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E VERY radio man who has had any part in the setting and operating of sound equipment at field-meets, football games and other public events where large crowds are present has been confronted with that ever-present problem of having someone trip over the microphone cable.

The writer has followed the sound business for past fifteen years and personally encountered these cable difficulties. He conceived the idea of eliminating the cable entirely by using a small low power transmitter, powered by batteries, and carried by the announcer. This relays his voice to a special receiver pick-up, located near the public address amplifier.

The output from the receiver is fed into the amplifier and after amplification delivered by the loud-speakers so that all present may hear.

A request was made to the FCC at Washington for permission to carry on some experiments in this field with a transmitter of suitable power, but they immediately turned thumbs down on the request, stating that no such service had ever been authorized.

RADIO STATION W8XWI

A two-year correspondence finally resulted in a hearing and the writer appeared before them with a full description of the new service he desired to establish.

About three months later a construction permit was granted for a small transmitter to operate on 310 megacycles with an output which was not to exceed one watt total.

After construction was complete, a class 21 experimental license was granted and the call letters W8XWI were assigned to the station.

The first transmitter placed in this service was built in pack form and carried on the back of the announcer.

While the operation of this equipment was satisfactory as long as the crowd remained at a distance from the announcer, when they crowded around him the UHF signals were absorbed to such an extent that the loud-speaker volume would fall below suitable levels.

To overcome this difficulty the transmitter was mounted on a tripod and the antenna changed to a fork or end-fire type, which being directional, permitted the beamings of the signals to the receiver.

Another advantage gained by this arrangement was the fact that the antenna was well above the heads of the people and the shifting of the crowd did not affect the signals.

This station with a wave-length of a little less than one meter, operates on what is known as line-of-sight transmission and best results are obtained when the path between the transmitter and receiver is free from obstruction.

The question usually asked is, how far will the signals carry? This can be answered by saying that in ninety-five percent of all occasions where this outfit is used, the distance covered is less than three hundred feet.

In any type of sound service where loud-speakers are located three hundred feet from the microphone, the time required for the sound to travel through the air from the speaker to the mike gives the impression of an echo. This is very annoying to the announcer and for this reason every attempt must be made to keep this distance as short as possible.

On one occasion where the announcer was covering an athletic contest on a recreation field, a clump of bushes stood between him and the radio waves were absorbed or reflected to such an extent that satisfactory operation was impossible. When the antenna was turned in such a way as to direct the waves against the recreation building at an angle, the reflected waves reached the receiver and perfect results were had from the loud-speakers.

On another occasion it was found that the waves when striking a concrete wall at an angle were reflected, but when striking squarely they penetrated the three foot thick wall and operated a public address system inside the building.

The transmitter will deliver about one-half watt when two 958 acorn tubes are used with 135 volts on the plates. With two 955 tubes using 180 volts on plates, an output of about three-quarters watt can be expected.

FREQUENCY STABILITY

This station, small as it is, comes under the regulations of the FCC and must be handled by a licensed commercial phone operator.

The FCC requires some means of frequency control on all transmitters and for those working on frequencies above 300 megacycles probably the best method is the use of tuned lines in both the plate and cathode circuits.

If these are rigidly constructed and well insulated, the frequency will remain constant over long periods of time. Their appearance and relative positions are easily seen in the two photographs.

One precaution must be taken in mounting the porcelain insulators to the aluminum chassis. If these are screwed down tight, the chances are they will crack and the radio tubes will not be held rigid enough to insure frequency stability.

The best way to prevent this, is to cut a piece of felt the shape of the base of the insulator and place it between the insulator and the aluminum chassis before tightening the screws. Any variation in the porcelain caused by temperature changes will be taken up by the felt pad and damage to the insulators avoided. These precautions must be taken, as frequency can be varied...
only too easily at the frequency used.

The chassis is formed from a one-sixteenth inch aluminum sheet by bending it over a wooden block. It measures two inches high, four and one-half inches wide and ten inches long. The circuit is shown in Fig. 1.

The plate tubes are made from hard-drawn copper tubing, sixteen-inch wall and outside diameter, three-eighth inch. They are spaced three-quarters inch between centers and are four inches long.

The plate tuning condenser is the usual two plate type, one of the plates fixed to one of the tubes and the other soldered to a machine screw, which is threaded through the other tube so that the distance between them can be varied by turning. These plates are three-quarters inch in diameter.

The two acorn sockets are mounted at one end of the chassis and each plate tube is connected by a short stout wire to the plate spring on each socket.

The dimensions of this receiver pick-up can be roughly judged by noting the size of the phone plug. There is, however, no crowding, and the efficiency of the receiver is in no way reduced by its extreme compactness.

On the front panel are shown two knobs, the bar knob on left controls the plate voltage on the 955 detector and the knob on right is the timer.

The jack at bottom of panel is for headphones reception when necessary.

The amplifier is shown in Fig. 3 Input may be either from the receiver or a microphone.

While a carbon microphone may be used in some classes of service, where the crowds are large and the noise level high, a good crystal microphone will give far better results.

Unfortunately the output from a good crystal mike is low and it must be built up before it can be fed into the modulator tube.

For this purpose, a two-tube speech amplifier is required and a circuit diagram is shown, also a photograph of the one used in these experiments. A volume control enables the operator to control feed-back when operating at various distances from the loud speakers. As the equipment is used almost entirely out-of-doors, this problem is not nearly as serious as in many P.A. installations, though care must be taken in certain set-ups.

The microphone used in these experiments is the Turner model 22X with tilting head. The tilting head feature makes it perfect for interviewing, as the head can be turned back and both sides of the conversation received.

Originally this was considered as merely an experimental model and a base for further development, but for nearly a year the writer has been instructing in radio and mathematics at the Fifth Command Signal Corps School, in Cincinnati and during this period has had no time to do experimental work of any kind.

However, as the equipment operates very well in its present state of development, this detailed description of same may be of interest.

**Figure 2** - Receiving unit of the relay system.

The far end of the tubes are connected to a heavy copper yoke, supported on a porcelain insulator.

The two grid leads on the acorn sockets are connected together and then grounded to chassis through a 25,000 ohm resistor.

The two plate tubes are made from hard-drawn copper tubing, sixteen-inch wall and outside diameter, three-eighth inch. The diameter is one-and-one-half inches.

The cathode tubes are mounted under the chassis and are identical in size and spacing to the plate tubes with the exception of the length, which is seven inches.

The cathode tuning condenser is constructed the same as the plate condenser but the diameter is one-and-one-half inches.

Between the acorn sockets is a small condenser, useful in tuning the filament when 958 tubes are used.

The two condensers, variable by screwing in and out the threaded rod connected to one plate, make tuning up—which is done in conventional manner—easier. A hairpin loop, Ls, mounted in the plate coil, furnishes coupling to the antenna.

If a carbon microphone is used, one end of the microphone transformer secondary is connected to the grid of the IQSGT tube and the other end is grounded to chassis.

**TWO-TUBE RECEIVER**

The receiver pick-up, removed from its case, is shown in the photograph, also its two cables. Fig. 2 is the schematic of this unit. The one with a four prong plug plugs into the side of the public address amplifier to draw filament and plate current and the other cable with a phone plug feeds the signals into the amplifier input jack. (Cable connections are not shown in the schematic.)

**Figure 3** - Speech amplifier uses high-mu tubes.

**List of Parts Used in Oscillator and Modulator**

- L—Carbide line, 3/8 inch O.D. copper tubing seven inches long
- L—Plate line, 3/8 inch O.D. copper tubing four inches long
- Both cathode and plate lines are spaced 1/4 inch between centers
- L—Copper antenna loop 1 inch wide and 2 inches long
- C—See text
- C—See text
- R—I.R.C. 25,000 ohm, 1 watt resistor
- C—See text
- M—Triplett 0-30 ma. meter
- T—Thordarson small modulation transformer.
- Hammond acorn sockets were used in this oscillator.

**List of Parts Used in Receiver Pick-up**

- ANT—1/4 inch brass roll with sliding sleeve. The length can be varied from 15 to 25 inches
- C1—National type M-30 mica condenser
- R1—I.R.C. 5 megohm 1/2 watt resistor
- C2—Cornell-Dubilier 0.0025 mica condenser
- C3—National type UM, cut down to three plates
- R2—I.R.C. 2500 ohm 1/2 watt resistor
- RFC—15 turns No. 20 DCC copper wire, close wound in one layer and bound with cutoff
- L—No. 6 100/000 ohm wire as shown, 3/4 inch wide and 1/4 inches long
- Thordarson T-13A44 transformer
- C4—Sprague 1/2 mfd. paper condenser
- C5—Sprague .001 mfd. paper condenser
- R2—I.R.C. 2500 ohm 1 watt resistor
- R3—I.R.C. 100,000 ohm 1/2 watt resistor
- R4—I.R.C. 1 megohm 1/2 watt resistor
- R5—Electrolyt 50,000 ohm volume control

**List of Parts Used in Speech Amplifier**

- C1, C2, C3, C4, C5—Sprague .05 paper condensers
- R1—I.R.C. 3 megohm 1/2 watt resistor
- R2—Electrolyt 200,000 ohm volume control
- R3, R6—I.R.C. 1 megohm 1/2 watt resistor
- R4, R7—I.R.C. 100,000 ohm 1/2 watt resistor
- R5—I.R.C. 25,000 ohm 1/2 watt resistor
ELECTRONIC GUITAR

The electronic music enthusiast will find this instrument well worth the time and effort required to build it. The sturdy unit requires less meticulous attention to detail in construction and adjustment than other types which use smaller parts. An amplifier is shown, but any high-fidelity amplifier should work well if carefully built and adjusted.

ELECTRONIC musical instrument amplifiers for electric guitars have been described by the dozen, ranging from high quality down to "junk box" super-duper amplifiers. However they rarely finish the job by giving complete instructions on how to make the guitar, as well as the amplifier. Following are a few constructional suggestions founded on a sad experience of tedious experiments both with the amplifier and the pick-up device, simplification of the latter being the greatest obstacle.

The main objective is, of course, to produce an instrument that really looks and performs like a commercial article. The compromise between portability and power output is always a stickler, but when it's boiled down it will be found that an amplifier of the size shown is quite portable, with no sacrifice of tone or power because of a small junky chassis and speaker.

The guitar itself is made of solid birch or some other hard wood. A soft wood can be used and may be easier to work with but it is impossible to keep the dints out of it. A soft wood also tends to vibrate with the strings, causing extraneous pick-up of objectionable noises. The body is shaped roughly with a band saw and then sanded very smooth using a power sander except in tight corners, of course. If you do not have power tools don't let it bother you, for it is surprising how little it costs to have it done. There are two output plugs on the end of the instrument. The extra one is for use with an extra foot volume control, if desired.

The finish should be a high grade varnish, two coats, rubbed down with rottenstone. If you don't feel capable of the job by all means have it done by a professional, as it is well worth the four dollars which it costs to get the mirror like finish. The fret markings are made carefully at right angles to the centre line of the instrument; the exact measurements of the frets may be copied from an ordinary Hawaiian guitar. Masking or adhesive tape placed 1/16" apart on either side of the fret marking line produces a smooth, straight and well defined line when filled with a quick drying white enamel of fairly thick consistency. The markers for the "main" frets are made so that the tops of the strings are level, especially the third or "A" string, in order to avoid undesirable scraping and buzzing noises while playing. The "nut" at the other extremity should of course be bought with this point in mind. The tail piece to which the strings are anchored is made of a standard one cut down, drilled and bent to fit. The physical contours of the guitar may be altered to suit personal tastes as desired. This has no effect on the tone of the instrument. To complete the guitar a zipper fastened canvas case may be made, not forgetting a side pocket for the connecting cable, plugs, picks and other playing accessories.

THE ELECTRONIC PICK-UP

The pick-up device or unit is the heart of the instrument. It is the most interesting and neglected part in constructional articles. Its operation is based on the theory of magnetic lines of force inducing a current in a conductor moving through the magnetic field. In this case things are reversed; the conductor, which is in this case the coil, remains stationary and the magnetic field moves in accordance with the disturbances caused by the steel strings vibrating in this magnetic field. The strength of the generated signal depends on

(a) Intensity of magnetic flux or field.
(b) Size of wire in coil.
(c) Proximity of the vibrating body, i.e. strings, to the magnetic field. It should be mentioned here that magnetized strings are NOT used.

The pick-up unit proper is constructed from a discarded 5" P.M. speaker having a fairly powerful magnet, usually of the new "Alnico" type and having a U shaped field extension, and not one of the pot shaped types.

Shown in Fig. 1 is a diagram illustrating the relative positions of the pick-up magnet, strings and coil. A polished metal panel is used to cover the opening in the back of the guitar through which the unit is installed. It is easily accessible without removing the strings. Fig. 2 shows the shape of the speaker magnet and the relative position of the coil. The dotted lines show the portion of the speaker frame assembly which should be removed with a hacksaw. Use of a magnet of this shape (cylindrical) provides a particular advantage in that construction of the coil is reduced to simplicity itself.

(Continued on following page)

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Fig. 1.—The unit in its place under the strings.

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Fig. 2.—How a loudspeaker is cut down to make the magnet and coil form for the electronic guitar.
CONSTRUCTING THE COIL

The coil is wound with the finest wire obtainable, No. 44 or better; wire obtained from the old faithful "Ford spark coil" works quite satisfactorily in a pinch. The actual size of the coil will, of course, vary slightly with the actual speaker unit used by the individual. It is a simple cylindrical coil and measures approximately 2000 ohms. It sits over the magnet "M" Fig. 1 and should fill, as completely as possible, the gap between the magnet and the field extensions.

Small angles are soldered to the pole extensions "E" (Fig. 1) so that the whole unit may be securely bolted down with rubber cushioning washers.

In order to bring the magnetic field as close as possible to the strings, an auxiliary extension "X" (Fig. 1) is made. It consists of a rectangular piece of soft iron as highly polished as possible, 2 1/2" x 1/2" x 2". This is cemented in place on top of the magnet proper ("M" Fig. 1) at the point "Y-Y". Its size may vary slightly as it must project through the top of the guitar far enough to come as near as possible to the strings, without touching them, even at their greatest vibration. Thus its size or height must vary according to the height of the bridge used.

The portion marked "A" in Fig. 1, which is the original voice coil extension, is sawed off, so that only about 3/4" of it remains. The top is filed smooth.

A special Alnico horse-shoe shaped magnet with special extensions and small high resistance coils gave no better results than the set-up shown and was much more difficult to construct. Even an ordinary head- phone with no changes made except to install a set of parallel extensions on the pole pieces worked fine.

Fig. 3 is a schematic of the hookup used for volume and tone control. Different tone control circuits may be used with equal results. Low resistance controls are essential to eliminate noise.

On completion the unit shown was given a comparative test by playing records of different artists through the phone input and through a guitar through one of the other inputs. This check of the tone quality as compared to that on different records proved the tone to be identical.

Moving the position of the pickup bodily nearer or farther away from the bridge, thus picking up the sound impulses at different points along the strings, produced no audible effect on the tone.

THE AMPFIFIER AND CASE

The amplifier is a standard set-up incorporating two high gain and one low input. It can be made simpler if desired or more complicated as regards tone circuits, etc. It may even be reduced to one input, and then the amplifier can be made of junk parts. A phase inverter may be preferred. In this rig a power of 12 to 14 watts is obtained in class AB1.

It is important to mount the driver transformer as far as possible from the power transformer to eliminate inductive hum pickup. It will be noted that in the picture they are mounted right next to each other. This resulted in a vicious hum which was eliminated very satisfactorily by turning the transformer for minimum hum pickup. The line bypass condensers were also found necessary in eliminating the last bit of hum and noise.

It will be noted that the tone and gain controls are not mounted on the chassis but on the cabinet. This has worked out very well and also is O.K. from an electrical standpoint. Some musicians prefer the volume control on the instrument for "swell" effects.

The A.C. switch wires and tone control wire were run separately from the other side of the chassis. It is most important that two speakers be used to realize full power and tone. If you don't believe it, at least try it and you'll find yourself using two. I cannot stress too much the importance of making a pictorial diagram, messy as it may be, of where every condenser and resistor goes in order to obtain a neat, trouble-free chassis. It's a lot easier to change a diagram than a 16 gauge chassis!

The case is made of plywood and covered with a good grade leathersette, black, put on with a paper stapling machine. The speakers are mounted on a board 3/4" smaller all around than the inside of the case so as to prevent resonant vibration of the whole box.

Experimenting showed that the manner in which the detailed depth and brilliance of tone are obtained is due almost solely to the musical key in which the selection is rendered. Proper use of the tone control merely serves to modify the effect produced. One trial is all that is required to convince even the most doubtful soul. Most music for this instrument is written in sharp keys for easy playing. When changed to any of the proper flat keys the difference is really startling.

All that is necessary to duplicate professional artists is to use the same key and tuning.

This note on the musical side is just as important as the construction notes for no matter how painstakingly and well the instrument is made it cannot be made to perform as it should unless properly used by the performer.

![Diagram of guitar body and pickup](image-url)
A Magnetic Recorder
Uses Supersonic Method for Wire Recording

A MAGNETIC wire recorder, an electronic machine for recording voice and music on wire about the size of a human hair, is one of the post-war “wonders” that any radio amateur or repairman can build from the spare parts lying around his shop.

The principle involved in wire recording is not new. It was invented in 1898 by Valdemar Poulsen, a Danish scientist, and since then has been improved and simplified. Wire recording has been more extensively used in Europe than in America. The machine can be used for office dictation, making oral notes in a laboratory, recording pilot’s weather observations, as well as home entertainment.

The amplifier used may be any conventional circuit capable of 5 to 10 watts output with a few modifications and the addition of a low frequency oscillator. The oscillator may be on a separate chassis if necessary. The recording head, which is also the reproducer, can be constructed from old radio dial assemblies. These components may be mounted in any number of ways to suit the individual builder.

The wire used for recording must be a steel wire with 5-9 to 12 gauge of one per cent carbon content. I have used piano wire .014 inch in diameter and smaller. The smaller the wire the better the quality.

I made the amplifier first. So from now on I’ll discuss the building of this machine piece by piece. In the bottom of my junk box I found an old radio chassis which measures 10 by 16 by 3 inches. First I built the power supply which consisted of a transformer capable of delivering 120 mls at 350 volts DC. Then I built a conventional line-of-four-tubes amplifier following. The only difference in this amplifier from conventional circuits is the addition of an audio filter inserted between the pre-amplifier and the driver tube. The filter is to attenuate the low frequency signal.

The complete set-up. Stroboscope is permanent part of the apparatus.

This filter consists of a resistance-capacity-inductance network.

The resistor is connected between the second stage coupling condenser and the driver. This consists of two 4,000 ohm resistors in series shunted with an .006 condenser, with a 125 millihenry choke connected from between the 4,000-ohm resistors to ground. Two of these are inserted in series. There is a switch between this control and ground. It is followed by a second identical network. A second coupling condenser isolates the filter from the grid of the following tube. This filter is used only when recording, the switches being opened when playing back. The setting of the controls when recording is found by experiment. If there appears to be too much bass tone in playing back it will be necessary to set the controls for less resistance in the circuit when recording.

The output of the amplifier is fed through a 0.25 mfd. condenser, C14, and a selector switch which connects to a pick-up coil on the oscillator when recording. When playing back the selector switch grounds the oscillator pick-up coil and connects the output to the voice coil of the speaker. For recording the magnetic pick-up is connected across the oscillator pick-up coil to ground. The magnetic recorder head is connected by a selector switch from the output of the amplifier, depending on whether you are recording or reproducing.

The complete circuit appears in Fig. 1.

The oscillator circuit is a conventional Hartley. The oscillator coil is wound on a form 3 inches in diameter and 3/4 inches long. The primary has 260 turns of No. 33 S.S.E. closely wound. I tapped the coil at 45 turns and then at every fifth turn up to 80 turns. The plate supply is fed into one of these taps. I found that my oscillator worked best connected to the third tap. At the terminations of the windings I used some 2-36 screws as terminals. I applied a good liberal coating of coil dope. After this dried I wound the second coil L2, or No. 1 secondary. This is the coil used in the audio circuit in recording. This coil consists of 27 turns which are also brought to two 2-36 screws as terminals. After dipping this winding and allowing it to dry I wound the second secondary, L3, which has 120 turns terminated in the same manner as the previous windings. This secondary is the pick up coil for the erase coil L4. Both secondaries are wound with old No. 32 enamel wire taken from an old speaker field coil. The oscillator is tuned with an .01 mica condenser and should produce a signal between 2'7 and 30 Kc. The action of this supersonic frequency added to the signal current is not well understood.

