QUESTIONS AND ANSWERS

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AUDELS NEW ELECTRIC LIBRARY

VOL. IX

FOR ENGINEERS, ELECTRICIANS
ALL ELECTRICAL WORKERS
MECHANICS AND STUDENTS

Presenting in simplest, concise form the fundamental principles, rules and applications of applied electricity.

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Based on the best knowledge and experience of applied electricity.

by FRANK D. GRAHAM, B.S., M.S., M.E., E.E.

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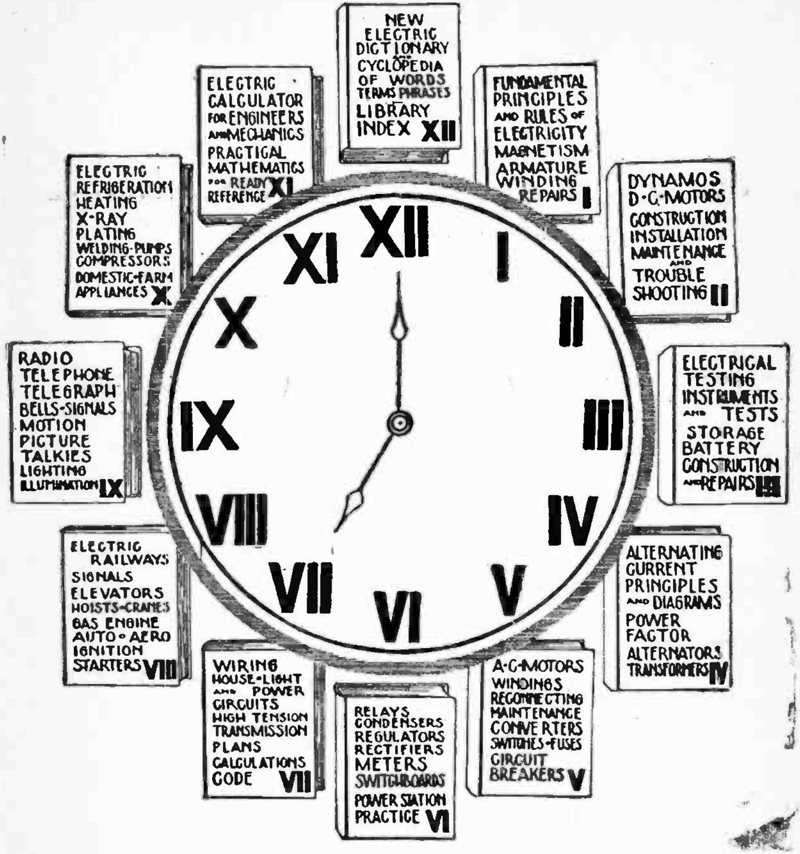

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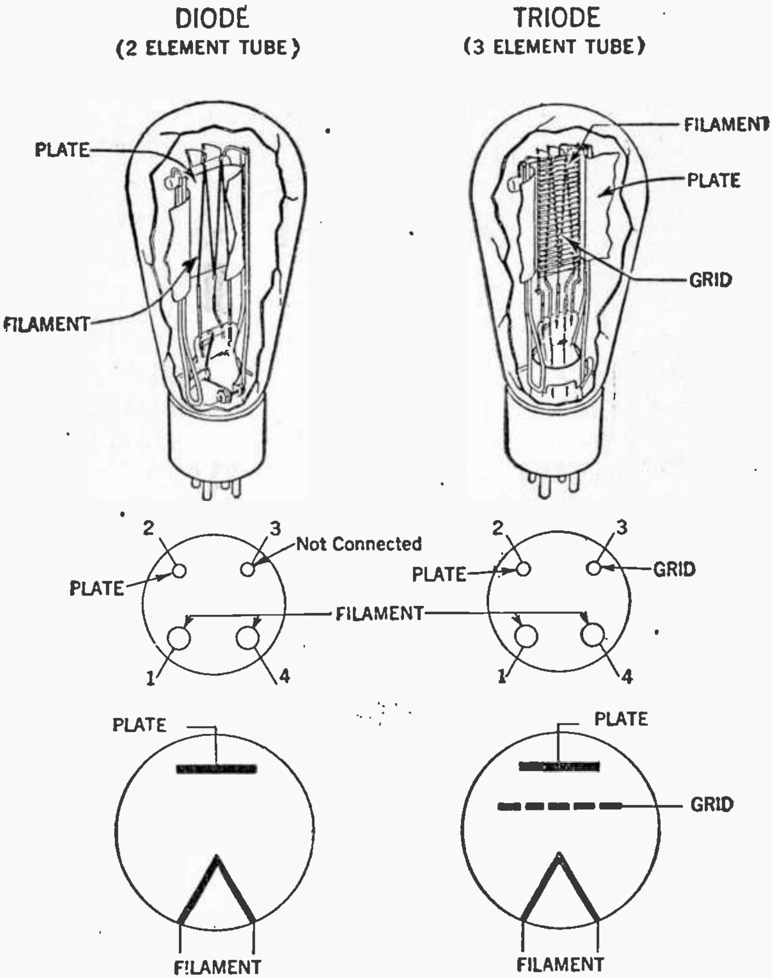

Views of two and three element vacuum tubes showing arrangement of prongs and wiring symbols

Foreword

This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

The author, following the popular appeal for practical knowledge, has prepared this progressive series for the electrical worker and student; for all who are seeking electrical knowledge as a life profession; and for those who find that there is a gap in their training and knowledge of Electricity.

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The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

The series will speak for itself and "those who run may read."

The Publishers.

How to Use This Book

Finder

IMPORTANT

To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

Each chapter is progressive, so that if the reader will use the outline following each general chapter heading, he will readily come to the information desired and the page on which to find it.

Get the habit of using this Index—it will quickly reveal a vast mine of valuable information.

"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."

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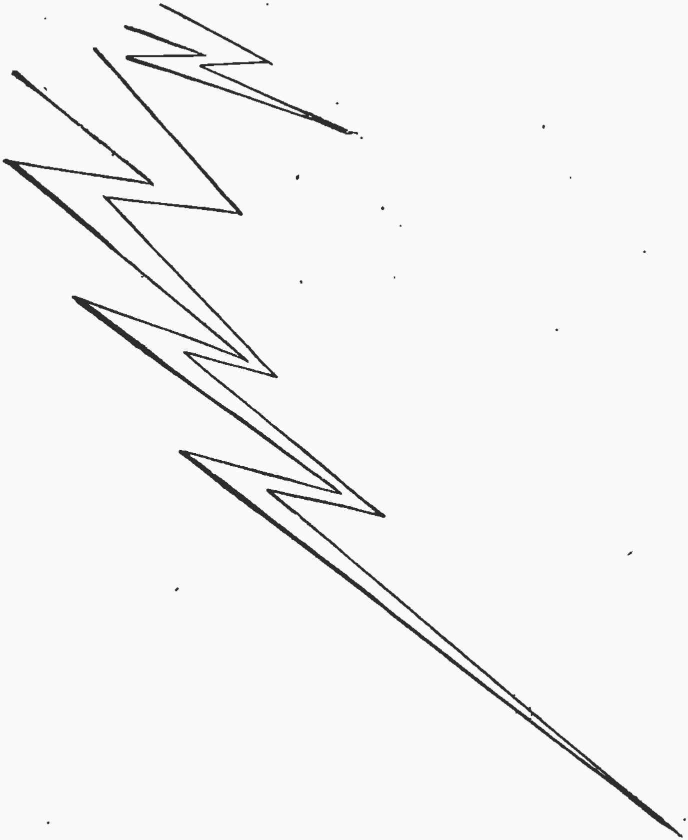

CHAPTER 174

Radio Principles

Dr. Albert Einstein discards the theory of the ether usually presented by writers in an attempt to explain radio transmission. Dr. Einstein derides radio's ethereal medium as fiction, calling it a makeshift fabricated to explain something for which scientists have not had the correct explanation. Einstein believes it is *an electro-magnetic phenomenon;* so did Charles Proteus Steinmetz.

Shortly before his death Steinmetz said: "*There are no ether waves.*" He explained that radio and light waves are merely properties of an alternating electro-magnetic field of force which extends through space. Scientists, he contended, need no idea of ether. They can think better in the terms of electro-magnetic waves.

If a coil of insulated wire surround a piece of soft iron and a direct current be sent through the coil, it is called an electromagnet. The space around the coil is the magnetic field. When the current is increased the magnetic field increases. When the current is decreased the breadth of the field is reduced. If the current be reversed, the field is reversed. When an alternating current is sent through the coil the magnetic field alternates. The field becomes a periodic phenomenon or a wave, described by Steinmetz as "an alternating magnetic field wave."

Steinmetz, like Einstein, pointed out that the conception of the ether is one of those hypotheses made in an attempt to explain some scientific difficulty. He declared that the more study is applied to the ether theory the more unreasonable and untenable it becomes. He held it to be merely conservatism or lack of courage which has kept science from abandoning the ethereal hypothesis.

Steinmetz called attention to the fact that belief in an ether is in contradiction to the relativity theory of Einstein, since this theory holds that there is no absolute position or motion, but that all positions and motions are relative and equivalent. Thus, if science agreed that the theory of relativity is correct the ether theory must be abandoned.

No space will be wasted here in talking about ether waves. The space surrounding a wire that carries an electric current *is an electro-magnetic field*, that is, *a combination of a magnetic field and an electrostatic field.*

If the current and voltage alternate, the electro-magnetic field alternates; that is, it is a periodic field or an electro-magnetic wave. Thus, the broadcast listener who wants to forget the ether can think of the aerial wire at the transmitter, setting up electro-magnetic waves in a field of electric force, which now, the theories contend, fills all space and therefore every receiving wire is within the field. This field, however, is supposed to be in a state of rest until the broadcast transmitter causes it to vibrate.

The action of the transmitter is like tapping a mold of jello. Waves pass through it, and so radio waves are produced in the electro-magnetic field.

The transmitter taps the hypothetical medium, causing it to vibrate. The receiving set is designed to detect the vibrations and so intelligence is carried from one point to another.

It is well known that a stone thrown into a pond **causes** *ripples or waves on the surface of the water, which move away*

NOTE.—***As stated by Dr. Lee de Forest:*** Radio is simply a cause and an effect. The *cause* is the radio transmitter. It makes an electro-magnetic splash that sets up radio waves. These waves travel through space in all directions. The *effect* is the setting up of delicate currents in the aerial or loop. These delicate currents are detected and converted into audible sounds by means of the radio receiving set. Imagine a boy operating a paddle at one end of a pond of still water. Ripples are set up in the water. They travel farther and farther away from the paddle, getting weaker as they move along until they reach a piece of wood which bobs up and down as it rides the waves. Put a bell on the piece of wood, in order that it will ring with the action of the waves, this illustrates the mechanical parallel of radio communication.

from the point of disturbance in concentric circles of ever increasing diameters until they reach the shore. The number of waves breaking on the shore in one second is called the *frequency* of the wave motion, and the distance between them measured from crest to crest, is the *wave length.*

The waves are strongest at the point of disturbance and gradually become weaker as they travel away from that point, as shown in figs. 7,180 and 7,181. If the distance be sufficiently great they will become so weak as to be invisible.

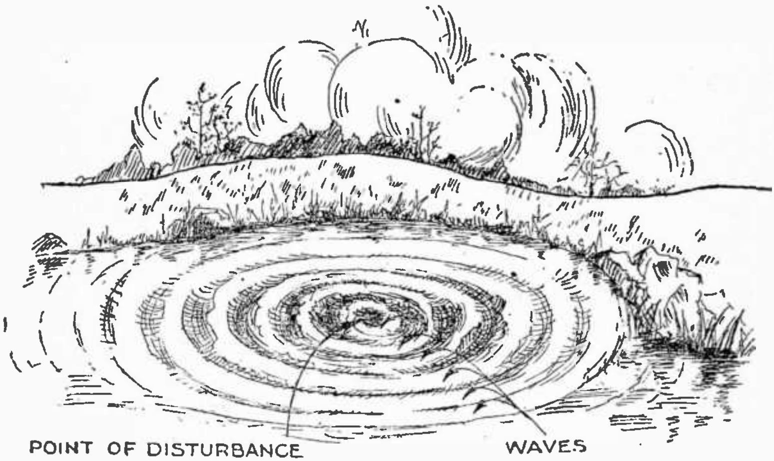

FIG. 7,180.—Effect of throwing stone in still water; production of waves which radiate or travel from the point where stone enters the water, or "point of disturbance."

NOTE.—*According to Marconi radio waves go to outer space.* In his inaugural address at the second meeting of the Italian Society for the Advancement of Science Sept. 11, 1930, Sen. Guglielmo Marconi expressed belief that radio waves may travel long distances, even millions of miles, beyond the earth's atmospheric layer. He said that he did not see any reason why, as some scientists maintain, waves produced on the earth should not travel such a distance, since light and heat waves reach the earth from the sun, penetrating the atmospheric layer. He referred to observations of such scientists as Stormer and Pedersen and commented that the former had said that electrified particles derived from the sun and under the magnetic influence of the earth acted as a reflector of electric waves from the earth after they had passed the so called Kenelly-Heaviside layer.

Radio communication as has been explained is *a form of wave motion which occurs in an electro-magnetic field, these waves acting in a similar manner to water waves.*

In radio communication it is first necessary to create electro-magnetic waves in varying groups and of varying strength, and second to intercept them with apparatus capable of changing them to sound waves.

To create the waves it is necessary to have two surfaces separated by a distance of from ten to several hundred feet and to create between them an electrical pressure which changes its direction (first toward one surface then toward the other) hundreds of thousands of times a second.

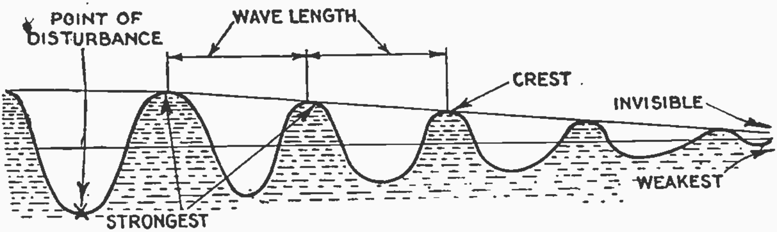

FIG. 7,181.—Sectional view of waves produced by throwing stone in still water, illustrating crest of wave, wave length and gradual weakening of the waves as they travel from the point of disturbance.

It is the common practice to use the ground for one surface and provide another surface by erecting a structure composed of one or more wires, insulated from the earth and suspended many feet above it.

Between these, by means of suitable transmitting equipment an electrical pressure is produced of from one to twenty volts which starts waves radiating out in all directions. These pressure waves are, however, only part of a radio wave. From any wire in which current is flowing are radiated electro-magnetic waves and radio waves are made up then, of both electro-magnetic and pressure electrostatic waves.

Comparing these waves to the action of hurling a rock into a pool of water, the amperes of electric current put into the antenna correspond to the size of the rock, while the volts of electrical pressure are equivalent to the force with which the rock is hurled. The larger the rock and the greater the force behind it, the bigger the splash and consequent waves. The more amperes of current flowing in the antenna circuit and the greater the pressure (volts) between antenna and ground, the stronger the waves radiated. These radio waves have similar characteristics to another class of waves—sound waves.

When the note C is struck on the piano (as in fig. 7,182) the sound waves vibrate 256 times per second and either a C tuning fork or a wire tuned to C and in the immediate vicinity will vibrate 256 times per second also. The two wires are said to be in resonance.

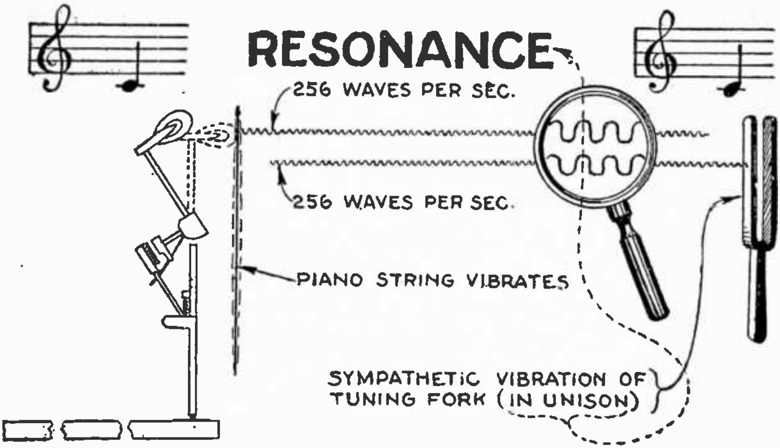

FIG. 7,182.—Sympathetic vibration of tuning fork with struck piano string when tuned to same pitch, illustrating the wave theory of radio.

The waves radiated by a radio transmitter always have a definite number per second and in order to hear a station, the receiving equipment must be put in resonance with the waves radiated by the transmitter. This operation is known as tuning.

Technical Terms.—For the convenience of the student definitions of the terms commonly used are here given; the list should be used as a reference in studying the text.

RADIO FREQUENCIES AND CORRESPONDING WAVE LENGTHS.

Frequency in KILOCYCLES	Wave Length in METERS	Frequency in KILOCYCLES	Wave Length in METERS
300,000	1	1,200	250
150,000	2	1,150	261
100,000	3	1,100	273
75,000	4	1,050	286
60,000	5	1,000	300
50,000	6	950	316
40,000	8	900	333
30,000	10	850	353
25,000	12	800	375
20,000	15	750	400
15,000	20	700	429
12,000	25	650	462
10,000	30	600	500
8,000	38	550	545
6,000	50	500	600
5,000	60	450	667
4,000	75	400	750
3,000	100	350	857
2,500	120	300	1,000
2,000	150	250	1,200
1,700	177	200	1,500
1,600	188	150	2,000
1,500	200	100	3,000
1,450	206	50	6,000
1,400	214	40	7,500
1,350	222	30	10,000
1,300	231	20	15,000
1,250	240	10	30,000

To convert frequency to wave length and wave length to frequency, the following formulas are used:

$$\text{Wave length} = \frac{300{,}000{,}000}{\text{frequency (cycles per second)}}$$

$$\text{Frequency} = \frac{300{,}000{,}000}{\text{wave length (in meters)}}$$

Kilocycles = 1000 cycles

Radio Principles Questions and Answers

What is meant by an "A" power supply?

Ans. A power supply device providing heating current for the cathode of a vacuum tube.

What is an alternating current?

Ans. A current, the direction of which reverses at regularly recurring intervals, the algebraic average value being zero.

What is meant by amplification factor?

Ans. A measure of the effectiveness of the grid voltage relative to that of the plate voltage in affecting the plate current.

Describe an amplifier.

Ans. A device for increasing the amplitude of electric current, voltage or power, through the control by the input power of a larger amount of power supplied by a local source to the output circuit.

What is an anode?

Ans. An electrode to which an electron stream flows.

What is an antenna?

Ans. A conductor or a system of conductors for radiating or receiving radio waves.

What is meant by the term atmospherics?

Ans. Strays produced by atmospheric conditions.

Describe what is meant by attenuation.

Ans. The reduction in power of a wave or a current with increasing distance from the source of transmission.

What is the approximate length of audio frequency waves?

Ans. A frequency corresponding to a normally audible sound wave. The upper limit ordinarily lies between 10,000 and 20,000 cycles per second.

What is an audio frequency transformer?

Ans. A transformer for use with audio frequency currents.

What is meant by autodyne reception?

Ans. A system of heterodyne reception through the use of a device which is both an oscillator and a detector.

Describe an automatic volume control device.

Ans. A self-acting device which maintains the output constant within relatively narrow limits while the input voltage varies over a wide range.

What is meant by a "B" power supply?

Ans. A power supply connected in the plate circuit of a vacuum tube.

Describe and give the function of a "Baffle."

Ans. A partition which may be used with an acoustic radiator to impede circulation between front and back.

Describe a band-pass filter.

Ans. A filter designed to pass currents of frequencies within a continuous band limited by an upper and a lower critical or cut-off frequency and substantially reduce the amplitude of currents of all frequencies outside of that band.

What is meant by the term "Beat"?

Ans. A complete cycle of pulsations in the phenomenon of beating.

What is meant by beat-frequency?

Ans. The number of beats per second. This frequency is equal to the difference between the frequencies of the combining waves.

What is meant by the term beating?

Ans. A phenomenon in which two or more periodic quantities of different frequencies react to produce a resultant having pulsations of amplitude.

What is meant by broadcasting?

Ans. Radio transmission intended for general reception.

Describe a by-pass condenser.

Ans. A condenser used to provide an alternating current path of comparatively low impedance around some circuit element.

What is meant by a "C" power supply?

Ans. A power supply device connected in the circuit between the cathode and grid of a vacuum tube so as to apply a grid bias.

What is meant by a capacity coupling?

Ans. The association of one circuit with another by means of capacity common or mutual to both.

Describe a carbon microphone.

Ans. A microphone which depends for its operation upon the variation in resistance of carbon contacts.

Describe the meaning of the term carrier.

Ans. A term broadly used to designate carrier wave, carrier current or carrier voltage.

What is meant by carrier frequency?

Ans. The frequency of a carrier wave.

What is meant by carrier-suppression?

Ans. That method of operation in which the carrier wave is not transmitted.

What is a carrier wave?

Ans. A wave which is modulated by a signal and which enables the signal to be transmitted through a specific physical system.

What is a cathode?

Ans. The electrode from which the electron stream flows.

Describe and give the function of a choke coil.

Ans. An inductor inserted in a circuit to offer relatively large impedance to alternating current.

Describe a condenser loud speaker.

Ans. A loud speaker in which the mechanical forces result from electrostatic reactions.

Describe a condenser microphone.

Ans. A microphone which depends for its operation upon variations in capacitance.

What is meant by continuous waves?

Ans. Continuous waves are waves in which successive cycles are identical under steady state conditions.

Define the meaning of Conversion transconductance.

Ans. The ratio of the magnitude of a single beat-frequency component (f_1+f_2) or (f_1-f_2) of the output current to the magnitude of the input voltage of frequency f_1 under the conditions that all direct voltages and the magnitude of the second input alternating voltage f_2 must remain constant. As most precisely used, it refers to an infinitesimal magnitude of the voltage of frequency f_1.

Describe a converter generally as applied to super-heterodyne receivers.

Ans. A converter is a vacuum tube which performs simultaneously the functions of oscillation and mixing (first detection) in a radio receiver.

What is meant by coupling?

Ans. The association of two circuits in such a way that energy may be transferred from one to the other.

What is meant by cross modulation?

Ans. A type of intermodulation due to modulation of the carrier of the desired signal in a radio apparatus by an undesired signal.

What is meant by current amplification?

Ans. The ratio of the alternating current produced in the output circuit of an amplifier to the alternating current supplied to the input circuit for specific circuit conditions.

What is a cycle?

Ans. One complete set of the recurrent values of periodic phenomenon.

What are damped waves?

Ans. Waves of which the amplitude of successive cycles at the source, progressively diminishes.

What is a decibel?

Ans. The common transmission unit of the decimal system, equal to 1/10 bel.

$$1 \text{ bel} = 2 \log_{10} \frac{E_1}{E_2} = 2 \log_{10} \frac{I_1}{I_2}$$

What is meant by detection?

Ans. Any process of operation on a modulated signal wave to obtain the signal imparted to it in the modulation process.

What is a detector?

Ans. A device which is used for operation on a signal wave to obtain the signal imparted to it in the modulation process.

Describe a diode vacuum tube.

Ans. A type of thermionic tube containing two electrodes which passes current wholly or predominantly in one direction.

What is meant by direct capacitance (C) between two conductors?

Ans. The ratio of the charge produced on one conductor by the voltage between it and the other conductor divided by this voltage, all other conductors in the neighborhood being at the potential of the first conductor.

What is meant by direct coupling?

Ans. The association of two circuits by having an inductor, a condenser, or a resistor common to both circuits.

What is a direct current?

Ans. An unidirectional current. As ordinarily used, the term designates a practically non-pulsating current.

Describe what is meant by distortion.

Ans. A change in wave form occurring in a transducer or transmission medium when the output wave form is not a faithful reproduction of the input wave form.

What is meant by double modulation?

Ans. The process of modulation in which a carrier wave of one frequency is first modulated by the signal wave and is then made to modulate a second carrier wave of another frequency.

Describe an R.C.A. dynamic amplifier.

Ans. This is a variable gain audio amplifier, the gain of which is proportional to the average intensity of the audio signal. Such an amplifier compensates for the contraction of volume range required because of recording or transmission line limitations.

What is meant by the dynamic sensitivity of a phototube?

Ans. The alternating current response of a phototube to a pulsating light flux at specified values of mean light flux, frequency of pulsation, degree of pulsation, and steady tube voltage.

What is an electro-acoustic transducer?

Ans. A transducer which is actuated by power from an electrical system and supplies power to an acoustic system or vice versa.

Describe what is meant by electron emission.

Ans. The liberation of electrons from an electrode into the surrounding space. In a vacuum tube it is the rate at which the electrons are emitted from a cathode. This is ordinarily measured as the current carried by the electrons under the influence of a voltage sufficient to draw away all the electrons.

What is an electron tube?

Ans. A vacuum tube evacuated to such a degree that its electrical characteristics are due essentially to electron emission.

What is meant by emission characteristics?

Ans. A graph plotted between a factor controlling the emission (such as the temperature voltage or current of the cathode) as abscissas, and the emission from the cathode as ordinates.

What is meant by facsimile transmission?

Ans. The electrical transmission of a copy or reproduction of a picture, drawing or document. This is also called picture transmission.

What is fading?

Ans. The variation of the signal intensity received at a given location from a radio transmitting station as a result of changes occurring in the transmission path.

What is meant by fidelity?

Ans. The degree to which a system, or a portion of a system, accurately reproduces at its output the signal which is impressed upon it.

What is a filament?

Ans. A cathode in which the heat is supplied by current passing through the cathode.

Generally define and give the function of a filter.

Ans. A selective circuit network, designed to pass currents within a continuous band or bands of frequencies or direct current, and substantially reduce the amplitude of currents of undesired frequencies.

What is meant by the term frequency?

Ans. The number of cycles per second.

Describe a full-wave rectifier.

Ans. A double element rectifier arranged so that current is allowed to pass in the same direction to the load circuit during each half cycle of the alternating current supply, one element functioning during one-half cycle and the other during the next half cycle, and so on.

What is meant by fundamental frequency?

Ans. The lowest component frequency of a periodic wave or quantity.

What is meant by fundamental or natural frequency of an antenna?

Ans. The lowest resonant frequency of an antenna, without added inductance or capacity.

What is a gas phototube?

Ans. A type of phototube in which a quantity of gas has been introduced usually for the purpose of increasing its sensitivity.

What is a grid?

Ans. An electrode having openings through which electrons or ions may pass.

What is meant by grid bias?

Ans. The direct component of the grid voltage.

What is a grid condenser?

Ans. A series condenser in the grid or control circuit of a vacuum tube.

What is a grid leak?

Ans. A resistor in a grid circuit, through which the grid current flows, to affect or determine a grid bias.

What is meant by the grid-plate transconductance?

Ans. The name for the plate current to grid voltage transconductance. This has also been called mutual conductance.

Describe a ground system of an antenna.

Ans. That portion of the antenna system below the antenna loading devices or generating apparatus most closely associated with the ground and including the ground itself.

What is a ground wire?

Ans. A conductive connection to the earth.

Describe a half-wave rectifier.

Ans. A rectifier which changes alternating current into pulsating current, utilizing only one-half of each cycle.

What is meant by a harmonic?

Ans. A component of a periodic quantity having a frequency which is an integral multiple of the fundamental frequency. For example, a component the frequency of which is twice the fundamental frequency is called the second harmonic.

Describe a heater.

Ans. An electrical heating element for supplying heat to an indirectly heated cathode.

Describe heterodyne reception.

Ans. The process of receiving radio waves by combining in a detector a received voltage with a locally generated alternating voltage. The frequency of the locally generated voltage is commonly different from that of the received voltage. Heterodyne reception is sometimes called beat reception.

What is meant by homodyne reception?

Ans. A system of reception by the aid of a locally generated voltage of carrier frequency. Homodyne reception is sometimes called zero-beat reception.

Describe an expansion type hot-wire ammeter.

Ans. An ammeter dependent for its indications on a change in dimensions of an element which is heated by the current to be measured.

What is meant by an indirectly heated cathode?

Ans. A cathode of a thermionic tube in which heat is supplied from a source other than the cathode itself.

Describe an induction loud speaker.

Ans. It is a moving coil loud speaker in which the current which reacts with the polarizing field is induced in the moving member.

What is meant by inductive coupling?

Ans. The association of one circuit with another by means of inductance common or mutual to both.

What is meant by interelectrode capacitance?

Ans. The direct capacitance between two electrodes.

Describe what is meant by interference.

Ans. Disturbance of reception due to strays, undesired signals, or other causes; also that which produces the disturbance.

What is meant by intermediate frequency in superheterodyne reception?

Ans. A frequency between that of the carrier and the signal, which results from the combination of the carrier frequency and the locally generated frequency.

What is meant by intermodulation?

Ans. The production in a non-linear circuit element, of frequencies corresponding to the sums and differences of the fundamentals and harmonics of two or more frequencies which are transmitted to that element.

Describe what is meant by interrupted continuous waves.

Ans. These are waves obtained by interruption at audio frequency in a substantially periodic manner of otherwise continuous waves.

What constitutes an ion?

Ans. It is an atom or molecule having an electrical charge either positive or negative.

What does the term "kilocycle" stand for?

Ans. When used as a unit of frequency, it is one-thousand cycles per second.

Describe a lead-in.

Ans. That portion of an antenna system which completes the electrical connection between the elevated outdoor portion and the instruments or disconnecting switches inside the building.

What is meant by linear detection?

Ans. That form of detection in which the audio output voltage under consideration is substantially proportional to the modulation envelope throughout the useful range of the detecting device.

Describe and give the function of a loading coil.

Ans. An inductor inserted in a circuit to increase its inductance but not to provide coupling with any other circuit.

What is generally meant by a loud speaker?

Ans. A telephone receiver or apparatus designed to radiate acoustic power into a room or open air.

What is meant by a magnetic loud speaker?

Ans. One in which the mechanical forces result from magnetic reactions.

What is a magnetic microphone?

Ans. A microphone whose electrical output results from the motion of a coil or conductor in a magnetic field.

Describe a master oscillator.

Ans. An oscillator of comparatively low power so arranged as to establish the carrier frequency of the output of an amplifier.

How many cycles per second is one megacycle?

Ans. When used as a unit of frequency, it is one million cycles per second.

Describe a mercury-vapor rectifier.

Ans. A mercury-vapor rectifier is a two electrode, vacuum-tube rectifier which contains a small amount of mercury. During operation, the mercury is vaporized. A characteristic of mercury-vapor rectifiers is the low voltage drop in the tube.

Describe a microphone.

Ans. A microphone is an electro-acoustic transducer actuated by power in an acoustic system and delivering power to an electric system, the wave form in the electric system corresponding to the wave form in the acoustic system. This is also called a telephone transmitter.

What is generally understood by a "Mixer tube" in superheterodyne receivers?

Ans. A mixer tube is one in which a locally generated frequency is combined with the carrier signal frequency to obtain a desired beat frequency.

What is a modulated wave?

Ans. A wave of which either the amplitude, frequency or phase is varied in accordance with a signal.

Describe what is meant by modulation.

Ans. Modulation is the process in which the amplitude, frequency or phase of a wave is varied in accordance with a signal, or the result of that process.

Describe what is meant by monochromatic sensitivity.

Ans. The response of a phototube to light of a given color, or narrow frequency range.

What is a moving-armature speaker?

Ans. A magnetic speaker whose operation involves the vibration of a portion of the ferromagnetic circuit. This is sometimes called an electromagnetic or a magnetic speaker.

Describe a moving coil loud speaker.

Ans. A moving coil loud speaker is a magnetic loud speaker in which the mechanical forces are developed by the interaction of currents in a conductor and the polarizing field in which it is located. This is sometimes called an electro-dynamic or a dynamic loud speaker.

What is meant by Mu-factor?

Ans. A measure of the relative effect of the voltages on two electrodes upon the current in the circuit of any specified electrode. It is the ratio of the change in one electrode voltage to a change in the other electrode voltage, under the condition that a specified current remains unchanged.

What is an oscillator?

Ans. A non-rotating device for producing alternating current, the output frequency of which is determined by the characteristics of the device.

Describe an oscillatory circuit.

Ans. A circuit containing inductance and capacitance, such that a voltage impulse will produce a current which periodically reverses.

Describe a pentode tube.

Ans. A type of thermionic tube containing a plate, a cathode, and three additional electrodes. Ordinarily the three additional electrodes are of the nature of grids.

What is meant by percentage modulation?

Ans. The ratio of half the difference between the maximum and minimum amplitudes of a modulated wave to the average amplitude, expressed in per cent.

Describe a phonograph pickup.

Ans. An electro-mechanical transducer actuated by a phonograph record and delivering power to an electrical system, the wave form in the electrical system corresponding to the wave form in the phonograph record.

What is a phototube?

Ans. A vacuum tube in which electron emission is produced by the illumination of an electrode. This has also been called photoelectric tube.

What is meant by the plate in a vacuum tube?

Ans. A common name for the principal anode.

Describe what is meant by power amplification of an amplifier.

Ans. The ratio of the alternating current power produced in the output circuit to the alternating current power supplied to the input circuit.

What is meant by power detection?

Ans. That form of detection in which the power output of the detecting device is used to supply a substantial amount of power directly to a device such as a loud speaker or recorder.

Describe what is meant by pulsating current.

Ans. A periodic current, that is, current passing through successive cycles, the algebraic average value of which is not zero. A pulsating current is equivalent to the sum of an alternating and a direct current.

What is a push-pull microphone?

Ans. One which makes use of two functioning elements 180 degrees out of phase.

Define the term radio-channel.

Ans. A band of frequencies or wave-lengths of a width sufficient to permit of its use for radio communication. The width of a channel depends upon the type of transmission.

What is a radio compass?

Ans. A direction finder used for navigational purposes.

Describe what is meant by radio frequency.

Ans. A frequency higher than those corresponding to normally audible sound waves.

What is a radio-frequency transformer?

Ans. A transformer for use with radio-frequency currents.

What is a radio receiver?

Ans. A device for converting radio waves into perceptible signals.

Describe what is meant by radio transmission.

Ans. The transmission of signals by means of radiated electro-magnetic waves originating in a constructed circuit.

What is a radio transmitter?

Ans. A device for producing radio-frequency power, with means for producing a signal.

Describe a rectifier.

Ans. A device having an asymmetrical conduction characteristic which is used for the conversion of an alternating current into a pulsating current. Such devices include vacuum-tube rectifiers, gas rectifiers, oxide rectifiers, electrolytic rectifiers, etc.

What is meant by a Reflex circuit arrangement?

Ans. A circuit arrangement in which the signal is amplified, both before and after detection, in the same amplifier tube or tubes.

Describe what is meant by regeneration.

Ans. The process by which a part of the output power of an amplifying device reacts upon the input circuit in such a manner as to reinforce the initial power, thereby increasing the amplification. This is sometimes called "feedback" or "reaction".

What is a resistance coupling?

Ans. The association of one circuit with another by means of resistance common to both.

What is meant by the term "resonance frequency" of a reactive circuit?

Ans. The frequency at which the supply current and supply voltage of the circuit are in phase.

Describe a rheostat.

Ans. A resistor which is provided with means for readily adjusting its resistance.

What is the function of the screen grid in a vacuum tube?

Ans. A screen grid is a grid placed between a control grid and an anode, and maintained at a fixed positive potential, for the purpose of reducing the electrostatic influence of the anode in the space between the screen grid and the cathode.

What is secondary emission?

Ans. Electron emission under the influence of electron or ion bombardment.

What is meant by the term selectivity?

Ans. The degree to which a radio receiver is capable of differentiating between signals of different carrier frequencies.

What is meant by sensitivity?

Ans. The degree to which a radio receiver responds to signals of the frequency to which it is tuned.

Describe sensitivity as applied to the photo-electric tube.

Ans. The electrical current response of a phototube with no impedance in its external circuit, to a specified amount and kind of light. It is usually expressed in terms of the current for a given radiant flux, or for a given luminous flux. In general the sensitivity depends upon the tube voltage, flux intensity, and spectral distribution of the flux.

What is meant by the term "service band"?

Ans. A band of frequencies allocated to a given class of radio communication service.

What is meant by the term "side band"?

Ans. The bands of frequencies, one on either side of the carrier frequency, produced by the process of modulation.

What is a signal?

Ans. The intelligence, message or effect conveyed in communication.

Describe what is meant by single-side band transmission.

Ans. That method of operation in which one side band is transmitted, and the other side band is suppressed. The carrier wave may be either transmitted or suppressed.

What is static?

Ans. Strays produced by atmospheric conditions.

What is meant by the static sensitivity of a phototube?

Ans. The direct current response of a phototube to a light flux of specified value.

Describe a stopping condenser.

Ans. A condenser used to introduce a comparatively high impedance in some branch of a circuit for the purpose of limiting the flow of low-frequency alternating current or direct current without materially affecting the flow of high frequency alternating current.

What is meant by the term "strays"?

Ans. Electromagnetic disturbances in radio reception other than those produced by radio transmitting systems.

Describe superheterodyne reception.

Ans. Superheterodyne reception is a method of reception in which the received voltage is combined with the voltage from a local oscillator and converted into voltage of an intermediate frequency which is usually amplified and then detected to reproduce the original signal wave. This is sometimes called double detection or supersonic reception.

What is meant by the term "swinging"?

Ans. The momentary variation in frequency of a received wave.

Describe a telephone receiver.

Ans. An electro-acoustic transducer actuated by power from an electrical system and supplying power to an acoustic system, the wave form in the acoustic system corresponding to the wave form in the electrical system.

What is television?

Ans. The electrical transmission of a succession of images and their reception in such a way as to give a substantially continuous reproduction of the object or scene before the eye of a distant observer.

Describe a tetrode vacuum tube.

Ans. A type of thermionic tube containing a plate, a cathode, and two additional electrodes. Ordinarily the two additional electrodes are of the nature of grids.

What is meant by the term thermionic?

Ans. It is a term relating to electron emission under the influence of heat.

Describe what is meant by thermionic emission.

Ans. Electron or ion emission under the influence of heat.

Describe a thermionic vacuum tube.

Ans. An electron tube in which the electron emission is produced by the heating of an electrode.

How does a thermo-couple ammeter operate?

Ans. An ammeter dependent for its indications on the change in thermo-electro-motive force set up in a thermo-electric couple, which is heated by the current to be measured.

What is meant by the term "total emission"?

Ans. The value of the current carried by electrons emitted from a cathode under the influence of a voltage such as will draw away all the electrons emitted.

What is meant by transconductance?

Ans. The ratio of the change in the current in the circuit of an electrode to the change in the voltage on another electrode, under the condition that all other voltages remain unchanged.

Describe a transducer.

Ans. A device actuated by power from one system and supplying power to another system. These systems may be electrical, mechanical or acoustic.

What is a transmission unit?

Ans. A unit expressing the logarithmic ratios of powers, voltages, or currents in a transmission system.

Describe a triode vacuum tube.

Ans. A type of thermionic tube containing an anode, a cathode, and a third electrode, in which the current flowing between the anode and the cathode may be controlled by the voltage between the third electrode and the cathode.

Describe a tuned transformer.

Ans. A transformer whose associated circuit elements are adjusted as a whole to be resonant at the frequency of the alternating current supplied to the primary, thereby causing the secondary voltage to build up to higher values than would otherwise be obtained.

What is tuning?

Ans. The adjustment of a circuit or system to secure optimum performance in relation to a frequency; commonly, the adjustment of a circuit or circuits to resonance.

What constitutes a vacuum?

Ans. Vacuum is absolutely nothing, if we can conceive of such a thing. The degree of vacuum is measured in microns, one micron represents one-millionth part of the usual atmospheric pressure which is approximately 14.7 pounds per square inch. Thus a perfect vacuum would be zero microns; such a state is however only a theoretical ideal that can never be realized even with the most perfect laboratory technique.

Describe a vacuum phototube.

Ans. A type of phototube which is evacuated to such a degree that the residual gas plays a negligible part in its operation.

What is a vacuum tube?

Ans. A device consisting of a number of electrodes contained within an evacuated enclosure.

What is a vacuum tube transmitter?

Ans. A radio transmitter in which vacuum tubes are utilized to convert the applied electric power into radio-frequency power.

Describe a vacuum tube volt-meter.

Ans. A device utilizing the characteristics of a vacuum tube for measuring alternating voltages.

Define voltage amplification.

Ans. The ratio of the alternating voltage produced at the output terminals of an amplifier to the alternating voltage impressed at the input terminals.

What is a voltage divider?

Ans. A resistor provided with fixed or movable contacts and with two fixed terminal contacts; current is passed between the terminal contacts and a desired voltage is obtained across a portion of the resistor. The term potentiometer is often erroneously used for this device.

Generally what is meant by the term "Wave"?

Ans. *a.* A propagated disturbance, usually periodic, as an electric wave or sound wave. *b.* A single cycle of such a disturbance, or *c.* A periodic variation as represented by a graph.

Describe what is meant by wavelength.

Ans. The distance traveled in one period or cycle by a periodic disturbance.

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
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5	• • • • •
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7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report*(to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

CHAPTER 174-A

Power Supply Units

Receiver power supplies generally may be classified as follows.

1. The *a.c.* supply group which operate from alternating current only.

2. The *d.c.* supply group which operate from direct current only.

3. The *a.c.* and *d.c.* supply group which furnish power to "A" and "B" batteries from either alternating or direct current.

A.C. Supply Systems.—The power supply in this group generally consist of a power transformer, rectifier tubes and filter units which consist of capacity condensers and choke coils.

The Power Transformer.—The purpose of the power transformer is to supply a high voltage to the rectifier tube for rectification of the *a.c.* current and to supply the filament or heaters with the required current and voltage.

Power transformers generally contain a primary winding and several secondary windings, on a laminated steel core. That part of the secondary winding which furnishes power to the rectifier tube contains more turns than the winding which is used for heater or filament supply.

The method of using only one transformer for the various requirements, makes a compact arrangement, facilitates the

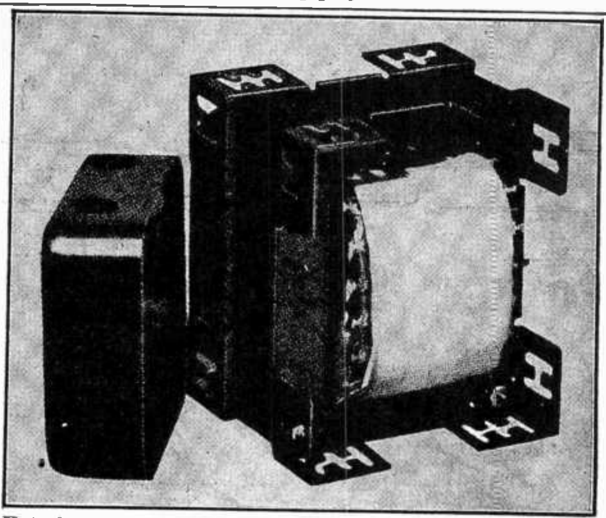


FIG. 1—Exterior view of typical power transformer.

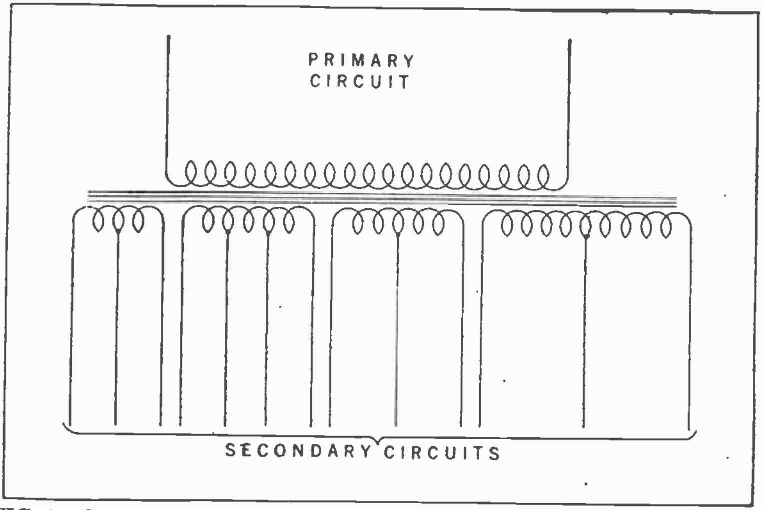


FIG. 2—Conventional diagrammatical representation of power transformer for 5 to 9 tube sets.

assembly and reduces the cost. A power transformer of the type described is shown in fig. 1, and a typical circuit diagram showing the connection of the several windings is shown in fig. 2.

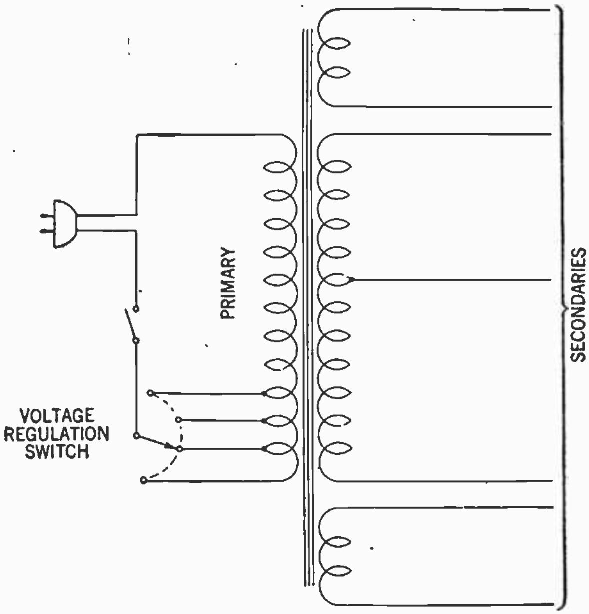


FIG. 3—Power transformer circuit showing voltage regulation switch.

The power transformer should be of ample size to supply the power required in each specific case without over-heating, i.e., the iron and copper should be dimensioned so that the secondary voltage will remain practically constant even in the case of slight variations in primary power supply.

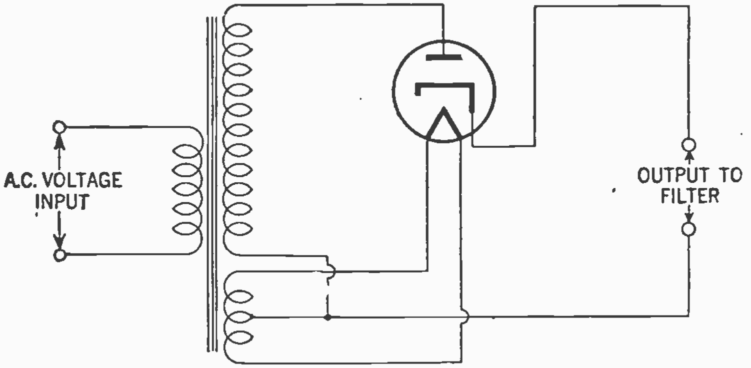


FIG. 4—Illustrates connection and rectifier tube to obtain half-wave rectification.

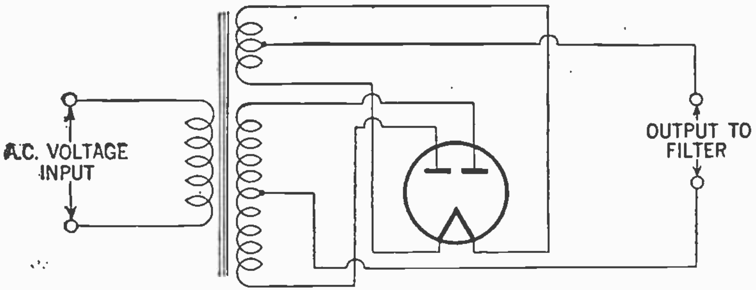


FIG. 5—Illustrates connection and rectifier tube to obtain full-wave rectification.

Method of Line Voltage Regulation.—In certain locations where comparatively large fluctuation in voltage is experienced, due to variation in the load requirements, the reception may be improved by providing a primary voltage regulating switch as shown in fig. 3. The voltage regulation switch is set for a higher voltage value during the time of the day when the line voltage is low, and put back to its original position when the supply voltage again becomes normal.

Rectifier Tubes.—The rectifier tubes are generally divided into two classes namely the half-wave and the full-wave. In modern *a.c.* systems however, the latter is most commonly employed. In half-wave rectifiers only one half of the current wave is utilized as shown in the diagram fig. 4 whereas in the full-wave rectifiers both halves of the waves are utilized. See fig. 5.

It is also possible to connect two half-way rectifier tubes in such a way as to obtain full-way rectification.

As the full-wave rectifier produces twice as many impulses, it is considerably easier to filter into the desired smooth direct current. It is obvious also that because of twice the number of pulsations during a certain time, that the current obtained in this latter system will be twice as great.

There are two general types of rectifier tubes in use. (1) The high vacuum type, in which the conduction is purely by means of the electronic stream from the cathode to the plate and (2) those in which a small quantity of mercury has been introduced after the tube has been evacuated. In the latter type, part of the mercury vaporizes when the cathode reaches its operating temperature and during the part of the cycle in which the rectifier is passing current the mercury vapor is broken down into positive and negative ions. Due to the fact that the positive ions decreases the normal resistance of the plate-cathode circuit the voltage drop in this type is less than in the high vacuum types.

As a result of this lower voltage drop the power loss (I^2R) is lower, and the efficiency of tne mercury vacuum rectifier is higher than in the high vacuum type.

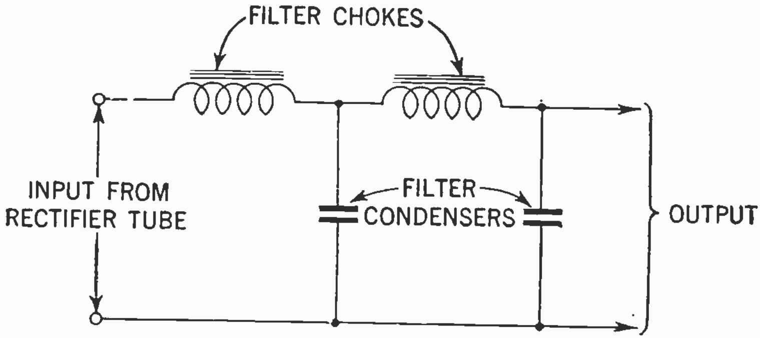


FIG. 6—Choke-input filter.

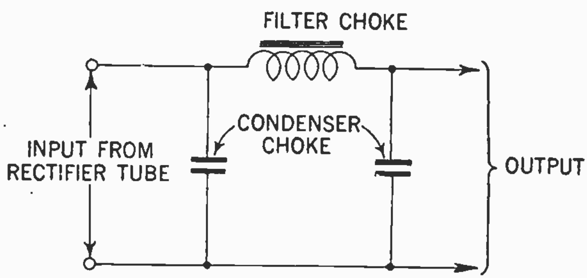


FIG. 7—Condenser-input filter.

Filter Systems.—The function of the filter system aside from that of preventing feed-backs into the receiver, is to smooth out the remaining ripples or pulsations in the voltage received from the rectifier.

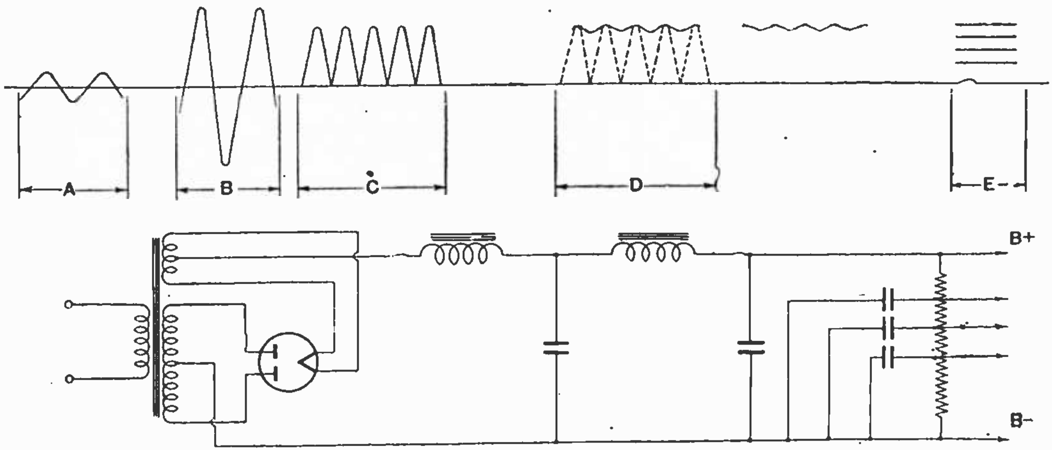


FIG. 8—Illustrates a "*B*" power supply unit of the full-wave type. The choke-input filter section is connected to the conventional voltage divider supplying plate voltages to the various tubes. The upper part of the diagram shows the approximate wave forms at various locations in the power supply unit. For example: "*A*" represents current supplied from power line; "*B*" high voltage current supplied to rectifier tube; "*C*" rectified unfiltered current as obtained from rectifier; "*D*" current as obtained from choke-input filter; "*E*" ripples direct current furnished to plates.

Smoothing filters are generally classified as choke-input or condenser-input according to whether a choke or a condenser is placed next to the rectifier output. Figs. 6 and 7 respectively show a choke-input and condenser-input filter.

If a condenser-input type be used consideration must be given to the instantaneous peak value of the *a.c.* input voltage. This peak voltage is $\sqrt{2}$ times the root mean square (R.M.S.) value as obtained by an *a.c.* voltmeter. Hence, filter condensers especially the input condenser should be of a rating high enough to withstand the instantaneous peak voltage if breakdown is to be avoided.

When the choke-input type is used, the available *d.c.* output voltage will be somewhat less than with the condenser-input type for a given *a.c.* plate voltage; however, in this latter type improved regulation together with lower peak current will be obtained.

D.C. Supply Systems.—Although alternating current is most commonly used in radio receiving sets, there are certain localities in which direct current is furnished, and hence the radio receiving sets in those localities must be designed for operation on *d.c.* current power supply.

It is obvious since the *d.c.* current is practically ripless, that no rectifier unit is necessary. All that is required is a filter system which serves to smooth out the slight remaining "ripples" due to the commutator (brush contact) action on the direct current generator.

The filament supply usually about 6 volts is obtained from the power voltage through a resistor or speaker field of a value to give the necessary voltage drop. See fig. 9.

The filaments may be arranged either in series or parallel. The disadvantage in both cases is a considerable amount of power dissipation in the form of heat, although the power loss is much less when the series arrangement is used.

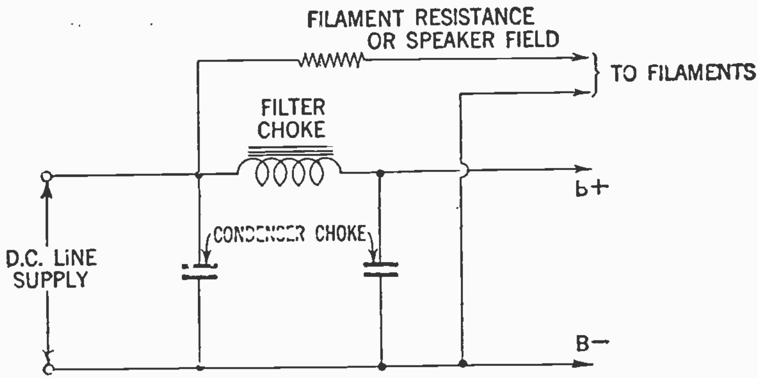


FIG. 9—Conventional filter system used on D.C. receivers.

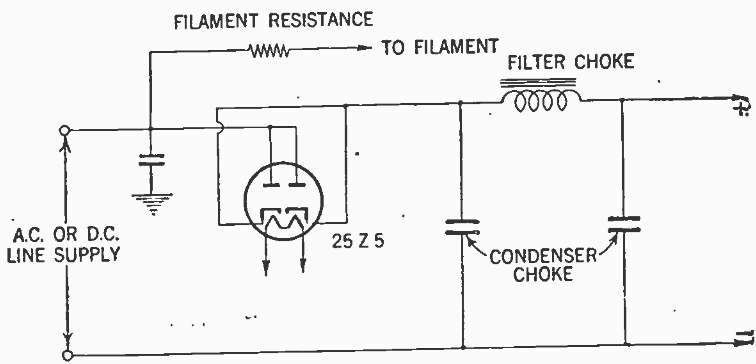


FIG. 10—Full wave rectifier tube circuit used for A.C.-D.C. receivers.

A.C. and D.C. Supply Systems.—When the power supply is alternately *a.c.* or *d.c.* the filament supply is connected through a series resistor as shown in fig. 10. This resistor must be of such value as to give the proper voltage drop. The disadvantage with this arrangement is the same as that of the straight *d.c.* supply system, in that a considerable amount of heat (I^2R) is dissipated in the filament resistor. The plate voltage is usually supplied by utilizing a full wave rectifier tube as shown in fig. 10.

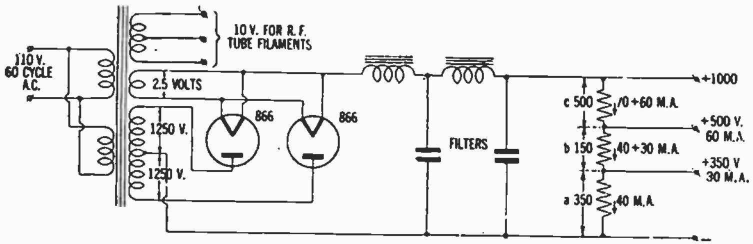


FIG. 11—Full wave rectifier circuit with conventional filters and voltage divider.

Voltage Dividers.—The function of a voltage divider is to supply the various plate voltages required by the various tubes employed in the receiver.

The principal method in each system is to lower the voltage by means of one or more resistors inserted in the circuit. When one resistor is utilized the resistor is tapped at suitable intervals, as shown in fig. 11.

In order to facilitate the calculation of the resistance required between the taps, the voltage divider should be laid off in sections as shown.

Example.—*Assume that the power supply unit shown in fig. 11 has 1,000 volts across its output terminal and that the required plate voltages and currents are as follows:*

1. 350 volts at 30 m.a. for the oscillator
2. 500 volts at 60 m.a. for the buffer-doubler
3. 1,000 volts for the final amplifier.

Solution.—By using Ohm's law the resistance of (a) or the 350 volt sections will be $\frac{350}{0.04}$ or 8,750 ohms.

The resistance of section (b) or the 150 volt section will be $\frac{150}{0.07}$ or 2,150 ohms approx.

The resistance required for section (c) will be $\frac{500}{0.13}$ or 3,850 ohms.

