c, the lamp should not light, unless the capacity of the condenser is very large, and in this case, only a dim glow should be emitted by the lamp. If the lamp lights at normal intensity, the condenser is shorted.

Now, we proceed to test for an open circuit. We do this by simply touching together our test leads, as in Fig. 11. If the condenser is in good condition, a small, sharp spark is produced as the leads are touched together. The intensity of this spark is determined by the capacity of the condenser. The above tests are more or less exact for condensers ranging from .05 mf upward, except in the case of electrolytic condenser.

The following test is used to determine whether or not the condenser "holds its charge," as sometimes small discharges occur across the dielectric -- this permits the condenser to dissipate its charge. As shown at the left of Fig. 12,we first charge the condenser by touching the test leads to it for a moment. Next, we short circuit the terminals with a screwdriver as shown at the right of Fig. 12.

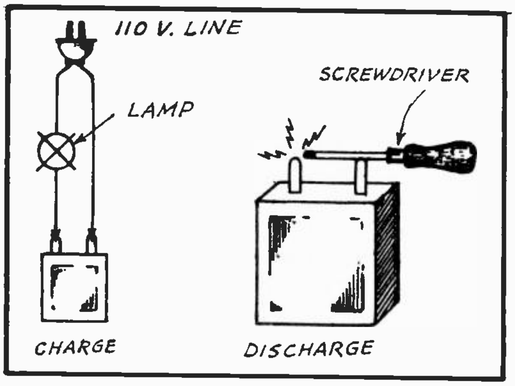


FIG. 12
ANOTHER CONDENSER TEST

A sharp, cracking spark will be produced upon thus shorting a condenser that is capable of holding its charge.

In order to charge a condenser properly, d-c energy of 110 volts or more should be used. However, one can also use a-c as long as one is careful in establishing very rapid contact. When using a-c, repeat this test several times, as frequently you may touch your leads to the condenser at an instant when the varying line voltage is at a low value.

Condensers smaller than .05 mf may be tested by the same method, but the results are not as definite. It is true that all condensers can be charged; yet, if the capacity is rather low,this charge becomes so small that the spark occurring during the discharge test cannot be seen easily.

Conditions being such,we emphasize the fact that testing smaller condensers by this method is only approximate. In other words, they may at times appear to test O.K. and still fail to function in a receiver -- hence, if in doubt, such condensers should be replaced with new ones that are known to be in good condition. Fortunately, the smaller condensers do not break down as often as do the condensers of larger capacity-rating.

TESTING ELECTROLYTIC CONDENSERS

This type of condenser is not so easy to test. However, you can get an idea of their condition, especially if they are shorted internally. For this test, connect your test leads in series with a lamp and the lighting circuit, as shown in Fig. 12. Touch your leads to the terminals of the condenser. If the current is a-c, the lamp will light dimly. If the lamp burns brightly, the condenser is shorted. Disconnect the circuit immediately after making the test.

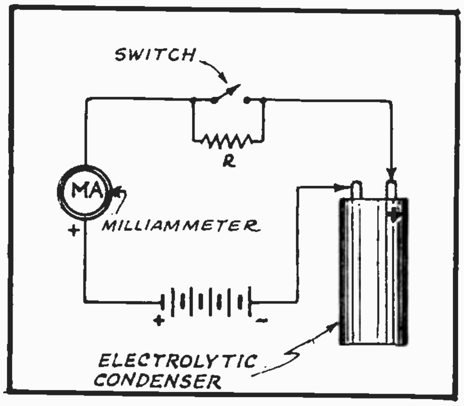


FIG. 13
TESTING AN ELECTROLYTIC CONDENSER

If the current being used is of the d-c type, be careful to connect the positive side of the line to the positive condenser terminal and the negative line to the negative condenser terminal. In this case, the bulb might light for a moment, but it will be extinguished as **soon as** the condenser is charged. Fig.13

illustrates a more exact method for testing a condenser of the electrolytic type. In this case a d-c line or a 90-volt battery is used. DO NOT USE A-C.

The resistor "R" which is used in this circuit should have a value that will limit the flow of current to the maximum reading provided on the meter scale. To determine the value of this resistor, simply divide the voltage being used by the maximum current-capacity of the milliammeter. For example, if you are using 90 volts and the maximum current value marked on the milliammeter's scale is 15 ma, the minimum value of the resistor should be 90 ÷ .015, or 6000 ohms. This is the smallest value that you should use in this case. Larger values can be used if they are available, as they will serve to protect the meter in case the condenser under test is shorted.

To conduct this test, proceed in the following manner: With the switch open as in Fig. 13, touch the test points to the condenser terminals and watch the deflection of the milliammeter needle. As soon as the condenser acquires its full charge, its counter-electromotive force will cause the current to stop flowing, and the meter needle will then move toward the zero mark of the scale.

When the needle drops to a low steady reading, close the switch. In so doing, the resistor is omitted from the circuit, and the meter will indicate exactly the amount of current leaking through the dielectric of the condenser.

Some leakage current always passes through these condensers. It varies with the capacity, age and make of condenser. As a general rule, the leakage should not exceed one-half milliampere for each microfarad of the condenser's capacity. If the leakage is greater, it may be caused by the destruction of the insulating film that is formed normally while the condenser is in use. If the condenser is left connected to the test circuit for a few minutes, the excess leakage should diminish considerably, unless the condenser is old or has other internal defects.

It is also well to note that electrolytic condensers may sometimes test as being serviceable, but still will not function properly in the circuits to which they are connected. In such a case, the only sure way to determine the condenser's condition is to replace it with a new one, noting the effect on the receiver. If this causes the symptom of the defect to disappear, then discard the old condenser, regardless of how well it may test.

CONSTRUCTING AN A-F OSCILLATOR

Your first construction project will be to build an audio-frequency (a-f) oscillator. Such an oscillator will produce a signal-voltage of low frequency that can be heard in the headphones. In Fig. 14 is shown a schematic diagram of this oscillator which, as you will observe, is extremely simple.

Let us proceed to examine this diagram very carefully. At the same time, we will bring up a few points which will make you familiar with other diagrams that are used in the more advanced experimental lessons.

The tubes are the principal objects that we must keep in mind when studying a diagram. Notice in Fig. 14 that we use a tube which is a combination of two diodes and a triode section. However, no circuit connections are made at the diodes, as they are not used in this particular experiment. In fact, we could use a simple triode tube instead;

nevertheless, we suggest that you use a double diode-triode for this purpose, as you will need this tube in the receiver which you will construct later. In this way, it will not be necessary for you to buy tubes which you cannot use later on.

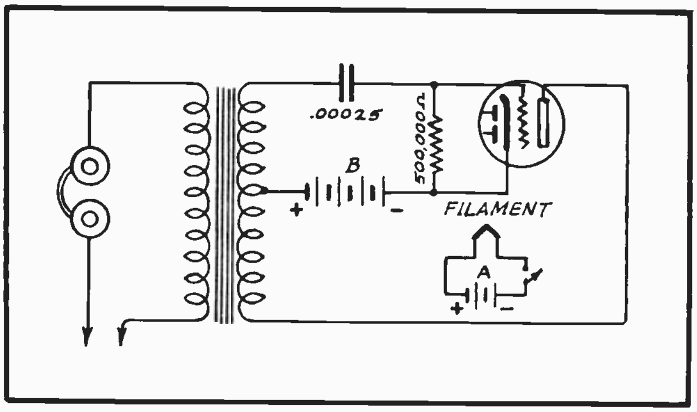


FIG. 14
DIAGRAM OF THE A-F OSCILLATOR

If your house-lighting system is of either the 110-volt or 220-volt type (a-c or d-c), you should buy a 6Q7 tube. This is a metal tube. If you are going to use batteries to operate your final receiver, then you must buy a 6T7G tube.

At this time, we also wish to direct your attention to the manner in which we represent a tube in a diagram. We follow this same system throughout our experimental lessons. Notice that the symbol of the tube is drawn so as to represent the true relation between the elements in the tube. This is why in Fig. 14 the two diodes are placed independently of the triode section, with the exception of the cathode which is common to both. You will also note that the grid is placed between the cathode and the plate, just as it is within the tube.

For greater clarity, the filament of tubes using indirect heating (cathode-type tubes) will be shown separately. This makes it possible to show the other elements more clearly. After all, the filament in this type of tube serves no other purpose but to heat the electron-emitting cathode.

Another original and practical method which we use is to place the tube element in our drawings in such manner as to show the actual connections to the socket. For example, Fig. 15 shows the correct connection for the 6Q7 and 6T7G tubes. The illustration does not show the exact form of the socket, but it does show very clearly the position of the contacts, with reference to the central-guide on the tube. The latter makes it impossible to insert the tube in more than one position.

Note the numerical order of the contacts and placement of the elements. As the grid of the triode is on top of the tube, it is indicated as being outside of the socket. The shield or metal casing of the tube is indicated by the heavy circle surrounding the elements.

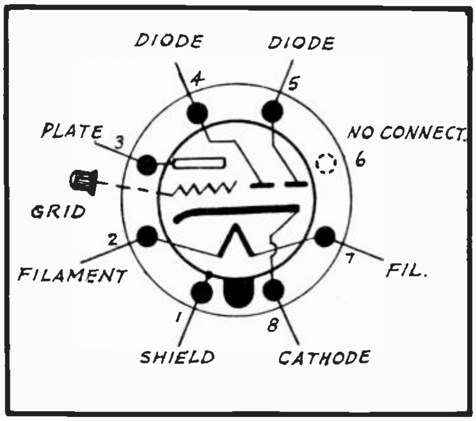


FIG. 15
VACUUM-TUBE CONNECTIONS AS VIEWED FROM BELOW

No element is connected to contact #6 of this particular tube. Therefore, we indicate this contact with dotted lines. You must bear in mind that in Fig. 15 you are looking at the socket from below.

Now let us turn to Fig. 14, where you will note that the filament circuit consists of the "A" battery, the filament and the wiring.

The diagram also shows that a switch is incorporated in the filament circuit so that the oscillator may be turned "on" or "off."

The plate circuit is comprised of the "B" battery, half of the a-f transformer's secondary winding, the plate of the tube, and finally the cathode -- whence we return to the negative terminal of the "B" battery. This battery may have a voltage ranging from 22.5 to 45 volts.

The 500,000-ohm resistor forms part of the grid circuit in that it connects the grid to the cathode. The .00025 mf condenser connects the grid to the upper end of the a-f transformer's secondary winding. The primary winding of the transformer is connected in series with the headphones and the two test leads, which, when touched together, complete the circuit.

HOW THE OSCILLATOR OPERATES

Although the operation of tubes is thoroughly discussed in other lessons of the course, we do give you at this time an explanation of the work done by the triode in the oscillator of Fig.14.

To begin with, bear in mind that the oscillator produces or generates oscillations that are identical to those obtained from an a-c generator. This being true, you are no doubt probably wondering how a tube operating with d-c applied to its elements is able to furnish an a-c output. To clear up this point, let us analyze Figs. 16 and 17, where is shown the same circuit as in Fig. 14, with the exception of the filament circuit and the primary winding of the a-f transformer.

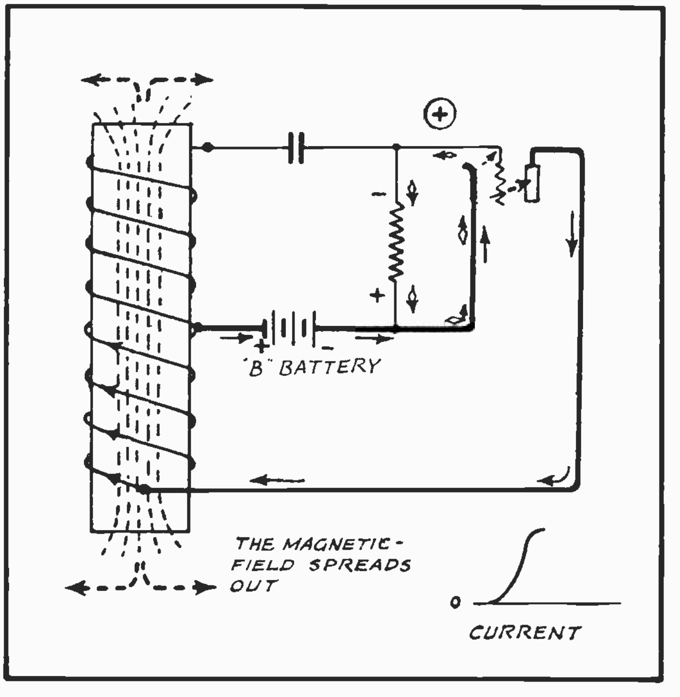


FIG. 16
CIRCUIT ACTION AS GRID BECOMES POSITIVE

As we have already mentioned, the filament serves no other purpose than to heat the electron-emitting cathode; therefore, we can eliminate it from our explanations.

Once the filament has been heated sufficiently to raise the temperature of the cathode and cause it to emit electrons, the path of electrons will be as follows: Starting from the negative terminal of the B-battery, they flow to the cathode, from whence they pass to the plate, continuing to the lower end of the winding, and finally returning to the positive terminal of the battery. This path is illustrated by the heavy black arrows in Fig. 16, and shows clearly how the current flows through the lower half of the winding during this time.

We should take into consideration that the current (electron-flow) does not reach its maximum value instantaneously, but increases gradually, even though only a millionth part of a second is required for it to increase from zero to the maximum value.

As a weak current begins to flow through the lower-half of the winding, a magnetic field is formed, extending outside of the solenoid. As a result, we have a moving magnetic field that cuts through the upper-half of the winding and generates therein a self-induced voltage.

As a result of the above action, the upper-half of the coil acquires a positive bias. This bias is applied to the grid through the condenser, causing the grid to become charged slightly positive. This allows the plate current to increase. Hence, the magnetic field will also be increased, the induced voltage becomes greater, and the grid becomes still more positive -- this will cause a further increase in plate current. The entire process repeats itself again and again until the plate current reaches its maximum value.

Upon examining Fig. 16 closely, you will notice that the positive potential on the grid will cause electrons to flow through the resistor in such direction as to make the grid negative, in relation to the cathode.

As the plate current increases in value, the positive voltage applied to the grid by means of induction also increases. At the same time, the negative voltage produced by the resistor also increases. Finally, a point is reached where these opposing voltages become equal and are thus neutralized.

If we were to illustrate graphically the increase in plate current during this period, we would obtain the curve shown in the lower right-hand corner of Fig. 16. This curve illustrates the action during which the plate current attains its maximum or peak value.

As soon as the current reaches its peak value, the magnetic field ceases to build up and remains stationary, and while there is no action in the field, no voltage is induced in the upper part of the coil. Since the grid is connected to the upper part of the coil, it will lose its positive potential, causing an immediate interruption in plate current. As soon as the current begins to decrease, a change takes place in the magnetic field -- that is, the field commences to collapse.

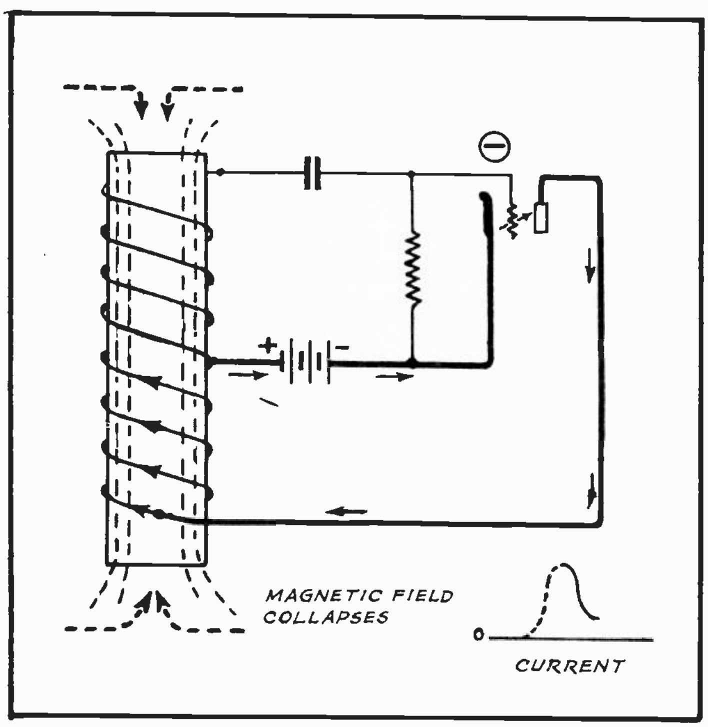


Fig. 17
Circuit Action as Grid Becomes Negative

The condition which causes the voltage-induction in the upper-half of the coil again comes into action, but as the lines of force are now moving in a direction opposite to their former movement, the induced voltage will be in opposition to that which existed previously. This causes the grid to become negative, and as we can easily see, it also causes the plate current to decrease. As the plate current decreases, it con trols the action of the magnetic field, and a voltage continues to be induced in the upper half of the winding, causing the grid to gradually become more negative.

Finally, an instant is reached where the current has decreased to such an extent that the induced voltage is very small --- at this time the grid cannot cause a greater reduction in voltage than that which has already been attained. Fig. 17 illustrates the condition as the plate current is about to reach its minimum value. (The dotted section of the curve in the lower right-hand corner of Fig. 17 shows how the current increases as the grid becomes more positive. The solid part of the line illustrates the decrease in current resulting from the grid becoming negative.)

Now, as soon as the plate current reaches its minimum value, the magnetic field reaches a stationary condition and the induction of voltage in the upper half of the coil ceases. The grid then loses its negative bias, allowing the current to again increase. The magnetic field then again begins to move outwardly and in so doing, causes the grid to gradually become positive.

Again, we find the same conditions as when we first started our analysis of Fig. 16. This cycle repeats itself as long as the cathode remains heated. The result is shown in Fig. 18, where the curve indicates the changes in plate current as the grid alternately becomes positive and negative.

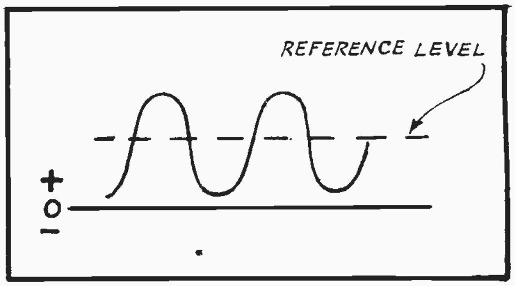


Fig. 18
Plate Current Variations Caused by Alternating Grid Voltage

Note how the plate current has maintained the same direction of flow. However, if we compare its variations with a zero reference line, we can immediately see that the curve is the same as that representing alternating current. Thus, although we are actually using pulsating d-c, its effects are exactly the same as those of a-c. Therefore, if we couple another independent circuit to the coil, a-c will be induced in it.

In the case of the transformer which is used in the oscillator, the so-called primary winding is inductively coupled to the center-tapped secondary winding. Therefore, a-c will be induced in the primary winding and the current flow therein will undergo the same changes that occur in the plate current of the tube.

The a-c, which is induced in the primary winding, will circulate through the headphones each time that the test leads are touched together, and will produce a musical note of the same frequency as the a-c.

The frequency of these changes is controlled by the relation between the inductance and capacity of the oscillator circuit, or "tank circuit," as it is commonly called when referring to transmitting oscillators. When dealing with a winding of many turns wound on an iron core, it is easy to understand that its inductance is very high and that the frequency of the oscillations will be in the audible range.

The capacity in this circuit is really quite small, as we only have the distributed capacity of the windings, the internal capacity of the tube, and the capacity of the connections to deal with. Nevertheless, the inductance is sufficiently high to keep the oscillations within the audible band, as desired.

Should we desire to produce r-f oscillations, then we would use a coil of low inductance and a condenser of low capacity, for, as you will learn in one of your regular lessons, the frequency of the oscillations depends on the product of the capacity and the inductance. This product is known as the "LC" factor; the smaller this product, the higher will be the frequency of the oscillations.

WIRING THE A-F OSCILLATOR

Now that we have studied the theoretical functions of the oscillator, let us continue with its construction. In radio work, the correct construction of the apparatus is as important as the preparation of the diagram or the design of the circuit. It would be of no value to carefully calculate the components, and then encounter difficulties because of the improper placement of parts and poorly-connected conductors. The correct construction of any radio receiver is relatively easy when the following important points are kept clearly in mind.

1 - Connections must be made directly from one terminal to the other, without splicing the wire at some intermediate point.
2 - The control grid circuit must be as short and direct as possible.
3 - The control grid circuit must be placed away from the plate circuit whenever conditions permit.
4 - Connections must be mechanically secure and well soldered.
5 - Conductors must not obstruct the contacts or terminals, so as to allow enough room to apply test leads later on.
6 - It is advisable to group the conductors against the base of the chassis, in order to allow sufficient space for condensers, resistors, etc.
7 - In complicated circuits, it is advisable to use wire equipped with an insulation of different color -- the different colors designating the various circuits.

The importance of the above points will become clearer as you progress with your practical construction jobs. However, the a-f oscillator falls into the category of a simple construction project and therefore requires no undue caution. In fact, these first jobs present no difficulty at all.

In constructing a set, the first step is to make a list of the parts needed, which information is acquired from the diagram. This means that you must carefully study Fig. 14 and then prepare your list.

Now comes the problem of deciding on the dimensions of the chassis, base or cabinet for the set. The simplest method is to use a piece of wood or thick cardboard for the base, the dimensions for which can be determined by provisionally placing upon a sheet of paper all of the parts and components to be used, arranging the parts to conform with the layout as given.

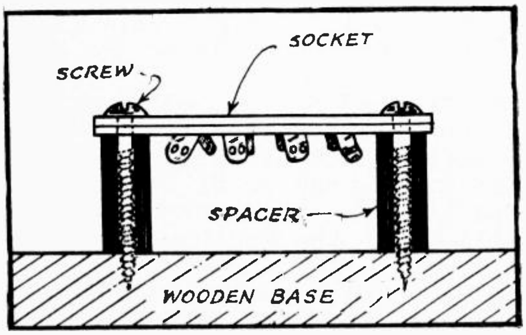


FIG. 19
SOCKET MOUNTING

The socket furnished by us is designed to be mounted on a metal chassis, but you can use it for the oscillator without difficulty by fastening it in place with two large screws and wooden spacers, as shown in Fig. 19.

Now, to continue with the placement of the parts. It is advisable

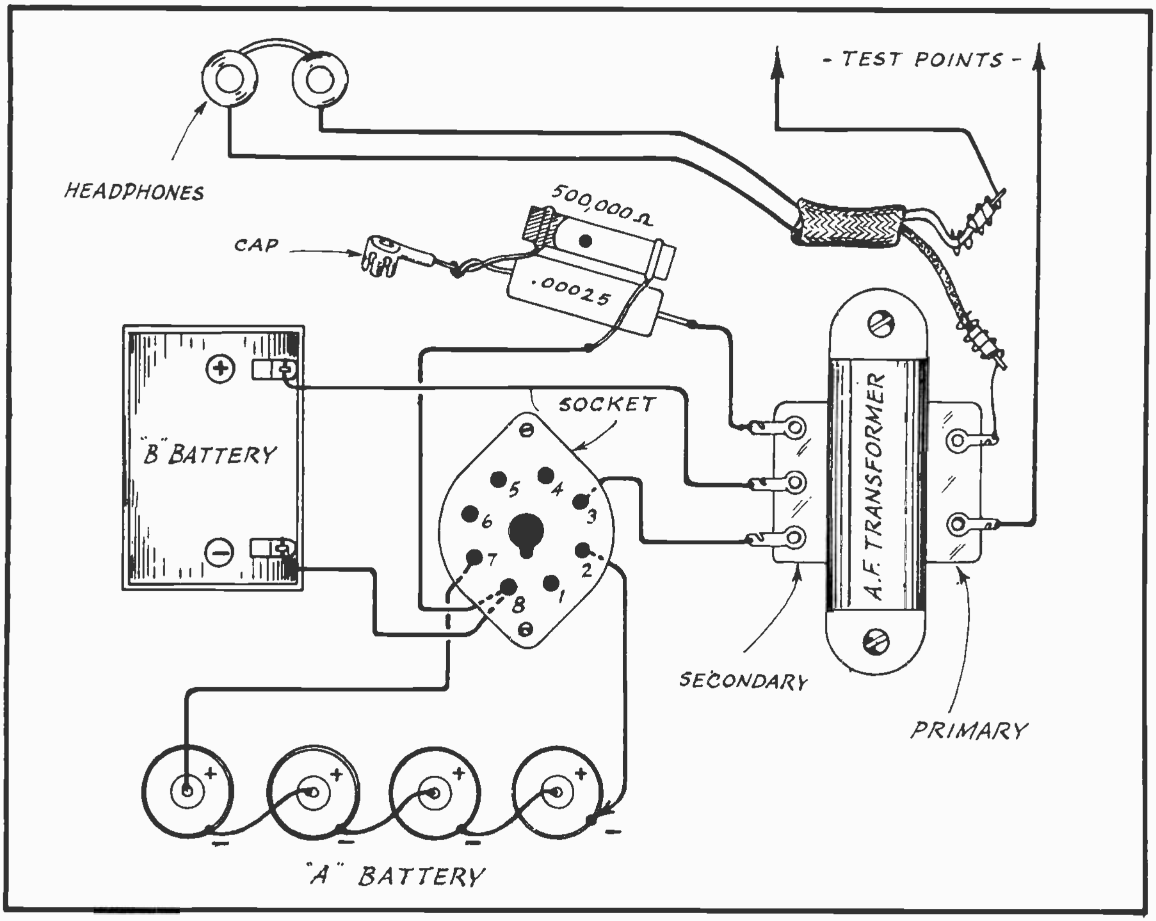


FIG. 20
PARTS ARRANGEMENT AND WIRING OF A-F OSCILLATOR

to draw a simple plan of the components and the wiring, placing them in their approximate positions. This will serve to show you how to place the equipment most conveniently and will enable you to wire the set in such manner as to avoid undesired coupling.

Even though the a-f oscillator is quite simple to construct, it is advisable for you to prepare the drawing or layout for the sake of experience. When you have determined the most convenient placement of the various parts, compare your layout with that shown in Fig. 20. This layout is not the only permissible way in which to arrange the parts -- in fact, it is only one of many ways. The same results would be obtained if we placed the transformer on the left and the battery on the right side, etc. The only thing we are striving for in this case is to arrange the parts so that the connections will be short and direct.

In Fig. 20 the different parts are illustrated as viewed from above, with the connections clearly shown so that you will have no difficulty whatsoever. With the exception of the wire leading from the negative side of the "A" battery, all connections should be made in a permanent manner. The negative A-lead serves the purpose of a switch so that the circuit can be opened and closed at will.

The plate circuit requires no switch because it is automatically interrupted when the filament of the tube becomes cold; that is, when no electrons are emitted by the cathode.

It is advisable to solder all of the permanent connections, with the exception of the headphone and battery connections. The headphones can be connected to the circuit by twisting the bared ends of the circuit wires around the phone tips, as shown in Fig. 20.

THE BATTERY-OPERATED OSCILLATOR

The oscillator diagrammed in Fig. 14 and constructionally illustrated in Fig. 20, is battery-operated. If you use a 6Q7, or 6T7G tube, the filament voltage should be 6.3 volts, which can be acquired from a 6-volt storage battery or from four series-connected dry cells of 1½ volts each (see Fig. 20).

The polarity of the "A" battery is not of great importance, as the filament has no direct bearing on the operation of the oscillator. Therefore, contact #7 of the socket may be connected to the negative terminal and contact #2 to the positive terminal, or vice versa.

However, this is not true of the "B" battery. In order for the plate current to flow through the tube properly, it is necessary that the plate be positive with respect to the cathode. This is accomplished by connecting the positive side of the battery to the center-tap of the a-f transformer's secondary winding.

HOW TO OPERATE THE OSCILLATOR FROM THE 110-VOLT LIGHTING CIRCUIT

This type of oscillator may also be operated by using the current supplied by a lighting circuit. Let us first consider a 110-volt line, whether it be of the a-c or d-c type.

As the line voltage is too high for the filament circuit,we must use a resistor in series, so that only 6.3 volts will be applied to the tube's filament. This resistance may be furnished by a common 110-volt lamp bulb, rated at between 25 and 40 watts.

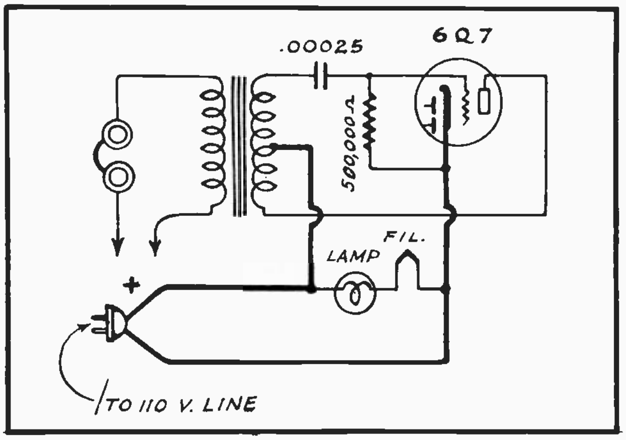


FIG. 21
OSCILLATOR OPERATED FROM 110-VOLT LINE

For the plate circuit we can use the full voltage of the line. However, if the lighting circuit is of the d-c type,we must be careful to connect the positive side of the line to the tube's plate. If the line is of the a-c type, there is no definite polarity, and we can then connect either side of the line to the plate.

You are probably now wondering how the tube can function with a-c applied to its plate. This can be explained as follows: The tube functions also as a rectifier, allowing current to flow during only every half-cycle. The direct current, thus obtained, will not be continuous, but will consist of pulsations that will produce a hum in the output of the oscillator. This is of no importance to the various uses to which the oscillator is tobe applied, but if you first operate your oscillator with batteries and then with a-c, you will notice that the resulting note is not clear when a-c is used.

Fig. 21 shows how the above requisites are put into practice. Notice how the filament is connected in series with a lamp and that the

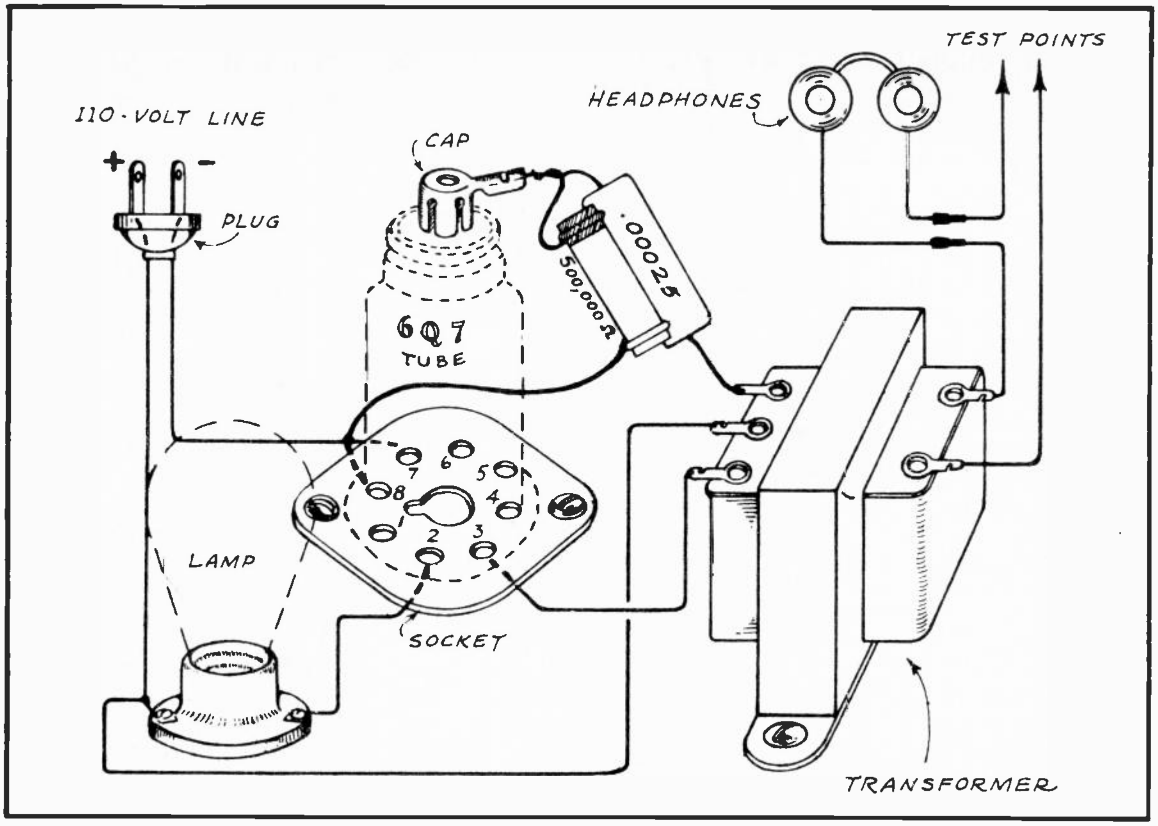


FIG. 22
PARTS ARRANGEMENT AND WIRING OF 110-VOLT OSCILLATOR

two sides of the line are also connected to the transformer's center-tap and also to the cathode. Fig. 22 will. also assist you in making the connections correctly. As we have already mentioned, the polarity shown on the plug applies only to d-c operation.

HOW TO OPERATE THE OSCILLATOR FROM A 150 OR 220-VOLT CIRCUIT

To operate this oscillator from a 150-volt lighting circuit, simply replace the 110-volt series lamp, previously prescribed, with a 150-volt lamp of any watt-rating between 30 and 50 watts.

If the oscillator is to be operated from a 220-volt circuit, it is necessary to reduce the plate voltage so as to permit the oscillator to operate in a stable manner. The solution in this case is to connect two ordinary lamp bulbs in a voltage divider arrangement as shown in Fig.23. Approximately, only one-half of the line voltage, or 110 volts, will now be applied to the plate of the tube.

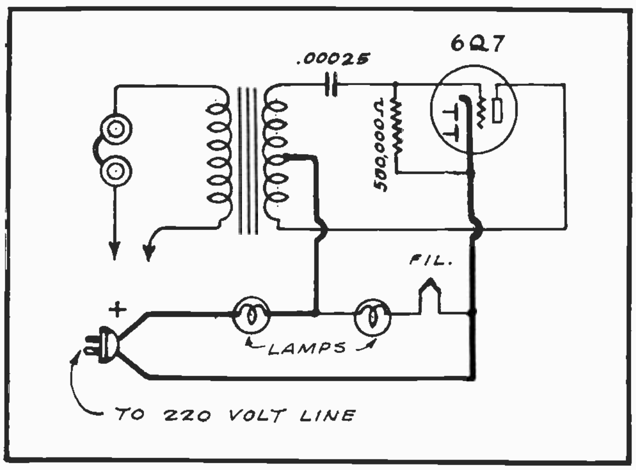


FIG. 23
OSCILLATOR OPERATED FROM 220-VOLT LINE

The construction of this oscillator needs no additional explanation. The connections are identical to those shown in Fig. 22, with the exception of the second lamp, which is connected in series with the line and the B+ lead. For this purpose, the lamps should be of the 40-watt, 110-volt type, or 200-watt, 220-volt type.

APPLICATION OF THE A-F OSCILLATOR

A very useful application of the oscillator is for testing the audio amplifying stages of a receiver. All that is required for this purpose is to connect one test-lead to the control grid of the first a-f tube, and the other to the chassis. If the amplifier is in good condition, the note produced by the oscillator should be heard loudly through the speaker.

By applying the leads to the control grid of the remaining a-f tubes, you can determine if trouble exists in preceding a-f stages.

The r-f or detector stages cannot be tested with the a-f oscillator, as such circuits operate at radio frequencies rather than audio frequencies. In this case you must use an r-f oscillator, like the one you will build in accordance with later experiment lessons.

TESTING RADIO PARTS

The a-f oscillator can also be used for testing the components of a receiver. These tests are carried out in the manner already explained relative to continuity tests; that is, instead of hearing only a click when testing through a complete circuit, you will now hear the musical note of the oscillator.

The results of these tests are practically the same as those already mentioned in connection with the simple continuity tester consisting of the headset connected in series with a battery. With a little practice, you will learn how to perform these tests most efficiently.

This completes the work outlined in this experiment lesson. We are confident that you have found it interesting and instructive, and that you appreciate the fact that the principles and instruction included herein will be of a definite value to you. As you progress with your studies, you will have the opportunity to conduct experiments of a more advanced nature, until you arrive at the point where you will construct a modern superheterodyne receiver, analyze circuit troubles, etc.

SPECIAL INSTRUCTIONS ON HOW TO USE THE OSCILLATOR AS A CODE-PRACTICE SET

Later in the course, you will receive intensive instruction on the International Continental Code (telegraphic code). However, we are furnishing the following basic instructions and suggestions for those who are interested in using the a-f oscillator at this time for beginning the study of "the code."

Since this type of communication consists of sending messages by means of dots and dashes, properly grouped, a telegraph key should be connected in series with your headphones and the primary winding of the oscillator's transformer. Thus, by depressing the key for only an instant, the "dot" of the code signal will be heard in your phones as the sound "dit." Holding the key closed for a longer interval of time will enable you to form the "dash" of the code signal, which will be heard in your phones as the sound "dah."

In case that you have no key, you can open and close the circuit with the ends of the circuit wires. One of the wires can then be braced on a table, and the other held between your fingers and manipulated as though it were the knob of a key. It is also very easy to construct a makeshift key for this purpose.

In Table I are given the alphabet, numerals, most commonly-used punctuation marks and common signals that are employed in the transmission of messages by means of the International Continental Code. There are still other characters to be learned but, for the present, this is all with which you need be concerned.

TABLE I

THE INTERNATIONAL CONTINENTAL CODE

ALPHABET

A	•—	N	—•
B	—•••	O	———
C	—•—•	P	•——•
D	—••	Q	——•—
E	•	R	•—•
F	••—•	S	•••
G	——•	T	—
H	••••	U	••—
I	••	V	•••—
J	•———	W	•——
K	—•—	X	—••—
L	•—••	Y	—•——
M	——	Z	——••

NUMERALS

1	•————	6	—••••
2	••———	7	——•••
3	•••——	8	———••
4	••••—	9	————•
5	•••••	0	—————

PUNCTUATION

Period	(.)	•• •• ••	Colon	(:)	———•••
Interrogation	(?)	••——••	Semicolon	(;)	—•—•—•
Break	(--)	—•••—	Quotation Marks	(" ")	•—••—•
Exclamation	(!)	——••——	Parenthesis	( )	—•— —•—
Comma	(,)	•—•—•—			

COMMON SIGNALS

Wait	•—•••	Distress Call (S.O.S.)	•••———•••
End of Message	•—•—•	General Call (C.Q.)	—•—• ——•—
End of Transmission	•••—•—	From	—•• •
Received (O.K.)	•—•	Error	••••••••
Invitation to Transmit	—•—	Repetition	•• ••

To produce and group the dots and dashes of any code character correctly, the following rules should be observed:

(1) A dash is equal in length to three dots.

(2) The interval of silence between parts of the same letter is equal to one dot.

(3) The space between two letters is equal to three dots.

(4) The space between two words is equal to five dots.

In memorizing the code, do not think of the various signals in terms of dots and dashes, but rather in terms of the "sound." That is, the letter "A" should be learned as the sound "dit dah" and not as "dot dash."

To simplify learning the code, it is advisable that you start with the alphabet, mastering the first five letters thoroughly before continuing with the next five, and so on. After the alphabet has been learned perfectly, start learning the numerals in groups of five. Later on, you can devote your attention to the punctuation marks, and finally, to the common signals.

The important thing is to take your time and "send" slowly at first, and do not start learning a new group until you have mastered the preceding ones. Your speed of sending will increase gradually and automatically, with practice.

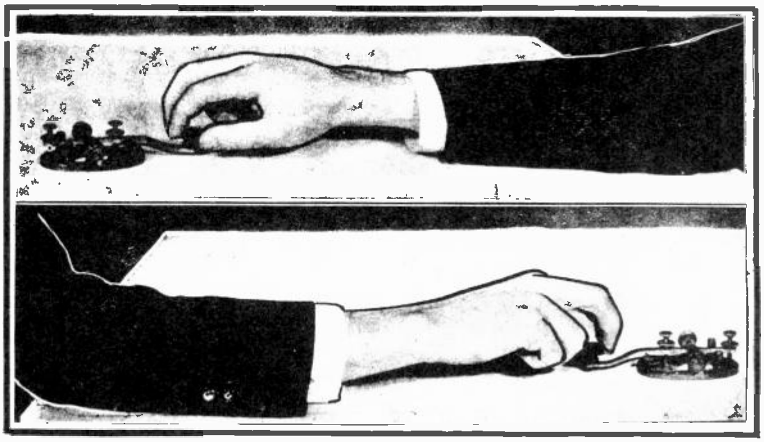


FIG. 24
CORRECT METHOD OF MANIPULATING THE "KEY"

If you are right-handed, the key should be placed in the position illustrated in Fig. 24. The thumb should be held against the left side of the key, whereas the first and second fingers should be bent slightly so as to hold the center and right side of the knob. Observe in the illustration that these three fingers are partly on top of the knob, while the remaining two fingers are entirely free of the key. The hand should rest lightly on the key, without actually grasping the knob in a firm grip.

The elbow should be rested on the table -- the wrist being held above the table at all times. The entire forearm should be used to manipulate the key, the elbow serving as the pivot. Do not use finger movement or a wrist motion.

You can obtain excellent experience in receiving code messages by simply tuning any ordinary shortwave or all-wave receiver to those wave bands on which telegraphic communication is being conducted. It is advisable that you select stations from which the messages are sent at a slow rate.

******

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. FG-1

Ans Nov 13/1941

1. - Describe a practical method for checking the condition of a paper condenser.

2. - What is the value of a resistor that has a red body, a green end and a yellow spot?

3. - What will happen if the headphones are connected directly across an a-c lighting circuit?

4. - A certain mica condenser has three colored dots, whose order of reading is as follows: Green-black-brown. What is its capacity?

5. - Mention three important points that should be considered when wiring a radio receiver?

6. - When the a-f oscillator described in this lesson is connected directly across the a-c line, how is a direct current obtained for the plate circuit?

7. - What precautions should be taken when connecting the a-f oscillator to a d-c lighting circuit?

8. - Describe briefly a practical test for determining the condition of the windings on an a-f transformer.

9. - How would you proceed to test a lightning arrestor?

10. - Does a direct current or an alternating current flow through the headphones when they are connected to the "primary" winding of the a-f oscillator?

EDUCATION

"Make a resolution that you are going to be an educated man."

"The best educated people are those who are always learning, always absorbing knowledge from every possible source and at every opportunity."

"Some people are always at school, always storing up precious bits of knowledge."

"The man who has learned the art of seeing things looks with his brain."

"It cannot be done," cries the man without imagination. "It can be done, it shall be done," cries the dreamer.

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LOS ANGELES, CALIFORNIA

EXPERIMENT LESSON NO. FG-2

AUDIBLE AND VISUAL TESTS

Before continuing with the various experiments that can be performed with the parts you received in the second kit of equipment, it is well for us to first consider some important points which have a very definite influence upon the performance of all types of radio apparatus. In fact, you will also find the information given at the beginning of this lesson to be quite helpful in applying your present knowledge to the simpler type of radio service jobs conducted in your spare time. First, let us consider the correct method of soldering.

SOLDERING

Soldering, as applied to radio, is generally done with the aid of an electric soldering iron or with a soldering iron of the flame-heated type. In radio work, it is recommended that the best kind of solder be used -- regular radio solder of the rosin-core type being preferred. In the event that rosin-core solder is not available, the solid type may be used, but it should always be employed in combination with a non-corrosive soldering paste that is suitable for soldering electrical connections.

HOW TO "TIN" A SOLDERING IRON: The soldering iron must be perfectly clean, tinned properly, and at the correct temperature so that solder will melt immediately upon contacting the tip of the iron. Whenever the tinned surface on the tip of the iron deteriorates, the iron should be re-tinned immediately. This is done in the following manner:

First, clean the tip of the iron with a wire brush until the copper surface shines brightly. Then heat the iron to a temperature where it will cause solder to flow freely. Next, apply a small amount of soldering paste to the tip and then apply a generous quantity of solder so as to cover the tip. After having coated the tip with solder in this manner, wipe the tip against a clean rag so as to remove all surplus solder. The tip will thus be furnished with a thin even coating of solder as pointed out in Fig. 1. We then say that the soldering iron has been properly tinned.

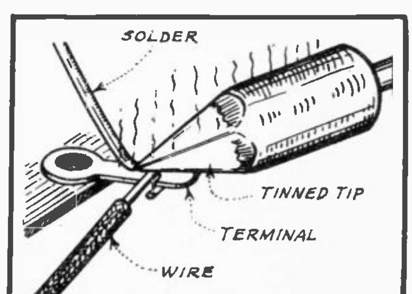

FIG. 1
TERMINAL CONNECTION

IMPORTANT POINTS TO BE CONSIDERED: Soldering acid should never be used for radio work, nor for any other type of electrical work.

Another point to bear in mind while soldering, is to make sure that the two surfaces being joined are kept in close contact with one another during the entire soldering procedure. This is necessary if a well soldered electrical connection is to be obtained.

Also, always bear in mind that the main object for soldering an electrical connection is to protect it from corrosion and to insure a good electrical contact under all normal conditions.

HOW TO SOLDER A WIRE TO A LUG: The correct method of soldering a wire to a lug is shown in Fig. 1. Here you will observe that the end of the wire has first been inserted through the hole in the lug, and then doubled back. The soldering iron is then applied to both the lug and the wire so that the heat from the iron will be transferred to the parts being joined.

When the temperature of the lug and the wire has been raised sufficiently, a little solder is applied to the tip of the soldering iron and allowed to run or spread over both surfaces being soldered. Should the solder run off the points being joined, it can be returned to the area desired by proper manipulation of the iron. However, when so doing, caution should be exercised so as not to move the parts being joined until the flowing solder has enveloped them completely and solidified.

HOW TO SOLDER A CONNECTION TO THE CHASSIS: When soldering a connection to the chassis, it is important that the chassis be scraped perfectly clean at the intended point of contact. Also, the iron should be well heated. The iron should then be held firmly against that point of the chassis where the solder is to be applied, allowing that portion of the chassis to become well heated. Next, pick up a small amount of soldering paste with the end of the solder and touch this end of the solder to the tip of the soldering iron, without withdrawing the iron from the chassis. Upon moving the tip of the iron gently around the heated area of the chassis, the solder will commence to flow, forming a bright spot on the chassis. The next step is to solder the wire or terminal to that point, being careful that the wire or terminal does not move until the solder has solidified.

As soon as the solder has solidified, test the mechanical strength of the connection by pulling slightly on the wire or terminal.

CLEANLINESS IS VITAL: Before soldering the terminal wires of condensers or resistors, always make sure that they are perfectly clean. Some of these wires or terminals are tinned at the factory and therefore require no further cleaning. Others need to be cleaned with the aid of sandpaper or scraped with a dull-edged knife before soldering. Whenever you find that solder does not "stick," always clean the surfaces involved until they are brilliant. All nickel-plated surfaces must be filed until the plating has been removed completely, as solder will not adhere to nickel.

Hook-up wire of the push-back type can be soldered easily, as it is generally well tinned at the factory. Rubber-covered wire, on the other hand, must be cleaned with a knife or sandpaper so as to remove all rubber and to provide a bright surface that will "hold" solder.

Whenever it is necessary to solder several wires to one terminal, it is good practice to bend all the wires over the terminal so as to prevent them from separating during the soldering procedure.

WHY PARTS SHOULD BE CHECKED BEFORE CONNECTIONS ARE SOLDERED: It is important to check all parts before soldering the connections of the circuits being wired. These tests have already been explained in other parts of your course, particularly as they apply to bypass condensers, electrolytic condensers, a-f and r-f transformers, etc. If all of the parts have first been checked in this manner, the testing procedure is greatly simplified in case the receiver does not operate satisfactorily upon completion.

Having covered the procedure of soldering, we are now ready to continue with our experimental work. The experiments, now to be described, will help you to better understand some of the more important basic principles of electricity as applied to radio. Therefore, no matter now simple they may seem, the knowledge acquired through this means will always be helpful to you.

HOW TO GENERATE AN ELECTRICAL CURRENT BY CHEMICAL MEANS

One of the simplest experiments, but also one of the most important, is that of generating electricity by chemical means. We shall therefore begin our experiments by constructing an elementary cell with the aid of various common materials.

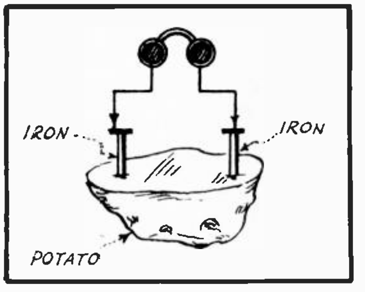

FIG. 2
NEGLIGIBLE VOLTAGE

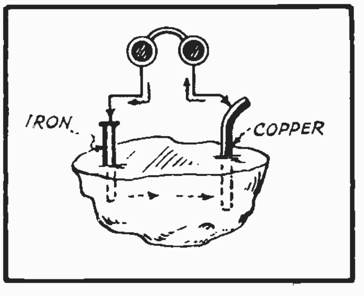

FIG. 3
A VOLTAGE IS GENERATED

For this experiment you will be required to use your headphones, a fresh raw potato, several iron nails, and a short piece of copper wire.

The potato will in this case serve as an electrolyte, as its juice contains acids which affect the electrodes being used. The headphones can be used to detect any existing voltage because when an electric current flows through their windings,a "click" will be heard every time the circuit is interrupted or completed. The stronger the current flow through the windings, the more noticeable will be the "click" upon interrupting or completing the circuit.

We shall begin our first experiment by inserting two iron nails into one-half of a potato, as shown in Fig. 2. The headphones are then connected between the two nails. Under normal conditions, no click will be heard when either interrupting or completing this circuit, as no voltage is developed by this arrangement.

In the illustrations appearing in Figs.2 and 3, you will notice that the electrodes are shown as being widely spaced; however, you should place them rather close together while performing the experiment,being careful that they do not touch each other. Also be sure to insert them deep in the potato so that more electrode surface will be exposed to the electrolyte (potato juice).

If the electrodes are made of pure iron, no voltage at all will be generated. However, nails are not made of pure iron; therefore, impurities contained in their structure will develop a potential difference, which, though insignificant, exists.

Now repeat the experiment,but this time use two pieces of copper wire instead of the two nails. The result will be exactly the same as in the previous case. That is, no "click" will be heard in the headphones. In the event that a very faint noise is perceptible upon interrupting or completing the circuit, it indicates only the presence of impurities in the electrodes.

From the above experiments, you have learned that electrodes of the same metal do not develop any potential difference.

Next, try using a piece of copper wire as one electrode and an iron nail as the other (see Fig. 3). Upon interrupting or completing this circuit, you will hear a rather strong "click" in your headphones. This indicates that the combination of metals now used as electrodes will enable the cell to generate an electromotive force of noticeable intensity, causing a current to flow through the windings of the headphones.

What really takes place in an arrangement as just described, is that the acids in the potato juice or electrolyte attack the iron more than they do the copper -- the chemical action being such as to generate an electromotive force. The combination of electrodes need not necessarily be copper and iron -- combinations of other metals will also produce an electromotive force. However, certain combinations of metals develop more voltage and others less. For instance, the combination of carbon and zinc when submerged in an ammonium electrolyte, such as used in the construction of present-day dry cells, develops a fairly high electromotive force.

The important fact to be acquired from these experiments is that the combination of different metal electrodes will generate an electromotive force when exposed to a suitable electrolyte.

CONSTRUCTION OF A SECONDARY CELL

Continuing with our electrochemical experiments, let us now consider the theory of the secondary cell or storage battery. However, since it is not practical to handle sulphuric acid and lead while conducting your experiments at home, we will again use the potato and two pieces of copper wire.

Once again, let us remind you that when inserting the copper wires into the potato, be sure that they are as close together as possible, without touching each other. Now, connect the headphones across the copper wires as done previously -- you will find that since both electrodes are made of the same metal, no "click" will be heard in the phones. Next, connect a dry cell across the electrodes in the manner illustrated in Fig. 4, thus permitting an electric current to flow through the circuit.

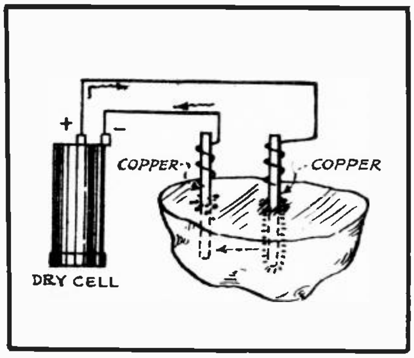

FIG. 4
CHARGING THE CELL

After a short while you will notice that a green substance will begin to form around the wire which is connected to the positive terminal of the dry cell, whereas a foamy substance will appear around the other wire.

The chemical action of the current flow through the circuit is now such that it combines the copper of one electrode with the electrolyte (potato juice) so as to form copper nitrate (the green substance). Hydrogen is liberated from the potato juice at the other electrode, forming bubbles that resemble foam. In other words, electrical energy is converted into chemical energy as the original chemical conditions in the arrangement are altered.

Upon disconnecting the dry cell from the circuit, you will have a secondary cell, the chemical composition of one of the copper electrodes having been changed with the current flow so as to become copper nitrate, while the other remains in the state of pure copper.

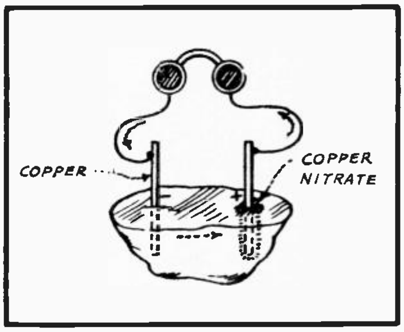

FIG. 5
DISCHARGING THE CELL

Upon connecting the headphones as shown in Fig. 5, you will hear a very distinct "click". This indicates that the cell was being charged during the time that the electric current from the dry cell flowed through it, and that it discharges when connecting the headphones across it. You must bear in mind that by "charging" a cell, is meant that electrical energy is being converted into chemical energy, whereas "discharging" a cell means the opposite -- that is, chemical energy is being converted into electrical energy. Another important point to remember is that the electrode that is connected to the positive terminal of the dry cell becomes the positive terminal of the secondary cell. This is also true in the case of a conventional storage battery.

HOW TO DETERMINE THE POLARITY OF D-C CIRCUITS

The foregoing explanation of the electrochemical action is very valuable in that it helps one to determine which is the positive side of a d-c circuit.

In the experiment illustrated in Fig. 6, the bare copper electrodes are inserted in a potato. Upon waiting a few seconds, copper nitrate will be seen to form around the wire that is connected to the positive side of the line.

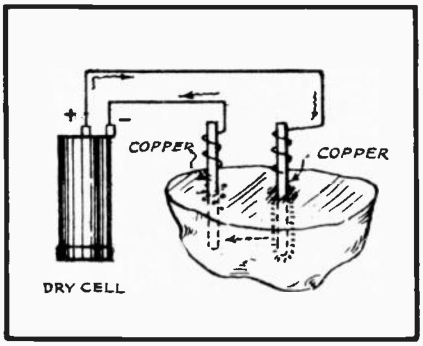

FIG. 6
HOW TO DETERMINE THE POSITIVE SIDE OF THE CIRCUIT

HOW TO DETERMINE IF A CIRCUIT IS OF THE A-C OR D-C TYPE

The experiment just described can also be applied to determine if an alternating or direct current is flowing through a given circuit. If the circuit in question is of the low-voltage type, as is the case when checking a circuit energized by batteries or a low-voltage (bell-type) transformer, simply insert the two bared ends of the copper wire in a potato as shown in Fig. 6, and observe results.

If green-colored copper nitrate forms around one of the wires and hydrogen bubbles around the other, you will know that the circuit is of the d-c type and that the wire surrounded by the copper nitrate is connected to the positive side of the circuit.

Repeating this same experiment with an alternating current circuit will disclose the presence of hydrogen bubbles around both wires and also a slight tinge of green copper nitrate around each of them. In other words, since alternating current flows through the arrangement first in one direction and then in the opposite direction, the electrodes will acquire both positive and negative characteristics.

Having applied an a-c voltage to the electrodes, no clicking sound will be heard upon applying the headphone test illustrated in Fig. 5, as alternating current is not suitable for charging a secondary cell. The reason for this is that the flow of a-c will charge and discharge the cell alternately in accordance with the current reversals.

If the tests just described are performed on circuits operating at voltages of 110 volts or more, special precautions should be taken so as not to blow a fuse in the circuit nor to subject yourself to an electric shock. To avoid these dangers, be sure that you are standing on a dry wooden floor, and that the insulation of the wire being used is dry and of adequate insulating ability for the voltage involved. When handling such circuits, never touch the bare wires while the circuit is closed, and be sure to include an incandescent lamp in series with the circuit under test. The lamp used for this purpose should be rated at about 40 watts and of the same voltage as the line. The set-up for this a-c line test is shown in Fig. 7.

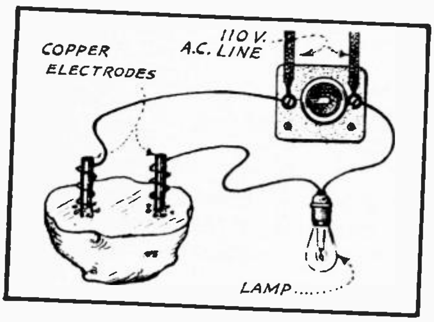

FIG. 7
EFFECT OF ALTERNATING CURRENT

THERMAL EFFECT OF AN ELECTRIC CURRENT

The experiment illustrated in Fig. 7 can also be used to demonstrate the effect of reducing the resistance in a circuit, and at the same time show how the temperature increases very rapidly with any increase in current flow. For this experiment, simply move the two line-wires closer and closer together, being careful that they do not touch each other at any time. You will observe that bringing the wires together will cause the lamp to burn brighter. More bubbles will also form around the wires, and the potato will become noticeably warm.

This action can be explained as follows: Moving the electrodes closer together reduces the resistance and permits a greater current to flow through the circuit. The chemical action is so rapid at this time that considerable heat is generated.

The chemical action as outlined for this experiment will be the same when d-c is used but the voltage must of course be much higher than the 1.5 volts furnished by the dry cell. A good radio "B" battery can be used effectively to demonstrate this.

WATER RHEOSTATS

The chemical decomposition of water by a flow of electric current can also be used to determine the polarity of d-c circuits, as well as to determine whether the circuit in question is of the d-c or a-c type. The decomposition of water by this means is called ELECTROLYSIS.

Such an experiment can be performed by connecting two pieces of copper wire to the terminals of a dry cell, and inserting the bare ends of these wires into a glass of water, as shown in Fig. 8.

This arrangement is called a <u>water rheostat</u>. The resistance value of this water rheostat depends upon the effective area of the electrodes, the separation betweem them and the conductivity of the liquid being used. By using ordinary drinking water and two pieces of wire, separated from each other by about 2 inches, the resistance of the rheostat will be approximately 7,000 ohms. However, moving the wires closer together -- say, until they are about one inch apart -- will reduce the resistance to about 4,000 ohms. (The wires are submerged in the water to a depth of about 12 inches.)

Now, by moving the wires still closer together, but being careful that they do not touch each other, you will observe numerous bubbles accumulating around the submerged wire that is connected to the negative electrode of the cell. If a battery voltage of 4.5 volts is employed, a still greater number of bubbles will form around the negative wire.

The reason for the formation of the bubbles is that the passage of an electrical current through the water decomposes the water into its chemical elements, oxygen and hydrogen. Oxygen bubbles form around the positive electrode and hydrogen bubbles around the other electrode, but there are more hydrogen bubbles than there are oxygen bubbles.

The chemical formula for water is expressed as H_2O, meaning that it consists of two atoms of hydrogen and one atom of oxygen. The fact that there are twice as many atoms of hydrogen as oxygen in a molecule of water explains why more bubbles form around the negative electrode than around the positive electrode. Since oxygen combines readily with the metallic substances of the electrode around which it is liberated, very little gas will escape to the top of the water in the form of bubbles.

THE EFFECT OF SALT UPON THE ELECTROLYTE

Now leave the circuit connections as shown in Fig. 8, and drop a little salt into the water. You will observe that adding more salt to the water will cause more current to flow through the arrangement. This increase in current intensity is indicated by the greater number of bubbles that form around the electrodes. The same results would be obtained if sulphuric acid were mixed with the water. However, since salt can be obtained more readily and handled more conveniently, it will serve our purpose better.

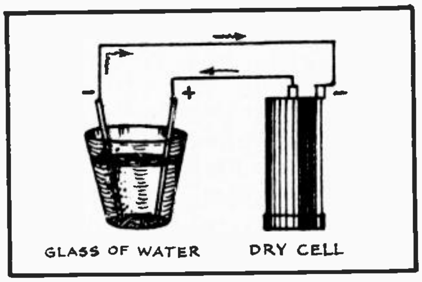

FIG. 8
WATER RHEOSTAT

During this experiment, you will also observe that the current flow through the circuit will increase momentarily and then immediately commence to decrease again. The reason for this is that the negative electrode eventually becomes covered with a hydrogen film that insulates this electrode from the electrolyte. Upon removing the wires, cleaning them and again inserting them in the water, you will observe the current to increase.

The type of current flowing through a circuit can also be determined by applying the principles of the electrolysis of water, as just described. However, when handling high voltage circuits, it is important to connect a lamp in series with the circuit and the electrodes that contact the water, the same as suggested for the experiment illustrated in Fig. 7.

When conducting this test, a d-c current will form an appreciable number of bubbles around the negative electrode only, whereas an alternating current will form bubbles around both electrodes equally.

Water rheostats are sometimes used in circuits where it is necessary to control a great amount of current for a short time. Current can be made to flow through a rheostat of this type even though the water temperature rises considerably. Such rheostats also provide a very effective and simple means for altering the resistance of a circuit. This is generally done by submerging more or less of the electrode in the water and thereby varying the electrode area that contacts the water. The resistance of the water rheostat can also be varied by altering the distance between the electrodes.

EXPERIMENTS WITH MAGNETISM

In the regular lessons of the course, we have mentioned that an electrical current forms a magnetic field around the conductor through which it flows. You can now prove this to your own satisfaction in the following manner:

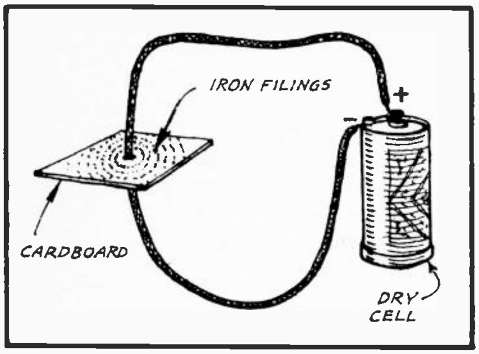

FIG. 9
LINES OF FORCE SURROUNDING A CONDUCTOR

Punch a hole in the center of a piece of cardboard, making it just large enough so that a piece of copper wire can be passed through it. The wire used for this purpose may be either of the bare or insulated type, as magnetism is not affected by insulation.

Support the wire in a vertical position as shown in Fig. 9, and connect its ends to a dry cell. It makes no difference which end is connected to the positive terminal of the cell and which to the negative terminal. The cardboard can be supported between two books, two glasses or by any other means that is convenient.

The only resistance offered by this circuit is that introduced by the wire itself, and therefore the cell will force considerable current through the circuit. For this reason, the circuit should remain closed only long enough to complete the test. Closing the circuit for a longer period will discharge the cell completely in a very short time.

Now then, while current is flowing through the circuit, drop some iron filings on the cardboard and while so doing, tap the edge of the cardboard lightly with your fingers. You will observe the iron filings to form a pattern of concentric circles around the conductor, as pictured in Fig. 9. These rings of iron filings mark the "path" of the invisible lines of magnetic force that surround the conductor.

Continue by opening the circuit and remove all of the iron filings from the cardboard. Now, upon sprinkling iron filings on the surface of the cardboard, you will find that the filings will not arrange themselves in any definite pattern. The experiment thus proves that magnetic lines of force surround a conductor that is carrying a current but do not surround a conductor that is not carrying a current. (Note: You can obtain the iron filings required for this experi-

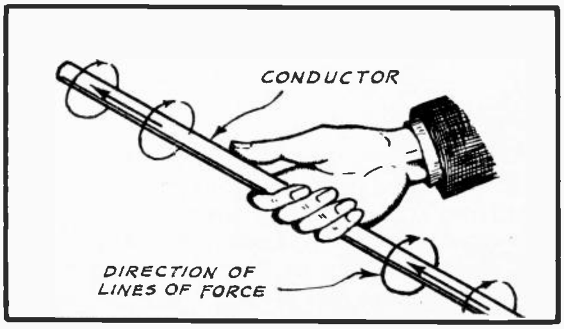

FIG. 10
THE RIGHT-HAND CONDUCTOR RULE

ment by filing a large nail and gathering together the filings thus produced.)

The magnetic field surrounds a conductor in one direction only, in accordance with the direction of current flow through the conductor. For example, by grasping the wire with the right hand, so that your thumb extends in the direction of current flow (see Fig. 10),the other four fingers will point in the direction in which the magnetic field encircles the conductor. This can be proven with the aid of a pocket compass. (It is to be noted that this is a practical electrician's rule, and for this reason the flow of current is considered as being from positive to negative.)

Upon bringing the compass near the conductor, the north end of its needle will always point in the direction in which the magnetic field encircles the conductor. Reversing the battery connections will cause the compass needle to reverse its position, thus showing that the lines of force are now encircling the conductor in the opposite direction.

SOLENOIDS AND ELECTROMAGNETS

Wrap a piece of heavy paper around a nail and then wind as many turns of insulated wire as possible over the heavy paper, as shown in Fig. 11. Upon completion of the winding, remove the nail. You will now have an air-core coil, or SOLENOID. Continue, by connecting the ends of the solenoid across the terminals of a dry cell and bring small pieces of iron or steel near the ends of the solenoid.

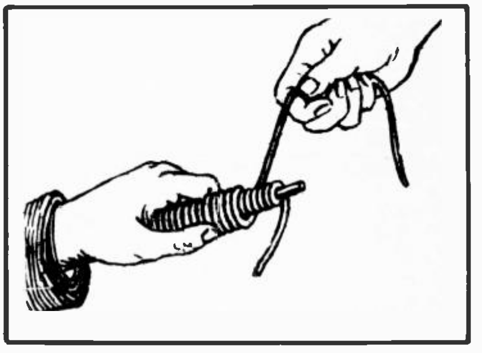

FIG. 11
CONSTRUCTING AN ELECTROMAGNET

You will notice that while current flows through the solenoid, any pieces of iron and steel near the ends of the coil will be attracted to it. This proves that the flow of an electric current through the solenoid produces a magnetic field of such pattern that magnetic poles are formed at the ends of the coil. The attraction for iron and steel at the ends of the coil will cease the moment that the circuit is interrupted. This proves still further that it is the flow of current that produces the magnetic poles.

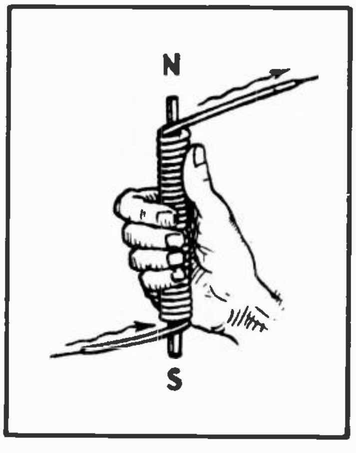

FIG. 12
RIGHT-HAND COIL RULE

The poles of a solenoid, electromagnet or any coil for that matter, can be identified by applying the right-hand rule as illustrated in Fig. 12. This rule is applied in the following manner: Grasp the electromagnet with the right hand so that the thumb is extended and so that the other four fingers follow the direction of current flow through the coil. The thumb will then be pointing toward the North pole of the coil. (Here again, current flow is considered as being from positive to negative in accordance with the practical electrician's custom.)

Now, insert the nail through the center of the coil. You will observe the intensity of the magnetic field to increase considerably, which proves that the permeability of the iron core is greater than that of the air-core. That is, iron is a better conductor of magnetic lines of force than is air.

You can perform numerous experiments with this electromagnet, such as proving with the aid of a pocket compass that the right-hand rule is true, proving that like magnetic poles repel while unlike magnetic poles attract, etc.

Also increase the voltage applied to the coil and note its effect upon the magnetic field. You can also add and remove turns of wire from the coil, observing results.

You will find that the magnetic field is affected noticeably by any increase or decrease in the number of turns of wire and also by any change in current intensity. For instance, if the number of turns of wire is increased, the intensity of the magnetic field will also increase. An increase in current intensity will also strengthen the magnetism. This experiment proves beyond any doubt what you learned in one of your regular lessons: namely, that the strength of the magnetic field of any coil depends upon the ampere-turns. You will recall that "ampere-turns" is a factor that is equal to the current flow in amperes multiplied by the number of turns of wire.

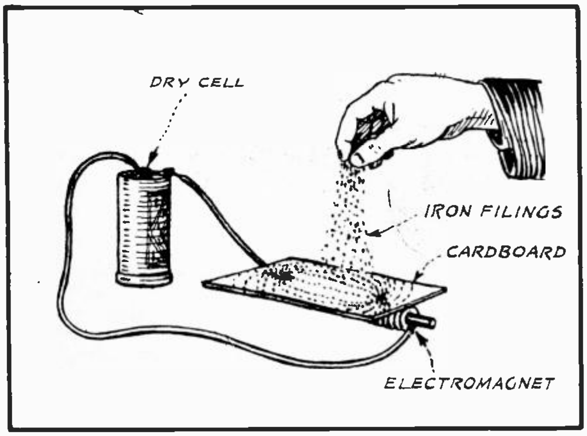

FIG. 13
FIELD SURROUNDING AN ELECTROMAGNET

For example, a coil wound with ten turns of wire and carrying a current of one ampere, will have a magnetomotive force of 10 x 1, or 10 ampere-turns. This same magnetic force will be obtained from a coil consisting of five turns of wire and carrying a current of 2 amps, as 5 times 2 also equals 10.

MAGNETIC FIELD OF AN ELECTROMAGNET

Place the electromagnet on top of a table and place a piece of cardboard or glass over it, as shown in Fig. 13.

Now, scatter a few iron filings on top of the cardboard and while so doing, tap the cardboard lightly with your fingers. You will find the filings to arrange themselves in accordance with the path followed by the lines of force.

Construction Projects

So much for the basic electrical experiments. Your next experimental assignments will be in the nature of construction projects, for which the following parts are sent in your second kit:

2 - Bakelite knobs
1 - 6-prong socket
1 - 5000-ohm potentiometer
1 - 100,000-ohm potentiometer
1 - 100,000-ohm resistor (brown-black-yellow)
1 - 100-ohm resistor (brown-black)

ANOTHER FORM OF A-F OSCILLATOR

In Fig. 14 is shown the diagram of an a-f oscillator. This oscillator differs noticeably from the one you constructed in accordance with the instructions furnished in your first Experiment Lesson.

The oscillator described to you at that time employed a single winding for both the grid and plate circuits. In such oscillators, the plate current flows through one-half of the winding and induces a voltage in the other half. The latter voltage is applied to the grid of the tube.

Transformers that couple the grid and plate circuits in this manner are called auto-transformers. In fact, all transformers wherein a single winding is divided into two sections to constitute the primary and secondary are classed as auto-transformers.

The primary of an auto-transformer is that section of the winding through which the power supply current flows, whereas the secondary is that section across which a voltage appears by induction. The transformer that you received in your first outfit of parts has a primary winding and a secondary winding. The secondary winding is the one that is center-tapped.

In constructing the a-f oscillator described in the previous Experiment Lesson, the actual secondary winding served as both primary and secondary of an auto-transformer, one half of this winding being the primary and the other half the secondary. The actual primary winding was at that time used solely as a means for coupling the auto-transformer winding to the headphones.

However, in the oscillator circuit shown in Fig. 14 of this lesson, both transformer windings are employed in their normal manner. That is, the primary winding is actually used as the primary and the secondary winding as the secondary. In this circuit, the plate current flows from the negative terminal of the "B" battery to the cathode, through the tube to its plate, and then through the primary winding of the transformer, headphones and back to the "B" battery.

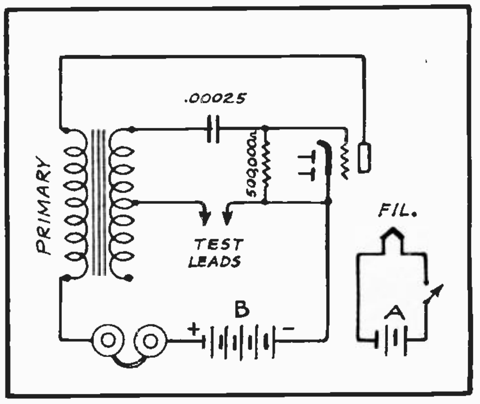

FIG. 14
DIAGRAM OF AN A-F OSCILLATOR

As the varying plate current flows through the primary of the transformer, it induces a voltage in the secondary which is impressed on the grid of the tube. The tube operates in the same manner as in the oscillator described in the previous experiment lesson. You will further notice in Fig. 14 that the grid circuit of the tube employs only one-half of the secondary, and that the test leads are connected between this winding and the cathode of the tube. The construction of this circuit is very simple. However,to still further aid you in its construction, we have prepared for you the detailed drawing appearing in Fig. 15. Here you are shown the layout of the parts and their respective connections. If upon completing this wiring job, you should find that the oscillator does not produce a sharp note when touching the test leads together, reverse the primary connections at the transformer and again listen for the signal.

The object is to apply a voltage of proper phase to the grid so that the tube will oscillate. To obtain such operation it is necessary that the current flow through the primary winding be in a definite direction. Hence, if the direction of current flow is not correct to produce oscillation, a reversal of the primary connections at the transformer will correct the condition.

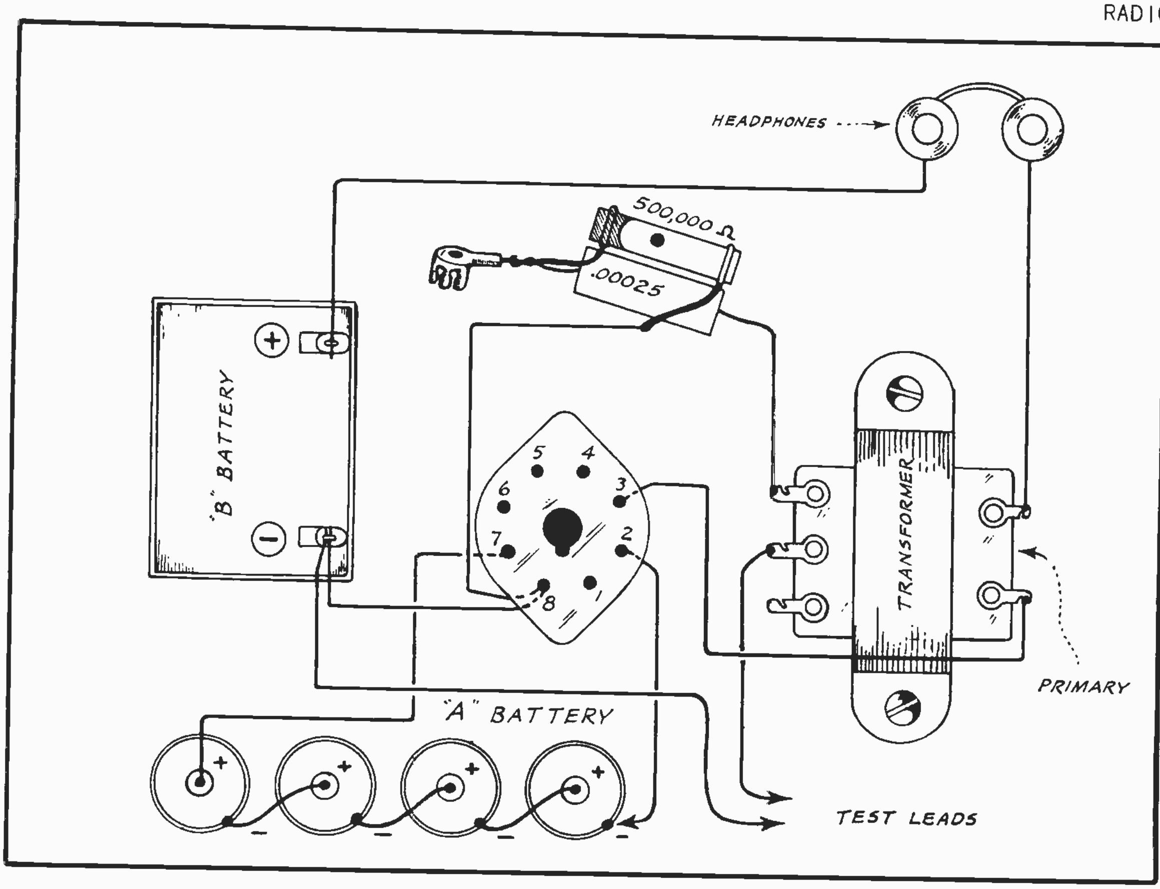

FIG. 15
PHYSICAL LAYOUT FOR THE A-F OSCILLATOR

This oscillator can be used for the same purposes as outlined in the previous experiment lesson. Although it could be connected to the lighting circuit, this is not recommended as the headphones would then also be connected in series with the line. Such a condition is likely to result in a dangerous shock. This danger does not exist in the a-f oscillator described in the previous experiment lesson,as in this case the headphones are not connected directly in series with the lighting circuit.

THE CATHODE-RAY TUNING INDICATOR TUBE

The audio oscillator, which you constructed according to the instructions furnished in the previous experiment lesson,enabled you to conduct various tests by means of audible sounds produced by your headphones. Such tests are known as AUDIBLE TESTS.

Your next construction project will be to build a tester wherein a cathode-ray tuning indicator tube will enable you to observe the results of various tests by visual means. Such tests are known as VISUAL TESTS.

The circuit diagram for the battery-operated visual tester is shown in Fig. 16. Here you will observe a 6U5 tube serving as the indicating device. However, before discussing the operating principle and application of this tester, it is well that you first familiarize yourself with the tube used herein.

The 6U5 tube was designed primarily to indicate when a receiver is tuned to resonance with any desired station. However, it is also being applied in a number of different ways, particularly in testing equipment. The tester here shown is one such application.

This tube is also known to the industry by various other names, as an "electron tuning indicator," "magic eye," etc. Besides the 6U5, other similar tubes are known as 2E5, 6E5, 6G5, 6H5 and 6N5. The only difference between these various tubes is in the voltages required for operation.

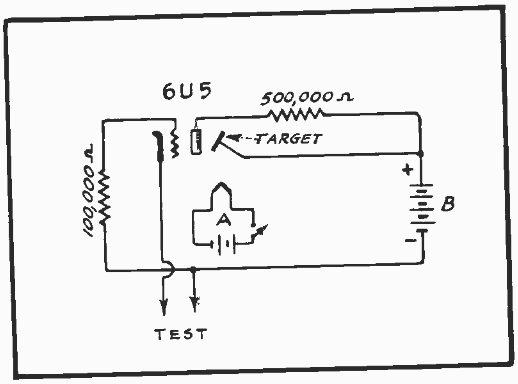

FIG. 16
BATTERY-OPERATED VISUAL TESTER

Cathode-ray tuning indicator tubes consist essentially of a heater, cathode, control grid, plate and a target. The latter is coated with a fluorescent substance that glows with a green color when "bombarded" by a stream of electrons. Basically, the tube can be considered as a triode that is fitted with the target. The triode elements are located at the lower end of the tube, but the cathode extends upward through a central opening in the target as does also a small extension of the plate. The latter is called the RAY-CONTROL ELECTRODE. Fig. 17 shows this construction clearly.

As will be seen in Fig. 16, the target of the tube is connected directly to the positive side of the "B" power supply, consisting of at least 90 volts. The plate is also connected to B+, but through a 500,000-ohm resistor. Thus, the positive potential of the plate and the ray-control electrode are lower in value than that applied to the target. Hence, the connections are such that the target will be maintained at a high positive potential of constant value, while the voltage effective at the plate varies in accordance with changes in the plate current. This can be explained in the following manner:

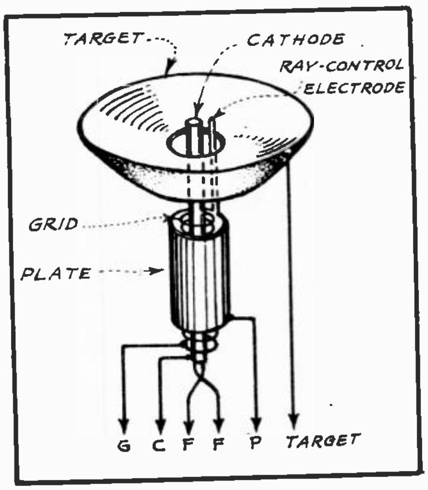

FIG. 17
DETAILS OF THE 6U5 TUBE

When no voltage is applied to the grid, the plate current will be of a relatively high value, the voltage-drop across the resistor will be considerable and the ray-control electrode will therefore be less positive than the target. Under these conditions electrons flowing toward the target are repelled by the electrostatic field of the electrode, and do not reach that portion of the target behind the electrode. Because the target does not glow where it is shielded from electrons, the control electrode casts a shadow on the glowing target. The distribution of electrons at this time is illustrated at the left of Fig. 18.

In this illustration you are looking down upon the target-end of the tube; the dotted lines represent the flow of the electrons. Notice, particularly, that the ray-control electrode deflects many electrons from a straight-line path toward the target.

Now, let us suppose that a negative voltage is applied to the grid. Under such conditions, the plate current will decrease, the voltage-drop across the resistor will decrease, and therefore a positive potential of greater magnitude than formerly will be applied to the plate and to the ray-control electrode.

The effect of this greater plate voltage is shown at the right of Fig. 18. Here you will observe that the increase in positive potential at the ray-control electrode causes this electrode to exert a lessened repelling force upon the electrons emitted by the cathode,and thus permits the electrons to follow a more straight-line path toward the target. This causes a larger area of the target to become illuminated, and thereby decreases the shadow area.

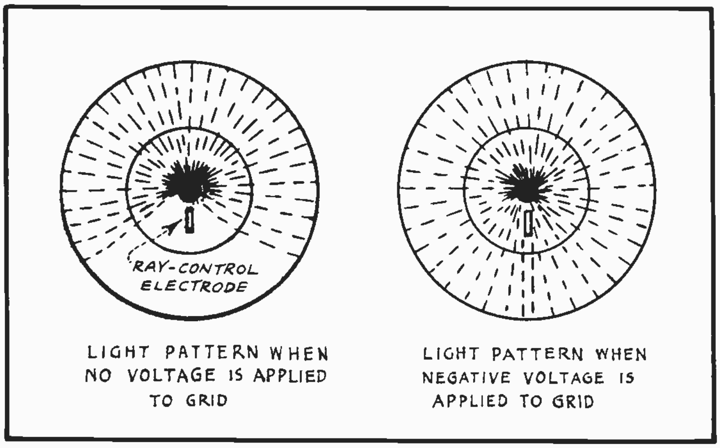

FIG. 18
EFFECT OF GRID VOLTAGE UPON THE TARGET

The higher the negative voltage applied to the grid, the lower will be the plate current and the greater the area of target illumination. In other words, the higher plate voltage alters the direction of the electrons in such a way that they are not deflected by the ray-control electrode, as at the left of Fig. 18, but follow a straight path as pictured at the right of Fig. 18.

In Fig.19 are shown the symbol and socket connections for the 6U5 tube,as viewed from below.

When using this tube as a tuning indicator in radio receivers, the grid is connected to the receiver's automatic volume control circuit, which system applies a higher negative voltage to the grid when the receiver is tuned to absolute resonance with the station being received. Therefore, the target illumination will be greater at resonance. This will be demonstrated clearly later on when you will be required to construct a receiver that employs an automatic volume control system.

So much for the action of the indicating tube. Let us now direct our attention to the problem of constructing the tester.

CONSTRUCTING A BATTERY-OPERATED VISUAL TESTER

Returning to the diagram in Fig. 16, you will note that the test leads are connected in series with the cathode circuit. Therefore, if the test points are applied across the ends of a resistor, the resistor being checked would act as a bias resistor in the cathode circuit and would thus determine the magnitude of the negative voltage that is applied to the grid. Hence, the value of the resistance between the test points would also control the area of illumination at the tube's target. This feature makes it possible to use this tester for checking radio circuits and parts, for determining the approximate value of resistors, etc.

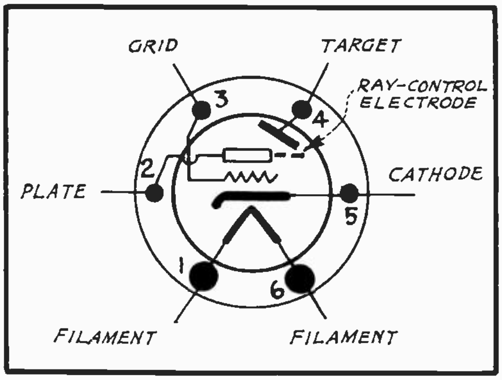

FIG. 19
SOCKET CONNECTIONS FOR THE 6U5

The visual tester is very simple to construct. However, you should first make a simple sketch of its connections and then check it

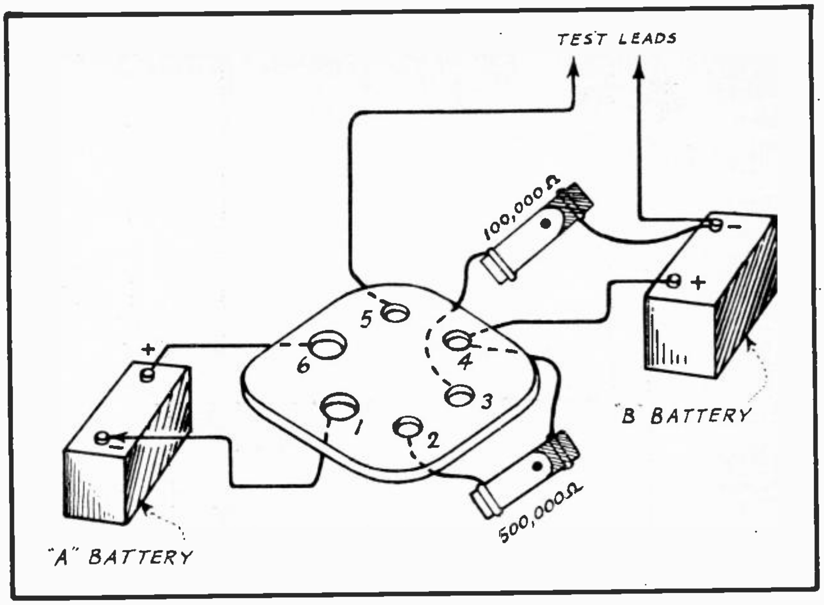

FIG. 20
PARTS ARRANGEMENT OF BATTERY-OPERATED TESTER

with those shown in Fig. 20 before commencing the actual work of construction.

The "A" supply may be furnished by a 6-volt storage battery or four dry cells connected in series. When the tester is not being used, the filament circuit can be interrupted by disconnecting the wire at the negative terminal of the "A" battery (see Fig.20). The "B" battery used for this purpose should furnish a voltage of at least 90 volts. It is of great importance that the positive terminal of the "B" battery be connected to terminal #4 of the socket, as shown in the illustrations.

CONSTRUCTING A VISUAL TESTER FOR OPERATION FROM A LIGHTING CIRCUIT

Students, whose homes are wired for electric lighting, need not construct the battery-operated tester just described, but should instead build the tester diagrammed in Fig. 21. This tester is designed to be operated from either an a-c or a d-c lighting circuit.

If the lighting circuit operates at 110 volts, the tester should be wired in accordance with the solid lines appearing in Fig. 21, using a 40-watt, 110-volt lamp in the same manner as in past experiments.

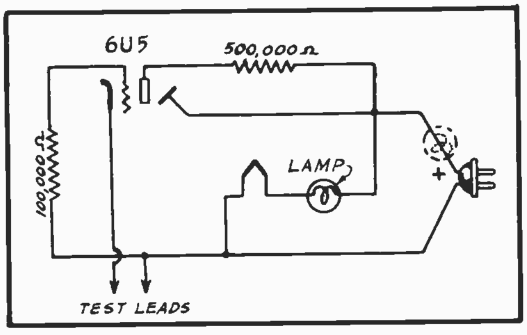

FIG. 21
A-C OR D-C OPERATED TESTER

If the line voltage is 220, it is necessary to use an additional lamp which is indicated in Fig. 21 by the dotted lines. This lamp should also be rated at 40 watts and 110 volts. In case that you are not able to obtain a lamp of this voltage, you can use two 100-watt, 220-volt lamps.

If the lighting circuit is of the d-c type, it is necessary that the positive side of the line be connected to the plate and target of the tube. If the circuit is of the alternating current type, then it is immaterial which side of the line is connected to the plate and target. As in the case of the a-f oscillator, the alternating current is rectified by the tube, the latter permitting current to flow from the cathode to the plate only, and never in the reverse direction. Before actually wiring the circuits of this tester, you should first make a diagram of it and check it with those shown in Figs. 21 and 22.

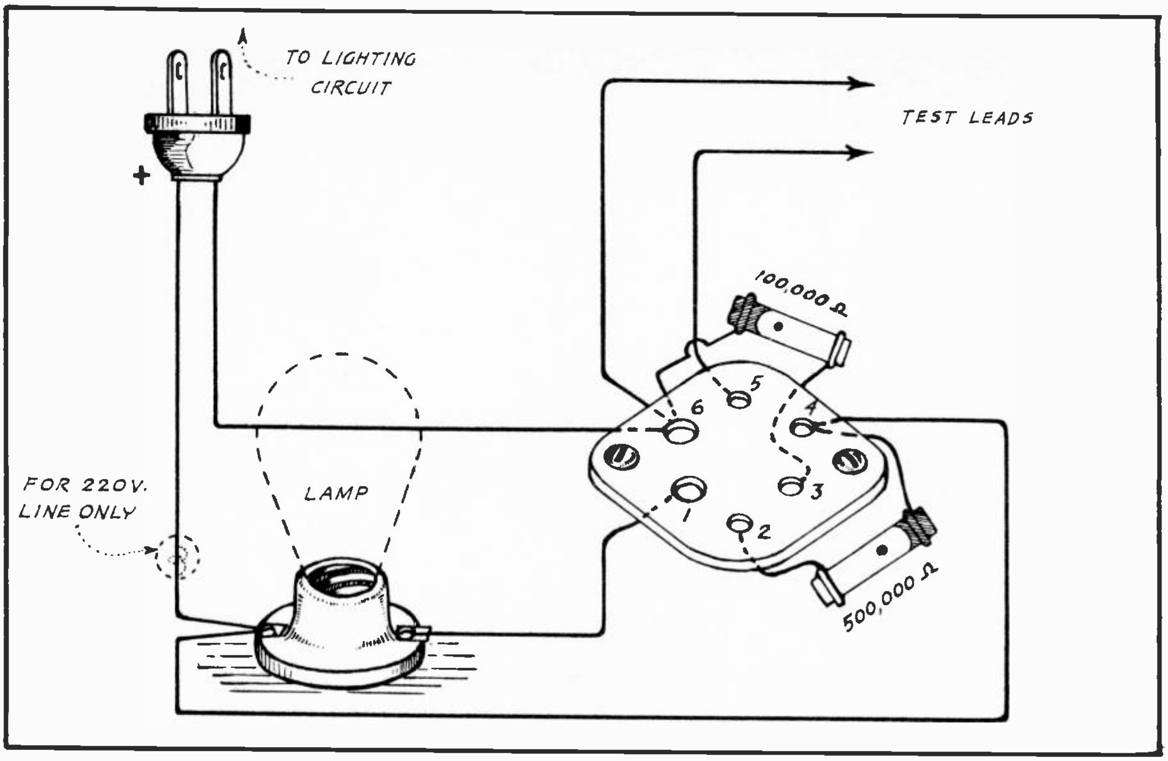

FIG. 22
CIRCUIT CONNECTIONS FOR THE 110-220 VOLT TESTER

APPLICATIONS FOR THE VISUAL TESTER

The indicator can be made to operate by connecting it to the line or closing the "A" battery circuit, according to the power supply being used. Sufficient time should then be allowed to permit the cathode temperature to rise to normal value. Upon touching together the two test points (wires) the target will become illuminated, leaving a dark area of about 90 degrees. Connecting resistors of different value in series with the test leads, will cause the illumination of the target to vary in proportion to the value of the resistor; that is, the higher the resistance value, the greater will be the area illuminated.

Resistance values exceeding 400 ohms should not be connected in series with the cathode circuit during this test, as larger values than this will reduce the plate voltage to such an extent that the target will not be illuminated at all. The behavior of the indicating tube being such, you can readily see how it can be used advantageously to determine if a short-circuit exists in a-f transformer windings, to check resistors of low values, as well as being suitable for conducting general continuity tests in low-resistance circuits that could not be tested accurately with the a-f oscillator described in the previous experiment lesson.

If you have on hand resistors of 100, 200, 300 and 400 ohms, you can calibrate the tester quite easily. To do this, fasten a piece of white adhesive tape around a portion of the tube as shown in Fig. 23, and mark on it points corresponding to the boundary of the illuminated area on the target. The calibrations are made as follows: First, connect a 100-ohm resistor in series with the test leads and mark on the tape the boundaries of the area illuminated at this time. Now, replace this resistor with another one of a different known value and mark the boundaries of the illuminated area. Continue in this manner, marking the tape with the corresponding values in ohms.

VISUAL TESTER FOR CHECKING RESISTANCES OF HIGHER VALUES

The cathode-ray tube can also be used to test circuits and components whose resistances are greater than 400 ohms and less than 100,000. However, an indirect method of testing must be employed for these tests.

In Fig. 24 is shown the circuit diagram of such a tester, operated by batteries, while Fig. 25 illustrates the connections for operating the same tester from a lighting circuit of either the a-c or d-c, 110 or 220-volt type.

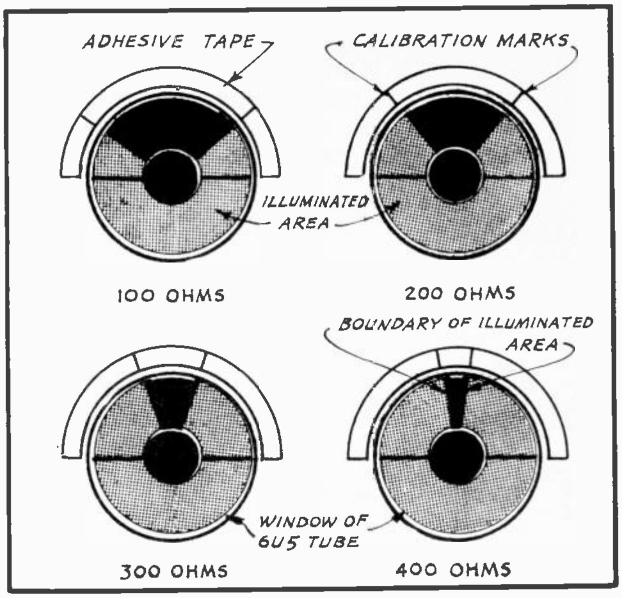

FIG. 23
CALIBRATION OF VISUAL TESTER

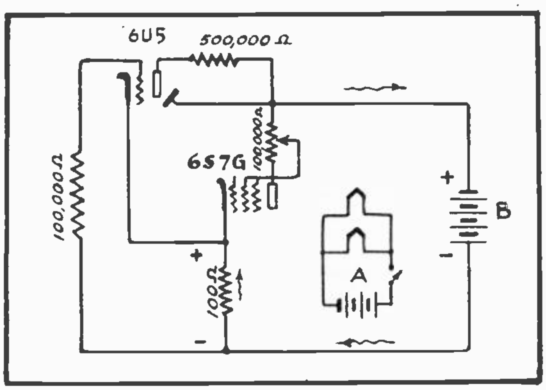

FIG. 24
BATTERY-OPERATED VISUAL TESTER

Comparing the two diagrams, you will immediately observe that the fundamental connections are basically the same. When operating the tester from batteries, the two tube filaments should be connected in parallel, as shown in Fig. 24. However, if operated from the lighting circuit, the two tube filaments should be connected in series with each other and also in series with an incandescent lamp. The series filament circuit is connected directly across the line.

If a 110-volt lighting circuit is being used, the lamp should be rated at 40 or 50 watts and 110 volts. If the lighting circuit operates at 220 volts, use another lamp of the same rating in series, as shown by the dotted lines in Figs. 25 and 26. In case that you are unable to obtain 110-volt lamps you can use two 100-watt, 220-volt lamps instead.

Also notice in Fig. 24 that a 6S7G tube and a 6U5 cathode-ray tube are specified for battery operation, whereas 6K7 and 6U5 tubes are specified for operating the tester from the lighting circuit.

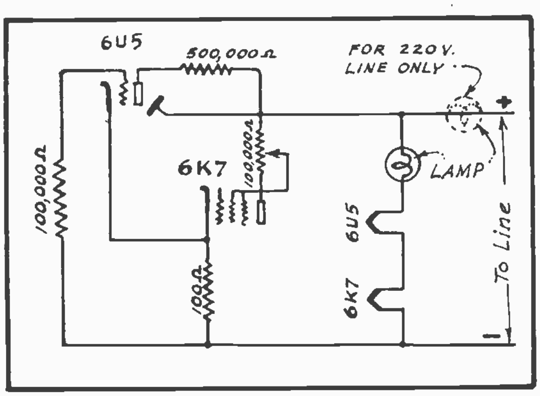

FIG. 25
LINE-OPERATED VISUAL TESTER

Both the 6K7 and 6S7G tubes are variable-"mu"amplifiers, having identical elements and base connections. These two tubes differ only as to the filament current drawn and the maximum voltage required at the plate. It is needless to say that if you have equipment for household lighting facilities, you should use a 6K7; and if your equipment is to be operated by batteries, you should use the 6S7G type tube. In either case, the tube specified will be used in receiver circuits that you will construct in accordance with later experiment lessons. Therefore, you are not being required to purchase tubes for which you will have no use later on.

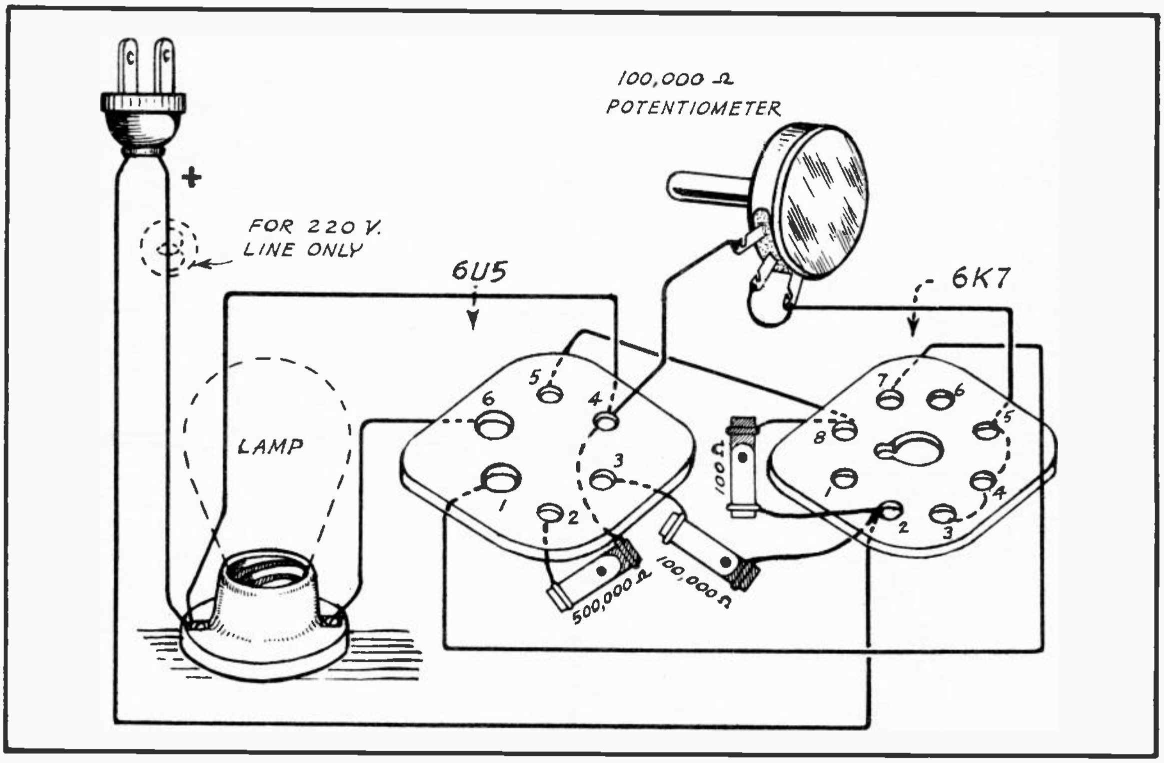

Fig. 26
Circuit Connections for 110-220 volt High-range Visual Tester

The connections for operating the tester from the lighting circuit are shown in Fig. 26.

CIRCUIT CHANGES FOR BATTERY OPERATION

If the tester is to be operated from batteries, it is only necessary to eliminate the lamp and line cord, and to connect the #4 contact of the 6U5 tube's base to the positive terminal of the "B" battery. Contact #2 of the 6S7G tube's base is then connected to the negative terminal of the "B" battery.

The filament circuit connections should be as follows: Join terminal #6 of the 6U5 socket with #7 of the 6S7G socket; connect terminal #1 of the 6U5 socket with #2 of the 6S7G socket. Finally, connect terminal #6 of the 6U5 socket to one side of the "A" battery and connect the other side of the "A" battery to terminal #1 of this same tube.

HOW THE CIRCUIT OPERATES

Although the 6K7 and 6S7G tubes are really intended to be used as variable-"mu" amplifiers, you are in this particular case using them as rectifiers. Fig. 27 illustrates the symbol and socket connections for these tubes, as seen from below, and if this data is compared with that shown in Figs. 24 and 25, you will notice that the plate, screen grid, and suppressor grid are all connected together so as to form a single positive electrode. The cathode forms the other electrode, whereas the control grid has no connection and is therefore not being used.

As will be observed in Figs. 24 and 25, a 100,000-ohm potentiometer is installed in the plate circuit of this tube, being connected between the plate and the B+ terminal of the power supply. A fixed resistance of 100 ohms is connected between the cathode and B-.

Also notice that the cathode of the 6U5 tube is connected directly to the cathode of the 6K7 (or 6S7G), and that the grid circuit terminates at B-. Because of these connections, the plate current of both tubes will flow through the 100-ohm resistor, producing a voltage across this resistor, which is applied to the grid of the 6U5 tube as a negative bias.

This tester operates in the following manner: Placing the potentiometer arm at its extreme right position eliminates all of its resistance from the circuit; therefore, maximum plate current will flow through the 6K7 tube. This causes the maximum voltage to be generated across the 100-ohm resistor, resulting in maximum negative bias voltage being applied to the grid of the 6U5 tube. This condition provides maximum area of illumination of the target.

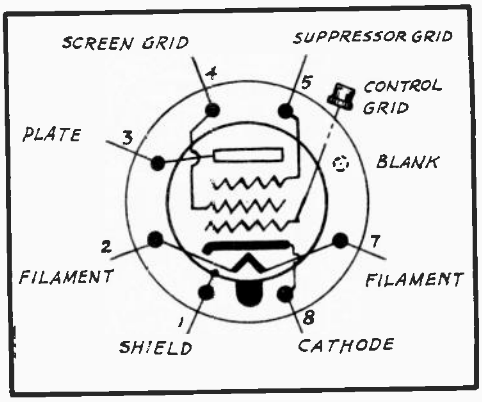

FIG. 27
SOCKET CONNECTIONS FOR 6K7 OR 6S7G TUBES

If we now continue to increase the potentiometer resistance, the current flowing through the 100-ohm resistance will decrease. This in turn will bring about a decrease in the negative voltage applied to the grid of the 6U5 which will result in less target illumination.

From the above explanation you will understand that if we eliminate the potentiometer and connect in its place two long test leads, the instrument will then enable us to test resistors and circuits up to 100,000 ohms.

Smaller resistance values will cause the target of the 6U5 tube to become illuminated over a greater area than will be the case if resistances of larger value are connected in series with the test points. If the resistance is too great, or in the event of an open circuit, the target illumination will suffer no change and will remain at a maximum.

CIRCUIT FOR TESTING OPERATION OF THE 6U5 TUBE

The previous experiments with the 6U5 have shown you that target illumination depends upon the negative voltage applied to the grid. This fact makes it possible to construct a simple circuit that will show definitely how grid voltages affect target illumination, which will at the same time serve as a means for testing the condition of cathode-ray tuning indicator tubes that have a 6.3-volt filament, and which have been in use for some time.

Cathode-ray tuning indicator tubes in general, except the 6H5 and the 6U5, are subjected to a fairly large current flow between the target and cathode. For this reason, the life of these tubes is very short. As a rule, the triode section continues to function but the electron emission from the upper end of the cathode finally becomes insufficient to provide normal target illumination, and will not respond to changes in voltage occurring at the ray-control electrode.

If a tube in such condition is used as a tuning indicator, it will not be possible to determine the exact point of dial travel at which the receiver is tuned to absolute resonance with the station being received.

The circuit diagrammed in Fig. 28 will test the condition and operating ability of cathode-ray tuning indicator tubes. While the tester diagrammed in Fig. 28 is designed for operation from a lighting circuit, it can also be adapted to battery operation by making the changes shown in Figs. 24 and 25.

That is, for battery operation, connect the two filaments across a 6-volt "A" battery and connect the end marked "+" to the positive terminal of the "B" battery. The end identified as "-" should then be connected to the negative terminal. A 6S7G tube should be used as the current control tube (rectifier in the a-c version).

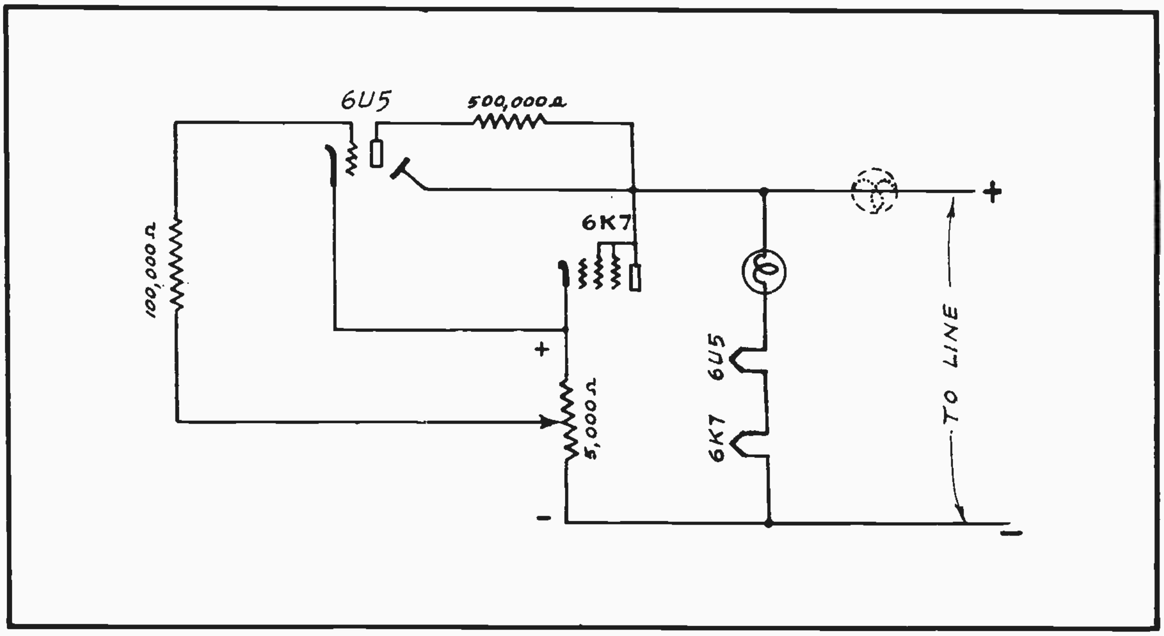

Fig. 28
Circuit of Cathode-ray Tuning Indicator Tube Tester

By comparing the diagrams with the pictorial drawings, you will notice that we have in all cases planned the set-up so that the circuit wires can be connected directly to the lugs or binding posts. This practice makes it possible to use a single piece of wire between connecting points instead of splicing several sections of wire together at intermediate points. The latter is very undesirable.

So that you may better accustom yourself to the correct method of wiring circuits, we are not furnishing you with a physical layout of the circuit appearing in Fig.28. Therefore,you must construct your tester with the help of the diagram alone, relying on your own initiative to apply the instruction given in other parts of this lesson.

HOW THE TUBE TESTER OPERATES

A 5000-ohm potentiometer is connected between the cathode of the rectifier tube and "B-". Thus,the current flow through it establishes a potential across its ends -- the lower end being negative with respect to the upper end.

By connecting the arm of the potentiometer to the grid circuit of the 6U5 tube, we will be able to vary the negative voltage that is applied to it.

To perform the test, the tube being checked should be inserted in the six-prong socket, the cathodes allowed to heat up and the potentiometer arm moved gradually. (The tube's target should be observed closely during this procedure.) If the tube is in good working condition, rotating the potentiometer arm through its range will cause the illuminated area on the target to vary in a progressive manner and without change in the light intensity.

GENERAL SUGGESTIONS CONCERNING YOUR EXPERIMENTS

Upon completing the wiring of any apparatus described in your experiment lessons, always make it a point to first check the wiring carefully against the diagram or pictorial drawing, before connecting it to the power supply. Such a practice will aid materially in reducing the damage to parts due to incorrect circuit connections.

Having performed all of the experiments described in any one lesson, you will often think of additional circuits and applications. In such a case, it is good practice to work out your own ideas and to perform the experiments necessary to prove your point. However, it is well that you adopt the habit of always first drawing a circuit diagram of your proposed plan so that you can study the situation carefully as to its practicability, and also to insure your circuit connections as being correct.

Also, bear in mind that many individual experiments are described in each of the lessons of this special series. It is important that you perform each and every one of them, and in the same order as given in your lessons. We suggest, however, that you budget your time for experimenting and your time devoted to the study of the regular lessons in such manner that your experimental work will be in the nature of <u>recreational study</u> -- to be done at convenient intervals between the study of the regular lessons. By following this plan, your studies as a whole will be more interesting and the time thus spent in experimenting will not slow up your progress through the course.

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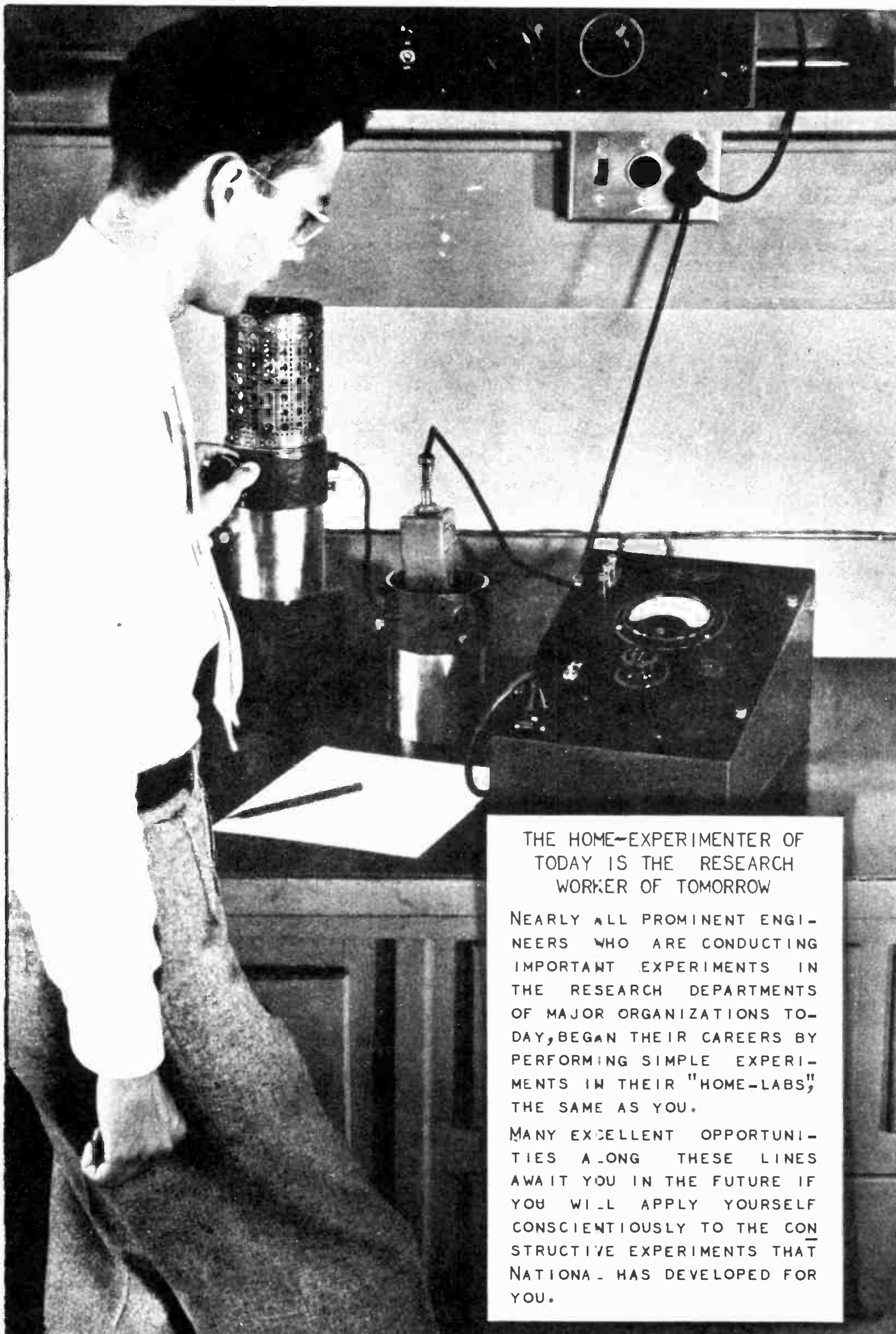

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EXAMINATION QUESTIONS

ans Nov/3/41

EXPERIMENT LESSON NO. FG-2

1. - State three ways whereby it is possible to increase the magnetic field of a solenoid?

2. - What would happen if the electrodes in the cell of a battery were constructed of the same material?

3. - If the voltage applied to the grid of a cathode-ray tuning indicator tube is made more negative will the illuminated area of the target become greater or less than originally?

4. - Why is it possible to determine the approximate value of resistors by means of the visual tester described in this lesson?

5. - What simple experiment will demonstrate that the lines of force arrange themselves in a definite pattern around a coil that is carrying an electric current?

6. - By what simple tests can you determine whether a circuit is of the a-c or d-c type?

7. - Why is a lamp connected in series with the filament of the cathode-ray indicator and the lighting circuit?

8. - Name two simple methods whereby you can demonstrate which side of a d-c circuit is positive and which is negative.

9. - What is a water rheostat?

10. - How does an auto-transformer differ from a conventional (regular) transformer?

"Opportunity Knocks at a Man's Door But Once"

Many a time you have heard that expression and perhaps it is true, but there is no law of God or man that prohibits a man from knocking at Opportunity's door just as often as he may wish. If he knocks often enough, sooner or later, he is sure to find opportunity at home. If he is ready it will mean Success.

Opportunity means nothing to the man who is not ready. If he is not prepared he won't even be recognized. Whatever we amount to in this world depends entirely upon ourselves, and our own efforts. If we make no effort we get nothing. If we make a big effort to get ahead we can and will succeed. In other words, we are going to be rewarded for exactly what we do.

Success will not come by merely wishing for it. It is something we must fight for. We have got to conquer every obstacle --- we cannot give in to pleasures or idle dreams. And the harder we fight the greater will be our success.

Opportunity waits for no one -- it's up to us to make ourselves ready and catch her.

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 PRINTED IN U. S. A.

EXPERIMENT LESSON NO. FG-3

CONSTRUCTION OF A REGENERATIVE RECEIVER

The parts included in your third kit of equipment will enable you to begin constructing actual radio receivers. You will find this work to be especially interesting and instructive, as it will enable you to apply, practically, important principles that have been explained to you in the regular part of the course. It will also provide you with excellent experience in solving construction and trouble-shooting problems of the type with which you will be confronted later on when you have established yourself in the radio business.

The parts comprising the third kit are as follows:

1 - Antenna-stage coil, having a frequency range of 550 to 1500 kilocycles.
1 - Three-gang variable condenser with a maximum capacity of .00035 mf.
1 - 1 megohm carbon resistor.
1 - .001 mf bypass condenser.
1 - .25 mf bypass condenser.
1 - .02 mf bypass condenser.
1 - .05 mf bypass condenser.

(Note: If the plan under which you are enrolled requires your experimental equipment to be operated from an a-c or d-c lighting circuit, you will receive the .02 mf and .05 mf bypass condensers appearing in the above list. These two condensers are not required for battery-operated equipment and are therefore not included therewith.)

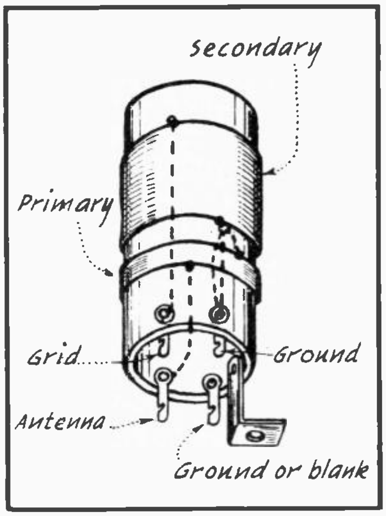

FIG. 1
ANTENNA-STAGE R-F COIL

As was already suggested relative to other kits sent you, it is advisable that you first examine all of the parts included in the kit so as to familiarize yourself with them.

THE ANTENNA-STAGE R-F COIL

Fig. 1 of this lesson illustrates the general construction of the antenna-stage r-f coil, and the manner in which the windings are connected to their respective terminals. Upon examining this unit closely you will observe that it comprises a cylinder made of insulative material, on which is placed a primary and a secondary winding. The primary winding contains fewer turns of wire than does the secondary.

Not all antenna coils are provided with a secondary of more turns than the primary, but where the number of primary turns exceed the number of secondary turns, it is customary to wind the primary in several layers so that the primary occupies a lesser winding-space than does the secondary. In the latter case, the primary can be identified by the lesser space it occupies in comparison with that of the secondary, rather than by the number of turns.

Fig. 1 illustrates the most common terminal connections for this type of coil. However, these connections vary among coils of different manufacture as well as among different coil designs of the same manufacturer. Therefore, it is advisable that you learn to identify coil connections by inspection. It is with this point in view that Fig. 2 is presented.

Fundamentally, the two windings in Fig. 2 may be considered as one continuous winding, cut at a certain point to form the primary and secondary sections of the coil. The primary and secondary windings may be easily identified in this illustration by applying the rule that the primary always occupies less space than does the secondary.

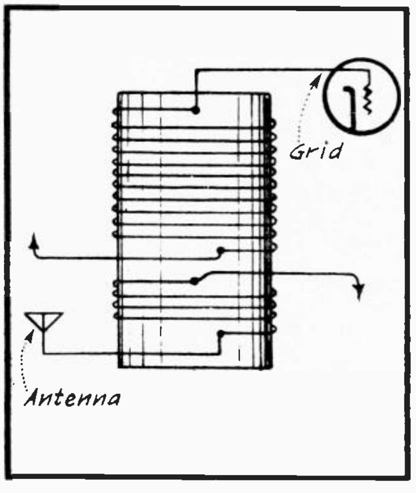

FIG. 2
R-F TRANSFORMER CONNECTIONS

To identify the terminal connections of the antenna-stage coil, consider the two outer ends of the windings as the grid and antenna leads. That is, the secondary-end which is farthest from the primary is considered as the grid lead, whereas the primary-end farthest from the secondary is considered as the antenna lead. The other ends of both windings are connected to the grid-return and grounding systems, respectively.

Since the grid-return end of the antenna coil is frequently connected to ground, it is the common practice among coil manufacturers to connect the ground-end of the primary winding and the grid-return end of the secondary winding to a common terminal as shown in Fig. 1. Thus, circuit connections need be made at only three of the coil terminals, which accounts for the unused (blank) fourth terminal in Fig. 1.

Observe if the coil you received is of the latter type or if all four terminals are used for the winding connections. In either case, mark the terminals clearly with a lead pencil or pen and ink, in accordance with the terminal-identifying method previously explained. This will facilitate matters when connecting these terminals to their respective circuits.

THE VARIABLE CONDENSER

Upon examining the variable condenser, you will observe that it comprises three separate variable condenser groups that are operated by a single shaft. The three rotor sections are mounted directly to the shaft, and since this shaft makes an electrical contact with the metal frame of the condenser assembly, all three rotor sections will be connected to "ground" automatically upon mounting the condenser-gang on a metal chassis. Bronze springs press against the shaft and frame of the unit, thereby assuring a good electrical connection between the rotor plates and the condenser frame.

All three stator (stationary) plate-groups are insulated from one another as well as from the frame of the assembly, and each stator section is equipped with a trimmer condenser, as shown in Fig. 3. Two terminals are provided for each stator plate-group, one is located next to the trimmer condenser and the other on the opposite side of the stator plate-group.

Since both of these terminals correspond to the same stator plate-section, either one may be used for connecting the condenser to the circuit. Check these terminals carefully, being sure that they do not touch the condenser frame. (These terminals are sometimes bent during shipment.) Any contact between the terminals and the frame will short circuit the particular condenser section which corresponds to those terminals. The circuit connected thereto will then be inoperative.

Each trimmer condenser is constructed in the form of a small metal plate, insulated from the condenser frame by a strip of mica. The tuning condenser frame thus serves as one trimmer plate which is connected to the rotor plates, whereas the adjustable metal plate is electrically connected to the stator plates. Each of these small semi-variable condensers is thus connected in parallel with one section of the regular tuning condenser. The separation between this small insulated metal plate and the frame of the condenser is varied by means of an adjusting screw, thereby varying the capacity of the trimmer.

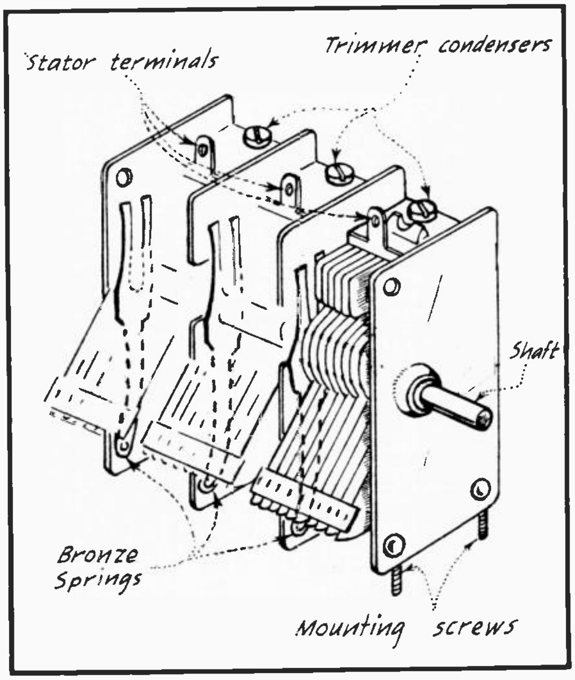

FIG. 3
THREE-GANG VARIABLE CONDENSER

The purpose of the trimmer condenser is to compensate for any differences in the tuning circuit characteristics, thereby making a more perfect alignment of the circuits possible. You will not use the trimmer condensers in the particular circuit which you are about to construct, as only one section of the three in the group is to be employed therein.

The capacity values are marked clearly on all bypass condensers that you received, whereas the resistor value is specified in accordance with the standard resistor color-code. Brown-black-green indicates a value of 1-0-00000 ohms, or 1 megohm, for the resistor which you received in the third kit.

CIRCUIT OF THE RECEIVER

In Fig. 4 of this lesson is shown the schematic diagram of the receiver that you are about to construct. As you will observe, a heater-cathode type triode is employed in a regenerative detector circuit. This type of receiver is not used commercially at present due to the extreme care required to tune-in the desired signal. However, the regenerative detector circuit is extremely sensitive. Regeneration is accomplished by using a regular antenna coil in conjunction with an additional coil, known as the "tickler" or feed-back coil. The rest of the circuit is of conventional design, the detector operating on the grid leak principle.

Further study of Fig. 4 will disclose that a 45-volt battery is used as the B supply, and that the headphones are connected in series with the B+ terminal, tickler coil and the tube's plate. The .001 mf condenser is connected across the headphones to bypass the r-f component of the plate current. The same applies to the .25 mf condenser which is connected across the B battery. The filament circuit has been omitted from Fig. 4, because it has no direct bearing upon the operation of the receiver. However, it is shown in detail in Fig. 5.

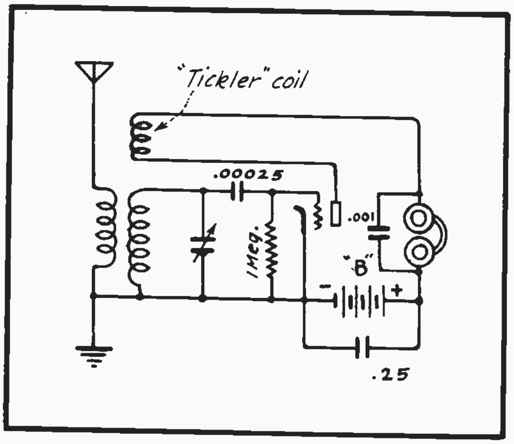

FIG. 4
REGENERATIVE DETECTOR CIRCUIT

If no electric lighting circuit is available in your district, you may use circuit (A) of Fig. 5 by employing a type 6T7G tube and connecting its filament across a 6-volt storage battery or across four dry cells connected in series. If an a-c lighting system is available for your experiments, you can eliminate the battery from the filament circuit and instead connect the filament of your 6Q7 tube across the a-c line, also connecting a lamp in series with the circuit as shown at (B) of Fig.5. If the circuit is of the 110-volt type, use a 110-volt lamp of a 25 to 40-watt rating; if the circuit is of the 220-volt type, use a 75-watt, 220-volt lamp.

Those students whose lighting system is of the d-c type may operate their receiver direct from the line, as shown later in this same lesson, using a 6Q7 tube.

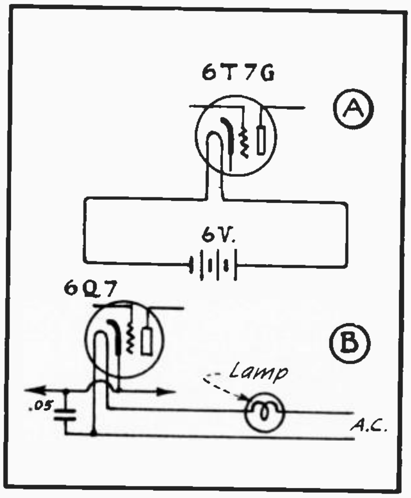

FIG. 5
FILAMENT CIRCUIT

MODIFYING THE ANTENNA COIL FOR REGENERATION

Your first step toward constructing the receiver will be to add the "tickler" coil to the antenna coil. This is done by winding six turns of insulated wire over the upper section of the transformer's secondary winding as shown in Fig. 6. The wire used for this purpose may be any insulated copper wire of small size, or if you prefer, you can use some of the hook-up wire that you received with your experimental kits.

The "tickler" coil must be just large enough in diameter so that it can slide up and down over the secondary of the antenna transformer, thus affording a means for varying the coupling between the two windings. This can be accomplished easily by wrapping a piece of paper around the secondary, winding the six turns of wire for the "tickler" coil over this paper and then removing both the paper and the tickler coil from the transformer. The paper may then be thrown away. It is recommended that you tie the turns of the tickler coil together at convenient intervals with adhesive tape so as to keep the tickler coil intact -- this is shown in Fig. 6.

The ends of the tickler coil must be long enough so that they can be used for completing the circuit and at the same time allow the coil to move freely over the entire length of the transformer's secondary. When placing the tickler coil over the secondary, be sure that the turns of the tickler are wound in the same direction as those of the secondary. The lower end of the tickler coil will then correspond to the plate connection of the tube.

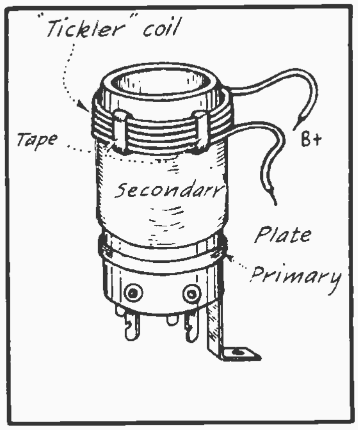

FIG. 6
MODIFIED ANTENNA COIL

CONSTRUCTION OF THE RECEIVER

The actual construction of the receiver is simple enough in itself. However, to derive all of the experience possible, it is recommended that you first make a drawing of the physical layout, showing the actual connections to the different parts of the receiver. Upon completing this drawing, compare it with the physical layout of the receiver appearing in Fig. 7. (The circuit in Fig. 7 is designed for battery operation). Also note that the tickler is shown only as a symbol, but as we have already explained, its correct location is over the upper end of the transformer's secondary as illustrated in Fig. 6.

All connections must be well soldered, except those to the batteries and the headphone terminals.

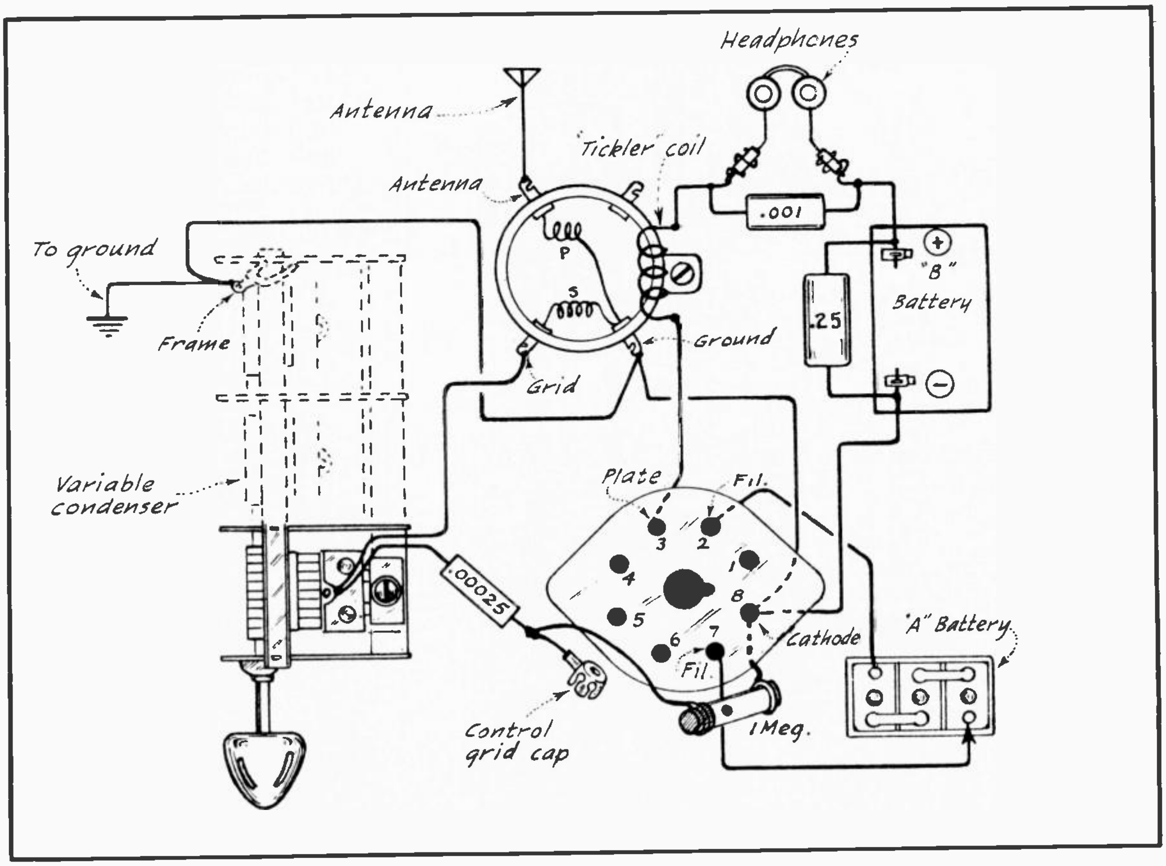

FIG. 7
TOP VIEW OF BATTERY-OPERATED RECEIVER

As a base on which to construct this experimental receiver, use a wooden board, bakelite, or heavy cardboard, cut to the shape of a square. All parts should be mounted on the board with wood-screws --- the tube socket can be mounted on small wooden separators or blocks as shown in previous lessons of this series.