(Continued on page 32)
WHILE the use of telephone lines for distribution of music is not new, the following article is written to clear up some of the mystery of that type of "Juke Box" where you are asked for the name of your selection and do not have to push a button.

In the first place, the building where the main equipment is located, is known as the Central Office. The place where the "Juke Box" is located is called the Remote Station. As the reader proceeds the use of the above two terms will be used to designate the two locations.

The speech equipment at the Central Office consists of:

1. The metal rack about five feet high, divided into two sections. The entire rack is known as the Board. Each Board consists of ten complete units. Each unit controls a remote station location. Fig. 1 shows a front view of the Board. On top of the Board is a wire rack, into which approximately 1000 phonograph records can be inserted. At the bottom of the Board can be seen another wire rack which holds another 1000 phonograph records. This allows the operator to have any record she may have to use at her finger tips on the instant it is asked for.

Beginning at the left in Fig. 1 are seen two dials set one above the other. Each dial is calibrated left to right from zero to twenty. These are the dials which light up and show the number of coins inserted at the Remote Station. A stepping relay is used to operate a pointer on this dial. Between the two dials and on either side can be seen the coin counting relays that record the number of coins inserted continuously. To the left of each dial can be seen push-buttons which control a buzzer to notify the operator that a coin has been inserted in case the stepping relay fails to operate. To the right is the permanent magnet monitor loud-speaker which is used to check the quality of the program and also can be used to hear what the person at the Remote Location has to say in case the operator's headset fails. Directly underneath is a toggle switch which turns the power on and off for two complete units. To the right and just below the monitor speaker are two push-buttons. The top push-button connects the monitor speaker to the output of the monitor amplifier for the top turntable and the bottom push-button connects it to the monitor amplifier for the bottom turntable. When not in use a dummy five ohm load is cut in across each amplifier output.

There are two phonograph turntables with each section, each one being associated with a Remote Station. These turntables are powered by sturdy, variable speed motors and are equipped with an electric stop. The operator merely puts the record on the turntable platter and moves the pickup arm to the right until a click is heard. By the time she has the pickup on the record the turntable is up to speed. These turntables require very little servicing. They are checked regularly once a week with a neon lamp and a stroboscopic disc for speed. They have no brushes and can be made to operate on 220 volts A.C. by a change in the strapping of the motor windings.

At the right and in the middle of each turntable is a triple pole, double-throw switch. This switch is used to operate a talk-back system to the Remote Station after it has signalled the operator by means of the stepping relay or buzzer. When pulled forward, it connects a two-stage microphone pre-amplifier into the circuit. The amplifier consists of a 6SL7 pentode, capacity-coupled to a 615 triode, with a volume control between the two tubes.

FIG. 1. Front view of typical Central Station panel. FIG. 2. Rear of panel. Letters are explained in text.

FIG. 3. Figs. 3 and 4, right—Front and rear views of the remote station. Some special parts, described in the text, are seen in the rear view.
I recently found it necessary to build my own signal tracer. As is usually the case now-a-days, parts specified were not immediately available. I did, however, have a two-stage TRF midget receiver on hand with a burnt-out 25Z5 rectifier which looked promising. From the demand for 25Z5’s many such receivers must be laying around.

As I wanted more than just a signal tracer I decided to substitute a 60 Ma transformer with an 80 rectifier to provide a small power supply for other testing work I wanted to carry out. The tester as it now stands contains a signal tracer with an R.F. and A.F. pick-up as well as an A.F. output for application to any audio section of a radio under test. It also contains a Volt-Ohmmeter and a condenser tester. Some future day I expect to add a Vacuum Tube Voltmeter.

The tester is housed in a sloping front cabinet made of 1/4-inch plywood, 12 1/2 inches high, 11 inches deep and 9 inches wide. The front straight drop at the bottom is 4 inches. This allows for a sub base with the tracer under it. The front panel is made of tempered masonite 9 x 12 inches.

When the tracer is used as an A.F. generator, a tuned coil and condenser is connected to the grid of the 6K7 by means of a SPDT switch located at the back of the tester, and an aerial is connected to the aerial pin jack in the front of the receiver. The available A.F. signal can be applied to any audio tube grid or plate of the set being tested. If the receiver’s audio section is OK, the signal will appear in the receiver’s loud-speaker. If not, the probe can be moved from tube to tube and the trouble isolated.

THE R.F. TUNER

In order to avoid controls the regular 2-gang timing condenser was removed and an old oscillator padder condenser insert-
THE term "Station riding" was first heard by the writer in San Francisco and was used by radio technicians of the Bay City to describe a type of radio interference very prevalent in that area. Station riding is the type of interference that allows an unwanted signal to "ride" the carrier of a wanted signal. When a signal is tuned in on a radio receiver and station riding is present, two or more signals are heard at the same time. When the receiver is detuned, neither the desired nor the undesired signals are heard. In the case of a broad tuning or non-selective receiver, interfering signals are usually heard between stations. Station riding affects highly selective radio receivers as well as receivers with poor selectivity characteristics.

Among the most serious problems faced by the serviceman are those arising from cross-modulation, an effect produced entirely outside the set itself. A description of this type of interference and some of the means of curing it are given.

Figs. 1 to 4 show causes of station riding and their remedies; 5 to 9 how wave trap circuits may be used. Fig. 9 is a sensitivity control.

(Continued on page 42)
HOW TO TRACK THE SUPERHET

Numerous abandoned sets are now being modernized and put into action, often by “cannibalizing” parts from other radios; TRF’s are being turned into supers; and no few constructors are “rolling their own,” in some cases winding their own coils, in others taking them from old receivers.

Too many of these amateur engineers get unexpected results from their completed jobs. Some of their receivers bring in stations at one end of the dial only, others tune correctly on the high frequencies, while stations are far from their correct markings on the lower ones. The opposite trouble may be found, or all stations may be faint and crowded together in one small section of the dial. The constructors are often sorely puzzled.

The reason for their troubles is that a superheterodyne includes two distinct circuits tuned to different frequencies. These frequencies must be a definite distance apart at all points on the dial. Unless a set is carefully constructed and adjusted, this distance is not maintained—the set does not track—and such stations as are tuned in are the result of accident, when the orbits of the two circuits cross each other or come close enough to permit reception.

Mixers and Mixing

In its simplest form, a super starts out with a mixer tube, which is really two tubes in one envelope. See Fig. 1. One section of this tube (cathode, grid 4 and plate) acts like an ordinary R.F. amplifier. The coil and condenser connected to it are tuned to the frequency of the station received. The other section (grids 1 and 2) acts like a triode, and is connected in an oscillatory circuit tuned to a frequency usually higher by a definite number of kilocycles than the station being received. The screen-grid and plate circuits are shared by both sections of the tube. Consequently two R.F. currents flow in the plate circuit. One of these is at the frequency of the station being received, the other at the frequency of the “local” oscillator. These two are truly mixed in the plate circuit. The main result of the mixing is the appearance of a third frequency, which is equal to the arithmetical difference of the other two, and changes in strength with any variation in either of them. The signal from the oscillator section is fairly constant—that from grid 4 is modulated by the broadcast station, so the difference frequency (or beat frequency) is similarly modulated. An I.F. transformer in the plate circuit is tuned to the frequency of this modulated signal, and rejects or shorts the others.

If the difference frequency is 455 Kc (as on many modern supers) and the I.F. transformers are tuned to that frequency, it is apparent that the oscillator must be tuned to 455 Kc. above the frequency of the station to be received. (It could be 455 below, at the cost of making tracking problems worse.) To receive a station at 600 Kc., the oscillator must be tuned to 1055 to produce the correct “beat” frequency for the sharply-tuned I.F. transformers. If the R.F. section is tuned to 650 Kc., very little of the 600-Kc. signal will get through to the control-grid of the mixer and weak or no reception will result. The R.F. must keep in step with the oscillator, and 455 Kc. below it, all across the dial, for satisfactory reception.

Where the Trouble Lies

These two circuits are usually tuned by one “gang condenser,” so it is necessary that they be designed to “track” closely together. This is not easy. In a TRF set, all stages are tuned to the same frequency at the same time, and the only problem is to make all coils the same size. The two circuits of the super must be tuned to two different frequencies, and the difference between them must remain the same over the whole dial.

The difficulty is illustrated in Fig. 2. Curve A is made with a 365 (maximum) microcuforad variable condenser and a 230 microhenry coil. The frequency is 550 Kc. with the condenser at 365 mmf and 1450 at 50 mmf. The oscillator circuit of the set must be so designed that, at any given setting, the oscillator frequency is 455 Kc. higher than the corresponding resonant frequency of the R.F. circuit.

A capacity-inductance table shows that to tune to 550 plus 455 Kc. with a 365 mmf. condenser requires a coil of 70 mH. (Values are approximate, having been taken with a table and a slide-rule, but are accurate enough for our purposes). When the condenser is turned down to 50 mmf, the resonant frequency of this combination is 2500 Kc., not the 1905 we would like to have (See curve B, made by subtracting 455 Kc. from the curve of the 70 mH-365 mmf combination, to show how close it comes to perfect tracking.) Only one or two stations close to 550 Kc. could be received with such a combination.

The attack might be made from the other end—the high-frequency one. To tune to 1450 Kc. with 50 mmf. capacity requires a 144 mH coil. Curve C—made the same as curve B—shows what would work out. Contrary to popular opinion only high-frequency stations on their radios will see what caused their troubles.

How to Make Circuits Track

The trick is to find some means of making the oscillator tuning curve lie exactly 455 Kc. above that of the R.F. coil-condenser combination. Experience with superheterodynes has already taught us that this can be accomplished by means of semi-variable condensers. An ordinary trimmer would be of little value to us, as can be seen from curve C. To make the oscillator track at 1450 Kc. would require almost exactly 50 mmf. trimmer capacity. Should we add that capacity by screwing down the trimmer on the oscillator section of the condenser gang (supposing we had such a big trimmer) curve B would merely be lowered by 50 mmf. right across the chart. Tuning would be out by 50 mmf. at 550 instead of 1450 Kc.

There is another adjustable condenser on most superheterodynes—the padder. This is in series with the oscillator variable condenser. Fig. 3-a shows the arrangement. It does not always look so simple. The padder on the broadcast band is usually made up of a fixed mica condenser with a trimmer shunting it, and schematics sometimes look like Fig. 3-b. The padder is 1; the oscillator section of the gang, 2; the large trimmer across the padder, 3; and the trimmer on the gang, 4. The circuit is only

(Continued on following page)
that of Fig. 3-a with a trimmer across padd er and another one across tuner.

HOW THE PADD ER WORKS
If two condensers are connected in series their joint capacity is smaller than that of the smaller one. This capacity cannot be arrived at by simple addition, but is expressed by the formula:

$$ C' = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} $$

With this formula we can select a padd er that will make the 144 mH coil and 365 mmf. condenser track at the low-frequency end of the band. According to the coil table, 176 mmf. is needed. Subtracting 1/365 from 1/176

$$ \frac{1}{176} - \frac{1}{365} = \frac{1}{539} $$

gives 1/365 approximately as the reciprocal of the padd er size.

Using a 350 mmf. padd er, we get curve D (Fig. 4), A is our original R.F. tuning curve. Note that the padd er throws tuning off only slightly at the high-frequency end, while it is much larger than the tuning capacity.

This is a great improvement. A set so tuned up would work through signals would be weak in the 650-850 Kc. region. It might be more effective to make the coil a little smaller, so that the two curves would coincide near the middle of the band. The padd er condenser could then be made a little bigger to bring the curves together at some point near 600 Kc. and the padd er could be adjusted to bring them together near 1400.

By varying the size of the coil, the padd er and padd er, it is possible to have the frequencies of the two coils in exactly the right relation at three points—near the top, middle and bottom of the band, and to strav very little at any intermediate point. Fig. 5 is made with a 120 mmf coil and a 390 mmf padd er. The tracking is almost perfect from 600 to 900. From there the two curves spread slowly apart. The padd er can be adjusted at 1400 to bring them exactly together.

Because of the padd er, a change in the trimmer capacity will not throw the tuning out as much at low-frequency points as it would be circuits without a padd er. It requires about 9 mmf. to bring the two curves together at 1400 Kc. At 800, this extra capacity makes a difference of a little less than one-fifth, and its influence rapidly disappears as the condenser is turned still further in.

In actual practice, with two adjustments of trimmer and padd er, the two curves can be kept close together practically from one end of the dial to the other.

THE PRACTICAL METHOD
The foregoing discussion is of little help to the person who has a set which fails to track, except as it acquaints him with the reasons for his difficulties. Fortunately, it is even easier to trim up a set of coils than to read about why they need such trimming.

All that is necessary is to free from the calibrated tuning dial all circuits but the one you are interested in at the moment. Each circuit is thus adjusted independently of the others.

The first step is to be sure that the I.F. is correct. This requires alignment with a good signal generator. (If you have none, have a service man do it. The signal generator is also useful in adjusting the coils, but not absolutely necessary, if you can identify a number of stations in different parts of the band. All that is needed is a variable condenser of capacity approximating that of one of the sections of the gang in the set.

Mount the new condenser firmly on some part of the chassis, or if impractical, make a good connection from its frame to the chassis and put it as close to the set as convenient. Then move the coil and grid connections from the stator of the R.F. section of the gang to the new "independent variable." Now the oscillator and the oscillator alone is tuned by the calibrated dial on the set.

Set the dial at 1400 or thereabouts, and rotate the independent condenser. If the oscillator is tuned to a station it will be picked up at some position of the R.F. tuning condenser. If not, move the dial a degree or two and try again till one is tuned in. Identify the station and check its dial marking. If it is too high or low, the oscillator may be the right size. If so, bring the dial to the correct point with the padd er, then turn to a station near 600 Kc. and adjust again, as in ordinary set alignment.

ADJUSTING THE OSCILLATOR
If the oscillator coil is too large, stations will tune in at much too high a figure on the dial—if too small, at too low a figure. Should the coil appear too large or small, it is a good idea to screw the padd er down pretty well, tune in a station between 800 and 1000 Kc., and add or take off turns till the dial reads correctly. Then tune in a station near 1400 and adjust the padd er till the dial is correct. Afterward tuning in a station near 600 Kc. and adjusting the padd er till the dial is also correct on it. Tune over the dial again, retun and repad, possibly adding or taking off another turn or two for uniform tracking. Check again to see that all stations come in on the right dial setting.

To adjust the R.F. section, move the leads from the stator of the oscillator section of the gang to the independent condenser and put the R.F. leads back in their place. You will see now why the curves do not have to lie exactly on top of each other. The R.F. section times rather broadly. Tuning it a degree or so off maximum signal makes little difference in the strength.

Bring in the station near 1400 with the independent condenser and note whether the R.F. circuit is nearly correct or not. If it is reasonably close, adjust to the exact point with the padd er and move up to the station near 600. If it is not lowest at its proper dial setting, add or take off turns till it also times in at exactly the right place. Correcting the R.F. section is easy compared to getting the oscillator lined up.

Bad tracking may occur because of wrong-size padding condensers rather than coils. If the padd er is too large, stations will be crowded and displaced toward the high-frequency end of the dial, only those near that end being tuned in near their correct dial markings. If too small, the displacement is in the other direction, and stations are spread apart. A larger or smaller padd er condenser is the remedy, of course.

Once the reasons for its action are understood a rebuilt super is not hard to adjust. If you follow the above method you can even wind your own coils with a fair chance of success.

New Idea In Detector Circuits
HERE is a receiver that brings in all kinds of distant with plenty of volume using but two tubes. Constructed from easily obtainable parts, I have received consistently stations within 100 miles by day and stations in Salt Lake, Denver, Portland, etc., by night, with unbelievable volume, and sharp tuning. I use a 12 ft. indoor antenna.

The idea for this set was suggested by a patent which I bought a while back. The patent describes a new way of using a pondete tube. This showed a circuit in which the suppressor of an ordinary vacuum tube acted as a diode detector, while the tube itself acted as an R.F. amplifier. The second tube acts as A.F. amplifier and power rectifier. I find it advisable to use a padd er in the plate tuning circuit.

Because of the multiple action of the first tube, this set is really hot!
This electronic metronome will be found very handy for all students of music, especially now when it is almost impossible to buy an ordinary metronome. It works on the principle of the multivibrator, in that it distorts the wave shape to produce a multitude of harmonics.

A multivibrator is essentially a two-stage resistance-coupled audio amplifier with the second stage coupled back to the first. By varying the size of the coupling circuit on Amscr and grid resistors, oscillations—varying in frequency from the supersonic range to one or so per minute—can be produced. This instrument is so constructed that two frequency ranges are available, one in the range required for a metronome; the other suitable for a code practice oscillator.

The principle may be easily understood from Fig. 1. On the metronome range, audio output from the 6J7 is fed to the 6C5 grid. The 6C5 output is fed through a 0.5 mfd. coupling condenser back to the 6J7 grid through a condenser of equal size. Variable 3-megohm grid resistors are provided. The frequency depends on the natural discharge rate of the resistor-condenser combinations, and if necessary can be calculated by the formula: 1/(RgC + R'gC') cycles per second. Rg, C, and R'g and C' are the blocking condensers and grid resistors of the first and second tubes respectively.

The 6J7 is connected also as an ordinary grid-tickler type radio-frequency oscillator, with one exception. The lower end of the grid coil returns to ground through a high resistance. When, as part of the multivibrator, the 6J7 is conducting, it oscillates at a broadcast frequency, determined by Ls and C. Pulses of R.F. are thus sent out at the multivibrator frequency.

The coil Ls, L1, is an ordinary broadcast antenna coil; the low-impedance aerial winding is Ls, the grid-tickler winding. If this type of coil is unobtainable, you can wind your own, on a coil form 1½ inches in diameter. Wind 90 to 110 turns of No. 28 wire on this. The grid-tickler is composed of fifteen to twenty turns of No. 30 or 32 wire. This should function satisfactorily with the two trimmer condensers in parallel, which serve as the tuning condenser, C1, for the R.F. oscillator. No antenna is necessary, as there is sufficient radiation from this coil.

The multi-vibrator frequency range is much greater than can be obtained with a metronome. With the values shown in the schematic (Fig. 2) it is possible to obtain a beat as slow as twenty per minute. By switching in the .01 condensers, the complete audio spectrum can be covered.

When the .01 condensers are thrown in the circuit, you have a code practice oscillator that is different. A key can be inserted between the cathode and ground, and any desired tone can be obtained by varying the 3-megohm potentiomenter.

Any suitable type tubes can be used in place of the 6J7 and 6C5. A 6A7 would be particularly suitable, as you can use the plate and the No. 4 grid as the R.F. oscillator and the No. 1 grid for the multivibrator control. A type 76 works very nicely in conjunction with a 6A7.

Operation of the metronome is simple. Just turn it on, tune it on your radio like a wireless phono oscillator, adjust it to the desired beat, and your radio will click out the rhythm while you proceed with your musical practice. One precaution: Be sure that you are not radiating such a strong signal that you are creating interference. The F.C.C. has established a definite ruling on that matter. There must be absolutely no interference with other radio reception. This is absolute. Should a neighbor in an adjoining apartment—say 30 feet away—hear your metronome or code oscillator while listening to a local station, your machine is clearly illegal.

A simple formula for determining if your "transmitter" is illegal or not is: 157,000 ft. frequency (Kc.)

For example: if a device is operating at 550 Kc., the permissible range is 157,000/550 or approximately 285 feet.

The metronome is adjustable for wide frequency variations.
This amplifier was originally designed and built a couple of years ago, partly to maintain the writer's reputation and show up some of the very inferior jobs used in dance-bands, etc., and show how much power could be got from how small an amplifier.

The tube line-up is: 6SC7 as first voltage amplifier for both crystal microphone and needle-armature hi-fi pick-up, 6567 as driver and phase inverter, a pair of 6N6G's in class AB1 and a 5V4G rectifier.