The current in this last section becomes 60 m.a. in addition to the 70 m.a. already flowing in sections (a) and (b) or $0.06+0.07=0.13$ amps.

The total resistance of the divider will therefore be $8{,}750+2{,}150+3{,}850=14{,}750$ ohms, which is safely below the value necessary to maintain constant output voltage when the tubes are not drawing current from the power supply.

The power loss may be calculated by multiplying the voltage drop across each resistance by the current flowing through it.

Accordingly the power dissipated

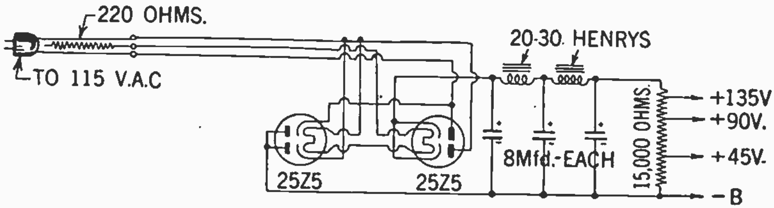
in section (a) $350\times0.04=14$ watts
in section (b) $150\times0.07=10.5$ watts
in section (c) $500\times0.13=65.0$ watts

It is evident from the above that this method of providing operating voltage is uneconomical.

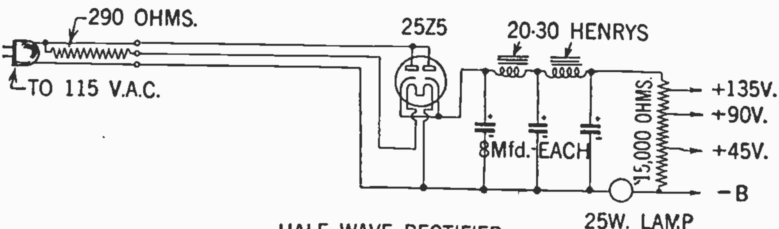
The power calculation should be done for both no-load and full-load conditions, and a resistor selected which should have a rating well above that of the higher of the two values.

In some cases it is desired to have the bleeder resistance total to a pre-determincd value—for example, if the bleeder in the above problem is to total 20,000 ohms instead of the calculated value of 14,750 ohms, the same method of calculation may be followed, but different value of idle current should be tried until the correct one is found.

The method outlined may be extended to any number of taps, and is equally applicable to calculation of voltage dividers for radio receivers.



FULL-WAVE RECTIFIER



HALF-WAVE RECTIFIER

FIGS. 12 and 13—Illustrates two transformerless power supplies, for full-wave and half-wave rectification respectively. Here a line cord resistor is utilized to drop the line voltage to that necessary for the filaments of 25Z5 tubes. The third element in the line cord resistor brings the full line voltage for the plate of the tubes.

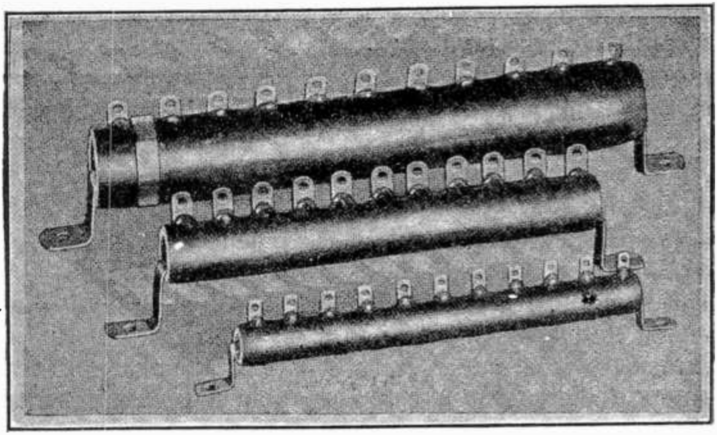


FIG. 14—Typical receiver power supply resistors.

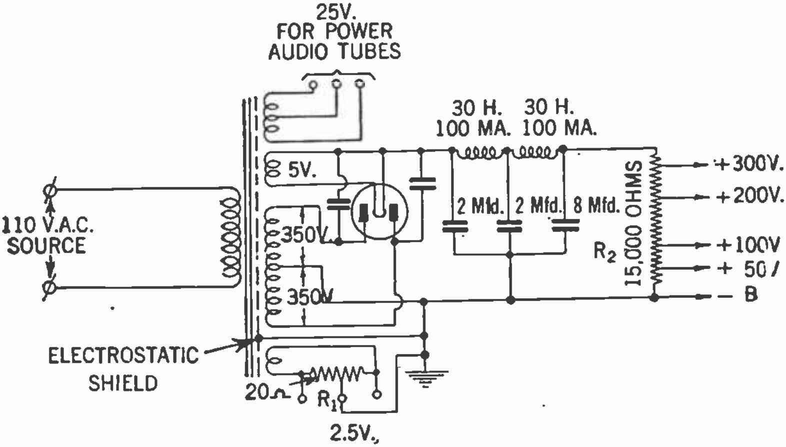


FIG. 15—Here the power transformer is used to step up the 110 volt alternating current to 350 volts on each side of the centre-top. This type of power supply will ordinarily be satisfactory for an ordinary armature receiver as well as an audio amplifier using a 47 or a pair of 45's in push-pull. The 2 m.f.d. condensers and the 30 henry chokes reduces the ripple to satisfactory proportion. Resistor R_1 is centre tapped with a value of 20 ohms. R_2 is the voltage divider for obtaining the different voltages from the power supply.

Bleeder Resistors and Their Use.—It is common practice to connect a bleeder resistor across a power supply to obtain a more stable output—to improve voltage regulation. However, this is often accomplished without any fundamental knowledge of how a bleeder resistor actually works, and how its exact size may be calculated.

Voltage regulation may generally be defined as the change in potential with a change in the load or current consumed.

This is an important consideration in power supply for radio receiving and transmitting circuits because the current may change with signal intensity, modulation, keying, line voltage fluctuation, etc. and it is highly desirable and often imperative that the voltage remains constant.

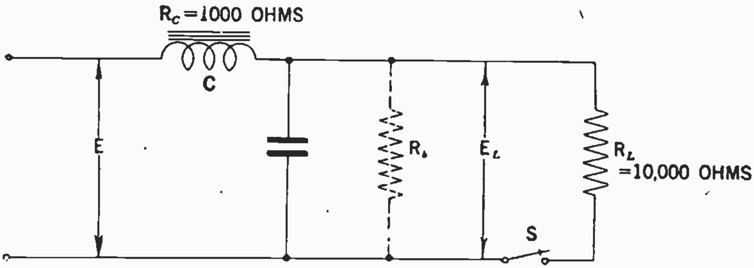


FIG. 16—Showing application of bleeder resistor across power supply.

A problem of this kind may best be studied by considering the arbitrary condition existing in the circuit shown in fig. 16 illustrating a simple filter system of a power supply.

In this circuit *E*, is a source of constant voltage. Choke *C*, has a resistance of 1,000 ohms. E_L is the potential supplied to the load R_L, which may be the plate circuit of a transmitter or receiver. Switch *S*, applies or removes the load.

It is assumed that the load is such that it requires 100 *m.a.* at 1,000 volts for the most efficient operation which according to Ohm's law gives R_L a resistance of 10,000 ohms. R_b is a 10,000 ohms bleeder resistor which at first, is not connected.

If R_L draws a current of 100 *m.a.* the drop through the choke *C*, will be 100 volts, and *E*, therefore must be 1,100 volts in order that E_L the load voltage shall provide the 1,000 volt potential.

However, with the switch open, the no load voltage E_L, will be the same as *E*, or 1,100 volts. When switch *S*, is closed this 1,100 volt potential will be momentarily applied to the load which will drop almost immediately to the required potential of 1,000 volts.

In other words, the change in voltage with the change in load has been a drop from 1,100 volts to 1,000 volts or a voltage regulation of 100 volts.

Assuming that R_b is also connected in the circuit, it is evident that as R_b also draws current that the drop through R_c will be increased. Hence if E_L is to be maintained at 1,000 volts, the source voltage will also have to be increased.

With E_L at 1,000 volts, R_L and R_b 10,000 ohms each, the current drain through the circuit will be 200 *m.a.* and the drop across *C*, 200 volts, therefore the voltage at *E*, will have to be raised to 1,200 volts.

It is evident that the no load voltage (switch *S*, being open) will no longer be the total voltage at *E*, but instead the voltage drop across R_b, this may be easily calculated by using Ohm's law.

The bleeder current through R_b will be $\frac{E}{R_c+R_b}$ or 0.109 amperes; the voltage drop across R_b (or the no load voltage) will be $I \times R_b = 0.109 \times 10{,}000$ or 1,090 volts. The no load voltage being 1,000 volts, hence, the change due to regulation will be 90 volts or an improvement of 10 volts over conditions when the bleeder is not employed.

With Resistor in Parallel.—In the above example the power supply was so designed that the correct load voltage was obtained when the bleeder was in the circuit. Very often the bleeder is added merely as an afterthought in hope that the regulation secured will compensate the loss in voltage.

With reference to the diagram, the bleeder resistor is connected without boosting the voltage (1,100) at *E*.

If considering resistors R_L and R_b in parallel, their combined resistance is 5,000 ohms. This plus R_c gives a total effective resistance of 6,000 ohms, and a total current of 184 *m.a.* The drop across R_c will be 184 volts, and the load voltage E_L will be *E* minus this value (1,100 − 184) or 916 volts. The no load voltage will be of course exactly 1,000 and the regulation therefore 84 volts.

This is better than the 100 volt regulations obtained when the bleeder is not employed, but the operating voltage has dropped to 916 volts.

Summary of Improvement in Regulation.—Summing up it will be observed that the improvement in regulation with the utilization of a bleeder resistor is not as much as might be assumed. While the conditions in the above problem have been arbitrarily assumed, similar arithmetic treatment will apply to actual cases.

It is evident that the lower the value of the bleeder resistor, the greater the regulating effect, but at the same time the supply voltage must be increased.

The bleeder is essentially a wasteful proposition and particularly so when its value is made sufficiently low to secure any real measure of regulatory effect. However, a bleeder of even high value, say 100,000 ohms, will be effective in preventing excessively high potentials under no-load conditions which might damage rectifying tubes and filter condensers.

Voltage regulation is best secured through the design of generous size transformer windings, low resistance chokes and mercury-vapor rectifying tubes.

Voltage Doubler Circuits.—By means of this type of circuit it is possible to obtain twice the *a.c.* input voltage without the conventional transformer.

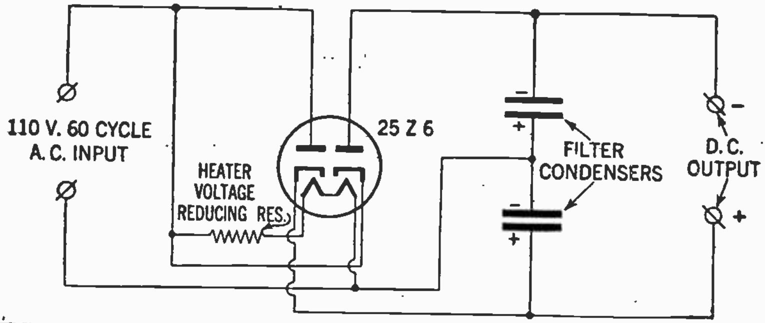


FIG. 17—Voltage doubler circuit utilizing a full-wave rectifier tube.

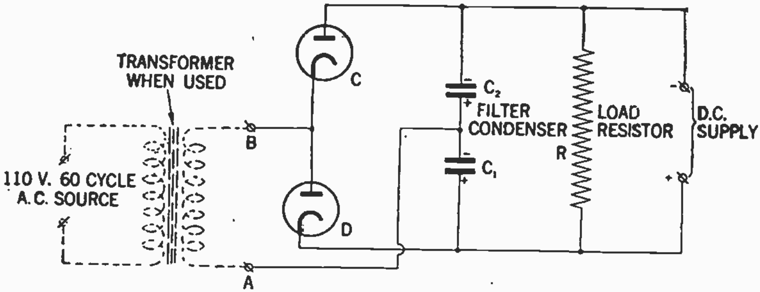


FIG. 18—Voltage doubler circuit utilizing two half-wave rectifier tubes.

The circuit shown in fig. 18 represents a typical voltage doubler without a transformer although a transformer may be used if the voltage requirements thereby will be facilitated.

The action that takes place within this circuit is briefly as follows: With reference to fig. 18 it may be observed that during that one half of the cycle when B, is positive with respect to A, rectifier D, is conducting and the condenser C_1 is being charged. The two condensers are connected in series with respect to the load resistor R, which results in doubling of the voltage appearing across this resistor.

Example.—*A five tube receiver using a 2 volt filament supply battery, takes 1.2 amperes of filament current. What is the total power expended in heating the filaments? If a 40 ohms potentiometer were placed across the battery terminals, what would be the increase in the power consumed?*

Solution.—Since direct currents are being dealt with, the power in watts is given by the product of the voltage and the current in amperes. Thus the power is $2\times1.2=2.4$ watts. The current taken by the potentiometer is easily found by Ohm's law. This gives $I(\text{amperes})=\frac{E}{R}=\frac{2}{40}$ or 0.05 ampere. As before, the power taken is equal to the product of the voltage and this current or $2\times0.05=0.1$ watt. A quicker method is to make use of the formula, power $=\frac{E^2}{R}$ watts or in this case $\frac{4}{40}=0.1$ watt as before.

CHAPTER 175

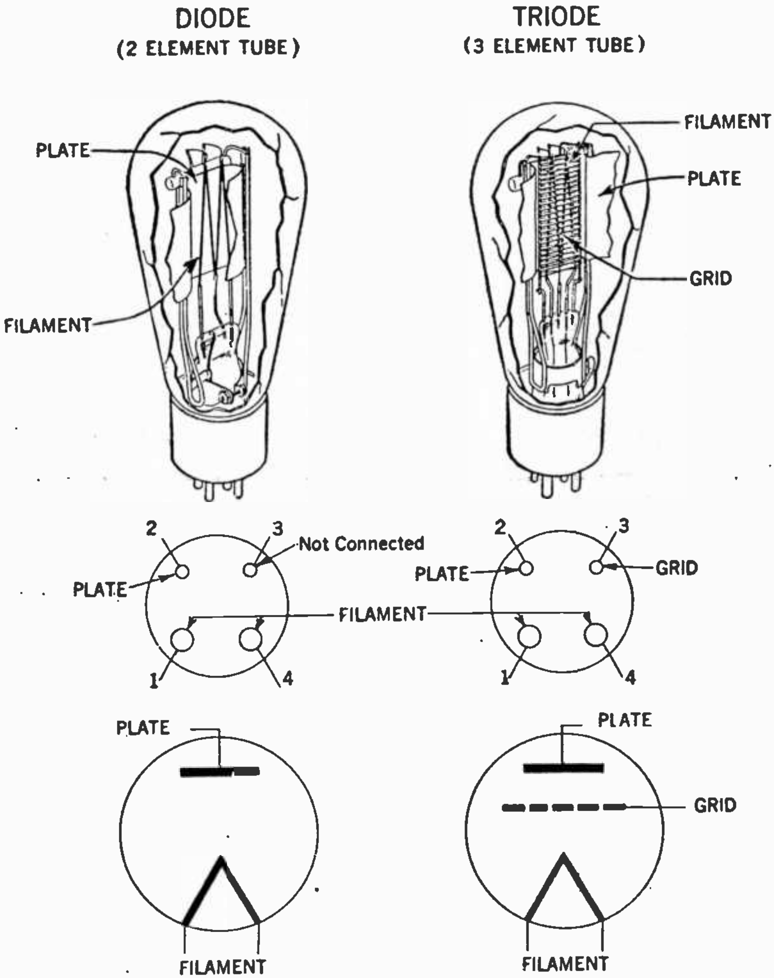
Vacuum Tubes

Electron Emission.—The phenomenon that electrons can be made to leave a conductor when properly stimulated to do so as in the case of a radio vacuum tube, is called *thermonic electron emission*, sometimes called only emission.

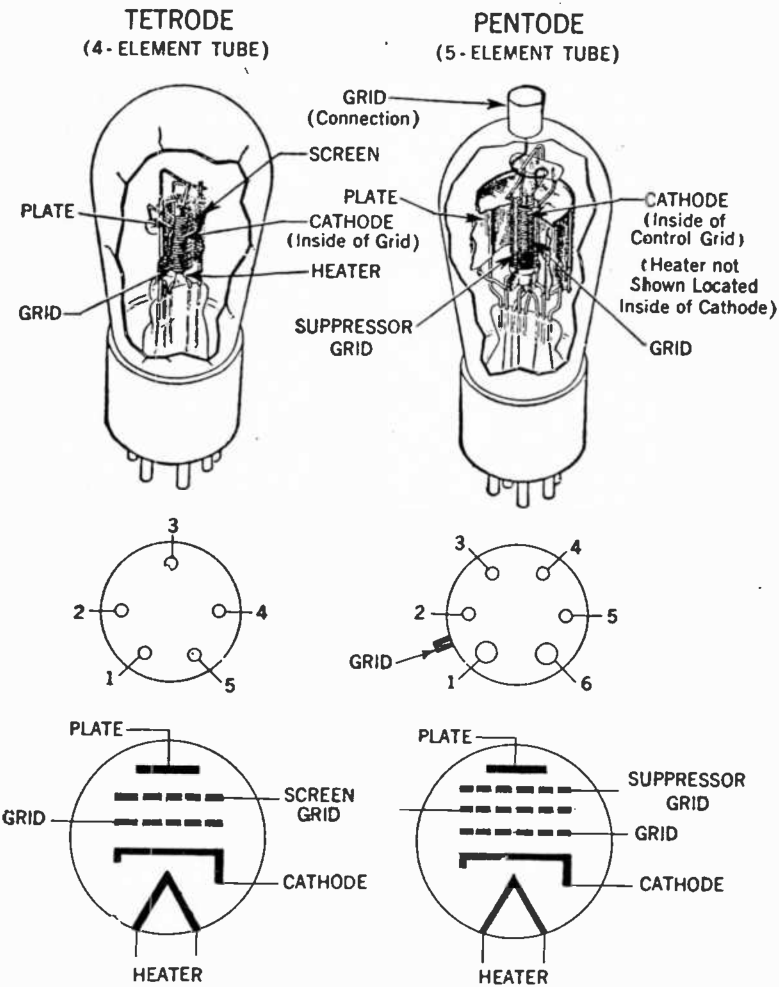
This movement of electrons may be accelerated by increasing the temperature of the conductor. Once free, most of the emitted electrons, in a vacuum tube make their way to the plate, but others return to the cathode, repelled by the cloud of negative electrons immediately surrounding the cathode. This cloud of electrons surrounding the emitting cathode is known as the *space charge*.

A few of the electrons that reach the plate may have sufficient velocity to dislodge one or more electrons already on the plate. The dislodging of those electrons from the plate by other fast moving electrons are called *secondary emission*.

When this occurs there is actually a simultaneous electron flow in two directions.



Views of two and three element vacuum tubes showing arrangement of prongs and wiring symbols.



Views of four and five element vacuum tubes, showing arrangement of prongs and wiring symbols.

Vacuum Tube Fundamentals.—By definition a vacuum tube consists of a cathode, which supplies electrons and one or more additional electrodes whose function it is to control and collect these electrons, mounted in an evacuated envelope. This envelope may consist of a glass bulb or it may be the more compact and efficient metal shell.

The outstanding properties of the vacuum tube lie in its ability to control almost instantly the motion of millions of electrons supplied by the cathode. On account of its almost instantaneous action the vacuum tube can operate very efficiently and accurately at electrical frequencies far above those obtainable with rotating machinery.

As previously stated the electronic movement may be accelerated by the supply of additional energy in form of heat. When the temperature of a metal becomes hot enough to glow, the agitation of the electrons becomes sufficiently great to enable a certain amount of them to break away from the metal, it is this action which is utilized in the radio tube to produce the necessary electron supply.

The Function of the Cathode.—A cathode is that part of a vacuum tube which supplied electrons which are essential for its operation. All cathodes in vacuum tubes are universally heated by electricity. The method of heating the cathode may be used to distinguish between the different forms.

The simplest form of a cathode is in the form of a wire or ribbon, heated directly by the passage of current through it as in (b) and (c) fig. 1. Radio tubes having such filaments for cathodes are sometimes referred to as *filamentary tubes* to distinguish them from tubes having indirectly heated cathodes.

A common arrangement of an indirectly heated cathode is shown in fig. 1 (a). Here the cathode consists of a metallic cylindrical sleeve, usually of nickel, coated with a mixture of barium and strontium oxides. This oxide coating is used on

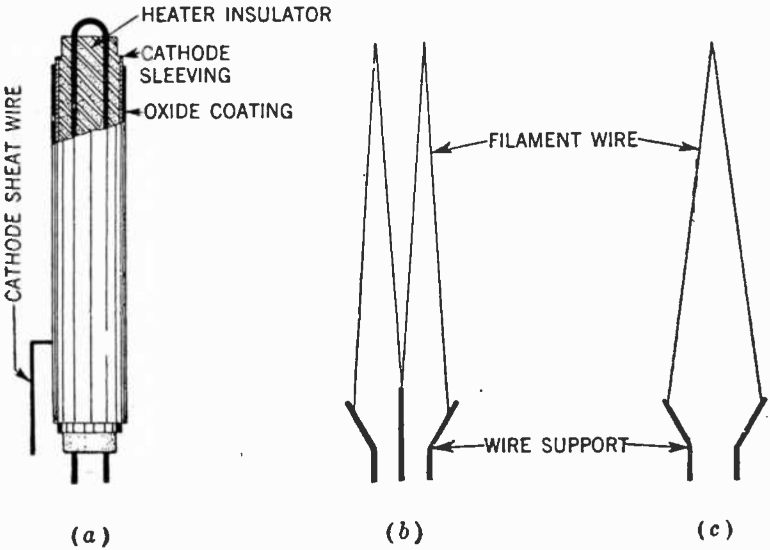


FIG. 1.—Schematic diagram of directly and indirectly heated cathodes.

account of their property to greatly increase the electron emission at a given temperature.

A lead wire from the cathode sheath is carried out to an external tube terminal in order that the cathode may be maintained at any desired potential.

The heater wire consists usually of tungsten and may be in the form of a spiral or as in the illustration, in the form of a hairpin threaded through parallel tubular holes in a ceramic insulator. Tubes having cathodes of this type are referred to as **heater type tubes.**

The heaters may be operated on either direct or alternating current. The one disadvantage of using alternating current

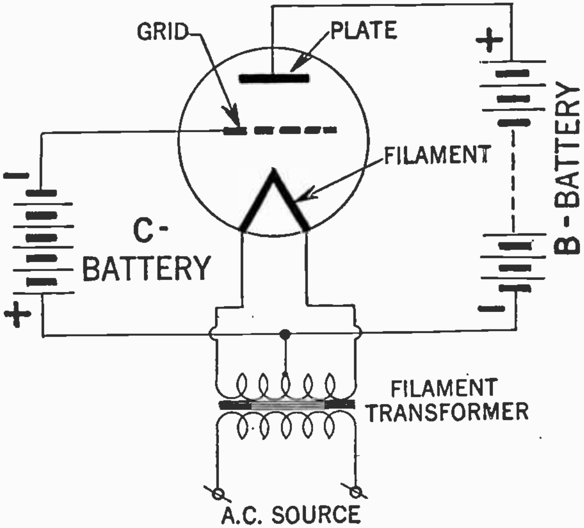


FIG. 2.—Diagram of connection to a triode employing a filament transformer.

for the filament of tubes used in audio-frequency circuits, is that it introduces objectionable hum in the output.

This hum may be lessened by connecting the plate and the grid circuits to the midpoint of the secondary of the transformer, as shown in fig. 2. Generally, however, it is not possible to use alternating current in the filament of tubes used in the early stages of high-gain amplifiers.

Classification of Tubes.—Tubes are usually classified according to the number of electrodes present, so for example a two-element tube is called a *diode;* a three-element tube a *triode,* and so on to tetrodes and pentodes. A pentode therefore is a tube having five elements. See page 4474 and 4475.

Tubes may also be classified according to whether there be high vacuum, gas or an element which vaporizes in the bulb.

Diodes.—From the foregoing it is evident that electrons are of no value in a tube unless they can be controlled or made to work according to a pre-determined schedule. The very simplest form of tube consists of one or two electrodes, a cathode and a plate, and is most often referred to as a *diode,* which is the family name for two-electrode tubes.

In common with all tubes, the electrodes are enclosed in an evacuated envelope with the necessary connection projecting out through airtight seals. The air is removed from the envelope to allow free movement of the electrons and to prevent injury to the emitting surface of the cathode. If the cathode be heated, electrons leave the cathode surface and form an invisible cloud in the space around it. Any positive electric potential within the evacuated envelope will offer a strong attraction to the electrons.

In a diode, the positive potential is applied to the second electrode, known as the anode, or plate. The potential is supplied by a suitable electrical source connected between the plate terminal and a cathode terminal. See fig. 3. Under the influence of the positive plate potential, electrons flow from the cathode to the plate and return through the external plate-battery circuit to the cathode, thus completing the circuit. This flow of electrons is known as the plate current and may be measured by a sensitive current indicator.

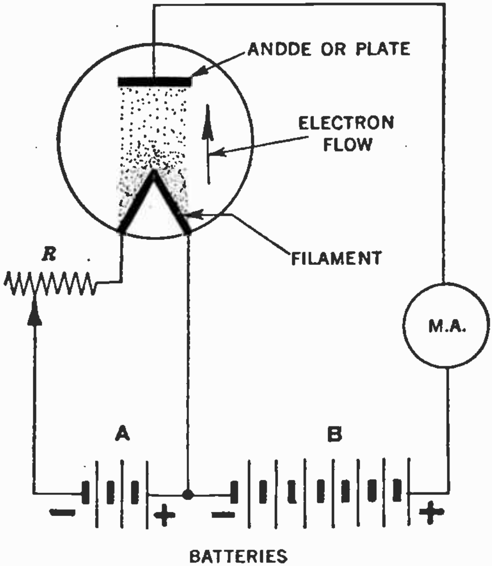


FIG. 3.—Connection diagram for a two electrode tube.

The Diode as a Rectifier.—It is obvious that under no conditions can the current flow from the plate to the cathode, i.e., the tube is as far as the direction of the current is concerned a one-way proposition. Increasing the positive potential will of course increase the flow of electrons from cathode to plate and consequently increase the current flow in the plate circuit, but if the plate is made negative instead of positive it will repel the electrons and no current will flow.

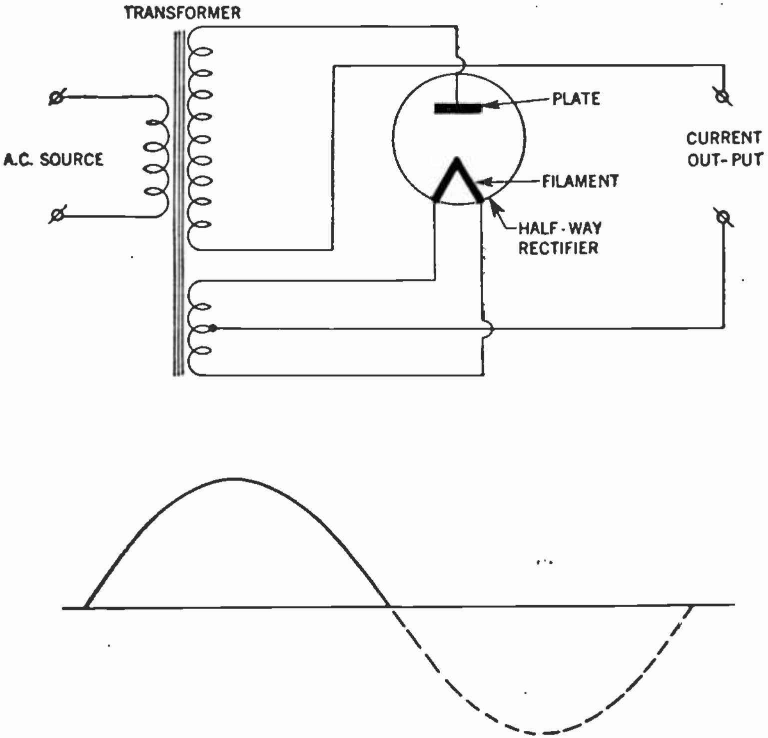


FIG. 4.—Connection diagram of the half-way rectifier. The rectified current is depicted on the upper half of the wave diagram.

The diode therefore acts as an *electrical valve* that will permit current to flow in one direction, but not in the other. It is this characteristic of the diode that has been utilized as a means of converting or rectifying an alternating current into a direct current.

The diode is therefore commonly used as a signal rectifier or detector in a radio receiver, and as a power rectifier in the unit employed to change the *a.c. house current* into a direct current for the operation of home receivers or transmitters.

Diode rectifiers may have one plate and one cathode and are as such called *half-way rectifiers*, (See fig. 4) since as stated the current can flow only during one-half of the alternating current cycle.

Full Wave Rectifier.—If two plates and one or more cathodes are used in the same tube, current may be obtained during both halves of the alternating current cycle as shown in fig. 5. The tube is then called a *full wave rectifier*. If as in the diagram shown the rectifier tube be connected to a power transformer, the primary of which is connected to a 110 volt a.c. source, then the disposition of the voltage developed in the secondary of the transformer winding will be such that the center tape will be at zero voltage with respect to terminals 1 and 2, and during the period terminal 1 is positive, terminal 2 will be negative.

Therefore plate P_1 will draw current while plate P_2 is idle and vice versa. In this manner both the positive and the negative half of the alternating current cycle are utilized and the resultant output current consists of a series of unidirectional pulses with no spacing between them as shown in the lower part of fig. 5. These unidirectional pulses may be further smothered by insertion of filters consisting of inductive and capacitive reactances interconnected to the output terminals of the rectifying system.

Space Charge Effect.—Not all of the electrons emitted by the cathode reach the plate. Some return to the cathode while

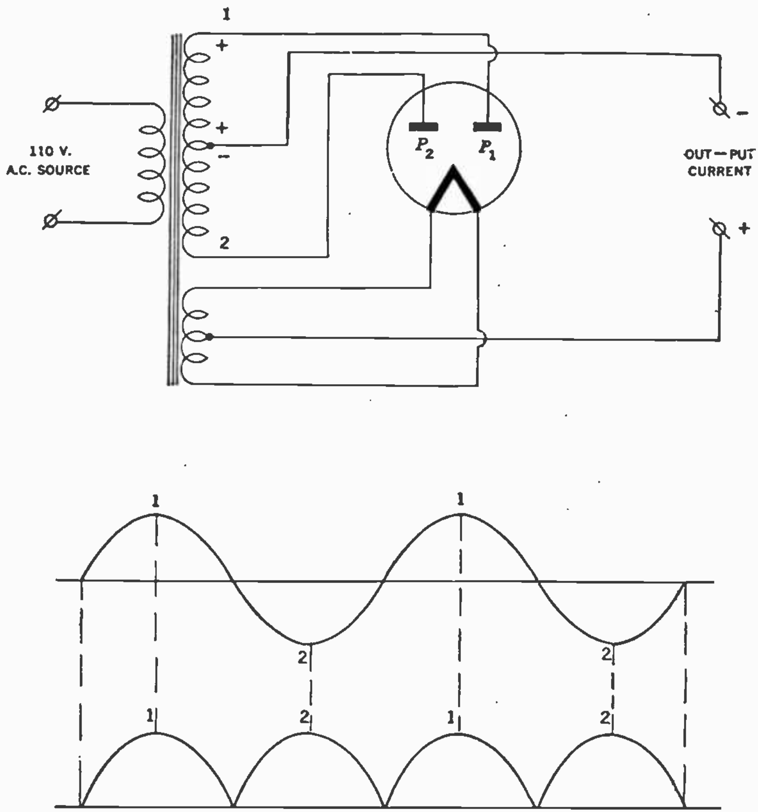


FIG. 5.—Connection diagram and depiction of the action of a full-wave rectifier tube.

others remain in the space between the cathode and plate for a brief period to form an effect known as *space-charge*. This charge has a repelling action on other electrons which leave the cathode surface and impedes their passage to the plate. The extent of this action and the amount of space-charge depend on the cathode temperature and the plate potential.

Plate voltage vs. Plate current relationship of a diode.—The higher the plate potential, the less is the tendency for electrons to remain in the space-charge region and repel others. This effect may be noted by applying increasingly higher plate voltages to a tube operating at a fixed heater or filament voltage. Under these conditions, the maximum number of available electrons is fixed, but increasingly higher plate voltages will as previously stated succeed in attracting a greater proportion of the free electrons.

Beyond a certain plate voltage, however, additional plate voltage has little effect in increasing the plate current. The reason is that all of the electrons emitted by the cathode are already being drawn to the plate. This maximum current is called *saturation current*, and because it is an indication of the total number of electrons emitted, it is also known as the *emission* current. See fig. 6.

Tubes are sometimes tested by measurement of their emission current. However, in this test it is generally not feasible to measure the full value of emission because this value would be sufficiently large to cause change in the tube's characteristics, or to damage the tube. For that reason, the test value of current in an emission test is less than the full emission current. However, this test value is larger than the maximum value which will be required from the cathode in the use of the tube.

The emission test, therefore, indicates whether the tube's cathode can supply a sufficiently large number of electrons for satisfactory operation of the tube.

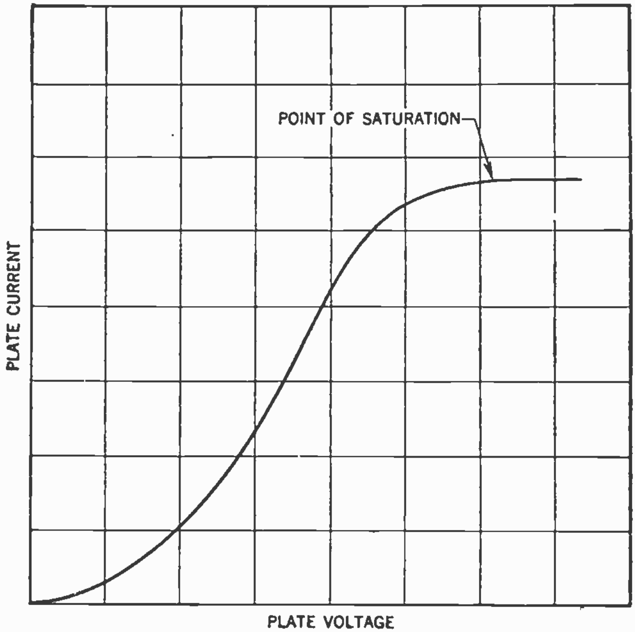


FIG. 6.—Characteristic curve of a diode.

Triodes.—The triode or three electrode tube is principally a two-electrode tube in which a third electrode, called the *grid*, is placed between the plate and the cathode. See fig. 7.

The grid consists usually of a mesh of fine wire extending the full length of the cathode. The spaces between the turns of the wire constituting the grid are comparatively large, so as not to impair the passage of the electrons from the cathode to the plate.

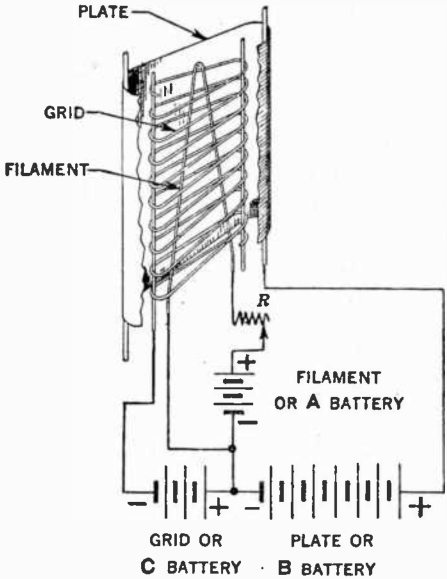


FIG. 7.—Schematic diagram showing triode connection to battery.

Grid Function.—The function of the grid is to control the plate current. By maintaining the grid at a negative potential, it will repel electrons and will in part, but not altogether, neutralize the positive or attractive force exerted upon them by the positive plate. Hence, a stream of electrons will flow from the grid to the plate, although smaller than it would be if the negative grid had not been present. Now if the grid is made less negative, it follows that its repelling effect will be reduced and consequently a larger current will flow through it to the plate.

Similarly if the grid be again made more negative its repelling force will increase and the current to the plate will correspondingly decrease. See fig. 8.

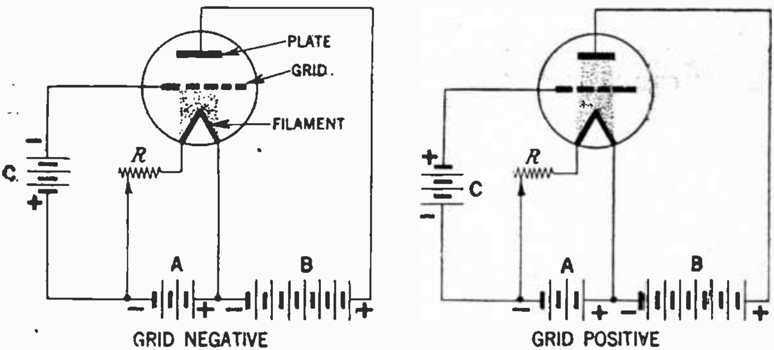


FIG. 8.—Illustrating the action of a grid in a triode vacuum tube.

From the above, it follows that when the potential of the grid be varied in accordance with some desired signal, the plate current will vary in a corresponding manner. Because the grid is assumed at all times to be at negative potential with respect to the cathode, it is evident that it can not collect electrons and so a small amount of energy will be sufficient to vary its potential in accordance with the input signal.

Capacitance Effect.—In a triode the grid plate and cathode form what is called an electro-static system, i.e., each electrode acts as a plate of a small condenser. The capacitances are those existing between grid and plate, plate and cathode, and grid and cathode. See fig. 9.

These capacitances are usually referred to as "Inter-electrode Capacitances." In this connection it may be mentioned that the capacitance between the grid and plate is of the utmost importance, because of the fact that in high-gain radio-fre-

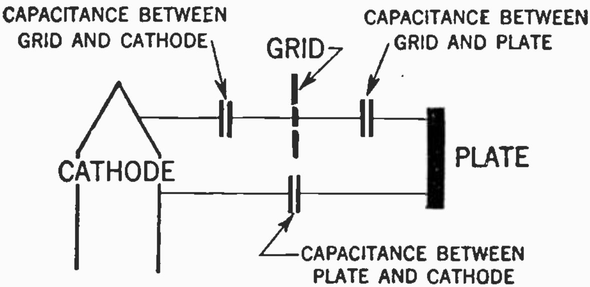


FIG. 9.—Diagram showing inter-electrode capacitances in a triode.

quency amplifier circuits, this capacitance may act to produce undesired coupling between the *input circuit*, the circuit between the grid and cathode, and the *output circuit*, the circuit between the plate and the cathode. The effect of this coupling may cause instability and unsatisfactory performance in the amplifier.

Tetrodes.—The undesirable capacitance between the grid and the plate in the triode can be decreased by inserting an additional electrode or *screen* between the grid and the plate as shown in fig. 10. With the addition of this fourth electrode the tube is accordingly referred to as a *tetrode*.

The Screen Function.—The position of the screen between the grid and the plate gives it the function of an electrostatic shield between them, thus reducing the capacitance between the two.

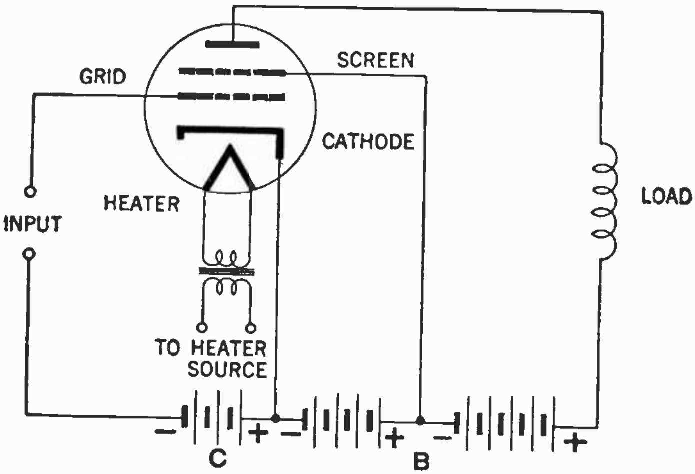


FIG. 10.—Connection of electrodes of a screen gride tube.

The effectiveness of this shielding action is further increased by inserting a by-pass condenser between the screen and the cathode. Therefore, by means of this screen and by-pass condenser, the grid to plate capacitance is very small.

The screen has another desirable effect in that it makes plate current almost independent of plate voltage over a certain range. The screen is operated at a positive voltage and therefore, attracts electrons from the cathode, but because of the comparatively large space between wires of the screen, most of the electrons drawn to the screen pass through it to the plate.

Hence, the screen supplies an electrostatic force pulling electrons from the cathode to the plate.

At the same time the screen shields the electrons between cathode and screen from the plate so that the plate exerts very little electrostatic force on electrons near the cathode. Therefore, plate current in a screen grid tube depends to a great degree on the screen voltage and very little on the plate voltage. This holds true only as long as the plate voltage is higher than the screen voltage.

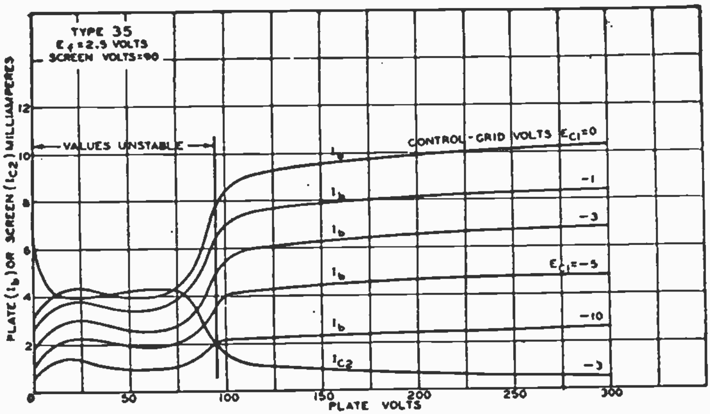


FIG. 11.—Average plate characteristics of a screen grid amplifier tube.

The fact that plate current in a screen grid tube is largely independent of plate voltage makes it possible to obtain much higher amplification with a tetrode than with a triode. The low grid to plate capacitance makes it possible to obtain this high amplification without plate-to-grid feed-back and resultant instability.

Pentodes.—It has previously been shown that when electrons strike the plate they may if moving at sufficient speed dislodge other electrons. This in the two and three electrode types does not cause any trouble since no other positive electrode than the plate is present to attract them.

These vagrant electrons therefore are eventually drawn back to the plate.

Emission from the plate caused by bombardment of the plate by electrons from the cathode is referred to as *Secondary Emission* on account of its effect being secondary to the original cathode emission.

In the case of the previously discussed screen grid or tetrode tube, the proximity of the positive screen to the plate offers a strong attraction to these secondary electrons, and more markedly so if the plate voltage be lower than the screen voltage. This results in lowering of the plate current and limits the permissible plate swing for tetrodes.

To overcome the effects of secondary emission a third grid, called the *suppressor grid* is inserted between the screen and plate. This grid, being connected directly to the cathode, repels the relatively low-velocity secondary electrons back to the plate without obstructing to any appreciable extent the regular plate-current flow. Larger undistorted outputs therefore can be secured from the *pentode* than from the *tetrode*.

Pentode-type screen-grid tubes are used as *radio-frequency voltage amplifiers*, and in addition can be used as *audio-frequency voltage amplifiers* to give high voltage gain per stage, since the pentode resembles the tetrode in having a high amplification factor. Pentode tubes also are suitable as audio-frequency power amplifiers, having greater plate efficiency than triodes and requiring less grid swing for maximum output. The latter quality can be indicated in another way by saying that the *power sensitivity*—ratio of power output to grid swing causing it, is higher. In audio power pentrodes, the function of the screen grid is chiefly that of accelerating the electron flow rather than shielding, so that the grid often is called the *accelerator grid*. In radio frequency voltage amplifiers the suppressor grid, in eliminating the secondary emission, makes it possible to operate the tube with the plate voltage as low as the screen voltage, which cannot be done with tetrodes.

As audio-frequency power amplifiers pentodes have inherently greater distortion (principally odd-harmonic distortion) than triodes. The output rating usually is based on a total distortion of 10%.

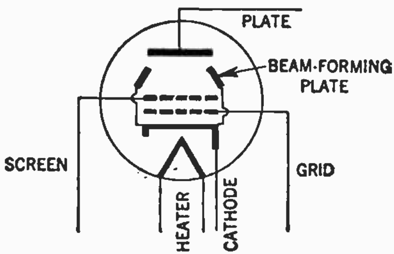


FIG. 12.—Conventional representation of beam power tube.

The Beam Power Tube.—In this tube a different method is used for suppressing secondary emission. The tube (See figs. 12 and 13) contains four electrodes, a cathode, grid, screen and plate respectively. The spacing between the electrodes is such that secondary emission from the plate is suppressed without the suppressor found in the pentode.

Due to this method of spacing the electrodes, electrons travelling to the plate slow down, when the plate voltage is low, the velocity being almost zero in a certain region between the screen and the plate. In this region the electrons form a stationary cloud—a space-charge. The effect of this space-charge is to repel secondary electrons emitted from the plate, and thus cause them to return to the plate, hence causing the suppression of *secondary emission*.

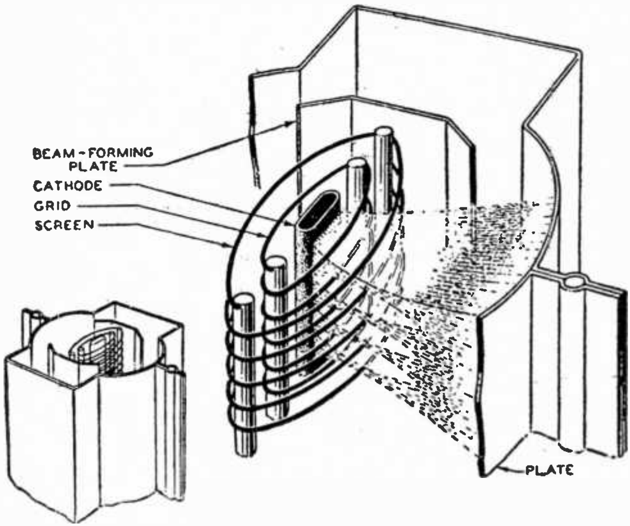


FIG. 13.—Internal structure of beam power tube.

An added advantage of the beam power tube is the low current drawn by the screen. The screen and the grid consists of spiral wires wound in such a way so that each turn of the screen is shaded from the cathode by a grid turn. On account of this alignment the screen and grid causes the electrons to travel in sheets between the turn of the screen so that very few of them flow to the screen. Because of the effective suppressor action provided by space charge and because of the low current drawn from the screen, the beam power tube has the advantage of high power output, high sensitivity and efficiency.

Multi-Purpose Tubes.—During the early stages of tube development and application, tubes were essentially of the so-called general purpose type, that is a *triode* was used as a radio-frequency amplifier, an intermediate frequency amplifier, an audio frequency amplifier, an oscillator or as a detector.

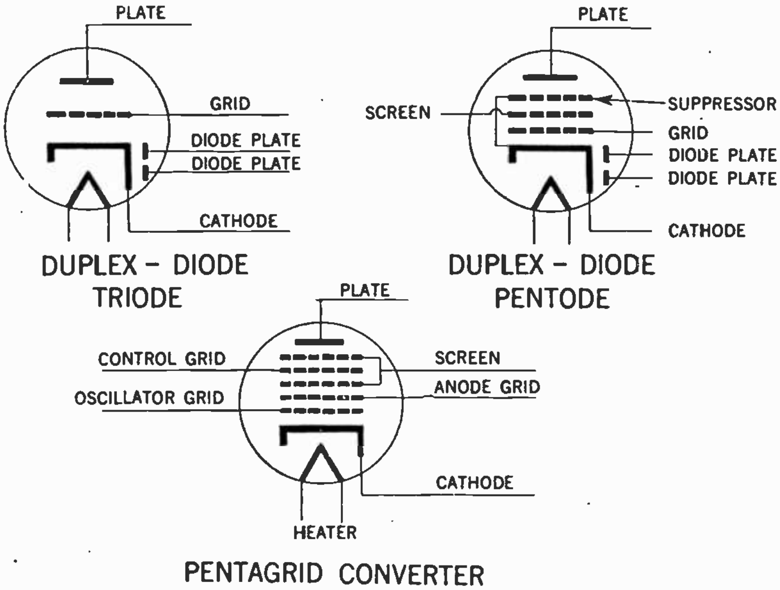
It is obvious that with this diversity of applications, this one type did not meet all requirements to the best advantage.

At present a great multiplicity of tube types have been developed to do special work in radio circuits. Among the simplest and most important in radio receiver circuits are the full-wave rectifiers, containing two separate diodes of the power type in one bulb, and twin-triodes consisting of two triodes in one bulb for class B audio amplification.

To add the functions of diode detection and automatic volume control to that of amplification, a number of types are made in which two small diode plates are placed near the cathode, but not in the amplifier-portion structure. These types are known as *duplex-diode triodes*, or *duplex-diode pentodes*, depending upon the type of amplifier section incorporated.

Another type is the *pentagrid converter*, a special tube working as both oscillator and first detector in superheterodyne receivers. There are five grids between cathode and plate in the pentagrid converter; the two inner grids serve as control grid and plate of a small oscillator triode, while the fourth grid is the detector control grid. The third and fifth grids are connected together to form a screen grid which shields the detector control grid from all other tube elements. The pentagrid converter eliminates the need for special coupling between the oscillator and detector circuits.

The convential diagram representation of these tubes are depicted in figs. 14 to 16. Another type of tube consists of a triode and pentode in one bulb, for use in cases where the oscillator and first detector are preferably separately coupled;



FIGS. 14 to 16.—Schematic representation of multi-purpose tubes.

while still another type is a pentode with a separate grid for connection to an external oscillator circuit. This "injection" grid provides a means for introducing the oscillator voltage into the detector circuit by electronic means.

Receiving screen-grid tetrodes and screen-grid pentodes for radio-frequency voltage amplification are made in two types. known as *sharp cut-off* and *variable-mu* or super-control types, In the sharp-cut off type the amplification factor is practically constant regardless of grid bias, while in the variable-mu type the amplification factor decreases as the negative bias is increased. The purpose of this design is to permit the tube to handle large signal voltages without distortion in circuits in which grid-bias control is used to vary the amplification, and to reduce interference from stations on frequencies near that of the desired station by preventing cross-modulation. Cross-modulation is modulation of the desired signal by an undesired one, and is practically the same thing as detection. The variable-mu type of tube is a poor detector in circuits for r.f. amplification, hence cross-modulation is reduced by its use.

CHAPTER 176

Radio Receivers

Generally any electrical circuit used in connection with radio reception is a radio receiving circuit.

The basic receiving circuits are as follows:

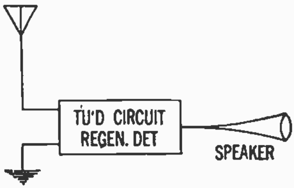
1. Regenerative
2. Tuned radio frequency regenerative
3. Super-heterodyne
4. Super-regenerative
5. Super-infra regenerative

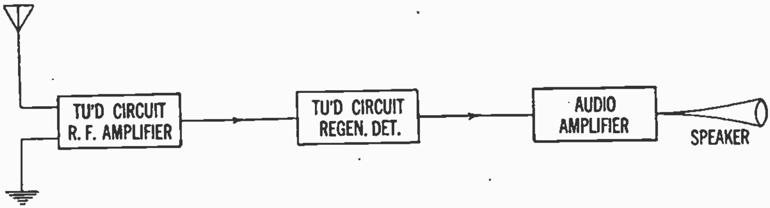
The two last circuits are classified as short wave receivers.

General Receiver Performance Characteristics.—The receiver performance may be divided into three groups namely:

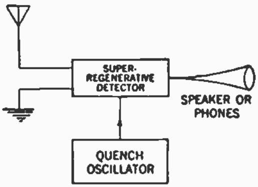
1. Selectivity
2. Sensitivity
3. Fidelity and stability

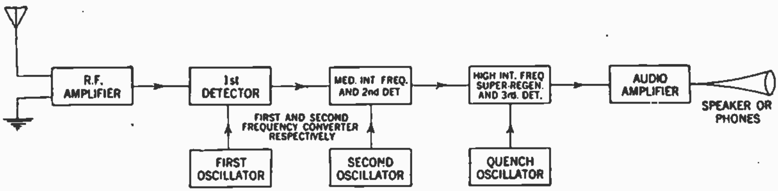
The three groups are inter-dependent with selectivity the most important factor.





FIGS. 1 and 2—Block diagrams showing essential units of a regenerative and a tuned radio frequency regenerative circuit respectively.





FIGS. 3 and 4—Block diagrams showing essential units of a super-regenerative and a super-infra regenerative circuit respectively.

By definition, *selectivity* of a receiver is its ability to discriminate between signals of various frequencies. The *sensitivity* of a receiver is the minimum radio frequency voltage input required to give a certain specified output. The *fidelity* is that proportionate response through the audio frequency range, required for a given type of receiver.

A receiver's *stability* is identified by its ability to maintain its output constant over a period of time with constant *signal* input.

Receiver Selectivity.—As aforementioned the selectivity is that characteristic which makes it possible to determine how well a set will tune out one signal and tune in another.

Measurements of Selectivity.—The selectivity is determined with the aid of a radio frequency oscillator by means of which it is possible to impress known *r.f.* potential on the input of a radio receiver.

There are various methods of carrying out this test, although the one generally used is to impress a small potential on the input of the set and note the output, and then to vary gradually the frequency of the *r.f.* oscillator, and at the same time adjust the potential supplied to the receiver so as to maintain the same output.

In this manner a set of figures will be obtained, indicating how the output of the set falls off at either side of the frequency to which it is tuned. Generally it is true that the more rapidly it falls off the better is the selectivity of the receiver.

However, as previously noted, the receiver's selectivity is closely allied with its fidelity, for generally if making the selectivity too great, the side-bands are suppressed and the high frequencies are partially suppressed. A typical selectivity curve is shown in fig. 5.

Such curves may be made up at various points throughout the broadcast band, and the variations in a receiver's selectivity thereby determined.

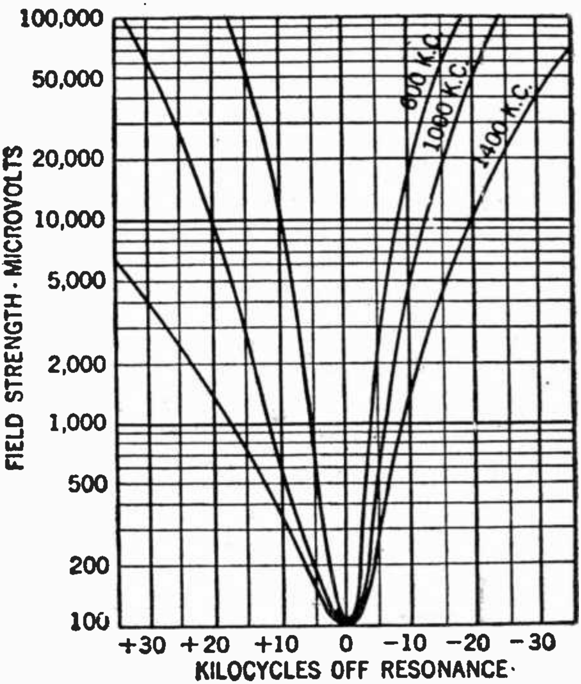


FIG. 5—A typical radio receiver selectivity curve.

Receiver Sensitivity.—The sensitivity of a receiver is not simply a matter of amplification, but is fundamentally limited by what is known as "the noise level" in that only signals that are audible above the prevailing noise background at the output are useful.

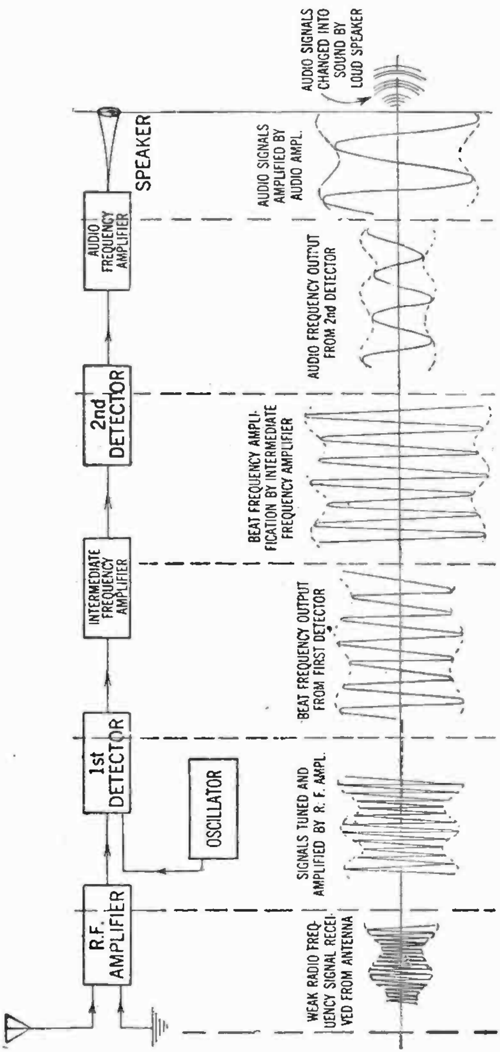


FIG. 6—Combination diagram showing arrangement of the different units of a typical super-heterodyne receiver with wave chart indicating how the radio signals are modified by each unit, that is, how the inaudible signals first picked up by the antenna undergo successive changes en route to the loud speaker.

In order to obtain a common basis facilitating the study and measurement of this characteristic, the term "noise equivalent" is used, which simply means the effective sensitivity of a receiver in terms of its own noise level.

Measurements of Sensitivity.—In connection with sensitivity measurements, a certain receiver is often expressed as having a sensitivity of so many micro-volts per meter. Just what this expression implies may best be conveyed by a description of what the term means.

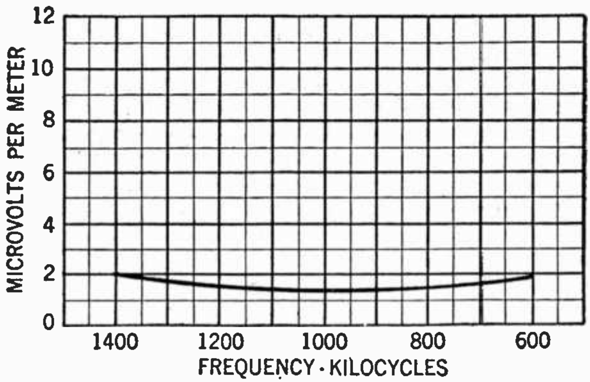


FIG. 7—Typical radio receiver, sensitivity characteristics.