If you so desire, you can construct a base-board or chassis by placing several sheets of strong cardboard on top of one another. The same wood screws as used for mounting the parts can then also be made to keep the cardboard sheets together. To protect this base against humidity, its surface can be coated with shellac.

The 45-volt B battery may be connected to the receiver in a permanent manner, as disconnecting one side of the filament circuit will make the receiver inoperative -- this is pointed out by the arrow in Fig. 7.

RECEIVER WITH A-C OPERATED FILAMENT

To operate the filament of the tube directly from an a-c lighting circuit, eliminate the A-battery and connect an ordinary incandescent lamp in series with one side of the tube filament and the line, as mentioned earlier in this lesson. Other sections of the receiver circuit remain the same, with the exception that a .05 mf by-pass condenser should be connected between one side of the line and ground so as to eliminate interference disturbances that might otherwise enter the circuit through the line. These changes are clearly shown in Fig. 8.

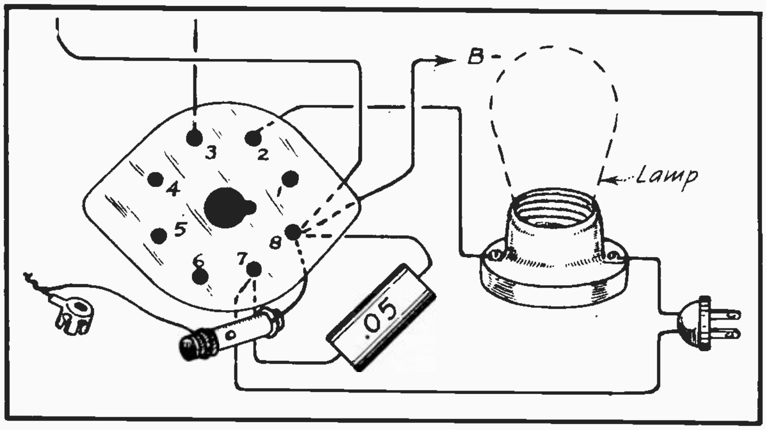

FIG. 8
A-C FILAMENT CIRCUIT

The use of a-c in the plate circuit of the tube is out of the question, for even though the circuit would operate with the tube being used as a rectifier, the signals would nevertheless be distorted by an excessive hum component. Therefore, the B-battery must be used in this circuit.

D-C OPERATED RECEIVER

This receiver may be operated directly from a d-c lighting system, without the aid of batteries, by employing the circuit diagrammed in Fig. 9. Here, the filament of the tube is connected in series with an ordinary incandescent lamp, and the plate circuit is also connected to the line.

Even though the lighting system is in this case of the d-c type, the current is nevertheless not sufficiently uniform in value to permit its being fed to the plate circuit of the tube directly. Therefore, a filter choke and two bypass condensers are interposed between the line and the tube's plate circuit. The primary winding of your a-f transformer should be used as the filter choke, while the .25 mf and .05 mf condensers serve as the filter condensers.

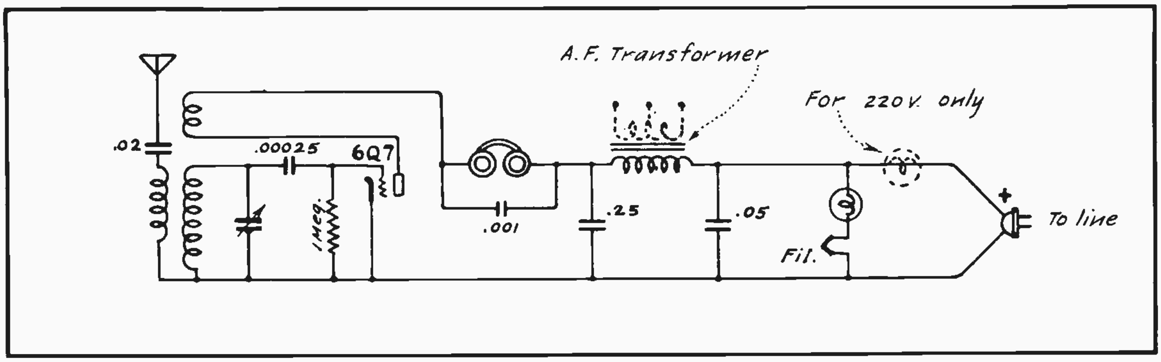

FIG. 9
DIAGRAM OF D-C RECEIVER

The primary of the a-f transformer has an inductance of about 100 henrys which is more than sufficient for filtering this circuit. Furthermore, since the current drawn by this receiver is very small, the size of wire used for the primary winding of the transformer is sufficiently large for this particular application. The secondary terminals of this transformer are not used and are therefore indicated on the diagram by dotted lines.

The use of the .02 mf condenser in the antenna circuit of Fig. 9 is of special importance and can be explained in the following manner:

The negative side of the lighting circuit is generally connected to ground by the power company, which ground connection will then also serve as the ground for the antenna system. Placing the .02 mf condenser between the antenna and the primary winding of the antenna coil will prevent d-c line current from passing through this winding in the event that the line plug should be reversed in its receptacle momentarily while the antenna is partially grounded through faulty installation. Line-current passing through the antenna coil would burn it out instantly. However, the r-f signals can pass through the .02 mf condenser with ease.

The physical layout and connections for this 110-volt d-c circuit are shown in Fig. 10. Should the line be of the 220-volt d-c type, then it will be necessary to connect an additional lamp in this circuit as indicated by the dotted symbol in Figs. 9 and 10.

CHECKING THE CIRCUITS

We wish to emphasize again that it is not good practice to connect any radio apparatus to the line or batteries immediately upon completion in order to find out "what will happen", or in the hope of finding everything O.K. Instead, you should always first check each connection carefully against the diagram. In fact, it is a good policy to "check off" each individual circuit on the diagram as it is found to be correct. For example, commencing with the filament circuit, trace it from beginning to end. Next, examine the plate circuit, followed immediately by a thorough examination of the control grid circuit, then the screen grid circuit, etc. This systematic inspection should be followed by a complete check-up of all bypass and filter condensers, making sure that all units are installed in their respective circuits and that they are well soldered.

By checking the wired circuit a few hours after completing the job of wiring, you are more likely to detect a mistake than will be the case if you check the circuit immediately upon completion of the wiring job.

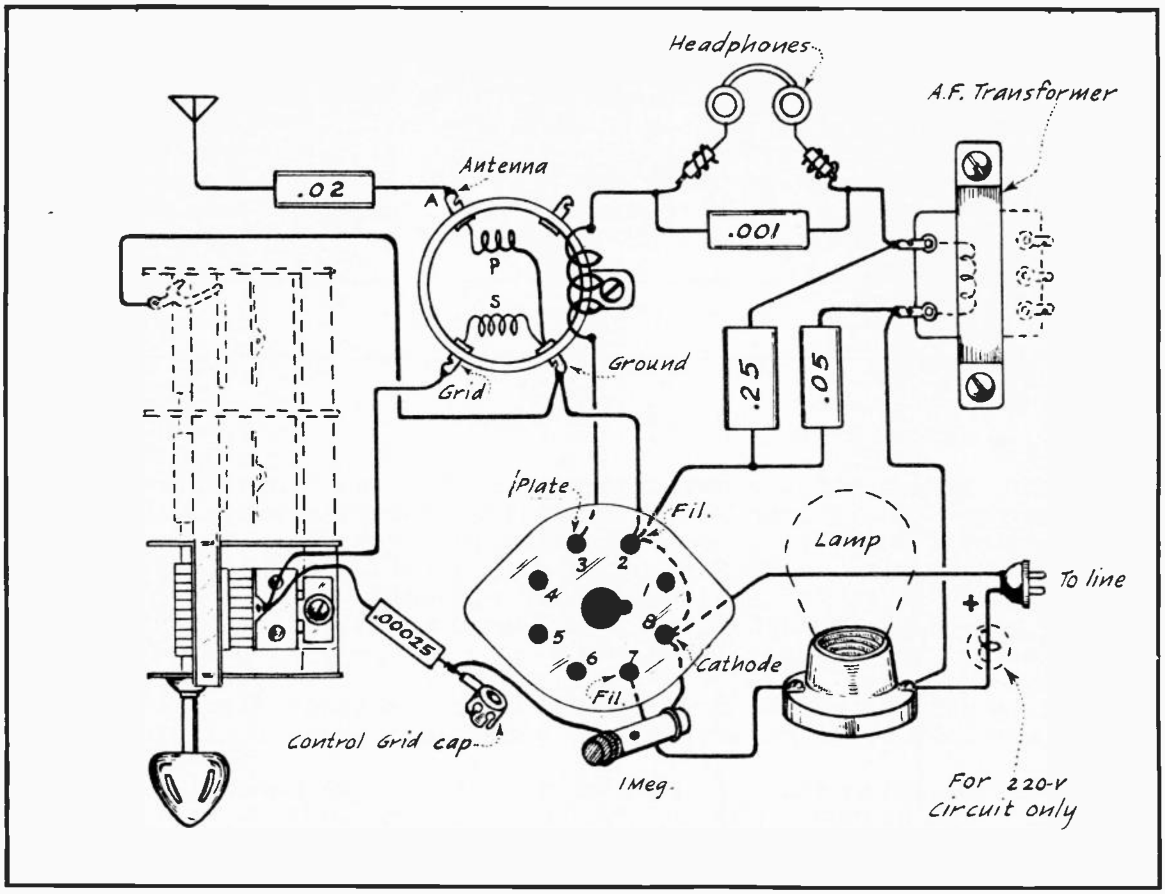

Fig. 10
Top-view of d-c Operated Receiver

It is also advisable that you inspect the insulation of the different parts, as well as that of the wiring. There is nearly always a probability that two wire leads may contact each other, resulting in a short-circuit that may cause serious damage or at least keep the receiver from operating properly. There is also a probability that an excess of molten solder may become lodged between two terminals or between a terminal and the metal chassis, and in this way produce a short-circuit.

Another common source of trouble is where a mounting screw of excessive length contacts some part that normally must be well insulated. Besides those mentioned, many other apparently insignificant circumstances may arise which will cause difficulties and loss of time unless the circuit is checked carefully before "turning on the power."

PREPARING THE RECEIVER FOR OPERATION

Having assured yourself that the receiver is in a condition to be operated, you may proceed by connecting the filament circuit to the A battery or to the lighting system. Since the tube is of the heater-cathode type, it does not make any difference which side of the filament circuit is positive and which negative, as the sole purpose of the filament is to heat the cathode.

Continue by connecting the negative terminal of the B battery to the cathode, and its positive terminal to the headphones. (Note: No batteries are required for the d-c receiver that is connected directly to a d-c lighting circuit.)

Now, connect the antenna and grounding systems to the receiver. Since this receiver employs only one tube, its sensitivity or ability to receive distant stations depends much upon the type of antenna being used. For best results, the antenna should be quite long, erected at a considerable height from the ground, and placed in a favorable location. The ground connection should be made according to good practice. (We recommend that you review your regular lessons treating with antenna and ground connections, while formulating plans for your own.)

HOW TO OPERATE THE RECEIVER

While operating the receiver, it is important to bear in mind that cathode-type tubes do not begin passing plate current immediately upon closing the filament circuit. Several seconds are required for the cathode temperature to rise to a value sufficiently high for electron emission to begin. The new rapid-heating tubes require from 10 to 15 seconds for the cathode to reach its normal operating temperature, while the older tubes require as much as one-half minute or more to begin operating satisfactorily.

As was mentioned previously, the detector circuit being used at this time is of the regenerative type. By means of the tickler or feed-back coil, some of the signal energy is returned from the tube's plate circuit to its grid circuit. This results in better selectivity and a considerable increase in volume and sensitivity.

To make regeneration possible, the feed-back signal must be in-phase with the station signal appearing in the grid circuit. There will be a marked decrease in amplification if the feed-back energy is out-of-phase with the signal energy in the grid circuit, as these two energies would then partially neutralize each other. (Connecting the leads of the tickler coil to the circuit in accordance with instructions given earlier in this lesson will insure the feed-back energy being in-phase with the signal energy in the grid circuit.)

Regeneration can be controlled by increasing or decreasing the amount of energy feed-back. However, there is a limit to the amount of feed-back that can be handled in this way. If this limit is exceeded, the circuit will oscillate, thereby converting the receiver into a small transmitter. Excessive regeneration or oscillation makes itself known through whistling and howling noises in the headphones, especially when operating the tuning condenser.

These whistling noises will be radiated by your antenna and will be picked up as interference disturbances by receivers in your locality. You must, therefore, prevent your circuit from oscillating in consideration for your neighbors,as well as to avoid annoying whistles in your own headphones.

Oscillation of the circuit offers a means for checking if the circuit is wired correctly. To do this, proceed as follows: With the tube at operating temperature and the B battery connected in the circuit correctly, alter the position of the tickler coil until a whistling noise is heard in the headphones. Bear in mind that the closer you bring the tickler coil to the center of the secondary, the closer will be the coupling between these two windings. Such movement of the tickler coil will increase regeneration until the point of oscillation is finally reached. Once the circuit has commenced oscillating, you may rest assured that it is functioning.

Having thus located the tickler coil position to promote oscillation, slide the tickler coil upward very slowly until oscillation just stops. This position of the tickler will provide the greatest sensitivity. Upon tuning-in a stronger signal, the circuit may commence oscillating again, in which case the tickler coil should be moved upward a little more until oscillation stops.

If the circuit oscillates, even though the tickler is moved to its maximum position at the upper end of the antenna coil, reduce the number of turns used on the tickler, removing one turn at a time and testing for results.

The number of tickler-turns recommended earlier in this lesson is satisfactory for general purposes. However, since the operating characteristics of different tubes vary considerably, as does also the distributed capacity of the receiver's wiring, it is well to experiment with regard to the number of turns used on the tickler coil. Bear in mind that regeneration increases with an increase in the number of turns and decreases as the number of turns is reduced.

When tuning-in a station, always be sure that the tuning condenser is adjusted to the exact point where the signal is heard best. If the desired signal "comes-in" very weak, a slight alteration of the tickler coil will often improve reception.

EXPERIMENTING WITH YOUR RECEIVER

Although this experimental receiver is rather small, it nevertheless offers you a splendid opportunity to conduct numerous instructive and interesting experiments.

EXPERIMENT #1: Disconnect the end of the tickler coil that is attached to the plate terminal of the tube socket and leave that wire free. Now connect another wire from the plate terminal of the tube socket to the B+ end of the tickler coil as shown in Fig.11. Under these conditions, the detector will no longer be of the regenerative type. This will result in a noticeable decrease in its sensitivity and selectivity.

EXPERIMENT #2: Reverse the tickler coil connections, and at the same time remove the additional wire which you used during the previous experiment. That is, the end of the tickler coil that was originally connected to the plate terminal of the tube socket, should now be connected to the headphones and vice versa. This change in the circuit will cause the feed-back energy to be out-of-phase with the grid circuit energy. The sensitivity of the receiver will be impaired by this change in connections.

EXPERIMENT #3: Re-connect the tickler coil for normal operation and reverse the B battery connections. That is, connect the positive terminal of the B battery to the cathode and the negative terminal to the plate of the tube. Under these conditions, no electrons will be attracted by the plate of the tube and the receiver will therefore be inoperative. (If your experimental receiver is of the d-c type, reverse the connecting plug in the receptacle of the line.)

EXPERIMENT #4: Re-connect the B battery to the circuit correctly. Then, disconnect the grid leak resistor from the cathode terminal of the tube socket and connect this free end of the leak resistor to the other side of the grid condenser as shown in Fig. 12.

This connection for the leak resistor is very common in the older receivers and results in almost identical performance as when the "leak" is connected directly between the grid and cathode.

EXPERIMENT #5: Disconnect one end of the grid leak resistor from the circuit. The passage of electrons from the grid of the tube will now be interrupted, causing the grid to become highly charged. The tube will thus be "blocked" so that it can no longer operate properly.

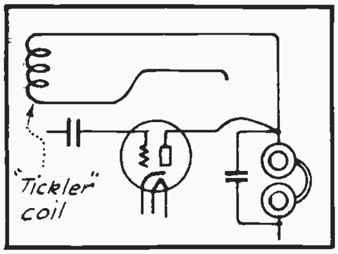

FIG. 11
ELIMINATING REGENERATION

EXPERIMENT #6: Connect two sections of the tuning condenser in parallel as shown in Fig. 13. To do this, simply connect a piece of wire from one stator section to the other. (The rotor plates are already connected together through the common shaft.)

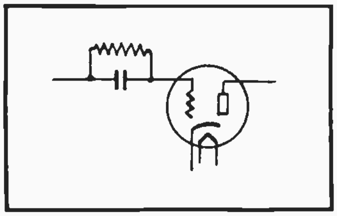

FIG. 12
CHANGED LEAK CONNECTION

The combined capacity will now be double that of a single section, and the receiver will therefore tune over a lower frequency band than originally. That is, the receiver will now tune-in signals of a lower frequency than before, but will not be capable of tuning-in stations at the high-frequency end of the broadcast band. You may be able to tune-in commercial code stations, ships at sea, etc., with the receiver operating in this condition.

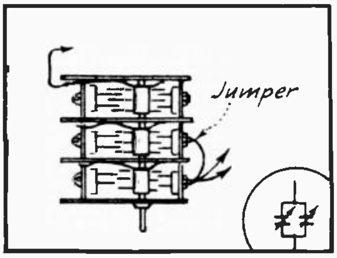

FIG. 13
PARALLELED CONDENSER SECTIONS

When receiving c-w (continuous wave) code signals, it is recommended to have the circuit oscillate a little. This will serve to modulate the code signals, so that they can be heard distinctly.

EXPERIMENT #7: Now remove the small wire that you used to connect two condenser sections in parallel and connect two sections of the tuning condenser gang in series as shown in Fig. 14. To do this, simply move the ground connection from the first tuning section of the condenser gang to the insulated terminal of the second stator-plate-section as also indicated in Fig.14. (The condenser shaft forms the connection between the two sections, since the rotor plates of all sections are mounted on the same shaft.)

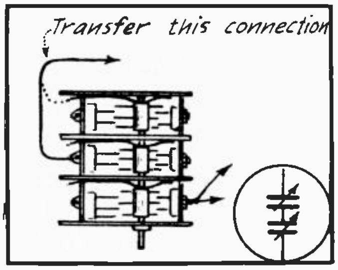

FIG. 14
SERIES-CONNECTED CONDENSER SECTIONS

The tuning capacity is now only one-half that of the actual capacity of any one section of the gang, which means that the receiver will now tune to higher frequencies than was originally possible. You may also hear code signals in this higher frequency band. It will now be impossible to tune-in some of the stations at the low-frequency end of the broadcast band.

EXPERIMENT #8: Connect the tuning circuit to only one section of the tuning condenser, in the normal manner, but reverse its connections. That is, the wire that was originally connected to the stator plates should now be connected to the rotor plates and vice versa.

Even though the circuit will operate under this condition, you will notice that tuning will be affected quite noticeably up on touching the tuning control knob and then removing your hand. This condition is due to body capacity, and can be corrected by simply connecting the rotor plates to ground and the stator plates to the grid of the tube as shown in Fig. 10.

EXPERIMENT #9: With the receiver in a condition for normal operation, disconnect one end of the condenser that is connected across the headphones. You will notice that regeneration will now be reduced considerably, and that the circuit will not oscillate as readily when the bypass circuit for the r-f component in the plate circuit has been eliminated. The chief purpose of this condenser is to pass the high frequencies (r-f) and at the same time block the audio frequencies, forcing the latter through the headphones.

EXPERIMENT #10: Interchange the primary and secondary windings in the circuit by using the latter in the antenna circuit and the primary as the tuning coil. Under these circumstances, a very pronounced effect will be observed due to the inductances not being properly matched to the circuits.

Besides the experiments herein outlined, you can also devise others by referring to your regular lessons for suggestions.

OPERATING PRINCIPLES OF THE RECEIVER

Having had the opportunity to experiment with a grid condenser and leak-type detector, you will no doubt be interested in learning more about its principles of operation. The illustrations appearing in Figs. 15 and 16, together with the following explanation, should give you a clear understanding of the theory involved.

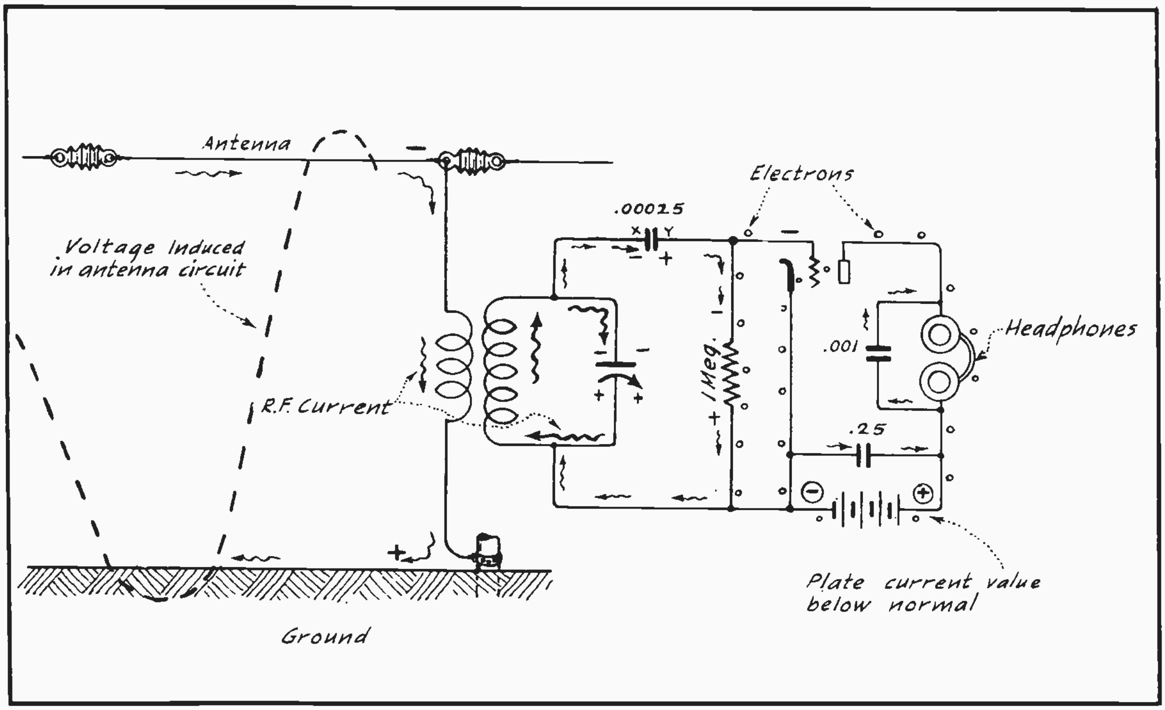

Fig. 15
Circuit Operation during First Alternation of Signal Voltage

With the receiver in operating condition, and no signals being received, plate current of constant value will flow through the plate circuit.

Now, let us assume that the signal wave, striking the antenna at one particular instant, causes the elevated portion of the antenna to become negatively charged with respect to ground as shown in Fig.15.

This condition will cause an electron-flow through the primary winding of the antenna coil in the direction indicated by the arrows. This electron-flow in turn builds up a magnetic field around the primary winding which links the secondary and induces therein a voltage that causes electrons to flow into the plates of the tuning condenser in such manner that a negative potential is produced at the stator (upper) plates and a positive potential at the rotor (lower) plates, as shown in Fig. 15.

Since the .00025 mf grid condenser is connected in parallel with the tuning condenser through the leak resistor, some electrons will also flow into plate X of the grid condenser, charging it to a negative potential with respect to plate Y. As this charging action of the grid condenser takes place, some electrons leave plate Y, flow through the 1 megohm leak resistor in the direction indicated, and over toward plate X. The direction of electron-flow being from the grid-end of the leak resistor toward its cathode-end causes its grid-end to become negative with respect to its cathode-end.

At radio frequencies, the capacitive reactance of the grid condenser is practically negligible in comparison to the resistance value of 1 megohm possessed by the leak resistor. Therefore, the voltage-drop produced across the leak resistor is far greater than that generated across the plates of the grid condenser. Such being the case, the net or effective voltage applied across the tube's grid and cathode terminals is practically equal to that produced across the ends of the leak resistor by the flow of electrons through it,and also of like polarity. Thus, during the instant illustrated in Fig. 15, the tube's grid is <u>negative</u> with respect to its cathode.

The grid of the tube, now being negative, decreases the flow of electrons between the cathode and plate, and in this way decreases the plate current below its normal value.

As the following alternation of signal-voltage occurs, the elevated portion of the antenna becomes electrically positive, and the grounding system, negative. The electrons through the antenna circuit will then reverse their direction of flow in accordance with the arrows appearing in Fig. 16. Similarly, the electron-flow in the tuning circuit, caused by induction, will also reverse its direction in accordance with the arrows in Fig. 16. The upper tuning condenser plates will therefore now be charged to a positive potential and the lower ones to a negative potential.

This action causes plate X of the grid condenser to become positively charged with respect to plate Y. During this charging period of the grid condenser, the electron-flow through the leak resistor is in such direction that its cathode-end becomes negative with respect to its grid-end. Also, the voltage-drop across the leak resistor is again much greater than that across the plates of the grid condenser for the reason given previously. Therefore, the voltage that is effective across the tube's grid and cathode is again practically equal to, and of the same polarity as, that appearing across the ends of the leak resistor. In other words, the tube's grid is now <u>positive</u> with respect to its cathode, which condition accelerates the flow of elec-

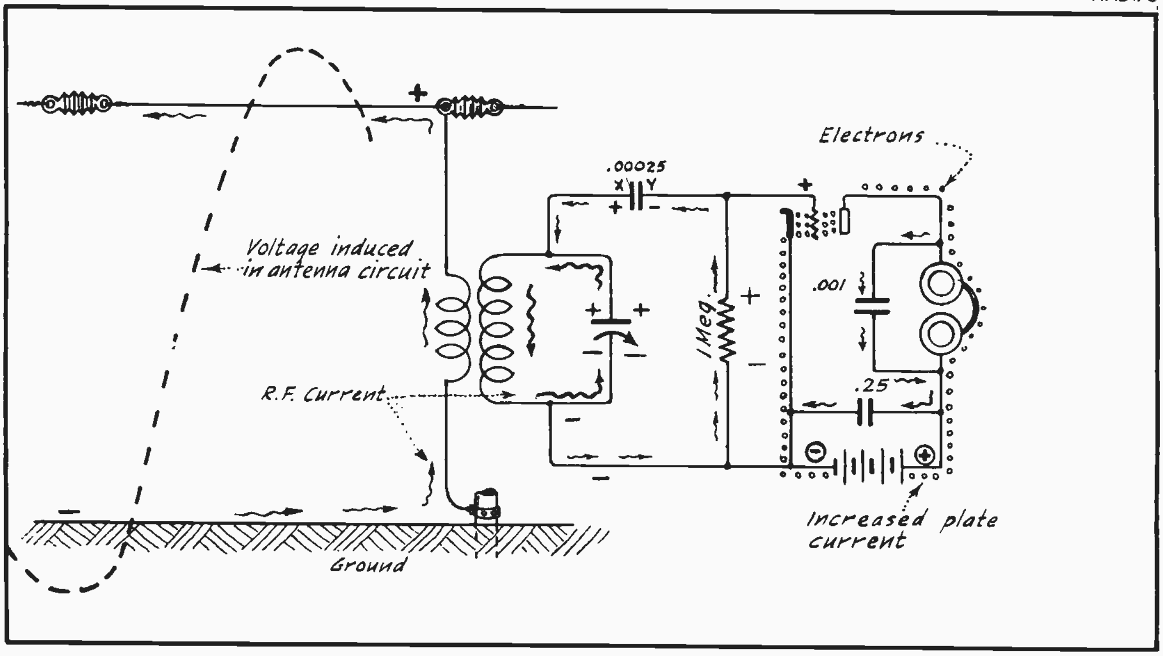

Fig. 16
Circuit Operation during Second Alternation of Signal Voltage

trons between the cathode and plate, causing the plate current to increase above its normal no-signal value.

However, it is also to be noted that each time the grid is positively charged (as in Fig. 16), it acts somewhat as a "plate" and attracts a few of the electrons emitted by the cathode. Assuming for the moment that the 1 megohm leak resistor is not included in the circuit, it is apparent that such electrons as are attracted by the grid, would become isolated because they cannot flow through the insulation of the grid condenser --- and, since they bear a negative electrical charge, they have a natural tendency to partially neutralize the positive signal potential and also to maintain a negative charge on plate Y of the condenser. Therefore, as the signal-voltage reverses to re-establish conditions as shown in Fig. 15, causing the grid to become negatively charged, the condenser plate Y and the grid will already be slightly negative. (This is due to the accumulation of electrons that are trapped on those parts, on account of this portion of the circuit being isolated during the absence of the leak resistor.) Thus,it is apparent that whenever the control grid is "swung" negative by the signal voltage, it will be slightly more negative than is made possible by the signal voltage alone,and the flow of plate current is therefore reduced accordingly.

Since electrons are accumulated by the grid during each positive alternation of signal-voltage, the average positive potential of the grid and its corresponding effect on the plate current will gradually become less during each successive cycle, for any given constant signal intensity. Also, the increasing effect of the negative grid potential during the negative alternation of each successive cycle will cause a steady decrease in the average plate current. Thus, these two factors, together, cause the average plate current to decrease in value during each successive cycle of the r-f wave-train.

In the absence of the leak resistor, this action would continue for a number of cycles of the signal voltage until so many electrons have collected on plate Y of the grid condenser that their charge would cause the grid to become so much negative that the flow of plate current would be stopped entirely. The tube would then be "blocked," and the system paralyzed.

The leak resistor prevents the occurrence of conditions described in the preceding paragraph. It does this by offering a high-resistance path between the tube's grid and cathode so that the excess electrons may drain off the grid before the state of blocking occurs. In fact, the relation between the values of the grid condenser and the leak resistor is such as to allow the excess electrons, accumulated during the r-f cycles constituting one-half of the audio cycle, to drain off the grid at the time that the following half of the modulated signal comes in. This draining of electrons by the leak resistor is illustrated in Fig. 15 by means of the small circles spaced along this path.

The action of the grid condenser and leak being as described, the plate current will vary as shown by the curve in Fig. 17. Notice that the average change in plate current has little ripples incorporated in it, which represent remaining r-f variations. These ripples, being an a-c component of the plate current, can be shunted or bypassed around the windings of the headphones by the .001 mf condenser and also around the B battery by the .25 mf condenser.

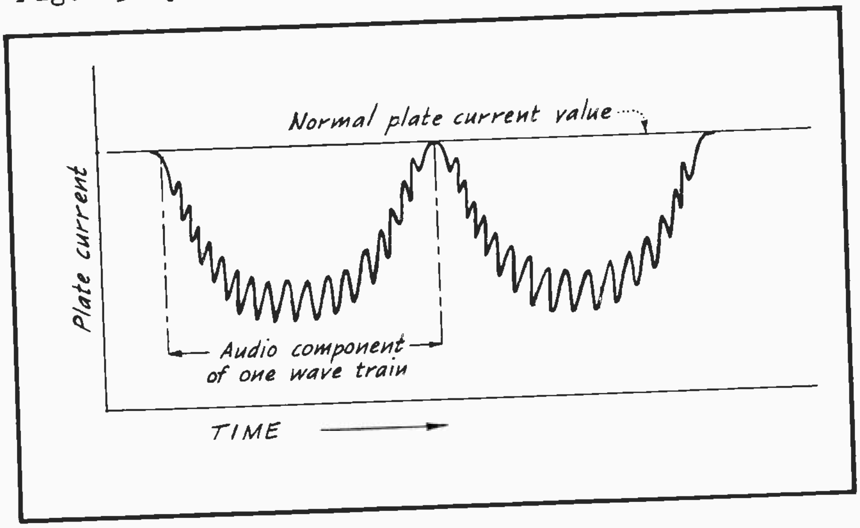

FIG. 17
AVERAGE CHANGE IN PLATE CURRENT

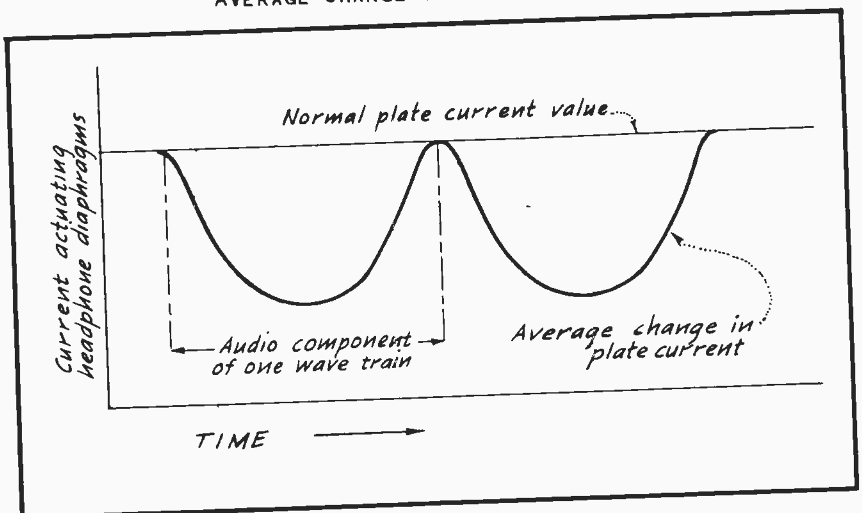

FIG. 18
HOW FILTERING AFFECTS PLATE CURRENT

The manner in which these r-f ripples are bypassed through these condensers is indicated by the small arrows in Figs. 15 and 16. It will be noted that the alternate charge and discharge of these bypass condensers is such as to store electrons during the peaks of the plate current r-f pulses and to deliver them to the plate circuit during the depressions, thereby acting as a filter and thus causing the flow of plate current through the headphone windings to more nearly conform with the curve appearing in Fig. 18. Thus, clear, audible sounds are produced by the headphones.

NOTICE TO STUDENTS WHO ARE TO RECEIVE A-C RECEIVER EQUIPMENT

If your enrollment-plan calls for a-c operated experimental equipment, you must continue using the B battery for the first experiments until you receive the necessary parts for the B power supply. The latter will enable you to operate from the a-c line all of the more complex circuits that are constructed with the parts and instructions furnished with future kits.

One must also bear in mind that thousands of battery-operated receivers are being used in localities where electric lighting facilities are not available. It is therefore necessary that all students become familiar with the application of batteries in receivers. If you are in the "a-c group", and do not wish to buy a B battery, you may lay this experiment lesson and kit aside until you receive the parts for the power pack, at which time you may conduct the experiments described in this lesson. However, we assure you that the small additional expense incurred by the purchase of a B battery will provide you with excellent practical experience which you would not obtain otherwise.

answered Nov 14, 1941

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. FG-3

1. - What precautions should be exercised as to the direction of winding the tickler coil and the connections of its ends to the receiver circuit?

2. - If the terminals of an antenna-stage r-f transformer are not marked, how can you determine which end of the secondary is to be connected to the control grid circuit and which end of the primary to the antenna?

3. - Why is the .02 mf condenser connected in series with the antenna system in the circuit diagrammed in Fig. 9?

4. - How can you determine whether or not regeneration is actually taking place in a regenerative type detector circuit, such as described in this lesson?

5. - What would happen if the grid leak resistor should accidentally become disconnected in the detector circuit?

6. - How is the performance of the receiver affected by reversing the tickler coil connections?

7. - What is the purpose of the .001 mf condenser that you connected across the headphones?

8. - How will an increase in the tuning circuit's capacity affect the performance of the receiver?

9. - How will a decrease in the tuning circuit's capacity affect the performance of the receiver?

10. - Is the signal-voltage across the grid and cathode of the tube in this receiver more nearly equal to the voltage-drop across the grid leak resistor or that across the grid condenser?

Practical - Technical

TRAINING IN **RADIO AND TELEVISION**

ESTABLISHED 1905 J. A. ROSENKRANZ, Pres.

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EXPERIMENT LESSON NO. F-4

RECEIVER CONSTRUCTION ON METAL CHASSIS

With the parts included in your fourth outfit of experimental equipment, together with those that you received previously, you will now be able to construct a receiver on a metal chassis. Since this form of construction is used exclusively by receiver manufacturers,you can readily see that the experience acquired in this way will be of great value to you.

Your kit of additional parts sent you at this time is comprised of the following:

Cadmium-plated chassis
Antenna-ground post assembly
Twin-jack
Hook-up wire
No. 6-32 machine screws and nuts

THE CHASSIS

The chassis is already provided with all of the holes necessary to accommodate the various parts required for the superheterodyne receiver that you will construct in accordance with instructions furnished in the last lesson of this special series. The chassis,as a whole, has been planned so that the completed receiver will have an attractive commercial appearance, as well as being arranged to make an efficient circuit possible.

During your preliminary construction projects you will of course not use all of the space and holes provided on the chassis, as the circuits being constructed at this time will employ only a limited number of tubes. However, as you progress with this work, guided by succeeding lessons of this series, you will gradually add more tubes and thereby enlarge the receiver until you finally arrive at the stage where you build the final master set -- a modern superheterodyne.

MOUNTING THE PARTS

So that you may become familiar with the problems involved when constructing a receiver on a metal chassis, you will build the same one-tube receiver that you constructed in accordance with instructions furnished in your previous experiment lesson, only that you will now use the metal chassis as its base. Fig. 4 illustrates the chassis as it will appear with all parts and wiring in their correct positions. To familiarize yourself with this circuit, it is well that you make a similar drawing before commencing the actual work of construction.

Fig. 4 shows clearly the position occupied by all parts, while Figs. 1, 2, 3, and 5 illustrate in detail the mounting of the individual parts.

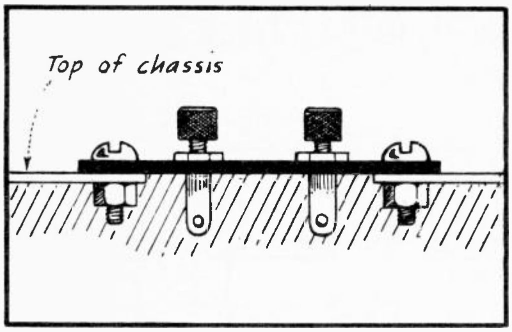

FIG. 1
ANTENNA-GROUND POST MOUNTING

ANTENNA-GROUND POST MOUNTING: Fig. 1 shows you the correct method for installing the antenna-ground post over the oblong hole on top of the chassis, near the rear edge. (The front and rear edges of the chassis can be identified in the following manner: The front of the chassis has four 3/8" holes arranged in a straight line. The rear of the chassis is provided with one large hole, another smaller one, and an oblong perforation -- the latter being similar to the one used for the antenna-ground post assembly on top of the chassis.)

The antenna-ground post assembly is mounted on top of the chassis so that neither the antenna wiring nor its connections will contact the metallic structure of the chassis. You will further observe in Fig. 1 that the insulative terminal strip is held in place by screws and nuts.

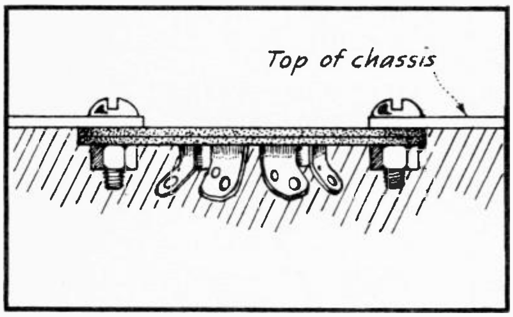

FIG. 2
TUBE-SOCKET MOUNTING

TUBE SOCKET MOUNTING: The correct method for installing the tube sockets on the chassis is clearly shown in Fig. 2. Notice that the socket is mounted on the underside of the chassis, care being exercised that the terminal prongs are kept more or less in the center of the chassis' socket hole.

R-F TRANSFORMER MOUNTING: Place the r-f transformer on top of the chassis, directly over the chassis hole, as shown in Fig. 3. For the one-tube receiver now being constructed, use the hole designated for this purpose in Fig. 4 so that the connecting leads between it and its associated parts may be as short as possible.

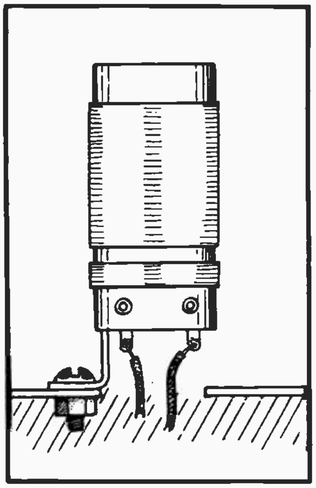

FIG. 3
R-F TRANSFORMER MOUNTING

TUNING CONDENSER MOUNTING: The gang tuning condenser should be installed so that its trimmer condensers face upward, and also so that the end of its shaft points toward the front edge of the chassis as shown in Fig. 5. Mounting screws have been riveted to the frame of the condenser at the factory and should be inserted in the holes provided for that purpose on the front center-section of the chassis deck (top). Upon inserting the screws in their respective holes,and applying the nuts from underneath the chassis, the tuning condenser will be held in place securely.

Before installing the tuning condenser in position, solder a piece of wire (about six inches long) to each of the three stator terminals on the mounting-screw side of the condenser and insert the free ends of these wires through the three

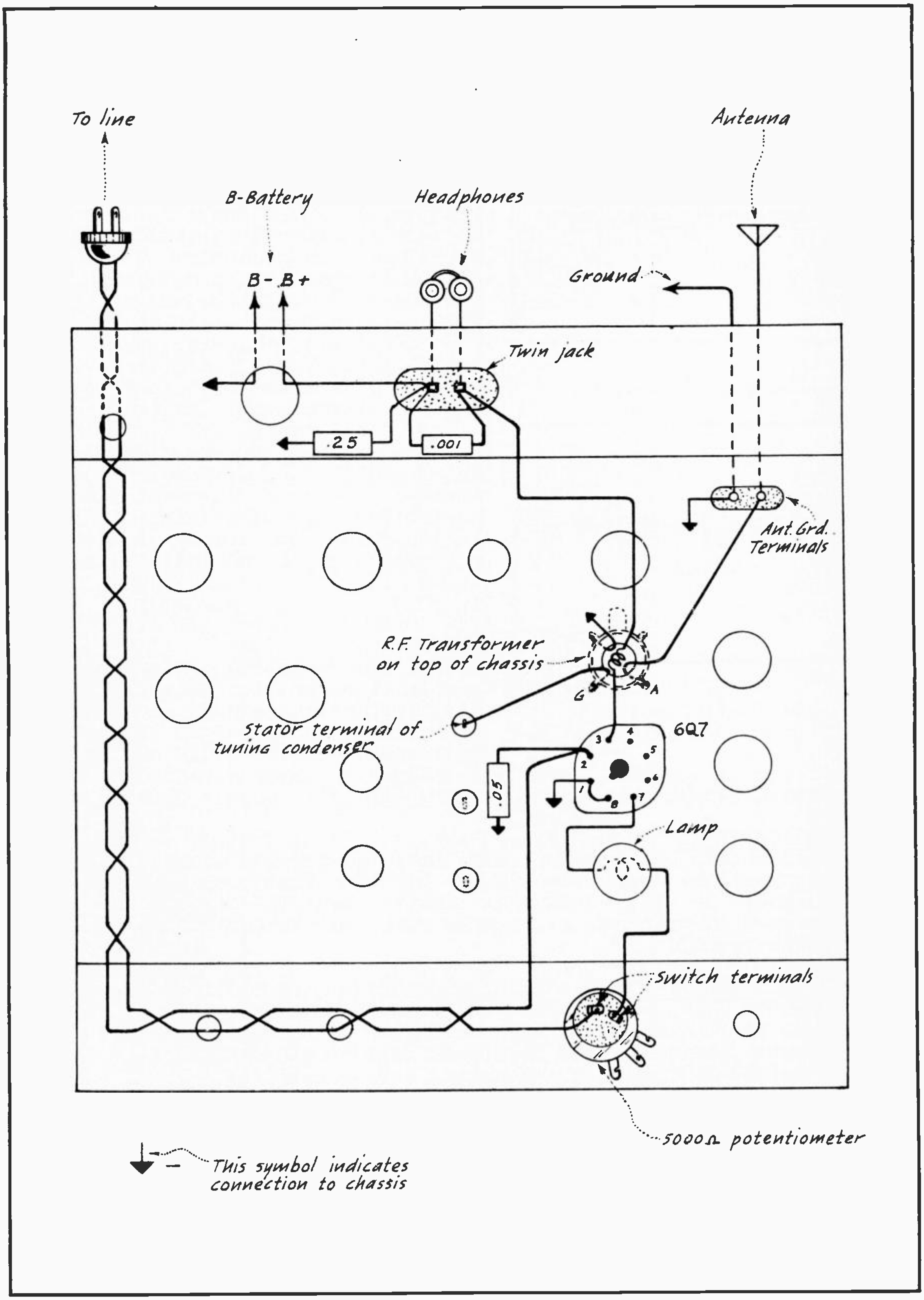

FIG. 4
CIRCUIT CONNECTIONS (CHASSIS VIEWED FROM BELOW)

holes of the chassis that line up with these terminals. Make sure that these leads are soldered to the condenser terminals securely so that they will not become loose and make removal of the condenser and resoldering necessary. (Bear in mind that for this one-tube receiver you will use only one section of the three-gang condenser. The other two sections which are not used at this time should not be connected to any circuit.)

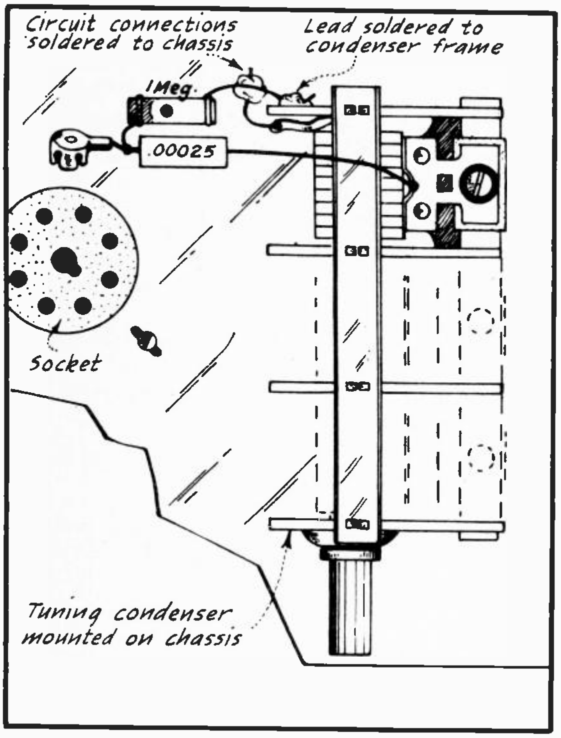

FIG. 5
GRID CIRCUIT WIRING

As soon as the tuning condenser has been mounted on the chassis, solder one end of a short length of hook-up wire to one of the rotor-plate terminals and the other end to the chassis. The purpose of this wire is to establish a more effective electrical connection between the condenser frame and the chassis.

POTENTIOMETER MOUNTING: So as to have a means for switching this receiver "on" and "off", mount your 5000-ohm potentiometer to the front edge of the chassis as shown in Fig. 4.

WIRING THE ONE-TUBE RECEIVER CIRCUIT

The complete wiring for this receiver is illustrated in Fig. 4, where the chassis is shown as viewed from below. For the sake of simplicity, the sides of the chassis are shown extended outward. All parts shown with dotted lines are installed on the outside of the chassis.

The cadmium plating on the chassis permits connections to be soldered to its surface readily. In the circuit which you are now about to wire, it is necessary to solder several connections to the metal chassis; therefore, it is well that you first read the following instructions carefully.

HOW TO SOLDER A CONNECTION TO THE CHASSIS: When soldering a connection to the chassis, it is important to first clean the surface thoroughly at the intended point of contact. This can be done by rubbing it briskly with a clean, soft rag until it is free of any oil film that is sometimes applied over the plating.

The soldering iron should be well heated, and the flat section of its point held firmly against the chassis where the solder is to be applied, allowing that area of the surface to become well heated. Next, pick up a small amount of soldering paste with the end of the solder and touch this end of the solder to the tip of the soldering iron, without withdrawing the iron from the chassis.

Upon moving the tip of the iron gently around the heated area of the chassis, the solder will commence to flow, forming a bright spot on the chassis. The next step is to solder the wire or terminal to that point, being careful that the wire or terminal does not move until the solder has solidified.

WIRING PROCEDURE: Do not start wiring until all parts are installed in their respective positions. It is good practice to begin wiring with the filament circuit,to be followed by the cathodé circuit, plate circuit and then the grid circuit. The antenna circuit should be wired last. With respect to Fig. 4,this wiring job could be done as follows:

Insert the free end of the line cord through the smaller hole at the rear of the chassis, and solder one of its wires to terminal #2 on the 6Q7 tube socket; then solder the other line-cord wire to one of the switch terminals on the back of the 5000-ohm potentiometer. Next, solder one lead of the .05 mf condenser to terminal #2 on the tube socket and its other lead to the metal chassis

Now, run a piece of wire from terminal #7 of the tube socket to one of the terminals on the lamp socket and connect the other terminal of the lamp socket to the vacant terminal on the potentiometer switch.

Connect a short length of wire between terminals #1 and #8 of the tube socket, extending this same wire to the chassis and soldering it at this point. Connect the ground terminal of the r-f transformer (that terminal to which one end of the primary and one end of the secondary are connected) to the chassis. Follow this by connecting the ground terminal of the antenna-ground post to the chassis.

Check the r-f transformer terminals and make sure that they do not contact the chassis and, if necessary, bend them away from the chassis. Connect one of the three leads previously soldered to the tuning condenser to the grid terminal of the r-f transformer (use that lead nearest the transformer).

As the next step,connect one end of the tickler coil to terminal #3 of the tube socket, and the other end of this coil to one of the twin-jack terminals. Connect a .25 mf condenser between the other jack terminal and the chassis. Also, run a long piece of wire from this same jack terminal to the positive terminal of the B-battery. Connect another long lead between the negative B-terminal and the metal chassis (the battery may be placed on top of the chassis for convenience). Continue by connecting a .001 mf condenser between the two jack terminals and then connect the antenna terminal of the r-f transformer to the antenna post

The final step is to complete the grid circuit outside of the chassis. To do this, connect a .00025 mf fixed condenser and a 1-meg-ohm resistor to the control grid clip, as shown in Fig. 5. You will observe that the free end of the condenser is connected to the stator plate terminal of the tuning condenser section being used, and that the free end of the resistor is soldered to the tuning condenser frame, which is equivalent to connecting it to the chassis.

When you have installed the tube in its socket and placed the control grid clip over the cap on top of the tube, make sure that the .00025 mf condenser does not touch the tuning condenser frame nor any other nearby object. If necessary, bend it away from any metallic object which it is likely to contact.

Proceed by inserting the headphone leads into their respective jacks; connect the batteries, the ground wire,the antenna lead-in, and also plug the line cord into the nearest lighting circuit outlet. The receiver will now be ready for operation upon closing the switch.

USING THE CHASSIS AS A RETURN-CIRCUIT

Upon comparing your present circuit with that constructed according to the previous experiment lesson, where you employed the "breadboard" method of construction, you will observe that the new system is much more simple. Under the new method, you have eliminated all long leads that were used previously as ground circuits to complete the cathode circuit of the tube, to connect the tuning condenser frame to ground, etc. In your new receiver, the metal chassis is used to complete all these ground-return circuits and thereby eliminates the need for the additional wiring otherwise required.

In most modern receiver circuits, as well as in other radio apparatus, the metal chassis serves three distinct purposes: first, it accommodates all parts; second, it serves as a base for the entire unit and at the same time acts as a shield for the greater part of the circuit wiring; and third, it is used as a common "return" for the various circuits.

Since the chassis forms part of the general shielding system, it must always be kept at a low potential with respect to ground. This means that it must not be used as the positive side of the plate circuit (B+), or for the control grid circuit of the tubes. However, it may be used to complete the negative or return-side of either the plate or control grid circuits.

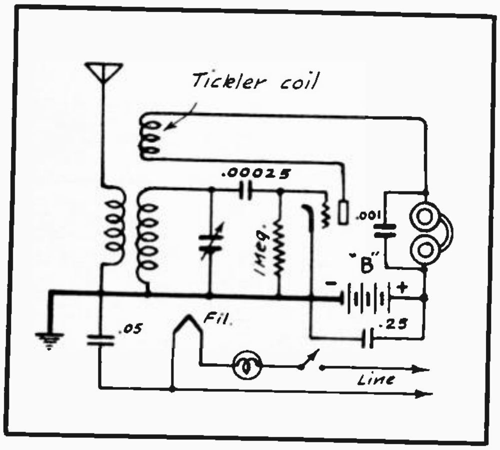

FIG. 6
CIRCUIT WITH A-C FILAMENT SUPPLY

In the case of the receiver that you have just constructed, those connections that have been made directly to the chassis are indicated by the heavy lines on the diagram of Fig. 6. This can be verified readily by comparing the circuit connections in Figs. 4 and 6.

It must be understood that radio diagrams in general do not always show the connections to the chassis by means of heavy lines as we have done in Fig. 6. Instead, such connections are usually designated by the standard "ground symbol," as is employed in Fig. 7 of this lesson as well as in other diagrams in our course. The latter practice eliminates all possibility of errors during the wiring procedure, and is therefore used extensively throughout the industry.

ONE-TUBE RECEIVER FOR D-C OPERATION

The circuit shown in Figs. 4 and 6 is designed for using alternating current for the filament supply, while a B-battery is used to furnish the plate current for the tube. Later on, you will be furnished with the parts necessary for obtaining the B-supply from the house-lighting circuit as well.

If the lighting circuit in your district is of the d-c type, you can eliminate the B-battery and connect the plate circuit of your receiver to the lighting circuit through a filter system. The schematic diagram for such a receiver is shown in Fig. 7, and though there is very little difference between it and the circuit shown in Fig. 6, we feel that an explanation of the changes made will help you to better understand the d-c circuit. To simplify our explanation, the necessary changes for the plate circuit of the d-c receiver are illustrated in Fig. 8.

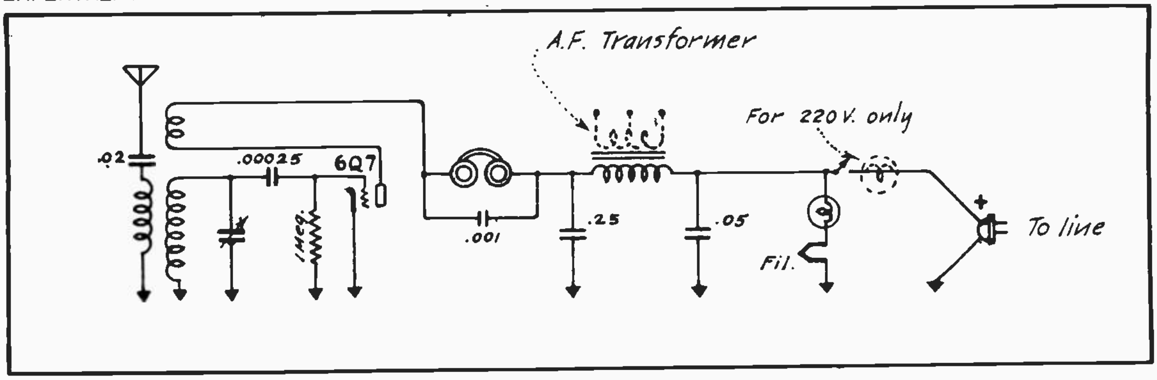

FIG. 7
D-C RECEIVER CIRCUIT

In addition to those instructions that have already been given relative to the a-c receiver, we will now furnish the necessary instruction for installing the a-f transformer which is to be used as the filter choke. This unit can be placed in any convenient location inside the chassis, care being taken that the side having only two terminals (corresponding to the primary winding) faces the tube socket.

Connect the wire marked B+ in Fig. 8 to one of the primary terminals on the a-f transformer. Connect the other primary terminal to that side of the .05 mf condenser that was originally connected to the chassis, and from the same primary terminal of the a-f transformer, run a wire to that switch terminal on the potentiometer to which also is connected one side of the lamp.

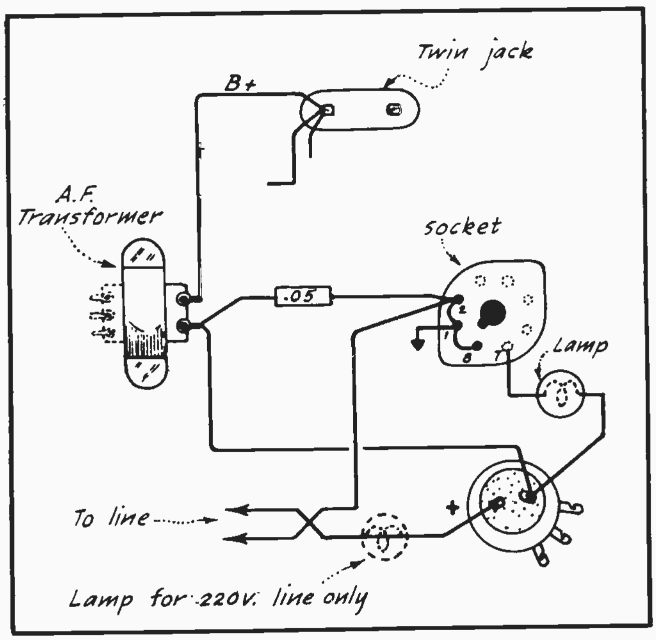

FIG. 8
CHANGES NECESSARY FOR THE D-C CIRCUIT

Proceed by connecting terminal #2 of the tube socket to terminal #1. This connects terminal #2 to ground, as terminals #1 and #8 have been connected to the chassis previously.

Connect a .02 mf bypass condenser between the antenna post and the antenna terminal of the r-f transformer (see Fig. 7). Disconnect the wire marked B- in Fig. 4, and also the external ground wire that is connected to the ground terminal of the antenna-ground post assembly. NO EXTERNAL GROUND CONNECTION IS NECESSARY for the d-c receiver, as the antenna circuit is completed through the lighting system.

Another point to bear in mind is that the line cord of any d-c receiver must always be plugged into the lighting system so that the switch and filter choke of the receiver are in series with the <u>positive</u> side of the line, as shown in Figs. 7 and 8.

SPECIAL INSTRUCTIONS FOR 220-VOLT CIRCUITS

When the line voltage is 220 volts, or any voltage near this value, the receiver may be connected to the line in the same manner as before, the only exception being that under these circumstances it is necessary to insert another lamp in series with the receiver and the positive side of the line, as shown in Figs. 7 and 8.

Answered November 12, 1921

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. F-4

1. - What are the advantages of using a metal chassis for a receiver?

2. - What precautions should be exercised when mounting the r-f transformer on the chassis?

3. - Why isn't an external ground wire necessary for the d-c receiver circuit described in this lesson?

4. - Is it the general practice to use the chassis as a part of the high or low potential side of the circuit?

5. - What means may be employed to assure a perfect electrical connection between the rotor plates of a variable tuning condenser gang and the metal chassis?

6. - In what order may the various circuits of a receiver be wired conveniently?

7. - What is the correct procedure for soldering a wire to the metal chassis?

8. - How does the antenna circuit of the a-c receiver described in this lesson differ from that of the d-c receiver?

9. - What is the customary method for designating on a wiring diagram that a certain circuit is connected to the metal chassis?

10. - In a d-c receiver, should the filter choke and switch be connected in the negative or positive side of the line?

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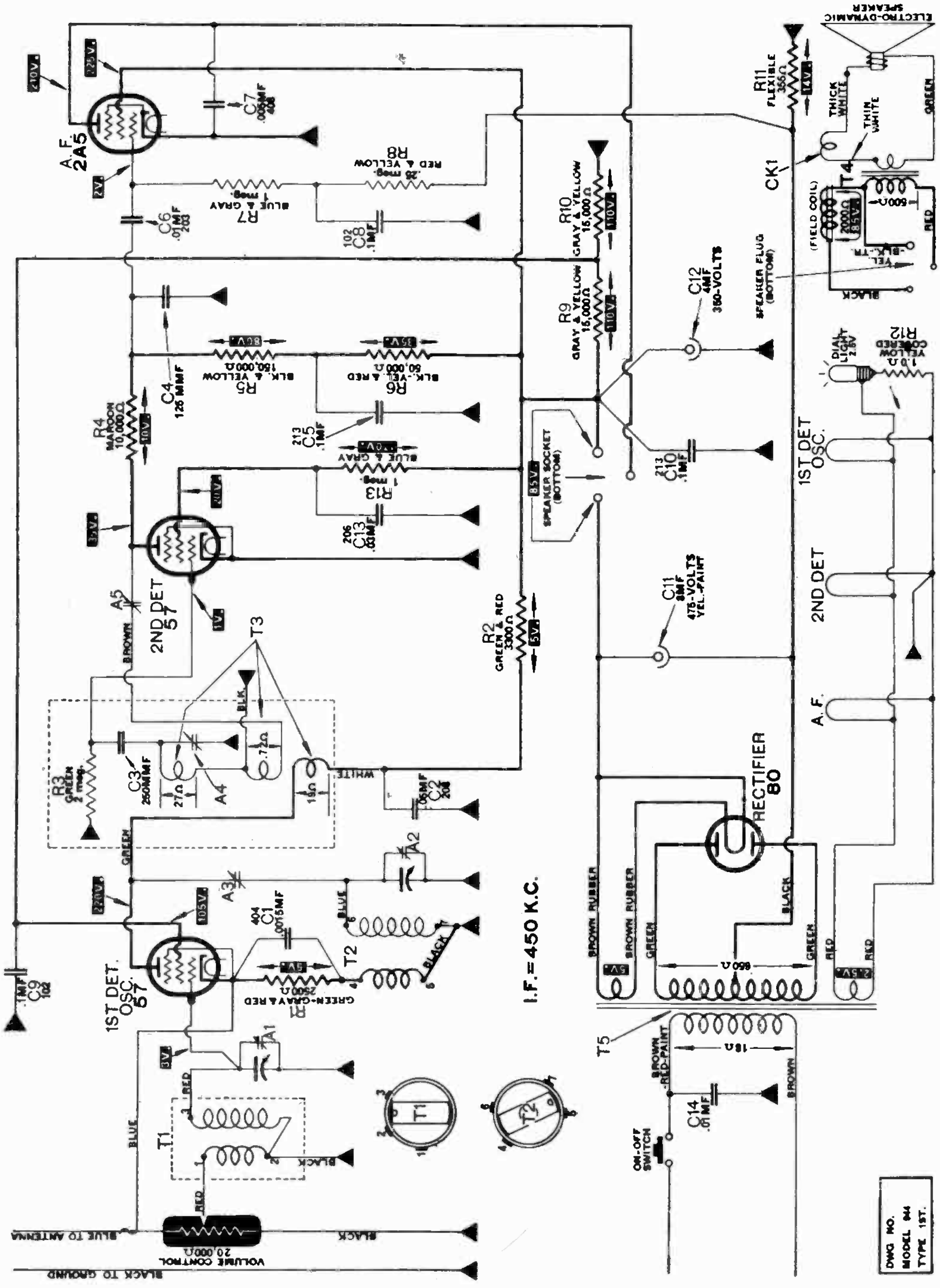
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 944



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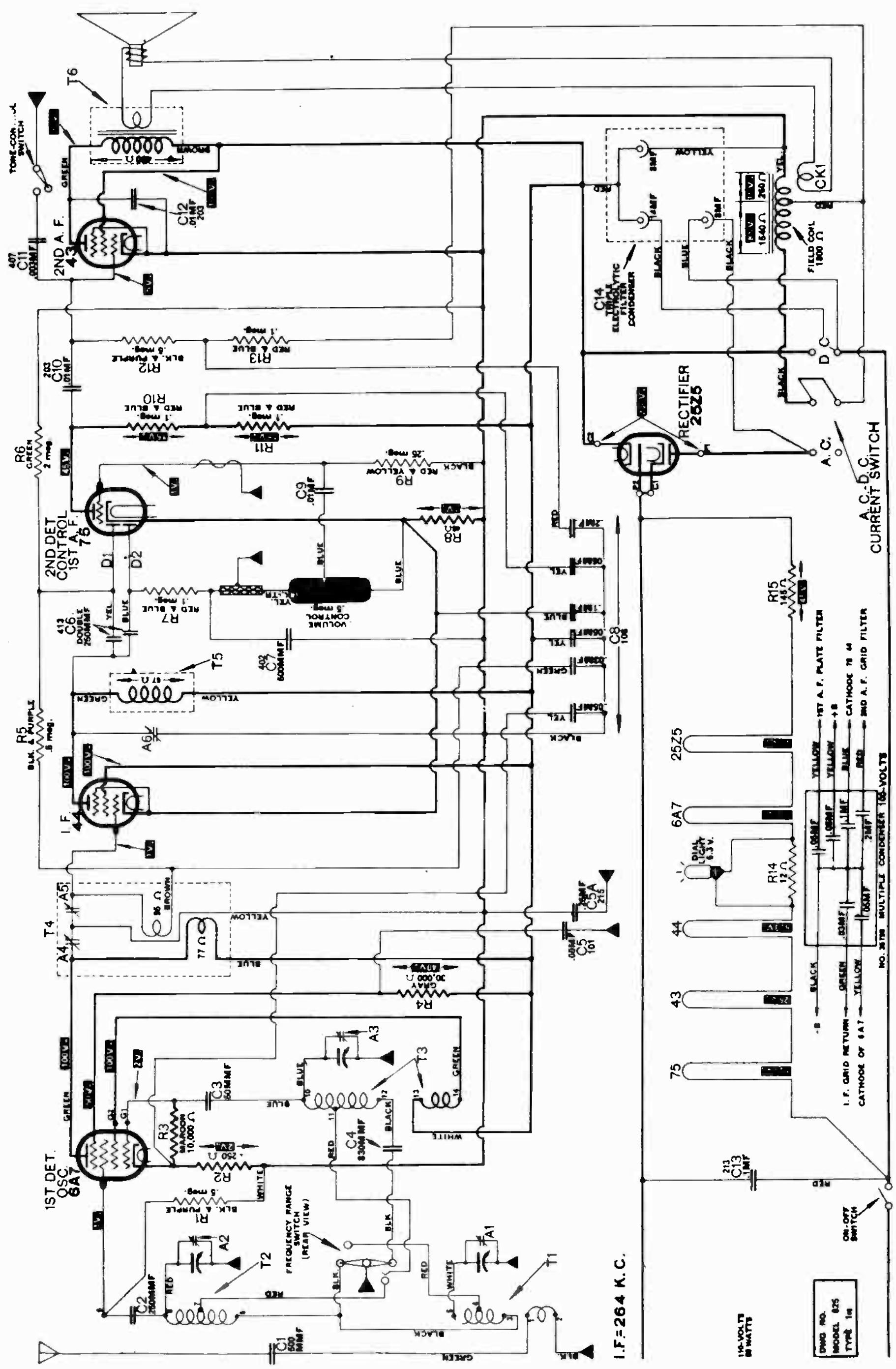
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT

MODEL 825 (A. C.—D. C.)



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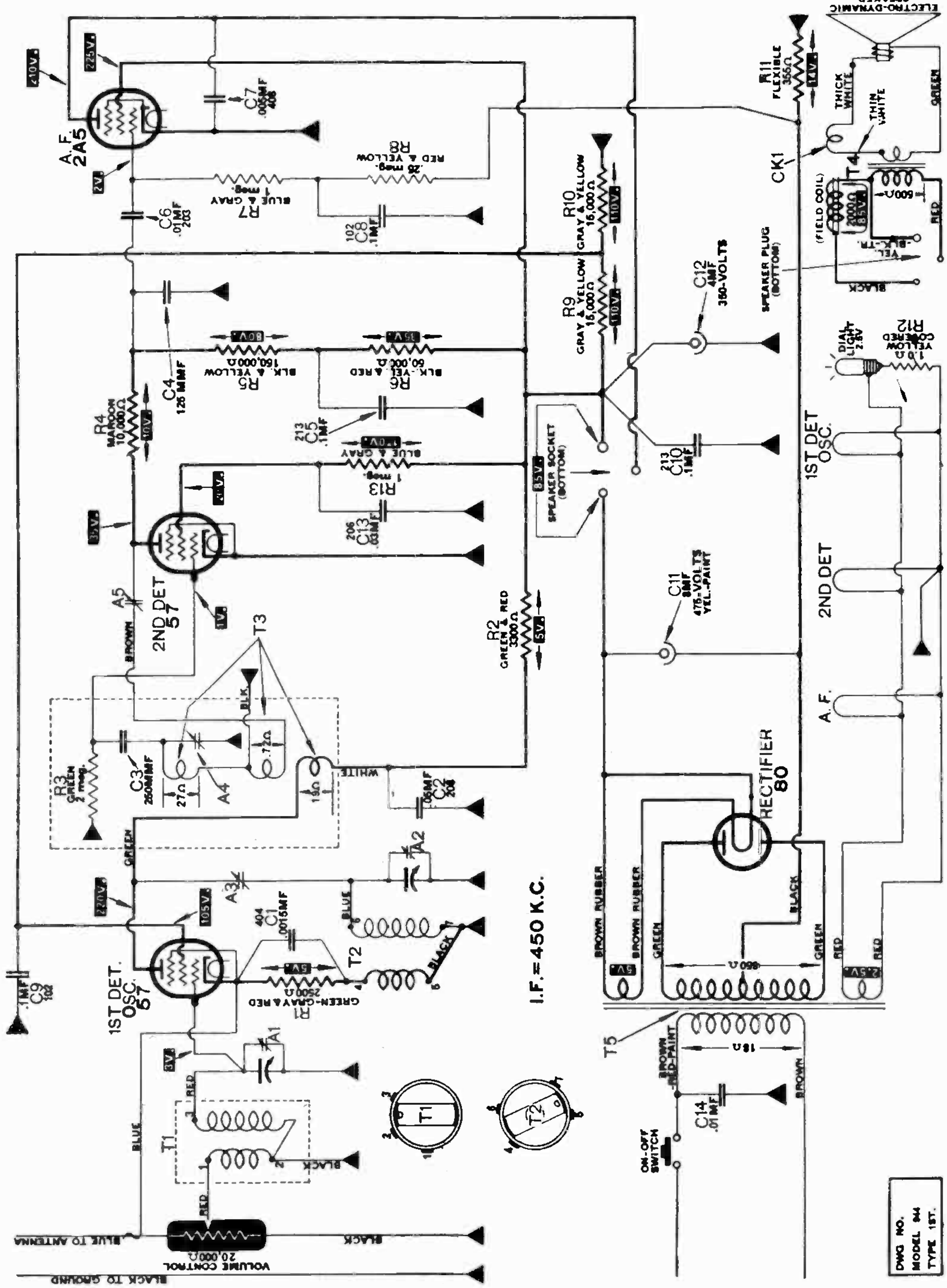
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT

MODEL 944



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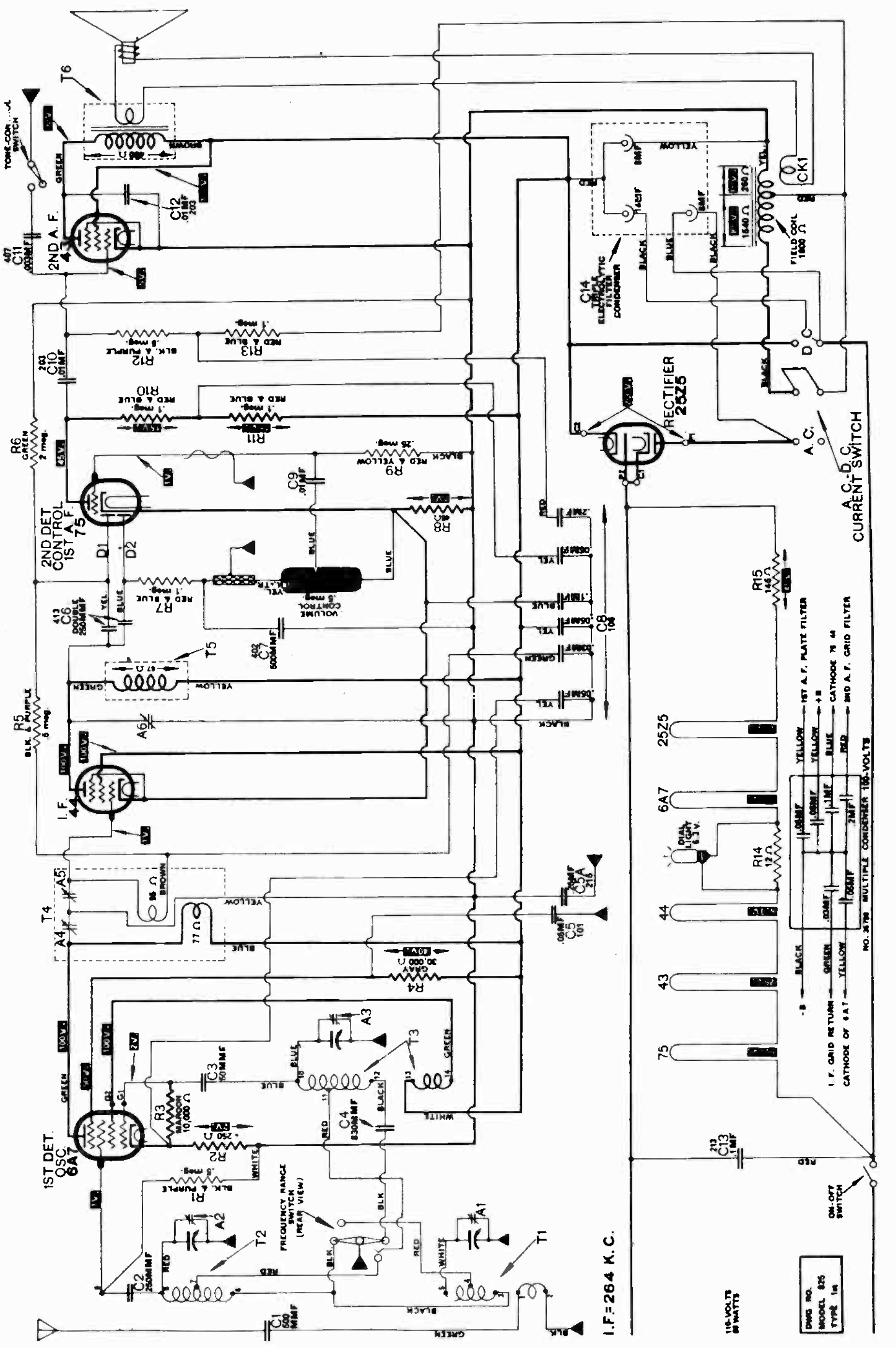
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT

MODEL 825 (A. C.—D. C.)



NATIONAL SCHOOLS
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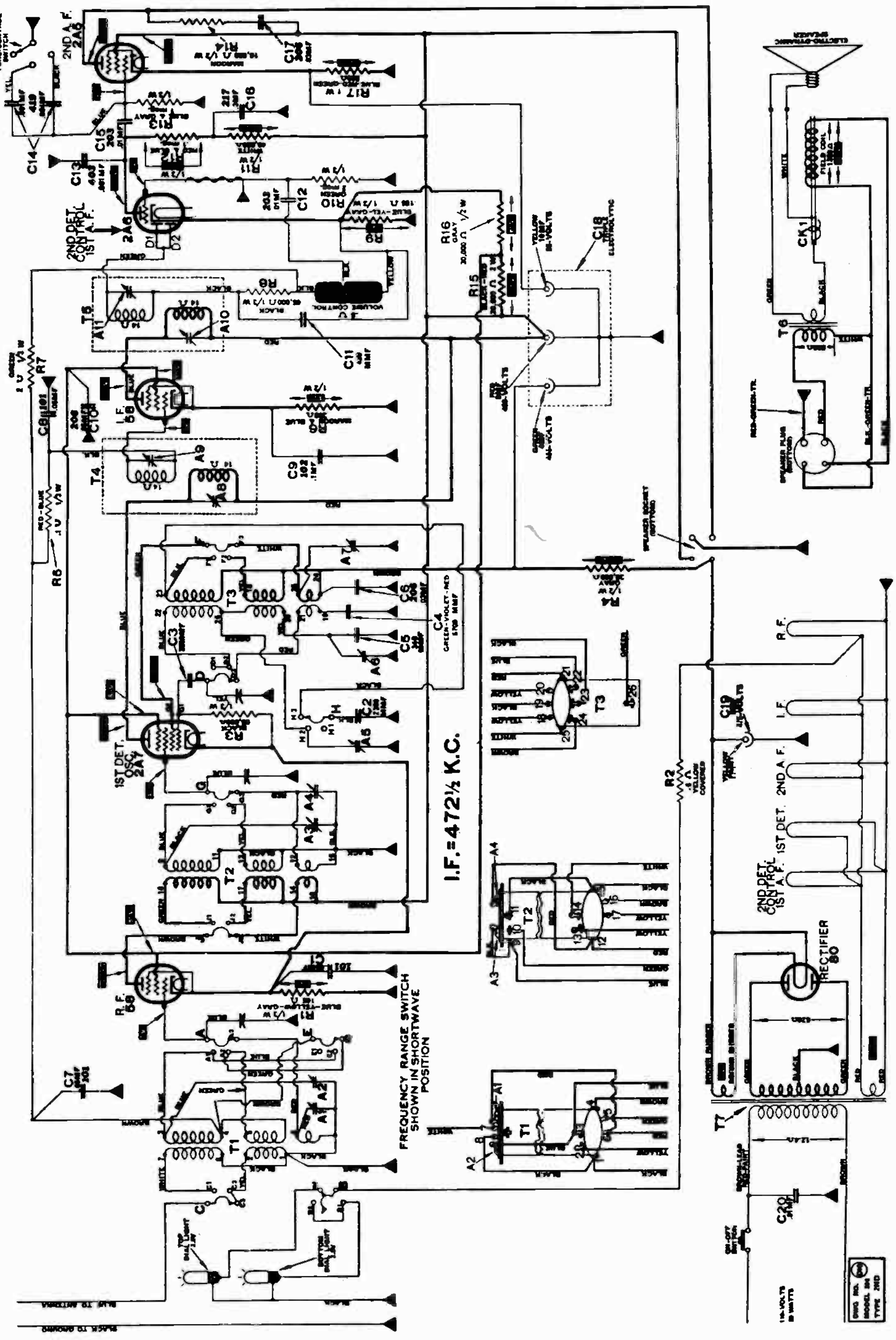
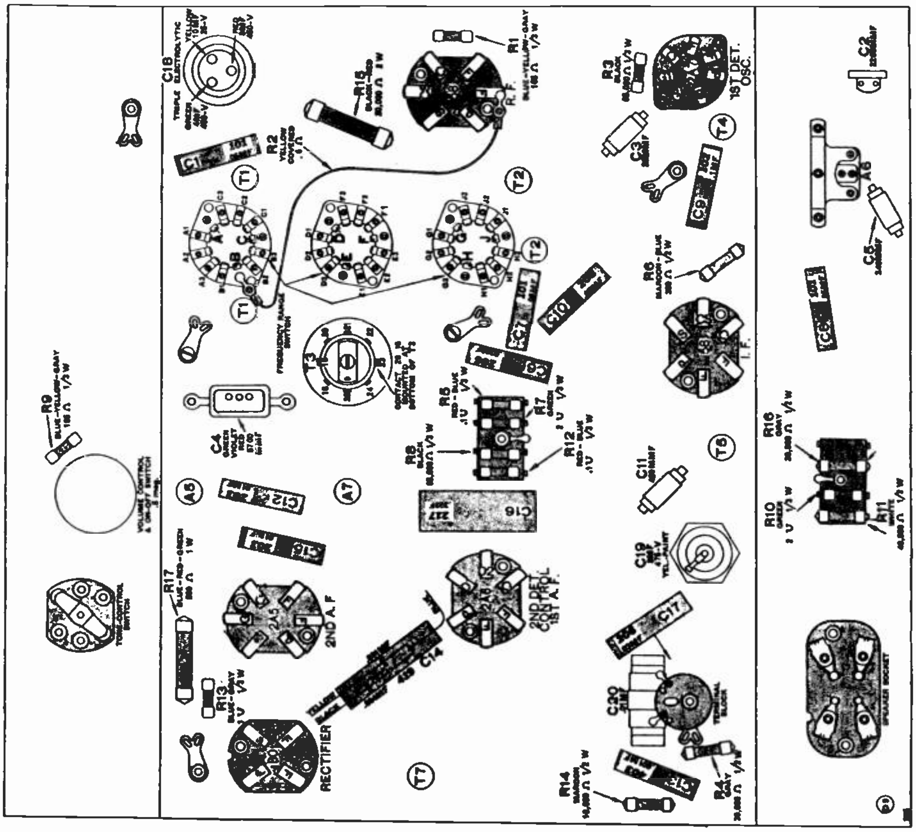
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT

MODELS 206 AND 376 (2nd TYPE)



NATIONAL SCHOOLS Los Angeles, California	COMMERCIAL CIRCUIT DIAGRAM *ATWATER-KENT*

MODELS 206 AND 376 (2nd TYPE)



ADJUSTING TRIMMERS, MODELS 206 AND 376 (2nd Type)

I. F. TRIMMERS.

Connect an I. F. test oscillator to the 1st-detector tube by means of the I. F. coupling unit shown in Fig. 1. Adjust the oscillator to 472½ KC. Use the weakest possible signal that will give a reading on the output meter with the radio volume control on full.

Peak trimmers A11, A10, A9 and A8 for maximum output. Remove the I. F. coupling unit and seal the I. F. trimmers.

DIAL POINTER ADJUSTMENT.

With the variable condenser rotor completely meshed, the dial pointer should be set at 535 KC.

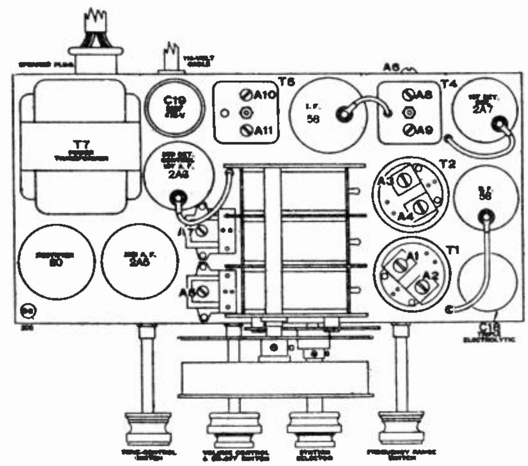
R. F. TRIMMERS.

Connect a suitable R. F. oscillator to the antenna and ground terminals of set.

Broadcast range. Oscillator at 1500 KC and dial pointer at 1500 KC mark, adjust trimmers A5, A2 and A3. Tune oscillator and set to 560. Peak A6. Repeat adjustments on A5 at 1500 KC and A6 at 560 KC if necessary.

Police range. There are no trimmer adjustments for this range.

Short-wave range. With oscillator at 15 MC and set turned to 15 MC, peak trimmers A7, A1 and A4.



R. F. TRIMMERS ON MODELS 206 AND 376.

	Short-Wave Range	Police Range	Broadcast Range
R. F.	A1	None	A2
1st-Detector	A4	None	A3
Oscillator	A7	None	A5
Tracking	None	None	A6

The I. F. trimmers are A8, A9, A10 and A11

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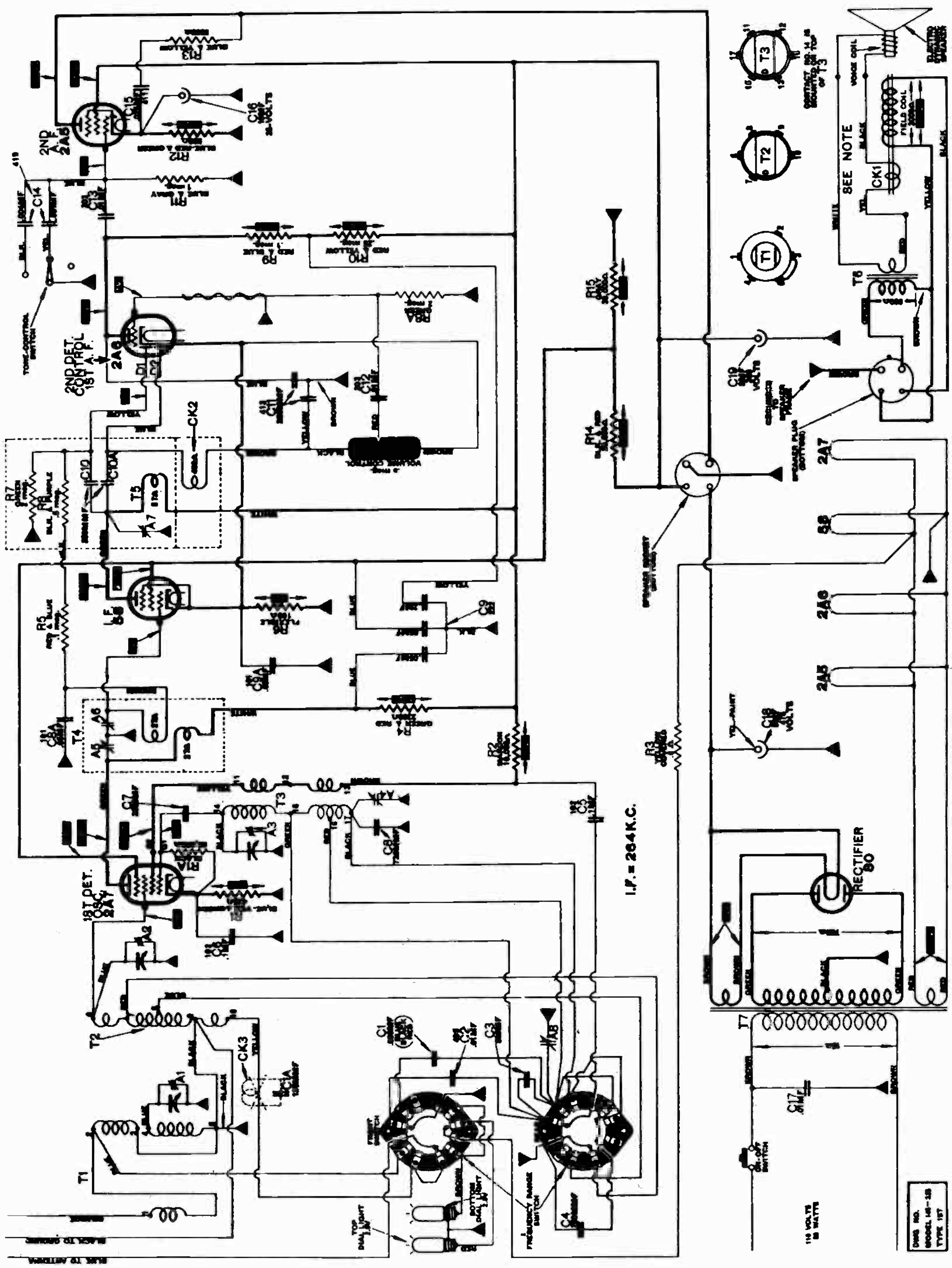
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 145 AND 325



In Model 325 the field coil is 1200 Ω and the voltages throughout are slightly higher than shown in diagram. In later sets C4 is not used, the diode circuit is changed and there are some minor changes in the frequency-switch circuit.

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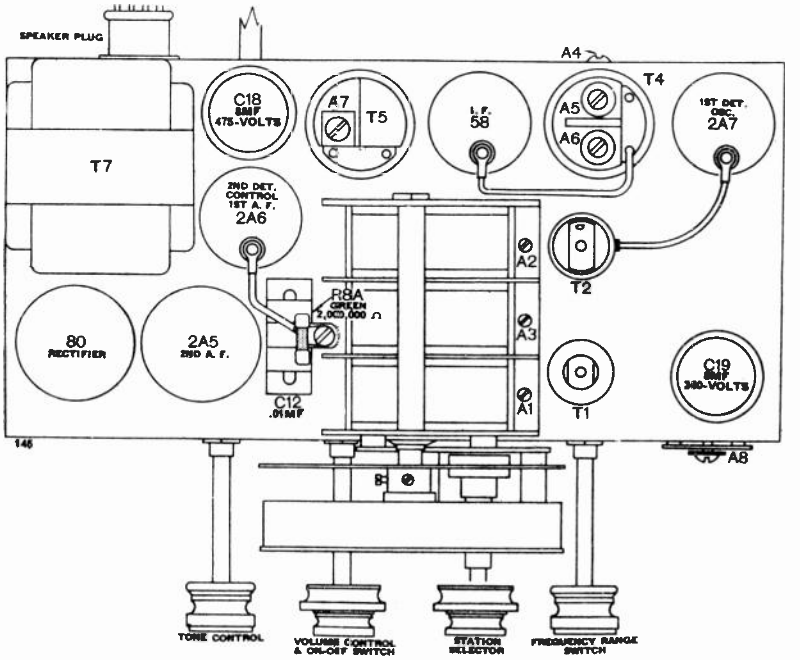
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

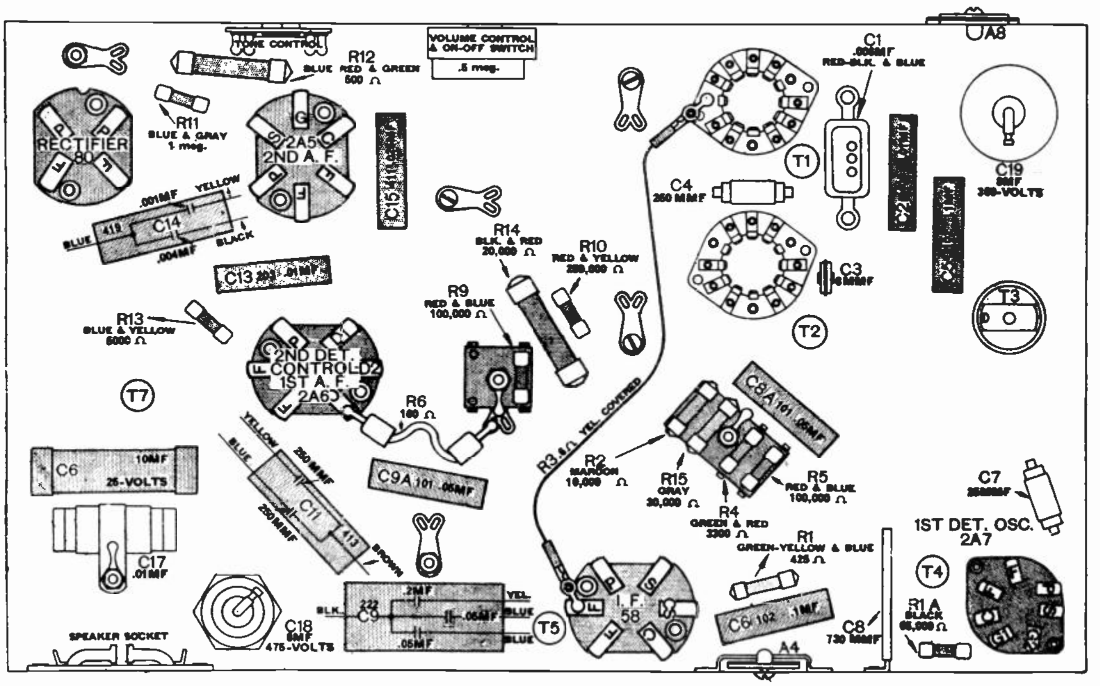
MODELS 145 AND 325
(I. F. = 264 KC.)



R. F. TRIMMERS ON MODELS 145 AND 325

	Short-Wave Range	Police Range	Broadcast Range
Antenna	None	None	A1
Detector	None	None	A2
Oscillator	A3	None	A8
Tracking	None	None	A4

The I. F. trimmers are A5, A6 and A7.



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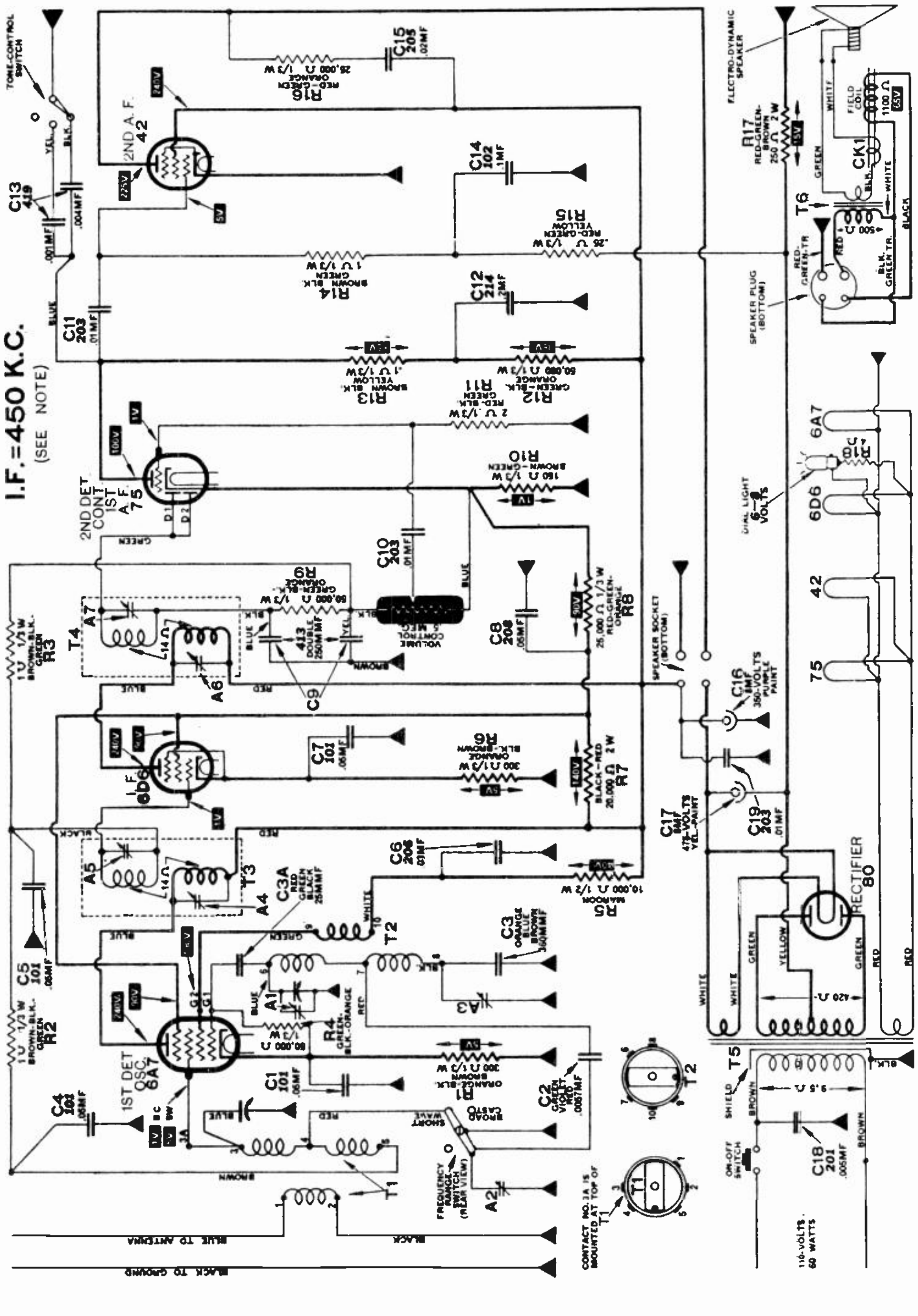
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 545



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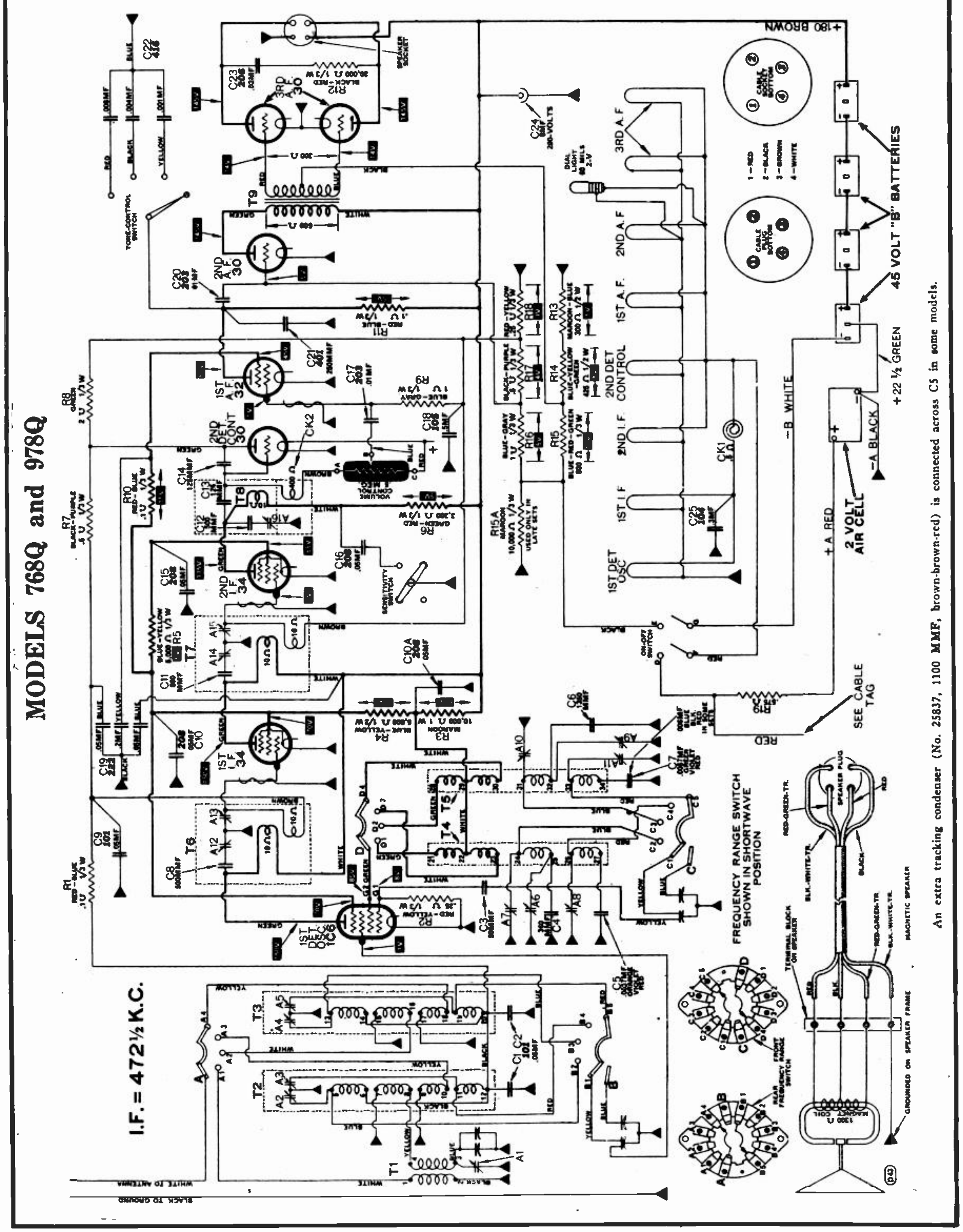
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT



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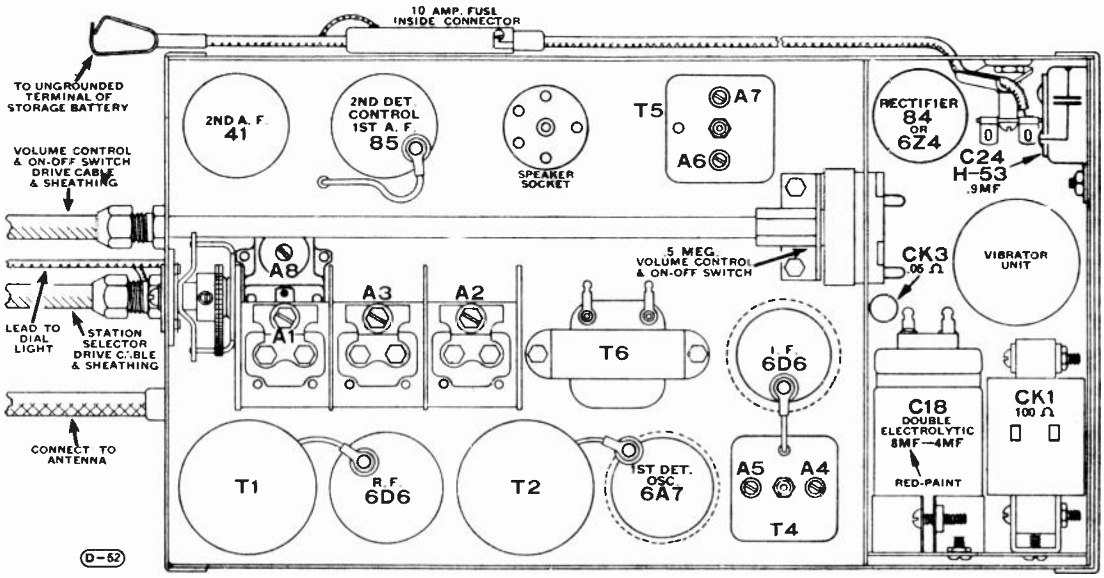
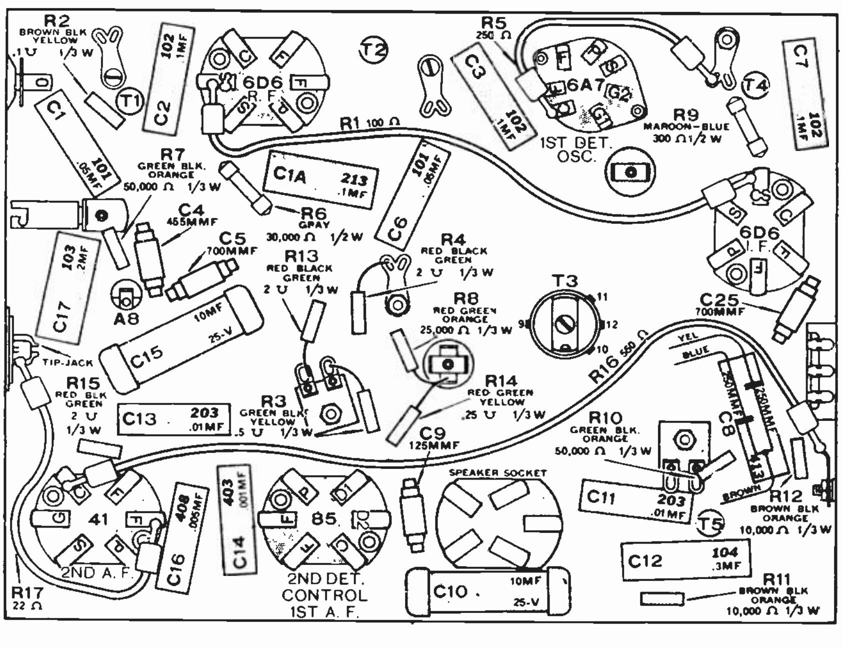
COMMERCIAL CIRCUIT DIAGRAM

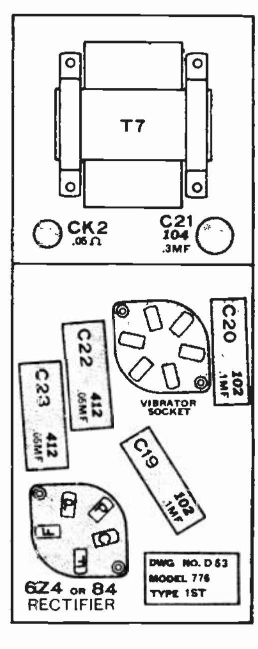
ATWATER-KENT

MODEL 776

TOP VIEW AND CHART







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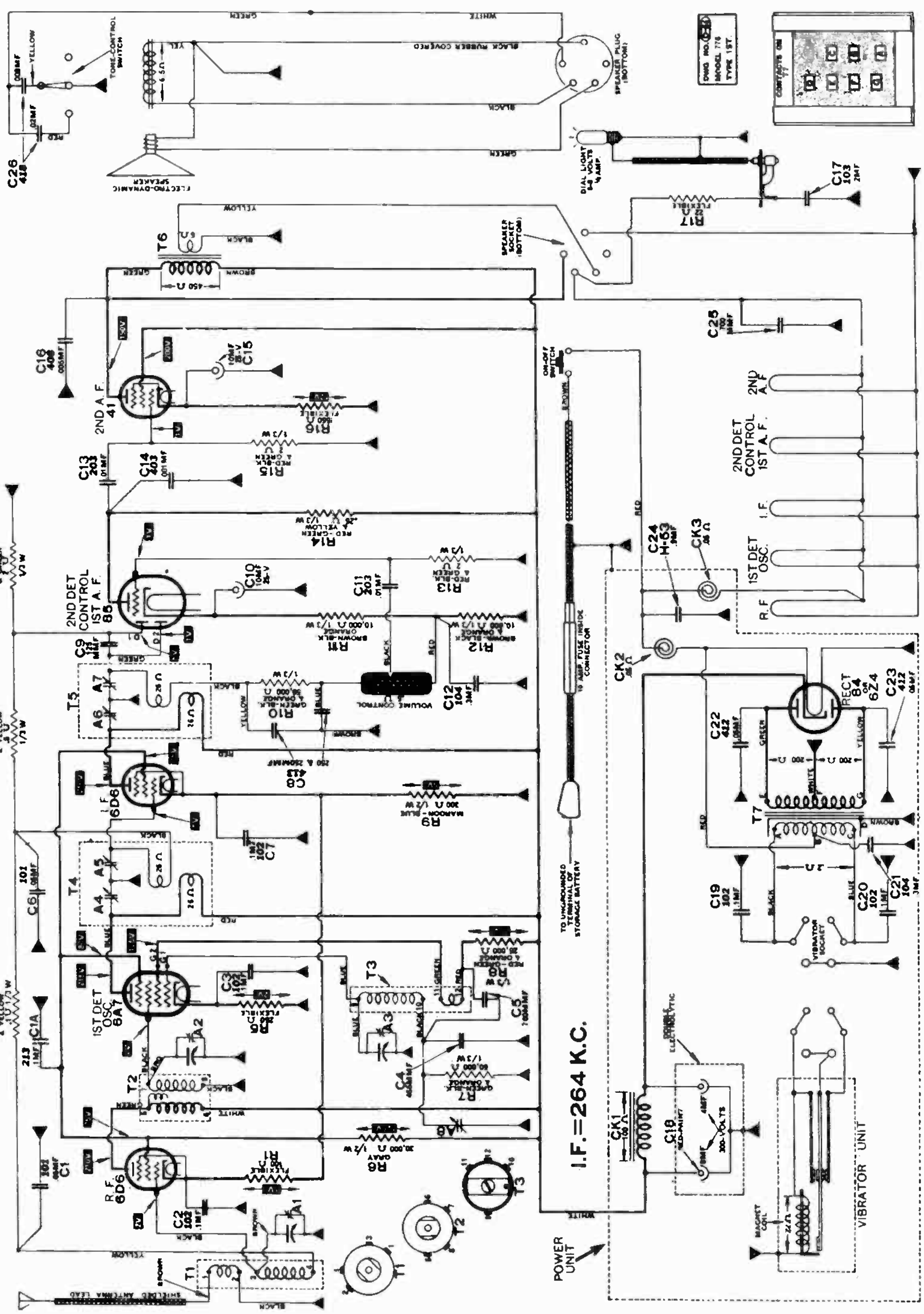
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT

MODEL 776 MOTOR CAR RADIO



In early sets R11 is 5,000 ohms with a drop of 4 volts and R12 is 15,000 ohms with a drop of 10 volts. In late sets these two resistors are each 10,000 ohms and there is approximately 6 volts across each. (At the same time this change was made, the 1st-A. F. plate resistor, R14 was changed from .1 meg. to .25 meg. With the .1 meg. resistor, the drop across it is 55 volts, and the plate voltage is 125. With the .25 meg. resistor, the plate voltage is lower. All voltages are measured with the 250-volt scale of a 1,000-ohm-per-volt voltmeter.)

The voltage across R11 regulates the "squelch" or minimum-signal level at which the 2nd-detector begins to function. The combined voltage across R11 and R12 acts as the bias on the AVC and the 1st-A. F. grid.

Early Model 776 sets do not have tone control, and the "A" filter circuit is slightly different from that shown. C17 in the lower right-hand part of the diagram is .2 MF.

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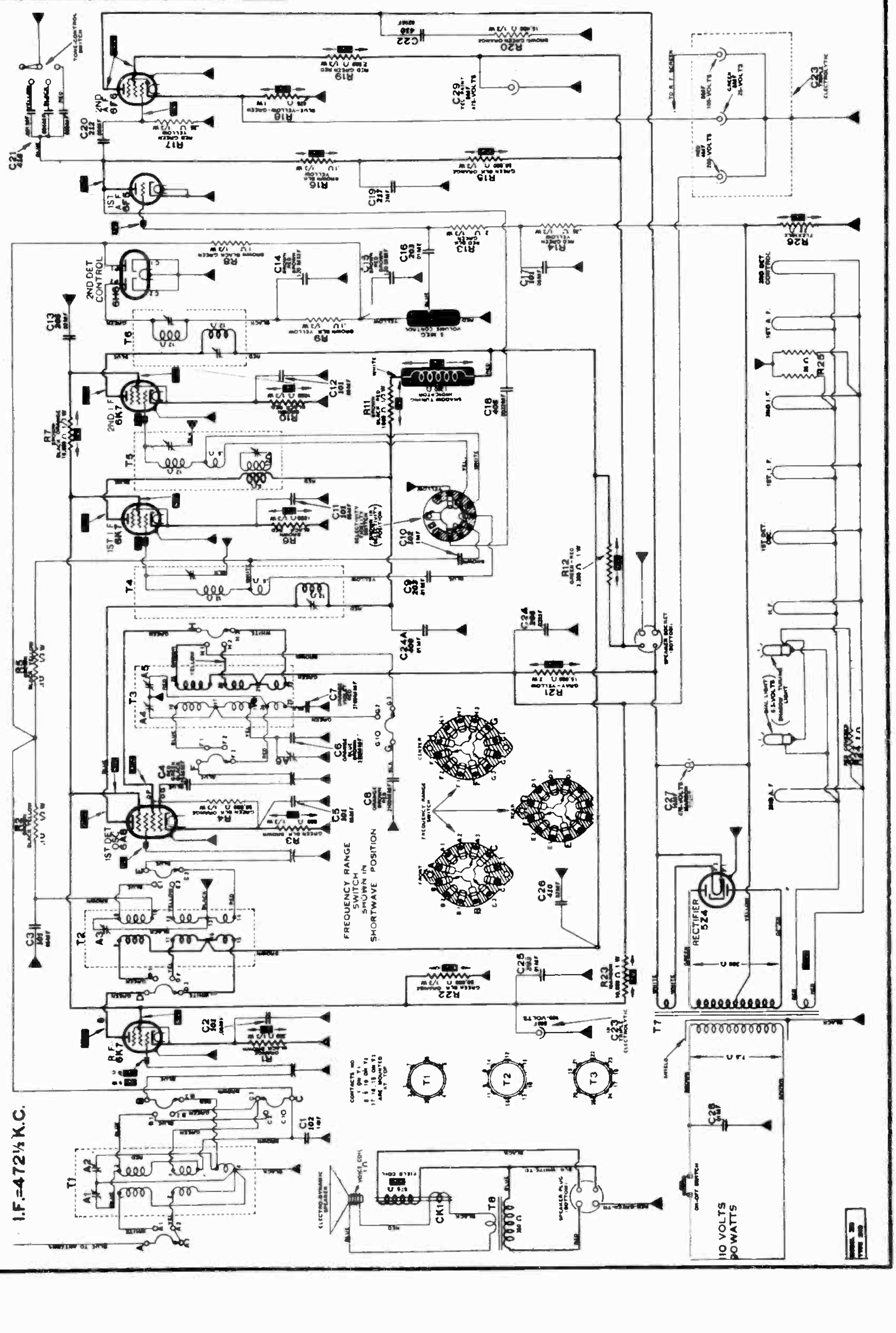
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 328, 2ND TYPE, ABOVE SERIAL No. 6438750



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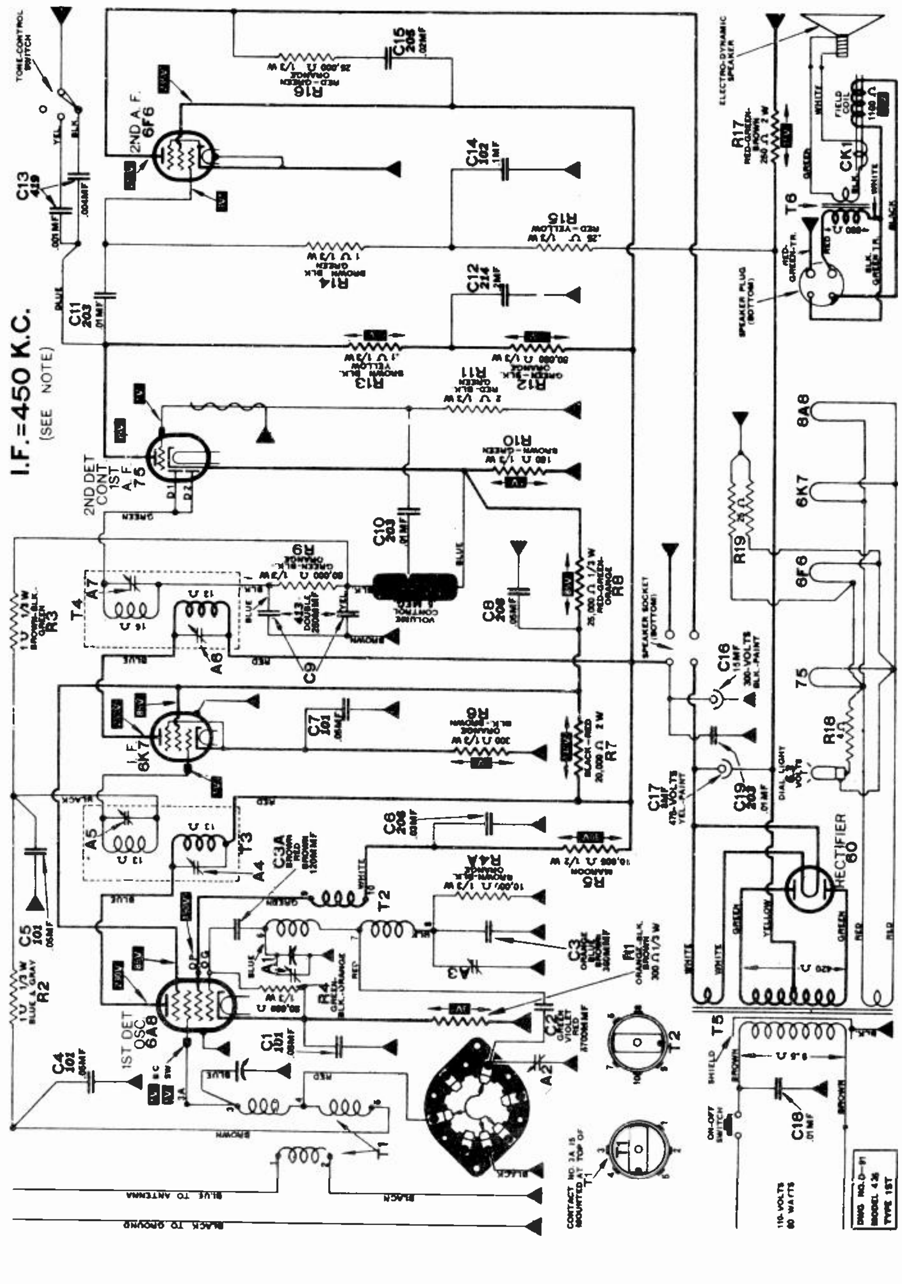
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 435 DIAGRAM (Early Type)

I.F.=450 K.C. (SEE NOTE)



The frequency-range switch is shown in the short-wave position.

The I. F. in some Model 435 sets is 472½ KC and a label to this effect is attached to the rear of the chassis. The I. F. transformers and trimmers, etc.. are exactly the same for either 450 or 472½ KC.

RADIO - TELEVISION

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Printed in U. S. A.

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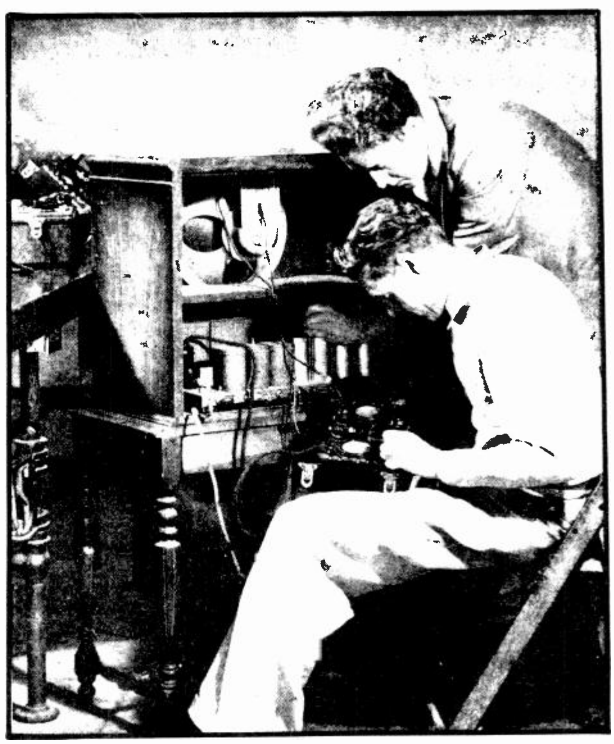

FIG. 1
Radio Service - A Profitable Profession.

YOU ARE NOW PREPARED TO COMMENCE YOUR ADVANCED STUDIES DEALING WITH TRANSMITTERS, TALKING PICTURES, TELEVISION ETC. THESE, YOU MUST REMEMBER, ARE ALL HIGHLY SPECIALIZED FIELDS OF THE RADIO INDUSTRY AND BEFORE ANYONE CAN UNDERTAKE AN INTELLIGENT STUDY OF ANY ONE OF THESE FIELDS, HE MUST FIRST HAVE THE FOUNDATIONAL TRAINING WHICH YOU HAVE AC-

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PRACTICALLY WITHOUT EXCEPTION, YOU WILL FIND THAT EVERY SUCCESSFUL MAN WHO TODAY IS AN EXPERT IN ANY ONE OF THESE ADVANCED FIELDS WAS AT SOME TIME OR OTHER A RADIO SERVICEMAN OR ELSE ACTIVE IN AN ENGINEERING CAPACITY INVOLVING RADIO RECEIVERS. THESE MEN ALL NEEDED THEIR FOUNDATIONAL TRAINING AND SO DO YOU -- PAST EXPERIENCES HAVE CONCLUSIVELY PROVED THIS TO BE THE SHORTEST AND MOST CERTAIN ROUTE TO SUCCESS.

BEFORE EVER COMMENCING TO WRITE THIS COURSE, IT WAS FIRST SCIENTIFICALLY PLANNED.

NATIONAL'S INSTRUCTION PROGRESSES IN LOGICAL STEPS. YOU BUILD YOUR PRACTICAL KNOWLEDGE FIRST AND BUILD YOUR TECHNICAL KNOWLEDGE UPON IT. WITH THIS SYSTEMATIC METHOD OF TRAINING THE STUDENT CAN FULLY VISUALIZE HOW TO APPLY THEORETICAL AND TECHNICAL PRINCIPLES TO PRACTICAL PROBLEMS AND THIS IN THE FINAL ANALYSIS IS THE KEY-NOTE TO RADIO SUCCESS.

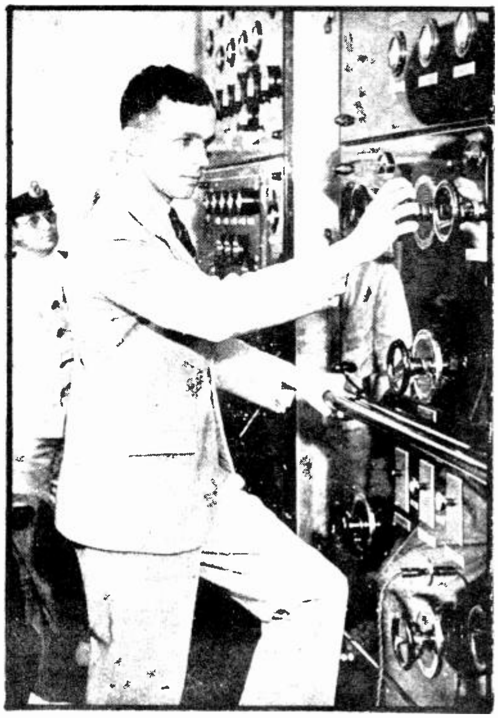


FIG. 2
Unlimited Opportunities in the Field of Transmission.

ALTHOUGH YOU HAVE SO FAR ONLY BEEN SHOWN HOW THE BASIC RADIO PRINCIPLES ARE APPLIED TO RECEIVERS, YET YOU MUST NOT OVERLOOK THE FACT THAT THESE SAME PRINCIPLES CAN ALSO BE APPLIED TO TRANSMITTERS, TO AMPLIFYING EQUIPMENT FOR PUBLIC ADDRESS INSTALLATIONS, TO TALKING PICTURES, TELEVISION ETC.

THIS MEANS THAT MANY OF THE IMPORTANT PRINCIPLES WHICH YOU HAVE ALREADY LEARNED, ARE GOING TO BE USED AGAIN IN YOUR COMING STUDY OF THE SPECIALIZED FIELDS OF RADIO. BY YOUR ALREADY KNOWING THEM, THERE WILL BE NO NEED TO EXPLAIN THEM AGAIN IN DETAIL WITH RESPECT TO THE EQUIPMENT TO BE DESCRIBED IN THE ADVANCED LESSONS. THIS IN TURN WILL CONSTITUTE A SAVING IN TIME AND WILL MAKE YOUR PROGRESS THROUGH THE ADVANCED SUBJECTS MORE RAPID, MORE INTERESTING AND FREE FROM UNNECESSARY REPETITION.

SINCE THIS FOUNDATIONAL TRAINING IS SO ESSENTIAL TOWARDS YOUR MASTERING THE ADVANCED WORK WHICH IS YET TO COME, WE MOST URGENTLY ADVISE YOU TO CONDUCT A SYSTEMATIC REVIEW OF ALL STUDY MATERIAL WHICH YOU NOW HAVE ON HAND. THIS GENERAL REVIEW SHOULD BE THOROUGH, FOR AFTER ALL IT ISN'T A QUESTION OF HOW MANY DIFFERENT RADIO SUBJECTS YOU READ ABOUT DURING THIS PERIOD OF YOUR TRAINING OR WHAT YOU SHOULD KNOW BUT WHAT YOU ACTUALLY REMEMBER ABOUT THEM NOW.

YOUR REVIEW

THE PLAN TO FOLLOW DURING THIS REVIEW IS TO START AT THE FIRST LESSON OF THE COURSE. READ THE TITLE OF THE LESSON AND THEN READ EACH OF THE SUB-TITLES OF THE LESSON CAREFULLY ONE AT A TIME AND AS YOU DO SO, PAUSE

FOR AN INSTANT AND ASK YOURSELF THIS QUESTION - "DO I REMEMBER THE IMPORTANT FACTS INCLUDED IN THIS SECTION OF THE LESSON?" -- IF YOU DO, FINE. THEN CONTINUE WITH THE NEXT SUB-TITLE IN THE SAME MANNER ETC. UNTIL YOU HAVE GLANCED THROUGH THE ENTIRE LESSON.

THE INSTANT YOU COME TO A SUB-TITLE FOR SOME SECTION OF A LESSON TREATING WITH A SUBJECT WHICH YOU CANNOT TRUTHFULLY ADMIT AS REMEMBERING, THEN READ THIS PART OF THE LESSON CAREFULLY UNTIL YOU ARE CERTAIN THAT YOU HAVE MASTERED IT. CONTINUE IN THIS MANNER THROUGH ONE LESSON AT A TIME. BY ALL MEANS, DON'T RUSH THROUGH THIS WORK -- YOU ARE THE ONE WHO IS GOING TO BENEFIT BY THIS GENERAL REVIEW, SO BE FAIR TO YOURSELF IN CONDUCTING THIS WORK CONSCIENTIOUSLY. EVEN IF IT TAKES YOU A WEEK OR TWO TO COMPLETE THIS REVIEW, THIS IS NO LOSS OF TIME -- ON THE CONTRARY, YOU ARE SIMPLY SPENDING A COMPARATIVELY LITTLE TIME NOW IN CHECKING UP ON YOUR KNOWLEDGE AND WHICH WILL WITHOUT A DOUBT SAVE YOU A GREAT DEAL OF TIME IN THE FUTURE IF YOU HAVE TO SUDDENLY LOOK UP SOMETHING WHICH YOU SHOULD HAVE REMEMBERED.

SO AS TO BE SURE THAT YOU ARE GETTING THE FULL VALUE FROM YOUR REVIEW, WE ARE REQUESTING YOU TO ANSWER COMPLETELY EACH OF THE QUESTIONS WHICH ARE INCLUDED IN THE SPECIAL EXAMINATION AT THE LATTER PART OF THIS MESSAGE. THIS EXAMINATION IS BASED UPON THE ENTIRE FOUNDATIONAL TRAINING AND IT IS IMPERATIVE THAT YOU RECEIVE A PASSING GRADE UPON IT BEFORE CONTINUING WITH YOUR ADVANCED WORK.

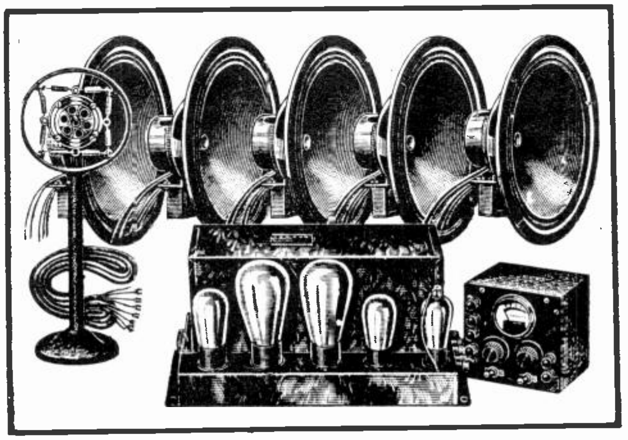


FIG. 3
Amplifying Systems -- A Most Fascinating Division of Radio.

YOUR ADVANCED TRAINING

YOUR ADVANCED TRAINING IS DIVIDED INTO FIVE GENERAL GROUPS OR DIVISIONS AND WHICH ARE CLASSIFIED AS "RADIO TRANSMISSION"; "PUBLIC ADDRESS SYSTEMS"; "TALKING PICTURES"; "TELEVISION" AND "PHOTO-ELECTRIC CELLS". AS YOU WILL IMMEDIATELY REALIZE, THESE ARE ALL INDIVIDUAL AND HIGHLY SPECIALIZED FIELDS OF THE RADIO INDUSTRY.

EACH OF THESE DIVISIONS ARE TREATED SEPARATELY AND IN THEIR PROPER ORDER. YOU DON'T STUDY ONE SUBJECT FOR A LITTLE WHILE AND THEN JUMP TO ANOTHER SPASMODICALLY BUT YOU START A SUBJECT AND FINISH IT AND THEN PROCEED WITH THE NEXT ETC. THERE IS ABSOLUTELY NO MIX-UP IN SUBJECT MATTER TO CAUSE CONFUSION ON YOUR PART.

YOU WILL FIND THESE DISTINCT DIVISIONS OF ADVANCED STUDY TO BE AN OUTSTANDING FEATURE OF NATIONAL TRAINING.

LET US NOW BRIEFLY CONSIDER WHAT YOU CAN HOPE TO ACCOMPLISH UPON COMPLETING YOUR FOLLOWING STUDIES PERTAINING TO THE ADVANCED SPECIALIZED FIELDS.

RADIO TRANSMISSION

WHEN YOU HAVE FINISHED YOUR STUDIES IN THIS DIVISION, YOU WILL HAVE

THE NECESSARY KNOWLEDGE TO ENABLE YOU TO BECOME A COMMERCIAL RADIO OPERATOR IN SHIP SERVICE, AERONAUTICAL SERVICE, POLICE SERVICE OR AS AN OPERATOR IN A BROADCASTING STATION. YOU WILL ALSO BE ABLE TO SERVICE ALL OF THIS EQUIPMENT AND LATER AS YOU ACQUIRE ADDITIONAL EXPERIENCE IN THIS PARTICULAR FIELD, YOU MAY QUALIFY AS AN ENGINEER AND DESIGNER.

BROADCASTING STATIONS, IN ADDITION TO REQUIRING THE SERVICES OF OPERATORS, ALSO NEED STUDIO TECHNICIANS, MONITORING MEN, AND AN ENGINEER IN CHARGE. ALL OF THESE MEN SHOULD HAVE THE TYPE OF TRAINING YOU ARE RECEIVING AND ALL OF THESE POSITIONS OFFER YOU UNLIMITED OPPORTUNITIES.

PUBLIC ADDRESS SYSTEMS

PUBLIC ADDRESS INSTALLATIONS ARE BECOMING INCREASINGLY POPULAR SO THAT THIS HAS BECOME A MOST PROFITABLE FIELD. YOUR STUDIES IN THIS DIVISION WILL FURNISH YOU WITH THE NECESSARY KNOWLEDGE TO CONSTRUCT, AND OPERATE EQUIPMENT OF THIS TYPE FOR PORTABLE USE, AS WELL AS TO MAKE PERMANENT INSTALLATIONS.

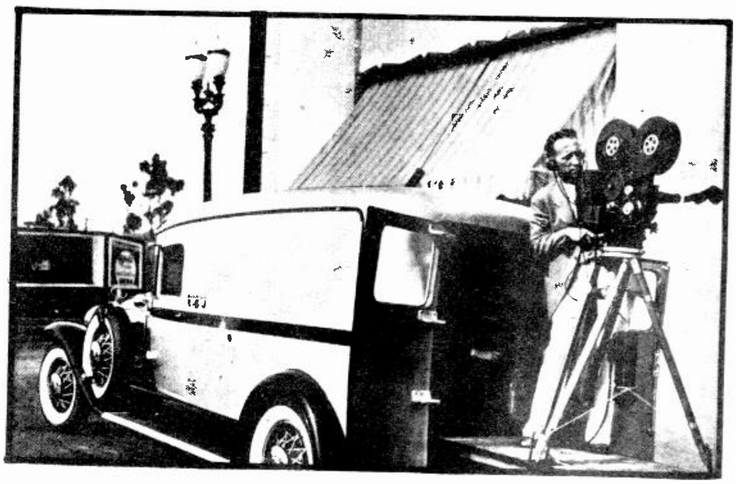


FIG. 4
Specialized Training Essential For Talking Picture Technicians.

MANY OF THE PUBLIC ADDRESS INSTALLATIONS PRESENT DIFFICULT PROBLEMS WHICH ONLY A MAN SPECIALLY TRAINED FOR THIS WORK CAN HANDLE SUCCESSFULLY. THESE PROBLEMS AND THE MOST EFFECTIVE MEANS OF SOLVING THEM WILL ALL BE BROUGHT TO YOUR ATTENTION.

ALL OF THE POPULAR AMPLIFYING CIRCUITS WILL BE FULLY EXPLAINED FROM A PRACTICAL AS WELL AS A TECHNICAL STANDPOINT.

TALKING PICTURES

THE TALKING PICTURE INDUSTRY ALONE REQUIRES THOUSANDS OF SKILLED TECHNICIANS TO CONSTRUCT, INSTALL, OPERATE AND SERVICE TALKING PICTURE EQUIPMENT FOR THEATERS, AS WELL AS TO CONSTRUCT, INSTALL, OPERATE AND SERVICE RECORDING EQUIPMENT IN THE STUDIOS. TALKING PICTURE EQUIPMENT IS RAPIDLY BEING ADAPTED BY SCHOOLS TO PROVIDE THEIR STUDENTS WITH INSTRUCTIVE PICTURES AND PORTABLE TALKING PICTURE EQUIPMENT IS NOW IN GREATER DEMAND THAN EVER BEFORE -- ALL OF THIS ACTIVITY MEANS MORE JOBS FOR THOSE MEN WHO ARE QUALIFIED TO HANDLE THEM.

THIS IS A LARGE AND MOST PROFITABLE FIELD FOR THE TRAINED MAN AND YOU WILL FIND YOUR INSTRUCTION UNDER THIS DIVISION TO ENABLE YOU TO TAKE ADVANTAGE OF ANY ONE OF THE GREAT MANY OPPORTUNITIES WHICH THIS GREAT FIELD OF RADIO HAS TO OFFER.

TELEVISION

YOUR TRAINING IN TELEVISION PREPARES YOU FOR THE FUTURE. ALTHOUGH

MANY TELEVISION STATIONS ARE ALREADY OPERATING ON REGULAR SCHEDULE AND BEING RECEIVED BY TELEVISION FANS, YET THIS BRANCH OF RADIO IS STILL IN ITS INFANCY AS COMPARED TO THE OTHER ALREADY HIGHLY DEVELOPED DIVISIONS.