Alternative tubes are a pair of 6075 followed by a pair of 6BS's with an 83V rectifier. For those tubes the circuit constants as shown in the schematic diagram need not be changed. For the output stage, a pair of 6L6G's can be used in class AB1, with the load reduced from 10,000 ohms to 9000 and the bias resistor increased to 325 ohms. In addition, a 300 ohm resistor of 5-watt rating must be connected in series in the high voltage supply. However, the 6N6G or 6BS tubes should be used if possible as these give superior tonal quality besides being very noncritical as regards gain (100% rise in load impedance causes less than 5% rise in power output).

The power supply is very economical indeed, as the transformer has a rating of only 100 Ma. This is quite enough as the total no-signal drain is only 92 Ma. for the whole amplifier and the average drains on speech and music are only 95 and 98 Ma. respectively, although peak drains of about 110 Ma. may be encountered for periods of about a tenth of a second.

**PHASE INVERTER**

The phase inverter uses the floating paraphase system, giving an automatic near-balance, the "second" output tube responding slightly less drive than the first. Inverse feedback is applied from the primary of the output transformer to the plate of the driver (first section of the second 6SC7). This feedback gives a reduction in distortion, a reduction in hum and also a reduction in the imbalance of the output tubes. The reduction in imbalance occurs in two ways—first the general negative feedback action reducing the drive more in one direction than the other, secondly the bias resistor of the phase inverter is not by-passed so that the first section (working at a higher level than the other, because of the feedback gain reduction) drives the second section, thereby increasing its output.

Between the phono pick-up input and the grid of the first 6SC7 is a resistance capacity network giving a bass boost of approximately 8 db at 100 cycles and 13 db at 50 cycles to compensate for the attenuation of bass in the ordinary lateral recording. The network has an impedance of approximately 3000 ohms at mid-frequencies, that being the load required for the pick-up employed. Should an ordinary crystal pick-up be employed, the load in the network must be shortened and each resistance increased in value 20 times. For an ordinary magnetic pick-up, the network can be left as it is for a pronounced bass, or the large condenser can be bridged by a 3000 ohm resistor for a more normal approach to bass reproduction.

**THE TONE CONTROL**

In order that worn records may not sound too bad and to eliminate some of the harshness from overpowering vocalists who hug the microphone, a simple high-frequency peaks—generally the freer the suspension and the lower the resonant frequency, the more liable is the diaphragm excursion to be excessive.

**ECONOMY 20-WATTER**

High fidelity and plenty of output with a minimum of tubes and components are obtainable with this circuit, which increases its output by using direct-coupled dual amplifier tubes.

It may be wondered why electronic mixing is not used as there is a triode section for each input. This would mean, however, the placing of each volume control right at the input—a quite sound arrangement only if each control is quite free from noise and can be completely shielded. The writer has found in practice that the conventional parallel mixer circuit shown is much better. Theoretically the movement of the microphone volume control should slightly change the volume from the pick-up and vice versa, but in practice the change is negligible, and is reduced still further in this amplifier by the tone-compensation resistors connected between the moving contact and grounded end of each volume control. These resistors reduce the bass response at full output to make up for the ear being relatively more sensitive to the lower frequencies at high volume levels and to prevent overload of the speaker. It is not commonly realized that the power handling capacity of a speaker is restricted in the low frequency region. A speaker capable of handling 30 watts at 400 cycles may be able to handle only 5 watts at 30 cycles, providing it has the same efficiency at the lower frequency. Nothing is more distasteful than the banging of a speaker diaphragm on the low-frequency peaks—generally the freer the suspension and the lower the resonant frequency, the more liable is the diaphragm excursion to be excessive.

The 6N6 output stage is actually two cascaded stages. A self-balancing inverter is employed.
THE condenser quality tester described in this article is the result of considerable experiment and design and it has the following advantages: (1) Checks the quality of the condenser while connected in the circuit. (2) Positive indication with no charts or figuring. (3) Ease of operation using ordinary test prods, no shielded wires or awkward terminal connections. (4) Provision to test resistance or voltage across the condenser, simultaneously with the quality test. (5) A locking circuit which could be used in cases where the tester had to remain across a suspected condenser for a period of time and would give a positive indication without the necessity of the operator constantly watching the indicator. (6) Low cost, easy construction and economical operation.

CHOICE OF CIRCUIT

The circuit decided upon consists of a 76 oscillator, link coupled to a tuned circuit, both operating at eighteen hundred kilocycles. The link circuit is broken on one side and brought out to pin tip jacks. The tuned circuit is connected to a 6B7 pentode section. The output of the pentode section is rectified in the diode section and the negative potential developed is applied to the grid of a 6E5 tuning indicator tube.

Since the link circuit is carrying radio frequency at low potential, any resistance or reactance in series with it will lower the energy transfer from the oscillator to the tuned circuit. The frequency chosen, 1800 kilocycles, will encounter a reactance of approximately 10 ohms when applied in series with a .01 mfd. condenser. Most condensers used in radios and associated circuits have capacities greater than this. It follows that their reactance will be less. Since the values of resistances used in radios are generally 200 ohms or greater, if a .01 mfd. condenser is placed across a 200 ohm resistor and this combination tested by this instrument, taking the energy transfer to represent 100 per cent, it will be found that 95 per cent passes through the condenser and only five per cent through the resistor. Therefore if the condenser should open circuit there will be a loss of 95 per cent of the energy transfer in the link circuit.

In a case where the resistance is developed internally in the condenser (contact resistance as it is generally called) the energy transference loss will be governed by the voltage drop across this resistance. It can readily be seen that the resistance or reactance connected across the condenser is so much higher than the reactance of the condenser itself, that it may for all practical purposes be disregarded. Any internal resistance or contact resistance in the condenser itself will reduce the energy transfer in direct proportion to the amount of resistance developed.

The locking part of the circuit is as follows. The negative bias used to close the 6E5 tube's shadow is also applied to the grid of a 6F5 used as the locking tube. Its plate is connected through a toggle switch to one side of the secondary of a three to one ratio, audio transformer. The primary of the transformer is connected to the A.C. line connections across the regular power transformer. The ground return of the secondary goes through a 500,000 ohm resistor.

It takes approximately eight volts negative bias to completely close the shadow on the 6E5 magic eye tube and this same voltage is applied to the grid of the 6F5. Due to the tube's high mutual conductance it is biased to plate current cutoff. However, if there is any failure of the energy transfer link circuit caused by the condenser under test opening or the circuit being opened in any way, there is no longer any radio frequency flowing through the circuit. The result is with no radio frequency to amplify and rectify in the tuned circuit, the grid bias falls to zero potential on both the indicator and locking tube grids, the indicator tube's shadow opens wide and the locking tube passes plate current the negative component of which is applied to the grid of the 6B7 pentode section stopping it from amplifying any further even if the energy transfer link circuit should be closed again. Therefore the indicator tube's shadow remains locked open until the switch in the plate circuit of the 6B7 tube is opened, allowing the other circuits to operate normally again.

CONSTRUCTING THE CHECKER

A chassis nine by twelve inches was used. A panel twelve by eight inches is mounted on one side with the indicator tube located in the upper center, the gain control and

(Continued on page 34)
Matching Loudspeakers
How to Attach Unlike Speakers to One Output Transformer

The technique of speaker matching is well understood by every radiofan—up to a certain point. When two speakers were of unequal impedance, they were to be matched to the same amplifier, this understanding is not so general. And if the speakers are of unequal wattage rating as well as voice-coil impedance—each to receive its correct proportion of the total power—few radio servicemen indeed can toss off an answer to the problem. More than one compromise installation is the result of their inability to do so.

As a simple example: We need to connect a pair of 5-watt speakers with 16-ohm voice coils and one 20-watt speaker with an 8-ohm voice coil to a 30-watt amplifier. How are we going to hook up the speakers so that the power will be properly distributed? Remember that the speakers have to be connected across the two separate windings of a universal output transformer, and the speaker load must be properly matched to what required by the tubes.

The problem is not too difficult. One of the reasons so many radioamateurs are stumped is that they have learned too much about matching. They cannot imagine attaching an 8-ohm voice coil to anything but an 8-ohm tap. If it becomes necessary to hook a monitoring speaker across the 500-ohm line, they do it with dark forebodings as though something awful might happen at the other end. It is necessary to forget all that. If we are going to connect several speakers to the same winding, obviously we cannot proceed as if we had only one, and that means we cannot “match” tap and speaker ohm and ohm.

TRANSFORMER CALCULATIONS

The chief reason for an output transformer is to match the impedance of the output tubes’ plate circuit (usually between 2,000 and 10,000 ohms) to that of the speakers’ voice coils (commonly between 2 and 16 ohms). If the voice-coil impedance is 6 ohms and that required by the output plate circuit for a certain transformer is 6,000 ohms, the impedance ratio is 1,000 to 1. The voltage ratio is the square root of the impedance ratio, or in mathematical terms:

\[ \frac{E_1}{E_2} = \sqrt{Z_1/Z_2} \]

Our specimen transformer then has a voltage step-down of \( \sqrt{1000} \), or about 31.5. It is likely to have about 2,000 to 3,000 turns of wire on its primary and from 60 to 90 turns on its secondary.

The impedances of a universal output transformer are usually marked, but the turns or voltage ratios are not. Our only interest in these voltage ratios is that they help us to understand some of the electrical actions of the transformer, and thereby to figure out which of the secondary terminals we have to attach our speakers to.

To get the underlying principles straight, let us try the simplest possible hookup (Fig. 1). 30 watts are being fed into one 8-ohm speaker. Voltage across the 8-ohm voice coil is 15.5 volts. The primary voltage is 125 volts, 425 volts approximately. This can be checked by calculating direct from the primary watts (30 = \( E_1^2 / R_1 \))

Now we can try a hookup like that of Fig. 2, which has two secondaries. We connect the two 16-ohm speakers in parallel, making an 8-ohm unit to place across one secondary. The 20-watt speaker, also an 8-ohm unit, goes across the other. What should be the impedance of the primaries?

First, 10 watts must be fed to the two speaker units. Using our formula, 10 = \( E_1^2 / 8 \)

or 80 = \( E_1^2 \), the voltage across the voice coil works out to slightly less than 9. To get the voltage ratio, we divide 425 by 9, which is 47.2. Since \( Z_1/Z_2 = (E_1/E_2)^2 \), we square 47.2, giving us 2,228. The impedance reflected on the secondary of a universal output transformer, and the speaker load must be properly matched to what required by the tubes.

The single speaker is to draw 20 watts. The same calculation makes the voltage \( E_2 \) about 15.5 volts. (20 = \( E_2^2 / 8 \) or 160 = \( E_2^2 \)).

Dividing that into 425, the turns (voltage) ratio is near 33.6. Squaring this, we get 1,128. The impedance of the secondary coil is 6,000/1128, or roughly 5.32 ohms.

Since the secondary impedances are effective in parallel, two separate windings are unnecessary. It is easier to hook each speaker to the proper impedance tap on a universal transformer, as in Fig. 3. This is what is done in actual practice.

THE REFLECTED IMPEDANCE

Now, are these impedances correct? On the surface, it would not seem so. One 8-ohm winding is attached to a tap whose impedance is slightly less than 3 ohms—the other to one of a little over 5 ohms impedance. Let us see if anything like 6,000 ohms is reflected back into the primary. If so, the speakers are matched to the output tubes. The impedance reflected into any primary winding is due to the resistance of the secondary load and the transformer ratio. An 8-ohm load across an 8-ohm tap reflects the rated impedance (6,000 ohms in the case of our transformer) back into the primary. Placing the same load across the other 8/5.32 x 6,000 = 9,060 ohms. Add-

flect 8/2.68 x 6,000 = 17,900 ohms and the other 8/4 the normal impedance.

One of our windings will therefore reflect 8/2.68 x 6,000 = 17,900 ohms and the other 8/5.32 x 6,000 = 9,060 ohms. Adding the two parallel impedances, we get 1/17,900 + 1/9,060 = 1/6,000. The impedance reflected into the primary is 6,000 ohms. The speakers are effectively matched to the amplifier.

In many cases the required impedance taps are not found on the output transformer. Connect the proper tap, checking the effect on power distribution and so averaging the mismatch of individual taps that the total reflected impedance will be as nearly correct as possible. If it is necessary to err in either direction, con-

nection should be made to taps of slightly lower than correct impedance. Thus the reflected impedance will be a little high. This will merely reduce the power slightly.
MEASUREMENT
OF CAPACITY

UNTIL very recently the subject of capacitance measurement has been rather neglected in radio publications, condenser testers usually taking the form of leakage or short indicators only. With commercial apparatus capable of measuring capacitance off the civilian market for some time, technical information on this subject is important to the serviceman and technician.

This article is concerned with methods whereby capacitance may be indicated on an A.C. or D.C. milliammeter or A.C. voltmeter. Either the meter face may be directly calibrated or the indication may be used with a prepared chart. Properly designed meters of the types to be discussed may be relied upon to within 2% accuracy, and the measurement may be quickly made so that a good deal of time is saved. Three general methods will be described, each requiring a different type of meter generally available to the radio man.

THE BALLISTIC METHOD

This method is often used in the laboratory for measurement of capacitance of transmission lines. Fig. 1 shows the set-up. First we charge the unknown condenser to a definite voltage E (direct current) which may be of any value less than the breakdown voltage of the condenser. If we use the maximum voltage permissible with the given condenser we automatically check for breakdown also.

After a second or so, the switch is thrown to “discharge,” and the total quantity of electricity on the plates now passes through the D.C. microammeter (or milliammeter). The meter kicks upwards to some value and then returns to zero. This method is often used with a “ballistic” or weighted movement type of meter. Strictly speaking, only the ballistic type will actually measure the total quantity of electricity in the condenser, because the total effect of every electron passing through has a bearing on the final indication.

In other words, the condenser is fully discharged before the maximum swing is reached. This type of measurement can, however, be used very successfully with an ordinary D.C. microammeter or milliammeter. A low leakage toggle switch (possibly the spring-action type which snaps up when released) can be used to good advantage here.

The accompanying table (Fig. 2) shows what to expect from this method. An ordinary Triplett type microammeter (with proper shunts) was used in obtaining these results. Note that larger deflections are obtained when using higher capacitances or higher voltages. Note especially the excellent LINEARITY which may be obtained with different voltages. This means that only a few values need be calibrated, and all others obtained by drawing a chart on linear squared paper. The graph will be a STRAIGHT LINE, so that it is possible to use whatever source of direct current is available.

While this linearity results with a change of voltage, note that a change of capacitance is not quite linear, although very nearly so. With a sensitive microammeter, a condenser of .005 mf. may be measured conveniently with a voltage of about 90. High capacitance condensers offer no problem and may be accurately indicated with very low voltages as shown. This is especially interesting in the case of low-voltage high-capacitance electrolytic filters upon which only a few volts may safely be impressed.

Since the condenser charges to the open-circuit voltage of the applied source within a short time, a new battery does not have to be used, nor is a voltmeter an absolute necessity, unless the highest order of precision is required.

Due to the fact that one quick swing of the pointer takes place, after which it settles back to zero, it is essential that the maximum indication be accurately noted when high precision is needed. For this purpose an optical shield may be used. This merely consists of a card with the maximum indication printed or marked on it. It may be pointed out here that the ballistic method is based upon the formula: Q = C X E, where the units are coulombs, farads, volts. A properly-designed “ballistic” meter reads in terms of coulombs or milli-coulombs and would therefore be linear throughout the range.

This type of measurement actually indicates several characteristics of the condenser under test: capacitance, by maxi-

<table>
<thead>
<tr>
<th>Cap.</th>
<th>Voltage</th>
<th>Microamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 mfd.</td>
<td>1.5</td>
<td>300</td>
</tr>
<tr>
<td>3.0</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>30 mfd.</td>
<td>1.5</td>
<td>520</td>
</tr>
<tr>
<td>3.0</td>
<td>1040</td>
<td></td>
</tr>
<tr>
<td>1 mfd.</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>3.0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>.1 mfd.</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>135</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>.05 mfd.</td>
<td>90</td>
<td>29</td>
</tr>
<tr>
<td>135</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2—Table of currents for a given meter.
mum swing; breakdown, by no reading (with no danger to the meter itself); leakage, by a much lower reading when the condenser is left to stand for a short while between “charge” and “discharge.”

By observing polarity, electrolytics may conveniently be measured in this manner.

A.C. MILLIAMMETER METHOD

The circuit is shown in Fig. 4. The unknown condenser is connected in series with the meter and a known source of alternating current, for instance the line. It is wise to fuse the circuit. Lower readings correspond to lower capacitances. The face of the meter may be calibrated in capacitance units for direct reading or reference may be made to a chart as in Fig. 5.

The chart shown is applicable to 115 volts, 60 cycles. (For any other frequency—such as 50 cycles—we may read off the chart as before and multiply the result by 115/110 = 1.045 for the factor to be used). Other voltages of the same frequency give proportionate indications. For example, 115 volts, 60 cycles, would give a reading only 1/10th as large as would 110 volts, for the same condenser.

This method is based upon the fact that the capacitive reactance of a condenser is

\[ X = \frac{2\pi f C}{E} \]

given by \( X = \frac{106}{C} \) (in microfarads), and that \( I = \frac{E}{X} \), disregarding fuse and meter resistances. This gives \( I = \frac{E}{377} \) C (in milliamperes) when \( E = 115 \) volts. 

This may be simplified to \( C \approx \frac{4336}{I} \) (in \( \mu F \)).

A.C. VOLTMETER METHOD

This method is illustrated in Fig. 6. It requires no fusing, since the voltmeter is first adjusted so that it reads full-scale when the terminals are shorted. Short-circuiting the circuit is then equivalent to infinite capacitance. As in the two previous methods, larger capacitances show greater deflections of the meter used as an indicator.

Another typical capacitance-measuring meter is the Weston 664, circuit of which is shown in Fig. 7. This is a more elaborate unit, having four ranges for capacitance “\( \times 100 \)”, “\( \times 10 \)”, “\( \times 1 \)”, “\( \times 0.1 \)” (besides other ranges for A.C. volts). The face is calibrated from 0 to 20 mfd., so that readings may be obtained from .001 to 200 mfd.

The basic A.C. meter used in the Weston 664 has a full scale of 3/4 ma. The multiplying ranges are obtained by suitably shunting the meter so that it reads higher values at the higher ranges. At “\( \times 10 \)” the meter reads 100 ma. full scale. For the higher reading scales the impressed voltage is reduced. For the lowest scale it is almost 100 volts, while for the highest it is but 4 volts, a small transformer being used for the stepdown. Isolation of the line voltage is used on all ranges and is a desirable feature.

Assuming that we now have an A.C. voltmeter arranged to read full-scale with no condenser in series with it (Fig. 6), let us discuss means for designing multiplying factors. For convenience, these factors may be 10, 100, etc.

Looking at Fig. 8-a, we may note that a definite reading will be obtained when the unknown \( C \) is placed in series with the voltmeter. Now we shunt the meter itself with \( R \), equal to \( 1/9 \) of the meter resistance and add a series resistor \( R \), sufficient to cause the meter to read full-scale when \( XX \) is shorted. The scale is now a \( \times 10 \) scale, all indications being ten times as large as previously. Notice that ten times the current is now flowing in the circuit.

Another multiplying method involves a decrease in the voltage source (Fig. 8-c and 8-d). To multiply all indications by 10 it is necessary to reduce the voltage source to one-tenth. The series resistor \( R \) is then reduced until we again obtain full-scale reading when \( XX \) is shorted. In both methods the multiplying range shows a total circuit resistance one-tenth the original range.

Instruments for all the above measuring methods are easily set up and require only a meter of a type usually available. The would-be constructor can adapt any one of several types to one or another of the circuits given above. Only a little ingenuity is required to construct a combination instrument capable of measuring capacitances over an extended range, and such instruments can be built up with either an A.C. or D.C. foundation meter.
FIXED-BIAS AMPLIFIERS

More output with smaller tubes results from the proper use of fixed bias.