The sensitivity measurements are generally accomplished in the following manner: The receiver is set up and a resistor is connected across the *a.f.* output of the set. The resistor should be of such value so as to give maximum power output per volt on the grid of the power tube. In most cases the resistor will have a value equal to twice the plate resistance of the output tube, which may easily be obtained from the tube performance chart.

The next procedure is to apply to an artificial antenna a known *r.f.* voltage modulated 30% at 400 cycles and to increase the *r.f.* input voltage until 50 milli-watts of audio-frequency power is developed across the output resistance.

The magnitude of the input *r.f.* voltage required to produce this output by dividing by the effective height of the artificial antenna, which is usually four meters is then determined.

Thus, finally the micro-volts per meter input required to produce the standard output of 50 milli-watts is obtained.

If it be assumed that the described method is utilized in determining the sensitivity of a certain receiver, it is simply necessary to give the micro-volts per meter input for standard output in order to define completely the sensitivity of the receiver in question.

It can therefore be said for example, that a certain receiver has a sensitivity of 10 micro-volts per meter. This means that if a 30% modulated *r.f.* signal is impressed across the input, then 50 milli-watts of power will be developed in the output at 400 cycles.

With the constant improvement in *r.f.* amplifier circuits, receiving sets at present are much more sensitive and it is not uncommon to find receivers having a sensitivity in the order of 3 to 5 micro-volts per meter or higher.

Fidelity.—Fidelity is the term being used to indicate the accuracy of reproduction, at the output of a radio receiver, of the modulation impressed on the *r.f.* signal applied to the input of the set under test.

This is generally determined by setting up the receiver to be tested and impressing on its input an *r.f.* signal modulated at 30%, the input signal having a value such that the normal output is obtained.

Next the frequency of the modulating signal is varied (the modulation being held constant) over the entire audio frequency band and the output power at each frequency is noted.

From the data so obtained, a curve can be charted showing how the audio-frequency output power from the set varies with the frequency applied.

Such curves are run at various radio frequencies for example at 600, 1000 and 1500 *k.c.* in the broadcast band, so that the variation of fidelity can be determined.

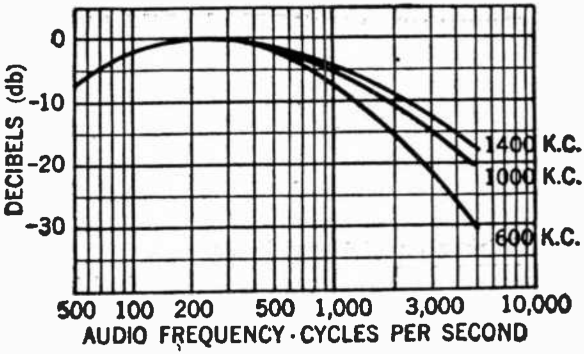


FIG. 8—Typical radio receiver, fidelity characteristics.

In this manner it is possible to obtain information regarding the characteristics of the *r.f.* amplifier system. It is obvious that if the system tunes too sharply at some point in the broadcast band, the side-bands will be suppressed partially and this will show up on the curve which is plotted as a falling off in response at the higher audio frequencies.

When making a test of this type, it is essential that the source of the audio frequency voltage used to modulate the *r.f.* input signal be quite pure (free from harmonics). Generally the total harmonic output from the audio frequency oscillator should not be allowed to exceed 5%.

Amplifier Classification.—There are four recognized classes of amplifier service. This classification depends primarily on the fraction of the input cycle during which the plate current is expected to flow under rated full-load conditions.

The term cut-off bias used in the following definitions is the value of grid bias at which plate current is of some very small value.

Class "A" Amplifiers.—A class A amplifier is one in which the grid bias and alternating grid voltages are such that the plate current in a specific tube flows at all times.

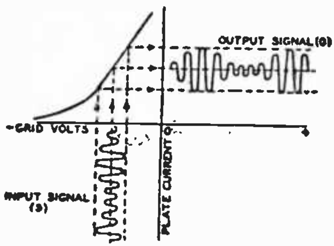


FIG. 9—A graphic illustration of method of amplification showing, by means of grid-voltage vs. plate-current characteristics, the effect of an input signal "S" applied to the grid of the tube. "O" is the resulting amplified plate-current variation.

Class A amplifiers of the voltage type find their application in reproducing grid voltage variations across an impedance or a resistance in the plate circuit. These variations are essentially of the same form as the input signal voltage impressed on the grid, but of increased amplitude. See fig. 9. This is accomplished by operating the tube at a suitable grid bias so that the applied grid-input voltage produces plate-current variations proportional to the plate swings. Since the voltage variation obtained in the plate circuit is much larger than that required to swing the grid amplification of the signal is obtained.

Class A amplifiers of the power type find their chief application as output amplifiers in audio systems, operating loud speakers in radio receivers and public address systems, where relatively large amounts of power are required.

For above applications, large output power is of much greater importance than high voltage amplification. Therefore gain possibilities are sacrificed in the design of power tubes to obtain this greater power handling capability.

Class "AB" Amplifiers.—A class AB amplifier is an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows for appreciable more than one-half but less than the entire cycle.

Class "B" Amplifiers.—A class B amplifier is an amplifier in which the grid bias is approximately equal to the cut-off value so that the plate current is approximately equal to zero when no exciting grid voltage is applied, and so that the plate current in a specific tube flows for approximately one-half of each cycle when an alternating grid voltage is applied.

Class B amplifiers of the power type employs two tubes connected in push-pull, so biased that the plate current is almost zero when no signal voltage is applied to the grids (see figs. 10 and 11). Because of this low value of no signal plate current, class B amplification has the same advantage as class AB, in that large power out-put can be obtained without excessive plate dissipation. The difference between class B and class AB is that, in class B, plate current is cut off for a larger portion of the negative grid swing.

Class C Amplifiers.—A class C amplifier is an amplifier in which the grid bias is appreciably greater than the cut-off value so that the plate current in each tube is zero when no alternating

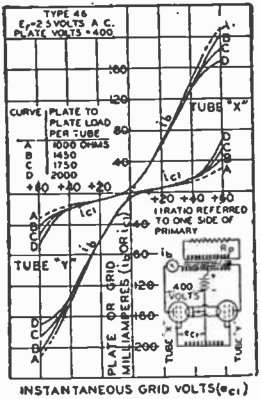


FIG. 10—Illustrates operation of tubes in class "B" circuit.

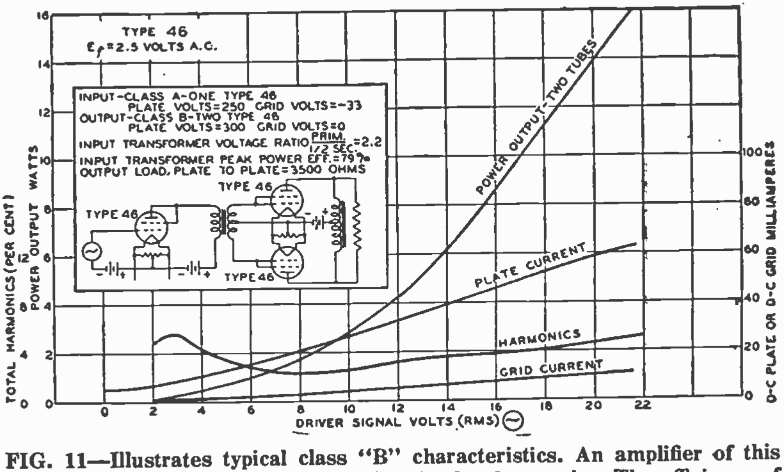


FIG. 11—Illustrates typical class "B" characteristics. An amplifier of this type generates considerable second and other harmonics. The efficiency of an amplifier of this type is higher than the previously discussed class A amplifier.

grid voltage is applied, and so that plate current flows in a tube for appreciably less than one-half of each cycle when an alternating grid voltage is applied.

Radio Frequency Amplifiers.—Radio frequency amplification is utilized to increase the volume of the weak radio frequency signals received from the antenna, and occurs before the radio frequency signals arrive at the detector circuit of the receiver.

There are three general methods for coupling the tube of one stage of radio frequency amplification to the next stage, namely:

1. Resistance coupled
2. Impedance coupled
3. Transformer coupled.

Resistance-coupled Radio Frequency Amplifier.—In this type of amplifier (see fig. 12) a high resistance is being utilized for the interstage coupling.

The advantage with this type when used as an audio amplifier is that on account of its simplicity it is economical to build, in addition, the amplification can be made very uniform over a rather wide frequency range. It is these characteristics which have made it useful in television devices.

The function of the blocking condenser is to prevent the plate potential of one stage being impressed on the grid of the next stage.

These blocking condensers, being series condensers, would trap electrons between the grid and the adjacent condenser plate, were it not for the high resistance leakage path provided for their return to the filament circuit.

Impedance Coupled Amplifiers.—The method of connection for inductive coupling (also known as choke coil coupling), is shown in fig. 13. The impedances X_1 and X_2 are in the form of auto-transformers; R_1 and R_2 are grid leaks ranging in value of between one-quarter and one-half megohms; C_1 and C_2 are the usual blocking condensers of about one microfarad capacity each.

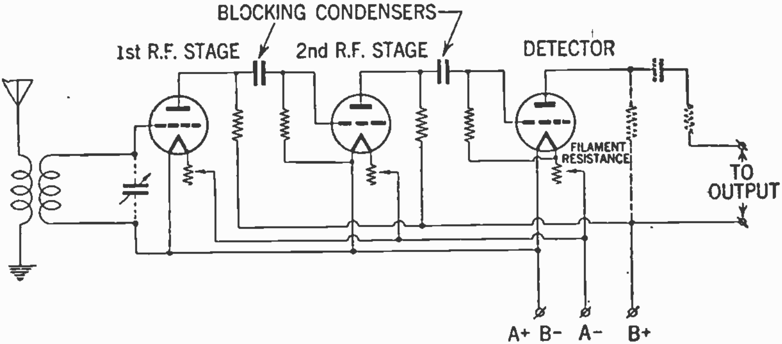


FIG. 12—Typical two stage resistance coupled radio frequency amplifier.

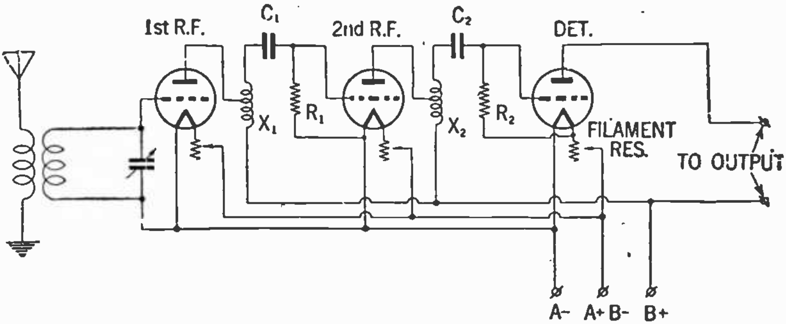


FIG. 13—Two stage impedance coupled radio frequency amplifier.

Transformer Coupled Amplifiers.—In this method the air-core transformers with a one to one transformer ratio, are most commonly used.

However, on very long wavelengths it has been found advantageous to use step-up ratio transformers, by having a greater number of secondary than primary turns.

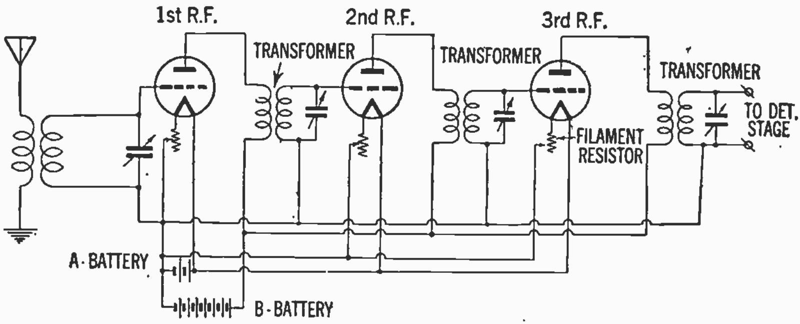


FIG. 14—Three stage radio frequency amplifier circuit.

In the transformer coupled circuit shown in fig. 14, the filaments are connected in parallel across the common "A" battery with a variable rheostat to adjust the filament current. A "B" battery is used to supply all the plate potentials, and a "C" battery (when necessary) to supply all grid biases.

Push-pull Amplifiers.—This type of amplifier is frequently used in receiving sets for supplying more power to the loud speaker than is ordinarily obtainable from one or two stage audio amplifiers.

Another advantage with this type of amplifier is that it eliminates any distortion which may exist in ordinary amplifiers due to the non-linear characteristics of the tube.

It will be found by observing circuit, fig. 15, that this is a balanced circuit, i.e. the cathode returns are made to the mid-point of the input and output devices.

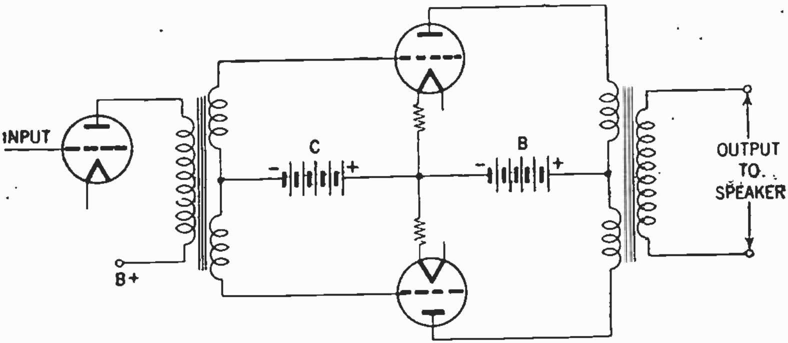


FIG. 15—Push-pull amplifier circuit. This type of amplification requires two identical tubes in each stage. The grids of the tubes are not connected together, as in the case of parallel operation, but are connected to opposite ends of a mid-tapped transformer secondary. The mid tap is used as a common connection for making connection to the negative bias voltage of the grids.

An *a.c.* current flowing through the primary winding of the input transformer will cause an *a.c.* potential to be induced in the secondary, since the ends of the winding will be at exactly opposite voltage with respect to the cathode connection. Hence it will be found that the grid of one tube is swung positive at the same instant that the grid of the other will be negative. From this it follows that the plate current in one tube is increasing, while the plate current of the other tube is decreasing. It is from this characteristic that the name "*push-pull*" has been derived.

Although ordinary amplifier tubes can be utilized in this type of amplifier, it is often desirable to use special power tubes which give a high amplification factor.

How Selectivity of a Receiver Is Affected by the Number of Radio Frequency Stages.—As previously explained the selectivity of a receiver is defined as its ability to discriminate between signals of various frequencies. However, this ability among other factors is affected by the number of stages of which the receiver is composed as well as the selectivity of each individual stage.

The influence of the number of stages upon the selectivity may best be understood by referring to fig. 16 which represents the selectivity characteristics of several radio frequency stages.

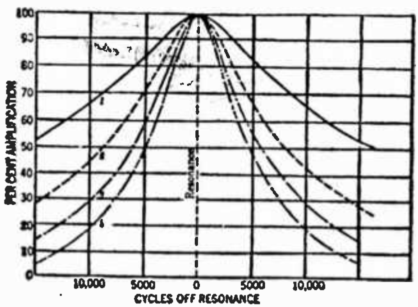


FIG. 16—Illustrates how the several stages of *r.f.* amplification increases the selectivity of a receiver by reducing the strength of undesired signals.

Curve 1 represents the selectivity of one single *r.f.* stage. At a point 5,000 cycles of resonance the circuit gives 84% of amplification at resonance and at 10,000 cycles off resonance the amplification has dropped to only 66% of the resonance amplification.

Assuming that instead of having only one *r.f.* stage that other stages be added having exactly the same characteristics as that of the first, the selective action as that represented by curve 2, will be obtained.

If now at a certain point off resonance, the first stage reduced the amplification factor to 84% then the second stage would reduce the amplification to 84% of what came through the first stage.

With reference to the chart at a point 5,000 cycles off resonance, the four stages would introduce a final amplification of only 49% of the resonant frequency.

Analyzing the result further, at a point 5,000 cycles off resonance the first stage is 84%; that of the second stage 84×84 or 70%; that of the third stage 84×84×84 or 59%, and finally the amplification of the fourth stage 84×84×84×84 or only a little better than 49%.

However, since a radio signal includes modulation frequencies up to 5,000 cycles off resonance, it is evident that a radio frequency amplifier having four stages would cause considerable side band suppression with consequent signal distortion.

Regenerative Circuits and Control Methods.—The term regenerative is applied to any detector circuit in which a coupling is provided between the plate and oscillatory grid circuit. The tube performs simultaneously the function of a detector and an oscillator.

A typical regenerative circuit is shown in fig. 17. The various methods for control of regeneration in receivers are known as potentiometers, ticklers, reversed capacity, etc. Figs. 18 and 19 shows two ways in which regeneration may be controlled by means of a screen grid detector. In fig. 18 the regeneration control is a variable condenser having a maximum capacity of 100 or 150 $\mu\mu$ *fd*. It acts as a variable by-pass between the low-potential end of the tickler coil and the cathode of the tube. If the by-pass capacity is too small the tube will not oscillate, while increasing the capacity will cause oscillations to start at a certain critical value of capacity.

This method of regeneration control is very smooth in operation, causes relatively little detuning of the received signal and, since the voltage on the screen-grid of the tube is fixed, permits the detector to be worked at its most sensitive point.

The sensitivity of a screen-grid detector depends a great deal upon maintaining the screen-grid voltage in the vicinity of 30 volts.

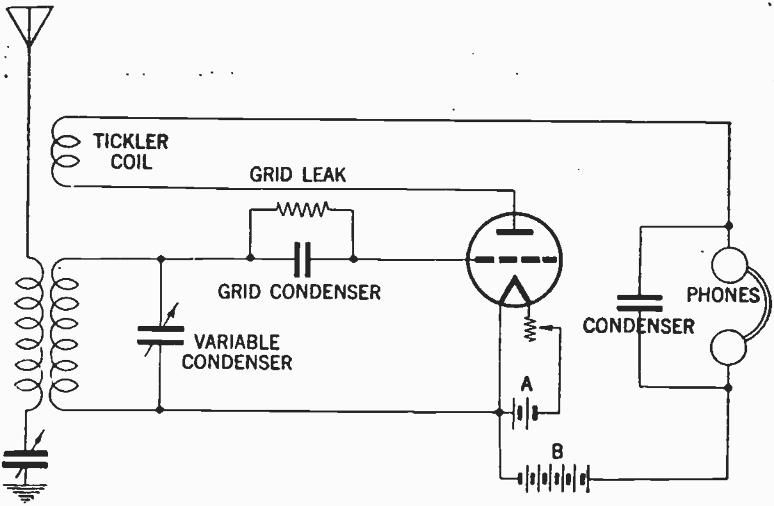
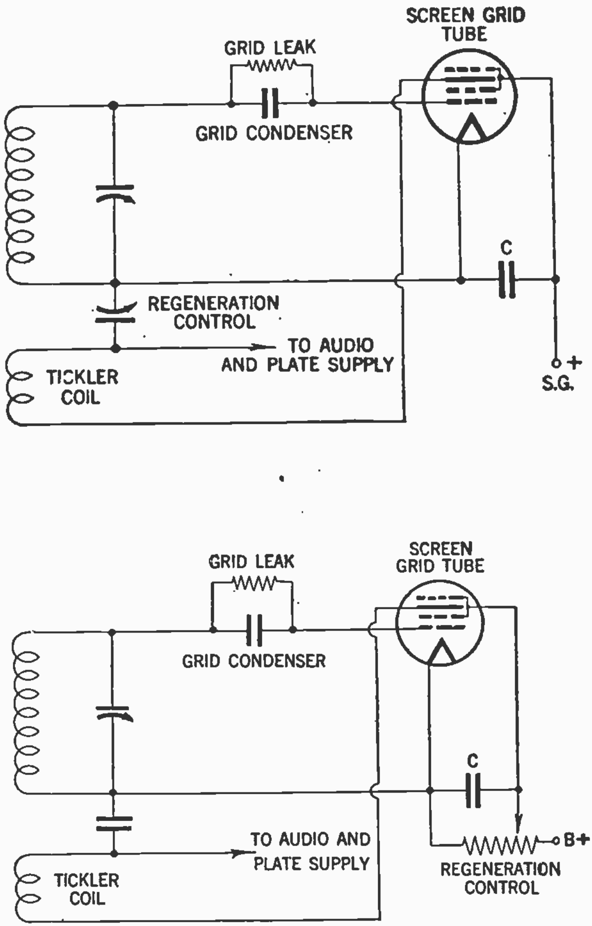


FIG. 17—Regenerative circuit. The scheme of combining a detector circuit with a separate oscillator circuit is called *heterodyning* and oscillators built exclusively for this purpose are called *heterodynes*. A circuit such as this is known as a *regenerative circuit*, and this term is applied to any detector circuit in which a coupling is provided between the plate and the oscillatory grid circuit.

In fig. 19 regeneration is controlled by varying the mutual conductance of the detector tube through varying its screen-grid voltage. The regeneration control is usually a voltage



FIGS. 18 and 19—Showing two methods for control of regeneration in radio receivers.

divider—or so-called "potentiometer"—with a total resistance of 50,000 ohms or more. This circuit causes more detuning of the signal than that in fig. 18 and the resistor is likely to cause some noise unless by-passed by a large capacity (about 1 μ *fd.*) at *C*. In fig. 18 condenser *C* may be .5 μ *fd.* or larger. With circuit, fig. 19, it is necessary to adjust the number of turns on the tickler coil to make the tube just start oscillating with about 30 volts on the screen grid if maximum sensitivity is desired.

Both the methods shown in figs. 18 and 19 may be applied to three-electrode detectors, although these tubes have been largely superseded as detectors by the more sensitive screen grid tubes. To use the method shown in fig. 19, the regeneration control resistor should be placed in series with the plate of the tube and it need not be used as a voltage-divider, but simply as a series variable resistor. It can also be used as a series resistor when controlling a screen-grid tube. Another type of regeneration control, more suitable for lower radio frequencies, uses a variable resistance across the feed-back portion of the *r.f.* circuit.

Conversion of a High Radio Frequency to a Low Radio Frequency.—This method is based on the simple electrical principle that when the energy of two different frequencies is combined in a suitable detector, there is produced a third frequency (termed the beat note or intermediate frequency) which is equal to the difference between the two first frequencies.

Thus if an amplifier is designed for 130 kilocycles and it is desired to receive a broadcast signal of 1,500 *k.c.* all that is needed, is to supply a locally-generated frequency either 130 *k.c.* higher or 130 *k.c.* lower than the received broadcast signal of 1,500 *k.c.*

The combination of the received broadcast signal and the locally-generated signal gives the beat note or intermediate frequency equal to the difference bteween them or 130 *k.c.*

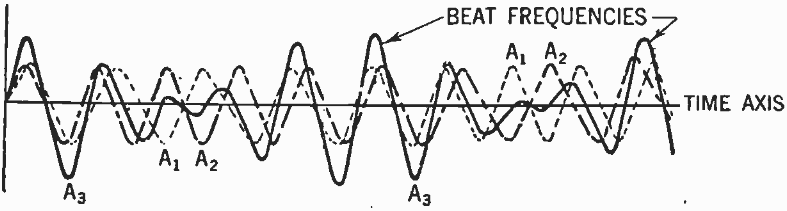


FIG. 20—Illustrates how beat frequencies are generated. With reference to curve A_1 and A_2, it may readily be observed how the frequencies are alternately in and out of phase with each other. The frequency with which these component curves are in phase with each other is equal to the difference between the frequencies of the two component currents, i.e. the frequency f_1 minus frequency f_2 equals frequency f_3. When the two frequencies f_1 and f_2 are the same, they are said to be adjusted to zero beat.

Detection.—It has been previously explained that *r.f.* amplification in a receiving set takes place before the radio signals arrival to the detector circuit. The function of the detector is to de-modulate the *r.f.* wave before it reaches the *audio* stage.

In the receiver it is desired to reproduce the original *a.f.* modulating wave, from the modulated *r.f.* wave, i.e. it is desired to de-modulate the *r.f.* wave.

The stage in the receiver in which this function is performed is often called the **demodulator** or **detector stage.** There are three detector circuits in general use, namely:

1. The diode detector
2. The grid-bias detector
3. The grid-leak detector.

A typical diode detector circuit is shown in fig. 21.

The action of this circuit when a modulated *r.f.* wave is applied is illustrated by fig. 22. The *r.f.* voltage applied to the circuit is shown in light line, the output voltage across the condenser *C* is shown in heavy line. Between points *a* and *b* on the first positive half-cycle of the applied *r.f.* voltage, the condenser *C* charges up to the peak value of the *r.f.* voltage.

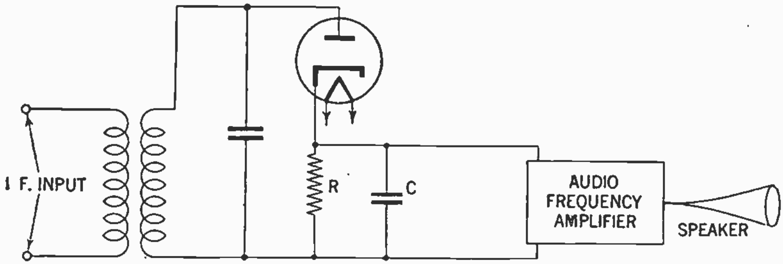


FIG. 21—Diode detector circuit.

Then as the applied *r.f.* voltage falls away from its peak value, the condenser holds the cathode at a potential more positive than the voltage applied to the anode. The condenser thus temporarily cuts off current through the diode. While the diode current is cut off, the condenser discharges from *b* to *c*, through the diode load resistor *R*. When the *r.f.* voltage on the anode rises high enough to exceed the potential at which the condenser holds the cathode, current flows again and the condenser charges up to the peak value of the second positive half-cycle at *d*. In this way, the voltage across the condenser follows the peak value of the applied *r.f.* voltage and thus reproduces the *a.f.* modulation.

The curve for voltage across the condenser, as shown in fig. 22 is somewhat jagged. However, this jaggedness, which represents an *r.f.* component in the voltage across the condenser, is exaggerated in the illustration. In an actual circuit the *r.f.* component of the voltage across the condenser is negligible. Hence, when the voltage across the condenser is amplified, the output of the amplifier reproduces the speech or music originating at the transmitting station.

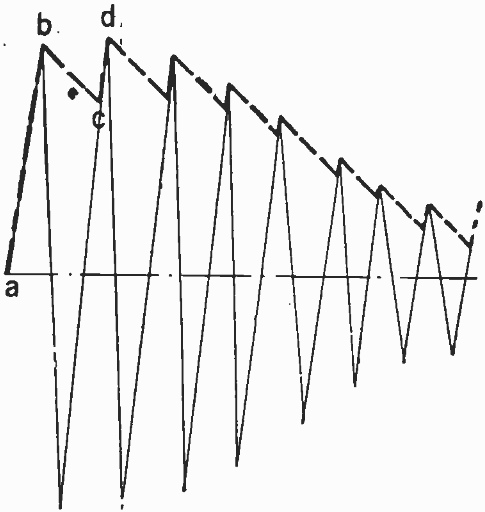


FIG. 22—Diode detector characteristics.

The diode method of detection has the advantage over other methods that it produces less distortion. The reason is that its dynamic characteristic can be made more linear than that of other detectors. It has the disadvantages that it does not amplify the signal, and that it draws current from the input circuit and therefore reduces the selectivity of the input circuit. However, because the diode method of detection produces less distortion and because it permits the use of simple *a.v.c.* circuits without the necessity for an additional voltage supply, the diode method of detection is most widely used in broadcast receivers.

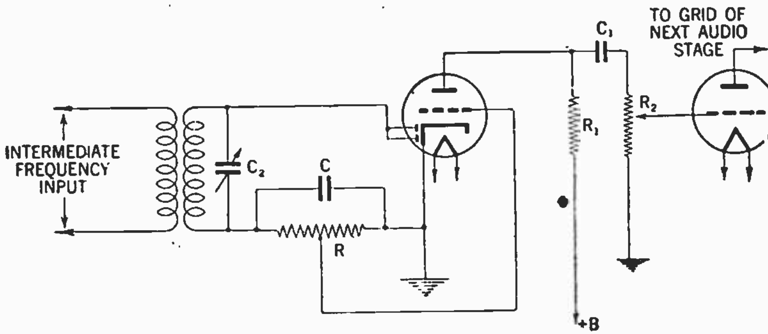


FIG. 23—Diode-biased detector circuit.

Another diode detector circuit, called a diode-biased circuit, is shown in fig. 23. In this circuit, the triode grid is connected directly to a tap on the diode load resistor. When an *r.f.* signal voltage is applied to the diode, the *d.c.* voltage at the tap supplies bias to the triode grid. When the *r.f.* signal is modulated, the *a.f.* voltage at the tap is applied to the grid and is amplified by the triode. The advantage of this circuit over the self biased arrangement shown in fig. 24 is that the diode-biased circuit does not employ a condenser between the grid and the diode load resistor, and consequently does not produce as much distortion of a signal having a high percentage of modulation.

However, there are restrictions on the use of the diode-biased circuit. Because the bias voltage on the triode depends on the average amplitude of the *r.f.* voltage applied to the diode, the average amplitude of the voltage applied to the diode should be constant for all values of signal strength at the antenna. Otherwise there will be different values of bias on the triode grid for different signal strengths and the triode will produce distortion.

This restriction means, in practice, that the receiver should have a separate-channel automatic volume control system. With such an *a.v.c.* system, the average amplitude of the signal voltage applied to the diode can be held within very close limits for all values of signal strength at the antenna.

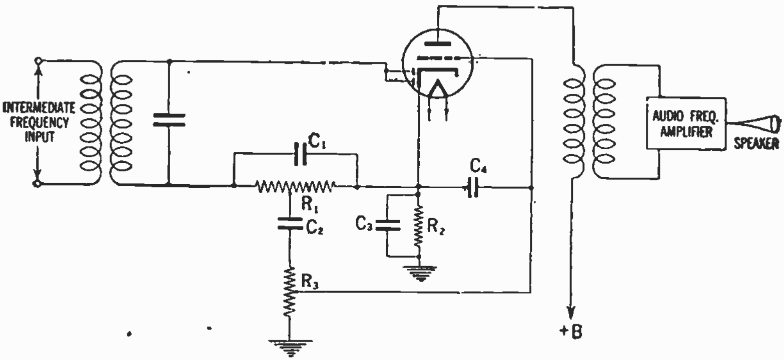


FIG. 24—A typical diode-detector circuit using a duplex-diode tube is shown above. In this circuit R_1 is the diode load resistor. A portion of the *a.f.* voltage developed across this resistor is applied to the triode grid through the volume control R_3. In a typical circuit, resistor R_1 may be tapped so that five-sixths of the total *a.f.* voltage across R_1 is applied to the volume control. This tapped connection reduces the voltage output of the detector circuit, but also reduces audio distortion and improves the *r.f.* filtering. *D.c.* bias voltage for the triode section is provided by the cathode-bias resistor R_2 and the audio by-pass condenser C_3. The function of condenser C_2 is to block the *d.c.* bias voltage of the cathode from the grid. The function of condesner C_4 is to by-pass any *r.f.* voltage on the grid to cathode. A duplex-diode pentode may also be used in this circuit. With a pentode, the *a.f.* output should be resistance-coupled rather than transformer-coupled.

The tube used in a diode-biased circuit should be one which operates at a fairly large value of bias voltage. The variations in bias voltage are then a small percentage of the total bias and hence produce small distortion. Tubes taking a fairly large bias voltage are types such as the 6R7 or 85 having a medium-mu triode.

Tube types having a high-mu triode or a pentode should not be used in a diode biased circuit. Since there is no bias applied to the diode-biased triode when no *r.f.* voltage is applied to the diode, sufficient resistance should be included in the plate circuit of the triode to limit its zero-bias plate current to a safe value.

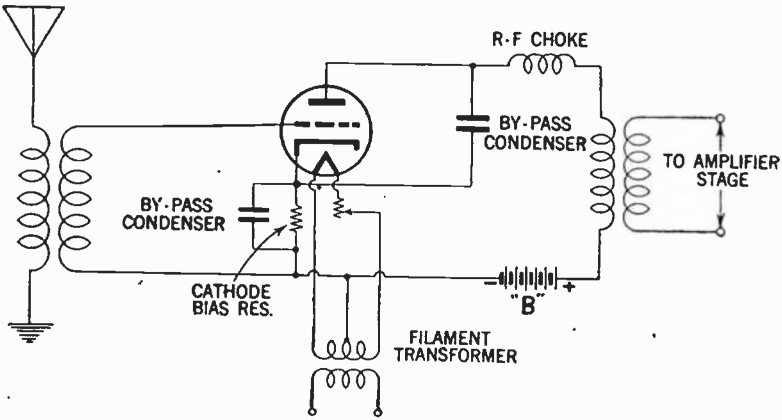


FIG. 25—Grid-biased detector circuit.

A grid-bias detector circuit is shown in fig. 25. In this circuit, the grid is biased almost to cut-off, i.e. operated so that the plate current with zero signal is practically zero. The bias voltage can be obtained from a cathode-bias resistor, a "C" battery, or a bleeder tap. Because of the high negative bias, only the positive half cycles of the *r.f.* signal are amplified by the tube. The signal is therefore detected in the plate circuit.

The advantages of this method of detection are that it amplifies the signal, besides detecting it, and that it does not draw current from the input circuit and therefore does not lower the selectivity of the input circuit.

The grid-leak and condenser method, shown in fig. 26 is somewhat more sensitive than the grid bias method and gives its best results on weak signals. In this circuit, there is no negative *d.c.* bias voltage applied to the grid. Hence, on the positive half-cycles of the *r.f.* signal, current flows from grid to cathode. The grid and cathode thus act as a diode detector, with the grid-leak resistor as the diode load resistor and the grid condenser as the *r.f.* by-pass condenser.

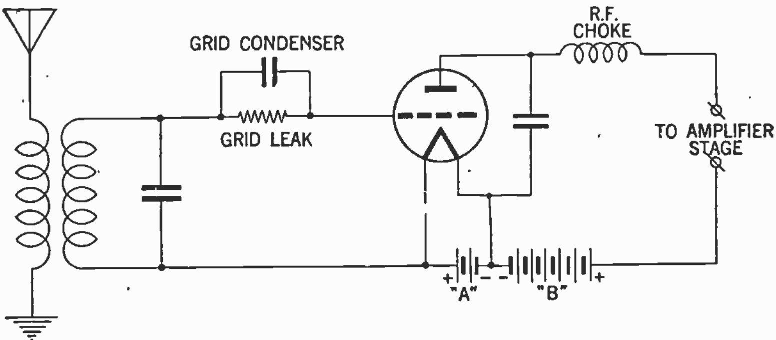


FIG. 26—Detector circuit grid-leak and condenser method.

The voltage across the condenser then reproduces the *a.f.* modulation in the same manner as has been explained for the diode detector. This voltage appears between the grid and cathode and is therefore amplified in the plate circuit. The output voltage thus reproduces the original *a.f.* signal.

In this detector circuit, the use of a high resistance grid leak increases selectivity and sensitivity. However, improved *a.f.* response and stability are obtained with lower values of grid-leak resistance. This detector circuit has the advantage that it amplifies the signal, but has the disadvantage that it draws current from the input circuit and therefore lowers the selectivity of the input circuit.

Tuned Radio Frequency Circuits.—The word *tuned* in this connection simply means that the circuit is brought into resonance with the desired signal. A tuned *r.f.* circuit is one in which

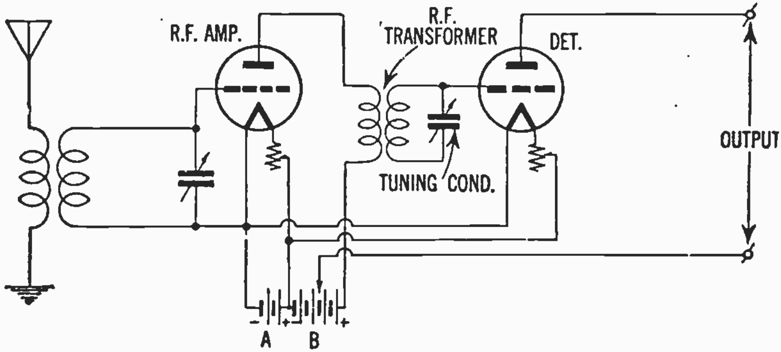


FIG. 27—Diagram illustrating principle of tuned radio frequency. The usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer. A potentiometer is used to control oscillations, as the greatest amplification is obtained when the circuits are operated just at the point before self oscillation starts.

the radio frequency amplifier circuits may be tuned to the desired wave lengths by adjusting the inductance or the capacity or both, although the usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer. (For theory of tuning see page 165.)

Reflex Circuits.—The reflex circuit principle is only one of several circuits developed, whose aim it was to extract the maximum use of a tube or a group of tubes, i.e. to reduce the number of tubes required in a multi-stage receiver.

The use of this circuit, however, with the versatility and relative inexpensiveness of the modern vacuum tube has become largely obsolete except in locations where space and weight of a receiver is at a premium—for example, in connection with portables, airplane, and automobile receivers.

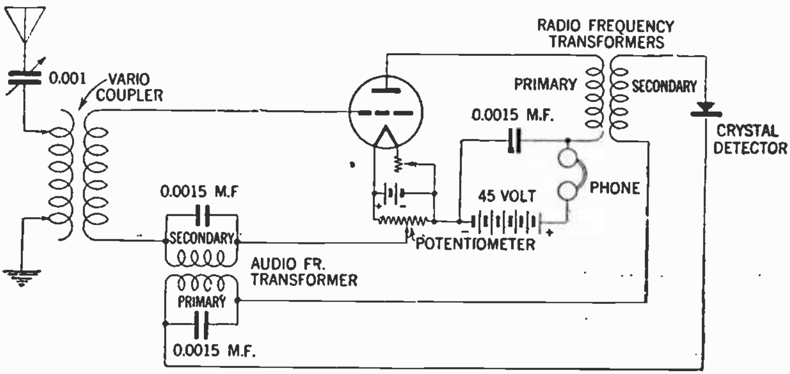


FIG. 28—Diagram showing typical reflex circuit.

In this circuit the vacuum tubes are made to perform the double duties of both radio and audio frequency amplifiers.

The incoming radio frequency signal is amplified at radio frequency, rectified by a detector, and then amplified at audio frequency using the same tube, or if so desired the circuit values can be chosen so that the stage can function as a radio frequency and intermediate frequency amplifier.

It can readily be understood that to construct a stage which will first amplify the signal at the *i.f.* and then further amplify the signal after it has been rectified and converted into an audio frequency, requires a very careful choice of circuit constants, because not only must the circuit elements give the proper load at both audio and intermediate frequencies but filters must also be inserted to separate the frequencies so as to prevent feedback. A typical reflex circuit using one tube and a crystal detector is shown in fig. 28.

Intermediate Frequency Amplifiers.—The function of the intermediate frequency amplifier in a super-heterodyne receiver is to convert the *r.f.* signal to an intermediate frequency.

To obtain this change in frequency, a frequency-converting device consisting of an oscillator and a frequency mixer is commonly employed.

In a circuit of this type two potentials of different frequency namely the radio frequency voltage and the potential generated by the oscillator are applied to the input of the frequency mixer.

The aforementioned potentials beat, or heterodyne with the mixer tube to produce a plate current having in addition to the frequencies of the input potential, numerous sum and difference frequencies.

Generally the output circuit of the mixer stage is provided with a tuned circuit adjusted to select only one beat frequency—that frequency which is equal to the difference between the impressed signal frequency and the oscillator frequency.

It is this selected output frequency which is known as the *intermediate frequency* or in abbreviated form *i.f.*

The output frequency of the mixer tube is kept constant for all signal frequency values by tuning the oscillator to the proper frequency. Methods of frequency conversion for super-heterodyne receivers are as follows:

The first method widely employed before the availability of tubes especially designed for this purpose utilizes as mixer tube either a triode, a tetrode or a pentode. In this method the oscillator and signal potential are applied to the same grid. The coupling between the oscillator and mixer circuits is obtained by means of inductance or capacitance.

A second method employs a tube which is especially designed for this type of service and is known as the *pentagrid converter* tube.

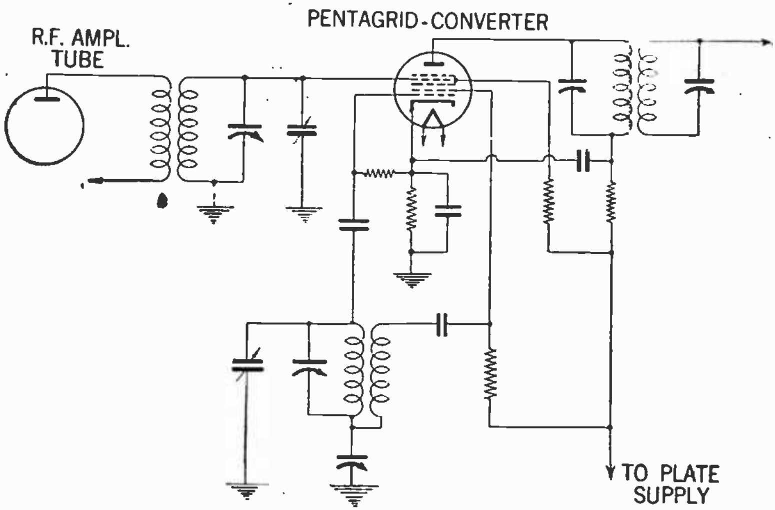


FIG. 29—Pentagrid converter tube employed as an oscillator mixer in a super-heterodyne receiver circuit.

In this tube the oscillator and frequency mixer are combined, and the coupling between the oscillator and mixer circuit is obtained by means of the electron stream within the tube. For the arrangement of elements in a pentagrid converter see page 4,494-A.

A third method employs a tube designed for short-wave reception, and is identified as the pentagrid mixer. It has two independent control grids, and is used with a separate oscillator tube.

In this tube the *r.f.* signal potential is applied to one of the control grids and oscillator potential to the other.

Audio Frequency Amplifiers.—An audio frequency amplifier is employed to increase the volume of the signals after leaving the detector tube, but before the signal is passed into the loud speaker.

There are three general methods of audio amplifier couplings whereby the tube of one stage of audio frequency amplifier may be connected to the following stage, identified as:

1. Resistance coupled
2. Impedance coupled
3. Transformer coupled.

Resistance Coupled Audio Frequency Amplifier.—Here, as in previously discussed *r.f.a.* a resistance is employed in the interstage coupling, as shown in fig. 30.

The function of the blocking condenser *C*, is that of insulating the grid of the tube from the high positive potential of the plate supply. In order to prevent the grid from the tendency of accumulating a negative charge, a high resistance leakage path is introduced through grid R_2, the size of which depends upon the value of the grid to filament resistance of the tube.

When a signal potential is received from the detector, a current is generated through coupling resistor R_1, in the plate circuit of the primary tube, these voltage variations lowered by the blocking condenser *C*, are impressed upon the input circuit of the second tube. Finally the grid voltage variations applied to the secondary tube causes corresponding variations of the plate potentials which are impressed on the input circuit of the final stage.

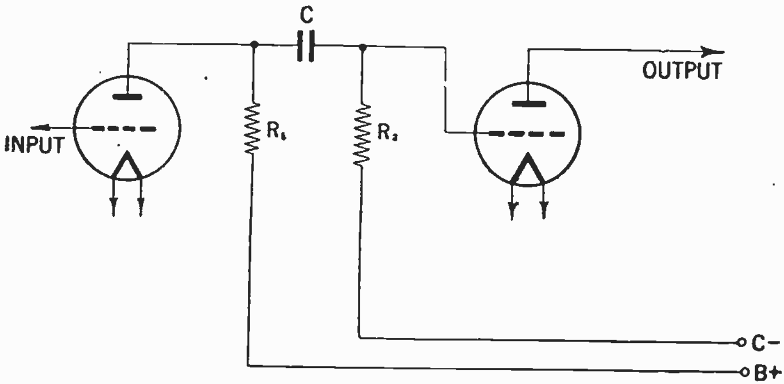


FIG. 30—Interstage coupling in a *resistance coupled* audio frequency amplifier.

Resistance coupling of the audio-frequency stages offer the advantages of good response at low audio frequencies. However, this increases the possibility of trouble from a common plate voltage supply. This is on account of the fact that the by-pass condensers are ineffective at very low audio-frequencies and hence the common voltage supply acts as coupling between the stages. This gives rise to oscillations which are known as motor-boating and may be prevented as suggested on page 288.

Impedance Coupled Audio Amplifiers.—The impedance coupled audio amplifier is similar to the resistance coupled amplifier just described except that in place of the resistance an inductance consisting of a coil of wire wound on a laminated steel core, is utilized.

This type of coupling is also known as choke coil coupling or choke coil amplification. The voltage amplification obtained in this type is, as in the case of the resistance coupled amplifier, due to the amplification of the tube employed.

The effect of the blocking condenser is similar as that described for the resistance coupled amplifier.

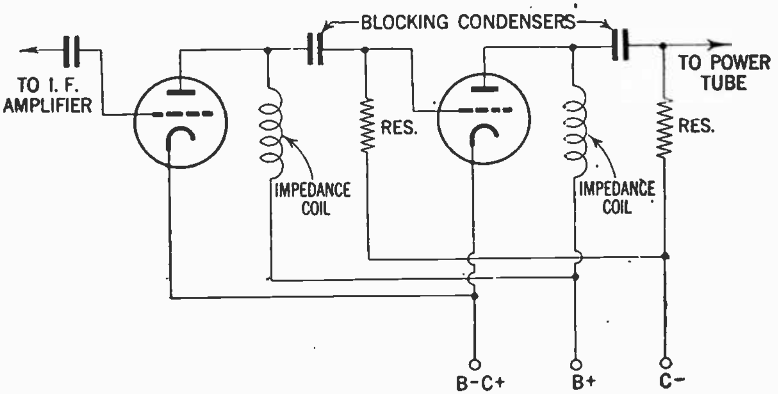


FIG. 31—Inter-stage coupling in an impedance coupled *audio frequency* amplifier.

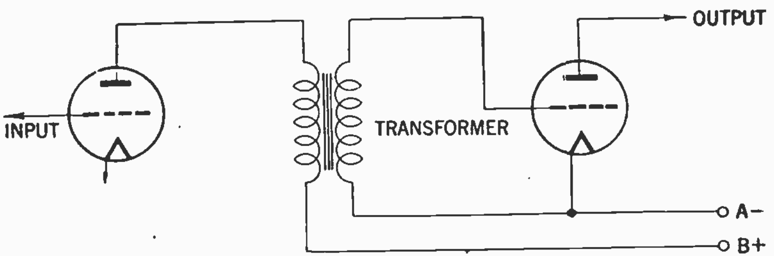


FIG. 32—Method of inter-stage connection of *transformer coupled* audio ferquency amplifier.

Transformer Coupled Audio Amplifier.—In the transformer amplifier shown in fig. 32, the coupling is made by means of a transformer consisting of two windings—one primary and one secondary.

This type of coupling used extensively in early radio receivers has now largely disappeared on account of a number of disadvantages as compared with previous mentioned types.

The voltage gain received in this type is largely defeated due to the fact that it is not linear for all frequencies.

The frequency distortion is caused largely by the distributed capacity existing between the windings of the transformer.

An additional form of distortion known as harmonic distortion is caused by saturation of the iron core in the transformer.

Tuning Indication.—Tuning indication in modern receivers is usually accomplished by the employment of an electronic device identified as the electron-ray tube.

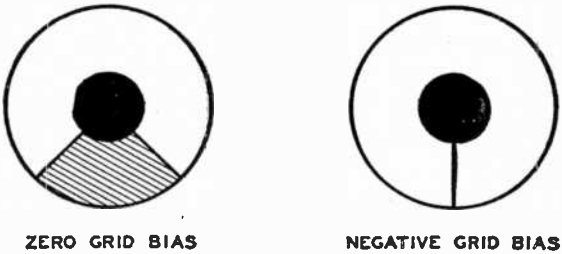


FIG. 33—Electron pattern on the 6E5 target for various grid bias.

The choice between the two types known as the 6E5 and 6G5 for a receiver depends largely on the receiver's automatic volume control characteristics. The 6E5 for example has a sharp cut-off triode which closes the shadow angle on a comparatively small value of *a.v.c.* potential, whereas the 6G5 has a remote cut-off triode which closes the shadow angle on a larger value of *a.v.c.* potential.

In both types the triode is mounted in an evacuated glass enclosure with a fluorescent target in a dome as shown in fig. 34. The target is operated at a positive potential and hence attracts electrons from the cathode.

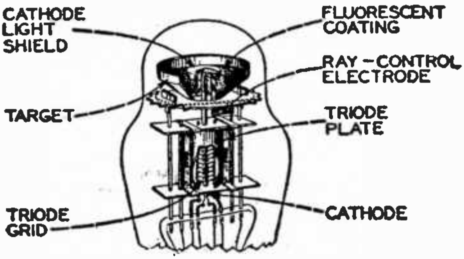


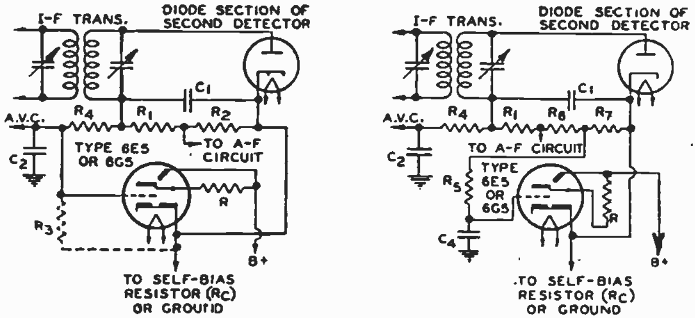
FIG. 34—Internal construction of electron ray indicator tube. (Courtesy R.C.A. Mfg. Co. Inc.)

When the electrons strike the target they produce a glow in the fluorescent coating on the target, which appears as a ring of light when the electrons are flowing over the whole circumference.

The extent of this glow pattern depends upon the grid voltage of the tube, and hence will give an indication on the amount of departure from the condition of resonance or sharpness of tuning.

The tubes may be connected for indicator service as depicted in figs. 35 and 36.

When the receiver reaches a condition of resonance during timing, the automatic control voltage is at maximum, and since this maximum voltage is applied to the grid of the triode, it acts to decrease the triode plate current, and decrease the shadow angle to a minimum, which gives an indication that the set is tuned exactly on the desired station.



FIGS. 35 and 36—Typical tuning indicator circuits. When the strongest carrier received produces sufficient *a.v.c.* voltage to exceed the cut-off bias value of 8 volts, the shadow area of fluorescent traget will overlap. In order to overcome this effect resistor R_3 should be connected, as shown, between the triode unit grid and cathode in order to reduce the control voltage. The value of this resistance may best be determined by applying a strong signal and then adjust R_3 until the shadow angle is nearly zero. (Courtesy R.C.A. Inc.)

$R = \begin{cases} 1.0 \text{ megohm for } B+ = 250 \text{ volts} \\ 0.5 \text{ megohm for } B+ = 100 \text{ volts} \end{cases}$
R_1 = 0.05 megohm *rf* (filter)
R_2 = 0.2 megohm
R_3 = determined by test
R_4 = *a.v.c.* filter resistor

$R_5 = R_4$
$R_6 + R_7$ = 0.2 megohm
C_1 = 100 to 200 $\mu\mu f$
C_2 = *A.v.c.* filter condenser
C_3 = 0.05 to 1.0 μf
$C_4 = C_2$

"Motor Boating" of Amplifiers.—Generally this term is derived from the erratic action of a receiving set in giving out a "put-put" sound somewhat resembling that of a motor used in propelling a boat. This is usually caused by inter-action coupling between stages, due to common coupling in the plate-supply unit.

To remedy this situation a circuit known as an "anti-motor-boating" has been found to give good results.

To add a circuit of this kind to any existing receiver it is simply necessary to connect the resistance *R*, in series with the lead connecting between the *B*+ detector terminal on the receiver and the *B*+ terminal on the detector terminal on the power unit.

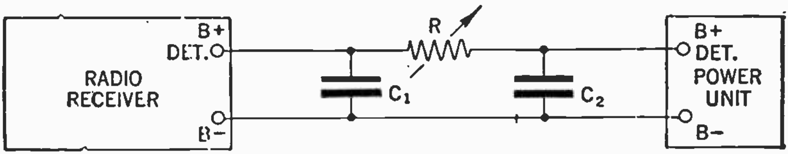


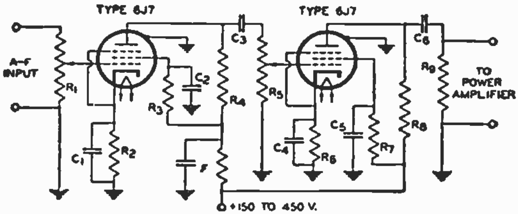
FIG. 37—A method whereby "motor boating" may be eliminated, by means of condensers and resistor connected between the receiver and "B" power supply unit as shown.

Condensers C_1 and C_2 each having a value of 2.0 mfd. are connected between the *B*+ and *B*− as illustrated. It is preferable to locate the resistance at a point close to the receiver rather than near the power unit.

The value of the resistance depends to some extent upon the characteristics of the receiver and the power unit. In some amplifiers a value of 10,000 ohms have been found to be satisfactory whereas in others a resistance of 50,000 to 100,000 ohms has been required to prevent "motor-boating" although in most cases a resistance of 50,000 ohms has been found satisfactory.

A non-motor boating resistance coupled amplifier using two type 6J7 tubes with a voltage gain of 9,000, using circuits values as indicated, is shown in fig. 38.

Various Methods of Obtaining Grid Bias.—The grid bias may generally be defined as the direct potential applied to the grid of a vacuum tube, to influence its operation by making it negative with respect to the filament or the cathode.



C_1, C_4 = 8 µf, LOW VOLTAGE
C_2, C_5 = 0.06 µf, VOLTAGE RATING AS HIGH AS VOLTAGE SUPPLY
C_3, C_6 = 0.006 µf, VOLTAGE RATING AS HIGH AS VOLTAGE SUPPLY
R_1 = VOLUME-CONTROL POTENTIOMETER
R_2, R_6 = 800 OHMS, 0.1 WATT
R_3, R_7, R_9 = 500000 OHMS, 0.5 WATT
R_4, R_8 = 100000 OHMS, 0.1 WATT
R_5 = 500000-OHM VOLUME-CONTROL POTENTIOMETER GANGED WITH R_1
F = DECOUPLING FILTER

FIG. 38—Schematic circuit diagram of "Non-motor boating" resistance coupled amplifier. (Courtesy R.C.A. Mfg. Co. Inc.)

Among the numerous methods of obtaining bias voltage for amplifier tubes, the simplest and most direct way is to connect the "C" battery in series with the grid return lead of each tube.

However, because of a rather popular aversion to the use of batteries, to mention nothing of its cost, this classical scheme is ruled out. The next method in order of simplicity is the use of a self-bias resistor, properly by-passed, as shown in fig. 39. This method is familiar to all set builders and experimenters, and therefore requires little comment. The only disadvantage is the high cost of resistors and by-pass condensers, especially when there are numerous tubes in the set.

A number of other bias circuits are available which have the advantages of simplicity, low cost and reliability. These schemes make use of the fact that the total *B* drain of the set returns to the power transformer through the minus *B*, lead of the set. Fig. 40 shows one of the circuits. A single tapped resistor is used to obtain the *C*, bias voltages for all the tubes. When using this circuit, the cathodes of all tubes are grounded.

Experimenters and set builders will appreciate how much this means in cleaning up the wiring around a tube socket.

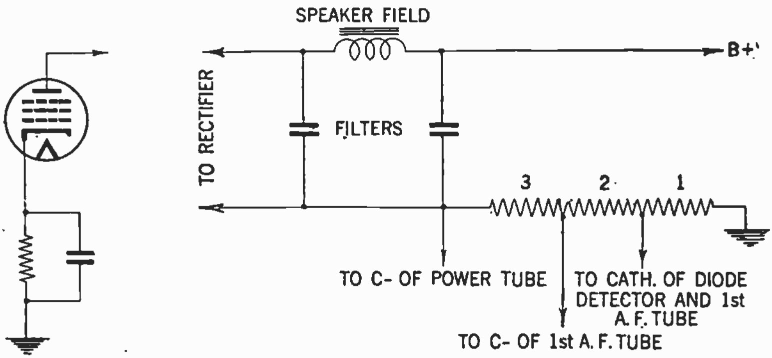


FIG. 39—Showing how grid bias may be obtained by the use of self biased by-passed resistor.

FIG. 40—Illustrating a simple and convenient grid bias scheme.

Finding Resistor's Value.—The proper value of this resistor is easy to determine. With reference to fig. 40 add up the plate and screen currents of all the tubes in the set (this value can be obtained from a tube chart) and divide the total into the value of grid bias of the output tube.

For example, if the sum of all the plate and screen currents is, say, 70 milliamperes (0.07 ampere); the grid bias of the output tube is, say 12.5 volts. The value of the entire resistor is then 12.5 divided by 0.07 or approximately 180 ohms. This resistor is divided into three parts: Part 1, is simply the value of the bias on the *r.f.* and *i.f.* tubes divided by 0.07; part 2, is the value of the bias on the first audio tube divided by 0.07, etc.

If trouble be encountered with this calculation, then find the value of the entire resistor and determine the position of the taps by trial and error; the same answer will be obtained either way.

Using Speaker Field.—Another convenient bias circuit is to make use of the voltage drop across the speaker field when it is connected in the negative leg of the filter. This circuit is shown in fig. 41. In this circuit, all cathodes are connected directly to chassis. The proper position of the taps is best calculated, because R should be about 0.5 megohm and accurate readings cannot be obtained on ordinary volt-meters with such high resistors in the circuit.

In a typical case, E is 100 volts. R_1 is 3 times 500,000 divided by 100, or 15,000 ohms. R_2 is 1.2 times 500,000 divided by 100 or 6,000 ohms; in a similar manner R_1 plus R_2 plus R_3 is determined.