TELEVISION IS THE THING FOR THE MAN WHO IS PLANNING AHEAD. THIS FIELD IS WAITING FOR NEW TALENT, CAPABLE OF ASSISTING IN THE DEVELOPMENT OF NEW EQUIPMENT, FOR THE EXPERIMENTER AND THE RESEARCH WORKER. TELEVISION IS BOUND TO BECOME A MOST POPULAR FORM OF ENTERTAINMENT IN THE NEAR FUTURE AND THE MEN WHO ARE GOING TO SHARE THE GREATEST PORTION OF THE PROFITS BROUGHT ABOUT BY THIS COMING INDUSTRY ARE THOSE WHO ARE PREPARING THEMSELVES NOW SO AS TO GET IN ON THE GROUND FLOOR.

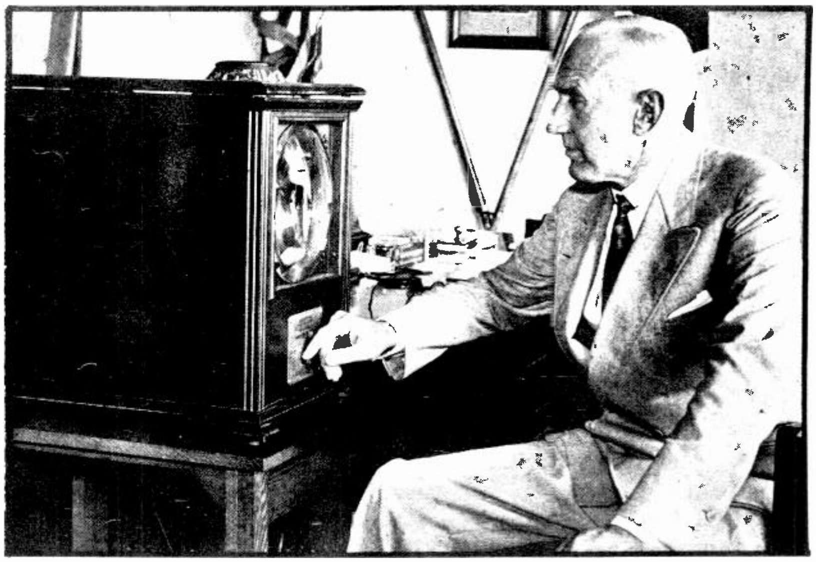


FIG. 5

Television - The Industry of Tomorrow.

YOU WILL FIND NATIONALS' INSTRUCTION IN TELEVISION TO PROVIDE YOU WITH A MOST THOROUGH KNOWLEDGE OF THIS SUBJECT SO THAT YOU WILL BECOME THOROUGHLY FAMILIAR WITH EVERY SUBJECT PERTAINING TO THIS FASCINATING BRANCH OF RADIO.

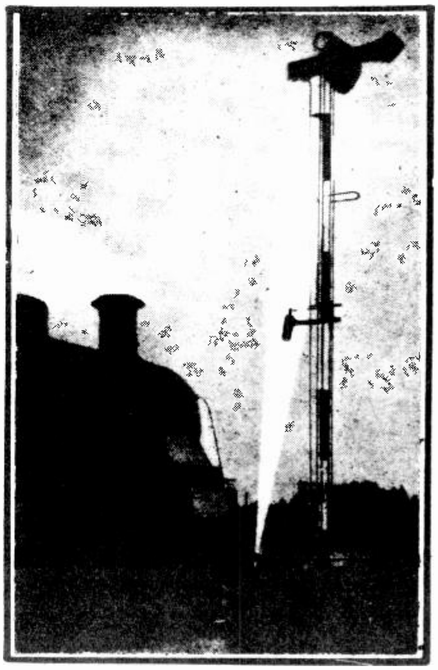


FIG. 6

Typical Application of the Photo Electric Cell.

PHOTO-ELECTRIC CELLS

CONTINUALLY, INDUSTRY IS FINDING NEW APPLICATIONS FOR THE PHOTO-ELECTRIC CELL OR "ELECTRIC-EYE" AS IT IS FREQUENTLY CALLED. THIS MARVELOUS DEVICE IS BEING USED IN A COUNTLESS NUMBER OF DIFFERENT WAYS FOR INDUSTRIAL PURPOSES, SUCH AS IN AUTOMATIC COUNTERS, ALARM SYSTEMS, SMOKE DETECTORS, COLOR ANALYZERS, PROTECTIVE DEVICES ETC.

EVERY ONE OF THESE MANY APPLICATIONS ARE BASED ENTIRELY UPON RADIO PRINCIPLES AND THE WORK ASSOCIATED WITH THIS EQUIPMENT IS CONFINED SOLELY TO THE RADIO MAN WITH SPECIALIZED TRAINING IN THIS FIELD SUCH AS YOU ARE RECEIVING.

WHEN YOU LOOK BACK AND CONSIDER WHAT YOU HAVE ALREADY LEARNED ABOUT RADIO THROUGH NATIONALS' SYSTEM OF TRAINING AND THEN LOOK AHEAD TO THE INSTRUCTION WHICH IS STILL IN STORE FOR YOU, YOU CANNOT HELP BUT REALIZE THE TREMENDOUS OPPORTUNITIES WHICH NATIONAL TRAIN ing is extending to you.

Upon completion of your training, you may select the branch of Radio in which you will specialize — Radio Service or Construction, Broadcasting or Commercial Transmission, Talking Pictures, Public Address Work, Television, Photo-Electric Cells or any other line of work associated with Radio.

Before you start this advanced work, we again caution you against rushing through your studies. From a financial standpoint, it is obvious that we would realize greater profits by forcing our students through this training program as quickly as possible but such a practice would be unfair to the student and is therefore not a policy of National.

This institution has offered residence training for over thirty years and not only have ambitious men come from all parts of the United States to take advantage of National's Time Tested Training but practically every country on the Globe has been represented in its Student Body. These many years of experience in vocational training have conclusively proved to us that our most successful graduates are those, who as students, progressed through their studies at a reasonable rate rather than centering their interest upon the rapidity with which they could complete the course.

Our Extension Training is by no means an ordinary correspondence course but is modeled after our Residence Curriculum where we have had the opportunity to personally supervise the instruction of every type of student. We are therefore offering you through the Extension Method the same high class form of instruction which you would receive as a student in our Residence Division and where every effort is made to offer the best type of instruction possible.

Although the lessons which are to come are of an advanced nature, yet we know that you are going to find them exceedingly interesting and to contain the type of information which will enable you to attain outstanding success in Radio or any of its branches.

Special Examination # 6

1. – Draw a circuit diagram of a six-tube T.R.F. receiver which is to be operated from an A.C. lighting supply. This receiver is to employ type -58 tubes in three R.F. stages, a -57 power detector, a 2A5 power amplifier and an -80 rectifier. This receiver is to be operated with a dynamic speaker whose 2500 ohm field coil is to be used as the only filter choke. This diagram is to be complete with power pack and the values of all resistors and condensers plainly marked.

2. – It is desired to wind the secondary winding of an R.F. transformer with #28 B&S enameled wire on a tubular-shaped cardboard form having a diameter of $1\frac{1}{2}$". This winding is to cover a frequency band of 540 to 1570 Kc. when tuned by a condenser having a rating of .00035 mfd. How many turns of wire should be used for this winding?

3. – Draw a circuit diagram of an A.C. operated superheterodyne receiver having the following features: One preselector R.F. stage using a type 58 tube; a first detector stage using a 58 tube; an oscillator using a 56 tube and two I.F. stages each employing type 58 tubes. The second detector is to be a 2A6 used simultaneously as a half-wave diode detector as an A.F. amplifier and to supply automatic volume control energy to the two I.F. stages, as well as to its own grid circuit. This second detector is to be followed by a push-pull power amplifier stage employing a pair of 2A5's. A dynamic speaker is to be used having a field coil of 2500 ohm resistance rating and which is to serve as the second filter choke of the power pack. The speaker field is to be preceded in the filter system by a choke of 30 henry rating.

This diagram is to be complete and with the values of all resistors and condensers clearly marked.

4. – A certain milliammeter has an internal resistance of 27 ohms and a scale calibrated from 0 to 1 ma. It is desired to use this meter as a multi-range milliammeter and voltmeter having the following ranges: 0-1-10-100-200 milliamperes and 0-10-100-200-400 volts D.C. Supply complete constructional data for building a test unit which will meet the requirements called for.

5. – If an inductance of 250 microhenries is connected in series with a condenser of .0005 mfd., to what frequency will this combination resonate? What will be the corresponding wavelength?

6. – If a certain A.C. receiver is inoperative but all tube filaments light and the plates of the -80 tube take on a red color when the switch is turned on, what is the most likely cause for the trouble?

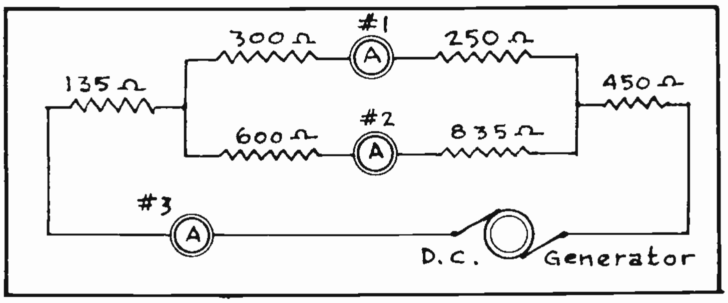
7. – If a certain superheterodyne radio-phonograph combination has the pick-up unit connected to the second detector tube through an impedance matching transformer and volume control, and phonograph reproduction is entirely satisfactory but radio reception is impossible, then where would you look to locate the trouble?

8. – A choke coil having an inductance value of 30 henries and a D.C. resistance of 100 ohms is connected in series with two condensers, each of which has a capacity rating of 4 mfd. What impedance will this arrangement offer to a 120 cycle current? What will be the power factor of this circuit?

9. – In order to deliver an output power of 3 watts, the recommended plate circuit load for the 2A5 tube is 7000 ohms. If two of these tubes are used in a push-pull power stage and are to be coupled to a dynamic speaker whose voice coil has an impedance rating of 8 ohms, then what turns ratio should be employed on the output or speaker coupling transformer?

10.– What rule can be applied in order to determine the capacitive rating of a condenser which is to be used for by-passing purposes around a resistor in an R.F. or A.F. circuit?

11.– What is the total or combined resistance of the circuit which is here illustrated? What value of current flow will the ammeter #1; #2 and #3 each indicate if the generator voltage is 650 volts? Show all calculations in your answers to this problem.



12.– Describe in detail how you would completely align a superheterodyne receiver which employs three I.F. transformers, a padded oscillator circuit, and a single tuned R.F. stage preceding the first detector tube (the tuning condenser is of the conventional three gang type).

13.– A certain superheterodyne receiver fails to reproduce any broadcast signals, and yet upon conducting an analyzer test at all tube sockets, the readings are found to be correct. Explain in detail how you can determine whether the trouble is located in the A.F. amplifier system, I.F. amplifier system, first detector stage, pre-selector stage or in the oscillator circuit.

14.– How can you determine the mutual inductance between two coils by measurement? Having determined this value, how can the coefficient of coupling be determined by calculation?

15.– The winding of a certain tuned circuit in an R.F. amplifier has an inductance of 280 microhenries and the D.C. resistance of the tuning circuit is 10 ohms. What will be the width of the resonance curve for this circuit at a point equivalent to .707 times the current at resonance, if the resonant frequency is 850 Kc.?

PRACTICAL RADIO JOB SHEET

NO. 1

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

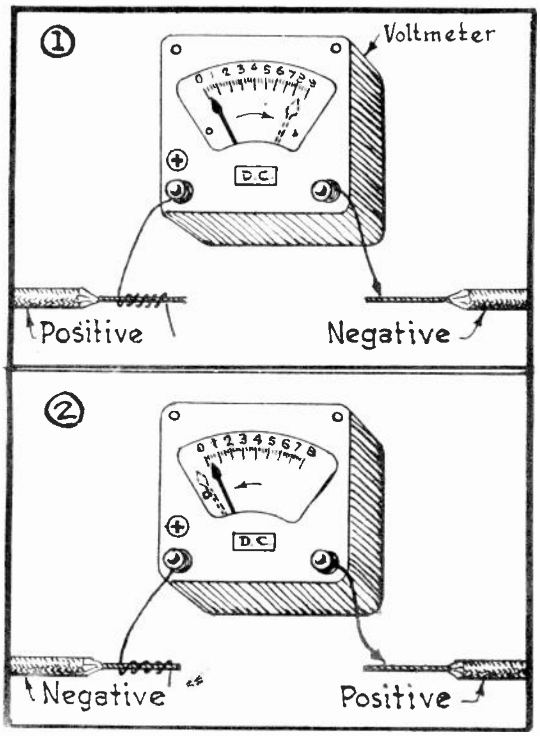
Los Angeles California

DETERMINING POLARITY OF D.C. CIRCUITS

WHEN ENGAGED IN RADIO WORK, THE OCCASSION FREQUENTLY ARISES WHERE IT BECOMES NECESSARY TO DETERMINE WHICH SIDE OF A D.C. (DIRECT CURRENT) CIRCUIT IS "POSITIVE" AND WHICH "NEGATIVE". THIS CAN BE DETERMINED THROUGH THE USE OF EITHER A D.C. VOLTMETER OR BY MEANS OF ELECTROLYSIS IN THE MANNER NOW TO BE EXPLAINED.

THE VOLTMETER METHOD

1. - USE A D.C. TYPE VOLTMETER WHOSE SCALE RANGE IS SUFFICIENTLY GREAT TO INDICATE THE VOLTAGE OF THE CIRCUIT UNDER TEST.



Voltmeter Method.

2. - CONNECT ONE TEST LEAD TO THE POSITIVE OR (+) TERMINAL OF THE VOLTMETER AND A SECOND TEST LEAD TO THE OTHER VOLTMETER TERMINAL AS SHOWN IN FIG. 1.

3. - TOUCH THE TWO TEST POINTS TO THE TWO SIDES OF THE CIRCUIT UNDER TEST AS ALSO SHOWN IN FIG. 1 AND NOTE THE MOVEMENT OF THE METER NEEDLE AS YOU DO SO. THIS CONNECTION SHOULD BE COMPLETED FOR ONLY AN INSTANT SO AS TO AVOID DAMAGING THE VOLTMETER IN CASE THAT THE NEEDLE SWINGS OFF ITS SCALE TOWARDS THE LEFT OF THE ZERO MARK.

4. - SHOULD THE VOLTMETER NEEDLE SWING OFF ITS SCALE TOWARDS THE LEFT OF ZERO AS IN FIG. 2, THEN THE TEST INDICATES THAT THE POSITIVE OR (+) TERMINAL OF THE VOLTMETER IS CONNECTED TO THE NEGATIVE SIDE OF THE CIRCUIT UNDER TEST. ON THE OTHER HAND, IF THE METER NEEDLE SWINGS ACROSS ITS SCALE TOWARDS THE RIGHT OR IN ITS NORMAL DIRECTION, AS IN FIG. 1, THEN THE TEST INDICATES THAT THE POSITIVE OR (+) TERMINAL OF THE VOLTMETER IS CONNECTED TO THE POSITIVE SIDE OF THE CIRCUIT UNDER TEST. THE OTHER SIDE OF THE CIRCUIT WILL THEN NATURALLY BE THE NEGATIVE SIDE.

THE ELECTROLYSIS METHOD

IF NO D.C. VOLTMETER IS AVAILABLE, THEN THE UNKNOWN LINE POLARITY CAN BE DETERMINED THROUGH THE PRINCIPLE OF ELECTROLYSIS AS ILLUSTRATED IN

(OVER)

FIG. 3. IN THIS CASE, PROCEED AS FOLLOWS:

1. – CONNECT A PAIR OF TEST LEADS ACROSS THE CIRCUIT UNDER TEST AND SUBMERGE THE FREE ENDS OF THE TEST LEADS IN A GLASS OF WATER TO WHICH A LITTLE TABLE SALT HAS BEEN ADDED. AN ALTERNATIVE IS TO SUBMERGE THE BARED COPPER ENDS OF THE CIRCUIT WIRES DIRECTLY INTO THE SALT WATER.

2. – USE CARE THAT THE TWO BARE ENDS OF THE WIRE OR TEST POINTS, WHICH ARE SUBMERGED IN THE SALT WATER, ARE NOT PLACED TOO CLOSE TOGETHER SO AS TO FORM A SHORT CIRCUIT AND WATCH FOR THE FORMATION OF BUBBLES. THE WIRE OR TEST LEAD, AROUND WHICH THE MOST BUBBLES ARE PRODUCED, CORRESPONDS TO THE NEGATIVE SIDE OF THE CIRCUIT.

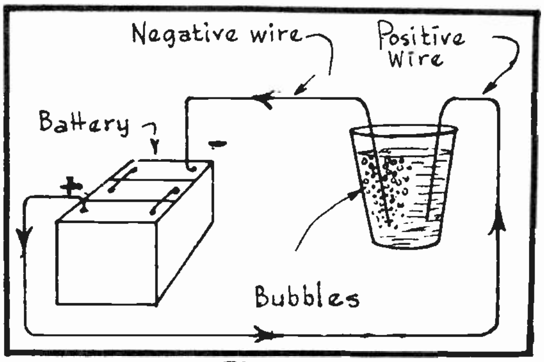


Fig. 3
Electrolysis Method.

3. – WHEN HANDLING WIRES ACROSS WHICH CONSIDERABLE VOLTAGE EXISTS, ALWAYS BE SURE NEVER TO GRASP THE BARE WIRES AT ANY TIME DURING ANY TEST WHILE THE CIRCUIT IS "ALIVE". ONLY GRASP THE INSULATIVE MATERIAL WHICH YOU ARE CERTAIN AS BEING ADEQUATE TO PREVENT YOUR RECEIVING AN ELECTRIC SHOCK.

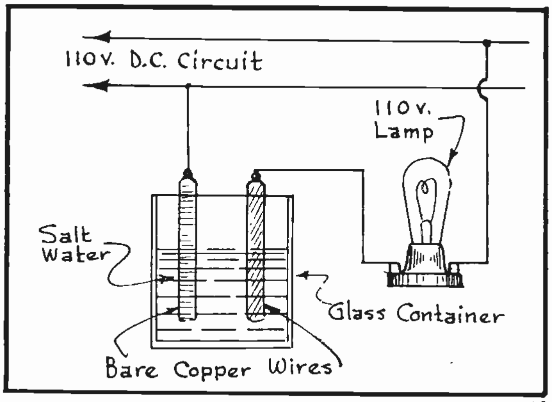


Fig. 4
Limiting The Current Flow.

4. – WHENEVER TESTING CIRCUITS, WHICH HANDLE VOLTAGE OF 110 VOLTS AND UP, A LAMP SHOULD BE CONNECTED IN SERIES WITH THE CIRCUIT BEING TESTED AND THE ELECTROLYTIC POLARITY INDICATOR AS SHOWN IN FIG. 4. THE LAMP WILL THUS ACT AS A RESISTANCE AND THEREBY PREVENT SHORT CIRCUITS AND DISASTROUS ACCIDENTS. FOR A 110 VOLT CIRCUIT, A 110 VOLT LAMP SHOULD BE USED AND FOR A 220 VOLT CIRCUIT, A 220 VOLT LAMP. THE LAMP IN EITHER CASE MAY BE RATED AT ABOUT 40 WATTS.

5. – ALL PARTS OUTSIDE OF THE SALT WATER IN THE GLASS CONTAINER SHOULD BE MAINTAINED IN A PERFECTLY DRY CONDITION WHEN USING THIS TESTER, AS SHOULD ALSO THE HANDS OF THE OPERATOR SO AS TO REDUCE TO A MINIMUM THE POSSIBILITY OF RECEIVING AN ELECTRIC SHOCK.

PRINTED IN U.S.A.

PRACTICAL RADIO JOB SHEET

NO. 2

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

HOW TO DETERMINE IF A GIVEN CIRCUIT IS OF A.C OR D.C. TYPE

PARTICULARLY WHEN A RECEIVER IS TO BE INSTALLED, THE QUESTION OFTEN ARISES AS TO WHETHER THE CIRCUIT FROM WHICH IT IS TO BE OPERATED IS OF THE A.C. OR D.C. TYPE. IT IS OF COURSE TRUE THAT THIS INFORMATION CAN BE OBTAINED FROM THE POWER COMPANY OR BY READING THE DATA SUPPLIED ON THE SPECIFICATION PLATE OF SOME OTHER ELECTRICAL APPARATUS SUCH AS A VACUUM CLEANER, WASHING MACHINE ETC. WHICH IS BEING OPERATED FROM THE SAME CIRCUIT, OR EVEN FROM THE COMPANY METER AT THE SERVICE ENTRANCE. IN THIS JOB SHEET, HOWEVER, A SIMPLE BUT PRACTICAL TEST IS DESCRIBED WHICH WILL DEFINITELY DEMONSTRATE WHETHER THE CIRCUIT IN QUESTION IS OF THE A.C. OR D.C. TYPE. THE TEST SHOULD BE CONDUCTED IN THE FOLLOWING ORDER:

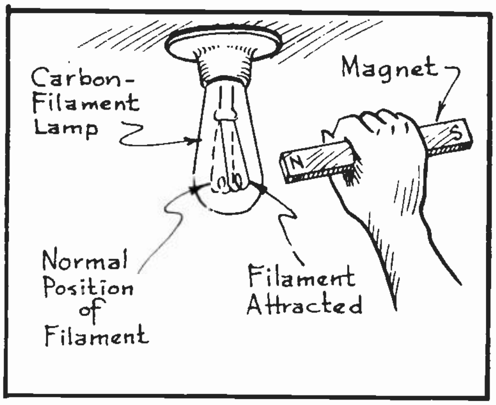


Fig. 1
The D.C. Indication.

1. - SCREW A CARBON-FILAMENT LAMP INTO A SOCKET WHICH IS CONNECTED ACROSS THE CIRCUIT TO BE TESTED. WHEN THE LAMP FILAMENT IS HEATED TO INCANDESCENCE, THE FILAMENT WILL BE NOTED TO REMAIN AT REST AT THE APPROXIMATE CENTER OF THE GLASS BULB.

2. - NOW SLOWLY MOVE A PERMANENT MAGNET (EITHER A BAR OR HORSESHOE TYPE) TOWARDS THE LAMP AS ILLUSTRATED IN FIG. 1 AND CAREFULLY NOTE THE REACTION UPON THE LAMP FILAMENT.

3. - IF THE MAGNET ATTRACTS THE LAMP FILAMENT AS SHOWN IN FIG. 1, THEN THE TEST DEMONSTRATES THAT THE CIRCUIT IN QUESTION IS OF THE D.C. TYPE.

4. - SHOULD THE LAMP FILAMENT UNDERGO A VIBRATIONAL MOVEMENT AS SHOWN IN FIG. 2 WHEN THE MAGNET IS SLOWLY BROUGHT TOWARDS IT, THEN THE TEST DEMONSTRATES THAT AN ALTERNATING CURRENT IS FLOWING THROUGH THE CIRCUIT.

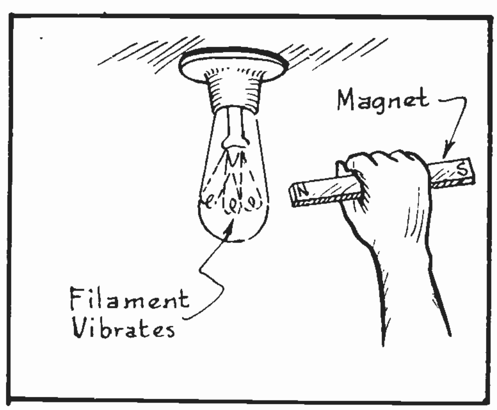


Fig. 2
The A.C. Indication.

5. - IT IS IMPORTANT TO NOTE THAT A CARBON-FILAMENT TYPE LAMP IS SPECIFIED FOR THIS TEST. THE REASON FOR THIS IS THAT THE FILAMENT IN THIS TYPE

(OVER)

OF LAMP IS NOT SO RIGIDLY SUPPORTED AS IN THE TUNGSTEN-FILAMENT LAMPS AND CAN THEREFORE RESPOND TO MOVEMENT MORE READILY WHEN ACTED UPON BY A MAGNETIC FIELD. ALSO BEAR IN MIND THAT WHEN THE TEST IS MADE ON AN A.C. CIRCUIT, THE MAGNET SHOULD NOT BE BROUGHT TOO NEAR THE LAMP AS EXCESSIVE VIBRATION OF THE FILAMENT WILL CAUSE IT TO BREAK AND THEREBY DESTROY THE LAMP.

VOLTMETER INDICATION

IF A DIRECT-CURRENT, PERMANENT MAGNET TYPE VOLTMETER IS AVAILABLE, IT WILL ALSO SERVE TO INDICATE WHETHER THE CIRCUIT IN QUESTION IS OF THE A.C. OR D.C. TYPE. IN THIS CASE, THE TEST SHOULD BE PERFORMED AS FOLLOWS:

1. FIRST MAKE SURE THAT THE RANGE OF THE VOLTMETER IS GREAT ENOUGH TO STAND THE VOLTAGE OF THE CIRCUIT ACROSS WHICH THE TEST IS TO BE MADE.

2. CONNECT THE VOLTMETER ACROSS THE CIRCUIT MOMENTARILY AS ILLUSTRATED IN FIG. 3. SHOULD THE NEEDLE TEND TO SWING OFF ITS SCALE TOWARDS THE LEFT OF THE ZERO MARK, THEN REVERSE THE CONNECTIONS.

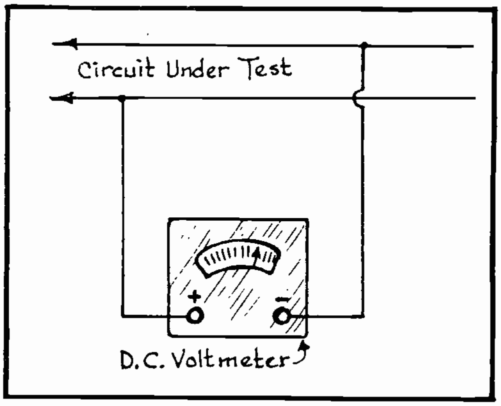


Fig. 3
The Voltmeter Test.

3. IF THE CIRCUIT IN QUESTION HAPPENS TO BE OF THE D.C. TYPE, THEN THE METER WILL OFFER A STEADY READING AND INDICATE THE VOLTAGE OF THE CIRCUIT IN THE NORMAL MANNER.

4. SHOULD THE CIRCUIT IN QUESTION BE OF THE A.C. TYPE, THEN THE VOLTMETER NEEDLE WILL VIBRATE SLIGHTLY.

5. WHEN CONDUCTING THIS TEST, IT IS NOT NECESSARY TO LEAVE THE VOLTMETER CONNECTED TO THE CIRCUIT FOR ANY APPRECIABLE LENGTH OF TIME. THE DESIRED INDICATION CAN BE OBTAINED AT A GLANCE.

NO. 3

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

DIMENSION, WEIGHT & RESISTANCE OF BARE SOLID COPPER WIRE

(Brown & Sharpe Gauge)

B&S WIRE SIZE	DIAM. IN MILS. AT 20° C.	CROSS-SECTIONAL AREA		WEIGHT LBS. PER 1000 FT.	FEET PER LB.	RESISTANCE OHMS PER 1000 FEET		
		CIRCULAR MILS.	SQUARE INCHES			AT 20° C. 68° F.	AT 25° C. 77° F.	AT 75° C. 167° F.
0000	460.0	211,600.	0.1662	640.5	1.561	0.04901	0.04998	.05961
000	409.6	167,800.	0.1318	507.9	1.968	0.06180	0.06302	0.07516
00	364.8	133,100.	0.1045	402.8	2.482	0.07793	0.07947	0.09478
0	324.9	105,500.	0.08289	319.5	3.130	0.09827	0.10020	0.11950
1	289.3	83,640.	0.06573	253.3	3.947	0.12390	0.12640	0.15070
2	257.6	66,370.	0.05213	200.9	4.977	0.15630	0.15930	0.19000
3	229.4	52,640.	0.04134	159.3	6.276	0.19700	0.20090	0.23560
4	204.3	41,740.	0.03278	126.4	7.914	0.24850	0.25330	0.30220
5	181.9	33,100.	0.02600	100.2	9.980	0.31330	0.31950	0.38100
6	162.0	26,250.	0.02062	79.46	12.58	0.39510	0.40280	0.48050
7	144.3	20,820.	0.01635	63.02	15.87	0.49820	0.50800	0.60590
8	128.5	16,510.	0.01297	49.98	20.01	0.62820	0.64050	0.76400
9	114.4	13,090.	0.01028	39.63	25.23	0.79210	0.80770	0.96330
10	101.9	10,380.	0.00815	31.43	31.82	0.99890	1.018	1.2150
11	90.74	8,234.	0.00646	24.92	40.12	1.260	1.284	1.5320
12	80.81	6,530.	0.00512	19.77	50.59	1.588	1.619	1.9310
13	71.96	5,178.	0.00406	15.68	63.80	2.003	2.042	2.4360
14	64.08	4,107.	0.00322	12.43	80.44	2.525	2.575	3.0710
15	57.07	3,205.	0.00255	9.858	101.4	3.184	3.247	3.8730
16	50.82	2,583.	0.00202	7.818	127.9	4.016	4.094	4.8840
17	45.26	2,048.	0.00160	6.200	161.3	5.064	5.163	6.1580
18	40.30	1,624.	0.00127	4.917	203.4	6.385	6.510	7.7650
19	35.89	1,288	0.00101	3.899	256.5	8.051	8.210	9.7920
20	31.96	1,022.	0.00080	3.092	323.4	10.15	10.35	12.350
21	28.46	810.10	0.00063	2.452	407.8	12.80	13.05	15.570
22	25.35	642.40	0.00050	1.945	514.2	16.14	16.46	19.630
23	22.57	509.50	0.00040	1.542	648.4	20.34	20.76	24.760
24	20.10	404.00	0.00031	1.223	817.4	25.67	26.17	31.220
25	17.90	320.40	0.00025	0.9699	1031.0	32.37	33.00	39.360
26	15.94	254.10	0.00019	0.7692	1300.0	40.81	41.62	49.640
27	14.20	201.50	0.00015	0.6100	1639.0	51.47	52.48	62.590
28	12.64	159.80	0.00012	0.4837	2067.0	64.90	66.17	78.930
29	11.26	126.70	0.00009	0.3836	2607.0	81.83	83.44	99.520
30	10.03	100.50	0.00007	0.3042	3287.0	103.2	105.2	125.50
31	8.928	79.70	0.00006	0.2413	4145.0	130.1	132.7	158.20
32	7.950	63.21	0.00004	0.1913	5227.0	164.1	167.3	199.50
33	7.080	50.13	0.000039	0.1517	6591.0	206.9	211.0	251.60
34	6.305	39.75	0.000031	0.1203	8310.0	260.9	266.0	317.30
35	5.615	31.52	0.000024	0.0954	10480.	329.0	335.5	400.10
36	5.000	25.00	0.000019	0.0756	13210.	414.8	423.0	504.50
37	4.453	19.83	0.000015	0.0600	16660.	523.1	533.4	636.20
38	3.965	15.72	0.000012	0.0475	21010.	659.6	672.6	802.20
39	3.531	12.47	0.000009	0.0377	26500.	831.8	848.1	1012.0
40	3.145	9.88	0.000007	0.0299	33410.	1049	1069	1276.0

PRACTICAL RADIO JOB SHEET

NO. 4

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

ALLOWABLE CARRYING CAPACITIES OF COPPER WIRE AND CABLE

B&S SIZE	CIRCULAR MIL AREA	CURRENT CARRYING CAPACITY		
		RUBBER INSULATION	ENAMELED COTTON COVERED	OTHER INSULATION
18	1,624	3	5	5
16	2,583	6	10	10
14	4,107	15	18	20
12	6,530	20	25	25
10	10,380	25	30	30
8	16,510	35	40	50
6	26,250	50	60	70
5	33,100	55	65	80
4	41,740	70	85	90
3	52,630	80	95	100
2	66,370	90	110	125
1	83,690	100	120	150
0	105,500	125	150	200
00	133,100	150	180	225
000	167,800	175	210	275
	200,000	200	240	300
0000	211,600	225	270	325
	250,000	250	300	350
	300,000	275	330	400
	350,000	300	360	450
	400,000	325	390	500
	500,000	400	480	600
	600,000	450	540	680
	700,000	500	600	760
	800,000	550	660	840
	900,000	600	720	920
	1,000,000	650	780	1,000
	1,000,000	690	830	1,080
	1,200,000	730	880	1,150
	1,300,000	770	920	1,220
	1,400,000	810	970	1,290
	1,500,000	850	1,020	1,360
	1,600,000	890	1,070	1,430
	1,700,000	930	1,120	1,490
	1,800,000	970	1,160	1,550
	1,900,000	1,010	1,210	1,610
	2,000,000	1,050	1,260	1,670

PRINTED IN U.S.A

NO. 5

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

ALIGNING THE TUNING CIRCUITS OF T.R.F. RECEIVERS – USING BROADCAST SIGNALS

BY "ALIGNING" A RECEIVER IS MEANT THAT THE VARIOUS SECTIONS OF THE GANG TUNING CONDENSER ARE ALL ADJUSTED SO THAT THEY WILL TUNE TOGETHER OR BE IN SYNCHRONISM THROUGHOUT THE ENTIRE TUNING RANGE. THIS PARTICULAR JOB SHEET OFFERS INSTRUCTIONS FOR DOING THIS WORK ON RECEIVERS OF THE STRAIGHT "TUNED RADIO-FREQUENCY" OR T.R.F. TYPE ONLY. LATER JOB SHEETS SUPPLY THE INFORMATION FOR DOING THIS WORK ON SUPERHETERODYNES.

PROPER ALIGNMENT WILL MAKE POSSIBLE A LOUDER AND CLEARER SIGNAL, BETTER TONE QUALITY AND GREATER FREEDOM FROM INTER-STATION INTERFERENCE.

1. – TO ALIGN THE RECEIVER, FIRST TUNE THE SET TO RESONANCE WITH THE SIGNAL OF SOME FAIRLY DISTANT STATION WHICH IS BROADCASTING AT A MEDIUM FREQUENCY (AROUND 1000 KC) AND SET THE VOLUME CONTROL AT THE POSITION OFFERING MEDIUM SIGNAL INTENSITY.

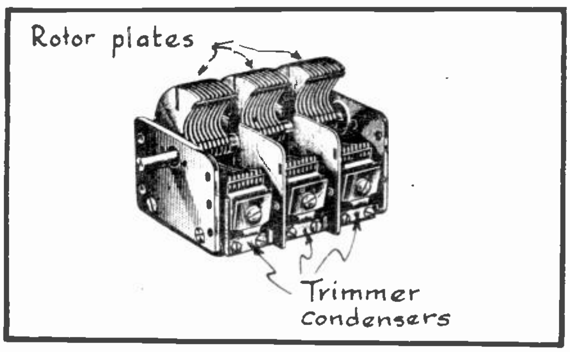


Fig. 1
Three-Gang Tuning Condenser.

2. – WITH THE TUNING DIAL SET TO THE POSITION OFFERING SHARPEST TUNING TO THIS FREQUENCY, ADJUST THE COMPENSATING OR TRIMMER CONDENSER OF THE DETECTOR STAGE UNTIL LOUDEST SIGNAL VOLUME IS EMITTED BY THE SPEAKER. THESE TRIMMERS SHOULD BE ADJUSTED WITH EITHER A BAKELITE SCREW-DRIVER OR BAKELITE WRENCH, WHICHEVER IS SUITABLE FOR THE PARTICULAR DESIGN. DO NOT ALTER THE POSITION OF EITHER THE TUNING OR VOLUME CONTROL WHILE MAKING THE ALIGNING ADJUSTMENTS.

3. – THE TRIMMERS OF THE FOLLOWING STAGES ARE THEN EACH ADJUSTED IN TURN AND SET FOR THE LOUDEST SPEAKER SIGNAL IN THE SAME MANNER AS JUST DESCRIBED.

4. – AFTER THIS AVERAGE SETTING HAS BEEN MADE FOR ALL SECTIONS OF THE TUNING CONDENSER, TUNE-IN ANOTHER SIGNAL AT THE HIGH FREQUENCY END OF THE DIAL OR AT ABOUT THE 1400 KC. POSITION. IF SLOTTED ROTOR PLATES ARE EMPLOYED ON THE CONDENSER, THEN BEND THE LAST SEGMENT OF THE TRAILING END OF EACH CONDENSER SECTION SLIGHTLY ONE WAY OR THE OTHER UNTIL EACH SECTION IS ADJUSTED FOR MAXIMUM VOLUME.

THIS PLATE SEGMENT WOULD CORRESPOND TO SEGMENT #1 AS POINTED OUT IN FIG.2 AND WHICH WILL BE FOUND ON THE OUTER ROTOR PLATES IN EACH SECTION OF MODERN GANG CONDENSERS.

(OVER)

5. - TUNE IN SIGNALS AT 1100 - 850 - 700 - 600 AND 550 KC. EACH IN TURN AND AT EACH SETTING, BEND FOR LOUDEST SIGNAL THE LAST SLOTTED SEGMENT OF EACH ROTOR PLATE GROUP WHICH CAME INTO MESH WITH THE STATORPLATES AS THE POSITION OF THE ROTOR PLATES WAS CHANGED.

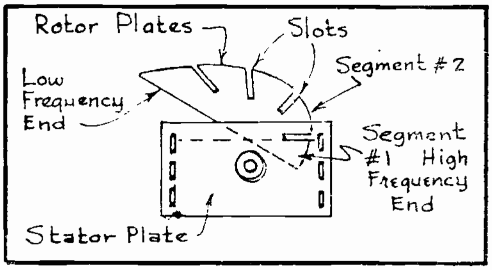


Fig. 2
Provisions For Bending Plates.

IN OTHER WORDS, AS THE DIALSETTINGS ARE GRADUALLY CHANGED FROM THE HIGHER TO THE LOWER FREQUENCIES, ROTOR PLATE SEGMENTS #2 AS PER FIG. 2 WILL BE ADJUSTED AT EACH SECTION AS THEY FOLLOW SEGMENTS #1 INTO MESH WITH THE STATOR PLATE GROUPS ETC., UNTIL THE FINAL SEGMENTS AT THE OTHER EXTREME POSITION HAVE BEEN ADJUSTED FOR THE LOWEST FREQUENCY SETTINGS.

6. - UPON COMPLETION OF THIS JOB, THE RECEIVER WILL BE PROPERLY ALIGNED THROUGHOUT ITS RANGE OF TUNING AND AS A FINAL CHECK, STATIONS AT VARIOUS FREQUENCIES CAN BE TUNED IN AND THE PERFORMANCE OF THE RECEIVER CAREFULLY NOTED. ANY ADDITIONAL ADJUSTMENT WHICH MAY BE FOUND NECESSARY CAN THEN BE MADE.

ALIGNING RECEIVER WITH SERVICE OSCILLATOR

INSTEAD OF USING A BROADCAST SIGNAL FOR ALIGNING PURPOSES, THE USE OF A MODULATED R.F. SERVICE OSCILLATOR, OR SIGNAL GENERATOR, OFFERS A MORE ACCURATE METHOD FOR MAKING THE ALIGNING ADJUSTMENTS. THIS IS DONE IN THE FOLLOWING ORDER:

1. DISCONNECT THE ANTENNA AND GROUND WIRES FROM THE RECEIVER.

2. CONNECT THE "ANTENNA" TERMINAL OF THE SERVICE OSICLLATOR TO THE ANTENNA TERMINAL OF THE RECEIVER AND THE "GROUND" TERMINAL OF THE SERVICE OSCILLATOR TO THE GROUND TERMINAL OF THE RECEIVER, AS SHOWN IN FIG. 3.

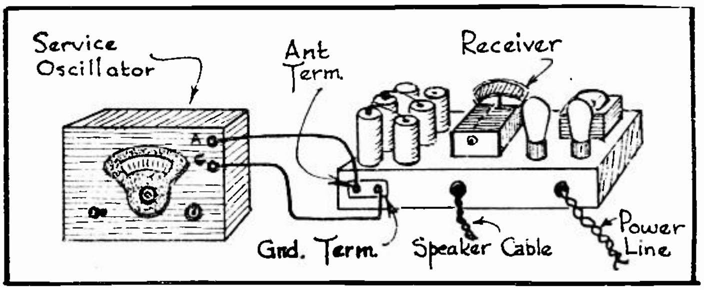


Fig. 3
Set-Up For Aligning Receiver With Service Oscillator.

3. PLACE THE OSCILLATOR AND RECEIVER IN OPERATION, ADJUST THE OSCILLATOR TO PRODUCE A 1000 KC. SIGNAL AND TUNE IN THIS SIGNAL ON THE RECEIVER AND ADJUST THE VOLUME CONTROL FOR MEDIUM OSCILLATOR SIGNAL THROUGH THE LOUD SPEAKER.

4. ADJUST THE RECEIVER'S TUNED CIRCUITS FOR MAXIMUM SIGNAL IN THE SAME ORDER AS ALREADY DESCRIBED WHEN USING A BROADCAST SIGNAL FOR THIS PURPOSE.

5. TUNE THE SERVICE OSCILLATOR AND RECEIVER IN TURN TO 1400-1100-850 - 700 - 600 AND 550 KC. AND ADJUST THE TUNED CIRCUITS FOR MAXIMUM SIGNALS IN THE SAME MANNER AS ALREADY EXPLAINED WHEN USING A BROADCAST SIGNAL FOR THIS PURPOSE.

PRACTICAL RADIO JOB SHEET NO. 6

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

NEUTRALIZING THE R.F. STAGES OF RADIO RECEIVERS

BY NEUTRALIZATION IS MEANT THE PROCESS OF COUNTERACTING THE REGENERATIVE FEED BACK, WHICH FLOWS FROM THE PLATE TO GRID CIRCUITS IN R.F. STAGES, IN WHICH TUBES OF THE NON-SCREEN GRID TYPE ARE USED.

IF AN ADJUSTMENT OF THIS NATURE IS NECESSARY, IT WILL MAKE ITSELF KNOWN BY THE FACT THAT THE RECEIVER, WHEN IN OPERATION, WILL OSCILLATE AND THEREBY CAUSE SQUEALING SOUNDS TO BE EMITTED FROM THE SPEAKER.

1. - TO MAKE A NEUTRALIZING ADJUSTMENT, YOU CAN EITHER USE THE SIGNAL ENERGY SUPPLIED BY A BROADCASTING STATION OR ELSE THE OUTPUT OF A MODULATED OSCILLATOR. THE LATTER IS PREFERABLE.

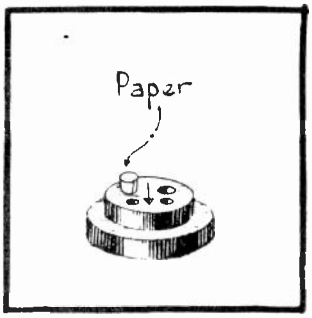


Fig. 1
Insulating The Filament Prong.

2. - TUNE THE RECEIVER TO A SIGNAL FREQUENCY OF ABOUT 1400 KC. AND SET THE VOLUME CONTROL AT ITS LOUDEST POSITION.

3. - REMOVE THE R.F. TUBE PRECEDING THE DETECTOR AND INSERT A PIECE OF PAPER INTO ONE OF THE FILAMENT HOLES OF THIS TUBE'S SOCKET, AS SHOWN IN FIG. 1, SO THAT ONE FILAMENT PRONG OF THE TUBE WILL BE INSULATED FROM THE SOCKET CONTACT WHEN THE BULB IS AGAIN INSERTED, THUS PREVENTING THE FILAMENT FROM BURNING.

4. - INSERT THE TUBE IN ITS SOCKET, LEAVING THE PAPER SLEEVE UNDISTURBED AND NOTE THAT ITS FILAMENT DOESN'T BURN. BE SURE THAT YOU DO NOT DISTURB THE SETTING OF NEITHER THE VOLUME OR TUNING CONTROL DURING THIS WORK AND ONLY USE THE SWITCH AS A MEANS OF STARTING OR STOPPING THE RECEIVER'S OPERATION, OR ELSE CONNECT AND DISCONNECT THE RECEIVER FROM THE LINE IN ORDER TO START AND STOP IT.

5. - WITH THIS "DEAD" TUBE INSERTED IN ITS SOCKET, NO SOUND SHOULD COME FROM THE SPEAKER. IF A SOUND IS HEARD, THEN ADJUST THE NEUTRALIZING CONDENSER FOR THIS STAGE BY MEANS OF A BAKELITE SCREW DRIVER. WITH A PROPER ADJUSTMENT OBTAINED, NO SIGNAL SHOULD BE HEARD AT THE SPEAKER. HAVING NEUTRALIZED THIS R.F. STAGE, OPEN THE SWITCH, REMOVE THE TUBE AND PAPER AND RE-INSERT THE TUBE IN ITS SOCKET.

6. - NOW PERFORM THE SAME ADJUSTING PROCESS WITH THE R.F. TUBE PRECEDING THE LAST R.F. TUBE, AND GRADUALLY CARRY OUT THIS WORK UNTIL YOU HAVE FINALLY ADJUSTED THE FIRST R.F. STAGE IN LIKE MANNER. EACH R.F. STAGE IS THUS NEUTRALIZED IN CONSECUTIVE ORDER FROM THE ONE PRECEDING THE DETECTOR TOWARDS THE ANTENNA.

7. - REMEMBER, THAT THE VOLUME AND TUNING CONTROL SETTINGS SHOULD NOT UNDER ANY CONDITIONS BE DISTURBED FROM THEIR ORIGINAL SETTING UNTIL

(OVER)

THE ENTIRE RECEIVER IS NEUTRALIZED.

8. – WHEN NEUTRALIZING THE R.F. STAGES OF A RECEIVER IN WHICH THE FILAMENTS OF THE VARIOUS R.F. TUBES ARE CONNECTED IN SERIES INSTEAD OF PARALLEL, THEN THE FILAMENT OF THE TUBE BEING NEUTRALIZED CAN BEPREVENTED FROM BURNING BY SHORTING ITS FILAMENT PRONGS CLOSE TO THE TUBE BASE BY MEANS OF A FAIRLY THIN PIECE OF WIRE AS SHOWN IN FIG.2. THIS WILL STILL PERMIT THE TUBE TO BE INSERTED INTO ITS SOCKET, AT THE SAME TIME PUTTING THE FILAMENT OUT OF COMMISSION.

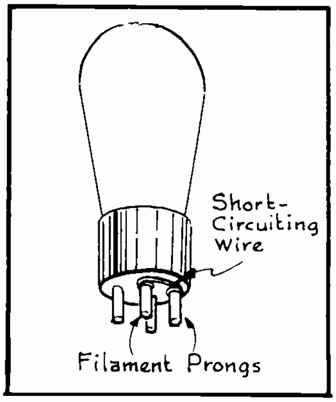


Fig. 2
Short Circuiting
The Filament Prongs.

THE OSCILLATOR METHOD

TO MAKE THESE NEUTRALIZING ADJUSTMENTS, IT IS ALSO POSSIBLE TO USE A MODULATED R.F. SERVICE OSCILLATOR AS THE SOURCE FOR THE SIGNAL AND THIS IS ACCOMPLISHED IN THE FOLLOWING MANNER:

1.– DISCONNECT THE ANTENNA AND GROUND WIRES FROM THE RECEIVER.

2.– CONNECT THE "ANTENNA" TERMINAL OF THE SERVICE OSCILLATOR TO THE ANTENNA TERMINAL OF THE RECEIVER AND THE "GROUND" TERMINAL OF THE SERVICE OSCILLATOR TO THE GROUND TERMINAL OF THE RECEIVER, AS SHOWN IN FIG.3.

3. PLACE THE OSCILLATOR AND RECEIVER IN OPERATION, ADJUST THE OSCILLATOR TO PRODUCE A 1400 KC. SIGNAL AND TUNE IN THIS SIGNAL WITH THE RECEIVER AT HIGH VOLUME.

4.–FROM THIS STEP ON, THE SAME PROCEDURE IS FOLLOWED AS OUTLINED IN PARAGRAPHS #3 TO #8 IN THIS SAME JOB SHEET, WHERE THE BROADCAST SIGNAL IS USED FOR THIS PURPOSE.

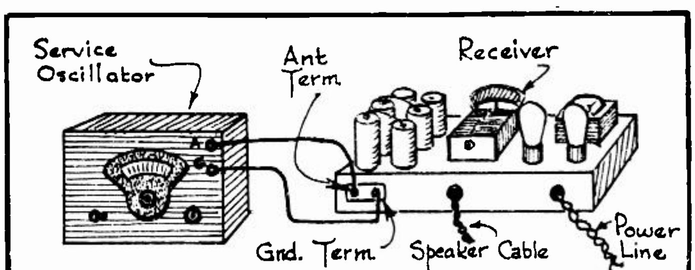


Fig. 3
Set-Up For Aligning Receiver With
Service Oscillator

5.–THE ADVANTAGE OF USING A MODULATED R.F. SERVICE OSCILLATOR FOR SUPPLYING THE SIGNAL FOR TESTING PURPOSES IN PREFERENCE TO BROADCAST SIGNALS IS THAT THE SIGNAL WHICH IS PRODUCED BY THE OSCILLATOR WILL BE STEADY AND OF UNVARYING INTENSITY AS IT IS REPRODUCED BY THE RECEIVER'S LOUD SPEAKER. THE BROADCAST SIGNALS WILL VARY ACCORDING TO THE LOUDNESS AND SOFTNESS OF THE SOUNDS WHICH ARE PICKED UP AT THE MICROPHONE AND THESE SOUND INTENSITIES WILL VARY CORRESPONDINGLY WHEN EMITTED FROM THE LOUDSPEAKER OF THE RECEIVER. THIS NATURAL VARIATION IN THE LOUDNESS OF SOUND MAKES IT SOMEWHAT MORE DIFFICULT TO ASCERTAIN WHETHER THE SOUND AT ANY INSTANT IS BEING AFFECTED BY THE RECEIVER ADJUSTMENT WHICH IS BEING MADE OR DUE TO THE PICK UP OF THE STUDIO MICROPHONE AT THE SAME INSTANT.

NO. 7

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

COMMON TROUBLES IN BATTERY OPERATED RECEIVERS

TROUBLE	POSSIBLE CAUSE	TESTS
No TUBES LIGHT.	1. "A" BATTERY RUN DOWN. 2. BAD CONNECTIONS OR OPEN "A" CIRCUIT.	1. TEST WITH VOLTMETER OR HYDROMETER. 2. INSPECT WIRING AND APPLY CONTINUITY TESTS.
ONE OR MORE TUBES (BUT NOT ALL) FAIL TO LIGHT.	1. DEFECTIVE TUBES. 2. OPEN OR SHORT IN FILAMENT CIRCUIT.	1. TRY OTHER TUBES. 2. APPLY CONTINUITY TESTS.
TUBES LIGHT BUT SIGNALS ARE NOT RECEIVED.	1. WRONG BATTERY CONNECTION. 2. "B" VOLTAGE LOW. 3. DEFECT IN ANTENNA OR GROUND CIRCUIT CONNECTIONS. 4. DEFECTIVE OR WORN OUT TUBE OR TUBES. 5. DEFECTIVE SPEAKER OR SPEAKER LEADS. 6. DEFECTIVE PLATE OR GRID CIRCUIT.	1. INSPECT. 2. TEST WITH VOLTMETER 3. INSPECT. 4. TRY OTHER TUBES. 5. TRY ANOTHER SPEAKER OR HEADPHONES. 6. TEST SOCKET VOLTAGES AND APPLY CONTINUITY TESTS.
LOW VOLUME.	1. RUN-DOWN BATTERY OR BATTERIES OR ELSE EXCESSIVE "C" VOLTAGE. 2. AERIAL SHORTER THAN RECOMMENDED; DEFECTS IN AERIAL OR GROUND SYSTEM; POOR LOCATION. 3. DEFECTIVE TUBE OR TUBES. 4. DEFECTIVE SPEAKER. 5. RECEIVER OUT OF ALIGNMENT. 6. DEFECTIVE AUDIO OR RADIO FREQUENCY TRANSFORMER. 7. DEFECTIVE CONNECTIONS, BAD SOLDERING ETC.	1. TEST BATTERY VOLTAGE WITH RECEIVER IN OPERATION. 2. INSPECT AERIAL AND GROUND SYSTEM FOR SHORTS, OPENS, BAD CONNECTIONS, DIRTY INSULATORS ETC. 3. TRY OTHER TUBES. 4. TRY ANOTHER SPEAKER. 5. CHECK ALIGNMENT. 6. APPLY CONTINUITY TESTS. 7. INSPECT
INTERMITTENT RECEPTION	1. LOOSE OR BROKEN CONNECTION IN AERIAL OR GROUND CIRCUIT. 2. LOOSE OR BROKEN CONNECTION IN RECEIVER.	1. EXAMINE FOR BREAKS AND POOR CONNECTIONS. 2. CHECK SOCKET VOLTAGES AND APPLY CONTINUITY TESTS, JARRING RECEIVER WHILE MAKING TESTS.

(OVER)

(CONTINUED)

INTERMITTENT RECEPTION	3. DEFECTIVE SPEAKER OR SPEAKER CONNECTIONS. 4. DEFECTIVE RESISTOR OR CONDENSER	3. TRY DIFFERENT SPEAKER. 4. CHECK RESISTORS AND CONDENSERS.
UNSATISFACTORY QUALITY.	1. RUN DOWN BATTERIES. 2. DEFECTIVE TUBE OR TUBES. 3. IMPROPER "C" BIAS 4. DEFECTIVE SPEAKER. 5. DEFECTS IN CIRCUIT, GRID LEAK ETC.	1. TEST ALL BATTERIES. 2. TRY OTHER TUBES. 3. TEST "C" BATTERY AND INSPECT CONNECTIONS. 4. TRY ANOTHER SPEAKER. 5. CHECK BY CONTINUITY TESTS, SOCKET VOLTAGES TESTS, AND INSPECTION OF WIRING.
OSCILLATIONS IN NEUTRODYNE RECEIVERS.	1. POOR R.F. TUBES. 2. AERIAL LENGTH DIFFERENT FROM THAT RECOMMENDED FOR RECEIVER OR ELSE A DEFECTIVE GROUND. 3. RECEIVER REQUIRES NEUTRALIZING ADJUSTMENT.	1. TRY CHANGING R.F. TUBES AROUND OR TRY DIFFERENT TUBES IN R.F. SOCKETS. 2. INSPECT 3. CHECK NEUTRALIZATION
OSCILLATIONS IN SCREEN GRID RECEIVERS.	1. AERIAL TOO SHORT OR ELSE AN OPEN IN AERIAL - GROUND CIRCUIT. 2. DEFECTIVE R.F. TUBES OR TUBES WITH TOO HIGH "MU". 3. HIGH RESISTANCE GROUNDS TO CHASSIS. 4. COUPLING BETWEEN SPEAKER LEADS AND ANTENNA OR GROUND WIRES. 5. OPEN OR DISCONNECTED SCREEN-GRID BYPASS CONDENSER.	1. INSPECT AND TRY RECEIVER ON A LONGER AERIAL. 2. TRY OTHER TUBES IN R.F. SOCKETS. 3. TIGHTEN UP ALL CONNECTIONS TO CHASSIS. EXAMINE VARIABLE CONDENSER ROTOR CONNECTION. 4. SEE THAT LEADS ARE AS FAR APART AS POSSIBLE. 5. INSPECT AND CHECK THESE CONDENSERS.
OTHER OSCILLATIONS, SQUEALS, A.C. HUM WITH ELIMINATOR-EQUIPPED RECEIVERS ETC.	1. RUN DOWN "C" BATTERY. 2. MICROPHONIC TUBE. 3. DEFECTIVE GROUND OR AERIAL SYSTEM. 4. DEFECTS IN CIRCUIT, ESPECIALLY IN A.F. TRANSFORMERS. 5. ELIMINATOR OR OTHER A.C. LEADS TOO CLOSE TO RECEIVER. 6. AERIAL TOO CLOSE TO POWER LINES	1. CHECK VOLTAGE WITH RECEIVER IN OPERATION. 2. PREVENT RECEIVER VIBRATIONS OR USE NEW TUBE. 3. INSPECT 4. INSPECT AND APPLY CONTINUITY TESTS. 5. INSPECT. 6. NOTE WHETHER OR NOT DISCONNECTING AERIAL STOPS A.C. HUM.

PRACTICAL RADIO JOB SHEET

NO. 8

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

COMMON TROUBLES IN A.C. RECEIVERS

TROUBLE	POSSIBLE CAUSE	TESTS
NO TUBES LIGHT.	1. POWER OFF AT SOCKET 2. FUSE BLOWN 3. OPEN IN SUPPLY CORD OR PRIMARY CIRCUIT OF POWER TRANSFORMER.	1. PLUG IN LAMP AT SOCKET OR USE VOLTMETER ACROSS LINE. 2. TRY NEW FUSE, NOTING WHETHER OR NOT TUBES LIGHT. 3. TEST FOR CONTINUITY.
ONE OR MORE (BUT NOT ALL) FAIL TO LIGHT.	1. BURNED OUT TUBE OR TUBES. 2. OPEN IN POWER TRANSFORMER SECONDARY WHICH SUPPLIES FILAMENTS. 3. SHORT OR OPEN FILAMENT CIRCUIT	1. TRY OTHER TUBES 2. USE VOLTAGE TEST AT SOCKETS. 3. TEST FOR CONTINUITY.
TUBES LIGHT BUT SIGNALS ARE NOT RECEIVED.	1. ANTENNA, GROUND OR BOTH DISCONNECTED, OPEN OR SHORTED. 2. OUTPUT TO SPEAKER NOT CONNECTED OR OPEN IN OUTPUT - SPEAKER CIRCUIT. 3. DEFECT IN PLATE CIRCUIT OF OTHER TUBES, SUCH AS OPEN RESISTOR ETC. 4. DEFECTS, SUCH AS OPEN RESISTORS IN GRID CIRCUITS ETC. 5. DEFECTIVE SPEAKER.	1. INSPECT AERIAL AND GROUND SYSTEM. 2. INSPECT CONNECTIONS AND CHECK OUTPUT PLATE VOLTAGES. 3. CHECK SOCKET PLATE VOLTAGES. 4. CHECK VOLTAGES OF OPERATING GRIDS AND SCREEN GRIDS. 5. TRY A DIFFERENT SPEAKER.
UNSATISFACTORY VOLUME.	1. AERIAL TOO SHORT; DEFECTS IN AERIAL, GROUND OR BOTH; POOR LOCATION. 2. LOW LINE VOLTAGE. 3. DEFECTIVE TUBE OR TUBES. 4. IMPROPER SOCKET VOLTAGES DUE TO DEFECTIVE CIRCUITS SUCH AS DEFECTIVE RESISTANCES ETC. 5. DEFECTIVE SPEAKER. 6. TUNED CIRCUITS NOT ALIGNED. 7. DEFECTIVE AUDIO OR R.F. TRANSFORMER 8. DEFECTIVE CONNECTIONS, BAD SOLDERING ETC.	1. INSPECT AERIAL AND GROUND SYSTEMS FOR SIZE, SHORTS, POOR INSULATION, POOR CONNECTIONS ETC. IF NECESSARY, TEST SAME WITH ANOTHER RECEIVER. 2. CHECK LINE VOLTAGE WITH A.C. METER. 3. TRY NEW TUBES. 4. TEST TO SEE IF "VOLTAGE LIMITS" ARE COMPLIED WITH. 5. TRY A NEW ONE. 6. CHECK FOR ALIGNMENT. 7. INSPECT CONNECTIONS AND APPLY CONTINUITY TESTS. 8. INSPECT ALL CONNECTIONS AND SOLDERED JOINTS.

(OVER)

(CONTINUED)

INTERMITTENT RECEPTION.	1. LOOSE OR BROKEN CONNECTION IN AERIAL OR GROUND CIRCUIT. 2. LOOSE OR BROKEN CONNECTION IN RECEIVER. 3. DEFECTIVE SPEAKER OR SPEAKER CONNECTIONS. 4. DEFECTIVE TUBE 5. DEFECTIVE RESISTOR OR CONDENSER.	1. EXAMINE THROUGHOUT FOR BREAKS AND POOR CONNECTIONS. 2. CHECK SOCKET VOLTAGES AND APPLY CONTINUITY TESTS JARRING RECEIVER WHILE MAKING TESTS. 3. TRY A DIFFERENT SPEAKER. 4. CHECK TUBES. 5. CHECK SAME.
UNSATISFACTORY QUALITY.	1. DEFECTIVE OR WORN OUT TUBES. 2. WRONG SOCKET VOLTAGES(ESPECIALLY BIAS)DUE TO DEFECTS IN CIRCUIT,DEFECTIVE RESISTORS ETC. 3. DEFECTIVE SPEAKER. 4. TUNING CIRCUITS IMPROPERLY ALIGNED.	1. TRY OTHER TUBES. 2. TEST TO SEE THAT SOCKET VOLTAGES COMPLY WITH "VOLTAGE LIMITATIONS". 3. TRY ANOTHER SPEAKER. 4. CHECK ALIGNMENT.
A.C. HUM.	1. DEFECTIVE TUBE(ESPECIALLY RECTIFIER) OR DETECTOR. 2. POOR GROUND. 3. SHORTED FILTER CHOKE OR OPEN CONDENSER 4. INDUCTIVE PICK-UP OF AERIAL SYSTEM,GROUND WIRE,LEAD-IN ETC.FROM POWER LINE OR A.C. LEADS. 5. OTHER DEFECTS IN CIRCUIT.	1. TRY OTHER TUBES. 2. INSPECT. 3. CHECK SOCKET VOLTAGES AND APPLY CONTINUITY TESTS. 4. INSPECT.SEE IF DISCONNECTED AERIAL OR GROUND STOPS HUM. 5. CHECK SOCKET VOLTAGES AND APPLY CONTINUITY TESTS THROUGHOUT.
MICROPHONISM.	1. JARRING OR VIBRATION OF RECEIVER. 2. DEFECTIVE DETECTOR TUBE.	1. INSPECT FOR CAUSE OF VIBRATION (OFTEN DUE TO SPEAKER VIBRATIONS TRANSFERRED TO SET). 2. TRY ANOTHER DETECTOR TUBE.
OSCILLATION IN NEUTRODYNE RECEIVER.	1. R.F. TUBES 2. IMPROPER AERIAL LENGTH. 3. RECEIVER NOT PROPER NEUTRALIZED.	1. CHANGE TUBES AROUND OR TRY DIFFERENT TUBES IN R.F. SOCKETS. 2. INSPECT. 3. CHECK FOR NEUTRALIZATION.
OSCILLATIONS IN SCREEN-GRID RECEIVER.	1. AERIAL TOO SHORT,OR OPEN IN AERIAL - GROUND CIRCUIT. 2. DEFECTIVE R.F. TUBES OR TUBES WITH TOO HIGH "MU" 3. HIGH-RESISTANCE GROUNDS TO CHASSIS. 4. TOO HIGH LINE VOLTAGE. 5. OPEN OR DISCONNECTED SCREEN GRID BY-PASS CONDENSER.	1. INSPECT AERIAL AND GROUND SYSTEM THROUGHOUT.IF NECESSARY TEST RECEIVER ON LONGER AERIAL. 2. TRY OTHER TUBES IN R.F. SOCKETS. 3. TRY TIGHTENING UP ALL CONNECTIONS. 4. TEST LINE VOLTAGE WITH A.C. METER. 5. INSPECT AND CHECK.

NO. 9

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

COMMON POWER PACK TROUBLES

TROUBLE	POSSIBLE CAUSE	TESTS
No D.C. Voltage Available at output of Power Pack.	1. Defective Power transformer.	1. Check suspicious winding for voltage with volt meter and also for continuity.
	2. If tube filaments also fail to burn, look for defective primary winding in power transformer or defective A.C. input line.	2. Check for continuity.
	3. Rectifier tube burned out.	3. Inspect and insert new rectifier tube.
	4. Filter condenser broken down.	4. Rectifier tube's plates will become red hot. Check filter condenser for short.
	5. Open or grounded choke coil.	5. Test for continuity and ground.
Low D.C. Output Voltages.	1. Low A.C. line voltage.	1. Check line voltage with A.C. voltmeter.
	2. Excessive load on D.C. circuit.	2. Check current drain with milliammeter.
	3. Worn out rectifier tube.	3. Try a new rectifier tube.
	4. Excessive D.C. resistance in filter system.	4. Check connections and also measure volt drop across each filter choke.
	5. Shorted divider resistor.	5. Check divider resistors.
Lack of D.C. voltage across a portion of divider only.	1. Shorted by-pass condenser in voltage divider.	1. Test voltage divider by-pass condensers.
	2. An open voltage divider resistor.	2. Check divider resistors for continuity.
A.C. hum, for which power pack may be responsible.	1. Low line voltage.	1. Check voltage with A.C. voltmeter.
	2. Defective rectifier tube.	2. Replace with a new tube.
	3. Shorted filter choke.	3. Test choke for continuity and note meter reading.
	4. An open or poor filter condenser.	4. Check condenser and try a replacement
	5. Open in a voltage divider by-pass condenser or lack of such a condenser.	5. Inspect and check such condensers for continuity
	6. Loose transformer laminations.	6. Listen for rattle.

NO. 10

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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Los Angeles California

COMMON TROUBLES IN DIRECT CURRENT RECEIVERS
(110 or 220 Volts)

TROUBLE	POSSIBLE CAUSE	TESTS
No tubes light.	1. One or more tubes "burned out."	1. In some D.C. receivers, all of the tube filaments are connected in series and if one burns out, all will fail to light. In other D.C. receivers, certain groups of tubes are connected in series while others are connected in parallel, so the effect of one open filament will be accordingly.
	2. Power off at socket.	2. Plug in lamp at socket or test with voltmeter across lines.
	3. Fuse or fuses blown.	3. Try new fuse or fuses (some D.C. receivers have 2 fuses, one on chassis and one on supply cord).
	4. Open in supply cord or filament circuit.	4. Test for continuity.
One or more tubes (but not all) fail to light.	1. Burned out tube	1. Possible only in cases where filaments of some tubes are paralleled.
	2. Defect in filament circuit.	2. Note (1) above also applies in this case. Apply continuity tests.
Tubes light but signals are not received.	1. Polarity may be reversed. Other possible causes are the same as those given relative to A.C. receivers in the preceding "Job Sheet".	1. Check polarity of line.
Unsatisfactory Volume.	1. Wrong line voltage. Other possible causes are the same as those given relative to A.C. receivers in a preceding "Job Sheet".	1. Test line voltage with a D.C. voltmeter.
1. Intermittent reception. 2. Unsatisfactory Quality. 3. Microphonism.	4. Oscillation in Neutrodyne Receivers. 5. Oscillation in Screen grid receivers.	The possible causes for these troubles are the same as those outlined with respect to these same troubles for A.C. receivers in a preceding "Job Sheet".

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NO. 11

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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TROUBLES AND TESTING OF MAGNETIC SPEAKERS

DEFINITION:- SPEAKERS, WHOSE FIELD IS ESTABLISHED BY A PERMANENT MAGNET OR MAGNETS AND WHICH ARE NOT EQUIPPED WITH A MOVING COIL, ARE CLASSIFIED AS "MAGNETIC SPEAKERS." THE BALANCED ARMATURE TYPE SPEAKER, FOR EXAMPLE, WOULD BE INCLUDED IN THIS GROUP. THE TERM "HIGH IMPEDANCE" IS ALSO FREQUENTLY ASSOCIATED WITH THIS CLASS OF SPEAKERS.

CAUTION:- ALL FAULTS INDICATED BY AN IMPROPERLY OPERATING SPEAKER DO NOT INDICATE THAT THE SPEAKER ITSELF IS DEFECTIVE. THE FOLLOWING TABLE ASSUMES THE TROUBLE TO BE WITHIN THE MAGNETIC SPEAKER AND NOT IN THE RECEIVER.

TROUBLE	POSSIBLE CAUSE	TESTS
NO SOUNDS FROM SPEAKER.	1. DEFECTIVE SPEAKER. 2. DEFECTIVE RECEIVER. 3. OPEN OR SHORTED SPEAKER LEADS. 4. OPEN SPEAKER COIL. 5. DEFECTIVE SPEAKER COUPLING.	1&2. CHECK OUTPUT OF RECEIVER WITH A DIFFERENT SPEAKER OR HEADPHONES. 3. TEST LEADS FOR CONTINUITY. 4. TEST COIL FOR CONTINUITY. 5. INSPECT AND TEST COUPLING FOR CONTINUITY.
LACK OF VOLUME.	1. A WEAK SPEAKER MAGNET. 2. AN OPEN SPEAKER COIL. 3. A SHORTED SPEAKER COIL. 4. POOR INSULATION IN CONNECTING CORD.	1. TEST WITH A KNIFE BLADE FOR MAGNETIC ATTRACTION AT POLES. 2. TEST FOR CONTINUITY. 3. TEST FOR CONTINUITY. 4. INSPECT CORD.
WEAK, TINNY SOUNDS.	DAMAGED OR CRUSHED CONE PAPER (ESPECIALLY NEAR APEX).	INSPECT AND REPLACE PAPER CONE WITH A NEW ONE.
LOUD CHATTERING SOUNDS.	ARMATURE STRIKING POLE TIPS.	INSPECT AND ADJUST BY CENTERING ARMATURE IN AIR GAP.
RASPY SOUNDS.	DIRT, IRON FILINGS, OR OTHER SMALL FOREIGN SUBSTANCE LODGED IN NARROW MAGNETIC GAPS.	INSPECT AND REMOVE DIRT BY FORCING A STIFF PIECE OF PAPER BETWEEN ARMATURE AND POLE TIPS.
RATTLING SOUNDS.	LOOSENESS IN SOME PART OF THE DRIVE SYSTEM; PROBABLY A LOOSE DRIVE PIN OR LOOSE CONE ATTACHMENT.	INSPECT

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PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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Los Angeles California

• TROUBLES & TESTING OF ELECTRODYNAMIC SPEAKERS •

TROUBLE	POSSIBLE CAUSE	TESTS
"DEAD" SPEAKER.	1. NO SIGNAL OUTPUT FROM RECEIVER. 2. LACK OF EXITING VOLTAGE FOR FIELD COIL. 3. OPEN FIELD COIL. 4. SHORTED FIELD COIL. 5. OPEN VOICE COIL. 6. DISCONNECTED VOICE COIL. 7. DEFECTIVE SPEAKER COUPLING.	1&2. CHECK OUTPUT WITH ANOTHER SPEAKER OR PHONES. 2. CHECK VOLTAGE ACROSS FIELD COIL WITH D.C. VOLTMETER. 3. TEST FIELD COIL FOR CONTINUITY. 4. CHECK WITH CONTINUITY TESTER. 5. TEST FOR CONTINUITY 6. INSPECT. 7. CHECK COUPLING.
WEAK, RASPY REPRODUCTION	WEAK MAGNETIZATION OF SPEAKER FIELD (PROBABLY DUE TO LOW EXITING VOLTAGE).	HOLD THE POINT OF A KNIFE BLADE AGAINST THE CENTRAL PORTION OF THE SPEAKER CORE PROJECTING IN APEX OF CONE AND TEST FOR MAGNETIC ATTRACTION WHILE SPEAKER IS IN OPERATION.
DISTORTED OUTPUT.	1. INCORRECTLY CENTERED VOICE COIL. 2. INCORRECT COUPLING UNIT SO THAT IMPEDANCES ARE NOT MATCHED. 3. IMPERFECTLY CENTERED CONE. 4. DAMAGED CONE. 5. EXCESSIVE HUM.	1. INSPECT. 2. CHECK AND TRY A DIFFERENT COUPLING 3. INSPECT. 4. INSPECT. 5. CHECK SPEAKER FOR HUM.
EXCESSIVE SPEAKER HUM.	1. WORN OUT RECTIFIER UNIT. IF SPEAKER IS OF THE A.C. TYPE. 2. POOR OPERATION OF "B" POWER PACK IF SPEAKER IS OF D.C. TYPE. 3. DEFECTIVE HUM BUCKING COIL. 4. SPEAKER LEADS INDUCTIVELY COUPLED TO A.C. LINES.	1. REPLACE RECTIFIER UNIT (SPEAKER CAN BE TESTED FOR HUM BY SHORTING THE PRIMARY TERMINALS OF THE COUPLING TRANSFORMER. ANY REMAINING HUM DOES NOT COME FROM RECEIVER BUT FROM SPEAKER CIRCUIT). 2. INSPECT. 3. INSPECT. 4. INSPECT.
SCRATCHING SOUNDS.	DIRT OR IRON FILINGS LODGED IN AIR GAP BETWEEN FIELD CORE AND APEX SLEEVE OF PAPER CONE.	INSPECT AND REMOVE FOREIGN PARTICLES.

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NO. 13

PRACTICAL RADIO JOB SHEET

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METER READINGS AND POSSIBLE RECEIVER TROUBLE

THE OUTLINE HERE GIVEN WILL OFFER YOU A NUMBER OF VALUABLE SUGGESTIONS REGARDING THE MOST COMMON RECEIVER TROUBLES WHICH CORRESPOND TO THE VARIOUS METER READINGS OBTAINED UPON TESTING THE CIRCUITS.

METER READINGS	POSSIBLE TROUBLES
VOLTMETER READS ZERO WHEN CONNECTED ACROSS THE FILAMENT TERMINALS OF THE TUBE SOCKET.	1. DISCHARGED "A" BATTERY IN BATTERY SETS. 2. AN OPEN OR ELSE COMPLETE SHORT IN THIS CIRCUIT. 3. DEFECTIVE TUBE SOCKET. 4. DEFECTIVE FILAMENT CIRCUIT SWITCH. 5. DEFECTIVE POWER TRANSFORMER. 6. PRIMARY CIRCUIT OF POWER TRANSFORMER INCOMPLETE.
FILAMENT OR HEATER VOLTAGE TOO HIGH.	1. HIGH LINE VOLTAGE, OR WRONG CONNECTION OF LINE VOLTAGE TAP. 2. HEATER OR FILAMENT BURNED OUT. 3. ONE OR MORE TUBES IN SAME CIRCUIT BURNED OUT, THEREBY DECREASING LOAD ON CIRCUIT. 4. TUBE OF WRONG TYPE FOR SOCKET. 5. PRIMARY WINDING OF POWER TRANSFORMER PARTIALLY SHORTED.
PLATE VOLTAGE LACKING AT ALL TUBES.	1. SHORTED FILTER CONDENSER. 2. OPEN FILTER CHOKE. 3. DEFECTIVE RECTIFIER TUBE. 4. DEFECTIVE POWER TRANSFORMER. 5. PLATE CIRCUIT OF POWER TUBE GROUNDED. 6. OPEN IN MAIN "B" CIRCUIT FEEDING ALL OTHER "B" CIRCUITS.
NO PLATE VOLTAGE ON ONE TUBE AND LOW PLATE VOLTAGE ON OTHER TUBES.	1. SHORTED BY-PASS OR COUPLING CONDENSER. 2. OPEN R.F. CHOKE. 3. DEFECTIVE TUBE. 4. GROUNDED PLATE CIRCUIT. 5. OPEN RESISTOR.
NO PLATE VOLTAGE ON POWER TUBES BUT PRESENT AT OTHER TUBES.	1. OPEN IN OUTPUT OR SPEAKER COUPLING UNIT. 2. OPEN IN POWER TUBE PLATE CIRCUIT.
LOW PLATE VOLTAGE ON ALL TUBES	1. DEFECTIVE RECTIFIER TUBE. 2. DEFECTIVE FILTER CONDENSER. 3. SHORTED BIAS RESISTOR BY-PASS CONDENSER. 4. SHORTED GRID BIAS RESISTOR. 5. DEFECTIVE BY-PASS CONDENSER. 6. LOW LINE VOLTAGE. 7. DEFECTIVE VOLTAGE DIVIDER. 8. DEFECTIVE FILTER CHOKE. 9. DEFECTIVE POWER TRANSFORMER.

(OVER)

(CONTINUED)

HIGH PLATE VOLTAGE.	1. HIGH LINE VOLTAGE. 2. SHORTED FILTER CHOKE. 3. SHORT CIRCUITED RESISTOR. 4. WORN OUT TUBES PLACING INSUFFICIENT "B" LOAD UPON POWER SUPPLY. (OPEN IN "B" CIRCUIT OF POWER STAGE WILL INCREASE THE "B" VOLTAGE AT TUBES IN THE OTHER STAGES). 5. EXCESSIVE GRID BIAS RESISTANCE IN POWER STAGE.
EXCESSIVE PLATE CURRENT.	1. EXCESSIVE PLATE VOLTAGE. 2. EXCESSIVE SCREEN GRID VOLTAGE. 3. OPEN GRID CIRCUIT. 4. NOT ENOUGH GRID BIAS. 5. GASEOUS TUBE.
LOW PLATE CURRENT WITH NORMAL PLATE VOLTAGE.	1. DEFECTIVE TUBE. 2. TOO MUCH BIAS RESISTANCE. 3. LOW FILAMENT VOLTAGE. 4. LOW SCREEN GRID VOLTAGE.
NO SCREEN GRID VOLTAGE.	1. SHORTED SCREEN-GRID BY-PASS CONDENSER. 2. DEFECTIVE TUBE. 3. DEFECTIVE RESISTOR. 4. OPEN SCREEN GRID CIRCUIT.
NO GRID BIAS.	1. OPEN GRID CIRCUIT. 2. GROUNDED CATHODE. 3. GROUNDED FILAMENT. 4. SHORTED GRID BY-PASS CONDENSER.
LOW GRID BIAS.	1. LOW PLATE CURRENT. 2. OLD TUBES. 3. DEFECTIVE BIAS RESISTANCE OR ONE OF INCORRECT VALUE. 4. DEFECTIVE BIAS RESISTOR BY-PASS CONDENSER.
HIGH GRID BIAS.	1. EXCESSIVE PLATE CURRENT. 2. BIAS RESISTOR OF TOO MUCH VALUE. 3. DEFECTIVE BIAS RESISTOR.

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PRACTICAL RADIO JOB SHEET

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RADIO TUBE CHART

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH X DIAMETER	CATHODE TYPE ■	RATING FILAMENT OR HEATER VOLTS	FILAMENT OR HEATER AMPERES	PLATE MAX. VOLTS	SCREEN MAX. VOLTS	USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICROMHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
1A6	PENTAGRID CONVERTER ◘	SMALL 6-PIN	FIG. 26	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5	CONVERTER	180	-3.0 min.	67.5	2.4	1.3	500000	Anode-Grid (#2) 135 max. volts, 2.3 ma. Oscillator Grid (#1) Resistor, 50000 ohms. Conversion conductance, 300 micromhos.				1A6
1C6	PENTAGRID CONVERTER ◘	SMALL 6-PIN	FIG. 26	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.12	180	67.5	CONVERTER	180	-3.0 min.	67.5	2.0	1.5	750000	Anode Grid (#2) 135 max. volts, 3.3 ma. Oscillator Grid (#1) Resistor, 50000 ohms. Conversion conductance, 325 micromhos.				1C6
2A3	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	5 3/8" x 2 1/16"	FILAMENT	2.5	2.5	250	—	CLASS A AMPLIFIER	250	-45	—	—	60.0	800	5250	4.2	2500	3.5	2A3
								300	—	PUSH-PULL AMPLIFIER	300 300	-62 -62	Self-bias Fixed-bias		40.0 40.0	Power Output is for 2 tubes at stated load, plate-to-plate			5000 3000	10.0 15.0	
2A5	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	2.5	1.75	250	250	CLASS A AMPLIFIER	250	-16.5	250	6.5	34.0	100000	2200	220	7000	3.0	2A5
2A6	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	FIG. 13	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250✖	-1.35	—	—	0.4	—	—	Gain per stage = 50-60			2A6
2A7	PENTAGRID CONVERTER ◘	SMALL 7-PIN	FIG. 20	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	100	CONVERTER	250	-3.0 min.	100	2.2	3.5	360000	Anode Grid (#2) 200 max. volts, 4.0 ma. Oscillator Grid (#1) Resistor, 50000 ohms. Conversion conductance, 520 micromhos.				2A7
2B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	FIG. 21	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	125	PENTODE UNIT AS R-F AMPLIFIER	100 250	-3.0 -3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	—	—	2B7
										PENTODE UNIT AS A-F AMPLIFIER	250✢	-4.5	50	—	0.65	—	—	—	—	—	
6A4 also LA	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 6	4 11/16" x 1 13/16"	FILAMENT	6.3	0.3	180	180	CLASS A AMPLIFIER	100 180	-6.5 -12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	100 100	11000 8000	0.31 1.40	6A4 also LA
6A7	PENTAGRID CONVERTER ◘	SMALL 7-PIN	FIG. 20	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	100	CONVERTER	250	-3.0 min.	100	2.2	3.5	360000	Anode Grid (#2) 200 max. volts, 4.0 ma. Oscillator Grid (#1) Resistor, 50000 ohms. Conversion conductance, 520 micromhos.				6A7
6B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	FIG. 21	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	125	PENTODE UNIT AS R-F AMPLIFIER	100 250	-3.0 -3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	—	—	6B7
										PENTODE UNIT AS A-F AMPLIFIER	250✢	-4.5	50	—	0.65	—	—	—	—	—	
6C6	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	4 15/16" x 1 9/16"	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	250	-3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	6C6
										BIAS DETECTOR	250	-1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms.**				
6D6	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	4 15/16" x 1 9/16"	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	250	-3.0 min.	100	2.0	8.2	800000	1600	1280	—	—	6D6
										MIXER IN SUPERHETERODYNE	250	-10.0	100	—	—		Oscillator peak volts = 7.0.				
6F7	TRIODE-PENTODE	SMALL 7-PIN	FIG. 27	4 17/32" x 1 9/16"	HEATER	6.3	0.3	100	—	TRIODE UNIT AS AMPLIFIER	100	-3.0	—	—	3.5	17800	450	8	—	—	6F7
								250	100	PENTODE UNIT AS AMPLIFIER	250	-3.0 min.	100	1.5	6.5	850000	1100	900	—	—	
								250	100	PENTODE UNIT AS MIXER	250	-10.0	100	0.6	2.8	Oscillator peak volts = 7.0. Conversion conductance = 300 micromhos.					
'00-A	DETECTOR TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	45	—	GRID LEAK DETECTOR	45	Grid Return to (−) Filament			1.5	30000	666	20	—	—	'00-A
01-A	DETECTOR★ AMPLIFIER	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	135	—	CLASS A AMPLIFIER	90 135	-4.5 -9.0	—	—	2.5 3.0	11000 10000	725 800	8.0 8.0	—	—	01-A
10	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	5 5/8" x 2 3/16"	FILAMENT	7.5	1.25	425	—	CLASS A AMPLIFIER	350 425	-31.0 -39.0	—	—	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	10
11 12	DETECTOR★ AMPLIFIER TRIODE	WD 4-PIN MEDIUM 4-PIN	FIG. 12 FIG. 1	4 1/8" x 1 3/16" 4 11/16" x 1 7/16"	D-C FILAMENT	1.1	0.25	135	—	CLASS A AMPLIFIER	90 135	-4.5 -10.5	—	—	2.5 3.0	15500 15000	425 440	6.6 6.6	—	—	11 12
19	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	FIG. 25	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.26	135	—	CLASS B AMPLIFIER	135 135	0 -3.0	—	—	Power output value is for one tube at stated load, plate-to-plate.				10000 10000	2.1 1.9	19
'20	POWER AMPLIFIER TRIODE	SMALL 4-PIN	FIG. 1	4 1/8" x 1 3/16"	D-C FILAMENT	3.3	0.132	135	—	CLASS A AMPLIFIER	90 135	-16.5 -22.5	—	—	3.0 6.5	8000 6300	415 525	3.3 3.3	9600 6500	0.045 0.110	'20
22	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	FIG. 4	5 1/32" x 1 13/16"	D-C FILAMENT	3.3	0.132	135	67.5	SCREEN GRID R-F AMPLIFIER	135 135	-1.5 -1.5	45 67.5	0.6* 1.3*	1.7 3.7	725000 325000	375 500	270 160	—	—	22
24-A	R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	FIG. 9	5 1/32" x 1 13/16"	HEATER	2.5	1.75	275	90	SCREEN GRID R-F AMPLIFIER	180 250	-3.0 -3.0	90 90	1.7* 1.7*	4.0 4.0	400000 600000	1000 1050	400 630	—	—	24-A
										BIAS DETECTOR	250●	-5.0 approx.	20 to 45	—	Plate current to be adjusted to 0.1 milliampere with no signal.						
26	AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	FILAMENT	1.5	1.05	180	—	CLASS A AMPLIFIER	90 180	-7.0 -14.5	—	—	2.9 6.2	8900 7300	935 1150	8.3 8.3	—	—	26
27	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	2.5	1.75	275	—	CLASS A AMPLIFIER	135 250	-9.0 -21.0	—	—	4.5 5.2	9000 9250	1000 975	9.0 9.0	—	—	27
										BIAS DETECTOR	250	-30.0 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
30	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-PIN	FIG. 1	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	—	CLASS A AMPLIFIER	90 135 180	-4.5 -9.0 -13.5	—	—	2.5 3.0 3.1	11000 10300 10300	850 900 900	9.3 9.3 9.3	—	—	30
31	POWER AMPLIFIER TRIODE	SMALL 4-PIN	FIG. 1	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.13	180	—	CLASS A AMPLIFIER	135 180	-22.5 -30.0	—	—	8.0 12.3	4100 3600	925 1050	3.8 3.8	7000 5700	0.185 0.375	31
32	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	FIG. 4	5 1/32" x 1 13/16"	D-C FILAMENT	2.0	0.06	180	67.5	SCREEN GRID R-F AMPLIFIER	135 180	-3.0 -3.0	67.5 67.5	0.4* 0.4*	1.7 1.7	950000 1200000	640 650	610 780	—	—	32
										BIAS DETECTOR	180♥	-6.0 approx.	67.5	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
33	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 6	4 11/16" x 1 13/16"	D-C FILAMENT	2.0	0.26	180	180	CLASS A AMPLIFIER	180	-18.0	180	5.0	22.0	55000	1700	90	6000	1.4	33
34	SUPER-CONTROL R-F AMPLIFIER PENTODE	MEDIUM 4-PIN	FIG. 4A	5 1/32" x 1 13/16"	D-C FILAMENT	2.0	0.06	180	67.5	SCREEN GRID R-F AMPLIFIER	135 180	-3.0 min.	67.5 67.5	1.0 1.0	2.8 2.8	600000 1000000	600 620	360 620	—	—	34
35	SUPER-CONTROL R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	FIG. 9	5 1/32" x 1 13/16"	HEATER	2.5	1.75	275	90	SCREEN GRID R-F AMPLIFIER	180 250	-3.0 min.	90 90	2.5* 2.5*	6.3 6.5	300000 400000	1020 1050	305 420	—	—	35
36	R-F AMPLIFIER TETRODE	SMALL 5-PIN	FIG. 9	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	90	SCREEN GRID R-F AMPLIFIER	100 180 250	-1.5 -3.0 -3.0	55 90 90	— — 1.7*	1.8 3.1 3.2	550000 500000 550000	850 1050 1080	470 525 595	—	—	36
										BIAS DETECTOR	100● 250●	-5.0 -8.0	55 90	—	Plate current to be adjusted to 0.1 milliampere with no signal.						
37	DETECTOR★ AMPLIFIER TRIODE	SMALL 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	90 180 250	-6.0 -13.5 -18.0	—	—	2.5 4.3 7.5	11500 10200 8400	800 900 1100	9.2 9.2 9.2	—	—	37
										BIAS DETECTOR	90 250	-10.0 -28.0	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
38	POWER AMPLIFIER PENTODE	SMALL 5-PIN	FIG. 9A	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	250	CLASS A AMPLIFIER	100 180 250	-9.0 -18.0 -25.0	100 180 250	1.2 2.4 3.8	7.0 14.0 22.0	140000 115000 100000	875 1050 1200	120 120 120	15000 11600 10000	0.27 1.00 2.50	38
39-44	SUPER-CONTROL R-F AMPLIFIER PENTODE	SMALL 5-PIN	FIG. 9A	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	90	SCREEN GRID R-F AMPLIFIER	90 180 250	-3.0 min.	90 90 90	1.6 1.4 1.4	5.6 5.8 5.8	375000 750000 1000000	960 1000 1050	360 750 1050	—	—	39-44
40	VOLTAGE AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	135✖ 180✖	-1.5 -3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
41	POWER AMPLIFIER PENTODE	SMALL 6-PIN	FIG. 15A	4 1/4" x 1 9/16"	HEATER	6.3	0.4	250	250	CLASS A AMPLIFIER	100 180 250	-7.0 -13.5 -18.0	100 180 250	1.6 3.0 5.5	9.0 18.5 32.0	103500 81000 68000	1450 1850 2200	150 150 150	12000 9000 7600	0.33 1.50 3.40	41
42	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	6.3	0.7	250	250	CLASS A AMPLIFIER	250	-16.5	250	6.5	34.0	100000	2200	220	7000	3.00	42
43	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	25.0	0.3	135	135	CLASS A AMPLIFIER	95 135	-15.0 -20.0	95 135	4.0 7.0	20.0 34.0	45000 35000	2000 2300	90 80	4500 4000	0.90 2.00	43
45	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	FILAMENT	2.5	1.5	275	—	CLASS A AMPLIFIER	180 250 275	-31.5 -50.0 -56.0	180 250 275	—	31.0 34.0 36.0	1650 1610 1700	2125 2175 2050	3.5 3.5 3.5	2700 3900 4600	0.82 1.60 2.00	45
46	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	FIG. 7	5 5/8" x 2 3/16"	FILAMENT	2.5	1.75	250	—	CLASS A AMPLIFIER □	250	-33.0	—	—	22.0	2380	2350	5.6	6400	1.25	46
								400	—	CLASS B AMPLIFIER ✧	300 400	0 0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				5200 5800	16.0 20.0	

◘ Grids #3 and #5 are screen. Grid #4 is signal-input control-grid.

✢ Applied through plate coupling resistor of 200000 ohms. **For grid of following tube.

✖ Applied through plate coupling resistor of 250000 ohms.

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.

● Applied through plate coupling resistor of 250000 ohms or 500-henry choke shunted by 0.25 megohm resistor. *Maximum.

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.

■Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D. C. on A-C filament types, decrease stated grid volts by ½ (approx.) of filament voltage.

● Applied through plate coupling resistor of 250000 ohms or 500-henry choke shunted by 0.25 megohm resistor.

♥Applied through plate coupling resistor of 100000 ohms.

*Maximum.

CONTINUED ON OTHER SIDE

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	RATING: FILAMENT OR HEATER AMPERES	RATING: PLATE MAX. VOLTS	RATING: SCREEN MAX. VOLTS	USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICROMHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
47	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 6	$5\frac{3}{8}'' \times 2\frac{1}{16}''$	FILAMENT	2.5	1.75	250	250	CLASS A AMPLIFIER	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
48	POWER AMPLIFIER TETRODE	MEDIUM 6-PIN	FIG. 15	$5\frac{3}{8}'' \times 2\frac{1}{16}''$	D-C HEATER	30.0	0.4	125	100	CLASS A AMPLIFIER	96 125	−19.0 −20.0	96 100	9.0 9.5	52.0 56.0	— —	3800 3900	— —	1500 1500	2.0 2.5	48
49	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	FIG. 7	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	D-C FILAMENT	2.0	0.12	135	—	CLASS A AMPLIFIER □	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	49
								180	—	CLASS B AMPLIFIER ◆	180	0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				12000	3.5	
50	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	$6\frac{1}{4}'' \times 2\frac{11}{16}''$	FILAMENT	7.5	1.25	450	—	CLASS A AMPLIFIER	300 400 450	−54.0 −70.0 −84.0	—	—	35.0 55.0 55.0	2000 1800 1800	1900 2100 2100	3.8 3.8 3.8	4600 3670 4350	1.6 3.4 4.6	50
53	TWIN-TRIODE AMPLIFIER ✓	MEDIUM 7-PIN#	FIG. 24	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	HEATER	2.5	2.0	300	—	CLASS B AMPLIFIER	250 300	0 0	—	—	Power output value is for one tube at stated load, plate-to-plate.				8000 10000	8.0 10.0	53
55	DUPLEX-DIODE TRIODE	SMALL 6-PIN	FIG. 13	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	2.5	1.0	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	135 180 250	−10.5 −13.5 −20.0	—	—	3.7 6.0 8.0	11000 8500 7500	750 975 1100	8.3 8.3 8.3	25000 20000 20000	0.075 0.160 0.350	55
56	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	FIG. 8	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	2.5	1.0	250	—	CLASS A AMPLIFIER	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	56
										BIAS DETECTOR	250	−20.0 (approx.)	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
57	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	$4\frac{15}{16}'' \times 1\frac{9}{16}''$	◆ HEATER	2.5	1.0	250	100	SCREEN GRID R-F AMPLIFIER	250	− 3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	57
										BIAS DETECTOR	250	− 1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms**				

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode
Requires different socket from small 7-pin.

□ Grid next to plate tied to plate. ◆ Two grids tied together. **For grid of following tube.
⌘ Applied through plate coupling resistor of 250000 ohms.

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	RATING: FILAMENT OR HEATER AMPERES	RATING: PLATE MAX. VOLTS	RATING: SCREEN MAX. VOLTS	USE	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICROMHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
58	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	$4\frac{15}{16}'' \times 1\frac{9}{16}''$	HEATER	2.5	1.0	250	100	SCREEN GRID R-F AMPLIFIER	250	− 3.0 min.	100	2.0	8.2	800000	1600	1280	—	—	58
										MIXER IN SUPERHETERODYNE	250	−10.0	100	—	—	Oscillator peak volts = 7.0.					
59	TRIPLE-GRID POWER AMPLIFIER	MEDIUM 7-PIN#	FIG. 18	$5\frac{3}{8}'' \times 2\frac{1}{16}''$	HEATER	2.5	2.0	250	—	AS TRIODE ¶ CLASS A AMPLIFIER	250	−28.0	—	—	26.0	2300	2600	6.0	5000	1.25	59
								250	250	AS PENTODE ** CLASS A AMPLIFIER	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.00	
								400	—	AS TRIODE ⊕ CLASS B AMPLIFIER	300 400	0 0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				4600 6000	15.0 20.0	
71-A	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	90 180	−19.0 −43.0	—	—	10.0 20.0	2170 1750	1400 1700	3.0 3.0	3000 4800	0.125 0.790	71-A
75	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	FIG. 13	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250⌘	−1.35	—	—	0.4	—	—	Gain per stage = 50-60			75
76	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	FIG. 8	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	76
										BIAS DETECTOR	250	−20.0	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
77	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	100 250	− 1.5 − 3.0	60 100	0.4 0.5	1.7 2.3	650000 1500000	1100 1250	715 1500	—	—	77
										BIAS DETECTOR	250	− 1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms**				
78	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	250	125	SCREEN GRID R-F AMPLIFIER	90 180 250 250	− 3.0 min.	90 75 100 125	1.3 1.0 1.7 2.6	5.4 4.0 7.0 10.5	315000 1000000 800000 600000	1275 1100 1450 1650	400 1100 1160 990	—	—	78
79	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	FIG. 19	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.6	250	—	CLASS B AMPLIFIER	180 250	0 0	—	—	Power output value is for one tube at stated load, plate-to-plate.				7000 14000	5.5 8.0	79
85	DUPLEX-DIODE TRIODE	SMALL 6-PIN	FIG. 13	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	135 180 250	−10.5 −13.5 −20.0	—	—	3.7 6.0 8.0	11000 8500 7500	750 975 1100	8.3 8.3 8.3	25000 20000 20000	0.075 0.160 0.350	85
89	TRIPLE-GRID POWER AMPLIFIER	SMALL 6-PIN	FIG. 14	$4\frac{17}{32}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.4	250	250	AS TRIODE ¶ CLASS A AMPLIFIER	160 180 250	−20.0 −22.5 −31.0	—	—	17.0 20.0 32.0	3300 3000 2600	1425 1550 1800	4.7 4.7 4.7	7000 6500 5500	0.300 0.400 0.900	89
										AS PENTODE ** CLASS A AMPLIFIER	100 180 250	−10.0 −18.0 −25.0	100 180 250	1.6 3.0 5.5	9.5 20.0 32.0	104000 80000 70000	1200 1550 1800	125 125 125	10700 8000 6750	0.33 1.50 3.40	
										AS TRIODE ⊕ CLASS B AMPLIFIER	180	0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				13600 9400	2.50 3.50	
V-'99 X-'99	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-NUB SMALL 4-PIN	FIG. 10 FIG. 1	$3\frac{1}{2}'' \times 1\frac{1}{16}''$ $4\frac{1}{8}'' \times 1\frac{3}{16}''$	D-C FILAMENT	3.3	0.063	90	—	CLASS A AMPLIFIER	90	− 4.5	—	—	2.5	15500	425	6.6	—	—	V-'99 X-'99
112-A	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	D-C FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	90 180	− 4.5 −13.5	—	—	5.0 7.7	5400 4700	1575 1800	8.5 8.5	—	—	112-A

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.
■ Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D. C. on A-C filament types, decrease stated grid volts by ½ (approx.) of filament voltage.
Requires different socket from small 7-pin.

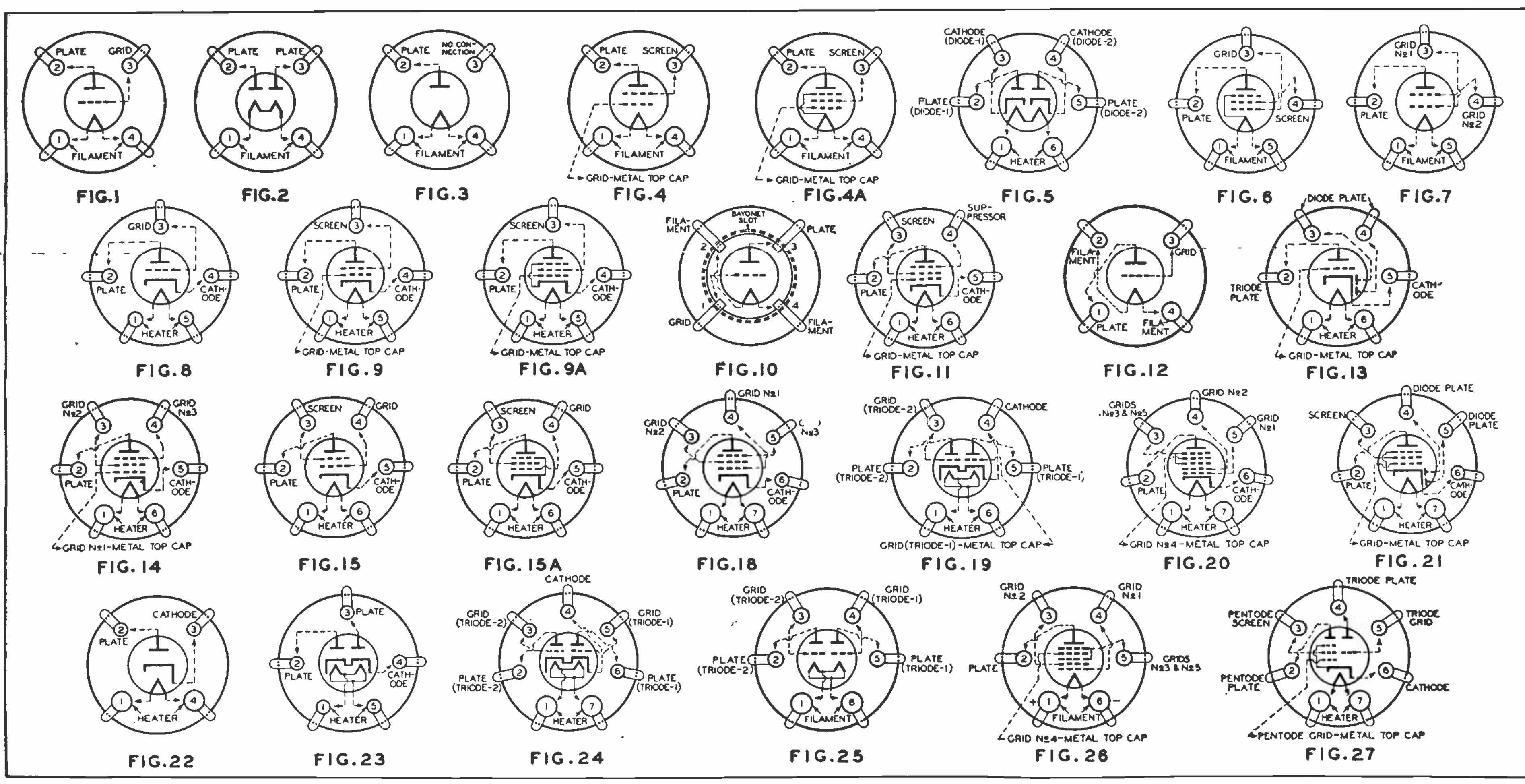
** Grid #1 is control grid. Grid #2 is screen. Grid #3 tied to cathode.
¶ Grid #1 is control grid. Grids #2 and #3 tied to plate. ⌘ Applied through plate coupling resistor of 250000 ohms.
⊕ Grids #1 and #2 connected together. Grid #3 tied to plate. **For grid of following tube.

RECTIFIERS

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS	CATHODE TYPE	VOLTS	AMPERES	PLATE MAX. VOLTS	SCREEN MAX. VOLTS	RATINGS	TYPE
5Z3	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 2	$5\frac{3}{8}'' \times 2\frac{1}{16}''$	FILAMENT	5.0	3.0	—	—	Maximum A-C Voltage per Plate .... 500 Volts, RMS Maximum D-C Output Current .... 250 Milliamperes	5Z3
12Z3	HALF-WAVE RECTIFIER	SMALL 4-PIN	FIG. 22	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	12.6	0.3	—	—	Maximum A-C Plate Voltage .... 250 Volts, RMS Maximum D-C Output Current .... 60 Milliamperes	12Z3
25Z5	RECTIFIER-DOUBLER	SMALL 6-PIN	FIG. 5	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	25.0	0.3	—	—	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 100 Milliamperes	25Z5
1-v°	HALF-WAVE RECTIFIER	SMALL 4-PIN	FIG. 22	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.3	—	—	Maximum A-C Plate Voltage .... 350 Volts, RMS Maximum D-C Output Current .... 50 Milliamperes	1-v°
80	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 2	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	FILAMENT	5.0	2.0	—	—	A-C Voltage per Plate (Volts RMS).. 350 400 550 D-C Output Current (Maximum MA.) 125 110 135 The 550 volt rating applies to filter circuits having an input choke of at least 20 henries.	80
'81	HALF-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 3	$6\frac{1}{4}'' \times 2\frac{7}{16}''$	FILAMENT	7.5	1.25	—	—	Maximum A-C Plate Voltage .... 700 Volts, RMS Maximum D-C Output Current .... 85 Milliamperes	'81
82	FULL-WAVE ➤ RECTIFIER	MEDIUM 4-PIN	FIG. 2	$4\frac{11}{16}'' \times 1\frac{13}{16}''$	FILAMENT	2.5	3.0	—	—	Maximum A-C Voltage per Plate .... 500 Volts, RMS Maximum D-C Output Current .... 125 Milliamperes Maximum Peak Inverse Voltage .... 1400 Volts Maximum Peak Plate Current .... 400 Milliamperes	82
83	FULL-WAVE ➤ RECTIFIER	MEDIUM 4-PIN	FIG. 2	$5\frac{3}{8}'' \times 2\frac{1}{16}''$	FILAMENT	5.0	3.0	—	—	Maximum A-C Voltage per Plate .... 500 Volts, RMS Maximum D-C Output Current .... 250 Milliamperes Maximum Peak Inverse Voltage .... 1400 Volts Maximum Peak Plate Current .... 800 Milliamperes	83
84 *also 6Z4*	FULL-WAVE RECTIFIER	SMALL 5-PIN	FIG. 23	$4\frac{1}{4}'' \times 1\frac{9}{16}''$	HEATER	6.3	0.5	—	—	Maximum A-C Voltage per Plate .... 350 Volts, RMS Maximum D-C Output Current .... 50 Milliamperes	84 *also 6Z4*

➤ Mercury Vapor Type. ° Interchangeable with Type 1.

TUBE SYMBOLS AND BOTTOM VIEWS OF SOCKET CONNECTIONS



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PRACTICAL RADIO JOB SHEET

No. 14-A

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

METAL TUBE CHARACTERISTICS

1. - THE TABLE BELOW CONTAINS THE OPERATING CHARACTERISTICS OF THE MORE POPULAR METAL TUBES, WHICH ARE EQUIPPED WITH THE "OCTAL" BASE (8 - PRONG BASE). IN THIS TABLE, THE LETTERS APPEARING TO THE RIGHT OF THE TUBE NUMBER IN THE TUBE TYPE COLUMN DO NOT APPEAR ON THE TUBE ITSELF AS A PART OF THE NUMBER BUT IN THIS PARTICULAR TABLE, THESE LETTERS INDICATE THE MANUFACTURER OF THE TUBE IN THE FOLLOWING MANNER:

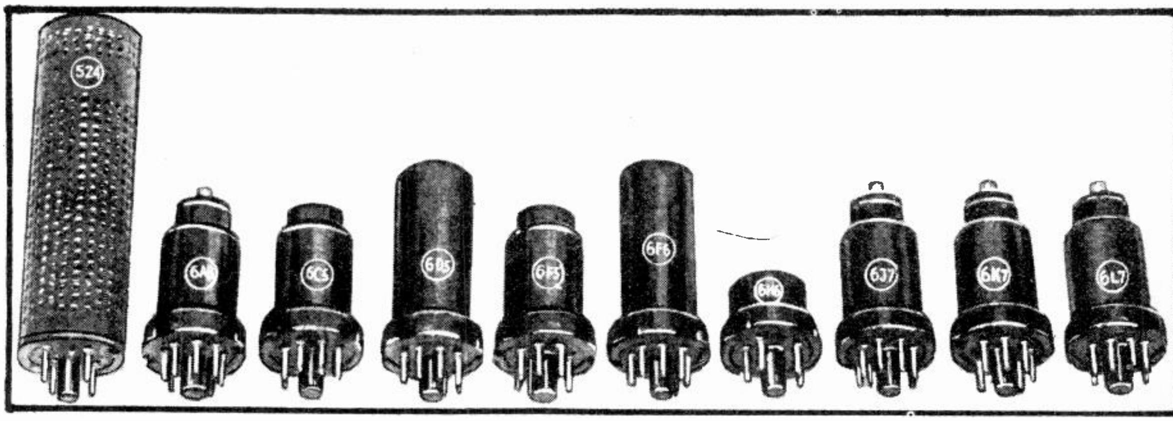

Fig. 1
A Group Of Popular Metal Tubes.

CHARACTERISTIC TABLE OF METAL TUBES.

TUBE TYPE	Fil. or Heater V.	Fil. or Heater A	Max. Pl. V.	Max. S.-G. V.	Grid V. Neg.	Pl. Ma.	Cath. Ma.	Plate Resis.	Mut-ual Cond.	Amp. Factor	Plate Load	Out-Put Watts	Equiv. Types	No. of Pins	Function
6A8 *RK*	6.3	0.3	250	100	3.0	4.0	14	300M	520				6A7	8	Pent. Converter
6A8 *A*	6.3	0.3	250	100	3.0	2.6	12.8						6A7	8	Pent. Converter
6A8 *TNS*	6.3	0.3	250	100	3.0	3.5		360M					6A7	7	Pent. Converter
6C5 *RATNKS*	6.3	0.3	250		8.0	8.0		10M	2,000	20			76	6	Triode Amply.
6D5 *RATNKS*	6.3	0.7	275		40	31		2,250	2,100	4.7	7,200	1.4	45	6	Triode Amp., Class A
6D5 *NKA*	6.3	0.7	300		50	23					-5,300	5.0	45	6	Triode Amp., Class AB
6F6 *RKS*	6.3	0.7	250	250	16.5	34		100M	2,300	200	7,000	3.0	42	7	Pentode Output, Class A
6F6 *TAN*	6.3	0.7	250	250	16.5	34	40.5	100M	2,200	220	7,000	3.0	42	7	Pentode Output, Class A
6F6 *KS*	6.3	0.7	250		20.0	31	31	2,600	2,700	7.0	4,000	.85	42	7	Triode Output, Class A
6F6 *K*	6.3	0.7	250	250	26.0	17	19.5				10,000	19.0	42	7	Pentode Output, Class AB
6F6 *K*	6.3	0.7	350		38.0	22.5					6,000	18.0	42	7	Triode Output, Class AB
6H6 *RATNKS*	6.3	0.3	100	Direct Current 2 Ma. (max.)									none	7	Duodiode Detector
6J7 *RTKANS*	6.3	0.3	250	100	3.0	2.0	2.5	1.5 meg. +	1,225	1,500 +			6C6	7	Pentode Det.-Amp.(Non-var. Mu.)
6K7 *RTANKS*	6.3	0.3	250	100	3.0	7.0	8.7	800M	1,450	1,160			6D6	7	Var. Mu. Amplifier
6L7 *RNKS*	6.3	0.3	250	150	6.0	3.5		2.0 meg. +	325				none	7	Pentagrid Mixer-Amplifier
6L7-G *A*	6.3	0.3	250	100	3.0	5.3		800M	1,100				none	7	Pentagrid Mixer-Amplifier
5Z4 *RKNTS*	5.0	2.0	400			125 Max							5Z3	5	Full-wave—H.-V. Amplifier
43-MG *T*	25.0	0.3	135	135	20	34	41	35,000	2,300	80	4,000	2.0	43	7	AC-DC Power Amp. Pentode
6F5 *NATKS*	6.3	0.3	250		2.0	0.9	0.9	66,000	1,500	100			none	5	High-Mu. Triode
25Z5-MG *T*	25.0	0.3	125	100									25Z5	7	Full-Wave Rectifier
50A2-MG *T*	50 V. total drop; 0.3-A.;												none	4	Ballast tube
50B2-MG *T*	50 V. total drop; 0.3-A.;												none	4	Ballast tube

(OVER)

R = RCA and Raytheon; K = Ken-Rad; A = Arcturus; T = Triad; N = National Union; S = Sylvania. These letters appearing after the tube types above mean that data was available from the makers on these particular types. Some manufacturers do not as yet make all the types at present available. Arcturus tube designations are all "terminated by "G", meaning glass-"metal"; the Triad termination is "MG", meaning metal-glass. Where manufacturers differ somewhat in their tube characteristics, the tube is listed twice, as is the case with the 6A8. The power tubes, 6D5 and 6F6 appear more than once because they are used under different operating conditions. The 6H6 is equivalent to the two diodes of a 75, while the 6F5 resembles the triode section of a 75. The Triad 50A2-MG and 50B2-MG are ballast tubes, both having a voltage drop of 50, the former for use with one Type No. 40 pilot lamp and the latter for use with two. They are to be used in A.C.-D.C. sets, in place of the usual series resistors.

2. - The arrangement of the elements, together with the base connections for these metal tubes, are illustrated in Fig. 2.

3. - The base connections for the remaining special tubes appearing in the table are illustrated in Fig. 3. In both Figs. 2 and 3 base prong #1 is grounded in all cases - in this manner grounding the metal shell of the tube.

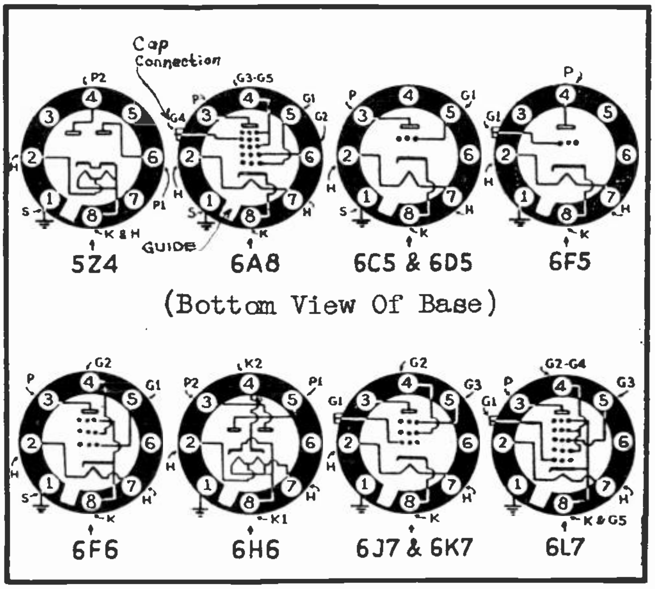

Fig. 2
Standard Metal Tube Bases

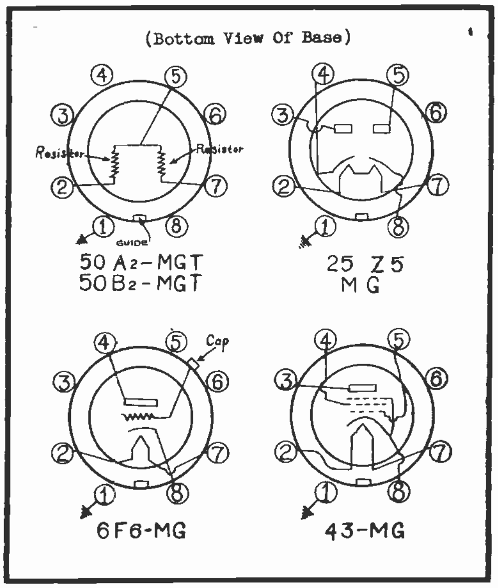

Fig. 3
Metal-Glass Octal-Base Tube Connections

NO. 15

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

CONTINUITY TESTS

THE PURPOSE OF THIS JOB SHEET IS TO DESCRIBE SIMPLE BUT ACCURATE METHODS FOR CHECKING THE CONTINUITY OF WINDINGS AND CIRCUITS, AS WELL AS THE METHOD OF TESTING RESISTORS AND CONDENSERS WITH THE AID OF THE MOST INEXPENSIVE EQUIPMENT. LATER JOB SHEETS DESCRIBE MORE ELABORATE TESTS OF THIS NATURE.

CHECKING A WINDING

1. – TO DETERMINE WHETHER OR NOT A WINDING SUCH AS USED IN AN A.F. TRANSFORMER, R.F. TRANSFORMER, CHOKE ETC. IS COMPLETE OR NOT PROCEED AS ILLUSTRATED IN FIG. 1, THAT IS, CONNECT A 4½ VOLT "C" BATTERY IN SERIES WITH A PAIR OF TEST LEADS AND A D.C. VOLTMETER HAVING A RANGE OF 0–10 VOLTS.

2. – TOUCH THE TWO TEST POINTS TO THE TWO TERMINALS ACROSS WHICH THE WINDING UNDER TEST IS CONNECTED. IF THE WINDING IN QUESTION IS OPEN CIRCUITED AS INDICATED IN FIG. 1, THEN THE VOLTMETER WILL OFFER A ZERO READING.

3. – SHOULD THE WINDING UNDER TEST BE INTACT OR COMPLETE, THEN THE VOLTMETER WILL OFFER A READING WHICH IS APPROXIMATELY EQUAL TO THE VOLTAGE OF THE BATTERY BEING USED. THE EXACT READING WILL DEPEND UPON THE RESISTANCE OF THE WINDING THROUGH WHICH THE TEST IS BEING MADE.

CHECKING A CONDENSER

1.– THE METHOD OF CHECKING A CONDENSER SO AS TO DETERMINE WHETHER IT IS SHORTED ("BURNED OUT") OR NOT IS ILLUSTRATED IN FIG.2. HERE THE SAME TESTING EQUIPMENT IS EMPLOYED AS HAS ALREADY BEEN DESCRIBED RELATIVE TO FIG.1.

2.– WHEN CONDUCTING THIS TEST, THE TEST POINTS ARE CONNECTED ACROSS THE CONDENSER TERMINALS

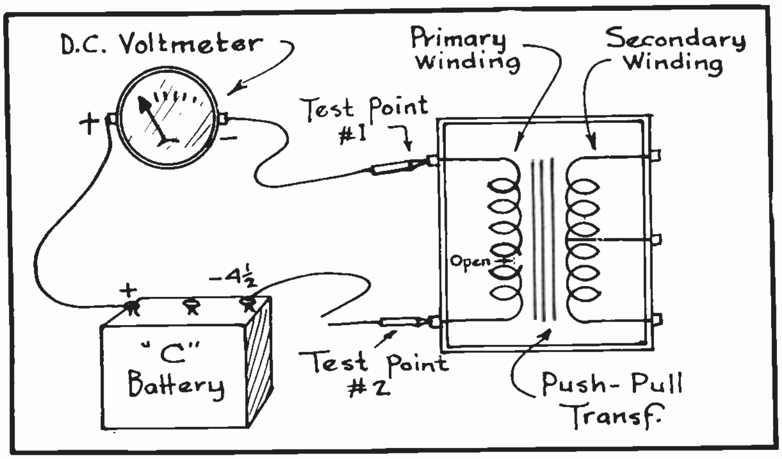

Fig.1
Checking A Transformer.

AND THE ACTION OF THE VOLTMETER CAREFULLY NOTED.

3. — IF THE VOLTMETER INDICATES THE VOLTAGE OF THE "C" BATTERY, THEN THE CONDENSER IN QUESTION IS SHORTED AND SHOULD BE REPLACED WITH A NEW ONE.

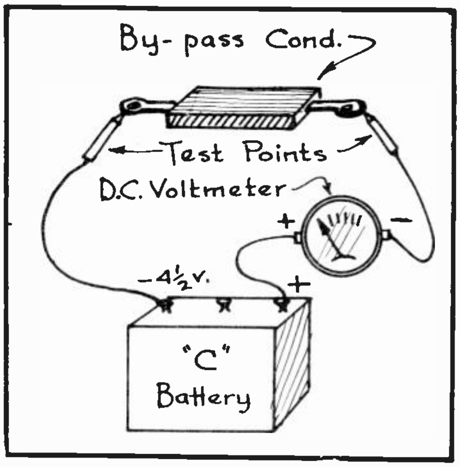

Fig. 2
Testing A Condenser.

4. — IF THE CONDENSER IS IN GOOD CONDITION THEN THE INSTANT THAT THE TEST POINTS ARE CONNECTED ACROSS THE CONDENSER TERMINALS, THE VOLTMETER NEEDLE WILL MOVE VERY SLIGHTLY TOWARDS THE RIGHT FROM THE ZERO MARK BUT ONLY FOR AN INSTANT. THE NEEDLE WILL THEN IMMEDIATELY DROP TO THE ZERO LINE OF THE VOLTMETER SCALE AND AT WHICH POSITION IT WILL REMAIN AS LONG AS THE TEST POINTS ARE HELD IN PLACE.

CHECKING RESISTORS

1. — RESISTORS WHOSE NORMAL RESISTANCE VALUE IS NOT TOO HIGH CAN BE CHECKED FOR CONTINUITY AS PER FIG. 3.

2. — IF THE RESISTOR IS OPEN CIRCUITED, THE VOLTMETER READING WILL BE ZERO. IF THE RESISTOR IS IN A GOOD CONDITION, A METER READING WILL BE OBTAINED — THE EXACT READING DEPENDING UPON THE RESISTANCE VALUE OF THE RESISTOR UNDER TEST.

3. — FOR RESISTORS OF HIGH OHMIC VALUE, THIS TEST ISN'T RELIABLE IN THAT THE RESISTANCE MAY NORMALLY BE SUFFICIENTLY GREAT SO THAT 4½ VOLTS IS NOT ABLE TO FORCE SUFFICIENT CURRENT THROUGH THE UNIT TO OFFER A LEGIBLE READING. AN OHMMETER RESISTOR CHECK IS MORE DESIRABLE AND IS FULLY EXPLAINED IN A LATER JOB SHEET.

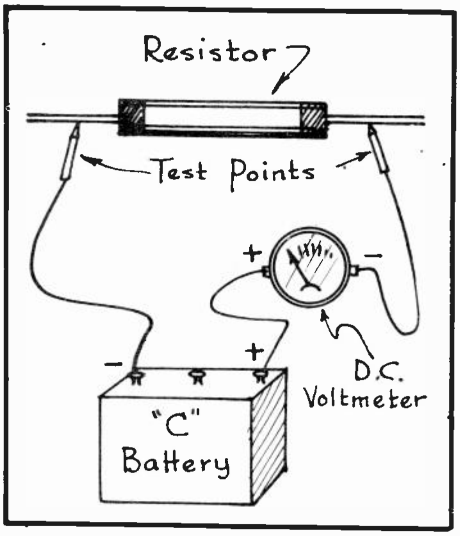

Fig. 3
Checking The Resistor.

NOTE: WHEN PERFORMING THE CONTINUITY TESTS AS DESCRIBED IN THIS JOB SHEET, IT IS ADVISABLE THAT THE UNIT WHICH IS BEING TESTED BE DISCONNECTED FROM THE RECEIVER CIRCUITS DURING THE TIME THAT THE TEST IS CONDUCTED. IN THIS WAY, YOU ARE CERTAIN THAT YOU ARE NOT TESTING THRU AN EXTERNAL CIRCUIT RATHER THAN THROUGH THE UNIT ITSELF.

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NO. 16

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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THE RESISTOR COLOR CODE

It is not the general practice among the manufacturers of resistors to mark the ohmic value upon the unit. Instead of this, the outer surface of the resistor unit is painted in a combination of colors and by properly interpreting this color-combination, one can readily determine the resistance value of the unit.

1. – Fig. 1 shows you the customary manner in which fixed resistors are colored. As you will observe, the body of the resistor is painted one color, the end of the resistor another color and a third color is added in the form of a spot or band at the center of the body.

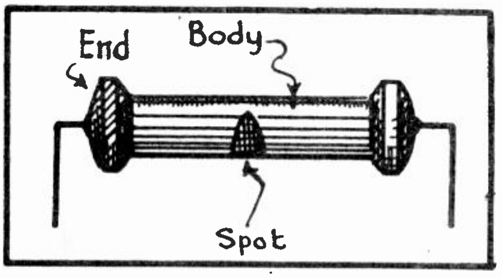

Fig. 1
A Color-Coded Resistor.

2. – The body color of the resistor indicates the first significant figure, the end color designates the second significant figure and the spot or band color designates the third significant figure of the unit's ohmic value.

3. – The following table explains the numerical value for the respective colors.

Body Color		End Color		Spot or Band Color	
Brown	1	Black	0	Black	0
Red	2	Brown	1	Brown	0.
Orange	3	Red	2	Red	00.
Yellow	4	Orange	3	Orange	000.
Green	5	Yellow	4	Yellow	0000.
Blue	6	Green	5	Green	00000.
Violet	7	Blue	6	Blue	000000.
Gray	8	Violet	7		
White	9	Gray	8		
Black	0	White	9		

Example: A fixed resistor has a red body color, a black end color and a green spot on its body. What is the resistance in Ohms of this unit?

Answer: Body color of red designates a first significant figure of 2; end color of black designates a second significant figure of 0, bringing the value so far to 20; green spot on body designates a third significant figure of 00000; the resistance of this particular unit is therefore 2,000,000 Ohms or 2 megohms.

PRACTICAL RADIO JOB SHEET NO. 17
SPECIALLY PREPARED FOR THE STUDENTS OF
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THE CONDENSER COLOR CODE

Some manufacturers of fixed mica condensers employ a color code for designating the capacitive value of their units. In such cases, three dots are placed on the trademark side and each of a different color as illustrated in Fig. 1.

1. - To interpret the code, the condenser is held in the position shown in Fig. 1 and the dots are read from the left towards the right. The first dot represents the first figure of the condenser capacity, the second dot represents the second figure of the condenser capacity and the third dot represents the number of zeros following the first two figures.

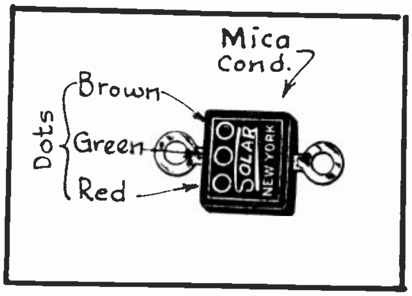

Fig. 1
Condenser Code Marks.

2. - The color code as used with this system appears in the table of Fig. 2 and when interpreted, the condenser capacity is expressed in micro-microfarads.

3. - With reference to both Figs. 1 and 2 of this Job Sheet, the capacitive value of the condenser shown in Fig. 1 works out as follows: The red dot indicates a capacitive value whose first digit is 2; the green dot indicates a second digit of this value as being 5 and the brown dot indicates that one zero follows the second digit. Thus the capacitive value of this condenser is 250 mmfd. or .00025 mfd.

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

Fig. 2
Color Code Table.

4. - As another example let us consider a condenser on which appear a green dot, a black dot, and a brown dot reading from left to right. In this case, the green dot indicates a first digit 5; the black dot indicates a second digit of 0; and the brown dot indicates that one zero follows the second digit. Therefore, the capacitive value of the condenser in this case will be 500 mmfd. or .0005 mfd.

NO. 18

PRACTICAL RADIO JOB SHEET

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IDENTIFYING POWER TRANSFORMER TERMINALS

As a general rule the terminals of power transformers are not marked by the manufacturer for identification purposes. In such cases, the method as described in this JobSheet can be employed so that one can ascertain definitely which of the transformer windings are connected to the various terminals.

1. – First connect a 110 volt–25 watt incandescent lamp in series with the 110 volt lighting circuit and a pair of test points as shown in the accompanying illustration. Naturally, if a 220 volt transformer is involved, a 220 volt lamp and circuit would be used.

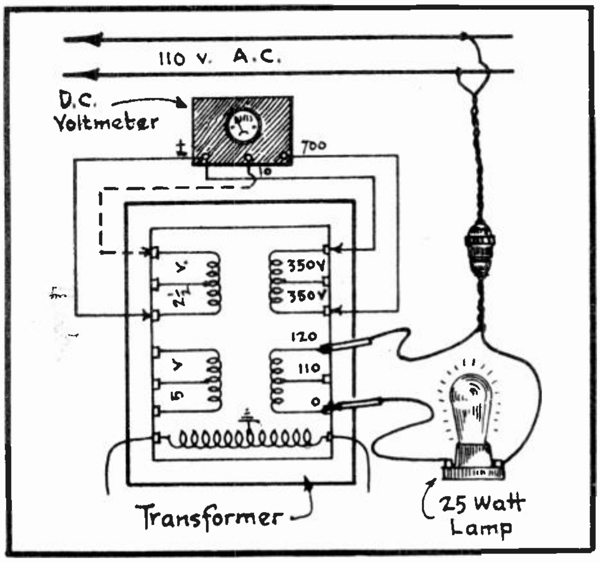

Fig. 1
Testing The Transformer.

2. – With the lamp circuit test points, test between the various terminals until you locate a pair which cause the lamp to burn very dim. These terminals have the primary winding connected to them.

3. – Connect the lamp circuit across these primary terminals and with an A.C. voltmeter of suitable range test between the remaining terminals until readings corresponding to the high voltage winding are obtained. For instance, if the high voltage winding is rated for 700 volts across its extremeties, then a voltmeter reading of this value will be obtained when connected across these two corresponding terminals. A reading of one-half this amount will be obtained between each end terminal of this winding and its center tap.

4. – Using the low range A.C. voltmeter scale, continue testing for the terminals of the low voltage windings, again remembering that between the center tap of any of these windings and either end terminal, the reading will be one-half that obtained across the two ends of the same winding. Also make it a practice to consider the transformer core as a terminal while testing.

5. – If the primary winding is designed for high and low line voltage, the lamp will burn dim when one test point is held in contact with one end of the primary and with the other test point in contact with either of the two remaining primary terminals.

NO. 19

PRACTICAL RADIO JOB SHEET

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APPLICATION OF A LINE VOLTAGE REGULATOR

IN SOME LOCALITIES IN WHICH A.C. RECEIVERS ARE OPERATED, THE LINE VOLTAGE VARIES TO SUCH AN EXTENT THAT THE VOLTAGE AT TIMES BECOMES SUFFICIENTLY GREAT TO BURN OUT THE RECEIVER TUBES OR ELSE DAMAGE THE POWER PACK.

1. – TO REMEDY SUCH A CONDITION A LINE VOLTAGE REGULATOR CAN BE CONNECTED IN SERIES WITH THE A.C. LINE AND THE PRIMARY WINDING OF THE RECEIVER'S POWER TRANSFORMER AS SHOWN IN FIG. 1.

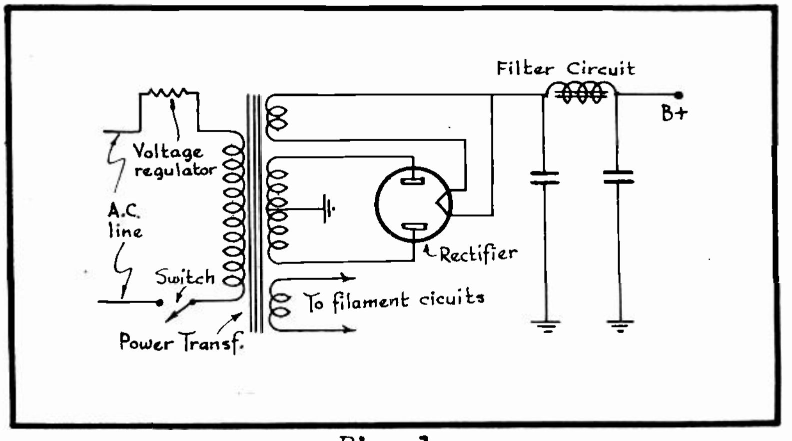

Fig. 1
Installation Of Voltage Regulator In Circuit.

2. – TWO POPULAR LINE VOLTAGE REGULATORS ARE SHOWN IN FIG. 2. THE ONE AT THE LEFT IS A "CLAROSTAT" AND CONSISTS OF A PERFORATED METAL CONTAINER IN WHICH A SPECIAL RESISTANCE ELEMENT IS CONTAINED. ITS DESIGN IS SUCH THAT IT CAN BE INSERTED INTO AN ORDINARY SCREW TYPE PLUG OR CONVENIENCE OUTLET OF THE LIGHTING CIRCUIT. THE PLUG WHICH IS ATTACHED TO THE RECEIVER'S POWER CORD IS THEN INSERTED IN THE TWO HOLES PROVIDED FOR THIS PURPOSE ON THE REGULATOR.

3. – THE TUBE TYPE REGULATOR ("AMPERITE") ALSO SHOWN IN FIG. 2 CAN BE MOUNTED AT ANY CONVENIENT POINT IN THE RECEIVER CABINET SO THAT THE UNIT WILL BE IN SERIES WITH THE A.C. LINE AND THE RECEIVER.

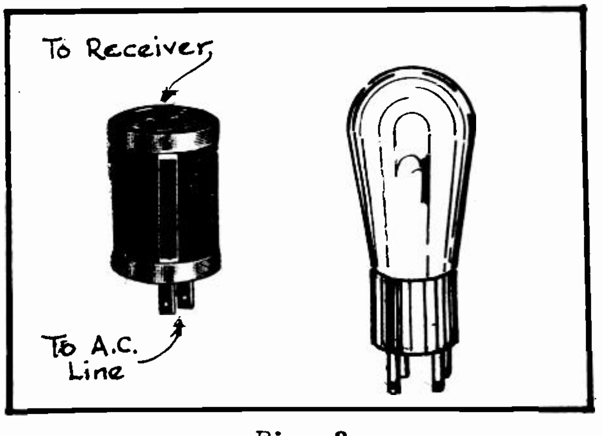

Fig. 2
Typical Voltage Regulators.

4. – FOR 110 VOLT RECEIVERS THESE REGULATORS WILL MAINTAIN THE RECEIVER VOLTAGE VERY NEARLY CONSTANT EVEN THOUGH THE LINE VOLTAGE MAY VARY BETWEEN 95 AND 140 VOLTS. WHEN ORDERING SUCH A REGULATOR FROM A DEALER, IT IS IMPORTANT TO SPECIFY THE VOLTAGE AND POWER CONSUMPTION RATING OF THE RECEIVER.

5. – WHEN PURCHASING A REGULATOR REPLACEMENT ALWAYS SPECIFY THE NAME AND MODEL OF RECEIVER.

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PRACTICAL RADIO JOB SHEET

NO. 20

SPECIALLY PREPARED FOR THE STUDENTS OF

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COMMON TROUBLES IN BROADCAST SUPERHETERODYNE RECEIVERS

IN THIS JOBSHEET ONLY THE MORE COMMON TROUBLES PECULIAR TO SUPERHETERODYNES ARE CONSIDERED. GENERAL CIRCUIT TROUBLES SUCH AS DEFECTIVE TUBES, RESISTORS, CONDENSERS ETC. WHICH MAY OCCUR IN ANY RECEIVER REGARDLESS IF IT BE OF THE T.R.F. OR SUPERHETERODYNE TYPE ARE NOT TREATED HERE.