HOW many experimenters, like the author, have looked at a small commercial radio filling a large room with crystal-clear volume and have thought it would be nice to have an amplifier of such small size that would give such high undistorted output. Perhaps you have looked in the back of the set and been amazed to find a single pentode or tetrode such as the 6F6 or 6V6 responsible for all the volume. You have taken down the number of the tube and gone home and immediately built up a little class A1 job, thinking that the use of that tube would cure all amplifier problems. And you have been cruelly disappointed. All voltages, resistances, and loads test exactly as they should to conform to the ratings given in the tube manual for that tube, and yet at a very low level compared to the level of the commercial set, terrific distortion sets in. If you have put away an attempt like this as a failure, get it out again, for there's fun ahead.

It's ten to one that you used something like the circuit of Fig. 1 when you decided to build a phono amplifier with that magic tube with which to amaze your friends. This is the typical circuit we all know well. You looked up the correct ratings for the tube, used mathematics correctly to determine the resistance values, and bought the right output transformer. Why does the set not work or so much less well than the commercial amplifier? One of the answers is, it uses self-bias, while the commercial probably has some form of fixed bias.

FIXED BIAS IS FEASIBLE

Let us see exactly what we are up against.

In the first place, the ordinary cathode-biased class A1 stage proves to be highly inefficient and low in fidelity for two main reasons: (1) the bias voltage, which should be very stable, is varied by being developed by a varying current, i.e., the plate and screen current of the tube, and, (2) since the effective plate voltage on a tube is measured between plate and cathode, raising the cathode to a positive potential, as is done with cathode-biasing, reduces the effective plate voltage on the tube by the amount of the bias voltage. This last disadvantage becomes important in A.C.-D.C. sets, where plate-voltage is low, and in sets using power triodes, such as the 2A3, where the required bias is very high.

As to the first trouble, stability (i.e., voltage regulation) of the bias voltage is of utmost importance, and, for good efficiency, a 10% variation should never be exceeded. Looking at the cathode-biased stage, we see that such regulation is impossible. Some experimenters connect hundreds of microfarads across the cathode, and this no doubt helps, but it cannot eliminate the fact that the bias voltage developed by this method is to some extent dependent on the varying conditions inside the tube, no matter how big a condenser is used. Besides, why waste money buying such huge capacities?

Our primary aim, then, is to make the bias voltage completely independent of the tube to be biased. To get true fixed bias we must begin by grounding the cathode and look elsewhere for a negative voltage which we may apply at the low end of the grid return. Here we see that the class A1 amplifier presents a much simpler problem than the class A3B2, chief figure in the nightmare aroused in most experimenters' minds by the mention of fixed bias. First, the class A1 amplifier never draws grid current. This is our prize postulate, dealing with fixed bias for small tetrodes and pentodes, for see what it allows us to do: We may put practically any combination or value of resistors we like in the grid return, and not worry about voltage drops, since (excepting by-pass condenser leakage) there is never any current whatsoever (under proper circuit conditions) flowing in anything in series with the grid of a class A1 stage.

Second, the ordinary receiving type power tube has no critical grid impedance, and so we may forget about that. All we have to do is to unground the grid return of our 6F6 in the circuit of Fig. 1 (or of any other tube in a similar application—the 6F6 is here used merely as an example) and apply the right bias from some source we find handy—anything that gives 22.5 volts and is stable. Some tubes, like the 6V6, have a fairly low maximum permissible grid resistance. The solution to this problem is merely to use transformer coupling.

AN OLD-TIME BIAS SYSTEM

One of the most widely used methods of biasing is the type using a resistor in the negative return of the power supply. It is

(Continued on page 45)
ULTRA RADIO

This single-tube, self-powered super-regenerator is capable of world-wide reception with a fifteen-inch antenna. A special tapped coil eases operation over wide frequency bands.

The short wave enthusiast who wants dependable reception on bands between 10 and 120 meters will find this receiver ideal. The 117P7-GT tube, which combines a half-wave rectifier and beam power amplifier, is employed as a self-powered superregenerative detector. The super-regeneration makes possible around the world reception with only a 15-inch antenna. Although the entire receiver with the case measures only 5 x 5½ x 3½ inches, many features are included in the design—such as plug-in-coils, tapped coil range-extender, band spread, stand-by "B" switch, and luminous dials.

CONSTRUCTION DETAILS

In the original model the panel was constructed from a masonite board measuring 5 inches across, 4½ inches tall, and ¾ of an inch thick. No shielding for hand capacity is necessary, for the receiver is very stable. After the holes are marked and drilled, the front side may be given one or two coats of colored brushing lacquer. After this is dry, the main parts may be mounted and the panel fastened to the chassis, which measures 4½ inches wide, 3½ inches long, and 1 inch tall.

After the parts that are fastened directly to the chassis or panel are firmly in place, the filter condenser (C1-C2) may be mounted. If not small enough to fit under the chassis, it may be fastened to the side of the potentiometer. After this is done, the 1000-ohm wire-wound resistor is mounted on a tie point terminal to prevent short circuiting to the chassis.

The wiring is very simple, but care should be exercised in not omitting any connections. The pilot lamp is optional. If it is used, it should be suited for 120-volt operation, and should be connected across the 117P7-GT tube's terminals 2 and 7. The plug-in coil data shown in Fig. 2 is only approximate, and minor adjustments will be necessary. It is better to have too many turns of wire to begin with, than not enough. All the plug-in coils are wound on 4-prong tube bases.

The broad tuning of the superregenerative receiver is helpful in picking up distant stations, but it tends to make the tuning range for one coil very short on the lower frequencies. It was noted that the opposite was true of the oscillating range. The lower frequencies will allow the detector to oscillate over a longer range without adjustment of the plate coil. Then, it was reasoned, if in some way grid turns could be added or subtracted at will, the range would be extended over a much longer band.

As a result a tapped coil was placed in series with the plug-in coil's grid circuit. (See Fig. 1.) This coil was wound with No. 24 S.C.C. wire on a ¾-inch form 1¼ inches long. It is tapped at the 2nd, 3rd, 12th, 17th, and 23rd (last) turn. When selector switch S3 is connected to contact 0, coil C1 is entirely shorted and reception at the high frequencies is possible with plug-in coils A, B, and C. But starting with plug-in coil D the range can be extended by switching in a few turns of wire to increase the inductance.

OPERATING POINTERS

Proper use of the receiver is as important as proper construction. The operating power is obtained from any 110-to 120-volt line, supplying either alternating current or direct current. If direct current is used, the power plug may have to be reversed to get the right polarity. Portable or emergency operation is possible with 90 to 112½ volts from heavy duty "B" batteries. Battery operation was found to be very satisfactory, except for the drain placed on the batteries.

The antenna is made of a stiff length of copper wire soldered to a phone tip, so that it can be plugged into a socket post. The length should not exceed a yard. The antenna can also consist of a few feet of insulated wire, if desired.

The continuous oscillation of the superregenerative type of receiver may cause interference with near-by short wave receivers. If any experimenting is to be done with out-door aerials it is advisable to connect a radio frequency amplifier between the detector and aerial. The use of an out-door aerial is not necessary, and the author...
**A Novel Feature in P. A. Systems**

This is a good-fidelity, low hum record player and audio amplifier combined with its own phonograph oscillator. The gain is quite sufficient for a low-level microphone and the output stage drives a 12-inch speaker with excellent volume. A standard circuit is used, the two 6V6's in push-pull being driven by a 6SC7 as phase inverter, with a 6J7 as a pre-amplifier stage. During the earlier part of its life, this amplifier used a 6SF5, in the first stage, but the 6J7 was substituted on account of the greater gain obtainable.

Some may wonder why a phono oscillator is included in a record player with its own amplifier. This is one of the most useful features of this instrument. The oscillator has considerable power and when the player is used in a large hall where there is some difficulty in covering the whole place properly, the oscillator helps out wonderfully. Several radios are placed in strategic positions, short antennas are rigged up both on the radios and the oscillator and the problem of coverage is solved. This is especially useful where there is a great deal of room noise, as at parties and dances, as the only way to be heard all over the hall is to have the sources of sound scattered around at a number of points.

**ANTI-HUM PRECAUTIONS**

Some care in building an amplifier is necessary if hum is to be kept down and quality up. This set starts out with a good filter system. The two chokes and three condensers assure proper smoothing of the rectified alternating current, and the careful shielding of the whole signal path right up to the grid of the second tube guarantees against 60-cycle pickup from outside sources.

It is unnecessary to say much about the chokes, except that they should be low-resistance and high-current types, preferably rated for double the current to be drawn by the amplifier. A low-resistance speaker field is also required, anything over a thousand ohms being entirely unusable. If you have a good speaker with too high a field resistance, it may be used as the first section of the choke, and the plate supply lead for the 6V6's taken off immediately after it.

The second section of the choke can then be a low-current type, as very little current is drawn by the first two tubes. Some of the advantages of double-choke filtering will nevertheless remain, as current smoothing is more important in the first stages of the amplifier than it is in the output.

Another important point in reducing hum is to ground all the leads to one point. This is a great help in cutting out hum set up in the chassis by the power transformer. As far as possible, all shielding may be brought to the same ground. It may be more convenient to have one ground point for each stage.

The 6J7 is hooked up in standard style. It will be noted that the screen resistor is taken off after the decoupling circuit which consists of R8 and C4, instead of running straight from the high voltage as in some amplifiers.

The volume control is not introduced until the signal has been amplified through the 6J7. This gives us a higher level of signal to work with. It was not considered a good idea to use a single volume control for phonograph and microphone, as the present arrangement makes "fading" possible, with a little manipulation, or phonograph and mike can be mixed.

The 6SC7 was found to give better results both in gain and freedom from distortion, than a 6F8 formerly used in its place.

Phase inversion is accomplished through a partially self-balancing circuit, which may not give as much gain as others, but in my opinion results in greater stability. The only features of note in the output circuit are the grounding of both the transformer core and the voice coil circuit to the common ground.

The mike being used at present is a 5-inch PM speaker. Used with the amplifier, there is far more than sufficient volume.

It is necessary to talk within six inches of it to make announcements over the oscillator, under which condition it operates satisfactorily.

The whole amplifier is encased in a box which measures 20 x 20 x 12 inches, as shown in the photo, and is thus a handy unit for portable work. The oscillator feature makes it useful for gatherings almost without limit as to the size of the hall.

The oscillator itself uses a standard circuit, and any phone oscillator could be used in its place. I used an ordinary broadcast coil with a small primary, then unwound a number of turns from the secondary and used an old condenser considerably larger than those now in use. This enables me to tune easily to a point right on the high or low edge of the range of any modern
Dynamic Tube Tester
Mutual Conductance Meter for Accurate Tests

With few exceptions, all the tube testers on the market today are the total emission type. All elements but the cathode are tied together, and the emission of the cathode is measured by a D.C. milliammeter. Such testers require few parts and are useful for short and emission tests of rectifiers, output tubes, etc., where the emitting ability of the cathode is one of the major factors. In other types of tubes they have severe limitations, for they give no indication of the tubes' transconductance, abbreviated Sm. (Mutual conductance, abbreviated Gm, means the same.)

Transconductance by formula is:

\[
\text{Sm} = \frac{\text{dI}p}{\text{dEg}}
\]

Thus, if an A.C. signal of 1 volt is impressed between grid and cathode of a tube with normal plate and bias voltages and its A.C. plate component measured in microamperes, the result is a direct reading in micromhos (µMhos). If the A.C. output is 1 MA:

\[
\text{Sm} = \frac{\text{dI}p}{\text{dEg}} = \frac{1}{1000} \text{ µMhos.}
\]

Since the tube's Sm is directly affected by emission, plate resistance, positioning of elements, etc., the test is made under conditions closely approximating actual working conditions. This type of test is greatly superior to straight emission tests. It has even been found in life tests on a number of tetrodes that while emission fell off with some tubes to a point where they might have been rejected by an emission tester, their Sm had actually increased and they were more efficient amplifiers than when first tested.

Figure 1 shows the basic circuit for such a tester. Theoretically the output measuring device should be an A.C. milliammeter of the dynamometer type which responds to the A.C. However, since such instruments are scarce, it has been replaced with a choke L1 to apply the plate voltage, an isolating capacitor C1, a diode rectifier and D.C. milliammeter M1. It will be noted that the output impedance of the circuit comprised of L1, C1, V2, M1 and R2 is quite low. Therein does the Sm test differ from actual operating conditions, for the purpose is to measure the A.C. output into a load small compared to the tube's plate resistance.

THE REQUIRED EQUIPMENT

Since, due to war shortages, odd parts are to be used, no specific values are given. T1 supplies the 60-cycle A.C. signal for the control grid and can be any step-down transformer, a winding on the power transformer, filament, bell-ringing or even an output transformer, since no current is drawn from it. R1 is to adjust the voltage applied to the grid and can be any value of volume control. It can be set at one volt, or if the meter hasn't sufficient flexibility, it can be put on the panel and set for various Mho scales. This would also be a simpler procedure than switching shunts across the meter for lower range meters. L1 can be a filter choke, audio choke or the primary of an output transformer. It should have low resistance so too great a D.C. drop will not be created across it when testing power tubes. It should have fairly high impedance at 60 cycles—say at least 30 H. C1 and C2 should be paper capacitors offering low impedance at 60 cycles—2 Mfd, preferably larger.

The meter can be any D.C. milliammeter with a fundamental range of from 1.6 MA, though a higher range could be used if the fixed grid input voltage of one volt was increased. Lower range meters can have their scales extended with suitable shunts. Since tubes vary in Sm from a few hundred millionths to many milliamperes, the scale or scales will have to be readable from approximately 0.2 to 6 Ma. V2 can be a diode such as 6H6 or 84. Any tube with good cathode emission can have its grids and plate tied together to operate as a diode, and will work here. R2 can be any potentiometer that will carry the meter current.

It forms the diode load and is adjusted for maximum meter reading with a given input signal. Once adjusted it can be left set or replaced with a fixed resistor. R4 is the potentiometer (any volume control) for giving the tube its required bias. It must be much larger in value than R5 so that it will not pass too much current due to the drop across R5. It will be a front panel control and will be calibrated. Its setting determined by meter measurement, and listed for each tube.

The rest of the instrument requires: 1—A tapped filament transformer T2, to supply all tube requirements between 1.1 and 117 v. 2—A source of B supply of about 350 v. with good regulation and bleeder tapped about every 50 v. to supply various plate and screen potentials and bias. 3—An array of test tubes.
A Pen-and-Ink Code Recorder

HERE is a code tape recorder you can construct from odds and ends. It will record with fidelity up to 50 words per minute. With this machine you can improve your sending by key or hag. It can also be connected to a short wave receiver, with proper relays and amplifier, so that it will record code directly from the radio to be transcribed later.

The construction of the recorder is very simple. It uses an electromagnet to vibrate a fountain pen in a vertical direction while a paper tape moves slowly in a horizontal direction, thus forming dots and dashes.

The first and most important consideration in the construction is the tape puller. The author used an Instructograph Jr. code practice machine. Many of these old units are in existence, and the constructor should have little trouble in obtaining one. If one is not available, it should be possible to build a tape puller with an old spring or small electric phonograph motor, with the necessary governor and worm gear to reduce the speed and supply the variable control necessary for the tape.

As most of the construction will depend on the physical features of the tape puller, the tape guides and manner of mounting the recorder unit will be left to the reader. With the photographs as a guide, he should have little difficulty.

The recorder unit was built on two pieces of Masonite. On the front piece (3 x 4 1/2 x 3/4-inch) brackets were mounted to hold the armature, electromagnetic and adjustable stop. These brackets are made of 1/16-inch steel but should be even stronger. The electromagnet and armature came from one of the relays in the cutout can of a 1939 or 1940 Ford. The electromagnet has a winding of one inch in length of 1/4-inch soft iron core. It is of No. 30 wire with a total resistance of 12 ohms. The armature has a piece of spring steel riveted onto it, which provides the pen with return action. A piece of 1/16 x 1/2-inch strip of iron is soldered onto the armature and this, with a bent piece and an adjustable screw, form the pen holder. The pen is an ordinary fountain pen using ordinary ink. The pen point is set in the grid circuit of the first amplifier tube.

For recording from the air the D.C. amplifier with relays shown has proven satisfactory when connected to the diode rectifier on a super-het, with the A.V.C. shorted out. The relays and recorder should be provided with 0.1 mfd. condensers to keep the relays from sticking and prevent radio interference.

The code recorder together with its amplifier and two rolls of tape is shown in the photographs. The back piece of Masonite has slots to adjust the position of the pen relative to the paper, making it possible to write three or four rows of code on each side of the tape. Spools of 2 to 2 1/2 inches in diameter 3/4-inch thick made of hardwood were used. The tape is about 3/16-inch wide and is made by splitting fifteen-cent rolls of 2 1/2-inch adding machine paper into three strips by using two razor blades and the proper tape guides mounted on a suitable board. The strips are 800 to 900 feet in length, which when recorded on both sides with three rows of code to a side, provide a very economical method of recording. Possibly tape of the proper width can be purchased, but the writer found it so convenient to cut the adding-machine tape into strips of the proper width that he did not bother to search for sources of supply.

The amplifier is connected to the diode circuit of any good receiver, as shown in Fig. 1. Obviously the grounds of the two receivers must be common, as the grid return of the first tube in the amplifier is through the diode lead circuit of the detector. The code recorder can also be connected straight across the output of a smaller short-wave receiver, such as the common two-tube regenerator. When so connected a condenser may be run to the plate of the receiver's output tube, and a resistor of .5 meg. ohm or greater is inserted in the grid circuit of the first amplifier tube. Better results will be obtained with receivers using A.V.C. as the output to the amplifier will not vary as much.

Because the power requirement is 6 volts D.C. at 1/2 ampere, some readers might hesitate to build this device. It was found, however, that the recorder would operate quite nicely without a battery, by using a dry rectifier to rectify the output of a shortwave receiver of five or six watts output. To record in this manner the signal must be tuned in and the output transformer disconnected from the loud-speaker and connected to the rectifier by means of a suitable switch. The switch should be connected to the 15- or 20-ohm tap on the transformer.

Circuit is shown in Fig. 2. Since the current flow is high, the small meter type rectifiers will not work satisfactorily. Those from old battery-chargers or certain loud-speakers work well. Even a broken-down unit may sometimes be used, by checking with an ohmmeter for shorted sections and removing them. Test first one way, then the other, across each pair of discs. In a good unit the resistance is much higher in one direction than the other.

When building a recorder of this type, the reader will find that many improvements will suggest themselves.
The radio trainee is never out of trouble. No sooner does he learn a thing—thoroughly—than he is told something that contradicts it flat. Starting off with common sense, the conductors and insulators, he assures himself that he knows just where electricity will go and where it won’t. Then is introduced to A.C. and the condenser, and sees current flowing in a circuit containing a perfectly good insulator. When he gets up to electron tubes, he finds cases in which even a power line, with the light on, appears to be ignored. When one can get through all these difficulties and—well, then he is up against a new stickler when he runs into antenna problems. He finally does learn how you can have current on a short piece of wire that goes nowhere, and as he fast becomes an authority on standing waves, nodes and loops, he believes that now, at last, he does know radio!

Then he runs into the transmission line. All that he has learned about tuned circuits goes into the discard. The critical interference and high-frequency currents which he was told to guide along carefully insulated and isolated wires, cut to the fraction of a wavelength, are supposed to find their way to the antenna along a pair of carelessly-twisted wires, any length! Traveling along these crude-looking conduits, they are actually expected to deliver power at the end, and that without serious loss. If it is inconvenient to use two wires in the line, one will do. It may also be any convenient length. The new radioman is both bewildered and suspicious.

These lines ignore all the rules of radio. They seem so simple as to be impossible to understand. There must be a catch somewhere!

Transmission lines really are as simple as they look, however, as we hope to show immediately. But—says the trainee who has been studying up a little—isn’t this contrary to everything we have ever learned about radio? And if it’s simple, what is this impossible-named ‘iterative impedance’ we read about? An impedance that remains the same whether you have a mile or ten feet of it? And doesn’t even change with frequency, so when you properly short or open it, you know for sure that you have a short or an open? And it appears to be “infinite” at one end, and “zo” at the other, and the current goes in one direction. Even if you were to wire the line on the end, you wouldn’t get a short, you’d get an open-wire current!