In circuit fig. 43 is another typical device which is used with much success. In this circuit, the *a.v.c.* resistors are used to form a voltage divider with another resistor R_3. The theory of the circuit is as follows: A bias voltage E, is developed across resistor R_4 in a manner similar to that described for circuit fig. 1. This voltage is impressed across R_1, R_2 and R_3 in series. It is the fraction of E, that is developed across R_1 plus R_2 that supplies bias for the *r-f* and *i-f* tubes. The entire voltage E

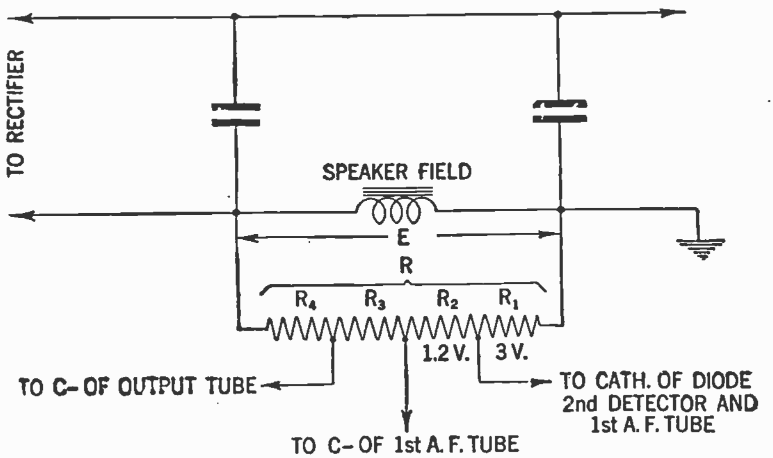
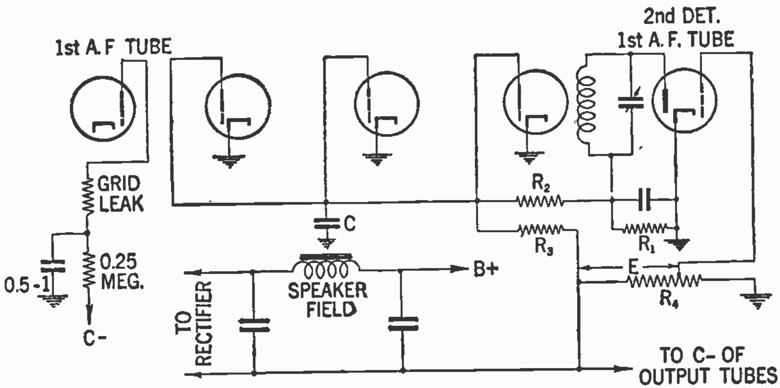


FIG. 41—Method of obtaining grid bias by utilizing voltage drop across speaker field coil.



FIGS. 42 and 43—Grid bias method when receiver is equipped with automatic volume control.

supplies bias for the output tube; the first *a-f* tube obtains bias from a tap on R_4. The merit of this circuit lies in the fact that any hum on R_4 is filtered from the grids of *r-f* and *i-f* tubes by the *a.v.c.* condenser *C*, which is normally in the circuit.

The circuits shown here are fundamental types and there are many deviations from them. This circuit is relatively new and is being adopted by an increasing number of manufacturers for reasons of economy.

Only one precaution need be taken. Should hum develop, simply insert a decoupling resistor in the grid lead of the first audio tube, as shown in fig. 42.

***R.M.S.* (Root mean-square) and Peak Voltage Relations in an Alternating Current.**—In order that a clear conception may be had regarding the exact meaning of the above terms, the definitions are as follows:

1. **The *R.M.S.* (Root mean-square) Value** sometimes identified as effective voltage is that part of an alternating current which has the same heating effect as a direct current of the same potential, and it is for this reason that the *r.m.s.* value of an alternating voltage is termed the effective value.

2. **The Peak Value** of an alternating voltage is the maximum value to which the voltage rises during any part of the cycle. The shape of ordinary *a.c.* voltages are such that the potential is proportional to the sine of an angle, hence the often heard expression of the term "sine curve" shown in fig. 44.

When the voltage has such a form the peak voltage is equal to the $\sqrt{2}$ times the *r.m.s.* value or if the peak voltage is known divide this voltage by the $\sqrt{2}$ to obtain the *r.m.s.* or effective value.

Example.—*What is the effective or (r.m.s.) value of an oscillating grid voltage whose peak values are 7 and 22 volts negative, and what is the grid bias?*

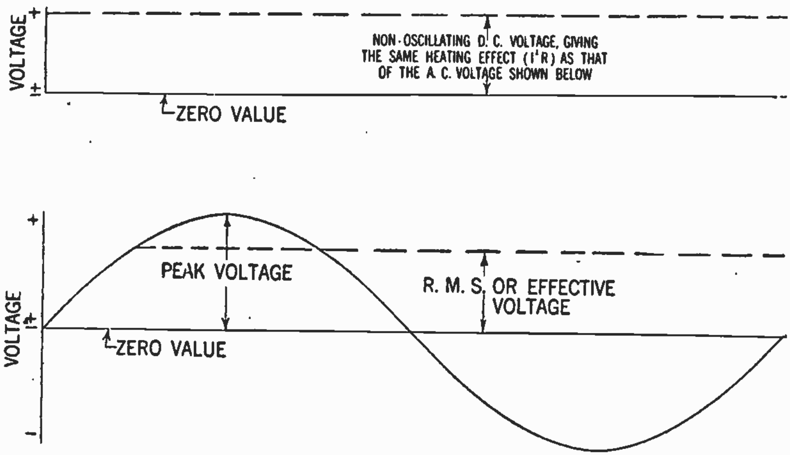


FIG. 44—Illustrating comparative values of *r.m.s.* and peak voltage in an alternating current.

Solution.—Since the extreme values of voltage variation are -7 and -22 volts, the total amount of grid "swing" will be their difference or 15 volts, while the amplitude of an oscillation will be half of this or 7.5 volts. Now the *r.m.s.* value is always $\frac{1}{1.41}$ or 0.707 of the corresponding amplitude; hence the *r.m.s.* value of the grid voltage oscillations will be $0.707 \times 7.5 =$ 5.3 volts approximately. The grid bias point or mean potential of the grid will obviously lie half-way between the extreme peaks of potential attained in the cycle; it will therefore be ½ (7+22) or 14.5 volts negative.

Example.—*If a* 2 *volt battery supplies* 0.85 *watt to a filament circuit, what is the current drain?*

Solution.—For the solution of this problem, it is necessary to re-write the equation $W = I \times E$ in the equivalant from $I = \frac{W}{E}$ in which as usual E and I are in volts and amperes, while W is expressed in watts. In the above example therefore—

$$I = \frac{0.85}{2} = 0.425 \text{ ampere}$$

CHAPTER 177

Radio Circuit Diagrams

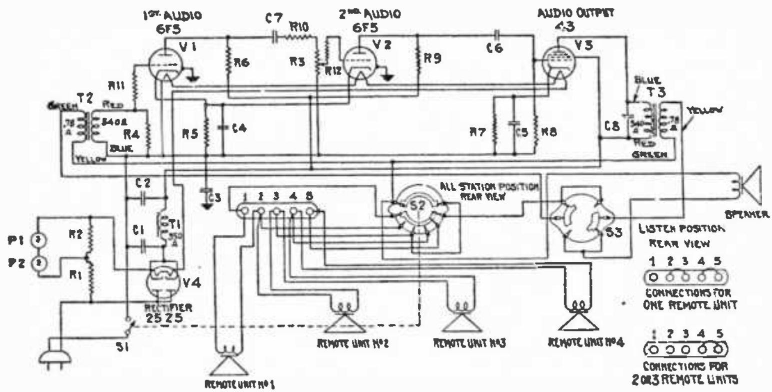


FIG. 7,318.—Schematic wiring diagram of a 4-tube Handy-phone for inter-office communication. (Model FM-41 General Electric.) The handy phone is an efficient loudspeaker phone system for use in offices, homes, hospitals or other places where voice communication between a central station and one of more remote stations is desirable. The system comprises one Model FM-41 master station and from one to four Moddl FS-5 remote speaker phone stations. The master station employs four General Electric tubes in a three-stage audio amplifier circuit, with power supply. When it is desired to operate over a distance of more than 2,000 feet, standard line transformers may be used, procurable from any radio supply house. The transformers should be designed to operate from a five-ohm source into a line of 200, 500 or 600 ohms impedance. The system may be operated from either *a.c.* or *d.c.* power supply. When the system is operated from an *a.c.* source, all *d.c.* potentials are supplied by the rectifier tube 25Z5 and its associated filter circuits. When the system is operated from a *d.c.* source it is necessary to insert the plug with proper polarity. If the unit fails to function after allowing time for the tubes to reach their proper operating temperature, the power plug should be reversed in the receptacle.

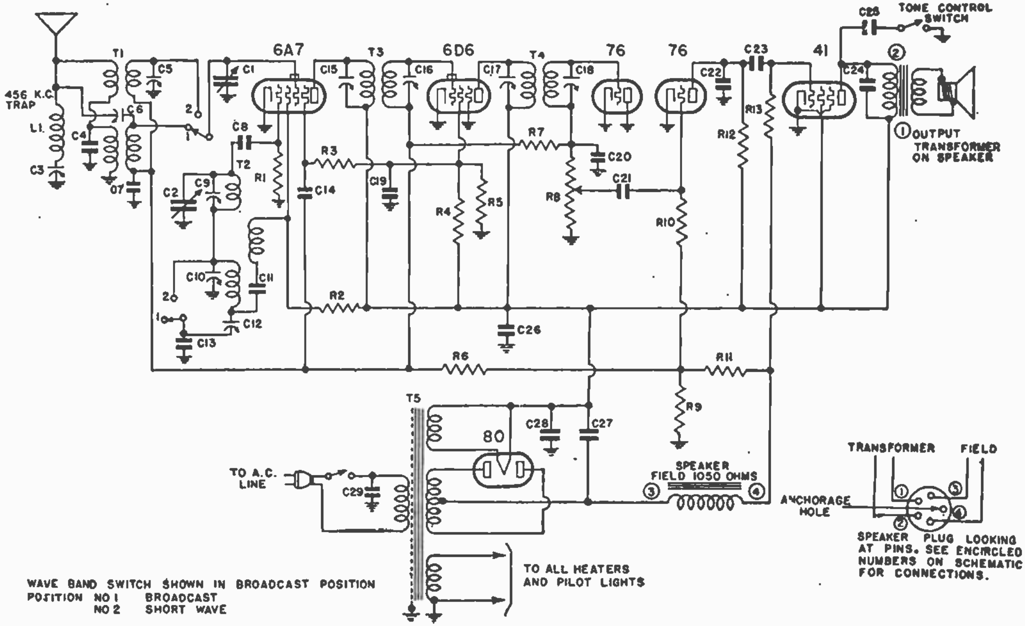
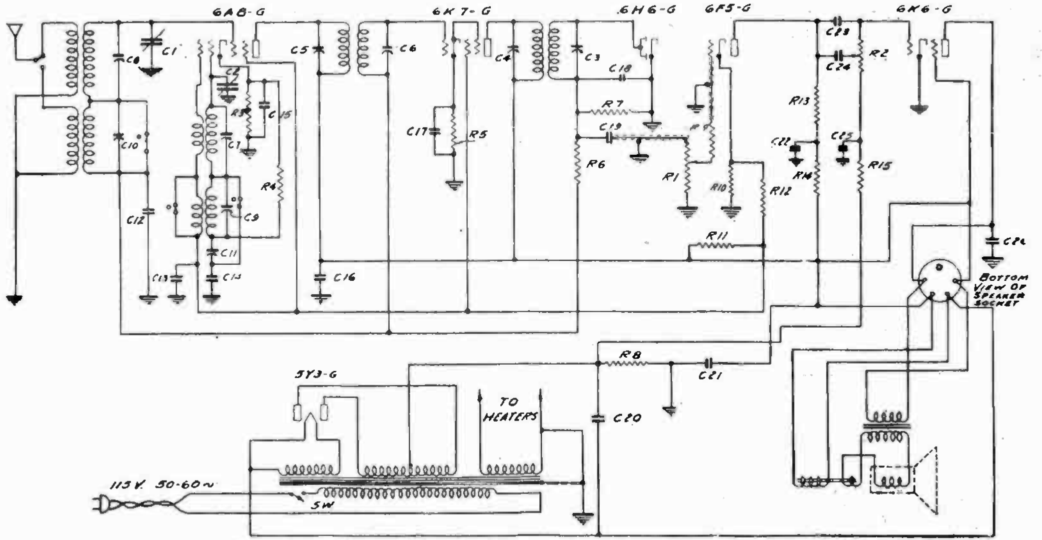


FIG. 4,319.—Schematic wiring diagram of a 6-tube *a.c.* dual-wave superheterodyne receiver. (Emerson Models, AR-171, AR-173, AR-174, AR-176, AR-180, AR-185, AT-170, AT-172, AT-181) *i.f.* peaked at 456 kilocycles. Voltage rating 105-125 volts *a.c.* Power consumption 55 watts. Frequency ranges 540 to 1,730 kilocycles and 5.6 to 18 megacycles.



VOLTAGE CHART						
TUBE	FUNCTION	Ef	Ep	E SCREEN	E BIAS	E OSC. PLATE
6A8G	Converter	6.3	210	115	4.7	115
6K7G	I. F. Amplifier	6.3	210	115	3.8	
6H6G	Detector—AVC	6.3				
6F5G	Audio Amplifier	6.3	125*		1.5	
6K6G	Power Output	6.3	200	210	14.5	
5Y3G	Rectifier	5.0				

FIG. 7,320.—Schematic wiring diagram of a 6-tube, 2-band *a.c.* radio receiver. (Majestic-620.) The set is designed to operate on 110-115 volts, 50-60 cycles. *I.f.* peak 456 kilocycles.

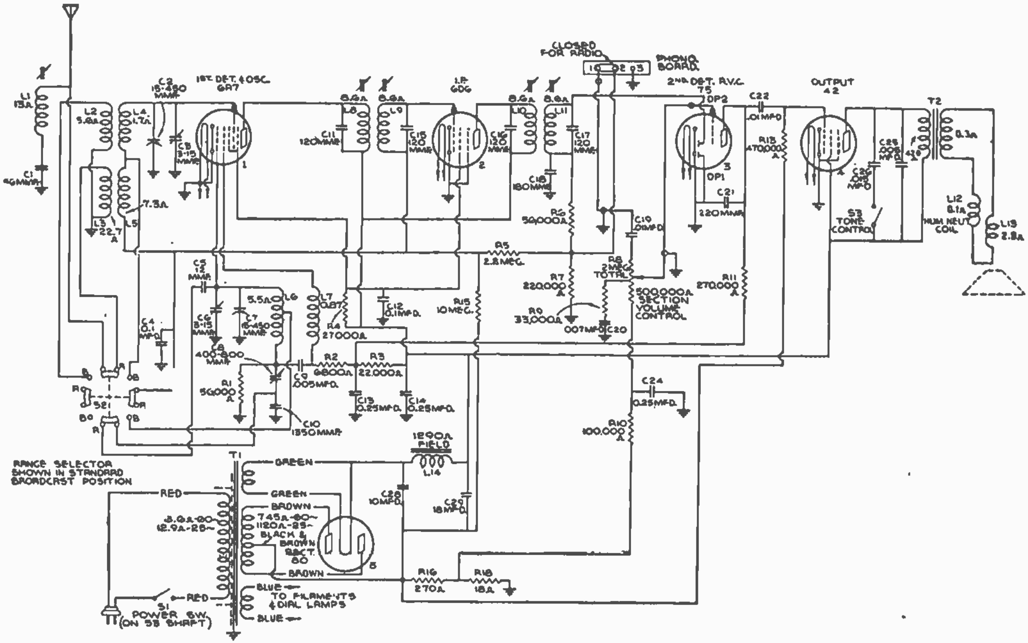


FIG. 7,321.—Circuit diagram of a 5-tube, 2-band *a.c.* superheterodyne receiver. R.C.A. Victor Mode 5T1. Its design includes magnetic-core adjusted *i.f.* transformers and wave-trap; aural-compensated volume control; two-point high frequency tone control; automatic volume control; resistance coupled audio system; phonograph terminal board; and a six-inch, dust-proof, electro-dynamic loudspeaker. Frequency ranges: "Standard broadcast" 540—1,820 kilocycles. Short wave—1,820-6,600 kilocycles.

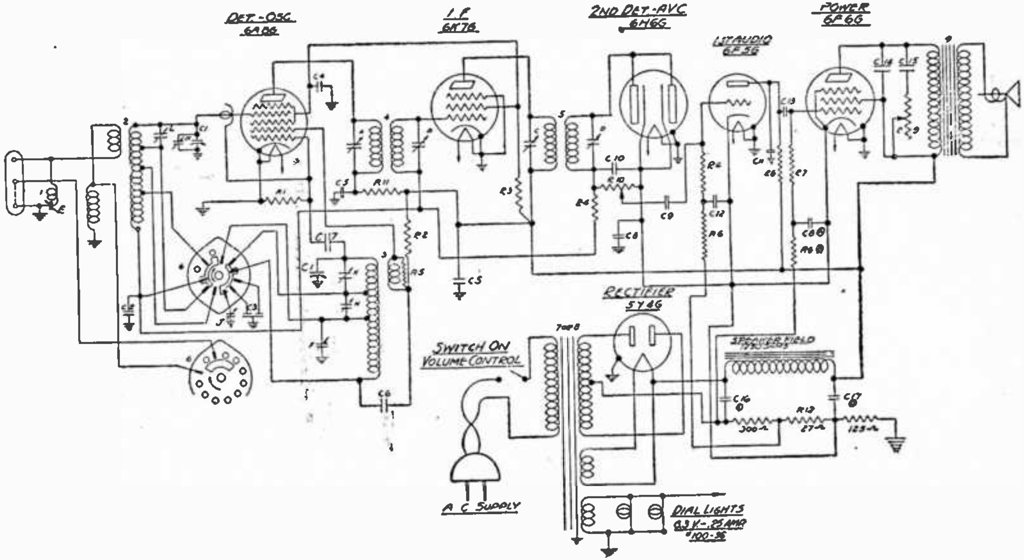


FIG. 7,322.—Schematic circuit diagram of a 6-tube superheterodyne, 2-band radio receiver. (Zenith Models, 6-S-203, 6-S-222, 6S-223, 6S-229, 6S-239, 6S-241.) *I.f.* frequency, 455 kilocycles. In locations subject to code interference adjust wave trap marked (E) for minimum interference with antenna connected and receiver operating in broadcast band. Line voltage 117 volts, *a.c.*, 50 to 60 cycles. Power consumption 65 watts.

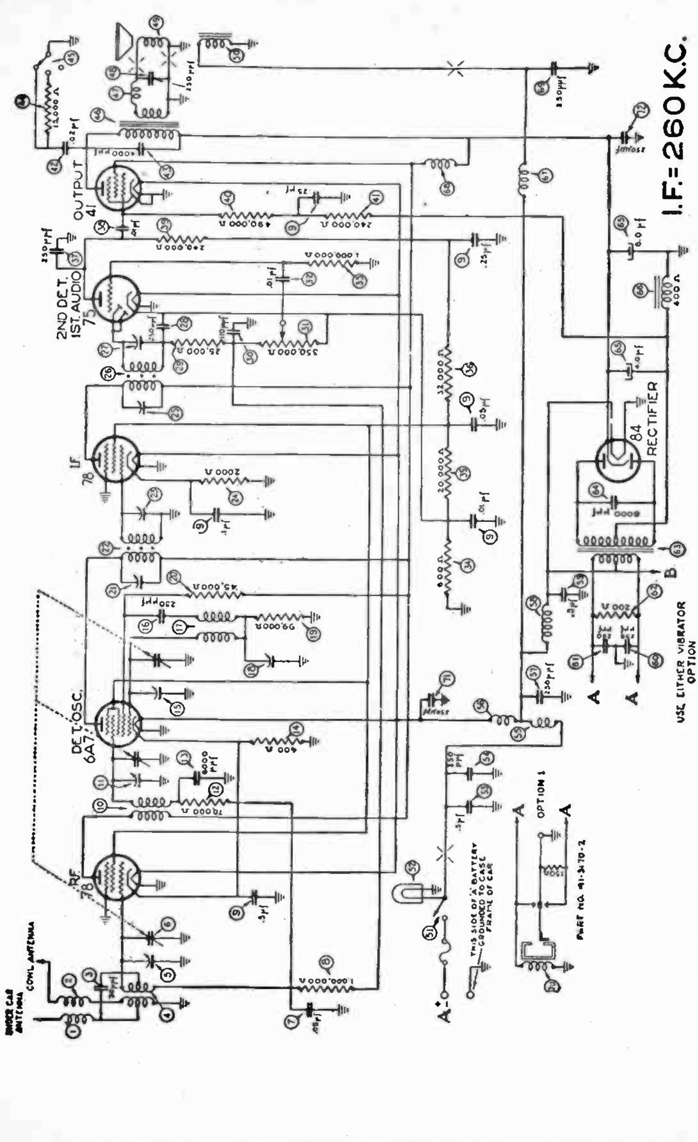


FIG. 7,323.—Schematic wiring diagram of a 6-tube automobile radio receiver. (Philco-Nash N-1434-H.) The speaker of the electrodynamic type is designed for mounting on a frame in the center above the windshield. For installation of the receiver mounting holes are provided in the left hand side of the dash. Since all late cars have an all-metal roof it is necessary to install either a cowl extension antenna or an under the car antenna. The under car antenna is installed beneath the running boards.

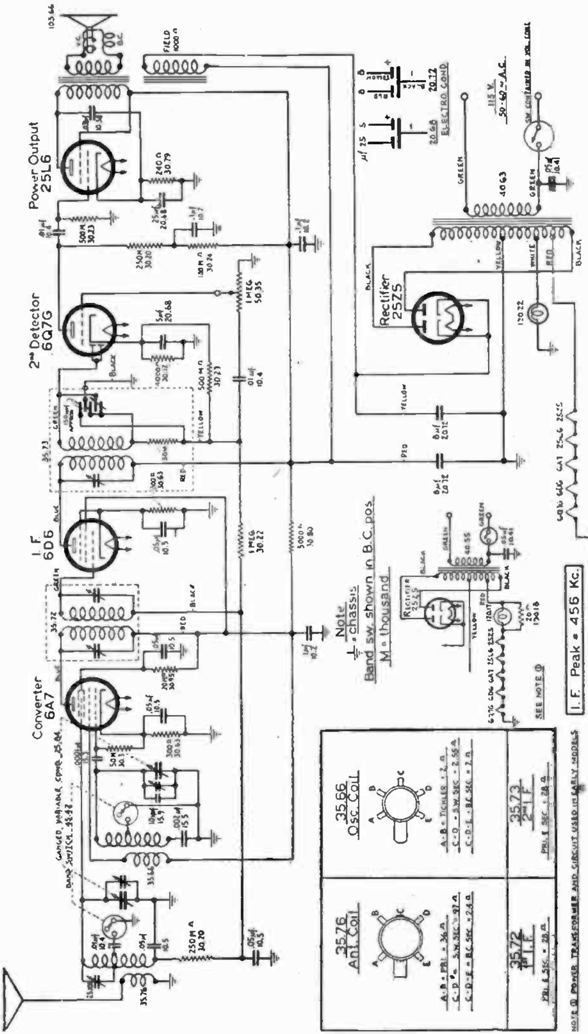


FIG. 7,324.—Circuit diagram of a 5-tube, alternating current, 115 volts, 50-60 cycle radio receiver. (Fada Model 354.)

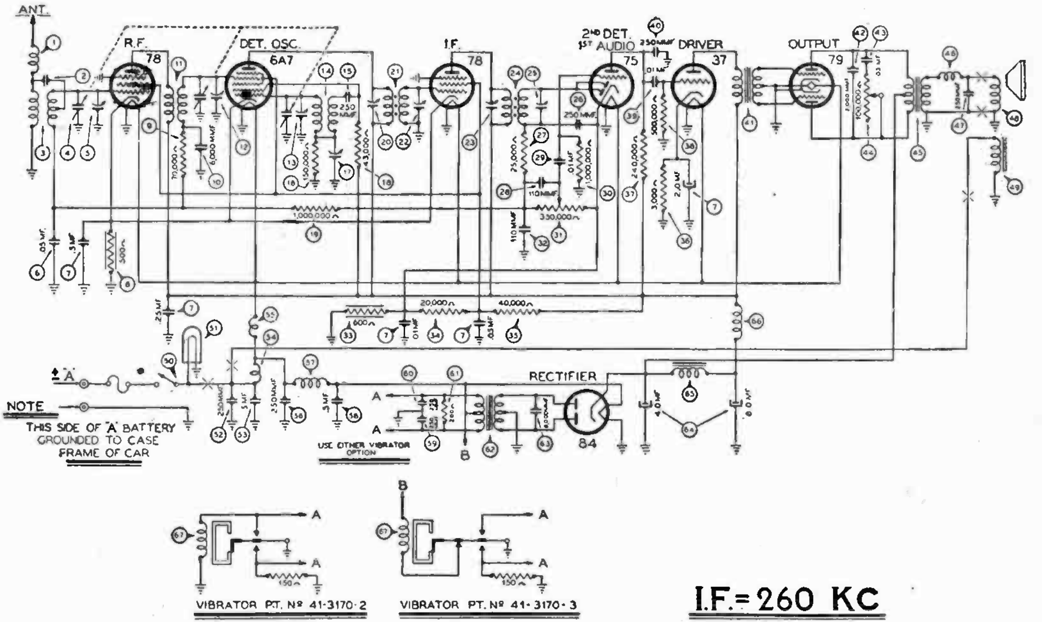


FIG. 7,325.—Circuit diagram of a 7-tube automobile radio receiver. (Philco Lincoln-Zephyr L-1424.) This receiver is equipped with an electro-dynamic speaker, which is mounted on the rear of the instrument board extension. The volume control is automatic, a specially designed input circuit to match the tire compartment door antenna, and an elaborate filter network to reduce ignition noise disturbance. The receiver is designed for location under the front seat on the right side, which gives accessibility to all parts for service.

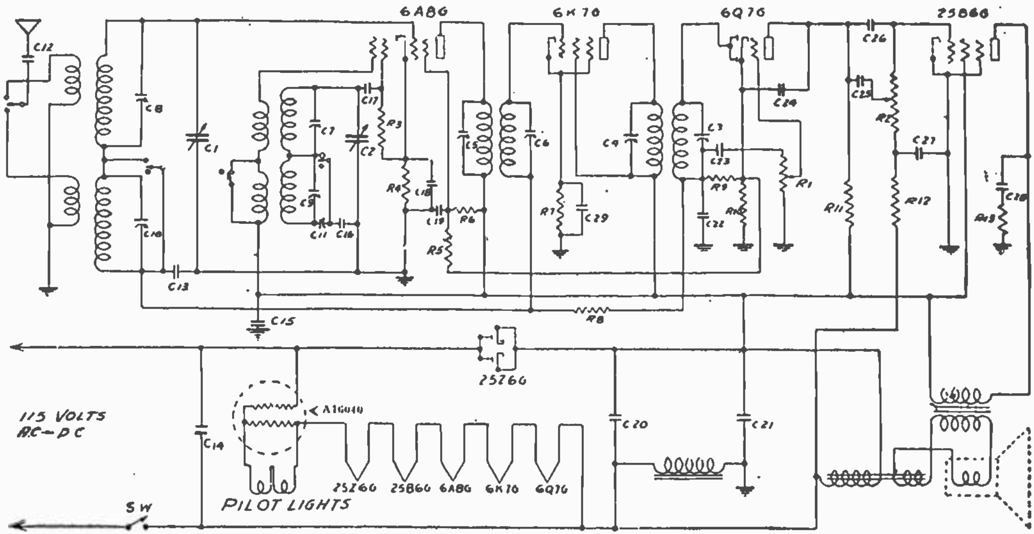


FIG. 7,326.—Schematic wiring diagram of a 6-tube 2-band *a.c.-d.c.* radio receiver. (Majestic Model-60.) The set is designed to operate on 105 to 125 volts, 50-60 cycles *a.c.* or *d.c.* *I.f.* peak 456 kilocycle; "B" supply voltage B+ to chassis (ground) = 106 volts. "B" supply voltage B+ to E · (line) = 121 volts. Voltage across filter choke (in negative lead) chassis ground to B− = 16.5 volts. Voltage across pilot lights approximately 4.8 volts each. These voltages will be approximately ten per cent lower for 115 volts *d.c.* power supply.

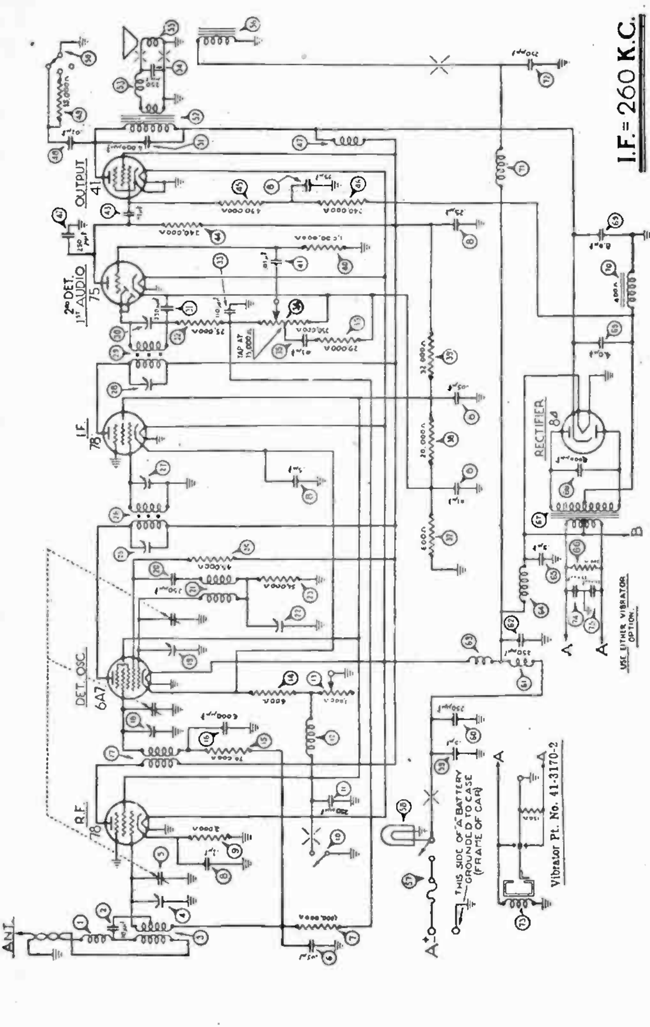


FIG. 7,327.—Circuit wiring diagram of a 6-tube automobile radio receiver. (Philco-Packard P-1432H.) The receiver is designed for installation above the steering column of the car. Special knockouts are provided in the dash for the receiver in all model 115-C and 120-C Packard cars. These plugs are easily removed with a screwdriver. The electrodynamic speaker is designed for location behind the header bar cloth directly above the rear vision mirror. All closed cars are equipped with a roof-type antenna, with the lead-in brought down inside the left front pillar post and coiled behind the cowl trim panel.

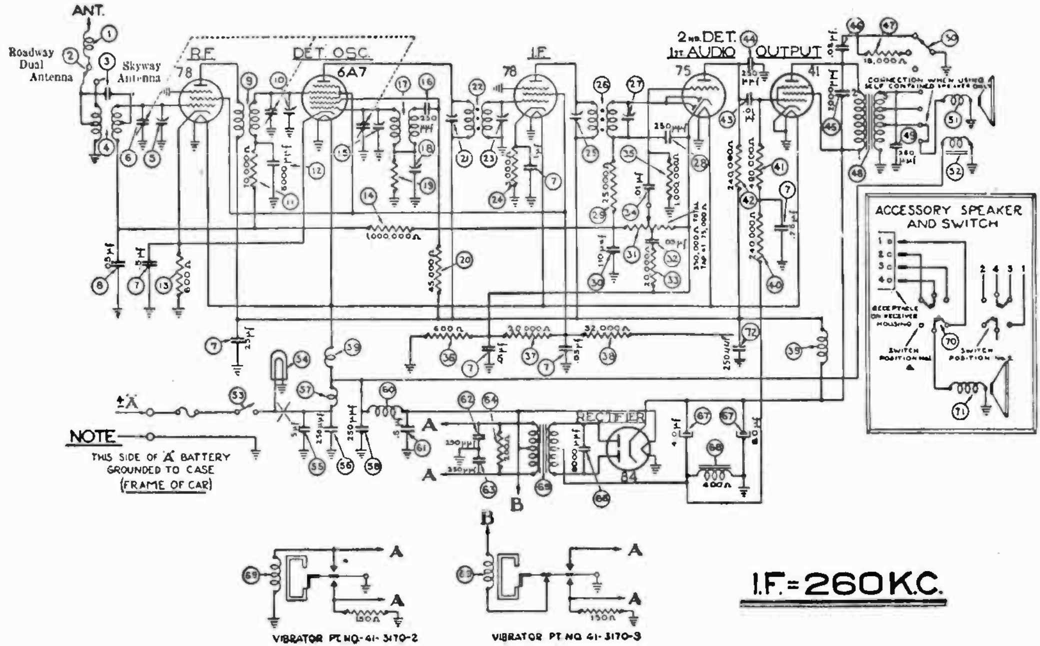


FIG. 7,328.—Schematic wiring diagram of a 6-tube superheterodyne automobile radio receiver. (Philco-Chrysler-Dodge-Plymouth-DeSoto Model C-1452.) The receiver is furnished with an electrodynamic speaker which is installed together with the receiver on the dash directly behind the steering column. Due to the fact that all late model cars have a steel roof, a separate external antenna must be used. The antenna may be either the "Roadway Dual" type which is installed under the running board or the "Skyway" type which is installed on the left side of the cowl and can be extended to meet varying conditions in the field.

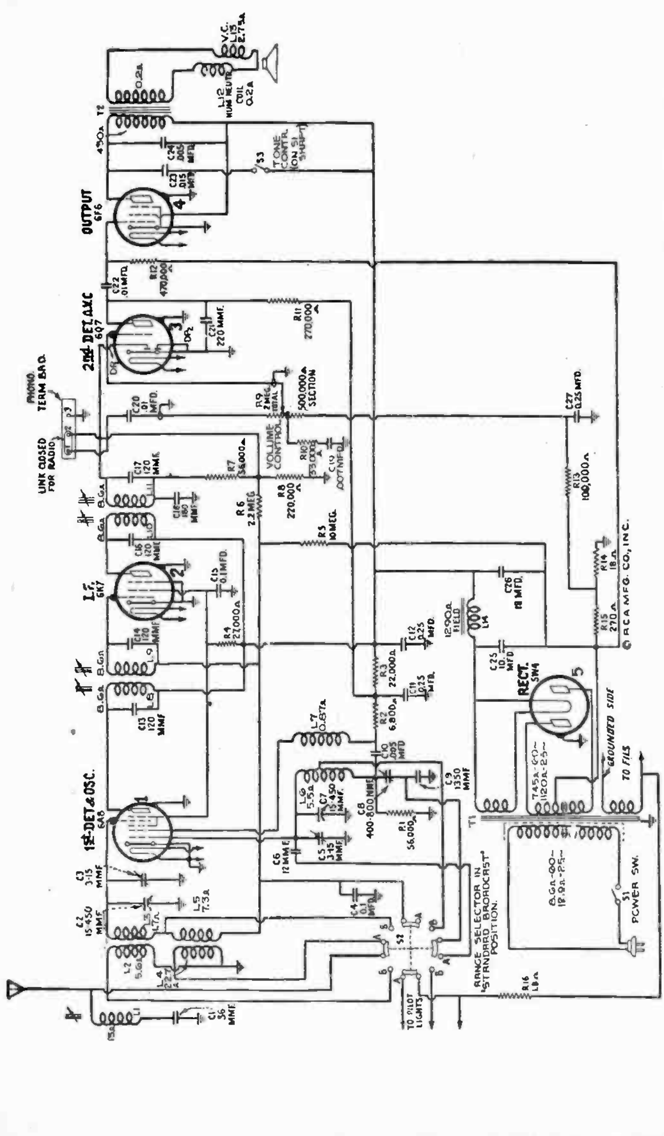


FIG. 7,329.—Circuit diagram of a 5-tube, 2-band *a.c.* superheterodyne receiver. (R.C.A. Victor 5T6, 5T7, 5T8.) Their design includes magnetic core adjusted *i.f.* transformers and wave trap; aural-compensated volume control; high-frequency tone control; resistance coupled audio system; phonograph terminal board; illuminated, band-indicating dial pointers; and a six-inch, dust-proof, electro-dynamic loudspeaker. Frequency ranges: Standard broadcast: 540—1,820 kilocycles. Short wave: 1,820-6,600 kilocycles.

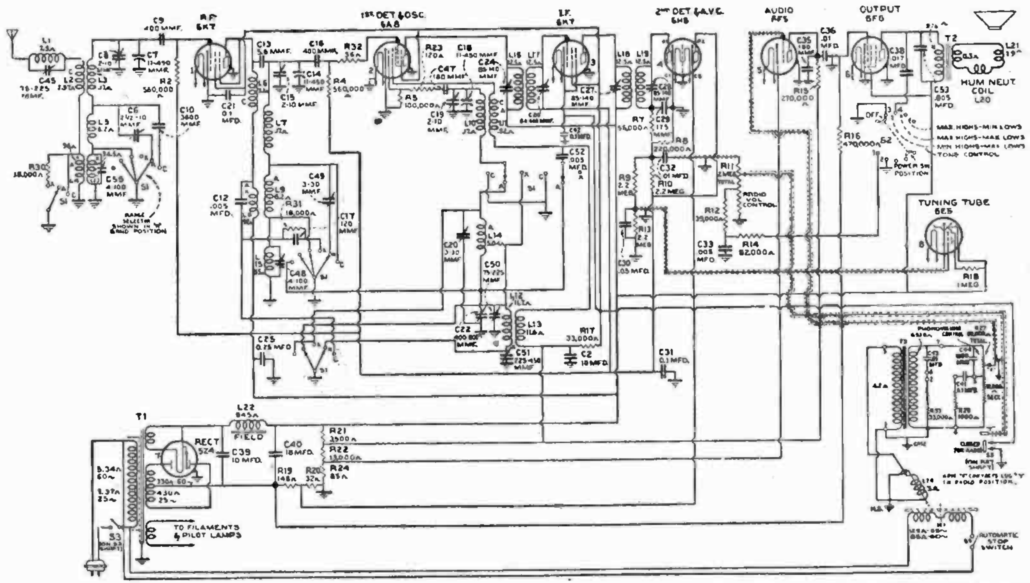


FIG. 7,330.—Circuit diagram of an 8-tube, 3-band *a.c.* superheterodyne radio-phonograph. (R.C.A. Victor 8U2.) This radio-phonograph combination consists of an 8-tube radio receiver and a manually operated phonograph combined in one cabinet. The superheterodyne circuit is used with such features of design as improved antenna wave-trap; an *r.f.* amplifier stage; all metal tubes; aurally-compensated volume control; 3-position tone control with music-speech switch; automatic volume control; resistance-coupled audio system; tuning tube; "Magic Eye"; edge-lighted band indicator dial, and a dust-proof electrodynamic loudspeaker. Trimming adjustments are located at accessible points. Their number is reduced to the least that is consistent with efficient operation. The tuning dial ratio of 10 to 1 with a 50 to 1 vernier permits ease of tuning, especially in the "short-wave" band. Frequency ranges: Long wave 155-320 kilocycles. Medium wave 530-1,500 kilocycles. Short wave 5,400-18,000 kilocycles. Intermediate frequency 460 kilocycles.

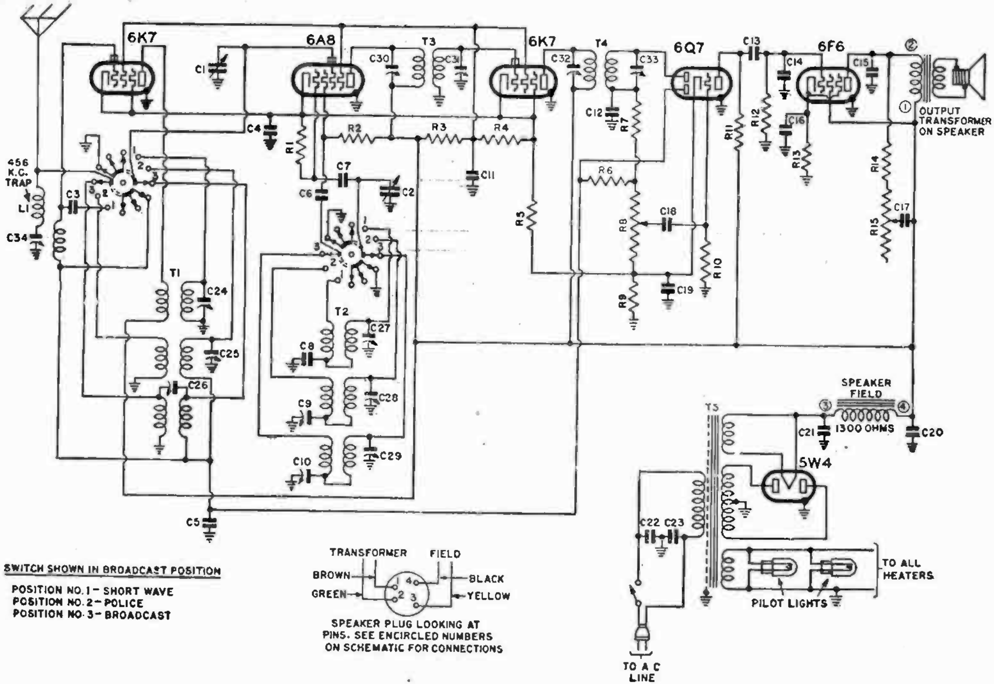


FIG. 7,331.—Circuit diagram of a 6-tube all-wave *a.c.* superheterodyne receiver. (Emerson Model S-147, S-151) *i.f.* peaked at 456 kilocycles. Voltage rating 105-125 volts. Current drain 0.55 amperes. Frequency ranges 550 to 1,750 kilocycles: 1,750 to 5,500 kilocycles: 5.7 to 18.0 megacycles.

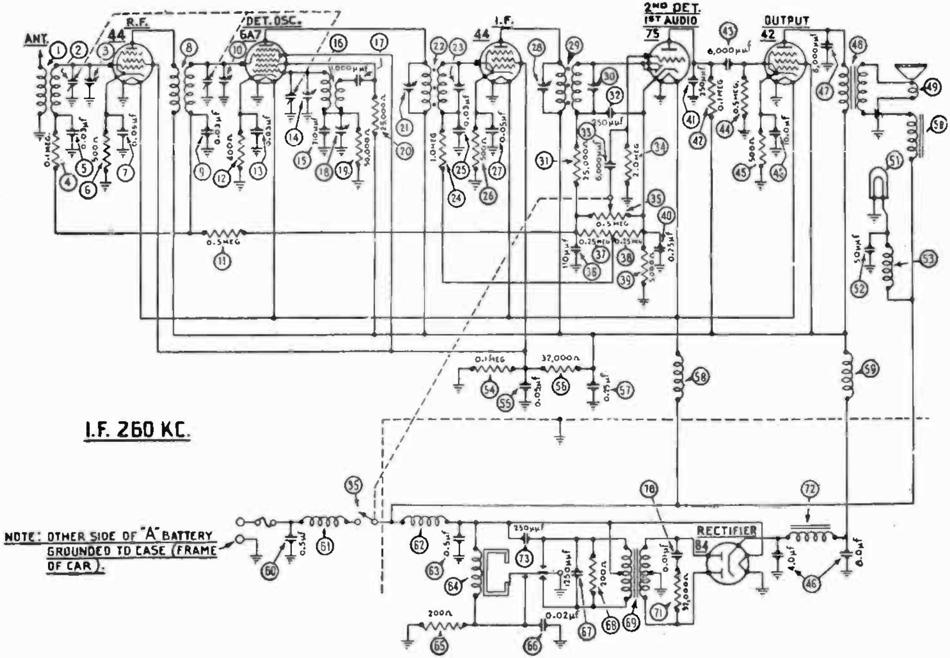


FIG. 7,332.—Circuit diagram ot a 6-tube Police automobile radio receiver. (Philco Model DPV.) This model is a superheterodyne, single unit receiver designed for operation on the standard emergency police frequency as allotted by the Federal Radio Commission. The tubes are all of the 6.3 volt type especially developed for auto radio service. There is a 39-44 tube in the r.f. stage, a 6A7 tube in the detector oscillator stage, a 39-44 in the *i.f.* stage, a 75-tube in the 2nd detector and 1st audio stage, a 42 tube in the output and an 84 rectifier tube in the power supply. The receiver is "all electric" operating entirely from the auto battery. The "B" power is supplied by the vibrator shown at 64 in the diagram.

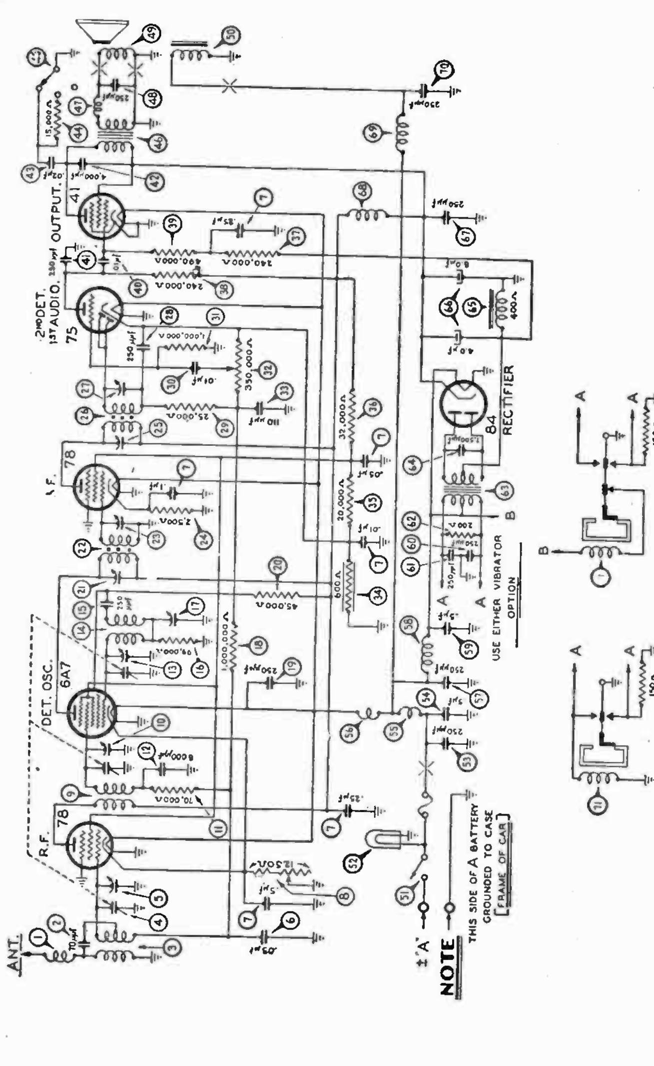


FIG. 7,333.—Circuit diagram of a 6-tube automobile radio receiver. (Ford-Philco F-1442.) The function of the vibrator (shown at 71) is to interrupt the direct current voltage produced by the storage battery, and so enabling the transforming of the current to a higher voltage by means of transformer (shown at 63). The reconverting to direct current is accomplished at the rectifier tube 84, and filtering at 65 and 66.

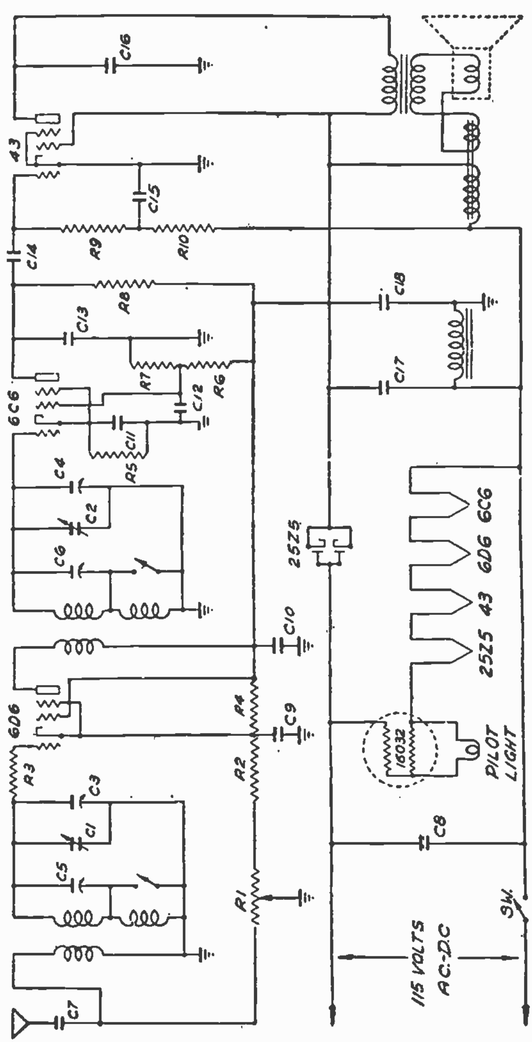


FIG. 7,334.—Schematic wiring diagram of a 5-tube, 2-band *a.c.-d.c.* radio receiver. (Majestic Model 50.) Operating voltage 105 to 125; *a.c.* or *d.c.* *I.f.* frequency 456 kilocycles. Broadcast band 540 to 1,550 kilocycles. Police band 1,550 to 4,000 kilocycles.

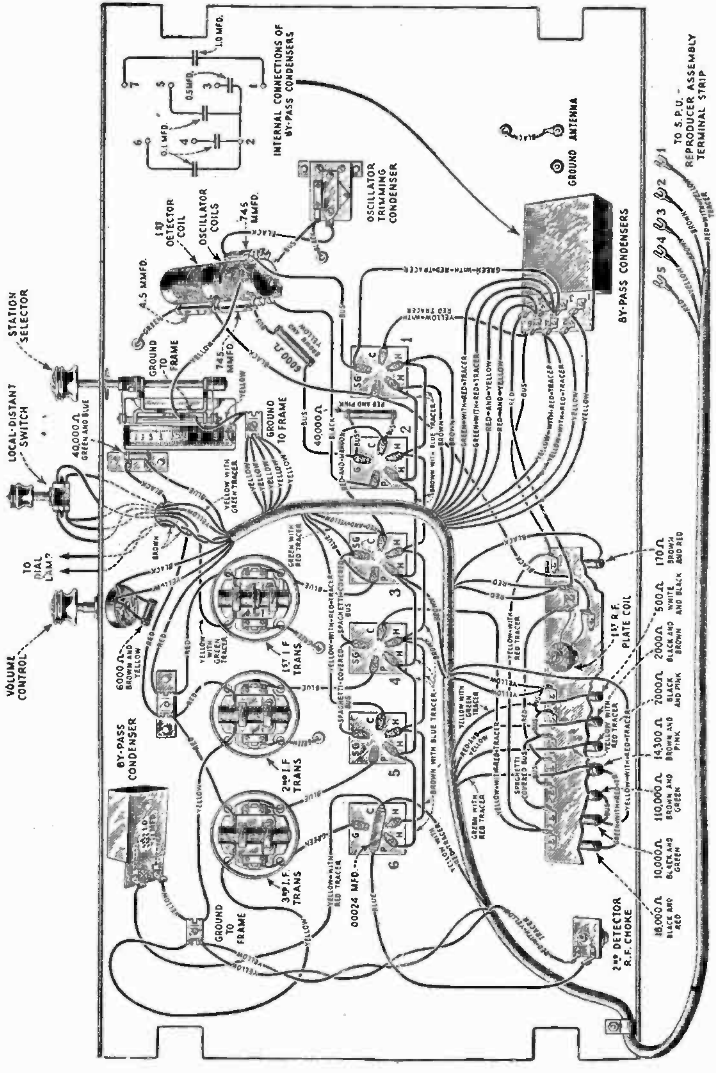


FIG. 7,339.—Pictorial wiring diagram of General Electric Model H 31 screen grid super-heterodyne receiver.

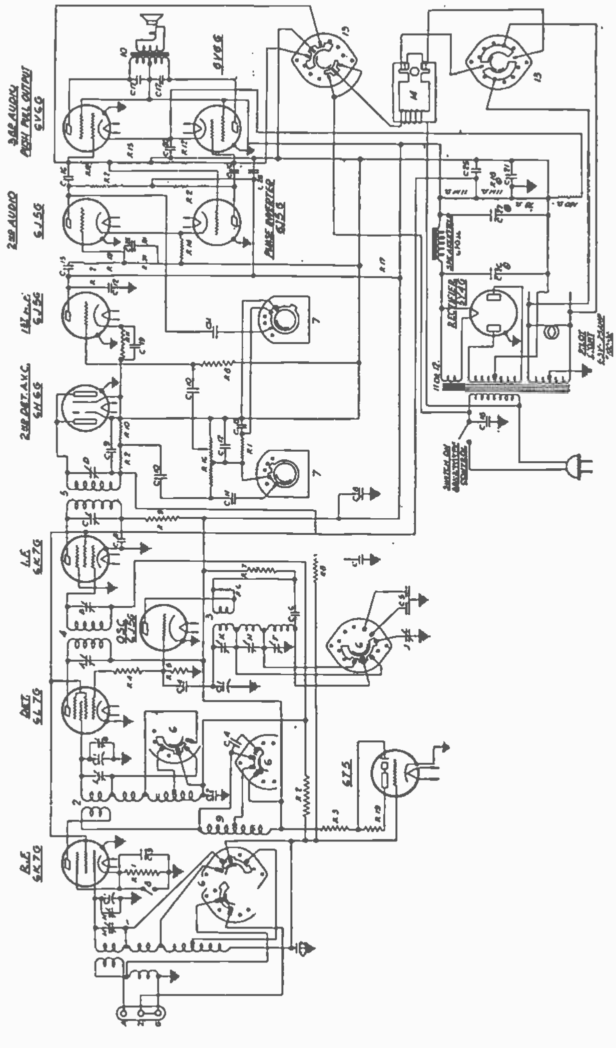


FIG. 7,335.—Schematic circuit diagram of a 12-tube superheterodyne, 3-band radio receiver. (Zenith Models 12-S-205, 12-S-232, 12-S-245, 12-S-265, 12-S-266, 12-S-267, 12-S-268.) *I.f.* frequency 456 kilocycles. Line voltage 117 volts *a.c.* 50 to 60 cycles. Power consumption 110 watts.

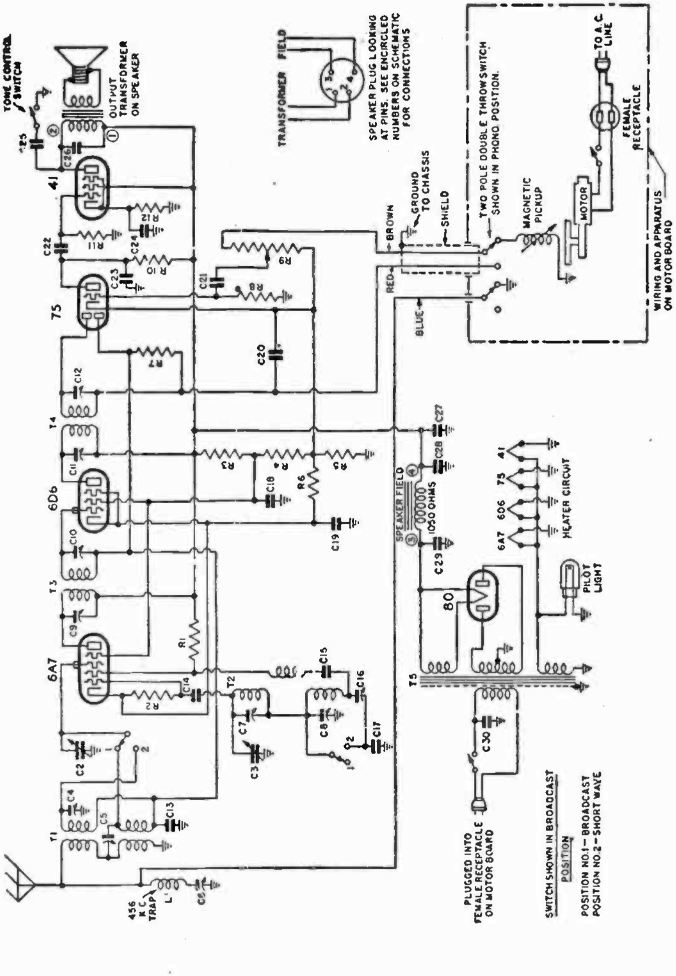
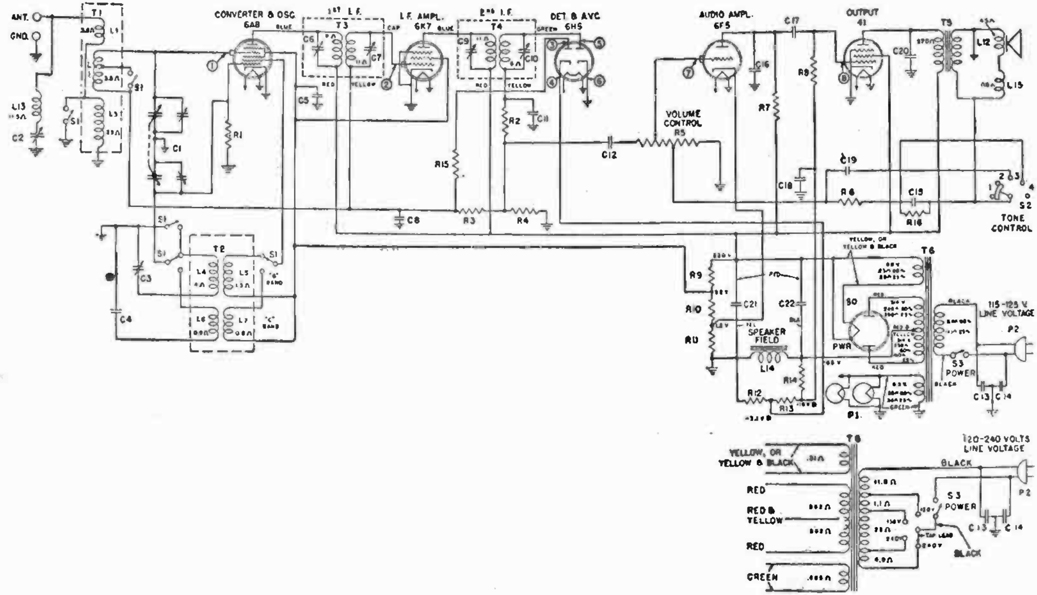


FIG. 7,336.—Circuit diagram of a 5-tube combination phonograph and dual-wave superheterodyne receiver. (Emerson Model L-143.) *I.f.* peaked at 456 kilocycles. Voltage rating 105 to 125 volts *a.c.* Current drain 0.5 amperes for receiver. Frequency range 540 to 1,750 kilocycles—2,200 to 7,500 kilocycles. Speed of phonograph motor 78 *r.p.m.* at 105 to 125 volts, 60 cycle *a.c.* supply



F G. 7,337.—Schematic circuit diagram of a 6-tube, 2-band *a.c.* superheterodyne receiver. (General Electric Models F-63, F-65 and F-66.) Intermediate frequency 456 kilocycles. Tuning frequency range: Band "B," 540-1,750 kilocycles. Band "C," 2.2-7.0 megacycles. Power consumption 70 watts at 115-125 volts. 4-point tone control; electrodynamic loudspeaker.