WEAK SIGNALS THROUGHOUT TUNING RANGE

1. – IMPROPER ADJUSTMENT OF I.F., OSCILLATOR, MIXER OR R.F. TRIMMERS OR A DEFECT IN ANYONE OF THESE UNITS.
2. – DEFECTIVE ANTENNA OR GROUND SYSTEM.
3. – DEFECTIVE R.F., MIXER, OSCILLATOR, OR I.F. TRANSFORMER.
4. – DEFECTIVE A.V.C. SYSTEM.
5. – POOR OSCILLATOR TUBE, OR CIRCUIT CONDITION IS SUCH THAT LOW OSCILLATOR OUTPUT IS FURNISHED.

WEAK SIGNALS OVER A PART OF TUNING RANGE

1. – IMPROPER ALIGNMENT OF R.F., MIXER, AND OSCILLATOR TRIMMERS OVER THAT PART OF THE BAND WHERE THE RECEIVER AFFORDS LOW OUTPUT
2. – POOR OSCILLATOR TUBE.
3. – DEFECTIVE COUPLING BETWEEN OSCILLATOR AND MIXER TUBES.
4. – WRONG VOLTAGE SUPPLIED TO OSCILLATOR.
5. – UNSATISFACTORY ANTENNA SYSTEM.

RECEIVER INOPERATIVE OVER A PORTION OF DIAL

1. – POOR OSCILLATOR TUBE.
2. – OSCILLATOR TUBE BEING OPERATED WITH WRONG VOLTAGES APPLIED TO IT.
3. – HIGH RESISTANCE IN TUNED CIRCUITS OF OSCILLATOR OR MIXER TUBE.

4. — R.F., MIXER, OR OSCILLATOR TRIMMERS NOT PROPERLY ADJUSTED.

5. — DEFECTIVE OSCILLATOR COIL.

6. — DEFECTIVE COUPLING BETWEEN OSCILLATOR AND MIXER.

7. — LEAK OR SHORT CIRCUIT BETWEEN TUNING CONDENSER PLATES AT CERTAIN POINTS OF THEIR TRAVEL.

DEAD RECEIVER

1. — DEFECTIVE OSCILLATOR TUBE.

2. — DEFECTIVE OSCILLATOR CIRCUIT OR COMPONENT THEREOF, SUCH AS THE COIL, CONDENSERS, ETC.

3. — DEFECTIVE A.V.C. SYSTEM.

4. — ALIGNMENT OF TUNING CIRCUITS COMPLETELY DISTURBED.

5. — DEFECT IN R.F. OR MIXER CIRCUIT (SAME AS COMMON TO T.R.F. RECEIVERS).

6. — DEFECT IN I.F. CHANNEL AS SHORTED TRIMMER CONDENSERS, OPEN OR SHORTED I.F. TRANSFORMER WINDINGS, ETC.

7. — DEFECT IN SECOND DETECTOR CIRCUIT OR A.F. CHANNEL.

8. — ANY OTHER DEFECT COMMON TO BOTH T.R.F. AND SUPERHETERODYNES SUCH AS DEFECTIVE POWER PACK, OPEN FEEDER CIRCUITS, GROUNDED CIRCUITS ETC.

HETERODYNE WHISTLE AS EACH STATION IS TUNED IN

1. — AN OSCILLATORY CONDITION IN THE R.F., I.F., OR MIXER TUBE CIRCUITS.

2. — INCORRECT LOCATION OF CONTROL GRID OR PLATE LEADS IN R.F., MIXER, OR I.F. CIRCUITS.

3. — OPEN BYPASS CONDENSERS IN A.V.C. VOLTAGE FEED CIRCUITS.

4. — SHORTED GRID FILTER RESISTORS IN R.F., MIXER, AND I.F. CIRCUITS.

5. — OPEN CONDENSERS IN R.F., MIXER, I.F., OR SECOND DETECTOR CIRCUITS.

6. — SHIELDS NOT PROPERLY GROUNDED.

WHISTLE OR GROWL BACKGROUND TO ALL STATIONS

1. — OSCILLATORY CONDITION IN I.F. OR A.F. AMPLIFIER.

2. — IMPROPER OPERATION OF OSCILLATOR CIRCUIT.

3. — EXCESSIVE RESISTANCE IN GRID CIRCUITS.

4. — IMPERFECT BIAS RESISTORS.

5. — IMPERFECT BYPASS CONDENSERS ACROSS BIAS AND GRID FILTER RESISTORS.

WHISTLE WHEN TUNING IN CERTAIN STATIONS ONLY

1. — INSUFFICIENT SELECTIVITY IN TUNING CIRCUITS PRECEDING THE MIXER TUBE.

2. — IMPROPER ALIGNMENT OF I.F. TUNING CIRCUITS.

3. — TRIMMERS OF R.F., OSCILLATOR, AND MIXER CIRCUITS NOT PROPERLY ADJUSTED FOR THAT PARTICULAR SECTION OF THE BAND.

4. — EXCESSIVE SIGNAL STRENGTH OF INTERFERING STATION PRECEDING THE MIXER CIRCUIT.

5. — UNDESIRED COUPLING BETWEEN ANTENNA OR GROUND LEADS AND SECOND DETECTOR CIRCUIT.

6. — POOR SHIELDING.

REPEAT POINTS (STATION RECEIVED AT MORE THAN ONE POINT ON DIAL)

1. — OSCILLATOR TRIMMER ADJUSTMENT NOT CORRECT.

2. — R.F. TUNING CONDENSER TRIMMER ADJUSTMENT NOT CORRECT.

3. — EXCESSIVE PICK-UP FROM STATION.

4. — MIXER CIRCUIT TRIMMER NOT PROPERLY ADJUSTED.

5. — INCORRECT LOCATION OF AERIAL LEADS.

6. — IMPERFECT SHIELDING.

7. — EXCESSIVE CONTROL GRID BIAS ON R.F. AND MIXER TUBES.

DISTORTION ALTHOUGH ALL CIRCUIT CONSTANTS ARE NORMAL

1. — R.F. MIXER OR OSCILLATOR CIRCUITS NOT PROPERLY ALIGNED.

2. — I.F. TRIMMERS OUT OF ALIGNMENT.

3. — OVERLOADING OF TUBES.

4. — EXCESSIVE CONTROL GRID BIAS WHEN RECEIVER IS OPERATED AT LOW VOLUME.

5. — IMPROPERLY DESIGNED OR OPERATING A.V.C. SYSTEM

6. — DEFECTIVE TUBE OR TUBES.

7. — DEFECTIVE TRANSFORMER IN R.F., MIXER, OR OSCILLATOR CIRCUIT.

8. — EXCESSIVELY SHARP TUNING.

9. — INSUFFICIENT STRENGTH OF HETERODYNING SIGNAL.

FREQUENT NEED FOR RETUNING

THIS CONDITION IS GENERALLY DUE TO OSCILLATOR FREQUENCY DRIFT AND WHICH MEANS THAT THE OSCILLATOR OUTPUT CHANGES AFTER THE RECEIVER HAS BEEN IN USE FOR A WHILE ALTHOUGH THE OPERATOR HAS MADE NO CHANGE IN THE SETTING OF THE TUNING DIAL. MOST PROBABLE CAUSES FOR THIS TROUBLE ARE:

1. — IMPERFECT MOUNTING OF TUNING CONDENSER OR SLIPPING TUNING CONDENSER DRIVE IN WHICH CASE TOO MUCH PLAY MAY CAUSE A SLIGHT SHIFT IN THE SETTING OF THE TUNING CONDENSER BECAUSE OF THE VIBRATIONS CREATED BY OPERATION OF THE SPEAKER IN THE SAME CABINET.

2. — IMPERFECT MOUNTING OF OSCILLATOR COILS OR IMPERFECT COUPLING BETWEEN OSCILLATOR AND MIXER CIRCUIT.

3. — FLUSTRATIONS IN THE APPLIED OPERATING VOLTAGE.

4. — IMPERFECT GROUND CONNECTION TO TUNING CONDENSER ROTOR OF THE OSCILLATOR.

5. — IF SHIELD IS USED ON OSCILLATOR COIL, IT MAY NOT BE GROUNDED PROPERLY.

6. — DEFECTIVE RESISTOR IN OSCILLATOR CIRCUIT, ESPECIALLY IN THE GRID CIRCUIT. ANY VARIATION IN RESISTANCE DURING THE COURSE OF OPERATION WILL PRODUCE A CHANGE IN THE FREQUENCY OUTPUT OF THE OSCILLATOR.

7. — DEFECTIVE (LEAKY) BYPASS CONDENSERS CONNECTED ACROSS THE VARIOUS RESISTORS WHICH ARE RELATED TO THE OSCILLATOR CIRCUIT.

INTERFERING SIGNAL APPEARS AFTER RECEIVER HAS BEEN IN OPERATION FOR SOME TIME AND DISAPPEARS IF SHUT OFF FOR AWHILE AND THEN AGAIN PLACED IN OPERATION.

SAME TROUBLES AS LISTED UNDER THE HEADING FREQUENT NEED FOR RETUNING.

PRACTICAL RADIO JOB SHEET

NO. 21

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

OUTPUT METER CONNECTIONS

WHEN ALIGNING THE TUNED CIRCUITS OF RECEIVERS AS WELL AS WHEN CONDUCTING OTHER TESTS IN WHICH THE OUTPUT OF THE SET IS TO BE CHECKED, OUTPUT METERS ARE USED EXTENSIVELY. THE PURPOSE OF THIS JOBSHEET, THEREFORE, IS TO FAMILIARIZE YOU WITH THE PROPER METHODS OF CONNECTING THE OUTPUT METER TO RECEIVERS EMPLOYING VARIOUS TYPES OF OUTPUT CIRCUITS.

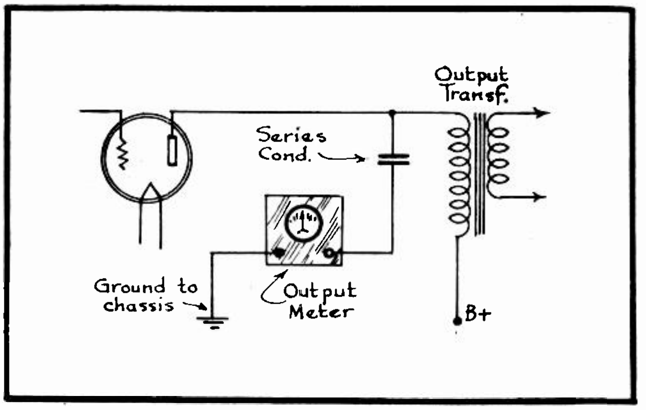

Fig. 1
Meter Connection For Single Tube Output.

SINGLE TUBE OUTPUT

1. — IN FIG. 1 YOU ARE SHOWN THE PROPER METHOD OF CONNECTING THE OUTPUT METER TO A RECEIVER WHICH IS EQUIPPED WITH AN OUTPUT STAGE EMPLOYING A SINGLE POWER TUBE AND WHERE A DYNAMIC SPEAKER IS USED.

2. — THE OUTPUT METER IN THIS CASE IS CONNECTED BETWEEN THE PLATE TERMINAL OF THE POWER TUBE'S SOCKET AND THE CHASSIS. A CONDENSER HAVING A CAPACITY FROM .1 MFD. TO 2 MFD. IS CONNECTED IN SERIES WITH THE OUTPUT METER IN ORDER TO PREVENT ANY DIRECT CURRENT FROM FLOWING THROUGH THE METER. IN THIS WAY ONLY THE ALTERNATING COMPONENT OF THE SIGNAL VOLTAGE IS PERMITTED TO ACT UPON THE METER. IN MOST COMMERCIAL OUTPUT METERS, THIS SERIES CONDENSER IS ALREADY INCLUDED IN THE UNIT.

3. — TO FASCILITATE THE METER CONNECTION TO THE PLATE CIRCUIT OF THE POWER TUBE, THE PLATE CIRCUIT CONNECTION CAN BE MADE AT THE PROPER TERMINAL OF THE RECEIVER'S OUTPUT TRANSFORMER WHEN CONVENIENT, OR ELSE THE POWER TUBE CAN BE REMOVED FROM ITS SOCKET, AN ADAPTER CLIP SLIPPED OVER ITS PLATE PRONG AND AFTER WHICH THE TUBE CAN BE RE-INSERTED IN ITS SOCKET.

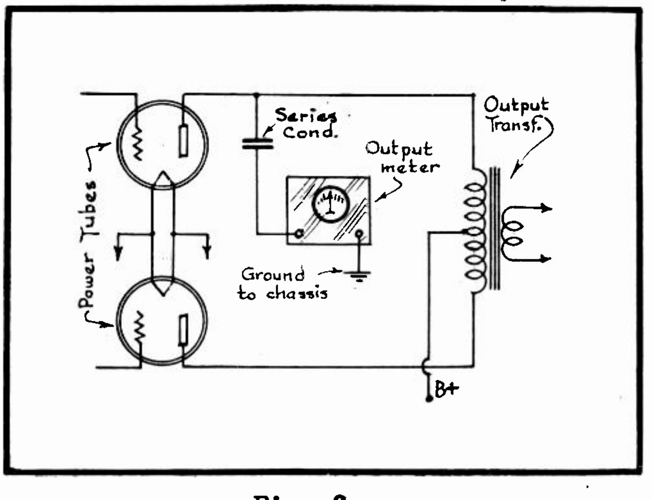

Fig. 2
Meter Connection For Push-Pull Output.

PUSH-PULL OUTPUT

1. — ON RECEIVERS WHICH EMPLOY A PUSH-PULL OUTPUT CIR-

CUIT, THE OUTPUT METER SHOULD BE CONNECTED BETWEEN THE CHASSIS AND THE PLATE TERMINAL OF EITHER ONE OF THE TWO POWER TUBES. IN THIS CASE ALSO, A CONDENSER SHOULD BE INSERTED IN SERIES WITH THE OUTPUT METER.

2. — ALTHOUGH IT IS POSSIBLE TO CONNECT THE OUTPUT METER DIRECTLY ACROSS THE PLATES OF THE TWO POWER TUBES THROUGH THE SERIES CONDENSER, YET THIS ARRANGEMENT WILL NOT PROVIDE METER DEFLECTIONS AS GREAT AS WILL THE CONNECTIONS ILLUSTRATED IN FIG.2.

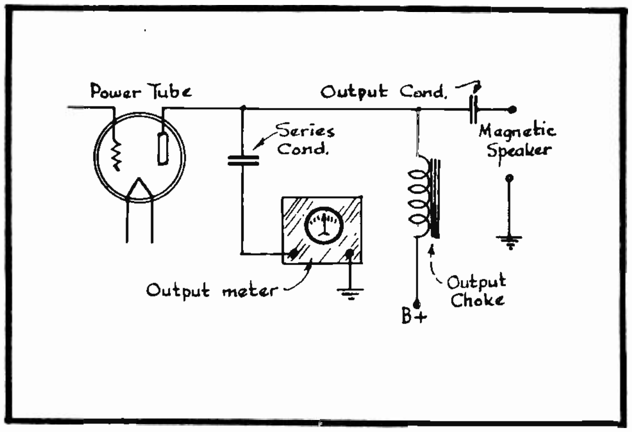

Fig. 3
Meter Connection When Using Magnetic Speaker.

OUTPUT FOR MAGNETIC SPEAKER

1. — IF A MAGNETIC SPEAKER IS BEING USED WITH A RECEIVER AND THE CIRCUIT ARRANGEMENT IS SUCH AS ILLUSTRATED IN FIG.3, THEN THE OUTPUT METER CONNECTION AS ALSO SHOWN IN THIS SAME DIAGRAM CAN BE USED.

EMERGENCY REPAIR OF A.F. TRANSFORMER

IN RECEIVERS WHERE AN A.F. TRANSFORMER IS USED AS A MEANS OF COUPLING BETWEEN THE A.F. STAGES, AS ILLUSTRATED IN FIG. 4, ONE OF THE WINDINGS SOMETIMES BECOMES OPEN CIRCUITED AFTER THE UNIT HAS BEEN IN SERVICE. IN THE EVENT THAT A NEW TRANSFORMER CANNOT BE OBTAINED READILY, AN EMERGENCY REPAIR CAN BE MADE IN THE FOLLOWING MANNER:

1. — IF THE PRIMARY WINDING IS OPEN CIRCUITED, THEN CONNECT A 25,000 OHM RESISTOR ACROSS THE PRIMARY TERMINALS OF THE TRANSFORMER AND CONNECT A .05 MFD. CONDENSER BETWEEN THE PLATE (P) AND THE GRID (G) TERMINAL OF THE TRANSFORMER AS SHOWN IN THE UPPER ILLUSTRATION OF FIG.4.

2. — SHOULD THE SECONDARY WINDING BE OPEN CIRCUITED, THEN CONNECT A 75,000 OHM RESISTOR ACROSS THE SECONDARY TERMINALS OF THE TRANSFORMER AND AN .05 MFD. CONDENSER BETWEEN THE PLATE AND GRID TERMINALS OF THE TRANSFORMER AS SHOWN IN THE LOWER ILLUSTRATION OF FIG.4.

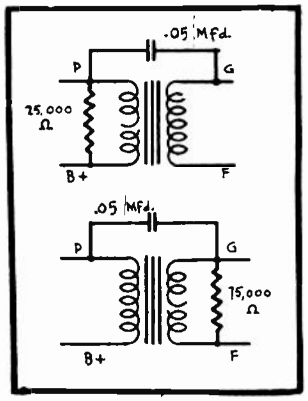

Fig. 4
The Connections.

3. — IF EITHER OF THESE TWO WINDINGS IS DEFECTIVE TO THE EXTENT OF BEING NOISY (CAUSING FRYING AND CRACKLING SOUNDS) THEN IT IS BEST TO DISCONNECT THAT WINDING FROM THE CIRCUIT ENTIRELY AND USE THE PROPER RESISTOR IN ITS PLACE.

PRACTICAL RADIO JOB SHEET

NO. 22

SPECIALLY PREPARED FOR THE STUDENTS OF

NATIONAL SCHOOLS

Los Angeles California

TABLE OF INTERMEDIATE FREQUENCIES

MODEL	K.C.
AIR KING	
37-39-52-54	456
ALLIED	
Knight 116 AVC	175
" 6 tube	175
" 7 tube	175
" P	175
" P9541	175
" P9616	175
" E9830	177.5
" E9831	177.5
" 12 tubes	177.5
" P9660	177.5
" P9640	177.5
" P9505	456
" P9511	456
" P9519	456
" P9531	456
" P9591	456
" P9501	456
" P9571	456
" P9631	456
" P9610	465
ATWATER KENT	
137	125
91-91B-91C	262.5
81-155-246-266	262.5
555-636-756-756B	262.5
165Q-525Q	264
217-427-667-217D	264
427D-667D-275-387	264
427Q-424-425-665	264
534	450
480-708-808-711	472.5
808A	472.5
93 Converter	1000
All Other Models	130
ALL AMERICAN MOHAWK CORP.	
See R. Wurlitzer	
ANSLEY RADIO CORP.	
All Models	175
AUDIOLA RADIO CO.	
1931 Super-Hets	175
5W-3374-3385	456
3387-33S10SW-3485LW	456
3386B-34C5AC-DC	456
3485AVC	456
All Others	177.5
BALKEIT RADIO CO.	
L7-L8-58-85-100	175
BELMONT RADIO CORP.	
81	105
625-650-660	175
670-750-1050	175
71C	175
775	370
525-530-540	456
550	456
BOSCH RADIO CO.	
See United American Bosch	
BROWNING DRAKE RADIO CORP.	
40-80	175
BRUNSWICK	
11-12-16	175
33AC-17-24-25	175
3NC8-5NC8	180
3NW8	180
BULOVA WATCH CO.	
All Models	175
CAPEHART CORP.	
All Models	180
CLARION RADIO	
See Transformer Corp. of America	
COLONIAL RADIO CORP.	
Laboratory Models 132 & 139	150
150	480
55	1000
All Others	175
COLUMBIA PHONOGRAPH CO., INC.	
All Models	175
CROSLEY RADIO CORP.	
120-121-122-123-124	175
124-1—125-126-126-1—127	175
127-1—128-131	175
148-154-155-156-159	456
163-166-167-169-172	456
173-173-5—174	456
All Others	181.5
DELCO APPLIANCE CORP.	
32 Volt DC Super 110 Volt AC Super	175
DELCO RADIO	
3026	175
De WALD	
AC746-7M - DAH-62	175
PLO	115
500A	130
58R-60-61-61R	455
55X 58EX-59-61-555	456
570-630	456
ECHOPHONE RADIO MFG. CO., LTD.	
62-72-92	115
All Others	175
ELEC. RESEARCH LAB., INC. Erla -- Sentinel	
1020A-1030A	115
513-570*	262
560-561-510-263	265
540-599-600-602	265
501-502-570*	465
622-623-634-635	465
5000-5010-6101-6102	465
6317-6321	465
All Others	175
ELEC. AUTO LITE	
062A-072A	262
EMERSON	
L-755 - 50-L	115
375-LW	125
35-30-250-300-310	172.5
H5-77-667-678-965	172.5
J8-K8-C8-M-AC-7-B-AC-10	175
40-375-M-755-50M	175
350-LW - H5L - 30LW	132
250LW-321LW	132
AW55	445
26-30AW-33AW	456
250AW-321AW-350AW	456
39-59-71-770-8-755	456
550	456
ERLA	
See Electrical Research Lab.	
EMPIRE ELEC. PRODUCTS	
74	462.5
All Others	175
FADA RADIO & ELEC. CORP.	
RX93-RX95-RX	125
RN106-RN107-RN108	470
RY-RS112	470
131-132RU-133-134-135	265
78-10-79-10-97-10-141NA	265
151-152NE	265
All Others	175
FEDERATED PURCHASER	
31-40	175
FORDSON	
F.U.-F.W.-F.P.32V-F.P.	456
FRANKLIN	
63L	130
100-102-200	175
94	450
53-54L	456
FREED TEL. & RADIO CORP.	
76	115
51DC-72-74-MB7-360	175
360X	175
56-70-72-74	177.5
A7-A9-355-365-365X	456
94-55-77	456
78	462.5
JESSE FRENCH	
Models - U-1 up	175
GALVIN MFG. CO.	
J-8-810	175
Dual 8 - Twin 8	262
44-55-66-77-77A	456
GENERAL ELECTRIC CO.	
K64-M65-M68	370
K80-K80X-K85	445
M41-K43-M49	460
All Others	175
GENERAL HOUSEHOLD UTILITIES	
700-701-801-901-902-1101	262
501-502-403	455
GENERAL MOTORS	
281	535
All Others	175
GRAYBAR ELEC.	
340	180
All Others	175
GREBE	
61R	456
All Others	175
GRIGSBY-GRUNOW CO.	
250A-260P	125
44-49-194-440-560	456
566-195-55-59-75	456
116-370-400	456
10	1000
All Others	175
GULBRANSEN CO.	
10-13-20-23-53	175
92-93-322-130-135	175
235-236-237-330-535	175
925-3225-3226	175
3925-8725	175
V6Z2-Z6Z1-352	262
352-06W-5521	262
3525-3622	262
HALSON	
All Models	456
HAMMARLUND MFG. CO.	
All Models	465
CHARLES HOODWIN CO.	
Models 11 tube rec.	465
All Others	175
H. H. HORN	
59-69-90-70-71-101B	175
102-101-110	175
24-36-58-156-158	456
HOWARD RADIO CO.	
EX	140
Q	170
Auto receivers	260
S-3	456
A S W Converter	680
All Others	175
INSULINE CORP.	
AC Super 7L.W.-AC Super 6L.W.	115
Super Conqueror Uni-nine	115
5 tube Uniradio-Elite-Classic	132
Super 7-AVC Super 6	175
INTERNATIONAL	
J8-K8-C8	175
Kaydette A-B-A8-9-10-CM	262.5
A7-BW-CD-D11-12-14	262.5
AW55	445
JACKSON BELL	
25-27-28-29-69	175
205	465
33	840
KELLER-FULLER MFG. CO., LTD.	
Radiette Models 70-80-90	175
120-508	175

MODEL	K.C.
COLIN B. KENNEDY CORP.	
Model 67 (Export)	110
" 52 (Export)	135
538W-548W	1000
54	1525
All Others	175
KOLSTER RADIO, INC.	
All Models	175
LANG RADIO CORP.	
All Models	175
C. R. LEUTZ, INC.	
C10	47
Special Short Wave Receiver	450
LINCOLN RADIO CORP.	
Deluxe SW-33	480
DC-SW10 - R9	480
LYRIC RADIO	
See R. Wurlitzer Co.	
MAJESTIC	
See Grigsby-Grunow	
MID-WEST	
Miraco Pentode 11 tube super.	175
RT9-G9-F9-H9-RT16	456
A16-B16-D16-F.R.16-RM16	456
MISSION BELL	
10A-11-19-19A-25A	252
14-40	456
MONTGOMERY WARD	
62-11-62-12-62-14-62-27	175
62-19-62-20-62-20X-62-25	175
1111-62-1611-811-62-1711	175
62-29-11-12-17-62-1-62-2	175
62-7-62-8-62-9-62-89	175
62-91-62-93-62-103-62-105	175
62-106-62-107-62-121-77	175
95-11-11X-811X-62-14X	175
62-19X-62-40-62-31-62-31X	175
62-54-62-54X-62-58X	175
62-52-62-64-62-64X	175
62-76-62-76X-62-74-62-74X	175
62-80-62-82-62-23-62-41	175
62-83-62-16-62-16X-62-18	175
62-13-62-15-11-12-17	175
22-1040	175
1236-1638-1638X-62-26	262
62-70X-62-46-62-46X-1358	262
1358X-1958-62-22-62-22X	262
62-30-62-30X-62-42-62-42X	262
62-48-62-48X-62-36	262
62-36X-62-34-62-34X-62-38	262
62-38X-62-44-62-44X-62-50	262
62-50X-62-68462-68X	262
62-21-13-15-16X-16	262
17-18-18X-62-1638	262
62-1955-62-40	262
Auto Radio-62-96-62-98	262
62-97-62-99-62-97X	262
62-99X-62-101-62-101X	262
62-104-87	262
62-70-62-70X-62-72	455
62-72X-62-81-62-81X	455
MOTOMETER GAUGE & EQUIP.	
10A	175
MOTOROLA AUTO RADIO	
See Galvin Mfg. Co.	
NATIONAL CO.	
A.O.S.	500
NORLETT SPARKS	
10A-30A	175
20A-20B	175
NORCO	
4 Super	250
PACKARD	
4-24-24C	235
4 tube Super 5	465
85 - 8 tube auto	470
PATTERSON RADIO CO.	
Straight Models	177.5
Amateur	457.5
70AW-107AW-207AW-210AW	262
80AW-84AW-508AW	262
104AW-510AW	262
PHILCO RADIO & TEL. CORP.	
7-8-12-15-17-37-48	175
51-51A-90-90A-111-111A-52	175
112-112A-116-116A-211-	175
211A-212-212A-Broadcast IF.	175
6-10-11-16-91-18-19-128	260
32-35-71-70-70A-270	260
270A-89-19-90-91A (with 2-47)	260
91-121-221-22L-23X 47DC	260
Broadcast I.F. 503	260
700-22-23-36-37-47DC Series	260
43-53-80	450
5-16-34-34A-38-38A	460
44-57-60-61-64-144	460
504-505-80	460
4-470-470A SW-1.R-490 SW-1.F.	1000
4 & 4C Series	3600

MODEL	K.C.
PILOT RADIO & TUBE CORP.	
8-81-10AC-11-28-39-41	115
1010	115
S148-S164-C162-C165	175
C153-C154-149	175
2-82-F14-18-20-D-3	456
81	482
4 tube D.C.	482.5
PLAZA MUSIC (HAMILTON LLOYD RADIOS)	
711 Super-6 tube LW-7 tube Super	175
5 tube Super	456
RADIO BAR	
505	175
508-526-21DP-510	262
RADIO CHASSIS	
L6D	115
L6W	125
Auto Set-A6D-LSA37	175
AC-36-QAC-36-LSA36	175
L5D	436
RCA-VICTOR CO., INC.	
R7LW	110
R51-62-64	180
121-122-221-Duo 320	370
Duo 321	370
140-141-141E-240-Duo 340	445
9 tube General Purpose-340-340E	445
301	460
SW Adapter	1000
SWAZ-RO-23 (SWIP)	1075
All Others	175
RADOLEK	
951	265
956-958	465
RADIOTROPE	
70R-71R-72R-73R	262
REMLER CO., LTD.	
Best 115KC	115
10-15-3-17-19-15-21	180
10-3-21-3	250
21-4-26-30-40-11-12-13	450
REPUBLIC INDUSTRIES	
SL6	115
SL5D-SL6D	175
Sky Hawk Patrician-S.K.PC5-PC6	175
SCOTT LABS., INC.	
All Wave Super	470
SEARS ROEBUCK	
1320-1322-1324-1390-1400	175
1402-1404-1406-1430	175
1462-1480-1482-1484	175
1580-1582-1584-1570	175
1572-1574-1590-1592	175
1630-1640-1700	175
1705	175
1708-1709-1710-1711	175
7090-1712-1713-1714	175
1715-1720-1725-7065	175
1721-1722-1732-1726X	175
1730-1750	175
1704-7070-7071-7072-7073	480
7074-1706-1707-1711A	480
7090A-1760-7075-7076	480
7077-7078-7091-7092	480
7093-7094	480
1600	1000
SENTINEL RADIO	
See Elec. Research Lab.	
SILVER-MARSHALL, INC.	
36A-Bearcat Midget-714	175
716-683-724-726-728	175
773-A-B-C-D-E-G-J-R	175
4801-4802-41-724B-726SW	175
782-1040-F	175
727-729SW-Z10-Q-QD-R-RT-V-X-Y	465
Z DEluxe Z13	472.5
736	1000
SIMPLEX RADIO CO.	
B-K-J-L-N-P-Q	175
P-AC-P-32V-W	456
V-T	465
SONORA	
70-71-72-73-84-85-86-87	262
SPARKS-WITHINGTON CO.	
10-12-14-15-16-16AW-18-25-26.	172.5
26AW-27-27A-30-33-34-36	172.5
45-56-72-74-78-28-30A-35	172.5
61-62-71-71P-81-82-333	454
STEINITE	
All Models	175
STEWART-WARNER	
102A-B & E-R102-A-B & E	177.5
R104A-B & E Broadcast I.F.	177.5
1090-91-92-93-94-95-96-97-98-1099	177.5
R106-R110-R117-R119-R120	177.5
R111-R115-R112-R116	456
105 (SWIP)	1525
STROMBERG-CARLSON	
33	260
All Others 175 KC	175

MODEL	K.C.
SUPERTONE PRODUCTS	
Superba	465
L. TATRO PRODUCTS	
L-74-M74-AK54-AM54-094	175
084-P54	177.5
TRANSFORMER CORP. OF AMERICA	
125 (Export Model	100
80-81-90-90A-91-84-85-94-25-94	175
100-120-139-160-25-160-220-260	175
280-300-320-340-420	175
422-423-425-440-480	465
240	490
200	600-1000-1500
TRAVELER RADIO & TEL. CO.	
8-8 - 8-9 - 8-10	175
UNITED AIR CLEANER	
All Models	175
UNITED AMERICAN BOSCH	
10-20J-20K-20L-31-32-36-37	175
40-41-92-100 Auto-108-150	175
160-236-237-242-243-250-251	175
312-313-226-313	175
140A-305A-360-500-502	456
305-405-805-117-127-500	456
260-261	517.5
325-20-22-36-40-91	125
100-150-224	125
UNITED MOTORS SERVICE	
2035-4036-4037 & BOP receivers	262
4048	455
U.S. RADIO & TELEVISION	
7-8-10-10C-9-19-12-120	262
69-99-1006-1007-3070-9A-9B	262
12B-19B-120B	262
5A-7D-24-25-3040-3056-25A	455
VICTOR RADIO	
See RCA Victor	
WARE MFG. CO.	
All Models	175
WELLS GARDNER, INC.	
00A-02A-06A-07A-022	175
073-092-40-40A-50	175
92-93-502-572	175
05A-05AA-05BA-06W-072	262
052-062-5B-V622-V621	262
6V	262.5
7D	456
WESTINGHOUSE	
Flat top in some cases	175
WEXTARK RADIO, INC.	
Knight 7 & 9 tube	175
WHOLESALE RADIO	
10-20-L1-80M-80MA	175
L-20 - Auto Radio	262
WILCOX-GAY	
3PA 6-66	115
285-2T5-2VA7-3D5	175
3R6-3J5-3K5-37566	175
3T665	175
WONDER BAR RADIO CORP.	
All Models	175
RUDOLPH WURLITZER CO.	
LW5	125
SA-133-SA120-SA99-SA8-SA6	175
B6-SA130-SA110-SA111-SA91	175
SA91A-S50-863-SA65-B80	175
S7-B6-S8-S10-DC65-880	175
SA130-460	175
C4-M4-P5-SU5-A60-U500	456
U50-840	456
SW8-LU5-450	456
SW8-A60-SW80-SW88	485
U50-U58	485
ZENITH RADIO CORP.	
91-92-AH-CH-RH-BH-LH-WH	175
MH-103-210-220-230-240-245	175
Broadcast I.F. 410-411-420-430	175
440-500-501-503-514-515	175
600-604-606-610-616-618-715	175
755-756-474-730-735-740	175
770-760-765-767-475-775	175
760-476-476A-770B-775B	175
215-216-217-221-225-241	175
244-263-271-412-414-441	175
442-443-470-502-516-520	175
521-530-531-532-602-603	175
605-607-608-611-612-614-615	175
617-619-620-621-622-623	175
210-5 - 211-5 - 270-5 - 510-5	125
462-650HD-651HE-660TD	252.5
661TE	252.5
701	456
460-705-706-707-711-617	485
712-750-2056-2056-1	485
518 - 550	485
250-251-252-260-261	485
272-472-473	175 & 1000
CANADIAN RECEIVERS	
Brunswick of Canada	175
Canadian Marconi Co.	175
Canadian Westinghouse Co., Ltd...Models 89, 90,99,99A, 110,120	171
Columaires 8, 10 and Models 101, 801, 802	178
DeForest Crosley	175
Grimes Radio Corp.	175
C. B. Kennedy of Canada, Ltd.	175
Mohawk Radio Ltd.	175
Northern Elec. Co., Ltd.	175
Rogers Majestic Co., Ltd.	175

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NO. 23

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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ALIGNING PEAKED I.F. AMPLIFIERS

ALL SUPERHETERODYNE RECEIVERS WHICH DO NOT EMPLOY A SPECIALLY DESIGNED FLAT-TOP OR BAND-PASS I.F. AMPLIFIER USE WHAT IS KNOWN AS A "PEAKED I.F. AMPLIFIER". THE PROCEDURE FOR ALIGNING A PEAKED I.F. AMPLIFIER IS AS FOLLOWS:

1. – FIRST ASCERTAIN THE EXACT INTERMEDIATE FREQUENCY FOR WHICH THE I.F. AMPLIFIER IN QUESTION IS DESIGNED. THIS CAN BE DETERMINED FROM FACTORY SPECIFICATIONS, BY REFERRING TO JOB SHEET #22, OR ELSE BY MEANS OF TESTS WHICH ARE DESCRIBED IN FOLLOWING JOBSHEETS.

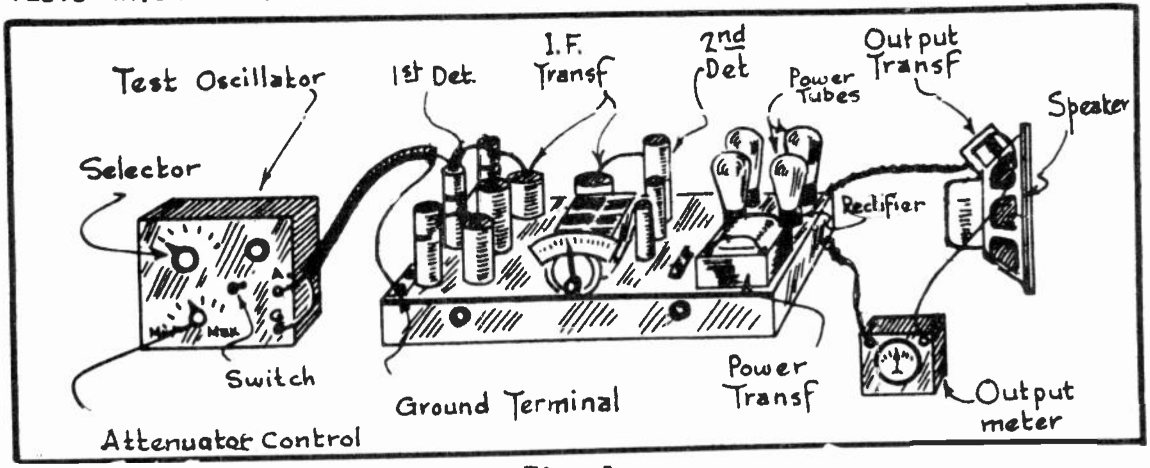

Fig. 1
Set-Up For Aligning The I.F. Stages.

2. – DISCONNECT THE ANTENNA LEAD-IN FROM THE RECEIVER BUT LEAVE THE GROUND WIRE IN PLACE.

3. – CONNECT THE INNER WIRE OF THE TEST OSCILLATOR'S SHIELDED OUTPUT CABLE TO THE CONTROL GRID OF THE FIRST DETECTOR OR MIXER TUBE AS SHOWN IN FIG. 1 AND CONNECT THE OUTER SHIELD OF THIS WIRE TO THE RECEIVER'S GROUND TERMINAL. PERMIT THE CONTROL GRID CONNECTION OF THE MIXER TUBE TO REMAIN IN POSITION AND ALSO PERMIT THE SHIELD OF THIS TUBE TO REMAIN IN PLACE.

4. – CONNECT THE OUTPUT METER TO THE RECEIVER CIRCUIT IN THE PROPER MANNER AND WITH THE TEST OSCILLATOR'S ATTENUATION CONTROL SET AT THE MINIMUM POSITION, ADJUST THE TEST OSCILLATOR FOR THE CORRECT I. F. FREQUENCY OF THE PARTICULAR RECEIVER IN QUESTION.

5. – TEMPORARILY SHORT CIRCUIT THE RECEIVER'S OSCILLATOR TUNING CONDENSER SO AS TO PREVENT ITS OPERATION DURING THE ALIGNING PROCESS. TURN ON BOTH THE RECEIVER AND THE TEST OSCILLATOR, TURN THE RECEIVER'S VOLUME CONTROL TO THE "FULL ON" POSITION AND CAREFULLY ADJUST THE ATT-

ENUATION CONTROL OF THE TEST OSCILLATOR UNTIL THE OUTPUT METER READS ABOUT ONE-HALF FULL SCALE DEFLECTION. BE SURE THAT THE OUTPUT SIGNAL OF THE TEST OSCILLATOR IS BEING MODULATED IN THE EVENT THAT A SWITCH FOR EITHER A MODULATED OR UNMODULATED SIGNAL IS FURNISHED ON IT.

6. - COMMENCING WITH THE TUNING CONDENSER OF THE SECONDARY WINDING CORRESPONDING TO THE I.F. TRANSFORMER PRECEDING THE SECOND DETECTOR, ADJUST THIS CONDENSER CAREFULLY WITH A SPECIAL INSULATED ALIGNING TOOL UNTIL THE GREATEST READING IS INDICATED ON THE OUTPUT METER. IF THE INDICATOR EXCEEDS A HALF-SCALE READING DURING THE PROCESS OF ADJUSTMENT, THEN READJUST THE ATTENUATION CONTROL OF THE TEST OSCILLATOR SO THAT THE OUTPUT METER RETURNS TO A HALF-SCALE READING.

7. - CONTINUE BY NEXT ADJUSTING THE PRIMARY TUNING CONDENSER OF THE SAME I.F. TRANSFORMER FOR MAXIMUM READING OF THE OUTPUT METER. WITH THIS ADJUSTMENT MADE, RE-CHECK THE SECONDARY TUNING CONDENSER ADJUSTMENT BECAUSE IT IS FREQUENTLY AFFECTED BY ANY CHANGE MADE IN THE TUNING OF THE PRIMARY CIRCUIT. ALSO RE-CHECK THE PRIMARY CIRCUIT TUNING AFTER MAKING ANY CHANGE IN THE SECONDARY TUNING CIRCUIT.

8. - REPEAT THE SAME PROCEDURE AS JUST EXPLAINED FOR EACH OF THE REMAINING I.F. TRANSFORMERS, GRADUALLY WORKING TOWARDS THE MIXER TUBE. IN ALL CASES, ALWAYS TUNE THE SECONDARY CIRCUIT BEFORE THE PRIMARY CIRCUIT AND THEN RE-CHECK BOTH CIRCUITS.

HOW TO OPERATE A 110 VOLT A.C. RECEIVER FROM A 220 VOLT CIRCUIT

OCCASIONALLY, THE RADIO TECHNICIAN IS CONFRONTED WITH THE PROBLEM WHERE A RECEIVER WHICH IS DESIGNED TO OPERATE FROM A 110 VOLT A.C. LINE IS EXPECTED TO BE OPERATED FROM A 220 VOLT A.C. LINE.

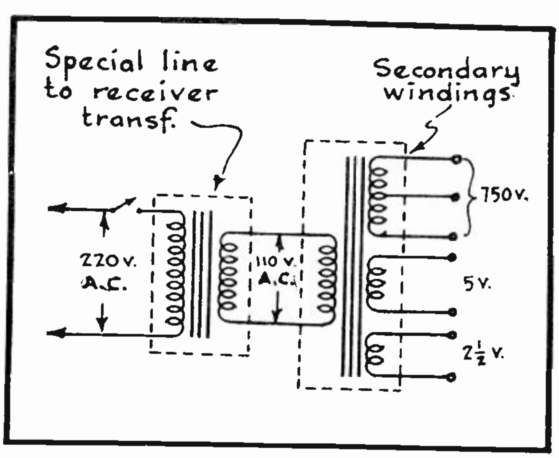

Fig. 2
Transformer Connections.

1. - ONE METHOD OF SOLVING THIS PROBLEM IS TO REMOVE THE POWER TRANSFORMER AND IN ITS PLACE MOUNT ANOTHER TRANSFORMER WHOSE PRIMARY WINDING IS DESIGNED FOR 220 VOLTS AND WHICH IS CAPABLE OF FURNISHING THE SAME SECONDARY VOLTAGES AND CURRENTS AS THE ORIGINIAL TRANSFORMER.

2. - ANOTHER SOLUTION IS TO LEAVE THE ORIGINAL POWER TRANSFORMER IN THE RECEIVER AND TO CONNECT A SPECIAL LINE TRANSFORMER BETWEEN THE A.C. LINE AND THE PRIMARY WINDING OF THE RECEIVER TRANSFORMER AS SHOWN IN FIG.2. THE PRIMARY WINDING OF THIS SPECIAL TRANSFORMER IS DESIGNED FOR 220 VOLTS AND ITS SECONDARY FOR 110 VOLTS. THE WATT-RATING OF THIS SPECIAL TRANSFORMER MUST CORRESPOND WITH THAT OF THE RECEIVER.

NO. 24

PRACTICAL RADIO JOB SHEET

SPECIALLY PREPARED FOR THE STUDENTS OF

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ALIGNING BAND-PASS I. F AMPLIFIERS

IN SUPERHETERODYNE RECEIVERS OF THE HIGH-FIDELITY TYPE THE I.F. TRANSFORMERS ARE SO DESIGNED AND ADJUSTED THAT THEY ARE RATHER BROAD TUNING SO AS TO AVOID SUPPRESSION OF THE SIDE BANDS AND THEREBY MAKE A BETTER TONE QUALITY POSSIBLE. THESE "FLAT-TOP" TRANSFORMERS HAVE THEIR WINDINGS MORE CLOSELY COUPLED THAN DO THE SHARP TUNING I.F. TRANSFORMERS AND ARE GENERALLY ADJUSTED TO PASS A BAND OF FREQUENCIES FROM 5 TO 7.5 KC. EACH SIDE OF THE MAIN INTERMEDIATE FREQUENCY.

TO ALIGN I.F. AMPLIFIERS OF THIS TYPE PROCEED IN THE FOLLOWING MANNER:

1. - FIRST DETERMINE FROM FACTORY SPECIFICATIONS THE MAIN INTERMEDIATE FREQUENCY BEING USED AND THE FREQUENCY RANGE OVER WHICH THE RESPONSE CURVE IS TO BE "FLAT-TOPPED". EXAMPLE: A CERTAIN RECEIVER REQUIRES THAT ITS MAIN INTERMEDIATE FREQUENCY BE 175 KC. AND THAT ITS RESPONSE CURVE BE FLAT-TOPPED FROM 170 KC. TO 180KC. THIS I.F. AMPLIFIER WOULD BE ALIGNED AS FOLLOWS:

2. - CONNECT A TEST OSCILLATOR AND OUTPUT METER TO THE RECEIVER IN THE SAME MANNER AS EXPLAINED IN JOBSHEET #23. ADJUST THE TEST OSCILLATOR FOR THE UPPER FLAT-TOP FREQUENCY LIMIT OF 180 KC. AND ADJUST FOR HIGHEST OUTPUT THE SECONDARY CIRCUIT OF THE I.F. TRANSFORMER WORKING IN TO THE SECOND DETECTOR. THEN ADJUST THE TEST OSCILLATOR FOR THE LOWER FLAT-TOP FREQUENCY LIMIT, OR 170 KC. IN THIS PARTICULAR CASE, AND ADJUST THE PRIMARY CIRCUIT OF THIS SAME I.F. TRANSFORMER FOR MAXIMUM OUTPUT AT THIS FREQUENCY.

3. - THE SAME PROCEDURE IS CARRIED OUT AT EACH I.F. TRANSFORMER, GRADUALLY WORKING TOWARDS THE MIXER TUBE AND EACH ADJUSTMENT SHOULD BE RE-CHECKED AT LEAST THREE TIMES SO AS TO INSURE AN ACCURATE SETTING.

4. - AS A FINAL CHECK ROTATE THE DIAL OF THE TEST OSCILLATOR THRU THE FLAT-TOP FREQUENCY RANGE CALLED FOR. THE OUTPUT METER READING SHOULD VARY ONLY SLIGHTLY AND THE CHANGE IN READING SHOULD BE THE SAME ON EITHER SIDE OF THE MAIN INTERMEDIATE FREQUENCY.

5. - ANOTHER METHOD WHICH IS SOMETIMES USED IS TO FIRST ADJUST BOTH THE SECONDARY AND PRIMARY OF EACH I.F. TRANSFORMER TO THE MAIN INTERMEDIATE FREQUENCY AND THEN SLIGHTLY DETUNE ONE OF THE WINDINGS ABOVE AND THE OTHER BELOW UNTIL ONLY A SLIGHT VARIATION IN THE OUTPUT METER READING IS OBTAINED UPON ROTATING THE DIAL OF THE TEST OSCILLATOR THRU THE FLAT-TOP FREQUENCY RANGE WHICH IS DESIRED.

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DETERMINING AN UNKNOWN INTERMEDIATE FREQUENCY

IN THE EVENT THAT THE CORRECT I.F. FOR A PARTICULAR RECEIVER IS NOT KNOWN AND CANNOT BE OBTAINED BY REFERRING TO ANY SPECIFICATION CHARTS, THEN IT CAN BE DETERMINED IN THE FOLLOWING MANNER:

1. – CONNECT A TEST OSCILLATOR AND OUTPUT METER TO THE RECEIVER IN QUESTION IN EXACTLY THE SAME MANNER AS WHEN ALIGNING THE I.F. AMPLIFIER.

2. – SLOWLY TUNE THE TEST OSCILLATOR FROM ITS LOWER I.F. FREQUENCY LIMIT TOWARDS ITS HIGHER I.F. FREQUENCY LIMIT AND NOTE AT WHICH OF ITS SETTINGS THAT THE OSCILLATOR FREQUENCY IS AMPLIFIED BY THE RECEIVER. ALSO NOTE THE EXTENT TO WHICH THE NEEDLE OF THE OUTPUT METER DEFLECTS.

3. – WE SHALL ASSUME THAT A SIGNAL IS OBTAINED AT THE 87.5 KC AND THE 175 KC. SETTING OF THE TEST OSCILLATOR AND THAT IN ADDITION THE SIGNAL STRENGTH AVAILABLE AT THE RECEIVER OUTPUT IS GREATER WHEN THE TEST OSCILLATOR IS ADJUSTED FOR 175 KC.

4. – UNDER THE CONDITIONS DESCRIBED, IT IS CLEAR THAT WHEN THE TEST OSCILLATOR WAS TUNED TO A FUNDAMENTAL OF 87.5 KC., THE RECEIVER AMPLIFIED ITS SECOND HARMONIC OR 175 KC. FURTHERMORE, THE FACT THAT THE SIGNAL STRENGTH AT THE RECEIVER OUTPUT WAS GREATEST WITH THE OSCILLATOR ADJUSTED FOR 175 KC., THAT THIS SAME VALUE IS AN EXACT HARMONIC OF THE 87.5 KC. SIGNAL AND THAT A FREQUENCY OF 175 KC. IS A STANDARD INTERMEDIATE FREQUENCY FOR SUPERHETERODYNE RECEIVERS, PERMITS US TO COME TO THE CONCLUSION THAT THE PROPER INTERMEDIATE FREQUENCY FOR THIS PARTICULAR RECEIVER IS 175 KC.

5. – SOMETIMES, YOU MAY FIND THAT SIGNALS APPEAR WHEN THE TEST OSCILLATOR IS ADJUSTED TO SOME ODD VALUE. THIS IS QUITE NATURAL SINCE THE FUNDAMENTAL WHICH HAS A HARMONIC EQUAL TO THE I.F. PEAK MAY BE AN ODD FREQUENCY. FOR EXAMPLE, IF THE I.F. AMPLIFIER OF A RECEIVER IS 252.5 KC., THEN A SIGNAL WILL APPEAR WHEN THE TEST OSCILLATOR IS TUNED TO THIS FREQUENCY AND ALSO WHEN IT IS TUNED TO 126.25 KC. LIKEWISE, IF THE I.F. AMPLIFIER IS PEAKED AT 460 KC., SIGNALS MAY APPEAR WITH THE TEST OSCILLATOR TUNED TO 460 KC., 230 KC., 153.3 KC. AND AT 115 KC.

6. – WHEN CONDUCTING TESTS OF THIS NATURE GREAT CARE MUST BE EXERCISED AND HASTY CONCLUSIONS SHOULD BE AVOIDED BECAUSE THE APPEARANCE OF HARMONICS CAN READILY CAUSE CONFUSIONS WHICH LEAD TO ERRORS.

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ALIGNING THE OSCILLATOR AND - R.F. SECTION OF SUPERHETERODYNES

NO ATTEMPT SHOULD BE MADE TO MAKE ANY ADJUSTMENT ON THE ALIGNMENT OF THE OSCILLATOR, FIRST DETECTOR OR PRE-SELECTOR STAGE OF A SUPERHETERODYNE RECEIVER UNTIL IT HAS FIRST BEEN DEFINITELY ASCERTAINED THAT THE I.F. STAGES ARE ALL PROPERLY ALIGNED.

ALIGNING THE OSCILLATOR

WITH THE RECEIVER IN AN OPERATING CONDITION, THE PROCEDURE FOR ALIGNING THE OSCILLATOR CIRCUIT IS AS FOLLOWS:

1. - FIRST CONNECT THE SERVICE OSCILLATOR AND OUTPUT METER TO THE RECEIVER AS ILLUSTRATED IN FIG. 1.

2. - THE ADJUSTMENTS FOR THE OSCILLATOR TUNING CIRCUIT IN THE CONVENTIONAL TYPE OF SUPERHETERODYNE RECEIVER ARE POINTED OUT TO YOU IN FIG. 2.

3. - COMMENCE ALIGNING THE RECEIVER'S OSCILLATOR CIRCUIT BY FIRST ADJUSTING THE HIGH FREQUENCY TRIMMER. TO DO THIS, SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR SO THAT THIS APPARATUS WILL PRODUCE A 1400 KC. SIGNAL FREQUENCY, SET THE VOLUME CONTROL OF THE RECEIVER TO ITS MAXIMUM POSITION AND ITS TUNING DIAL TO THE 1400 KC. POSITION.

4. - TURN "ON" THE SWITCH OF BOTH THE RECEIVER AND THE SERVICE OSCILLATOR AND ADJUST THE ATTENUATOR OF THE SERVICE OSCILLATOR UNTIL A

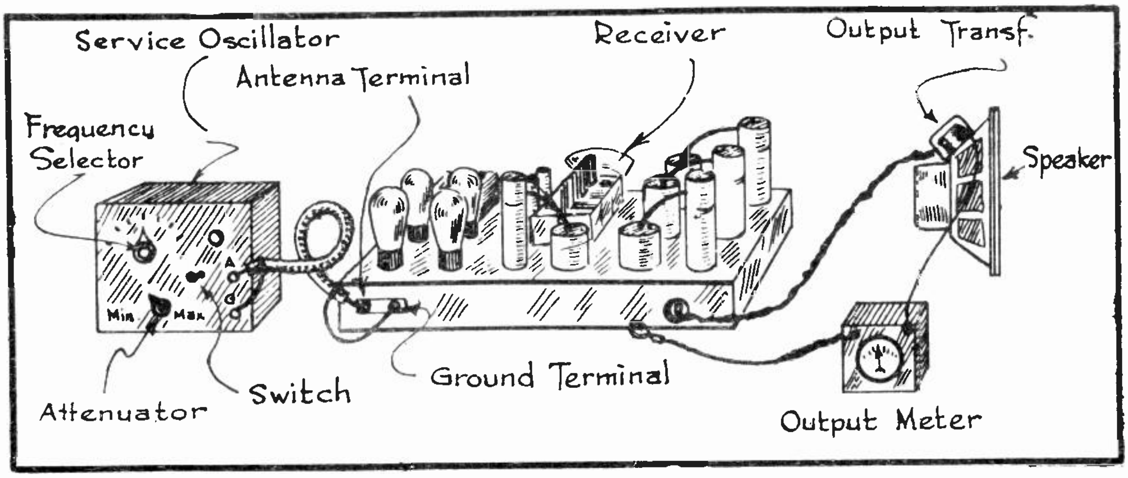

FIG. 1
SET-UP FOR ALIGNING RECEIVER'S OSCILLATOR AND R.F. CIRCUITS.

ONE-HALF SCALE READING IS OBTAINED ON THE OUTPUT METER. IF THE RECEIVER IS BADLY OUT OF ADJUSTMENT, THEN THIS METER READING MAY BE DIFFICULT TO OBTAIN BUT IF SUCH BE THE CASE, THE SIGNAL AS COMING FROM THE SPEAKER CAN BE USED AS A TEMPORARY GUIDE.

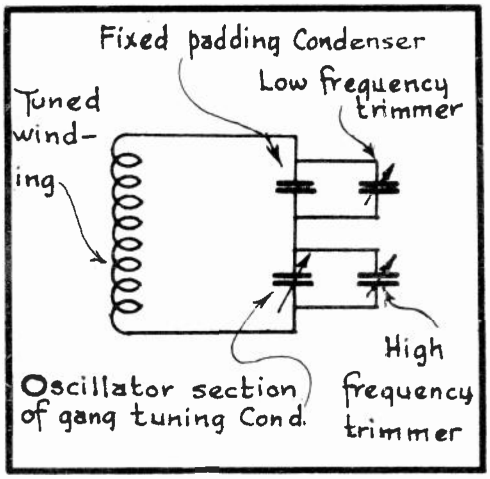

FIG. 2
OSCILLATOR ADJUSTMENTS.

5. - ADJUST THE HIGH FREQUENCY TRIMMER CONDENSER OF THE RECEIVER'S OSCILLATOR CIRCUIT CAREFULLY FOR MAXIMUM READING ON THE OUTPUT METER OR FOR MAXIMUM SIGNAL VOLUME IN THE SPEAKER. AFTER MAKING THIS ADJUSTMENT,TURN THE TUNING DIAL OF THE RECEIVER SLIGHTLY BOTH WAYS FROM ITS 1400 KC. SETTING AND NOTE WHETHER OR NOT ANY INCREASE IN THE METER READING OR SOUND VOLUME IS OBTAINED. IF SO, THEN THE R.F. AND FIRST DETECTOR TRIMMER CONDENSERS MUST BE ADJUSTED AS WILL BE DESCRIBED SHORTLY.

6. - THE NEXT STEP IS TO ADJUST THE RECEIVER OSCILLATOR AT THE LOW FREQUENCY END OF THE DIAL. TO DO THIS, LEAVE THE SERVICE OSCILLATOR AND OUTPUT METER CONNECTIONS JUST AS THEY ARE BUT SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR TO THE 700 KC. POSITION AND ALSO SET THE TUNING DIAL OF THE RECEIVER TO THE 700 KC. POSITION. NOW ADJUST THE "LOW FREQUENCY TRIMMER" FOR MAXIMUM READING ON THE OUTPUT METER OR MAXIMUM SIGNAL STRENGTH IN THE SPEAKER. IT IS ADVISABLE TO AGAIN RECHECK THE HIGH FREQUENCY ADJUSTMENT IN CASE THAT IT HAS BECOME AFFECTED BY THE LOW FREQUENCY ADJUSTMENT AND TO MAKE ANY FINAL CORRECTION AS FOUND NECESSARY.

ALIGNING THE R.F. STAGES

7. - TO ALIGN THE R.F. AND FIRST DETECTOR STAGES, LEAVE THE SERVICE OSCILLATOR AND OUTPUT METER CONNECTIONS AS THEY ARE AND ALSO LEAVE THE ANTENNA LEAD-IN WIRE CONNECTED TO THE RECEIVER. SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR TO THE 1400 KC. POSITION AND ALSO SET THE TUNING DIAL OF THE RECEIVER TO THE 1400 KC. POSITION. THEN ADJUST THE TRIMMER OR COMPENSATOR CONDENSERS OF THE R.F. AND FIRST DETECTOR SECTIONS OF THE GANG TUNING CONDENSER SO AS TO OBTAIN THE MAXIMUM READING ON THE OUTPUT METER.

8. - AFTER THE ENTIRE SET HAS ONCE BEEN ALIGNED IN THIS MANNER, IT IS ADVISABLE TO RECHECK THE OSCILLATOR, FIRST DETECTOR, AND R.F. ADJUSTMENTS OF THE RECEIVER OVER THE ENTIRE TUNING RANGE.. IF ANY FURHTER ADJUSTEMNTS ARE REQUIRED IN THE MEDIUM FREQUENCY RANGE, THEY CAN BE MADE BY BENDING THE SLOTTED ROTOR PLATES OF THE TUNING CONDENSER.

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ALIGNING RECEIVERS USING A. V. C.

THE OPERATION OF AUTOMATIC VOLUME CONTROL SYSTEMS IS SUCH THAT THE RECEIVER OUTPUT IS KEPT PRACTICALLY CONSTANT WITH CHANGES IN THE INPUT SIGNAL INTENSITY DUE EITHER TO SIGNAL STRENGTH OR SENSITIVITY OF THE CIRCUIT. THIS BEING TRUE, WIDE CHANGES IN THE ALIGNMENT OF THE RECEIVER WILL IN SOME INSTANCES NOT PRODUCE ANY NOTICEABLE CHANGES IN THE INDICATION OF THE OUTPUT METER. FOR THESE REASONS, SPECIAL PRECAUTIONS MUST BE EXERCISED WHEN ALIGNING SUPERHETERODYNES WHICH ARE EQUIPPED WITH AN AUTOMATIC VOLUME CONTROL SYSTEM. THE METHODS USED IN SUCH CASES MAY BE ANY ONE OF THE FOLLOWING:

1. - USE A VERY WEAK SIGNAL FROM THE TEST OSCILLATOR SO THAT THE A.V.C. ACTION DOES NOT OCCUR. THIS APPLIES PARTICULARLY WHEN DELAYED A.V.C. IS USED.

2. - IF A SEPARATE A.V.C. TUBE IS EMPLOYED IN THE CIRCUIT, THEN OPEN THE LEAD WHICH DELIVERS THE SIGNAL TO THE CONTROL GRID OF THE A.V.C. TUBE. THIS LEAD SHOULD REMAIN OPEN DURING ALL ALIGNING PROCEDURES.

3. - IN SYSTEMS WHERE A SINGLE TUBE FUNCTIONS AS AN A.V.C. TUBE AS WELL AS A SECOND DETECTOR (ALSO AS AN A.F. AMPLIFIER IN SOME INSTANCES), DISCONNECT THE LEAD WHICH PICKS OFF THE A.V.C. VOLTAGE FROM THE A.V.C. CIRCUIT AND DELIVERS IT TO THOSE TUBES OF THE CIRCUIT WHICH ARE CONTROLLED BY A.V.C. ACTION.

4. - IN SOME RECEIVERS OF THE TYPE MENTIONED IN NOTE #3, THE RECEIVER WILL NOT OPERATE PROPERLY DUE TO LACK OF SUFFICIENT BIAS VOLTAGE FOR SOME OF THE R.F. TUBES. IF THIS IS TRUE, THE NORMAL BIAS CAN BE FURNISHED BY CONNECTING THE END TERMINALS OF A 100,000 OHM POTENTIOMETER ACROSS THE TERMINALS OF A 45 VOLT B BATTERY. CONNECT THE POSITIVE B BATTERY TERMINAL TO THE RECEIVER CHASSIS, OPEN THE SAME RECEIVER LEAD AS DESCRIBED IN NOTE #3 AND TO THE ARM TERMINAL OF THE POTENTIOMETER CONNECT THAT PART OF THE LEAD WHICH GOES TO THE GRID CIRCUITS OF THE CONTROLLED TUBES. ADJUST THIS POTENTIOMETER FOR NORMAL BIAS VOLTAGE AND PROCEED WITH THE ALIGNING WORK.

5. - ANY ONE OF THESE METHODS WILL MAKE THE A.V.C. SYSTEM INOPERATIVE SO THAT ACCURATE OUTPUT METER INDICATIONS MAY BE OBTAINED DURING THE PROCESS OF ALIGNING THE RECEIVER.

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TESTING ELECTROLYTIC CONDENSERS

1. - WHEN IN DOUBT AS TO THE CONDITION OF AN ELECTROLYTIC CONDENSER, THIS TYPE OF CONDENSER CAN BE TESTED BY MEANS OF THE CIRCUIT SHOWN IN FIG. 1.

2. - A COMPLETELY SHORTED OR OPEN CONDENSER CAN OF COURSE BE DETERMINED VERY QUICKLY, SIMPLY BY MAKING A CONVENTIONAL CONTINUITY TEST THROUGH THE CONDENSER BUT THIS CRUDE METHOD DOES NOT TELL ONE HOW GOOD AN ELECTROLYTIC CONDENSER IS.

3. - NOTICE IN FIG. 1 THAT A D.C. VOLTAGE OF ABOUT 400 VOLTS SHOULD BE AVAILABLE AND THIS CAN BE IN THE FORM OF SERIES CONNECTED "B" BATTERIES OR ANY FILTERED "B" POWER SUPPLY. THE POSITIVE END OF THE BATTERY MUST BE CONNECTED TO THE POSITIVE SIDE OF THE CONDENSER. THE 2000 OHM RESISTOR IS USED SOLELY AS A PRECAUTIONARY MEASURE IN ORDER TO PROTECT THE METER IN CASE THE CONDENSER SHOULD BECOME SHORT CIRCUITED.

4. - IF THE CONDENSER HAS BEEN OUT OF USE FOR SOME TIME, IT IS ADVISABLE TO FIRST CONNECT THE BATTERY ACROSS IT WHILE THE METER IS DISCONNECTED FROM THE CIRCUIT. THE CONDENSER SHOULD BE CHARGED IN THIS MANNER FOR AT LEAST 5 MINUTES, SO THAT A GOOD DIELECTRIC WILL BUILD UP.

5. - WITH THE CIRCUIT CONNECTED AS SHOWN IN FIG. 1, THE MILLIAMMETER SHOULD REGISTER A LEAKAGE CURRENT OF FROM 0.05 TO 0.5 MILLIAMPERE PER MICROFARAD. THAT IS, IF AN 8 MFD. CONDENSER IS BEING TESTED IN THIS MANNER AND THE LEAKAGE CURRENT IS FOUND TO BE ANYWHERES BETWEEN .4 AND 4 MILLIAMPERES, THEN THE CONDENSER CAN BE CONSIDERED AS BEING IN A GOOD CONDITION.

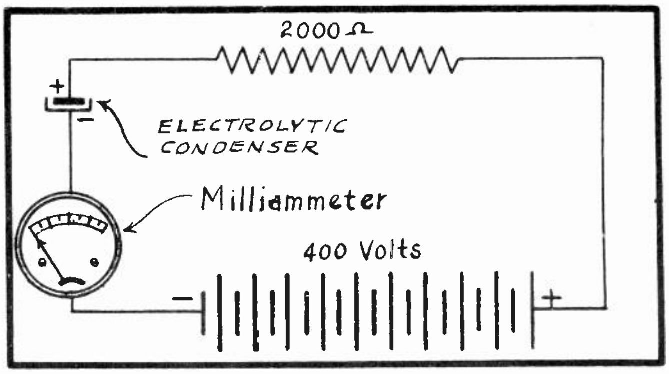

FIG. 1
SET-UP FOR TEST.

6. - THE LEAKAGE CURRENT GENERALLY DECREASES TO ITS MINIMUM VALUE AFTER THE CONDENSER HAS BEEN WORKING FOR A CONSIDERABLE TIME.

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AUTOMATIC VOLUME CONTROL TROUBLES

WEAK RECEPTION

1. - POOR A.V.C. TUBE -- IT MAY BE GASSY OR SUPPLY TOO HIGH AN EMISSION. CHECK FOR THIS CONDITION BY TUNING IN A WEAK STATION AND THEN WITHDRAW A.V.C. TUBE FROM ITS SOCKET. IF THE VOLUME INCREASES CONSIDERABLY, REPLACE THIS TUBE WITH A NEW ONE. QUITE OFTEN, SEVERAL TUBES OF THE SAME TYPE MUST BE TRIED UNTIL SATISFACTORY OPERATION IS OBTAINED.

2. - IF A.V.C. TUBE IS O.K., CHECK GRID VOLTAGE AND PLATE CURRENT OF A.V.C. TUBE. IF GRID VOLTAGE IS TOO LOW, THIS TUBE WILL PASS PLATE CURRENT WHEN NO SIGNAL VOLTAGES ARE APPLIED TO ITS GRID AND THUS DELIVER AN EXCESSIVE BIAS VOLTAGE TO THE CONTROLLED TUBES, THEREBY REDUCING THE VOLUME.

3. - CHECK BIAS VOLTAGE OF CONTROLLED TUBES WHEN TUNED TO A STATION. IF THIS VOLTAGE IS EXCESSIVE, SUSPECT A LEAKY BY-PASS CONDENSER BETWEEN GROUND AND THE A.V.C. LEADS TO THE GRID CIRCUITS OF THE CONTROLLED TUBES.

NO RECEPTION

1. - CHECK GRID BIAS OF CONTROLLED TUBES. IF THIS IS EXCESSIVE, THERE IS A POSSIBILITY OF A LACK OF BIAS VOLTAGE AT THE A.V.C. TUBE DUE TO AN OPEN RESISTOR IN THE GRIDCIRCUIT OR LEAKY BY-PASS CONDENSERS.

2. - DEFECTIVE A.V.C. TUBE.

3. - OPEN CIRCUITED A.V.C. COUPLING CONDENSER.

INTERMITTENT A.V.C. ACTION

1. - IF RECEPTION IS NORMAL FOR A MINUTE OR TWO AFTER FIRST TURNING ON RECEIVER AND THE VOLUME THEN GRADUALLY DECREASES UNTIL EVEN POWERFUL STATIONS ARE RECEIVED WEAKLY, THEN THE GRID BY-PASS CONDENSERS OF THE A.V.C. SYSTEM SHOULD BE CHECKED FOR LEAKAGE.

2. - IF RECEPTION HAS BEEN NORMAL FOR AN HOUR OR TWO AND THEN GRADUALLY FADES, LEAKY A.V.C. GRID BY-PASS CONDENSERS SHOULD BE SUSPECTED.

ABRUPT A.V.C. ACTION

IF STATIONS ARE TUNED IN WITH A SUDDEN "PLOPPING" SENSATION SO AS TO MAKE IT DIFFICULT TO TUNE THE RECEIVER TO A POINT OF RESONANCE, THEN THIS MAY BE DUE TO ANY ONE OF THE FOLLOWING CONDITIONS: (A) EXCESSIVE HEATER VOLTAGE FOR THE A.V.C. TUBE; (B) PLATE RESISTOR OF TOO HIGH VALUE USED IN A.V.C. CIRCUIT.

DISTORTION

DISTORTION CAUSED BY OVERLOADING OF R.F. OR I.F. STAGES, POOR A.V.C. CONTROL, OSCILLATION, AND MOTOR-BOATING MAY BE CAUSED BY A LEAKY OR SHORT CIRCUITED BY-PASS CONDENSER IN THE GRID-RETURN CIRCUITS OF THE R.F. AND I.F.STAGES TO WHICH THE A.V.C. ACTION IS APPLIED. FADING, WEAK,UNSTABLE, AND INTERMITTENT OPERATION MAY RESULT FROM THIS SAME CONDITION.

NO CONTROL OF VOLUME

IN SOME RECEIVERS EMPLOYING A.V.C. THE VOLUME IS NOT AFFECTED WHEN OPERATING THE VOLUME CONTROL. THIS IS ONLY THE CASE IF THE VOLUME CONTROL IS LOCATED IN SOME PART OF THE A.V.C. CIRCUIT AND NOT IN THE AUDIO PORTION OF THE RECEIVER. THIS CONDITION MAY BE DUE TO ANY ONE OF THE FOLLOWING REASONS:

1. - WEAK A.V.C. TUBE

2. - LEAKY BY-PASS CONDENSERS IN THE CONTROL GRID RETURN CIRCUITS OF A.V.C. CONTROLLED TUBES.

TIME LAG

MOST A.V.C. SYSTEMS ARE DESIGNED FOR OPERATION WITH A "TIME LAG". IN THIS WAY THE A.V.C. ACTION IS PREVENTED FROM BEING ABRUPT IN ACTION AND THUS ELIMINATES EXCESSIVE NOISE BETWEEN STATIONS WHEN OPERATING THE DIAL AT A REASONABLE SPEED. IF THE TIME LAG IS EXCESSIVE, SO AS TO MAKE IT DIFFICULT TO TUNE STATIONS TO THE POINT OF RESONANCE, THEN IT CAN BE REDUCED BY LOWERING THE VALUE OF THE BY-PASS CONDENSERS OR ISOLATING RESISTORS IN THE A.V.C. SYSTEMS.

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SERVICING SILENT TUNING SYSTEM

IN FIGS. 1 AND 2 ARE SHOWN TWO TYPICAL CIRCUITS WHICH INCLUDE THE FEATURES OF BOTH THE DUPLEX DIODE TYPE TUBE AND NOISE SUPPRESSION. BY USING THESE AS EXAMPLES, THE FOLLOWING TROUBLE ANALYSIS CAN BE MADE.

INTER-STATION NOISE

IN A SYSTEM OF THE TYPE ILLUSTRATED IN FIG. 1, THIS CONDITION MAY BE DUE TO ANY ONE OF THE FOLLOWING CAUSES:

1. - ARM OF POTENTIOMETER R_2 SHORTED TO CHASSIS.

2. - OPEN SCREEN GRID RESISTOR IN SILENCING TUBE CIRCUIT.

3. - DEFECTIVE SILENCING TUBE.

IN THE CASE OF THE CIRCUIT APPEARING IN FIG. 2 THIS CONDITION MAY BE DUE TO:

1. - SHORTED OR LEAKY 0.1 MFD. CONDENSER BY-PASSING THE CATHODE OF V_3.

2. - LEAKAGE BETWEEN CATHODE AND HEATER OF V_3. THIS SAME CONDITION WILL CAUSE A HUM WHEN THE RECEIVER IS TUNED TO RESONANCE AND NO A.V.C. ACTION WILL OCCUR.

DISTORTION

IN THE ARRANGEMENT ILLUSTRATED IN FIG. 1, DISTORTED OR A CHOKED-REPRODUCTION MAY BE DUE TO:

1. - FAULTY ADJUSTMENT OF

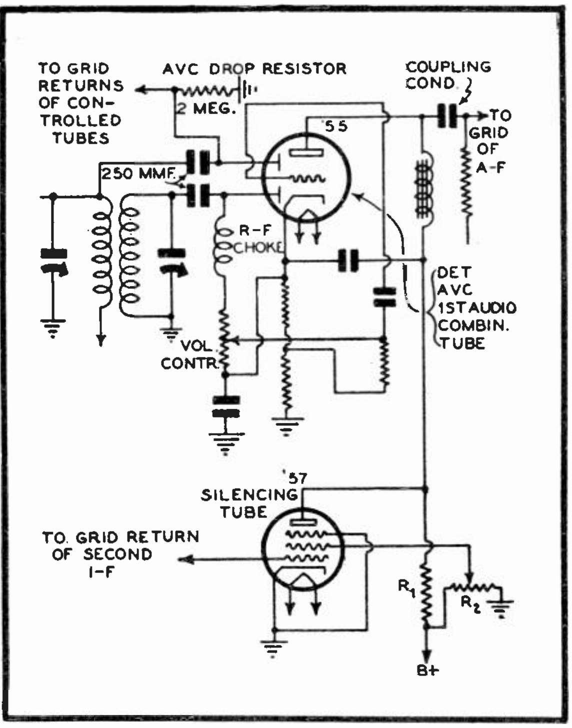

FIG. 1
A.V.C. WITH NOISE SUPPRESSION.

R_2 OR WRONG RESISTANCE VALUE AT THIS POINT.

2. - GROUNDED SILENCING TUBE CONTROL-GRID LEAD.

3. - LEAKY BY-PASS CONDENSER IN THE A.V.C. CIRCUIT TO WHICH THE CONTROL GRID LEAD IS CONNECTED.

HEADPHONE CONNECTIONS

QUITE OFTEN, IT IS DESIRABLE TO CONNECT A SET OF HEADPHONES TO A MODERN RECEIVER WHICH IS BEING USED IN CONJUNCTION WITH A LOUD SPEAKER. THIS CAN BE DONE IN THE FOLLOWING MANNER:

1. - THE CIRCUIT AT "A" OF FIG. 3 ILLUSTRATES HOW THE HEADPHONE CONNECTION IS MADE ON A RECEIVER EMPLOYING A POWER STAGE WITH A SINGLE TUBE. THE 10,000 OHM POTENTIOMETER SERVES AS A VOLUME CONTROL FOR THE HEADPHONES. A "PLUG-JACK OFFERS A CONVENIENT METHOD BY MEANS OF WHICH THE HEADPHONES CAN BE CONNECTED TO THE CIRCUIT WHENEVER DESIRED.

2. - "B" OF FIG. 3 ILLUSTRATES HOW TO MAKE THE HEADPHONE CONNECTIONS IN A PUSH-PULL POWER STAGE.

3. - THE SWITCH IN THE SPEAKER CIRCUIT CAN EITHER BE USED OR NOT, DEPENDING UPON THE REQUIREMENTS OF THE PARTICULAR INSTALLATION. THE SWITCH IN THE HEADPHONE CIRCUITS AFFORDS A MEANS OF DISCONNECTING THE SHUNTING EFFECT OF THE HEADPHONE CIRCUIT WHEN NOT EMPLOYING HEADPHONE RECEPTION.

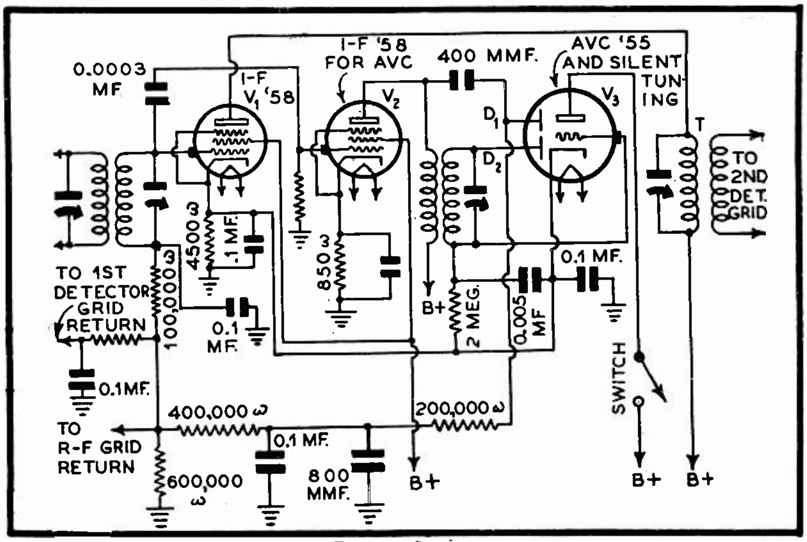

FIG. 2
COMBINATION A.V.C. AND SILENCING TUBE.

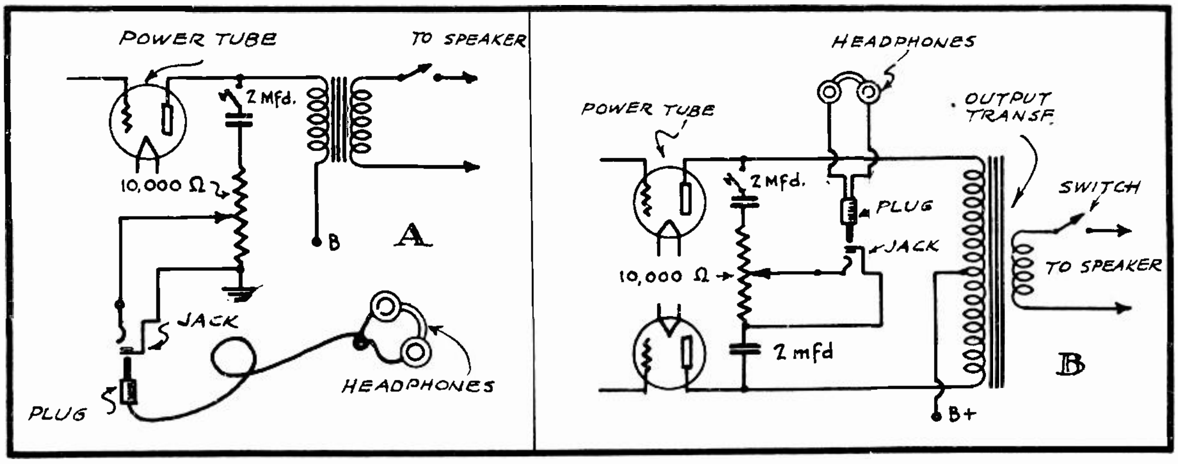

FIG. 3
HEADPHONE CONNECTIONS.

NATIONAL RADIO AND ELECTRICAL SCHOOL
LOS ANGELES, CALIF.

EDUCATIONAL DEPT.

SPECIAL EXAMINATION #1

Answered February 24 1940

DEAR STUDENT:

ALTHOUGH YOU HAVE BEEN ENROLLED IN MY COURSE OF TRAINING FOR ONLY A SHORT TIME AND ARE JUST BEGINNING TO GET A GOOD START, YET I AM CERTAIN YOU WILL ADMIT THAT YOU HAVE ALREADY LEARNED CONSIDERABLE ABOUT RADIO.

Grade 100

AS I TOLD YOU BEFORE IN ONE OF MY EARLY MESSAGES—IN ORDER TO SUCCEED IN THE RADIO PROFESSION, IT IS NECESSARY THAT YOU REMEMBER THE IMPORTANT FACTS WHICH ARE PRESENTED.

SOME EXCEPTIONALLY IMPORTANT RADIO PRINCIPLES HAVE BEEN BROUGHT TO YOU ATTENTION IN YOUR FIRST TEN LESSON ASSIGNMENTS AND SO THAT I MAY HAVE A MEANS OF CHECKING UP ON YOU AND SEEING HOW WELL YOU REMEMBER THEM, I AM ASKING YOU TO ANSWER IN FULL ALL OF THE QUESTIONS WHICH ARE INCLUDED IN THIS SPECIAL EXAMINATION.

ALL OF THESE QUESTIONS ARE BASED UPON THE FIRST TEN LESSONS, SO REVIEW THESE LESSONS, IF NECESSARY, AND ANSWER ALL OF THE QUESTIONS TO THE BEST OF YOUR ABILITY. NUMBER ALL OF YOUR ANSWERS SO THAT THEY WILL CORRESPOND WITH THE QUESTION NUMBER. WRITE PLAINLY OR USE TYPEWRITER AND THINK OUT ALL OF YOUR ANSWERS CAREFULLY SO AS TO AVOID ANY UNNECESSARY ERRORS BECAUSE THE WORK YOU DO ON THESE SPECIAL EXAMINATIONS IN A GREAT MEASURE AFFECTS YOUR FINAL GRADE.

I AM LOOKING FORWARD TO A FINE SET OF ANSWERS FROM YOU, SO PLEASE MAIL THEM TO ME AS SOON AS YOU CAN.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS

1. — DESCRIBE IN DETAIL THE OPERATING PRINCIPLES OF THE MICROPHONE.

2. — HOW MAY SOUND WAVES BE PRODUCED?

3. — WHAT DO WE MEAN BY THE TERM "ELECTROMOTIVE FORCE"?

4. — IF TWO COPPER WIRES, ONE HAVING A GREATER DIAMETER THAN THE OTHER, ARE BOTH CONNECTED ACROSS THE SAME SOURCE OF VOLTAGE, THEN WHICH OF THESE TWO WIRES WILL PASS THE MOST CURRENT?

5. — WHAT PARTS CONSTITUTE THE CONVENTIONAL TYPE OF TUNING CIRCUIT IN A RADIO RECEIVER?

6. — WHAT IS A RHEOSTAT?

(OVER)

7. - WHAT IS THE DIFFERENCE BETWEEN A DAMPED AND CONTINUOUS TYPE RADIO WAVE?

8. - IF A CONDENSER IS CONNECTED IN A CIRCUIT THROUGH WHICH AN ALTERNATING CURRENT IS FLOWING, WILL THE CONDENSER PASS MORE OR LESS CURRENT IF THE FREQUENCY OF THE ALTERNATING CURRENT IS INCREASED?

9. - IF FOUR RESISTANCES, HAVING THE RESPECTIVE VALUES OF 10 OHMS, 6 OHMS, 4 OHMS AND 3 OHMS ARE ALL CONNECTED IN PARALLEL ACROSS A VOLTAGE SOURCE OFFERING AN ELECTROMOTIVE FORCE OF 100 VOLTS, THEN HOW MUCH CURRENT WILL FLOW THRU EACH RESISTOR? WHAT WILL BE THE TOTAL CURRENT FLOWING THROUGH THE ENTIRE CIRCUIT?

10.- IF TWO COILS ARE EACH WOUND ON A TUBULAR-SHAPED FORM HAVING A DIAMETER OF 1" AND ONE OF THESE COILS CONSISTS OF 10 TURNS OF WIRE WHILE THE OTHER CONSISTS OF 30 TURNS OF WIRE, THEN WHICH OF THE TWO COILS WILL HAVE THE GREATER INDUCTANCE?

11.- DESCRIBE THE OPERATING PRINCIPLES OF A GRID CONDENSER AND LEAK TYPE DETECTOR.

correspond.

12.- IF THE FILAMENTS OF TWO TUBES DRAWING 1 AMPERE EACH ARE CONNECTED IN PARALLEL AND TOGETHER CONNECTED ACROSS A 2 VOLT "A" SUPPLY, THEN WHAT WILL BE THE TOTAL FILAMENT CURRENT WHICH IS DRAWN BY THIS COMBINATION OF TUBES?

co respond

13.- IF YOU SHOULD HAVE A MAGNET, WHOSE POLARITY IS NOT MARKED, HOW CAN YOU IDENTIFY ITS NORTH AND SOUTH POLES WITH THE AID OF A MAGNETIC COMPASS?

14.- WHAT IS THE CHIEF ADVANTAGE OBTAINED FROM RESISTANCE-CAPACITY INTER-STAGE COUPLING IN AN A.F. AMPLIFIER?

15.- WHAT IS THE DIAMETER OF A #26 B&S COPPER WIRE?

16.- A RESISTANCE OF 10 OHMS, 5 OHMS, 30 OHMS AND 50 OHMS ARE ALL CONNECTED IN SERIES AND AN ELECTROMOTIVE FORCE OF 200 VOLTS IS APPLIED ACROSS THE EXTREMITIES OF THE ENTIRE GROUP. HOW MUCH CURRENT WILL FLOW THROUGH THE CIRCUIT? WHAT WILL BE THE VOLTAGE DROP ACROSS EACH RESISTOR?

17.- DESCRIBE EXACTLY WHAT OCCURS IN EACH CIRCUIT OF A CRYSTAL RECEIVER DURING THE RECEPTION OF A BROADCAST PROGRAM.

18.- IF THE VOLTAGE SUPPLIED BY A SOURCE OF E.M.F. IS GREATER THAN CAN BE TOLERATED BY A CERTAIN APPLIANCE WHAT MEANS MAY BE EMPLOYED TO REDUCE THIS VOLTAGE THE PROPER AMOUNT?

19.- DRAW A CIRCUIT DIAGRAM OF A ONE-TUBE RECEIVER EMPLOYING REGENERATION.

20.- DRAW A CIRCUIT DIAGRAM OF A TRANSFORMER-COUPLED A.F. AMPLIFIER.

NATIONAL SCHOOLS
LOS ANGELES, CALIF.

RADIO DIVISION

SPECIAL EXAMINATION #2

Answered May 27, 1940

DEAR STUDENT:

HAVING COMPLETED TWENTY LESSONS OF YOUR COURSE, IT IS AGAIN TIME FOR US TO FIND OUT HOW MUCH KNOWLEDGE YOU HAVE ACQUIRED SINCE ANSWERING YOUR FIRST SPECIAL EXAMINATION. FROM THE GRADE YOU RECEIVED IN THAT EXAMINATION, WE KNOW THAT YOU HAVE MASTERED THE FIRST TEN LESSONS. THE QUESTIONS IN THIS SECOND SPECIAL EXAMINATION ARE BASED UPON LESSONS #11 TO 20, INCLUSIVE. I AM SURE THAT YOU REALIZE THE IMPORTANCE OF THIS EXAMINATION AND THAT YOU WILL GIVE IT CAREFUL CONSIDERATION TO OBTAIN THE BEST POSSIBLE GRADE.

YOU ARE NO DOUBT PLEASED BECAUSE YOU ARE IN THE HEART OF YOUR RADIO SERVICE STUDY AT SUCH AN EARLY STAGE OF YOUR TRAINING. BY IMMEDIATELY APPLYING THIS INFORMATION TO PRACTICAL USE, MANY STUDENTS HAVE BEEN ABLE TO EARN CONSIDERABLE MONEY IN SPARE TIME WORK DURING THE ENTIRE LATER PERIOD OF THEIR STUDIES.

REMEMBER THAT IT PAYS TO REVIEW YOUR LESSONS FROM TIME TO TIME, TO FIX THE IMPORTANT POINTS IN YOUR MIND. ALSO BEAR IT IN MIND THAT TO OBTAIN THE GREATEST POSSIBLE BENEFIT FROM YOUR LESSONS REQUIRES EARNEST STUDY; JUST READING THE LESSON ONCE OR TWICE IS NOT SUFFICIENT.

WE WILL BE ESPECIALLY INTERESTED IN YOUR ANSWERS TO THE SECOND SPECIAL EXAMINATION AND HOPE THAT YOU WILL GIVE THIS IMPORTANT MATTER YOUR IMMEDIATE ATTENTION.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS

1. - WHAT IS MEANT BY RADIO FREQUENCY AMPLIFICATION?

2. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF A TYPICAL MODERN R.F. TRANSFORMER.

3. - SUPPOSE THAT YOU DESIRE TO WIND A SECONDARY WINDING OR TUNING COIL OF AN R.F. TRANSFORMER FOR BROADCAST RECEPTION ON A PIECE OF BAKELITE TUBING HAVING A DIAMETER OF 1", AND THAT THE TUNING CONDENSER TO BE USED WITH THIS COIL HAS A RATED CAPACITY OF .00035 MFD. WHAT SIZE AND TYPE OF WIRE, AND HOW MANY TURNS, WOULD YOU USE IN THIS COIL?

4. - DESCRIBE HOW NEUTRALIZING PRINCIPLES MAY BE EMPLOYED TO PREVENT OSCILLATION IN AN R.F. AMPLIFIER IN WHICH TRIODES ARE USED.

5. - BY MEANS OF A DIAGRAM, SHOW THE NUMBER AND ARRANGEMENT OF DRY CELLS YOU WOULD USE TO OBTAIN A VOLTAGE OF 4 1/2 VOLTS AND SUPPLY A CURRENT DEMAND OF 1/2 AMPERE.

6.- How would you test a #6 dry cell to determine if it is serviceable?

7. - What minimum voltage would you allow a nominal 45-volt "B" battery before considering its replacement?

8. - Describe the construction of a lead-acid type storage cell.

9. - If a lead-acid type storage cell is fully charged, what should be its specific gravity?

10.- What specific gravity reading indicates a lead-acid storage cell as being fully discharged?

11.- What is the normal voltage developed across a fully-charged lead-acid storage cell?

12.- Describe the constructional features of an electrolytic type of trickle charger.

13.- Draw a circuit diagram of a trickle charger in which a copper-oxide rectifier is used.

14.- Draw a circuit diagram of a "B" eliminator in which a Raytheon gaseous rectifying tube is used.

15.- Describe the construction and operation of an electromagnetic type of dynamic speaker.

16. - Describe the construction of the type of screen-grid tube used in battery-operated receivers.

17.- Why is shielding used in modern receivers?

18.- What are the operating characteristics of the type 2A5 power tube?

19.- What are the operating characteristics of the type -58 tube?

20.- How is the grid bias voltage generally obtained in A.C. receivers?

21.- Draw a circuit diagram showing how two type 2A5 tubes may be connected in a push-pull power stage.

22.- Draw a circuit diagram showing how the field coil of a dynamic speaker may be used as a filter choke in the power supply of an A.C. receiver.

23.- Describe the operating principles of a standard type superheterodyne receiver.

24.- What important facts would you take into consideration when designing an antenna installation?

25.- Name the most important items which should be included in the radio man's service equipment.

NATIONAL SCHOOLS

RADIO DIVISION

4000 South Figueroa St. , Los Angeles, California

Special Examination #3

answered oct 13/40

DEAR STUDENT:

UPON COMPLETING YOUR 27TH LESSON, YOU HAVE PASSED ANOTHER IMPORTANT STAGE OF YOUR TRAINING. BY CHECKING BACK OVER THE LAST NINE LESSONS WHICH YOU STUDIED, YOU WILL FIND THAT YOU HAVE LEARNED CONSIDERABLE ABOUT RECEIVER TROUBLES, RADIO INTERFERENCE, AUTOMOBILE RECEIVERS, MIDGET RECEIVERS, AND PORTABLE RECEIVERS, AS WELL HAVING RECEIVED MANY SUGGESTIONS REGARDING THE CONSTRUCTION OF RECEIVERS IN GENERAL. THIS, YOU WILL NO DOUBT AGREE, IS A GREAT DEAL OF INFORMATION TO HAVE ACQUIRED IN ONLY NINE LESSONS AND MIGHTY IMPORTANT INFORMATION TOO.

I WANT YOU TO REALIZE THAT I AM DEEPLY INTERESTED IN HOW WELL YOU REMEMBER THE MANY THINGS WHICH YOUR LESSONS HAVE MADE KNOWN TO YOU AND IT IS FOR THIS REASON THAT I AM ASKING YOU TO ANSWER THE QUESTIONS OF THIS SPECIAL EXAMINATION.

EACH OF THE QUESTIONS TO FOLLOW IS BASED UPON LESSONS #19 TO 27 INCLUSIVE AND SO IT WOULD BE ADVISABLE THAT YOU REVIEW THESE LESSONS CAREFULLY BEFORE ATTEMPTING TO ANSWER THE QUESTIONS.

I ALSO WISH TO TAKE THIS OPPORTUNITY OF CONGRATULATING YOU FOR THE FINE WAY IN WHICH YOU HAVE APPLIED YOURSELF TO YOUR STUDIES SO FAR AND I AM CONFIDENT THAT YOU WILL CONTINUE TO DO YOUR UTMOST IN MAINTAINING A HIGH STANDARD IN THE WORK WHICH IS YET TO COME.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS

10/13/40

1. – IF IN A BATTERY OPERATED RECEIVER, THE FILAMENT WIRES TO ONE OF THE TUBES BECOME SHORT CIRCUITED, HOW WILL THIS AFFECT THE RECEIVER AND THE "A" BATTERY?

2. – EXPLAIN HOW YOU CAN DETERMINE IF A WINDING OF A TRANSFORMER IS OPEN CIRCUITED OR NOT.

3. – WHAT SYMPTOMS WOULD CAUSE YOU TO SUSPECT A FILTER CONDENSER IN THE POWER PACK OF AN A.C. RECEIVER BEING SHORT CIRCUITED?

4. – WHAT ARE SOME OF THE POSSIBLE CAUSES FOR WEAK SIGNAL REPRODUCTION?

(OVER)

5. – If you were called upon to diagnose the cause for the failure of an A.C. receiver to operate, how would you proceed to determine the trouble?

6. – Explain a quick and simple test which will enable you to determine which stage of a tuned R.F. receiver is preventing the set · from operating?

7. – What are the most probable causes for poor tone quality?

8. – What are the most common causes for excessive hum in A.C. receivers?

9. – What are some of the most common causes for scratching and crackling noises in a receiver?

10.– If plate voltage is lacking at all of the R.F. tube sockets in a receiver but is present at the other tube sockets, where would you look for the trouble?

11.– Explain how you would determine if an interference noise originates within the receiver or not.

12.– How would you go about the task of locating an external source of interference?

13.– If an electric motor is known to produce an interfering noise, how could you correct the condition?

14.– Describe an interference rejecting antenna system.

15.– Describe a suitable antenna system for an automobile receiver installation.

16.– Explain what provisions should be made in the electrical system of an automobile to prevent the receiver from picking up excessive interference noise.

17.– Draw a circuit diagram of a vibrator type Automotive "B" eliminator using a vacuum tube rectifier.

18.– Explain the operating principle of the "B" eliminator which you have drawn as your answer for question #17 of this examination.

19.– Describe one common method of supplying the bias voltage for a filament type power tube in a midget A.C. receiver, illustrating your description by means of a simple diagram.

20.– What are the most important points which you would take into consideration upon comtemplating the construction of a portable receiver?

21.– Describe the constructional features of a typical loop antenna.

22. – What important facts would you take into consideration upon contemplating an antenna installation?

NATIONAL SCHOOLS

RADIO DIVISION

4000 South Figueroa St. Los Angeles, California

Special Examination # 4

DEAR STUDENT:

YOU ARE PROGRESSING SPLENDIDLY WITH YOUR STUDIES AND IT IS INDEED MOST PLEASING TO ME TO SEE YOU TAKE SUCH A COMPLETE INTEREST IN YOUR WORK. FROM NOW ON, YOUR STUDIES ARE GOING TO BECOME MORE TECHNICAL AND IT MAY REQUIRE A LITTLE HARDER STUDY FOR YOU TO MASTER THEM. HOWEVER, YOU MUST BEAR IN MIND THAT THIS ADVANCED TYPE OF STUDY IS MOST NECESSARY IN ORDER THAT YOU MAY PREPARE YOURSELF FOR THE BETTER JOBS WHICH THE RADIO INDUSTRY HAS TO OFFER YOU.

IT IS NOW TIME FOR ANOTHER SPECIAL EXAMINATION. THIS PARTICULAR EXAMINATION IS BASED SOLELY UPON LESSONS #28 TO #36 INCLUSIVE AND SO BEFORE COMMENCING TO ANSWER THE FOLLOWING GROUP OF QUESTIONS, I SUGGEST THAT YOU FIRST REVIEW THESE LAST NINE LESSONS CAREFULLY, SO THAT YOU WILL BE SURE TO HAVE A PERFECT UNDERSTANDING OF EVERYTHING WHICH HAS BEEN EXPLAINED IN THEM.

I AM CERTAIN THAT YOU WILL FIND THIS EXAMINATION TO BE INTERESTING, AS WELL AS INSTRUCTIVE AND THAT YOU WILL DO YOUR BEST TO RECEIVE A SPLENDID GRADE UPON IT.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS

1. – DRAW A DIAGRAM OF A TYPICAL AUTOMATIC VOLUME CONTROL CIRCUIT, USING A SEPARATE A.V.C. TUBE AND EXPLAIN HOW IT OPERATES.

2. – WHY IS IT THAT RECEIVERS EMPLOYING AN AUTOMATIC VOLUME CONTROL SYSTEM HAVE A TENDENCY TO AMPLIFY BACK GROUND NOISE CONSIDERABLY WHEN TUNED TO SOME POINT BETWEEN STATIONS?

3. – DRAW A CIRCUIT DIAGRAM OF AN AUTOMATIC NOISE SUPPRESSION CIRCUIT, SHOWING HOW IT IS USED IN CONJUNCTION WITH AN AUTOMATIC VOLUME CONTROL SYSTEM OF A RECEIVER.

4. – EXPLAIN THE OPERATION OF THE CIRCUIT WHICH YOU HAVE DRAWN IN ANSWER TO QUESTION #3.

(OVER)

5. – Illustrate by means of a diagram how a type 2A6 tube can be used in a superheterodyne receiver so as to function simultaneously as a second detector, A.F. amplifier and an A.V.C. tube.

6. – When using a duplex-diode triode tube so that it will function as a half-wave detector, how will the amount of its rectified signal voltage compare with that obtained when this same tube is used in a full-wave detector arrangement?

7. – Explain the mechanism and operation of the shadow-tuning instrument.

8. – Show by means of a diagram how in a series storage battery charging circuit the rate of charge through one of the batteries can be reduced without reducing the rate of charge through the other batteries of the circuit.

9. – Draw a circuit diagram showing how a phonograph pick-up unit can be connected to the grid circuit of a receiver's detector stage.

10.– Draw a circuit diagram showing how a phonograph pick-up unit can be connected to the second detector of a supheterodyne receiver in which a type 2A6 tube is employed.

11.– Draw a circuit diagram which illustrates a tone-control circuit.

12.– What is an important advantage of controlling regeneration in short wave receivers through variation of the detector tube's screen-grid positive potential.

13.– Explain how you would test a lead-acid storage battery by means of the cadimum test.

14.– How does the Edison storage cell differ from the lead-acid type storage cell?

15.– Explain the "skip-distance" phenomena as experienced with short-wave reception.

16.– Describe briefly how a receiver designed for 110 volt D.C. operation differs from a receiver designed for 110 volt A.C. operation.

17.– How does a 110 volt A.C. receiver differ from a 220 volt A.C. receiver?

18.– Describe briefly any one universal receiver circuit.

19.– Describe the 25Z5 tube and explain how it may be used.

20.– What are some of the more important points which should be considered at the time the construction of any receiver is contemplated?

NATIONAL SCHOOLS
RADIO DIVISION
4000 South Figueroa St. · Los Angeles, California

Special Examination #5

Dear Student:

During the past nine lessons, you have learned many new things of a technical nature which are going to prove themselves of great value to you later on. The principles and formulas given you in the lessons from #37 to 45 form the basis of Radio design work in general.

It is knowledge of the type which you are now acquiring that will permit you to rise above the ranks of the average technician. Furthermore, this is the type of training which enables you to derive real dividends from the investment you made at the time you enrolled.

Bear in mind that this examination is based on Lessons #37 to 45, so be sure to review these lessons carefully first before attempting to answer the following questions.

Sincerely yours,

[signature]
President

EXAMINATION QUESTIONS

1. – How does the impedance of a series resonant tuning circuit compare with that of a parallel resonant circuit at the resonant frequency?

2. – What is meant by the term POWER FACTOR?

3. – If a condenser of .00025 mfd. capacity is connected in series with a coil having an inductance value of 4 microhenries, at what wavelength will this tuned circuit resonate?

4. – If a condenser of 140 Mmfd. capacity is connected in series with a coil having an inductance value of 4 microhenries, at what wavelength will this tuned circuit resonate?

5. – How many turns to the inch can a #30 B&S enamelled copper wire be wound if no spacing is allowed between adjacent turns?

6. – To what frequency does an "LC" factor of 0.1013 correspond?

(over)

7. — If it is desired to wind a coil on a 1" diameter tubular form with a #30 B&S enamelled wire and so that it will tune over a frequency band of 550 to 1500 Kc. when used in conjunction with a .00035 mfd. tuning condenser, then how many turns of this wire should be used if no spacing is allowed between turns?

8. — An unknown resistance is being measured on a Wheatstone Bridge and a 10 ohm resistor is used as a standard. With the "bridge" in a state of balance, the distances "S" and "T" are found to be 20 cm. and 80 cm. respectively. What is the value of the unknown resistance?

9. — What is the advantage of using a band-pass or band-selector circuit in the R.F. amplifier of a receiver?

10.— Draw a circuit diagram showing how a fixed condenser may be used as the means of coupling in a band-pass circuit.

11.— In order to have a ganged tuning condenser tune the oscillator, as well as the pre-selector and first detector stages in a superheterodyne receiver employing a padding system in the oscillator's tuned circuit, what relation may exist between the inductance rating of the oscillator's tuned winding and the other tuned windings and between the size of padding condenser and the ratings of the ganged condenser sections so as to obtain proper tracking?

12.— If the peak voltage in a certain A.C. circuit is 450 volts, what will be the effective voltage of this circuit?

13.— If four resistors having respective values of 10; 20; 5 and 4 ohms are all connected in parallel, what will be their combined resistance?

14.— If the voltage of an A.C. circuit as measured with a voltmeter is found to be 130 volts, then what peak voltage will be present in this same circuit?

15.— What inductive reactance will an 85 millihenry R.F. choke offer towards a 600 Kc. current?

16.— What capacitive reactance will a .00035 mfd. condenser offer towards an oscillating current having a frequency of 850 Kc.?

17.— A circuit consisting of a 100 millihenry choke, a .005 mfd. condenser and 15 ohms of D.C. resistance are all connected in series. If the ends of this combination are connected across a source of 2 volts signal voltage and of 600 Kc. frequency, then how much current will flow through the circuit?

18.— What is the phase relation between the voltage and current in a pure inductive A.C. circuit?

19.— If three condensers having respective capacitive values of .00025 mfd., .0005 mfd. and .00075 mfd. are all connected in series, what will be their combined capacity?

NATIONAL SCHOOLS
LOS ANGELES CALIFORNIA
ESTABLISHED 1905 J. A. ROSENKRANZ, *President*

RADIO DIVISION

SPECIAL EXAMINATION NO. 7

DEAR STUDENT:

YOU HAVE JUST COMPLETED AN INTENSIVE STUDY TREATING WITH A-F AMPLIFYING SYSTEMS AND MATHEMATICS. THIS KNOWLEDGE IS GOING TO BE OF TREMENDOUS HELP TO YOU IN CONSTRUCTING SOUND AMPLIFYING EQUIPMENT, BROADCAST TRANSMITTERS, TALKING PICTURE EQUIPMENT, TELEVISION EQUIPMENT, ETC.

I ADVISE YOU MOST URGENTLY TO REVIEW THIS SERIES OF LESSONS ON AMPLIFIERS SO THAT THERE WILL BE NO DOUBT IN YOUR MIND CONCERNING ANY OF THE SUBJECTS DISCUSSED THEREIN. THIS IS IMPORTANT BECAUSE IN THE STUDIES THAT FOLLOW YOU WILL HAVE NEED FOR THIS INFORMATION -- ALSO, THE EXPLANATIONS AS GIVEN IN SUCCEEDING LESSONS ASSUME THAT YOU REMEMBER THESE FACTS.

I AM DELIGHTED IN SEEING YOU MAKE SUCH SPLENDID PROGRESS IN YOUR STUDIES, AND AM ANXIOUSLY LOOKING FORWARD TO THE TIME WHEN YOU WILL TAKE YOUR PLACE IN THE INDUSTRY AS A THOROUGHLY QUALIFIED TECHNICIAN.

SINCERELY YOURS,

J. A. Rosenkranz
PRESIDENT

EXAMINATION QUESTIONS

1. - DRAW A CIRCUIT DIAGRAM OF AN A-F AMPLIFIER EMPLOYING A 57 TUBE IN THE INPUT STAGE, A 56 TUBE IN THE INTERMEDIATE STAGE AND TWO 2A5'S IN A PUSH-PULL POWER STAGE. SHOW HOW YOU WOULD CONNECT A DOUBLE-BUTTON CARBON MICROPHONE TO THIS AMPLIFIER AND HOW YOU WOULD CONNECT FOUR SPEAKERS TO THE OUTPUT OF THE AMPLIFIER. EACH OF THE SPEAKERS USED IS TO BE OF THE A-C TYPE AND HAVING A VOICE COIL IMPEDANCE OF 8-OHMS. THIS DIAGRAM IS TO BE COMPLETE, WITH THE VALUES OF ALL PARTS DESIGNATED.

2. - FOUR DYNAMIC SPEAKERS, HAVING VOICE COIL IMPEDANCES OF 9-OHMS EACH AND INDIVIDUAL INPUT TRANSFORMERS, ARE TO BE CONNECTED TO A 200-OHM TRANSMISSION LINE. SHOW BY MEANS OF A DIAGRAM HOW YOU WOULD MAKE THE CONNECTIONS, INDICATING THE IMPEDANCE VALUES OF THE VARIOUS PARTS INVOLVED.

3. - EXPLAIN IN DETAIL HOW YOU WOULD PROCEED TO DETERMINE THE ACOUSTIC CONDITIONS OF A ROOM, PREPARATORY TO INSTALLING AMPLIFYING EQUIPMENT.

4. - DRAW A DIAGRAM OF A PRE-AMPLIFIER CIRCUIT, SHOWING HOW A CONDENSER MICROPHONE IS CONNECTED TO IT AND HOW YOU WOULD COUPLE THIS AMPLIFIER TO THE INPUT OF A MAIN AMPLIFIER THROUGH A 500-OHM TRANSMISSION LINE. THIS DIAGRAM IS TO BE COMPLETE, WITH ALL NECESSARY PARTS VALUES SPECIFIED.

(OVER)

5. - Describe the principles involved in designing a direct-coupled A-F amplifier, and illustrate your explanation with a suitable drawing.

6. - Make a diagram showing how a type 53 tube may be used as a phase-inverter, driving a pair of resistance coupled push-pull 56 tubes and which in turn drive a pair of resistance coupled push-pull 2B6 tubes.

7. - Reduce the following fraction to its lowest terms:

$$\frac{(X+Y)\,(X-Y)^2}{X(X-Y)^2}$$

8. - Reduce the following to equivalent fractions having a lowest common denominator:

(A) $\frac{A}{X-A}$ (B) $\frac{X}{X-A}$ (C) $\frac{A^2}{X^2-A^2}$

9. - Solve for X in the following equation: $2X-(5X+5) = 7$.

10.- Divide $4x^4y^6+8x^7y^3 - 12x^6y^4$ by $2x^2y^2$

11.- Solve for "X" in the following equation: $X^2 - 16 = 48$

12.- Divide $\frac{3X+Y}{9}$ by $\frac{4X}{3}$

13.- Solve the following problem by using logarithms, showing all your work:

$$\frac{110 \times 3.1 \times 0.650}{33 \times 0.7854 \times 1.7}$$

14.- An amplifier has an EMF of one volt applied across its input resistance of 20,000-ohms. An EMF of 18 volts appears across its output resistance of 5000-ohms. What is the power-gain in Db and what is the voltage gain in Db of this amplifier? Would it be worth while to increase the amplification so that 30 volts appeared across the output?

15.- A certain amplifier is known to offer a gain of 80 Db, and at which time a signal voltage of 35 volts is available at its output. Assuming the input and output impedances to be equal, what is the signal-voltage input to the amplifier at this time?

16.- Draw a diagram showing how three microphones can be made to operate into a mixer circuit which in turn feeds into the input of an amplifier. T-pad volume controls are to be used in this system.

17.- It is desired to design an H-pad for a 500-ohm transmission line which is being used to connect two amplifiers together. This pad is expected to furnish an attenuation of 8 Db. Work out the design for this pad and make a drawing of the system, designating the electrical values for all resistor values used in the pad, as well as the source and load impedances.

18.- Design a Db volume control to meet the following specifications: This control is to be used as the grid leak resistor for an amplifier tube and the assumed grid leak resistor value is to be 250,000 ohms. The total attenuation is to be 30 Db. There are to be ten steps of attenuation, 3 Db per step, in addition to the "full-on" and "off" positions.

NATIONAL SCHOOLS

RADIO DIVISION

4000 South Figueroa St. Los Angeles, California

Answered March 12 1940 grade 98

SPECIAL JOB SHEET EXAMINATION #1

DEAR STUDENT:

YOU HAVE BY THIS TIME STUDIED THE FIRST TEN JOB SHEETS AND BEFORE CONTINUING WITH THOSE WHICH ARE TO FOLLOW, IT IS ADVISABLE THAT WE TAKE THE TIME NOW TO ASSURE OURSELVES THAT YOU ARE LEARNING FROM THEM ALL THAT YOU SHOULD.

IT IS OF COURSE TRUE THAT THIS FIRST GROUP OF TEN JOB SHEETS ARE OF A RATHER ELEMENTARY NATURE BUT NEVERTHELESS THEY CONTAIN MANY IMPORTANT FACTS WHICH YOU CANNOT AFFORD TO PASS BY UNNOTICED. AS YOU PROGRESS, YOU WILL FIND YOUR JOB SHEETS TO TREAT WITH THE MORE COMPLEX SUBJECTS AND TO BECOME INCREASINGLY INTERESTING.

BEFORE COMMENCING TO ANSWER THE QUESTIONS WHICH FOLLOW, PLEASE NUMBER YOUR EXAMINATION PAPER AS JS-1 FOR IDENTIFICATION PURPOSES.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS
(JS-1)

1. – EXPLAIN IN DETAIL HOW YOU WOULD ALIGN THE TUNING CIRCUITS OF A T.R.F. RECEIVER WITH THE AID OF A SERVICE OSCILLATOR.

2. – DESCRIBE TWO METHODS WHEREBY YOU CAN DETERMINE WHICH SIDE OF A D.C. CIRCUIT IS POSITIVE AND WHICH NEGATIVE.

3. – A CERTAIN HOME WHICH YOU ARE CALLED UPON TO VISIT IS WIRED FOR ELECTRIC LIGHTING AND YOU ARE EXPECTED TO DETERMINE WHETHER THIS PARTICULAR INSTALLATION IS OF THE A.C. OR D.C. TYPE AND ALSO THE VOLTAGE OF SAME. HOW WOULD YOU PROCEED TO DETERMINE THESE FACTS?

4. – WHAT IS THE DIAMETER OF A #10 B&S COPPER WIRE EXPRESSED IN MILS AND WHAT IS THE RESISTANCE PER THOUSAND FEET OF THIS WIRE?

5. – YOU ARE CALLED UPON TO SERVICE AN OLD T.R.F. RECEIVER WHICH EMPLOYS TRIODES IN AN R.F. AMPLIFIER OF NEUTRODYNE DESIGN. THE SELECTIVITY OF THIS RECEIVER IS FOUND TO BE SATISFACTORY BUT THE SET HAS A TENDENCY TO SQUEAL OR WHISTLE ESPECIALLY WHEN TUNED TO THE HIGHER FREQUENCIES. WHAT IS WRONG WITH THIS RECEIVER AND HOW WOULD YOU PROCEED TO CORRECT THE CONDITION?

(OVER)

6. – How much current can be passed safely through a #12 B&S rubber covered wire?

7. – Upon being called upon to service a battery operated receiver, you find that the tubes light but no signals are received. What is the probable cause of the trouble and how would you remedy it?

8. – Upon testing an A.C. receiver, it is found that no "B" voltages are available from the power pack and the plates of the rectifier tube become red hot. What is the most probable cause for this trouble and how would you remedy it?

9. – A certain receiver has a tendency to emit a howling sound when certain strong notes are reproduced by the speaker and also if the chassis is jarred. What is the most probable cause for this trouble and how would you remedy it?

10.– What may be the trouble in a 110 or 220 volt D.C. receiver in which none of the tube filaments light?

11.– How would you proceed to align the tuning circuits of a T.R.F. receiver in the event that no service oscillator is available?

12.– What are some of the most common causes for excessive hum in an A.C. receiver and how would you reduce it in each case?

13.– What are some of the most common causes for low volume in A.C. receivers?

14.– If the line plug of a D.C. receiver should be reversed in the receptacle of the D.C. lighting circuit, how would this affect the performance of the receiver?

15.– What are some of the most common causes of intermittent reception?

16.– If voltage is lacking across only a portion of a power pack voltage divider system, what is the most probable cause of trouble? How would you correct the condition?

17.– What are some of the most common causes for low volume in battery operated receivers?

18.– What are some of the most common causes for poor tone quality in receivers, assuming that the quality was satisfactory originally?

19.– A certain receiver which uses screen-grid tubes in the R.F. stages has a tendency to oscillate, that is, produce squealing sounds. What are some of the most probable causes for this trouble and how would you correct it?

20.– What precautions should be exercised when measuring line voltage or when making a line polarity test?

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NATIONAL SCHOOLS
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LOS ANGELES, CALIF.

RADIO DIVISION

EDUCATIONAL DEPT.

Answered May 9, 40

SPECIAL JOB SHEET EXAMINATION #2

DEAR STUDENT:

SINCE ANSWERING YOUR LAST JOB SHEET EXAMINATION YOU HAVE RECEIVED AN ADDITIONAL GROUP OF JOBSHEETS AND WHICH YOU HAVE NO DOUBT FOUND TO BE OF GREAT VALUE.

THESE JOBSHEETS ARE A SPECIAL FEATURE OF NATIONAL TRAINING AND OFFER YOU IN A CONDENSED FORM AND FOR EASY REFERENCE ALL OF THE MORE IMPORTANT SERVICE JOBS PERTAINING TO RADIO. IT IS THEREFORE ESSENTIAL THAT YOU STUDY THESE JOBSHEETS WITH THE SAME ATTENTION AS YOU WOULD DEVOTE TO YOUR REGULAR LESSONS.

AS YOU RECEIVE ADDITIONAL JOB SHEETS, YOU WILL FIND THEM TO CONTAIN DETAILED INFORMATION TREATING WITH THE ALIGNING OF SUPERHETERODYNE RECEIVERS AND ALL-WAVE RECEIVERS, SPECIAL ALIGNING PROCEDURES WHEN AUTOMATIC VOLUME CONTROL SYSTEMS ARE USED, COMMON TROUBLES IN AUTOMATIC VOLUME CONTROL SYSTEMS AND THEIR CORRECTION, SPEAKER REPAIRS, PHONOGRAPH PICK-UP TROUBLES AND REPAIRS, SPECIAL CONDENSER AND RESISTOR TESTS ETC. BY ADDING ALL THIS INFORMATION TO THAT CONTAINED IN THE MANY REGULAR LESSONS, YOU WILL HAVE A MOST COMPLETE REFERENCE LIBRARY.

THIS PARTICULAR EXAMINATION IS BASED ON JOBSHEETS #11 TO 20 INCLUSIVE AND IT IS THEREFORE ADVISABLE THAT YOU STUDY THIS GROUP OF JOBSHEETS WITH SPECIAL CARE SO THAT YOU CAN ANSWER THE GREATER PORTION OF THE FOLLOWING QUESTIONS WITHOUT REFERRING BACK TO THE JOBSHEETS THEMSELVES.

AGAIN LET ME SUGGEST THAT BEFORE COMMENCING TO ANSWER THE QUESTIONS WHICH FOLLOW, TO PLEASE NUMBER YOUR EXAMINATION PAPER AS JS-2 FOR IDENTIFICATION PURPOSES.

SINCERELY YOURS,

J. A. Rosenkranz

PRESIDENT

EXAMINATION QUESTIONS
(JS-2)

1. – IN A CERTAIN RECEIVER USING A MAGNETIC SPEAKER NO SOUNDS ARE EMITTED BY THE SPEAKER AND YET UPON CONNECTING A PAIR OF HEADPHONES TO THE OUTPUT, SIGNALS ARE HEARD SATISFACTORILY. WHAT ARE THE MOST PROBABLE CAUSES FOR THIS TROUBLE? (BE SPECIFIC IN YOUR ANSWER).

2. – WHAT ARE SOME OF THE MORE COMMON CAUSES FOR A "DEAD" DYNAMIC SPEAKER?

3. – EXPLAIN IN DETAIL AND ILLUSTRATE BY MEANS OF A DIAGRAM HOW YOU WOULD TEST A TRANSFORMER WINDING FOR CONTINUITY.

4. – FOR WHAT PURPOSE IS A TYPE 6C6 TUBE SUITABLE? DRAW THE SYMBOL AND SOCKET CONNECTIONS FOR THIS TUBE AND SPECIFY ITS OPERATING CHARACTERISTICS.

(OVER)

5. – For what purpose is a 5Z3 tube suitable? Draw its symbol and socket connections and specify its operating characteristics.

6. – If in an A.C. receiver, plate and screen voltage is available at a certain R.F. tube but no grid bias voltage reading is obtained, what is the most likely cause of trouble?

7. – In a certain receiver plate voltage is available in the detector and A.F. stages but not in any of the R.F. stages. What are the most likely troubles?

8. – Explain in detail and illustrate by means of a diagram how you would determine whether or not a by-pass condenser in a certain receiver circuit is short circuited.

9. – A certain mica condenser is color coded with dots of the following colors — brown, black, and brown and which are arranged in the same order as here given. What is the capacitive value of this condenser?

10.– A certain color coded resistor has an orange body color, a yellow end color, and a red spot. What is the resistance value of this unit?

11.– What are the advantages to be acquired by the use of a voltage regulater in a receiver? How should such a unit be installed and what precautions should be taken in selecting a voltage regulator of correct rating for a given receiver?

12.– Explain in detail how you would proceed to identify the various terminals of a power transformer in the event that these are not marked by the manufacturer.

13.– In a certain superheterodyne receiver a whistling sound is heard as each station is tuned in. What are the most likely causes for this trouble?

14.– After tuning in a local station on a certain superheterodyne it is found that after listening to the program for awhile the station's signal gradually becomes weaker and finally disappears altogether. However, by simply resetting the tuning control knob again, the same signal will once more come through clear. What are the most likely causes for this trouble.

15.– If a superheterodyne receiver tunes satisfactorily over one section of the dial but not over the remaining section of the dial, what are the most probable causes for this trouble?

16.– What are some of the more probable causes for distortion in a superheterodyne receiver even though all tube voltages and general circuit constants are correct?

17.– What are some of the more probable causes for a superheterodyne receiver being dead? (Not considering general circuit troubles as power pack breakdowns etc. which may occur in any type of receiver)

NATIONAL SCHOOLS

RADIO DIVISION

4000 South Figueroa St. Los Angeles, California

SPECIAL JOB SHEET EXAMINATION #3

Dear Student:

I am confident that you realize the full value of the JobSheets and that you are studying them diligently. The various jobs and tests as described by them are representative of the types of problems which will confront you in the industry and it is therefore necessary that you familiarize yourself thoroughly with the correct manner of handling them.

The questions appearing in this examination are based on JobSheets #21 to #30 inclusive, so be sure to review this series well before attempting to answer these questions. Also please number your examination papers for this set of questions as JS-3.

Sincerely yours,

President

answered Nov 6, '40

EXAMINATION QUESTIONS
(JS-3)

1. - Explain in detail how you would proceed to determine the intermediate frequency of a superheterodyne receiver in the event that this information is not known nor available in specification form.

2. - Explain and illustrate with a diagram how you would connect an output meter to the push-pull power stage of a receiver.

3. - Explain in detail how you would proceed to align a band-pass type I.F. amplifier used in a superheterodyne receiver.

4. - How would you proceed to align a peaked I.F. amplifier?

5. - If you were called upon to operate a 110 volt A.C. receiver from a 220 volt A.C. circuit, how would you accomplish this?

6. - What special steps must be taken in order to align the tuning circuits of a superheterodyne receiver equipped with A.V.C.?

7. - How would you proceed to adapt a set of headphones to a receiver which is already equipped with a speaker?

(OVER)

8. - WHAT ARE SOME OF THE MOST PROBABLE CAUSES FOR INTERMITTENT ACTION OF A RECEIVER'S A.V.C. SYSTEM?

9. - WHAT ARE SOME OF THE MOST PROBABLE CAUSES FOR INTER-STATION NOISE IF THE RECEIVER IS EQUIPPED WITH A SILENT TUNING SYSTEM?

10.- EXPLAIN IN DETAIL HOW AN ELECTROLYTIC CONDENSER SHOULD BE TESTED.

11.- HOW WOULD YOU PROCEED TO ALIGN THE OSCILLATOR OF A SUPERHETERODYNE RECEIVER?

12.- EXPLAIN HOW YOU WOULD ALIGN THE R.F. SECTION OF A SUPERHETERODYNE.

13.- HOW CAN THE TIME-LAG OF A SUPERHETERODYNE'S A.V.C. ACTION BE REGULATED?

14.- DESCRIBE A SIMPLE EMERGENCY REPAIR OF AN A.F. TRANSFORMER.

15.- WHAT ARE SOME OF THE MOST PROBABLE CAUSES FOR WEAK RECEPTION WHEN THE RECEIVER IS EQUIPPED WITH AN A.V.C. SYSTEM?

16.- (A) WHAT IS A FLAT-TOP I.F. TRANSFORMER?
(B) WHAT SPECIAL PRECAUTIONS MUST BE EXERCISED IN TUNING SUCH TRANSFORMERS?

17.- MAKE A DIAGRAM AND EXPLAIN IN DETAIL HOW AN OUTPUT METER MAY BE CONNECTED TO A RECEIVER'S POWER STAGE IN WHICH A SINGLE TUBE IS EMPLOYED.

18.- WHAT ARE SOME OF THE MOST PROBABLE CAUSES OF ABRUPT A.V.C. ACTION?

19.- WHY IS IT ADVISABLE TO CONNECT A RESISTANCE IN SERIES WITH THE TEST CIRCUIT WHEN TESTING ELECTROLYTIC CONDENSERS?

20.- WHAT ARE THE MOST PROBABLE CAUSES FOR NO CONTROL OF VOLUME IN RECEIVERS EMPLOYING AN A.V.C. SYSTEM?

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RADIO EXPERIMENTS

LESSON NO. 1

In addition to having a good technical understanding of Radio, it is also of vital importance that you learn how to apply this knowledge to PRACTICAL use. So that you may attain both of these qualifications, we are including a complete assortment of experimental equipment as a regular part of your training.

The experiments, which you are going to perform, will enable you to prove for yourself many of the important principles which were presented to you in your regular lessons. With each experimental outfit, you will receive a complete set of instructions regarding their use so that you may be assured of deriving the greatest benefit from this part of your work.

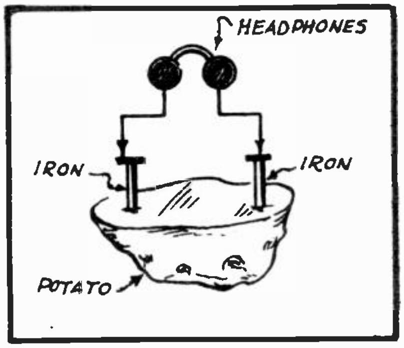

Fig. 1
Very Low Voltage.

Naturally, your first experiments are going to be of a very elementary nature, dealing mostly with fundamental electrical principles. However, as you progress and receive additional equipment, you will construct many different types of receiver circuits, perform service adjustments and cope with any number of good practical trouble shooting jobs. In all this work, you will be closely guided by carefully prepared instructions.

EXPERIMENT #1: - THE PRODUCTION OF AN E.M.F. BY CHEMICAL MEANS

Our first experiment is going to be a very simple one, however, it is going to illustrate how an E.M.F. may be produced by chemical action.

The first step will be to obtain a fairly good sized piece of a fresh raw potato and to insert two iron nails into it as illustrated in Fig. 1. This done, clamp your headphones over your ears and then touch one of the phone tips to one nail and the second phone tip to the other nail as also pointed out in Fig. 1. Listen carefully for a "click" in the headphones as you establish this contact.

HAVING COMPLETED THIS TEST, CONTINUE BY REMOVING BOTH OF THE NAILS AND INSERT TWO PIECES OF CLEAN BARE COPPER WIRE IN THEIR PLACE AND ESTABLISH CONTACT TO THE COPPER WIRES WITH THE HEADPHONE TIPS. LISTEN CAREFULLY FOR A CLICK IN YOUR HEADPHONES AS YOU MAKE AND BREAK CONTACT WITH YOUR HEADPHONE TIPS.

FROM THESE TWO SIMPLE TESTS, YOU WILL FIND THAT NO PERCEPTIBLE CLICK WILL BE EXPERIENCED IN THE HEADPHONES WHEN ESTABLISHING CONTACT WITH EITHER THE TWO NAILS OR THE TWO PIECES OF COPPER WIRE, THUS SHOWING THAT NO APPRECIABLE VOLTAGE EXISTS WITH WHICH TO FORCE AN ELECTRIC CURRENT THROUGH THE HEADPHONE WINDINGS SO AS TO ACTUATE THEIR DIAPHRAGMS.

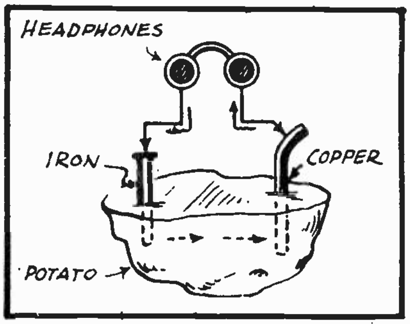

Fig. 2
Appreciable Voltage.

NOW INSERT ONE NAIL AND ONE PIECE OF COPPER WIRE INTO THE POTATO AND AGAIN ESTABLISH CONTACT WITH THE HEADPHONE TIPS AS ILLUSTRATED IN FIG.2. THIS TIME, YOU WILL HEAR A PRONOUNCED CLICK IN THE PHONES EACH TIME THAT THE CIRCUIT IS COMPLETED AND THE TEST THUS SHOWS YOU THAT A DEFINITE VOLTAGE NOW EXISTS WHICH IS CAPABLE OF FORCING A CURRENT THROUGH THE HEADPHONE WINDINGS SO AS TO ACTUATE THE DIAPHRAGMS.

WHAT WE REALLY HAVE HERE IS A SIMPLE FORM OF PRIMARY CELL, WHERE THE ACIDS CONTAINED IN THE POTATO SERVE AS THE ELECTROLYTE AND THE TWO PIECES OF METAL WHICH ARE INSERTED INTO THE POTATO ACT AS ELECTRODES.

WHEN USING TWO DISSIMILAR METALS FOR ELECTRODES, SUCH AS IRON AND COPPER IN OUR LAST TEST, THE ACIDS OF THE POTATO OR ELECTROLYTE ATTACK THE IRON MORE THAN THEY DO THE COPPER, THEREBY RESULTING IN A POTENTIAL DIFFERENCE ACROSS THE TWO ELECTRODES. IN OTHER WORDS, A VOLTAGE IS THUS ESTABLISHED AND IT IS CAPABLE OF CAUSING AN ELECTRIC CURRENT TO FLOW THRU A COMPLETED CIRCUIT. THE HEADPHONES IN THIS CASE SERVE TO COMPLETE THIS CIRCUIT AND THE MAGNETIC REACTION CAUSED BY THIS CURRENT FLOW IS SUCH AS TO ACT UPON THE DIAPHRAGM OF THE HEADPHONES AS ALREADY EXPLAINED IN YOUR REGULAR LESSONS.

IF TWO LIKE METALS ARE USED AS THE ELECTRODES, THE CHEMICAL REACTION OCCURING AT EACH OF THEM IS THE SAME AND CONSEQUENTLY NO POTENTIAL DIFFERENCE IS ESTABLISHED ACROSS THEM.

IT IS POSSIBLE TO USE SEVERAL COMBINATIONS OF DISSIMILAR METALS AS ELECTRODES AND WHEN IMMERSED IN VARIOUS TYPES OF ELECTROLYTES, THEY WILL PRODUCE VARIOUS VOLTAGE VALUES.

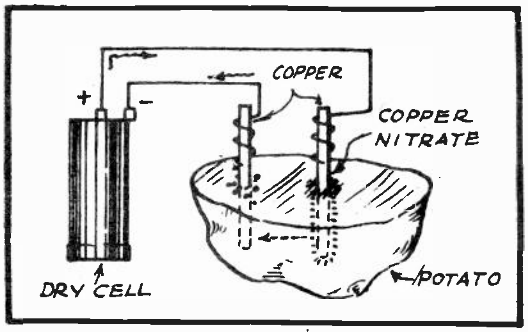

Fig. 3
Charging The Cell.

FOR INSTANCE, ZINC AND CARBON WHEN IMMERSED IN AN ELECTROLYTE CONSISTING CHIEFLY OF AMMONIUM CLORIDE AND ZINC CHLORIDE WILL PRODUCE AN E.M.F. OR 1.5 VOLT; COPPER AND ZINC IN AN ELECTROLYTE CONSISTING OF ZINC

SULPHATE AND COPPER SULPHATE WILL PRODUCE 1 VOLT ETC.

EXPERIMENT #2: - A SIMPLE SECONDARY CELL

NOW LET US TEST THE THOERY OF THE SECONDARY CELL OR STORAGE CELL BY MEANS OF A SIMPLE EXPERIMENT. WE SHALL BEGIN BY AGAIN INSERTING TWO PIECES OF BARE COPPER WIRE INTO THE RAW POTATO BUT THIS TIME, BE SURE THAT THE TWO WIRES ARE QUITE CLOSE TO EACHOTHER BUT NOT TOUCHING.

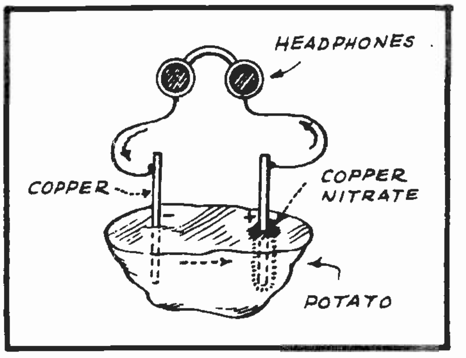

Fig. 4
Discharging The Cell.

NOW MAKE A PRELIMINARY TEST BY CONNECTING YOUR HEADPHONES ACROSS THE TWO COPPER WIRES. YOU WILL HEAR NO CLICK BECAUSE NO APPRECIABLE VOLTAGE EXISTS AT THIS TIME, AS YOU ALREADY LEARNED.

THE NEXT STEP WILL BE TO CONNECT A DRY CELL ACROSS THE TWO COPPER ELECTRODES AS SHOWN IN FIG. 3. THE DRY CELL WILL DISCHARGE THROUGH THE POTATO AS SHOWN IN FIG. 3. BECAUSE THE MOISTURE AND ACID WITHIN THE POTATO ACTS AS A CONDUCTOR.

AFTER A LITTLE TIME HAS ELAPSED, YOU WILL OBSERVE THE FORMATION OF A GREEN COLORED MATERIAL AROUND THE COPPER ELECTRODE WHICH IS CONNECTED TO THE POSITIVE TERMINAL OF THE DRY CELL, WHILE SMALL GASEOUS BUBBLES RESEMBLING FOAM WILL ACCUMULATE AROUND THE ELECTRODE WHICH IS CONNECTED TO THE NEGATIVE TERMINAL OF THE CELL. THESE OBSERVATIONS CLEARLY DEMONSTRATE THAT A CHEMICAL ACTION IS NOW TAKING PLACE.

WHAT ACTUALLY HAPPENS DURING THIS TIME IS THAT THE FLOW OF CURRENT THROUGH THE SYSTEM CAUSES A CHEMICAL ACTION OF SUCH A NATURE THAT ONE OF THE COPPER ELECTRODES COMBINES WITH THE ELECTROLYTE TO FORM COPPER NITRATE OR THE GREENISH LOOKING SUBSTANCE; WHILE HYDROGEN, WHICH IS EXTRACTED FROM THE WATER CONTAINED IN THE POTATO IS LIBERATED IN THE FORM OF BUBBLES AT THE OTHER ELECTRODE.

IN OTHER WORDS, ELECTRICAL ENERGY IS NOW BEING CONVERTED INTO CHEMICAL ENERGY AND THE ORIGINAL CHEMICAL CONDITIONS ARE BEING ALTERED.

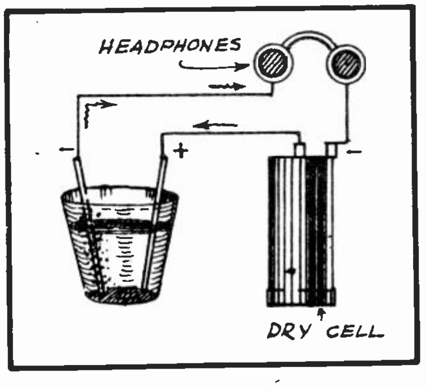

Fig. 5
The Water Rheostat.