Note that high-frequency currents can flow back and forth on a single piece of wire connected to nothing. (We can set up such currents by exciting a similar piece of wire with a transmitter, a few feet away from the “free” aerial.) At the middle of this wire, fairly heavy currents flow. We would expect the impedance here to be fairly low. Out toward the ends, voltages rise and current drops, the impedance becomes infinite, or, in other words, zero. At the ends we have practically infinite impedance (no place for the current to go), zero current and high voltages.

A high voltage is due to crowding together of electrons at one end of the wire, with corresponding scarcity at the other end. As soon as the exciting voltage drops, these electrons start to rush back again. The radioman says they are reflected from the end of the wire. The result is that we have two sets of waves on the wire—these due to the impulses from the transmitter, and the reflected waves. If the wire is cut to a suitable length (a half-wavelength for example) the two sets of waves reinforce each other and we have a standing wave.

AN INFINITE TRANSMISSION LINE

Standing waves can take place on wires other than carefully-cut antennas. It was because of unpleasant and unexpected problems on the first A.C. power lines that the critical interference was brought home emphatically to the attention of the engineering profession. These lines showed queer characteristics—insulators would pop at certain points, always the same—points, though voltages were kept well within the supposed bounds of safety. At other points the conductors would burn out continuously. Investigators rushed to the scene of trouble. They soon discovered that voltages found many times higher than then allowed at the points where the insulators kept on burning through. To go over the ground they did, let us study a line like that of Fig. 1. This may be a power line, or the more familiar radio line, consisting of two pieces of wire about four inches apart. It may also be the well-known “doublet lead-in” (two pieces of insulated wire, more or less tightly twisted), a piece of coaxial cable, an ordinary telephone line, or even a single length of wire. We refer to the transmission line of Fig. 1 (b) is the common transposed radio lead-in.

For the purposes of our study, we are going to imagine this line infinitely long. It just isn’t going to end! (No one is planning to continue re-thinking about one just makes it easier to imagine some of the things that happen on an ordinary transmission line, complete with beginning and end.)

Our “infinite line” (yes, that’s all an infinite line is) is now connected to a source of power. We may attach its ends to a 60-cycle generator, or terminate them in a loop of wire and couple it to the output of a radio transmitter. We may expect to put some power into it, as the two wires have a certain capacity to each other (or the single line to earth). We can consider it a sort of condenser, and expect a charging current to flow. But as current flows into the line, it meets with some resistance, and as the advancing current builds up a magnetic field around the wire, it also has to overcome some inductive reactance.

WHAT THE LINE IS MADE OF

The line then looks to the current very much like the structure of Fig. 1 (c). For purposes of study, it can be broken down into a number of parallel lengths of wire, each having a certain amount of inductance and resistance and with a certain capacity between each length. You can make your lengths a centimeter or a mile—it makes no difference.

It should be quite possible to measure the impedance of such a line, if it were not for the fact that it is infinitely long, and measuring the infinite is not a practical proposition.

We can measure the impedance of such a line, though, and do it with a rather short section. Fig. 2 shows how. We first measure the section with the ends open, and then with them shorted. If the section is short enough, the impedance when open-circuited should be practically infinite, and there will be no measurable impedance when it is shorted (as the case will be with the lines a little, the open-circuit impedance drops (due to the increasing capacity), while the short-circuited impedance remains (because of the inductive reactance of the strengthened wire).

Obviously, if the line were made long enough, there would be little difference between the short- and open-circuited impedances. Actual experiment with a few
CAPACITOR CHECKERS

A Wheatstone bridge circuits and novel oscillators are combined to make three good instruments

from 10 to 100,000 ohms, and of capacities down to 100 mmf., with a reasonable degree of accuracy. The bridge is energized by a Neon lamp connected as a relaxation oscillator and a pair of telephones are employed as a balance indicator. "B" voltage of the oscillator is no longer heard in the phones when a balance is obtained, as well as a greater range of measurement. This bridge will measure resistances from 10 ohms to 10 megohms and capacities from 10 mmf. to 10 mfd. It incorporates a leakage test using a Neon lamp and also has provision for measurement of power factor. When constructed with close tolerances it is a most versatile instrument, and should help fill the need of servicemen for a reliable and portable instrument.

EASILY BUILT AND CALIBRATED

The instrument is A.C. operated and completely self-contained. There is nothing difficult in its construction and it is quite easily calibrated against known values. If possible a resistance box should be used for the calibration. This will ensure a greater degree of accuracy. When an unknown resistance or capacity is connected across the C and R terminals and the balance indicator is adjusted to the appropriate position, the potentiometer is turned until maximum shadow is indicated on the 6E5. The value of the unknown element is then read on the calibration scale. When testing condensers, if balance is difficult to obtain, probably the condenser has a large loss. The variable 2500 ohm resistor in series with the 1 mfd. condenser will assist in obtaining a balance. This resistor is also used for the measurement of power factor. It should be calibrated in power factor in the same way as a variable resistor. The method of doing so is as follows: Temporarily short-circuit the 1 mfd. condenser and balance the 2500-ohm variable resistor against fixed standards for power factor. The range or measurement is from 100 ohms to 10 megohms and from 10 mfd. to 10 microfarads. The tube oscillates at a low frequency to energize the bridge, and a pair of telephones are employed as a balance indicator. "B" voltage of the oscillator is no longer heard in the phones, and also has provision for measurement of power factor.

HOW TO OPERATE THE BRIDGE

(1) Connect to D.C. supply.
(2) Connect a pair of headphones to the terminals provided.
(3) Connect the resistor or condenser to be tested across terminals C and R.
(4) Set the switch to the C or R standard.
(5) Rotate the potentiometer knob until the audio note provided by the relaxation oscillator is no longer heard in the phones or is at a minimum. The scale of the potentiometer is calibrated, this being done by placing known values of resistors and condensers across the C and F terminals. A reversing switch may be incorporated to reverse the bridge action, then calibration on the resistance range will hold good for capacity also. As the current drain is very small it is suitable to use "B" batteries as a D.C. source.

A small self-contained portable bridge is shown in Fig. 4. This unit may be built into a box measuring 7 by 5 by 4/5 inches. The range or measurement is from 100 ohms to 10 megohms and from 10 mfd. to 10 microfarads. The tube oscillates at a low frequency to energize the bridge, and a pair of telephones are employed as a balance indicator. "B" voltage of the oscillator is no longer heard in the phones, and also has provision for measurement of power factor.

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The third bridge—shown in Fig. 5—utilizes the 6E5 magic eye tube as the balance indicator, so doing away with head phones and enabling greater accuracy to be obtained, as well as a greater range of measurement. This bridge will measure resistances from 10 ohms to 10 megohms and capacities from 10 mmf. to 10 mfd. It incorporates a leakage test using a Neon lamp and also has provision for measurement of power factor. When constructed with close tolerances it is a most versatile instrument, and should help fill the need of servicemen for a reliable and portable instrument.

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SHORT-WAVE INTERFLEX

Truest high-fidelity is obtained with a crystal detector. This old-time circuit has crystal quality combined with tube sensitivity.

The long-scorned crystal detector is still unchallenged as the best from the standpoint of fidelity, in spite of all modern technical advances. All that is necessary to prove this is to hook one up to the input of a really good modern amplifier, and listen to a good local station. The improvement over a high-fidelity band expanding superhet, or even T.R.F. receiver, is striking, and one does not have to be a musician to appreciate it.

The crystal is well ahead from the standpoint of simplicity, too. No other detector is as cheap to build or as foolproof in operation. In spite of these facts, two things have kept the crystal out of common use. First is the troublesome and time-consuming process of getting the cat-whisker properly adjusted, and of keeping it so. Second, the crystal's lack of amplification limits its range to a few miles under most normal conditions.

The modern fixed crystal completely eliminates the first obstacle. A good fixed crystal requires less attention and adjustment than a vacuum tube. Many precautions have been made to overcome the second difficulty. Some have been successful, others not. As already stated, adding a good amplifier makes the crystal a practical receiver for local stations. High, long aerials may increase its range to hundreds of miles or more. The lack of selectivity in the ordinary crystal circuit is a further obstacle, and to gain distance without interference it is necessary to use vacuum-tube circuits with the crystal.

Among the most practical of such successful circuits were the Harkness Reflex and Hugo Gernsback's Megadyn and Interflex. Though the Interflex was put out in three forms—straight, balanced and regenerative—I am following the original set.

On examination the schematic can be broken down into three parts—the crystal detector, audio amplifier (which includes both tubes), and the power supply. In my case the second tube was so hooked up that it could be used as an amplifier in connection with other experimental work. The set could of course be built in one unit if desired.

The crystal detector is hooked up in standard fashion, the only difference between it and any other being that instead of having a pair of phones and a phone condenser across the output it has the 500,000-ohm gridleak and the grid-cathode capacity of the tube. This manner of connecting a crystal detector to its audio amplifier deserves some attention. Instead of using a transformer with its attendant losses, the Interflex uses a direct coupling from the crystal to the audio grid. The only voltage present in the detector circuit is the signal voltage. The most important purpose of any coupling device is to isolate the plate voltage from the next stage, while letting the signal pass through.

Therefore there is no reason here for using any coupling other than an ordinary piece of copper wire.

Construction of this is too simple to warrant much discussion. If it is the builder's desire to hook it up all in one unit, the filaments may all be hooked in series and a line cord of approximately 200 ohms used. The condenser in the antenna circuit will be found useful in increasing selectivity. Some people are a bit puzzled by the low resistance of the first tube grid resistor, but if you remember it is an audio amplifier and not a detector, the resistance looks more like normal.

There are only three cautions to be impressed:

1. Keep all leads as short as possible.
2. Do not ground the set except as shown in the circuit diagram.
3. When using the additional power amplifier section be sure that the leads to it are properly connected.

After you have finished the construction, it is wise to check the wiring at least twice to make sure you have no mistakes.

This set is a joy to handle—there are no tricky regeneration circuits to whistle and howl at you. There are no image interference problems as with a superheterodyne, no distortion with strong signals as with condenser- leak detectors, and least of all, plenty of volume. It is a really fine high-quality set for either the fellow who is about to build his first A.C.-D.C. receiver or the experienced builder who wants to get the best possible short-wave set with the least cash outlay.

If regeneration is desired, it can be added by using any of the common short-wave regenerative circuits. A tickler can be inserted in the plate circuit or the cathode return brought to a tap in the grid coil, using standard regeneration control means.

A list of the parts used in constructing this set follows:

**Parts List:**

- C1, C2—140 muf. variable
- C3—8 muf., 35-volt electrolytic
- C4—0.003 mica or good paper
- C5, C6—5 muf. 250-volt electrolytics
- C7—10 muf., 35-volt electrolytic
- C8—0.005, (if required)
- R1—6.8 or 0.3 megohm, 50 watt
- R2—9000 ohms, 2 watts
- R3—0.25 megohm, 1/2 watt
- L—Standard 10-coil unit
- CH—Any good A.C.-D.C. diode

**Schematic of the Short-Wave Interflex, including its semi-independent amplifier unit.**

1946 RADIO-ELECTRONIC REFERENCE ANNUAL
Two Cigar-Box Radios
A Special Regenerator and a Standard 3-Tuber

The circuit sketched is a champion. Tuned to any one of the four Toronto broadcast stations or WGR or WBEN, Buffalo, one 6A8-GT will drive the 3-inch speaker at any time of the day, and will pick up a few more, including WHN, New York, in the evening. Volume is quite adequate for a personal radio—all one should use in a hotel to avoid disturbing guests in adjoining rooms.

The circuit makes any explanation almost unnecessary. The inner two grids of the 6A8-GT are used as grid and plate of a grid-leak detector, the output of which is transformer-coupled to the control grid as an audio stage. Exceptional stability is an outstanding feature of the circuit. Good shot primaries. I heated one until the primary would push out and rewound it from the other secondary. Building backwards in this fashion, it was hard to get enough turns on the primary to keep the turns ratio low, so the condenser eliminates a slight tendency to distort on loud highs otherwise noted.

As for power supply, almost any type will do—I used a 6K7-G for a rectifier. Either a capacity-resistance or capacity-inductance filter is satisfactory the latter giving slightly better speaker volume. Hum was non-existent in either case. The choke was a tiny output transformer that I could never match with anything. Note that when resistive filter was used the bleeder was placed at the cathode rather than the B-plus side to avoid the considerable voltage drop resulting from forcing this surplus through the filter.

The rather large antenna coupling condenser is necessary for speaker operation as is an antenna of approximately 40 feet overall length. For headphone operation, selectivity may be increased by reducing antenna length or using a small coupling condenser.

A coil of 90 turns of No. 28 enamel wire, close-wound on a 1/2-inch form, will prove suitable, as will any ready-wound broadcast coil. The tap for regeneration on my set was taken off at only two turns from the ground end. While I would not like to try to explain how, the action of the set leads me to believe that there is some further regenerative effect due to some special kind of coupling inside the multi-grid tube.

The set is at present on a cigar-box breadboard, but I intend shortly to put it in a "cabinet" similar to the set shown in the photographs. This is the receiver I carry in my grip, and really is a honey—2 6S5F5's and a 5L7. A circuit diagram is appended in case anyone should be interested, though there is absolutely no departure from the orthodox circuits—which by this time should be known to everybody—in this receiver.

Neon Checker from Old Parts

The little voltage tester offered here is made from odds and ends available to most experimenters and is very useful if care is used in calibrating it.

The indicator is a 3/4-watt neon bulb connected to a potentiometer so that the voltage can be adjusted till the bulb just "strikes." This striking voltage is very constant; though it is different on A.C. and D.C. and calibration curves must be run for each, using known voltages. The tester has an A.C. range from 1 volt to 300, and a D.C. range from 75 to 300 volts. The ranges can be extended higher by the addition of a couple of resistors.

The main feature of the set is the transformer, which is an ordinary push-pull output type. Other parts needed are a 10,000-ohm wire-wound potentiometer, the neon bulb, several resistors for multipliers, several tip jacks, a pair of test leads and a jumper with phone tips on each end, and dial plate and knob.
Record Changers
Notes on Maintenance and Repair

What is the most efficient method of attack on record changers in need of repair? The answer: simply the same logical approach used on electronic circuits. Putting it into general terms:

Visualize the mechanical actions step by step in a manner similar to the way electrical reactions are considered stage by stage in a radio set.

Many faults are so logical as to be perfectly obvious to anyone possessing sufficient curiosity to try a few simple adjustments.

The greatest variety of troubles occur in newly installed machines. It is improbable that brand-new phonographs will be sold for some time. The statement still applies to machines that have been transported considerable distance and set up in new locations. This appears less of a paradox when the causes are considered in detail. It is easy to see that only a minor misadjustment can interfere with the working of the entire unit. The cause of the breakdown is all too often due to the set owner's ignorance of proper care and operation of the set. Since prevention is the best cure in this case, some of the more usual causes are discussed first.

1. Improper Unpacking

The unpacking of any radio-phonograph consists of more than merely removing it from the shipping box. During shipment the radio chassis and phonograph unit are both secured by "packing bolts." These are usually painted red for easy identification.

Legs of the set are leveled by placing a block under one corner. Don't guess; use a spirit level.

2. Improper Packing

The above method of packing would be used by the factory or a service man in preparing a set for shipment, but the customer often ships the set himself. He may fail to safely secure loose parts (probably not even using a box if he intends to carry it in the family car. That physical damage can occur is obvious, but loss of rubber or spring mountings can make it impossible for the phonograph unit to rest on an even keel. This may interfere with the balance of the many small tension springs used to position the levers.

3. Forcing of Mechanism

This is probably the most prolific source of serious trouble. Many people have become familiar with old style hand operated phonographs, and seemingly cannot overcome the habit of reaching for the pickup arm when it is time for another record to start playing. They inadvertently forget that something else is handling the pickup. The sensitive gears and cams of the repeat mechanism located below the motor board. Levers can be bent and springs broken this way, but it usually occurs that adjustment screws are forced out of position. These are equivalent in importance to the tuning screws in R.F. and I.F. transformers.

4. Use of Old Records

An example of unintentionally improper operation is the use of phonograph records (Continued on page 38)

<table>
<thead>
<tr>
<th>SYMPTOM OR TROUBLE</th>
<th>ADJUSTMENT ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too loose—Repeat mechanism fails to trip.</td>
<td>1. Friction Clutch (Turnbuckle)</td>
</tr>
<tr>
<td>Too tight—Repeats groove over and over. (Using a good record)</td>
<td>2. Height of Pick-up (Turnbuckle)</td>
</tr>
<tr>
<td>Needle drags on top record when 10 or 12 records are stacked on turntable.</td>
<td>3. Needle landing place for 10&quot; records. (Set screws on pick up shaft)</td>
</tr>
<tr>
<td>Needle misses edge of record or starts too far in on 10&quot; records. (Eccentric Stud)</td>
<td>4. Needle landing place for 12&quot; records. (Eccentric Stud)</td>
</tr>
<tr>
<td>Same as above but for 12&quot; records. This must be set after adjustment for 10&quot; records.</td>
<td>5. Distance between Selector Blades. (Screw and lock nut)</td>
</tr>
<tr>
<td>Record selector blades strike the edges of records instead of separating them and sliding in between.</td>
<td>6. Distance of rotation of Selector Blades. (Set screw on Selector Blade shaft)</td>
</tr>
<tr>
<td>Records, when released, fail in a leopolded manner instead of both sides simultaneously.</td>
<td>7. Reject Lever (Requires bending or reshaping)</td>
</tr>
<tr>
<td>Reject Lever inoperative because of too forceful handling by inexperienced operator.</td>
<td>8. Leveling of player. (Boring retaining screws at each end)</td>
</tr>
<tr>
<td>Needle may fall to side of starting groove of record if turntable is not level.</td>
<td>9. Oilings. (Use SAE No. 10 oil on motor and petrolatum on other moving parts)</td>
</tr>
<tr>
<td>squeaks that can spoil listening pleasure and &quot;droggiog&quot; of motor during operation.</td>
<td></td>
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</tbody>
</table>
TWO-TUBE FM RECEIVER

THE receiver is usually not only the weakest link in an FM set. It is also the trickiest piece of equipment to construct, and completely out of the range of the average experimenter's facilities in these days, unless some means of getting around the use of the big FM superheterodyne is found. The receiver about to be described is not a time-tried circuit. Reception of FM signals has been satisfactory on a set of this design, but there is plenty of room for refinement, improvement, and such general putting around as the ham experimenter loves.

In attempting to get around the use of the big FM super, let us see just what we are up against. The U.H.F. ham working with A.M. gets around it by falling back on the time-tried super-regenerative detector, self-quenched or otherwise as the case may be. What relation do these two types of receivers bear to each other? If we analyze the superhet, we find that basically it is built around a diode or triode detector ignominiously shoved away unnoticed under the title of "second detector stage." The rest of the tubes, while placing the greatest drain on the amateur pocket and causing him to consume much headache powder, are actually nothing but devices to increase the selectivity and boost the signal a bit. These two diode detectors are driven from the same source and have their outputs connected in reverse series—that is, the two detectors are interconnected in such a way that their outputs are in series, but in series so that the two outputs oppose each other and tend to cancel instead of helping each other. Now let us make some curves by plotting input frequency against output voltage on each diode separately and then on the whole system. These curves are shown in Fig. 2.

If we study this circuit for a bit we find that it really consists of two ordinary A.M. diode half-wave detectors. Each detector uses one diode unit of the 6H6 in conjunction with the respective tuned circuit z or y and the respective 100,000-ohm load resistor.

The circuit of Fig. 1B depends for its operation on a series of phase relationships and resulting voltages in different parts of the circuit. It is therefore very difficult to adapt to any kind of regenerating system such as must be used to get a satisfactory single-tube receiver on the U.H.F. The circuit of Fig. 1A, however, operates on a simple principle and therefore (in spite of the fact that its more complicated coil construction has caused it to become less and less popular as a second detector in FM superhet's) affords the experimenter the opportunity he needs.

If we study this circuit for a bit we find that it really consists of two ordinary A.M. diode half-wave detectors. Each detector uses one diode unit of the 6H6 in conjunction with the respective tuned circuit z or y and the respective 100,000-ohm load resistor.

These two detectors are driven from the same source and have their outputs connected in reverse series—that is, the two detectors are interconnected in such a way that their outputs are in series, but in series so that the two outputs oppose each other and tend to cancel instead of helping each other. Now let us make some curves by plotting input frequency against output voltage on each diode separately and then on the whole system. These curves are shown in Fig. 2.