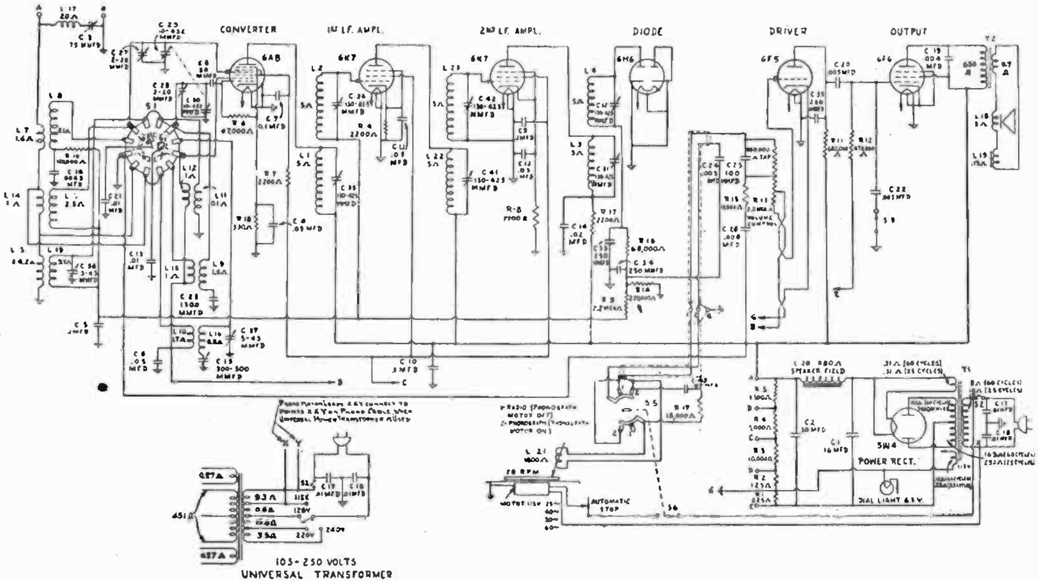


FIG. 7,338.—Schematic circuit diagram of an all-wave radio receiver and phonograph combination. 7-tube *a.c.* superheterodyne. (General Electric Model E-79.) Tuning frequency range: "Band B," 540-1,600 kilocycles. Band "C," 1,560-5,800 kilocycles. Band "D," 5.6-18.0 megacycles (5,600-18,000 kilocycles). Power consumption 105 watts at 115 volts. Speed of phonograph motor 78 *r.p.m.* at 115 volt, 60 cycles, *a.c.*

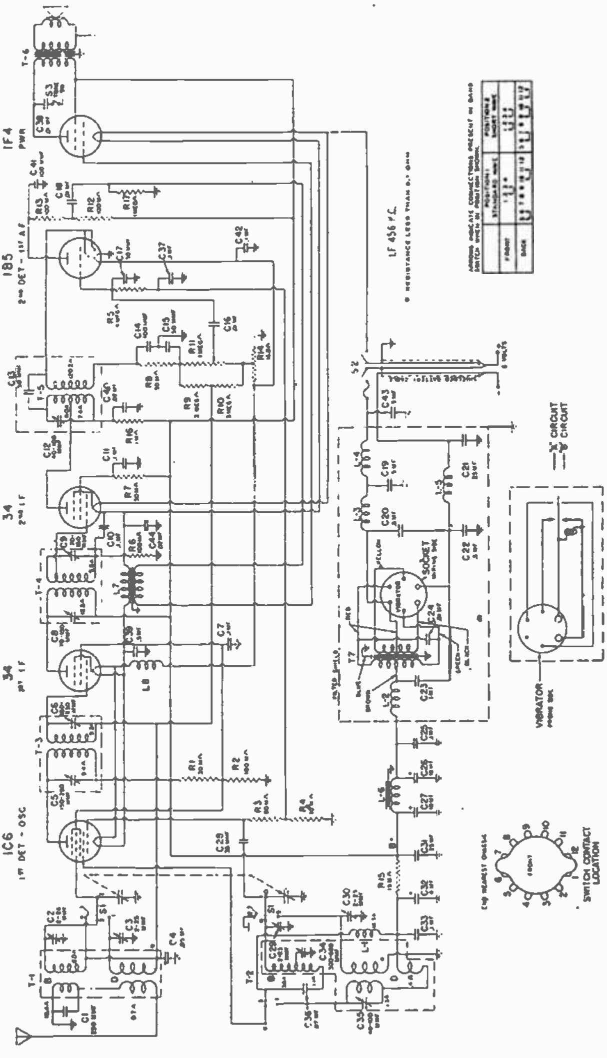


FIG. 7,339-A.—Schematic circuit diagram of a 6-volt synchronous vibrator radio receiver. 5-tube, 2-band (General Electric Models U51 and U55). Intermediate frequency 456 kilocycles. Tuning frequency range: "R" range—528-1,730 kilocycles. "D" range, 5,650-16,000 kilocycles. Power consumption 1.1 amperes at 6.3 volts.

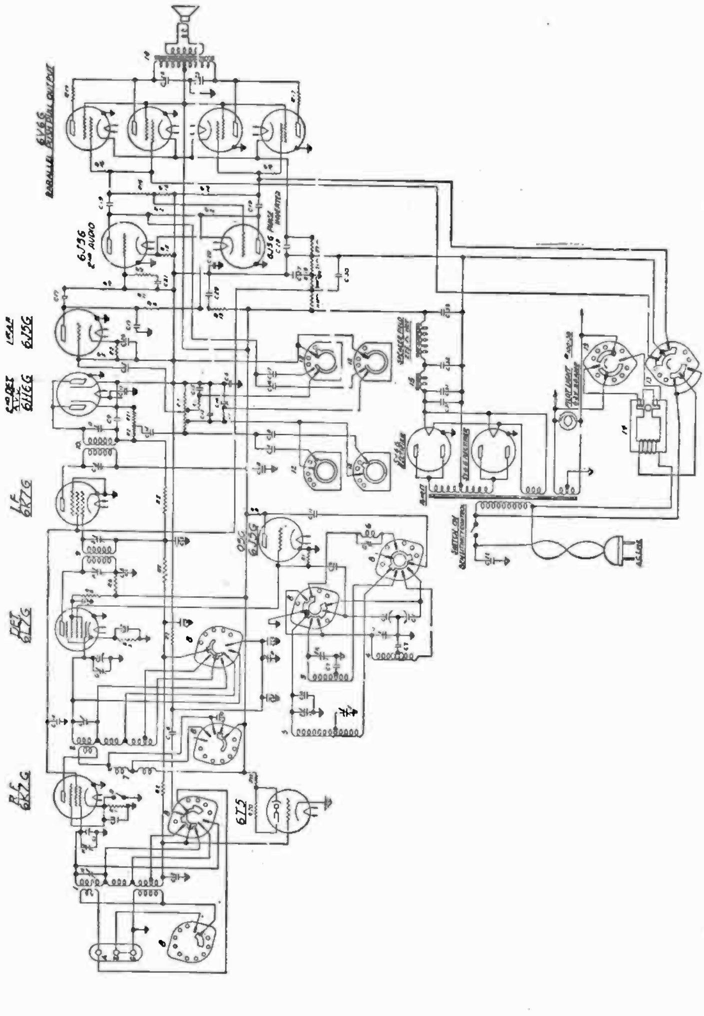


FIG. 7,339-B.—Schematic circuit diagram of a 15-tube superheterodyne 4-band radio receiver. (Zenith Models 15-U-246, 15-U-269 15-U-270, 15-U-271, 15-U-272, 15-U-273.) *I.f.* frequency 456 kilocycles. Line voltage 117 volts *a.c.* 50 to 60 cycles. Power consumption 160 watts.

CHAPTER 178

Control Systems

AUTOMATIC FREQUENCY CONTROL (A. F. C.)

In the early kinds of radio sets the receiver control had to be operated manually by the turning of one or more volume control knobs. In modern receivers however, automatic frequency control has been incorporated to make this constant manipulation of the volume control knobs unnecessary.

The action of the automatic frequency control circuits in superheterodyne receivers is such that any mis-tuning by the listener or any frequency drift in the set after it has been properly tuned is automatically corrected by the incoming signal itself.

The requirement for an automatic frequency control circuit are:

1. A *d.c.* detector operated through an *i.f.* frequency discriminator network, and

2. An oscillator frequency control circuit.

How the Discriminator-Detector Circuit Works.—The discriminator-detector network as the name implies, discriminates between applied intermediate frequencies which are too low and those which are too high, and produces a corresponding direct current or voltage whose polarity depends upon the direction of frequency departure from a prescribed intermediate frequency. This *d.c.* voltage is applied to a control element which in turn causes a shift in frequency of the local oscillator such as to bring the *i.f.* signal to very nearly the correct inter-

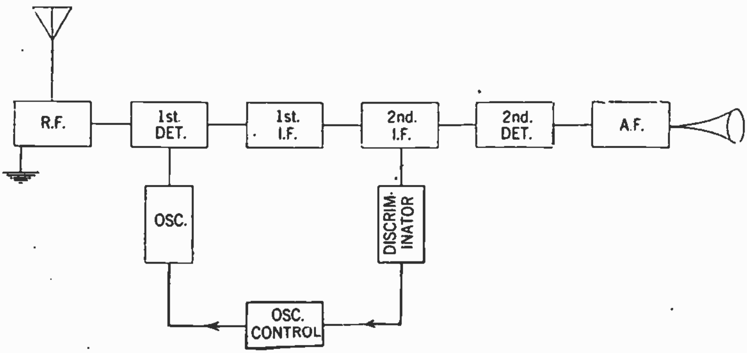


FIG. 1—Conventional block diagram of an automatic radio frequency control circuit.

mediate frequency. Since production of the *d.c.* voltage is due to departure from the resonant or center frequency of the *i.f.* system, obviously the correction cannot be strictly complete; but in the system described a correction ratio of more than 100 to 1 is feasible.

In other words, when the dial of the receiver is mis-tuned 100 *k.c.* for the received signal, the automatic correction may be made to bring the actual *i.f.* signal frequency to only 100 cycles off resonance in the *i.f.* system. Of course that is easily sufficient.

The Frequency Discriminator.—A method for obtaining differential *d.c.* potentials (or currents) whose magnitude and polarity are determined by the amount and the sign, respectively, of the difference between an applied frequency and the true intermediate frequency is described herewith. Side circuits tuned above and below the center frequency are not used.

The action depends upon the fact that a 90° phase difference exists between the primary and secondary potentials of a double-tuned, loosely-coupled transformer when the resonant frequency is applied and that this phase angle varies as the applied frequency varies. Thus if the primary and secondary voltages are added vectorially, the absolute magnitude of the resultant vector will be greater on one side of resonance then on the other.

The vector sum of the primary and secondary voltages may be physically realized by connecting the two parallel tuned, coupled circuits in tandem, applying the input potentials to one circuit and taking the output across both circuits in series. In this manner, an action similar to that of a side circuit is produced even though the primary and secondary are both tuned to the center frequency.

The potentials at either end of a secondary winding with respect to a center tap on that winding are 180° out of phase. Therefore, if the center tap, rather than one end, of the secondary is connected to the primary, two potentials may be realized, one maximizing above and one maximizing below the center frequency. See fig. 2.

If a transformer is connected in this manner and the resonant frequency is applied to the primary the two resulting output potentials will be equal in magnitude. If these are then applied to two separate, like detectors and the resulting *d.c.* voltages are added in opposition, the sum will be equal to zero. If, however, the applied frequency departs from responance, the sum of their outputs will be some real value whose polarity will depend upon the sign of the frequency departure.

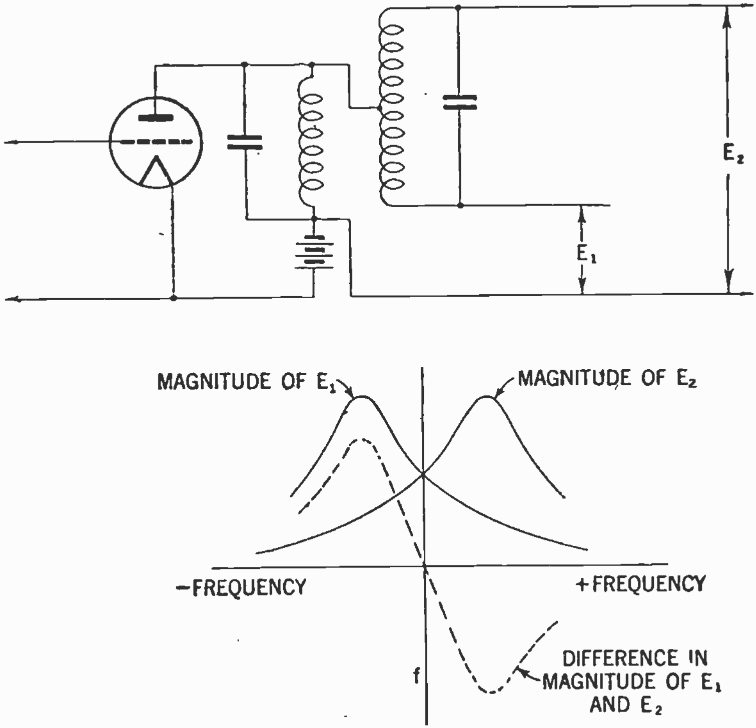


FIG. 2—Diagram and plotted curves illustrating how the potentials at either end of secondary are 180° out of phase.

Referring to fig. 3, the action is as follows: If the resonant or center frequency is applied to the grid of the amplifier tube, equal amplified voltages will exist between the point *A* and ground and between the point *B* and ground. These are rectified by the diodes and direct currents will flow in the resistors R_1 and R_2 in opposite directions with respect to ground. Thus, the net *d.c.* potential produced by the two *IR* drops between *E*, and ground is equal to zero. If, however, the applied frequency departs from resonance the potentials across the diodes will be unequal in magnitude, unequal *IR* drops will be produced in the two resistors and a *d.c.* potential will exist between *E* and ground, the polarity of which will depend upon the sign of the frequency departure.

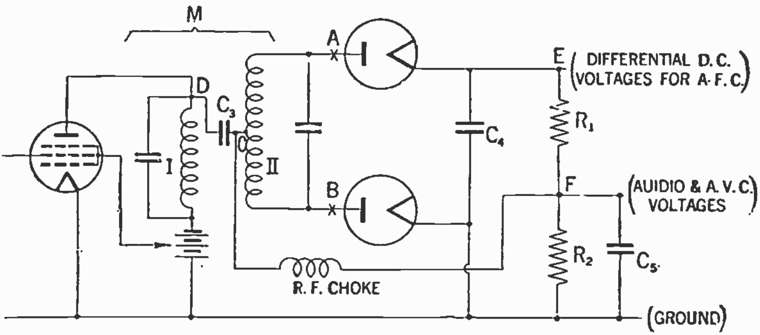


FIG. 3—Automatic radio frequency control detector diagram.

If a carrier at the resonant frequency with normal intensity modulation, but without frequency modulation, is applied to the system, the *a.f.* as well as the *d.c.* voltages across R_1 and R_2 will be equal and opposed. Therefore at resonance there will be no *a.f.* potentials between *E* and ground, and as far as audio components are concerned, the system acts exactly as though point *E*, were grounded with the outputs of the two diodes acting in parallel. Actually if C_4 is sufficiently large to have negligible reactance at the lowest modulating frequency, this is the case. Then the point *F*, becomes a potent source of audio voltages to supply the *a.f.* amplifier system and no other audio detector is necessary.

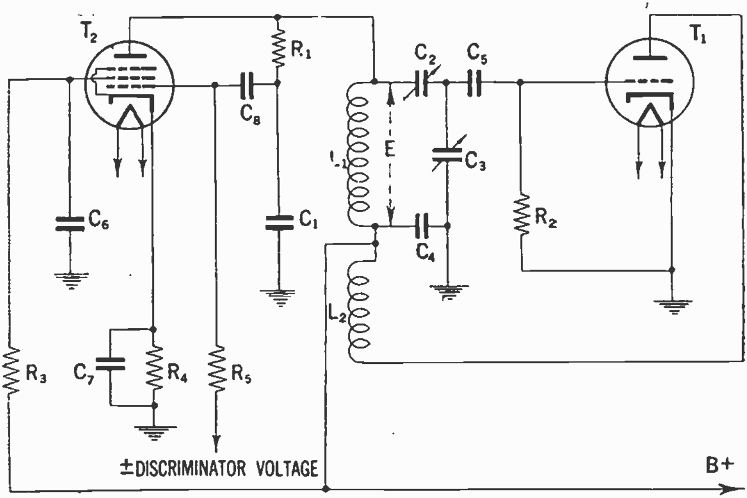


FIG. 4—Typical control circuit diagram.

It can be seen that the *d.c.* potential between ground and the point *F*, will have the proper polarity to be used for *avc* action, and that this potential will bear the same ratio to the developed audio voltages as is found in the conventional diode detector *avc* system. The fact that it maximizes at one side of resonance is of no significance if automatic frequency control is used. When the *afc* is cut out of circuit (manually) point *E*, is grounded. This causes the *d.c.* potential at *F*, to maximize on resonance.

The Control Circuit.—A circuit which will convert *d.c.* discriminator voltages into changes in oscillator frequency is shown in fig. 4. In this figure T_1 is the oscillator tube and T_2 the control tube. The combination of R_1 and C_1 connected across the oscillator tank circuit produces a voltage on the grid of the control tube 90° out of phase with that existing across the tank circuit. Variations in grid bias of the control tube (obtained from the discriminator) vary the plate current of that tube. This plate current is 90° out of phase with the tank circuit voltage and therefore the control tube acts like a reactance in shunt to the tank circuit. The magnitude of the reactance and therefore the oscillatory frequency are varied by the control tube grid bias.

With the circuit shown in fig. 4 the control tube is equivalent to an inductance in parallel with the tuned circuit. An increase in mutual conductance of the control tube produces a decrease in the magnitude of this equivalent inductance and consequently an increase in the oscillator frequency.

Control Tube.—The amount of control is proportional to G_m, but is also affected by the control grid voltage for this G_m, since a high value of bias permits R_1 or C_1 to be smaller for a given oscillatory voltage. Consequently maximum control is proportional to the product of G_m and E_c. Sensitivity of control is however, another important requirement, since it is desired that the frequency change be as large as possible for a given change in bias. This means the control tube should be of the short cut-off type. Further requirements are high r_p, linear change of G_m with bias, and for economy, low plate and screen currents.

All of these requirements are best met by the short cut-off, *r.f.* pentodes such as 57, 77, 6C6 and 6J7. By proper choice of R_1 and C_1 the maximum amount of frequency correction can be adjusted to suit required conditions.

The frequency control readily obtainable by this circuit is of the order of 9.5% of the oscillator frequency in the broadcast band and 1.5% in the region of 10 megacycles.

In a receiver it has been found that a discriminator sensitivity of 100 volts per *k.c.* and a control sensitivity of 7 *k.c.* per volt can be easily obtained, so that an overall control ratio of 700 to 1 results. A tuning misadjustment of 7 *k.c.* will therefore result in only a 10 cycle shift of the intermediate frequency.

The use of *afc* on the short-wave bands has the very much needed advantage of making the tuning operation easier. The tuning control has to be moved only until the frequency is close enough to resonance that the discriminator will develop sufficient voltage to bias the control tube the amount required for the departure from resonance. Short-wave stations are thus spread out on the dial, making them easier to locate and easier to hold.

In the broadcast band this characteristic would have the disadvantage that the receiver would appear to laymen to be broad in tuning in comparison with receivers without *afc*. This apparent disadvantage can be eliminated by combining the *afc* switch with the tuning mechanism so that the *afc* automtically becomes inoperative during the tuning operation.

PUSH BUTTON TUNING SYSTEMS

Push-Button Station Selectors.—Push button station selectors is primarily an arrangement whereby the process of tuning has been greatly simplified. It is thus possible by means of a mechanical arrangement to choose a selected number of stations each one of which may be tuned in by the method of some control to a pre-determined position.

It is only recently however, that these systems have achieved the measure of popularity that it undoubtedly deserves, and this is probably because of the technical difficulties involved in producing a receiver which has the same capabilities as any ordinary set—the problem being not only to incorporate this additional device, but of maintaining it consistently in operation.

These early difficulties, however, have been largely overcome, primarily by the employment of apparatus of a higher standard of quality than was previously possible, and also due to a better understanding of the problems involved.

Various Systems in Use.—There are many push-button tuning systems in use as well as many different methods of control. Perhaps most common, however, is that of a series of push buttons (one for each station) located on the receiver itself, although sometimes these buttons may be duplicated, one set being mounted on the receiver, and the other at the end of an extension cable of suitable length.

Typical Extension Cable System.—A typical system of this kind is incorporated in the current line of General Electric receivers.

In this system remote tuning and volume control is accomplished by extending the push-button tuning circuits by means of a cable to the remote control box.

Changes in the volume level are effected through the use of a motor on the volume control shaft as shown in fig. 5. A reversible motor is employed and controlled by two switches on the remote control box.

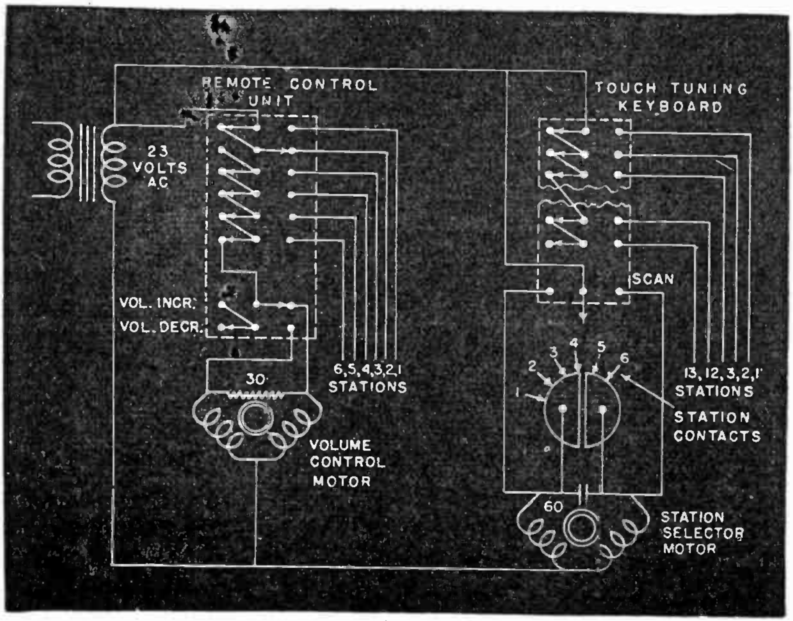


FIG. 5—Schematic wiring diagram of a General Electric push button remote control system.

The station selector consists of the usual electric motor mechanism with a split stator winding. On account of the split stator winding arrangement, the device is *homing*, i.e., goes directly to the selected station.

The capacity of the remote tuning system makes thirteen stations available at the remote control box. The arrangement is such that when the button is depressed for any one of the thirteen stations, the power is automatically turned on to the set.

The remote control keys are non-latching in order to avoid any interference with the buttons on the receiver. At present only six of the stations have been extended for the remote control, which is attached to the set by means of a plug on the rear of the set.

To avoid the possibility of keeping the tuning motor running, by pressing two buttons simultaneously, single pole-double throw switches are utilized at both the receiver as well as at the remote control station.

The power to the volume control motor is supplied from the same transformer which supplies the tuning motor.

It is possible to change the volume of the receiver only after the station button at the remote control station has been released on account of the interlocking feature.

Finally a scan switch for rapid manual tuning from one of the bands to another is provided on the receiver. This switch is of the double throw type, normally open, which permits directive operation of the motor.

Again, instead of the usual push-button system a similar effect may be obtained by a mechanism similar to that of the well-known automatic telephone, and as a matter of fact it is perfectly possible to utilize standard telephone parts in the design of such a tuning control system.

Another remote control system in which the previously discussed control cable is being eliminated, and in which the tuning is accomplished by means of tuning pulses oscillations emanating from a dial, is described on page 4,548.

How the System Works.—Electrically these various systems divide themselves into two main classes, namely:

1. Those in which a large number of pre-set switch selected condensers are used.

2. Those in which an ordinary variable condenser is provided for tuning but can be remotely controlled by means of an electric motor.

Considering the former the basis for a tuned circuit is given in fig. 6.

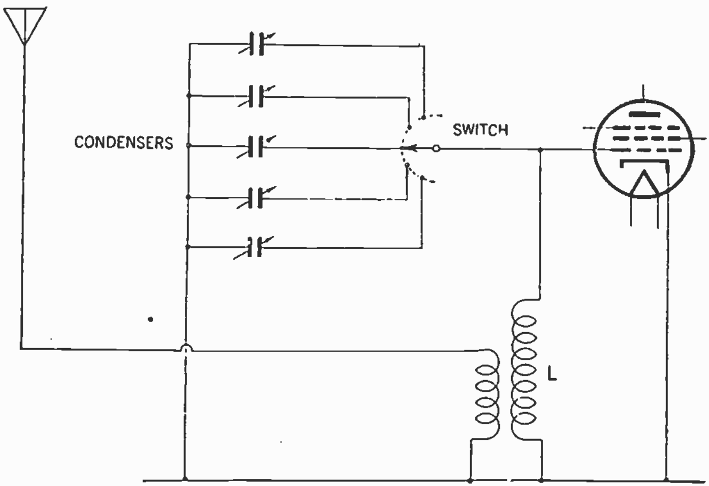


FIG. 6—Schematic diagram showing general principles of simple tuning circuits. In this system a separate pre-set condenser is provided for each station and selected by a switch, as shown.

It may be observed that instead of a variable condenser for tuning the coil *L*, a number of pre-set condensers are provided and the one desired can be selected by means of the switch shown.

It is obvious that each tuned circuit in the receiver must be provided with a similar bank of condensers and switches. With the system under discussion, the switch is set to the first position, and one station is tuned in on the opposite condensers; the switch is then set to the next position and another station is tuned in and so on.

For every station required, it is necessary to provide an extra condenser and switch contact for each tuned circuit.

This particular system has been commonly employed in the past in simple types of receivers. The system has a great merit especially where only two or three stations are required on account of its simplicity.

It is obvious, however, that if a dozen or more stations are required, it begins to be complicated by virtue of the large number of condensers required. There is also a further drawback when it is applied to a selective receiver such as a super-heterodyne, and this drawback is that it may not prove stable enough for satisfactory operation.

Where the circuits are flatly tuned as in the case of the local station receiver, small changes in tuning capacities and the input capacities of tubes have very little effect upon the performance of the receiver, but where the set is selective, then these changes do command quite a large effect.

In a super-heterodyne the oscillator is the critical circuit, and it is common experience with ordinary receivers that the tuning drift somewhat, for perhaps a quarter of an hour or so after switching on.

Where systems of this kind are used, therefore, great care must be taken to maintain stability, and the oscillator circuit must itself be designed to this end.

In addition, the layout of components must be carefully chosen so that their temperature remains as nearly as possible constant and the condensers themselves often have to be of special types, with unusually high stability of capacity.

Motor Tuning.—In this type of remote control tuning systems, the use of a standard type receiver with a gang condenser is utilized.

For the purpose of control the tuning condensers are driven through a chain of gears from a small electric motor of the

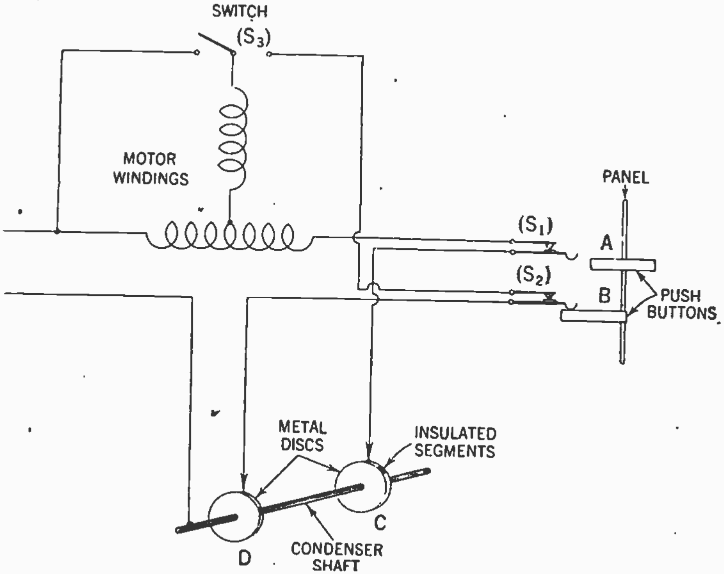


FIG. 7—Diagram illustrating a typical push button control system. The tuning condenser is driven by an electric motor which is controlled by press buttons.

reversible type. This motor usually operates from a 24 volt supply and the method of operation may readily be understood with reference to fig. 7 but there will be one disc for every station required and at the remote control there will be one push button for every disc.

It will be noted that of the two push buttons shown, *A* will be out while *B* is pushed in, so that the contacts of S_2 are closed. The circuit is then completed through the ring *D*, and the motor revolves turning the variable condenser and also the disc *D*.

When the insulated segment comes opposite the contact the circuit is broken and the motor stops. The receiver is then tuned to the desired station, for the initial set-up, the discs have been so aligned on the condenser shaft that the insulated segments in every case correspond to the condenser position for the wanted station.

This is a comparatively easy matter and it could for example be imagined that each disc is being held on by its own set screw to the shaft.

To set up any one disc for a particular station, one would tune in that station manually in the usual manner and then twist the disc so that the insulated segment comes opposite the contact and then tighten up the set screw.

It will be seen that upon pressing a button the condenser may start moving away from the desired station instead of towards it. When this happens the condenser goes on moving to minimum or maximum as the case may be, and then trips the automatic reversing switch S_3 and comes back to the desired station.

With some of the latest systems this reversing switch is unnecessary, for means are included to insure that the motor always start off with the correct direction of rotation.

It is clear, however, that a system of the kind under discussion would by itself hardly be satisfactory since it would not be possible to guarantee sufficiently accurate tuning for a selective receiver. It is, therefore, that this system is almost invariably associated with an *A.F.C.* system which most usually takes the form as shown on page 4,536. Such *A.F.C.* circuits properly arranged, will give very good control and take out quite large changes in tuning of the medium and long-wave bands, but in general they are not directly applicable to short-wave reception although naturally they can be employed in a double super-heterodyne.

The disadvantage of *A.F.C.* is that it increases the cost of the receiver, because it increases the number of tubes, and the initial adjustments of the circuit involved is fairly critical. It is therefore generally only found in the more expensive types of receivers. In the less expensive sets it is less often included and a good performance is then secured by paying great attention to stability.

Mechanical Accessories.—It is not within the scope of this discussion to go deeply into mechanics of the actual control circuits because they vary so widely and generally do not effect the principles of operation.

The use of systems which may be known variably as push-button or dial tuning is not confined to remote control, and in some cases these controls are mounted instead of on the ordinary tuning dial, on the receiver itself.

They are then often very much simpler and one arrangement consists merely of mounting a telephone type of disc with the usual finger holes on the shaft of the gang condenser.

Again in another system the condenser shaft carries a number of heart-shaped discs, one for each station. One operating key is provided for each disc, and its pressure moves the cams around in the manner shown in fig. 8.

Still another system has a series of control bars mounted on the condenser shaft. One such bar with its actuating lever is shown in fig. 9.

The lever presses against the rounded portion of the bar and so rotates the condenser shaft, until it reaches the flat part.

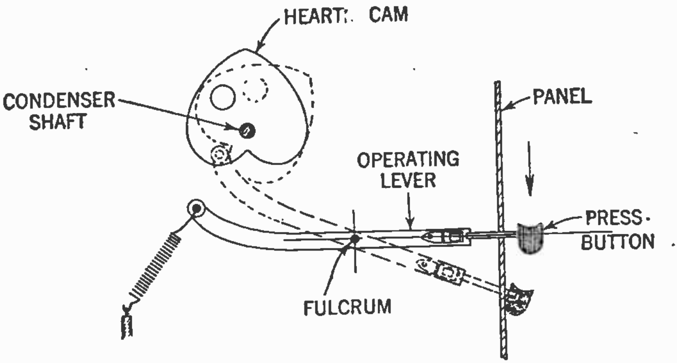


FIG. 8—Principles of control in which the tuning condenser is rotated by the pressure of a lever against a heart cam.

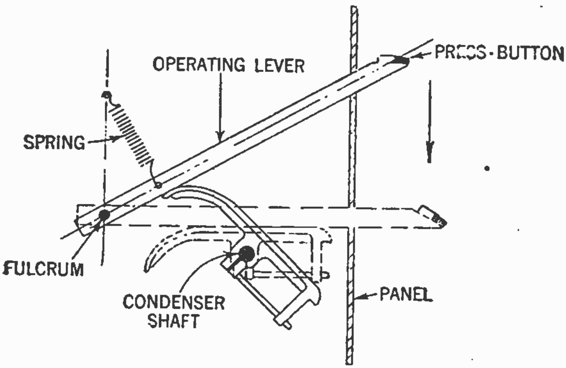


FIG. 9—Method of condenser control by lever system. When pressing the lever it contacts the rounded portion of control bar and so turns the condenser until the flat position is parallel with the lever.

WIRELESS CONTROL SYSTEM

Wireless Remote Control Device.—By utilizing a device recently developed by the Philco Radio & Television Corp., it is possible to operate a radio receiver by means of remote control.

The control box popularly known as the "Mystery Control" is portable, and the desired station may be dialed in a manner similar to that of a dial-type telephone, except that no connected wires are necessary.

With reference to fig. 11, showing the control box, the tube and coils form an oscillator which can be preset to 355, 367, 375, 383, or 395 kilocycles.

The dial mechanism is technically called the "Pulser unit" since it keys or pulses the output of the oscillator.

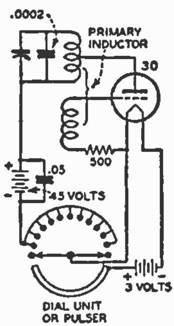
Since the control box is battery operated, the device is easily turned on while selecting a station or changing the volume. This means that the battery drain is practically nil.

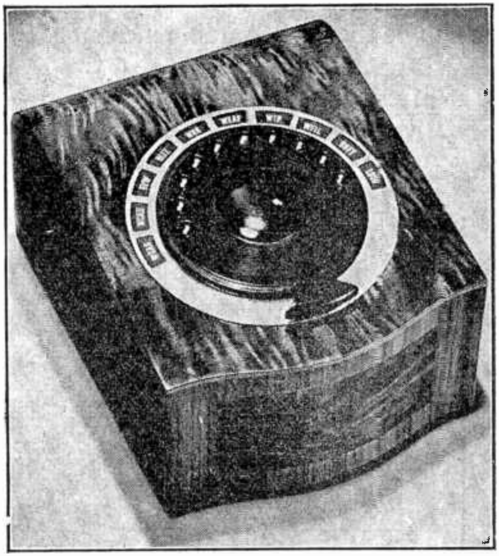
When the dial is operated, the filament circuit to the tube is closed by means of the lower switch arm and the continuous contact bar.

According to *Radio Today*, the device works principally as follows:

The Pulses Tune Radio.—The pulses are caused by making and breaking the plate battery circuit. As the dial mechanism turns, the plate circuit is opened and closed as the switch-arm touches the equally spaced contacts. Each station has a certain definite number of contacts that must be made. Corresponding to the station to be dialed, from 4 to 11 pulses are transmitted by the device. Two pulses increase the volume of the set, while 3 pulses decrease the volume. During the volume changes, a thumb-lever is held down which causes a continuous signal to be emitted. This lever is released when the volume reaches the proper value.

The signal from the control box is transmitted to a loop or secondary coil in the radio set by induction. The remote control





FIGS. 10 and 11—Fig. 10 shows circuit diagram of the portable control box. Impulses sent out from the box are picked up by the five tube unit (fig. 12) and amplified to the proper degree to actuate the tuning mechanism shown in fig. 13. All control boxes are adjusted to use one of the five frequencies specified above.

box fig. 11 has a tuned coil (oscillator coil) which acts as a primary to induce a signal in the secondary. The coil in the control box can be likened to the primary of an induction coil. When a current flows in the primary, a current is induced in the secondary. The dimensions of both coils are made as large as possible so as to effect a maximum transfer of energy.

In the mystery control it is desired to transfer energy over a distance approaching 75 feet while avoiding any form of wire connection. It is also desired to limit the maximum operating range of the device as sharply as possible. For numerous reasons, electro-magnetic induction (rather than radiation) seems to be the most suitable means for the purpose.

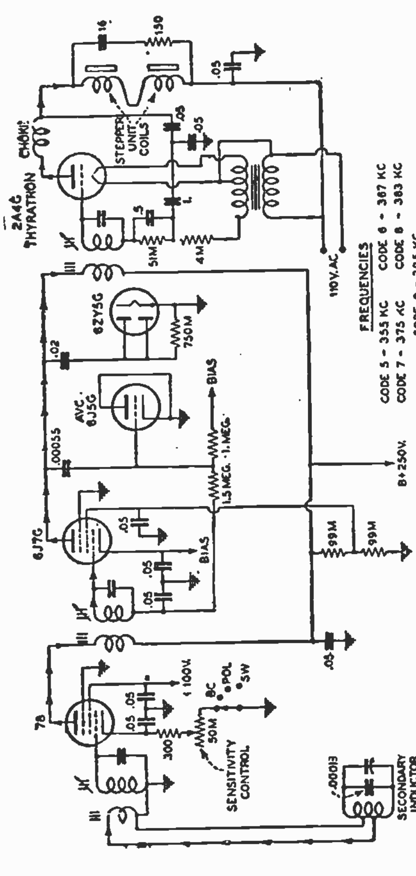


FIG. 12—Five tube stepper unit inter-connected with the high frequency part of the receiver shown in fig. 13. As previously described the receivers are equipped for five different control frequencies with range from 350 to 400 *k.c.* The purpose of the different control frequencies is to prevent interaction between two similarly equipped receivers which may be located on the same floor or are exceptionally close together. When several such receivers are to be located close together it will be necessary to utilize different control frequencies to avoid interaction between the receivers. In order to prevent interaction between receivers, there should be a difference of 20 *k.c.* between their control frequencies. If three receivers are to be operated at the same time and are closely situated, it will be advisable to adjust the control frequency of the first to 355 *k.c.*, the second set to 375 *k.c.* and the third to 395 *k.c.*, etc.

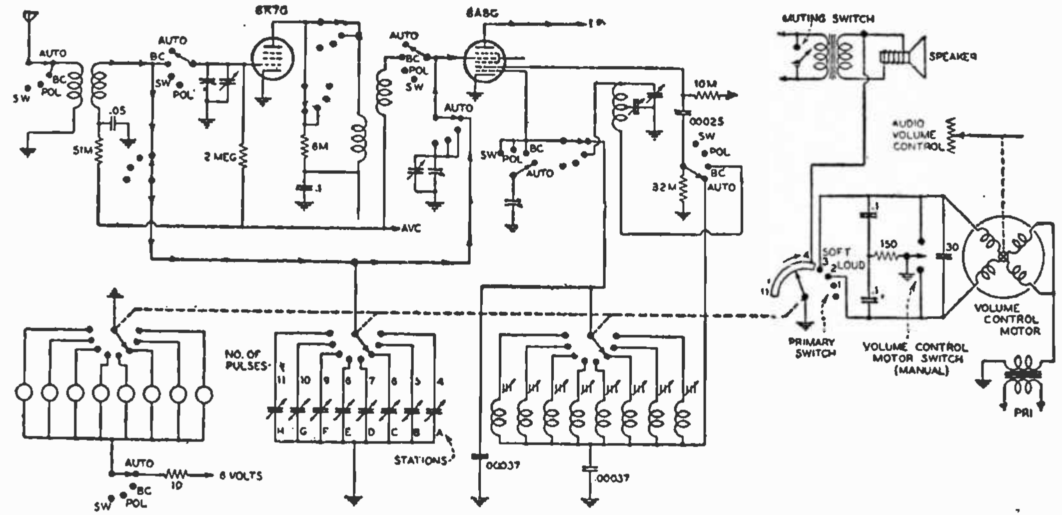


FIG. 13—Circuit diagram of high frequency part of broadcast receiver which is manipulated from a remote point by the control box. The stepper unit, fig. 12, energized by the thyratron tube switches to the desired station. Volume is also controlled remotely by means of a small motor attached to the volume control.

The Pulse Amplifier.—Because the pulses sent out from the primary (remote box) unit are rather feeble at the radio set, it is necessary to tune the remote oscillator to the frequency of the secondary coil and amplifier. As the range of the remote control device may be 75 feet under normal conditions, a variable frequency in both the oscillator and amplifier is provided so that no interference will be produced on neighboring mystery control sets. A choice of 5 frequencies from 355 to 395 *k.c.* is provided to eliminate the possibility of two or more sets interfering with one another.

The signals picked up by the loop are coupled to a tuned grid coil by a low-impedance link circuit. From the grid coil, the signals go through two stages of amplification to the grid of a 2A4G thyratron tube. The output from the thyratron tube is fed into the relays which in turn control the stepper unit and station selecting switch.

The Sensitivity Control.—In the control (pulse) amplifier circuit there is a sensitivity control which is employed for the purpose of adapting the set to the particular location where it is used. This control is in the cathode of the type 78 first amplifier tube.

The setting of this sensitivity control is of tremendous importance to the mystery control operation. The normal range of mystery control is within a circle of the receiver with a radius of about 25 feet. It is important to remember that mystery control operates in a circle around the receiver cabinet. To get the most from mystery control it is therefore advisable to place the cabinet as close to the center of the "operating circle" as possible.

If the receiver be located against the front wall of a home only half of the effective operating area is within the house. The remainder is outside the walls. There is a distinct advantage in operating the control amplifier sensitivity control at the lowest possible setting.

Extra sensitivity in the control frequency amplifier is provided so as to permit operation in the presence of inductive shields such as steel girders, metal lath construction and large bodies of metal, furnaces, boilers, stoves, refrigerators, chandeliers, or any similar metallic objects.

The sensitivity of the control frequency amplifier is variable to fit a large range of operating conditions. Normally, sufficient precautions are taken in the amplifier and remote control circuits to greatly reduce the possibility of electrical interference. The control amplifiers are very much less subject to interference than an ordinary radio receiving system. It requires an extreme and unusual type of interference to interfere with the operation of mystery control. There is no possibility of interference affecting mystery control receivers if the sensitivity control is kept down to the first half of its total movement. This illustrates the importance of setting the sensitivity control to the minimum position possible.

In some installations, however, owing to the presence of large metal objects around or near the receiver chasses of the mystery control cabinet, it will be necessary to increase the sensitivity of the control frequency amplifiers owing to the absorption of the metal surfaces.

When this occurs, it will very likely be found that the same metal objects are shielding the receiver from excess static which would normally interfere with the mystery control circuits in a high setting of the sensitivity control. Therefore, when it is necessary to increase the setting of the sensitivity control in order to get operation of mystery control, it will likely be found that interference is not present and that a higher setting of the control is possible.

In all installations be careful to set the sensitivity control at the lowest possible position and to locate the receiver away from metal objects which would absorb the induction field of mystery control.

The 6ZY5G and 6J5G tubes act as a noise gate to exclude unwanted interference which might control the stepper assembly. This noise gate makes the amplifier respond only to pulses having a time interval equal to that of the pulser mechanism. Thus pulses of random timing do not operate the set:

The operation of the thyratron tube is entirely different from any tube so far encountered by the radio serviceman. It is a gas-filled tube which can handle large plate currents—in other words, large amounts of power. Before getting into the operation of the stepper relay unit for station selection, the *r.f.* circuits of the receiver should be examined. The wave-switch selects any one of three wave-bands or automatic tuning (mystery control operation).

The Tuning Circuits.—To illustrate the automatic operation, the wave switch has been drawn in that position. The wave switch sections disconnect the *r.f.* amplifier from the circuit and transfer the antenna coil to the grid of the converter tube. Also, the antenna coil is connected to the station selector switch which selects the proper trimmer condenser for any one station. The gange condenser is cut out of the circuit for remote operation.

The oscillator coil system is completely cut out of the circuit and trimmer type inductances with iron-core tuning are connected by the station selector switch.

A third rotary switch turns on the proper station indicator lamp. The assembly for the station selecting circuits is located beneath the chassis and is driven by the stepper assembly.

There are three groups of contacts operated by the switch. One group switches in the oscillator coils, the second group switches in the antenna padding condensers and the third group of switches, lights the pilot lamps indicating the station dialed.

Excessive friction in this switch would cause improper action of the stepper assembly. It should be adjusted so that when the relays have selected the station dialed, the contact arm is squarely on the contact. The tension of the contact arm is regulated by the setting of the hub on the switch shaft. The long wiper contacts exert a firm pressure on the contacts which may be increased or decreased by adjusting the location of the hub.

The position of the contact arm is determined by the set screws which hold the driver arm on its shaft. This is located above the chassis but beneath the stepper assembly. If the contact arms do not come to rest on the contacts it may be necessary to loosen the set screws on the switch shaft and re-locate the position of the driver arm so that the contacts are made correctly.

Excessive tension in the switch would act as a load on the relays and might result in chattering on one of the stations, part way up, and then failing to reach the station dialed.

The Stepper Assembly.—The stepper assembly which operates the station selecting switch is operated by the thyratron tube referred to previously. The coils which operates this assembly as shown as the plate load of the thyratron in fig. 12.

When the thyratron tube lights, the holding relay closes and the stepping relay pushes a ratchet as many times as there are pulses sent out by the pulser in the mystery control box. There is a primary and a secondary ratchet. The stepper relay operates the primary ratchet which is connected to the primary switch. This switch controls the volume control motor and shorts the voice coil to ground in the station selecting positions.

A muting switch, which connects the plates of the output tubes together, is closed during the station selecting operation. The set, of course, is playing during changes in volume but it is muted as the secondary ratchet returns to its home position, and climbs to the station dialed.

This means that whenever any of the eight stations are dialed the set is muted as the secondary ratchet switch turns the "station tuning" switch contacts.

Failure of the primary switch to return home or the secondary ratchet arm to return home, failure of the receiver to mute during dialing would indicate trouble in the stepper assembly, and would make it necessary to return it to the manufacturer for replacement. Dialing of an incorrect station, the skipping of stations or the galloping past of stations also indicates trouble in the stepper assembly.

The Volume Control Assembly.—The volume control and the on-off switch are motor driven. The motor has an automatic clutch which releases and drops back as soon as the volume control is released by the stepper primary switch. This prevents "over-shooting" when changing volume and immediately stops the gear train which drives the volume control when the volume control lever is released on the mystery control box. There is also a clutch in the volume control itself, so that the mechanism will not jam if the volume control lever is held down after the set is shut off.

The primary switch is a single pole, double throw switch which connects the desired winding in the volume control motor to increase or decrease volume, as shown in fig. 13. In parallel with this switch there is a single pole, double throw switch connected to the manual volume control. This switch is mounted directly beneath the receiver dial bezel.

The pilot lamp cable is close to this switch. If any of the pilot lamp wires become tangled with the switch they might cause the motor to continue running and might possibly cut through the insulation of the pilot lamp lead, causing the lamp to stay lit. It is important when the chassis has been removed, to check the location of the pilot lamp wiring cable to make certain that it is entirely clear of the volume control motor switch.

Method of Inter-station Noise Elimination in Automatic Control Systems.—In modern super-heterodyne receivers the potential amplification is very high, hence the tuning problem would be very difficult if an automatic volume control were not included in the receiver.

It is however a well known fact that all *a.v.c.* systems are designed to regulate the gain of the receiver only while a signal is being received; therefore between stations the sensitivity rises to a maximum.

This means, of course, a great increase in the background noise between stations and unless there be a noise suppression auxiliary provided in the receiver to limit this audible noise it often becomes objectionable, especially in locations where there is a large amount of man-made static.

Several schemes have been advanced to solve the interstation noise problem in the *a.v.c.* equipped receiver. Perhaps the simplest one is to provide an adjustable bias on the *i.f.* tube (in addition to the *a.v.c.*) so that the receiver's maximum sensitivity may be manually decreased below the noise level. This undoubtedly settles the noise problem, but it may, through excessive adjustment, reduce the receiver's sensitivity to such an extent that weak stations, which might otherwise be received fairly well, will be skipped by unnoticed. Then, too, if this manual sensitivity control has to be continually retarded and advanced in an effort to locate weak stations, it loses much of its effectiveness as far as noise is concerned.

Another idea for checking inter-station noise and one which has found greater favor among set designers and experimenters than that outlined previously, is the utilization of a vacuum tube as a carrier controlled relay to block the audio amplifier when no signal is being received. This system is very efficient as a noise suppressor.

It is fully automatic in action once the circuit has been properly adjusted. However, while some radio men have successfully installed it in existing receivers, it is generally most effective when included in the original design of the set since it is quite critical in its voltage requirements.

In analyzing the nature of this between-station noise, it has been found that most of it occurs in the high audio frequency spectrum; thus, if the high frequency response of the receiver is checked by a tone control, the intensity of the noise will be greatly reduced. However, the degree of high note suppression needed to limit inter-station noise is much greater than can be tolerated where good fidelity of tone is desired from a local station.

For this reason on the usual radio which is equipped with a manual tone control, it is necessary to adjust the control frequently to meet existing conditions. By adding a tube to the diode detector circuit as shown in fig. 14 this tone control action may be effected automatically in the *a.v.c.* equipped receiver. It is an idea that has been successfully used for noise suppression purposes in several of the larger super-heterodynes, and due to its simplicity it can be easily adapted to any receiver using *a.v.c.* A worthy feature of the system is that it will decrease noise without reducing the overall sensitivity.

This automatic tone control must operate in conjunction with a diode type detector. The left half of the accompanying diagram shows the fundamental diode second detector and *a.v.c.* rectifier circuit found in the majority of modern superheterodynes. Although the tube shown is a 6H6, it may also be the diode portion of a diode-triode or diode-pentode tube; and in some older model receivers, it may even be a triode connected as a diode.

If the associated parts of the detector circuit consisting of resistors R_1, R_2 and R_3 and condensers C_1 be arranged as shown,

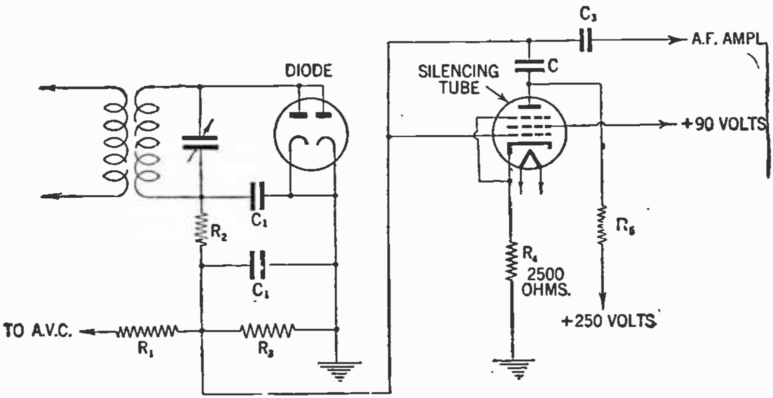


FIG. 14—Automatic tone control circuit.

they need not be disturbed when adding the tone control tube to the receiver. However, if R_3 is a volume control potentiometer, it must be removed and used instead in the grid circuit of the first audio tube to control the input to the grid of this tube. The original fixed resistor in the audio grid circuit may then be shifted to the R_3 position if it be .25 to .5 megohms in value.

In some sets, R_2 may be replaced by an *r.f.* choke or it may be omitted altogether without affecting the performance of the circuit. The experimenter may also find that some receivers divide the functions of *a.v.c.* and detection, using separate diode sections or tubes for each purpose. In this case, connect the tone control tube to the detector diode circuit and disregard the separate *a.v.c.* system.

The circuit that is to be added to the receiver is shown in the right half of the diagram. The tube may be any sharp cut-off type, either tetrode or pentode, such as the 24, 36, 57, 77, 6C6 or 6J7. Experiment has shown that all of these types work equally well. The choice, therefore, will depend mainly upon the filament voltage available. The tone control tube and associated parts should be mounted as close to the diode detector as possible. Resistor R_4 is non-critical in value, a good compromise being 2,500 ohms. R_5 should not exceed 100,000 ohms regardless of the plate supply voltage.

The audio coupling condenser C_3 is probably already in the receiver and need not be changed. The rating of condenser C will have to be determined by experiment and values from .0001 to .001 (mica dielectric) should be tried. The final choice will depend upon the maximum degree of high note suppression that can be tolerated when the set is tuned to an extremely weak station. If distortion be encountered on some of the medium powered stations, the screen voltage should be slightly lowered.

CHAPTER 179

Loud Speakers

The function of a loud speaker is to convert the amplified audio frequency currents into sound waves. In order to accomplish this the loud speaker must be designed in such a way that it will cause the varying electric currents to set in vibration a diaphragm similar to that used in a telephone receiver, only larger.

The vibration of the diaphragm in turn sets the surrounding air molecules into motion. The vibration of this comparatively large volume of air produces the sound, which the ear receives and the brain sometimes appreciates.

The efficiency of a loud speaker is defined as the ratio of the useful acoustical power radiated, to the electrified power supplied to the load and is very low even in the most carefully designed.

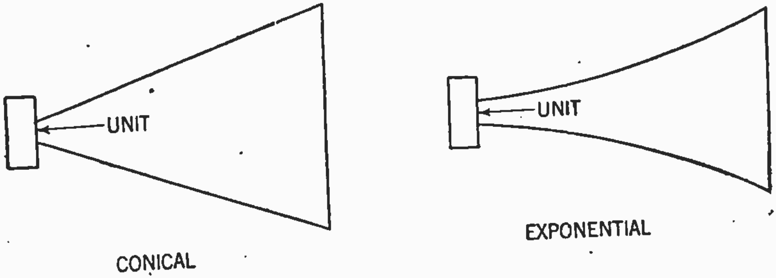
The most efficient type in common use in sound picture work has an efficiency of only about 30%.

Speaker Parts.—Generally loud speakers consist of two main parts:

1. That part of a loud speaker which changes the varying currents of the audio frequency amplifier into mechanical vibrations, which is called variously *the driving unit or motor*.

2. The other part is that which acts in conjunction with the driving unit to produce the vibration of the air molecules, and consists of a surface of various geometrical designs such as a *conical* or *flat shaped horns*.

The horn has been known and widely used for centuries for increasing the radiation from a sound source. Although it is not within the province of this chapter to enter into a discussion of



FIGS. 1 and 2—Conical and exponential horn forms.

horn design, it may be well to mention that the horns most commonly used for sound reproduction are the *conical* and the *exponential* types.

Figs. 1 and 2 show the two forms of horns most commonly in use.

The *conical* horn may be defined as one in which the cross-sectional area of the horn varies in direct proportion to its length, whereas in the exponential form the area of the horn varies as an exponent of its length.

Classification of Speakers.—Loud speakers may be divided into the following general classes, depending upon the principle involved in operation of the driving unit, namely:

1. Magnetic
2. Dynamic, variously called electro-dynamic
3. Balanced armature
4. Induction
5. Metal strip
6. Electro-static, variously called condenser speaker
7. Piezo-electric, variously called crystal speaker.

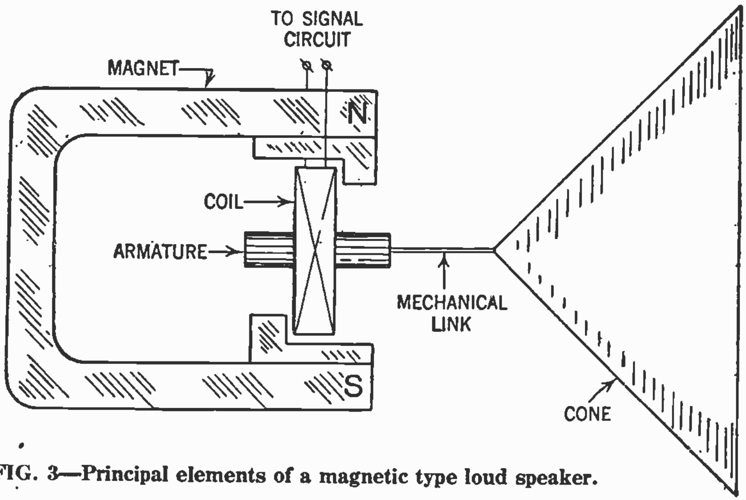


FIG. 3—Principal elements of a magnetic type loud speaker.

Magnetic Speakers.—In this type the moving iron driving type is employed. The principle of operation is based on the varying of the magnetic polarity of the armature. These variations are caused by the electrical impulses flowing through the coil winding which encircles the armature.

The movement to the armature is effected by the induced magnetism, causing it to oscillate between the two poles of the permanent magnet.

Dynamic Speakers.—A speaker of this type illustrated in figs. 4 and 5 consists principally of the following parts: 1, field coil; 2, voice coil; 3, cone.

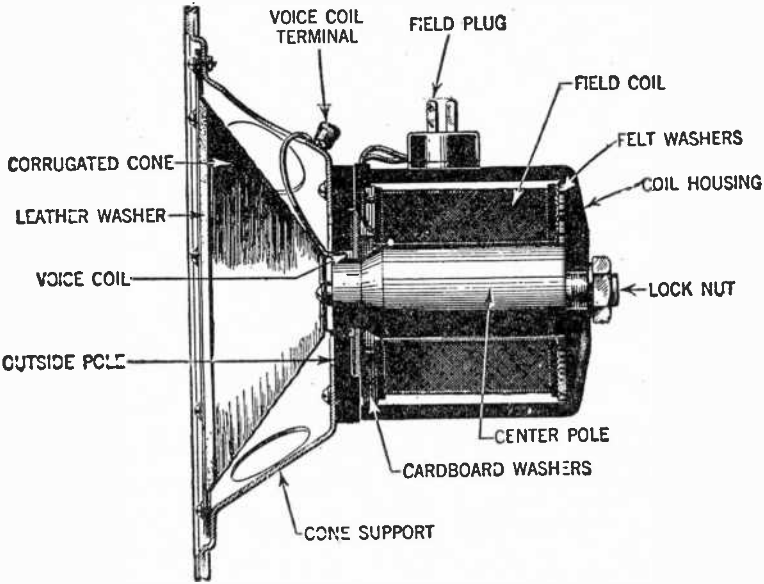


FIG. 4—Cross-section view of a dynamic type loud speaker with a moving coil driving a cone type diaphragm. Details of the various units are here clearly represented.