NOW BY DISCONNECTING THE DRY CELL, WE HAVE LEFT A CHARGED SECONDARY CELL AT THE POTATO. THAT IS, THE CHARGING CURRENT AS FURNISHED BY THE DRY CELL HAS CHANGED THE CHEMICAL CONDITION OF OUR HOME-CONSTRUCTED CELL TO SUCH AN EXTENT THAT THE ACTIVE ELEMENT AT ONE OF THE ELECTRODES WILL BE PURE COPPER WHILE THE ACTIVE ELEMENT AT THE OTHER ELECTRODE HAS BECOME COPPER NITRATE.

TO PROVE THAT THE CELL HAS ACTUALLY BECOME CHARGED DURING THIS PROGRESS, IT IS ONLY NECESSARY TO AGAIN CONNECT THE HEADPHONES ACROSS THE TWO COPPER WIRES AS SHOWN IN FIG. 4. THIS TIME, A VERY PRONOUNCED CLICK WILL BE

EXPERIENCED IN THE HEADPHONES AS THE CELL DISCHARGES THROUGH THE HEADPHONE WINDINGS IN THE DIRECTION DESIGNATED IN FIG.4.

THUS WE HAVE SEEN THAT AN INITIAL FLOW OF CURRENT IS CAPABLE OF CHARGING THE CELL BY CONVERTING ELECTRICAL ENERGY TO CHEMICAL ENERGY AND THAT IN TURN, THE CELL WAS CAPABLE OF CONVERTING CHEMICAL ENERGY TO ELECTRICAL ENERGY, THEREBY FULFILLING THE REQUIREMENTS OF A SECONDARY CELL.

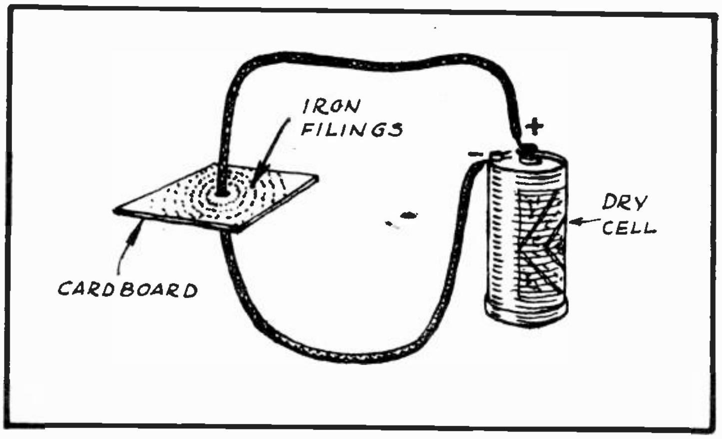

Fig. 6
Lines Of Force Encircle The Conductor.

NATURALLY, THIS WAS ACCOMPLISHED IN ONLY A SMALL WAY IN THIS SIMPLE EXPERIMENT BUT THESE SAME PRINCIPLES ARE EMPLOYED MORE PRACTICALLY IN THE POPULAR LEAD-ACID TYPE STORAGE BATTERY, WHERE THE POSITIVE PLATES ARE IN THE FORM OF LEAD PEROXIDE, THE NEGATIVE PLATES BEING SPONGY LEAD AND A DILUTE SULPHURIC ACID SOLUTION SERVING AS THE ELECTROLYTE.

EXPERIMENT #3: - DETERMINING D.C. POLARITY

THE HUMBLE POTATO ALSO OFFERS A MEANS WHEREBY ONE CAN DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE AND THIS CAN BE ACCOMPLISHED IN THE FOLLOWING MANNER: INSERT TWO PIECES OF BARE COPPER WIRE INTO THE POTATO AND CONNECT THE SOURCE OF VOLTAGE ACROSS THEM THE SAME MANNER AS WAS ALREADY SHOWN YOU IN FIG. 3 OF THIS LESSON.

THE GREEN COPPER NITRATE WILL THEN FORM AROUND THE COPPER ELECTRODE WHICH IS CONNECTED TO THE POSITIVE TERMINAL OF THE VOLTAGE SOURCE AND IN THIS WAY INDICATES THE POLARITY.

EXPERIMENT #4: - THE WATER RHEOSTAT

FILL A GLASS CONTAINER ABOUT 3/4 FULL WITH ORDINARY WATER AND ADD A LITTLE TABLE SALT TO IT. NOW IMMERSE TWO BARE PIECES OF COPPER WIRE IN THE SALT WATER SO THAT THEY WILL SERVE AS ELECTRODES.

CONNECT A DRY CELL WITH THE HEADPHONES IN SERIES ACROSS THE ELECTRODES AS IN FIG.5. VARY THE DISTANCE BETWEEN THE ELECTRODES AND MAKE AND BREAK THE THE HEADPHONE CIRCUIT. AS YOU DO SO YOU WILL FIND THAT THE CLICK IN THE PHONES WILL INCREASE AS THE DISTANCE BETWEEN THE ELECTRODES IS DECREASED, THUS SHOWING THAT THE CURRENT FLOW THROUGH THE HEADPHONES INCREASES AS THE ELECTRODES

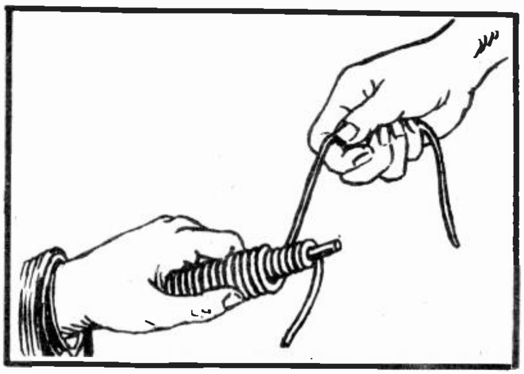

Fig. 7
The Electromagnet.

ARE BROUGHT CLOSER TOGETHER. IN OTHER WORDS, THE POSITION OF THE ELECTRODES WILL CONTROL THE RESISTANCE OF THE CIRCUIT AND THE ARRANGEMENT THEREFORE SERVES AS AN EFFECTIVE RHEOSTAT. WE CALL SUCH A DEVISE A "WATER RHEOSTAT."

REPEAT THE ABOVE EXPERIMENTS BY INCREASING THE SALT CONTENT OF THE SOLUTION. YOU WILL FIND THAT AS THE AMOUNT OF SALT IS INCREASED FOR A GIVEN QUANTITY OF WATER, THE BETTER WILL BE THE ELECTRICAL CONDUCTING QUALITIES OF THE SOLUTION.

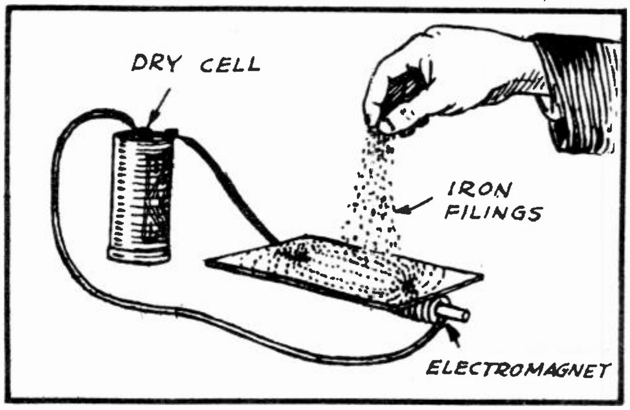

Fig. 8
Demonstration Of The Magnetic Field.

BY MEANS OF THIS SAME "SET UP", IT IS ALSO POSSIBLE FOR YOU TO DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE DUE TO THE FACT THAT BUBBLES WILL COLLECT AROUND THE ELECTRODE WHICH IS CONNECTED TO THE NEGATIVE POLE OF THE VOLTAGE SOURCE. THESE BUBBLES ARE DUE TO THE DECOMPOSITION OF THE WATER BROUGHT ABOUT BY THE ELECTRICAL CURRENT WHICH IS FLOWING THROUGH IT.

EXPERIMENT #5: - MAGNETIC FIELD SURROUNDING A CONDUCTOR

TAKE A PIECE OF LIGHT CARDBOARD AND PASS A LENGTH OF WIRE THROUGH ITS CENTER, CONNECTING THE ENDS OF THIS WIRE ACROSS THE TERMINALS OF A DRY CELL AS SHOWN IN FIG.6.

SPRINKLE SOME IRON FILINGS UPON THE SURFACE OF THE CARDBOARD AND TAP THE CARDBOARD LIGHTLY WITH YOUR FINGERS. YOU WILL FIND THE IRON FILINGS TO ARRANGE THEMSELVES INTO A DEFINITE PATTERN ENCIRCLING THE CONDUCTOR, THEREBY ACTUALLY SHOWING YOU HOW THE LINES OF FORCE SURROUND A CONDUCTOR THROUGH WHICH AN ELECTRICAL CURRENT IS FLOWING.

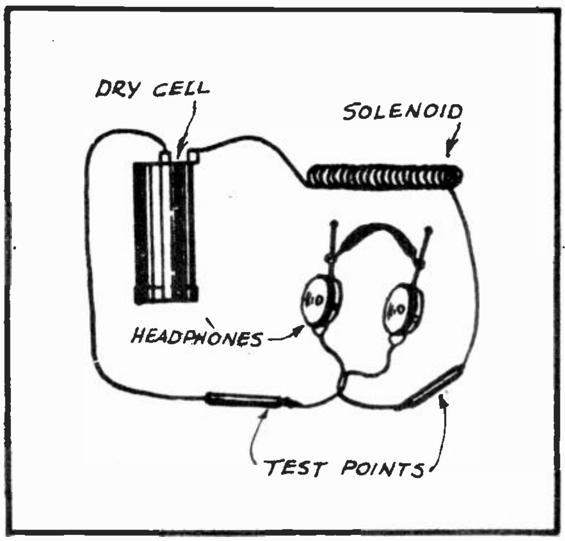

Fig. 9
A Continuity Test With Headphones.

(YOU CAN OBTAIN THE NECESSARY IRON FILINGS FOR THIS EXPERIMENT BY SIMPLY FILING A LARGE NAIL AND GATHERING TOGETHER THE FILINGS WHICH WILL THUS BE PRODUCED).

EXPERIMENT #6: - THE ELECTROMAGNET

WRAP A LAYER OF HEAVY PAPER AROUND A LARGE NAIL AND THEN WIND SEVERAL LAYERS OF INSULATED WIRE OVER THE PAPER AND ACROSS THE GREATER PORTION OF THE NAIL'S LENGTH AS ILLUSTRATED IN FIG.7. CONNECT THE FINISHED WINDING ACROSS A DRY CELL AND TEST THE MAGNETIC PROPERTIES OF THIS ELECTROMAGNET BY OBSERVING ITS ATTRACTION UPON SMALL PIECES OF IRON, NAILS, TACKS ETC. ALSO NOTICE HOW THE POWER OF ATTRACTION IS LOST THE

INSTANT THAT THE ELECTRICAL CIRCUIT IS INTERRUPTED.

NOW PLACE A PIECE OF LIGHT CARDBOARD OVER THE ELECTROMAGNET AS ILLUSTRATED IN FIG.8 AND SPRINKLE IRON FILINGS OVER ITS SURFACE. BY TAPPING THE CARDBOARD LIGHTLY, THE IRON FILINGS WILL ARRANGE THEMSELVES INTO A PATTERN SIMILAR TO THAT SHOWN IN FIG.8, IN THIS MANNER DEMONSTRATING THE PATHS ALONG WHICH THE LINES OF FORCE SURROUNDING THE ELECTROMAGNET EXERT THEMSELVES.

CAREFULLY, REMOVE THE IRON CORE WITHOUT DESTROYING THE WINDING. YOU WILL NOW HAVE A "SOLENOID" AND BY PERFORMING ALL OF THE PRECEDING ELECTROMAGNET EXPERIMENTS WITH THIS SOLENOID YOU WILL NOTICE THAT ITS MAGNETIC POWER HAS DECREASED CONSIDERABLY WITH THE REMOVAL OF THE IRON CORE.

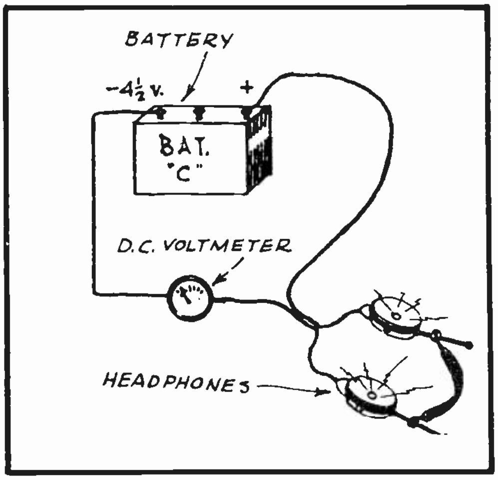

Fig. 10
A Voltmeter Continuity Test.

EXPERIMENT #7: - TESTING CIRCUIT CONTINUITY WITH HEADPHONES

YOUR HEADPHONES ALSO OFFER YOU A MEANS WHEREBY YOU CAN TEST THE CONTINUITY OF A CIRCUIT OR ANY PART THEREOF. THAT IS, YOU CAN DETERMINE WHETHER THE CIRCUIT IS COMPLETE OR NOT.

TO DO THIS, CONNECT THE HEADPHONES IN SERIES WITH A CELL OR BATTERY. THEN TOUCH THE ENDS OF THIS TEST CIRCUIT ACROSS THE UNIT OR CIRCUIT TO BE TESTED. FOR INSTANCE, IN FIG.9 THE SOLENOID WINDING IS BEING TESTED FOR CONTINUITY.

IF THE WINDING OF THE SOLENOID IS COMPLETE THEN A CLICK WILL BE HEARD IN THE PHONES UPON TOUCHING THE TEST POINTS TO THE CIRCUIT UNDER TEST. HOWEVER, IF THE WINDING OF THE SOLENOID SHOULD BE BROKEN OR OPEN CIRCUITED, THEN NO CLICK WILL BE EXPERIENCED DURING THIS TEST.

PRACTICALLY ANY PIECE OF ELECTRICAL EQUIPMENT CAN BE TESTED FOR CONTINUITY IN THIS WAY, PROVIDED THAT ITS NORMAL RESISTANCE IS NOT EXCESSIVE SO THAT THE CELL OR BATTERY COULD NOT POSSIBLY FORCE SUFFICIENT CURRENT THROUGH THE SYSTEM TO ACTUATE THE HEADPHONE DIAPHRAGMS EVEN THOUGH THE CIRCUIT OR COMPONENT BEING TESTED WERE FREE FROM DEFECTS.

EXPERIMENT #8: - A VOLTMETER TYPE CONTINUITY TESTER

A VERY EFFECTIVE VISUAL TYPE OF CONTINUITY TESTER CAN BE MADE BY CONNECTING A BATTERY IN SERIES WITH A D.C. TYPE VOLTMETER HAVING A RELATIVELY LOW VOLTAGE SCALE. THE BATTERY MAY CONSIST OF ABOUT TWO OR THREE SERIES CONNECTED DRY CELLS, OR ELSE A 4½ VOLT RADIO "C" BATTERY CAN BE USED SATISFACTORILY.

WHENEVER, THE FREE ENDS OF THIS TEST CIRCUIT ARE TOUCHED TOGETHER, THE VOLTMETER WILL INDICATE THE FULL VOLTAGE OF THE BATTERY BUT WHEN THESE SAME ENDS ARE HELD APART OR SEPARATED, THE VOLTMETER WILL OFFER A ZERO READING.

FIG. 10 SHOWS YOU HOW THE WINDINGS OF A PAIR OF HEADPHONES MAY BE TESTED FOR CONTINUITY. NOTICE HOW THE TEST POINTS OF THE TESTING CIRCUIT ARE CONNECTED TO THE TIPS OF THE HEADPHONES. IF THE WINDINGS ARE IN GOOD CONDITION, THE METER WILL INDICATE VERY NEARLY THE VOLTAGE OF THE BATTERY BEING USED, WHEREAS A ZERO READING WOULD INDICATE THE HEADPHONE WINDINGS AS BEING OPEN CIRCUITED.

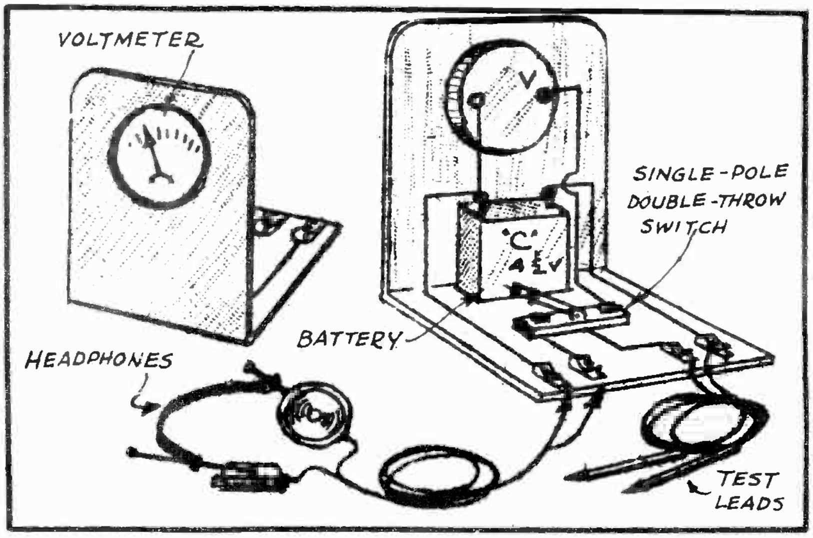

Fig. 11
The Continuity Tester.

THIS SAME TEST CAN BE APPLIED TO VARIOUS TYPES OF ELECTRICAL EQUIPMENT, RESPONDING IN THE SAME MANNER AS JUST DESCRIBED. HOWEVER, WHEN TESTING WITH THIS APPARATUS THRU CIRCUITS HAVING CONSIDERABLE RESISTANCE, THE METER READING WILL VARY WITH THE AMOUNT OF RESISTANCE THROUGH WHICH THE TEST IS BEING MADE. IN OTHER WORDS, THE GREATER THE RESISTANCE OF THE CIRCUIT, THE LOWER WILL BE THE METER READING. THIS FACT MUST BE TAKEN INTO CONSIDERATION WHEN MAKING A TEST OF THIS KIND. YOU WILL HAVE AMPLE OPPORTUNITY OF BECOMING FAMILIAR WITH THIS TEST AS YOU APPLY IT TO THE VARIOUS RECEIVER CIRCUITS AND PARTS WHILE EXPERIMENTING WITH THE EQUIPMENT WHICH IS GOING TO BE SENT YOU IN THE FUTURE.

THE VOLTMETER ALSO OFFERS YOU A MEANS FOR DETERMINING THE POLARITY OF A D.C. VOLTAGE SOURCE, PROVIDED THAT THE VOLTAGE DOES NOT EXCEED THE MAXIMUM VOLTAGE VALUE FOR WHICH THE PARTICULAR INSTRUMENT IS CALIBRATED. IN THIS CASE, IT IS ONLY NECESSARY TO CONNECT THE VOLTMETER ACROSS THE TERMINALS OF THE VOLTAGE SOURCE BEING TESTED. THEN IF THE METER NEEDLE SWINGS ACROSS ITS SCALE IN THE PROPER DIRECTION, THAT SIDE OF THE CIRCUIT WHICH IS CONNECTED TO THE (+) METER TERMINAL WILL BE THE POSITIVE SIDE OF THE CIRCUIT.

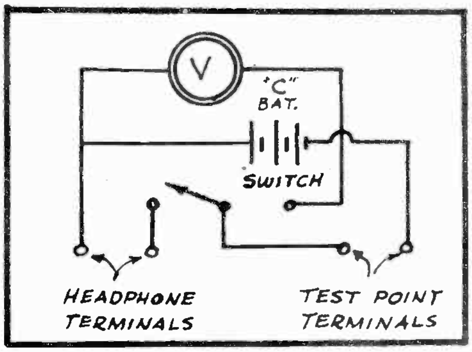

Fig. 12
Circuit Of The Tester

SHOULD THE METER NEEDLE TEND TO MOVE ACROSS ITS SCALE IN THE WRONG DIRECTION WHEN MAKING THIS TEST, THEN THE METER CONNECTIONS WILL HAVE TO BE REVERSED. THE SAME RULE CONCERNING POLARITY, WHICH WAS JUST GIVEN YOU, CAN THEN BE APPLIED.

CONSTRUCTION OF A CONTINUITY TESTER

SHOULD YOU WISH TO CONSTRUCT A COMPACT CONTINUITY TESTER WHICH WILL BE QUITE HANDY IN YOUR WORK FROM NOW ON, YOU CAN USE THE HEADPHONES, VOLTMETER AND "C" BATTERY

WHICH YOU NOW HAVE ON HAND AND BUILD A UNIT SOMEWHAT AS THAT ILLUSTRATED IN FIG.11.

THE VOLTMETER CAN BE MOUNTED FLUSH WITH THE PANEL BY CUTTING A HOLE IN THE PANEL EQUAL TO THE DIAMETER OF THE VOLTMETER BODY. THE MOUNTING RING SHOULD THEN BE REMOVED FROM THE VOLTMETER AND THE METER INSERTED IN ITS MOUNTING HOLE WITH ITS FACE TOWARD THE FRONT. THE MOUNTING RING CAN THEN BE REPLACED FROM THE BACK OF THE METER AND LOCKED IN POSITION SO AS TO HOLD THE METER FIRMLY IN PLACE.

ANOTHER SMALLER HOLE SHOULD BE DRILLED IN THE PANEL BELOW THE VOLTMETER TO ACCOMMODATE THE SWITCH. THE "C" BATTERY CAN BE HELD IN PLACE WITH A METAL STRAP AND A PAIR OF WOOD-SCREWS. THE CIRCUIT DIAGRAM FOR THIS CONTINUITY TESTER IS SHOWN IN FIG.12 SO THAT YOU MAY BECOME MORE FAMILIAR WITH IT.

WHEN THE DOUBLE-THROW SWITCH IS CLOSED TO POSITION "V", THE VOLTMETER WILL OFFER A READING WHENEVER THE TEST POINTS ARE TOUCHED TOGETHER, WHEREAS CLOSING THIS SWITCH TO POSITION "H" WILL CAUSE A CLICK TO BE HEARD IN THE HEADPHONES WHENEVER THE TEST POINTS ARE TOUCHED TOGETHER. IN THIS MANNER, EITHER OF THESE TWO TESTING METHODS CAN BE EMPLOYED SIMPLY BY CLOSING THE SWITCH IN THE PROPER DIRECTION.

THIS SAME TESTER CAN ALSO BE HOUSED IN A BOX IF SO DESIRED AND MORE ELABORATE TERMINALS MOUNTED ON ITS FRONT PANEL FOR THE HEADPHONE AND TEST POINT CONNECTIONS. THIS IS A MATTER OF PERSONAL CHOICE. YOU ARE NOT REQUIRED TO BUILD THIS TESTER IN THAT NOT ALL OF THE NECESSARY PARTS ARE INCLUDED IN YOUR EXPERIMENTAL EQUIPMENT. HOWEVER, IF YOU SHOULD WISH TO DO SO, YOU WILL NO DOUBT FIND THESE SUGGESTIONS HELPFUL.

Answ May 28 /40

Examination Questions

EXPERIMENT LESSON NO. 1

1. – WHY IS THAT AN E.M.F. IS PRODUCED WHEN ONE IRON AND ONE COPPER ELECTRODE ARE STUCK INTO THE POTATO BUT NOT WHEN TWO COPPER OR TWO IRON ELECTRODES ARE USED TOGETHER. (AS ILLUSTRATED BY EXPERIMENT #1)
2. – WHAT OCCURS IN YOUR EXPERIMENT #2 WHICH ENABLES AN E.M.F. TO BE PRODUCED EVEN THOUGH TWO COPPER ELECTRODES ARE USED?
3. – DESCRIBE ONE SIMPLE METHOD WHEREBY YOU CAN DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE WITHOUT THE USE OF A METER.
4. – DESCRIBE YOUR OBSERVATIONS WHILE CONDUCTING EXPERIMENT #4.
5. – HOW WERE YOU ABLE TO DEMONSTRATE THE FACT THAT LINES OF FORCE SURROUND A CONDUCTOR THROUGH WHICH AN ELECTRIC CURRENT IS FLOWING?
6. – DURING YOUR EXPERIMENTS WITH THE ELECTROMAGNET, HOW DID THE PRESENCE OF AN IRON CORE AFFECT THE MAGNETIC STRENGTH AS COMPARED TO THE PERFORMANCE OF THE UNIT WHEN NO IRON CORE WAS USED?
7. – DESCRIBE HOW YOU CAN USE A SET OF HEADPHONES IN ORDER TO TEST THE CONTINUITY OF A CIRCUIT.
8. – DESCRIBE HOW YOU CAN TEST A CIRCUIT FOR CONTINUITY WITH A D.C. VOLTMETER HAVING A LOW VOLTAGE RANGE.
9. – DESCRIBE AND ILLUSTRATE BY MEANS OF A DIAGRAM A SIMPLE CONTINUITY TESTER.
10. – HOW DOES THE NUMBER OF TURNS USED ON THE WINDING OF AN ELECTROMAGNET AFFECT ITS MAGNETIC STRENGTH?

RADIO - TELEVISION

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NATIONAL SCHOOLS

Established 1905

Los Angeles, California

RADIO EXPERIMENTS

LESSON NO. 1

In addition to having a good technical understanding of Radio, it is also of vital importance that you learn how to apply this knowledge to practical use. So that you may attain both of these qualifications, we are including a complete assortment of experimental equipment as a regular part of your training.

The experiments, which you are going to perform, will enable you to prove for yourself many of the important principles which were presented to you in your regular lessons. With each experimental outfit, you will receive a complete set of instructions regarding their use so that you may be assured of deriving the greatest benefit from this part of your work.

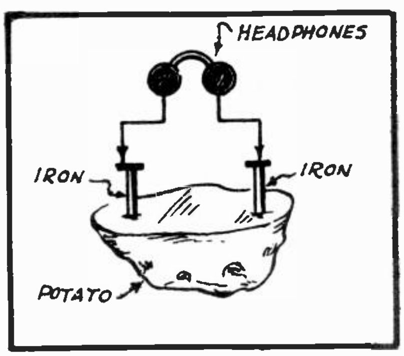

Fig. 1
Very Low Voltage.

Naturally, your first experiments are going to be of a very elementary nature, dealing mostly with fundamental electrical principles. However, as you progress and receive additional equipment, you will construct many different types of receiver circuits, perform service adjustments and cope with any number of good practical trouble shooting jobs. In all this work, you will be closely guided by carefully prepared instructions.

EXPERIMENT #1: – THE PRODUCTION OF AN E.M.F. BY CHEMICAL MEANS

Our first experiment is going to be a very simple one, however, it is going to illustrate how an E.M.F. may be produced by chemical action.

The first step will be to obtain a fairly good sized piece of a fresh raw potato and to insert two iron nails into it as illustrated in Fig. 1. This done, clamp your headphones over your ears and then touch one of the phone tips to one nail and the second phone tip to the other nail as also pointed out in Fig. 1. Listen carefully for a "click" in the headphones as you establish this contact.

HAVING COMPLETED THIS TEST, CONTINUE BY REMOVING BOTH OF THE NAILS AND INSERT TWO PIECES OF CLEAN BARE COPPER WIRE IN THEIR PLACE AND ESTABLISH CONTACT TO THE COPPER WIRES WITH THE HEADPHONE TIPS. LISTEN CAREFULLY FOR A CLICK IN YOUR HEADPHONES AS YOU MAKE AND BREAK CONTACT WITH YOUR HEADPHONE TIPS.

FROM THESE TWO SIMPLE TESTS, YOU WILL FIND THAT NO PERCEPTIBLE CLICK WILL BE EXPERIENCED IN THE HEADPHONES WHEN ESTABLISHING CONTACT WITH EITHER THE TWO NAILS OR THE TWO PIECES OF COPPER WIRE, THUS SHOWING THAT NO APPRECIABLE VOLTAGE EXISTS WITH WHICH TO FORCE AN ELECTRIC CURRENT THROUGH THE HEADPHONE WINDINGS SO AS TO ACTUATE THEIR DIAPHRAGMS.

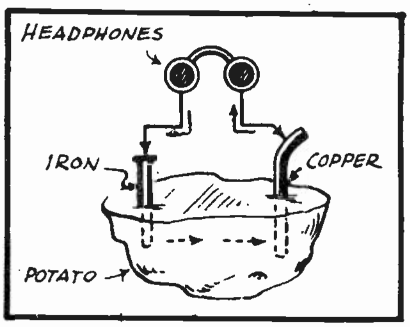

Fig. 2
Appreciable Voltage.

NOW INSERT ONE NAIL AND ONE PIECE OF COPPER WIRE INTO THE POTATO AND AGAIN ESTABLISH CONTACT WITH THE HEADPHONE TIPS AS ILLUSTRATED IN FIG.2. THIS TIME, YOU WILL HEAR A PRONOUNCED CLICK IN THE PHONES EACH TIME THAT THE CIRCUIT IS COMPLETED AND THE TEST THUS SHOWS YOU THAT A DEFINITE VOLTAGE NOW EXISTS WHICH IS CAPABLE OF FORCING A CURRENT THROUGH THE HEADPHONE WINDINGS SO AS TO ACTUATE THE DIAPHRAGMS.

WHAT WE REALLY HAVE HERE IS A SIMPLE FORM OF PRIMARY CELL, WHERE THE ACIDS CONTAINED IN THE POTATO SERVE AS THE ELECTROLYTE AND THE TWO PIECES OF METAL WHICH ARE INSERTED INTO THE POTATO ACT AS ELECTRODES.

WHEN USING TWO DISSIMILAR METALS FOR ELECTRODES, SUCH AS IRON AND COPPER IN OUR LAST TEST, THE ACIDS OF THE POTATO OR ELECTROLYTE ATTACK THE IRON MORE THAN THEY DO THE COPPER, THEREBY RESULTING IN A POTENTIAL DIFFERENCE ACROSS THE TWO ELECTRODES. IN OTHER WORDS, A VOLTAGE IS THUS ESTABLISHED AND IT IS CAPABLE OF CAUSING AN ELECTRIC CURRENT TO FLOW THRU A COMPLETED CIRCUIT. THE HEADPHONES IN THIS CASE SERVE TO COMPLETE THIS CIRCUIT AND THE MAGNETIC REACTION CAUSED BY THIS CURRENT FLOW IS SUCH AS TO ACT UPON THE DIAPHRAGM OF THE HEADPHONES AS ALREADY EXPLAINED IN YOUR REGULAR LESSONS.

IF TWO LIKE METALS ARE USED AS THE ELECTRODES, THE CHEMICAL REACTION OCCURING AT EACH OF THEM IS THE SAME AND CONSEQUENTLY NO POTENTIAL DIFFERENCE IS ESTABLISHED ACROSS THEM.

IT IS POSSIBLE TO USE SEVERAL COMBINATIONS OF DISSIMILAR METALS AS ELECTRODES AND WHEN IMMERSED IN VARIOUS TYPES OF ELECTROLYTES, THEY WILL PRODUCE VARIOUS VOLTAGE VALUES.

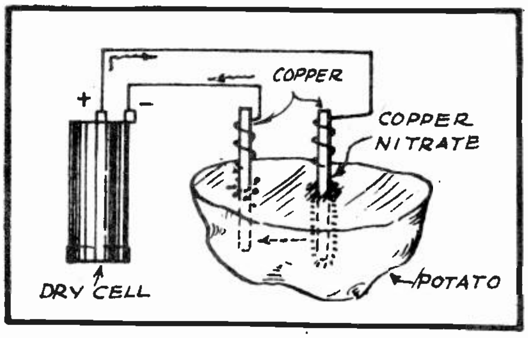

Fig. 3
Charging The Cell.

FOR INSTANCE, ZINC AND CARBON WHEN IMMERSED IN AN ELECTROLYTE CONSISTING CHIEFLY OF AMMONIUM CLORIDE AND ZINC CHLORIDE WILL PRODUCE AN E.M.F. OR 1.5 VOLT; COPPER AND ZINC IN AN ELECTROLYTE CONSISTING OF ZINC

SULPHATE AND COPPER SULPHATE WILL PRODUCE I VOLT ETC.

EXPERIMENT #2: - A SIMPLE SECONDARY CELL

NOW LET US TEST THE THOERY OF THE SECONDARY CELL OR STORAGE CELL BY MEANS OF A SIMPLE EXPERIMENT. WE SHALL BEGIN BY AGAIN INSERTING TWO PIECES OF BARE COPPER WIRE INTO THE RAW POTATO BUT THIS TIME, BE SURE THAT THE TWO WIRES ARE QUITE CLOSE TO EACHOTHER BUT NOT TOUCHING.

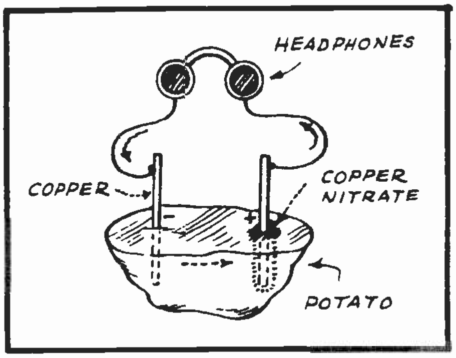

Fig. 4
Discharging The Cell.

NOW MAKE A PRELIMINARY TEST BY CONNECTING YOUR HEADPHONES ACROSS THE TWO COPPER WIRES. YOU WILL HEAR NO CLICK BECAUSE NO APPRECIABLE VOLTAGE EXISTS AT THIS TIME, AS YOU ALREADY LEARNED.

THE NEXT STEP WILL BE TO CONNECT A DRY CELL ACROSS THE TWO COPPER ELECTRODES AS SHOWN IN FIG. 3. THE DRY CELL WILL DISCHARGE THROUGH THE POTATO AS SHOWN IN FIG. 3. BECAUSE THE MOISTURE AND ACID WITHIN THE POTATO ACTS AS A CONDUCTOR.

AFTER A LITTLE TIME HAS ELAPSED, YOU WILL OBSERVE THE FORMATION OF A GREEN COLORED MATERIAL AROUND THE COPPER ELECTRODE WHICH IS CONNECTED TO THE POSITIVE TERMINAL OF THE DRY CELL, WHILE SMALL GASEOUS BUBBLES RESEMBLING FOAM WILL ACCUMULATE AROUND THE ELECTRODE WHICH IS CONNECTED TO THE NEGATIVE TERMINAL OF THE CELL. THESE OBSERVATIONS CLEARLY DEMONSTRATE THAT A CHEMICAL ACTION IS NOW TAKING PLACE.

WHAT ACTUALLY HAPPENS DURING THIS TIME IS THAT THE FLOW OF CURRENT THROUGH THE SYSTEM CAUSES A CHEMICAL ACTION OF SUCH A NATURE THAT ONE OF THE COPPER ELECTRODES COMBINES WITH THE ELECTROLYTE TO FORM COPPER NITRATE OR THE GREENISH LOOKING SUBSTANCE; WHILE HYDROGEN, WHICH IS EXTRACTED FROM THE WATER CONTAINED IN THE POTATO IS LIBERATED IN THE FORM OF BUBBLES AT THE OTHER ELECTRODE.

IN OTHER WORDS, ELECTRICAL ENERGY IS NOW BEING CONVERTED INTO CHEMICAL ENERGY AND THE ORIGINAL CHEMICAL CONDITIONS ARE BEING ALTERED.

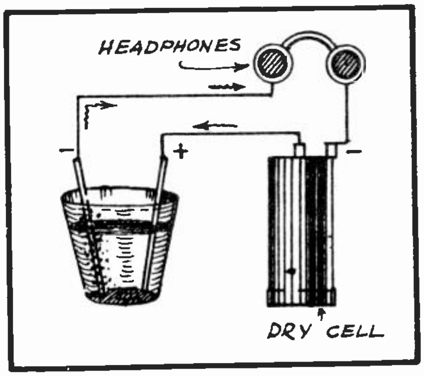

Fig. 5
The Water Rheostat.

NOW BY DISCONNECTING THE DRY CELL, WE HAVE LEFT A CHARGED SECONDARY CELL AT THE POTATO. THAT IS, THE CHARGING CURRENT AS FURNISHED BY THE DRY CELL HAS CHANGED THE CHEMICAL CONDITION OF OUR HOME-CONSTRUCTED CELL TO SUCH AN EXTENT THAT THE ACTIVE ELEMENT AT ONE OF THE ELECTRODES WILL BE PURE COPPER WHILE THE ACTIVE ELEMENT AT THE OTHER ELECTRODE HAS BECOME COPPER NITRATE.

TO PROVE THAT THE CELL HAS ACTUALLY BECOME CHARGED DURING THIS PROGRESS, IT IS ONLY NECESSARY TO AGAIN CONNECT THE HEADPHONES ACROSS THE TWO COPPER WIRES AS SHOWN IN FIG. 4. THIS TIME, A VERY PRONOUNCED CLICK WILL BE

EXPERIENCED IN THE HEADPHONES AS THE CELL DISCHARGES THROUGH THE HEADPHONE WINDINGS IN THE DIRECTION DESIGNATED IN FIG.4.

THUS WE HAVE SEEN THAT AN INITIAL FLOW OF CURRENT IS CAPABLE OF CHARGING THE CELL BY CONVERTING ELECTRICAL ENERGY TO CHEMICAL ENERGY AND THAT IN TURN, THE CELL WAS CAPABLE OF CONVERTING CHEMICAL ENERGY TO ELECTRICAL ENERGY, THEREBY FULFILLING THE REQUIREMENTS OF A SECONDARY CELL.

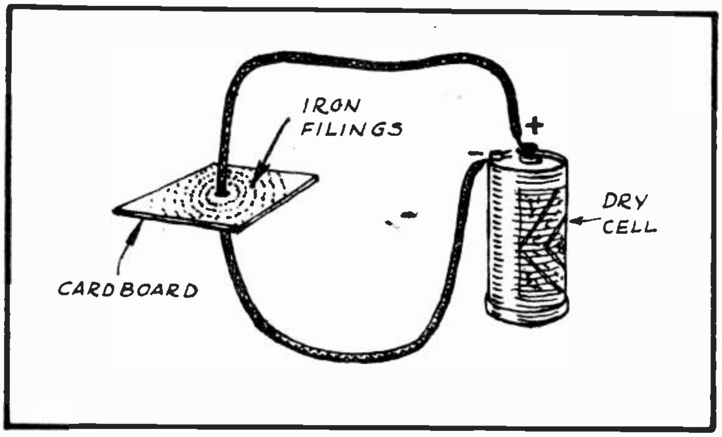

Fig. 6
Lines Of Force Encircle The Conductor.

NATURALLY, THIS WAS ACCOMPLISHED IN ONLY A SMALL WAY IN THIS SIMPLE EXPERIMENT BUT THESE SAME PRINCIPLES ARE EMPLOYED MORE PRACTICALLY IN THE POPULAR LEAD-ACID TYPE STORAGE BATTERY, WHERE THE POSITIVE PLATES ARE IN THE FORM OF LEAD PEROXIDE, THE NEGATIVE PLATES BEING SPONGY LEAD AND A DILUTE SULPHURIC ACID SOLUTION SERVING AS THE ELECTROLYTE.

EXPERIMENT #3: - DETERMINING D.C. POLARITY

THE HUMBLE POTATO ALSO OFFERS A MEANS WHEREBY ONE CAN DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE AND THIS CAN BE ACCOMPLISHED IN THE FOLLOWING MANNER: INSERT TWO PIECES OF BARE COPPER WIRE INTO THE POTATO AND CONNECT THE SOURCE OF VOLTAGE ACROSS THEM THE SAME MANNER AS WAS ALREADY SHOWN YOU IN FIG. 3 OF THIS LESSON.

THE GREEN COPPER NITRATE WILL THEN FORM AROUND THE COPPER ELECTRODE WHICH IS CONNECTED TO THE POSITIVE TERMINAL OF THE VOLTAGE SOURCE AND IN THIS WAY INDICATES THE POLARITY.

EXPERIMENT #4: - THE WATER RHEOSTAT

FILL A GLASS CONTAINER ABOUT 3/4 FULL WITH ORDINARY WATER AND ADD A LITTLE TABLE SALT TO IT. NOW IMMERSE TWO BARE PIECES OF COPPER WIRE IN THE SALT WATER SO THAT THEY WILL SERVE AS ELECTRODES.

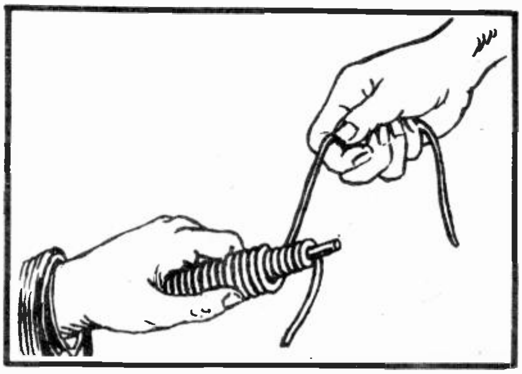

Fig. 7
The Electromagnet.

CONNECT A DRY CELL WITH THE HEADPHONES IN SERIES ACROSS THE ELECTRODES AS IN FIG.5. VARY THE DISTANCE BETWEEN THE ELECTRODES AND MAKE AND BREAK THE THE HEADPHONE CIRCUIT. AS YOU DO SO YOU WILL FIND THAT THE CLICK IN THE PHONES WILL INCREASE AS THE DISTANCE BETWEEN THE ELECTRODES IS DECREASED, THUS SHOWING THAT THE CURRENT FLOW THROUGH THE HEADPHONES INCREASES AS THE ELECTRODES

ARE BROUGHT CLOSER TOGETHER. IN OTHER WORDS, THE POSITION OF THE ELECTRODES WILL CONTROL THE RESISTANCE OF THE CIRCUIT AND THE ARRANGEMENT THEREFORE SERVES AS AN EFFECTIVE RHEOSTAT. WE CALL SUCH A DEVISE A "WATER RHEOSTAT."

REPEAT THE ABOVE EXPERIMENTS BY INCREASING THE SALT CONTENT OF THE SOLUTION. YOU WILL FIND THAT AS THE AMOUNT OF SALT IS INCREASED FOR A GIVEN QUANTITY OF WATER, THE BETTER WILL BE THE ELECTRICAL CONDUCTING QUALITIES OF THE SOLUTION.

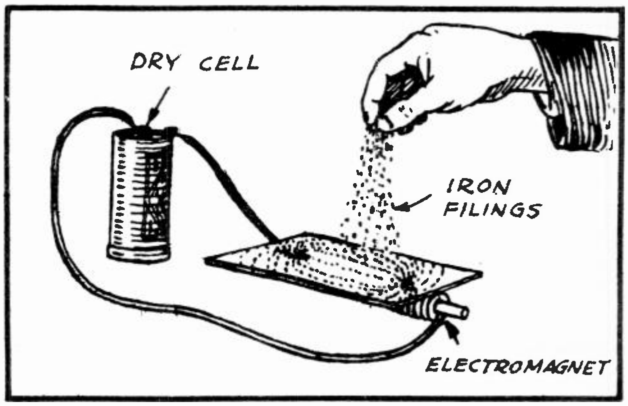

Fig. 8
Demonstration Of The Magnetic Field.

BY MEANS OF THIS SAME "SET UP", IT IS ALSO POSSIBLE FOR YOU TO DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE DUE TO THE FACT THAT BUBBLES WILL COLLECT AROUND THE ELECTRODE WHICH IS CONNECTED TO THE NEGATIVE POLE OF THE VOLTAGE SOURCE. THESE BUBBLES ARE DUE TO THE DECOMPOSITION OF THE WATER BROUGHT ABOUT BY THE ELECTRICAL CURRENT WHICH IS FLOWING THROUGH IT.

EXPERIMENT #5: - MAGNETIC FIELD SURROUNDING A CONDUCTOR

TAKE A PIECE OF LIGHT CARDBOARD AND PASS A LENGTH OF WIRE THROUGH ITS CENTER, CONNECTING THE ENDS OF THIS WIRE ACROSS THE TERMINALS OF A DRY CELL AS SHOWN IN FIG.6.

SPRINKLE SOME IRON FILINGS UPON THE SURFACE OF THE CARDBOARD AND TAP THE CARDBOARD LIGHTLY WITH YOUR FINGERS. YOU WILL FIND THE IRON FILINGS TO ARRANGE THEMSELVES INTO A DEFINITE PATTERN ENCIRCLING THE CONDUCTOR, THEREBY ACTUALLY SHOWING YOU HOW THE LINES OF FORCE SURROUND A CONDUCTOR THROUGH WHICH AN ELECTRICAL CURRENT IS FLOWING.

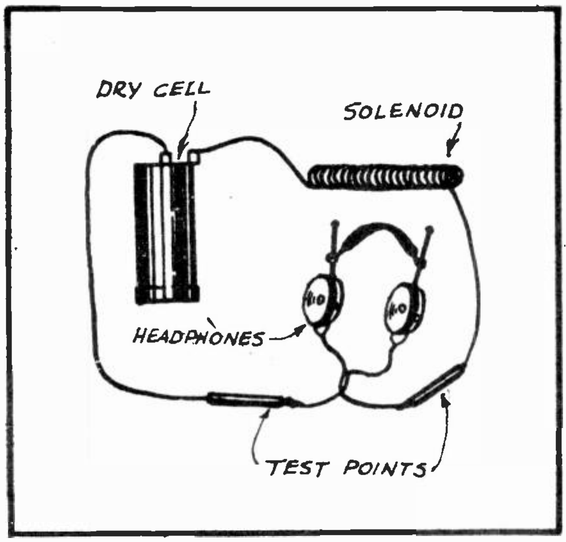

Fig. 9
A Continuity Test With Headphones.

(YOU CAN OBTAIN THE NECESSARY IRON FILINGS FOR THIS EXPERIMENT BY SIMPLY FILING A LARGE NAIL AND GATHERING TOGETHER THE FILINGS WHICH WILL THUS BE PRODUCED).

EXPERIMENT #6: - THE ELECTROMAGNET

WRAP A LAYER OF HEAVY PAPER AROUND A LARGE NAIL AND THEN WIND SEVERAL LAYERS OF INSULATED WIRE OVER THE PAPER AND ACROSS THE GREATER PORTION OF THE NAIL'S LENGTH AS ILLUSTRATED IN FIG.7. CONNECT THE FINISHED WINDING ACROSS A DRY CELL AND TEST THE MAGNETIC PROPERTIES OF THIS ELECTROMAGNET BY OBSERVING ITS ATTRACTION UPON SMALL PIECES OF IRON, NAILS, TACKS ETC. ALSO NOTICE HOW THE POWER OF ATTRACTION IS LOST THE

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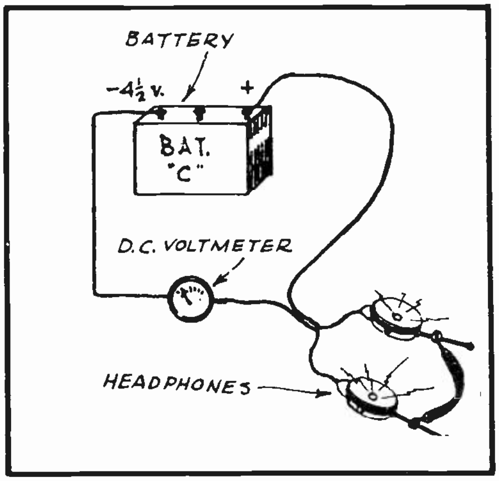

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TO DO THIS, CONNECT THE HEADPHONES IN SERIES WITH A CELL OR BATTERY. THEN TOUCH THE ENDS OF THIS TEST CIRCUIT ACROSS THE UNIT OR CIRCUIT TO BE TESTED. FOR INSTANCE, IN FIG.9 THE SOLENOID WINDING IS BEING TESTED FOR CONTINUITY.

IF THE WINDING OF THE SOLENOID IS COMPLETE THEN A CLICK WILL BE HEARD IN THE PHONES UPON TOUCHING THE TEST POINTS TO THE CIRCUIT UNDER TEST. HOWEVER, IF THE WINDING OF THE SOLENOID SHOULD BE BROKEN OR OPEN CIRCUITED, THEN NO CLICK WILL BE EXPERIENCED DURING THIS TEST.

PRACTICALLY ANY PIECE OF ELECTRICAL EQUIPMENT CAN BE TESTED FOR CONTINUITY IN THIS WAY, PROVIDED THAT ITS NORMAL RESISTANCE IS NOT EXCESSIVE SO THAT THE CELL OR BATTERY COULD NOT POSSIBLY FORCE SUFFICIENT CURRENT THROUGH THE SYSTEM TO ACTUATE THE HEADPHONE DIAPHRAGMS EVEN THOUGH THE CIRCUIT OR COMPONENT BEING TESTED WERE FREE FROM DEFECTS.

EXPERIMENT #8: – A VOLTMETER TYPE CONTINUITY TESTER

A VERY EFFECTIVE VISUAL TYPE OF CONTINUITY TESTER CAN BE MADE BY CONNECTING A BATTERY IN SERIES WITH A D.C. TYPE VOLTMETER HAVING A RELATIVELY LOW VOLTAGE SCALE. THE BATTERY MAY CONSIST OF ABOUT TWO OR THREE SERIES CONNECTED DRY CELLS, OR ELSE A $4\frac{1}{2}$ VOLT RADIO "C" BATTERY CAN BE USED SATISFACTORILY.

WHENEVER, THE FREE ENDS OF THIS TEST CIRCUIT ARE TOUCHED TOGETHER, THE VOLTMETER WILL INDICATE THE FULL VOLTAGE OF THE BATTERY BUT WHEN THESE SAME ENDS ARE HELD APART OR SEPARATED, THE VOLTMETER WILL OFFER A ZERO READING.

FIG. 10 SHOWS YOU HOW THE WINDINGS OF A PAIR OF HEADPHONES MAY BE TESTED FOR CONTINUITY. NOTICE HOW THE TEST POINTS OF THE TESTING CIRCUIT ARE CONNECTED TO THE TIPS OF THE HEADPHONES. IF THE WINDINGS ARE IN GOOD CONDITION, THE METER WILL INDICATE VERY NEARLY THE VOLTAGE OF THE BATTERY BEING USED, WHEREAS A ZERO READING WOULD INDICATE THE HEADPHONE WINDINGS AS BEING OPEN CIRCUITED.

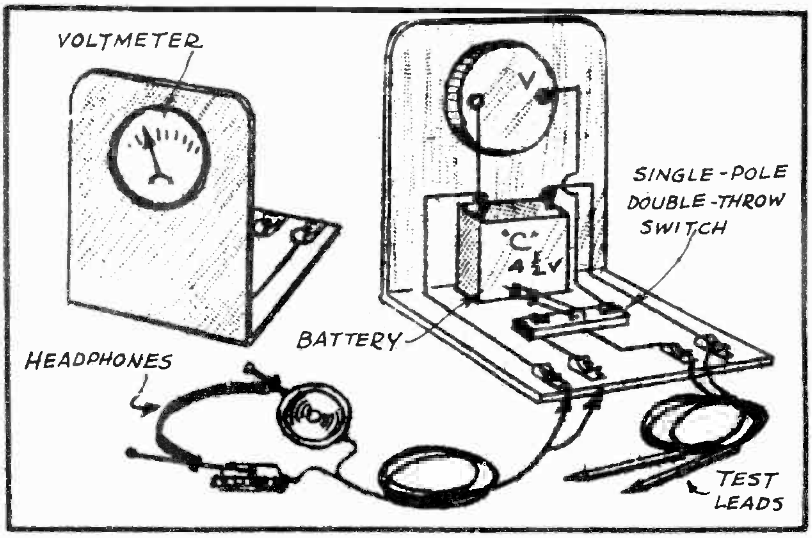

Fig. 11
The Continuity Tester.

THIS SAME TEST CAN BE APPLIED TO VARIOUS TYPES OF ELECTRICAL EQUIPMENT, RESPONDING IN THE SAME MANNER AS JUST DESCRIBED. HOWEVER, WHEN TESTING WITH THIS APPARATUS THRU CIRCUITS HAVING CONSIDERABLE RESISTANCE, THE METER READING WILL VARY WITH THE AMOUNT OF RESISTANCE THROUGH WHICH THE TEST IS BEING MADE. IN OTHER WORDS, THE GREATER THE RESISTANCE OF THE CIRCUIT, THE LOWER WILL BE THE METER READING. THIS FACT MUST BE TAKEN INTO CONSIDERATION WHEN MAKING A TEST OF THIS KIND. YOU WILL HAVE AMPLE OPPORTUNITY OF BECOMING FAMILIAR WITH THIS TEST AS YOU APPLY IT TO THE VARIOUS RECEIVER CIRCUITS AND PARTS WHILE EXPERIMENTING WITH THE EQUIPMENT WHICH IS GOING TO BE SENT YOU IN THE FUTURE.

THE VOLTMETER ALSO OFFERS YOU A MEANS FOR DETERMINING THE POLARITY OF A D.C. VOLTAGE SOURCE, PROVIDED THAT THE VOLTAGE DOES NOT EXCEED THE MAXIMUM VOLTAGE VALUE FOR WHICH THE PARTICULAR INSTRUMENT IS CALIBRATED. IN THIS CASE, IT IS ONLY NECESSARY TO CONNECT THE VOLTMETER ACROSS THE TERMINALS OF THE VOLTAGE SOURCE BEING TESTED. THEN IF THE METER NEEDLE SWINGS ACROSS ITS SCALE IN THE PROPER DIRECTION, THAT SIDE OF THE CIRCUIT WHICH IS CONNECTED TO THE (+) METER TERMINAL WILL BE THE POSITIVE SIDE OF THE CIRCUIT.

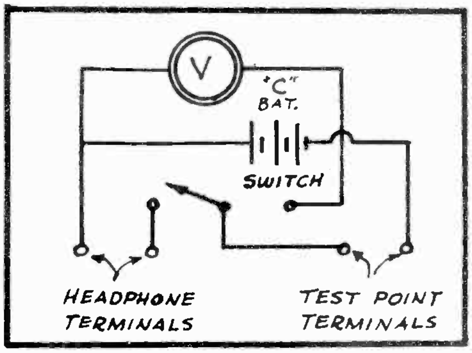

Fig. 12
Circuit Of The Tester

SHOULD THE METER NEEDLE TEND TO MOVE ACROSS ITS SCALE IN THE WRONG DIRECTION WHEN MAKING THIS TEST, THEN THE METER CONNECTIONS WILL HAVE TO BE REVERSED. THE SAME RULE CONCERNING POLARITY, WHICH WAS JUST GIVEN YOU, CAN THEN BE APPLIED.

CONSTRUCTION OF A CONTINUITY TESTER

SHOULD YOU WISH TO CONSTRUCT A COMPACT CONTINUITY TESTER WHICH WILL BE QUITE HANDY IN YOUR WORK FROM NOW ON, YOU CAN USE THE HEADPHONES, VOLTMETER AND "C" BATTERY

WHICH YOU NOW HAVE ON HAND AND BUILD A UNIT SOMEWHAT AS THAT ILLUSTRATED IN FIG. 11.

THE VOLTMETER CAN BE MOUNTED FLUSH WITH THE PANEL BY CUTTING A HOLE IN THE PANEL EQUAL TO THE DIAMETER OF THE VOLTMETER BODY. THE MOUNTING RING SHOULD THEN BE REMOVED FROM THE VOLTMETER AND THE METER INSERTED IN ITS MOUNTING HOLE WITH ITS FACE TOWARD THE FRONT. THE MOUNTING RING CAN THEN BE REPLACED FROM THE BACK OF THE METER AND LOCKED IN POSITION SO AS TO HOLD THE METER FIRMLY IN PLACE.

ANOTHER SMALLER HOLE SHOULD BE DRILLED IN THE PANEL BELOW THE VOLTMETER TO ACCOMMODATE THE SWITCH. THE "C" BATTERY CAN BE HELD IN PLACE WITH A METAL STRAP AND A PAIR OF WOOD-SCREWS. THE CIRCUIT DIAGRAM FOR THIS CONTINUITY TESTER IS SHOWN IN FIG. 12 SO THAT YOU MAY BECOME MORE FAMILIAR WITH IT.

WHEN THE DOUBLE-THROW SWITCH IS CLOSED TO POSITION "V", THE VOLTMETER WILL OFFER A READING WHENEVER THE TEST POINTS ARE TOUCHED TOGETHER, WHEREAS CLOSING THIS SWITCH TO POSITION "H" WILL CAUSE A CLICK TO BE HEARD IN THE HEADPHONES WHENEVER THE TEST POINTS ARE TOUCHED TOGETHER. IN THIS MANNER, EITHER OF THESE TWO TESTING METHODS CAN BE EMPLOYED SIMPLY BY CLOSING THE SWITCH IN THE PROPER DIRECTION.

THIS SAME TESTER CAN ALSO BE HOUSED IN A BOX IF SO DESIRED AND MORE ELABORATE TERMINALS MOUNTED ON ITS FRONT PANEL FOR THE HEADPHONE AND TEST POINT CONNECTIONS. THIS IS A MATTER OF PERSONAL CHOICE. YOU ARE NOT REQUIRED TO BUILD THIS TESTER IN THAT NOT ALL OF THE NECESSARY PARTS ARE INCLUDED IN YOUR EXPERIMENTAL EQUIPMENT. HOWEVER, IF YOU SHOULD WISH TO DO SO, YOU WILL NO DOUBT FIND THESE SUGGESTIONS HELPFUL.

Examination Questions

EXPERIMENT LESSON NO. 1

1. – WHY IS THAT AN E.M.F. IS PRODUCED WHEN ONE IRON AND ONE COPPER ELECTRODE ARE STUCK INTO THE POTATO BUT NOT WHEN TWO COPPER OR TWO IRON ELECTRODES ARE USED TOGETHER. (AS ILLUSTRATED BY EXPERIMENT #1)
2. – WHAT OCCURS IN YOUR EXPERIMENT #2 WHICH ENABLES AN E.M.F. TO BE PRODUCED EVEN THOUGH TWO COPPER ELECTRODES ARE USED?
3. – DESCRIBE ONE SIMPLE METHOD WHEREBY YOU CAN DETERMINE THE POLARITY OF A D.C. VOLTAGE SOURCE WITHOUT THE USE OF A METER.
4. – DESCRIBE YOUR OBSERVATIONS WHILE CONDUCTING EXPERIMENT #4.
5. – HOW WERE YOU ABLE TO DEMONSTRATE THE FACT THAT LINES OF FORCE SURROUND A CONDUCTOR THROUGH WHICH AN ELECTRIC CURRENT IS FLOWING?
6. – DURING YOUR EXPERIMENTS WITH THE ELECTROMAGNET, HOW DID THE PRESENCE OF AN IRON CORE AFFECT THE MAGNETIC STRENGTH AS COMPARED TO THE PERFORMANCE OF THE UNIT WHEN NO IRON CORE WAS USED?
7. – DESCRIBE HOW YOU CAN USE A SET OF HEADPHONES IN ORDER TO TEST THE CONTINUITY OF A CIRCUIT.
8. – DESCRIBE HOW YOU CAN TEST A CIRCUIT FOR CONTINUITY WITH A D.C. VOLTMETER HAVING A LOW VOLTAGE RANGE.
9. – DESCRIBE AND ILLUSTRATE BY MEANS OF A DIAGRAM A SIMPLE CONTINUITY TESTER.
10. – HOW DOES THE NUMBER OF TURNS USED ON THE WINDING OF AN ELECTROMAGNET AFFECT ITS MAGNETIC STRENGTH?

RADIO - TELEVISION

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BUSINESS LESSON #1

How to Earn Money in Spare Time Radio Work

Up to this point of your training, you have learned considerable about radio and should by this time have built for yourself a most substantial foundation upon which to build your future work.

Probably since starting your studies, it appeared as taking you quite awhile until you finally got into the actual practical trouble shooting work and it is possible that you expected to get into this work sooner. Bear in mind, however, that many years of experience in training men has proved to us that before any man can INTELLIGENTLY perform any kind of service work on even the simplest types of receivers, he must first have a definite amount of technical knowledge to back him up. It is for this reason that we have carefully planned our course of training the way you have found it.

As you know, lessons #19 to 23 inclusive provide you with an excellent series of informative lessons dealing directly with practical service problems. We urge you now to apply this knowledge to commercial use immediately for two important reasons: First, it offers you an excellent opportunity for turning your leisure hours into profit. You can still continue with your studies and any other work which you may now be doing to earn a living and in addition commence earning money on the side thru doing radio work among your neighbors, relatives and acquaintances. The second important reason why you should commence doing service work NOW is that thru doing so, you will obtain actual PRACTICAL EXPERIENCE working with commercial equipment and this will in itself be of tremendous value to you. In other words, if you go about this spare-time work in the

Earn While You Learn.

right way, you will already have a satisfactory amount of experience out in the field by the time you graduate and at the same time be ahead of the game from a financial standpoint.

Furthermore, by breaking into the service game now in a rather small way, you will have the opportunity of contacting a great many people---- all of whom will remain as your steady customers when you finally are prepared to enter the radio business on a larger scale. By starting NOW in your spare time, you should in a few months have all the business you can handle.

You certainly couldn't find a better investment anywhere than honest to goodness radio training which already pays dividends long before you have completed it and which pays for itself so quickly.

Getting Started

Sample Business Card.

In order to build up a clientele, the first thing which you will have to do is to let people KNOW that you are in the radio business and qualified to take care of their radio needs. One way of spreading the news is to have some attractive business cards printed, based upon the sample which we are showing you here. These cards are inexpensive and offer a most effective means towards bringing about an introduction between you and your prospective customer.

You can distribute these cards to the homes in your neighborhood, as well as to furnish friends with a supply so that they can in turn distribute them among acquaintances and people whom they contact during their routine of business and social activities.

Another method which will frequently bring results is to canvass the community in person and thus contact the set owner directly.

A simple way to strike up an acquaintance with prospective customers is to take note of all antenna installations in your vicinity--the majority of them will be crude in construction, inefficient, and thereby offering you an ideal opportunity for engaging the set owner in worth-while conversation.

Approach the prospective customer in a business-like manner, being certain that your appearance is inviting. Be pleasant and mention the fact that you are actively engaged in the service business in this vicinity and in passing have noticed the appearance of his antenna. Then continue and suggest that you can improve his reception tremendously by installing an efficient antenna system designed especially to best meet his particular requirements.

If he is bothered by interference noises, inform him that you are in a position to clear up the disturbance for him. Tell him about the many features of static-rejecting antenna systems which were brought to your

ATTENTION IN A PREVIOUS LESSON AND EXPLAIN HOW HIS RECEPTION WILL BE IMPROVED THEREBY. LET HIM KNOW THAT THIS IS SOMETHING NEW BUT BACKED UP BY RECOGNIZED MANUFACTURERS AND IS BASED UPON SCIENTIFIC PRINCIPLES.

SHOULD THE SET OWNER RESIDE IN A DISTRICT FREQUENTED BY ELECTRIC STORMS AND NO LIGHTNING ARRESTER IS INSTALLED IN HIS ANTENNA SYSTEM, THEN POINT OUT TO HIM THE PROTECTION WHICH SUCH A UNIT WILL AFFORD.

IN PLAIN WORDS, THE THING FOR YOU TO DO IS TO CONVINCE THE SET OWNER THAT HE NEEDS A FIRST CLASS ANTENNA SYSTEM AND THAT YOU ARE THE MAN TO DO THE JOB.

HAVING "LANDED THE JOB", YOUR FIRST STEP WILL BE TO PROVIDE YOURSELF WITH THE NECESSARY MATERIALS, SUCH AS THE ANTENNA WIRE, INSULATORS, LIGHTNING ARRESTER, ETC. AND A COMPLETE NOISE REDUCING KIT IF THIS TYPE OF JOB IS SOLD. ALL OF THIS EQUIPMENT CAN OF COURSE BE PURCHASED READY FOR USE AND IT IS ADVISABLE THAT YOU BUY IT FROM A LARGE RADIO SUPPLY HOUSE WHOSE CHIEF BUSINESS LIES IN SUPPLYING EQUIPMENT TO THE RADIO TRADE.

SUCH CONCERNS ARE ESTABLISHED IN ALL OF THE LARGER CITIES AND BY MAKING IT KNOWN TO THEM THAT YOU ARE A RADIO SERVICEMAN, THEY WILL ALLOW YOU AN APPRECIABLE DISCOUNT. AS A RULE, YOU WILL BE ABLE TO PURCHASE YOUR EQUIPMENT FROM THEM AT ABOUT 40% LESS THAN THE LIST PRICE.

THUS YOU CAN CHARGE THE CUSTOMER THE LIST PRICE FOR THE EQUIPMENT AND THEREBY REALIZE A RIGHTEOUSLY EARNED 40% FROM THE SALE OF PARTS ALONE. THEN IN ADDITION, FIGURE YOUR LABOR CHARGES AT AN AVERAGE RATE OF ABOUT $1.00 PER HOUR. SO ALTOGETHER THEN, YOU CAN SEE THAT YOU WILL MAKE A FAIR PROFIT ON THE DEAL AND AT THE SAME TIME BE ASSURED OF A SATISFIED CUSTOMER.

SERVICING RECEIVERS

IN THE EVENT THAT A NEW ANTENNA ISN'T ABSOLUTELY ESSENTIAL OR YOU FIND IT IMPOSSIBLE TO INTEREST THE SET OWNER IN ONE, THEN INQUIRE ABOUT THE GENERAL PERFORMANCE OF HIS SET. PERHAPS HE WILL COMPLAIN ABOUT WEAK RECEPTION, FADING, NOISY RECEPTIONS, LACK OF SELECTIVITY ETC. IN FACT, IF ANY THING AT ALL IS PREVENTING HIM FROM ENJOYING GOOD PROGRAMS, HE WON'T HESITATE TO MAKE THIS FACT KNOWN, ESPECIALLY SO WHEN HE HAS THE CHANCE TO TALK ABOUT IT TO A MAN WHOM HE IS CONFIDENT OF BEING CAPABLE TO OFFER SOUND ADVICE AND ASSISTANCE.

AT ANY RATE, YOU CAN OFFER TO CHECK AND TEST HIS RECEIVER FREE OF CHARGE AND HONESTLY ADVISE HIM AS TO THE RECEIVER'S TRUE CONDITION. THEN IF YOUR INSPECTION THEREOF SHOULD DISCLOSE ANY DEFECTS OR ANY FORM OF OBJECTIONABLE PERFORMANCE, POINT OUT THIS FACT TO THE OWNER AND EXPLAIN TO HIM HOW YOU CAN CORRECT THE CONDITION.

QUITE OFTEN, YOU WILL COME ACROSS SOME MINOR JOBS, SUCH AS RENEWING A CONNECTION HERE OR THERE, INSTALLING NEW TUBES, ALIGNING A TUNING CONDENSER GANG, REPLACING A NOISY VOLUME CONTROL OR DEFECTIVE SWITCH ETC. ALL OF THESE ARE SIMPLE JOBS BUT DO THEIR PART TO INCREASE YOUR INCOME, AS WELL AS OFFERING YOU AN OPPORTUNITY TO LOOK INTO ALL OF THE DIFFERENT TYPES OF COMMERCIAL RECEIVERS SO AS TO FAMILIARIZE YOURSELF WITH THE MANY DIFFERENT CONSTRUCTIONAL FEATURES INCORPORATED IN THEM.

WHENEVER YOU COME ACROSS A JOB WHICH REQUIRES THE REMOVAL OF THE CHASSIS FROM THE CABINET, SUCH AS WHEN REPLACING A TRANSFORMER, CONDENSER, RESISTOR ETC., THEN MAKE IT A POINT TO TAKE THE CHASSIS TO YOUR HOME WORK SHOP WHERE YOU HAVE EVERYTHING AVAILABLE FOR DOING A FIRST CLASS JOB. IT IS NEVER ADVISABLE TO CONDUCT ANY FORM OF RECONSTRUCTION JOB IN THE SET OWNERS HOME FOR SEVERAL REASONS. (1) ALL TOOLS ETC. ARE NOT GENERALLY AVAILABLE. (2) THERE IS A POSSIBILITY OF SCRATCHING FURNITURE AND CLUTTERING UP THE ROOM WITH DIRT. (3) A PARTIALLY DISASSEMBLED RECEIVER DOESN'T MAKE A FAVORABLE IMPRESSION UPON THE OWNER.

NATURALLY, WHEN YOU ARE CANVASSING A NEIGHBORHOOD IN PERSON, YOU SHOULD HAVE YOUR SERVICE EQUIPMENT WITH YOU OR AT LEAST WITHIN EASY REACH SO THAT WHEN YOU DO GET A JOB, YOU CAN TAKE CARE OF IT IMMEDIATELY INSTEAD OF STALLING OFF THE CUSTOMER UNTIL YOU GET YOUR EQUIPMENT. REMEMBER THAT IF YOU KEEP A CUSTOMER WAITING TOO LONG, HE IS LIKELY TO CHANGE HIS MIND IN THE MEAN TIME ABOUT HAVING THE WORK DONE.

IN THE EVENT THAT YOU CONTACT THE SET OWNER THROUGH ONE OF YOUR BUSINESS CARDS AND HE COMMUNICATES WITH YOU BY PHONE, QUESTION HIM CONCERNING THE MAKE OF HIS RECEIVER AND HOW IT ACTS. THIS WILL ENABLE YOU TO JUDGE WHAT MIGHT BE WRONG BEFORE YOU EVEN SEE THE SET AND YOU CAN THEREBY ESTIMATE WHAT EQUIPMENT IT WILL BE BEST FOR YOU TO TAKE TO THE JOB.

INSTALLING RECEIVERS

MANY DEPARTMENT STORES ETC. SELL RECEIVERS BUT DO NOT INCLUDE A RADIO TECHNICIAN AMONG THEIR EMPLOYEES. THEY SIMPLY SELL THE SET TO THE CUSTOMER AND LET HIM INSTALL IT HIMSELF AS BEST HE CAN OR ELSE EXPECT THE DRIVER OF THE GENERAL DELIVERY TRUCK TO HOOK IT UP FOR HIM. IN SUCH CASES, THE ANTENNA GENERALLY CONSISTS OF A PIECE OF HOOK UP WIRE AND SOMETIMES THE SET ISN'T EVEN BALANCED UP CORRECTLY. THE PROPER USE OF A LONG AND SHORT ANTENNA TERMINAL IS NOT HEEDED ETC.

ANY NEW RECEIVER, EVEN THOUGH IT LEAVES THE FACTORY IN PERFECT CONDITION, IS LIKELY TO REACH THE FINAL OWNER SLIGHTLY OUT OF ADJUSTMENT DUE TO SHOCKS RECEIVED DURING SHIPMENT AND IT ISN'T REALLY FAIR TO THE FINAL OWNER IF THE SET ISN'T FIRST SERVICED PROPERLY BEFORE TURNING IT OVER TO HIM.

HERE IS ANOTHER OPPORTUNITY FOR YOU.

THE THING FOR YOU TO DO IS TO CONTACT THESE CONCERNS WHICH SELL RADIOS WITHOUT OFFERING TECHNICAL SERVICE. MANY MEN HAVE MADE AN AGREEMENT WITH THESE CONCERNS WHEREBY THEY TAKE OVER THE RESPONSIBILITY OF TESTING THE SET BEFORE DELIVERY, MAKE ANY NECESSARY SERVICE ADJUSTMENTS AND INSTALL THE SET IN THE NEW OWNER'S HOME IN EXPERT FASHION. FOR THIS, THEY RECEIVE A DEFINITE FEE FROM THE STORE FOR EACH SET INSTALLED OR ELSE THE CUSTOMER IS QUOTED A CERTAIN PRICE FOR THE RECEIVER AND CAN AT HIS OWN CHOICE HAVE THE SET PROPERLY INSTALLED FOR AN ADDITIONAL REASONABLE FEE.

YOU CAN DO THE SAME THING AND MANY SALES ORGANIZATIONS WILL BE ONLY TOO GLAD TO MAKE SOME SUCH A DEAL WITH YOU.

IN FACT, SUCH AN ASSOCIATION WITH ANY SALES ORGANIZATION WILL PLACE YOU IN AN ADVANTAGEOUS POSITION TO EVEN SERVICE RECEIVERS SOLD BY THEM AND WHICH DEVELOPE DEFECTS AFTER BEING IN OPERATION FOR SOME TIME. IF THIS

HAPPENS, IT SEEMS TO BE THE NATURAL THING FOR THE SET OWNER TO "AIR HIS TROUBLES" TO THE FIRM FROM WHICH HE PURCHASED THE RECEIVER, AND THE FIRM CAN THEN IN TURN PLACE THE SERVICE JOB IN YOUR HANDS. SUCH A PRACTICE IS BENEFICIAL TO BOTH YOU AND THE CONCERN WHO DOESN'T HAVE SUFFICIENT CALLS FOR SERVICE WORK TO WARRANT EMPLOYING A MAN SOLELY FOR THIS PURPOSE.

WORK OF THIS NATURE IS GENERALLY HANDLED ON A PERCENTAGE BASIS IN WHICH THE SERVICE MAN IS GIVEN A DEFINITE PERCENTAGE OF THE MONEY RECEIVED FOR THE JOB, THE BALANCE BEING RETAINED BY THE DEALER. IN THE EVENT THAT THE SERVICEMAN SELLS SOME ADDITIONAL EQUIPMENT DURING A SERVICE CALL, HE ALSO RECEIVES A PERCENTAGE FROM THE DEALER FOR HIS EFFORT.

FOR MOST SERVICE WORK, YOU WILL GENERALLY FIND IT THE PRACTICE AMONG SERVICEMEN TO PURCHASE THE REPLACEMENT PARTS AND ANY OTHER EQUIPMENT AT A 40% DISCOUNT OFF THE LIST PRICE AND TO CHARGE THE CUSTOMER THE LIST PRICE OF THE UNIT. FOR EACH SERVICE CALL REQUIRING ONE-HALF HOUR OF YOUR TIME, A FEE OF $1.00 SHOULD BE SATISFACTORY WHILE LABOR CHARGES CAN BE FIGURED AT THE RATE OF $1.00 PER HOUR.

NATURALLY, CIRCUMSTANCES ARISE WHERE YOU MAY HAVE TO ADJUST THE PRICE SO AS TO MEET CERTAIN SPECIAL REQUIREMENTS AND IN THIS RESPECT YOU CAN USE YOUR OWN JUDGEMENT.

UPON COMPLETING A JOB, ALWAYS BE SURE TO LEAVE YOUR BUSINESS CARD WITH THE SET OWNER UPON TAKING LEAVE. SOME SERVICEMEN TACK THEIR CARD INSIDE THE RECEIVER CABINET SO THAT THERE WILL BE NO POSSIBILITY OF THE CUSTOMER'S MISPLACING IT.

IF YOU CONTACT A PROSPECTIVE CUSTOMER WHO DOESN'T REQUIRE ANY WORK AT THE TIME, THEN LEAVE YOUR CARD WITH HIM AND TELL HIM THAT YOU WILL APPRECIATE HIS CALLING YOU BY TELEPHONE WHEN IN NEED OF SERVICE AT ANY FUTURE TIME.

ADOPT THE PRACTICE OF DOING YOUR BEST REGARDLESS OF HOW SMALL THE JOB. A SATISFIED CUSTOMER WILL CALL YOU AGAIN WHEN HE NEEDS YOU AND WILL BE MORE THAN WILLING TO RECOMMEND YOU TO HIS ACQUAINTANCES.

GIVE THE CUSTOMER A SQUARE DEAL, FOR HONESTY IN SERVICE AND WORKMANSHIP ALWAYS PAYS BIGGER DIVIDENDS IN THE LONG RUN.

SHOULD YOU BY ANY CHANCE RUN INTO A JOB WHICH YOU CANNOT SATISFACTORILY HANDLE, YOU MAY FEEL FREE TO WRITE TO US FOR ADDITIONAL ADVICE. IF YOU DO, PLEASE GIVE US AS MUCH INFORMATION AS POSSIBLE CONCERNING THE JOB SO THAT WE WILL BE BETTER ABLE TO GIVE YOU A MOST HELPFUL ANSWER.

NATURALLY, DO NOT DELIBERATELY TAKE UPON YOURSELF A JOB OF AN ADVANCED NATURE WHICH INVOLVES EQUIPMENT AND WORK ABOUT WHICH YOU HAVE NOT YET HAD A CHANCE TO STUDY. IT IS NO MORE THAN FAIR THAT YOU TAKE THIS INTO CONSIDERATION BECAUSE YOU ARE STILL IN AN EARLY STAGE OF YOUR TRAINING AND MUST THEREFORE KEEP YOUR ACTIVITIES IN THE FIELD WITHIN THESE LIMITS.

EXPERIENCE

PERHAPS YOU INTEND TO ULTIMATELY SPECIALIZE IN SOME BRANCH OF THIS WONDERFUL INDUSTRY OTHER THAN RADIO SERVICING SUCH AS BROADCASTING, COMM-

ERCIAL OPERATING, TALKING PICTURES, OR TELEVISION. EVEN IF THIS BE THE CASE, YOU STILL SHOULD MAKE IT A POINT TO ENGAGE IN SERVICING RECEIVERS FOR THE TIME BEING AT LEAST BECAUSE OF THE VALUABLE EXPERIENCE IT WILL GIVE YOU.

HERE IS A CHANCE FOR IMMEDIATE FINANCIAL RETURNS, WHEREAS YOU WILL REQUIRE CONSIDERABLY MORE TRAINING BEFORE BECOMING QUALIFIED TO ACCEPT A POSITION IN THE OTHER BRANCHES OF THE INDUSTRY. FURTHERMORE, THE PEOPLE WHOM YOU CONTACT NOW THROUGH SERVICE WORK, MAY BE PROSPECTS FOR A TELEVISION RECEIVER LATER ON. THEN TOO, SOME CONCERNS WITH WHICH YOU ESTABLISH DEALINGS NOW, MAY BE IN A POSITION TO OFFER YOU FUTURE OPPORTUNITIES IN SOME OTHER PROFITABLE FIELD OF RADIO. YOU SIMPLY MUST MEET THESE PEOPLE SOMETIME OR OTHER -- SO WHY NOT NOW?

MAYBE YOU FIND YOURSELF IN SUCH A FORTUNATE POSITION THAT YOU HAVE NO SPECIAL NEED FOR SPARE-TIME MONEY. ALTHOUGH THIS MAY BE TRUE, YET YOU DO NEED EXPERIENCE, SO IT IS UP TO YOU TO MAKE THE MOST OF THE OPPORTUNITIES WHICH WE ARE EXTENDING TO YOU IN THIS RESPECT.

THE EXPERIENCE WHICH YOU OBTAIN NOW WILL ENABLE MY EMPLOYMENT DEPARTMENT TO HELP YOU MORE EFFECTIVELY WHEN YOU GRADUATE. IT IS FOR THIS REASON THAT I WANT YOU TO MAIL ME A COMPLETE REPORT OF EVERY SPARE-TIME JOB YOU DO -- DESCRIBING THE JOB IN DETAIL AND THE PRICE YOU CHARGED. I EXPECT THIS REPORT FROM YOU AND AM FRANK TO TELL YOU THAT ALL SUCH REPORTS WILL FORM A PART OF MY EMPLOYMENT DEPARTMENT RECORDS. IN THIS WAY I CAN TELL AT A GLANCE JUST EXACTLY WHAT PRACTICAL EXPERIENCE YOU HAVE ACQUIRED DURING YOUR PERIOD OF TRAINING AND CAN THEREFORE RECOMMEND YOU ACCORDINGLY TO YOUR PROSPECTIVE EMPLOYER. THIS IS AN IMPORTANT MATTER AND I AM CERTAIN THAT YOU REALIZE ITS VALUE TO YOURSELF.

WHEN YOU GET A SERVICE JOB, BY ALL MEANS DO THE WORK YOURSELF. THIS IS YOUR EXPERIENCE AND ALTHOUGH YOU MIGHT MAKE A LITTLE MONEY ON THE DEAL BY ONLY "SELLING THE JOB" AND LETTING SOMEONE ELSE DO THE ACTUAL WORK, YET SUCH A PRACTICE WOULD BE OF NO SPECIAL BENEFIT TO YOU. REMEMBER THAT WE ARE WILLING TO HELP YOU THROUGH SPECIFIC SUGGESTIONS AND ADVICE.

BEAR IN MIND THAT IN THIS LESSON, OUR SUGGESTIONS APPLY PARTICULARLY TO SPARE-TIME WORK, CONSIDERING THE FACT THAT YOU ARE NOT YET FULLY TRAINED. HOWEVER, AS YOU ADVANCE WITH YOUR STUDIES, YOU WILL RECEIVE ADDITIONAL BUSINESS SUGGESTIONS WHICH WILL ASSIST YOU MATERIALLY IN CONDUCTING A PROFITABLE RADIO BUSINESS TO WHICH YOU WILL DEVOTE YOUR FULL-TIME.

WE HOPE THAT YOU WILL FIND THE INFORMATION CONTAINED IN THIS SPECIAL LESSON OF THE BUSINESS SERIES TO BE OF VALUE TO YOU AND THAT YOU WILL TAKE IT UPON YOURSELF TO MAKE THE MOST OF YOUR OPPORTUNITIES.

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RADIO EXPERIMENT

LESSON AC-3

This lesson concerns radio experiments designed to fix in your mind some of the principles thus far explained to you.

In order to operate the 8-tube A-C receiver which was promised you, it is necessary that you first have a source of electric power. This will be the 110-volt A-C lighting circuit of your home, transformed to the required voltages by the power transformer which is now being sent.

Before attempting to connect this transformer to your lighting circuit, it is advisable that you first read all of this lesson very carefully to avoid blowing out fuses in your lighting circuit, injuring the transformer, and to prevent possible electrical shocks to yourself.

The power transformer is of the highest quality, capable of operating your receiver at maximum efficiency, so treat it with care and consideration, to maintain it in proper condition.

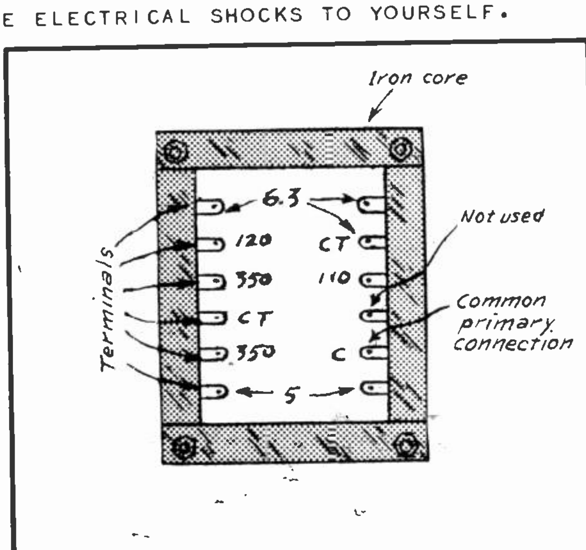


Fig. 1
Power Transformer Terminal Identification

POWER TRANSFORMER TERMINAL MARKINGS

To avoid any possibility of a mistake in identifying the terminals on this transformer, they are all marked as illustrated in Fig. 1, which shows the terminal arrangement of a typical unit. The terminal connected to one end of the primary winding is marked "C", indicating the common connection for this winding. The rminal connected to the other end of the primary winding is marked "120" and a tap from this same winding is connected to the terminal marked "110".

If the line voltage of the lighting circuit is within 4 or 5 volts of 110 volts, connect "C" and "110" terminals of your power transformer across this circuit. Should the line voltage exceed 115 volts and approach 120, connect the "C" and "120" terminals of the transformer across the lighting circuit. This will be explained more fully in a later lesson.

The two terminals marked "6.3", located opposite each other and interconnected by the line, are connected to the 6.3-volt secondary winding. The center-tap from this winding connects to the terminal indicated in Fig. 1 as C.T. The two terminals marked "5" connect to the ends of the 5-volt secondary winding, and the terminals marked "350" connect to the ends of the high-voltage secondary winding. The center-tap from this same winding is located between the high-voltage terminals, and is marked C.T.

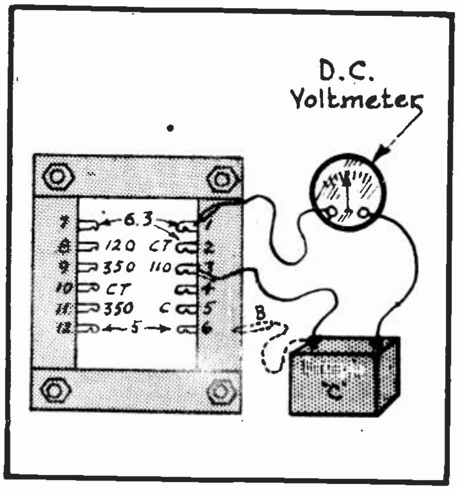


Fig. 2
Continuity Tests With
Voltmeter Method

Some types of power transformer do not have marked terminals, and in such cases the terminals must be identified by means of tests as explained later in this course.

Before attempting to make test connections to any of the transformer terminals, be sure to scrape off the varnish baked on the terminals while the unit was constructed. This varnish is an insulator and will prevent a good electrical contact on the solder lugs. For this reason, it is necessary that it first be scraped off the terminals. Scrape them bright before soldering or otherwise making electrical connections.

EXPERIMENT #1 -- VOLTMETER METHOD FOR TESTING THE CONTINUITY OF TRANSFORMER WINDINGS

Your first experiment will be the continuity test on the transformer windings, by aid of your voltmeter. To do this, connect the voltmeter in series with a 4 1/2-volt "C" battery and a pair of test leads, and test between the various terminal lugs of the transformer in the manner illustrated in Fig. 2. Begin by placing test point "A" on the terminal indicated as #1 in Fig. 2, and then touch the other test point "B" successively to the terminals indicated as #2, 3, 4, etc. Then place test point "A" on terminal #2, and test point "B" successively on terminals 3, 4, 5, etc. Continue by placing test point "A" on terminal #3, and test point "B" successively on terminals #4, 5, 6, etc. Proceed in this manner until you have tested between every pair of terminals. Also, test in this manner between every terminal and ground (ground in this case is the iron core of the transformer).

Each time that you test through a complete circuit, the voltmeter

WILL SHOW A READING. WITH THE PARTICULAR TRANSFORMER CONNECTIONS ILLUSTRATED IN FIG. 2, FOR EXAMPLE, THE METER READING SHOULD BE AS FOLLOWS:

BETWEEN TERMINALS 1, 2, AND 7 YOU SHOULD OBTAIN A READING EQUIVALENT TO BATTERY VOLTAGE, BUT FROM THESE TERMINALS TO ALL OTHERS A ZERO READING SHOULD BE OBTAINED. OTHER READINGS SHOULD BE AS FOLLOWS: BETWEEN TERMINALS 6 TO 12, BATTERY VOLTAGE; TERMINALS 6 OR 12 TO ALL OTHER TERMINALS, ZERO; BETWEEN TERMINALS 9, 10, AND 11, BATTERY VOLTAGE; FROM TERMINALS 9, 10, AND 11 TO ALL OTHERS, ZERO; BETWEEN TERMINALS 5, 3, AND 8, BATTERY VOLTAGE; FROM TERMINALS 5, 3, AND 8 TO ALL OTHERS, ZERO; FROM ALL TERMINALS TO THE TRANSFORMER CORE, ZERO, FOR NONE OF THE WINDINGS SHOULD BE GROUNDED WITHIN THE TRANSFORMER ITSELF.

IF NO READING IS OBTAINED BETWEEN A PAIR OF TERMINALS, WHERE A READING SHOULD BE OBTAINED, THAT PARTICULAR WINDING IS OPEN-CIRCUITED.

WITH A VERY SENSITIVE VOLTMETER YOU WOULD NOTICE THAT WHEN TESTING THROUGH EITHER HALF OF THE HIGH-VOLTAGE WINDING, OR THROUGH THIS ENTIRE WINDING, THE READING WOULD BE SLIGHTLY LESS THAN BATTERY VOLTAGE, BECAUSE THE WIRE USED IN THIS WINDING IS SO SMALL AND THE NUMBER OF TURNS SO GREAT, THAT THE OHMIC RESISTANCE OF THE WINDING IS COMPARATIVELY HIGH.

IT IS A GOOD PLAN TO MAKE AN ELECTRICAL DIAGRAM OF YOUR TRANSFORMER SOMEWHAT AS SHOWN IN FIG. 3. REMEMBER, HOWEVER, THAT THE TERMINAL ARRANGEMENTS ON ALL COMMERCIAL POWER TRANSFORMERS ARE NOT ALIKE, AND THEREFORE THE CONTINUITY TESTS DO NOT NECESSARILY HAVE TO BE THE SAME AS OBTAINED WITH THE EXAMPLE OF FIG. 2.

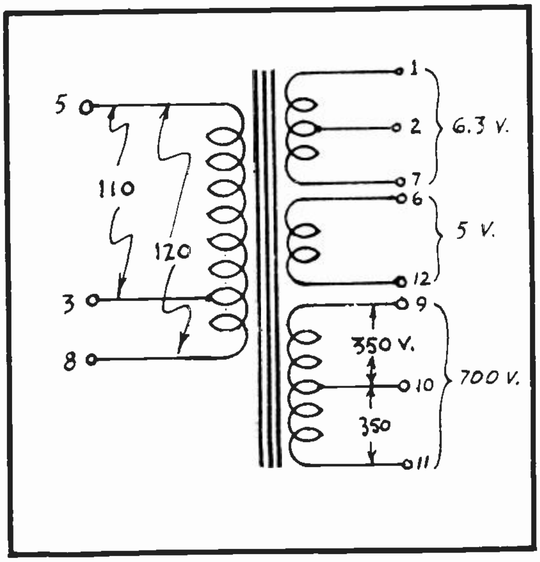


Fig. 3
Diagram of the Power Transformer

EXPERIMENT #2 -- TESTING THE TRANSFORMER WINDINGS FOR CONTINUITY USING HEADPHONES

HEADPHONES CAN BE USED IN PLACE OF THE VOLTMETER, AS SHOWN IN FIGURE 4, AND THE RESULTS AS OBTAINED WITH THIS EXPERIMENT SHOULD CORRESPOND WITH THOSE OBTAINED IN THE PREVIOUS EXPERIMENT. THAT IS, ACROSS THOSE CONNECTIONS WHERE THE VOLTMETER INDICATED BATTERY VOLTAGE, YOU SHOULD NOW HEAR A DISTINCT "CLICK" IN YOUR HEADPHONES, BUT NONE WHERE THERE IS NO CIRCUIT CONTINUITY.

MAKE THIS HEADPHONE CLICK TEST ACROSS ALL PAIRS OF CONNECTIONS, AS YOU DID WITH YOUR VOLTMETER TESTS. CHECK THE RESULTS CAREFULLY AGAINST THOSE OBTAINED IN THE FIRST EXPERIMENT, AND NOTE HOW THEY COMPARE.

EXPERIMENT #3 -- 110-VOLT LAMP TESTING ACROSS WINDINGS

ARRANGE A 110-VOLT LAMP IN SERIES WITH ONE OF A PAIR OF TEST LEADS AS ILLUSTRATED IN FIG. 5. THE LAMP MAY BE AN INCANDESCENT LAMP OF ANY

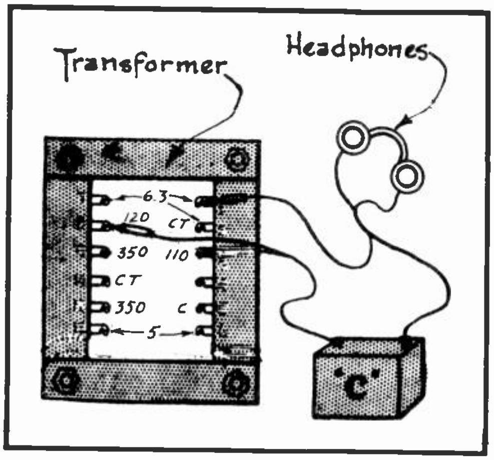


Fig. 4
Continuity Tests With
Headphone Method

RATING BETWEEN 25 AND 100 WATTS--WHATEVER YOU HAPPEN TO HAVE ON HAND--BUT A 25-WATT LAMP IS PREFERABLE. CONNECT THE TEST LEADS TO THE 110-VOLT A-C LIGHTING CIRCUIT BY MEANS OF AN ATTACHMENT PLUG, AS SHOWN, AND PLUG-IN AT ANY SOCKET OR PLUG RECEPTACLE.

THUS CONNECTING A LAMP IN SERIES WITH THE TEST LEADS MAKES IT IMPOSSIBLE TO BLOW OUT A FUSE IN THE LIGHTING CIRCUIT IN CASE THAT THE TEST PRODS ARE ACCIDENTALLY TOUCHED TOGETHER OR OTHERWISE SHORT-CIRCUITED. THE LAMP WILL BURN AT FULL BRILLIANCE WHENEVER THE TEST-LEADS ARE SO SHORTED.

UPON CONNECTING THE TEST LEADS ACROSS 6.3 VOLT WINDINGS, OR ACROSS THE 5-VOLT WINDING, THE LAMP WILL BURN QUITE BRIGHTLY, BECAUSE THESE ARE LOW RESISTANCE WINDINGS HAVING A RELATIVELY SMALL NUMBER OF TURNS OF FAIRLY LARGE WIRE.

UPON CONNECTING THE TEST LEADS ACROSS THE HIGH-VOLTAGE SECONDARY WINDING THE LAMP WILL FAIL TO BURN,BECAUSE THIS WINDING CONTAINS A GREAT NUMBER OF TURNS OF VERY FINE WIRE, AND OFFERS GREAT OPPOSITION TO THE CURRENT FLOW--IN FACT, SO MUCH OPPOSITION THAT 110 VOLTS WILL NOT FORCE ENOUGH CURRENT THROUGH IT TO HEAT THE LAMP FILAMENT TO INCANDESCENCE.

IF THE TEST LEADS ARE CONNECTED ACROSS THE "C" AND "110" PRIMARY TERMINALS, A 25-WATT LAMP WILL BURN DIMLY, A 50-WATT LAMP STILL MORE DIM AND A 100-WATT LAMP WILL NOT SHOW LIGHT AT ALL. THE PURE RESISTANCE OF THE PRIMARY WINDING DOES NOT NECESSARILY PREVENT THE LAMP FROM LIGHTING, BUT IN ADDITION, THE PRIMARY WINDING IS DESIGNED TO PRODUCE A COUNTER-ELECTROMOTIVE FORCE, WHEN THE LIGHTING CIRCUIT IS CONNECTED ACROSS IT, THAT PRACTICALLY COUNTER BALANCES THE LINE VOLTAGE. CONSEQUENTLY, IF LINE VOLTAGE AND THIS COUNTER-ELECTROMOTIVE FORCE EXACTLY OR NEARLY BALANCE EACH OTHER, VERY LITTLE CURRENT WILL FLOW THROUGH THE WINDING, WITH WHICH TO LIGHT THE LAMP.

EXPERIMENT #4 -- EXPERIMENTS WITH 60-CYCLE HUM

CONNECT THE LAMP-TEST LEADS ACROSS THE PRIMARY TERMINALS OF THE POWER TRANSFORMER, AS ILLUSTRATED IN

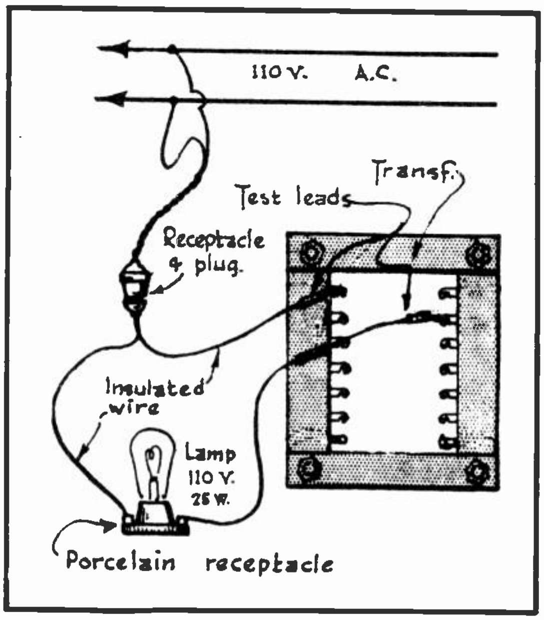


Fig. 5
Testing Across Windings
With a 110-V Lamp

NATIONAL SCHOOLS
LOS ANGELES, CALIFORNIA

Examination Sheet

GRADE

CORRECTED BY

PRINT YOUR NAME AND ADDRESS PLAINLY

William Lieske
1346 Hoyt
Salem, Oregon

DATE Feb 3, 1941

LESSON NO. Ac 3

STUDENT NO. RB-1712

WHAT OTHER LESSONS HAVE YOU? "

ANS. NO. USE THIS SHEET FOR YOUR EXAMINATION ANSWERS ONLY - DO NOT COPY OUT THE QUESTIONS

1. Simply because greater voltage provides greater actuation of the 'phones diaphragms, thus louder clicks

2 No indication would be noted on volt-meter.

3 The primary of the power-transformer is for 220 volts instead of 110, as on the lower voltage model. In AC-DC sets, a larger dropping resistor or a special adapter is needed.

4 It is open circuited.

5 Clicks can be heard on all windings. On the high voltage windings the meter deflection will be less than on lower voltage ones due to the greater resistance of the H.V. windings

6. In case of a short, the fuses will not be blown, or the transformer overloaded.

7 The counter-electromotive force in the transformer almost counter balances the line voltage when no load is put on the transformer. But when a load is put on the transformer, that is, current is drawn from one of the secondaries, this power must be supplied thru the medium of the primary.

ANS. NO.

Thus the effective resistance of the primary is greatly reduced.

8. It means that the primary is shorted to the core.

9. The low voltage windings have very low resistance: a comparitively small number of turns of comparitively larger wire than the secondary.

10. If the winding is continous, when the prods are connected across it, the voltage is connected across the phones, thus causing the click. Not continous, no click.

IMPORTANT -- IF NECESSARY, USE ANY SIMILAR PLAIN PAPER TO COMPLETE YOUR ANSWERS.

FIG. 6. TO AVOID AN ELECTRICAL SHOCK WHEN HANDLING THIS 110-VOLT CIRCUIT, BE CAREFUL THAT YOU DO NOT TOUCH BOTH BARE ENDS OF THE 110-VOLT TEST CIRCUIT WITH BOTH HANDS AT THE SAME TIME. NEVER TOUCH ONE TERMINAL OF ANY LIGHTING CIRCUIT WHILE STANDING ON A WET FLOOR, ON THE GROUND, OR IN CONTACT WITH ANY METAL CONNECTED TO GROUND-- SUCH AS A WATER PIPE.

HAVING MADE THE CONNECTIONS ACROSS THE PRIMARY CIRCUIT, CONNECT YOUR HEADPHONES ACROSS THE 6.3-VOLT SECONDARY WINDING, AS ALSO SHOWN IN FIG. 6. UPON DOING THIS YOU WILL HEAR THE CHARACTERISTIC 60-CYCLE A-C HUM. ALSO CONNECT YOUR HEADPHONES ACROSS THE 5-VOLT SECONDARY, BETWEEN THE CENTER TAP AND EACH EXTREMITY OF THE 6.3 VOLT SECONDARY, AND BETWEEN THE IRON CORE AND EACH END OF THE 6.3-VOLT WINDING. DO NOT CONNECT YOUR HEADPHONES ACROSS THE HIGH-VOLTAGE SECONDARY WINDING DURING THIS TEST. ALSO, BE SURE NOT TO TOUCH THE TERMINALS OF THE HIGH-VOLTAGE SECONDARY WHILE THE PRIMARY IS CONNECTED ACROSS THE 110-VOLT LIGHTING CIRCUIT, OR YOU WILL RECEIVE A PAINFUL SHOCK.

UPON THE COMPLETION OF THIS TEST, YOU WILL FIND THAT WITH THE HEADPHONES CONNECTED ACROSS THE ENDS OF THE 6.3-VOLT SECONDARY, THE HUM INTENSITY WILL APPEAR TO BE ABOUT TWICE AS GREAT AS WITH THE HEADPHONES CONNECTED ACROSS ONLY ONE-HALF OF THIS WINDING.

EXPERIMENT #5 - EFFECT OF POWER DEMAND UPON THE TRANSFORMER

WITH THE 110-VOLT LAMP CIRCUIT CONNECTED ACROSS THE PRIMARY TERMINALS OF THE POWER TRANSFORMER, TAKE A SHORT PIECE OF HOOK-UP WIRE AND MOMENTARILY TOUCH ITS ENDS ACROSS THE TERMINALS, AS ILLUSTRATED IN FIG.7. UPON SO SHORT-CIRCUITING THE 6.3-VOLT WINDING, THE LAMP WILL BURN AT FULL BRILLIANCE.

THE LAMP CAN ALSO BE MADE TO BURN AT FULL BRILLIANCE BY MOMENTARILY SHORT-CIRCUITING THE 5-VOLT SECONDARY. DO NOT SHORT-CIRCUIT THE HIGH VOLTAGE SECONDARY WINDING DURING THIS EXPERIMENT.

IT SHOULD BE OF SPECIAL INTEREST TO YOU TO NOTE THAT WITH ONLY THE LAMP CIRCUIT CONNECTED ACROSS THE TRANSFORMER'S PRIMARY WINDING, IT WILL ONLY BURN VERY DIMLY; WHEREAS, IT SHOWS FULL BRILLIANCE UPON SHORT-CIRCUITING ANY OF THE LOW-VOLTAGE SECONDARY WINDINGS. THIS TEST SHOWS HOW A SECONDARY LOAD AFFECTS THE AMOUNT OF POWER WHICH THE TRANSFORMER DRAWS FROM THE LIGHTING CIRCUIT. WHAT REALLY HAPPENS IS THAT WITH ONLY THE PRIMARY WINDING CONNECTED ACROSS THE 110-VOLT CIRCUIT, AND NO COMPLETE CIRCUIT PROVIDED FOR EITHER OF THE SECONDARY VOLTAGES, THE COUNTER-ELECTROMOTIVE FORCE GENERATED BY THE PRIMARY WINDING PRACTICALLY COUNTER-BALANCES THE LINE VOLTAGE, WITH THE RESULT THAT ALMOST NO POWER IS CONSUMED BY THE TRANSFORMER. THE SMALL AMOUNT OF A-C CURRENT FLOWING

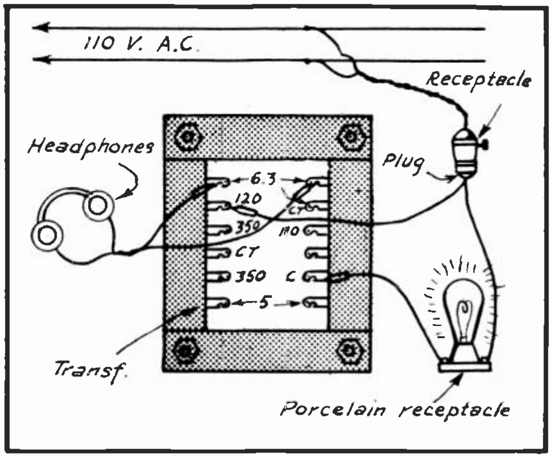


Fig. 6
Listening for 60 Cycle Power Hum

IN THE PRIMARY WINDING UNDER SUCH CONDITIONS, WHICH SERVES ONLY TO ESTABLISH THE FLUX OR LINES OF FORCE GENERATING THE COUNTER-ELECTROMOTIVE FORCE, IS OFTEN SPOKEN OF AS WATTLESS CURRENT.

SHORT-CIRCUITING ONE OF THE LOW-VOLTAGE SECONDARY WINDINGS COMPLETES THAT CIRCUIT AND PERMITS CURRENT TO FLOW. THIS PARTICULAR WINDING THEN CONSUMES ELECTRICAL POWER WHICH MUST BE SUPPLIED BY THE 110-V. CIRCUIT BY SIMPLE TRANSFORMER ACTION. THE ADDITIONAL CURRENT DRAWN FROM THE LIGHTING CIRCUIT TO MEET THIS POWER DEMAND, IS SUFFICIENT TO CAUSE THE LAMP TO BURN AT FULL BRILLIANCE. IN OTHER WORDS, THE GREATER THE LOAD IMPRESSED UPON THE SECONDARY WINDINGS, OR THE LESS THE OPPOSITION OF A COMPLETED SECONDARY CIRCUIT--THE GREATER WILL BE THE CURRENT FLOW THROUGH THE SECONDARY AS WELL AS THROUGH THE PRIMARY WINDING. IN YOUR PRESENT EXPERIMENTS, HOWEVER, THE 25-WATT LAMP LIMITS THE PRIMARY CURRENT TO AN AMOUNT WHICH WILL NOT INJURE THE WINDINGS DURING THESE SHORT-CIRCUITING TESTS.

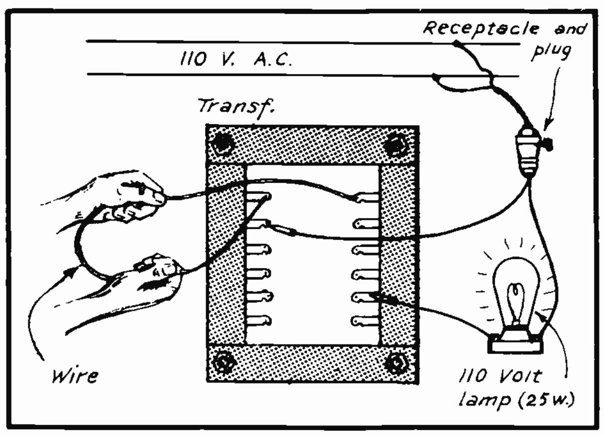


Fig. 7
Putting a Load on the Transf.

SPECIAL NOTICE TO STUDENTS HAVING 220-VOLT A-C SERVICE

AS YOU WILL HAVE NOTICED IN THE STUDY OF THIS LESSON, IT CONCERNS ONLY POWER TRANSFORMERS DESIGNED FOR CONNECTION TO 110-VOLT A-C LIGHTING CIRCUITS, SINCE THIS POWER SUPPLY IS MOST COMMON. HOWEVER, TO THOSE STUDENTS WHO REQUEST THAT THEIR EXPERIMENTAL OUTFITS BE DESIGNED FOR 220-VOLT A-C OPERATION, WE SEND A POWER TRANSFORMER DESIGNED FOR THIS LINE VOLTAGE. OTHER THAN THE DESIGN OF THE POWER TRANSFORMER, THE DESIGNS OF THE 8-TUBE 110-VOLT AND 220-VOLT A-C RECEIVERS ARE EXACTLY ALIKE.

IN CONDUCTING THE EXPERIMENTS OUTLINED IN THIS LESSON, BUT WITH A 220-VOLT TRANSFORMER, YOU WILL PROCEED EXACTLY AS SPECIFIED FOR THE 110-VOLT TRANSFORMER, EXCEPT THAT YOU WILL CONNECT THE 220-VOLT PRIMARY WINDING OF THE TRANSFORMER TO THE 220-VOLT LIGHTING CIRCUIT, AND WHEN USING A LAMP IN ANY OF THE EXPERIMENTS, A 220-VOLT LAMP MUST BE USED INSTEAD OF THE 110-VOLT LAMP SPECIFIED IN THIS LESSON. YOUR METHODS OF PROCEDURE, AND THE RESULTS IN CONNECTION WITH THE EXPERIMENTS, WILL THEN BE THE SAME AS STATED IN THIS LESSON WITH RESPECT TO THE 110-VOLT TRANSFORMER.

SPECIAL TRANSFORMER INFORMATION FOR GLASS-TUBE RECEIVER

THE ILLUSTRATIONS AND EXPLANATIONS THUS FAR GIVEN IN THIS LESSON APPLY TO THE POWER TRANSFORMER WHICH WE FURNISH TO OUR STUDENTS FOR USE IN CONSTRUCTING THE A-C RECEIVER EQUIPPED WITH METAL TUBES. FOR THE GLASS-TUBE RECEIVER, HOWEVER, A CHANGE IN THE DESIGN OF THE POWER TRANSFORMER IS NECESSARY.

THE TERMINAL ARRANGEMENT OF THE TRANSFORMER FOR THE GLASS-TUBE REceiver is illustrated in Fig. 8, and its circuit diagram appears in Figure 9. As you will note, two 2 1/2-volt secondaries replace the single 6.3-volt winding of the glass-tube transformer.

Although these changes have been made, you can nevertheless perform the same experiments as outlined in this lesson, by simply bearing in mind the change in the transformer's terminal arrangement, and substituting tests on the 2.5-volt windings for the prescribed tests on the 6.3-volt winding.

IDENTIFYING TERMINALS

When testing out transformers on which the several terminals are not marked, it is well to mark them for future information. The marks may be on adjacent material, or on tags attached to each terminal, or a strip of white paper may be attached to adjacent material by means of shellac (not glue) and the marks made thereon. If wire ends are the on-

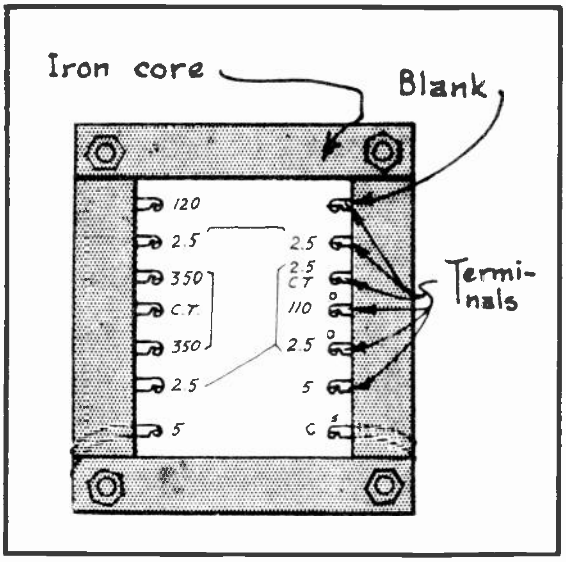


Fig. 8
Terminal Arrangement

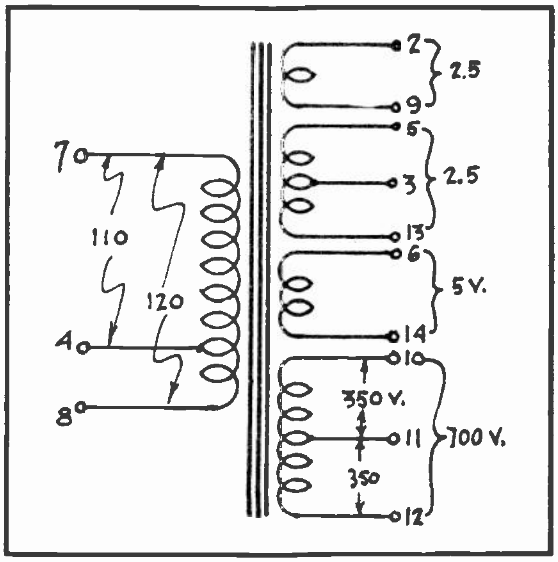


Fig. 9
Transformer Diagram

ly terminals, a short piece of white adhesive tape bent over the wire can be marked with ink.

WEAKENED INSULATION

If any transformer appears damp when received, do not connect it to the A-C line until it has been well dried by hanging it three or four feet above a heating stove for two or three days, or baking it for at least 12 hours at 180 - 190°F.

When first connecting a transformer, disconnect it from the A-C line quickly if it begins to steam, smoke, or smell like burning paint or varnish. Disconnect all load, and retest for shorts and grounds.

EXAMINATION QUESTIONS

RADIO EXPERIMENT LESSON AC-3

Ans Feb 3, 41

1. - WHEN MAKING THE "HUM TEST," WHY IS IT THAT THE HUM INTENSITY, AS HEARD IN THE PHONES, APPEARS GREATER WITH THE PHONES CONNECTED ACROSS THE 6.3-VOLT SECONDARY WINDING THAN WHEN CONNECTED ACROSS THE 5-VOLT WINDING?

2. - IF A TRANSFORMER WINDING SHOULD BE OPEN-CIRCUITED, HOW WOULD THIS REACT UPON THE VOLTMETER WHEN THE CONTINUITY TEST IS MADE ACROSS THE EXTREMITIES OF THIS WINDING?

3. - WHAT IS THE ESSENTIAL DIFFERENCE BETWEEN A 110-VOLT RECEIVER AND A 220-VOLT RECEIVER?

4. - UPON MAKING A CONTINUITY TEST ACROSS TERMINALS 1 AND 7 OF THE TRANSFORMER ILLUSTRATED IN FIG. 2, WITH YOUR VOLTMETER CONNECTED IN SERIES WITH A 4 1/2-VOLT "C" BATTERY, IF THE METER NEEDLE INDICATES "ZERO", WHAT IS THE CONDITION OF THE WINDING CONNECTED BETWEEN THESE TERMINALS?

5. - HOW DO THE RESULTS OBTAINED WITH THE HEADPHONE "CLICK" TESTS COMPARE WITH THE VOLTMETER TESTS ON THE SAME CIRCUITS?

6. - WHAT IS ONE OF THE CHIEF ADVANTAGES OF CONNECTING A LAMP IN SERIES WITH THE 110-VOLT LIGHTING CIRCUIT WHILE TESTING YOUR POWER TRANSFORMER?

7. - WHY DOES THE TEST LAMP IN THE SYSTEM OF FIG. 7 BURN BRIGHTLY WHEN A LOW-VOLTAGE SECONDARY WINDING IS SHORT-CIRCUITED, BUT BURNS DIMLY WHEN NONE OF THE SECONDARY WINDINGS ARE SHORT-CIRCUITED?

8. - IF YOU SHOULD TEST THE TRANSFORMER ACCORDING TO THE VOLTMETER METHOD, AND FIND THE METER TO INDICATE FULL "C"-BATTERY VOLTAGE UPON CONTACTING ONE TEST POINT ON TERMINAL #5 AND THE OTHER TEST POINT ON THE IRON CORE OF THE TRANSFORMER (FIG. 2) WHAT WOULD THIS TEST INDICATE?

9. - WHY IS IT THAT THE 25-WATT TEST LAMP BURNS AT FULL BRILLIANCE WHEN THE 110-VOLT TEST LEADS ARE CONNECTED ACROSS THE ENDS OF A LOW-VOLTAGE SECONDARY WINDING, BUT BURNS VERY DIMLY WHEN THE TEST LEADS ARE CONNECTED ACROSS THE ENDS OF THE TRANSFORMER'S PRIMARY WINDING?

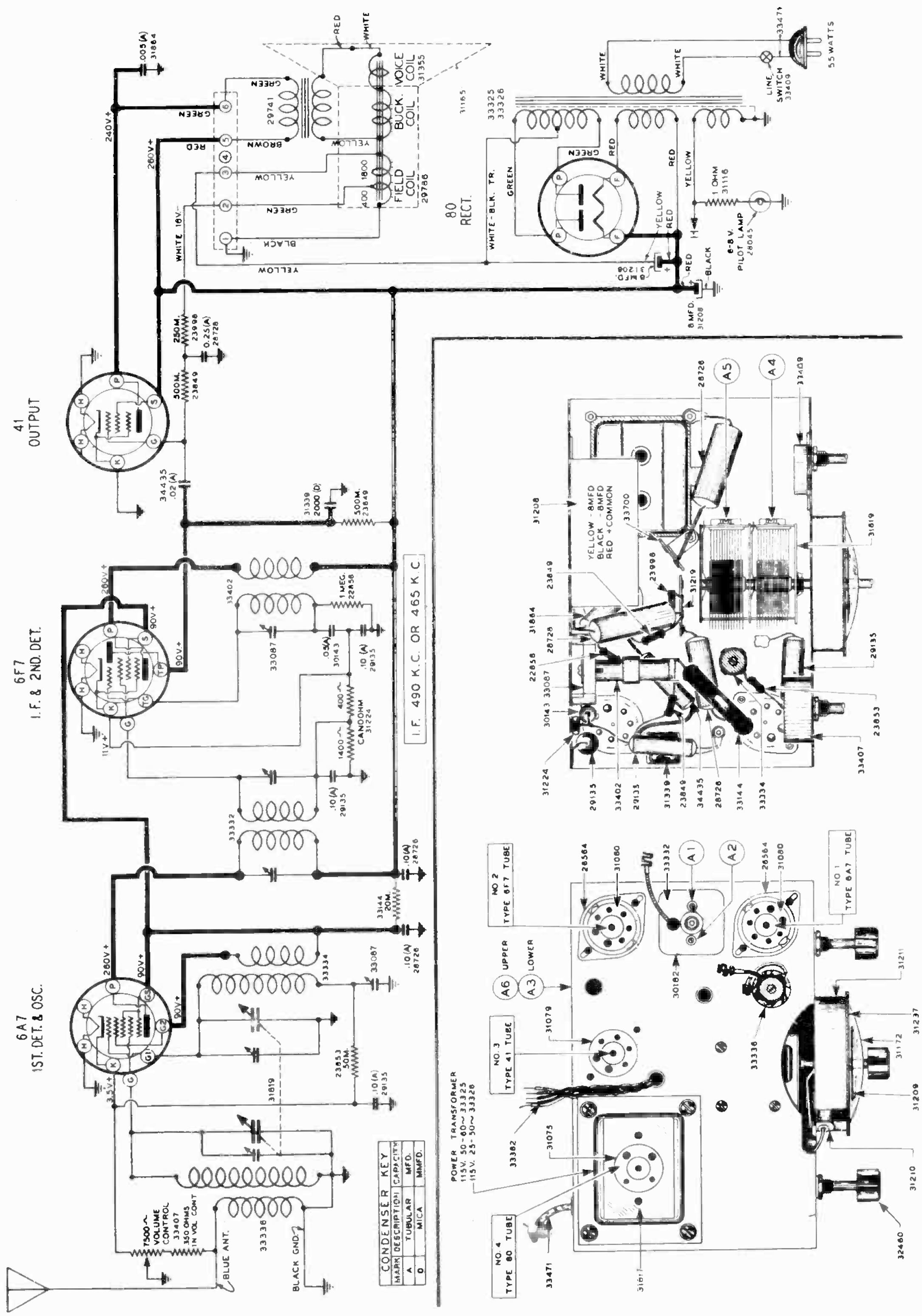
10. - WHY IS IT THAT A "CLICK" IS HEARD IN THE HEADPHONES WHEN TESTING THRU A GOOD TRANSFORMER WINDING, ACCORDING TO THE METHOD ILLUSTRATED IN FIG. 4 OF THIS LESSON?

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

MODEL 470 (Chassis 4C)

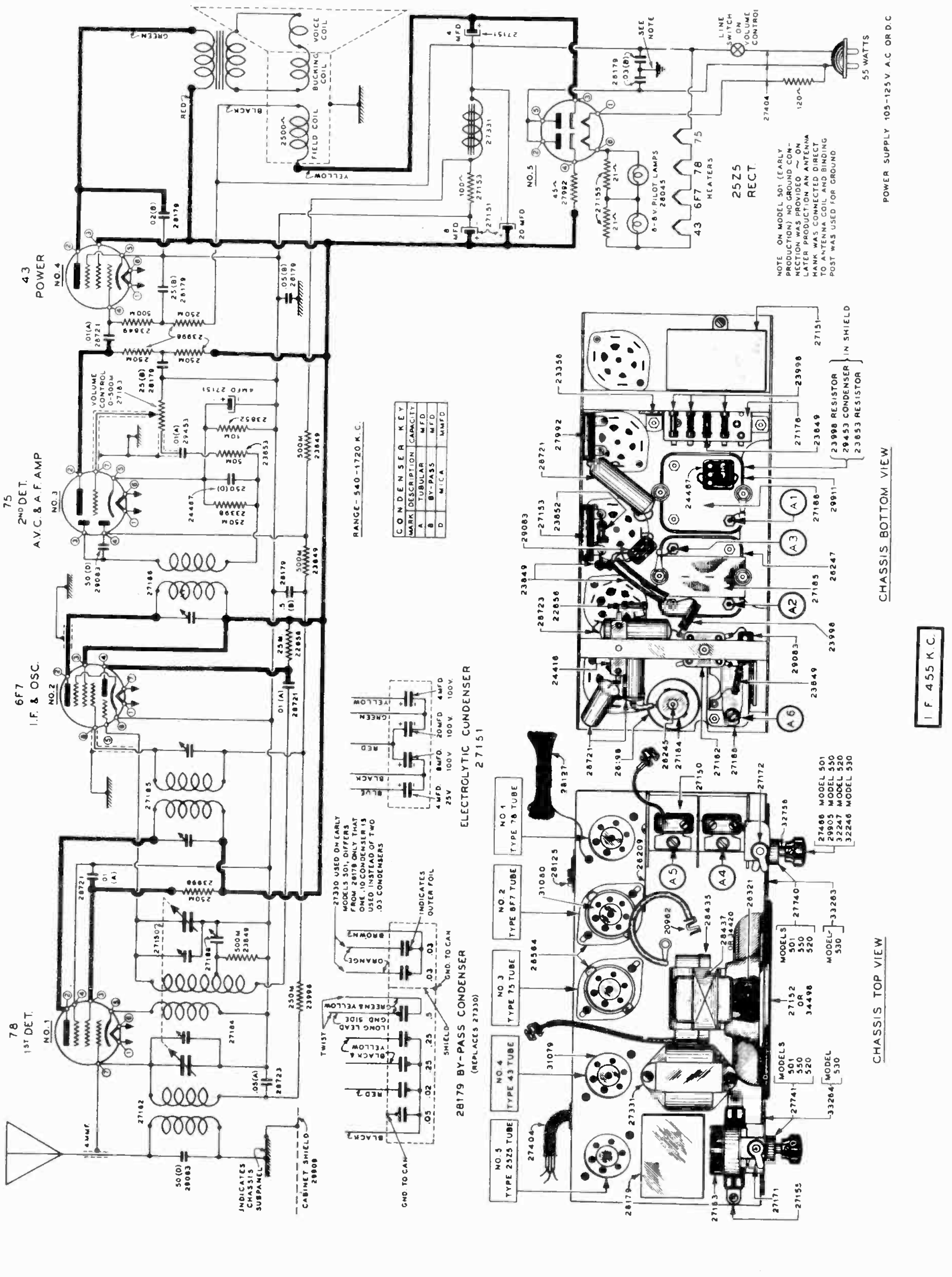


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

MODELS 501-520-530-550 (Chassis 5B)

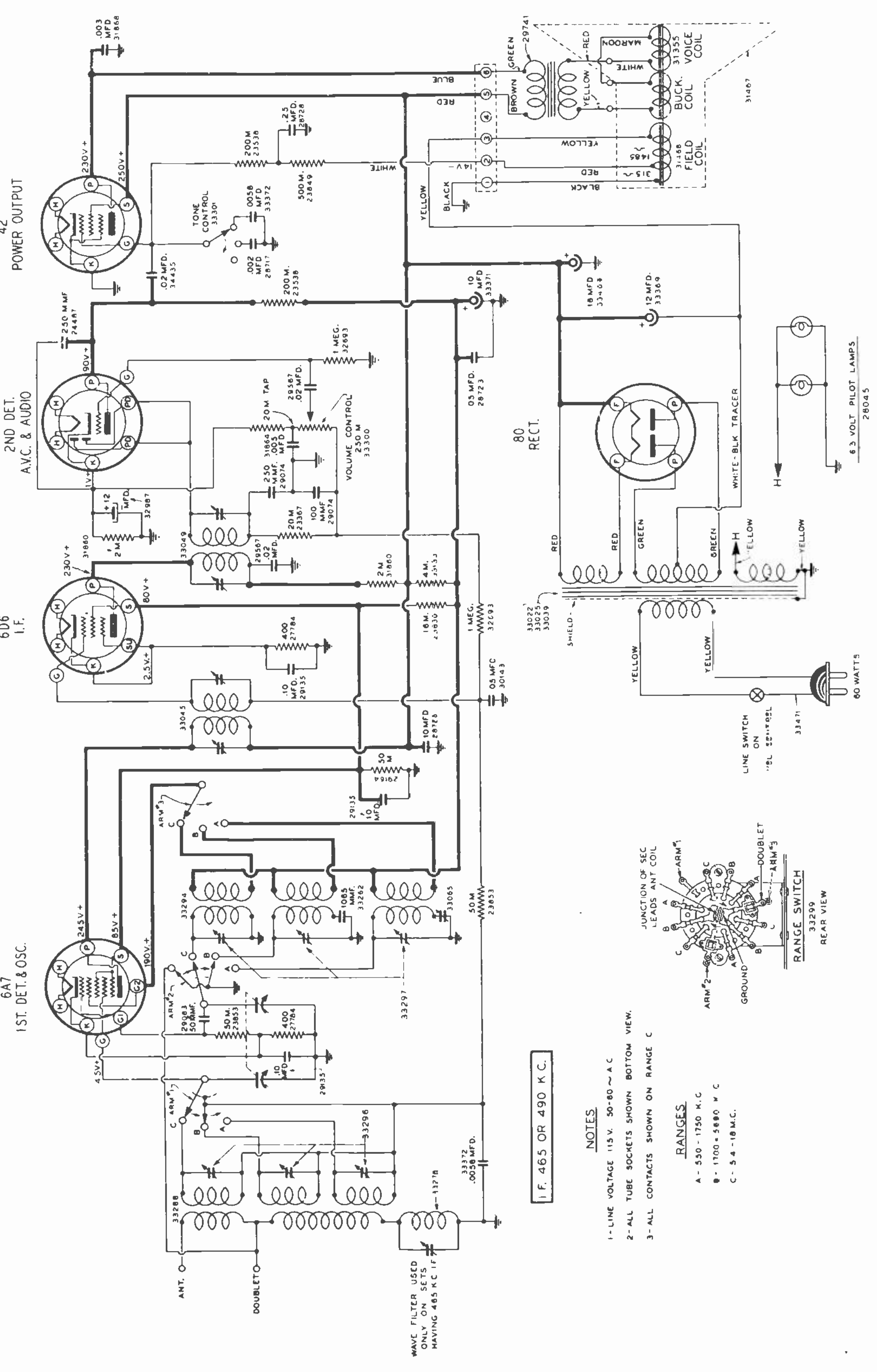


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

MODELS 580 - 581 (Chassis 5 G)



NATIONAL SCHOOLS
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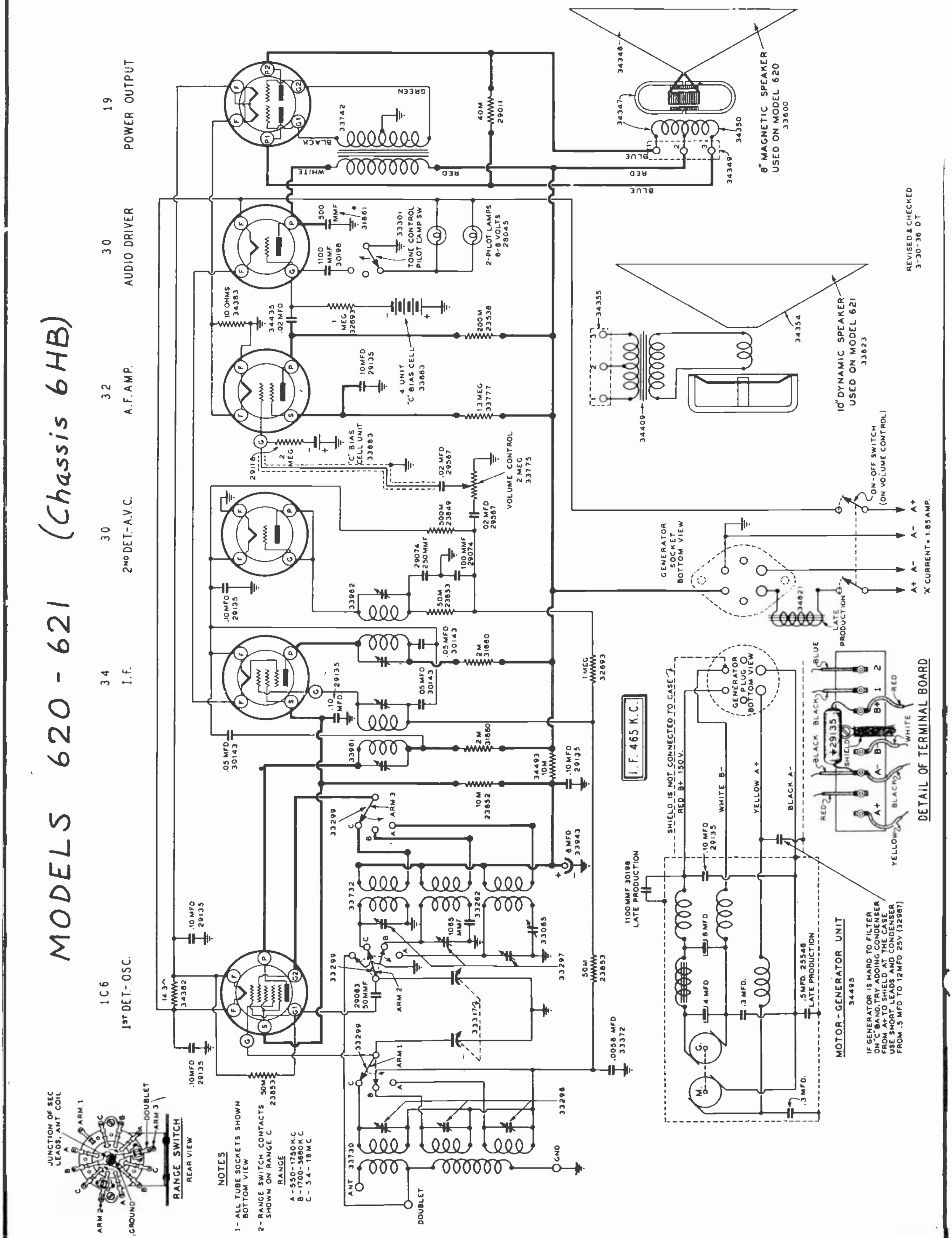
COMMERCIAL CIRCUIT DIAGRAM

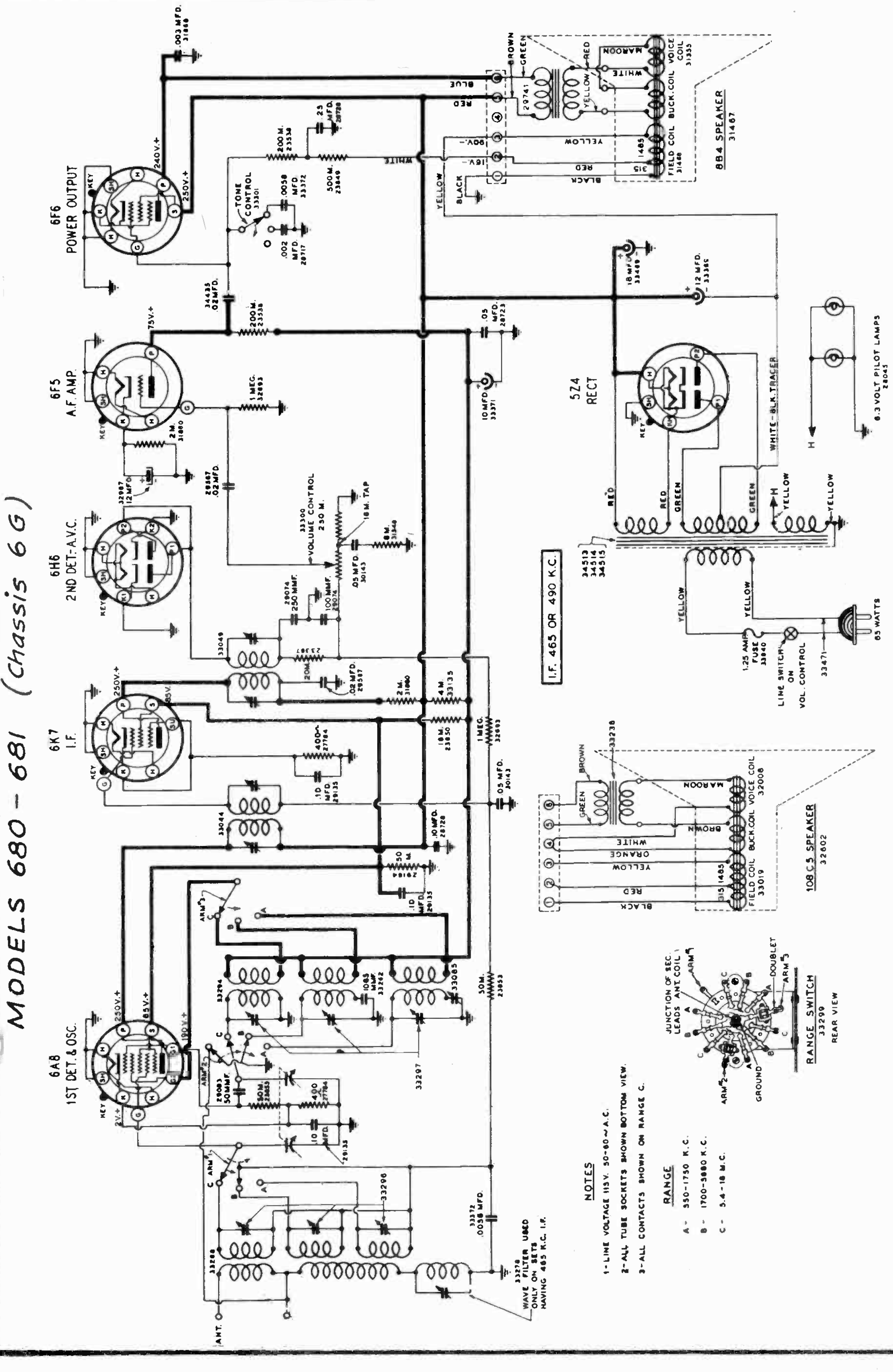
GRUNOW



NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

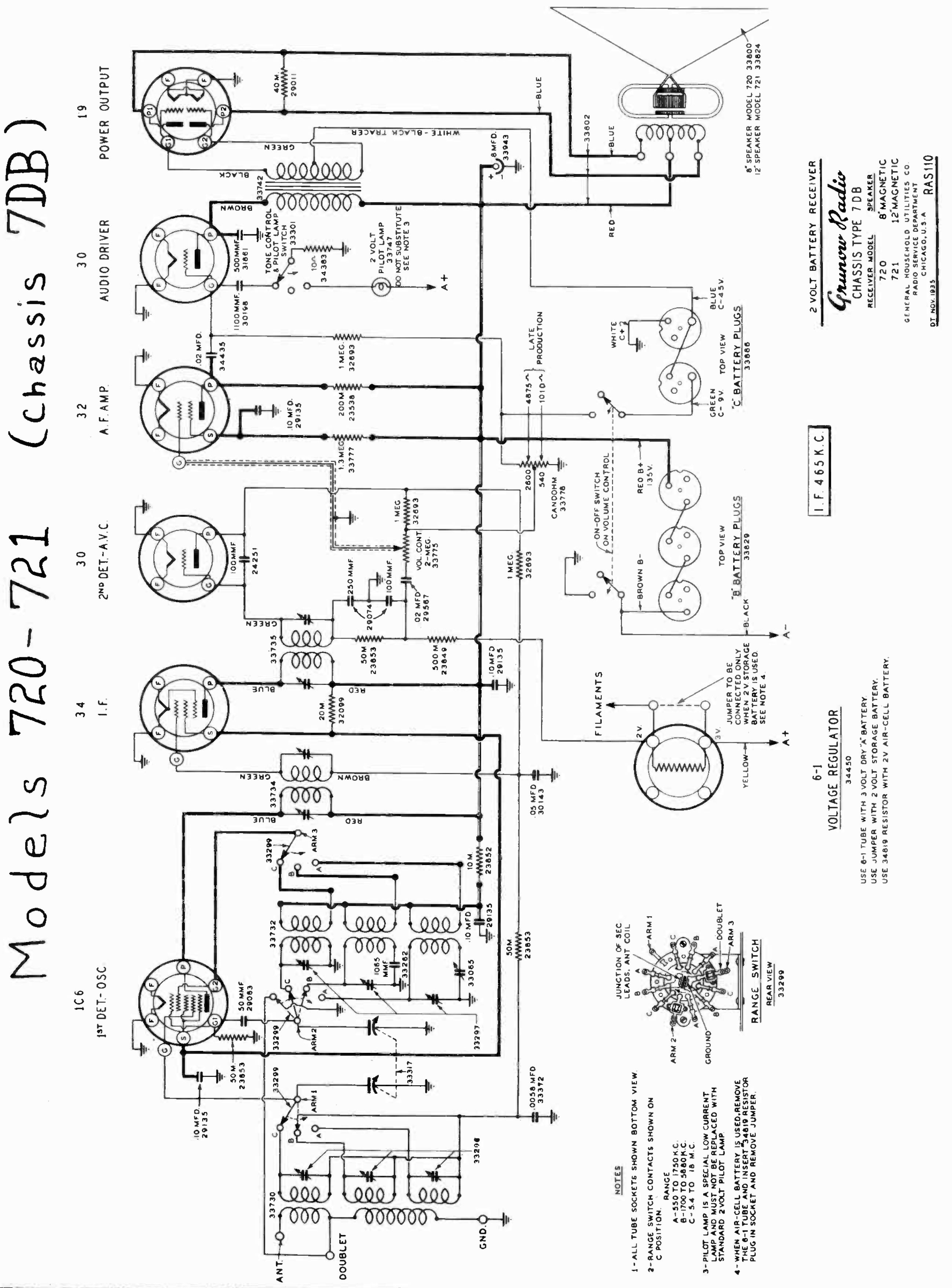


The GRUNOW 6G Chassis is a six tube, 115 V-50-60 cycle A.C., three band receiver with A.V.C., Tone Control and a "Band Spread" dial. The tubes used are: 6A8 1st Detector and Oscillator, 6K7 I.F. Amplifier, 6H6 2nd Detector and A.V.C., 6F5 1st Audio Amplifier, 6F6 Power Output tube and a 5Z4 Rectifier tube. The frequency range is divided into three bands or divisions, one covering the band of 550 to 1750 K.C. (A), one the band from 1700 to 5680 K.C. (B), and the other from 5.4 to 18 megacycles (C).