In Fig. 2A are shown the curves of each half wave detector operating alone. A regular selectivity curve appears in each case, the only difference being that one is positive and the other is negative. This is because one rectifier uses as the "low" side of its output the opposite side from the one used by the other rectifier. Now let us drive both detectors from the same source and tune one so that its resonant frequency approaches that of the other until the two curves just barely overlap. We have the output curve of Fig. 2B for the complete system. The slight overlap of the two waves is used to straighten out the curved portion of the output at the base of the waves by cancellation so that the wave will be as near a straight line as possible between points OP-OP.

It will now be noted that the section of the curve between these points is in the form of a good discriminator characteristic. If an FM transmitter is now tuned so that its resting (unmodulated) frequency is that marked "operating frequency" in Fig. 2B and then frequency-modulated so that the sweep lies between the limits OP-OP', the discriminator-detector will give out the modulating signal with a very high degree of fidelity.

Now that we have seen the operation of this circuit, let us return to the fundamental elements of the system. These, we found, were two A.M. half-wave detectors driven from the same R.F. source and having their outputs connected in reverse series. So we see that essentially our system consists of two AM detectors. And that gives us just what we want. It is now possible to substitute a couple of triode super-regenerative circuits for the diode detectors we have hitherto been talking about, connect their outputs in the same way and couple their tuned circuits to the same antenna. Then we have a receiver with the sensitivity of an ordinary AM super-regenerative and incorporating the frequency discriminating characteristic necessary for proper reception of FM signals. Using each triode unit of a double triode tube such as the 6F8-G as a superregenerator, we find that we have achieved our goal—a one-tube super-regenerative FM receiver.

The circuit of this set appears in Fig. 3, complete with an audio output tube. Some experimenting may be necessary with the connections on the windings of the two audio transformers to make sure that the outputs from the two detectors oppose each other. It may also be necessary to provide individual regeneration controls for each detector in case the output of one proves to be appreciably greater than that of the other.

Alignment of the set is simple. Tune in an AM signal on the high end of the band, set the tuning condenser at or near minimum capacity and adjust one of the 3-30 mmHg trimmers to bring the signal on that detector. Adjust the trimmer accurately to give maximum output as shown by (Continued on page 30)

Fig. 1, left—Two fundamental FM discriminator circuits. The system at B is the one now most commonly used in commercial FM receivers. Fig. 2, right—How the two separate AM detectors of Fig. 1-A can be made to operate as a discriminator for detection of FM signals.
Carrier communication has attracted a great deal of attention during the past few years. This simple equipment can be operated as an intercommunicator or used in experimenting with the various phases of "wired-wireless" transmission.

Very good "wired wireless" results are obtainable with the simple equipment described here. I have been experimenting with these circuits for some time, using approximately 200 kc. as carrier. Communication has been carried on a distance of 6 blocks in a crowded residential district of Berkeley, and undoubtedly greater distances are easily possible. Either phone or C.W. signals may be transmitted.

The receiver, shown in Fig. 1, uses a regeneration detector, one stage of R.F. and two stages of audio. It is built on a 7 x 7 x 2 chassis in a plywood cabinet with Masonite panel.

The receiver has sufficient sensitivity, considering the high static level of the power lines. High selectivity is obtained when it is in an almost-regenerating state. The tuning is broad when non-regenerating. The R.F. stage minimizes trouble due to frequency shifting as a result of ever-changing load on the power lines.

During periods of transmission, the receiver is silenced by throwing the switch from "receive" to "stand by." This switch is mounted on the regeneration potentiometer. The coil L1 is 5 turns of No. 24 to 30 wire, simply scramble-wound on a temporary paper or glass tube, just big enough to fit over the pies on the 2.5-MH choke. All other coil constants are given in the diagram. The turns of L1 are cemented together and then slipped over L2, its position being changed until best results are obtained.

A transmitter for both C.W. and phone is shown in Fig. 2. It is a 6.3-volt bulb used as an R.F. indicator. It is fed from a single turn around the tank coil. The center tap on the tank is adjusted for maximum brilliance of the bulb. "Ch" is a 100-ma. modulation choke. If an audio amplifier is already available, Fig. 3 may be used. The regular output transformer is connected to terminals "A.F." to feed the large output transformer Ti in the figure. A modulation transformer or large class-B audio unit should be used in this circuit, as the current circuits for tank tuning adjustment.

The circuit may be adjusted for greatest brightness of the indicator lamp with the line not coupled to it. Then the center-tap of Ls is moved a turn or two toward the plate end of the coil. This will reduce appreciable power, slightly, with notable increase in stability and quality of speech transmitted.

Choice of frequency is an important point in the operation of any transmitter working over light or power lines. Changing the frequency only a few kilocycles may make a tremendous difference in the amount of power that can be put into the line.

The indicator will show whether a normal amount of power is being taken. If the lamp burns at full brilliance when the line is coupled, little power is being transferred. If it goes out entirely, probably too much is being absorbed.

All the circuits shown are straight forward and used standard parts, many of which may be found in the junk-box. I am very pleased with my carrier current results and hope some of you experimenters will join me.

Fig. 1—Coils for the 200-ke. receiver are constructed from 2.5-millihenry R.F. chokes.
1-Tube Metal Locator

This Smallest Treasure Locator is Compact, Simple and Reasonably Sensitive.

A short while ago I finished building a very compact treasure-finder which for a small-size job is unusually sensitive for metal detection. Really good results have been obtained with it. The schematic is shown and the photo gives an idea of physical size. Incidentally, this is quite an easier design to make than most, as the circuit was one of the latest and complex circuits, and can state that I am now quite expert in the use of all treasure locators and components improve in quality, better results being obtainable with less difficulty.

My first treasure locator used the buzzer system. This was ultra-modern at the time and the circuit was one of the latest and great sensitivity was claimed for it. The exploring coil consisted of 500 turns of metal detection. Really good results have been obtained with it because it happened to be available. The 3A8-GT requires only .1 amp at 1.4 volts when its filaments are wired in parallel as it is in this case. The total drain on the "B" battery is less than a milliamperc, so that the drain on the pocketbook is no hardship.

After making all connections a friend and I tried out the gadget. For hours we strained at the phones but were able to hear only a constant, weak buzz. Finally we strained at the phones but were able to hear only a constant, weak buzz. Finally the signal was tuned in exactly. Then tune the other detector. This will be indicated by the meter reading falling to 0 or to a minimum very near 0. The trimmer should then be backed off until the meter just returns to the peak previously shown by it. The receiver will now receive FM signals. To bring it to peak efficiency, the FM transmitter already described should be modulated with a constant audio tone and the signal picked up on the receiver and tuned in for maximum output. The last trimmer mentioned above may then be adjusted to give maximum output and fidelity. This may be done by ear, or with an output meter.

The one-tube treasure locator Li, L2 is an ordinary plug-in coil tuned to 1700 kc. L2, the exploring coil 24" x 24", it is wound with 14 turns of No. 14 wire. C1, C2 = 65-350 mmfd. paddlers. C1, 3-30 mmfd. trimmer used with short 1- or 2-foot aerial.

TWO-TUBE FM RECEIVER

(Continued from page 28)

an output meter, indicating that the signal is tuned in exactly. Then tune the other trimmer until the signal is received on the other detector. This will be indicated by the meter reading falling to 0 or to a minimum very near 0. The trimmer should then be backed off until the meter just returns to the peak previously shown by it. The receiver will now receive FM signals. To bring it to peak efficiency, the FM transmitter already described should be modulated with a constant audio tone and the signal picked up on the receiver and tuned in for maximum output. The last trimmer mentioned above may then be adjusted to give maximum output and fidelity. This may be done by ear, or with an output meter.

**Fig. 3**—Complete diagram of the 2-tube FM receiver, with 1-stage audio for headphones.
Cross-Over Networks

Because of the difficulty of designing a loud-speaker which will function efficiently over a wide frequency range, it has been common practice in F.M. radios and movie sound work to use a "woofer" for the lower frequencies and a "tweeter" for the highs. The tweeter is generally a low-power unit since the high frequency sound energy is small in comparison with the low. The woofer is a rugged, heavy-duty unit. The job of dividing the electrical energy into two paths falls to the dividing network. A simple type of network is shown in Fig. 1. It is the voice coil resistance or speaker resistance in ohms, C is the capacity in farads and f is the crossover frequency in cycles. L is the inductance in henries.

The circuit action is easy to visualize. A condenser is connected in series with the high-frequency speaker. Smaller condenser reactance decreases as frequency rises more high frequency current gets through to the tweeter than low frequency current, thus favoring the highs as far as the tweeter is concerned. Also note that in Fig. 1 a coil is connected across the high frequency speaker terminals. Thus the shunt current through the coil will be greater at the higher frequencies since the coil has low reactance at these frequencies. As the frequency rises the coil current is decreased and the current in the high-frequency speaker rises. The opposite action occurs so far as the low frequency or woofer speaker is concerned. It has a condenser in parallel with it. The shunt resistance of the condenser decreases as the frequency is raised, shunting away an ever greater amount of current from the woofer at higher and higher frequencies.

Still another form of dividing network is shown in Fig. 2. The action here is somewhat the same as in Fig. 1, but note that as X increases not only is there less opposition to the flow of high frequency current in the tweeter, but also an increased shunting of high frequency current in the tweeter, but also an increased shunting of high frequency current in the tweeter which will drop and the output voltage of the input terminals of this network at a peak value which may be undesirable. Hills and valleys in the response of the speakers are not wanted, but a flat response is often desired. A great deal depends on other design factors. For example, if the speaker cabinet is of such design that the lows are not properly reproduced the peak may be permissible or even desirable in the case of the woofer and the series resonant circuit associated with it. An expansion of this network which is quite simple in nature, involves adding an additional inductive element, as indicated in Fig. 3. An additional capacitive element is added in series with the tweeter.

The division of frequencies is not complicated nor difficult to arrive at, but from a practical viewpoint there may be complications in properly distributing the power. If too much power is fed to a tweeter it will overload.

A circuit that can be used on a practical basis is that of Fig. 6. Considerable flexibility is afforded by this design. The amount of power fed to the speakers can be controlled by selection of the turns ratios on the transformers. (See "Matching Loudspeakers"). Further, in the case of the tweeter, the power can be controlled by selection of the series capacitive element C5 if necessary. Usually, C5 is made large enough so that it offers little opposition to high frequency currents and the amount of tweeter power is then controlled by T2 and C6.

References:

Ultra Radio

(Continued from page 19)

Several loudspeaker cross-over systems. Fig. 6, bottom, is a highly practical, flexible circuit.

egin{tabular}{|c|c|c|c|c|c|}
\hline
CL1 TAPS & COIL & CL2 & CL3 & Approximate Wavelength
\hline
O & A & 2½ turns spaced No. 20 wire & 3½ turns close No. 28 wire & 10-18 meters
\hline
O & B & 4½ turns spaced No. 28 wire & 4½ turns close No. 28 wire & 16-21 meters
\hline
O & C & 4½ turns close No. 28 wire & 4½ turns close No. 28 wire & 19-24 meters
\hline
O-1 & D & 4½ turns close No. 28 wire & 7½ turns close No. 36 wire & 23-35 meters
\hline
O-4 & E & 5½ turns close No. 28 wire & 11½ turns close No. 36 wire & 35-75 meters
\hline
O-6 & F & 7½ turns close No. 28 wire & 21 turns close No. 36 wire & 75-120 meters
\hline
\end{tabular}

Within the oscillating band will usually indicate a station. Code wireless stations may be rather hard to read, because of the silent space present when the station is sending out a dot or dash, and the hiss sound present when the station is not sending.

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but it is essential to good recording. It seems
that it "loosens up" the wire mag-
netically, thus permitting the signal to be
impressed on it.

As previously stated, when recording the
output of the amplifier is fed through the
No. 1 secondary of the oscillator to the
recording head and then to the ground. The
selector switch opens the oscillator cathode
connection to ground when the machine is
powered off. Each one used a different coil in
either physical size, shape, number of turns,
or D.C. resistance. Therefore I will de-
scribe the construction of only one, the one
that has worked best.

After the head and its mount were as-
sembled, I drilled a hole in the engine plate
differed mainly in
recording. The coil I used came from an
old Atwater Kent magnetic speaker, the
D.C. resistance measuring 700 ohms. The
physical dimensions were 3/4 by 25/32 by 5/16
inches. The core was 3/16 by 5/16. Refer to
Fig. 2 for the shape and manner of as-
sembling. I have found that almost any coil
will work as long as the gap in the core
is kept between .001 to .003 inches. I used a
piece of brass shim stock to maintain the
gap at .002. I used a jeweler's hack saw
with the finest blade obtainable to cut the
slot to run through. After filing the core to shape, I assembled the
pieces without putting them on the coil.
I had them clamped together to enable me to
tie the wires with 2-56 screws. Then I
put the pieces on the coil, being careful to
observe the order in which they were as-
sembled so they may be reassembled in the
exact way they were when the holes were
drilled. With the wire strung out so the
drilled laminations were well separated
I then heated them red hot with a blow
torch and then left them to cool gradually.

I have also tried cooling them in an A.C.
field—using an old speaker field
for the purpose—and I believe this im-
proved the efficiency of the core. After
cooling, I assembled the laminations on the
core and together with 2-56 brass
screws and nuts. Before tightening dip the
whole thing in dipping varnish, tighten and
allow to dry.

Next get a small piece of phenolic tubing
3/8-inch diameter or some similar material,
to wind the erase coil. I used No. 26 enameled wire
for the purpose and believe this im-
proved the efficiency of the core. After
cooling, I assembled the laminations on the
coil together with 2-56 brass screws and nuts.

I then heated the core to the coil and
then left them to cool gradually. I have also tried cooling them in an A.C.
drilled lam
magnet

to the recording head. Then the erase coil is assembled.

A MAGNETIC RECORDER

on the drive shaft. The two wire-pulling
drums I used were about 3 inches in diam-
eter with a rim on each side to keep the
wire from running off. I used microphone
cable to connect the recording head and
erase coil to the amplifier-oscillator assem-
by. A word of caution here in regard to
running the wire pulled; use your hand as
a brake when stopping the reels! The wire
may become hopelessly snarled if the reels
are allowed to coast after the power
is turned off. I rewind the wire by hand. In-
cidentally, when recording or reproducing
the wire should move through the head at
a constant speed of about 180 feet per
minute. Whatever your speed is (it will work
at slower speeds but not so well) it must be
constant all the time.

You will have to find by trial and error
how high to run the volume control and
the audio filters with recording. Each set
will vary, of course. If the reproduction
sounds too bass and garbled it indicates
you haven't filtered out the low frequencies
enough. By connecting a pair of earphones
across a small coil similar to the one used
in the recording head and held close to the
recording head you can monitor the record
continuously.

Before you have taken the "bugs" out
you should have broken your recording wire
many times, unless you're exceptionally for-
tunate—and I've never yet met a radio ham
that lucky. So remember this suggestion:

A final reduction in hum is, of course,
front, the very slight mismatch being of
no importance and not detectable by ear.
If a dynamic type of speaker must be
used a 750-ohm field can be substituted for
the filter coil with a reduction in
power output to about 15 watts. At full
volume, the field regeneration is about 8
watts so the magnetic circuit must be of
high efficiency. Suitable Australian speak-
ers are the Amplon TO75, a 10-in.
heavy duty dynamic with a 1 1/2-inch voice
cord, or a Magnavox 122. Suggested Amer-
ican speakers are the Jensen A15PM, the
Lafayette P12G or the Utah G12P.

A very low hum level is obtained for
several reasons. All earth returns are made
to a busbar consisting of a strip of copper
1/4-inch wide, this being connected to the
metal chassis at one point only—just near
the No. 1 terminal of the 0SC7. Small shields of tin-plate are soldered to
the chassis in appropriate places to elec-
trastically screen the 5 megohm mixing
resistors, the anode resistors of the first
tube and the pick-up bass-boost network.
The input connections are made by means of
UX and UZ tube sockets and these, too,
are shielded.

The filament wiring is connected to a
simple voltage divider, thereby being about
35 volts positive with respect to the chassis.
and therefore making the grids about 20
volts negative with respect to the fil-
aments, thus preventing filament emission.

A final reduction in hum is, of course,
front, the very slight mismatch being of
to 35 volts positive with respect to the chassis.

The phono pick-up is a four-pole needle-
armature type with an output of about 4
volt. It has negligible bass boom owing to the mass of the head being large, hence the
boosting network. Although the pick-
up head is heavy, a counter-balance re-
duces the thrust on the record to about 1
ounce, only a small thrust being needed
on account of low needle point impedance.

The microphone generally employed is
either an Australian version of the D104
or a Shure model 902A. Sometimes a
directional floating-cone dynamic micro-
phone is used when wide-range music is to be amplified. The amplifier is not
suitable for use with sound-cell mixers or
low-level dynamics.

The tone and volume of this amplifier
are surprisingly good, the freedom from
unpleasant distortion enabling the speakers
to be placed close to the audience without
exciting rude remarks.

R17—200 ohms 10 W
R18—250 ohms
R19—500 ohms
R20—1000 ohms v.c.
R21—2500 ohms—10 W
R22—25m ohms
R23—50m ohms

ECONOMY 20-WATTER

(Continued from page 13)
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(314 pages)

covers the subjects: Algebra; Geometry; and Arithmetic.

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**BOOK II**

covers the subjects: Advanced Algebra; Trigonometry; and Complex Numbers.

(320 pages)


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**CAPACITESTER**

(Continued from page 14)

A.C. switch on the lower left and the locking switch on the lower right. The pin tip jacks are mounted one pair on each side. The oscillator and radio frequency amplifier coils are ordinary solenoid broadcast coil forms with the primary removed. The oscillator coil is tapped two-thirds of the way down from the ground end for the cathode connection. Two holes were drilled in each coil form, one inch apart and a quarter inch below the bottom of the winding. A single turn of hookup wire was wound here and cemented in place, with the ends threaded through the holes and leading out the bottom of the coil form and shield can in which each coil is mounted. A 15 mmid. mica trimmer condenser is connected across each of the larger windings and a hole drilled in each shield can oppose the trimmer screw to permit the coils being tuned to the same frequency. A screwdriver is used for the tuning.

The frequency used does not have to be exactly 1800 kilocycles; any frequency near this will be satisfactory, preferably the highest one to which both coils will tune accurately. Circuit testing should be done with the coils mounted under the chassis three inches apart and the link coupling turn leads are fastened in place by means of tie points. The oscillator coil is held in place of the parts to suit himself, providing the oscillator and the tuned circuit are so arranged there will be no interaction with the link coupling circuit.

On the opposite side of the link circuit connected to the pin tip jacks, the circuit is again broken and a one tenth mfd. condenser inserted. This enables checking for voltage tests across the condenser being tested simultaneously with the quality test. A small condenser is connected from one side of the pin-jack circuit to ground. This prevents any radio frequency pickup due to capacity between the larger winding and the link coupling turn. This tip-jack should be marked and used as the ground point for making tests of combinations of various sized resistors and condensers in parallel, noticing the shadow positions with the insertion and out of the circuit.

If a condenser is to be intermittent the test leads should be clipped across it and the condenser squeezed with the fingers or taped with a rubber band or similar instrument. If the condenser makes and breaks contact due to this treatment it will be shown by the indicator tube's shadow blinking or opening. To test a condenser for continuity it will be satisfactory, preferably the leads are clipped across it and the locking switch closed. If the condenser open circuits at any time the locking tube will keep the indicator tube's shadow blinking or opening showing the condenser to be intermittent. A shorted or partially shorted condenser will be shown by the discrepancy of the ohmmeter or voltmeter reading in comparison with the circuit diagram or voltage chart. This makes a very handy combination; both a condenser quality check and a point-to-point resistance or voltage reading simultaneously, using the ohmmeter or voltmeter already in the shop.