The field coil is connected to a *d.c.* source, effecting a strong magnetic field across an air gap in which the voice coil is inserted. The signal current from the output terminal of the receiver, flowing through the voice or moving coil placed around the middle pole of a three pole magnet, causes the voice coil to oscillate corresponding to the oscillations of the signal current.

The diaphragm being mechanically connected with the voice coil oscillates in a similar manner.

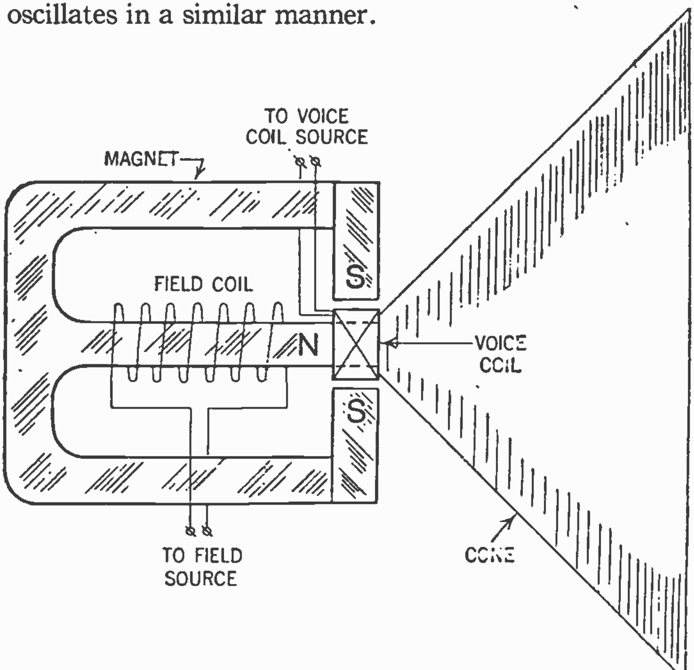


FIG. 5—Simplified diagram of dynamic speaker units shown in fig. 4.

Balanced Armature Speaker.—In this type of speaker the armature (as the name implies) is balanced between the two poles of a permanent magnet as shown in fig. 8. The armature is provided with a coil through which the signal current flows as indicated, so that the reaction between the magnetic field due to this current and that due to the permanent magnet causes the armature to oscillate about its pivot.

These movements are communicated to the diaphragm by means of the link connection in a similar manner as in the dynamic speaker previously described.

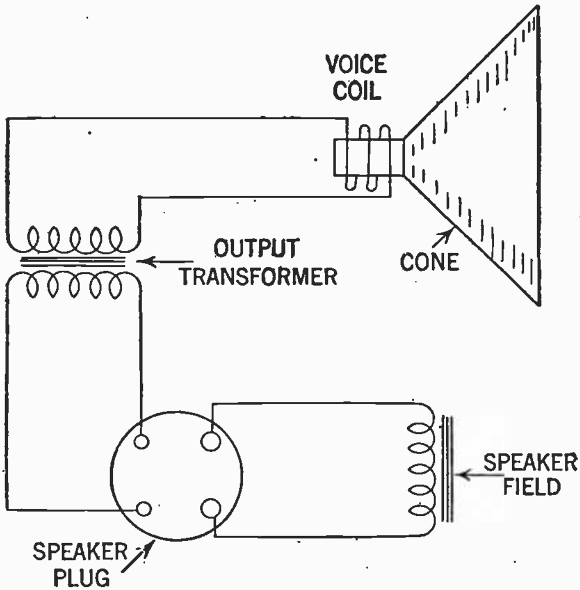


FIG. 6—When the dynamic speakers as in some commercial sets are connected by means of plug and cable to the chassis, the connections may be as shown in fig. 6 or 7; generally however, there is no set rule for these connections. The output transformer may be mounted on the receiver chassis or on the speaker frame. Again, the output tubes may be connected in parallel or in push-pull. Therefore, the connections shown are typical only and may not be considered as standard, but in each case the makers diagram should be carefully checked and followed.

The principal features in this construction is a complete elimination of chattering on loud signals, usually encountered in the magnetic type. However, one of its limitations is that for a good sensitivity the air gap between the armature and the pole pieces must of necessity be made very small to reduce the reluctance and so as to obtain a strong magnetic field. This is objectional since when receiving low notes the movement of the armature may be so great as to strike the pole pieces, emitting a rattling sound.

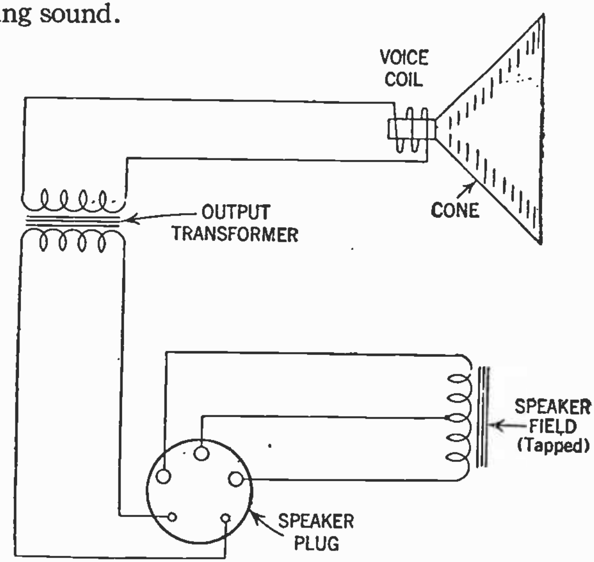


FIG. 7.—Schematic diagram of connections to speaker by means of plug-cable arrangement.

When the air gap is made larger, eliminating this rattling, the field strength decreases with a proportional loss in sensitivity.

Induction Type Speakers.—The name induction speaker is derived from the fact that the motion of the driving unit is obtained from a magnetic induction similar to that of the well known A.C. induction motor, where a rotor revolves under the influence of a changing magnetic field.

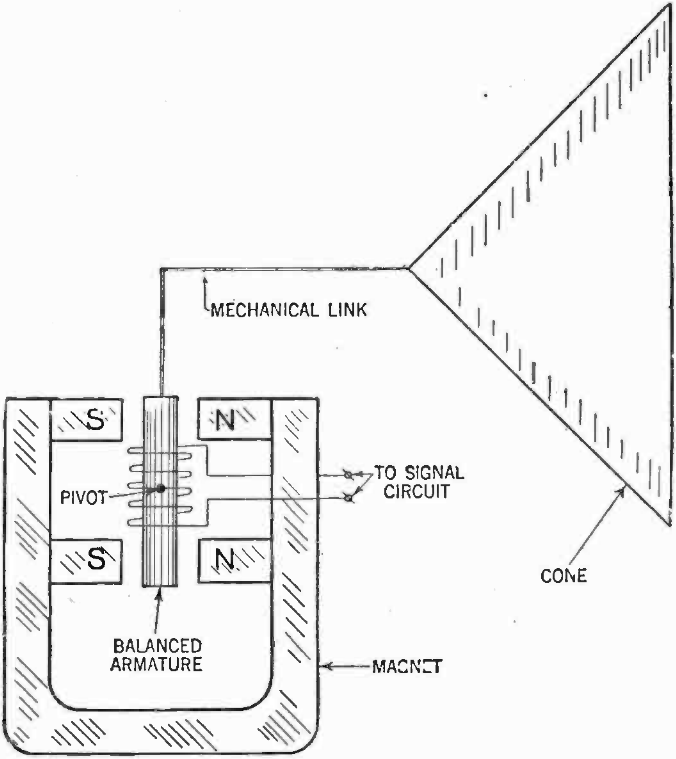


FIG. 8—Balanced armature type speaker. *In construction* the balanced pivoted armature is a soft iron bar forming a core of a coil of several thousand turns of fine wire supplied with audio frequency current. *In operation* when a signal current flows through the coil, a magnetic field is produced. which magnetizes the soft iron armature. The poles react on the poles of the permanent magnet and attraction between the unlike poles and repulsion between the like poles take place. With the polarities shown, the top end of the armature would move to the left and the bottom end to the right when the signal current flows through the coil in the corresponding direction. The amount of pull or movement is proportional to the current flowing through the coil, so the armature moves in accordance with the variations in the current.

As shown in fig. 9, the diaphragm is placed between two sets of concentric coils. Direct current is applied to the two sets of coils in opposite directions, causing a radial field.

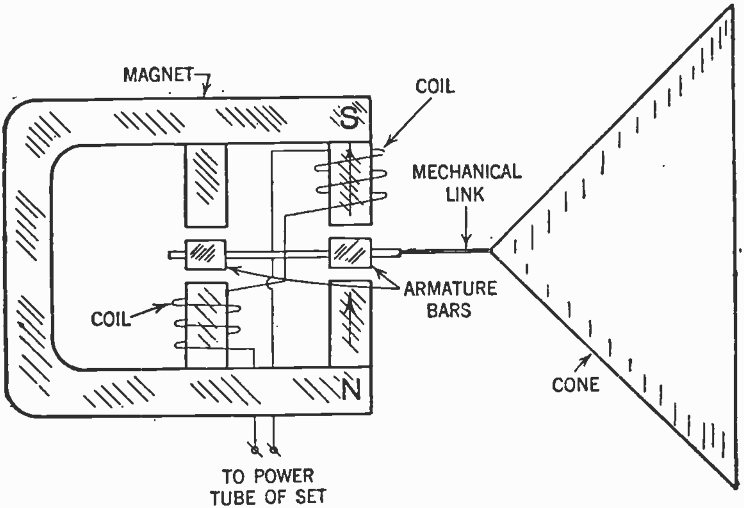


FIG. 9—View showing various units and connections for an induction type loud speaker.

The signal current is also passed through the coils which causes the steady field due to the direct current to vary and which in turn induces eddy currents in the diaphragm.

Since the eddy currents give polarity to the faces of the diaphragm these poles react with the poles of the coils, thus causing vibration of the diaphragm and resulting sound waves.

The utilization of strong permanent magnets makes for a low-priced and simple unit, and since there is very little possibility of objectionable hum being introduced when used in connection with battery operated receivers, it is particularly adaptable for automobile radio use.

Metal Strip Types.—In this type a metal strip is suspended between the poles of a permanent or electro-magnet. The signal current passes through this strip (see fig. 10) establishing a magnetic field around it which reacts with the field, due to the permanent magnet, which acts to displace the metal strip in accordance with the variations in the signal currents.

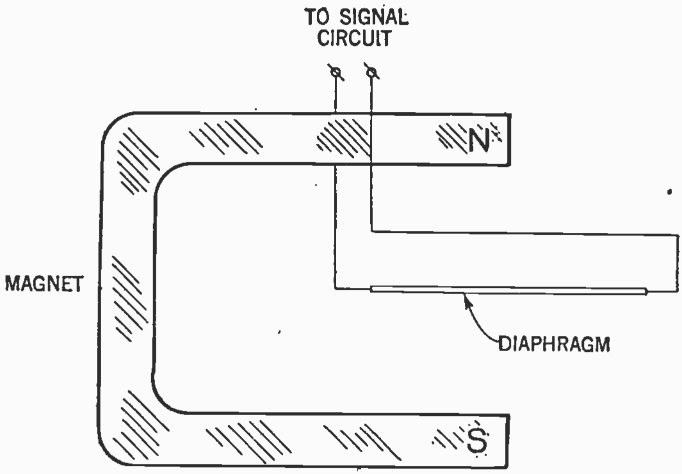


FIG. 10—Principal element of metal strip speaker. A megaphone is usually associated with this type of speaker.

The metal strip is in this case the diaphragm and obviously need not be of magnetic metal.

Electro-Static Types.—This type variously called a condenser speaker consists essentially of three parts, namely: two plates of which one is stationary and the other free to vibrate, in addition to the dielectric, assembled as shown in figs. 11 and 12.

It operates on the well known principle of electrostatic attraction and repulsion, in that two bodies of similar charges of electricity repel each other, whereas two opposite charges attract each other.

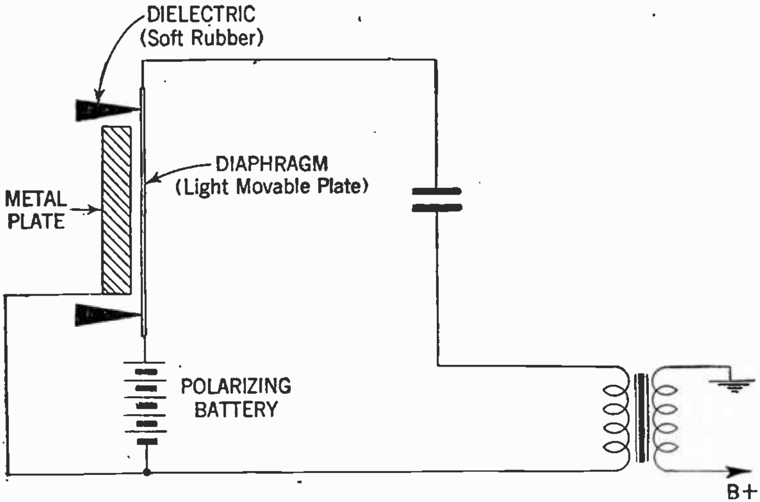


FIG. 11—Electrostatic speaker showing circuit connections. In construction, the metal plate is made rigid. The diaphragm consists of a thin layer of metal sprayed on the rubber dielectric.

When a polarizing voltage is applied to the plates a steady electric field is built up; superimposed upon this is the audio-frequency alternating electrostatic field. This, according to the foregoing, causes an attraction and repulsion between the two plates, producing in the free plate oscillations corresponding to the audio-frequency impulses.

The back or stationary plate in the commercial types of condenser speakers consist usually of stiff metal such as copper, iron or aluminum. The back plate is usually perforated with slots in order to prevent compression of air between the two plates.

To obtain a large force on the movable plate the dielectric must be very thin and flexible and must have the largest possible dielectric constant, in addition to a high break-down voltage.

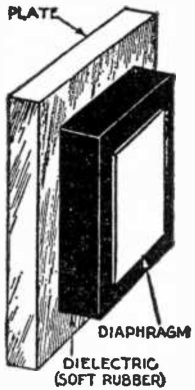
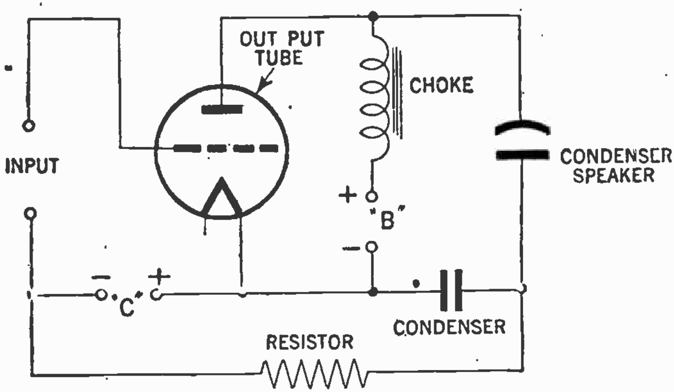
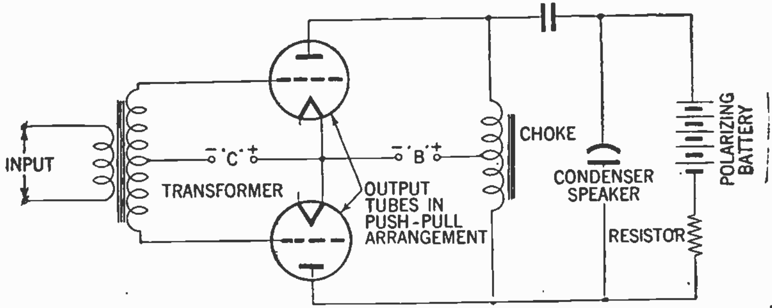


FIG. 12—Elements of an electrostatic speaker. It consists essentially of a form of condenser, hence the name as it is often called a condenser speaker.

Piezo-Electric Speakers.—This type of speaker (often referred to as *crystal speaker*) depends for its operation on the property of a crystal of expanding and contracting in accordance with the electrical strain to which it is subjected.

The crystal speakers are often used in connection with high-frequency reproduction, its use up to the present, however, has been limited to small units. As a speaker of this type is inherently a rectifier. it is obvious that there is no need for any separate output transformer or frequency filtering network.





FIGS. 13 and 14—Showing two circuit arrangements for connections of a condenser type speaker to the power amplifier stage of the receiver.

Loudspeaker Baffle.—In a loudspeaker such as that shown in fig. 4 the material constituting the cone is driven forward and backward in the manner of a piston by the action of the impressed audio frequency signal. This constant movement displaces a certain amount of air, and it is this displaced air which generates sound that is perceived by the ear.

The air pushed back in the forward motion must go somewhere, and as a partial vacuum is created in the back as the cone moves forward, the displaced air in the front encounters very little resistance and hence flows rapidly to fill the vacuum created by the forward thrust of the cone.

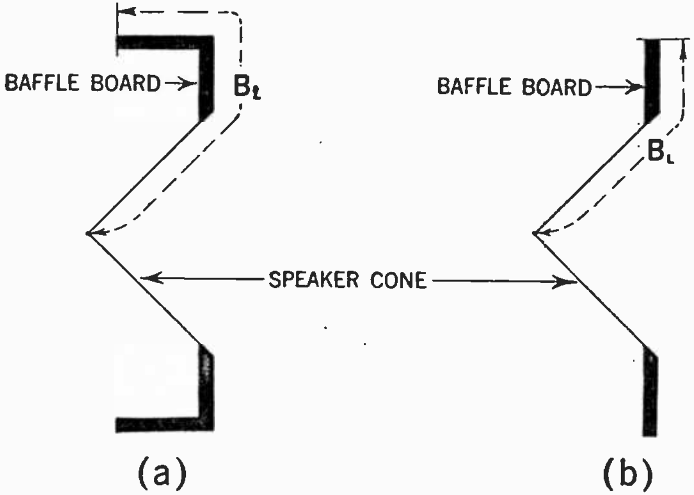


FIG. 15—Various speaker baffles; *a*, and *b*, indicates box and flat baffle types respectively. Dotted lines indicate length of baffle board in each type.

If these air movements were allowed to neutralize each other completely, there would be no air movements and hence no sound waves would be created. The method used to delay these rapid movements is to increase the path of air travel by means of a *baffle board* surrounding the cone as shown in fig. 15.

The amplitude of air movement in a speaker however, is relatively low and therefore theoretically at least sound waves are produced only in the air very close to the moving cone. This is true for low, but not for high frequencies.

Thus in practice an unbaffled speaker will reproduce high tones, but will lack almost entirely all low tones due to the neutralization already described.

Baffle Purpose.—The purpose of the *baffle* is to delay the meeting of the air creating the sound waves, by an artificial lengthening of the path of its travel.

The baffle, can be anything that will lengthen the airpath from cone center back, to cone center rear.

In practical speakers the baffle is made up of some acoustically suitable material, such as soft wood, thick felt, Celotex, etc.

Calculation of Baffle Length.—By recalling that the speed of sound is 1130 feet per second in air, it is possible to calculate the minimum baffle length for a certain frequency.

If B_L denotes the baffle length in feet, and f the frequency of the sound wave, then

$$B_L = \frac{1}{4} \times \frac{1130}{f} = \frac{282.5}{f} \quad \ldots\ldots (1)$$

or expressed in a non-mathematical form, the baffle length in feet is equal to one quarter the wave-length of the note to be reproduced.

Example.—*Assuming* 40 *cycles as the lowest tone to be reproduced by a speaker, what is the minimum baffle length required:*

Solution.—Substituting the numerical values in equation (1) we obtain:

$$B_L = \frac{282.5}{40} \text{ or 7 feet (approximately)}$$

In a similar manner the following baffle lengths for low frequency cut-offs below which a loud speaker will not reproduce is as follows:

Lowest frequency to be reproduced.	*Baffle length from cone center in feet.*
100	2.825
60	4.708
40	7.006
30	9.417
20	14.125

As the tones corresponding to the lowest frequency of various instruments are approximately 20 cycles per second, it follows that for their reproduction baffles of considerable length must be created.

Example.—*A loud speaker whose inductance is* 1.15 *henries is coupled to a power tube through a condenser of* 2 *micro-farads capacity. To what frequency will the combination be resonant?*

Solution.—In this example it is only necessary to find the resonant frequency of a series tuning circuit. When in such a circuit the inductance L, and capacity C, are both expressed in the fundamental units of henries and farads, then the resonant frequency in cycles per second is given by the expression

$$f=\frac{1}{2\pi\sqrt{L\times C}}$$

In the present example however, the condenser is of 2 micro-farads capacity, hence it is necessary to convert this unit into the terms of farads before substitution into the above formula.

Inserting values, it is found—

$$f=\frac{1}{2\pi\sqrt{1.15\times2\times10^{-6}}}=\frac{1{,}000}{2\pi\sqrt{2.3}}=105 \text{ cycles per second.}$$

CHAPTERS 180 to 184

Radio Testing

It is of the utmost importance that the serviceman, in order to intelligently cope with the various faults liable to develop in radio sets should be provided with the necessary testing instruments, of which there are a great variety available (some of which have very desirable characteristics).

The selection of instruments described in this chapter however, are by no means essential for intelligent servicing of radio sets.

Testing instruments to be of value to a radio serviceman must have the following features:

1. They should be easily portable.

2. They should be ruggedly constructed so that instruments will not be damaged or their calibration changed in transport.

3. The instruments must be designed to stand considerable overloads without damage, as in service work it is often difficult to estimate the exact magnitude of the measurements being taken.

The following instruments are required to properly service any radio set:

1. A volt-ohm milliammeter for measuring voltage, resistance and current.

2. Analyzer with the necessary selector switches and analyzer cable with adapters.

3. Output meter.

4. All-wave oscillator.

5. Capacity meter.

6. Inductance meter.

7. Tube tester.

This equipment may be supplemented by a cathode-ray oscillograph, a vacuum tube voltmeter, etc., and hence will provide the serviceman with equipment necessary to successfully cope with almost any servicing problem.

Analyzers and How to Use Them.—The fundamental purpose of an analyzer is to locate trouble in receivers without undue waste of time and without disturbance to the wiring of the radio set.

A modern analyzer consists of various resistances, capacitances, inductances and meters, which by means of switches are connected to the circuit whose values it is desired to verify, and mounted in a compact cabinet to facilitate transportation.

Preliminary Pointers.—However, before analyzing the radio set for trouble, it is well to consider possibilities of trouble in the installation itself. The aerial may be grounded or touching foreign parts; the aerial connection may be corroded; or the lead-in wire itself possibly broken inside its insulation. The lightning arrester may be leaky or short-circuited. A poor ground connection is also a frequent cause of trouble due to interference with reception from outside causes. If, by disconnecting the aerial and ground the noise disappears, the trouble is undoubtedly located outside the set.

If it be evident that the trouble is inside the radio set itself, a careful examination of the wiring connections and interior parts of the set is next in order. The condition of soldered joints should be examined to be sure that there is a good electrical connection.

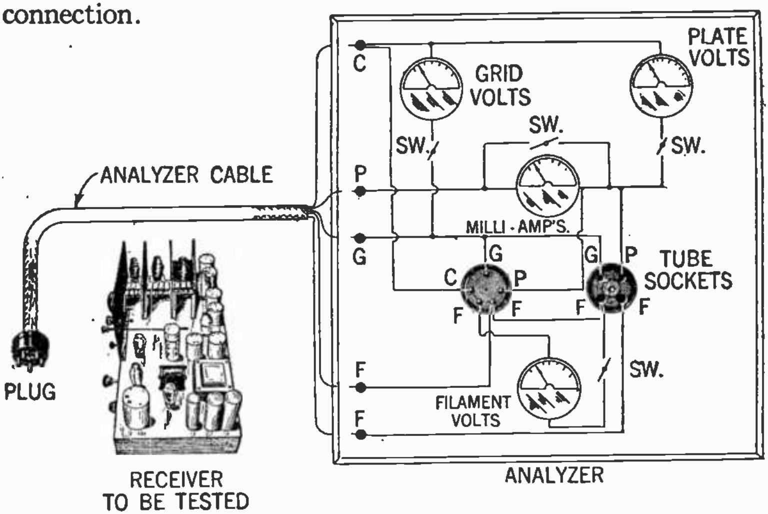


FIG. 1—Principal parts of a simple analyzer. The performance of the test is as follows: After a preliminary investigation of possible outside sources of trouble such as faulty or grounded aerials, open soldering joints, broken parts, etc., remove tube to be tested from set to proper socket in analyzer, and insert analyzer plug in place of the tube removed from set. Test the tubes one by one, starting with the antenna stage and proceed until the power amplification stage is reached. This test will indicate the location of troubles in the various circuits or in the tubes as well as in their power supply.

It should be noted that the insulation of the wiring be not cut or frayed where it passes through metal, around the edges of tube socket contacts, etc. The tube socket fingers should be clean and tight. The possibility of variable condenser plates touching should be checked. A visual inspection of this kind may quickly locate the cause of the trouble.

Electrical Tests.—The first electrical check on the set should be on the power supply to insure a normal supply of voltage to the various circuits in the radio set.

If the set be a battery operated type, check the condition of the various batteries by making use of the tip jacks on the analyzer and the test leads supplied with it. If the set be supplied with power from an alternating current house lighting circuit, measure the line voltage to be sure that it is correct for the set as indicated on the name plate of the radio set. The various batteries should give approximately their rated voltage readings with the radio set connected and turned on. If the batteries are low they should be re-charged or replaced.

Having checked the source of power to the radio set, the next step is to check the current and voltage supplied to each tube. A suggested method is to check the tubes in the order in which the signal passes through them. That is, start with the antenna stage and end with the power amplifier stage.

After making preliminary tests and a visual inspection and finding everything in good order, the electrical tests should be made. These electrical tests will show the location of troubles in the various circuits, in the tubes and in the power supply to them.

First, place the radio set as near as possible in good operating condition. If battery operated, all batteries should be properly connected. If power operated, connect to the proper power circuit. Turn on the set and make such adjustments as are normally necessary to bring in a good signal.

In general, all electrical tests should be made with the volume control in the maximum volume position, since this position generally gives the optimum distribution of currents and voltages through the various circuits in the radio set. A second set of readings with the volume control in the average working position is often helpful in locating trouble. This second set of readings is the current and voltage values in the various circuits under average conditions and should compare favorably with the first set. Radical differences should be checked up for a possible source of trouble.

In a battery operated set all batteries should be checked; any which are low in voltage should be replaced beiore proceeding with a more detailed analysis of the radio set.

Selection of Voltmeter Scales.—It is advisable when reading direct current voltages to set the selector switch on the range which will give the smallest deflection of the instrument which can be read satisfactorily. While this may seem to be contrary to general practice, the fact that many modern radio receivers have individual voltage divider networks for each tube, allows the current drawn by the voltmeter to throw the voltage applied to the tube somewhat in error.

It is obvious that a network supplying three milliamperes plate current to a tube will be upset to a considerable extent by connecting a voltmeter to it which requires one milliampere full scale. Consequently, deflections of less than half scale, as would be obtained on a higher range, will introduce less error than deflections of approximately full scale on a lower range, since the latter require considerably more current from the voltage divider network. When a difference in voltage indicated on the instrument scale exists as the range selection is changed, the indication read on the highest full scale voltage should be taken as the more accurate.

Selection of Current Scales.—In reading current always take the reading on the range which will give the largest possible deflection. By doing this the greatest possible accuracy will result.

Testing a Triode.—For a complete analysis of a triode for example, it is necessary to measure the following values:

1. Plate voltage
2. Plate current
3. Grid voltage
4. Grid current
5. Filament voltage.

In addition where cathode screen grid or pentode tubes are being tested, it is necessary to measure—

6. Cathode voltage
7. Screen grid voltage.
8. Screen grid current.

A complete outline of the above tests is given on pages 4,590. to 4,595.

Test Oscillators and Their Use.—The fundamental use of a test oscillator is to replace the broadcast signal for test and adjustment of radio receivers. Of special importance to the servicemen are the following uses:

Alignment of *IF*, *RF* and oscillator padding circuits. Checking the condition of tubes. To determine the gain in any part of radio receivers. For testing *a.v.c.* circuits. For checking selectivity.

Alignment Procedure.—Unless the manufacturer of the receiver instructs otherwise the following sequence should be followed in the alignment of a radio set:

1. The various tuned circuits of the *IF* amplifier are first aligned properly at the intermediate frequency for which the amplifier was designed.

2. The oscillator tracking condenser should then be adjusted at about 1,400 *k.c.* so that it tracks properly at the high frequency end of the dial. Adjust the padding condenser at about 600 *k.c.* so that it tracks at the low frequency end of the dial.

3. Align the radio frequency, the pre-selector, amplifier or tuned circuit last.

If double spot or image suppression circuit be employed in the receiver, the manufacturer's instructions should be consulted for the proper procedure. Maximum transfer of energy in output is only obtained when every section is synchronized properly.

Use of Output Meters.—To determine the condition of tubes feed the signal from the oscillator to the aerial and ground connections of the receiver. Connect an output meter to the radio set; substitute new tubes for those in the radio set, one at a time and if the output meter indicates a greater value when each new tube is placed in the set, the original tube should be replaced.

To determine the gain in any part of the receiver, connect output meter as before and feed signal to aerial connection of radio set. Adjust oscillator to a high output and move the oscillator aerial connection to each succeeding *RF* or *IF* stage, noting the drop in the output voltage as shown on the output meter. Always use the proper frequency and proper scales for the output meter.

To check *a.v.c.* to determine when it is functioning properly, wide changes in the alignment with a large signal voltage will produce no appreciable change in output.

To check selectivity feed a signal of low value to aerial and ground connections, tune oscillator to perfect resonance, move oscillator signal dial until signal disappears. Note number of kilocycles between resonance and inaudibility.

Capacity Measurements.—On account of the fact that capacitors very frequently give rise to trouble in *a.c.* receivers, it is necessary to be able to measure and compare the value received by that as given in the manufacturer's circuit diagram. Hence it is important that the serviceman should understand the theory of capacity values and how they are derived.

The dial of most *a.c.* milliammeters are calibrated to read directly in microfarads (*M.F.*). The capacitive reactance of a condenser in ohms is given by the following formula:

$$X_c = \frac{1,000,000}{2 \times \pi \times f \times C_{m.f}} \text{ohms} \ldots\ldots\ldots\ldots\ldots (1)$$

When a 60 cycle current is used ($f=60$) and C is measured in microfarads, this formula then becomes:

$$C_{m.f} = \frac{2,650}{X_c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From this last equation it is possible to calibrate an *a.c.* milliammeter to read directly in capacity.

If any other frequency than 60 cycles is used, the result obtained in equation 1 or 2, must be multiplied by the fraction $\frac{F}{f}$, where (F) is 60 cycles and (f) is a cycle of the current being used. For example, if a 50 cycle current be used, then the values of equations 1 or 2 must be multiplied by $\frac{60}{50}$ or 1.2.

Before using any instruments designed for use on 60 cycles, on any other frequency, one must make sure that the equipment will function at the new frequency.

How to Make Capacity Measurements When the Capacitor Be Shunted by a Non-Inductive Resistor.—In *a.c.* receivers it is very frequently desired to obtain the values in microfarads when an ohmic resistor is shunted by a condenser as shown in fig. 2.

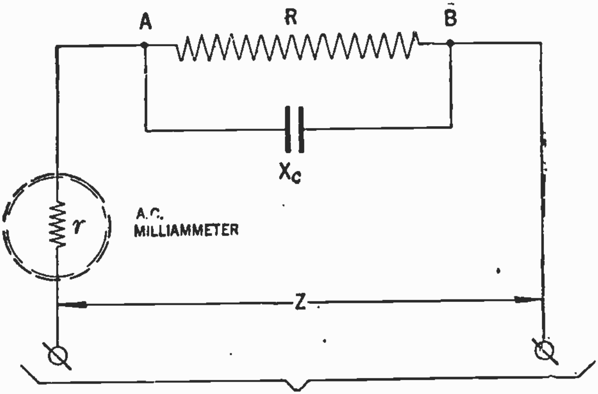


FIG. 2—Connection for measurement of capacity when capacitor is shunted by a non-inductive resistor.

The impedance *Z*, of the above circuit combination is obtained by the following formula:

$$Z=\sqrt{r^2+\frac{(R+2r)RX_c^2}{R^2+X_c^2}} \quad (3)$$

in which r = Resistance of the *a.c.* milliammeter in ohms

R = Resistance of the shunt resistor in ohms

X_c = The reactance of the capacitor to be measured in ohms

Z = The impedance of the circuit combination, in ohms.

The X_c values as used in formula (3) are the effective resistance values of capacitors given by formula (1).

From the above mathematical relationship, curves may be plotted as shown in chart, fig. 3. In this chart the resistance value from 500 to 5,000 ohms and capacitors from 0.1 to 15 microfarads are covered. The chart is used as follows:

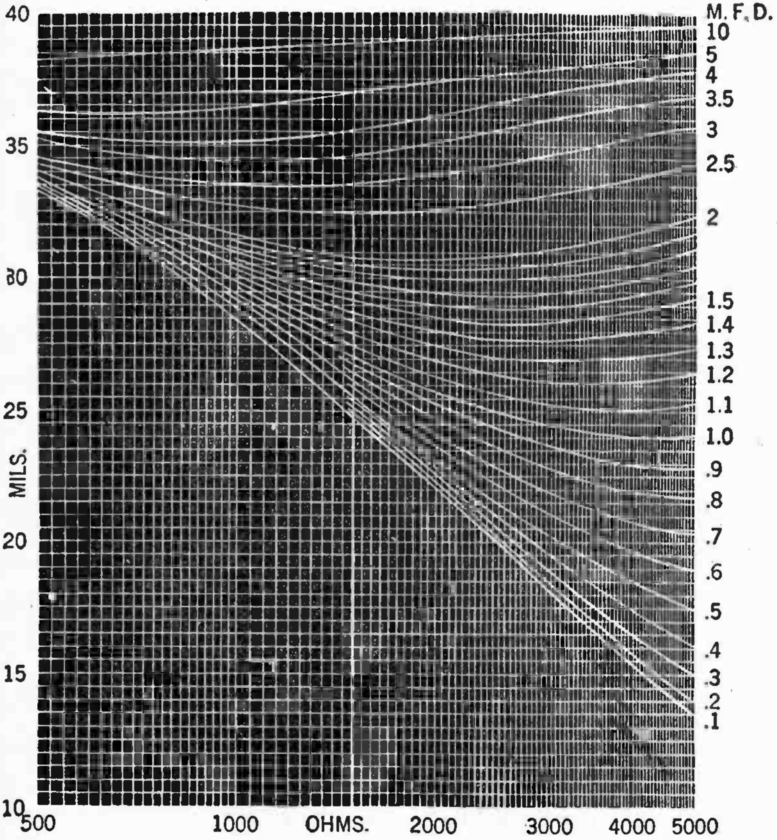


FIG. 3—Parallel resistance–capacity chart. Charts may conveniently be designed to suit individual requirements.

The value of r, is the resistance of the meter being used.

The value of R is obtained by an ohmmeter (*d.c.*). The *a.c.* milliammeter reading is obtained by placing it across the points A and B of fig. 2 as indicated.

The intersection of the line corresponding to the *a.c.* milliammeter readings and the resistance given by the ohmmeter will intersect on one of the curves and following this curve out, the value of the condenser in microfarad is obtained.

Example.—*If the* a.c. *milliammeter reads* 30 *M.A., and the resistance* (R) *is found by the ohmmeter to be* 2,500 *ohms, what is the value of the condenser?*

Solution.—Following the curve fig. 3 at the intersection of the 30 *M.A.* and the 2,500 ohms line shows the value of C to be 1.82 microfarads.

Inductive Measurements.—Inductance values may be obtained in a manner similar to that already described in capacity measurements. It should however be remembered that inductive reactance is vectorially positive whereas capacitive reactance is negative, and that the larger the value of the inductive reactance the lower will be the reading of the *a.c.* milliammeter. Also the larger the capacitive reactance the higher will be the reading of the *a.c.* milliammeter.

The formula for the inductive reactance (X_L) in ohms is:

$$X_L = 2\pi f L \text{ ohms} \qquad (4)$$

or if $f = 60$ cycles, then

$$L = \frac{X_L}{377} \text{ henries} \qquad (5)$$

When i = the *a.c.* current in amperes

e = Impressed *a.c.* voltage

R = Resistance of *a.c.* meter in ohms

X_L = Effective resistance of the inductor in ohms

then the formula for current is as follows:

$$i=\frac{e}{\sqrt{R^2+X_L^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The reading of the *a.c.* milliammeter may conveniently be referred to a chart computed from equation (4) from which the value of the inductance can be found similarly as previously shown.

If 50 cycles is used instead of 60 cycles the results should be multiplied by $\frac{60}{50}$ or 1.2.

Commercial Type Analyzers

Weston Model 665 Selective Analyzer.—The external view of this instrument is shown in fig. 4. and its internal connection diagram in fig. 5.

The instrument is principally a volt-ohm-milliammeter for both *a.c.* and *d.c.* service.

All voltage ranges are available at the pin jacks, and by means of socket selector units may be had through the plug. They are 0–1/2.5/5/10/25/100/250/500/1,000 volts, either *a.c.* or *d.c.* The individual ranges are selected by means of the large selector switch. A reading cannot be had till either the *d.c.* or *a.c.* push button at the bottom of the panel is pressed. These are locking types and should be returned to their original position after each test is completed.

All current ranges are available at the pin jacks and are also available for current measurements at the socket by means of the socket selector units. These ranges are 0–/2.5/5/10/25/50/-100/250/500 milli-amperes, *d.c.* only.

Resistance measurements may be had with test leads and the various ohmmeter pin jacks, as a point-to-point tester. Also by means of a socket selector unit, resistance measurements may be taken between any two socket prongs or a socket prong and ground.

A very useful feature in this instrument is that it may easily be converted into a complete analyzer by addition of the 666 socket selector shown in fig. 6, thus bringing the tube socket connections to the analyzer circuit.

With reference to the **Tube Base Chart** shown on page 4,593. the various measurements should be made as follows:

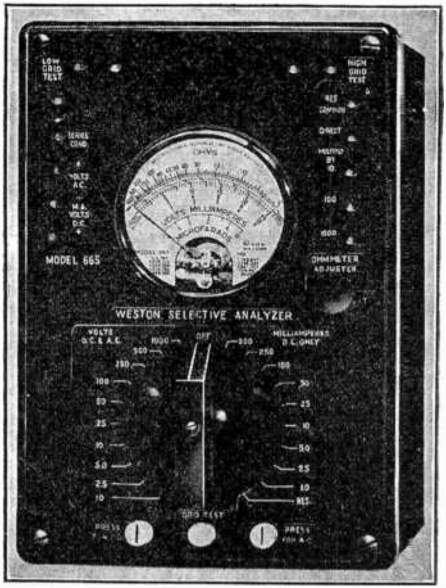


FIG. 4—Front view of Weston Model 665 selective analyzer.

Heater Voltage.—This is read between 1 and 4 on 4 prong tubes; 1 and 5 on 5 prong tubes; 1 and 6 on 6 prong tubes, and 1 and 7 on 7 prong tubes. However, it is advisable to check with the tube base chart because no fixed rule for the location of any terminal can be given.

Plate Voltage.—The plate is generally terminal No. 2 and for heater type tubes this voltage would be read between plate and cathode and for filament type between plate and negative filament. Since the plate and cathode terminal are not in the same locations for all type tubes, reference to the tube base chart is suggested.

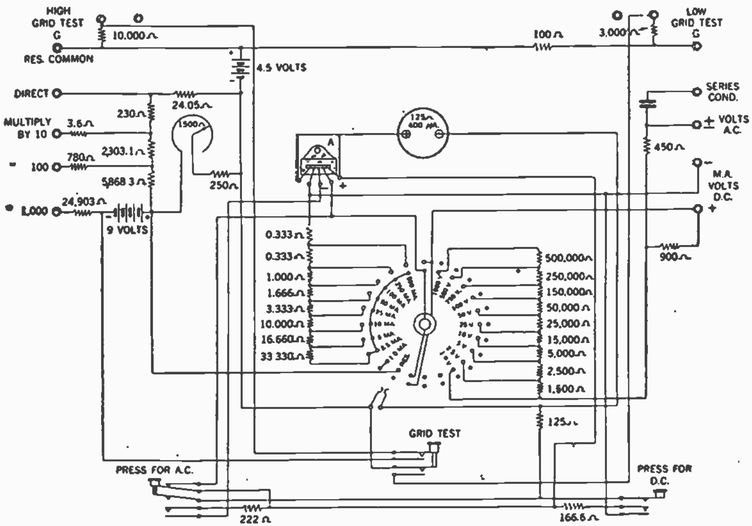


FIG. 5—Internal connection diagram of Weston Model 665 selective analyzer.

Grid Voltage.—There are a number of grids such as control, screen, suppressor, anode, etc. For heater type tubes the voltage is measured from the cathode to the desired grid and for filament type tubes from the negative filament to the desired grid. Reference to the tube base chart will give the correct location of the various grids for the tube in question.

Reference should be made to the service manual of the radio set being tested for the determination of the correct values of grid and plate voltage.

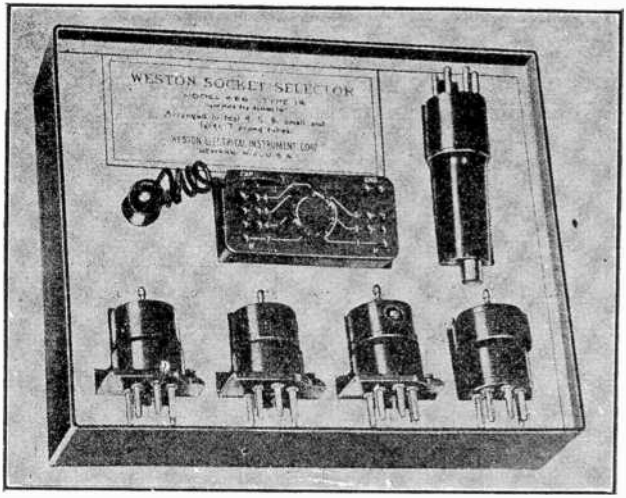


FIG. 6—Socket selector for use with Weston Model 665 analyzer.

Plate Current.—A pair of leads are plugged into the M.A. pin jacks on the panel; the other ends of these leads are placed in the two jacks opposite the plate terminal on the socket selector unit. The dial switch is turned to the desired milliampere range. This will give a plate current reading on the milliammeter. It is necessary to hold down the "Press for D.C." button.

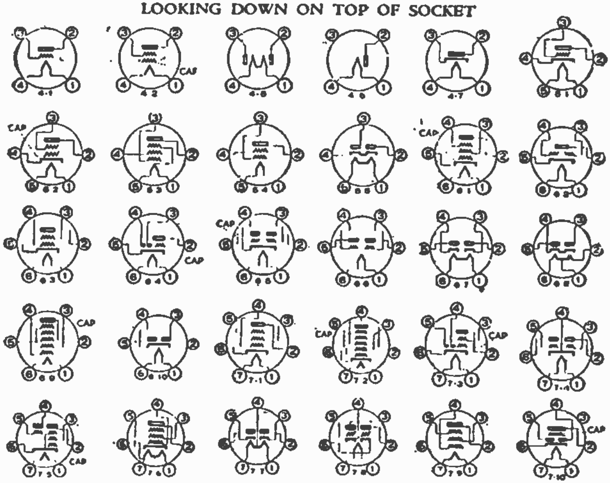
True total current in any lead is read in this way, since the inner jack of each pair functions as a closed circuit jack switch. When a pin tip is plugged into the inner of a pair of jacks, the main circuit is opened between the jacks. The total current,

TUBE BASE CHART

FOR USE WITH
THE WESTON METHOD OF SELECTIVE ANALYSIS

Tube	Base	Tube	Base	Tube	Base	Tube	Base	Tube	Base	Tube	Base
00A	4-1	27	5-1	47	5-3	71	4-1	98	5-5	12A5	7-6
01A	4-1	27HM	5-1	48	6-3	71A	4-1	X99	4-1	14Z3	4-7
01AA	4-1	29	6-2	49	5-4	71B	4-1	1A6	6-9	25Z3	4-7
1	4-7	30	4-1	50	4-1	75	6-4	2A3	4-1	25Z5	6-7
1V	4-7	31	4-1	51	5-2	76	5-1	2A3H	4-1	182B	4-1
G2	5-5	32	4-2	52	5-3	77	6-1	2A5	6-3	183	4-1
G4	5-5	33	5-3	53	7-4	78	6-1	2A6	6-4	213	4-5
KR1	4-7	34	4-2	55	6-4	79	6-5	2A7	7-2	216B	4-6
KR2	4-7	35	5-2	56	5-1	80	4-5	2B6	7-8	482A	4-1
KR5	5-3	36	5-2	57	6-1	80M	4-5	2B7	7-3	482B	4-1
10	4-1	36A	5-2	57AS	6-1	81	4-6	5Z3	4-5	483	4-1
12A	4-1	37	5-1	58	6-1	81M	4-6	6A4	5-3	484	5-1
WX12	4-1	37A	5-1	58AS	6-1	82	4-5	6A7	7-2	485	5-1
14	5-2	38	5-2	59	7-1	82V	4-5	6B7	7-3	585	4-1
15	5-2	38A	5-2	59B	7-9	83	4-5	6C6	6-1	586	4-1
17	5-1	39	5-2	64	5-2	83V	4-5	6C7	7-10	864	4-1
18	6-3	39A	5-2	64A	5-2	84	5-5	6D6	6-1	950	5-3
19	6-6	40	4-1	65	5-2	G84	4-6	6D7	7-2	951	4-2
20	4-1	41	6-3	65A	5-2	85	6-4	6E7	7-2	AD	4-7
22	4-2	42	6-3	67	5-1	89	6-1	6F7	7-5	AF	4-5
24	5-2	43	6-3	67A	5-1	90	6-2	6Y5	6-10	AG	4-5
24A	5-2	44	5-2	68	5-2	92	6-2	6Z3	4-7	LA	5-3
KR25	6-3	45	4-1	68A	5-2	95	6-3	6Z4	5-5	PZ	5-3
26	4-1	46	5-4	69	6-2	96	4-7	6Z5	6-8	PZH	6-3

LOOKING DOWN ON TOP OF SOCKET



therefore, must flow out through the measuring instrument and back into the other jack. Note that voltage measurements cannot be made in the inner jacks, since the circuit is opened when pin tips are placed in them.

Grid Current.—Grid and screen current measurements are made in the same manner as the plate current. All current ranges are available for this purpose. The push button marked "Press for D.C." must be held down for this test. These readings are obtained by placing one end of each of a pair of leads in the "M.A." pin jacks and the other ends in the two pin jacks opposite the terminal of the grid desired.

The plate current of the second plate of rectifier tubes is tested as above. It is advisable to consult the tube base chart for location of the terminals for the various elements.

Grid Tests.—Two grid tests are available, one with a low shift of 4.5 volts, the other a high shift of 13.5 volts for power tubes only. A separate set of pin jacks is provided on the panel for each shift.

A pair of short leads is plugged into the panel at the upper corner marked "Grid test" and the other ends plugged into the pin jacks opposite the control grid terminal desired on the selector unit. Be sure lead from "G" pin jack is inserted in the pin jack nearest the tube on selector unit.

Another pair of leads is plugged into the M.A. pin jacks on the panel, the other ends of these leads are placed in the two jacks opposite the plate terminal on the socket selector unit. The dial switch is turned to the desired M.A. range. This will give a plate current reading on the milliammeter. Pressing the "Grid Test" button (located in center of lower edge of panel) will give an increase in the plate current reading.

The grid test reading is an indication of the relative goodness of the tube, and is proportional to the mutual conductance. No values can be given for this reading because of the high plate circuit resistance in many radio sets.

Cathode Voltage.—Cathode voltage is measured with reference to the heater. In some sets the cathode is connected directly to the heater, in which case the cathode voltage reading will be zero.

In other sets the cathode is grounded through the grid bias resistor with heater connected to some positive potential, in which case the cathode will read negative with reference to the heater. In most alternating current radio sets the cathode is grounded through the grid bias resistor with the heater grounded, in which case the cathode will read positive with reference to the heater.

Output Test.—This test is made exactly like the measurement of *a.c.* voltage, except when *d.c.* is present in the output circuit, then the "Series Condenser" pin jack must be used. All voltage ranges are available for this test. It is necessary to hold down or lock in position the "Press for A.C." push button.

Weston Model 571 Output Meter.—The external view of this meter is shown in fig. 7 and its internal connection in fig. 8.

This instrument has a constant resistance of 4,000 ohms on each range, is usually used as a terminating impedance on sound line or receiver output circuits. It can be used, however, on bridging measurements on low impedance lines. It is also valuable as a multi-range *a.c.* volt-meter of wide adaptability.

The 5 voltage ranges are available at pin-jacks and are selected by means of a dial switch. It also has a self-contained condenser for blocking any *d.c.* components. This condenser is connected to a separate pin-jack.

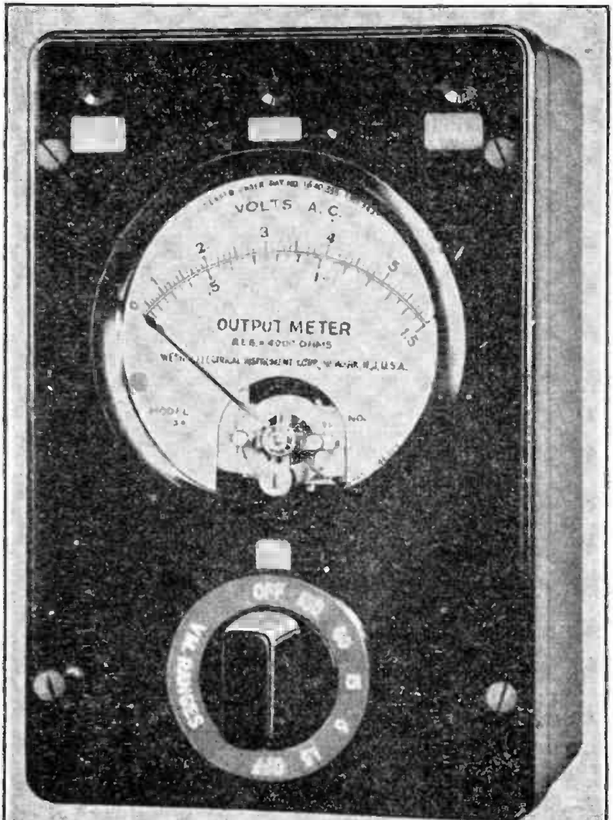


FIG. 7—Panel view of Weston Model 571 output meter.

The voltage ranges are: 0–1.5/6/15/60/150. Test leads and adapter for connection to the plate pin of any output vacuum tube are provided for the meter.

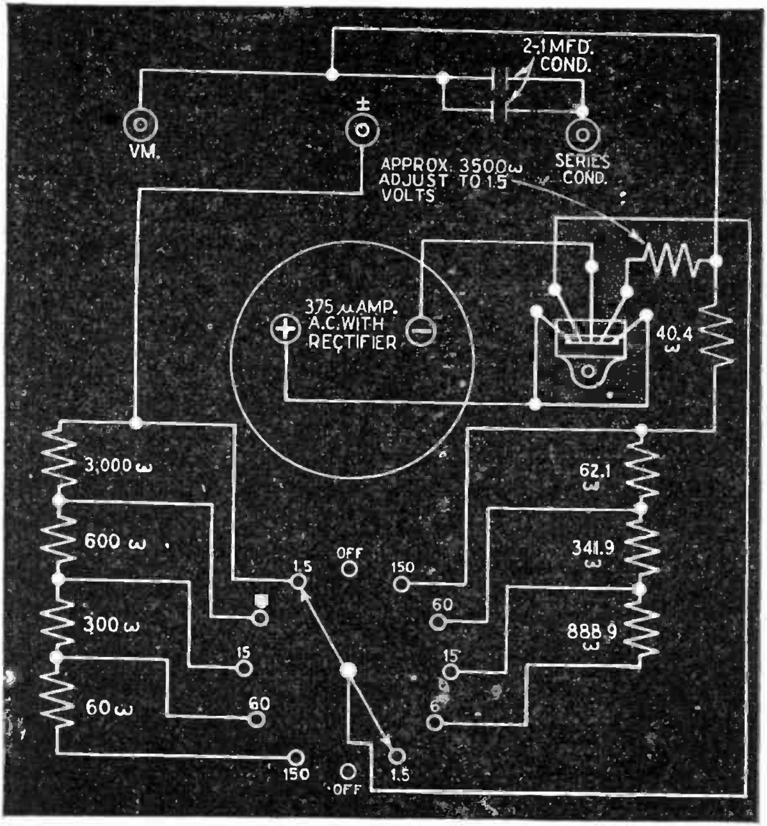


FIG. 8—Schematic wiring diagram of Weston Model 571 output meter.

Weston Model 763 Ohmmeter.—Front view and connection diagram of this instrument is shown in figs. 9 and 10 respectively.

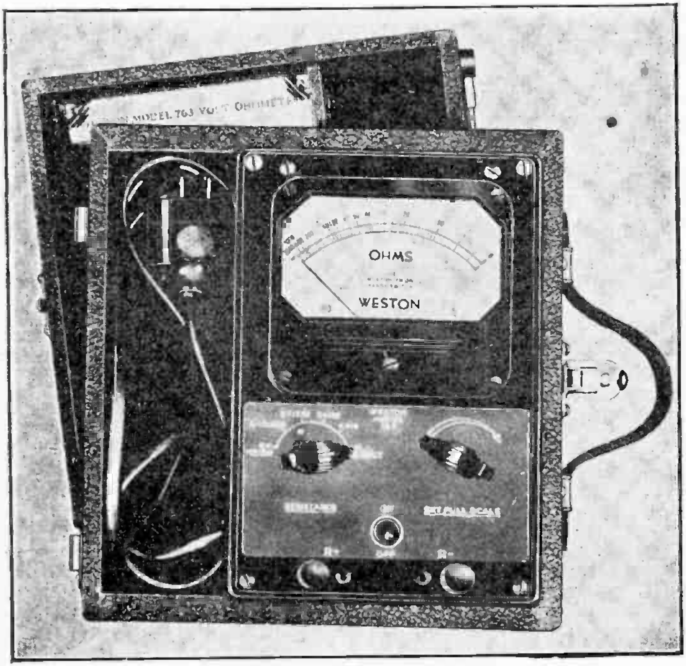


FIG. 9—Panel view of Weston Model 763 ohmmeter.

With this instrument resistance measurements of from 0.2 ohms to 300 megohms may be made with high accuracy on 6 ranges. It can also be used with good results on the top range as a modified megger in which 125 volts (maximum current 50 microamperes) is available for insulation tests.

The power consumption is small, as the instrument requires only 50 microamperes for full scale deflection.

Leakage on all types of condensers, even those having resistances of up to approximately 300 megohms can easily be measured. A filament type vacuum tube requiring a very short heating time is used as a rectifier, and the operating power is obtained from any 105-130 volts, 50-60 cycle *a.c.* source.

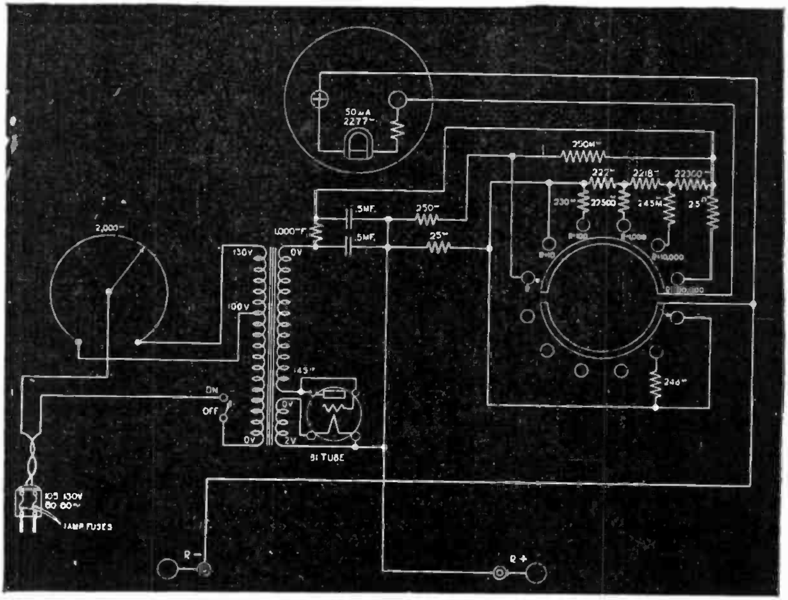


FIG. 10—Wiring diagram for internal connection of Weston Model 763 ohmmeter.

Weston Model 765 Analyzer.—A front view and internal connection diagram of this instrument is shown in figs. 11 and 12 respectively.

This instrument is claimed to be of very high sensitivity. For

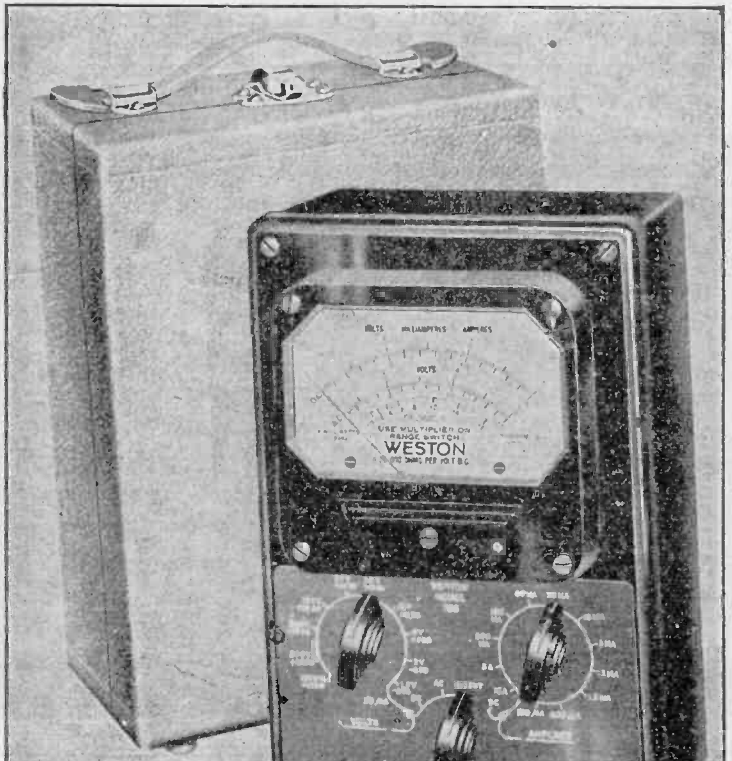


FIG. 11—Front view of Weston Model 765 analyzer.

example the *d.c.* and *a.c.* sensitivity according to the manufacturer is 20,000 ohms per volt and 1,000 ohms per volt respectively. This minimum loading effect permits checking of sensitive relay circuits without interrupting operation and facilitates a great multiplicity of measurement which are practically impossible with instruments of lower sensitivity.