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

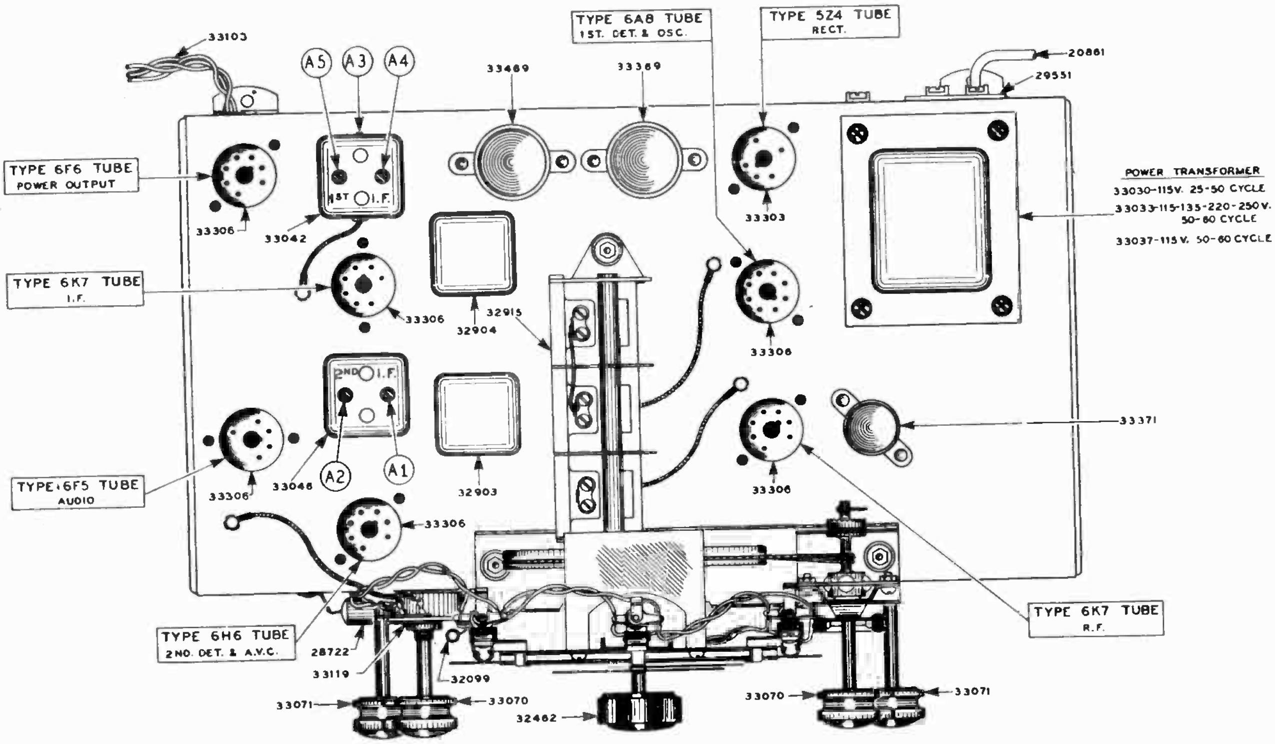


NATIONAL SCHOOLS
Los Angeles, California

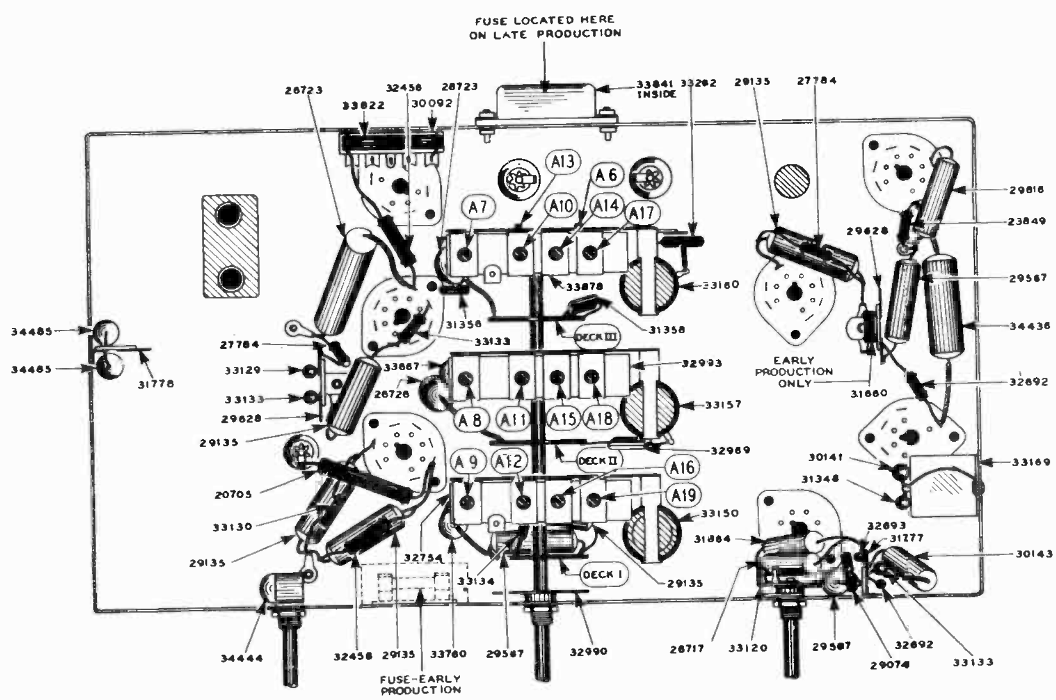
COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

MODELS 760-761 (Chassis 7C)



TOP VIEW



BOTTOM VIEW

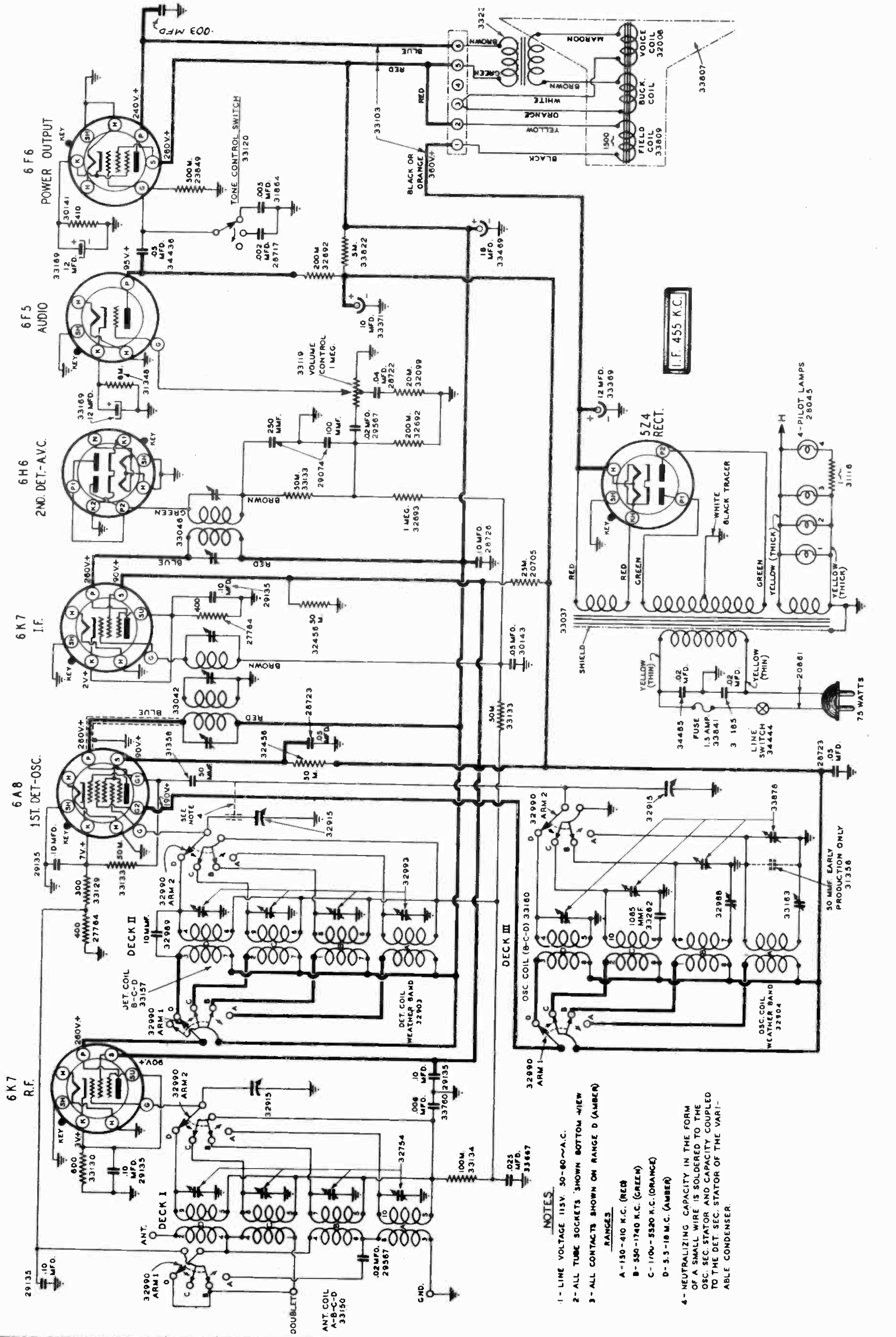
CHASSIS 7C
NOV. 1935
RAS 111

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GRUNOW

MODELS 760 - 761 (Chassis 6G)



NATIONAL SCHOOLS
Los Angeles, California

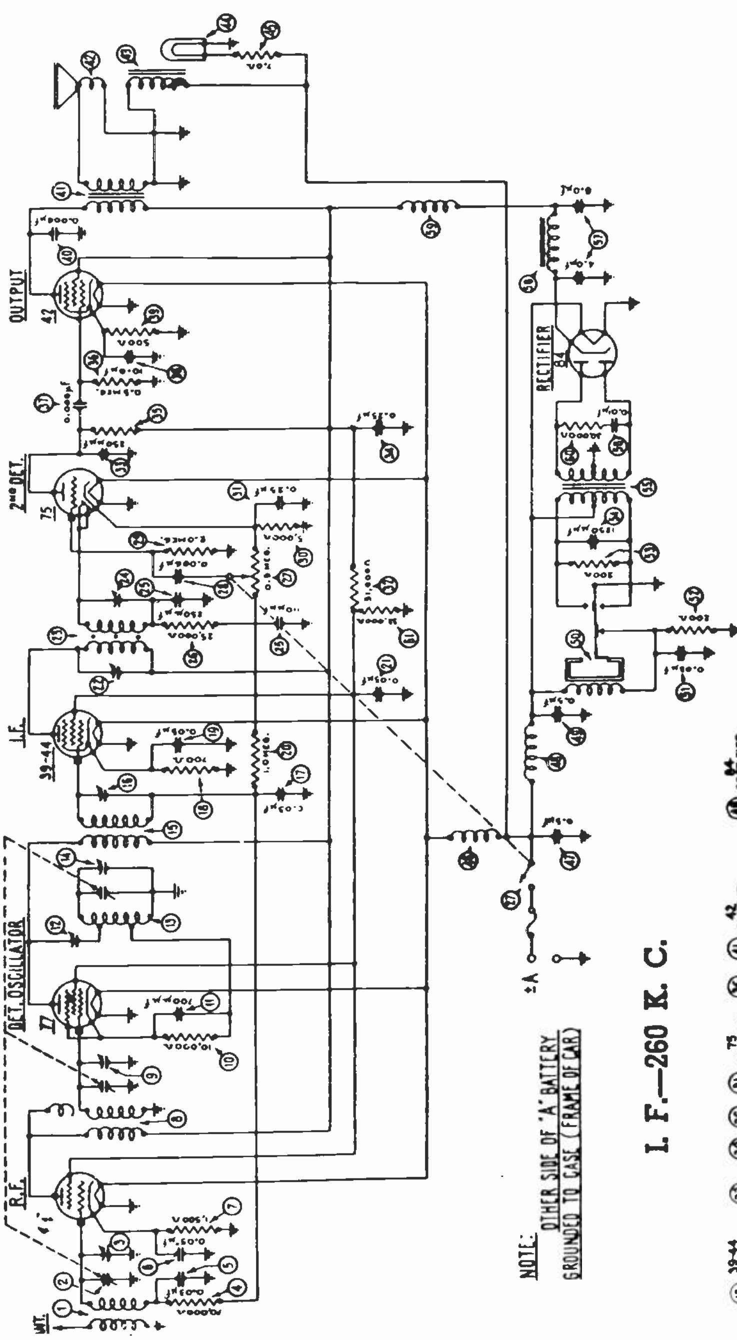
COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 11
(Auto Radio)

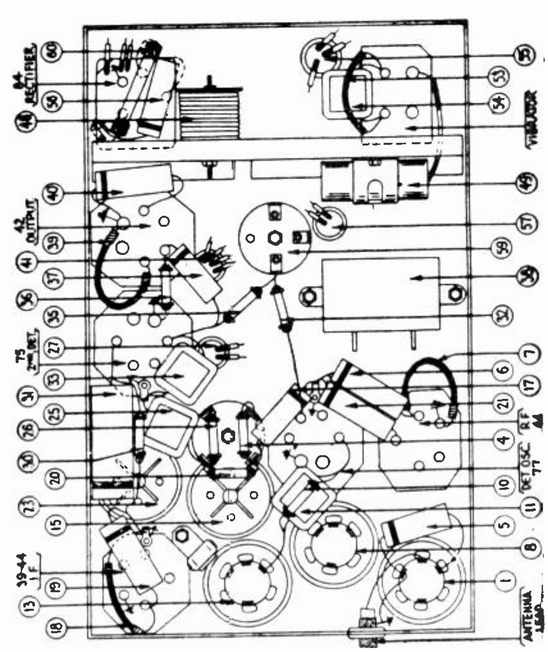
PARTS LIST

1	Antenna Transformer	32-1331
2	Tuning Condenser	31-1149
3	1st Padder (on tun. cond.)	
4	Resistor (70,000 ohms)	33-1115
5	Condenser (.03 mfd.)	30-4025
6	Condenser (.05 mfd.)	30-4020
7	Resistor (1500 ohms)	33-3047
8	R. F. Transformer	32-1332
9	2nd Padder (on tun. cond.)	
10	Resistor (10,000 ohms)	33-1000
11	Condenser (.0007 mfd.)	5983
12	Padder (Prim. 1st I. F. Tran.)	
13	Oscillator Transformer	32-1333
14	3rd Padder (on tun. cond.)	
15	1st I. F. Transformer	32-1329
16	Padder (Sec. 1st I. F. Tran.)	
17	Condenser (.03 mfd.)	30-4025
18	Resistor (700 ohms)	6443
19	Condenser (.05 mfd.)	30-4020
20	Resistor (1,000,000 ohms)	33-1096
21	Condenser (.05 mfd.)	30-4020
22	Padders (Prim. 2nd I. F.)	
23	2nd I. F. Transformer	32-1237
24	Padder (Sec. 2nd I. F. Tran.)	
25	Cond. (.00011-.00025 mfd.)	30-1020
26	Resistor (25,000 ohms)	33-1013
27	Vol. Con. and Switch Assm.	33-5058
28	Condenser (.006 mfd.)	30-4125
29	Resistor (2,000,000 ohms)	33-1025
30	Resistor (5000 ohms)	6096
31	Condenser (.25 mfd.)	30-4146
32	Resistor (51,000 ohms)	5868
33	Condenser (.000025 mfd.)	3082
34	Condenser (.25 mfd.)	04380
35	Resistor (100,000 ohms)	6099
36	Resistor (500,000 ohms)	6097
37	Condenser (.008 mfd.)	30-4125
38	Condenser (10 mfd.)	7440
39	Resistor (500 ohms)	33-3031
40	Condenser (.008 mfd.)	30-4024
41	Output Transformer	32-7214
42	Cone and Voice Coil	02861
43	Field Coil Assembly	36-3097
44	Pilot Light	6608
45	Resistor (7 ohms)	33-3035
46	"A" Choke	32-1286
47	Condenser (.5 mfd.)	30-4047
48	Vibrator Choke	32-1235
49	Condenser (.5 mfd.)	30-4147
50	Vibrator Unit	38-5036
51	Condenser (.05 mfd.)	30-4039
52	Resistor (200 ohms)	7217
53	Resistor (200 ohms)	7217
54	Condenser (.00125 mfd.)	5886
55	Power Transformer	32-7216
56	Condenser (.01 mfd.)	30-4051
57	Condenser (4.-8. mfd.)	30-2072
58	"B" Choke	32-7215
59	R. F. Choke	32-1281
60	Resistor (30,000 ohms)	7836
61	Resistor (32,000 ohms)	3525
	Spark Plug Resistor	33-1015
	Distributor Resistor	4546
	Screw Type Resistor	4851
	Interference Condenser	30-4007
	Dial	27-5038
	Studs	28-6036
	Nuts (mounting)	W55A
	Knobs (tuning)	03334
	Knobs (volume)	06886
	Battery Cable	38-5296
	Acorn Nut	W821
	Key	6091
	Fuse	7227
	Fuse Insulator	27-7131
	4-Prong Socket	27-6006
	5-Prong Socket	27-6014
	6-Prong Socket	6417
	Cont. Unit Assm. (Dir. Dr.)	42-5150
	Shafts—Tuning	28-8139
	Volume	28-8141
	Cont. Unit Assm. (Gr. Dr.)	42-5157
	Shafts—Tuning	28-8217
	Volume	28-8217



NOTE: OTHER SIDE OF "A" BATTERY GROUNDED TO CASE (FRAME OF CAR)

I. F.—260 K. C.



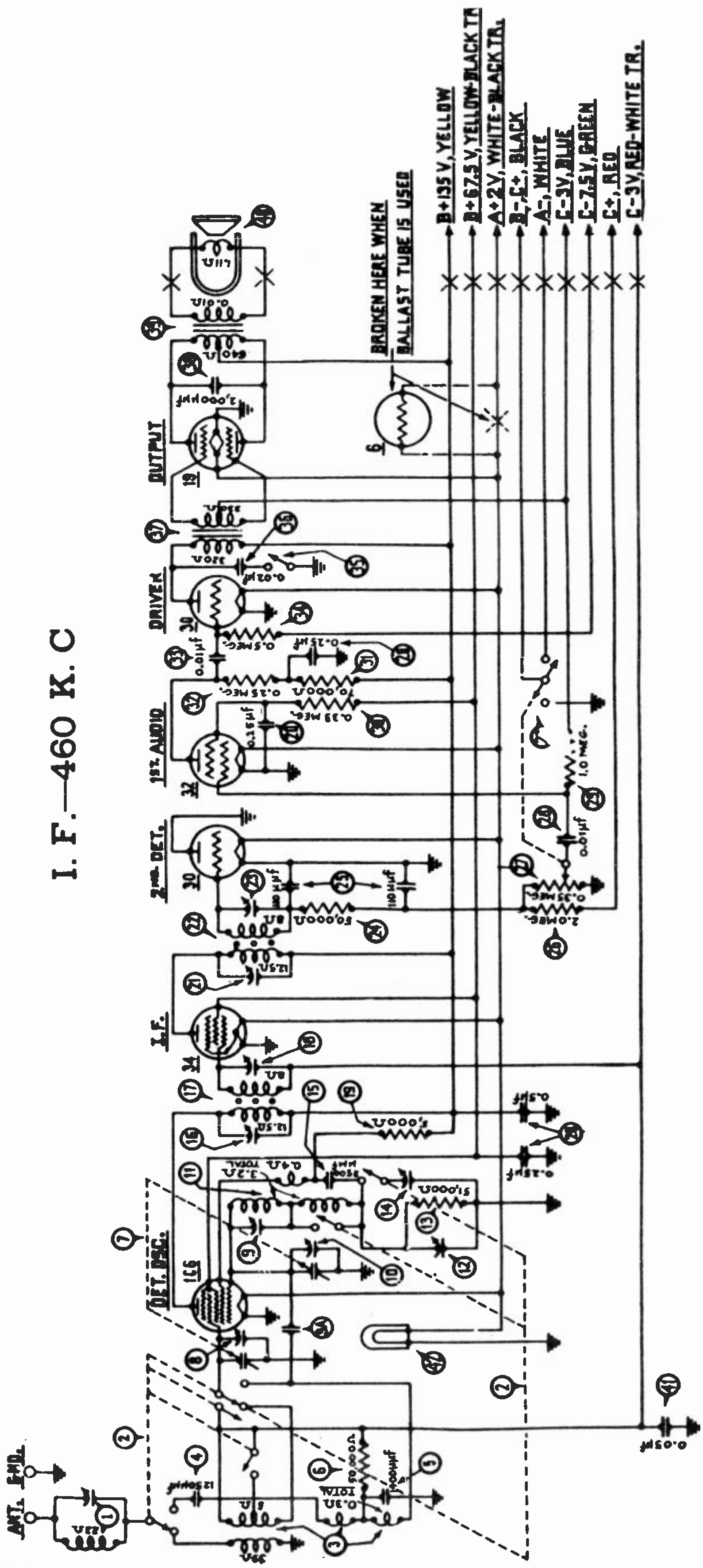
NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 39
(Battery Operated)

I. F.—460 K. C



39 (Battery Operated) Two-Band: 550–1720 K.C. 5.5–16.0 M.C.	Fil. Cur. 670 M.A. Plate Cur. 19 M.A.	I.F. 460 K.C.	1–1C6, 1–34, 2–30, 1–32, 1–19 (Model 39-A uses also 1 type 6 ballast)

Tube Voltages

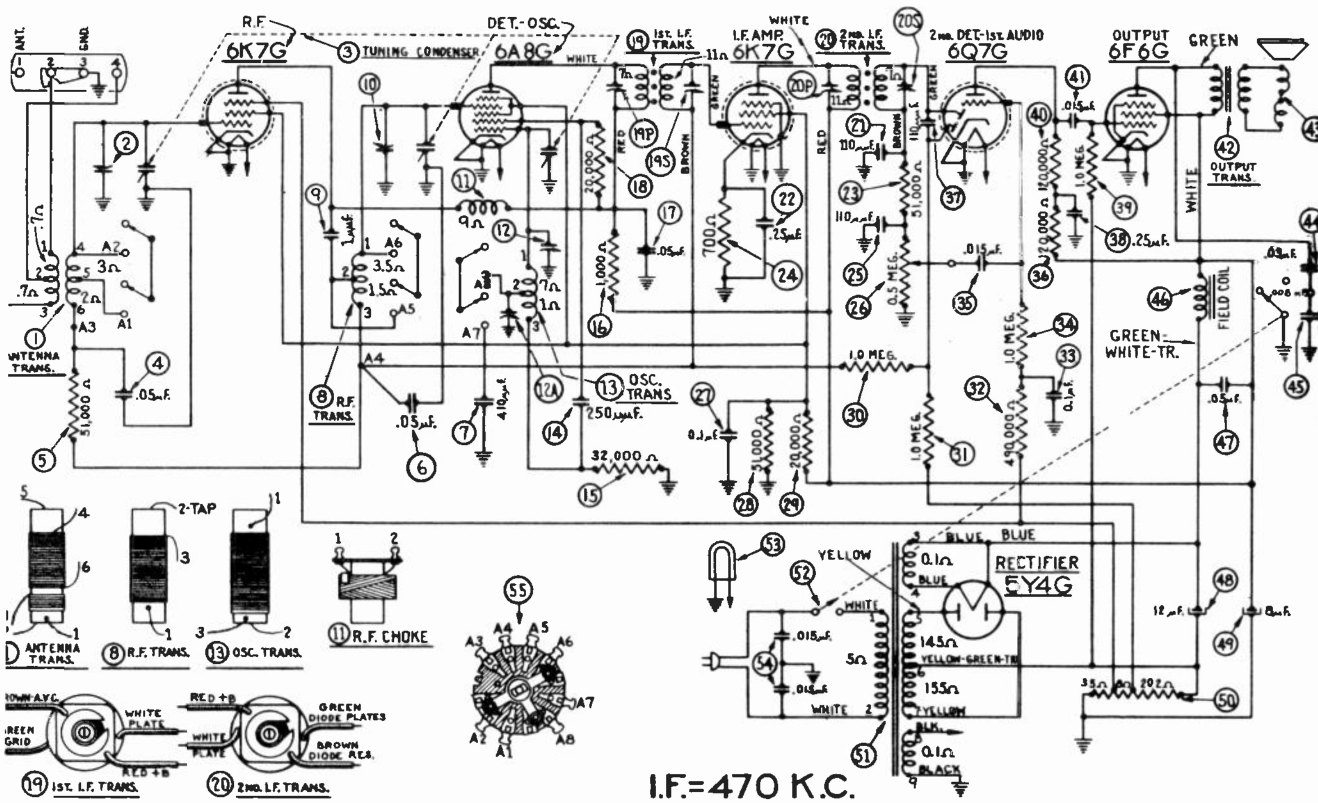
	1C6	34	30	32	30	19
Plate	130	130	...	45	130	130
Screen Grid	66	66	...	30	...	130
Osc. Plate	112	...	...	..	...	...

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 37-89



Replacement Parts—Model 37-89

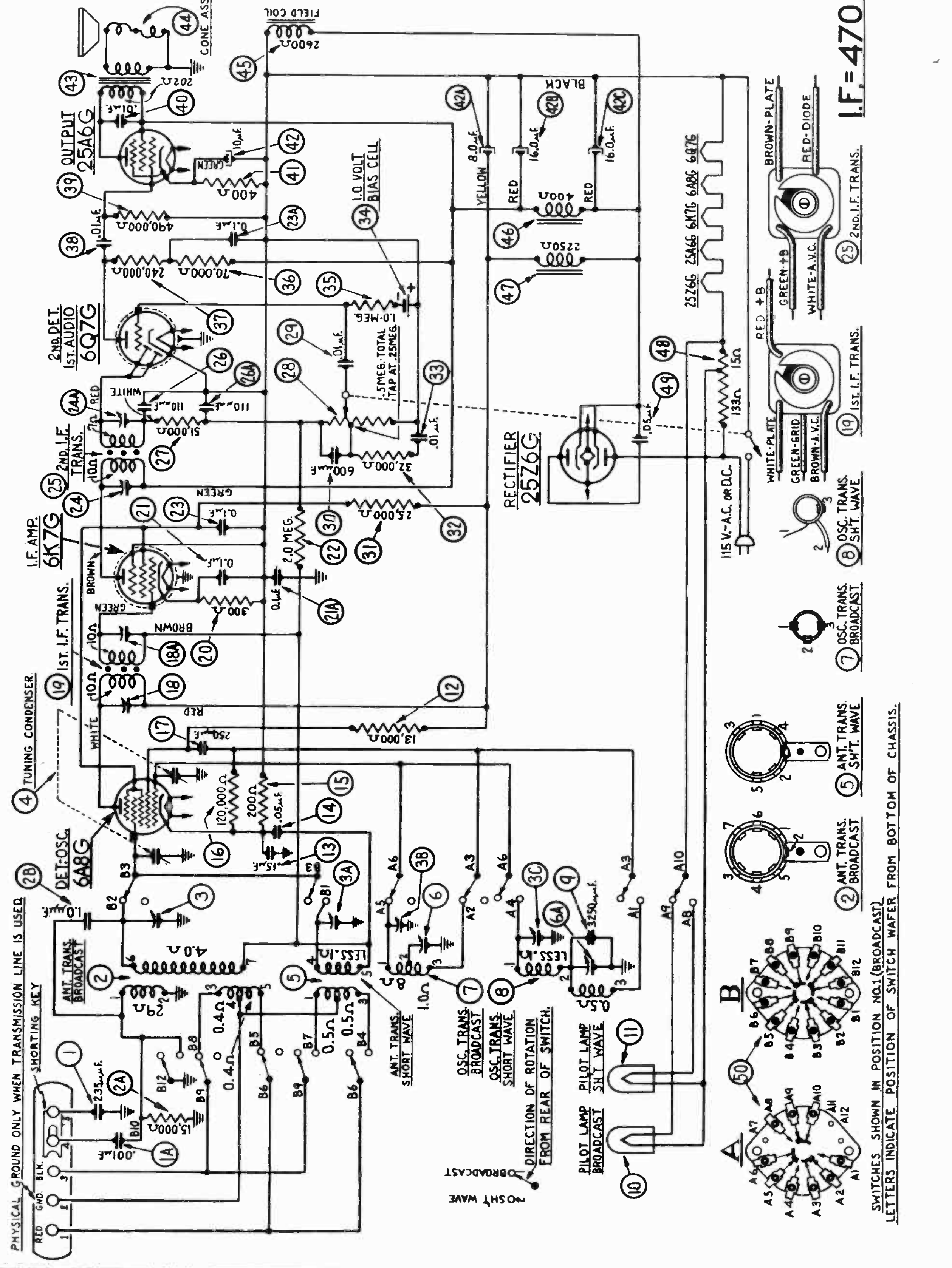
Schem. No.	Description	Part No.
1	Antenna Transformer	32-2127
2	Compensator	31-6100
3	Tuning Condenser	31-1833
4	Condenser (.05 mfd. tubular)	30-4020
5	Resistor (51000 ohms ½ watt)	33-351339
6	Condenser (.05 mfd. tubular)	30-4020
7	Condenser (410 mmfd.)	30-1000
8	R. F. Transformer	32-2128
9	Condenser Two Wires Twisted	
10	Compensator	31-6100
11	Choke	32-2139
12	Compensator	31-6101
13	Osc. Transformer	32-2120
14	Condenser (250 mmfd. mica)	30-1032
15	Resistor (32,000 ohms ½ watt)	33-351339
16	Resistor (1000 ohms, ½ watt)	33-210339
17	Condenser (.05 mfd. tubular)	30-4123
18	Resistor (20000 ohms, ½ watt)	33-320339
19	1st I. F. Transformer	32-2100
20	2nd I. F. Transformer	32-2102
21	Condenser (110 mmfd. mica)	30-1031
22	Condenser (.25 mfd. tubular)	30-4446
23	Resistor (51000 ohms, ½ watt)	33-351334
24	Resistor (700 ohm, ½ watt)	33-1220
25	Condenser (110 mmfd. mica)	30-1031
26	Volume Control	33-5157
27	Condenser (0.1 mfd. tubular)	30-4455
28	Resistor (51000 ohms, 1 watt)	33-351439
29	Resistor (20000 ohms, 2 watt)	33-320539
30	Resistor (1 meg. ½ watt)	33-510339
31	Resistor (1 meg. ½ watt)	33-510339
32	Resistor (490000 ohms ½ watt)	33-449339
33	Condenser (0.1 mfd. tubular)	30-4122
34	Resistor (1 megohm, ½ watt)	33-510339
35	Condenser (.015 mfd. tubular)	30-4358
36	Resistor (120000 ohms, ½ watt)	33-412339
37	Condenser (110 mmfd. mica)	30-1031
38	Condenser (.25 mfd. tubular)	30-4134
39	Resistor (1 megohm, ½ watt)	33-510339
40	Resistor (120000 ohms, ½ watt)	33-412339
41	Condenser (.015 mfd. tubular)	30-4226
42	Output Transformer	32-7019
43	Cone & Voice Coil	36-3157
44	Condenser (.03 mfd. bakelite)	8318-SU
45	Condenser (.006 mfd. tubular)	30-4112
46	Field Coil & Pot Assembly	36-3664
47	Condenser (.05 mfd. tubular)	30-4020
48	Electrolytic Condenser (12 mfd.)	30-2117
49	Electrolytic Condenser (8 mfd.)	30-2024
50	Bias Resistor (245 ohms, Taps 35 and 43 ohms)	33-3277
51	Power Transformer (115 volt, 50 to 60 cycle)	32-7583
52	Tone Control & A. C. Switch	42-1180
53	Pilot Lamp	34-2039
54	Condenser (.015, 015 mfd. bakelite)	3793-DG
55	Wave Switch	42-1194
	Dial	27-5204
	Dial Hub	28-7152
	Dial Clamp	28-2837
	Screen Bracket & Screen Assembly	31-1878
	Screw	W-650
	Vernier Drive	31-1844
	Pilot Lamp Assembly	38-7706
	Insulator Tone Control	27-8320
	Nut Tone Control	W-684
	Lock Washer	W-1624
	Volume Control Shaft	28-6498
	Shaft Spring	28-4117
	Washer	6717
	Washer	4436
	Shaft Retaining Clip	28-8610
	Mtg. Grommet	27-4317
	Mtg. Washer Sleeve	28-2257
	Mtg. Sleeve Bushing	27-8339
	Mtg. Screw	W-729
	Mtg. Washer	28-3927
	R. F. Unit Support	28-3856
	Support Locking Plate	28-3975
	Support Locking Plate	28-3889
	Screw	W-644
	Knob Tuning	27-4321
	Knob Volume, Waveswitch, Tone	27-4332
	Baffle Silk Assembly B, Cabinet	40-5935
	Baffle Silk Assembly F, Cabinet	40-5933
	Speaker S-16	36-1225
	Screw Speaker Mtg.	W-1604
	Lockwasher Speaker Mtg.	W-291
	Washer Speaker Mtg.	W-410
	Nut Speaker Mtg.	W-124
	Screw Chassis Mtg.	
	Washer Chassis Mtg.	28-2089
	Bezel Frame & Plate	40-5938
	Bezel Gasket	27-8311
	Bezel Glass	27-8298
	Bezel Ring	28-3967
	Bezel Screw	W-1644
	Bottom Shield Plate F, Cabinet	
	I. F. Coil Shield	38-7763
	Speaker 816 B, F Cabinets	36-1225

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 37-604



NATIONAL SCHOOLS
Los Angeles, California

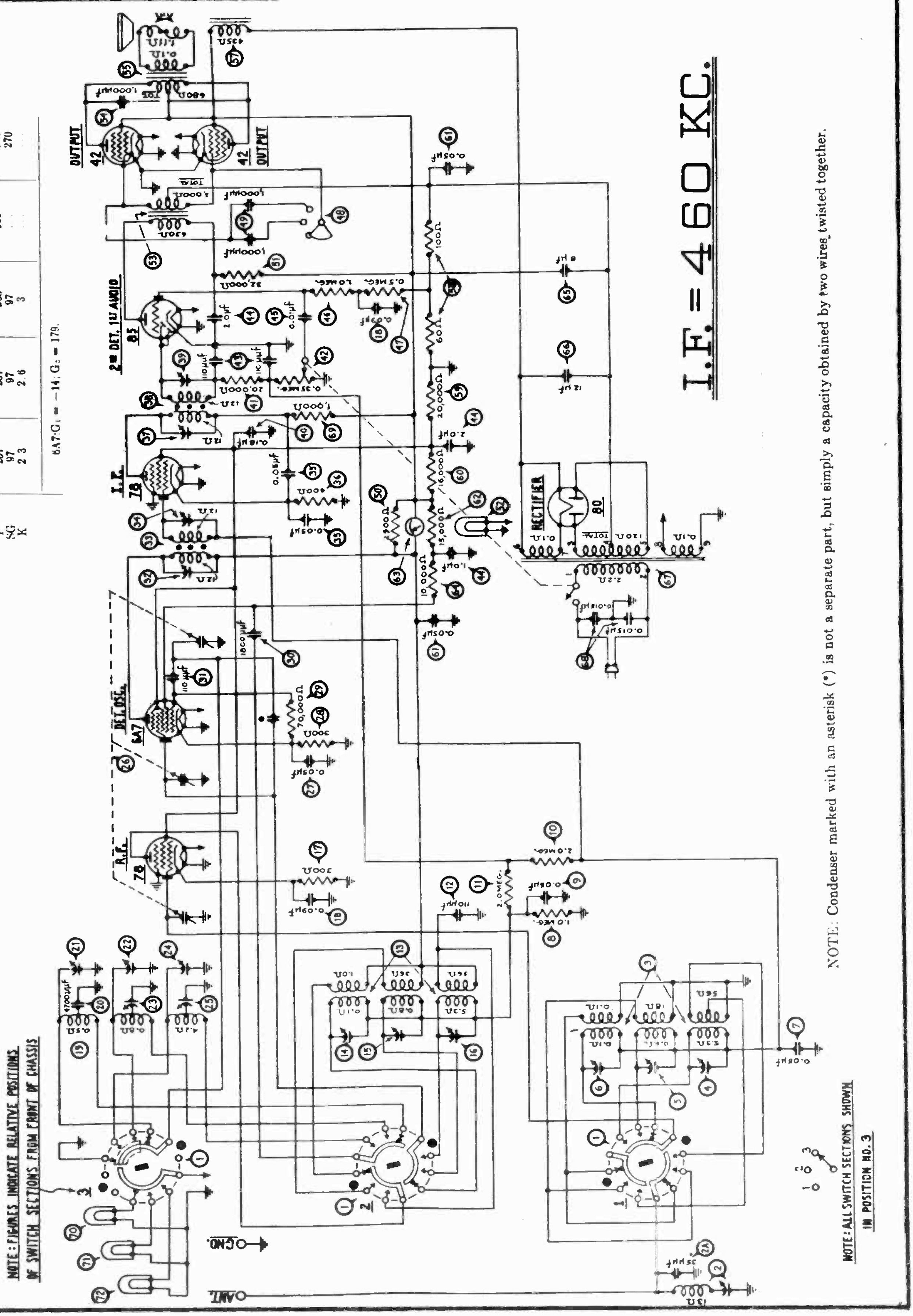
COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 97

Tube	78 R.F.	6A7 Det. Osc.	78 I.F.	85 2nd Det.	42 Output
Point					
P	257	257	265	105	260
SG	97	97	97		270
K	2 3	2.6	3		

6A7: G_1 = −14; G_2 = 179.

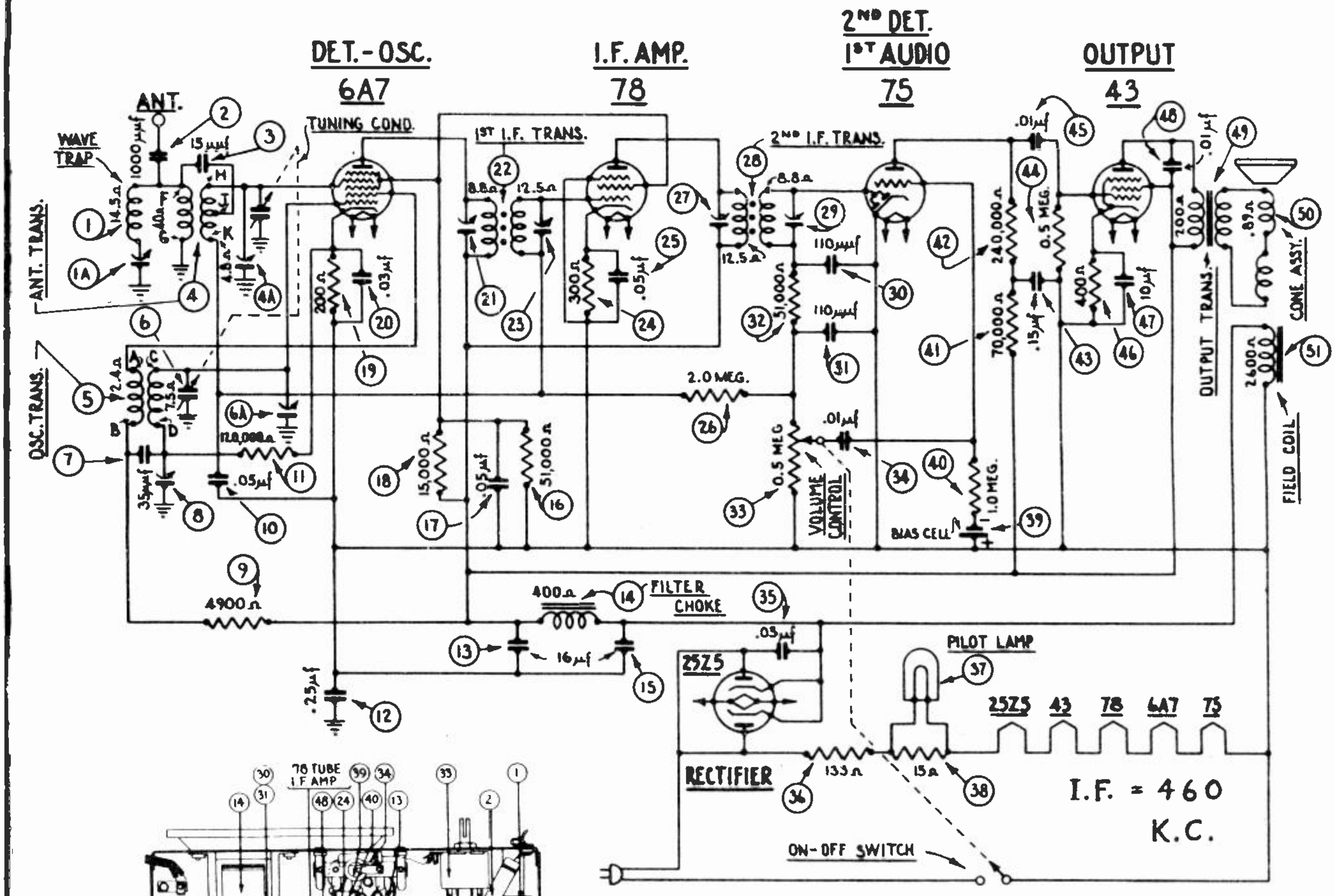


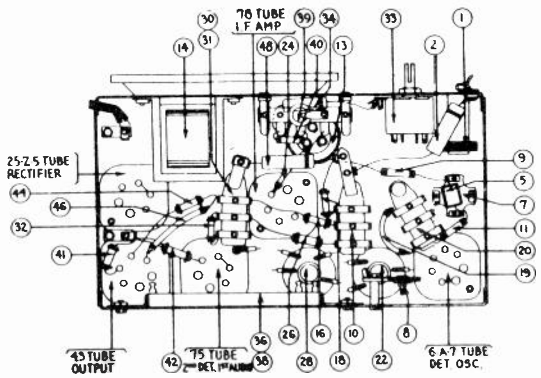
NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 602





Point	Tube→ 6A7	78	75	43	25Z5
F	6.3	6.3	6.3	25	25
P	102	102	40	97	. .
SG	47	47	. . .	102	. .
K	0.7	0.9	. . .	12.5	. . .
G2	94	. . .	. . .	. . .	. . .

Replacement Parts for Model 602

Schematic Number	Part and Description	Part No.
1	Wave Trap Coil	32-2007
1a	Wave Trap Compensator	04000D
2	Condenser (.001 Mf. Tubular)	30-4201
3	Condenser (15 mmf. Mica)	30-1030
4	Ant. Transformer	32-2003
4a	Compensater (Osc. 1800 KC.)	
5	Osc. Transformer	32-2041
6	Tuning Condenser	31-1794
6a	Compensater (Ant. 1800 KC.)	
7	Condenser (35 mmf. Mica)	30-1044
8	Compensator (Osc. Series) (600 Kc.)	04000S
9	Resistor (4900 ohm, ½ watt)	33-249333
10	Condenser (.05 Mf. Bakelite)	3615-OSU
11	Resistor (120,000, ½ watt)	33-412334
12	Condenser (.25-.05-.05-.05-.15-.01 mf)	30-4410
13	Elec. Condenser (16-16-10 mf.)	30-2148
14	Filter Choke	32-7544
15	Elec. Condenser (16 mf.)	Part of 13
16	Resistor (51,000 ohm, ¼ watt)	33-351143
17	Condenser (.05 mf.)	Part of 12
18	Resistor (15,000 ohm. ¼ watt)	33-315133
19	Resistor (200 ohm wirewound)	7217
20	Condenser (.03 mf. Bakelite)	8318-OSU
21	Compensator (1st I.F. Pri.)	Part of 22
22	1st I.F. Transformer	32-2005
23	Compensater (1st I.F. Sec.)	Part of 22
24	Resistor (300 ohm wirewound)	33-3010
25	Condenser (.05 mf.)	Part of 12
26	Resistor (2.0 meg., ¼ watt)	33-520143
27	Compensater (2nd I.F. Pri.)	Part of 28
28	2nd I.F. Transformer	32-2006
29	Compensator (2nd I.F. Sec.)	Part of 28
30	Condenser (.00011 mf. twin)	8035-ODU
31	Condenser (.00011 mf.)	Part of 30
32	Resistor (51,000 ohm. ¼ watt)	33-351143
33	Volume Control (0.5 meg.)	33-5145
34	Condenser (.01 mf. Tubular)	30-4145
35	Condenser (.05 mf.)	Part of 12
36	B. C. Resistor (133-15 ohm)	33-3225
37	Pilot Lamp	34-2068
38	Resistor (15 ohm)	Part of 36
39	Bias Cell	41-8009
40	Resistor (1.0 meg., ¼ watt)	33-510144
41	Resistor (70,000 ohm, ¼ watt)	33-370133
42	Resistor (240,000 ohm, ¼ watt)	33-424143
43	Condenser (.15 mf.)	Part of 12
44	Resistor (490,000 ohm, ¼ watt)	33-449143
45	Condenser (.01 mf.)	Part of 12
46	Resistor (400 ohm wirewound) (Flexible)	33-3122
47	Elec. Condenser (10 mf.)	Part of 13
48	Condenser (.01 mf. Tubular)	30-4169
49	Output Transformer	32-7566
50	Voice Coil Cone Assy	36-3029
51	Field Coil Assy	36-3040
	Volume Control Mtg. Nut	W-684-A
	B.C. Resistor Mtg. Screw	W-650-A
	B.C. Resistor Mtg. Nut	W-95-A
	Tube Shield Base	28-2725
	Tube Shield Body	28-2726
	Chassis Mtg. Screw	W-1587-A
	Chassis Mtg. Nut	W-124-A
	Chassis Mtg. Washer	W-410-A
	Chassis Mtg. Washer	W-291-A
	Speaker Baffle	40-5840
	Dial	27-5188
	Pointer	27-8236
	Shield Bottom Assy	29-3605
	Shield Bottom Insulator	27-8182
	Tube Socket (6-prong)	27-6036
	Tube Socket (7-prong)	27-6037
	Knob (Volume, On-Off)	27-4273
	Knob (Station Selector)	27-4302
	Elec. Condenser Support	6440
	Elec. Condenser Insulator	27-7836
	Pilot Lamp Bracket Assy	38-7513
	Ant. Coil Mfg. Bracket	28-3546
	Bias Cell Assy	38-7436
	Coupling (For Tuning Knob)	28-6426

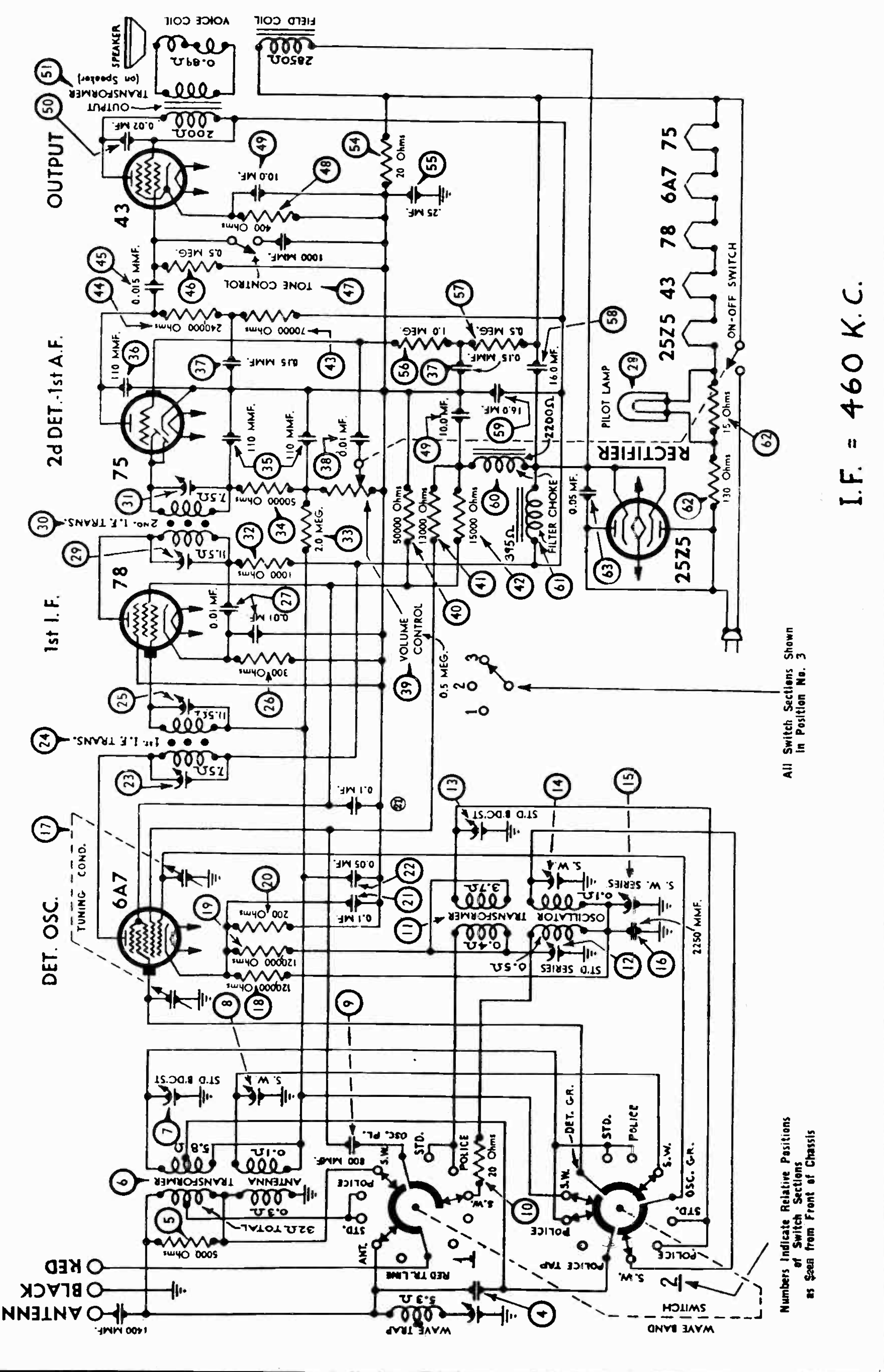
NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

Tube	6A7 Det. Osc.	78 I.F.	75 2nd Det. A.F.	43 Output	25Z5 Rect.
Point P	106	102	41	101	
SG	55	55		106	
K	0 8	1 1	0	12.5	121

MODEL 611
(A.C. - D.C.)



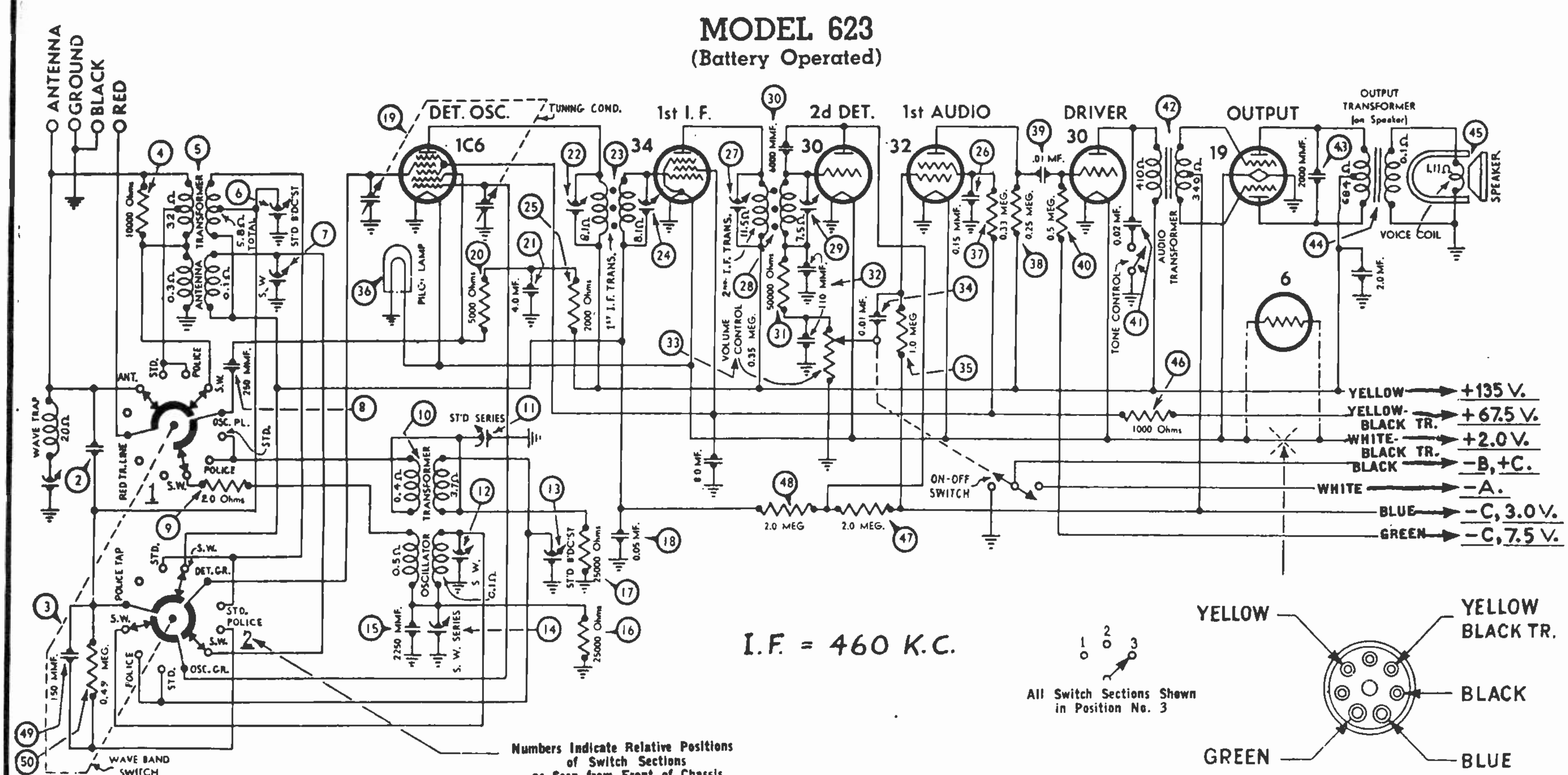
I.F. = 460 K.C.

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 623
(Battery Operated)



PRODUCTION CHANGES

The Oscillator Circuit was changed to series feed.

Part	Remove Old Part No.	Schematic	Add New Part No.
Condenser	30-1033 (.00015 mf.)	49	30-1049 (.0006 mf.)
Resistor	6097 (490,000 ohm)	50	
Resistor	33-1018 (25,000 ohm)	19	
Oscillator Trans.	32-1831	13	32-1973
Resistor	33-1206 (20 ohm)	9	
Condenser	6359 (.006 mf.)	50	30-1031 (.00011 mf.)

S. W. SECTION OF OSC. TRANSFORMER

Condenser 49 and Resistor 50 were removed and the wires connected to the ends of these parts were connected together. The wires between the police tap at the left of Switch Section No. 2 and the joint in the wire just above that was broken and Condenser No. 30-1049 inserted.

The connection between the bottom (S. W.) primary and secondary of the Oscillator Transformer was broken and condensers 14 and 15 connected between the bottom of the secondary and ground. Resistor 19 removed. The lead connected to the top of the primary disconnected and brought down to the bottom of the secondary. Resistor 9 also removed.

A lead from the bottom of the primary was connected to the lead running from Condenser 8 to Resistor 20. The oscillator plate wire was disconnected from this lead and brought down to the top of the primary.

BROADCAST AND POLICE SECTION OF OSC. TRANSFORMER

Resistor 17 was disconnected from the bottom of the upper section of the Osc. Transformer and connected to the switch side of the Condenser 8

Tube	1C6 Det.-Osc.	34 I.F.	30 2nd Det.-A.V.C.	32 1st A.F.	30 Driver	19 Output
Point P	135	135	0	52	133	134
SG	64	64	...	24	...	...
G	...	0.2	0.1	..	0.18	3.0 ea.
Osc. Pl.	106	...	...	..	...	...

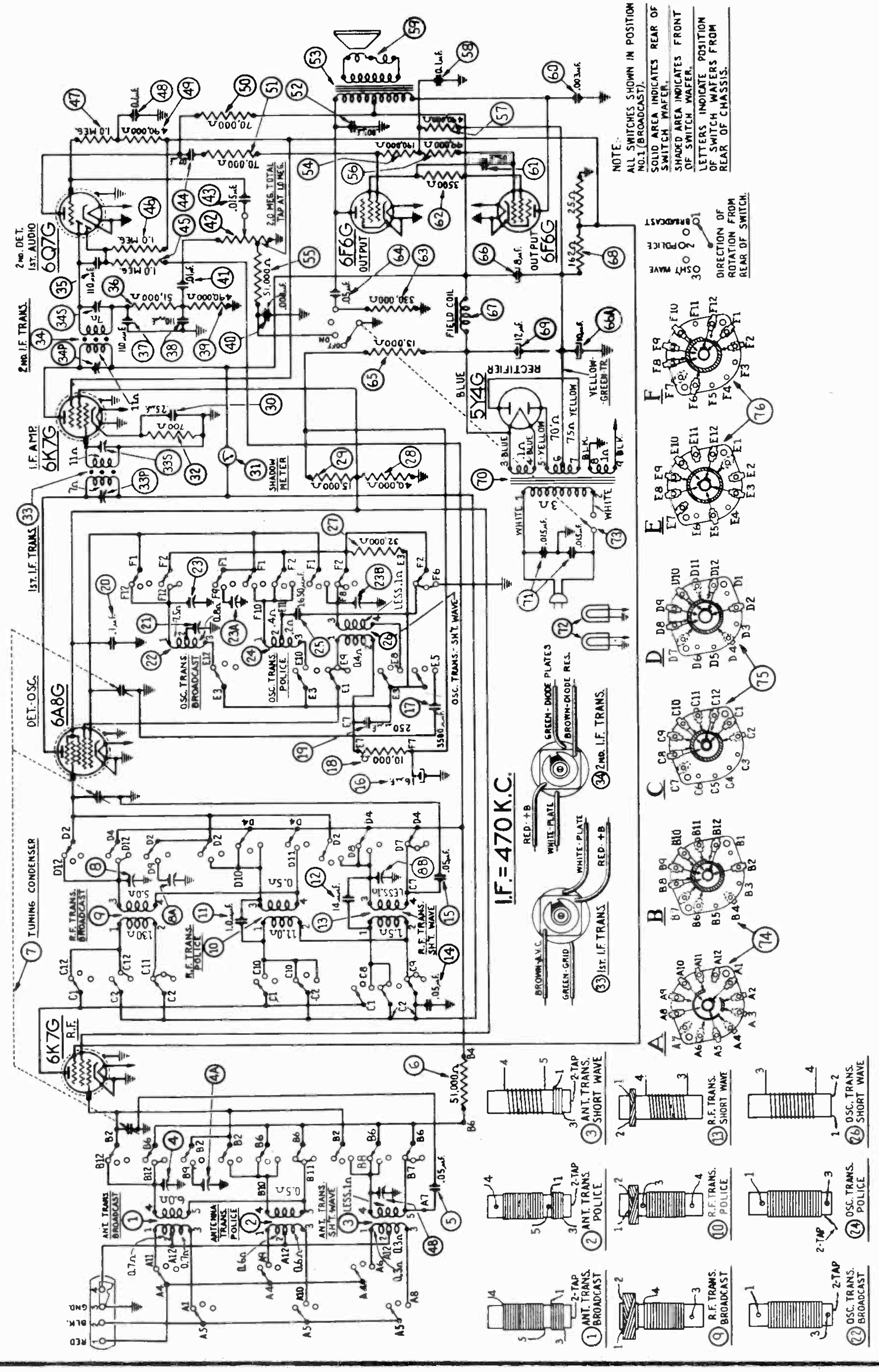
10,000 ohm Resistor, part 4, Part No. 33-1000, no longer necessary.

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 37-640

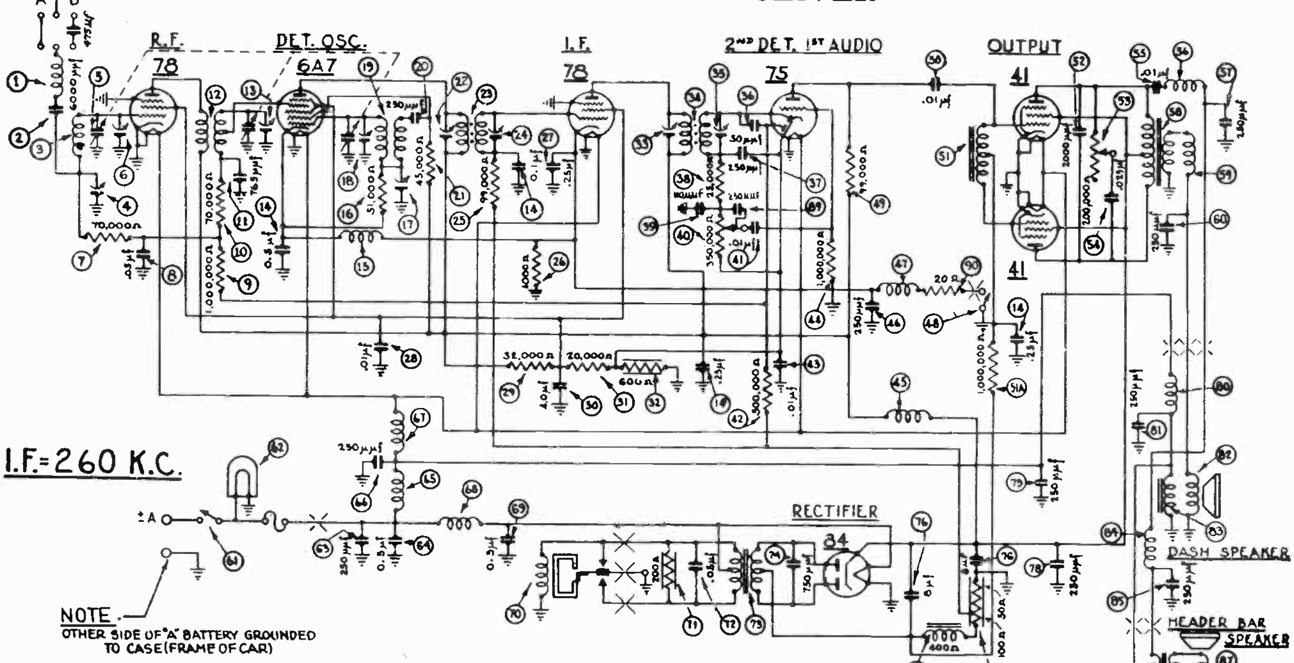


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

PHILCO

MODEL 819-819H RECEIVER



NOTE: When the Receiver is installed in a car having a top antenna, under-car antenna, spare wheel antenna or antenna having a similarly low relative capacitance (50 mmf. to 450 mmf.) use connector plug in "A".

When the Receiver is installed in a car having a metal insert top antenna, insulated door antenna, insulated trunk cover antenna or antenna having similarly high relative capacitance (450 mmf. to 2500 mmf.) use condenser plug in "B".

Figure 1

MODELS 819 AND 819H — PARTS LIST

No.	Description	Part No.
1	Antenna Choke	38-7516
2	Condenser (6000 mmfd.)	30-4125
3	Antenna Transformer	32-1984
4	Antenna Coupling Condenser	31-6082
5	Tuning Condenser	31-1769
6	First Padder (on tun. cond.)	....
7	Resistor (70,000 ohms)	33-370334
8	Condenser (.05 mfd.)	3615-OSG
9	Resistor (1,000,000 ohms)	33-510344
10	Resistor (70,000 ohms)	33-370334
11	Condenser (765 mmfd.)	30-1069
12	R. F. Transformer	32-1985
13	Second Padder (on tun. cond.)	....
14	Condenser (.1-.25-.25-.5 mfd.)	30-4415
15	Choke	32-2063
16	Resistor (51,000 ohms)	33-351344
17	Low Frequency Padder	31-6083
18	Third Padder (on tun. cond.)	....
19	Oscillator Transformer	32-1986
20	Condenser (250 mmfd.)	30-1032
21	Resistor (45,000 ohms)	33-345344
22	Padder (Pri. 1st I. F. Trans.)	....
23	First I. F. Transformer	32-2050
24	Padder (Sec. 1st I. F. Trans.)	....
25	Resistor (99,000 ohms)	33-399344
26	Resistor (1,000 ohms)	33-210334
27	Condenser (.25 mfd.)	30-4146
28	Condenser (.01 mfd.)	30-4124
29	Resistor (32,000 ohms)	33-332434
30	Condenser (4 mfd.)	30-2151
31	Resistor (20,000 ohms)	33-320334
32	Resistor (600 ohms)	33-1212
33	Padder (Pri. 2nd I. F. Trans.)	....
34	Second I. F. Transformer	32-2034
35	Padder (Sec. 2nd I. F. Trans.)	....
36	Condenser (50 mmfd.)	30-1029
37	Condenser (250 mmfd.)	30-1032
38	Resistor (25,000 ohms)	33-325344
39	Condenser (110 mmfd.)	30-1031
40	Volume Control (350,000 ohms)	33-5149
41	Condenser (.01 mfd.)	3903-OSU
42	Resistor (500,000 ohms)	33-449344
43	Condenser (.01 mfd.)	3903-OSG
44	Resistor (1,000,000 ohms)	33-510344
45	"B" Choke	32-1281
46	Condenser (250 mmfd.)	30-1032
47	Choke	32-2063
48	Local-Distance Switch	42-1160
49	Resistor (99,000 ohms)	33-399344
50	Condenser (.01 mfd.)	3903-OSU
51	Audio Choke	32-7547
51a	Resistor (1,000,000 ohms)	33-510344
52	Condenser (2000 mmfd.)	30-4177
53	Tone Control (200,000 ohms)	33-5150
54	Condenser (.025 mfd.)	7653-OSU
55	Condenser (.01 mfd.)	30-4381
56	Choke	32-1930
57	Condenser (250 mmfd.)	30-1032
58	Output Transformer	32-7551
59	Choke	32-1930
60	Condenser (250 mmfd.)	30-1032
61	On-Off Switch Assembly	42-1160
62	Pilot Lamp	34-2039
63	Condenser (250 mmfd.)	30-1032
64	Condenser (.5 mfd.)	30-4015
65	"A" Choke	32-1432
66	Condenser (250 mmfd.)	30-1032
67	Filament Choke	32-2038
68	Vibrator Choke	32-2039
69	Condenser (.5 mfd.)	30-4015
70	Vibrator	41-3170D
71	Resistor (200 ohms)	33-1210
72	Condenser (.05 mfd.)	30-4020
73	Power Transformer	32-7550
74	Condenser (750 mmfd.)	30-4420
75	Filter Choke	32-7545
76	Filter Condenser (8-8 mfd.)	30-2152
77	Resistor (100-50 ohms)	33-3238
78	Condenser (250 mmfd.)	30-1032
79	Condenser (250 mmfd.)	30-1032
80	Choke	32-1644
81	Condenser (250 mmfd.)	30-1032
82	Cone and Voice Coil	36-3159
83	Field Coil Assembly	36-3513
84	Choke	32-2038
85	Condenser (250 mmfd.)	30-1032
86	Output Transformer (overhead speaker)	32-7507
87	Cone and Voice Coil (overhead speaker)	36-3526
88	Field Coil Assembly (Overhead Speaker)	32-9236
89	Condenser (250 mmfd.)	30-1032
90	Resistor (20 ohms)	33-020133
	Four Prong Socket	27-6044
	Five Prong Socket	27-6035
	Six Prong Socket	27-6036
	Seven Prong Socket	27-6037
	Idler Gear	28-7176

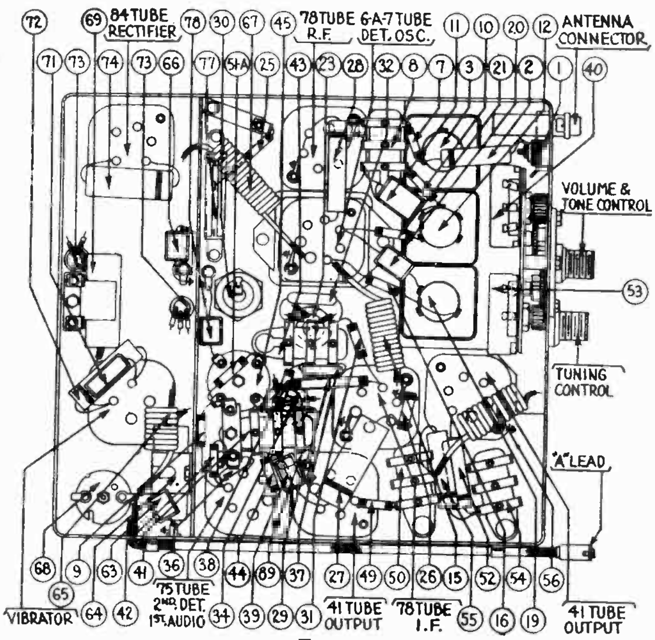


Figure 2

No.	Description	Part No.
	Pinion Gear	28-7178
	Dash Speaker Complete (A37)	36-1207
	Dash Speaker Only	36-1212
	Overhead Speaker (AD)	36-1211
	Control	42-5537
	Pilot Lamp Assembly	38-7213
	Tuning and Volume Knob	27-4288
	Tuning Shaft	28-8495
	Volume Shaft	28-8499
	Scale Assembly	42-5539

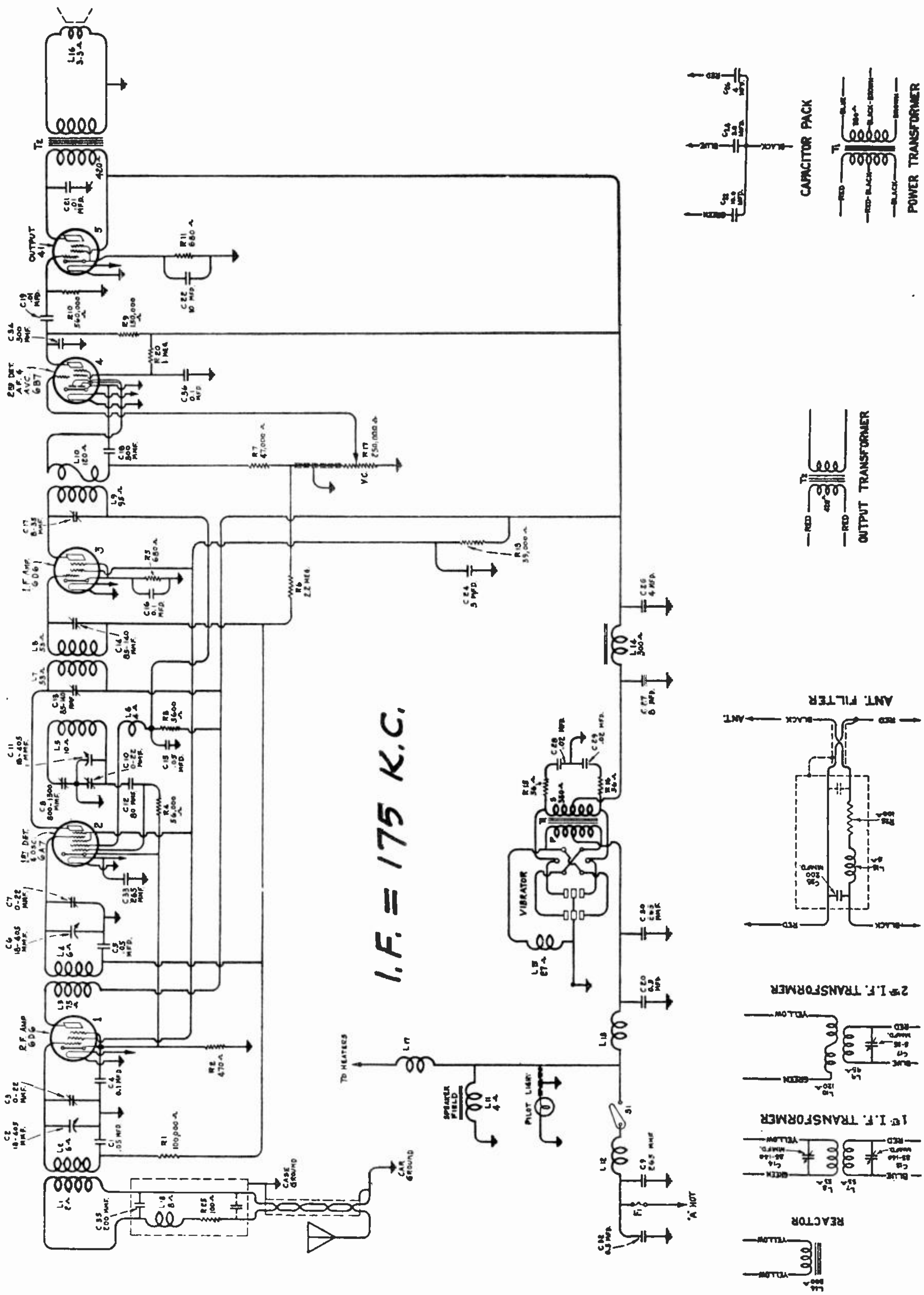
No.	Description	Part No.
	Distributor Resistor	33-1196
	Interference Condenser (.5 mfd.)	30-4007
	Condenser Connector	30-4412
	Connector Plug	29-6423
	Fuse	7227
	Fuse Insulator	27-7729
	"Tee" Bolt (Rec. Mtg.)	28-6161
	Nut (Rec. Mtg.)	W518A
	Stud (Speaker Mtg.)	6122
	Nut (Speaker Mtg.)	W55A

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODEL D-50



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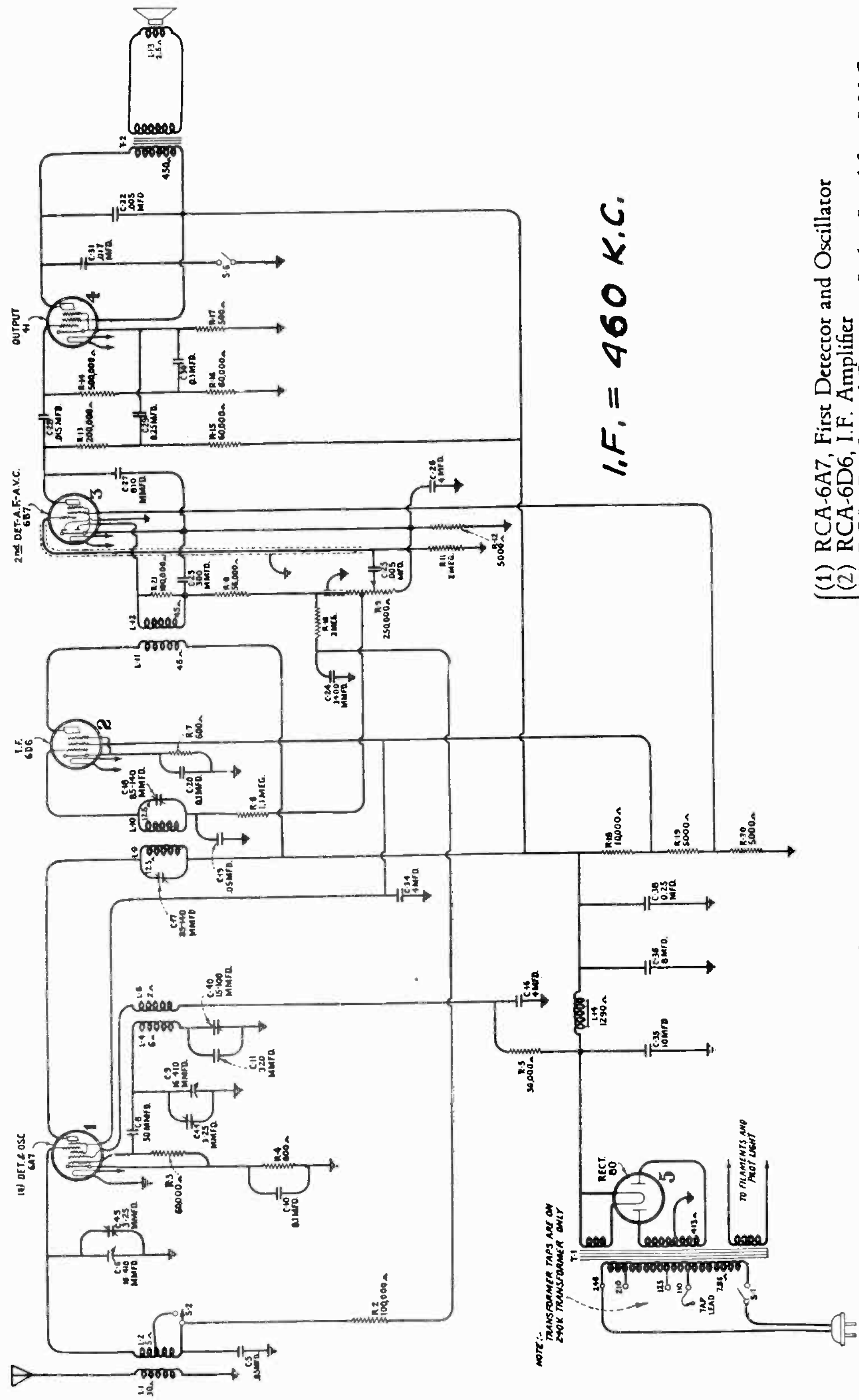
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODEL M-52



I.F. = 460 K.C.

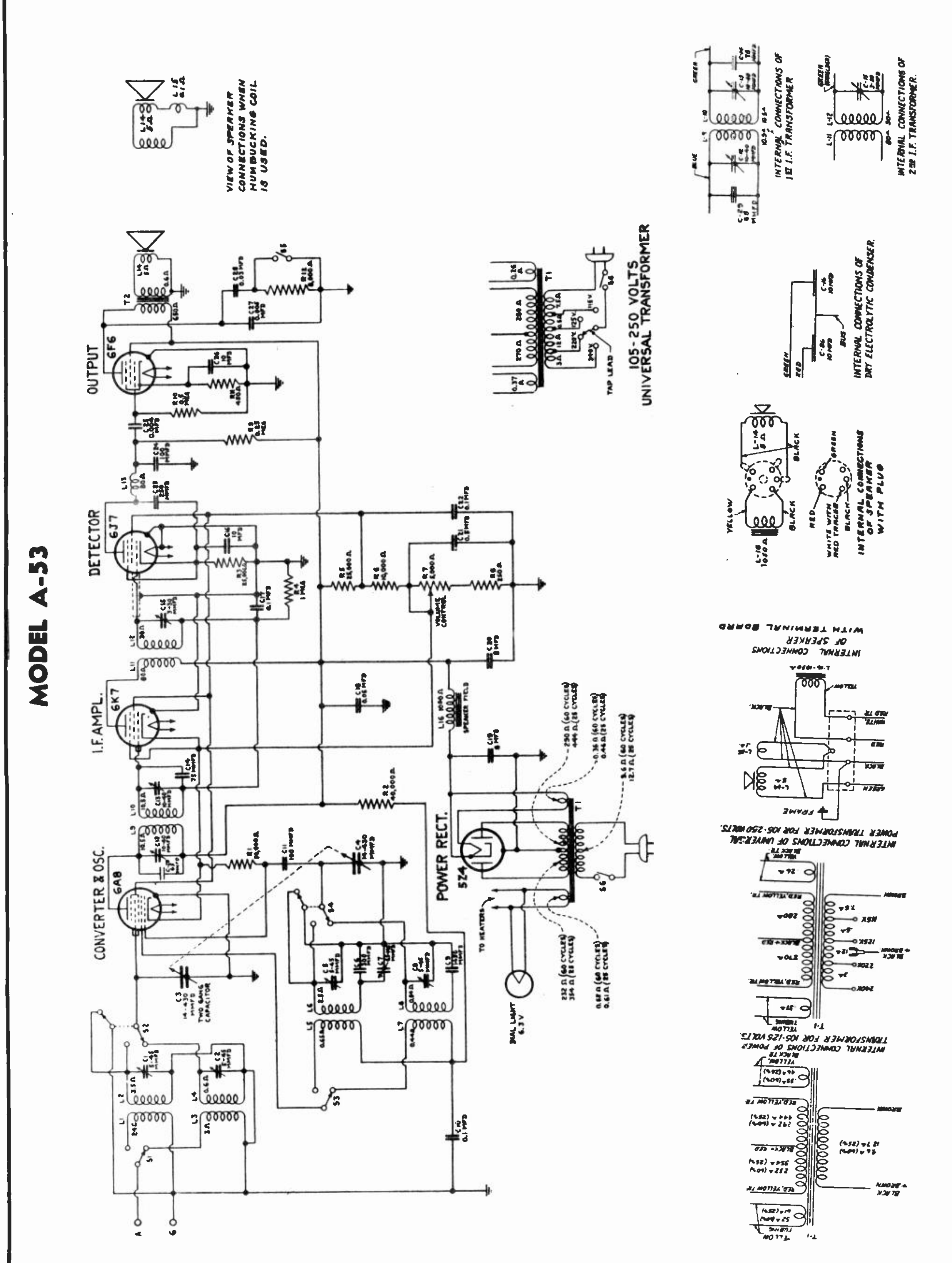
Radiotrons and Functions
(1) RCA-6A7, First Detector and Oscillator
(2) RCA-6D6, I.F. Amplifier
(3) RCA-6B7, Second Detector–Audio Amplifier–A.V.C.
(4) RCA-41, Power Output
(5) RCA-80, Rectifier

Tuning Frequency Ranges .... 540 KC. to 1720 KC. and 1600 KC. to 3500 KC.
Alignment Frequencies .... 460 KC. (I.F.), 1720 KC. (R.F. and Oscillator) 600 KC. (Oscillator)
Undistorted Output .... 1.75 Watts
Maximum Output .... 3.5 Watts
Loudspeaker .... 6-Inch, Electro-Dynamic

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC



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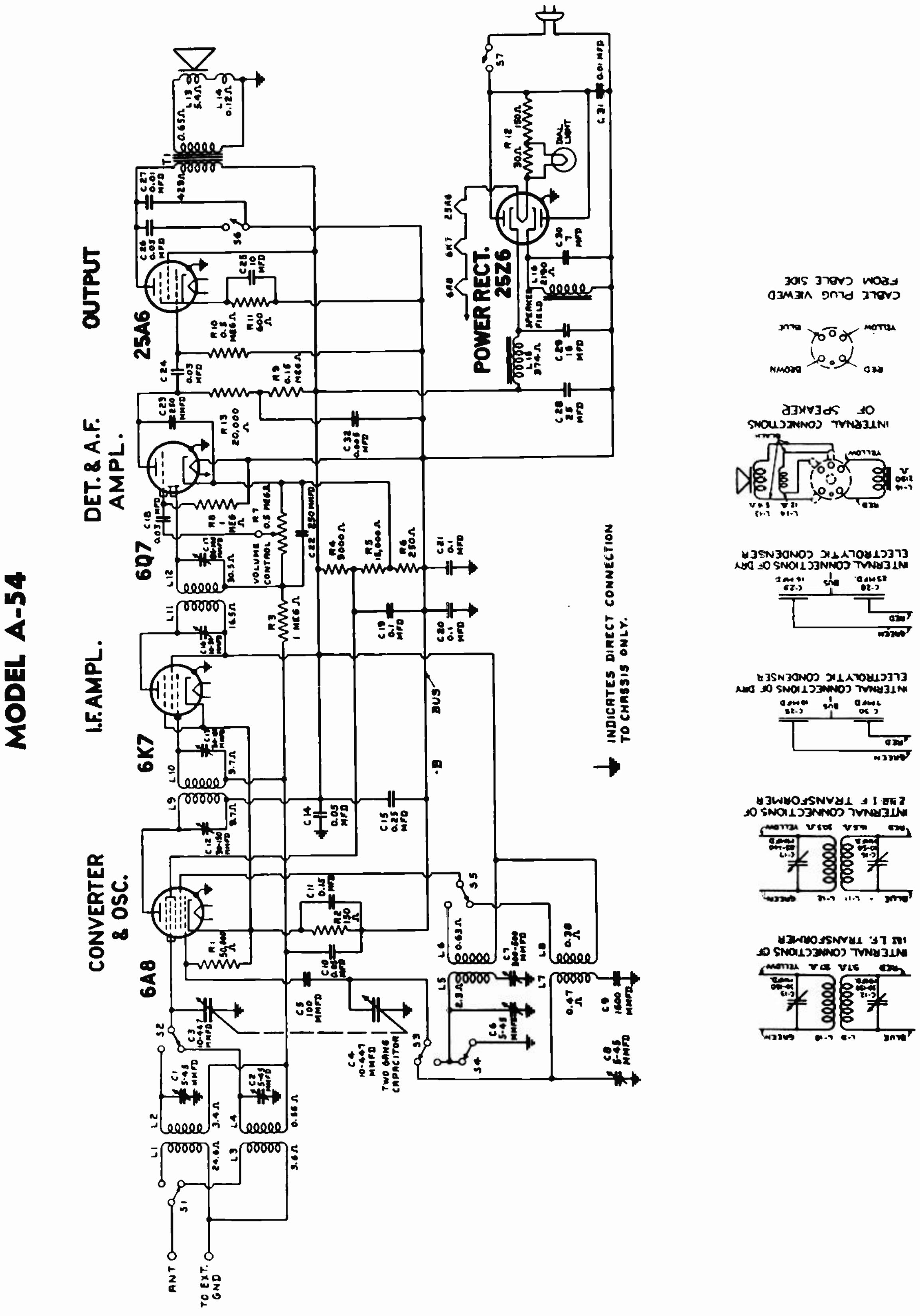
COMMERCIAL CIRCUIT DIAGRAM

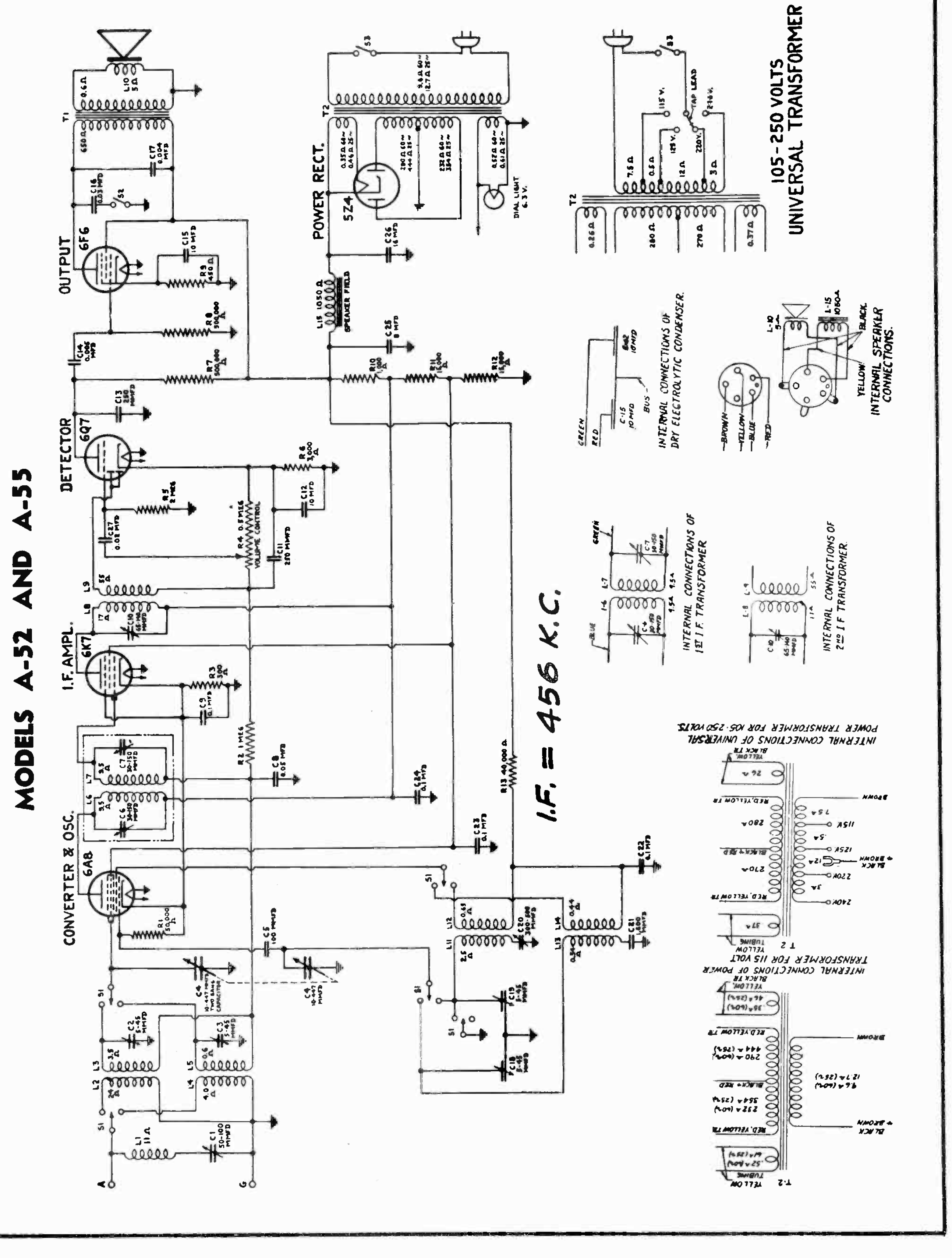
GENERAL ELECTRIC



NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC



NATIONAL SCHOOLS
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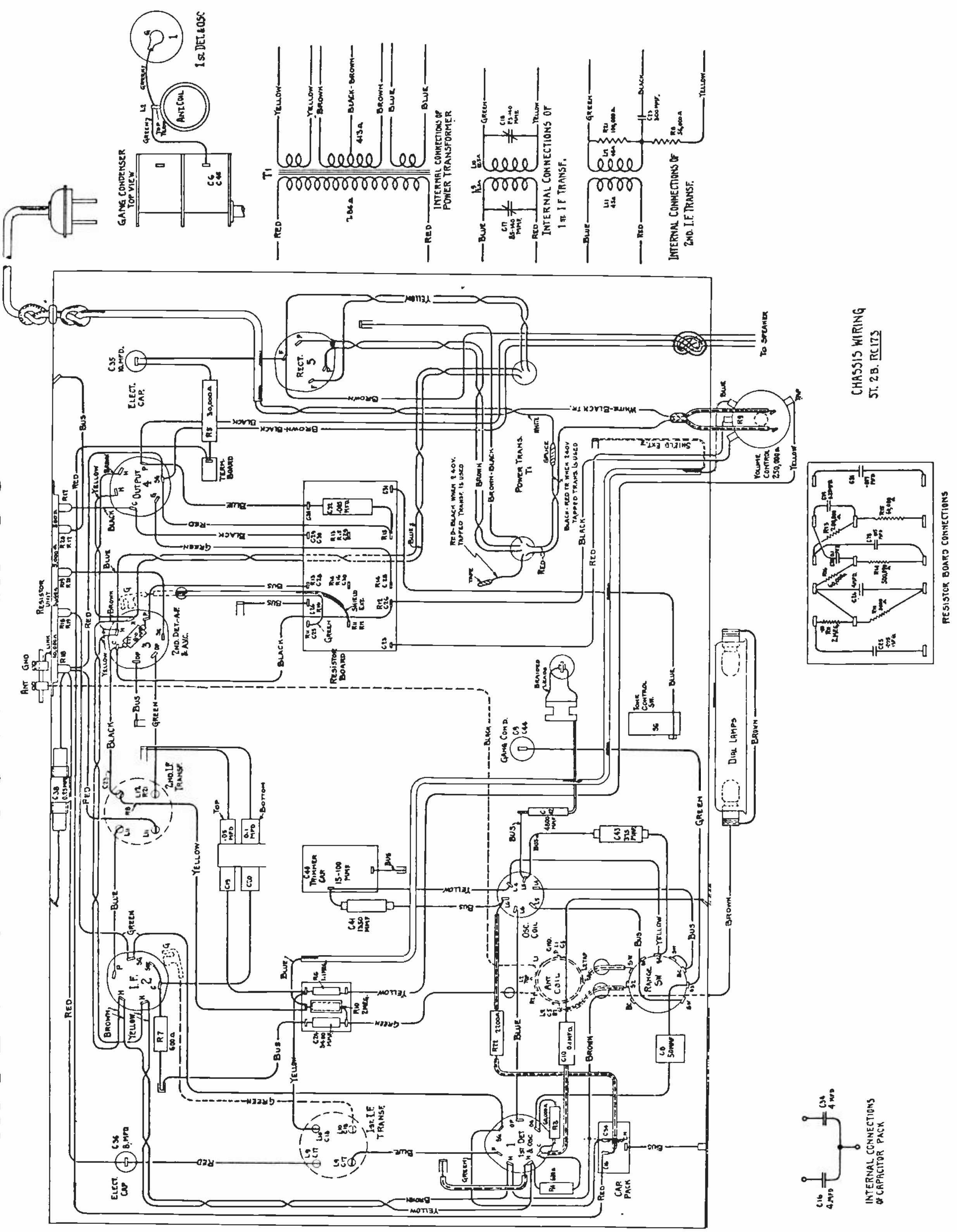
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODELS M-50 AND M-55



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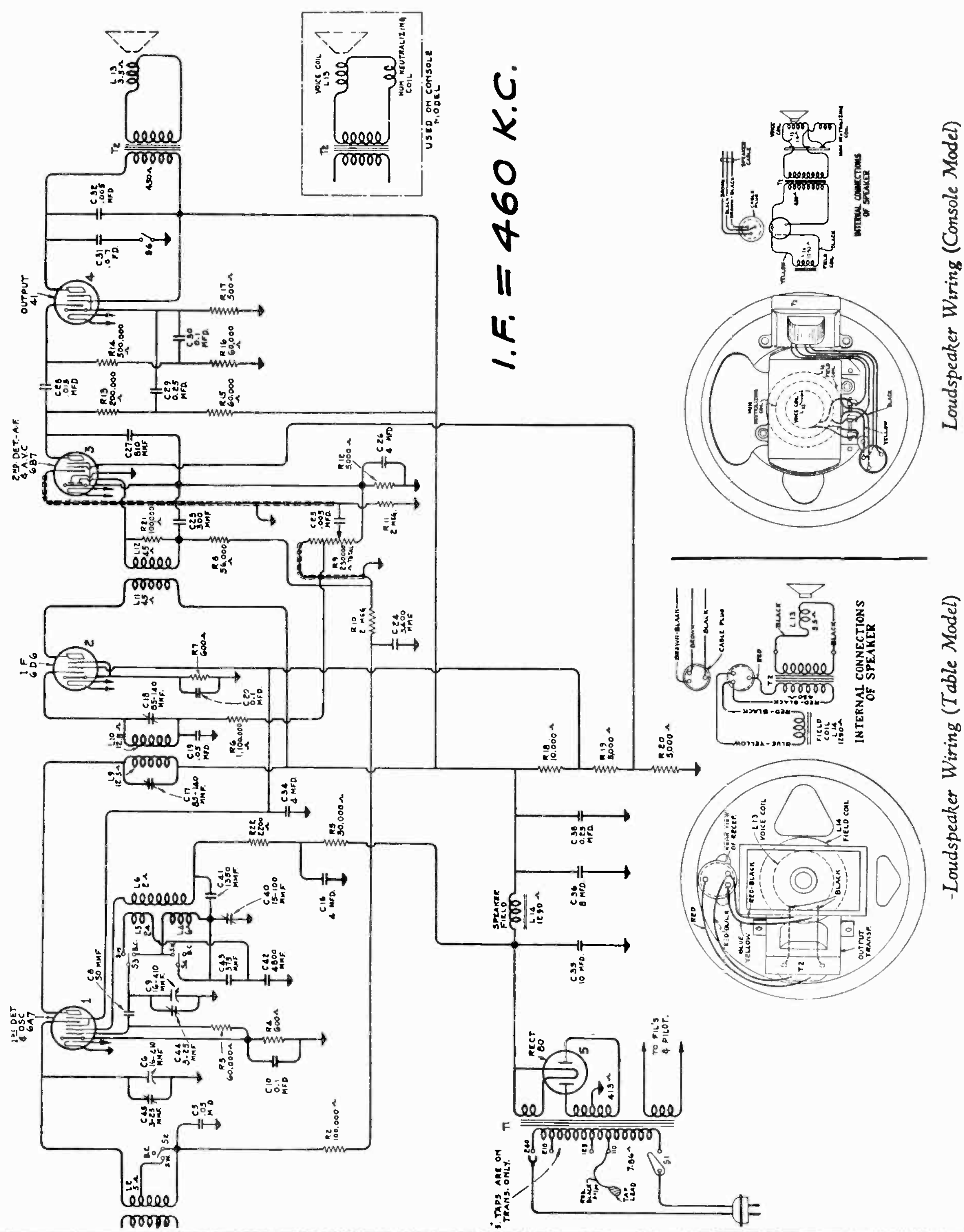
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

GENERAL ELECTRIC CO.

MODELS M-50 AND M-55

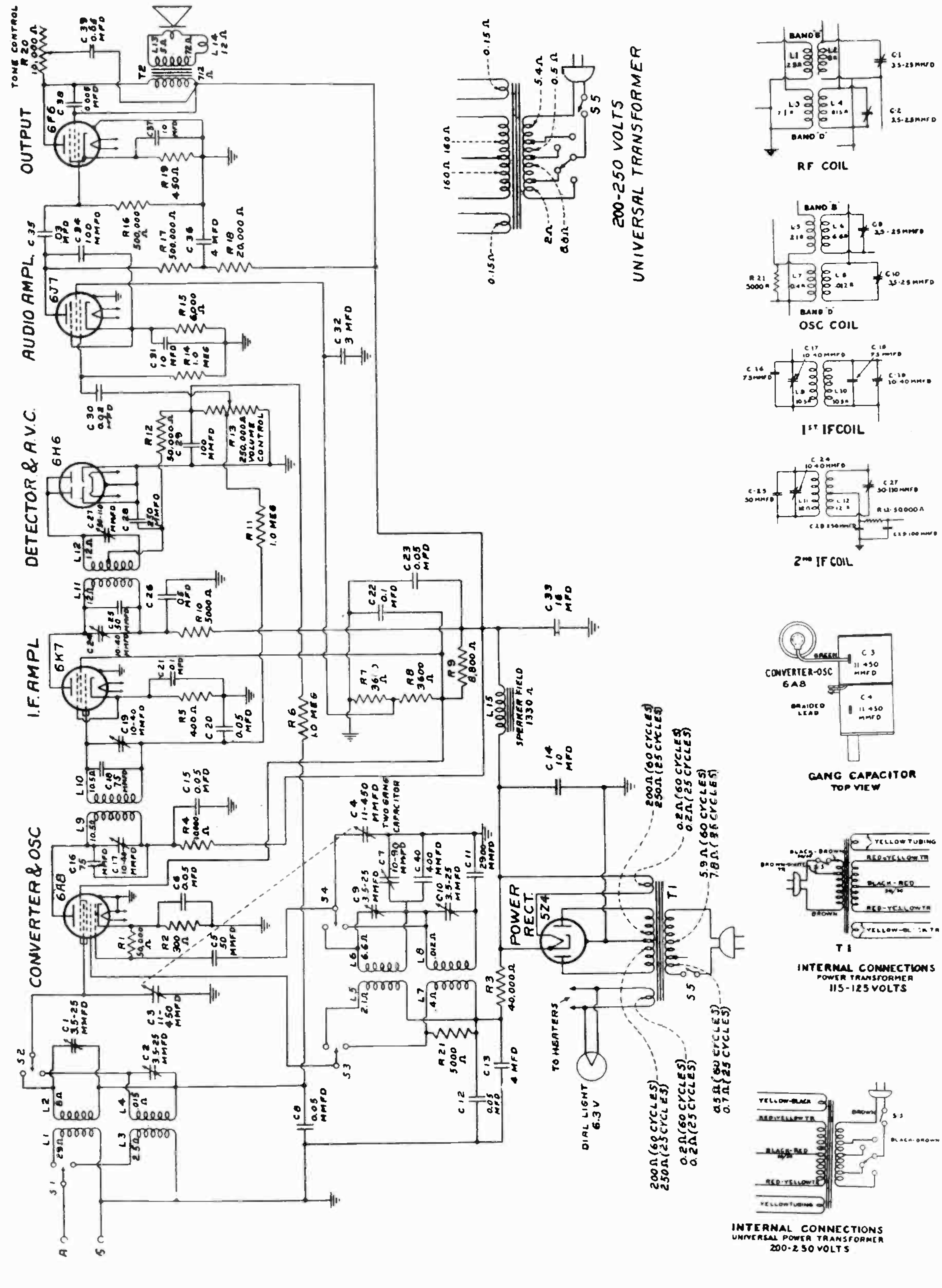


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODELS A-64 AND A-67



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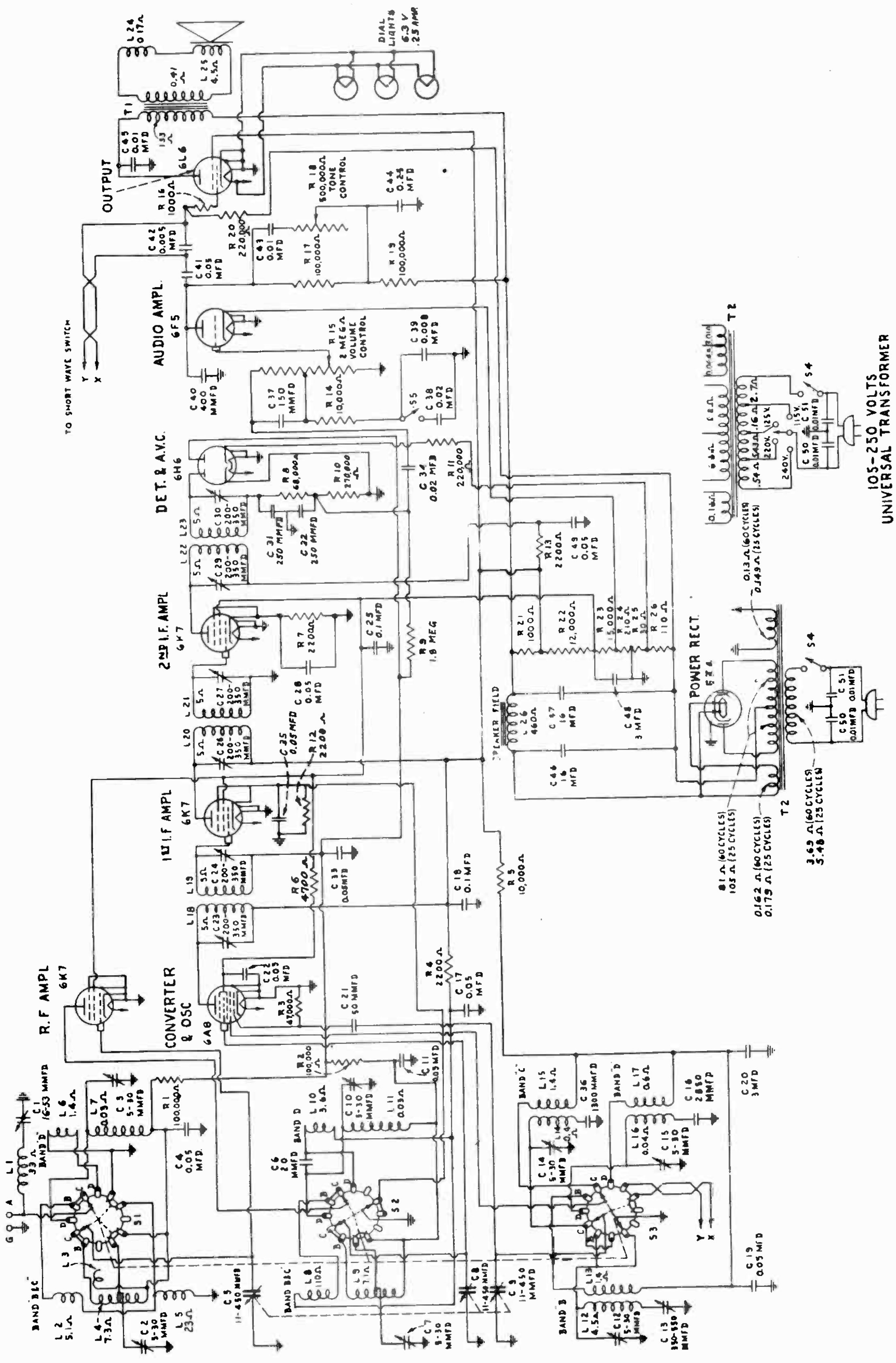
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

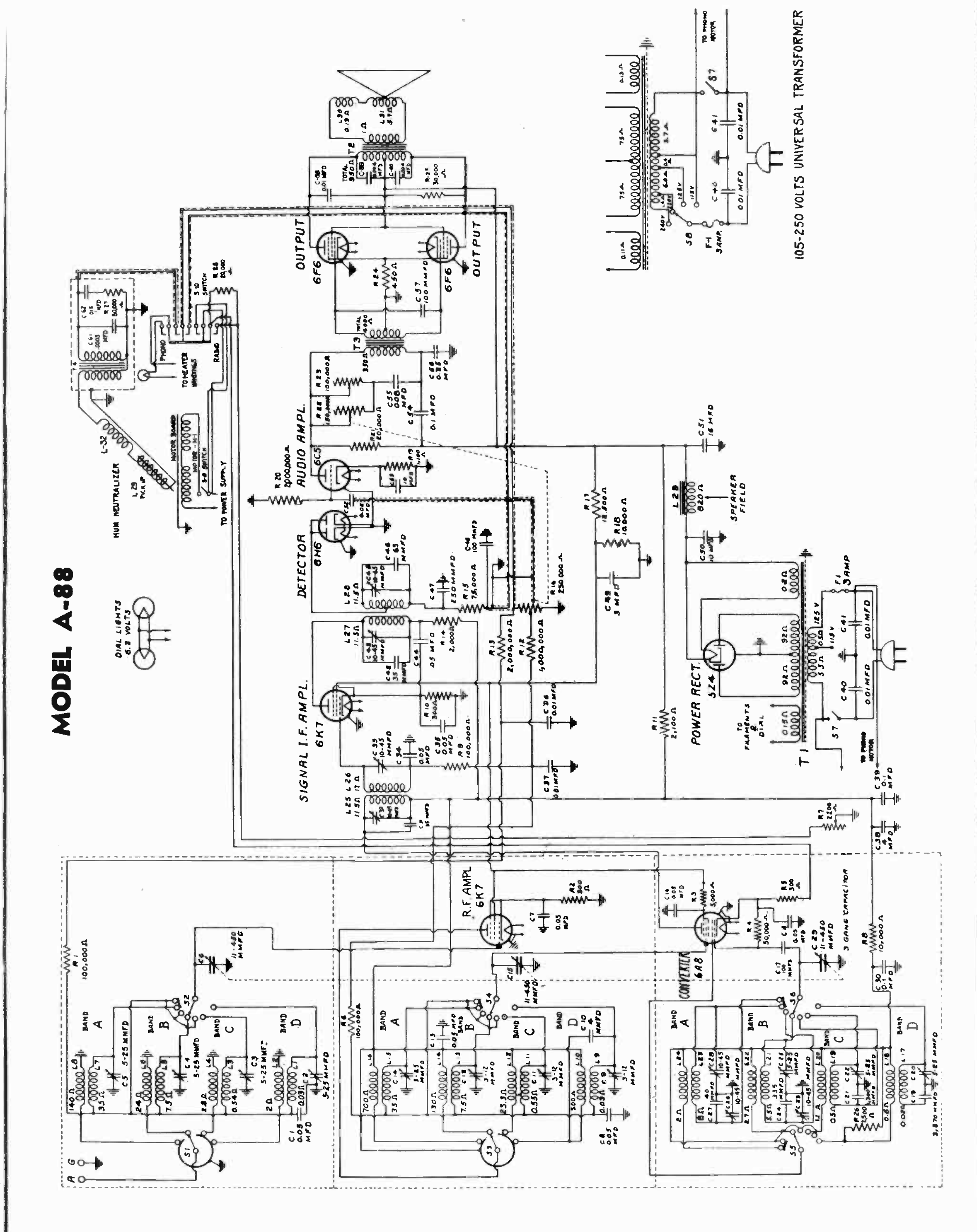
MODELS E-81 AND E-86



NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC



NATIONAL SCHOOLS

RADIO DIVISION

4000 South Figueroa St. · Los Angeles, California

Special Examination # 4

Dear Student:

You are progressing splendidly with your studies and it is indeed most pleasing to me to see you take such a complete interest in your work. From now on, your studies are going to become more technical and it may require a little harder study for you to master them. However, you must bear in mind that this advanced type of study is most necessary in order that you may prepare yourself for the BETTER JOBS which the Radio industry has to offer you.

It is now time for another special examination. This particular examination is based solely upon Lessons #28 to #36 inclusive and so before commencing to answer the following group of questions, I suggest that you first review these last nine lessons carefully, so that you will be sure to have a perfect understanding of everything which has been explained in them.

I am certain that you will find this examination to be interesting, as well as instructive and that you will do your best to receive a splendid grade upon it.

answered

Sincerely yours,

J. A. Rosenkranz

President

EXAMINATION QUESTIONS

1. – Draw a diagram of a typical automatic volume control circuit, using a separate A.V.C. tube and explain how it operates.

2. – Why is it that receivers employing an automatic volume control system have a tendency to amplify back ground noise considerably when tuned to some point between stations?

3. – Draw a circuit diagram of an automatic noise suppression circuit, showing how it is used in conjunction with an automatic volume control system of a receiver.

4. – Explain the operation of the circuit which you have drawn in answer to question #3.

(over)

5. — ILLUSTRATE BY MEANS OF A DIAGRAM HOW A TYPE 2A6 TUBE CAN BE USED IN A SUPERHETERODYNE RECEIVER SO AS TO FUNCTION SIMULTANEOUSLY AS A SECOND DETECTOR, A.F. AMPLIFIER AND AN A.V.C. TUBE.

6. — WHEN USING A DUPLEX-DIODE TRIODE TUBE SO THAT IT WILL FUNCTION AS A HALF-WAVE DETECTOR, HOW WILL THE AMOUNT OF ITS RECTIFIED SIGNAL VOLTAGE COMPARE WITH THAT OBTAINED WHEN THIS SAME TUBE IS USED IN A FULL-WAVE DETECTOR ARRANGEMENT?

7. — EXPLAIN THE MECHANISM AND OPERATION OF THE SHADOW-TUNING INSTRUMENT.

8. — SHOW BY MEANS OF A DIAGRAM HOW IN A SERIES STORAGE BATTERY CHARGING CIRCUIT THE RATE OF CHARGE THROUGH ONE OF THE BATTERIES CAN BE REDUCED WITHOUT REDUCING THE RATE OF CHARGE THROUGH THE OTHER BATTERIES OF THE CIRCUIT.

9. — DRAW A CIRCUIT DIAGRAM SHOWING HOW A PHONOGRAPH PICK-UP UNIT CAN BE CONNECTED TO THE GRID CIRCUIT OF A RECEIVER'S DETECTOR STAGE.

10.— DRAW A CIRCUIT DIAGRAM SHOWING HOW A PHONOGRAPH PICK-UP UNIT CAN BE CONNECTED TO THE SECOND DETECTOR OF A SUPHETERODYNE RECEIVER IN WHICH A TYPE 2A6 TUBE IS EMPLOYED.

11.— DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES A TONE-CONTROL CIRCUIT.

12.— WHAT IS AN IMPORTANT ADVANTAGE OF CONTROLLING REGENERATION IN SHORT WAVE RECEIVERS THROUGH VARIATION OF THE DETECTOR TUBE'S SCREEN-GRID POSITIVE POTENTIAL.

13.— EXPLAIN HOW YOU WOULD TEST A LEAD-ACID STORAGE BATTERY BY MEANS OF THE CADIMUM TEST.

14.— HOW DOES THE EDISON STORAGE CELL DIFFER FROM THE LEAD-ACID TYPE STORAGE CELL?

15.— EXPLAIN THE "SKIP-DISTANCE" PHENOMENA AS EXPERIENCED WITH SHORT-WAVE RECEPTION.

16.— DESCRIBE BRIEFLY HOW A RECEIVER DESIGNED FOR 110 VOLT D.C. OPERATION DIFFERS FROM A RECEIVER DESIGNED FOR 110 VOLT A.C. OPERATION.

17.— HOW DOES A 110 VOLT A.C. RECEIVER DIFFER FROM A 220 VOLT A.C. RECEIVER?

18.— DESCRIBE BRIEFLY ANY ONE UNIVERSAL RECEIVER CIRCUIT.

19.— DESCRIBE THE 25Z5 TUBE AND EXPLAIN HOW IT MAY BE USED.

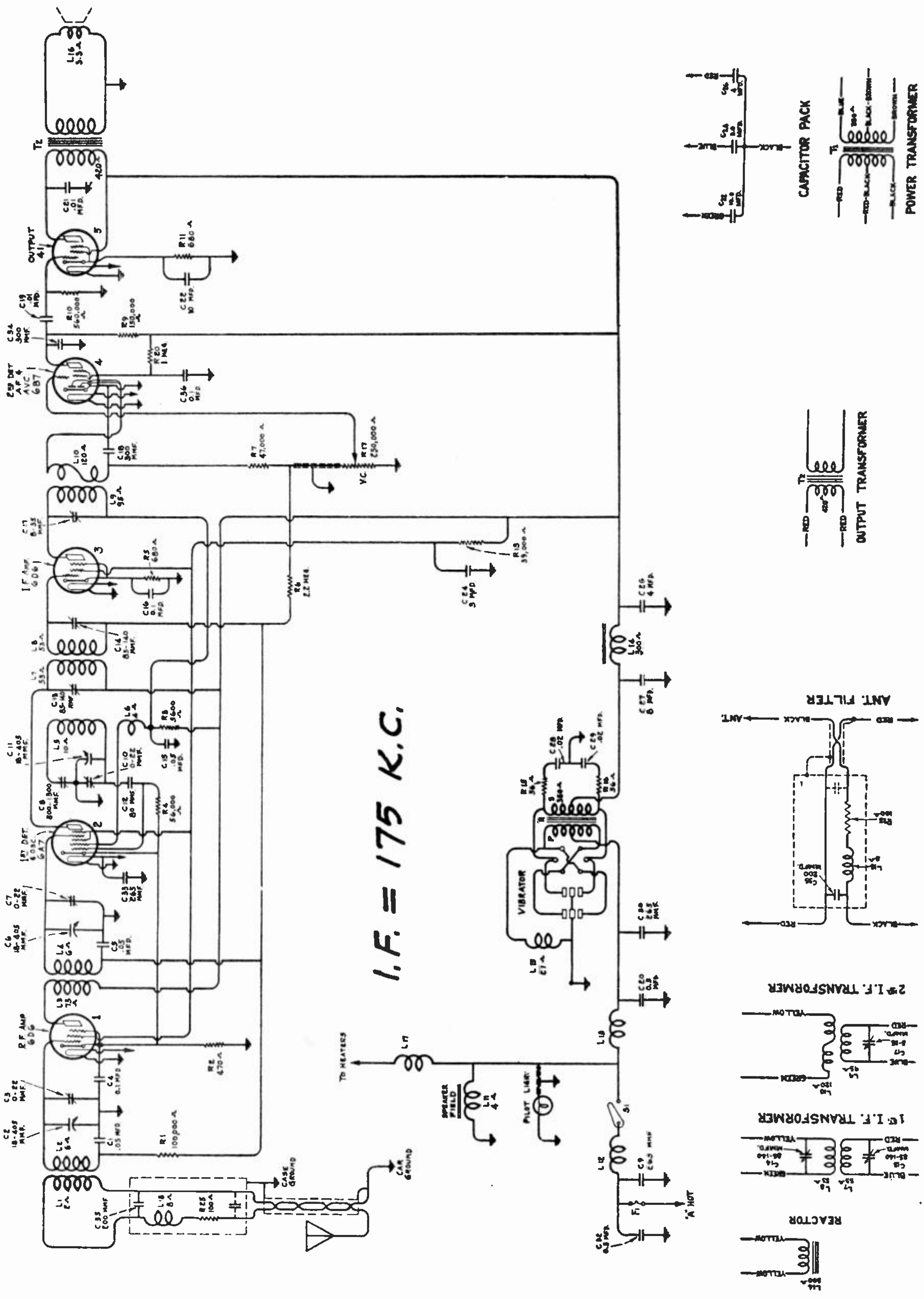
20.— WHAT ARE SOME OF THE MORE IMPORTANT POINTS WHICH SHOULD BE CONSIDERED AT THE TIME THE CONSTRUCTION OF ANY RECEIVER IS CONTEMPLATED?

NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODEL D-50

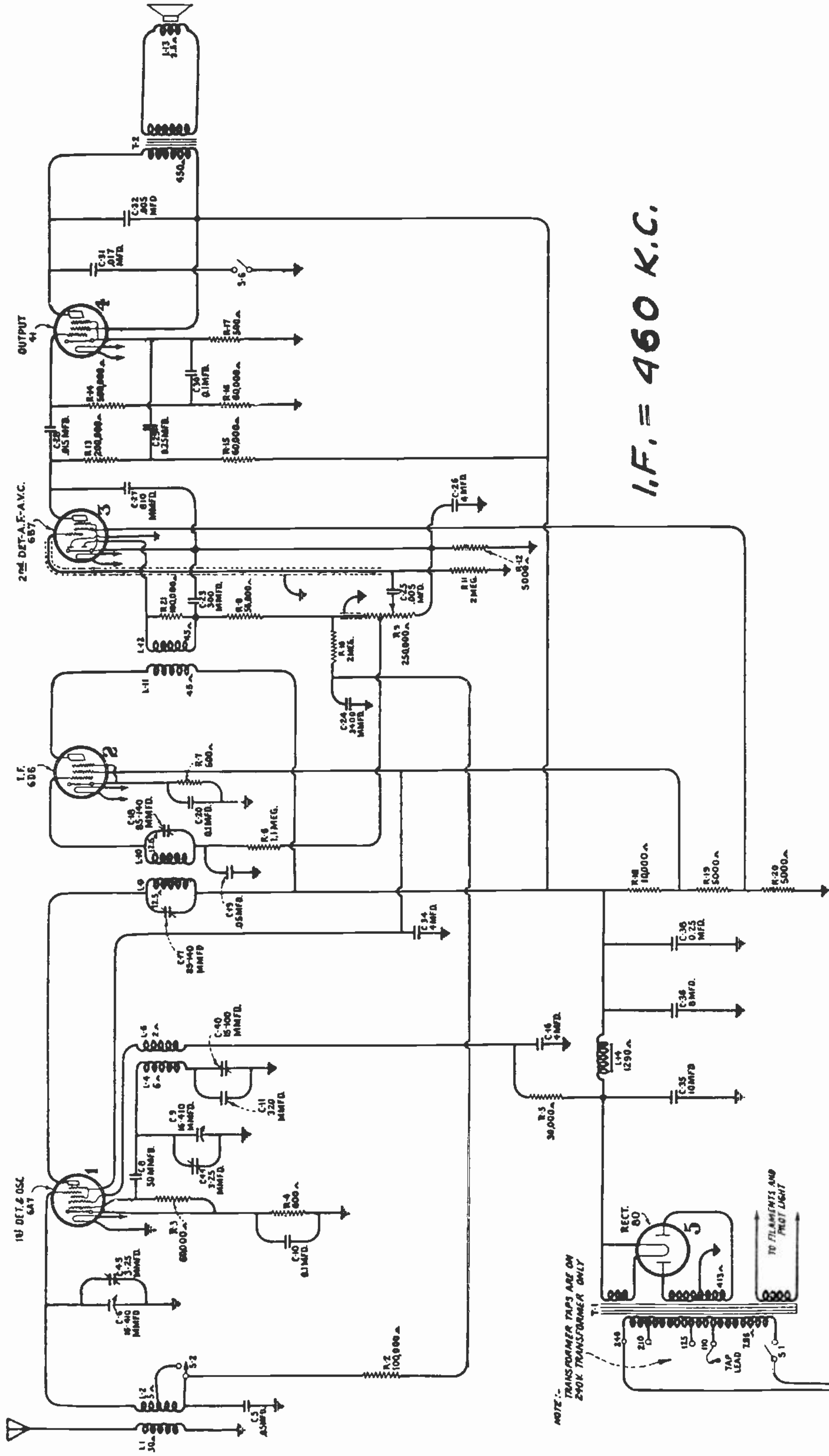


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODEL M-52



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NATIONAL SCHOOLS
Los Angeles, California

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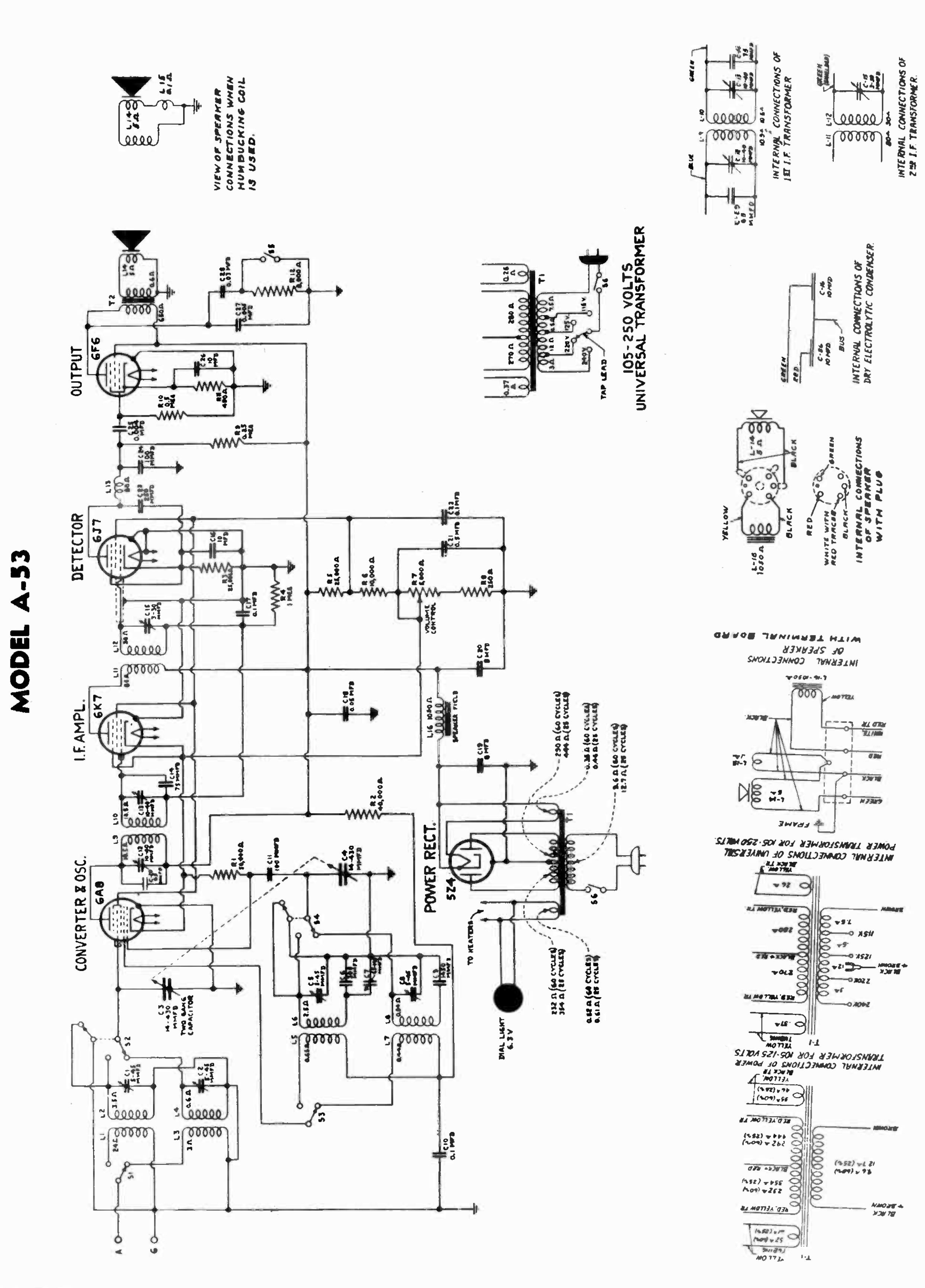

DIAGRAM OF A-53 GE TWO BAND A.C. RECEIVER
CLIFF NAZZARO

NATIONAL SCHOOLS
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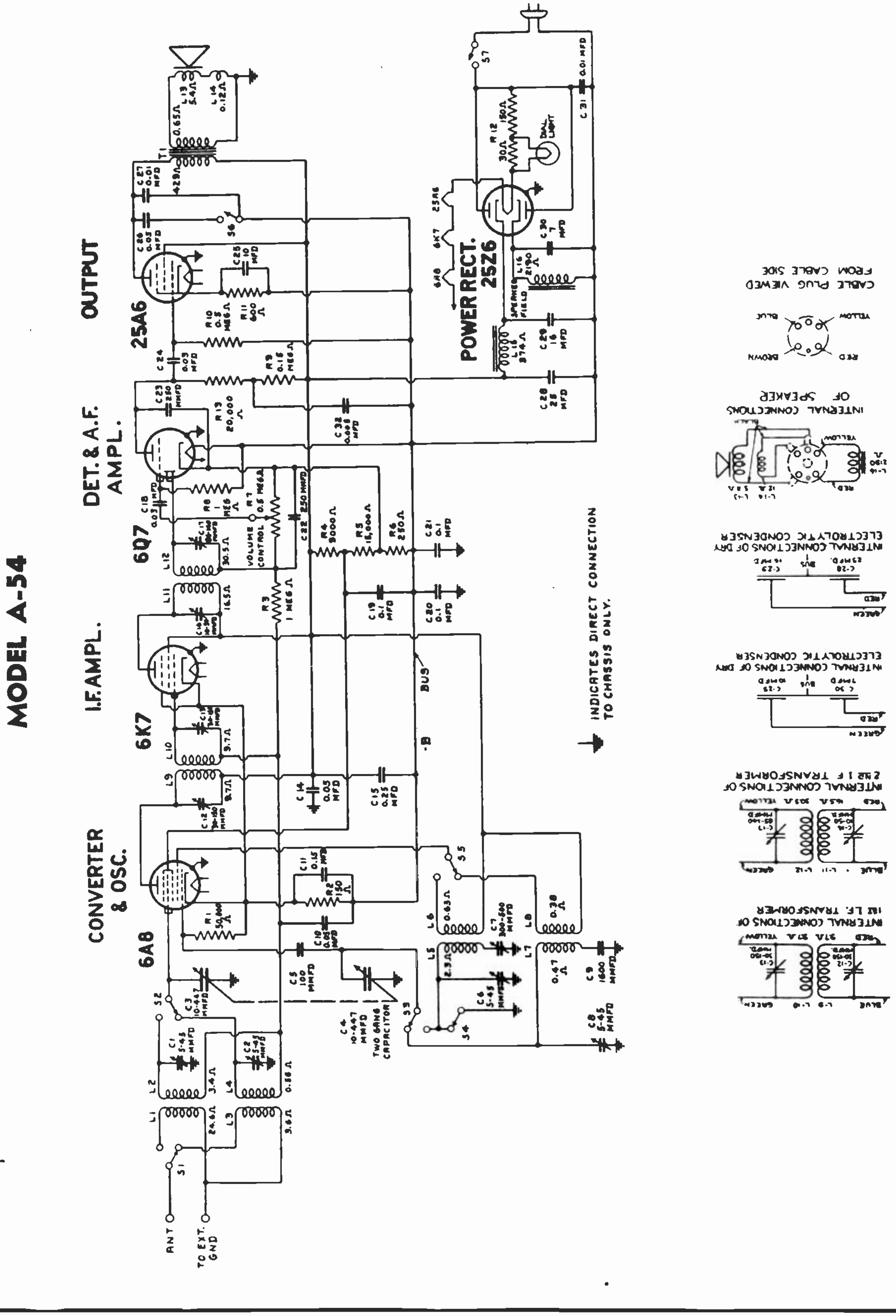
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC



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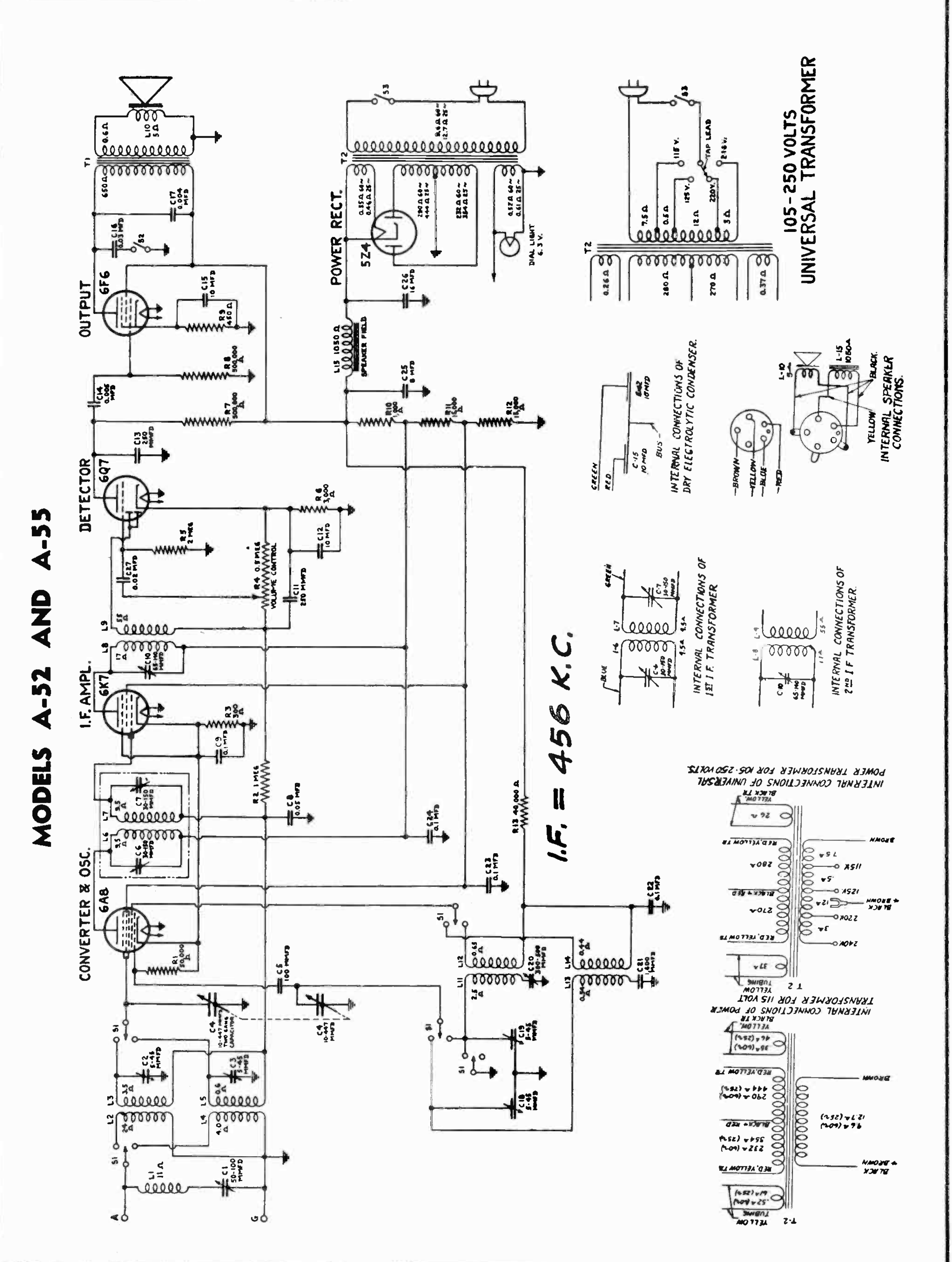
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC



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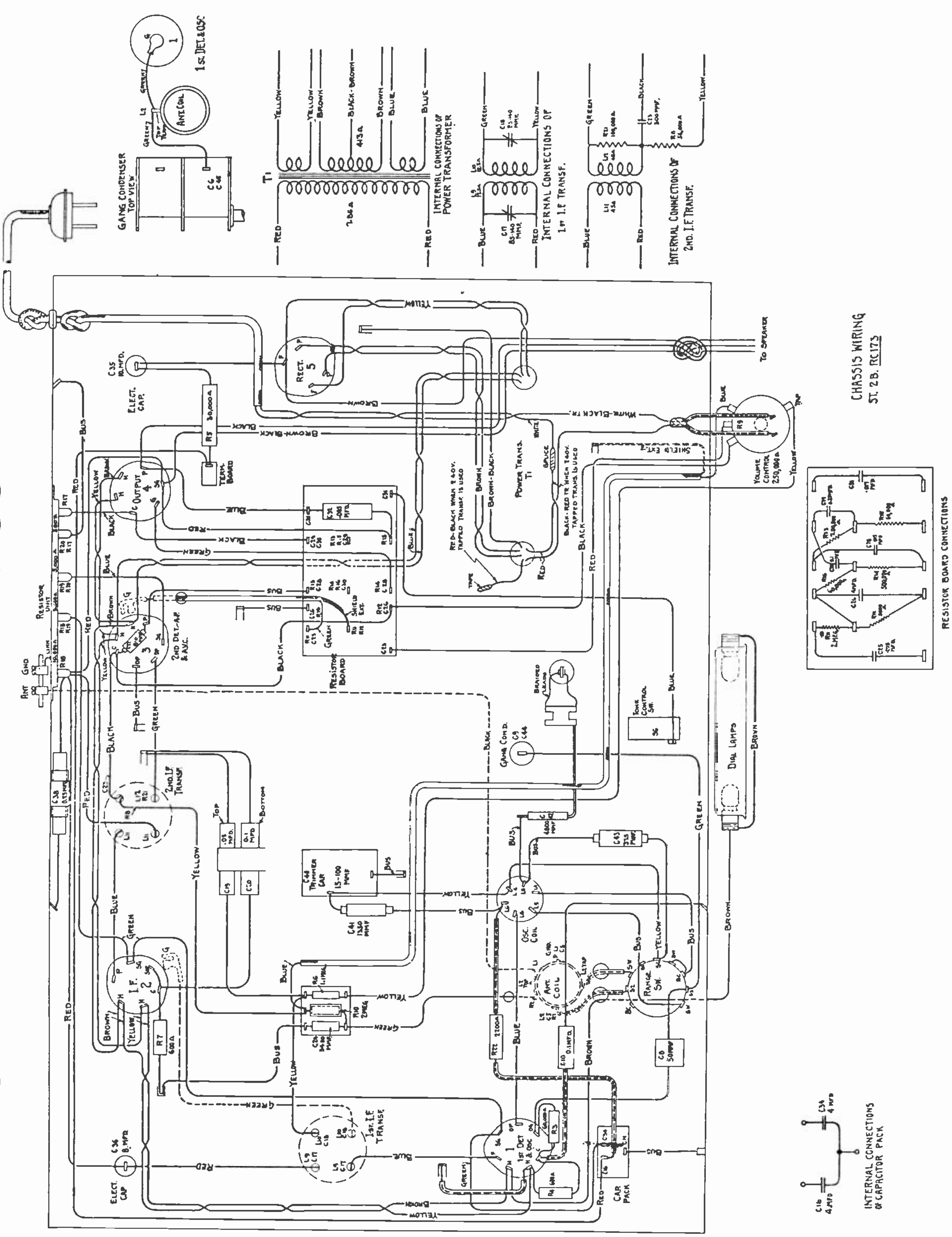
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODELS M-50 AND M-55



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COMMERCIAL CIRCUIT DIAGRAM

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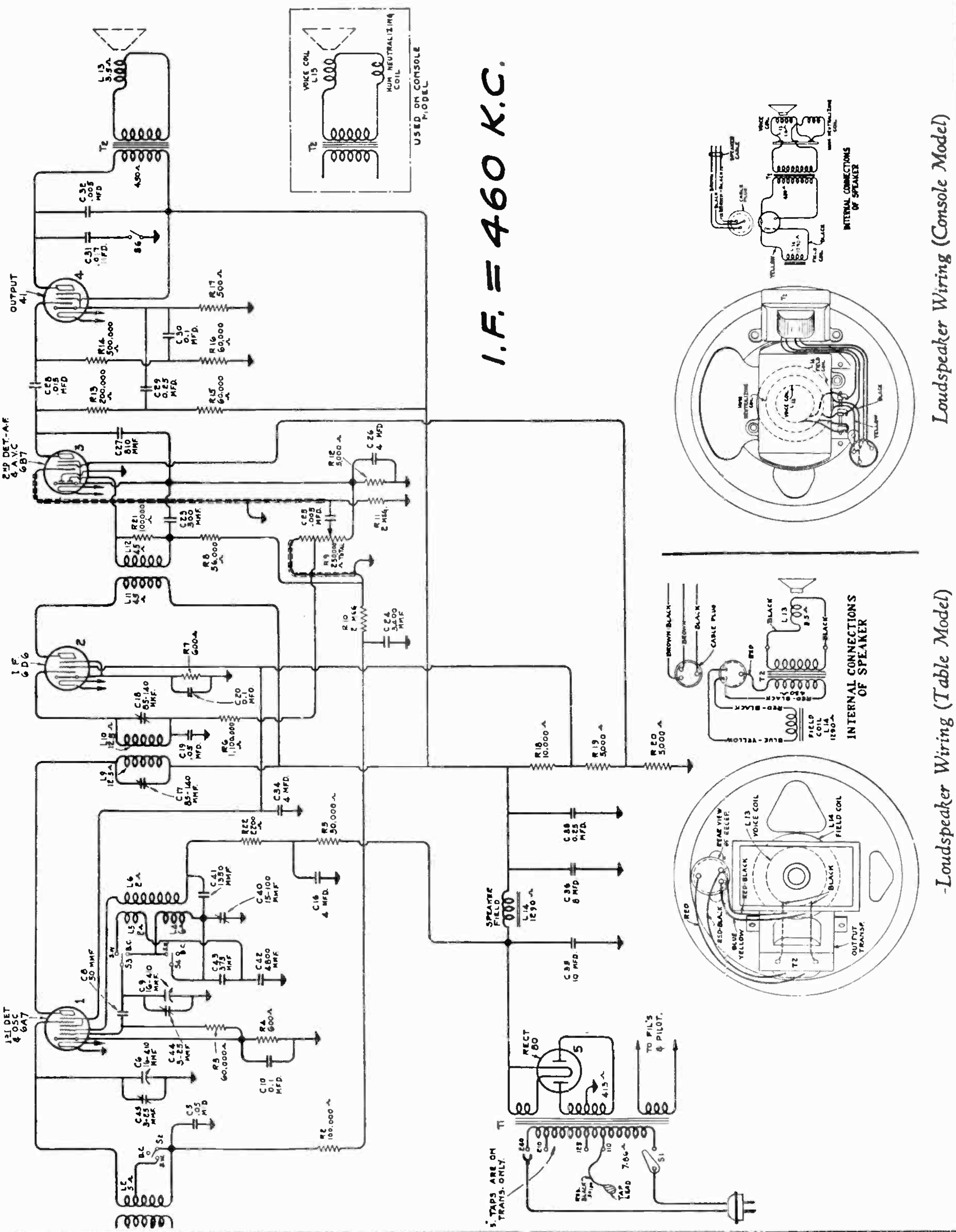
GENERAL ELECTRIC CO.

MODELS M-50 AND M-55



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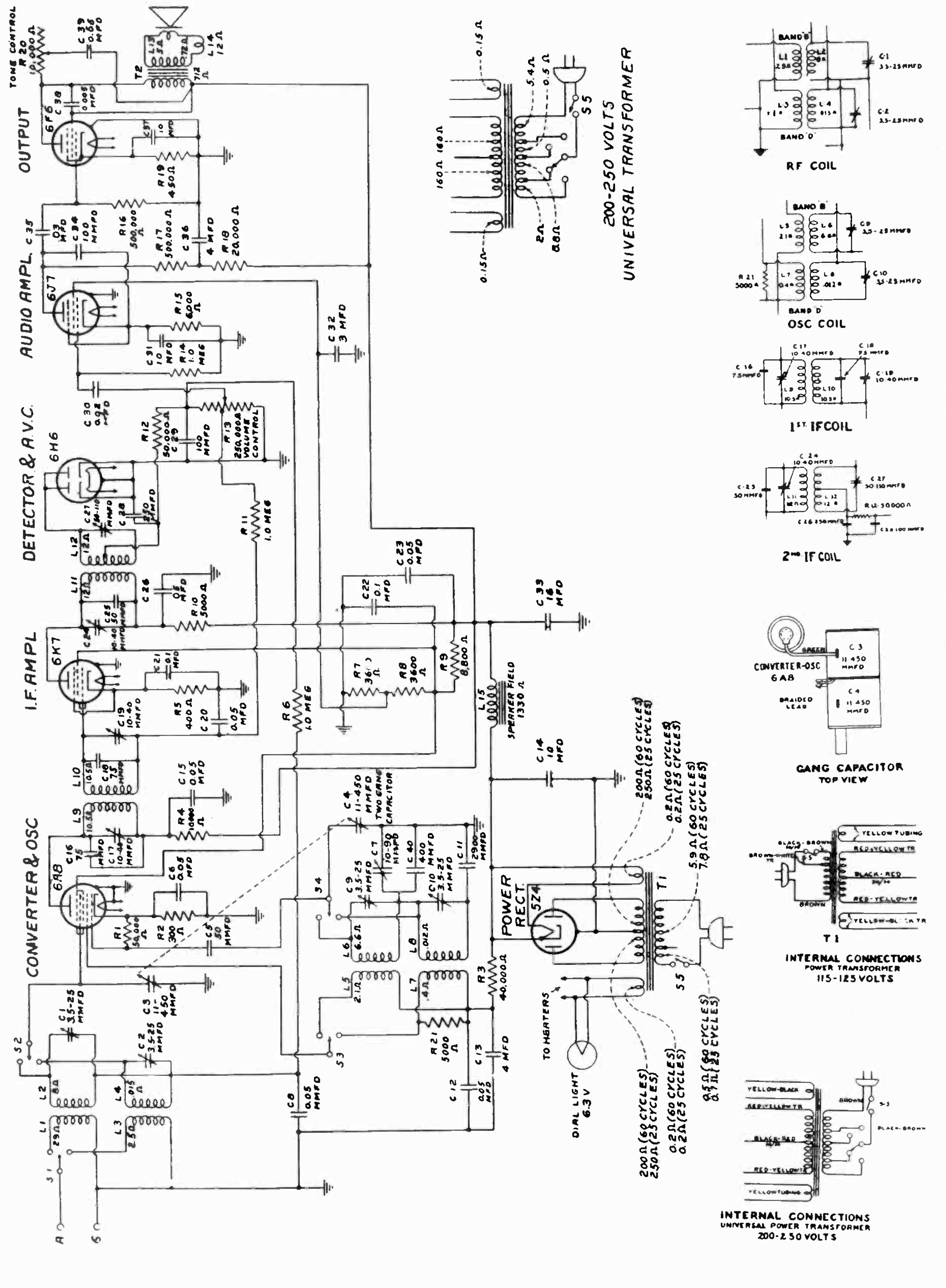
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODELS A-64 AND A-67



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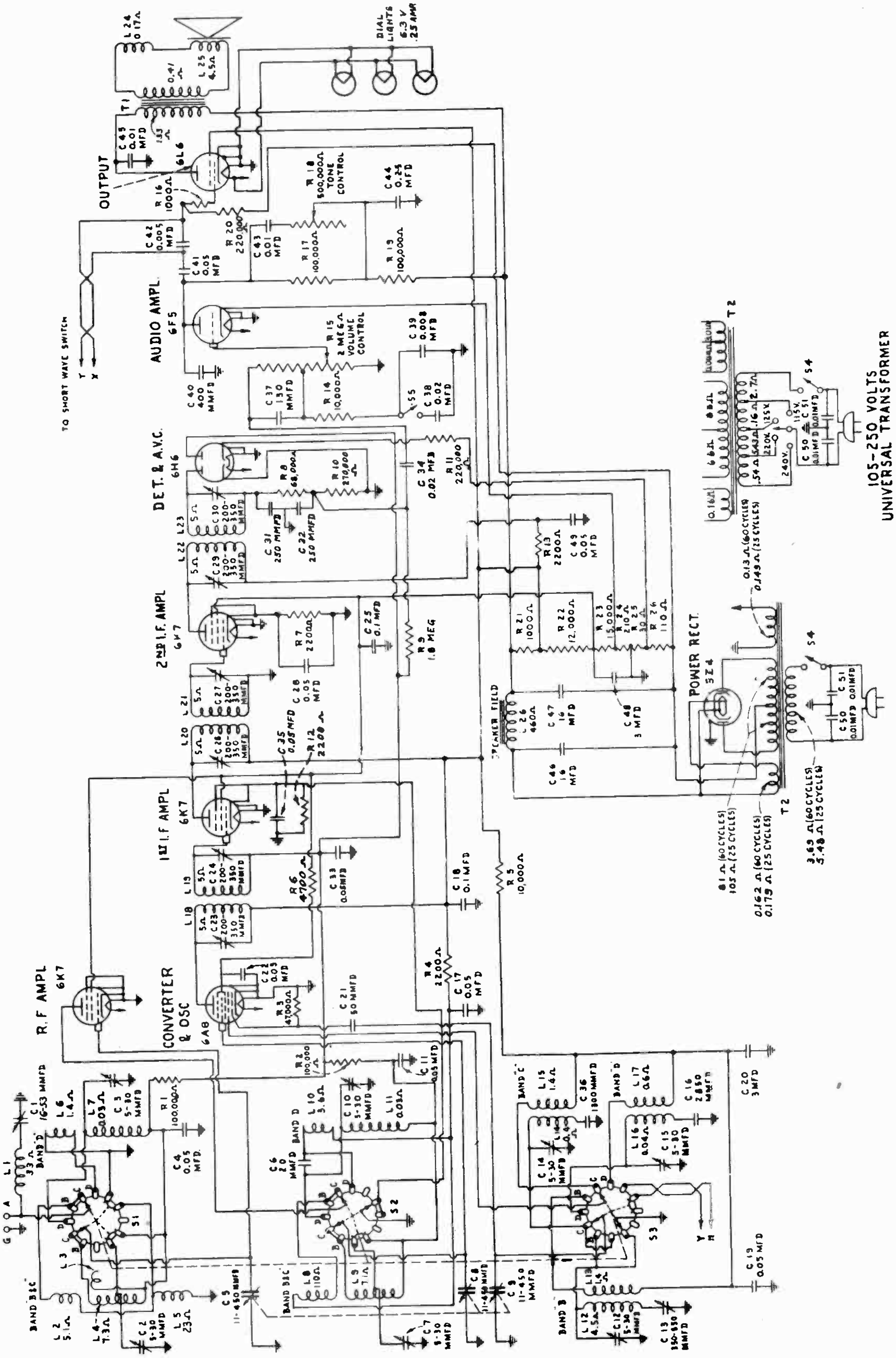
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC

MODELS E-81 AND E-86



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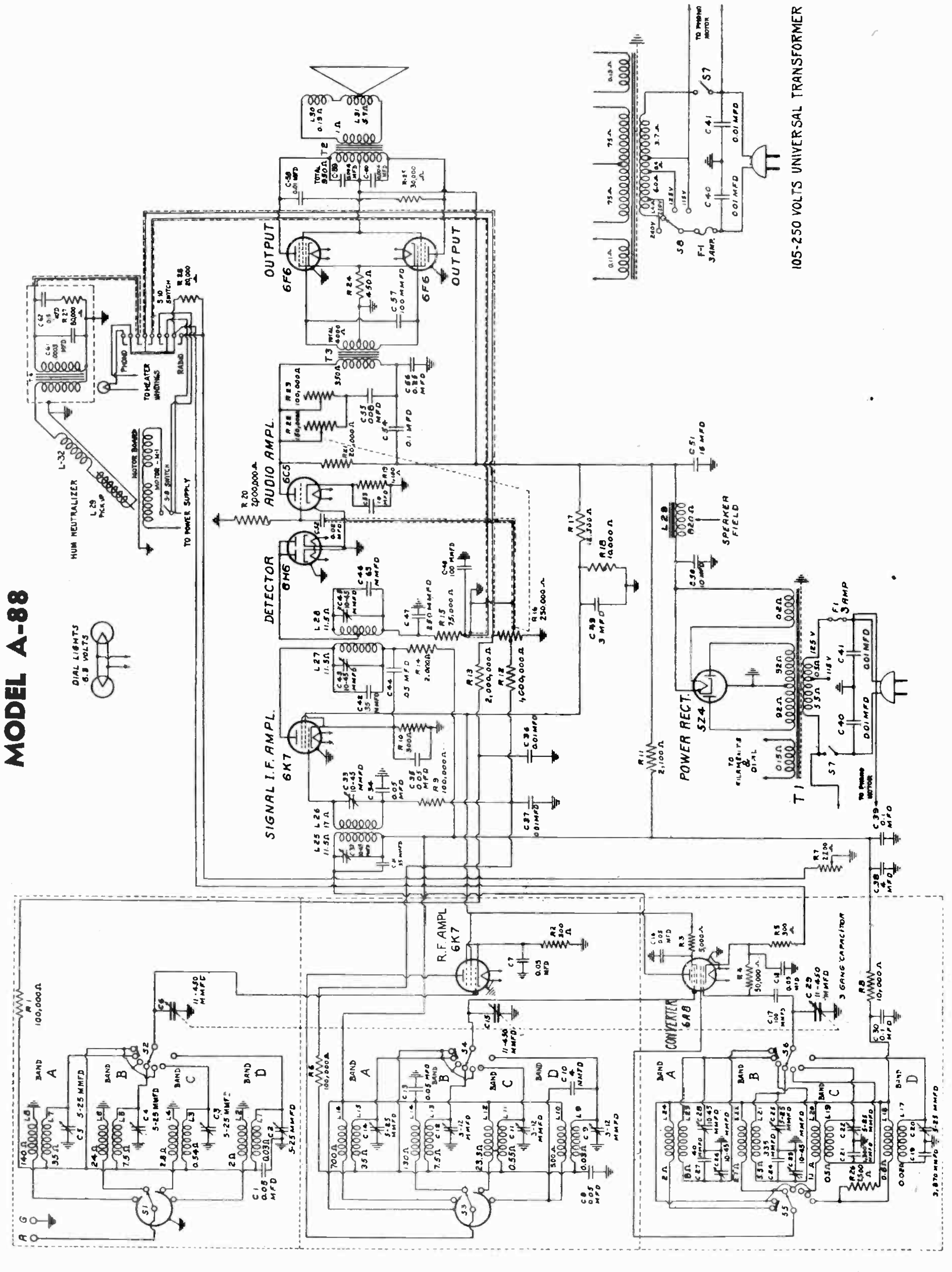
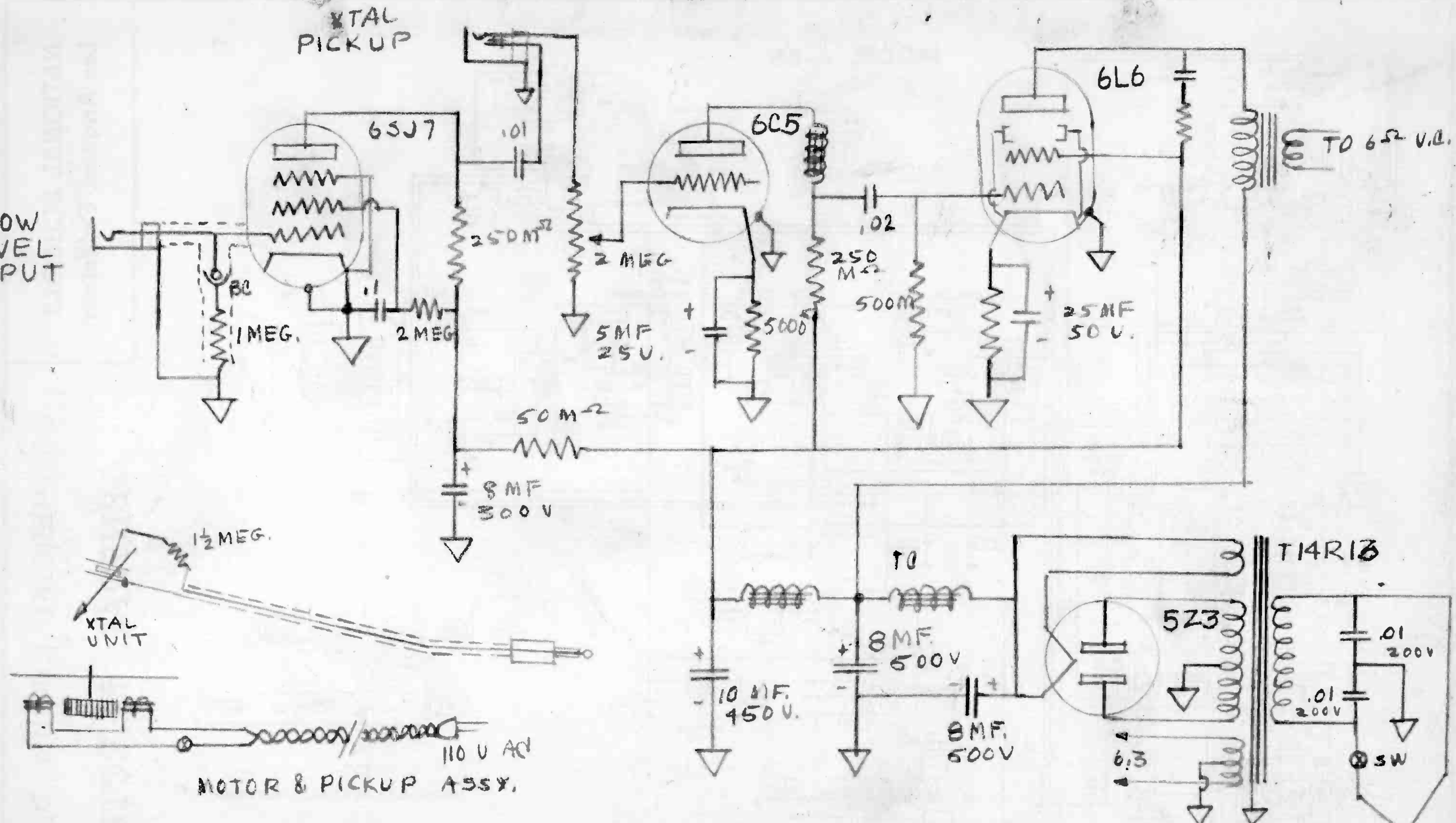
COMMERCIAL CIRCUIT DIAGRAM

GENERAL ELECTRIC





WILLIAM F. LIESKE

☆ HIGH GAIN P.A. FOR PHONO OR INSTRUMENTS

RADIO - TELEVISION
Practical Training
NATIONAL SCHOOLS
Established 1905
Los Angeles, California
J. A. ROSENKRANZ, Pres.

Television

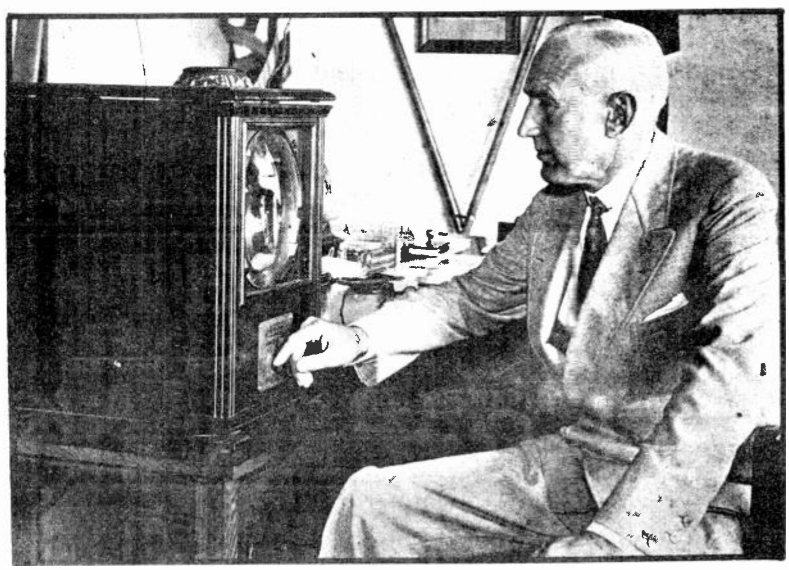
LESSON NO. 1

THE ESSENTIALS OF TELEVISION

YOU HAVE ALREADY WITNESSED THE WONDERS,WHICH HAVE BEEN ACCOMPLISHED IN THE TRANSMISSION AND RECEPTION OF SOUND BY RADIO AND ALTHOUGH THIS IS A MARVELOUS ACHIEVEMENT OF MODERN SCIENCE, YET STILL GREATER RADIO WONDERS AWAIT US IN THE VERY NEAR FUTURE. THE AMBITION OF SCIENTISTS AND ENGINEERS HAS ALWAYS BEEN TO GO A BIG STEP FARTHER, SO THAT THEY WOULD EVENTUALLY BE ABLE TO NOT ONLY TRANSMIT SOUND BUT TO TRANSMIT IMAGES OR SCENES AS WELL. IN OTHER WORDS, THEIR DESIRE HAS ALWAYS BEEN TO ENABLE THE ARDENT RADIO LISTENER TO SEE THE PERFORMING ARTISTS, AS WELL AS TO HEAR THEM.

THE ART OF TRANSMITTING AND RECEIVING IMAGES BY RADIO HAS ALREADY BECOME A REALIZATION AND WECALL THIS NEW BRANCH OF RADIO"TELEVISION" IT IS TRUE THAT TELEVISION IS STILL IN ITS EARLY STAGES OF DEVELOPEMENT BUT REMARKABLE PROGRESS HAS BEEN MADE INTHIS NEW FIELD WITHIN THE LAST FEW YEARS.

A NUMBER OF TELEVISION BROADCASTING STATIONS ARE ALREADY OPERATING ON REGULAR SCHEDULE AND SEVERAL WELL KNOWN FIRMS ARE OFFERING TELEVISION RECEIVING EQUIPMENT TO THE RADIO PUBLIC. WHEN WE CONSIDER HOW QUICKLY RADIO RECEIVERS WERE DEVELOPED



NO. 1
"Tuning-In" a Television Program.

FROM THE SMALL CRYSTAL AND PHONE STAGE TO THE ULTRA MODERN ALL-WAVE SUPERHETERODYNES WITH DYNAMIC SPEAKER, WE CANNOT HELP BUT EXPECT A BRILLIANT FUTURE FOR RADIOS' PARTNER, TELEVISION.

ENGINEERS, TODAY, HAVE A MUCH MORE THOROUGH UNDERSTANDING OF COMPLICATED RADIO PRINCIPLES THAN WAS POSSESSED BY THE EARLY EXPERIMENTERS. YEARS OF DEVELOPMENT HAVE OF COURSE MADE THIS POSSIBLE AND ALL OF THE PRESENT DAY KNOWLEDGE OF RADIO IS EQUALLY APPLICABLE TO TELEVISION. THIS NATURALLY MEANS THAT TELEVISION IS AT AN ADVANTAGE, FOR ALL OF THIS ADVANCED KNOWLEDGE IS ALREADY AVAILABLE, SO THAT IT CAN BE APPLIED TO TELEVISION RESEARCH AND DEVELOPMENT.

THE RELATION BETWEEN RADIO AND TELEVISION

AS YOU PROGRESS WITH YOUR TELEVISION STUDIES, YOU WILL BE IMPRESSED WITH THE FACT OF THE CLOSE RELATION BETWEEN TELEVISION PRINCIPLES AND RADIO PRINCIPLES. THE TRUTH OF THE MATTER IS THAT YOU HAVE ALREADY MASTERED THE MOST DIFFICULT PART OF TELEVISION IN THAT IN THIS SCIENCE WE USE EVERYTHING WHICH YOU HAVE SO FAR LEARNED CONCERNING RADIO THEORY

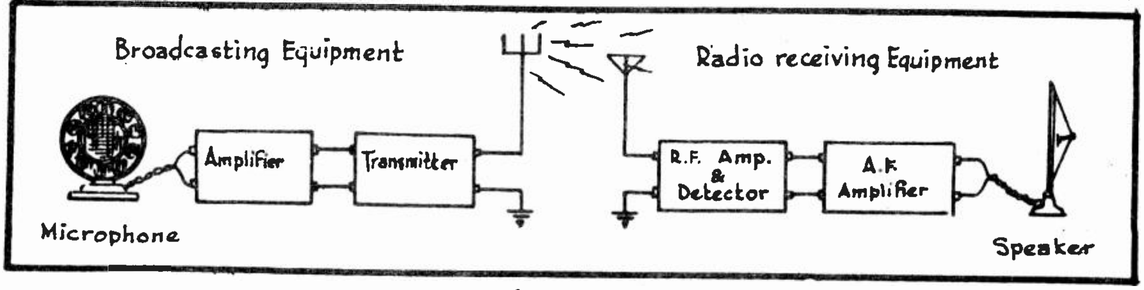


FIG. 2

General Lay-out of Sound Broadcasting and Receiving Equipment.

IN GENERAL, RECEIVERS, R.F. AND A.F. AMPLIFIERS, TUNING CIRCUITS, DETECTORS, POWER SUPPLIES, TRANSMITTERS, ETC. IN OTHER WORDS, ALL OF YOUR STUDIES UP TO THIS POINT HAVE BEEN JUST AS MUCH A PART OF YOUR TELEVISION INSTRUCTION AS ARE THIS SPECIAL SERIES OF TELEVISION LESSONS.

THIS MEANS THAT YOU DO NOT HAVE A GREAT DEAL MORE TO LEARN CONCERNING TELEVISION AND THE SOLE PURPOSE OF THIS SPECIAL LESSON SERIES IS TO SHOW YOU HOW TO ADAPT YOUR PRESENT KNOWLEDGE TO TELEVISION CIRCUITS IN PARTICULAR, AS WELL AS TO FAMILIARIZE YOU WITH THE VARIOUS METHODS OF CONVERTING SCENES TO ELECTRICAL IMPULSES AND CONVERTING ELECTRICAL IMPULSES INTO CORRESPONDING SCENES.

THE RELATION BETWEEN THE SOUND BROADCASTING AND TELEVISION BROADCASTING SYSTEM IS CLEARLY ILLUSTRATED IN FIGS. 2 AND 3. TURNING YOUR ATTENTION TO FIG.2 FIRST, WHERE THE SOUND BROADCAST SYSTEM IS SHOWN, YOU WILL NOTE THAT HERE WE IMPRESS SOUND WAVES UPON THE MICROPHONE, WHICH CONVERTS THEM INTO CORRESPONDING VARIATIONS OF ELECTRIC CURRENT, AND VOLTAGE IMPULSES ARE THEN SUCCESSIVELY AMPLIFIED, USED TO MODULATE THE CARRIER FREQUENCY, AND THE MODULATED CARRIER WAVE IS THEN RADIATED FROM THE ANTENNA OF THE TRANSMITTER.

THE RECEIVER ANTENNA "PICKS-UP" THE MODULATED CARRIER WAVE AND THE RECEIVER CIRCUITS AMPLIFY IT, SEPARATE THE AUDIO COMPONENT FROM THE CARRIER FREQUENCY, AMPLIFIES THE AUDIO FREQUENCIES, AND CONVERTS THEM BACK INTO SOUND WAVES BY MEANS OF A SPEAKER. THIS IS AN OLD STORY TO YOU BY

THIS TIME BUT NOTE HOW CLOSELY IT LINKS UP WITH THE CORRESPONDING SERIES OF EVENTS AS OCCUR IN THE TELEVISION SYSTEM OF FIG.3

IN FIG.3, A PHOTO-ELECTRIC CELL REPLACES THE MICROPHONE. CHANGES IN LIGHT INTENSITY ARE IMPRESSED UPON THE PHOTO-ELECTRIC CELL, WHICH CONVERTS THESE LIGHT VARIATIONS INTO ELECTRIC CURRENT AND VOLTAGE VARIATIONS OF CORRESPONDING FREQUENCY. THESE VOLTAGE IMPULSES ARE THEN AMPLIFIED AND ARE USED TO MODULATE A CARRIER FREQUENCY IN THE TRANSMITTING EQUIPMENT AND THE RADIATED CARRIER WAVE IS THEN SENT OUT INTO SPACE, CARRYING WITH

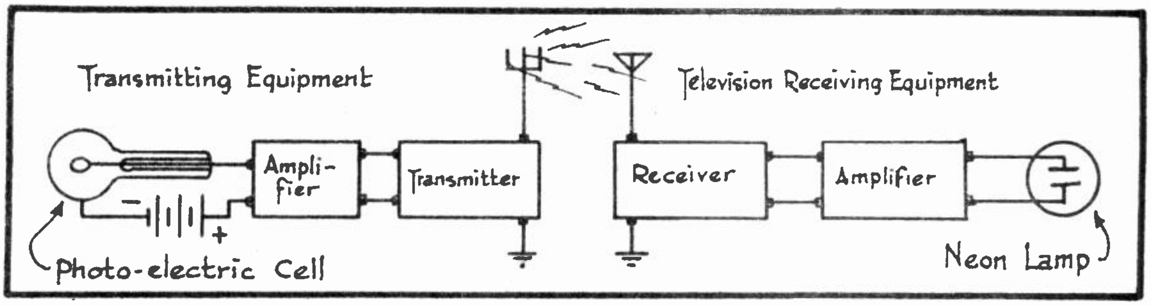


FIG. 3

General Lay-out of Television Transmitting and Receiving Equipment.

IT, THE MODULATION FREQUENCY CORRESPONDING TO THE ORIGINAL LIGHT VARIATIONS, WHICH WERE IMPRESSED UPON THE PHOTO-ELECTRIC CELL.

THE RECEIVER "PICKS-UP" THE MODULATED WAVE, AMPLIFIES IT, AND SEPARATES THE FREQUENCIES OF LIGHT VARIATION FROM THE CARRIER FREQUENCY. THE FREQUENCIES OF LIGHT VARIATION ARE THEN AMPLIFIED THE SAME AS THE A.F. CURRENTS IN THE BROADCAST RECEIVER AND THEN THEY ARE APPLIED TO A NEON LAMP. THE NEON LAMP, AS YOU WILL LEARN LATER, CONVERTS THE VOLTAGE CHANGES OF THE ORIGINAL LIGHT VARIATION BACK INTO LIGHT VARIATIONS WHICH ARE IDENTICAL TO THOSE IMPRESSED UPON THE PHOTO CELL AT THE TRANSMITTER.

OBSERVE THAT THE ONLY ESSENTIAL DIFFERENCE BETWEEN FIG.2 AND FIG.3 IS THAT IN THE TELEVISION SYSTEM, THE NEON LAMP REPLACES THE LOUD SPEAKER AND THE PHOTO ELECTRIC CELL REPLACES THE MICROPHONE. OTHERWISE, THE TWO SYSTEMS ARE PRACTICALLY THE SAME AND IN THIS WAY YOU ARE SHOWN BEFORE-HAND, THE CLOSE RESEMBLANCE BETWEEN RADIO AND TELEVISION. FROM YOUR PRESENT KNOWLEDGE OF RADIO, YOU CAN NO DOUBT ALREADY VISUALIZE THE POSSIBILITIES OF THE PRINCIPLES AS OUTLINED RELATIVE TO FIG.3.

FIG. 4
Guglielmo Marconi

SO FAR, WE HAVE GIVEN YOU A BIRD'S-EYE-VIEW OF TELEVISION, SO THAT YOU WILL HAVE SOMEWHAT OF AN IDEA OF THE COMPLETE SYSTEM, BEFORE WE GO INTO A DETAILED STUDY OF THE COMPONENT PARTS OF WHICH IT IS COMPOSED. WITH THIS COMPLETE PICTURE IN MIND, WE WILL NOW START AT THE

VERY BEGINNING WITH AN ANALYSIS OF HOW THE IMAGE TO BE TRANSMITTED IS PICKED UP BY THE PHOTO-ELECTRIC CELL AND THEN STEP BY STEP THROUGHOUT THIS LESSON AND THE LESSONS IMMEDIATELY TO FOLLOW, WE WILL COVER THE SUBJECT OF TELEVISION IN DETAIL.

SOME FUNDAMENTAL PRINCIPLES CONCERNING SIGHT

NOW WHEN WE LOOK AT A PERSON OR OBJECT, WE ARE ABLE TO DISTINGUISH FORM, SHAPE, AND COLOR DUE TO THE VARIATIONS OF DARK AND LIGHT SHADINGS OF WHICH THE IMAGE IS COMPOSED. FOR EXAMPLE, IN THE PHOTOGRAPH OF FIG.4, WE RECOGNIZE THIS PHOTOGRAPH AS BEING THAT OF GUGLIELMO MARCONI, THE FAMOUS RADIO ENGINEER, BECAUSE THE SHADING OF THE PHOTOGRAPH OUTLINES THIS IMAGE, SO THAT THE IMPRESSION IS CARRIED TO OUR BRAIN BY WAY OF OUR EYES. SINCE WE ALREADY HAVE A MENTAL PICTURE OF MARCONI, THE PHOTOGRAPH HERE SHOWN IS A GOOD COMPARISON WITH OUR MENTAL CONCEPTION, SO THAT WE RECOGNIZE THE MAN.

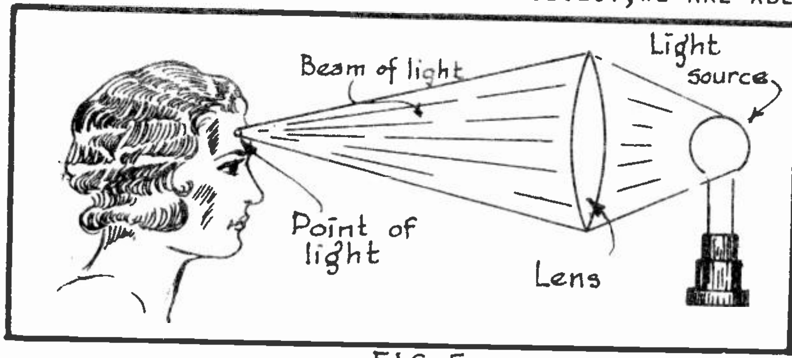


FIG. 5
Concentrating a Beam of Light Upon an Object.

SHOULD THIS SAME PICTURE BE SOLID WHITE, SOLID BLACK, OR ANY OTHER SINGLE COLOR WITHOUT ANY SHADING WHATEVER, THEN WE WOULD NOT BE ABLE TO TELL WHO THE PERSON IS. HOWEVER, UPON ANALYZING THIS PHOTOGRAPH, WE NOTE THAT THE FEATURES OF THE FACE ARE BROUGHT OUT DUE TO THE LIGHT AND DARK SHADING AND THE SAME IS TRUE WITH RESPECT TO THE COLLAR, COAT, ETC., AND THE DARK OUTLINE OF THE BODY AGAINST THE WHITE PAPER PROVIDES THE FORM OF THE IMAGE.

NOW THERE IS ANOTHER THING WHICH WE MUST CONSIDER RELATIVE TO VISION AND THAT IS THE FACT THAT WHEN THE IMAGE IS EXPOSED TO LIGHT, THE LIGHTER COLORS OF THE IMAGE WILL REFLECT MORE LIGHT THAN THE DARKER COLORS. THAT IS, WHITE WILL REFLECT THE MOST LIGHT AND BLACK THE LEAST LIGHT.

THIS CAN PROBABLY BE ILLUSTRATED SOMEWHAT BETTER WITH THE AID OF FIG.5. HERE THE SOURCE OF LIGHT IS BEING SUPPLIED BY A LAMP, AND A CONDENSING LENS, WHICH IS PLACED BETWEEN THIS LAMP AND THE OBJECT OR IMAGE, FOCUSES THE LIGHT BEAM TO A TINY SPOT OF LIGHT. WITH THIS SPOT OF LIGHT FOCUSED UPON THE WOMAN'S LIGHT COLORED FOREHEAD, CONSIDERABLE LIGHT WILL BE REFLECTED, BUT IF THIS SMALL BEAM SHOULD BE MOVED TO SOME DARKER PORTION OF THE WOMAN, SUCH AS HER HAIR OR DRESS, THEN LESS LIGHT WILL BE REFLECTED FROM THE SPOT OF LIGHT ETC.

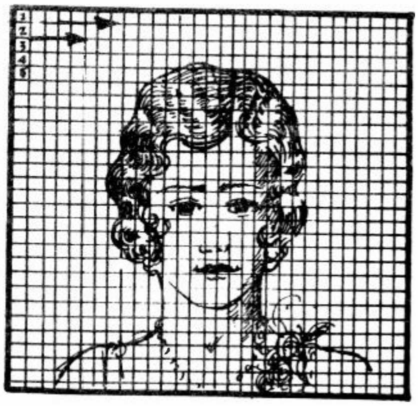


FIG. 6
Horizontal Division of Image.

NOW IF THE WOMAN IS FLOODED WITH ONE MASS OF SOLID LIGHT, THEN THOUSANDS OF SUCH TINY SPOTS WILL REFLECT A CERTAIN AMOUNT OF LIGHT, DEPENDING UPON HOW DARK OR LIGHT THESE SPOTS ARE. ALL OF THESE LIGHT REFLECTIONS OF VARIOUS INTENSITIES WILL STRIKE THE OBSERVER'S EYES SIMULTANEOUSLY, THUS REPRODUCING THE IMAGE ON THE BRAIN, WITH THE DARK AND LIGHT PATTERN ARRANGED IN THE SAME FORM AS ON THE OBJECT BEING SEEN.

EVEN THOUGH THE HUMAN EYE WILL RESPOND TO A GREAT MANY LIGHT REFLECTIONS AT THE SAME TIME AND THUS "PICK UP" THE ENTIRE IMAGE AT ONCE, YET UP TO THE PRESENT TIME, IT IS NOT POSSIBLE TO TRANSMIT THE ENTIRE IMAGE IN ITS COMPLETE FORM BY TELEVISION.

IN "PICKING UP" THE IMAGE FOR TELEVISION TRANSMISSION, WE "PICK UP" THE IMAGE IN SECTIONS AND ALSO TRANSMIT IT IN SECTIONS AT THE RECEIVER, THESE VARIOUS SECTIONS ARE AGAIN PUT TOGETHER IN THE PROPER ORDER, SO AS TO FORM THE ORIGINAL COMPLETE IMAGE WHICH IS LOCATED IN THE STUDIO OF THE TRANSMITTER.

DIVIDING THE OBJECT INTO SECTIONS

WE WILL BEGIN DIVIDING THE IMAGE TO BE TRANSMITTED INTO A NUMBER OF SMALL SQUARES AS SHOWN IN FIG.6. THESE SQUARES ARE MADE UP OF A NUMBER OF HORIZONTAL AND VERTICAL LINES. NOW LET US SUPPOSE THAT WE HAVE AT OUR DISPOSAL A CONCENTRATED BEAM OF LIGHT, WHICH WILL JUST COVER ONE OF THESE SMALL SQUARES AND NO MORE.

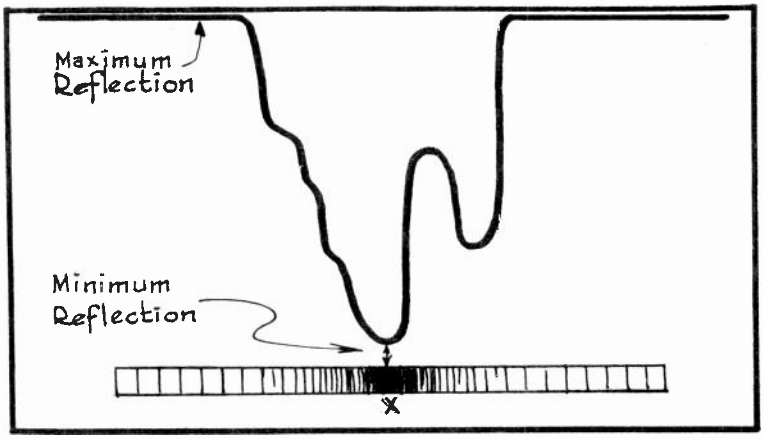


FIG. 7
Variations of Light Reflections.

WE WILL FIRST FOCUS THIS BEAM OF LIGHT UPON THE UPPER LEFT HAND SQUARE OF THE FRAME AT (1) AND WE WILL GRADUALLY MOVE THIS BEAM OF LIGHT ACROSS THE TOP ROW OF SQUARES IN A HORIZONTAL DIRECTION, FROM LEFT TOWARDS RIGHT AS INDICATED BY THE UPPER ARROW. THUS IT IS SEEN THAT EACH OF THE SQUARES IN THIS TOP ROW WILL BE ILLUMINATED ONE AT A TIME AND IN CONSECUTIVE ORDER.

EACH OF THE SQUARES IN THIS ROW, HOWEVER, IS PLAIN WHITE AND THEREFORE, THE LIGHT REFLECTED BY EACH WILL BE THE SAME. AFTER HAVING PASSED THIS LIGHT BEAM CLEAR ACROSS THIS UPPER ROW OF SQUARES, WE WILL FOCUS IT UPON THE EXTREME LEFT HAND SQUARE OF THE SECOND ROW AND THENCE GRADUALLY PASS THE BEAM ACROSS THIS SECOND ROW OF SQUARES FROM LEFT TOWARD RIGHT. AGAIN EACH OF THE SQUARES IN THIS ROW WILL REFLECT THE SAME AMOUNT OF LIGHT BECAUSE THE SHADING OF ALL OF THEM IS IDENTICAL.

IN THIS SAME WAY, WE PASS THIS LIGHT BEAM OVER ONE HORIZONTAL ROW OF SQUARES AT A TIME, GRADUALLY WORKING FROM THE TOP OF THE FRAME TOWARDS THE BOTTOM AND FROM THE LEFT TOWARDS THE RIGHT. FINALLY, LET US ASSUME THAT WE COME TO ROW #5. IN FIG.7, THIS ROW OF SQUARES IS SHOWN IN DETAIL, WITH THE VARIOUS DEGREES OF SHADING CORRESPONDING TO THE CONDITION IN

FIG. 6 AT THIS SAME SECTION OF THE FRAME.

THE FIRST NINE SQUARES FROM THE LEFT ARE PLAIN WHITE AND SO FROM THESE, WE GET THE SAME AMOUNT OF LIGHT REFLECTION, AS THE BEAM IS GRADUALLY MOVED FROM THE LEFT TOWARD THE RIGHT. FINALLY WE COME TO THE TENTH SQUARE FROM THE LEFT IN FIG.7, WHICH IS PARTIALLY SHADED BY THE WOMAN'S HAIR (REFER TO FIG.6) AND THE FOLLOWING FEW SQUARES IN FIG.7 EACH HAVE A VARYING AMOUNT OF SHADING, WITH THE DARKEST REGION BEING AT THE SECTION MARKED "X" IN FIG.7.

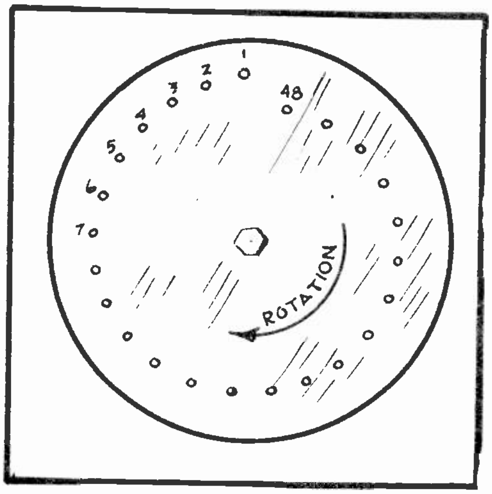


FIG. 8
A Typical Scanning Disc.

THESE SHADED SQUARES WILL NOW EACH REFLECT A DIFFERENT PERCENTAGE OF LIGHT, WITH THE DARKEST PORTION REFLECTING THE LEAST. SHOULD WE INDICATE THIS VARIATION OF LIGHT REFLECTION AS A CURVE WHILE THE BEAM IS BEING PASSED FROM THE LEFT TOWARD THE RIGHT OF ROW 5, WE WOULD OBTAIN A CURVE WITH VARIATIONS SOMEWHAT AS PICTURED AT THE TOP OF FIG.7. NOTE THAT THE CURVE INDICATES MAXIMUM LIGHT REFLECTION ABOVE THE WHITE SQUARES BUT THEN IT DECREASES AND INCREASES OVER THE SHADED REGION, COMING TO ITS MINIMUM VALUE OVER THE DARKEST REGION (X).

THIS LIGHT REFLECTION CURVE OF FIG.7, YOU WILL NOTE, LOOKS A GREAT DEAL LIKE THE CURVES ILLUSTRATING VARIATION IN MICROPHONE CURRENTS, AS CAUSED BY SOUNDS OF VARYING FREQUENCIES BEING IMPRESSED UPON ITS DIAPHRAGM AND SO WE CAN GIVE YOU A HINT AT THE PRESENT TIME, THAT IT IS THE VARIATIONS OF LIGHT REFLECTIONS AS ILLUSTRATED IN FIG.7 THAT ARE GOING TO BE USED TO MODULATE THE TRANSMITTER'S CARRIER FREQUENCY.

RETURNING TO FIG.6, YOU WILL OBSERVE THAT AS WE GRADUALLY MOVE DOWNWARD ONE ROW OF SQUARES AT A TIME AND PASS THE BEAM OF LIGHT FROM THE LEFT TOWARDS THE RIGHT, WE WILL OBTAIN A WHOLE SERIES OF CHANGES IN LIGHT REFLECTION, SUCH AS SHOWN IN FIG.7 BUT THE REFLECTION CURVE OF EACH HORIZONTAL ROW WILL BE DIFFERENT, BEING DEPENDENT ENTIRELY UPON THE DEGREE OF SHADING AT THAT PARTICULAR SECTION OF THE IMAGE.

WE CALL THIS ACTION, NOW UNDER DISCUSSION, "SCANNING", WHICH SIMPLY MEANS THAT THE IMAGE IS BEING DIVIDED INTO TINY SECTIONS. NOW THAT YOU ARE FAMILIAR WITH THE PRINCIPLES ENVOLVED IN SCANNING, YOU WILL NEXT BE INTERESTED IN LEARNING HOW SCANNING IS ACCOMPLISHED IN ACTUAL PRACTICE.

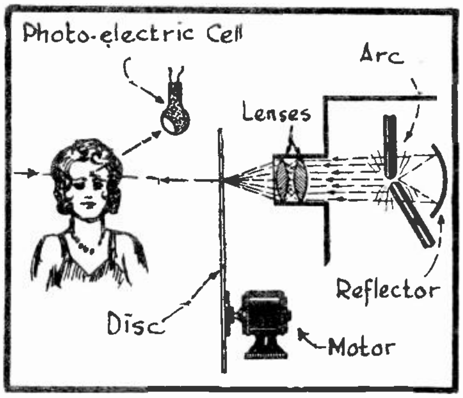


FIG. 9
The Scanning System and Photo-Cell Pickup.

IN FIG.8 YOU ARE SHOWN A TYPICAL

SCANNING DISC AND THIS UNIT IS A THIN, LIGHT, CIRCULAR, METALLIC DISC, HAVING A MOUNTING HOLE AT ITS CENTER AND A ROW OF SMALL HOLES ARRANGED IN A SPIRAL FORMATION NEAR ITS RIM.

THIS SCANNING DISC IS MOUNTED TO THE ARMATURE OF AN ELECTRIC MOTOR BY MEANS OF ITS CENTER HOLE, AS PICTURED IN FIG.9. THE IMAGE TO BE SCANNED (THE WOMAN IN THIS CASE) TAKES HER POSITION IN FRONT OF THE SCANNING DISC AND A LIGHT SOURCE, OR ARC LAMP IS PLACED ON THE OTHER SIDE OF THE SCANNING DISC.

THE LIGHT SOURCE IS FOCUSED UPON THE ROW OF HOLES IN THE RIM OF THE SCANNING DISC AND WITH ANY ONE OF THE DISC HOLES LINED UP WITH THE LIGHT SOURCE, A THIN BEAM OF LIGHT WILL PASS THROUGH THE HOLE AND AND STRIKE ONE POINT ON THE IMAGE TO BE TELEVISED. IN FIG. 9, FOR EXAMPLE, THE PARTICULAR DISC HOLE, WHICH IS ALIGNED WITH THE LIGHT SOURCE, DIRECTS A TINY BEAM OF LIGHT UPON THE WOMAN'S FORHEAD. THE LIGHT, WHICH IS REFLECTED FROM THIS TINY SPOT, IS THEN DIRECTED TOWARDS A PHOTO-ELECTRIC CELL.

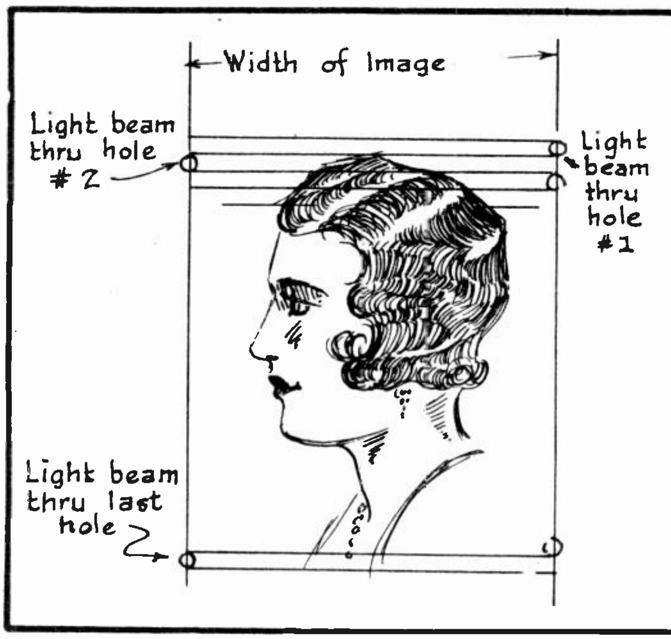


FIG. 10
Scanning the Image.

RETURNING TO THE DETAILED ILLUSTRATION OF OUR SCANNING DISC OF FIG.8, WE FIND THAT AS THE DISC IS DRIVEN IN THE DIRECTION SHOWN AND HOLE #1 COMES IN TO THE PATH OF THE LIGHT SOURCE, THIS FIRST HOLE WILL DIRECT THE SMALL PENCIL OF LIGHT ACROSS THE IMAGE FROM THE LEFT TOWARDS THE RIGHT, AS SHOWN IN FIG. 10. THE INSTANT THAT HOLE #1 HAS PASSED ACROSS THE PICTURE, HOLE #2 OF THE DISC WILL NEXT COME INTO THE PATH OF LIGHT AND THUS PASS A PENCIL OF LIGHT ACROSS THE PICTURE. NOTICE, HOWEVER, IN FIG.10 THAT THE LIGHT FROM #2 PASSES ACROSS THE PICTURE AT A LOWER LEVEL THAN THE BEAM FROM HOLE #1. THE REASON FOR THIS IS THAT THE DISTANCE BETWEEN HOLE #2 AND THE CENTER OF THE SCANNING DISC IS EQUAL TO THE DISTANCE FROM HOLE #1 TO THE DISC CENTER MINUS THE DIAMETER OF ONE HOLE. (ALL HOLES ARE OF EQUAL DIAMETER.)

ANOTHER IMPORTANT POINT TO NOTICE RELATIVE TO FIGURES 8 AND 10 IS THAT THE WIDTH OF THE PICTURE FRAMED BY THE SCANNING DISC IS EQUAL TO THE DISTANCE BETWEEN ADJACENT HOLES.

AFTER HOLE #2 HAS SCANNED THE PICTURE, IT WILL BE FOLLOWED BY HOLES #3 ONE LINE LOWER ETC. UNTIL ALL 48 HOLES OF THE DISC HAVE PASSED ACROSS THE PICTURE. WE THEN SAY THAT THE PICTURE HAS BEEN DIVIDED INTO 48 LINES. FROM THE EXPLANATION JUST GIVEN, YOU WILL ALSO NOTE THAT THE HEIGHT OF THE PICTURE FRAMED BY THE SCANNING DISC IS EQUAL TO THE DIFFE

ERENCE BETWEEN THE DISTANCE OF THE FIRST AND LAST HOLE FROM THE CENTER OF THE DISC.

THEN TOO, IT IS CLEAR THAT THE PICTURE WILL BE COMPLETELY SCANNED AFTER ONE REVOLUTION OF THE DISC. HOWEVER, IN ORDER TO MAKE THE PICTURE APPEAR CONTINUOUS AT THE RECEIVER, IT IS NECESSARY TO SCAN THE PICTURE COMPLETELY 15 TIMES PER SECOND AND THIS MEANS THAT THE DISC WILL HAVE TO BE DRIVEN BY THE MOTOR AT THE RATE OF 900 REVOLUTIONS PER MINUTE.

THE EFFECT OF SCANNING SPEED

THE NECESSITY OF SCANNING THE PICTURE 15 TIMES PER SECOND, IN ORDER TO PRODUCE A CONTINUOUS PICTURE, CAN PROBABLY BE BEST ILLUSTRATED WITH THE MOVING PICTURE FILM. AS YOU ALREADY KNOW, MOVING PICTURE FILM CONSISTS OF A STRIP OF SMALL INDIVIDUAL PICTURES. SHOULD EACH OF THESE PICTURES BE PROJECTED UPON THE SCREEN INDIVIDUALLY, THEN THE CHARACTERS WOULD NOT APPEAR TO BE IN MOTION AND WE WOULD MERELY SEE THE REPRODUCTION OF A SERIES OF PHOTOGRAPHS.

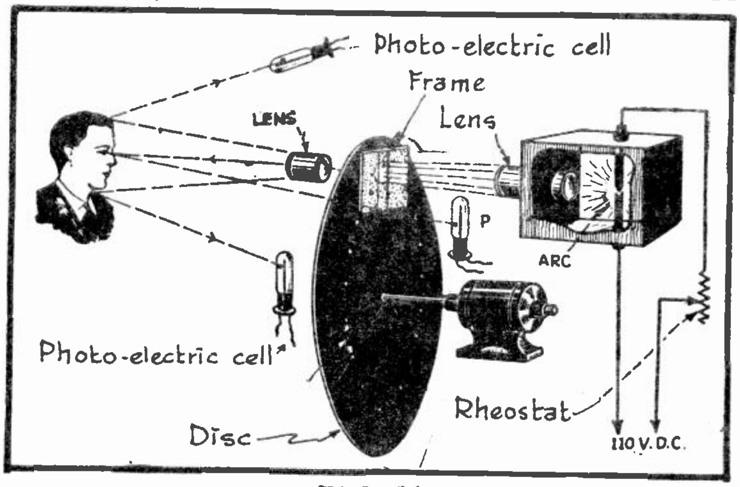


FIG. 11
Using A Group of Photo-electric Pick-up Cells.

OUR EYES, HOWEVER, HAVE A PECULIAR PROPERTY, WHICH TO SCIENCE IS KNOWN AS "PERSISTENCE OF VISION THIS MEANS THAT AFTER WE FIRST LOOK AT AN OBJECT, WE STILL RETAIN A VISION OF IT FOR MORE THAN 1/20 OF A SECOND AFTER THE OBJECT IS TAKEN FROM VIEW. THEREFORE, IF THE PICTURES OF THE MOVIE FILM ARE PROJECTED ON THE SCREEN CONSECUTIVELY IN RAPID SUCCESSION, WE WILL STILL RETAIN THE VISION OF THE FIRST WHEN THE SECOND ALREADY COMES INTO VIEW ETC. THE RESULT IS THAT THE CHARACTERS ON THE PICTURE APPEAR TO US AS BEING IN MOTION AND THE STANDARD RATE ADOPTED BY THE MOVIE INDUSTRY FOR SHOWING THESE FRAMES, OR INDIVIDUAL PICTURES MAKING UP THE FILM, IS 15 PICTURES PER SECOND.

THIS RATE IS SUFFICIENT TO DECEIVE OUR EYES INTO "SEEING MOTION PICTURES" AND THIS SAME PRINCIPLE APPLIES TO SCANNING IN TELEVISION, FOR HERE TOO, IF 15 SEPARATE PICTURES ARE SHOWN TO THE EYE IN EACH SECOND, THE CHARACTERS OF THE PICTURE WILL APPEAR AS BEING IN MOTION.

PICTURE DETAIL

YOU WILL ALSO FIND THAT THE GREATER THE NUMBER OF HOLES IN THE SCANNING DISC, THE GREATER WILL BE THE DETAIL OF THE PICTURE BEING SCANNED AND THIS IN TURN MEANS A CLEARER REPRODUCTION OF THE IMAGE. THAT IS, THE SMALLER THE SIZE OF THE HOLES IN THE DISC AND THE GREATER THE NUMBER OF THEM, THE SMALLER WILL BE THE ELEMENTARY AREAS INTO WHICH THE PICTURE IS DIVIDED. THIS OF COURSE WILL MEAN THAT A GREATER NUMBER OF INDIVIDUAL

LIGHT REFLECTIONS WILL BE OBTAINED FROM THE OBJECT BEING SCANNED,THEREBY MAKING IT POSSIBLE TO MORE CLEARLY DIFFERENTIATE BETWEEN SMALL CHANGES OF SHADING.

FOR THE ABOVE REASON,YOU WILL FIND SCANNING DISCS HAVING 24;48;50; 60 OR 72 HOLES BUT AT PRESENT, THE 48 HOLE DISC IS THE MOST COMMON.TELEVISION SETS USING A 48 HOLE SCANNING DISC ARE GENERALLY REFERRED TO AS BEING A 48 LINE SYSTEM, MEANING THEREBY THAT THE DISC DIVIDES THE PICTURE INTO 48 LINES PER REVOLUTION OF THE DISC.

ALTHOUGH A DISC WITH MORE HOLES WILL PROVIDE GREATER PICTURE DETAIL, YET SUCH A SYSTEM CALLS FOR A MORE EXPENSIVE AMPLIFIER, CAPABLE OF HANDLING A WIDER RANGE OF FREQUENCIES.

TELEVISION "PICK-UP" UNITS

THE MODERN PRACTICE IS NO LONGER TO "PICK UP" THE LIGHT REFEECTIONS FROM THE OBJECT BEING TELEVISED BY A SINGLE PHOTO-ELECTRIC CELL BUT TO CONNECT A BANK OF PHOTO-ELECTRIC CELLS IN PARALLEL WITH EACHOTHER. THE CELLS ARE THEN SUITABLY ARRANGED, SO THAT THEY WILL BE AFFECTED BY LIGHT REFLECTIONS COMING AT DIFFERENT ANGLES AS THE OBJECT IS BEING SCANNED. THIS IS ILLUSTRATED IN FIG.11.

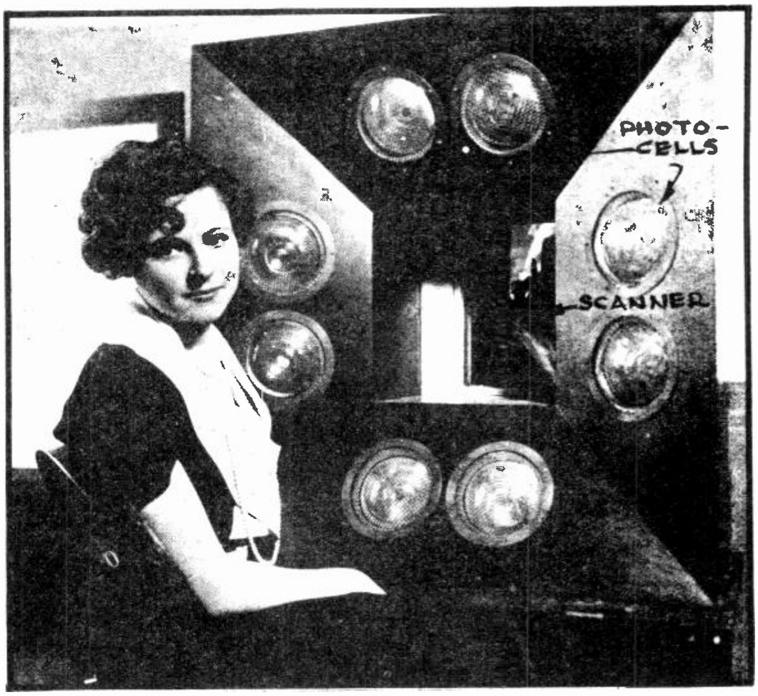


FIG. 12
The Photo Cell Pick-up.

THE ACTUAL PHOTOELECTRIC CELL PICK-UP AS USED BY MODERN TELEVISION TRANSMITTERS IS SHOWN IN FIG.12. THE OBJECT OR PERSON TO BE TELEVISED TAKES HIS POSITION IN FRONT OF THIS LARGE PICK-UP UNIT AND THE SCANNING BEAM COMES THRU THE SQUARE OPENING AT THE BACK OF THE PICK-UP UNIT. THE REFLECTIONS FROM THE OBJECT ARE DIRECTED TOWARDS THE ENTIRE GROUP OF PHOTO-ELECTRIC CELLS, ACTING CHIEFLY UPON THOSE IN THE DIRECT PATH OF THE REFLECTED BEAM.

THE "DIRECT-VISION" METHOD OF ILLUMINATING AND SCANNING AN OBJECT IS ILLUSTRATED IN FIG.13. IN THIS CASE, A BANK OF STRONG LIGHTS WITH REFLECTORS ARE ARRANGED ABOUT THE OBJECT BEING TELEVISED,SO THAT THEIR STRONG LIGHT BEAMS WILL BE DIRECTED UPON AND FLOOD THE OBJECT WITH ILLUMINATION. THE REFLECTED LIGHT FROM THE MAN'S FACE IN FIG.13 IS ALL DIRECTED TOWARDS A CONDENSING LENS , BY MEANS OF WHICH IT IS FOCUSED UPON THE ROW OF HOLES IN THE SCANNING DISC. THE PHOTO-ELECTRIC CELL IS HOUSED IN A "DARK BOX", BEING SEPARATED FROM THE SCANNING DISC BY A RECTANG

ULAR SHAPED DIAPHRAGM OF BLACK MATERIAL,HAVING A RECTANGULAR HOLE CUT IN IT. THIS DIAPHRAGM ACTS AS A SHIELD OR FRAME, PERMITTING THE LIGHT THROUGH ANY ONE DISC HOLE TO PASS TO THE PHOTO-ELECTRIC CELL FOR ONLY A LIMITED TIME AS THE HOLES OF THE ROTATING DISC MOVE PAST THE OPENING IN THE DIAPHRAGM.

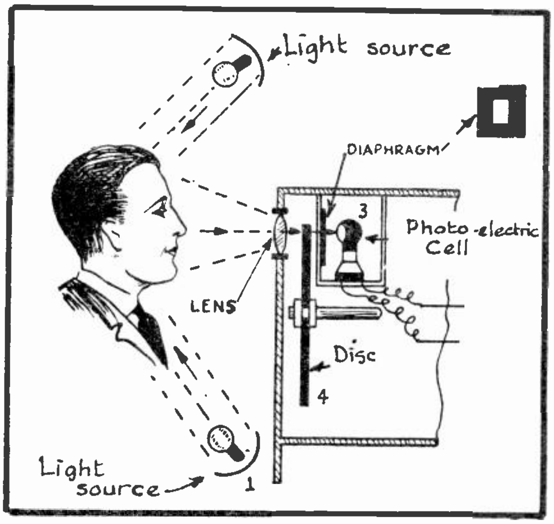


FIG. 13
"Direct Vision Method" of Illumination and Scanning.

SO BY THIS METHOD, IT IS ALSO SEEN THAT THE REFLECTION FROM ONE SPOT OF THE MAN'S FACE AT A TIME WILL ACT UPON THE PHOTO-ELECTRIC CELL, DEPENDING ENTIRELY UPON THE ALIGNMENT OF THE DISC HOLES WITH THE REFLECTED LIGHT BEAMS.

OUR AIM SO FAR HAS BEEN TO DIVIDE THE OBJECT BEING TELEVISED INTO AS MANY SMALL PARTS OR ELEMENTARY AREAS AS POSSIBLE, SO THAT AN INDIVIDUAL REFLECTED BEAM WILL BE PROVIDED FROM EACH OF THESE AREAS OR SPOTS. FURTHERMORE, THESE REFLECTED BEAMS ARE GOING TO DEPEND ENTIRELY UPON THE SHADING OF THAT PART OF THE OBJECT AND THEREFORE IT IS CLEAR THAT THESE VARIATIONS IN INTENSITY OF THE REFLECTED LIGHT WILL ACT UPON THE LIGHT-SENSITIVE PHOTO-ELECTRIC CELL.

CHANGING LIGHT VARIATION INTO CURRENT VARIATIONS

NOW THAT WE HAVE OUR REFLECTIONS OF LIGHT DIRECTED UPON THE PHOTO ELECTRIC CELL, LET US PROCEED BY INVESTIGATING THE CONSTRUCTION OF THE PHOTO-ELECTRIC CELL AND THE MANNER IN WHICH IT CHANGES VARIATIONS OF LIGHT INTENSITIES INTO CORRESPONDING ELECTRICAL CURRENT VARIATIONS.

TWO DIFFERENT TYPES OF PHOTO-ELECTRIC CELLS ARE SHOWN IN FIG.14 AND THE SYMBOL FOR THE PHOTO-CELL, AS IT IS FREQUENTLY CALLED, IS SHOWN IN THE LOWER PORTION OF FIG.14. THE CELL AT THE LEFT IS KNOWN AS THE "VISITRON" PHOTO-ELECTRIC CELL AND IN THIS CASE, THE CATHODE CONSISTS OF A CONCAVE METAL SURFACE UPON WHICH A LIGHT-SENSITIVE MATERIAL IS DEPOSITED AND THE ANODE IS IN THE FORM OF A CENTRALLY LOCATED WIRE. BOTH OF THESE ELEMENTS ARE SEALED WITHIN A GLASS BULB,WHICH IN SOME CASES IS EVACUATED WHILE IN OTHER CASES

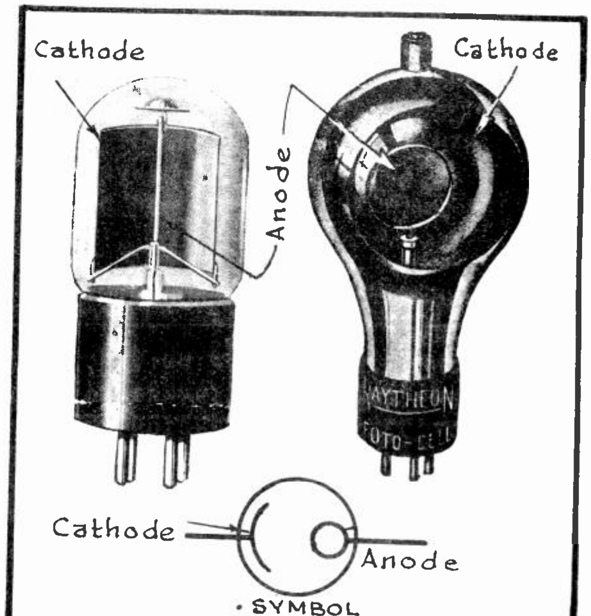


FIG. 14
Photo Electric Cells.

BEING FILLED WITH SOME INERT GAS, SUCH AS HELIUM, ARGON, OR NEON AT LOW PRESSURE. CELLS OF THE LATTER TYPE ARE GENERALLY REFERRED TO AS BEING OF THE GAS-FILLED TYPE. FROM ITS OUTER APPEARANCE THIS PHOTO-CELL SOMEWHAT RESEMBLES A RADIO TUBE.

THE PHOTO-CELL AT THE RIGHT OF FIG. 14 IS A "RAYTHEON" AND IN THIS CASE, THE SHAPE OF THE GLASS BULB IS DIFFERENT AND THE ANODE TAKES THE FORM OF A METALLIC RING. THE ACTIVE OR LIGHT SENSITIVE MATERIAL IN THIS RAYTHEON PHOTO-CELL IS APPLIED TO A METALLIC COATING ON THE INNER SURFACE OF THE GLASS BULB, THUS FORMING THE CATHODE.

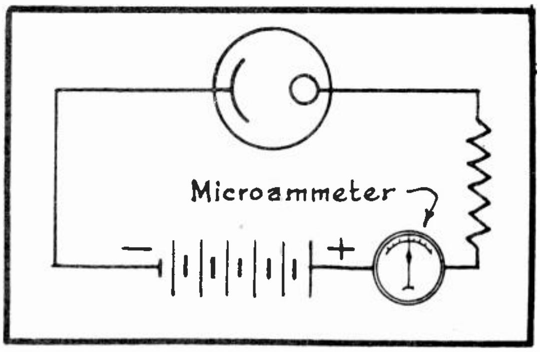


FIG. 15
A Circuit for the Photo-Cell.

A CIRCULAR PORTION OF THE GLASS, HOWEVER, IS LEFT CLEAR AND THIS IS KNOWN AS THE "WINDOW" AND THROUGH THIS TRANSPARENT PORTION, WE PASS A BEAM OF LIGHT FROM THE OUTSIDE SOURCE. SO MUCH FOR THE CONSTRUCTION OF PHOTO-CELLS. NOW LET US CONTINUE WITH THE DISCUSSION CONCERNING THEIR OPERATION.

OPERATION OF THE PHOTO-ELECTRIC CELL

IN FIG. 15, WE HAVE A FUNDAMENTAL PHOTO-ELECTRIC CELL CIRCUIT AND AS YOU WILL NOTE, WE HAVE THE POSITIVE END OF A BATTERY CONNECTED TO THE ANODE OF THE PHOTO-CELL THROUGH A RESISTOR AND THE NEGATIVE END OF THE BATTERY IS CONNECTED TO THE CATHODE SURFACE OF THE CELL. THE ANODE OF THE CELL NOW CORRESPONDS TO THE PLATE OF AN ORDINARY RADIO TUBE AND THE CATHODE TAKES THE PLACE OF THE FILAMENT OR CATHODE OF A RADIO TUBE.

IN ALL TYPES OF RADIO TUBES, WE DEPEND UPON HEAT, IN ORDER TO OBTAIN AN ELECTRON EMISSION AND THE HEAT IS FURNISHED BY A FILAMENT

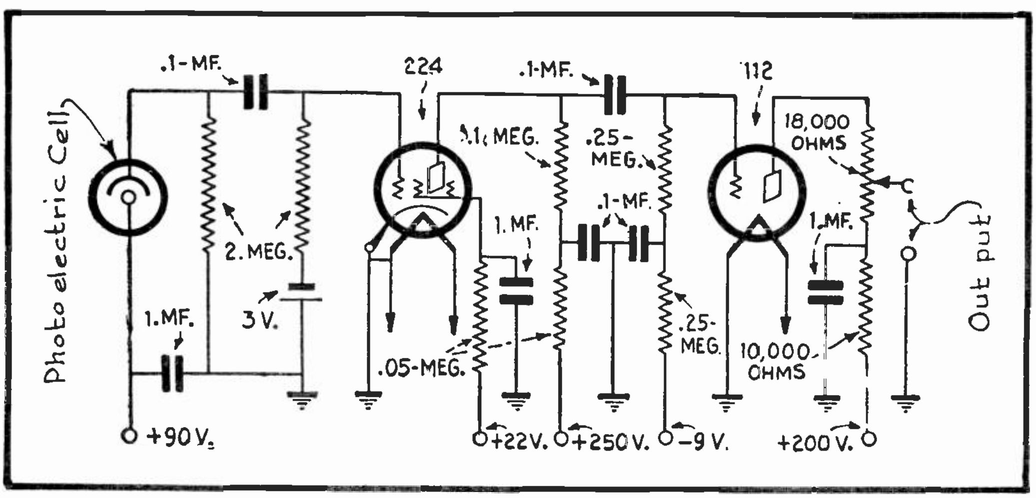


FIG. 16
A typical Television Amplifier for use With a Photo-Cell.

CURRENT. IN THE CASE OF THE PHOTO-CELL, WE HAVE NO HEATING ELEMENT BUT IN PLACE OF THIS, ELECTRONS ARE EMITTED FROM THE CATHODE DUE TO THE EFFECTS OF LIGHT RAYS STRIKING THE LIGHT-SENSITIVE SURFACE OF THE CATHODE.

MANY SUBSTANCES WILL EMIT ELECTRONS WHEN PLACED UNDER THE INFLUENCE OF LIGHT BUT CERTAIN SUBSTANCES WILL EMIT MANY MORE ELECTRONS UNDER THESE CONDITIONS THAN OTHERS. ALKALI METALS OR ALKALI-METAL HYDRIDES ARE QUITE SENSITIVE TO LIGHT RAYS AND AMONG THE MOST COMMONLY USED ALKALI-METAL HYDRIDES FOR PHOTO-CELL PURPOSES ARE SODIUM HYDRIDE, POTASSIUM HYDRIDE AND CAESIUM HYDRIDE. THERE ARE STILL OTHER SUBSTANCES, WHICH EXHIBIT PRONOUNCED EFFECTS WHEN SUBJECTED TO LIGHT RAYS BUT THOSE MENTIONED ARE THE MOST EFFECTIVE MATERIALS, WHICH HAVE BEEN FOUND UP TO THE PRESENT TIME. WE SPEAK OF THESE SUBSTANCES AS BEING "LIGHT-SENSITIVE".

SHOULD THE PHOTO-CELL OF FIG.15 BE PLACED IN TOTAL DARKNESS, THEN THE MICROAMMETER WOULD INDICATE NO CURRENT FLOW BECAUSE NO ELECTRONS

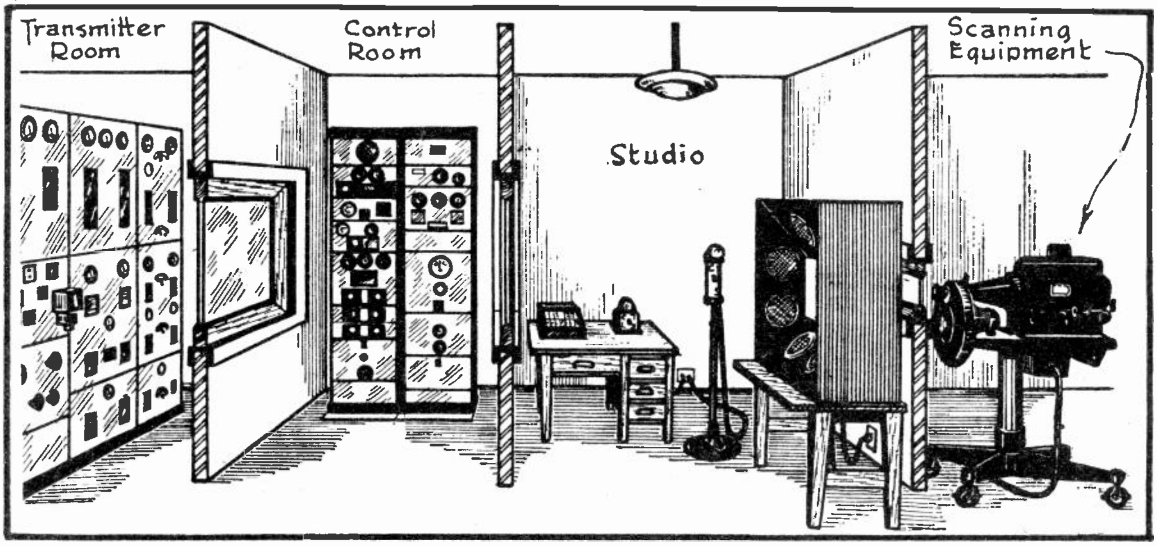


FIG. 17
General Lay-out of Television Transmitting Equipment.

ARE BEING EMITTED FROM THE CATHODE SURFACE. NOW IF A BEAM OF LIGHT WERE TO BE DIRECTED TO THE LIGHT SENSITIVE SURFACE OF THE CATHODE, A STREAM OF ELECTRONS WILL BE EMITTED FROM THIS SURFACE AND SINCE THE ANODE IS AT A POSITIVE POTENTIAL, DUE TO THE BATTERY CONNECTION, IT WILL ATTRACT THE EMITTED ELECTRONS. THE RESULT IS THAT WE HAVE A STREAM OF ELECTRONS AT THIS TIME FLOWING FROM THE CATHODE OVER TO THE ANODE AND THEREFORE CURRENT WILL FLOW THROUGH THE SYSTEM AS INDICATED, THE SAME AS PLATE CURRENT FLOWS THROUGH THE CONVENTIONAL RADIO TUBE.

IF THE LIGHT BEAM IS INTENSIFIED, THEN THERE WILL BE AN INCREASED ELECTRON EMISSION FROM THE CATHODE, ACCOMPANIED WITH A CORRESPONDING INCREASE IN THE SO CALLED "PLATE CURRENT", OR PHOTO-CELL CURRENT. THUS IT IS SEEN THAT THE CURRENT FLOW WILL VARY AS THE INTENSITY OF LIGHT, WHICH IS FOCUSED UPON THE PHOTO-CELL VARIES.

THE PHOTO-CELL CAN BE COMPARED VERY NICELY TO A MICROPHONE, FOR THE MICROPHONE CHANGES AIR PRESSURE VARIATIONS INTO ELECTRICAL CURRENT VARIATIONS OF CORRESPONDING FREQUENCY, WHEREAS THE PHOTO-CELL CHANGES LIGHT VARIATIONS INTO ELECTRICAL CURRENT VARIATIONS OF CORRESPONDING FREQUENCY. THE CURRENT THROUGH THE PHOTO-CELL IS SO SMALL THAT IT IS MEASURED IN MICROAMPERES (MILLIONTHS OF AN AMPERE).

GAS-FILLED PHOTO-CELLS ARE MORE SENSITIVE THAN THE VACUUM TYPE. THE REASON FOR THIS IS THAT THE PHOTO ELECTRONS IONIZE THE INERT GAS IN THEIR PASSAGE FROM THE CATHODE SURFACE OVER TO THE ANODE. THAT IS, THE PHOTO-ELECTRONS FLOW FROM THE CATHODE OVER TO THE ANODE AT SUCH A TREMENDOUS VELOCITY, THAT WHEN THEY COLLIDE WITH MOLECULES OF THE INERT GAS, THEY BREAK THESE MOLECULES UP INTO THE ELECTRONS AND PROTONS OF WHICH THEY ARE COMPOSED. WE CALL THIS ACTION "IONIZATION BY COLLISION". THESE EXTRA ELECTRONS ARE THEN ALSO ATTRACTED TO THE POSITIVELY CHARGED ANODE, IN ADDITION TO THOSE LIBERATED BY THE CATHODE AND THE RESULT IS THAT THE PHOTO-ELECTRIC CURRENT IS INCREASED OVER WHAT IT WOULD BE WITH THE FLOW OF PHOTO-ELECTRONS ALONE. (PHOTO-ELECTRONS ARE THE ELECTRONS

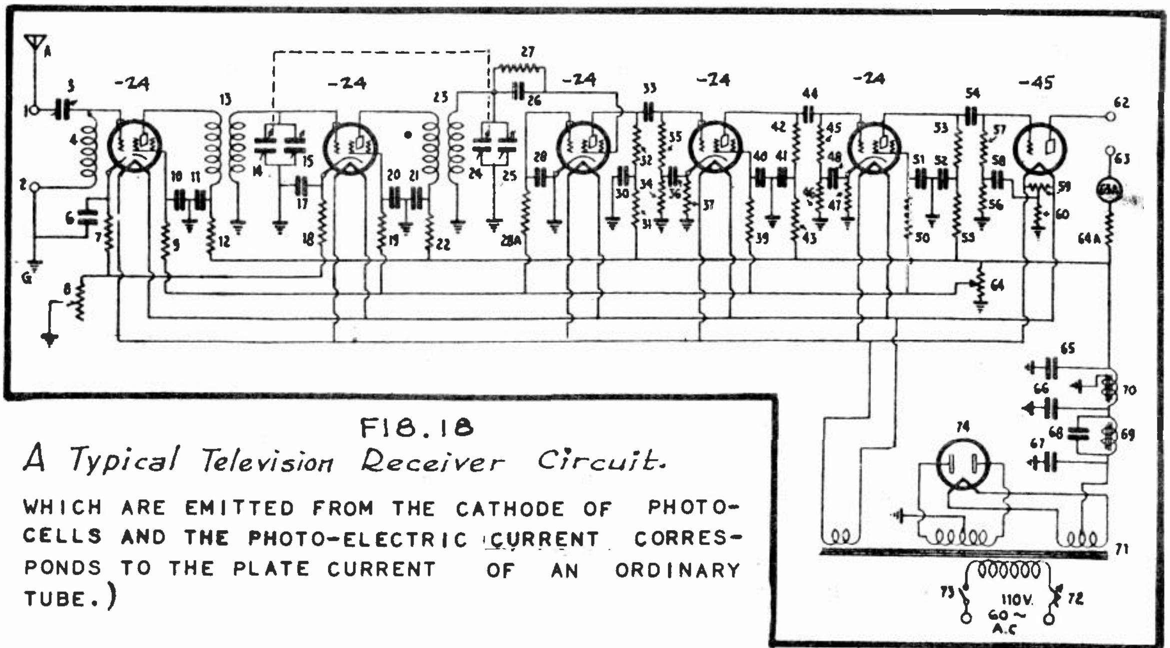


FIG. 18
A Typical Television Receiver Circuit.

WHICH ARE EMITTED FROM THE CATHODE OF PHOTO-CELLS AND THE PHOTO-ELECTRIC CURRENT CORRESPONDS TO THE PLATE CURRENT OF AN ORDINARY TUBE.)

NOT ONLY IS THE PHOTO-ELECTRIC CURRENT AFFECTED BY THE INTENSITY OF THE LIGHT DIRECTED UPON ITS CATHODE SURFACE BUT A CHANGE IN THE POTENTIAL APPLIED TO THE ANODE WILL ALSO PRODUCE A PRONOUNCED EFFECT UPON THIS CURRENT.

WITH THIS INFORMATION OF PHOTO-CELL ACTION WELL IN MIND, YOU CAN READILY SEE THAT BY HAVING THE PHOTO-CELL CONNECTED IN A CIRCUIT WITH A BATTERY IN THE TELEVISION TRANSMITTER EQUIPMENT, THE BEAM OF LIGHT AS REFLECTED FROM THE OBJECT BEING TELEVISED CAN BE DIRECTED UPON THE PHOTOCELL AND THEREBY CONVERT THE LIGHT AND DARK SHADES OF THE OBJECT INTO ELECTRICAL CURRENT VARIATIONS HAVING CORRESPONDING CHARACTERISTICS.

NOW THAT WE HAVE A METHOD OF OBTAINING THE PROPER LIGHT VARIATIONS TO OPERATE A SINGLE OR GROUP OF PARALLEL CONNECTED PHOTO-ELECTRIC CELLS, LET US NEXT CONSIDER THE AMPLIFIER INTO WHICH THE CURRENT VARIATIONS ARE PASSED. A TYPICAL TELEVISION AMPLIFIER FOR USE WITH A PHOTO

ELECTRIC CELL IS SHOWN IN FIG.16 AND NO DOUBT YOU WILL IMMEDIATELY RECOGNIZE IT AS BEING A RESISTANCE-CAPACITY COUPLED AMPLIFIER, SIMILAR TO THAT USED IN REGULAR RADIO PRACTICE, ONLY THAT THE PHOTO-ELECTRIC CELL IS CONNECTED ACROSS THE INPUT.

IN CASE THAT SEVERAL PHOTO-ELECTRIC CELLS ARE USED TO "PICK-UP" THE OBJECT BEING TELEVISED, THEN THEY ARE CONNECTED IN PARALLEL AND THE ENTIRE GROUP IS CONNECTED ACROSS THE INPUT OF THE AMPLIFIER. SUCH A PARALLEL COMBINATION OF PHOTO-ELECTRIC CELLS OFFERS A GREATER ENERGY PICK-UP THAN WHEN ONE CELL IS USED ALONE. FURTHERMORE, THIS ARRANGEMENT MAKES IT POSSIBLE FOR THE PHOTO-CELL GROUP TO SATISFACTORILY PICK-UP AT VARIOUS ANGLES THE LIGHT REFLECTIONS FROM THE OBJECT BEING TELEVISED, AND THUS MAKES A CLEAR PICTURE POSSIBLE.

NOTICE IN FIG.16 THAT THE ANODE OF THE PHOTO-CELL IS CONNECTED TO THE POSITIVE END OF THE "B" SUPPLY, WHILE THE CATHODE OR LIGHT SENSITIVE ELEMENT IS CONNECTED TO GROUND (B-) THROUGH A 2 MEGOHM RESISTOR. THE VOLTAGE CHANGES DEVELOPED ACROSS THIS RESISTOR BY THE LIGHT VARIATIONS IMPRESSED UPON THE PHOTO-CELL FORCE THE "SIGNAL" THROUGH THE .1 MFD. FIXED CONDENSER, ONTO THE GRID OF THE -24 TUBE AND THUS THIS SIGNAL CORRESPONDING TO LIGHT INTENSITY CHANGES IS SUCCESSIVELY AMPLIFIED BY THE FOLLOWING STAGES, THE SAME AS REGULAR RADIO SOUND SIGNALS.

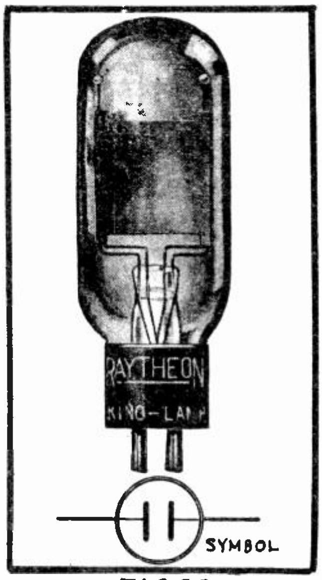


FIG.19
Television Lamp.

PRACTICALLY ALL TELEVISION AMPLIFIERS, WHETHER IN THE TRANSMITTER OR RECEIVER, ARE OF THE RESISTANCE-CAPACITY COUPLED TYPE BECAUSE THIS CLASS OF AMPLIFIER IS BETTER ABLE TO HANDLE THE REQUIRED WIDE FREQUENCY RANGE THAN IS THE TRANSFORMER COUPLED AMPLIFIER.

TRANSMITTING THE PICTURE

AT THE OUTPUT OF THIS PHOTO-CELL AMPLIFIER WE NOW HAVE THE SCANNED PICTURE IN THE FORM OF ELECTRICAL CURRENT AND VOLTAGE CHANGES JUST LIKE THE SOUND WAVES WOULD BE IN THE FORM OF CURRENT AND VOLTAGE CHANGES AT THE OUTPUT OF THE MICROPHONE AMPLIFIER. THEREFORE, IT IS REASONABLE THAT THE OUTPUT OF THE PHOTO-CELL AMPLIFIER CAN BE USED TO MODULATE A CARRIER FREQUENCY, WHICH IS GENERATED BY A REGULAR TRANSMITTER, THE SAME AS CAN BE DONE WITH THE OUTPUT OF THE AUDIO AMPLIFIER IN A REGULAR BROADCAST STATION. THIS IS JUST EXACTLY WHAT IS DONE IN TELEVISION AND THERE IS NO NEED FOR US TO GO INTO THE DETAILS CONCERNING THE GENERATION OF THE CARRIER WAVE BY THE TRANSMITTER, MODULATION, RADIATION ETC. BECAUSE THE PRINCIPLES ENVOLVED ARE EXACTLY THE SAME AS THOSE COVERED IN YOUR RADIO TRANSMITTER LESSONS.

THE ONLY THING WILL BE THAT IN THE CASE OF TELEVISION, THE CARRIER WAVE IS MODULATED ACCORDING TO THE VARIATIONS IN THE INTENSITY OF THE LIGHT BEAMS, WHICH ARE REFLECTED FROM THE SCANNED OBJECT BEING TELEVISED. WHEREAS IN THE CASE OF RADIO, THE CARRIER FREQUENCY IS MODULATED ACCORDING TO THE SOUND WAVES WHICH ARE IMPRESSED UPON THE STUDIO MICROPHONE.

The general lay-out of a typical television transmitting station, is shown in Fig. 17. At the right of Fig. 17 we see the scanner and lamp house (light source) mounted as a single unit on a common stand. Then comes the studio with the photo-cell pick-up for television and the light beam from the scanner passes through an opening in the wall and television "pick up" box". Next to the studio comes the control room and then the transmitter room.

THE TELEVISION RECEIVER

Now that we have the modulated carrier wave radiated into space, our following problems will concern the manner in which we are able to reproduce the transmitted image at the receiver. Present television transmission is being carried on at short wave lengths and therefore, it is necessary that the tuned R.F. stages of the television receiver be of the short wave type. Another important point relative to the television receiver is that the R.F. circuits should tune broad enough, so as to pass all of the modulating frequencies with the carrier.

In broadcast receivers, the R.F. stages must only pass a band approximately 10 Kc. in width, in order to retain all of the broadcasted audio frequencies, whereas in the case of television, the R.F. stages of the receiver must be capable of passing a band from 40 to 100 Kc. in width and therefore, the television receiver may not be as sharp tuning as the broadcast receiver.

The circuit diagram of a typical television receiver is shown in Fig. 18 and although it does not employ the latest types of tubes, it nevertheless illustrates the principle clearly. In later lessons, more modern circuits will be brought to your attention. The parts values for this receiver are as follows:

3 = .00026 mfd. tuning condenser.
4 = Special R.F. inductance for television.
6 - 10-11-17-20 and 21=.1 mfd.
7 - 18-37-and 47=1,000 ohms.
8 - Electrad type R.1.=202 volume control.
9 - 19-28A-32-34-39-42-46-50-53-56=50,000 ohms.
12 - -22-=75,000 ohms.
13 - 23 -- Television R.F. transformers.
14 - 24=.0002 mfd. variable condensers.
15 - 25=140 mfd. (max.) adjusting condensers.
26 = .0001 mfd. grid condenser.
27 = 50,000 ohm leak.
28 = 1 mfd.
30 = 4 mfd.
31 - 43-55=25,000 ohms
33 - 44-54=.25 mfd.
35 - 45-57=250,000 ohms.
36 - 40-41-48-51-52-58=2 mfd.
63A=Milliammeter 0-50 ma.
64A=Type B-30 Electrad truvolt resistor.

65 - 66-67 = 8 MFD.
68 = .1 MFD.
69 - 70 = 30 HENRY CHOKES
71 = POWER TRANSFORMER
72 = AMPERITE SELF-ADJUSTING LINE VOLTAGE REGULATOR.

NOTICE IN FIG.18, THAT THE DETECTOR IN THIS PARTICULAR RECEIVER EMPLOYS A -24 TYPE TUBE USED AS A SPACE-CHARGE TUBE BUT THIS IS NOT THE CASE IN ALL TELEVISION RECEIVERS.THE MODULATED CARRIER FREQUENCY IS AMPLIFIED IN THE R.F. STAGES BY THE SAME PROCESS AS CARRIED OUT IN BROADCAST RECEIVERS AND THE GRID CONDENSER AND LEAK TYPE DETECTOR SEPARATES THE CARRIER FREQUENCY FROM THE MODULATING FREQUENCY IN THE CUSTOMARY MANNER.

A RESISTANCE-CAPACITY COUPLED AMPLIFIER FOLLOWS THE DETECTOR IN FIG. 18 AND THIS CORRESPONDS TO THE A.F. AMPLIFIER OF THE BROADCAST SET, ONLY IN THE CASE OF THE TELEVISION RECEIVER,THE ELECTRICAL EQUIVALENT OF THE ORIGINAL LIGHT VARIATION IS BEING AMPLIFIED HERE IN PLACE OF VOICE CURRENTS.

FINALLY,AT THE OUTPUT OF THE POWER STAGE,WE FIND THAT A FLAT PLATE NEON LAMP IS CONNECTED IN THE PLATE CIRCUIT OF THE POWER STAGE TO REPLACE THE LOUD SPEAKER. THE NEXT THING THEN WILL BE TO SEE WHAT PURPOSE THAT THIS NEON LAMP SERVES.

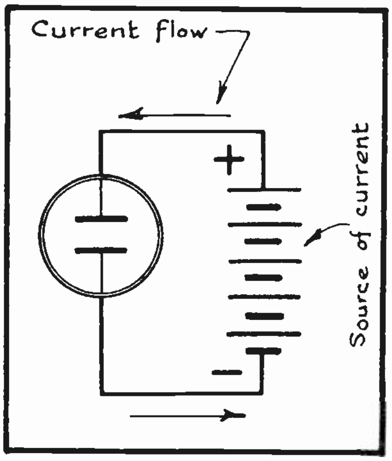


FIG. 20
Fundamental Circuit

THE NEON OR TELEVISION LAMP

A PHOTOGRAPH OF ONE TYPE OF TELEVISION LAMP IS SHOWN IN FIG.19. SOMETIMES THIS LAMP GOES BY SOME OTHER NAME SUCH AS A"GLOW TUBE", "NEON-LAMP" ETC., ALL MEANING THE SAME THING. THE SYMBOL FOR THE LAMP IS ALSO SHOWN IN FIG. 19 AND BECAUSE OF THE IMPORTANT WORK THAT IT DOES,THIS LAMP CAN BE CONSIDERED AS THE HEART OF THE TELEVISION RECEIVER.

THE TELEVISION LAMP, AS ILLUSTRATED HERE, CONSISTS OF A GLASS BULB FROM WHICH ALL AIR HAS BEEN PUMPED. A CERTAIN AMOUNT OF NEON GAS AT A DEFINITE PRESSURE IS THEN PUMPED INTO THE EVACUATED BULB.INSIDE OF THE BULB YOU WILL FIND AS THE CATHODE, A THIN METAL PLATE AND AS THE ANODE A FRAME WHICH GOES AROUND THE SURFACE OF THE CATHODE. IN ONE PARTICULAR STYLE,THE ANODE OR PLATE IS 1½ INCHES SQUARE AND SINCE IT IS NECESSARY THAT THE PLATE AREA OF THIS PLATE BE A LITTLE LARGER THAN THE IMAGE REPRODUCED AT THE RECEIVER,A LAMP OF THE SIZE JUST MENTIONED WILL BE ABLE TO TAKE CARE OF A PICTURE ABOUT 1 INCH SQUARE OR A TRIFLE LARGER.

A CUSTOMARY FOUR-PRONG BASE IS MOUNTED ON THE LOWER END OF THE GLASS BULB AND THIS FITS INTO A STANDARD FOUR-PRONG SOCKET. SO MUCH FOR ITS CONSTRUCTION AND NOW LET US SEE HOW THIS LAMP OPERATES.

SHOULD THE TELEVISION LAMP BE CONNECTED ACROSS A SOURCE OF VOLTAGE, AS IN FIG.20, THEN AN ORANGE GLOW WILL APPEAR AROUND THE LAMP ELEMENT WHICH IS CONNECTED TO THE NEGATIVE END OF THE BATTERY. IN TELEVISION RECEIVERS FOR HOME USE, THE VOLTAGE APPLIED ACROSS THE PLATES OF THE LAMP

GENERALLY AMOUNTS TO ABOUT 180 VOLTS. AS LONG AS SUFFICIENT VOLTAGE IS IMPRESSED ACROSS THE LAMP, PLATE CURRENT WILL FLOW THROUGH THE CIRCUIT FROM THE POSITIVE FRAME, THROUGH THE ELECTRON STREAM BETWEEN THE PARTS AND THENCE INTO THE NEGATIVE SIDE OF THE CIRCUIT. THIS DIRECTION OF CURRENT FLOW IS CLEARLY INDICATED BY MEANS OF THE ARROWS IN FIG.20. IN LAMPS SUCH AS GENERALLY EMPLOYED FOR HOME USE, THIS CURRENT WILL VARY FROM ABOUT 10 TO 20 MILLIAMPERES, PROVIDED THAT THE LAMP IS BEING OPERATED ACCORDING TO FACTORY SPECIFICATIONS REGARDING THE APPLIED VOLTAGE ETC.

SO FAR, WE HAVE A STEADY ORANGE-COLORED GLOW SURROUNDING THE CATHODE PLATE, WHICH IN ITSELF WOULD NOT SOLVE THE PROBLEMS OF TELEVISION BUT THE IMPORTANT THING IS THAT THE BRIGHTNESS OF THIS GLOW DEPENDS UPON THE VOLTAGE APPLIED ACROSS THE ELEMENTS OF THE LAMP. THE GREATER THIS VOLTAGE, THE BRIGHTER WILL BE THE GLOW AND VICE VERSA.

COUPLING THE TELEVISION LAMP TO THE RECEIVER

NOW WE WILL CONNECT THE TELEVISION LAMP TO THE OUTPUT OF THE RECEIVER'S POWER STAGE BY MEANS OF THE CIRCUIT ARRANGEMENT SHOWN IN FIG.21. HERE YOU WILL SEE THAT THE "B" SUPPLY OF THE RECEIVER HAS ITS POSITIVE END CONNECTED TO THE PLATE OF THE POWER TUBE THROUGH LOAD RESISTOR "R_1". THE TELEVISION LAMP IS ISOLATED FROM THE RECEIVER'S POWER STAGE BY MEANS OF THE BLOCKING CONDENSER AND THE LAMP HAS ITS INDIVIDUAL SUPPLY CONNECTED ACROSS ITS PLATES.

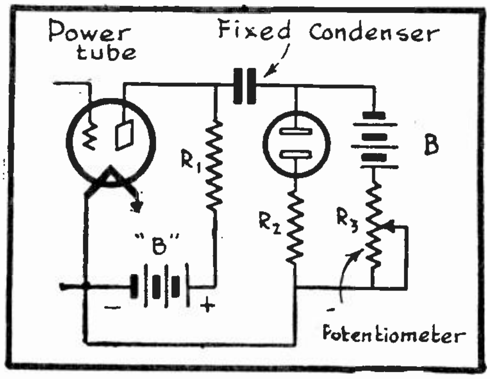


FIG. 21
Coupling the Television Lamp To The Receiver.

THE POTENTIOMETER IS USED AS A MEANS WHEREBY THE INITIAL BRILLIANCE OF THE LAMP IS ADJUSTED. NOW BY HAVING THE LAMP SO CONNECTED TO THE RECEIVER CIRCUIT, IT IS CLEAR THAT THE SIGNAL VOLTAGES DEVELOPED ACROSS THE LOAD RESISTOR "R_1", IN THE PLATE CIRCUIT OF THE POWER TUBE, WILL CAUSE THESE SAME VOLTAGE CHANGES TO BE IMPRESSED ACROSS THE LAMP CIRCUIT THRU THE COUPLING CONDENSER.

THESE VARYING VOLTAGE CHANGES WILL ADD TO AND SUBTRACT FROM THE INITIAL VOLTAGE BEING IMPRESSED ACROSS THE LAMP AND THE RESULT IS THAT THE BRILLIANCE OF THE LAMP WILL INCREASE AND DECREASE FROM ITS NORMAL OR INITIAL BRILLIANCE IN DIRECT STEP WITH THE SIGNAL VOLTAGE CHANGES, WHICH ACT THROUGH THE COUPLING CONDENSER. THESE SIGNAL VOLTAGES, HOWEVER, ARE THE EXACT ELECTRICAL REPRESENTATIONS OF THE LIGHT VARIATIONS ACTUATING THE PHOTO-ELECTRIC CELL AT THE TRANSMITTER, THEREFORE, THE NEON LAMP AT THE RECEIVER WILL NOW BE PRODUCING VARIATIONS IN LIGHT INTENSITY CORRESPONDING TO THOSE IMPRESSED UPON THE PHOTO-ELECTRIC CELL.

RESISTOR "R_2" IN FIG. 21 IS A CURRENT LIMITING RESISTOR. THE REASON FOR USING IT IS TO COUNTER-BALANCE THE NEGATIVE CHARACTERISTICS OF THE NEON LAMP. THAT IS, THE RESISTANCE OF THE LAMP BECOMES LESS WITH AN INCREASE IN CURRENT FLOW AND THUS IT IS OBVIOUS THAT WITH NO CURRENT

LIMITING RESISTANCE EMPLOYED, THE CURRENT FLOW THROUGH THE LAMP WOULD CONTINUALLY INCREASE. FINALLY, IT MIGHT BECOME GREAT ENOUGH TO CAUSE ARCING WITHIN THE LAMP AND THEREBY DESTROY THE LAMP ENTIRELY.

SINCE THE TELEVISION LAMP ONLY SERVES TO REPRODUCE THE ORIGINAL LIGHT VARIATIONS ACTING UPON THE PHOTO-ELECTRIC CELLS AT THE TRANSMITTER, WE ARE ONLY SO FAR REPRODUCING THE TINY SECTIONS OF THE OBJECT BEING TELEVISED AS IT IS BEING DIVIDED INTO THE SMALL ELEMENTARY AREAS BY THE SCANNER. THE NEXT THING THEN WILL BE TO RE-ASSEMBLE THE LIGHT VARIATIONS PRODUCED BY THESE ELEMENTARY AREAS INTO A DUPLICATE OF THE ORIGINAL OBJECT.

USE OF THE SCANNING DISC AT THE RECEIVER

SINCE WE USED A SCANNING DISC TO DIVIDE THE OBJECT INTO TINY PARTICLES, IT IS LOGICAL THAT WE CAN AGAIN USE A SIMILAR SCANNING DISC TO REASSEMBLE THESE ELEMENTARY AREAS INTO THEIR ORIGINAL FORMATION AND THIS IS JUST EXACTLY WHAT WE DO.

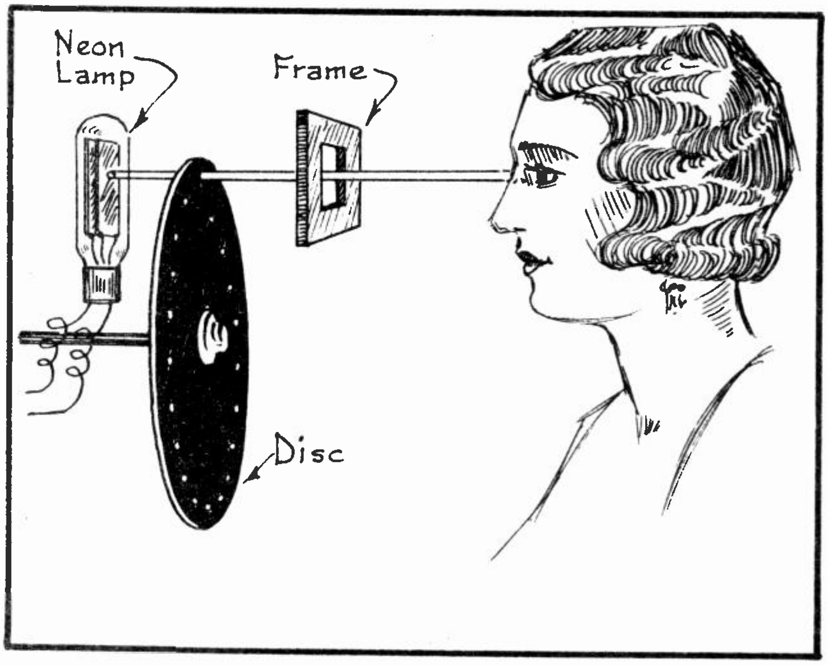


FIG. 22

Reproducing the Image.

AT THE RECEIVER, A SCANNING DISC OF THE SAME TYPES AS THAT USED AT THE TRANSMITTER IS PLACED BETWEEN THE OBSERVER AND THE TELEVISION LAMP. WITH THE DISC STATIONARY AND ANY ONE OF THE HOLES ALIGNED WITH THE LINE OF VISION BETWEEN THE OBSERVER'S EYE AND THE CATHODE (NEGATIVE PLATE) OF THE TELEVISION LAMP, THE OBSERVER WILL BE ABLE TO SEE ONLY ONE PARTICULAR SPOT ON THE LAMP'S CATHODE AS ILLUSTRATED IN FIG. 22.

SHOULD THE OBSERVER CONCENTRATE HIS VISION UPON THIS ONE DISC HOLE, AS THE DISC IS SLOWLY TURNED BY HAND, THIS SPOT MOVES ACROSS THE PLATE OF THE LAMP IN A HORIZONTAL PLANE. IF THE SCANNING DISC IS ROTATED CLOCKWISE, THIS SPOT WOULD MOVE ACROSS THE CATHODE ELEMENT FROM THE LEFT TOWARDS THE RIGHT.

NOW BY PLACING A DARK SCREEN OR FRAME IN THE LINE OF VISION BETWEEN THE DISC AND THE OBSERVERS EYE, THE AREA OF VISION WILL BE LIMITED. THAT IS, THE CATHODE CAN ONLY BE SEEN AS LONG AS THE DISC HOLE IS IN

LINE WITH THE RECTANGULAR OPENING IN THE SCREEN. CONSEQUENTLY, AS ANY ONE HOLE COMES INTO THE LINE OF SIGHT,THE OBSERVER'S VISION WILL BE DIRECTED ACROSS THE LAMP'S CATHODE FROM LEFT TO RIGHT BUT AS SOON AS THIS HOLE DISAPPEARS OFF TO THE RIGHT SIDE OF THE SCREEN'S OPENING,THE FOLLOWING HOLE OF THE DISC WILL APPEAR IN THE LINE OF SIGHT AND WILL AGAIN DIRECT THE OBSERVER'S VISION ACROSS THE CATHODE OF THE LAMP FROM THE LEFT TOWARDS THE RIGHT BUT THIS TIME, HE WILL SCAN THE SECTION OF THE CATHODE SLIGHTLY BELOW THAT AS OBSERVED BY THE FIRST HOLE. THIS IS DUE TO THE SPIRAL ARRANGEMENT OF THE HOLES IN THE SCANNING DISC.

FINALLY, AFTER ONE COMPLETE REVOLUTION OF THE SCANNING DISC, THE OBSERVER, WILL HAVE COMPLETELY SCANNED AN AREA OF THE LAMP'S CATHODE PLATE EQUIVALENT TO THE AREA OF THE OPENING IN THE SCREEN. BY REVOLVING THE SCANNING DISC AT A SPEED OF 900 R.P.M., HOWEVER, THE OBSERVER WILL NO LONGER BE ABLE TO DISTINGUISH THE INDIVIDUAL HOLES OF THE DISC BUT INSTEAD OF THIS HE WILL SEE A COMPLETE SECTION OF THE PLATE ALL AT ONCE.

BY APPLYING THE INITIAL VOLTAGE ACROSS THE TELEVISION LAMP,WHILE THE SCANNING DISC IS ROTATING AT 900 R.P.M.,THE OBSERVER WILL SEE AN ORANGE COLORED SQUARE DUE TO THE GLOW ON THE CATHODE PLATE. THIS ORANGE SQUARE WILL NOT VARY IN BRILLIANCE AND IT WILL BE OF EQUAL SIZE TO THE OPENING IN THE SCREEN, WHICH BY THE WAY,IS GOING TO BE THE SIZE OF THE REPRODUCED PICTURE.

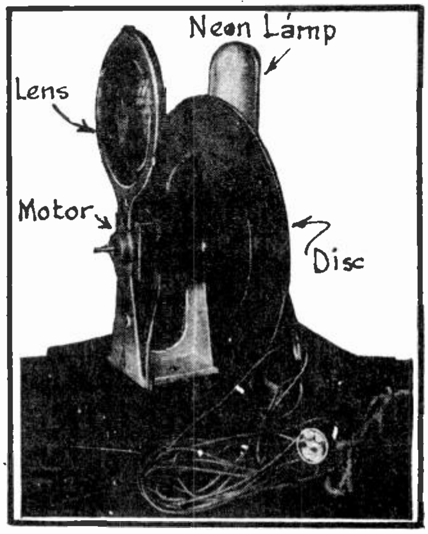


FIG. 23

The Jenkins Radiovisor.

IT IS IMPERATIVE THAT THE SCANNING DISC AT THE RECEIVER BE DRIVEN AT EXACTLY THE SAME SPEED AS THE SCANNING DISC AT THE TRANSMITTER AND THAT THESE TWO DISCS WILL BE SO SYNCHRONIZED THAT THE SAME HOLE OF THE DISC AT THE RECEIVER WILL BE IN THE LINE OF SIGHT OF THE OBSERVER AS THE DISC HOLE PASSING THE BEAM OF LIGHT AT THE TRANSMITTER AT THIS SAME INSTANT.

THIS BEING THE CASE, THEN WHEN THE SIGNAL VOLTAGES ARE APPLIED ACROSS THE LAMP AT THE RECEIVER, THE OBSERVER WILL NOT ONLY SEE VARIATIONS IN THE INTENSITY OF THE ORANGE GLOW AS HE LOOKS THROUGH THE FRAME BUT THESE CHANGES IN LIGHT INTENSITY WILL OCCUR AT DEFINITE SPOTS ON THE LAMP'S CATHODE, SO THAT THE CHANGES OF LIGHT AND DARK WILL BE ARRANGED IN THE SAME PATTERN AS ON THE ACTUAL IMAGE BEING TELEVISED.

DO NOT MISUNDERSTAND THIS STATEMENT BECAUSE CERTAIN SPOTS ON THE CATHODE OF THE TELEVISION LAMP DO NOT ACTUALLY CHANGE IN BRILLIANCE BUT THE BRILLIANCE OF THE ENTIRE PLATE VARIES AT THE SAME TIME. HOWEVER,DUE TO THE HOLES IN THE SCANNING DISC, THE OBSERVER ACTUALLY SEES ONLY ONE TINY SPOT OF THE CATHODE AT A TIME AND THE INSTANT THAT HE OBSERVES THIS ONE SPOT,THE ENTIRE CATHODE WILL ALREADY HAVE BECOME BRIGHTER OR DIMMER BUT HE IS UNAWARE OF THIS FACT AND NOTES ONLY THE CHANGE IN LIGHT INTENSITY AT THE ONE PARTICULAR SPOT. HENCE DUE TO THE PRESISTENCE OF VISION, HE STILL SEES THIS SAME SPOT AS THE OTHERS RAPIDLY COME INTO VIEW,

WITH THE RESULT THAT IN HIS MIND, HE SEES THEM ALL AT ONCE, PROPERLY ARRANGED SO THAT THE SHADING OF LIGHT AND DARK IS IN A DEFINITE PATTERN, THEREBY REPRODUCING THE ORIGINAL IMAGE.

ENLARGING THE REPRODUCED PICTURE

THE PRESENT IMAGES REPRODUCED BY TELEVISION IN THE HOME ARE STILL RATHER SMALL, BEING APPROXIMATELY ONE INCH SQUARE AND SO TO INCREASE THEIR SIZE, THE GENERAL PRACTICE IS TO MOUNT A MAGNIFYING LENS BETWEEN THE SCREEN OR FRAME AND THE OBSERVER. THE OBSERVER THEN SEES THE PICTURE THROUGH THE LENS WHICH ENLARGES IT TO SUFFICIENT SIZE FOR COMFORTABLE RECEPTION. AN EXAMPLE OF THE PICTURE REPRODUCER OR "RADIO-VISOR" FOR A TELEVISION RECEIVER IS SHOWN IN FIG.23 AND THROUGH THE LENS IN THIS CASE, THE PICTURE WILL APPEAR AS BEING ABOUT 4" SQUARE.

IN THIS LESSON, WE HAVE DISCUSSED THE FUNDAMENTAL PRINCIPLES UNDERLYING THE TRANSMISSION AND RECEPTION OF TELEVISION AND IN THE FOLLOWING LESSON, WE WILL CONTINUE THE STUDY OF TELEVISION, CONSIDERING AT THAT TIME OTHER METHODS OF SCANNING, VARIOUS TELEVISION RECEIVER CIRCUITS, METHODS OF SYNCHRONIZING TELEVISION EQUIPMENT ETC.

Examination Questions

LESSON NO. TEL-1

1. - WHAT ARE THE ESSENTIAL DIFFERENCES BETWEEN A TELEVISION RECEIVER AND A BROADCAST RECEIVER?
2 - DO DARK SURFACES REFLECT LIGHT BETTER THAN DO SURFACES OF A LIGHTER COLOR?
3. - AT A TELEVISION TRANSMITTER, IS THE ENTIRE IMAGE TO BE TELEVISED "PICKED-UP" ALL AT ONCE BY THE PHOTO-ELECTRIC CELLS? EXPLAIN.
4. - AS FAR AS THE SCANNING DISC ITSELF IS CONCERNED, WHAT DETERMINES THE WIDTH AND HEIGHT OF THE "PICTURE"?
5. - WHEN USING A SCANNING DISC HAVING 48 HOLES, HOW MANY REVOLUTIONS OF THE DISC ARE REQUIRED TO SCAN THE OBJECT ONCE?
6. - WILL PICTURE DETAIL BE BETTER IF A SCANNING DISC OF A GREATER NUMBER OF HOLES IS USED?
7. - IF THE VOLTAGE ACROSS THE NEON LAMP IS INCREASED, WILL THE LAMP INCREASE IN BRILLIANCE?
8. - DOES THE GLOW IN THE NEON LAMP OCCUR AROUND THE POSITIVE PLATE OR AROUND THE NEGATIVE PLATE?
9. - WHAT IS THE PURPOSE OF THE SCANNING DISC AT THE TELEVISION RECEIVER?
10 - ARE SOME PORTIONS OF THE NEON LAMP'S CATHODE ILLUMINATED BRIGHTER THAN OTHERS? EXPLAIN.

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Television

LESSON NO. 2

NEON LAMP CIRCUITS --MECHANICAL SCANNERS

IN THE PREVIOUS LESSON, YOU WERE SHOWN ONLY ONE FUNDAMENTAL NEON LAMP CIRCUIT CONNECTED TO THE OUTPUT OF THE TELEVISION RECEIVER. ALTHOUGH THIS ONE CIRCUIT SERVED TO ILLUSTRATE HOW THE TELEVISION LAMP IS MADE TO OPERATE, YET YOU SHOULD ALSO BECOME FAMILIAR WITH OTHER POPULAR LAMP CIRCUITS.

DIRECTLY COUPLED LAMP CIRCUIT

PROBABLY THE THOUGHT HAS ALREADY PRESENTED ITSELF TO YOU AS TO WHY THE TELEVISION LAMP CANNOT BE CONNECTED DIRECTLY INTO THE PLATE CIRCUIT OF THE POWER TUBE AS ILLUSTRATED IN FIG.2, INSTEAD OF USING A COUPLING CIRCUIT. ALTHOUGH THE CIRCUIT OF FIG.2 CAN BE USED, YET IT IS NOT ADVISABLE BECAUSE NO PROVISION IS MADE, WHEREBY THE INITIAL INTENSITY OF THE LAMP CAN BE ADJUSTED FOR BEST RESULTS. FURTHERMORE, THIS SYSTEM DOES NOT PERMIT THE USE OF VOLTAGES BEST SUITED FOR BOTH THE NEON LAMP AND POWER TUBE.

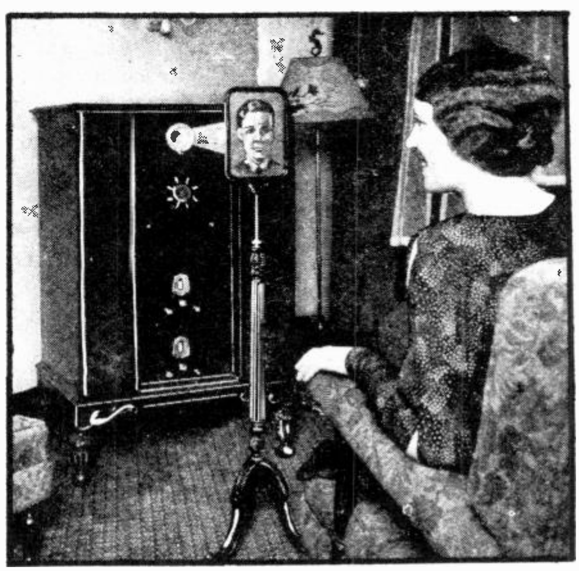

FIG. 1
Television in the Home.

THE SYSTEM OF FIG. 2 HAS BEEN IMPROVED UPON IN THE CIRCUIT DIAGRAM OF FIG.3. THE ESSENTIAL IMPROVEMENTS BEING THE POTENTIOMETER AND THE 2000 OHM RESISTOR, WHICH AIDS IN OBTAINING A BETTER IMPEDANCE MATCH BETWEEN THE POWER TUBE AND ITS PLATE CIRCUIT. EVEN WITH THESE ADDED IMPROVEMENTS, THE SYSTEM IS NOT AL

TOGETHER SATISFACTORY, CHIEFLY BECAUSE IF THE POTENTIOMETER IS ADJUSTED FOR THE MOST SUITABLE BRILLIANCY OF THE LAMP, THE PLATE VOLTAGE OF THE TUBE WILL ALSO BE EFFECTED AND WOULD THUS PREVENT THE TUBE FROM OPERATING AT ITS RECOMMENDED VALUES.

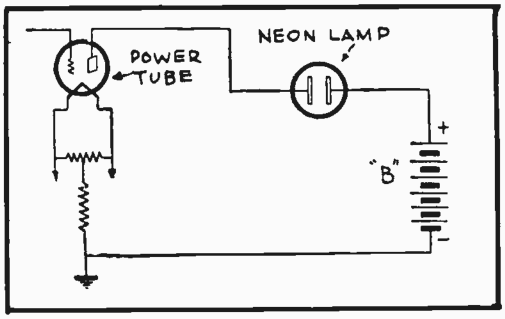

FIG. 2
Neon Lamp Connections.

SO YOU SEE, CONSIDERING ALL OF THESE CONDITIONS, IT IS BEST TO USE A SEPARATE SOURCE OF VOLTAGE FOR THE LAMP. THIS VOLTAGE SOURCE FOR THE LAMP, HOWEVER, DOES NOT NECESSARILY HAVE TO BE SUPPLIED BY BATTERIES BUT MAY BE FURNISHED BY ANY CONVENTIONAL TYPE OF "B" ELIMINATOR. IN THIS CASE, THE CURRENT, AS FURNISHED BY THE ELIMINATOR, MUST BE ABSOLUTELY FREE FROM A.C. RIPPLE AS OTHERWISE IT WILL SPOIL THE PICTURE.

INDIRECT LAMP COUPLING WITH COMMON "B" SUPPLY

FIG. 4 ILLUSTRATES A GOOD SYSTEM IN WHICH THE SAME "B" SUPPLY CAN BE USED FOR BOTH THE POWER TUBE OF THE RECEIVER AND THE NEON LAMP. NOTICE THAT IN THIS EXAMPLE, THE "B" SUPPLY AS FURNISHED TO THE POWER TUBE, WILL NOT BE AFFECTED BY ANY CHANGE OF RESISTANCE IN THE LAMP CIRCUIT BECAUSE AS FAR AS D.C. IS CONCERNED, THE POWER TUBE AND LAMP CIRCUITS ARE CONNECTED IN PARALLEL WITH EACHOTHER AND A FIXED CONDENSER PREVENTS THE D.C. OF THE LAMP CIRCUIT FROM FLOWING THROUGH THE LOAD OF THE POWER TUBE. AN IRON CORE IMPEDANCE OR CHOKE COIL IS USED AS THE LOAD IN THE PLATE CIRCUIT OF THE POWER TUBE.

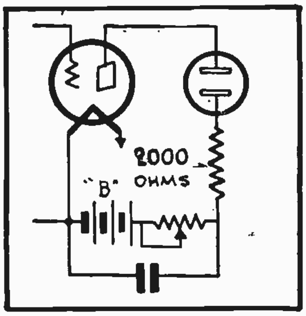

FIG. 3
Additional load.

THE RESISTOR R_1 OF FIG. 4 IS USED TO ADJUST THE INITIAL INTENSITY OF THE TELEVISION LAMP, WHILE THE 1000 OHM RESISTOR IS THE CURRENT LIMITING RESISTOR. RESISTOR R_3 SERVES AS A LOAD ACROSS WHICH THE SIGNAL VOLTAGES CAN BE DEVELOPED TO ACT UPON THE LAMP AND THIS SAME RESISTOR ALSO SERVES TO COMPLETE THE "B" CIRCUIT THROUGH THE LAMP.

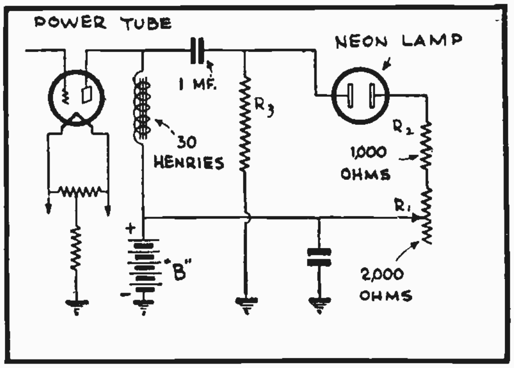

FIG. 4
Indirect Coupling.

THE GLOW LAMP IS EXCEEDINGLY SENSITIVE TOWARD VOLTAGE VARIATIONS ACTING UPON IT AND IT HAS BEEN ESTIMATED THAT SUCH A LAMP IS CAPABLE OF CONVERTING VOLTAGE CHANGES INTO VARIATIONS IN LIGHT INTENSITY AT THE REMARKABLE RATE OF 100,000 CYCLES PER SECOND. IN OTHER WORDS, VOLTAGE AND CURRENT VARIATIONS AS RAPID AS 100,000 CYCLES CAN BE FOLLOWED BY THE GLOW-LAMP.

MORE ABOUT MECHANICAL SCANNING

NOW LET US RETURN TO THE SUBJECT

OF SCANNING. YOU WILL RECALL THAT IN THE PREVIOUS LESSON, THE ONLY SCANNING DEVICE, WHICH WE CONSIDERED, WAS THE DISC HAVING A NUMBER OF HOLES ARRANGED IN A SPIRAL FORMATION NEAR ITS RIM. THIS TYPE OF SCANNING DISC IS KNOWN AS THE "NIPKOW SCANNING DISC" BUT BESIDES THIS TYPE, STILL OTHERS ARE BEING USED AND IT IS WITH SOME OF THESE OTHER TYPES TO WHICH WE SHALL DEVOTE THE PRESENT DISCUSSION.

THE SANABRIA SYSTEM OF SCANNING

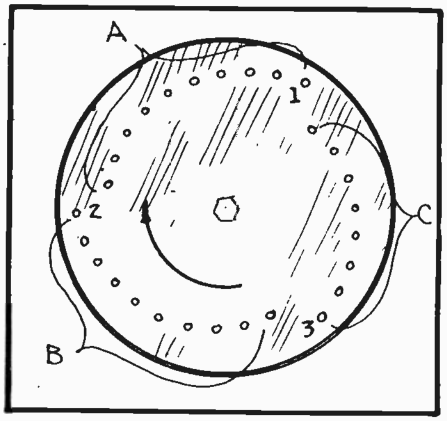

FIG. 5
The "Sanabria" Scanning Disc.

A DIFFERENT TYPE OF SCANNING DISC IS SHOWN IN FIG.5. THIS IS THE "SANABRIA DISC" AND IN THIS CASE, INSTEAD OF HAVING ONE CONTINUOUS SPIRAL, WE HAVE THREE SECTIONS, NAMELY "A", "B" AND "C". THIS TYPE OF DISC WILL COMPLETELY SCAN THE PICTURE THREE TIMES DURING ONE REVOLUTION. THAT IS, EACH SECTION OF HOLES SCANS THE PICTURE ONCE AND SHOULD WE START WITH THE HOLE MARKED 1, THE ENTIRE PICTURE WILL HAVE BEEN SCANNED ONCE BY THE TIME THE LAST HOLE OF GROUP "A" COMES INTO THE LINE OF VISION. THE HOLE MARKED 2 WILL THEN COMMENCE SCANNING THE PICTURE FOR THE SECOND TIME, COMPLETING THE JOB WITH THE LAST HOLE IN SECTION "B" THIS SAME PROCESS IS THEN BEGUN BY HOLE #3 AND SECTION "C" WILL SCAN THE PICTURE FOR THE THIRD TIME AS THE DISC COMPLETES A SINGLE REVOLUTION.

IN THIS CASE, HOWEVER, THE OBJECT IS NOT REALLY COMPLETELY SCANNED BY EACH SECTION OF THE DISC BECAUSE THE ADJACENT HOLES IN ANY ONE SECTION APPROACH THE CENTER OF THE DISC AT TWICE THE RATE AS IN DISCS OF THE CONTINUOUS SPIRAL TYPE. THIS CAN PROBABLY BE BEST ILLUSTRATED BY MEANS OF FIG.6, WHERE THE PICTURE FRAME HAS BEEN DIVIDED INTO 45 HORIZONTAL LINES TO CONFORM WITH THE 45 HOLES IN THE DISC.