In some instances it may be necessary to insert a low resistance radio frequency chokegalley with the pin-tip jacks used for the meter connection, but in most cases it will be found the meter movement has enough reactivity in itself that it will not move the needle; it may be seen from the chart connected to this instrument. This condenser tester does not indicate the capacity of electrolytic condensers. The capacity of the tapped condenser is marked on them or the diagram chart, and does not vary with age or use as with the electrolytic ones. This instrument will check the amount of radio frequency reactivity and will pick out a defective one that may be causing radio or audio feedback due to common coupling in the filter circuit. In this way the constructor is given an easy check both on the resistor or capacitor and on the condenser, aided by the oscillographic test of the tube the indicator tube shadow will open and remain so indefinitely until the locking switch is turned off.

There are only two controls, the R.F. amplifier gain control and the locking switch. Heat the tubes to operating temperature, hold the test probes together and adjust the gain control until the indicator tube's shadow just closes. Plug an ohmmeter or voltmeter, depending on whichever method you prefer, in the two extra pin-tip jacks provided for this purpose and proceed to check the condensers in their circuit, remembering to use the prod so marked on the ground potential end of the circuit. An open condenser is indicated by the indicator tube's shadow refus- ing to close completely and in most cases by refusing to move at all. The operator of the oscillograph can familiarize himself with its operation by making tests of combinations of various sized resistors and condensers in parallel, noticing the shadow positions with the insertion and out of the circuit.

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WESTON INSTRUMENTS
A COMPACT AMPLIFIER

The amplifier here has excellent fidelity when used with a well-baffled 10-inch speaker. It is shown removed from its cabinet, where it has of late been in use as a small phonograph system.

The two knobs on the front are volume and tone controls. Above them may be seen the input jack and indicator jewel. The input lead, as shown, is short and well-shielded to avoid hum pickup.

The chassis base, 7x4½x2 inches, was taken from an old kit, as were some of the other parts. The speaker field acts as one of the filter chokes.

This set may be used as a phone amplifier; with one of the new medium-output dynamic or crystal mikes; or as a small set amplifier. I have used it to supply the "B" and heater voltages as well, when working with small receivers.

The amplifier is the result of considerable experimentation in circuit and design in an attempt to build an economical but efficient amplifier. Metal tubes were available, so they were used, but of course their G or GT equivalent may be used. The power supply is quite conventional, and built large enough to supply extra power for equipment associated with the amplifier. Any of the usual rectifier tubes might be substituted for the 5Z4, with an accompanying change in circuit design if necessary. Following is the parts list:

RESISTORS
R1—1000 ohm 1 watt resistor
R2—9000 ohms, 2 watts
R3—250,000 ohm ½ watt resistor
R4—100,000 ohm ½ watt resistor
R5—250,000 ohm tone control
L1—Speaker Field
L2—10-Henry choke

This neat and versatile unit is conservatively rated at four watts. If it is carefully built of excellent materials, it is capable of good work in many small-amplifier applications.

R6—450 ohm 1 watt resistor
R7—500,000 ohm volume control

CONDENSERS
C1—10 mfd. 25 volt electrolytic
C2, C4—0.01 mfd. 400 volt condenser
C3—8 mfd. 450 volt electrolytic
C5—25 mfd. 25 volt electrolytic
C6, C7, C8—16 mfd. 450 volt electrolytic
C9—0.005 mfd. mica condenser

AUSTRALIAN CHAMPION

This simple amplifier is a national champion. It is the winner of a contest staged by the Melbourne (Australia) radio paper, "Listener-In," in conjunction with their Australian DX Radio Club.

Forty-two amplifiers were entered, and ten of these made the finals. These ten were allowed to play three recordings each, after which the judges announced their decisions. Proponents of the triode will be interested to know that the contest narrowed down to a struggle between this amplifier and another push-pull 2A3 job.

That simplicity and high-fidelity go together is amply demonstrated by this set. Triodes are used throughout, as is resistance coupling. The phase inverter is the famous Australian "kangaroo" circuit. The plate resistor, and its balancer between the 6C5-G cathode circuit and ground, are kept to a low value, in the interests of high-fidelity. These resistors are often 100,000 ohms or higher, but in this amplifier are limited to 50,000.

The 6N7-G is then used as a straight push-pull amplifier. The plate resistors on these tubes are also kept down—to 100,000 ohms in this case—and grid leaks of the 2A3 are 250,000 ohms, the signal being transferred through 1-mfd. condensers. A fairly high voltage is used on the 2A3's. This also increases the efficiency of the resistance-coupled stages slightly.

Excellent filtering is a feature of this circuit. Even the push-pull output of the 6N7 circuit is filtered, in spite of the fact that most variations in this circuit would be self-neutralized. A 20,000-ohm resistor and an 8-mfd. condenser act as filter in the plate circuit of the first stage. No cathode
condensers are used anywhere in the amplifier. The runner-up job also used 2A3 output, preceded by a 6V6 phase-changer. Fixed bias featured the circuit, which was nosed out by the winner only after a stiff battle. The constructor of the champion gives credit for his victory to the infinite baffle used with his amplifier. Correct speaker loading and proper reproduction of low notes made for a noticeable increase in quality as compared with the same outfit used with an ordinary baffle, according to him. Full constructional details of this baffle are given in the sketch.

The speaker cabinet is the infinite-baffle type. Its width may be from 20 to 24 inches.

NOVEL FEATURE IN P. A.
(Continued from page 20)

broadcast receiver.
It has its own power supply, using a 76 with plate and grid tied together as rectifier. Thus there is no possibility of coupling with the amplifier, as might be the case with a common power supply. I have actuated radios with it at a distance of 200 feet, though in practice this is never necessary.

Parts List
R1—5 meg.
R2, R6—1,000 ohms
R3—1.5 meg.
R4—0.25 meg.
R5, R7, R8—60,000 ohms
R9, R10, R12—100,000 ohms
R11, R13—0.33 meg.
R14—100 ohms
R15—0.33 meg.
R16—0.5 meg.
R17—0.5 megohm volume controls
C1—10 mfd. 25 volt
C2, C5, C10—6.1 mfd. 400 volt
C3, C11—0.1 mfd.
C4, C6, C7, C9—5 mfd. 450 volt
C5—4 mfd.
C12—250 mfd.
C13, C14—0.02 mfd. paper

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ALLIED RADIO CORP.
333 W. Jackson Blvd., Chicago 7, Illinois
Write for Quantity Quotations
MATCHING LOUDSPEAKERS

(Continued from page 15)

reflected the correct impedance back into the primary.

The method of distributing power is simple enough. Many servicemen do it unconsciously. With two 8-ohm speakers to attach to an output transformer, few would have to be told they could both be connected in parallel across a 4-volt tap. Each speaker is faced with a 4-ohm impedance, half its own, and receives half the power. What could be more simple, if we wish to divide the power in parts of one-third and two-thirds, to tap one speaker across a tap 1/3, and the other across 2/3 of its impedance? All we have to do is multiply the voice-coil impedance by the fraction of the output we want it to take.

But will matching to the output tubes be correct? Back to the 8-ohm speaker and 4-ohm tap again! A 4-ohm speaker would reflect the correct impedance back into the primary, and maximum power would be drawn from the amplifier. The 8-ohm speaker reflects 8/4 or twice the correct impedance back into the primary. If two of them are paralleled, each reflects its 12,000 ohms. The resultant of these two 12,000-ohm impedances in parallel is 6,000, the correct load. If our two 8-ohm speakers are connected to divide the load into 2/3 and 1/3, the reflected impedances will be 8 x 3/2 x 6,000 = 9,000 and 8 x 3/1 x 6,000 = 18,000. Adding these impedances in parallel, the resultant impedance is 6,000, which is what we want.

The method can be extended to several speakers, as in the example of Fig. 4. Here we wish to supply 2 watts to a 500-ohm line, 6 watts to a 16-ohm and 12 watts to an 8-ohm speaker. This works out to 0.1, 0.3 and 0.6 of the total output (20 watts). Again assuming a primary of 6,000 ohms, we can get correct matching and power distribution by calculating output taps as follows:

For the 2-watt 500-ohm line, 500 x 0.1 = 50 ohms; for the 6-watt, 16-ohm speaker, 16 x 0.3 = 4.8 ohms, and for the 12-watt, 8-ohm tap, 8 x 0.6 = 4.8 ohms also. Reflected impedances are 6,000 x 10 = 60,000; 6,000 x 10/3 = 20,000 and 6,000 x 10/6 = 10,000. These paralleled impedances add up to 6,000 ohms.

By the above method it is possible to hook up the most complicated speaker combination. All that is necessary is to know the impedance of each speaker and the portion of the total amplifier power we want to put into each one. Another essential is an output transformer with a variety of taps. In conclusion, it might be well to point out that an output transformer has a large number of impedances not marked. For example, the impedance between the 2-ohm and 16-ohm tap is 6.6 ohms. Sometimes these odd ohmages make a closer match possible than would otherwise be the case.

References:

RECORD CHANGERS

(Continued from page 27)

of ancient vintage. Many are in use date back to “tin-horn” days. Unfortunately, the man who records them had none of the qualifications of Nostradamus. Not being conscious. With the obvious cure of disarding the old records. Remember, they require parts. These small boxes taken from the stock shelf are quite practical for this purpose (see Fig. 1). Many service men prefer more elaborate supports installed in a permanent home position. Naturally, some operations will require placing the player carefully upside down or rubber mat.

The “wow” effect of warped records on the music is well known and many complaints that the motor is “draging” or alternately speeding up and slowing down can be traced to this reason, especially if the unit refuses to misbehave when the repairman is present. Look through the record stack for the offenders.

Symptoms
The “wow” effect of warped records on the music is well known and many complaints that the motor is “draging” or alternately speeding up and slowing down can be traced to this reason, especially if the unit refuses to misbehave when the repairman is present. Look through the record stack for the offenders.

Procedure
Before actual repair work can be accomplished a device must be provided by which the player can be supported in a right-side-up and level position, since this is the only position in which it can be tested for proper operation. The writer finds that two small boxes taken from the stock shelf are quite practical for this purpose (see Fig. 1). Many service men prefer more elaborate supports installed in a permanent home position. Naturally, some operations will require placing the player carefully upside down or rubber mat.

The “wow” effect of warped records on the music is well known and many complaints that the motor is “draging” or alternately speeding up and slowing down can be traced to this reason, especially if the unit refuses to misbehave when the repairman is present. Look through the record stack for the offenders.
amplifier is transformer coupled in and out. Equalization is inserted in this amplifier to make it peak in the voice range, and frequency response being from about 80 to 6000 cycles.

In the middle of the Board can be seen a volume level meter. This meter is used across the output of each program amplifier to indicate the correct operating level. Below the decibel meter is a row of push-buttons. Each push-button is associated with a program amplifier output.

At no time during the playing of a record does the volume rise to more than minus 2.0 Db. on the peaks. The program amplifier output is set by using a record which has an abundance of high and low frequency passages. I suppose it will be asked, "Why not set the maximum program level by means of a standard audio frequency record?" This has been found by actual practice to be useless for a good many reasons, the main one being that all crystal pick-up tubes are not rugged enough for the abuse they get.

Hanging down from the front of the Board is the operator's breast-set. This consists of a pair of low impedance headphones, connected in parallel, and a dy-parallel, and a dy-nohedron microphone. These are little used in this type of work as they are not rugged enough for the abuse they get. Also the circuits are of low impedance to cut down noise and hum, and using the high-impedance microphone would necessitate the use of an induct transformer with its hum problems. The microphone can be raised or lowered to compensate somewhat for the different speaking voices of the operators.

Looking at the back of the Board as shown in the photograph, Fig. 2, is the following apparatus. At "A" in the upper left hand corner is the back of the permanent magnet speaker. In the upper right hand corner and labelled "B" are the two dial stepping relays.

In the middle is seen the back of the turntable motor. On the first shelf and to the left labelled "E" is the program monitor amplifier chassis. The phonograph pickup amplifier consists of a dual 100,000-ohm potentiometer working into the grids of a 6N7 tube. The crystal pickup is not ground ed on the usual practice. The 6N7 tube is transformer-coupled out to a 50-ohm line. The monitor amplifier con-

(Continued on following page)
REMOTE JUKE BOXES

(Continued from previous page)

sists of an input transformer with a poten-
tiometer across its secondary, into a 615 tube. This potentiometer not only controls the voltage on the grid of the next tube, but also controls the volume level of the monitor speaker. The operator's headset. A second poten-
tiometer in the grid of the 61F tube controls the volume level of the monitor speaker. On the above chassis is the copper oxide rectifier, which controls the single throw relay on the panel and the buzzer. On the same shelf as the above chassis and labelled "D" is the conversion unit, or line-adjusting equipment.

This unit consists of a resistance-capacity network and two 1:1 hybrid coils. A brief description of this unit which is very im-
portant to the frequency response and opera-
tion of the equipment is as follows:

The amplifiers will operate over a maxi-
imum length of ten miles of telephone line. However, these conversion units plus the amplifiers are required to work over a seven mile class "C" telephone line or any un-
balanced circuit of that length. Whether the line between the Central Station and the Remote Station be a full seven mile line or any fraction thereof, the network in the conver-
sion unit will make up the line difference so that our equipment it still is a seven mile line.

The capacitance of this seven mile line was figured at 0.6 Mfd., and its resistance at 1,344 ohms. Thus each conversion unit (one being used at each end of the line) is divided to have a capacity of 0.3 Mfd. and a resistance of 672 ohms. Each of these units are divided into seven units. There are three 1-mile line units, two ½-mile line units, one 1/3-mile line unit and one ¼-mile line unit. Each of these units is arranged like an "H" pad, as shown in Fig. 5.

Each one-mile line unit consists of four 56-ohm resistors, and a 0.1 Mfd. condenser. Each ½-mile line unit consists of four 27-ohm resistors, and a 0.05 Mfd. condenser. The 1/3-mile line unit consists of four 15-ohm resistors and a 0.02 Mfd. condenser. The ¾-mile line unit is made up of four 12-ohm resistors and a 0.02 Mfd. condenser. While 27-ohm and 15-ohm resistors do not figure exactly right, as stock resistors were used, they fall within the ten percent tolerance range and are all right for the purpose. There are two controls on the conversion unit, one for the high and one for the low frequencies. These controls peak the line at frequencies from 4,000 cycles to 100,000 cycles respectively.

To equalize the line requires the use of an audio frequency oscillator and a calibrated volume level indicator with the necessary test equipment. The test equipment is shown in Figs. 6 and 7. When the telephone lines are equalized and balanced, their frequency response is within ½ Db, from 100 to 6000 cycles.

Fig. 5—Three sections of the artificial line.

Fig. 6—Rough diagram of the Central Station.

Fig. 7—Block diagram of the remote receiver.

As one of the photos shows, another 6K7 was tried, to boost the R.F. gain. The use of such a tester is a revelation to one who has never used a signal tracer.

SIGNAL TRACER—PLUS

(Continued from page 8)

can be seen a front and back view of the "Juke Box" used at the remote location. Behind the metal grill at top center is the microphone which the customer uses to tell the operator the number of the phonograph record he or she wishes to hear. Either a crystal mike or a small two-inch permanent magnet speaker with an input transformer is used as a microphone. Below this and just above the words "Rhythm-Listener" are the nickel, slugs that might be inserted. Below this, and shown with a twin-pair conductor is the equivalent of a full wave circuit.

The %-mile line unit is made up of four 6V6G's. These two output tubes are transformer coupled 6N7, with a dual pickup transformer, resistance-capacity coupled to two 6N7 tubes in resistance-capacity coupling, pushpull. The output is transformer coupled to a 500-ohm line. A volume control is used in the grid of the first 6N7 which is a phase inverter for the second 6N7.

The power amplifier for the speaker is a transformer coupled 6N7, with a dual po-
tentiometer volume control across its sec-
tary, resistance-capacity-coupled to two 6V6G's. These two output tubes are trans-
tformed coupled to the speaker. A resistance-
capacity filter across the plates of the beam-power tubes flattens out the amplifier resonance and reduces the selective load impedance for all frequencies in the middle and upper range. This is used in place of degenerative feedback. Also on this chassis is a loud-speaker terminal. This connects her headset through the monitor amplifier to the incoming telephone line, and also connects the output of the micro-
phone pre-amplifier to the same line. She then can not only hear what record the customer would like to hear played but also talk back to him. If the record is not avail-
able, she can ask him to request another.

When the operator throws the key to talk to the Remote Station, it automatically drops the level of the phonograph record that might be playing at that time so the customer can hear her voice over the music. A block diagram of the Central Station equipment and also the Remote Station equipment is shown, in Figs. 6 and 7. When the telephone lines are equalized and balanced, their frequency response is within ½ Db, from 100 to 6000 cycles.
somewhere in the neighborhood of the tube plate prong. Hum and noise can be picked up just as easily. Loss of gain can be isolated right to the offending stage.

A real set of test probes made as the photos show will prevent any detuning of the circuit. If the probes available the shielding test probe shown will prove a valuable addition to the tester. Use 30 inches of microphone cord and bring the end of the shield out in a probe tip which is to be inserted in the ground jack. When testing the grid circuit of the first tube the ground tip should be removed from the ground jack to increase the signal strength, as the shield acts as a small condenser by-passing some of the R.F. energy to ground.

The small capacity tip is made by turning or grinding down a small phone-tip jack in a lathe or grinder until it is just a thin shell. Cut the end off to fit the length of the insulator of the phone tip (Sec. Photo). Insulate the turned surface of the jack with wax paper and wind on 50 turns of wire from an old transformer secondary. Fasten the wiring by painting the coil with lime. Test the assembly for continuity to be sure you have no short. There must be no direct connection; only a small capacity coupling between the cord wire and the jack should exist.

When cutting off the end of the jack to fit the space within the insulated phone tip, the gripping jaws will slip out. To hold the assembly together, solder the jaw and the end of the jack together.

The A.F. tip probe was made by cutting off a phone jack and soldering a 50,000 ohm resistor to the end of the jack and the inside gripped jaws. The photo is self explanatory. When using the tester only one such probe is necessary if the tester ground tip and the two probes are connected together with a jumper. The same probe can then be used for all voltage and resistance tests by using it without the tips, which are easily put on and removed.

THE VOLT-OMMETRE SECTION

As we had a power supply the tester could be adapted to many more uses. It is a handy V.O. Ommeter, also a condenser and continuity tester. My only transformer had a 21/4 volt filament winding so I used a 2,000 ohm -500 volt electrolytic condenser to keep the filament winding. If so you can do away with the line-cord supply 6.3 volts on the filament winding. Similar type can be substituted if you can have the same current drain. Any tubes can be used in their places if they have a few left. May we suggest to follow the lead of American Electric Laboratories... results made possible by new inventions obtainable only in "VOMAX." No wonder "VOMAX" is sold out for 1946 on advance order. These are the facts manufacturers... manufacturers... manufacturers... manufacturers... manufacturers... manufacturers... make you the time saved by shorting the condenser leads. The meter needle will read zero on a shorted condenser. The meter needle will not wrap on an open-circuited condenser. For 150 and 450 volt testers there is special a.f. and d.c. metering, 25 and 50 volt testers. The meter needle will not clip on an open-circuited condenser.

In the original receiver design engineer specifically stated that you follow the lead of American Electric Laboratories to post-war service or of its, as before by the wafer switch. The two wafer switch which selects the voltages and the end of the shield out in a phone tip which is to be inserted in the ground jack. When testing the grid circuit of the first tube the ground tip should be removed from the ground jack to increase the signal strength, as the shield acts as a small condenser by-passing some of the R.F. energy to ground.

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Electronic Multi-Checker

For the technician interested in construction and experiment, the need often arises for a compact instrument to measure the values of those parts on hand. A good many experimenters do not possess the necessary meters to measure resistance and voltage, or to measure capacity and inductance. They may find this three tube combination "magic-eye" vacuum tube voltmeter, ohmmeter and A.C.-D.C. voltmeter combined with an inductance and capacity indicator useful.

As any radioamateur will immediately see, the unit consists basically of a Wheatstone bridge with an electron ray tube as the indicator. The type No. 41 or similar type provides the control voltage for the eye while the type 80 rectifier provides the high voltage for the B circuit. A resistance bridge type smooths the pulsating D.C. from the rectifier.

As can be seen from the diagram, the unit has built-in standards for measuring most values of resistors, condensers, and chokes. A pair of pin-jacks are provided so that additional standards can be hooked in place of those in the unit and switched in or out as desired.