The over-all *a.c.* accuracy of the instrument is held within 3%, whereas for *d.c.* measurements the accuracy is within 2%.

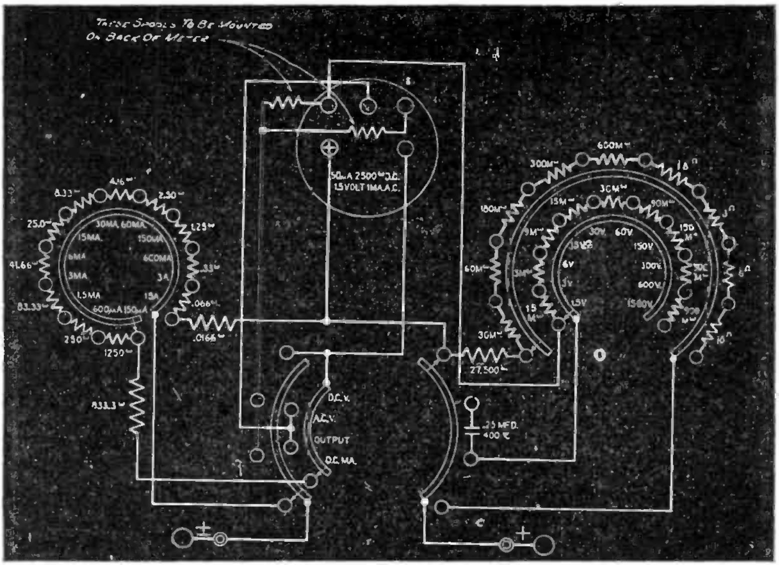


FIG. 12—Diagram showing internal connection of Weston Model 765 analyzer.

In addition a special rectifier circuit is incorporated designed for temperature compensation between 50 and 110 degrees F. limiting temperature errors to within 2%.

The ranges for *a.c.* and *d.c.* voltage measurements are as follows: 0–/1.5/3/6/15/30/60/150/300/600/1,500.

Ranges for *d.c.* current measurements are:
0–150 μ.*a.*/600 μ.*a.*/1.5/3/6/15/30/60/150/600 *m.a.*/3*a*/15*a*.

The decibel ranges provides measurements of power levels between—18 to +58 *db*.

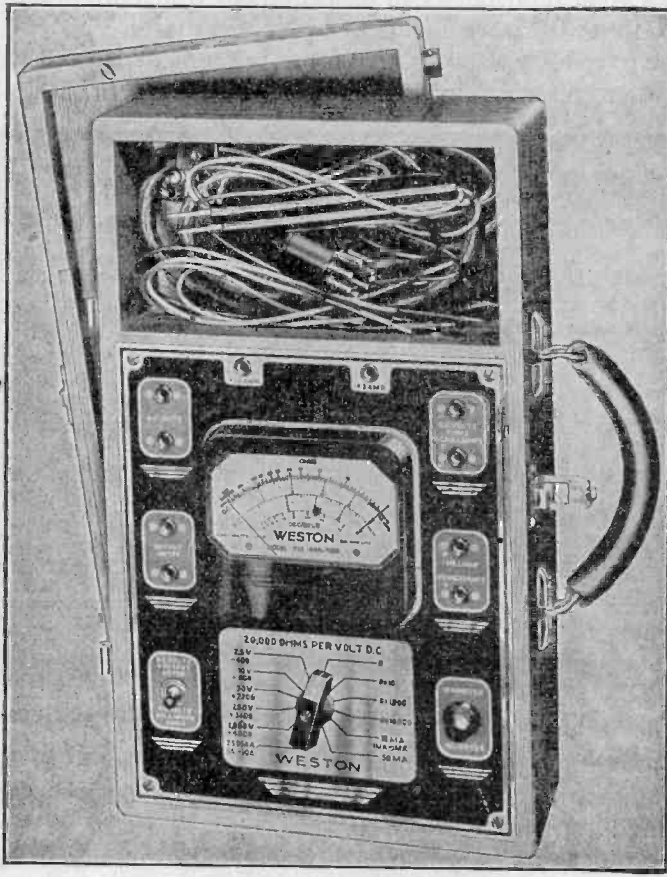


FIG. 13—Panel view of Weston Model 772 analyzer.

Weston Model 772 Analyzer.—This analyzer is designed to make the necessary tests on present day equipment such as commercial radio receivers, transmitters, television receivers,

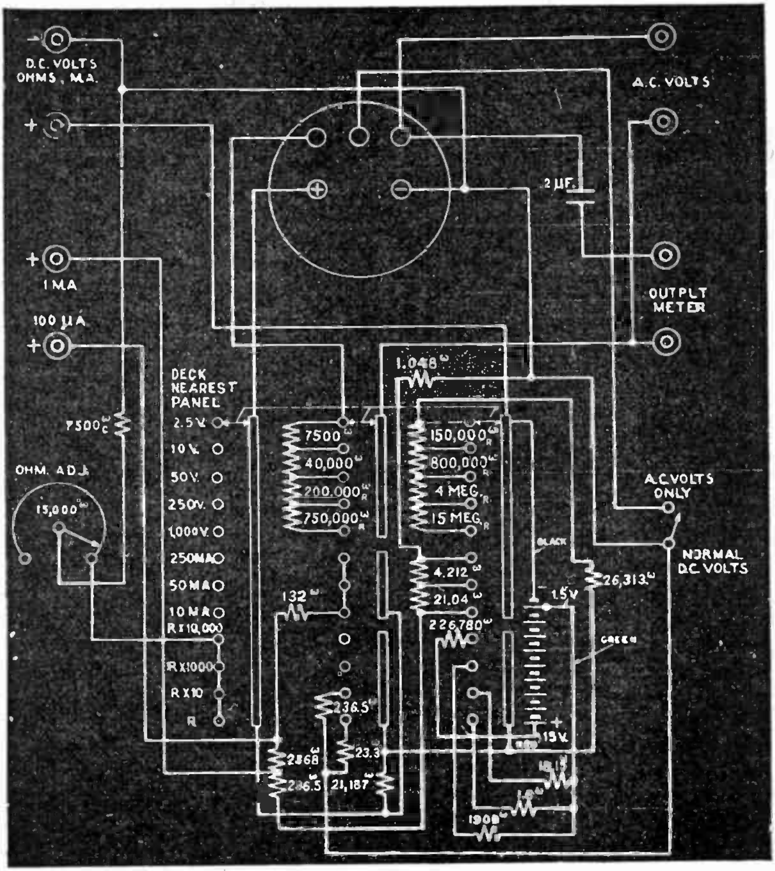


FIG. 14—Wiring diagram of Weston Model 772 analyzer.

public address systems, vacuum tube and cathode ray equipment, etc.

The instrument is illustrated in fig. 13 and its connection diagram in fig. 14.

It has a 20,000 ohms per volt sensitivity on five *d.c.* voltage ranges. *A.c.* readings are made on single arc scale.

The ranges for *d.c.* current measurements are 0–/0.1/10/50/-250 *m.a.*/1*a*/10*a*.

A.c. or *d.c.* voltage measurements have the following ranges: 0–2.5/10/50/250/1,000 *v*. Five decibel ranges provide power level measurement from—14 to +54 *db*.

Resistances are measured on the following scales 0–3,000/-30,000/3 Meg./30 Megohms.

The instrument is equipped with pin jacks for mounting model 666 socket selector unit.

Weston Model 773 Tube Checker.—This instrument is manufactured both for counter and movable service, as shown in figs. 15 and 17 with a common diagram of connections in fig. 16. It has eight sockets for the various types of tubes, a direct reading "Bad-Good" meter scale, two selector switches, voltage adjustment switch, in addition to position and test switches.

With this instrument a complete analysis of any tube may readily be obtained. Separate electrode switches for grid, plate, screen, suppressor, diode or cathode are provided for emission, short and leakage tests. This point to point testing feature will be recognized as extremely important whenever doubtful tubes are encountered.

A most frequent source of trouble in radio tubes are the defects in circuit continuity of the electrodes and although an over-all efficiency test may at times fail to disclose these defects, a point to point electrode check will nearly always disclose the trouble.

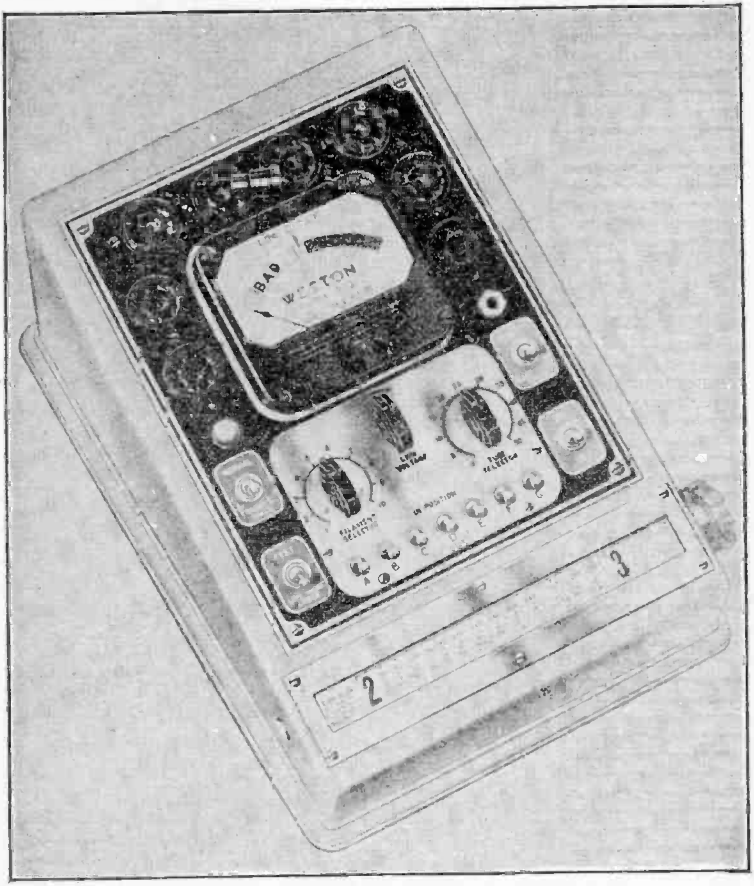


FIG. 15—Front view of counter type Weston Model 773 tube checker.

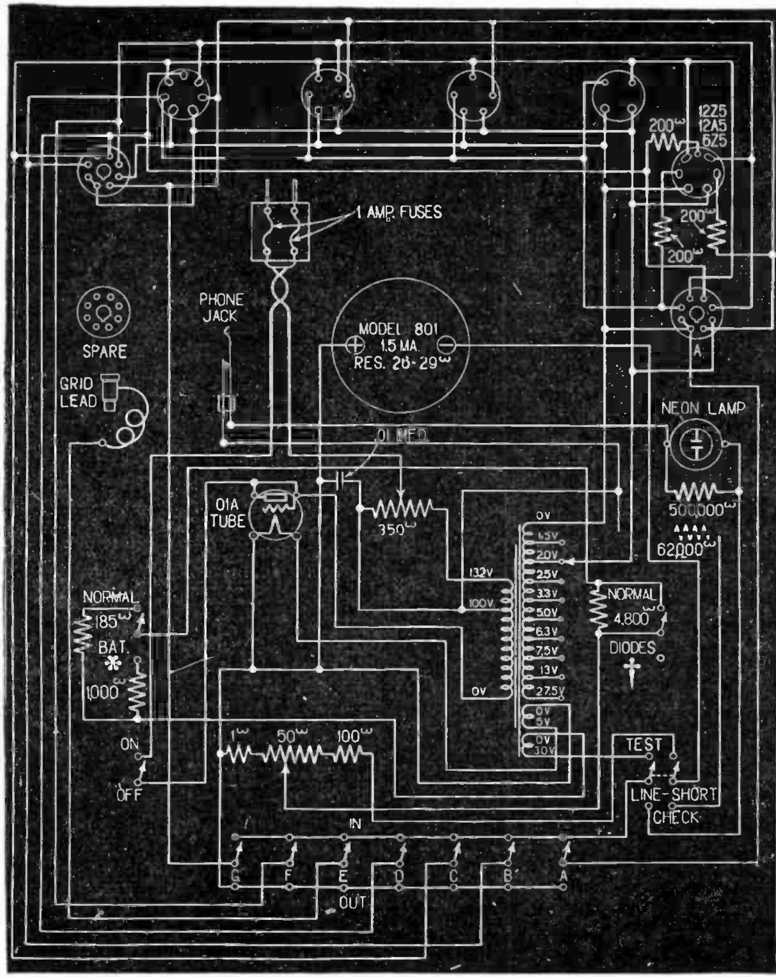


FIG. 16—Diagram of connection for Weston instruments Model 773.

FIG. 17—Panel view of Weston Model 773 movable type tube checker.

Weston Model 655-2 Selective Analyzer.—The internal connection of this instrument is shown in fig. 18.

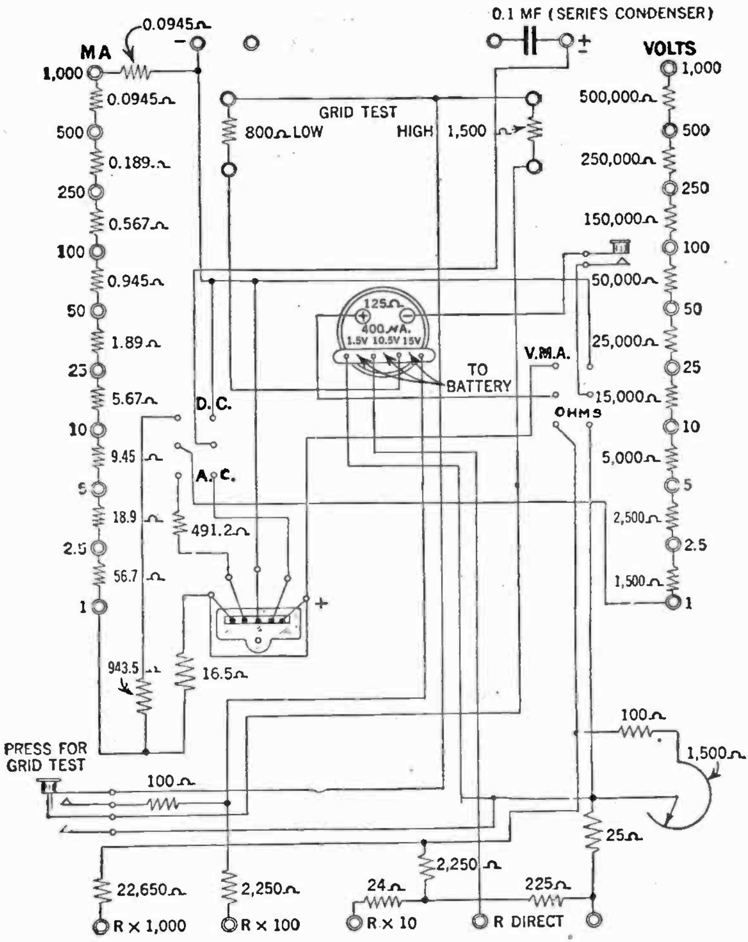


FIG. 18—Connection diagram of Weston Model 665-2 radio set analyzer.

The principal difference between this instrument and the 655 previously described is that the various scales are available by means of pin jacks instead of a rotary switch. The volt meter ranges *a.c.* or *d.c.* are: 0–1/2.5/5/10/25/50/100/250/500/1000 volts. The current ranges *d.c.* only are 0–1/2.5/5/10/25/50/100/250/500/1000 milliamperes.

Supreme Model 339 Analyzer.—The panel view and connection diagram of this instrument is shown in figs. 19 and 20 respectively.

It has five sockets for various types of tubes, a sensitive d'Arsonval fan shaped meter, and a rugged 4-gang, 5-position rotary switch for selectivity connecting the meter to any of the following measuring circuits:

(a) *d.c.* milliammeter—0/5/25/125/250/500 *m.a.*, and 0/1.25 ampere.
(b) *d.c.* voltmeter—0/2/25/125/250/500/1,250 volts.
(c) Ohmmeter—0/2,000/20,000/200,000 ohms and 0/2/20 megohms.
(d) *a.c.* voltmeter—0/5/25/125/250/500/1,250 volts.
(e) Capacity Meter—0/0.05/0.25/1.25/2.5/5.0/12.5 *mfds.* electro-static (paper) and electrolytic.

For current, potential and resistance measurement the meter is "built up" to a resistance value of 300 ohms by means of a multiplier resistor connected in series with the meter, and all shunt and multiplier resistance values are calculated on the basis of a full scale current sensitivity of 1.0 milliampere and a resistance value of 300 ohms for the meter.

The actual armature resistance of the meter is approximately 115 ohms. The operating procedure for the various measurements is as follows:

1. **Current Measurements.**—When it is desired to obtain current in terms of milliamperes the meter is shunted as shown

in fig. 20. The total shunt value of 75 ohms is determined by the lowest current-measuring range of 5 milliamperes. The meter, with its resistance built up to a value of 300 ohms, requires a potential of 0.3 volt (300 millivolts) to cause a full scale current of 1.0 milliampere to pass through the meter.

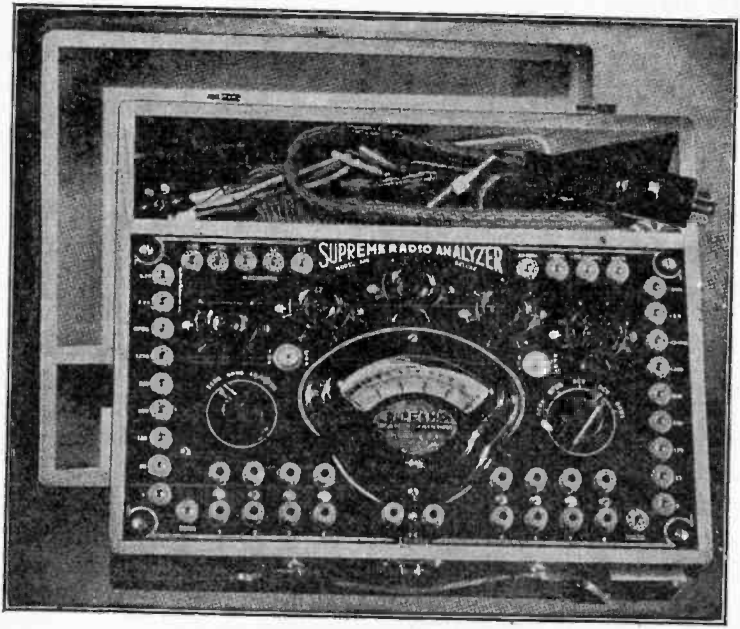


FIG. 19—Front view arrangement of Supreme Model 339 radio set analyzer.

The shunt resistor for the 5 milliampere range, being in parallel with the meter, will have the same 0.3 volt potential difference. Since 1.0 milliampere of the 5 milliampere range will pass through the meter, the shunt resistor will pass the other 4.0 milliamperes and its value is determined by dividing 4.0 milliamperes (0.004 ampere) into 300 millivolts (0.3 volts).

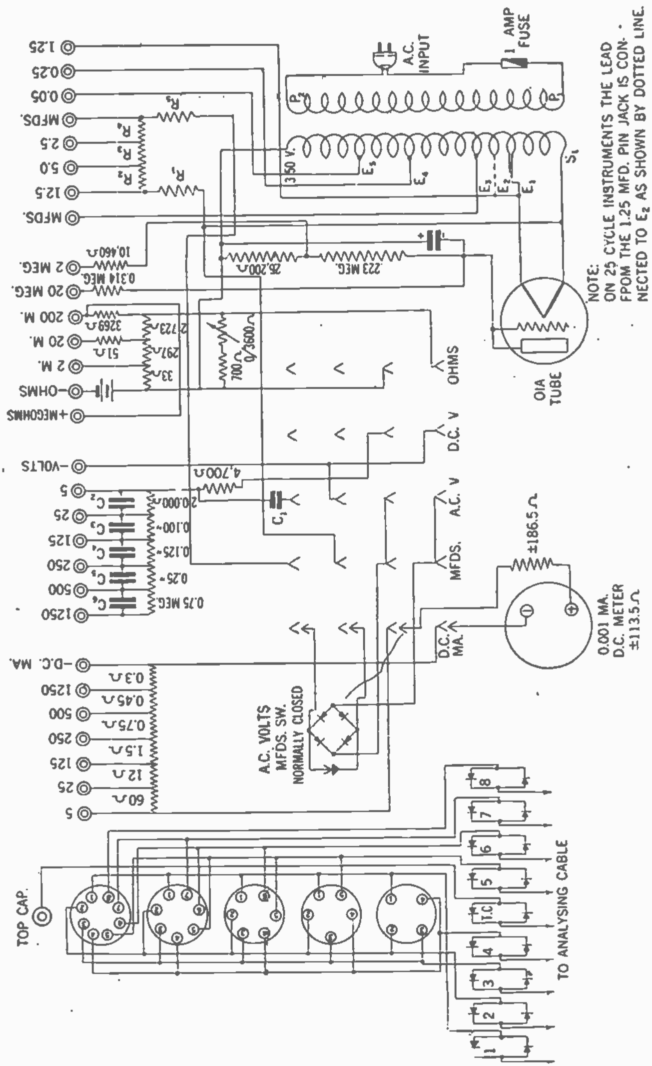


FIG. 20—Wiring arrangement and resistance values in Supreme Model 339 radio set analyzer.

For the current measuring ranges above the 5.0 milliampere range, the 75 ohm shunt resistor is divided into smaller values, thereby forming what is known as a "ring type" shunt, the total "ring" resistance value being 375 ohms.

The resistance values of the 75 ohm shunt resistors are determined by multiplying the total "ring" resistance by the full scale current of the meter, dividing the result by each range value, in turn, from the common terminal, and subtracting the sum of the preceding values from each newly-determined value.

When the "ring" value of 375 ohms is multiplied by the full scale sensitivity value of 0.001 ampere, 0.375 is the result, into which each range value is divided, in turn, for determining the required shunt values. For example, the shunt value for the 1.250 ampere range is determined by dividing 1.250 into 0.375, giving a value of 0.3 ohm for that range.

For the 500 milliampere range, 0.500 ampere is divided into 0.375, giving a value of 0.75 ohm for the 500 milliampere range; but since there already is a value 0.3 ohm for the preceding range, it is necessary to subtract 0.3 ohm from 0.75 ohm, leaving a value of 0.45 ohm for the second section of the shunt.

For the 250 milliampere range, 0.250 ampere is divided into 0.375, giving a value of 1.5 ohms for the 250 milliampere range; but since there already is a value of 0.75 ohm for the two preceding ranges, it is necessary to subtract 0.75 ohm from 1.5 ohms, leaving a value of 0.75 ohm for the third section of the shunt. The shunt sections for the other ranges are determined in a similar manner, and can be checked by Ohm's law.

For example, the shunt value of 0.3 ohm for the 1.250 ampere (1,250-milliampere) range is in parallel with the remaining 374.7 ohms of the "ring" circuit, which when multiplied by the meter current of 0.001 ampere, produces a potential drop of 0.3747 volt. With 0.001 ampere going through the meter, the remaining value of 1.249 amperes will be going through the 0.3 ohm shunt, producing potential drop of 0.3 times 1.249 or 0.3747 volt. Since the potential drop across both parallel paths is identical by Ohm's law, it is concluded that the calculations are correct. The other ranges may be similarly checked by Ohm's law.

2. **D.C. Potential Measurements.**—When the meter is being used for potential measurements, enough resistance must be connected with it to limit the current to within the full scale sensitivity value of the meter.

The value of the multiplier resistor for the 5-volt range is established by subtracting the meter resistance value of 300 ohms from the 1,000 ohms-per-volt value of 5,000 ohms leaving a multiplier resistance value of 5,000-300 or 4,700 ohms.

For the higher ranges the multiplier resistance values are calculated on this basis of 1,000 ohms per volt.

3. **Resistance Measurements.**—For resistance measurements, the meter is used primarily as a voltmeter, with the current passing through the meter calibrated on an "Ohms" scale instead of being calibrated on a "Volts" scale. In the multi-range ohmmeter circuits of this tester, however, shunts are used to enable the different sensitivities required for each range, and to this extent, the ohmmeter circuits resemble current measuring circuits in which shunts are usually required.

It will be observed from diagram fig. 20, that for the lowest or 2,000 ohm range, the 33 ohm resistor is a shunt resistor, while the 297 ohm and the 2,723 ohm resistors act as multipliers to the meter with its 700/4,300-ohm shunting resistor made up of a fixed 700 ohm resistor and a variable 3,600 ohm rheostat for accommodating battery potential variations.

For the 20,000 ohm range, the 33 ohm and the 297 ohm resistors, totaling 330 ohms, act as a shunting resistor, with the 51 ohm and 2,723 ohm resistors functioning as multipliers. For the 200,000 ohm range, the 33 ohm, 297 ohm and 2,723 ohm resistors act as a shunting resistor, and a 3,269 ohm resistor acts as a multiplier resistor.

4. **A.C. Potential Measurements.**—The *a.c.* potential measuring functions differ from the *d.c.* potential in that the meter is connected to the output terminals of a full-wave instrument rectifier and a capacitor is substituted for the 4,700 ohm multiplier resistor, the capacitor being connected in series with the rectifier input circuit. Each of the multiplier resistors above the 5-volt range is by-passed with a calibration capacitor. The elements involved in the *a.c.* potential measuring functions are indicated in wiring diagram.

5. **Capacity Measurements.**—When the meter is used for capacity measurements, the resistance value of the meter and of the shunt and multiplier resistors associated with the measuring circuit constitutes one leg of an impedance triangle. See fig. 21. The reactance of a capacitor of unknown value, which may be connected into the measuring circuits for the purpose of determining its value, constitutes another leg of the same impedance triangle.

It is obvious that the resistance value of the meter and of its associated shunt and multiplier resistors is a constant value for any particular capacity-measuring range, regardless of the capacitive value of any capacitor which may be connected to that range, and that the capacitive reactance, in every case, is determined by the capacitive value of the capacitor which may be subjected to the measurement; therefore, the capacitive leg of the triangle is the variable element.

It is further obvious that the meter current is related directly to the hypotenuse of the impedance triangle and will not, therefore, have a linear relationship to capacitive values. For example, assume an impedance triangle in which a full-scale meter current corresponds to a certain hypotenuse length, and in which the reactance leg corresponds to a capacitive value of

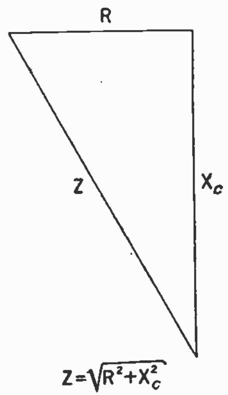


FIG. 21—Arrangement of impedance triangle in capacity measurements.

5.0 microfarads; if we remove the 5.0 mfd. capacitor and put in its place a 2.5 mfd. capacitor, the length of the reactive leg of the triangle will be doubled, but the length of the hypotenuse will not be doubled, and, therefore, the meter current will not be reduced to one-half of its former full scale value. In other words, a linear or evenly-divided scale cannot be used on the basis of fixed resistance values for the meter and its associated shunt and multiplier resistors.

From what has just been explained, it is natural to ask a question as to how capacitive measurements are enabled on an evenly divided scale in this tester. The answer lies in the fact that, although the meter, shunt and multiplier resistance values constitute a fixed resistive value for each capacity measuring range, a variable resistive value is introduced by the full wave instrument rectifier employed, and shunts and multipliers are employed of such values as will enable the variable element of the rectifier resistance to approximately counterbalance the variable reactive element introduced by the different capacitive values which may be encountered for measurement.

In other words, the divisions of a meter scale would be crowded on the upper end of the scale for capacitive measurements if the rectifier were linear in its characteristics, and the non-linear characteristics of the rectifier would cause the divisions of the meter scale to be crowded on the lower end of the scale, if no capacitive variable elements are introduced into the circuit; but when both variable elements are introduced into the circuit in approximately equal and opposite proportions, the meter scale divisions can be equally separated across the whole scale, or, what amounts to the same thing, the regular evenly-divided scales can be utilized for capacitive measurements.

For the measurement of electrostatic (paper) capacitive values, comparatively high *a.c.* potentials are used, but it is necessary to use comparatively low *a.c.* potential values for the measurement of electrolytic capacitive values, so as not to puncture the electrolytic film around the electrodes. Actually the *a.c.* potential applied to electrolytic capacitors in the 0/1.25/2.5/12.5 mfd. ranges is about 9 volts. The capacity-measuring circuits are shown in the wiring diagram.

Supreme Model 585 Diagnometer.—This instrument shown in fig. 22 with the connection diagrams of the tube testing circuit in fig. 23 has the following service facilities. It actually consists of 14 instruments in one compact assembly, for complete circuit and tube checking on all radios, P.A. amplifiers and television sets.

The instrument is a complete point to point set tester, or the "Free Reference" system of analysis direct from tube sockets may be chosen.

The meters provide for the following ranges:

1. Six *d.c.* potential ranges of 0–7/35/140/350/700/1,400 volts.

2. Six *a.c.* potential measuring ranges of 0–7/35/140/350/700/1,400 volts.

3. Seven *d.c.* current measuring ranges of 0–1/7/35/140/350/700/1,400 *m.a.*

A *d.c.* scale 0–14 amp. is provided for checking drain of auto radios and 6 volt mobile sound systems. There are six output meter ranges, ohms 0–200/2,000/20,000/200,000. The first division on the 200 ohm scale is 0.25 ohm. Can be read to 0.05 ohm. Megohmeter 0–2/20.

The 20 megohm range operating at 450 volts is an excellent electrostatic and main filter electrolytic condenser breakdown tester.

Decibels—10 to +6/0 to +16/+10 to +26/+20 to +36/+30 to +46 direct reading on the 500 ohm line; zero level 0.006 watts Electrostatic capacity meter 0–.07/0.35/1.4/3.5/7.0/14.0 Mfd.

Electrolytic capacity meter 0–3.5/7.0/14.0 Mfd. Direct meter leakage test for main filter electrolytics on colored "Good-Bad" scale.

Also a sensitive full size neon test for electrolytic condensers.

All meter services and ranges are selected by indicating rotary switches. New "Free Reference" tube for all old and new radio, P.A. and television tubes, except thyratrons and kinescopes.

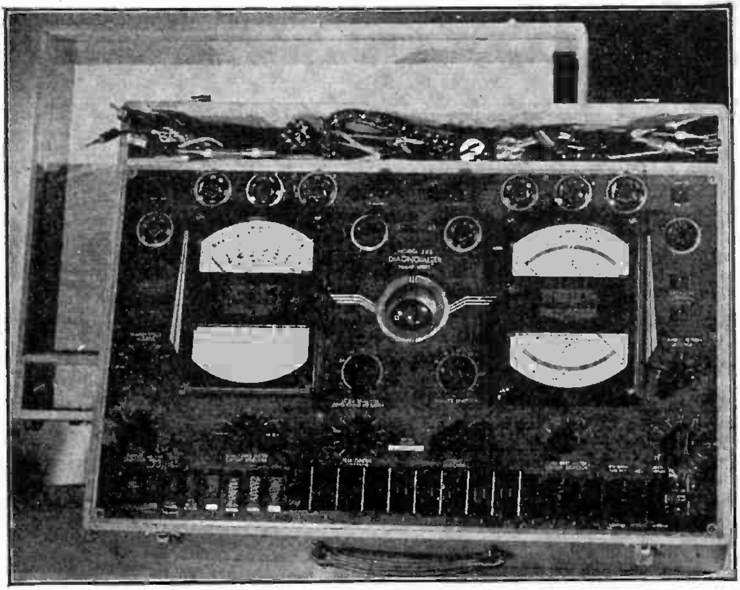


FIG. 22—Front view showing arrangement of instruments and switching devices in Supreme Model 585 diagnometer.

With this diagnometer it is possible to test all multi-purpose tubes section by section, as well as for overall performance, there are 48 possible basic combinations of load and voltage to insure proper and accurate tests of every conceivable type of tube.

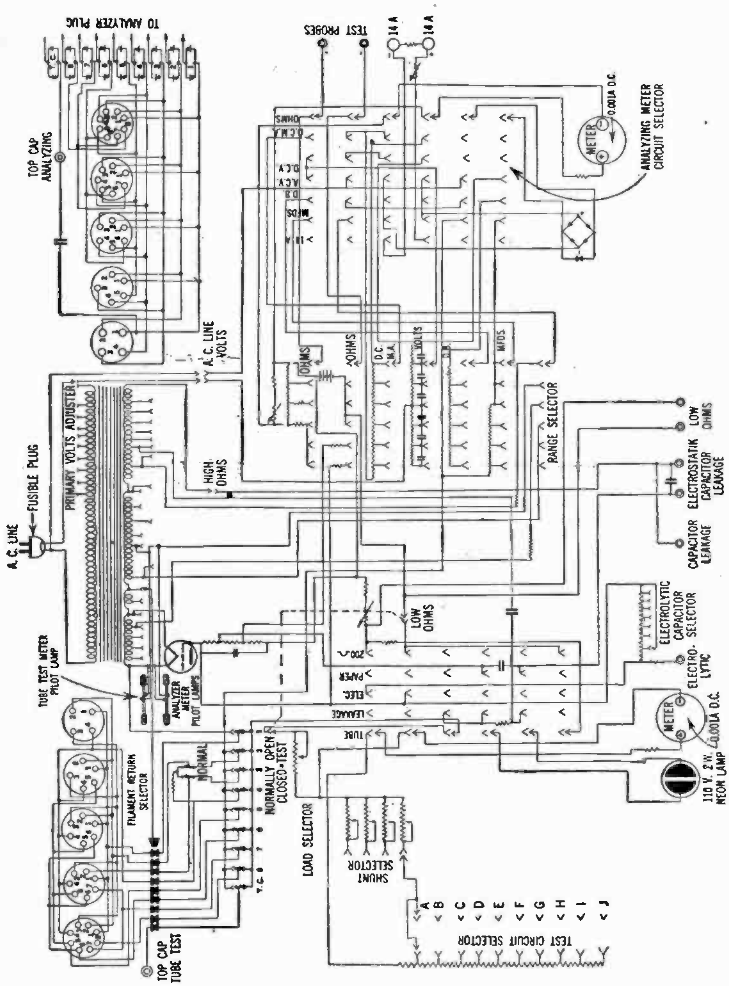


FIG. 23—Internal connection of Supreme Model 585 diagnometer.

Supreme Model 501 Tube Tester.—The panel view of this tester is shown in fig. 24 and illustrates the various controls. The connection diagram is shown in fig. 25. This new improved circuit tests all old and new tubes for radio, public address systems, and television, except thyratrons and kinescopes. It tests all multi-purpose tubes section by section, as well as for overall performance.

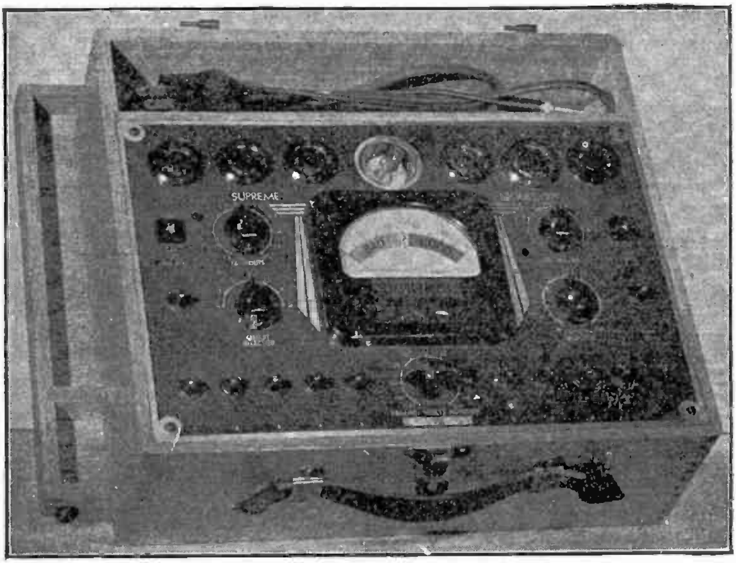


FIG. 24—Front view of Supreme Model 501 tube tester.

All quality tests are made at full rated load for highest accuracy. Six sockets test all types and combinations of tubes, as both ends of the filament or heater are free, through switches, for instant connection to any pair of tube terminals including the top cap.

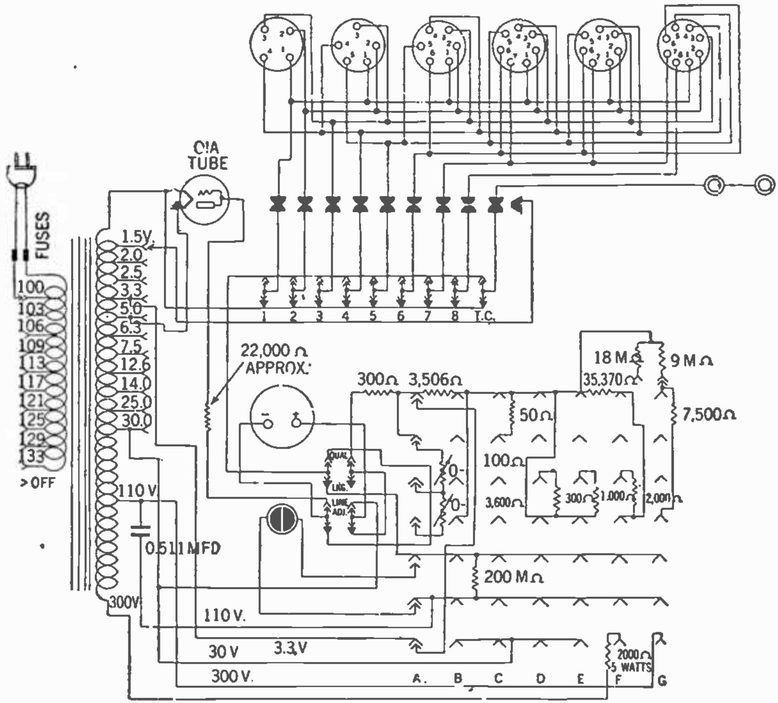


FIG. 25—Schematic wiring diagram of internal connection in Supreme Model 501 tube tester.

Supreme Model 551 Analyzer.—The panel view and connection diagram of this instrument are shown in figs. 23 and 24 respectively.

This set analyzer will handle all service and circuit problems of all types of radios, P.A. amplifiers and television sets. It is also as useful in servicing industrial vacuum tubes and photocell devices.

It has five sockets for the various types of tubes, and a sensitive 4 in. square meter, with easily readable scale. The various ranges and services are quickly available by means of an indexed rotary switch connecting the meter to any of the following measuring circuits:

a. *D.c.* volts....................0–7/140/350/1,400

b. *A.c.* volts....................0–7/140/350/1,400

c. *D.c.* milliamperes.............0–1/7/35/140

d. Ohms............................0–200/2,000/20,000

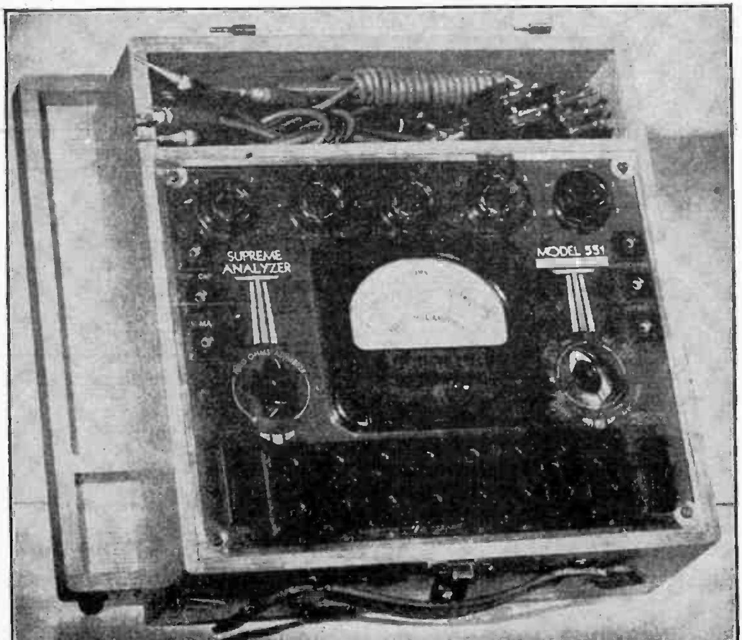
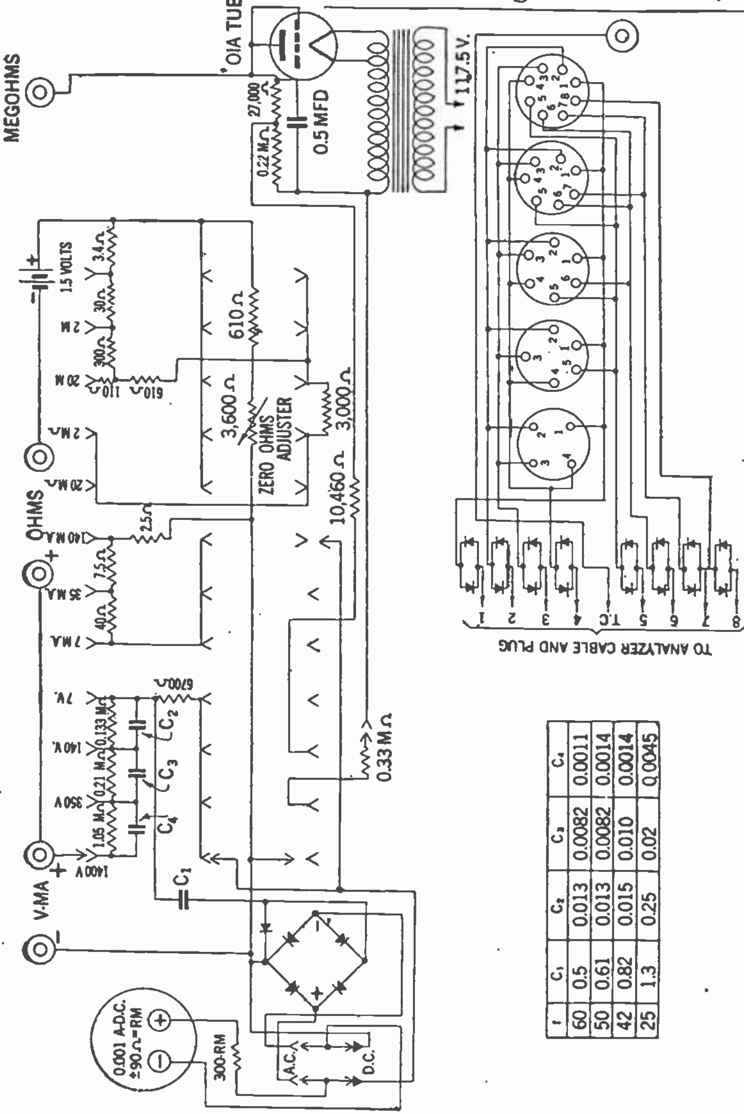


FIG. 26—Exterior view of Supreme Model 551 analyzer



f	C_1	C_2	C_3	C_4
60	0.5	0.013	0.0082	0.0011
50	0.61	0.013	0.0082	0.0014
42	0.82	0.015	0.010	0.0014
25	1.3	0.25	0.02	0.0045

FIG. 27—Wiring diagram of Supreme Model 551 analyzer.

The first scale division of the 0–200 ohm range is 0.1 ohm, and at center scale the resistance reading is 3.5 ohms. This extreme open scale which can easily be read as close as 0.02 ohms is especially valuable when checking the resistance of shorted voice coils, filament windings on transformers, rosin joints, shorted turns in converter armatures, etc.

The megohmeter has two ranges 0–2/20 megs, which is operated from a self-contained power supply for high resistance and cable leakage testing.

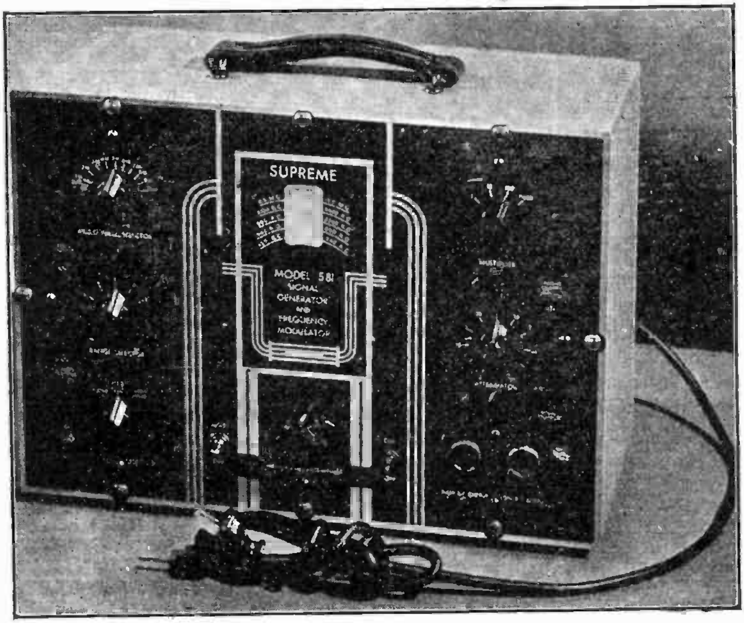


FIG. 28—Panel view of Supreme Model 581 signal generator.

Supreme Model 581 Signal Generator.—This all wave *r.f.* oscillator has a range of 130 *k.c.* to 60 *m.c.* cn 5 fundamental bands and 3 harmonically related bands.

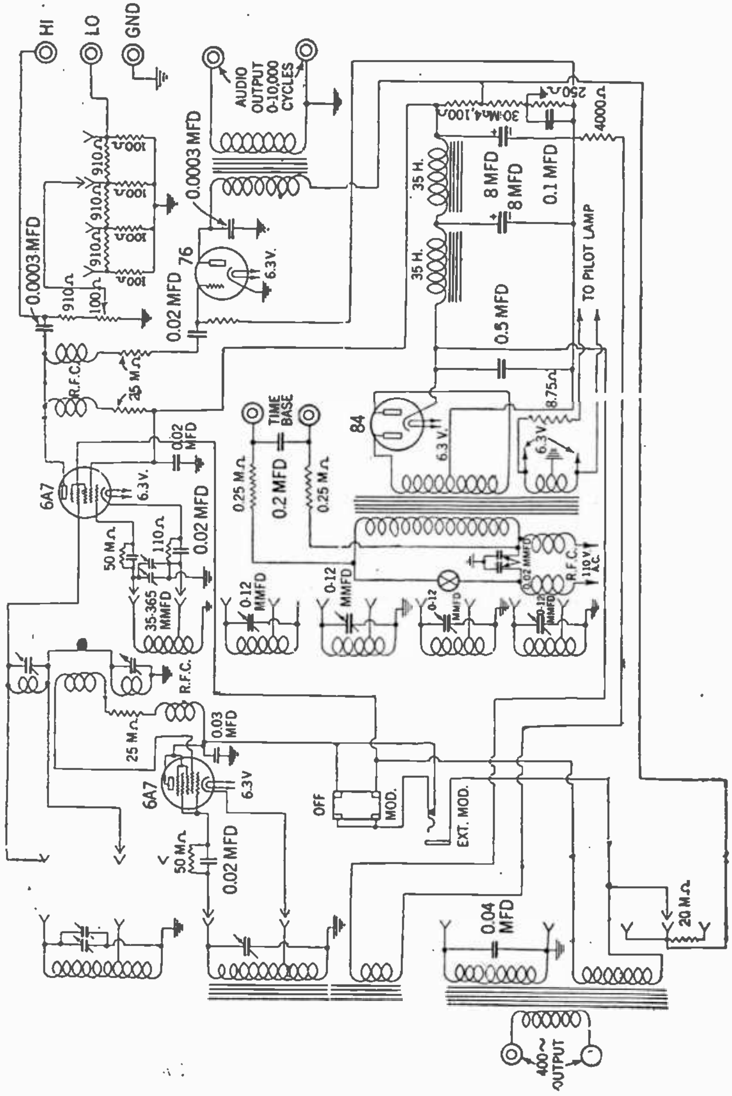


FIG. 29—Circuit diagram of Supreme Model 581 Signal generator.

Other noteworthy features includes a 400 cycle modulating oscillator which modulates the *r.f.* carrier the standard 30%; a beat frequency audio frequency oscillator having a 60/10,000 cycle range with less than 5% harmonic distortion; and an electronic frequency modulator or "Wobbulator."

This model is useful for alignment testing by the output meter (amplitude modulated *r.f.* signal) method or the visual cathode ray tube (frequency modulated *r.f.* signal) method; demodulation and detector testing; checking fidelity and overall response, and gain of audio and P.A. amplifier systems, band pass width; selectivity curves of *i.f.* amplifiers, etc.

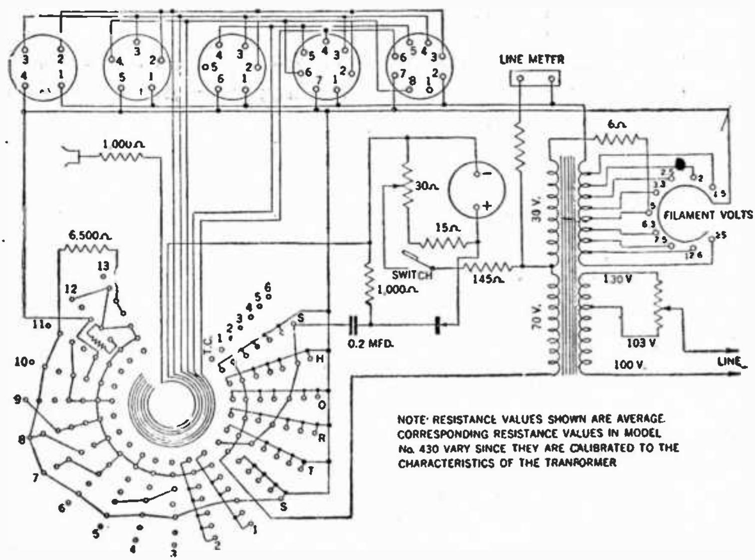


FIG. 30—Internal connection diagram of Readrite Model 430 tube tester.

The whole circuit is very stable, using a modified electron coupled system, which will not drift due to changes in line voltages, ambient temperature or attenuator control operation.

The circuit shown in fig. 29 has incorporated in it two 6A7, one 84 and one 76 tube.

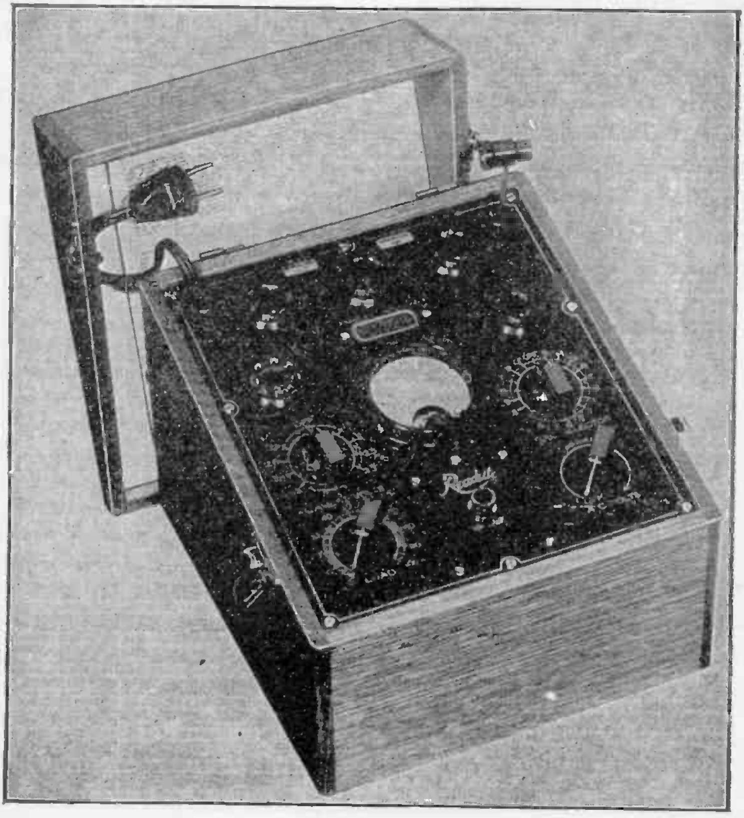


FIG. 31—Front view arrangement of devices in Readrite Model 430 tube tester.

Readrite Model 430 Tube Tester.—The wiring diagram and panel view of this type of instrument is shown in figs. 30 and 31 respectively.

This instrument is designed to test both metal and glass types of tubes.

The panel has five sockets and a direct reading "GOOD-BAD" meter scale, two selector switches, one load control knob, one *a.c.* voltage adjustment knob and one push button switch to indicate the condition of the tube under test.

The circuit is designed on the "emission" principle in that the meter indication depends on an emission test of the tube.

Cathode-leakage and short-circuit tests can also be made with this instrument.

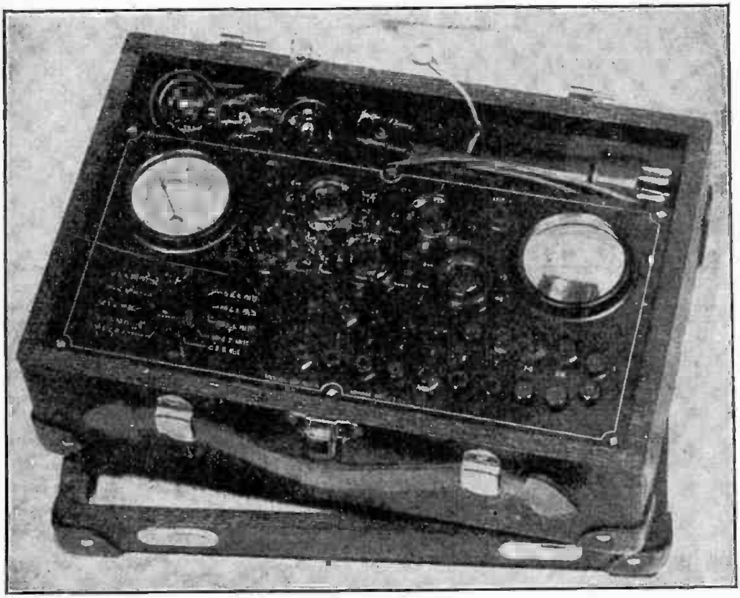
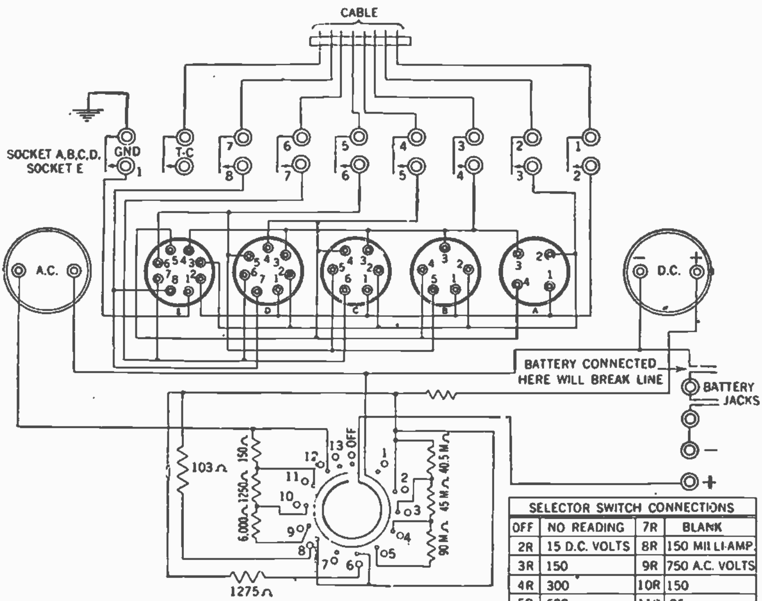


FIG. 32—Panel view of Readrite Model 720-A point to point panel.

Readrite Model 720-A Point-to-Point Tester.—This tester is equipped to handle both the glass and the glass-metal tubes. It may be used to measure resistance capacity and continuity, as well for voltage checking of any tube circuit.

The point-to-point tests are made through an eight conductor cable, which is plugged into the receiving set socket. Tester socket terminals are arranged according to R.M.A. standards, thereby making it unnecessary to remove chassis from cabinet when localizing faults. Arrangement of the different tube elements does not affect tests.



SELECTOR SWITCH CONNECTIONS			
OFF	NO READING	7R	BLANK
2R	15 D.C. VOLTS	8R	150 MILLI-AMP.
3R	150	9R	750 A.C. VOLTS
4R	300	10R	150
5R	600	11R	25
6R	15 MILLI-AMP.	12R	10
		13R	BLANK

FIG. 33—Connection diagram of Readrite Model 720-A point to point tester.

The tester is equipped with two meters; a *d.c.* meter having scale for reading 15-150-300-600 volts, 15-150 milliamperes and an *a.c.* meter for reading 10-25-150 and 750 volts.

Separate meter ranges made available by connecting a single pair of jacks and using the selector switch. For diagram of connection and panel view, see figs. 33 and 32.