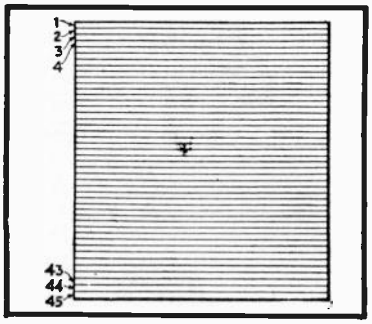

FIG. 6
Sequence of Scanning.

NOW AS SECTION "A" DOES THE SCANNING, IT DOES NOT SCAN THE LINES IN CONSECUTIVE ORDER BUT IT SCANS LINE #1 FIRST AND THEN LINES 4-7-10-13-16 ETC. AND FINISHES WITH THE 43rd LINE. SECTION "B" OF THE DISC COMMENCES ITS SCANNING OPERATION WITH LINE #2 IN FIG.6 AND THEN CONSECUTIVELY LINES 5-8-11-14 ETC., FINISHING WITH THE 44TH LINE.

SECTION "C" THEN FOLLOWS BY SCANNING THE LINES IN THE ORDER OF 3-6-9-12-15 ETC. AS SEEN IN FIG.6 AND THEN AFTER ONE COMPLETE REVOLUTION OF THE DISC, THE PICTURE WILL HAVE BEEN SCANNED IN DETAIL. BY ROTATING THE DISC AT SUFFICIENT SPEED, THE FIELD OF VIEW, AS OBSERVED THROUGH THE HOLES OF THE DISC, WILL TAKE ON THE APPEARANCE OF A SQUARE OR RECTANGLE, WHOSE WIDTH IS EQUAL TO THE DISTANCE BETWEEN ADJACENT HOLES AND WHOSE HEIGHT IS EQUAL TO THE DIFFERENCE BETWEEN THE CENTER OF THE DISC AND THE FIRST AND LAST HOLE OF EACH SECTION.

LENS-EQUIPPED SCANNING DISCS

LIGHT RAYS HAVE A NATURAL TENDENCY TO SPREAD APART AS THEY GET FARTHER AWAY FROM THEIR SOURCE. THIS MEANS THAT THE FARTHER WE GO FROM THE LIGHT SOURCE, THE GREATER WILL BE THE AREA COVERED BY THE BEAMS AND TO COVER A LARGER AREA WITH A GIVEN AMOUNT OF LIGHT, IT IS CLEAR THAT THE ILLUMINATION WILL DECREASE WITH AN INCREASE IN AREA ON WHICH THE LIGHT RAYS ARE SPREAD.

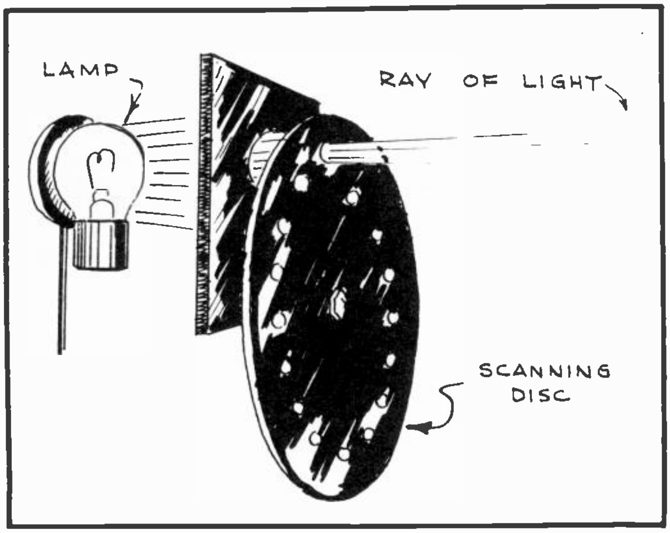

FIG. 7
Spreading of Light Rays.

THE LAW CONTROLLING THIS PHENOMENA IS KNOWN AS THE "INVERSE SQUARE LAW" AND THIS LAW STATES THAT AS THE DISTANCE FROM THE SOURCE IS DOUBLED, THE ILLUMINATION AT THE LATTER OR FARTHER POINT IS ONLY 1/4 THAT AT THE POINT NEARER THE LIGHT SOURCE. IN OTHER WORDS, AT 10 FT. FROM THE LIGHT SOURCE, THE ILLUMINATION IS ONLY 1/4 THAT AT A POINT ONLY 5 FT. FROM THE SOURCE.

THIS CONDITION WILL TEND TO SPREAD THE LIGHT BEAM OVER TOO GREAT AN AREA WHEN SCANNING THE SUBJECT TO BE TELEVISED AND THIS OF COURSE IS UNDESIRABLE IF GOOD PICTURE DETAIL IS EXPECTED. TO REMEDY THIS UNFAVORABLE CONDITION, SOME SCANNING DISCS HAVE AN INDIVIDUAL CONDENSING LENS MOUNTED IN EACH HOLE OF THE DISC.

THE CONDENSING LENS ACTS THE SAME AS AN ORDINARY MAGNIFYING LENS, IN THAT IT COLLECTS THE SPREADING LIGHT RAYS AND FOCUSES THEM DOWN TO A SMALL SPOT. THE USE OF SUCH A LENS-EQUIPPED SCANNING DISC IS SHOWN IN FIG. 8 AND HERE YOU WILL NOTE HOW A SHARP, CONCENTRATED BEAM OF LIGHT COVERS BUT A VERY SMALL AREA AT A TIME, AS THE TELEVISED SUBJECT IS BEING SCANNED.

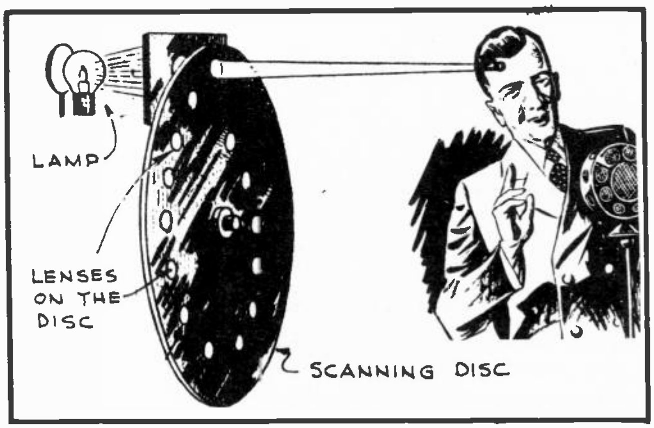

FIG. 8
Lens-Equipped Scanning Disc.

LENS-EQUIPPED SCANNING DISCS CAN ALSO BE USED AT THE RECEIVER AS ILLUSTRATED IN FIG. 9. HERE YOU WILL NOTE THAT THE CONCENTRATED LIGHT BEAM IS FOCUSED UPON A SEMI-TRANSPARENT SCREEN, UPON WHICH THE TELEVISED IMAGE IS FORMED BY THE BEAM

OF THE GLOW LAMP. THIS SYSTEM IS BEING USED IN THE PHOTOGRAPH SHOWN IN FIG.1 OF THIS LESSON.

MULTI-SYSTEM SCANNING DISC

SINCE NO STANDARD HAS YET BEEN ADOPTED AS TO THE NUMBER OF LINES INTO WHICH AN OBJECT SHOULD BE DIVIDED WHILE SCANNING, YOU WILL FIND SOME SYSTEMS USING 48 LINES, OTHERS 60 LINES ETC. THIS BEING THE CASE, IT IS OBVIOUS THAT A DIFFERENT SCANNING DISC MUST BE USED AT THE RECEIVER, IN ORDER TO RECEIVE PICTURES FROM STATIONS TRANSMITTING WITH ANY ONE OF THE POSSIBLE SYSTEMS. HOWEVER, THE NECESSITY OF SEPARATE DISCS CAN BE DONE AWAY WITH QUITE EASILY, SIMPLY BY MAKING A DISC SUCH AS ILLUSTRATED IN FIG.10, WHERE TWO SETS OF SPIRAL HOLES "A" AND "B" ARE PROVIDED.

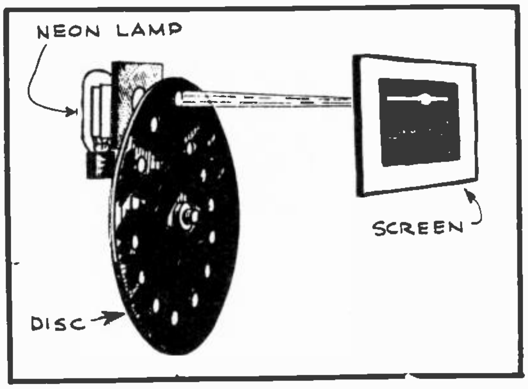

FIG. 9
Reproduction of Picture Upon a Screen

ASSUMING ONE OF THESE SPIRALS OF FIG.10 TO CONSIST OF 60 HOLES AND THE OTHER OF 48 HOLES, YOU CAN USE EITHER SECTION MERELY BY CHANGING THE POSITION OF THE GLOW LAMP SO THAT IT WILL BE ALIGNED WITH WHATEVER SET OF HOLES IS BEING USED AT THE TIME. THE TWO SETS OF HOLES ARE SPACED FAR ENOUGH APART, SO THAT BOTH OF THEM CANNOT BE IN THE FIELD OF VIEW AT THE SAME TIME. IT IS ALSO POSSIBLE TO MAKE A SIMILAR DISC, HAVING ONE OR MORE SETS OF HOLES FOR THE NIPKOW SYSTEM OF A DIFFERENT NUMBER OF LINES PER SET AND IN ADDITION, TO ALSO HAVE A THREE-SECTION SET OF HOLES FOR THE SANABRIA SYSTEM, THUS HAVING WHAT MIGHT BE CLASSIFIED AS A UNIVERSAL SCANNING DISC.

THE SCANNING BELT

IN FIG.11 YOU WILL SEE STILL ANOTHER SCANNING DEVICE. THIS UNIT IS EMPLOYED WITH THE BAIRD TELEVISION EQUIPMENT AND AS YOU WILL NOTE, THE SCANNING MEMBER CONSISTS OF A THIN METALLIC BELT OR HOOP, HAVING THE SCANNING HOLES SPIRALLY ARRANGED AROUND ITS CIRCUMFERENCE. THE SCANNING BELT IS MOUNTED ON A SPIDER AND THE SPIDER IS DRIVEN BY AN ELECTRIC MOTOR.

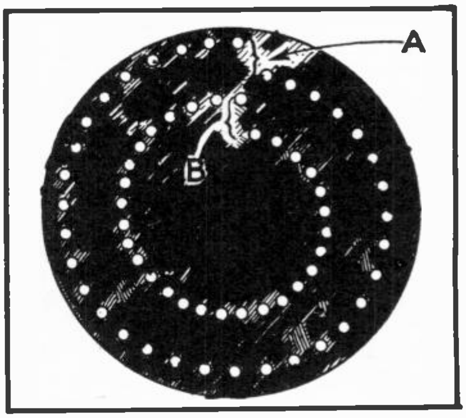

FIG. 10
Two Scanning Discs in One.

THE GLOW LAMP IS MOUNTED IN POSITION BEHIND THE SCANNING BELT, THAT IS, INSIDE THE DRUM-SHAPED CHAMBER SO THAT THE GLOWING PLATE CAN BE OBSERVED THRU THE SCANNING HOLES AS THE BELT IS RAPIDLY ROTATED. ONE COMPLETE REVOLUTION OF THE BELT WILL SCAN THE PICTURE ONCE, THE SAME AS IN THE CASE OF THE NIPKOW DISC TYPE SCANNER.

THE BELT IS REMOVABLE FROM THE SPIDER AND CAN BE REPLACED WITH BELTS HAVING A DIFFERENT NUMBER OF HOLES, SO THAT THE UNIT IS ADAPTABLE TO THE 48 LINE, 45-LINE, AND 60 LINE SYSTEM.

SCANNING WITH A DRUM

IN FIG.12, YOU ARE SHOWN A REAR VIEW PHOTOGRAPH OF THE IMPROVED JENKIN'S DRUM TYPE RADIOVISOR. THIS UNIT CONSISTS OF A SCANNING DRUM AND SHUTTER OR OBSCURING DISC, BOTH DRIVEN BY THE SAME ELECTRIC MOTOR.

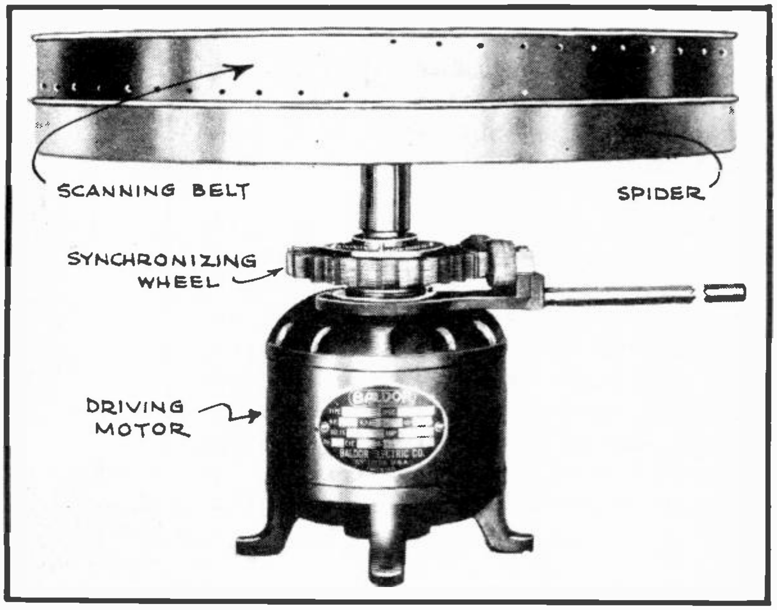

FIG. 11
Belt Type Scanner.

THE CIRCUMFERENCE OF THE DRUM IS PERFORATED WITH FOUR ROWS OF HOLES, EACH ROW FORMING ONE COMPLETE TURN AND EACH ROW IS ARRANGED SO AS TO FORM ONE TURN OF A HELIX. THAT IS, THE FOUR ROWS OF HOLES ARE JUST LIKE FOUR THREADS AROUND A SCREW. TWO MORE VIEWS OF THIS SAME UNIT ARE SHOWN IN FIGS. 13 AND 14.

THE NEON LAMP IS MOUNTED INSIDE OF THE DRUM, SO THAT THE CATHODE PLATE FACES ONE SIDE OF THE DRUM AS SHOWN IN FIGS. 13 AND 14. THE OBSERVER SEES THE GLOW OF THE LAMP THROUGH THE HOLES OF THE DRUM, AS THE DRUM RAPIDLY REVOLVES AROUND THE STATIONARY LAMP. BEING THAT THERE ARE FOUR DRUM HOLES CONTINUALLY VERTICALLY ALIGNED WITH EACHOTHER, THE OBSERVER WOULD ACTUALLY SEE FOUR DIFFERENT SPOTS ON THE CATHODE OF THE NEON LAMP AT THE SAME TIME. TO PREVENT THIS, HOWEVER, AN ENGENIOUS SHUTTER OR OBSCURING DISC IS USED IN CONJUNCTION WITH THE DRUM.

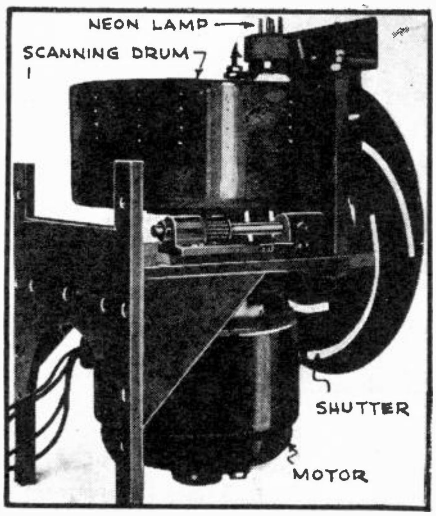

FIG.12
The Jenkins Radiovisor.

THIS SHUTTER DISC HAS SLOTS CUT IN IT AT SUCH ANGLES, SO THAT WHEN THE SHUTTER DISC AND DRUM ARE DRIVEN SIMULTANEOUSLY, ONE SLOT WILL ONLY UNCOVER ONE ROW OF DRUM HOLES AS THE DRUM AND SHUTTER COMPLETE ONE REVOLUTION. THAT IS, AS THE PICTURE BEGINS, ONE SHUTTER SLOT WILL UNCOVER THE TOP ROW OF DRUM HOLES AND ALL OTHER DRUM HOLES WILL BE HIDDEN FROM VIEW AT THIS TIME. DURING THE SECOND REVOLUTION OF THE DRUM, THE SECOND ROW OF DRUM HOLES WILL BE EXPOSED BY A SHUTTER SLOT ETC. AND IN ORDER

TO COMPLETELY SCAN THE PICTURE, FOUR REVOLUTIONS OF THE DRUM ARE REQUIRED.

FIG. 14 ILLUSTRATES HOW THE OBSERVER SEES THE PICTURE AT THIS TYPE OF RADIOVISOR. THIS ILLUSTRATION CLEARLY SHOWS THE RELATION BETWEEN THE DRIVING MOTOR, SCANNING DRUM, NEON LAMP, SHUTTER DISC, MAGNIFYING LENS , SHADOW BOX, AND THE OBSERVER. STUDY THIS DRAWING CAREFULLY.

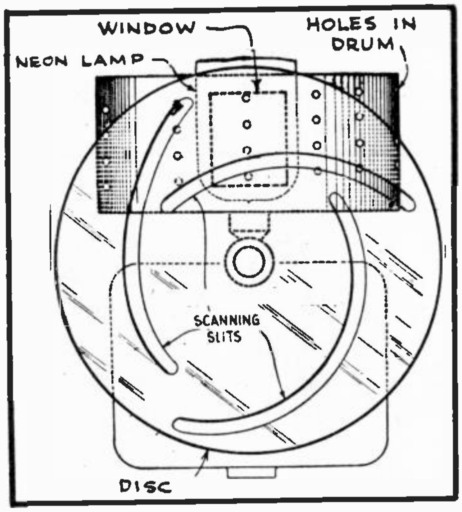

FIG. 13
Front View of Jenkins Drum Type Radiovisor.

THE ENTIRE RADIOVISOR IS INSTALLED IN A CABINET AS OUTLINED IN FIG. 14 AND THE COMPLETE UNIT THEN APPEARS FROM THE OUTSIDE AS SHOWN IN FIG. 15. TO OBSERVE THE PICTURE, ONE SIMPLY LOOKS INTO THE SHADOW BOX BUT IT IS NOT NECESSARY FOR ONE TO ACTUALLY INSERT THEIR HEAD INTO THE BOX AS WAS FREQUENTLY THE CASE IN SOME OF THE EARLIER EXPERIMENTAL MODELS.

THE PURPOSE OF THE "SHADOW BOX" IS TO PREVENT TOO MUCH OUTSIDE LIGHT FROM FALLING UPON THE PICTURE BECAUSE SUCH LIGHT WOULD TEND TO MAKE THE PICTURE INDISTINCT, THE SAME AS WHEN TOO MUCH LIGHT IS PERMITTED TO FALL UPON THE SCREEN AT A MOTION PICTURE THEATER. THE SHADOW BOX SIMPLY SERVES THE SAME PURPOSE AS THE DARKENED ROOM WHERE MOTION PICTURES ARE SHOWN.

A SINGLE PLATE NEON LAMP IS USED IN THIS PARTICULAR RADIOVISOR. BY A SINGLE PLATE LAMP IS MEANT THAT THE CATHODE IS IN THE FORM OF A CUSTOMARY LAMP PLATE BUT THE ANODE INSTEAD OF BEING A PLATE, TAKES THE FORM OF A RECTANGULAR SHAPED FRAME PLACED CLOSE TO THE CATHODE. THE OPERATING PRINCIPLES, HOWEVER, ARE IDENTICAL TO THE LAMP WHERE BOTH THE CATHODE AND ANODE TAKE THE SHAPE OF PLATES.

A DOUBLE SCANNING DISC

ANOTHER SCANNING SYSTEM, WHICH HAS BEEN USED WITH SOME OF THE BAIRD TELEVISION EQUIPMENT, IS SHOWN IN FIG. 16. IN THIS CASE, WE HAVE TWO SCANNING DISCS-AN OUTER ONE AND AN INNER ONE. THE INNER DISC HAS LONG NARROW HOLES PLACED RADIALLY AROUND ITS CIRCUMFERENCE AND THE OUTER DISC HAS BUT ONE CONTINUOUS SPIRAL CUT AROUND ITS CIRCUMFERENCE. THE TWO DISCS ARE PLACED BETWEEN THE NEON LAMP, SCREEN, AND OBSERVER AS ILLUSTRATED AND THEY ARE THEN DRIVEN IN OPPOSITE DIRECTIONS.

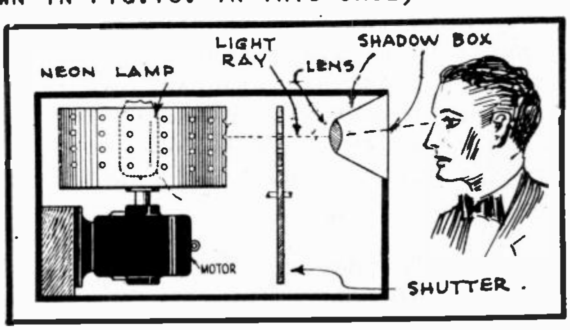

FIG. 14
Observing the Picture.

THE INNER DISC ALONE WOULD

EXPOSE A LONG NARROW SECTION OF THE LAMP'S CATHODE WHEN IN THE LINE OF VISION BUT THE WIDTH OF THE SPIRAL SLOT IN THE OTHER DISC DETERMINES THE HEIGHT OF THE PLATE SECTION SEEN BY THE OBSERVER. THUS THE INNER SLOTTED DISC DIRECTS THE OBSERVER'S VISION HORIZONTALLY OR ACROSS THE PICTURE, WHILE THE OUTER SPIRAL DISC DIRECTS HIS VISION VERTICALLY FROM THE TOP TOWARD THE BOTTOM OF THE PICTURE.

SCANNING WITH MIRRORS

THE MIRROR TYPE SCANNER IS ILLUSTRATED FOR YOU IN FIG. 17 AND HERE THE SCANNING DEVICE CONSISTS OF A WHEEL CALLED THE "MIRROR WHEEL" AND

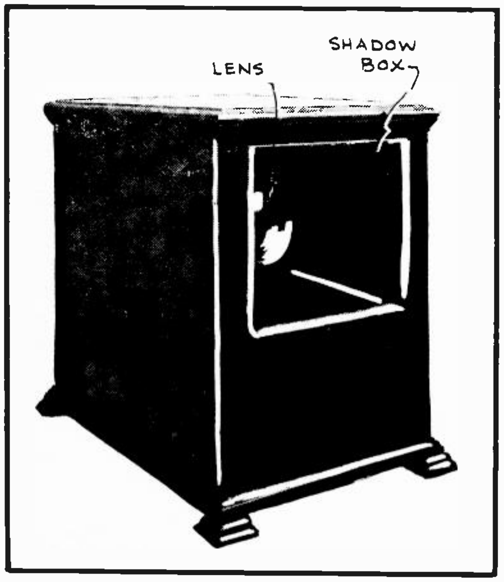

FIG. 15
Jenkins Radiovisor Cabinet.

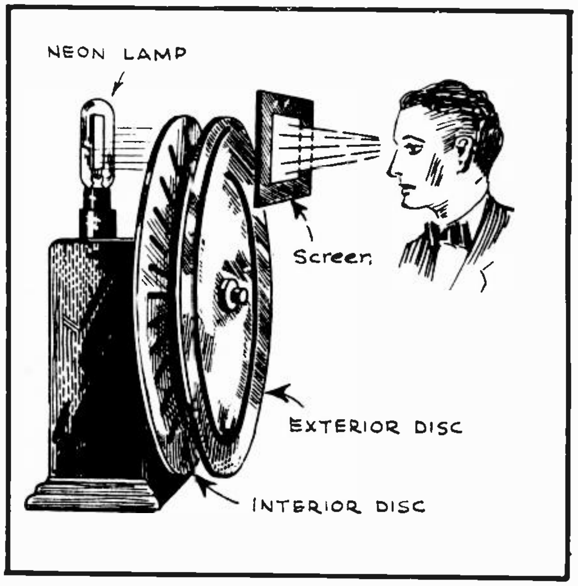

FIG. 16
A Dual Scanning Disc

MANY SMALL INDIVIDUAL MIRRORS ARE MOUNTED AROUND THE CIRCUMFERENCE OF THIS WHEEL.

THE LIGHT BEAM FROM THE TELEVISION LAMP IS PASSED THROUGH A CONDENSING LENS, WHICH DIRECTS IT UNTO THE MIRROR SURFACES AS A SHARPLY DEFINED BEAM. AS THE MIRROR WHEEL IS CAUSED TO ROTATE BY THE ELECTRIC MOTOR, EACH OF THE SMALL MIRRORS WILL TAKE ITS TURN IN HAVING THE LAMP'S LIGHT BEAM FOCUSED UPON IT. THE LIGHT STRIKING ANY ONE OF THE MIRRORS WILL BE REFLECTED FROM IT AT AN ANGLE AND WE CALL THIS REFLECTED LIGHT THE "SCANNING BEAM".

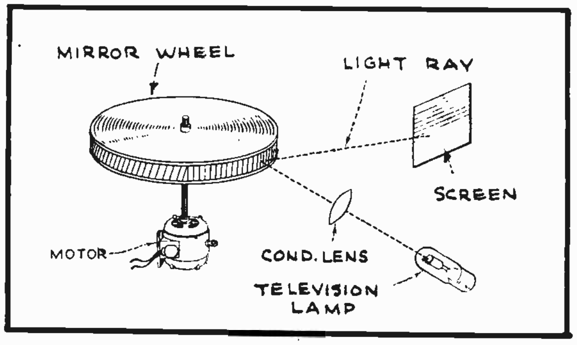

FIG. 17
Scanning With the Mirror Wheel.

A "TRANSLUCENT", THAT IS, A SEMI-TRANSPARENT SCREEN IS PLACED IN THE PATH OF THE SCANNING BEAM, SO THAT AS ANY ONE MIRROR QUICKLY PASSES THE BEAM GIV-

EN OFF BY THE NEON LAMP, IT WILL DRAW THE SCANNING BEAM HORIZONTALLY ACROSS THE SCREEN. THIS IS OF COURSE POSSIBLE DUE TO THE CHANGE IN THE ANGLE OF REFLECTION AS THE MIRROR MOVES IN ITS CIRCULAR PATH OR ORBIT. THIS ACTION, AS JUST DESCRIBED, ACCOUNTS FOR THE HORIZONTAL SCANNING.

THE VERTICAL SCANNING OF THE PICTURE IS ACCOMPLISHED BY THE FACT THAT EACH OF THE SMALL MIRRORS IS TILTED IN A SLIGHTLY DIFFERENT VERTICAL PLANE, SO THAT AS THE MIRROR WHEEL IS ROTATED, EACH MIRROR WILL SCAN A HORIZONTAL LINE SLIGHTLY BELOW THE ONE SCANNED BY THE PRECEEDING MIRROR. FINALLY, AFTER ONE COMPLETE REVOLUTION OF THE WHEEL, THE PICTURE WILL HAVE BEEN SCANNED COMPLETELY FROM THE TOP TOWARD THE BOTTOM, AS WELL AS HORIZONTALLY.

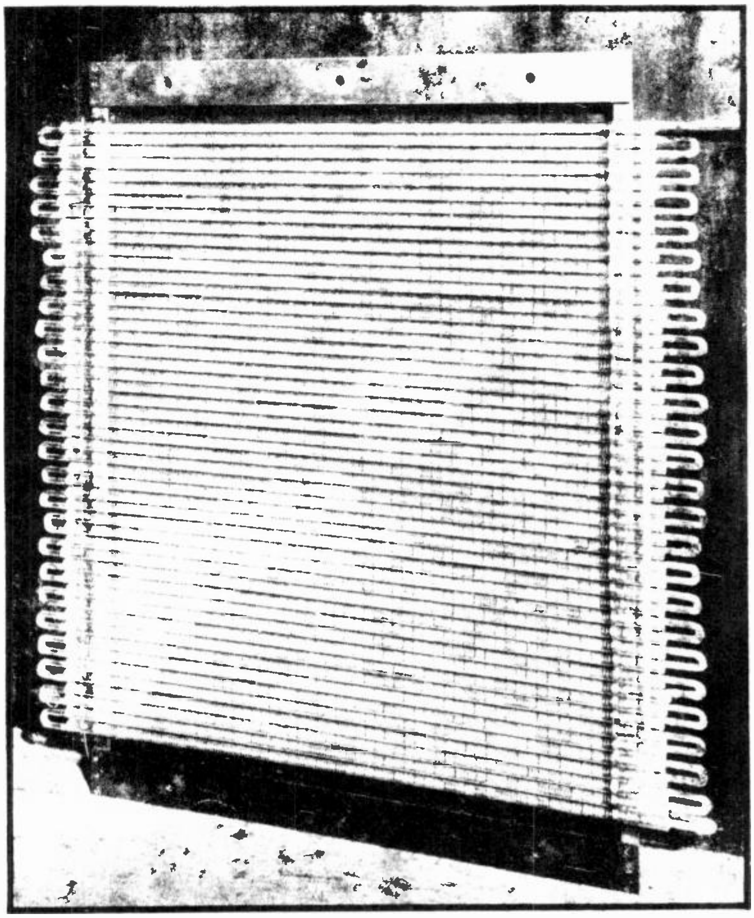

FIG. 18
Reproducing Grid of Bell Laboratories.

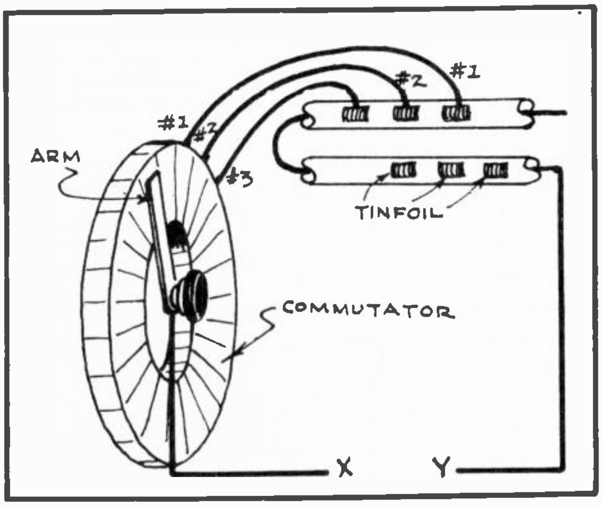

FIG. 19
Diagram of the Bell Reproducing Grid.

THE BELL SYSTEM OF REPRODUCING PICTURES

QUITE A COMPLEX TELEVISION REPRODUCING DEVICE WAS CONCEIVED BY THE BELL LABORATORIES. THE UNIT IS ILLUSTRATED IN FIG. 18 AND IT CONSISTS OF A CONTINUOUS GLASS TUBING, WHICH IS BENT BACK AND FORTH ACROSS A FRAME-WORK, THUS FORMING A GRID SHAPED BODY. THIS GLASS TUBING IS FILLED WITH NEON GAS AND A CONTINUOUS SPIRALLY WOUND WIRE RUNS THROUGH THIS TUBING THRUOUT ITS ENTIRE LENGTH. UNIFORMLY SPACED ON THE OUTSIDE OF THE GLASS TUBING, THERE ARE 2500 SMALL RECTANGLES OF FOIL.

EACH OF THESE SMALL PIECES OF FOIL IS CONNECTED TO A COMMUTATOR BAR BY MEANS OF A PIECE OF WIRE. THIS COMMUTATOR IS SHOWN IN FIG.19 AND THE BARS ARE ALL INSULATED FROM EACHOTHER. ALSO NOTICE THE CONNECTION BETWEEN THE PIECES OF FOIL AND THE COMMUTATOR BARS IN FIG.19.

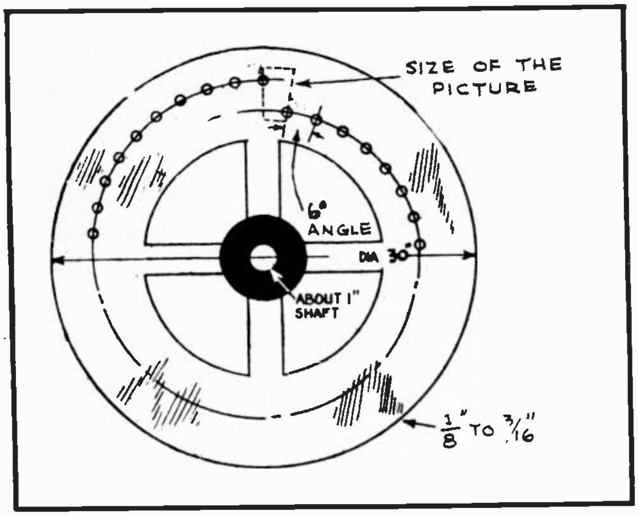

FIG. 20
Scanning Disc Layout.

SINCE 2500 PIECES OF FOIL ARE MOUNTED ON THE OUTSIDE OF THE GLASS TUBING, THERE MUST BE 2500 BARS IN THE COMMUTATOR AND 2500 WIRES FOR CONNECTIONS. ONE END OF THE TUBE'S CENTRAL WIRE TERMINATES AT POINT "Y" AND THE ARM OF THE COMMUTATING DEVICE IS CONNECTED TO POINT "X". POINTS "X" AND "Y" ARE THEN CONNECTED IN THE OUTPUT OF THE TELEVISION RECEIVER'S POWER STAGE IN PLACE OF THE CUSTOMARY NEON LAMP. THE SIGNAL VOLTAGES WILL THEREFORE BE IMPRESSED ACROSS POINTS "X" AND "Y" AND WITH THE CONTACT ARM ON COMMUTATOR SEGMENT #1 IN FIG.19, THE SIGNAL VOLTAGE WILL BE IMPRESSED ACROSS FOIL #1 AND THE CENTRAL WIRE AND THEREFORE THE NEON TUBE WILL GLOW AT THIS PARTICULAR POINT, WITH THE BRILLIANCE OF THE GLOW DEPENDING UPON THE APPLIED SIGNAL VOLTAGE AT THIS PARTICULAR INSTANT.

SHOULD THE CONTACT ARM BE DRIVEN IN A CLOCKWISE DIRECTION BY A MOTOR, THEN THE CIRCUIT WILL AT THIS INSTANT BE COMPLETED THROUGH CIRCUIT #2 AND THE SECTION OF THE NEON TUBE AT FOIL #2 WILL GLOW. IN LIKE MANNER, AS THE COMMUTATOR ARM COMPLETES ONE REVOLUTION, THE NEON TUBE WILL GLOW AT EACH OF THE 2500 RECTANGLES OF FOIL AND THE BRILLIANCE OF THE GLOW AT ANY ONE OF THESE POINTS WILL DEPEND ENTIRELY UPON THE SIGNAL VOLTAGE BEING APPLIED ACROSS X AND Y AT THE TIME.

BY REVOLVING THE CONTACT ARM FAST ENOUGH, THESE SEPARATE GLOWS WILL APPEAR TO THE EYE AS ONE MASS OF LIGHT, AND THE VARIATIONS IN BRILLIANCE AT THE DIFFERENT SECTIONS OF THE NEON GRID WILL BE ARRANGED INTO A DEFINITE PATTERN, SO AS TO REPRODUCE THE LIGHT AND SHADING EFFECT AS THEY ARE ON THE ORIGINAL OBJECT BEING TELEVISED. THE PICTURE WILL BE COMPLETELY SCANNED AFTER EACH REVOLUTION OF THE COMMUTATOR ARM.

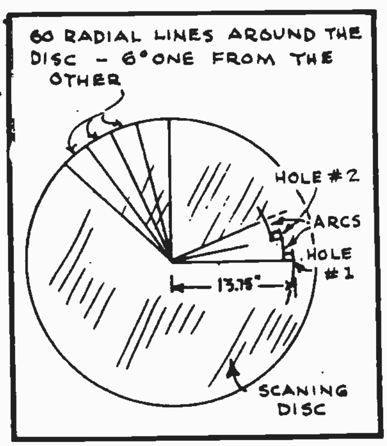

FIG.21
Spotting the Holes.

CONSTRUCTION OF A NIPKOW SCANNING DISC

SINCE THE NIPKOW SCANNER IS THE CHEAPEST, AS WELL AS THE MOST EASILY CONSTRUCTED SCANNER, IT IS USED MORE THAN ANY OTHER SYSTEM

BY THE HOME EXPERIMENTER. FOR THIS REASON, THE FOLLOWING CONSTRUCTIONAL INFORMATION HAS BEEN PREPARED. OUR FIRST STEP IN THIS DIRECTION WILL BE TO LAY-OUT A 60 HOLE DISC AS A SPECIFIC EXAMPLE.

IN THIS CASE, THE IMAGE WILL BE 60 ELEMENTS HIGH AND 72 ELEMENTS WIDE, WHICH MEANS THAT THE PICTURE WILL BE OBLONG RATHER THAN SQUARE. THE IMAGES FOR THIS SYSTEM ARE SCANNED AT A RATE OF 20 PICTURE PER SECOND AND THIS CORRESPONDS TO A SCANNING DISC SPEED OF 1200 R.P.M.

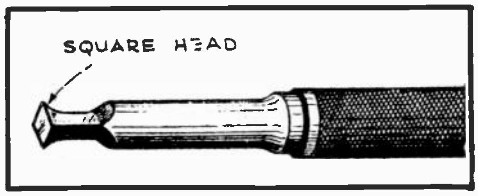

FIG.22
The Punching Tool.

THE GENERAL LAY-OUT FOR THE REQUIRED DISC IS SHOWN IN FIG.20 AND IN THIS ILLUSTRATION ROUND SCANNING HOLES ARE SHOWN. YOU WILL FIND, HOWEVER, THAT SQUARE SCANNING HOLES WILL GIVE STILL BETTER RESULTS BECAUSE THEY MAKE A GREATER AMOUNT OF LIGHT AVAILABLE TO THE OBSERVER'S EYE THAN DO ROUND HOLES.

FOR THIS DISC, YOU CAN OBTAIN A CIRCULAR BLANK OF 20 GUAGE ALUMINUM, WHICH IS ABOUT 30" IN DIAMETER. THE NEXT STEP IS TO LAY-OUT THE HOLES IN THIS DISC AND WE COMMENCE BY FIRST LOCATING THE EXACT CENTER OF THE DISC. NOW THEN, WE ALREADY KNOW THAT THE NUMBER OF HOLES REQUIRED IS 60 AND SINCE THESE 60 HOLES MUST ALL BE EQUALLY SPACED AROUND THE CIRCUMFERENCE OF A CIRCLE IN WHICH THERE ARE 360°, THEN THE ANGLE OF DISPLACEMENT OR THE ANGULAR DISTANCE BETWEEN THESE HOLES WILL HAVE TO BE EQUAL TO $\frac{360}{60} = 6°$.

THE WIDTH OF THE PICTURE WILL BE DETERMINED BY THE SIZE OF THE PICTURE AND THE SIZE OF THE NEON TUBE'S PLATE, WHICH IS AVAILABLE FOR THE FIELD OF VIEW. WE WILL ASSUME THAT FOR THE CONDITIONS AT HAND, THE WIDTH OF THE PICTURE CAN BE MADE 1.44". THEN SINCE THIS PICTURE WIDTH IS TO CONSTITUTE 72 ELEMENTS AS ALREADY STATED, IT IS CLEAR THAT THE SIZE OF EACH OF THE SCANNING HOLES MUST BE $\frac{1.44"}{72} = .02"$ SQ.

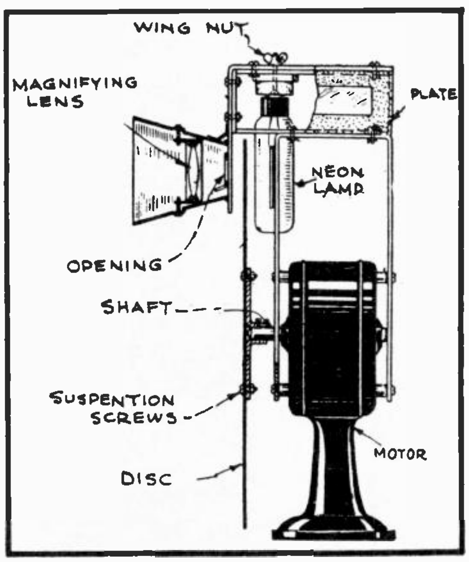

FIG.23
The Assembled Scanner.

THEN SINCE THE PICTURE IS TO BE 60 ELEMENTS HIGH, THE HEIGHT OF THE PICTURE WILL BE 60 X .02" OR 1.2 INCHES.

WITH A SHARP PUNCH OR SCRIBER, CAREFULLY MARK THE CENTER OF THE DISC AND MARK A LIGHT LINE FROM THIS CENTER POINT TO THE EDGE OF THE DISC. NOW BY USING A PROTRACTOR, DRAW LINES FROM THE CENTER TO THE DISC EDGE AT INTERVALS OF 6° UNTIL YOU HAVE DRAWN 60 OF THESE RADIAL LINES. THESE LINES SHOULD BE DRAWN AS LIGHT AS POSSIBLE, FOR THEIR ONLY PURPOSE IS TO SERVE YOU AS A GUIDE, INDICATING THE DISTANCE BETWEEN ADJACENT SCANNING HOLES.

NOW THE CIRCUMFERENCE OF THE CIR-

CLE, ON WHICH HOLE #1 IN FIG.20 IS LOCATED, WILL BE 1.44" X 60 OR 86.4" AND THE RADIUS FOR A CIRCLE OF THIS SIZE WILL BE EQUAL TO 86.4" DIVIDED BY 6.2832 OR 13.75 INCHES. THEREFORE, PICK OUT ANY ONE OF THE RADIAL LINES, WHICH YOU DREW ON THE DISC AND MEASURE OFF A DISTANCE ON IT OF 13.75" FROM THE CENTER OF THE DISC AS SHOWN IN FIG.21. THIS WILL FIX THE LOCATION FOR HOLE #1. THIS DONE, TAKE A PAIR OF DIVIDERS AND WITH THE RADIUS ADJUSTED TO 13.75" DRAW AN ARC THROUGH THIS POINT.

A TYPICAL TOOL FOR PUNCHING SQUARE HOLES IS SHOWN IN FIG.22. YOU CAN EITHER MAKE THIS TOOL YOURSELF OR ELSE HAVE ONE MADE BY A MACHINIST. THIS TOOL CAN BE MADE READILY FROM AN ORDINARY DRIFT, NAIL-SET, OR CENTER PUNCH, WHICH FOR THIS PURPOSE SHOULD BE GROUND DOWN TO A FLAT SURFACE .02" SQUARE. FIG. 22 SHOWS THE GROUND END OF THE TOOL CONSIDERABLY ENLARGED, SO THAT THE DETAIL OF THE GRINDING WORK CAN BE CLEARLY VISIBLE.

AFTER THE TOOL IS FINISHED AND READY FOR USE, THE NEXT THING IS TO OBTAIN A BLOCK OF SOFT WOOD TO USE AS AN ANVIL WHILE PUNCHING THE HOLES. THE LARGER THIS BLOCK, THE BETTER, AND THE END GRAIN SHOULD BE CAREFULLY LEVELLED OFF.

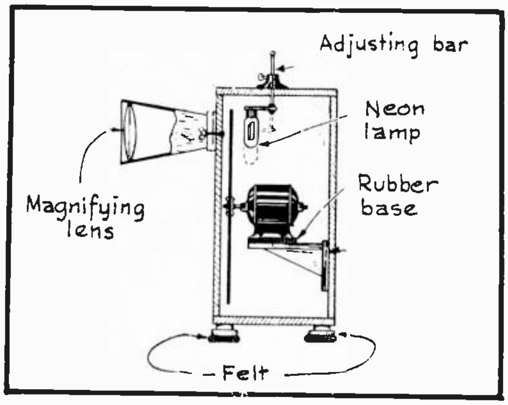

FIG. 24
Installation in Cabinet

NOW LAY THE DISC OVER THE END GRAIN OF THIS BLOCK OF WOOD, SO THAT THE POINT WHERE YOU ARE GOING TO PUNCH THE FIRST HOLES IS RESTING UPON THE BLOCK FIRMLY. PLACE THE WORKING END OF THE PUNCH AT THE MARK WHICH YOU MADE 13.75" FROM THE DISC CENTER ON ONE OF THE RADIAL LINES AND ALIGN ITS SQUARE CUTTING END AGAINST THE RADIAL LINE AND ARC WHICH CROSS EACHOTHER AT THIS POINT, AS SHOWN IN FIG.21 AND STRIKE THE PUNCH A SHARP BLOW WITH A HAMMER. THUS HOLE #1 IS FORMED.

THE REASON FOR PUNCHING INTO THE END GRAIN OF THE WOOD BLOCK IS THAT THIS WILL PERMIT THE METAL TO CUT CLEARLY WITHOUT LEAVING A BURR. SHOULD, HOWEVER, BURRS REMAIN, THEN YOU CAN REMOVE THEM BY CAREFUL FILING.

AFTER HOLE #1 IS PUNCHED, THEN AGAIN TAKE YOUR DIVIDERS AND ADJUST THE RADIUS, SO THAT WITH ONE OF ITS POINTS PIVOTED AT THE CENTER OF THE DISC, THE OTHER POINT WILL JUST TOUCH THE EDGE OF HOLE #1 WHICH FACES TOWARDS THE CENTER OF THE DISC AND WITH THIS SETTING, DRAW AN ARC SUFFICIENTLY LONG TO CUT THROUGH THE NEXT RADIAL LINE. THIS IS ALSO ILLUSTRATED IN FIG.21. THEN PUNCH HOLE #2 SO THAT THE EDGES OF THIS HOLE WILL BE ALIGNED WITH THE NEXT RADIAL LINE AND THE ARC AS SHOWN IN FIG. 21.

THIS DONE RE-ADJUST THE DIVIDERS SO THAT WITH ONE POINT PIVOTED AT THE CENTER OF THE DISC, THE OTHER WILL JUST REACH THE EDGE OF HOLE #2 WHICH FACES THE CENTER OF THE DISC AND DRAW AN ARC LONG ENOUGH TO CUT

THE NEXT RADIAL LINE. THEN PUNCH ANOTHER HOLE AT THIS NEW POINT OF INTERSECTION ETC. UNTIL YOU HAVE PUNCHED ALL 60 HOLES AROUND THE DISC.

SHOULD YOU CARE TO PROVIDE A 48 HOLE SPIRAL ON THIS SAME DISC, SO THAT THE PICTURE WILL BE 48 ELEMENTS HIGH AND 60 ELEMENTS WIDE AND STILL USING THE SAME PUNCH, THEN THE FOLLOWING FACTS WILL HOLD TRUE. FIRST, THE WIDTH OF THE PICTURE WOULD BE 60 X .02" OR 1.2" AND THE RADIUS TO THE OUTER HOLE OR HOLE #1 WOULD BE 9.16" (CIRCUMFERENCE OF THIS CIRCLE= 1.2" X 48 = 57.6" AND SO ITS RADIUS IS 57.6 DIVIDED BY 6.2832, WHICH IS EQUAL TO 9.16").

THE HEIGHT OF THE IMAGE IN THIS CASE WOULD BE .02" X 48 OR .96" AND THE DISTANCE BETWEEN SUCCESSIVE RADIAL LINES ON THE DISC WILL HAVE TO BE $\frac{360}{48}$ = 7.5 OR 7°30′.(7 DEGREES AND 30 MINUTES). WITH THIS INFORMATION, THE HOLES FOR THIS SYSTEM COULD ALSO BE LAID OUT ON THE SAME DISC WITH COMPARATIVE EASE. GREAT CARE, HOWEVER, MUST BE EXERCISED IN MAKING ALL OF THE NECESSARY MEASUREMENTS ETC., SO THAT THE FINISHED DISC WILL BE ACCURATE.

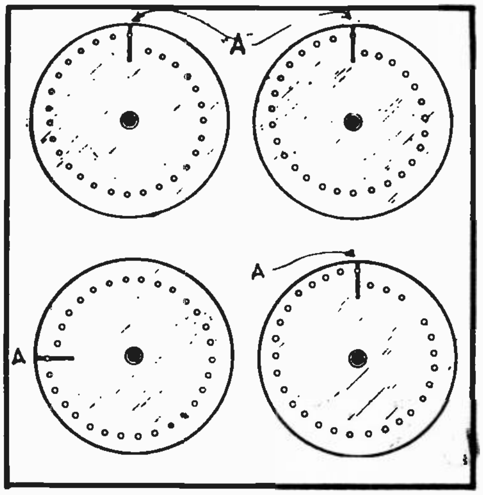

FIG. 25
Synchronism – Isochronism.

FINALLY, AFTER ALL SCANNING HOLES HAVE BEEN MADE IN THE DISC, THE HOLE FOR MOUNTING PURPOSES CAN BE MADE AT ITS CENTER BUT THE SIZE OF THIS HOLE WILL OF COURSE DEPEND UPON THE TYPE OF MOUNTING WHICH YOU ARE USING. THIS WILL BE OBVIOUS AT THE TIME OF CONSTRUCTION.

SOME EXPERIMENTERS GO SO FAR AS TO CUT AWAY A PORTION FROM THE CENTRAL PORTION OF THE DISC, SO AS TO REMOVE EXCESS WEIGHT SO THAT LESS POWER WILL BE REQUIRED TO REVOLVE THE DISC. THIS, HOWEVER, IS NOT ALTOGETHER NECESSARY, ESPECIALLY WHEN THE DISC IS MADE OF STOCK WHICH IS NOT TOO HEAVY BUT IF IT IS DONE, THEN EXTREME CARE MUST BE USED WHEN REMOVING METAL, SO THAT THE DISC IS NOT THROWN OUT OF BALANCE.

ASSEMBLING THE SCANNING EQUIPMENT

SO MUCH FOR SCANNING DISCS -- NOW LET US TURN YOUR ATTENTION TO FIG.23 WHICH SHOULD OFFER YOU A NUMBER OF SUGGESTIONS RELATIVE TO ASSEMBLING THE HOME-MADE SCANNER. HERE THE MOTOR FROM AN ORDINARY ELECTRIC FAN IS BEING USED TO SUPPLY THE DRIVING POWER FOR THE DISC. THE SAME FITTING IS USED FOR COUPLING THE SCANNING DISC TO THE MOTOR SHAFT AS WAS ORIGINALLY USED FOR THE FAN BLADE MOUNTING.

THE SHADOW-BOX IN THIS CASE IS A SECTION OF A MEGAPHONE, CUT TO LENGTH SO AS TO PROVIDE A SUITABLE FORM. A DOUBLE CONVEX LENS IS THEN MOUNTED IN THE SHADOW BOX AS SHOWN, SO AS TO ENLARGE THE SIZE OF THE IMAGE WHEN OBSERVED THROUGH THIS LENS. THE NEON TUBE IS MOUNTED IN AN INVERTED POSITION AND ITS BASE IS HELD IN PLACE BY A MACHINE SCREW AND WING-NUT, SO THAT UPON LOOSENING THE WING-NUT, THE BASE AND TUBE CAN BE

ROTATED TO THE PROPER POSITION, SO THAT THE PLATE OF THE TUBE CAN BE ALIGNED PARALLEL WITH THE FACE OF THE SCANNING DISC.

FIG.24 SHOWS YOU HOW THE SCANNING SYSTEM CAN BE MOUNTED IN A BOX-LIKE CABINET. NOTE THAT IN THIS CASE, THE MOTOR AND NEON TUBE ARE BOTH MOUNTED ON ADJUSTABLE SUPPORTS, SO THAT THE ENTIRE SYSTEM CAN BE PROPERLY ALIGNED WITH THE APERTURE OR OPENING IN THE END OF THE SHADOW BOX THROUGH WHICH THE IMAGE IS OBSERVED. ALSO OBSERVE HOW RUBBER MOUNTINGS ARE USED, SO THAT VIBRATION WILL BE KEPT TO A MINIMUM, FOR THIS WILL AID IN BRINGING ABOUT A REDUCTION IN PICTURE DISTORTION.

SYNCHRONIZATION OF SCANNING DISCS

ONE OF THE GREATEST PROBLEMS IN TELEVISION ENGINEERING IS TO MAINTAIN ACCURATE SYNCHRONISM BETWEEN THE SCANNING SYSTEM AT BOTH THE TELEVISION TRANSMITTER AND RECEIVER. YOU ARE NOW GOING TO BE SHOWN HOW THIS CAN BE ACCOMPLISHED AT THE RECEIVER WHEN USING MECHANICAL DISC SCANNERS. FIRST OF ALL, HOWEVER, LET US BE SURE THAT YOU HAVE A CORRECT UNDERSTANDING OF THE EXPRESSION "SYNCHRONISM".

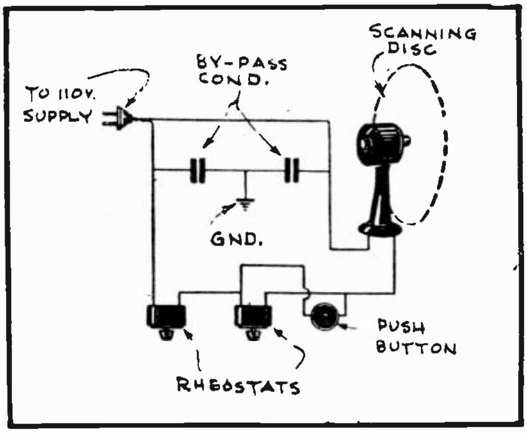

FIG. 26
Manual Synchronizing System.

AT THE TOP OF FIG.25, WE HAVE TWO DISCS WHICH ARE SYNCHRONIZED. THAT IS, THEY ARE TRAVELING AT THE SAME SPEED AND IN ADDITION, THE SAME HOLE IN EACH OF THE DISCS IS AT THE SAME POINT OF TRAVEL. NOTICE THAT THE FIRST HOLE OF THE SPIRAL OF BOTH DISCS ARE LINED UP WITH POINT "A" AT THE SAME INSTANT.

THE TWO DISCS AT THE BOTTOM OF FIG.25 ARE NOT SYNCHRONIZED, ALTHOUGH THEY ARE ROTATING AT THE SAME SPEED. AS YOU WILL NOTE, THE TWO DISCS ARE ONE-QUARTER REVOLUTION OUT OF STEP WITH EACHOTHER. THE TWO DISCS WHEN OUT OF STEP BUT ROTATING AT THE SAME SPEED ARE SAID TO BE IN A STATE OF ISOCHRONISM BUT FOR TELEVISION PURPOSES, THEY MUST BE ABSOLUTELY SYNCHRONIZED.

ONE METHOD OF SYNCHRONIZING THE TRANSMITTER AND RECEIVER SCANNING DISC IS TO DRIVE BOTH OF THESE DISCS WITH SYNCHRONOUS MOTORS WHICH ARE CONNECTED TO A.C. POWER OR LIGHT LINES OF LIKE FREQUENCY. THE SPEED OF THIS TYPE OF MOTOR IS GOVERNED BY THE FREQUENCY OF THE A.C. POWER SUPPLY WHICH OPERATES IT. ALTHOUGH IT IS TRUE THAT MOST COMMERCIAL POWER COMPANIES FURNISH 50 OR 60 CYCLE SUPPLY TO THEIR LINES, YET ALL OF THE DIFFERENT COMPANIES DO NOT REMAIN EXACTLY AT THEIR GIVEN FREQUENCY, THAT IS, THE FREQUENCY MAY BE SOMEWHAT MORE OR LESS. FOR LIGHTING PURPOSES, THIS VARIATION IS NOT NOTICEABLE BUT FOR SYNCHRONIZING TELEVISION, A VARIATION OF $\frac{1}{3000}$ OF 1% WOULD GIVE ONLY FAIR SYNCHRONIZATION.

A SIMPLE MANUAL SYNCHRONIZING SYSTEM

IN FIG.26 WE ARE ILLUSTRATING A VERY SIMPLE, ALTHOUGH A RATHER

CRUDE METHOD OF SYNCHRONIZING A FAN MOTOR AT THE RECEIVER. HOWEVER, IT DOES ILLUSTRATE A PRINCIPLE. HERE YOU ARE SHOWN HOW THE MOTOR IS CONNECTED ACROSS THE 110 VOLT A.C. OR D.C. POWER LINE BUT TWO RHEOSTATS ARE CONNECTED IN SERIES IN ONE SIDE OF THIS CIRCUIT.

ONE OF THESE RHEOSTATS HAS A MAXIMUM RESISTANCE VALUE OF ABOUT 100 TO 150 OHMS WHILE THE OTHER IS A SMALLER UNIT, HAVING A MAXIMUM RESISTANCE VALUE OF BUT 10 TO 15 OHMS AND A PUSH BUTTON, SUCH AS USED FOR DOOR BELLS, IS SHUNTED OR CONNECTED ACROSS THE SMALLER RHEOSTAT.

ALSO NOTICE THAT IN THE DIAGRAM SHOWN IN FIG.26, TWO ½ OR 1 MFD. BY-PASS CONDENSERS ARE CONNECTED ACROSS THE POWER CIRCUIT WITH THEIR CENTER CONNECTION MUTUALLY GROUNDED. THESE CONDENSERS ARE NOT ALTOGETHER NECESSARY BUT NEVERTHELESS THEY ARE ADVISABLE WHEN USING A MOTOR HAVING A COMMUTATOR AND BRUSHES. BY USING THEM, DISTURBING INTERFERENCE CAUSED BY THE BRUSH AND COMMUTATOR OPERATION WILL BE BY-PASSED TO GROUND RATHER THAN BEING PERMITTED TO DESTROY THE QUALITY OF THE PICTURE.

TO USE THIS SYNCHRONIZING SYSTEM, YOU FIRST ADJUST THE TWO RHEOSTATS UNTIL THE SCANNING DISC ROTATES JUST BELOW THE DESIRED SPEED AND YOU THEN PUSH THE BUTTON PERIODICALLY. WHENEVER THIS BUTTON IS DEPRESSED, IT WILL SHORT-CIRCUIT THE SMALLER RHEOSTAT AND THIS WILL PERMIT THE MOTOR TO PICK UP SPEED. THUS THE PUSH BUTTON WILL HAVE TO BE DEPRESSED PERIODICALLY WHILE THE SYSTEM IS OPERATING, IN ORDER TO KEEP THE SCANNING DISC ROTATING AT THE PROPER SPEED.

ALTHOUGH ONE RHEOSTAT WOULD GIVE AN APPROXIMATE SPEED SETTING, YET A LARGE AND SMALL ONE, WHEN USED TOGETHER AS SHOWN, WILL PERMIT THE OPERATOR TO MAKE A FINER ADJUSTMENT THAN IS POSSIBLE WHEN USING ONE RHEOSTAT ALONE.

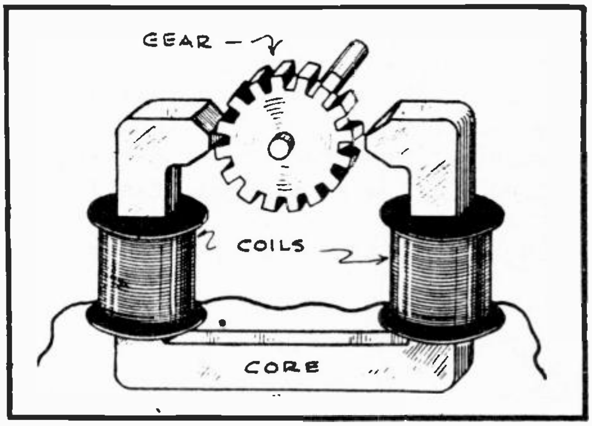

FIG. 27
The Phonic Motor.

SYNCHRONIZING WITH THE PHONIC MOTOR

AS YOU HAVE SEEN, THIS METHOD OF SYNCHRONIZING IS QUITE CRUDE AND PRESENTS THE DISADVANTAGE IN THAT IT REQUIRES CONTINUAL ATTENTION DURING THE TELEVISION PROGRAM. FOR THIS REASON, WE SHALL ALSO FAMILIARIZE YOU WITH WHAT IS NOW THE MOST POPULAR TYPE OF TELEVISION SYNCHRONIZER AND IN WHICH WE MAKE USE OF THE "PHONIC-MOTOR".

THE MOST OUTSTANDING ADVANTAGE OF THE PHONIC-MOTOR IS THAT IT PREMITS THE TELEVISION TRANSMITTER TO CONTROL THE SPEED OF THE RECEIVER'S SCANNING DISC AND IT IS NO MORE BUT REASONABLE TO EXPECT AN ARRANGEMENT OF THIS TYPE TO BE MOST PRACTICAL.

BEFORE GOING INTO THE CONSTRUCTIONAL DETAILS REGARDING THE PHONIC MOTOR, LET US FIRST BRIEFLY CONSIDER THE PRINCIPLES OF ITS OPERATION.

A SIMPLE TYPE OF PHONIC MOTOR IS SHOWN YOU IN FIG. 27 WHILE ITS OPERATING PRINCIPLE IS ILLUSTRATED IN FIG.28. AS YOU WILL NOTE IN FIG. 28, WE HAVE A "U"-SHAPED LAMINATED IRON CORE WITH THE TWO POLE TIPS A AND C.

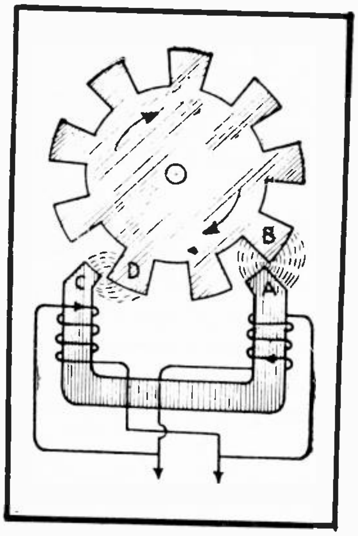

FIG. 28
Principle of Motor

WINDINGS ARE PROVIDED ON EACH OF THESE POLES, WITH THE TURNS SO WOUND THAT WHEN CURRENT FLOWS THROUGH THEM IN A GIVEN DIRECTION, ONE OF THE POLES WILL ASSUME A NORTH POLARITY WHILE THE OTHER AT THE SAME TIME ASSUMES A SOUTH POLARITY. ALSO NOTE THAT THESE TWO WINDINGS ARE CONNECTED IN PARALLEL.

JUST ABOVE THIS IRON CORE, WE HAVE AN IRON GEAR, WHICH IS PIVOTED BUT FREE TO MOVE ABOUT ITS CENTRAL AXIS. THIS ENTIRE ARRANGEMENT FORMS A SIMPLE TYPE OF SYNCHRONOUS MOTOR. THIS MOTOR, HOWEVER, IS NOT POWERFUL ENOUGH TO START RUNNING FROM A STATIONARY POSITION AND MUST FIRST BE GIVEN A START EITHER BY HAND OR ELSE BY SOME OTHER FORM OF MOTIVE POWER. YET, AFTER ONCE STARTED, THE GEAR WILL CONTINUE ROTATING UNDER ITS OWN POWER.

ASSUMING IN FIG.28 THAT AT THE INSTANT SHOWN, THE FLOW OF A.C. THROUGH THE COILS IS SUCH THAT POLE "A" IS MAGNETIZED TO A SOUTH POLARITY AND POLE "C" TO A NORTH POLARITY, THEIR MAGNETIC LINES OF FORCE WILL REACT UPON THE GEAR. THAT IS, POLE "C" WILL ATTRACT GEAR TOOTH "D" AND POLE "A" WILL ATTRACT GEAR TOOTH "B" AND THE GEAR WILL ROTATE IN THE DIRECTION INDICATED BY THE ARROWS UNTIL GEAR TOOTH "D" LINES UP WITH POLE "C" AND GEAR TOOTH "B" LINES UP WITH POLE "A".

PROVIDED THAT THE UNIT IS PROPERLY DESIGNED, YOU WILL FIND THAT THE INSTANT THAT THIS ALIGNMENT OF POLES AND GEAR TEETH OCCURS, THE CURRENT FLOW THROUGH THE COILS WILL BE AT SUCH A POINT OF ITS CYCLE, SO THAT ITS VALUE IS PRACTICALLY ZERO. THEREFORE, THERE IS NO LONGER AN ATTRACTIVE FORCE BEING EXERTED BY THE POLES OF THE CORE AND THE GEAR THENCE ROTATES A LITTLE FURTHER DUE TO ITS INERTIA. THAT IS, IT COASTS. HOWEVER, THE CURRENT FLOW THRU THE COILS HAS COMMENCED TO INCREASE AGAIN BY THIS TIME, SO THAT THE NEXT PAIR OF GEAR TEETH ARE ATTRACTED TOWARD THE POLES AND THIS ACTION CONTINUES OVER AND OVER AGAIN, WITH THE RESULT THAT THE GEAR ROTATES BUT ITS SPEED OF ROTATION WILL BE GOVERNED BY THE VARIATION OF CURRENT THROUGH THE COILS.

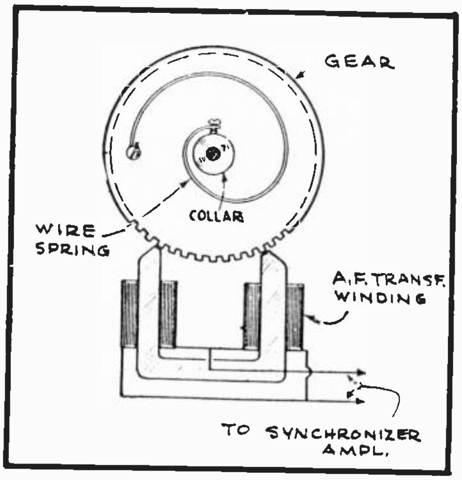

FIG. 29
Constructional Detail of Phonic Motor.

CONSTRUCTING A PHONIC MOTOR

NOW AS TO THE CONSTRUCTION OF THE PHONIC MOTOR. THE "U" SHAPED CORE CAN

EITHER BE OBTAINED FROM AN OLD POWER TRANSFORMER OR ELSE YOU CAN ASSEMBLE ONE YOURSELF FROM IRON LAMINATIONS. IT MAKES NO DIFFERENCE HOW MANY GEAR TEETH ARE INCLUDED WITHIN THE SPACE BETWEEN THESE TWO POLES BUT THE TIPS OF THESE TWO POLES SHOULD BE TAPERED, SO THAT THEIR FACES HAVE THE SAME SHAPE AS THE PORTION OF THE TEETH WHICH FACE THE POLES. THE WINDINGS FOR THIS CORE CAN BE THE PRIMARY COILS OF AN OLD AUDIO TRANSFORMER AS SHOWN IN FIG.29 BUT THEY SHOULD BE CONNECTED IN PARALLEL IN ADDITION TO HAVING THEIR POLARITY PROPERLY RELATED SO THAT ONE WILL PRODUCE A NORTH POLE AND THE OTHER A SOUTH POLE AT THE POLES OF THE CORE.

ALTHOUGH A GEAR MADE OF LAMINATED IRON OR SILICON STEEL SHEETS WOULD BE MOST PREFERABLE, YET THIS ARRANGEMENT OFFERS CONSIDERABLE CONSTRUCTION DIFFICULTIES. THEREFORE, THE GENERAL PRACTICE IS TO USE AN ORDINARY CAST-IRON GEAR, HAVING A DIAMETER OF 4 OR 5 INCHES AND BEING ABOUT 3/4" THICK.

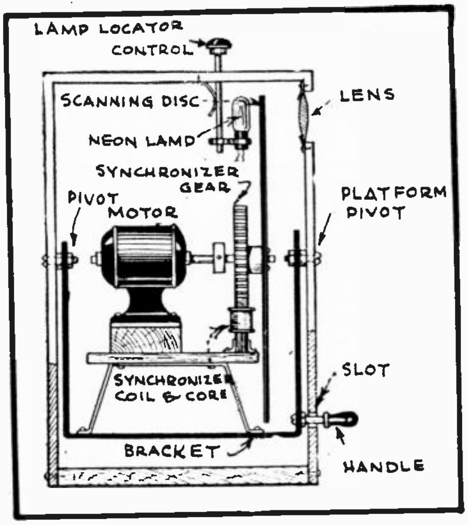

FIG. 30
The Assembled Scanner.

THIS GEAR SHOULD HAVE THE SAME NUMBER OF TEETH AS THERE ARE HOLES IN THE SCANNING DISC USED FOR REPRODUCING THE PICTURE. IN OTHER WORDS, FOR RECEIVING A 48 LINE PICTURE, A GEAR WITH 48 TEETH SHOULD BE USED, FOR A 60 LINE PICTURE, A GEAR WITH 60 TEETH SHOULD BE USED ETC.

THE ASSEMBLY OF THE PHONIC MOTOR IS ILLUSTRATED BOTH IN FIGS. 29 AND 30. IN THE CASE OF FIG.29 YOU ARE LOOKING AT THE PHONIC MOTOR FROM THE REAR, WHEREAS IN FIG.30 YOU ARE LOOKING AT IT FROM THE SIDE. AS YOU WILL NOTE IN FIG. 30, THE GEAR IS MOUNTED ON THE SAME SHAFT THROUGH WHICH THE DRIVING MOTOR DRIVES THE SCANNING DISC BUT THE DISC IS DRIVEN BY THIS SHAFT THROUGH AN INDIRECT DRIVE OR COUPLING. THAT IS, THE SCANNING DISC IS FASTENED FIRMLY TO THE FLAT SIDE OF THE GEAR AND WHEN THE GEAR AND SCANNING DISC ARE AT FIRST SLIPPED OVER THE END OF THE SHAFT DURING ASSEMBLY, THEY ARE FREE TO ROTATE UPON THIS SHAFT AND SO FAR, IT IS CLEAR THAT THE DRIVE MOTOR CANNOT AS YET ROTATE THE DISC.

THE DRIVING FORCE IS DELIVERED FROM THE SHAFT TO THE DISC IN THE FOLLOWING WAY: A COLLAR IS MOUNTED ON THE DRIVE SHAFT, BEING LOCKED TO THE SHAFT BY A SET SCREW. THIS COLLAR IS SHOWN BOTH IN FIGS. 29 AND 30.

A SPIRAL SPRING, MADE OF BRASS WIRE, CONNECTS THIS COLLAR TO THE GEAR. THAT IS, ONE END OF THIS SPRING IS FASTENED TO THE SET SCREW IN THE COLLAR AND THE OTHER END OF THE SPRING IS FASTENED TO THE GEAR BY MEANS OF A SCREW. THIS IS CLEARLY ILLUSTRATED IN FIG.29. THUS IT IS SEEN THAT THE MOTOR'S DRIVING FORCE IS ALL TRANSMITTED TO THE GEAR AND SCANNING DISC THROUGH THE SPRING.

THE PURPOSE OF THE SPRING IS TO TAKE UP ANY VARIATIONS IN THE speed of the motor. Consequently, the gear and disc will always run at the correct speed. Should the motor's speed vary due to power line voltage fluctuations, then it will tend to wind or unwind the spring, with the spring tension finally adjusting the scanner disc speed to normal.

SUPPORTING THE DRIVE MECHANISM

Observe in Fig.30 how the drive motor and core of the phonic motor are mounted on the same base or bed and that this motor bed is in turn mounted on a pivoted bracket or platform, whose pivots are in line with the drive shaft. The entire scanning assembly is mounted in a wooden cabinet as shown and a circular slot is cut in the lower front portion of the cabinet through which passes a threaded bolt with a handle.

This bolt is fastened to the mounting bracket and by unscrewing the handle part way, the bolt can be pulled across the slot, swinging the pivoted mounting bracket with it. This adjustment is provided to aid in framing the picture and with the setting properly determined, the handle is screwed tight, thus locking the bracket to this setting. It will also be well to add at this point that the clearance between the gear teeth and the poles of the core of the phonic motor should be as small as possible, without touching.

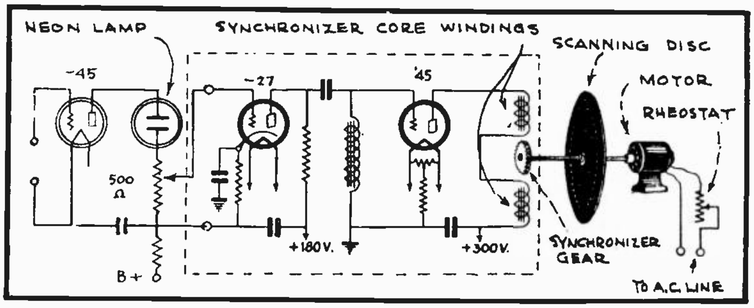

FIG. 31
Synchronizer Amplifier Connections.

USING THE TRANSMITTER SIGNAL FOR SYNCHRONIZING PURPOSES

The television signal, as radiated from the transmitter in addition to the picture frequencies, also contains a strong component of the scanning frequency, which is derived from the number of scanned lines per picture multiplied by the picture frequency. That is, in the case of a 48-line picture, transmitted at 15 pictures per second, the scanning frequency is 720 cycles per second and a strong component of this frequency is found in the signal. This frequency will vary with any variation in the speed of the scanning disc at the transmitter.

This scanning frequency can be amplified and filtered out of the signal frequency by connecting an amplifier tuned to 720 cycles to the lamp circuit of the receiver as shown in Fig.31. This amplifier is called the SYNCHRONIZER AMPLIFIER and its output circuit is connected across the coils of the phonic motor as also shown in Fig.31. The design of this synchronizer amplifier is not very critical because the scanning frequency component is quite strong.

The phonic motor will not develope sufficient torque (that is, turning effort,) to overcome the friction of the disc's driving mechan-

ISM AND THEREFORE THE VARIABLE-SPEED MOTOR, OPERATED OFF THE A.C.LIGHTING CIRCUIT, IS ALSO COUPLED TO THE SYSTEM AS SHOWN BOTH IN FIGS.30 AND 31.

THUS IT IS SEEN THAT THE A.C. DRIVEN VARIABLE SPEED MOTOR ACTUALLY DRIVES THE SCANNING DISC BUT THE SMALL SYNCHRONOUS MOTOR AT THE OTHER END OF THE DRIVE TENDS TO BE DRIVEN BY THE SCANNING FREQUENCY WHICH IS FLOWING THROUGH ITS WINDINGS. THEREFORE, THE SPEED OF THE VARIABLE SPEED DRIVE MOTOR IS CONTROLLED BY THE SPEED OF THE SMALL SYNCHRONOUS MOTOR AND THE VARIABLE SPEED MOTOR SIMPLY SUPPLIES THE POWER NEEDED TO OVERCOME FRICTION.

A SPEED CONTROL IS PROVIDED IN THE CIRCUIT OF THE VARIABLE SPEED MOTOR BY MEANS OF WHICH THE OPERATOR CAN MANUALLY VARY THE SPEED OF THE SCANNING DISC UNTIL THE PICTURE IS PROPERLY FRAMED. AT THIS TIME, THE RECEIVER DISC WILL BE IN STEP WITH THE TRANSMITTER DISC AND BY LEAVING THE SPEED CONTROL SET AT THIS POSITION, THE SYNCHRONOUS MOTOR WILL MAINTAIN THE PROPER SPEED RELATION BETWEEN THE RECEIVER AND TRANSMITTER SCANNING DISCS AND THUS PROVIDES AUTOMATIC SYNCHRONIZATION THROUGHOUT THE BALANCE OF THE "SHOW".

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE MECHANICAL METHODS OF SCANNING BUT IN LATER LESSONS YOU WILL BE SHOWN HOW SCANNING CAN BE ACCOMPLISHED ELECTRICALLY WITH THE AID OF CATHODE-RAY TUBE. HOWEVER, BEFORE GOING INTO DETAILS PERTAINING TO THESE MORE COMPLICATED METHODS OF SCANNING, YOU WILL FIRST BE TOLD IN THE NEXT LESSON MORE ABOUT THE DESIGN FEATURES OF TELEVISION RECEIVERS.

EXAMINATION QUESTIONS

LESSON NO. TEL-2

"Most of us would be successful if we would keep on doing the things we KNOW we SHOULD DO -- and STOP doing the things we KNOW we SHOULD NOT DO."

1. - DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES A PRACTICAL METHOD OF CONNECTING A NEON LAMP TO THE OUTPUT OF A TELEVISION RECEIVER AND DESCRIBE THE FEATURES OF THE CIRCUIT YOU HAVE DRAWN.

2. - EXPLAIN IN DETAIL HOW THE SANABRIA SCANNING DISC OPERATES.

3. - EXPLAIN IN DETAIL THE OPERATION OF THE JENKINS DRUM TYPE SCANNER.

4. - DESCRIBE THE SCANNER AS USED BY THE BELL SYSTEM AND EXPLAIN HOW IT OPERATES.

5. - HOW MAY SCANNING BE ACCOMPLISHED WITH THE AID OF MIRRORS?

6. - EXPLAIN IN DETAIL WHAT IS MEANT BY THE TERM "SYNCHRONISM".

7. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF THE PHONIC MOTOR AND EXPLAIN HOW IT MAY BE USED FOR SYNCHRONIZING PURPOSES.

8. - DRAW A CIRCUIT DIAGRAM OF A SYNCHRONIZING AMPLIFIER, SHOWING HOW IT IS CONNECTED TO THE TELEVISION RECEIVER AND SCANNING EQUIPMENT, AND EXPLAIN HOW IT OPERATES.

9. - EXPLAIN FULLY THE PROCEDURE WHICH YOU WOULD FOLLOW IN ORDER TO CONSTRUCT A NIPKOW SCANNING DISC.

10.- WHAT IS THE OBJECT OF USING A CONVENTIONAL MOTOR IN CONJUNCTION WITH THE PHONIC MOTOR FOR DRIVING A SCANNING DISC?

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RADIO - TELEVISION

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NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Television

LESSON NO. 3

TELEVISION RECEIVERS

NOW THAT YOU ARE FAMILIAR WITH TELEVISION IN GENERAL, AS WELL AS WITH THE CONSTRUCTION AND OPERATION OF MECHANICAL SCANNING SYSTEMS, YOU WILL NEXT BE INTERESTED IN LEARNING MORE ABOUT THE CONSTRUCTIONAL DETAILS AND THE PROCEDURES FOR OPERATING TELEVISION RECEIVERS.

GENERALLY SPEAKING, TELEVISION RECEIVERS ARE VERY SIMILAR IN DESIGN AND CONSTRUCTION TO CONVENTIONAL BROADCAST RECEIVERS, WITH THE EXCEPTION THAT THEIR TUNED RADIO FREQUENCY SECTION IS DESIGNED TO TUNE TO THOSE FREQUENCY BANDS WHICH HAVE BEEN SET ASIDE BY THE GOVERNMENT FOR TELEVISION PURPOSES. AT THE SAME TIME, THE TUNING CIRCUITS MUST ALSO BE SO CONSTRUCTED AS NOT TO BE TOO SHARP TUNING SO THAT A BAND-WIDTH OF APPROXIMATELY 40 KC. CAN BE PASSED THROUGH THIS SYSTEM IN ORDER TO RETAIN ALL OF THE NECESSARY PICTURE FREQUENCIES.

FIG. 1
Adjusting the Receiver Scanner.

THE AUDIO CHANNEL OF TELEVISION RECEIVERS, AS YOU HAVE ALREADY LEARNED, MUST ALSO BE DESIGNED SO AS TO AMPLIFY FAITHFULLY THE WIDE RANGE OR AUDIO FREQUENCIES (PICTURE FREQUENCIES) WHICH ARE REQUIRED FOR GOOD TELEVISION REPRODUCTION.

TELEVISION STATIONS

IN TABLE I YOU

ARE GIVEN A LIST OF THE MORE POPULAR TELEVISION STATIONS, TOGETHER WITH THEIR LOCATIONS AND THE FREQUENCY BAND IN WHICH THEY OPERATE. FROM THIS LIST, YOU WILL READILY NOTE THAT THE TELEVISION BANDS ARE AS FOLLOWS: 2000-2100 KC., , 2750-2850 KC.; 42,000-56,000 KC.; AND 60,000-86,000 KC. THIS THEN, WILL DETERMINE THE TUNING RANGE OR RANGES FOR WHICH THE TELEVISION RECEIVER SHOULD BE DESIGNED.

TABLE I
TELEVISION STATION LIST

2000-2100 KC.	
VE9AU	-- LONDON, ONT., CAN.
VE9DS	-- MONTREAL, QUE.
W2XDR	-- LONG ISLAND CITY, N.Y.
W8XAN	-- JACKSON, MICH.
W9XK	-- IOWA CITY, IA.
W9XAK	-- MANHATTAN, KANS.
W9XAO	-- CHICAGO, ILL.
W6XAH	-- BAKERSFIELD, CALIF.
2750-2850 KC.	
W3XAK	-- PORTABLE
W9XAP	-- CHICAGO, ILL.
W2XBS	-- BELLMORE, N.Y.
W9XAL	-- KANSAS CITY, MO.
W9XG	-- W. LAFAYETTE, IND.
W2XAB	-- NEW YORK, N.Y.
VE9AR	-- SASKATOON, SASK., CAN.
VE9ED	-- MT. JOLI, QUE., CAN.
42,000-56,000 & 60,000-86,000 KC.	
W2XAX	-- NEW YORK, N.Y.
W6XAO	-- LOS ANGELES, CALIF.
W9XD	-- MILWAUKEE, WIS.
W2XBT	-- PORTABLE
W2XF	-- NEW YORK, N.Y.
W3XE	-- PHILADELPHIA, PA.
W3XAD	-- CAMDEN, N.J.
W10XX	-- PORTABLE & MOBILE (VICINITY OF CAMDEN)
W2XDR	-- LONG ISLAND CITY, N.Y.
W8XAN	-- JACKSON, MICH.
W9XAT	-- PORTABLE
W2XD	-- NEW YORK, N.Y.
W2XAG	-- PORTABLE
W1XG	-- BOSTON, MASS.
W9XK	-- IOWA CITY, LA.
VE9BZ	-- VANCOUVER, B.C., CAN.
VE9DS	-- MONTREAL, QUE., CAN.
VE9AU	-- LONDON, ONT., CAN.
VE9RC	-- QUEBEC, QUE., CAN.
VE9AG	-- WALKERVILLE, ONT., CAN.

RECEIVER CONSTRUCTION

FROM AN EXAMINATION OF FIGS. 2&3 OF THIS LESSON YOU WILL READILY BECOME ACQUAINTED WITH THE GENERAL APPEARANCE OF RECEIVERS OF THIS TYPE. DUE TO THE CLOSE RESEMBLANCE BETWEEN TELIVISION RECEIVERS AND RADIO BROADCAST RECEIVERS, THERE WILL BE NO NEED FOR US TO SPEND ANY MORE TIME ON THIS SUBJECT. INSTEAD, IT WILL BE MORE ADVISABLE TO CONSIDER THE DETAILS REGARDING THE CIRCUITS OF THESE RECEIVERS.

A GOOD EXAMPLE OF A MODERN CIRCUIT DESIGN IS SHOWN YOU IN FIG.5. THIS RECEIVER IS OF CONVENTIONAL T.R.F. DESIGN AND EMPLOYS TYPE 58 TUBES IN THE FIRST THREE R.F. STAGES, A 57 POWER DETECTOR, A 57 FIRST A.F., A 2A3 POWER TUBE AND AN 80 RECTIFIER.

THE PURPOSE OF SWITCH S_1 IS TO PROVIDE A MEANS OF CUTTING THE SPEAKER IN AND OUT OF THE CIRCUIT CONVENIENTLY. WITH THIS SWITCH IN AN OPEN POSITION, THE TELEVISION SIGNALS WILL BE HEARD IN THE SPEAKER IN THE FORM OF A STEADY WHIRRING SOUND SOMEWHAT AS THAT WHICH IS PRODUCED BY A BUZZ-SAW WHEN IN OPERATION.

BY CLOSING THIS SAME SWITCH, THE PRIMARY WINDING OF THE SPEAKER OUTPUT TRANSFORMER WILL BE SHORT CIRCUITED, THEREBY PREVENTING OPERATION OF THE SPEAKER WHILE THE PICTURE IS BEING OBSERVED.

THE R.F. TRANSFORMERS AS USED IN THIS RECEIVER ARE OF THE

SOLENOID, CLOSE-WOUND TYPE, THE SECONDARY INDUCTANCE BEING SO CHOSEN THAT FOR A VARIABLE CONDENSER OF GIVEN RATING, THE ARRANGEMENT WILL TUNE OVER THE BAND DESIRED. NOTICE ESPECIALLY IN FIG. 5 THAT A POWER DETECTOR IS USED IN THIS PARTICULAR CIRCUIT.

APPLICATION OF GRID DETECTION

IN FIG. 6 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SEVEN-TUBE TELEVISION RECEIVER IN WHICH GRID DETECTION IS USED. THIS IS AN A.C. TYPE RECEIVER EMPLOYING, TWO STAGES OF R.F. AMPLIFICATION, FOLLOWED BY A SPACE-CHARGE DETECTOR OF THE GRID CONDENSERAND LEAK TYPE. THE DETECTOR FEEDS INTO TWO STAGES OF RESISTANCE-CAPACITY COUPLED A.F. AMPLIFICATION AND THE PICTURE SIGNALS ARE FINALLY IMPRESSED ACROSS THE OUTPUT OF A SINGLE POWER TUBE.

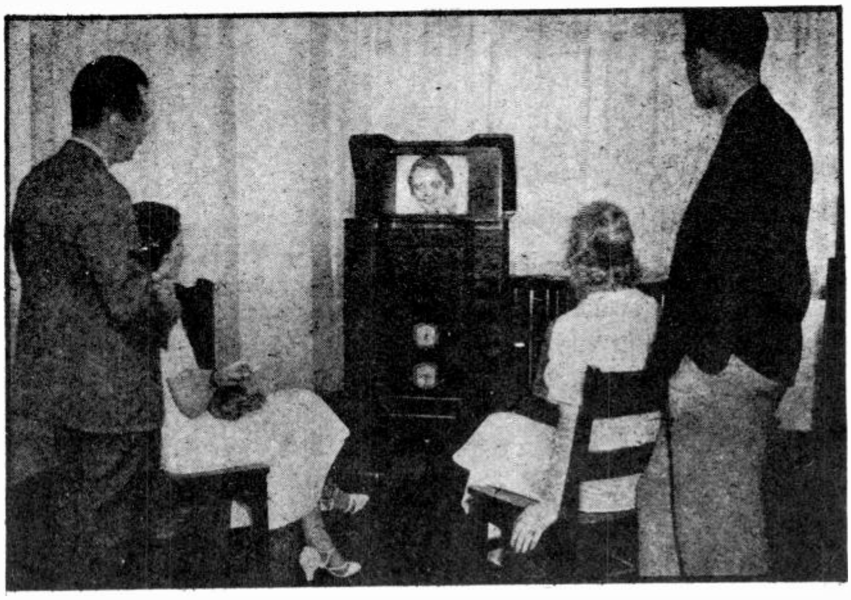


FIG. 2
Console Type Television Receiver.

TUNING CHARACTERISTICS OF TELEVISION RECEIVERS

THE R.F. AMPLIFIER IN THIS CASE IS DESIGNED TO TUNE OVER THE WAVE BAND IN WHICH THE DESIRED TELEVISION TRANSMITTER IS OPERATING. THIS R.F. AMPLIFIER IS ALSO SPECIALLY DESIGNED TO PASS A FREQUENCY BAND WHICH IS FROM 30 TO 40 KC. IN WIDTH, WHICH YOU WILL NOTE AS BEING MUCH BROADER TUNING THAN BROADCAST RECEIVERS, WHERE ONLY A MAXIMUM FREQUENCY BAND OF 10 KC. IS PASSED BY THE R.F. AMPLIFIER.

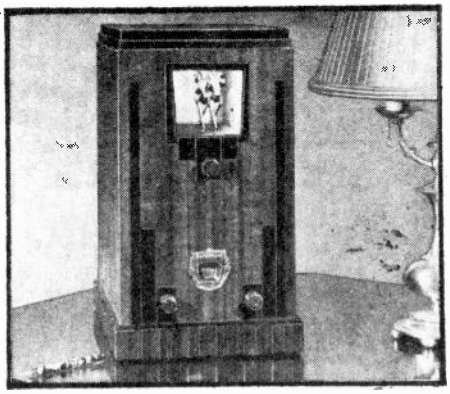


FIG. 3
Midget Type Television Receiver.

PROVIDING CORRECT BAND WIDTH

IN ORDER TO HAVE AN R.F. AMPLIFIER, WHICH IS ACCURATELY DESIGNED TO PASS A FREQUENCY BAND OF THIS WIDTH, MOST EXPERIMENTERS BUY THE R.F. TRANSFORMERS FROM CONCERNS, WHOSE LABORATORIES ARE EQUIPPED WITH THE NECESSARY TESTING APPARATUS TO PRODUCE ACCURATELY DESIGNED R.F. TRANSFORMERS, AND SUCH IS THE CASE FOR THE RECEIVER ILLUSTRATED IN FIG. 6. YOU CAN, HOWEVER, WIND YOUR OWN R.F. TRANSFORMER IF YOU SO DESIRE AND IF YOU DO, RE

MEMBER THAT THEY MUST BE WOUND SO AS TO TUNE OVER THE WAVE BAND REQUIRED.

SINCE TELEVISION STATIONS OPERATE IN VARIOUS BANDS, IT IS ALSO POSSIBLE TO EQUIP THE TELEVISION RECEIVER WITH PLUG-IN COILS SO AS TO FASCILITATE CHANGING FROM ONE TELEVISION BAND TO ANOTHER, OR ELSE TO USE A MULTIPLE-COIL AND SWITCH ARRANGEMENT SIMILAR TO THAT USED IN ALL-WAVE RECEIVERS. AS A GENERAL RULE, HOWEVER, YOU WILL FIND TELEVISION RECEIVERS TO BE DESIGNED FOR BEST OPERATION IN ONE PARTICULAR BAND IN WHICH THE NEAREST STATION OPERATES BECAUSE THE REPRODUCED IMAGES BECOME POORER AS THE DISTANCE BETWEEN THE TRANSMITTER AND THE RECEIVER IS INCREASED.

TABLE I
(SPECIFICATIONS FOR TELEVISION RECEIVER CIRCUIT OF FIG.6)

#3 -- .000365 MFD.	#31 -- 43, 55-25,000 OHMS.
#4 -- SHIELDED ANT. INDUCTANCE COIL	#33 -- 44,54-.25 MFD.
#5 -- 16,29,38,49 - TYPE -24 TUBES	#36 -- 40,48,51,52,58-2MFD.
#6 -- 10,11,17,20,21 - .1 MFD.	#45 -- 57-250,000 OHMS
#7 -- 18,37,47 - 1000 OHM.	#59 -- CENTER TAPPED 20 OHM RESISTOR OR HUM ADJUSTER
#8 -- TYPE RI-202 ELECTRAD VOLUME CONTROL.	#60 -- 1500 OHMS
#9 -- 19,28A,32,39,42,50,53 - 50,000 OHMS	#62A - ELECTRAD TRUVOLT - FIXED RESISTANCE TYPE B-30
#12 -- 22 - 75,000 OHMS	#63A - MILLIAM.(0-50 MA.)
#13 -- 23 - TELEV. R.F. TRANSF.	#64 -- TYPE C-200 ELECTRODE VOLTAGE DIVIDER
#14 -- 24 - TWO-GANG COND. .0002 MFD.EACH SECTION	#64A - 4 MFD.
#15 -- 25 - 140 MMFD.	65 -- 16 MFD.
#26 -- .0001 MFD.	#66&67 8 MFD.
#27 -- 50,000 OHMS	#68 --.1 MFD.
#28 -- 1 MFD.	#69&70- 30 HENRY 80 MIL CHOKES
#30 -- 41 - 4MFD.	#71 -- POWER TRANSFORMER WITH REQUIRED OUTPUT

EFFECT OF DETECTOR UPON IMAGE

BY AGAIN COMPARING THE CIRCUIT IN FIG.5 WITH THAT IN FIG.6YOU WILL NOTICE THAT WHEN POWER DETECTION IS EMPLOYED, AS IN FIG.5, THEN AN EVEN NUMBER OF A.F. STAGES FOLLOW THE DETECTOR. THAT IS, WE CAN IN THIS CASE USE 2, 4 OR 6 A.F. STAGES. WHILE ON THE OTHER HAND, WHEN USING GRID DETECTION AS IN THE CIRCUIT OF FIG.6, WE USE AN ODD NUMBER OF A.F. STAGES FOLLOWING THE DETECTOR, THAT IS, 1, 3 OR 5 A.F. STAGES.

THE REASON FOR THIS CHOICE IN THE SELECTION OF THE NUMBER OF A.F. STAGES IS THAT GRID CIRCUIT DETECTION INTRODUCES A PHASE-REVERSAL IN THE DETECTOR STAGE AND THIS MEANS THAT THE IMAGE WILL BECOME A "NEGATIVE" OR REVERSED PICTURE AT THE OUTPUT OF THE DETECTOR. THE IMAGE OR PICTURE WILL THEN BE ALTERNATELY REVERSED OR CHANGED FROM NEGATIVE TO POSITIVE AND VICE VERSA AS THE PICTURE SIGNALS ARE PASSED THROUGH EACH SUCCESSIVE A.F. STAGE.

CONSEQUENTLY, BY USING AN ODD NUMBER OF A.F. STAGES WITH GRID DE-

TECTION, A POSITIVE PICTURE WILL BE FURNISHED AT THE OUTPUT OF THE FINAL POWER STAGE. ON THE OTHER HAND, WHEN POWER DETECTION IS USED, A POSITIVE IMAGE WILL APPEAR AT THE OUTPUT OF THE DETECTOR AND THEREFORE THIS WILL BECOME A NEGATIVE AT THE OUTPUT OF THE FIRST A.F. STAGE, POSITIVE AT THE OUTPUT OF THE SECOND A.F. STAGE ETC. THUS IT IS SEEN THAT WHEN USING POWER DETECTION, AN EVEN NUMBER OF A.F. STAGES WILL RESULT IN A POSITIVE PICTURE AT THE OUTPUT OF THE RECEIVER.

TELEVISION RECEIVER WITH BAND-PASS FEATURES

ANOTHER INTERESTING TELEVISION RECEIVER CIRCUIT IS SHOWN IN FIG. 7. HERE TYPE 57 TUBES ARE USED IN THE TWO R.F. STAGES, AS WELL AS IN THE DETECTOR, FIRST A.F. AND SECOND A.F. STAGES, WHILE A 2A5 IS EMPLOYED IN THE FINAL OR OUTPUT STAGE.

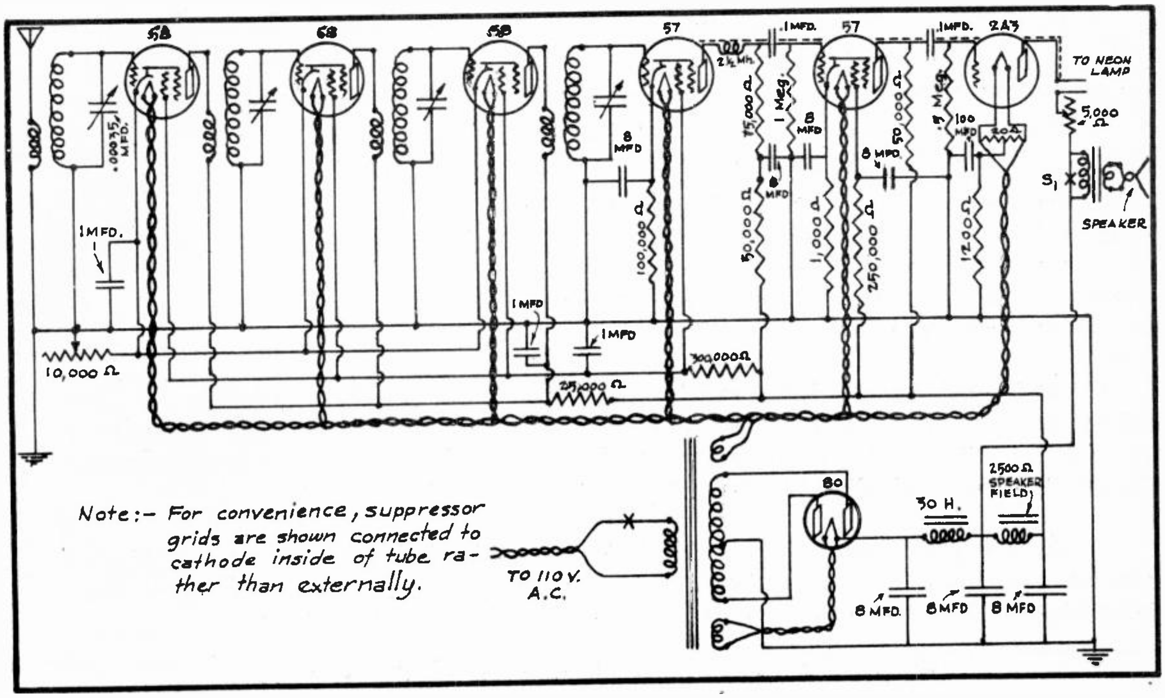


FIG. 5
A Seven-Tube Television Receiver

THE FIRST POINT OF INTEREST IN THIS CIRCUIT IS THE FACT THAT BOTH THE PRIMARY AND SECONDARY WINDINGS OF THE R.F. TRANSFORMERS USED BETWEEN THE FIRST AND SECOND R.F. TUBES AND BETWEEN THE SECOND R.F. AND THE DETECTOR TUBES ARE TUNED. THIS, YOU WILL READILY REALIZE, RESULTS IN A BAND-PASS EFFECT AND THE PURPOSE OF THE RESISTORS R IN THIS SAME CIRCUIT IS TO FLATTEN THE RESPONSE CURVE IN SUCH A MANNER THAT A PRACTICALLY CONSTANT OUTPUT IS MAINTAINED OVER THE DESIRED FREQUENCY RANGE.

ANOTHER POINT OF INTEREST REGARDING THIS CIRCUIT IS THAT THREE STAGES OF A.F. AMPLIFICATION ARE USED ALTHOUGH POWER DETECTION IS EMPLOYED AND WHICH DOES NOT ALTOGETHER AGREE WITH THE RULE PREVIOUSLY GIVEN. THIS CAN BE EXPLAINED, HOWEVER, IN THE FOLLOWING MANNER: THIS PARTICULAR RECEIVER WAS DESIGNED PRIMARILY TO BE USED IN CONJUNCTION WITH A CATHODE-RAY TYPE SCANNING UNIT AND WHICH IS EXPLAINED FULLY IN LATER LESSONS. FURTHERMORE, WITH THREE AUDIO STAGES AND A POWER DETECTOR, AN INCREASE IN RADIO-

FREQUENCY INPUT WILL CAUSE THE UNGROUNDED OUTPUT TERMINAL TO BECOME MORE POSITIVE. IF THIS TERMINAL IS USED TO APPLY VOLTAGE TO THE MODULATING GRID OF A CATHODE-RAY TUBE, A POSITIVE PICTURE WILL RESULT FOR MOST TELEVISION SIGNALS.

THE TRANSMITTING STATION GENERALLY INCREASES ITS OUTPUT ON THE BRIGHT PARTS OF THE PICTURE, BUT IF IT DOES THE OPPOSITE, THE PHASE OF

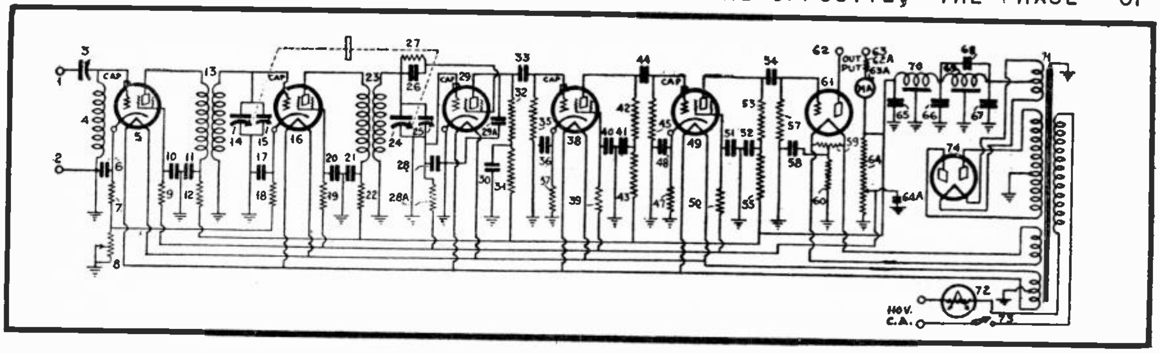


FIG. 6
Television Receiver With Grid Leak Detection.

THE CATHODE-RAY TUBE GRID VOLTAGE AT THE RECEIVER MUST BE REVERSED OR ELSE A NEGATIVE PICTURE WILL RESULT. THIS REVERSAL IN THIS INSTANCE IS BEST ACCOMPLSIHED BY ADDING AN EXTRA RESISTANCE-COUPLED AUDIO STAGE WITH LITTLE OR NO AMPLIFICATION; FOR INSTANCE, A 56 OR A 57 TUBE WITH A 1000 OHM COUPLING RESISTOR.

ALSO NOTICE IN THE CIRCUIT OF FIG.7 THAT NO R.F. FILTER IS USED IN THE OUTPUT OF THE DETECTOR. THIS HAS BEEN PURPOSELY OMITTED SO THAT THERE WILL BE NO POSSIBILITY OF BY-PASSING ANY OF THE HIGHER AUDIO FREQUENCIES TO GROUND AND THEREBY REDUCE THE CLARITY OF THE PICTURE.

SO FAR, ALL OF THE CIRCUITS WHICH WERE BROUGHT TO YOUR ATTENTION ARE OF THE T.R.F. TYPE. YOUR NEXT STEP THEN, WILL BE TO SEE HOW THE SUPERHETERODYNE PRINCIPLE CAN BE ADAPTED TO TELEVISION RECEPTION.

TELEVISION RECEIVERS OF SUPERHETERODYNE DESIGN

KNOWING THAT THE TELEVISION RECEIVER MUST BE BROAD TUNING IN ORDER

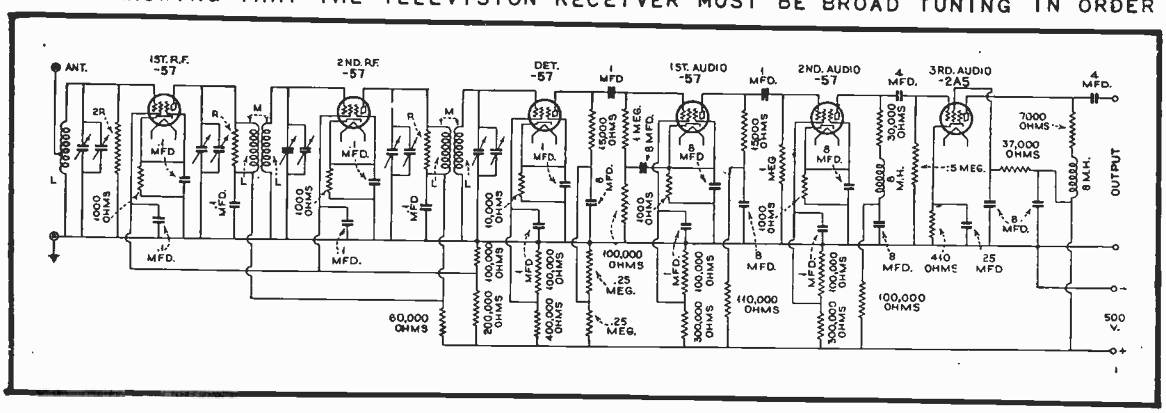


FIG. 7
Television Receiver With Band-Pass Features.

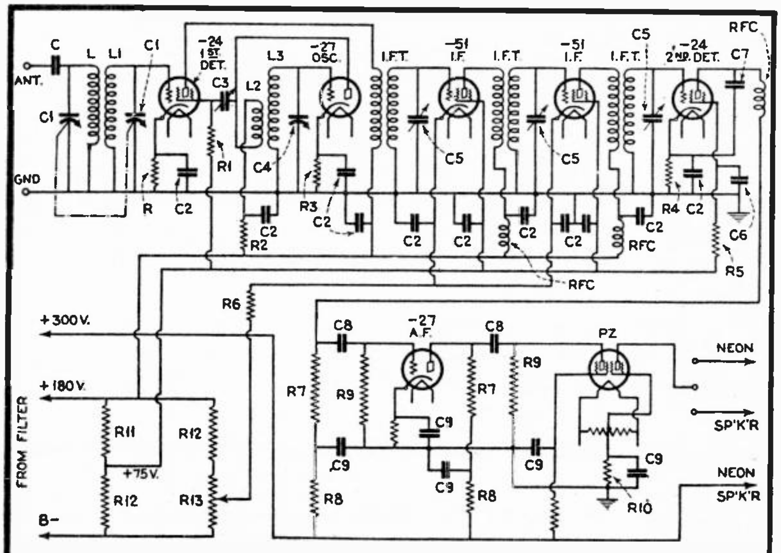
TO RETAIN THE ENTIRE BAND OF PICTURE FREQUENCIES, IT MAY AT FIRST APPEAR TO YOU THAT A RECEIVER OF SUPERHETERODYNE DESIGN MAY BE TOO SELECTIVE FOR TELEVISION PURPOSES. HOWEVER, UPON DEVOTING A LITTLE MORE THOUGHT TO THE SUBJECT YOU WILL SOON REALIZE THAT BY APPLYING CERTAIN PRINCIPLES OF DESIGN SUCH AS FLAT-TOP I.F. TRANSFORMERS ETC., THE RESONANCE CURVE OF THE SUPERHETERODYNE RECEIVER CAN BE BROADENED CONSIDERABLY.

ONE OF THE FIRST PROBLEMS TO BE CONSIDERED IN THIS RESPECT IS THE SELECTION OF THE MOST SUITABLE INTERMEDIATE FREQUENCY. IF TOO LOW AN I.F. FREQUENCY WERE EMPLOYED, THEN THE IMAGE INTERFERENCE PROBLEM WILL BECOME TOO BOTHERSOME. THAT IS TO SAY, UNDER THESE CONDITIONS, THERE WILL THEN BE CONSIDERABLE POSSIBILITY OF TWO OSCILLATOR FREQUENCIES HETERODYNING A SIGNAL TO THE INTERMEDIATE FREQUENCY. ALSO ONE OSCILLATOR SETTING WILL SERVE TO HETERODYNE TWO SIGNALS TO THE INTERMEDIATE FREQUENCY. FURTHERMORE, BY USING TOO LOW AN INTERMEDIATE FREQUENCY WILL REQUIRE EXCESSIVE SELECTIVITY OF THE FIRST DETECTOR'S TUNING CIRCUIT AND OTHER PRE-SELECTOR CIRCUITS.

ON THE OTHER HAND, BY USING TOO HIGH AN INTERMEDIATE FREQUENCY, THE I.F. AMPLIFIER BECOMES LESS STABLE IN OPERATION AND TROUBLES DUE TO FEED-BACK ARE LIKELY TO BE ENCOUNTERED.

ALTHOUGH IT IS A COMMON PRACTICE TO USE I.F. TRANSFORMERS OF THE PLATE-TUNED, GRID-TUNED TYPE AND ADJUSTING THEM FOR FLAT-TOP RESPONSE, YET YOU WILL ALSO FIND A NUMBER OF CASES WHERE ONLY THE SECONDARY WINDINGS ARE TUNED AS IN THE CIRCUIT ILLUSTRATED IN FIG. 8. THIS METHOD, AS WELL AS CLOSE COUPLING BETWEEN THE PRIMARY AND SECONDARY WINDINGS OF THE I.F. TRANSFORMERS, PREVENTS EXCESSIVE SELECTIVITY IN THIS PART OF THE CIRCUIT.

ALSO, BY CLOSELY STUDYING THE SUPERHETERODYNE CIRCUIT IN FIG. 8, YOU WILL NOTE THAT A BAND-SELECTOR TUNING ARRANGEMENT IS USED IN THE FIRST DETECTOR CIR-



C	Antenna coupling condenser .000025 mfd.	RFC	Long-wave r-f. chokes.
C1	Two-gang tuning condenser .00015 mfd.	R	First detector bias resistor 10,000 ohms.
C2	.1 mfd. by-pass condensers.	R1	First detector screen-grid resistor 50,000 ohms.
C3	Oscillator coupling condenser .000025 mfd.	R2	Oscillator voltage dropping resistor 25,000 ohms.
C4	Oscillator tuning condenser .00015 mfd.	R3	Oscillator bias resistor 1500 ohms.
C5	I-F. "peaking" condensers .00005 to .0001 mfd.	R4	2nd detector bias resistor 50,000 ohms.
C6	Second detector screen-grid by-pass condenser 1 mfd.	R5	2nd detector screen-grid resistor 10,000 ohms.
C7	Second detector plate by-pass .00015 mfd.	R6	I-F. bias resistor 300 ohms.
C8	Audio coupling condensers .1 mfd.	R7	Plate resistors 100,000 ohms.
C9	Audio by-pass and filter condensers 1 to 4 mfd.	R8	Filter resistors 25,000 ohms.
L, L1	Short-wave band filter coils.	R9	Grid resistors 250,000 ohms.
L2, L3	Oscillator coils.	R10	Bias resistors 400 ohms.
IFT	Intermediate-frequency transformers.	R11	10,000 ohms.
		R12	30,000 ohms.
		R13	Volume control 10,000 ohms.

FIG. 8

Television Receiver of Superheterodyne Type.

CUIT. THIS AIDS IN MAKING REASONABLY SHARP TUNING POSSIBLE WITHOUT SIDE BAND CUTTING. THE OUTPUT OF THE SECOND DETECTOR FEEDS INTO A HIGH FIDEL ITY RESISTANCE-COUPLED AUDIO AMPLIFIER CONSISTING OF ONE TYPE 27 TUBE AND ONE 47 TUBE. THE POWER PACK,WHICH IS NOT SHOWN HERE,IS OF CONVENTIONAL DESIGN AND ASIDE FROM THE FEATURES SO FAR POINTED OUT REGARDING THIS CIRCUIT, IT FOLLOWS THE SAME GENERAL DESIGN PRACTICE AS USED FOR RADIO RECEIVERS OF THE SUPERHETERODYNE TYPE.

RECEIVER FOR A.C.-D.C. OPERATION

ANOTHER INTERESTING TELEVISION RECEIVER CIRCUIT OF THE SUPERHETERODYNE TYPE IS SHOWN YOU IN FIG.9. THIS PARTICULAR RECEIVER EMPLOYS A 25Z5 TUBE AS THE RECTIFIER, A 6F7 AS THE COMBINATION FIRST DETECTOR AND OSCILLATOR, AND 6C6 TUBES IN ALL OF THE OTHER STAGES.

A UNIQUE FEATURE OF THE CIRCUIT IN FIG.9 IS THE MANNER IN WHICH A PUSH-PULL ACTION IS OBTAINED IN THE POWER STAGE THROUGH A RESISTANCE-CAPACITY COUPLING SYSTEM RATHER THAN WITH THE AID OF TRANSFORMERS. WITH A DEFINITE SETTING OF THE PHASING POTENTIOMETER,THE PROPER PHASE RELATION BETWEEN THE TWO OUTPUT TUBES IS OBTAINED WHICH WILL RESULT IN PROP

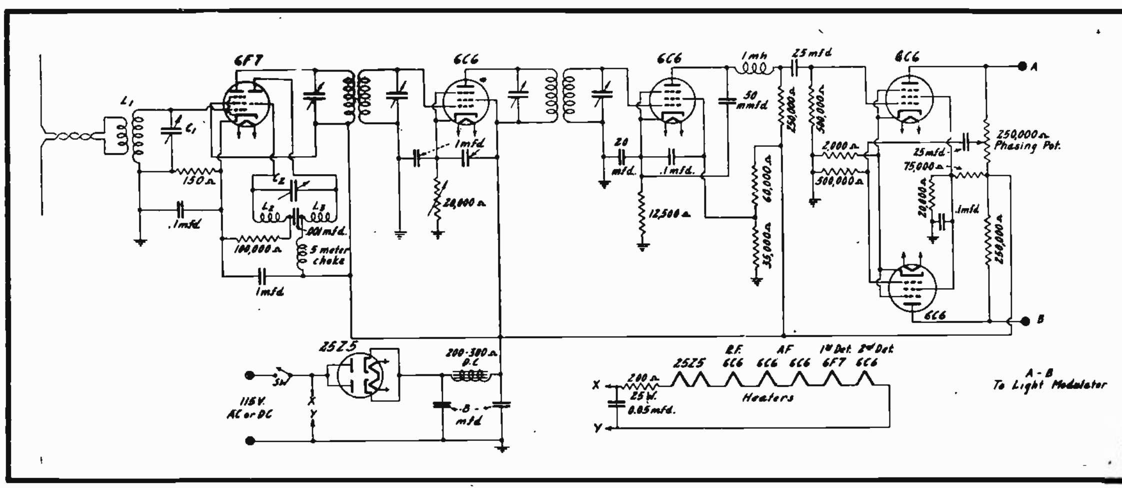


FIG. 9

The A.C.-D.C. Superheterodyne Television Set.

ER PUSH-PULL OPERATION. ANY POTENTIOMETER SETTING TO EITHER SIDE OF THIS POSITION WILL RESULT IN A SHIFTING OF PHASE AND THUS IT CAN BE SEEN THAT THE PURPOSE OF THIS POTENTIOMETER IS TO SUPPLY A MEANS FOR ADJUSTING THE PHASE RELATION BETWEEN THE TWO OUTPUT TUBES.

A 20,000 OHM RHEOSTAT IN THE CATHODE CIRCUIT OF THE FIRST I.F.TUBE SERVES AS THE VOLUME CONTROL. THE PARTICULAR CIRCUIT ILLUSTRATED IN FIG. 9 WAS DESIGNED PRIMARILY FOR THE RECEPTION OF SIGNALS FROM TELEVISION TRANSMITTERS WHICH OPERATE IN THE 5 & 6 METER CHANNEL. SINCE THIS WAVE LENGTH CORRESPONDS TO RATHER HIGH FREQUENCIES WHICH INTRODUCE COMPLICATIONS IN CIRCUIT CONSTRUCTION AND ARRANGEMENT, IT WILL BE WELL TO POINT OUT AT THIS TIME SOME OF THE MORE IMPORTANT POINTS REGARDING THIS MATTER.

ULTRA HIGH-FREQUENCY CIRCUIT

THE TUNED WINDINGS FOR CIRCUITS OPERATING AT THESE VERY HIGH FRE-

QUENCIES GENERALLY CONSIST OF COILS WOUND EITHER WITH LARGE SIZE COPPER WIRE OR WITH COPPER TUBING SIMILAR TO THOSE ALREADY DESCRIBED RELATIVE TO RADIO TRANSMITTERS. IT IS ALSO THE COMMON PRACTICE TO MOUNT THESE COILS ON STAND-OFF INSULATORS SO AS TO REDUCE LOSSES AS MUCH AS POSSIBLE.

AN EXAMPLE OF A COIL FOR THIS PURPOSE IS ILLUSTRATED IN FIG. 10. THIS COIL CONSISTS OF 12 TURNS WOUND WITH #12 B&S SELF-SUPPORTING WIRE AND WRAPPED WITH 1/32" SPACING BETWEEN TURNS TO THE DIMENSIONS DESIGNATED IN FIG. 10. FOR THIS PARTICULAR COIL DESIGN A 10 MMFD. TUNING CONDENSER CAN BE USED TO PERMIT TUNING THE CIRCUIT IN THE 56 MEGACYCLE BAND.

HAVING THUS FAR FAMILIARIZED YOURSELF WITH THE CONSTRUCTIONAL FEATURES OF TELEVISION RECEIVERS, LET US NOW PROCEED WITH THE METHOD OF OPERATING THESE RECEIVERS DURING THE RECEPTION OF TELEVISION PROGRAMS.

OPERATING TELEVISION RECEIVERS

THE LOUD SPEAKER IS A GREAT AID IN TUNING-IN THE TELEVISION SIGNAL, BECAUSE TELEVISION SIGNALS ARE AUDIBLE. IT WOULD BE RATHER DIFFICULT TO LOCATE A TELEVISION STATION ON THE TUNING DIAL OF THE RECEIVER AND AT THE SAME TIME "BRING IN" THE PICTURE WITH THE TELEVISOR (SCANNING AND OPTICAL EQUIPMENT) ON ACCOUNT OF THE NECESSITY OF SYNCHRONIZING THE SCANNER IN ORDER TO SEE A PICTURE. THEREFORE, WE DON'T USE THE TELEVISOR AT ALL WHILE TUNING IN THE STATION BUT INSTEAD, WE CONNECT A LOUD SPEAKER ACROSS THE OUTPUT OF THE TELEVISION RECEIVER.

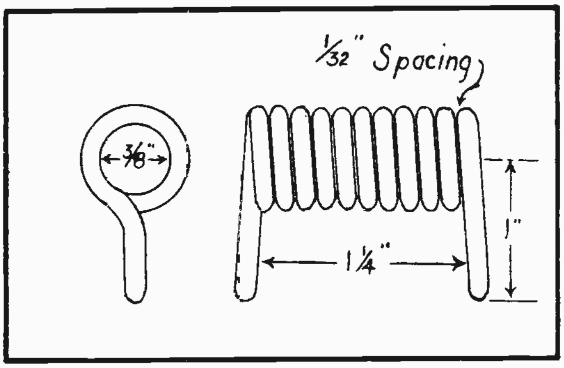


FIG.10
A Typical High Frequency Coil.

BY CONSULTING A LOG BOOK FOR TELEVISION STATIONS, WE CAN JUDGE THE APPROXIMATE SETTING OF THE TUNING CONTROLS IN ORDER TO BRING IN THE DESIRED TRANSMITTER FREQUENCY. SO WE TUNE THE SET SLOWLY AND CAREFULLY UNTIL THE TELEVISION SIGNAL IS HEARD IN THE SPEAKER. THE TELEVISION SIGNAL CAUSES A CHARACTERISTIC SOUND IN THE SPEAKER WHICH SOUNDS SOMEWHAT LIKE A BUZZ-SAW OR A STEADY WHIRRING SOUND.

WITH THE STATION THUS TUNED IN, DISCONNECT THE SPEAKER FROM THE CIRCUIT, AND CONNECT THE NEON LAMP IN ITS PLACE. THIS CHANGEOVER IS MOST EASILY ACCOMPLISHED WITH THE USE OF A SWITCH. AS SOON AS THE TELEVISION LAMP IS CONNECTED IN THE CIRCUIT, START UP THE MOTOR OF THE SCANNER.

AT THIS TIME, ADJUST THE MOTOR CONTROL RHEOSTAT SO THAT THE SCANNING DISC REVOLVES SOMEWHAT FASTER THAN REQUIRED AND GRADUALLY VARY THIS RHEOSTAT SETTING UNTIL THE IMAGE APPEARS. AS SOON AS THE SETTING IS FOUND AT WHICH THE IMAGE TAKES FORM, IMMEDIATELY CONNECT THE PHONIC MOTOR TO THE CIRCUIT, SO THAT SYNCHRONISM OF THE SCANNING DISC WILL BE MAINTAINED.

THE CAUSES AND REMEDY FOR FAULTY PICTURES

WHEN RECEIVING TELEVISION IMAGES, THE PICTURE IS NOT ALWAYS AS GOOD AS IT SHOULD BE AND THE VARIOUS CAUSES FOR SUCH TROUBLES ARE GENERALLY DETERMINED BY THE SYMPTOMS OFFERED BY THE PICTURES THEMSELVES.

FIG.11
Side to side Shifting.

FOR EXAMPLE, IN FIG.11, WE HAVE THE CASE WHERE THE IMAGE IS SHIFTING FROM SIDE TO SIDE. THE CAUSE FOR THIS TROUBLE IS THAT THE RECEIVING AND TRANSMITTING SCANNING DISCS ARE NOT SYNCHRONIZED AND THIS IS A COMMON COMPLAINT IN SUCH SYSTEMS WHERE A PHONIC MOTOR IS NOT EMPLOYED. THE ONLY REMEDY FOR THIS CONDITION IS TO USE A GOOD SELF-SYNCHRONIZING DEVICE SUCH AS THE PHONIC MOTOR. IN CRUDER SYSTEMS, ONE WILL HAVE TO CONTENT HIMSELF WITH "JUGGLING" THE RHEOSTAT CONTROLS OF THE DRIVING MOTOR, IN ORDER TO MAINTAIN SOME ORDER OF SYNCHRONISM.

FIG.12
Out, Horizontally

A COMPLAINT WHICH OCCURS IN MOST PRESENT DAY TELEVISION RECEIVING EQUIPMENT IS SHOWN IN FIG.12. HERE THE PICTURE IS OUT OF FRAME HORIZONTALLY AND THE CAUSE FOR THIS CONDITION IS THAT THE RECEIVER SCANNING DISC IS IN STEP WITH THE TRANSMITTER SCANNER ALRIGHT, BUT THEY ARE SLIGHTLY OUT OF PHASE WITH EACHOTHER. TO REMEDY THIS CONDITION, THE NEON LAMP SHOULD BE MOVED SLIGHTLY AROUND THE PERIPHERY OF THE DISC UNTIL THE IMAGE IS CENTERED.

FIG.13
Out, Vertically

IN FIG.13, YOU WILL SEE AN EXAMPLE OF WHERE THE PICTURE IS OUT OF FRAME VERTICALLY. THE REASON FOR THIS CONDITION IS THAT THE RECEIVING SCANNING MECHANISM IS OUT OF PHASE WITH THE TRANSMITTING SCANNER. IF A SYNCHRONOUS MOTOR OPERATED OFF THE A.C. POWER LINES IS USED, THEN THIS PICTURE CAN BE CENTERED BY CONTINUALLY STOPPING AND STARTING THE MOTOR UNTIL THE PICTURE BECOMES CENTERED.

A REVERSED OR "NEGATIVE IMAGE" IS SHOWN YOU IN FIG.14. THIS TYPE OF PICTURE IS SIMILAR TO THAT OF A NEGATIVE CAMERA PICTURE. THAT IS, THE DARK PORTIONS OF THE IMAGE ARE LIGHT AND VICE VERSA AND THE IMAGE IS LITERALLY REVERSED. THIS TROUBLE ONLY OCCURS WHEN AN EVEN NUMBER OF AUDIO STAGES FOLLOW THE GRID-LEAK TYPE DETECTOR OR AN ODD NUMBER OF AUDIO STAGES FOLLOW A POWER DETECTOR AND CONSEQUENTLY, THE SOLUTION TO THIS PROBLEM IS EITHER TO ADD OR SUBTRACT ONE STAGE OF RESISTANCE-COUPLED AUDIO AMPLIFICATION OR ELSE CHANGE THE TYPE OF DETECTOR.

YOU MIGHT RUN INTO A CONDITION, SUCH AS ILLUSTRATED IN FIG. 15, WHERE THE IMAGE IS INVERTED OR UP SIDE DOWN. THE CAUSE FOR THIS TROUBLE IS THAT THE DISC OR SCANNING MECHANISM IS RUNNING BACKWARDS. THE LOGICAL CORRECTION FOR THIS TROUBLE IS TO CHANGE THE DIRECTION OF THE SCANNING MECHANISM'S ROTATION.

No doubt, the most common complaint of all is pictured for you in Fig. 16. In this case, light splotches are scattered over the image. The cause for this trouble is either static, or noise from the receiver which may be brought about by a bad tube, poor connections, etc. The first thing to do in this case is to determine whether or not the receiver is at fault and if so, to correct the trouble. However, if static is responsible for the trouble, then there is no satisfactory remedy, although it may be reduced by installing static reducing devices in the system.

FIG. 14
Reverse or Negative Image.

FIG. 15
Inverted Image

FIG. 16
Light Splotches over Image.

Sometimes, instead of such irregular splots of light upon the image, you will find cases where regular black lines cross the image horizontally. This may be caused by accumulations of dirt in the holes of the scanning disc or else a hole in the disc may be radially "off-center" due to inaccurate punching. The remedy for the first condition is to clean the scanning holes but to correct the second condition, you will either have to attempt to repunch the faulty hole and dress it with a file, or else an entire new disc will have to be obtained.

If the image is otherwise satisfactory but only dim, then the trouble is either due to insufficient signal strength, too much current thru the television lamp or too much outside light. If due to insufficient signal strength, use a more powerful amplifier. To reduce the current thru the television lamp, when it is connected in series with the output tube, either reduce the plate voltage or the grid bias for the output stage or else add a resistor in the plate circuit. If too much outside light is present, darken the room, use a more efficient shadow box, or both.

Examination Questions

LESSON NO. TEL-3

"Improvement comes with practice."

1. - DRAW A CIRCUIT DIAGRAM OF A T.R.F. TYPE TELEVISION RECEIVER.

2. - DESCRIBE THE MOST OUTSTANDING FEATURES OF THE CIRCUIT WHICH YOU HAVE DRAWN IN ANSWER TO QUESTION #1 AND EXPLAIN IN DETAIL HOW THE TELEVISION SIGNAL IS HANDLED BY THIS SAME CIRCUIT.

3. - WHAT IMPORTANT PRECAUTIONS MUST BE CONSIDERED IN THE DESIGN AND CONSTRUCTION OF A SUPERHETERODYNE RECEIVER SUITABLE FOR TELEVISION RECEPTION?

4. - WHAT EFFECT DOES THE TYPE OF DETECTOR HAVE UPON THE OPERATION OF A TELEVISION RECEIVER?

5. - EXPLAIN HOW YOU WOULD "TUNE-IN" A TELEVISION PICTURE?

6. - WHAT DETERMINES THE NUMBER OF RESISTANCE-CAPACITY COUPLED A.F. STAGES WHICH SHOULD BE USED IN A TELEVISION RECEIVER?

7. - DESCRIBE THE MOST COMMON FAULTS OF TELEVISION PICTURES AND EXPLAIN HOW EACH OF THESE CONDITIONS CAN BE CORRECTED AT THE RECEIVER.

8. - WHAT IS THE REASON FOR USING THE RESISTOR R IN THE CIRCUIT OF FIG.7 IN THIS LESSON?

9. - WHY IS SWITCH S_1 PROVIDED IN THE CIRCUIT WHICH IS ILLUSTRATED IN FIG.5 OF THIS LESSON?

10. - IF THE IMAGE AS PRODUCED AT THE TELEVISION RECEIVER IS SOMEWHAT DIM BUT OTHERWISE SATISFACTORY, THEN HOW MAY THIS CONDITION GENERALLY BE CORRECTED?

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Student Service Department

NATIONAL SCHOOLS

Pioneers of Practical Training Since 1905

4000 S. Figueroa Street, Los Angeles, Calif.

J. A. ROSENKRANZ, Pres.

December 2, 1940

Mr. William Lieske RB-1712
1346 Hoyt St.
Salem, Oregon

Dear Mr. Lieske:

Nearly all commercial all-wave receivers have "dead spots" in the shortwave bands. These points seem to occur in practically the same place on the dial for nearly all makes of receivers. The reason they occur is due to the close coupling between various coils for the other bands and the particular shortwave band which is affected most.

Then again, you may be situated in such a position that the shortwave bands are all attenuated at this certain frequency. That is, your surroundings, the direction of your antenna, and the close proximity of mountains may all contribute to an overall reduction of the signal at this frequency.

Commercial receivers are always tuned for maximum sensitivity on the second shortwave band at about 4000 Kc. This usually leaves the middle portion of the band at a lower sensitivity than the two ends.

There is very littly you can do to correct this condition beyond realigning the r-f shortwave trimmers so that the receivers have maximum sensitivity at a lower point. However, if you do this, you will find that the sensitivity will be corresponding lower at the higher frequencies again. Therefore, it is a better policy to just leave the shortwave bands as they are, unless perhaps the oscillator alignment has been changed.

Very truly yours,

May Day

Technical Division
Consultation Service

MD:AG

In the Spirit of Christmas

December 6, 1940

Dear Friend:

There is no need to remind you that Christmas will soon be here -- and like the rest of us, you are undoubtedly looking forward to the Holidays.

This season of the year, with its good cheer, its happiness and expression of fellow-feeling, offers a welcome relief from the stress of daily life. And this year, more than ever before, we can rejoice that we are living in a land where peace still resides. If all men would TRY earnestly to make the Spirit of Christmas prevail throughout the entire year, we would perhaps not have the turmoil which exists in the world today.

At National, we have, for 36 years, carried the thought of giving into each day's activities. Although you may not realize it, many of the Special Features and extra Services of National Training have been made posssible because of this attitude.

However, at Christmas time, as evidence of our sincere regard for you and your fellow students, we want to do something special. Last year we made a very helpful Christmas offer -- in the form of an unusually liberal Tuition Credit Arrangement. It was so enthusiastically received that we feel we can not do anything more constructive this year than to repeat that Offer. You will find it explained in detail in the enclosed announcement. This is our gift to you -- and I want you to know that it carries with it all the sincerity and good wishes that it would if it were wrapped in tissue paper, tied with colored ribbon, and placed upon your doorstep.

SERVICE to OTHERS, we believe, is an essential ingredient of the success of individuals and of institutions. We have given unstintingly of the best that is in us, of service, help, guidance -- everything that will make life richer, fuller, happier, for the ambitious men who turn to us for assistance. And never will we cease in this effort.

So, as a student of National Schools, soon, we hope, to be a successful graduate, let yourself become imbued with the spirit of your school. Remember, too -- that the more you do to help yourself, the more you will be able to help those near and dear to us.

I send you my Best Wishes for a Joyous Christmas -- but more than anything else, I constantly wish for you a successful career built on SERVICE.

Your friend,

President

JAR:CDO

UNDER THIS SPECIAL CHRISTMAS OFFER, IF YOU MAKE A PAYMENT OF --

$18	YOU RECEIVE CREDIT ON YOUR ACCOUNT FOR	$20
$27	" " " " " " "	$30
$36	" " " " " " "	$40
$45	" " " " " " "	$50
$54	" " " " " " "	$60
$63	" " " " " " "	$70
$72	" " " " " " "	$80
$81	" " " " " " "	$90
$90	" " " " " " "	$100

IF YOUR BALANCE IS OVER $100 -- AND YOU WOULD LIKE TO PAY IT ALL NOW, YOU MAY DEDUCT 12% OF THE TOTAL, AND YOU WILL RECEIVE CREDIT FOR PAYMENT IN FULL.

HERE IS AN UNUSUALLY LIBERAL TUITION CREDIT ALLOWANCE REPRESENTING A WORTHWHILE SAVING FOR YOU

Study the table in the upper right-hand corner. Note the very liberal credit allowances. Do they not represent an exceptionally acceptable opportunity, in keeping with the spirit of Christmas? From past experience, we know that this offer will appeal to the man who is anxious to save every dollar he can.

Of one thing we want to make absolutely certain -- that you DO have an opportunity to share in National's Christmas Offer. Accordingly, we have made the list of credits very complete so that you may take your choice. Naturally, the larger the payment you make, the greater credit you will receive.

IMPORTANT---PLEASE READ CAREFULLY

If you have already sent your payment when you receive this offer, send the difference and you will receive credit. In other words, if you have made a payment of $10, send an additional $8 and you will receive credit for $20 -- and so on down the entire list of credits.

Of course, it is understood that the total amount sent under this Christmas Offer -- unless the amount sent pays your account in full -- can only be applied to your December payment, but the total will be deducted from your present balance.

THIS OFFER EXPIRES DECEMBER 31, 1940

To receive credit, the envelope carrying your remittance must be postmarked on or before midnight December 31, 1940. Don't wait until after Christmas to take advantage of this unusual credit allowance. Be safe -- ACT NOW, WITHOUT DELAY.

Return the coupon below with your remittance. Retain the upper part of this sheet as a record of the credit you will receive.

NATIONAL SCHOOLS
LOS ANGELES, CALIF.

DATE ____________________

THANK YOU FOR YOUR CHRISTMAS OFFER. I CERTAINLY WANT TO TAKE ADVANTAGE OF IT. ENCLOSED IS MY REMITTANCE OF $____, WHICH ENTITLES ME TO A CREDIT OF $____, AS DESCRIBED IN THIS ANNOUNCEMENT.

IF YOU HAVE ALREADY SENT YOUR REGULAR PAYMENT FOR DECEMBER, FILL IN THE SPACE BELOW:

I HAVE ALREADY SENT MY PAYMENT FOR THIS MONTH. ENCLOSED IS THE DIFFERENCE OF $____, WHICH ENTITLES ME TO A TUITION CREDIT OF $____.

NAME ____________________ STUDENT NUMBER ____________

ADDRESS ____________________ CITY ____________ STATE ____________

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LOS ANGELES, CALIFORNIA

Examination Sheet

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PRINT YOUR NAME AND ADDRESS PLAINLY

DATE

LESSON NO.

STUDENT NO.

WHAT OTHER LESSONS HAVE YOU?

ANS. NO. USE THIS SHEET FOR YOUR EXAMINATION ANSWERS ONLY - DO NOT COPY OUT THE QUESTIONS

ANS.NO.

IMPORTANT -- IF NECESSARY, USE ANY SIMILAR PLAIN PAPER TO COMPLETE YOUR ANSWERS.