In building the unit all leads must be as short as possible and the bridge part of the circuit must be wired with fairly large wire so as not to affect the measurements. The voltage and bridge measurements use a common ground jack. Switch A disconnects the bridge circuit from the vacuum tube voltmeter part of the circuit. As all condensers resonate at some frequency, and since the unit measures A.C. of a wide range of frequencies, it is necessary to use 801 condensers across the cathode by-pass and the final B filter condensers.

To calibrate the meter, proceed as follows: The center point of the dial may be marked 1. The 50,000-ohm point is marked 1 and the corresponding point on the opposite end of the potentiometer 100. If you set the standard resistor on 10,000 and 10,000 ohms, a 1,000-ohm and a 100,000-ohm resistor of known accuracy by these points can be located definitely. The same points will be 1,000 and 10,000 ohms at the low end of the 1,000-ohm scale, and so with all the others.

As these points fall on the same markings no matter which scale is used, all that is necessary is to measure as large a number of resistors as possible (say between 1,000 and 100,000 ohms) and mark down the points. Then a number of concentric circles can be drawn, and marked for the other standards.

Condensers work the same as resistors. If the 1 microfarad standard is used, point 10 will measure 1 microfarad. Point 1 will measure 0.1 mfd and point 100 will measure 10 mfd.

Inductors also follow the same principle, but as all inductors have more or less resistance, the indications are not as reliable as in the case of resistors or condensers.

The voltmeter scale must be calibrated separately for A.C. and D.C. voltage. The 10,000-ohm potentiometer does not require setting once it is calibrated. It is set and the 50,000-ohm unit setting will determine the voltage being measured. In other words, the potentiometer should be adjusted until the eye closes and this point of the dial marked to correspond with the known voltage being fed into the unit. The accuracy of the entire instrument will depend largely upon the care taken in calibration.

Long celluloid or plastic pointers may be used on the 100,000-ohm potentiometer in the bridge circuit and the 50,000-ohm one in the voltmeter circuit, so that a number of scales may be drawn under them. Both these potentiometers must, of course, be of the linear type if the scales are to be regular.
Better Signal Generator

The above calculations were based on the 00053 condenser and ranges will be slightly different with an American 00053 variable. For the broadcast and intermediate frequencies, plenty of universal-wound coils are available from old receivers, and will be practically pre-calibrated. Plate coils should have approximately one-quarter the number of turns given above, though this may be exceeded for the high frequencies. Experimental adjustment is necessary.

Five bands are covered by the signal generator. A constructor satisfied with less range could make one with fewer coils. The excellent attenuator is worthy of special note. Feedback is prevented by the transformer and the two choke coils.

For audio oscillations I used a small interstage transformer parallel-fed to triode section of 6K8. Checking with an oscilloscope, almost perfect wave form was found at 400 cycles with depth of 30%. The attenuator was governed by values on hand and works quite well.

The whole instrument was built in three decks, allowing coils and attenuator to be triple shielded, and the rest double. All hot wires were also shielded, complete dimensions being 12 inches high, 7 wide, and 5 deep.

The large 180° plastic dial had a 31 reduction drive, pointer being a piece of scrap plastic with hair line. Calibration was accomplished by heating with a standard signal generator and all-wave receiver, also with a 100-kc crystal oscillator locked in with a 50-kc oscillator which I built.

I had to borrow the crystal, as they are not obtainable except for industrial use. Graphs presented no difficulty since the calibration follows a gentle curve except for the extreme minimum and maximum had the dial engraved directly in frequencies.

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THE PORTABLE LAB THAT GIVES YOU—
Everything!

* Design proven by over 5 years production of thousands of this model.
* Operation as simple as ABC. Multi-staged push-button switches do all work. Simply "follow the arrows" for tube checking. No roaming test leads for the multiplier.
* Open face wide scale ¾-inch rugged meter built especially for this tester—500 microampere sensitivity.
* Each AC and DC range individually calibrated.
* Professional appearance. Solid gold finish carrying case.
* Guaranteed Ratchifer.

APPLICATIONS:

DC MICROAMPERES:
0-10
DC MILLIAMPERES:
0-2.5-5-10-50-250
DC AMPERES:
0-1-10
DC VOLTAGES—1000 OHMS PER VOLT:
0-0.75-1.5-3.00-6.00-12.00-24.00
AC VOLT:
0-6-12-24-36-48-60-72-96-110-120-230-250
OUTPUT VOLTS:
0-0.3-0.6-1.0-1.5-2.0-2.5-3.0-3.5-4.0-4.5-5.0-5.5-6.0-6.5-7.0-7.5-8.0-8.5-9.0-9.5-10.0
OUTPUT CURRENT:
0-0.2-0.5-1.0-1.5-2.0-2.5-3.0-3.5-4.0-4.5-5.0-5.5-6.0-6.5-7.0-7.5-8.0-8.5-9.0-9.5-10.0
OUTPUT VOLTAGE:
0-0.75-1.5-3.00-6.00-12.00-24.00

A CHASSIS CRADLE FROM PIPE FITTINGS

The sturdy chassis cradle illustrated permits working on a radio set with all wiring, etc., in full view, but without the usual hazard to tubes and other components. The rig can be quickly constructed.

All parts, including the "C" clamps, can be obtained from your local hardware plumbing supply house. The lengths of pipe listed are correct. The parts list follows: "A" is a twelve-inch length of pipe. Four required. "B" is a Tee. Three

```
SPECIFICATIONS

DC MICROAMPERES:
0-10
DC MILLIAMPERES:
0-2.5-5-10-50-250
DC AMPERES:
0-1-10
DC VOLTAGES—1000 OHMS PER VOLT:
0-0.75-1.5-3.00-6.00-12.00-24.00
AC VOLT:
0-6-12-24-36-48-60-72-96-110-120-230-250
OUTPUT VOLTS:
0-0.3-0.6-1.0-1.5-2.0-2.5-3.0-3.5-4.0-4.5-5.0-5.5-6.0-6.5-7.0-7.5-8.0-8.5-9.0-9.5-10.0
OUTPUT CURRENT:
0-0.2-0.5-1.0-1.5-2.0-2.5-3.0-3.5-4.0-4.5-5.0-5.5-6.0-6.5-7.0-7.5-8.0-8.5-9.0-9.5-10.0
OUTPUT VOLTAGE:
0-0.75-1.5-3.00-6.00-12.00-24.00
```

The chassis cradle above was built entirely of ready-cut easily-obtained pipe fittings required. "C" is a 45-degree Street Elbow. Eight required. "D" is an Elbow (90 deg.) Four required. "E" is a Cross. One required. Four required. "F" is a Tee. Three

The most useful size for pipe and fittings should be from one to one and one-half inches. The "C" clamps should be installed in the positions shown in the illustration so that the clamping pressure will come up against the top of the inverted chassis.

I have found pipe fittings very useful in the radio shop. They come in a number of ready-cut lengths, which can be employed with elbows, bases for attachment to wood benches, and other fittings, to build up numerous handy devices.

SUPREME TESTING INSTRUMENTS

Supreme Instruments Corp.
Greenwood, Miss., U. S. A.
the one found in 90% of the commercial A.C. sets. In this type, a resistor is inserted between the power transformer's high voltage secondary centertap and ground. The entire B+ current must pass through the resistor in such a direction that a voltage, negative with respect to ground, builds up across the resistor. By using the correct resistance value, the correct voltage for biasing the output stage may be obtained.

This method is still far from true fixed bias. The drop across the negative-bias resistor prevents the full voltage output of the power supply from being effective as "B+" voltage. Since the drop is dependent on varying tube conditions, the bias system will not be absolutely constant and independent of varying tube conditions.

In hooking up the amplifier, one should remember that setting the optimum bias voltages is done with an electronic voltmeter. The bias voltages for a half-wave rectifier can be made to serve for both power and bias supplies. See Fig. 3.

"A GOOD AMPLIFIER"

Finally, I give the circuit (Fig. 4) and general view (photograph) of another amplifier operating on the same principle as the units of Figs. 2 and 3 but of greater power output. The 6L6G in the output stage will deliver full 10 watts at a minimum of distortion. The power transformer delivers 375 volts R.M.S., each side of the centertap, at 150 ma. For this reason the author thought it necessary to use a separate, ungrounded winding for the 1-V plate heater to insure against breakdown between cathode and heater. This is probably not necessary, but it is best to be on the safe side. Moreover, a small resistance was inserted as shown between the 1-V plate and the first filter condenser, since the light load placed on the 1-V by the bias voltage divider will otherwise cause an excessive voltage to build up across said condenser; as it is, a 500-volt rating is desirable for that part. In other words, the bias supply is similar to the one of Fig. 2. The rest of the amplifier follows standard practice.

A GREAT AMPLIFIER

Another disadvantage is a greater tendency toward hum, which requires a series of decoupling resistor-condenser networks, to prevent the hum from reaching the grids of the output stage. Extra filtering is also required. Low supply voltage and additional difficulty in filtering the output of a half-wave rectifier make the system entirely impractical for A.C.-D.C. sets.

In looking up the amplifier, one should be sure to ground the positive leads of C1, C2, C3, and C4, since the voltage being filtered is negative with respect to ground. The values of R1 and R2 may be allowed to vary over quite a range. In general, the current drawn by the bias system should be kept pretty low—around 10 ma. or less—so as to avoid unnecessary current drain and plate current variations in one stage are 180 degrees out of phase with the variations in the next, the average bias current in such sets may be fairly close to constant. Another disadvantage is a greater tendency toward hum, which requires a series of decoupling resistor-condenser networks, to prevent the hum from reaching the grids of the output stage. Extra filtering is also required. Low supply voltage and additional difficulty in filtering the output of a half-wave rectifier make the system entirely impractical for A.C.-D.C. sets. It is cheaper to use two tubes in push-pull with cathode bias than to buy the condensers and find the extra chassis space required to bias a single tube by this method.

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 TRANSMISSION LINES

(Continued from page 24)

short sections shows that these two impedances approach each other with remarkable rapidity if a point is so reached where they are so close it is hardly worth while to add more sections. If the impedance of the line when open is for instance 200 ohms and that of the same section shorted 199 ohms, we must believe that however far the line is extended, the impedance will be close to 200 ohms. If we are working with short lines at low frequencies, and cannot bring these impedances so near together with the length of lines at our disposal, the 'characteristic impedance' can readily be calculated.

Simply measure the open-circuit and short-circuit impedance of the section and take the geometrical mean. (Multiply the two figures together and get the square root of the product.)

The single-line wire is a special case. Its impedance cannot be easily computed, and is usually taken as about 500 ohms, though obviously it must vary somewhat according to its surroundings.

A FINITE "INFINITE" LINE

Now for the reason we have made the line infinitely long. High-frequency (or other) currents are not bothered by standing waves on such a line. They just keep right on going. It is true that there is nothing to reflect them back. This is why even very high frequencies can be piped down such a line with the ease of D.C. in a battery circuit without bothering about turning.

Again our watchful student breaks in. "But there ain't no such animal!" he insists. "First you introduce your infinite line single-ended, and then you demand that you are proposing to run current along it. You are simply trying to kid us."

There is no intention of trying to deceive the reader. We are out for a bigger game. What we intend to do is kid Mr. High-Frequency himself! And that can be done by a very simple trick. It has already been made evident that at any point on our hypothetical 200-ohm line, the current sees a 200-ohm impedance before it. (We simply cut the line at any convenient point, and slip a 200-ohm resistor across the open ends. The line is the same as if the line extended into infinity. The current has no way of finding out that it doesn't.)

TERMINATIONS THAT TAKE POWER

So now we can get an infinitely long line into a good-sized room. Our problems are not all solved, however. We must not only find a way of terminating the line so that it looks infinitely long to the currents travelling on it, but we have to get them all to come again, if we are going to deliver any power to another circuit.

This is comparatively simple. If we are working with 60-cycle current, all we have to do is terminate our line with a transformer winding. A normal transformer, or other piece of apparatus so designed as to present the proper impedance to the line. You can then calculate from the finite "infinite line" with no trouble.

The same thing can be done with radio frequency. In most cases transmission lines are used to carry currents from a transmitter to a receiving system. We have learned that the impedance of a straight half-wave antenna is close to zero at the center and practically infinite at the ends. We can therefore, by connecting across larger or smaller sections of it, match any desired impedance. This can be done as shown in Fig. 3, (a) and (b). The ordinary "double antenna" of Fig. 3 (a) is fed by a transmission line of about 75 ohms impedance, so connected that the ends are about ten inches apart, at the center of the antenna. The impedance at this point is then about 100 ohms, sufficient to prevent shorting our transmission line, the center 10 inches of the antenna is taken out and an insulator inserted. This is another example of the troubles you can play on radio frequency. The antenna is used to meet an impedance of 75 ohms at this point, and does not know that its middle section has been taken away and the line now extends down the other end. In fact, the line, meeting its characteristic impedance of 75 ohms, imagines that it extends indefinitely.

If we have a higher-impedance (widenspaced) "feeder" we simply connect its ends to points farther from the center. In this case it is not necessary to use inductors, the feeder terminals "looking into" the same impedance, whether they look to the center or the ends of the line. (This type of connection is actually not quite as simple, because it made across points on the aerial which present a higher impedance than the characteristic of the straight part of the line, and the line current increases steadily through the V-shaped portion, which acts as an impedance transformer.)

(Two things are needed to complete the circuit. The feeder is simply applicable to receivers, and is as much a transmission line when transmitting energy to the antenna as it is when taking it from the output of a transmitter to the aerial.)

When a transmission line is used to couple two coils together, as in a transformer, the job is even easier. Such "links" are made with a turn or two of wire at each end, as coupling loops, and coupling to the coils is varied for best results.

CAPACITOR CHECKERS

(Continued from page 24)

When testing electrolytic capacitors for leakage, it is best to connect them for correct polarity, although accuracy does not warrant it, and the condenser will certainly not be harmed by the brief application of incorrect voltage while it is under test.

The leakage test may be used for detecting leakage anywhere, but its main purpose in this unit is for detecting leakage in resistors. The neon lamp employed should have a striking voltage of about 80 volts as the voltage available is only 100 volts. When a condenser is connected across the leakage terminals the neon lamp will flash momentarily, due to charging. If the condenser is good it may take a short time until the neon lampflashes, but with an open circuit the neon lamp will flash every second or so, and one that is really bad shape will show a continuous light. Care must be exercised when employing this type of test on electrolytic condensers, as they always have a certain degree of leakage.

The rectifier circuit in the bridge introduces some novel details. The tube employed is that versatile diode, the 6H6, which has gained so much popularity for use in detection, A/C systems, electron voltmeters, etc., and is employed in this bridge in the capacity of a low voltage half-wave rectifier. One of the main reasons for its inclusion was the limited space available for construction and that a total rectifier chassis would be too bulk.

Secondly, the heater has the same rating as the 6L5. Thus the filament transformer winding serves both. Last but not least, the current per anode for the 6H6 is 4 milliamperes. All that is required is the current drawn by the 6L5 target and grid plate current approximately 15 milliamperes at 100 volts—so the 6H6 is not overloaded by lamp consumption. On actual tests the total consumption of the unit was 1.6 milliamperes, a light load for even the 6H6.

CALIBRATION FOR CAPACITY

The voltage supplied to the 6L5 target is approximately 115 volts, which is sufficient for efficient operation.

The double diode and toggle switch is incorporated in the instrument, so that scales calibrated on resistance will also hold good for capacity. By employing this switch, the action of the bridge is reversed for capacity measurements, thus enabling a single scale reading from 01 to 100 to be employed for both. All that is necessary is to place the switch in the correct position for measuring a resistor or a capacitor. The values of the standards chosen are in multiples of 10. Thus the reading on the scale is multiplied by the factor on which the measurement has been made. For instance, if a resistor is being measured on the 100-ohm range and a reading of 41 is obtained, one of the resistors is 4 times 100, which is of course 40 ohms.

The resistance R1—of value 1000 ohms is the essential part of the bridge circuit and potentialmeter automatically graduates the bridge voltage to suit the impedance being measured. It will be seen that for resistance values of high ohms and no toggle switch is required, the transformer and potentialmeter automatically graduates the bridge voltage to suit the impedance being measured. It will be seen that for resistance values of high ohms and no toggle switch is necessary in the operation is to place the switch in the correct position for measuring a resistor or a capacitor. The values of the standards chosen are in multiples of 10. Thus the reading on the scale is multiplied by the factor on which the measurement has been made. For instance, if a resistor is being measured on the 100-ohm range and a reading of 41 is obtained, one of the resistors is 4 times 100, which is of course 40 ohms.

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of sockets to accommodate all types of receiver tubes in use, wired together according to standard pin numbering, with each of the nine possible contacts brought out to pin jacks or terminals on the panel. The sockets, transformer, meter, and filament switch of an old emission tester could be adapted to the purpose.

**PATCH-CORD SYSTEM**

This is essentially a technician's instrument and switching arrangements would be complicated and costly. Therefore, with the exception of the filament, no switching arrangement was considered. Instead pin jacks and pin tip leads are used to make the various connections externally. This gives the instrument complete flexibility and freedom from obsolescence unless new types of sockets are brought out, at which time they could easily be added.

Referring to Figure 3, it will be seen that the instrument must be used with a tube manual for the application of proper voltages to the output pins and to find the Sm to be expected under these conditions unless the builder prefers to make a complete list of pin numbers, voltages and Sm to be expected. The writer found it simpler to enter the bias setting and Sm in the tube manual.

Calibration of new scales for the Sm meter is carried out with known good tubes. The procedure will vary with the type of D.C. milliammeter used. Let us assume that it is a 0-6 Ma. This should give us a range up to 6000 µMhos. First we set R1 to apply one volt peak between cathode and grid. This should be measured with a V.T.V.M. if resistance of R1 is high. If one is not available calculate it from the output of T1 and the resistance ratio of R1:

\[ E_g = \frac{E_p}{\beta} \]

when Eg is signal output, E1 is transformer output and equals 1.441 times voltage measured on ordinary meter; x and y are values in ohms either side of tap.

Insert a known good tube, say a 6C5, and apply voltages for an Sm of 2000 µMhos. If the output circuit were completely efficient a reading of about 2 Ma should be obtained. In any case, mark the scale for 2000 µMhos. Similarly, repeat with say a 615 for 3000 µMhos, a 27 for 1000, a 6V6 for 4000 and so on. By consulting the tube manual, tubes with other values can be chosen and different tubes with the same Sm used for a double-check of the calibration, which should be fairly linear.

Some constructors may prefer to put R1 on the front panel and log an arbitrary value for each tube which will give it the correct Sm reading to correspond to the manual data for given conditions. It should also be mentioned that the bias control R4 can be used to vary the output reading.

If a 1 or 2 Ma. meter is used it would be best to have two or even three scales, increasing the meter's range with a switch and shunts. In the case of a heavy current meter of 10 Ma. or more it would be advisable to increase the input signal voltage to give full scale deflection for 6000 µMhos reading. An Sm scale of 0-3000 will handle the great majority of tubes; in fact all but about twenty. A 0-6000 µMhos scale will take care of such as the 25L6 and 6N5 and 6Y6. The 1633 is highest with an Sm of 10,000. The builder can decide whether or not it is justifiable to extend the ranges in order to measure these tubes at their full rated value.

**CONSTANT VOLTAGE NEEDED**

It is of course essential to hold all voltages constant, hence, rheostat R7, capable of dissipating 30 to 40 watts. If an A.C. voltmeter is not available it can be wound on any power transformer with a good 110 V. primary. The voltage is stepped up to 250 V and then regulated down to 125 V. It is advisable to filter the output of the transformer with a heavy copper tape. Pin tips were made from tape.

No provision was made for emission or short tests since it would further complicate the circuit and it is assumed that a conventional emission test is available for such tests. However, the output circuit could be modified as shown in Figure 2 to provide emission tests by throwing S1. The switch is double-pole double-throw type. When used for emission tests the meter shunt R6 is connected across the meter to give it a suitable range and the meter is inserted in series with the plate supply. Emission tests correspond with manual data for given voltages. The meter should cover from a few mls to at least 60, and it may be desired to add another shunt and switch to give more easily read ranges. Hooked up as straight emission tester, tubes can be checked quickly enough to permit its use in a commercial radio service shop. When more precise measurements are required, it becomes a transconductance tester with the flip of a switch.
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