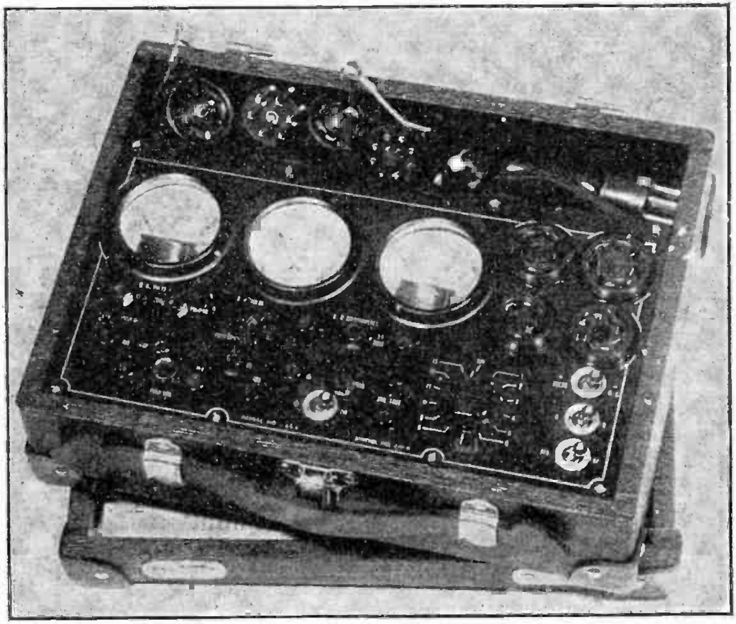
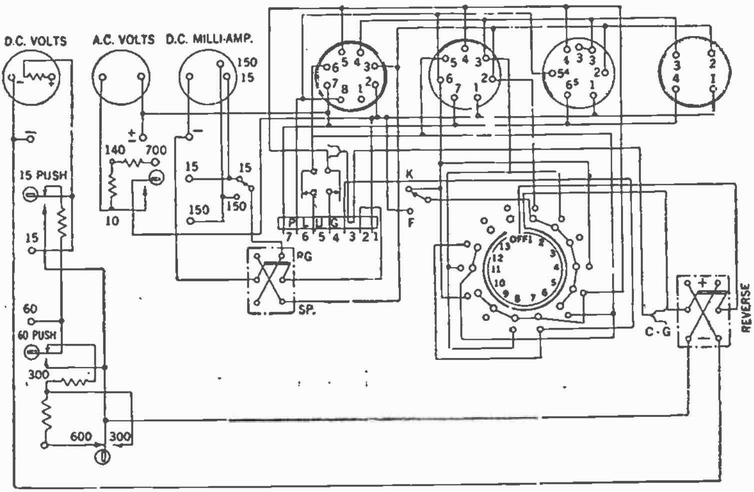


FIG. 34—Front view arrangement of Readrite Model 710-A tester.

Readrite Model 710-A Tester.—This instrument is used to test all parts of the tube circuits by plugging directly into the receiving set socket.

It will handle sets equipped with either glass or glass-metal tubes.

There are three meters, a *d.c.* volt-meter which reads 0–20/60/300/600 volts, and has 1,000 ohms resistance per volt, a *d.c.* milli-ammeter scale 0–15/150 and an *a.c.* voltmeter, scale 0–10/140/700.



SELECTOR SWITCH	CONTACTS 7-PRONG SOCKET	SELECTOR SWITCH	CONTACTS 7-PRONG SOCKET
1	2–6	7	4–2
2	3–6	8	4–3
3	C·G–6	9	4–5
4	1–6	10	4–6
5	6–4	11	5–3
6	6–5	12	5–4

FIG. 35—Schematic diagram of connections in Readrite Model 710-A tester.

A special positive contact selector switch connects all *d.c.* circuits to the *d.c.* volt meter. Panel jacks are provided to make individual range connections for the three meters.

The panel view and connection diagram are shown in figs. 34 and 35.

Philco Model 025 Signal Generator and Radio Tester.—This instrument consists principally of a volt-ohm-milliammeter for both *a.c.* and *d.c.* service.

The *a.c.* and *d.c.* voltage scales are 0–10/30/100/300/1,000. Current up to 10 amperes may be read directly on the milliammeter by using a special shunt.

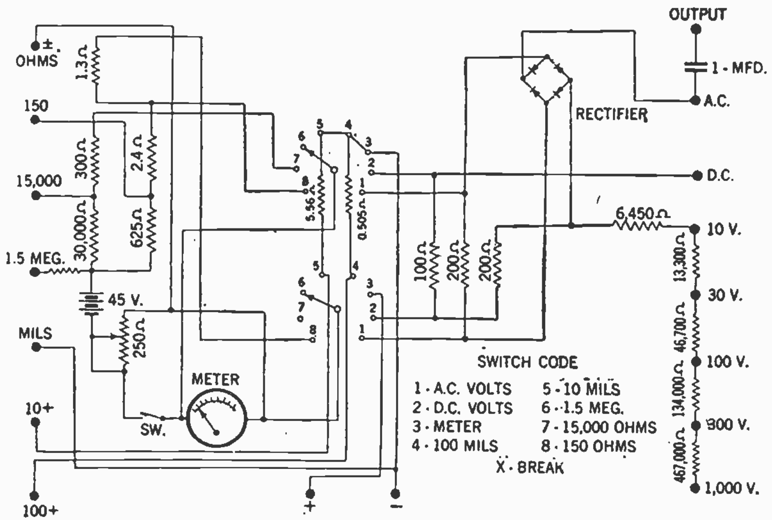


FIG. 36—Wiring diagram of Philco Model 025 radio tester.

The circuit is designed for capacity and resistance measurements which values are recorded on special scales, although in reading capacity (Mfd.) a special calibration chart should be consulted.

For internal connection and exterior views of instrument, see figs. 36 and 37.

Readrite Model 557 Signal Generator.—This signal generator is equipped with coil combinations to obtain frequency band as follows:

Coil "A" covers the band from	110	to	295	K.C.
Coil "B" covers the band from	275	to	840	"
Coil "C" covers the band from	820	to	2,800	"
Coil "D" covers the band from	2,500	to	8,500	"
Coil "E" covers the band from	8,000	to	20,500	"

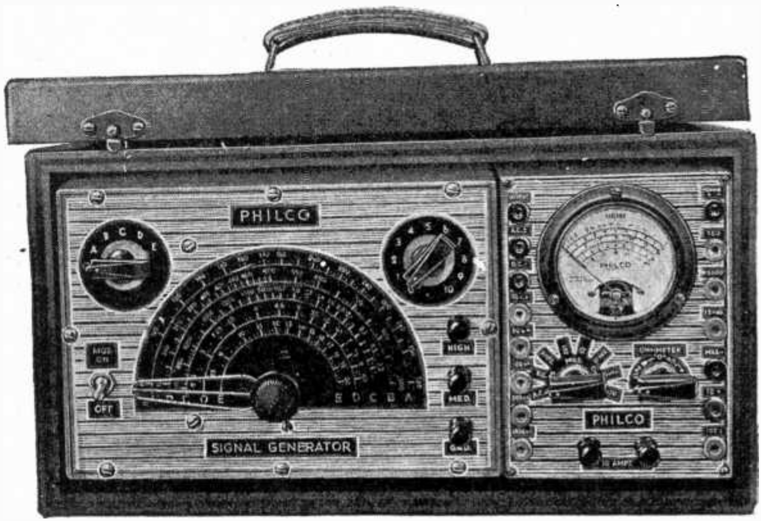


FIG. 37—Panel view of Philco Model 025 Signal generator and radio tester.

The operation of the oscillator is as follows: After determination of the frequency to be covered, select proper plug in the coil as shown under heading "Plug-in Coils"; place coil in 6-hole socket in shield can which is accessible by removing the nickle cap near the toggle switch marked **"On-Off"**. Connect oscillator and set the attenuator to approximately 75 on the dial, after which the toggle switch marked "MOD-UNMOD" is set to position desired.

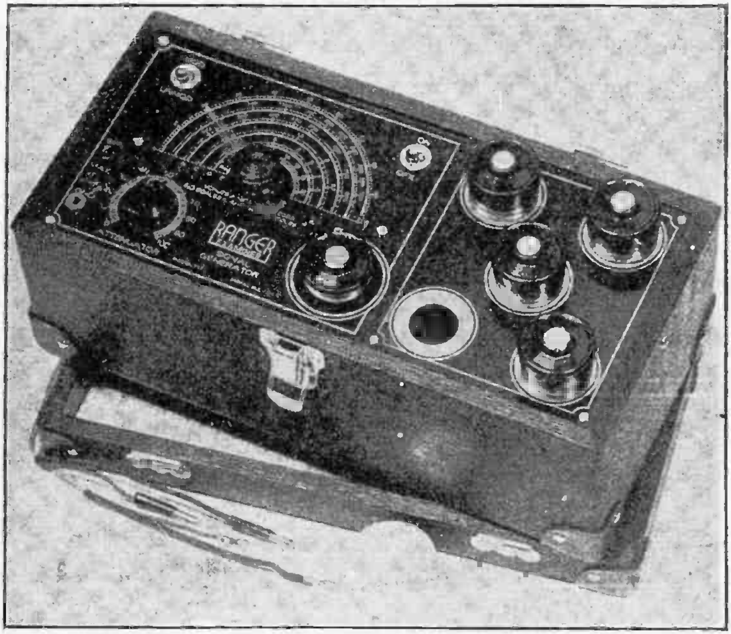


FIG. 38—Panel arrangement of Readrite Model 557 signal generator.

Generally speaking, all oscillator alignments are made with a modulated signal. Consult graph chart for the coil selected. Note dial setting for the frequency desired. Set dial pointer of frequency selector dial to the position as shown on graph. Turn oscillator power on by throwing the OFF-ON switch to the ON position and attenuate the signal to desired level by rotating the attenuator control so that a minimum signal is reached. If further reduction in signal strength is wanted, use jacks marked Minimum and Ground.

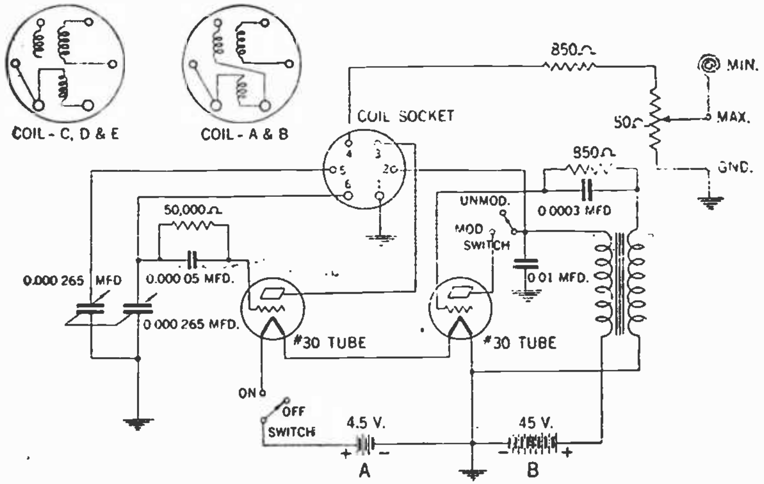


FIG. 39—Wiring diagram and coil arrangement in Readrite Model 557 signal generator.

Output Meter.—An output meter should always be connected to the radio output when using a signal generator. In order to avoid serious energy loss the output meter should be connected between the plate of output tube and chassis. If the output meter does not have a condenser there should be a condenser inserted in the output plate lead. This will prevent a burnout of meter. A .5 mfd. 400 volt condenser is suitable.

Vacuum Tube Voltmeters (General).—The vacuum tube voltmeter is an instrument used in service work for direct measurement across high impedance circuits, such as in the measurements of radio-frequency and audio-frequency voltages where the use of power consuming instruments would be unsatisfactory on account of the small current in the circuit.

For example, the impedance of an *r.f.* circuit such as is used in the first and second stage of a receiver may be as high as 2 or 3 megohms when adjusted to resonance with an incoming signal.

To make any measurement of potential across such a circuit it is obvious that a meter having a resistance of 3 to 4 megohms would be required, as a meter having a lower resistance might change the potential condition in the circuit it is desired to measure, too much, and hence make the measurement unsatisfactory.

It has been found that the only connection that could profitably be made across such a circuit without upsetting the circuit potentials would be that of another vacuum tube, the connection being made across the grid and cathode of said tube.

Essentially, the vacuum tube volt meter as the name implies, is nothing more than a vacuum tube connected through a meter in its plate circuit to a suitable power supply.

The grid and the cathode of the tube are connected across the circuit to be measured, the potential of said circuit causing a change in grid voltage on the tube and thus, a resultant change in plate current is indicated on the instrument.

As the vacuum tube is also a rectifier, potentials of any frequency placed across the grid and cathode of the vacuum tube voltmeter will result in a direct current deflection on the instrument in the plate circuit.

It is for this reason that the vacuum tube voltmeter can be used for measuring audio as well as radio frequency potentials provided the circuit is worked out correctly to cover this broad range of frequency.

Weston Model 669 Vacuum Tube Voltmeter.—Front view and internal connection of the instrument is shown in figs. 40 and 41 respectively. The principal characteristics of this type of instrument is as follows:

1. It has 6 self-contained ranges controlled by a rotary switch in the lower left hand corner, the full scale readings being 0–/1.2/3/6/8/12/16 volts. This meter is different from other multiple range vacuum tube voltmeters in that on all of these ranges only the grid to cathode impedance of the vacuum tube appears across the circuit to be measured.

2. The device operates directly from a 120 volt 60 cycle *a.c.* line, a self-contained transformer and power supply providing the necessary direct current potentials. A neon regulator bulb is used to hold the *d.c.* grid and plate voltages fixed irrespective of variations in line voltage. Up to the present time the problem of eliminating variations in vacuum tube meter readings with line voltage fluctuations has been a serious problem. The use of this regulator bulb has therefore put measurements of this type on a different plane as readings in the vicinity of .2 to 1 volt were practically impossible without having some sort of regulation of supply voltages.

3. Tubes used in the instrument are a type 78 and a type 1V, the former being the measuring tube and the latter the rectifier for the power supply. The 78 tube is mounted with the top projecting through the panel so that direct connection can be made to the grid cap using short leads. In the same way the grid is kept approximately 1 in. from any other metal surface and in this way input capacity is kept at a minimum.

4. A six range scale is provided, all *a.c.* readings being made directly without reference to curves or charts of any kind. The circuit has been worked out so that readings can be taken on 60 cycle lines without visible error, the frequency coverage of the device being from approximately 40 cycles up through receiver

short wave ranges. On very high frequencies such as from 10 to 20 megacycles slight errors will occur due to tube capacity even though this has been kept at a very low value. Such errors, however, are not very great being of approximately the same order as attained on other instruments used in this frequency range.

Among the measurements which can be made on this instrument is analysis of oscillator performance on super-heterodyne receivers, measurements of gain per stage in all types of receivers, checking of resonance, automatic volume control measurements, etc.

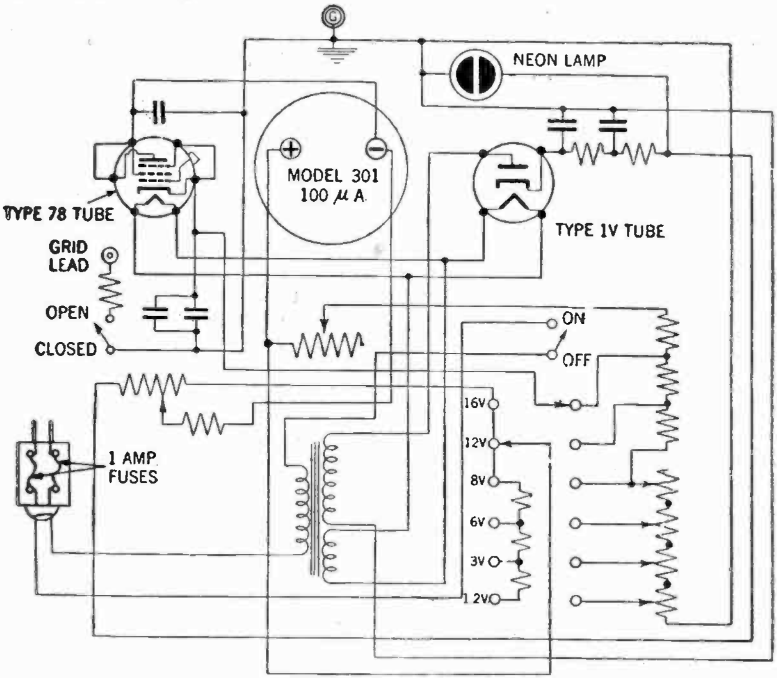


FIG. 41—Schematic wiring diagram of Weston Model 669 vacuum tube voltmeter.

CHAPTER 185

The Telephone

By definition the telephone is *an instrument for the transmission of articulate speech by electric current.*

Principle of the Telephone.—The operation of the telephone is based upon a simple principle, namely, *using a continuous*

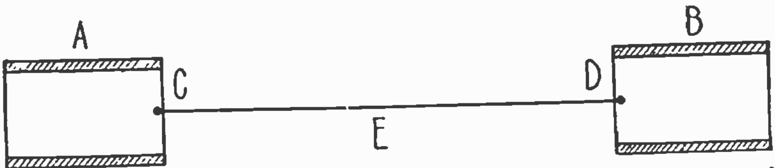
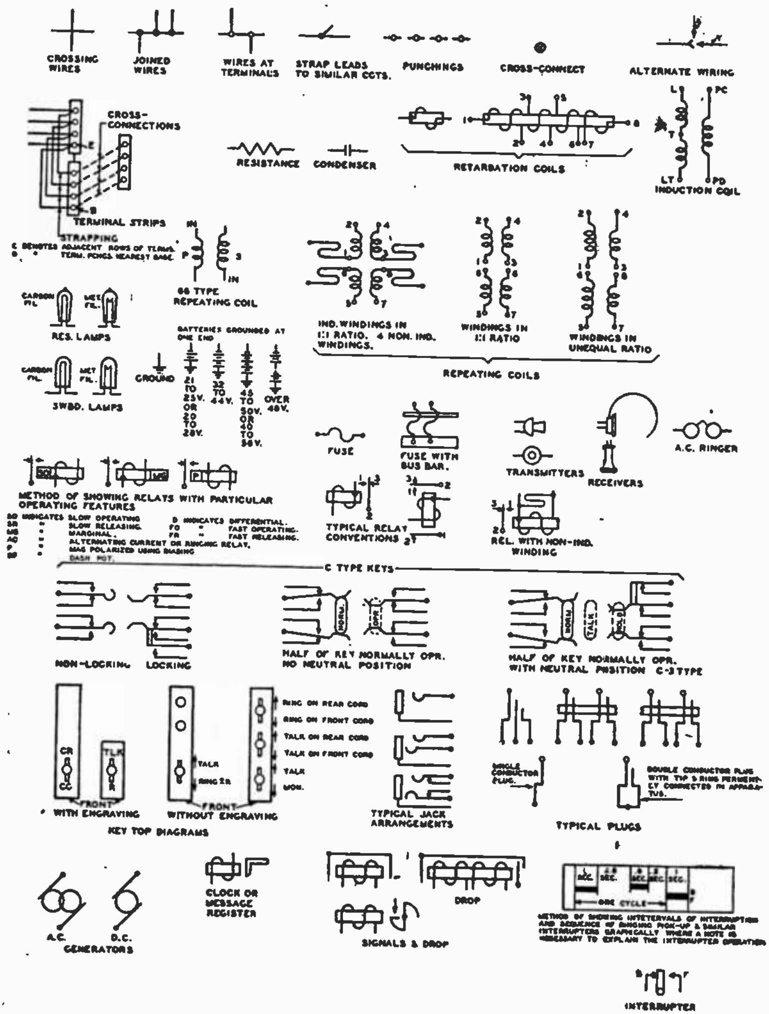


FIG. 7,413.—Diagram of simple toy telephone, consisting of two combined transmitters and receivers A and B, made of metal or wood cylinders, one end of each being covered by a membrane C and D, and the centers of which are connected by string E.

current of electricity and varying its strength exactly as the air varies in density during the production of sound. This is illustrated by the simple toy telephone shown in fig. 7,413.

In operation, when the open end of the tube A, is placed before the mouth, the vibrations of the membrane C, caused by the varying sound waves representing the human speech, are transmitted with mechanical action by the

NOTE.—***The principle of the telephone*** was discovered by Alexander Graham Bell in Boston, Mass., on June 2nd, 1875. The first telephone was actually operated on March 10, 1876; it was then a crude instrument and not very sensitive. Since that date however many improvements have been made in this agency of communication that has made America a neighborhood.



FIGS. 7,414 to 7,477.—Symbols used in manual telephony.

string E, to the membrane D, and set up in the latter vibrations corresponding to those of C. The vibrations of D, cause sound waves in the air which are transmitted to the ear placed at the open end of the cylinder B.

The Transmitter.—In the electric telephone, the string is replaced by a wire having at one end a small unit consisting of

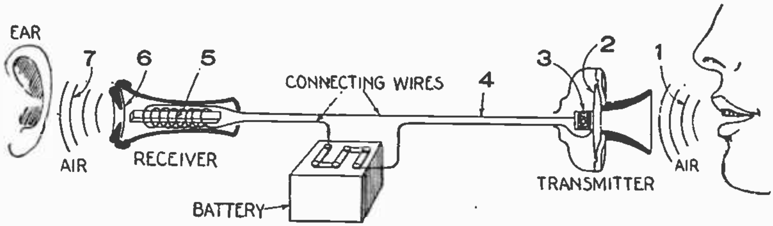


FIG. 7,478.—Electric telephone. *The parts are:* 1, air vibrations caused by voice; 2, diaphragm; 3, carbon buttons; 4, line wires; 5, electro-magnet; 6, diaphragm; 7, reproduced air vibrations representing speech.

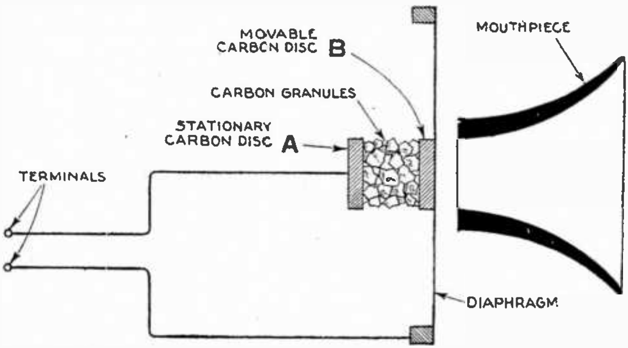


FIG. 7,479.—Simple electric telephone transmitter.

two carbon discs separated by about $\frac{3}{32}$ of an inch and the space between filled with sharp carbon particles called granules. as shown in fig. 7,479. This unit is connected to a steady source of electricity so that the current must flow from one carbon disc through the carbon granules and out through the second carbon disc.

The arrangement normally offers a certain amount of resistance to the passage of the electric current. However, if the space between the carbon discs be decreased the carbon granules become packed closer together, lessening the resistance and allowing a greater amount of electricity to flow through. Vice versa, if the space between the granules be increased, the result will be an increase in resistance and a decrease in the electric current.

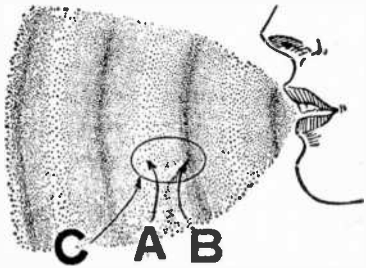


FIG. 7,480.—Microscopic view showing molecules of air at 1, in fig. 7,478. In a spoken word, or in any musical sound, the molecules dance back and forth as in fig. 7,481.

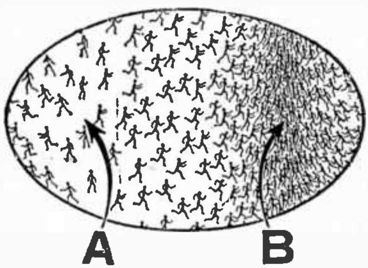
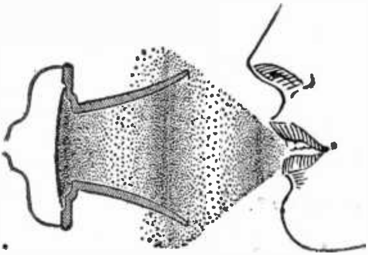


FIG. 7,481.—Enlargement of section C of fig. 7,480 with molecules represented as tiny beings rushing from A to B (fig. 7,480). First they advance, pushing against the ear drum, and then they retire and the membrane of the ear flies back. Over and over again this happens, hundreds and even thousands of times a second. The higher pitched the voice of the speaker, the more rapid is the dance, yet it is a dainty dance, for the weight of a snip of human hair only about one-thousandth of an inch in length would press as heavily upon the sensitive ear drum.

One of the carbon discs A, is held in a fixed position and the other B, is attached to the center of an aluminum disc called a *diaphragm*. The entire arrangement is called a *transmitter*. In operation the voice sets the air into vibrations which beat upon the transmitter diaphragm and set it into rapid back and forth movements, causing changes in the resistance of the carbon unit and resulting in the rapid variations of electric current which flows to the distant end where there is a receiver, as shown in fig. 7,478.



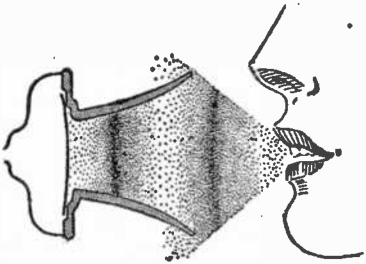
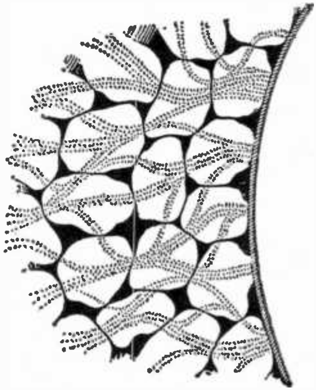
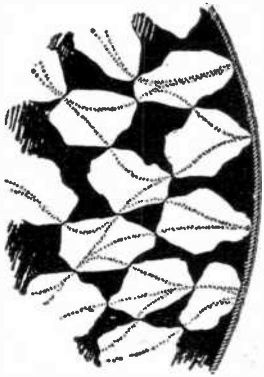


FIG. 7,482.—Effect on diaphragm caused by molecules of air which are set in motion by the voice of the speaker—they rush against the diaphragm of the transmitter and bend it in.

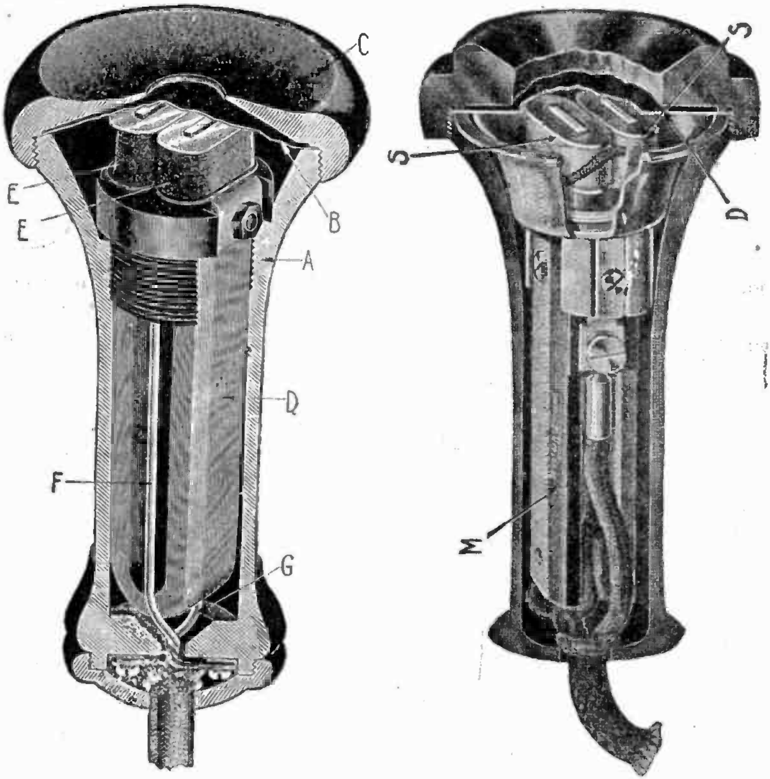
FIG. 7,483.—Effect on diaphragm when the molecules rush away—it springs back out of its bent position.



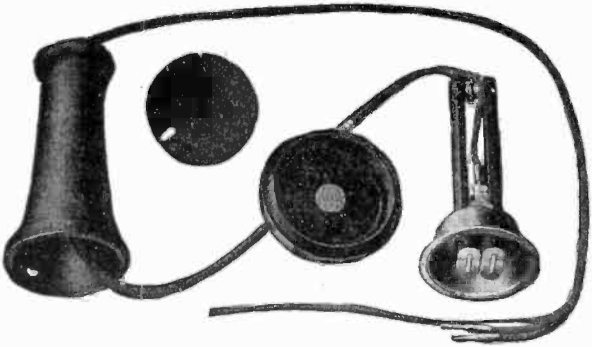


FIGS. 7,484 and 7,485.—Action of diaphragm on carbon grains. Fig. 7,484 shows carbon grains in a transmitter magnified about fifty times each way. When the diaphragm is bent in, the grains are closely packed together and many electrons can pass through, but when the diaphragm springs back, as in fig. 7,485, the grains are loosely packed and fewer electrons can pass from grain to grain through the chamber containing the carbon grains.

The Receiver.—This consists of an electro-magnet with an iron disc or diaphragm, very near its poles. The varying



FIGS. 7,486 and 7,487.—Standard bi-polar hand receiver. The winding of the coils is done with silk covered copper magnet wire. The outside terminals are soldered to metal strips which are insulated and extend to the cord terminals within the shell. The magnet is a single piece, being formed from a bar of magnet steel. It slips into the casing which forms a support for all the parts and is held by a screw cap. All parts are thus firmly clamped together, but the screw cap plays no part in the adjustment. The metal strips terminate in a brass support to which are fastened the receiver cord terminals.



FIGS. 7,488 and 7,489.—Kellogg subscriber's receiver disassembled showing construction.

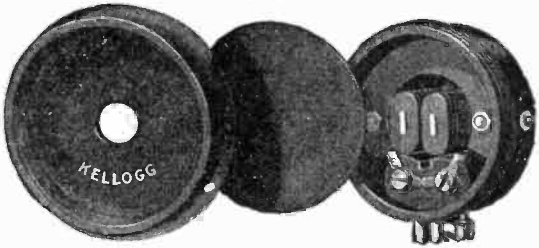
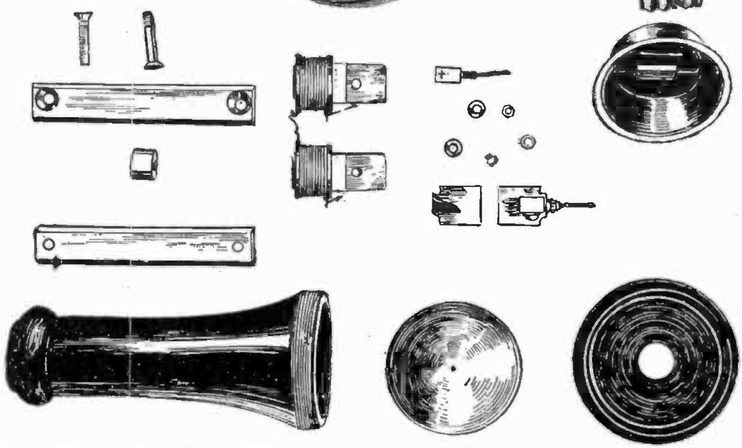
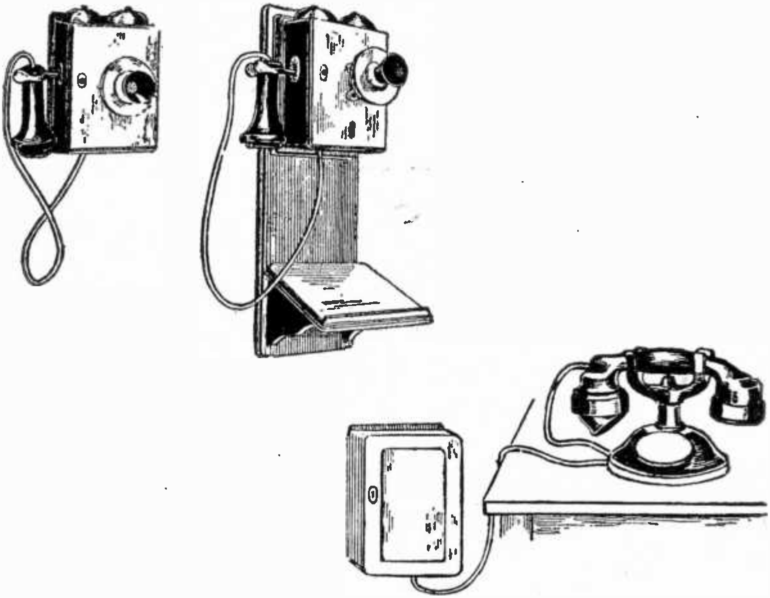


FIG. 7,490.—Kellogg operator's receiver disassembled showing diaphragm and magnet.



FIGS. 7,491 to 7,509.—Parts of Kellogg shell receiver.

amounts of electricity in passing through the receiver magnet change the strength of the magnet and as a result the diaphragm is pulled and released partly or totally at a very rapid rate, precisely the rate at which the transmitter vibrates.



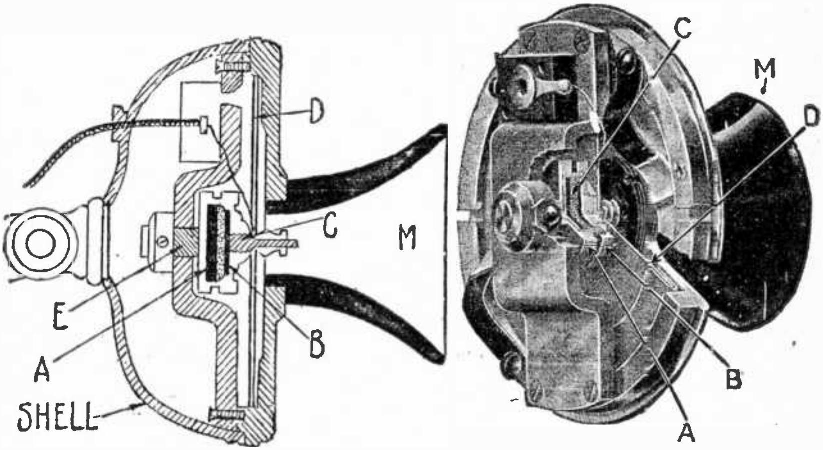
FIGS. 7,510 to 7,512.—Types of station apparatus. Fig. 7,510, wall set; fig. 7,511, wall set with writing shelf; fig. .512, desk stand or hand set with a separate bell box. The wall set is the smallest and lightest of these three types of instrument and is generally used where mountings on plaster walls are required. Where a writing shelf is desired the wall set is mounted on a back board equipped with a shelf. It is fastened to the wall with anchor bolts. Where a table or desk is used by the subscriber, a desk stand or hand set is installed, the bell box being mounted under the table and connected to the desk stand by a flexible wire cord.

The vibrations of the receiver diaphragm in turn cause the air to vibrate and subsequently the human ear drum to vibrate when the latter is placed close to the receiver. The result of course is the reproduction of speech.

Ques. Of what does a telephone station consist?

Ans. It consists of a transmitter and a receiver usually on a desk stand with a hook to hold the receiver, and also to serve as an automatic switch when the receiver is removed from the hook, as in fig. 7,523, connected to a bell box which contains 1. A condenser. 2. A bell, and 3. An induction coil.

The electric current necessary for talking purposes is obtained from a storage battery located at a central point known as the "common battery central office" and the alternating current to ring the bell is furnished by a ringing machine, also located in the Central Office. This is known as the common battery system.



Figs. 7,513 and 7,514.—Commercial transmitter. *The parts are:* A, fixed carbon disc attached to the bridge at E; B, movable carbon disc attached to the center of the aluminum diaphragm D, at C; M, hard rubber mouth piece. The shell is for protection and for mounting the transmitter to a stand or bracket.

A commercial transmitter is shown in figs. 7,513 and 7,514, and a typical receiver in fig. 7,487. The receiver generally consists of a small U magnet M, made of a very good grade of steel with many turns of fine insulated wire S S, wound around its two poles, and an iron diaphragm D, located very near the poles, but not in contact with them.

Subscriber's Set.—In the bell box, known as the subscriber's set, shown in fig. 7,515 are three pieces of equipment:

1. Ringer. 2. Induction coil. 3. Condenser.

These are designated A, B, and C, respectively, in fig. 7,515.

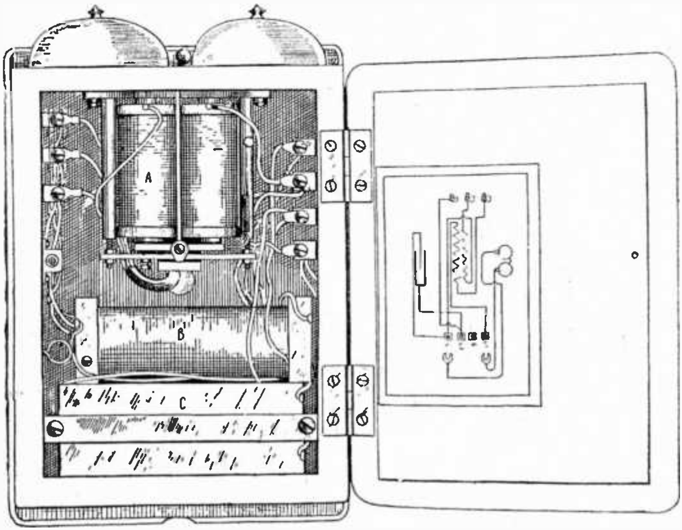
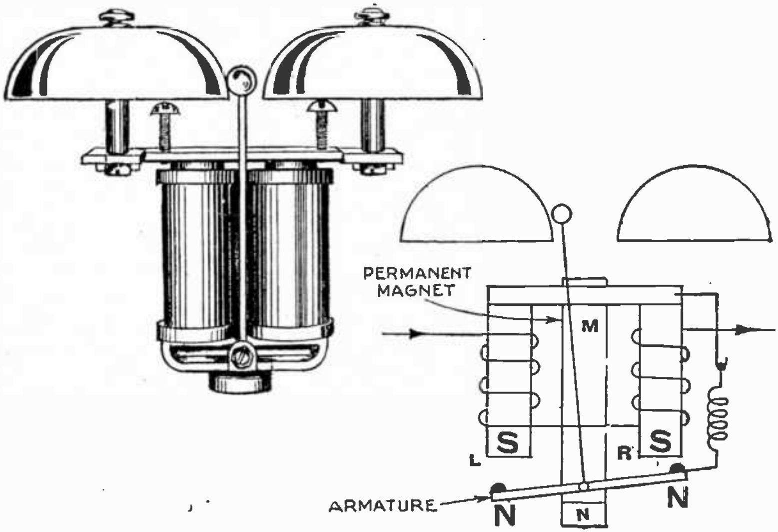


FIG. 7,515.—A typical telephone bell box with door open showing the ringer A, the induction coil B, and the condenser C.

Ringer of Subscriber's Set.—This is shown in figs. 7,516 and 7,517, and is a combination of a permanent magnet M, N, and an electro-magnet L and R, which is an inverted U magnet with many turns of fine insulated wire on each of the soft iron cores L and R, equal turns on each. The permanent magnet M, N, is attached at M, to the center of the electro-magnet. This establishes two south poles S, S, of equal strength, and by induction two north poles N, N, also of equal strength at the ends of a piece of soft iron pivoted near the poles of the electromagnet. This piece of soft iron acts as the armature and carries the hammer which strikes the bells.

A biasing spring is attached to the armature at one end, which forces the armature to assume the normal position shown in the figure. If the biasing spring were not there, the armature would just float.

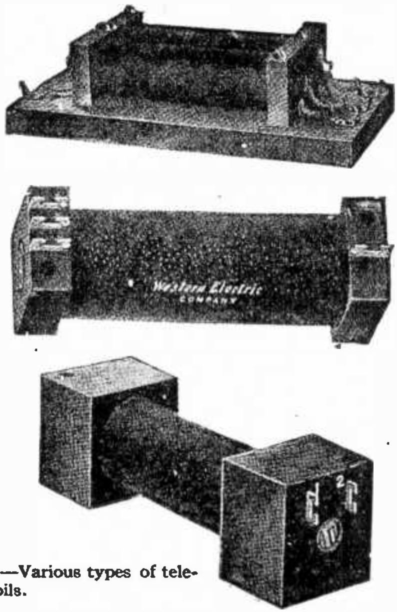


FIGS. 7,516 and 7,517.—Ringer and diagram of its operation.

The ringing current is alternating and reverses itself completely sixteen times in each second. Consequently at some instant the current may be flowing from L, to R, causing the **S** pole at L, to become stronger and the **S** pole at R, to become weaker, and as a result, the armature is pulled toward the **S** pole at L.

When in the next instant the ringing current reverses, the opposite action takes place with the addition of returning power from the biasing spring, so that the armature moves with the reversals of the ringing current sixteen times in one second. The hammer, being attached to the armature, will follow the movements and strike the bells.

Induction Coil of Subscriber's Set.—This consists of two windings on a soft iron core made up of a bundle of soft iron wires or laminations. The primary is wound over the iron core and the secondary over the primary. The induction coil is connected so that it is between the transmitter and the distant receiver in order to amplify the talking currents and enable them to reach a comparatively longer distance. Figs. 7,518 to 7,520 show various types of telephone induction coils.



Figs. 7,518 to 7,520.—Various types of telephone induction coils.

Condenser of Subscriber's Set.—The condenser consists of two sheets of tin foil separated by a double thickness of paraffined tissue paper. The tin foil sheets are approximately 3½ ins. wide and are very long, so as to give the effect of a large surface.

The paraffined paper is slightly larger in width and is interposed between the two sheets of tin foil to prevent their coming in metallic contact. The combination is rolled up so as to occupy a small space, and is then boiled in paraffin and encased in a metal container for protection. A lug is attached to each sheet of tin foil so that wires may be soldered to it.

Fig. 7,521 shows a typical telephone condenser.

In operation, a condenser acts as an insulator in a telephone circuit where direct current is applied, but it readily allows the passage of alternating current. It is used in the subscriber's set connected in series with the bell so as to prevent the storage battery current passing through the bell from one side of the line to the other causing unnecessary waste of electricity.

FIG. 7,521.—Typical telephone condenser.

Station Line Circuit.—The connections of the apparatus in the bell box and the receiver and transmitter, are shown in fig. 7,522. On a call originating at this station the telephone user lifts the receiver off the hook.

This completes the path of the electric current from one side of the line at A, through the primary of the induction coil and transmitter to the other side of the line at C, and causes a relay in the subscriber's line circuit in the Central Office to operate and a lamp to light on the switchboard in front of an operator to notify her that a connection is desired.

On a call coming into this station line circuit a connection is made in the Central Office which places generator current (16 cycles *a.c.*) on the line and rings the bell shown in fig. 7,522.

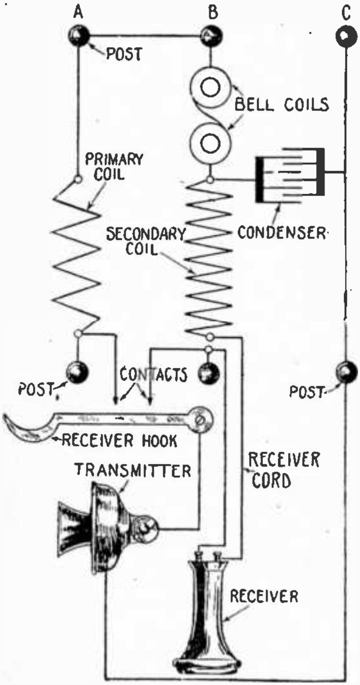


FIG. 7,522.—Diagram showing the inside connections of a telephone bell box, the binding posts of which are shown, top and bottom. Flexible wire cords connect these to the transmitter and receiver, as shown. When the receiver is off the hook the contacts there are closed by the upward spring of the hook and the circuits are closed for operation. The line is always connected to the two outer posts A and C, the middle post B often stamped G and used for ground connection on party line instruments. Terminals A and C, are generally designated T and R (tip and ring).

Desk Stand Telephone.—This piece of apparatus is shown unassembled in fig. 7,523. The connections in the stand are in general, as shown in fig. 7,524.

Coin Box Telephones.—This type of telephone is shown in fig. 7,525, and consists of the usual transmitter and receiver, and a bell box containing an induction coil, a condenser, and a bell. In addition there is a *coin collect and return* magnet.

The coin machine consists of an upper housing encasing a chute with entrance points at the top for 5c, 10c and 25c coins. The lower portion of the chute opens into a hopper. The coin when dropped into the chute follows a zig-zag path and finally drops onto a small platform or *coin trap*. However, before reaching this point, the coin has accomplished two things: 1, struck a gong; and 2, tripped a small lever which causes a set of contact springs to come together. This in turn causes a lamp to light at the Central Office switchboard giving notice to the operator that a connection is desired.

A 5c piece when dropped into the chute strikes a solid gong once, a 10c piece strikes the same gong twice and a 25c piece strikes a gong of the cathedral type once. The resultant characteristic tones are transmitted to the operator in the Central Office over the telephone wires.

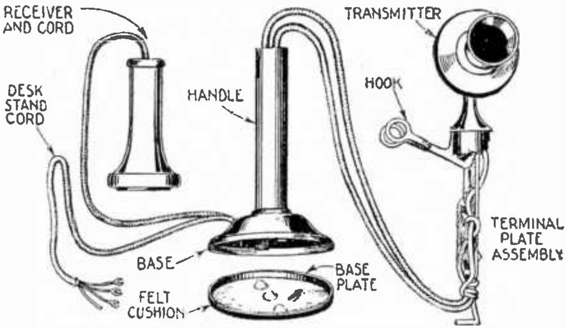


FIG. 7,523.—Desk stand parts.

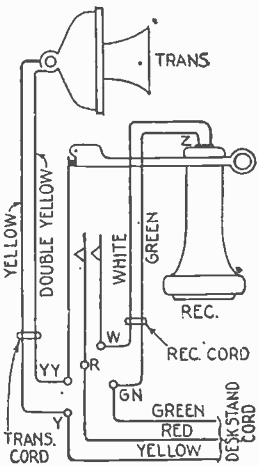


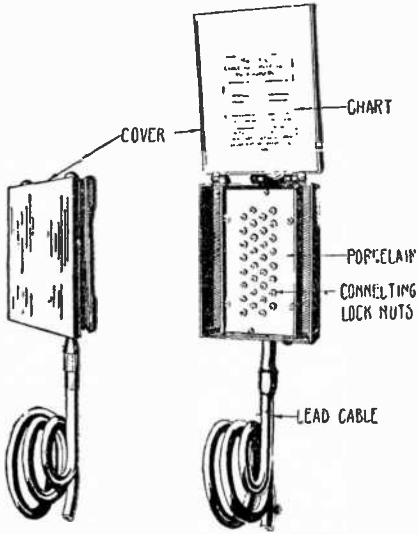
FIG. 7,524.—Wiring of desk stand.

FIG. 7,525.—Coin box telephone.

The operator in the Central Office can either collect or return the coin by operating a *collect* or *return* key.

If the collect key be operated, a magnet in the coin box telephone causes its armature to swing in such a direction as to tip the coin platform toward the coin compartment on account of the weight of the coin, with the result that the coin slides off the platform into a safe.

If the return key be operated, the same magnet operates the armature in the opposite direction, causing the coin to slide off the platform down into the coin return chute. The magnet of this coin box telephone is operated in the same manner as the bell ringer of fig. 7,517.



Figs. 7,526 and 7,527.—Outdoor cable connecting box. This device is placed in a back yard in cities, or on a pole in the country, and accommodates the two line wires for each telephone in a block or street.

The operation of the collect key sends electric current through the electromagnet of the coin box in one direction, and the operation of the return key reverses the direction of the current flow.

The Common Battery Central Office.—The subscriber station equipment of fig. 7,522 is connected by means of two twisted insulated wires to a cable terminal located either in the basement of the same building or sometimes outside on a pole or side of the building. This cable terminal, as shown in figs. 7,526 and 7,527, has facilities for connecting a number of telephones.

The wiring from the cable terminal is extended by means of a large lead-covered cable run, either through underground ducts or overhead on poles, to the Central Office.

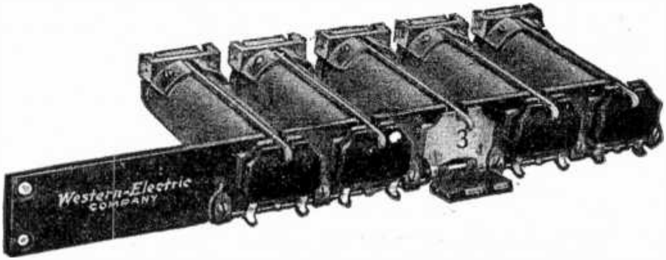


FIG. 7,528.—Mounted trunk drops. Tubular trunk drops are mounted on a metal strip each being held by two small screws underneath the drop shutter. The tubular casing of each drop is soft iron inside of which is the drop winding; the ends of the coil wires terminating at lugs which protrude from the casing and are insulated therefrom. The drop shutters are then screwed fast to the metal strip and adjusted so that they may fall easily when the armature is held up by the magnet.

Ques. What is a Central Office or Telephone Exchange?

Ans. It is a telephone building which contains terminal facilities and equipment to supply the telephone needs of a given district and contains also a switchboard operated by girl attendants who make connections between the telephone subscribers in the same district or with subscribers in another telephone district, or *exchange* by using *trunks*.

Ques. What is the capacity of a Central Office?

Ans. A Central Office may be designed with facilities to handle as many as 10,000 subscribers.

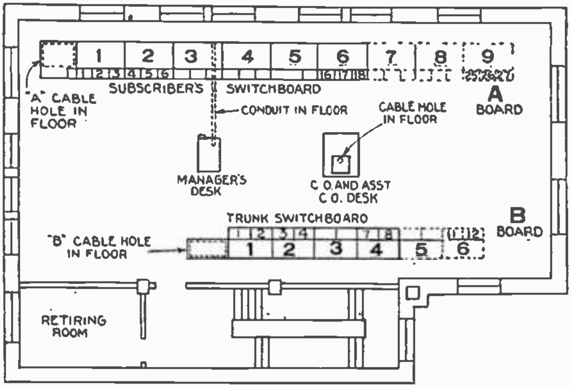


FIG. 7,529.—Typical layout of a Central Office operating room showing the A and B boards.

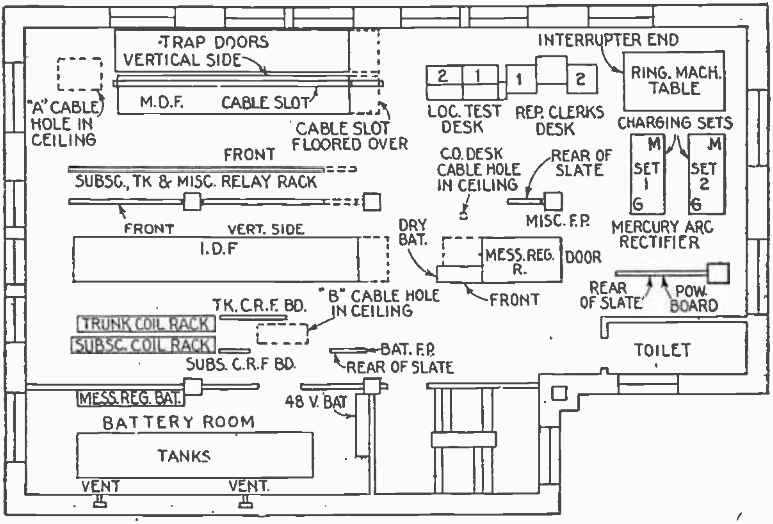


FIG. 7,530.—Typical layout of a Central office terminal room which also contains the power plant equipment.

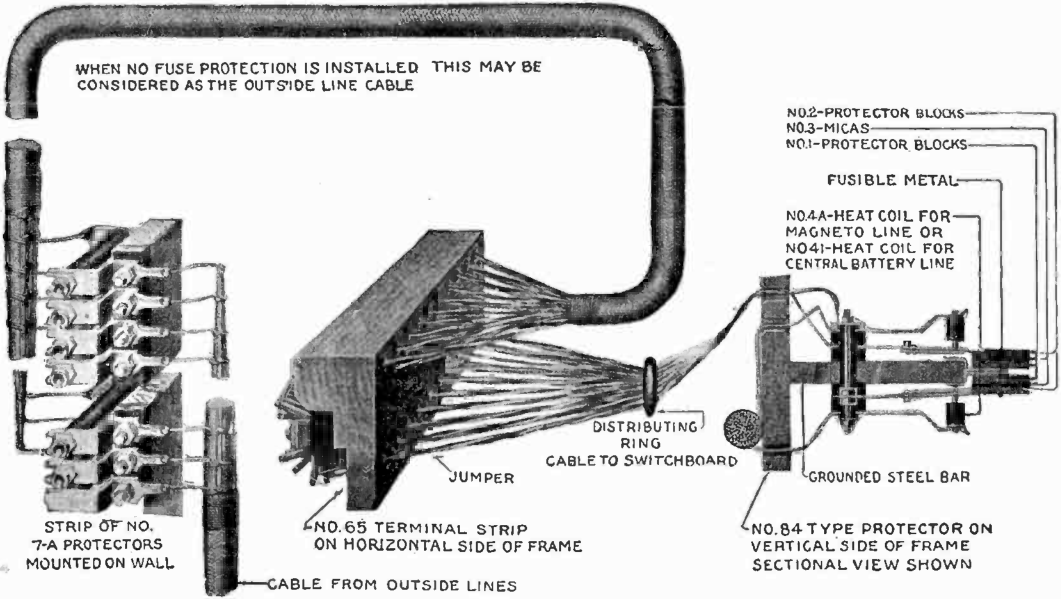
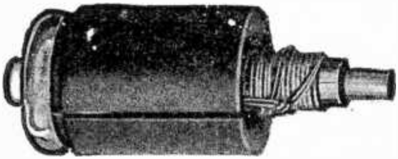
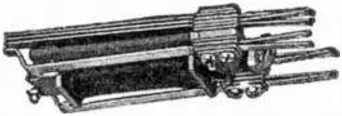


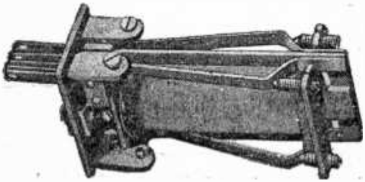
FIG. 7,531.—Typical main distributing frame and connections. All cable wires and jumper wires are in twisted pairs. The terminal strips are mounted on self supporting floor type steel frames. The heat coils, as shown in fig. 7,532, are constructed so that when heavy currents are picked up by the line wires, as in the case of lightning striking the line or crossing with power lines, the heavy current heats a small coil of resistance wire (in the heat coil) which causes a fusible metal to melt and allow a small tube to slide over a pin a distance of $^1/_{16}$ in. and to make connection with the spring on the grounded steel bar of the distributing frame thereby leading the excess current to ground and protecting the telephone apparatus.

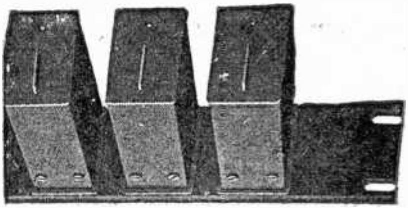
It is made up of two distinct sections, namely an operating room, fig. 7,529, and a terminal room, fig. 7,530.

The operating room contains an A and a B switchboard, and the terminal room contains distributing frames, relays, fuse panels, storage batteries, charging machines and ringing machines. The apparatus is described in detail in the sections following.









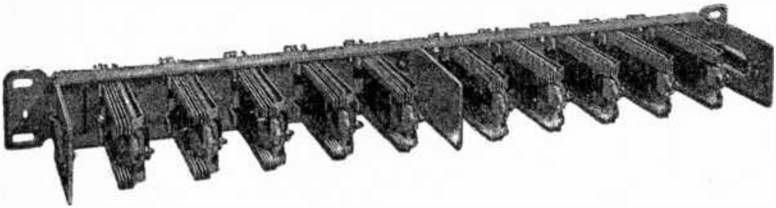


Fig. 7,532.—Heat coil, enlarged view.

Figs. 7,533 to 7,535.—Various relays. The principle of operation and elementary construction is the same in all. They differ in constructional details, which allow one type to mount in a smaller space, or allow the closing or opening of several circuits in one operation.

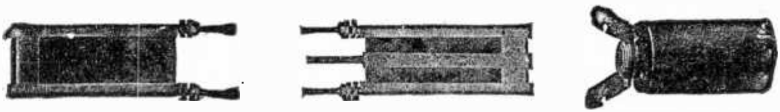
Fig. 7,536.—Relays on mounting plate.

Distributing Frame.—A typical distributing frame is made of structural steel with terminal strips on one side mounted horizontally and terminal strips or heat coil protector blocks on the other side mounted vertically.

The lead covered cable from the subscriber's cable terminal shown in fig. 7,526 is brought to the horizontal side of the Central Office distributing frame, and is connected to the terminal strips as shown in fig. 7,531.

From this distributing frame, or M.D.F., the line wires are led to a second frame, generally called intermediate distributing frame, or I.D.F., where cross-connections are made to terminal strips containing cable wires to line and cut off relays, and to the multiple jacks on the "B" switchboard.

The Relays.—As used in telephone circuits the relays are of various types, some of which are shown in figs. 7,533 and 7,534, and are generally mounted on mounting plates, as in figs. 7,535 and 7,536, which are installed on *relay racks*, the latter being iron I-beams vertically supported and drilled for the mounting plate holding screws



Figs. 7,537 to 7,539.—Flat and round type resistances made of German silver, or other similar wire, wound on mica or asbestos.

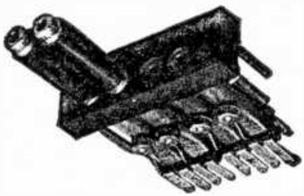


Fig. 7,540.—Jacks mounted in a hard rubber jack mounting.

Resistances.—For telephone circuits resistances are of the flat type as in figs. 7,537 and 7,538. They are used to take up the excess voltage in connection with the operation of relays or the lighting of lamps on switchboards. Resistances are also mounted on mounting plates with the associated relays on the relay racks.

The B Switchboard.—As previously mentioned, the subscriber's line is connected by means of cable from the I. D. F., in the terminal room to the B board in the operating room. At the B board the line terminates in a *multiple jack* located in a jack panel in front of an operator.

Each operator can reach 10,000 jacks. In order to locate so many jacks within the reach of an operator, 20 of these jacks are moulded in a hard rubber strip about 10 to 12 ins. long, and these jack strips are piled up one over the other.

Each pile-up of jacks is known as a jack panel and there may be as many as 1,500 jacks in each panel, as shown in fig. 7,541

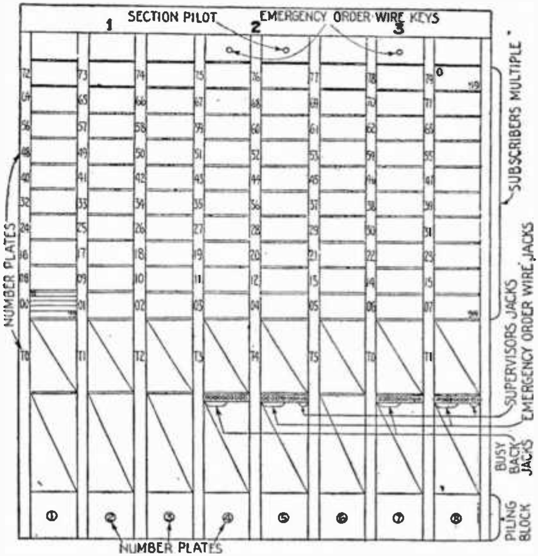
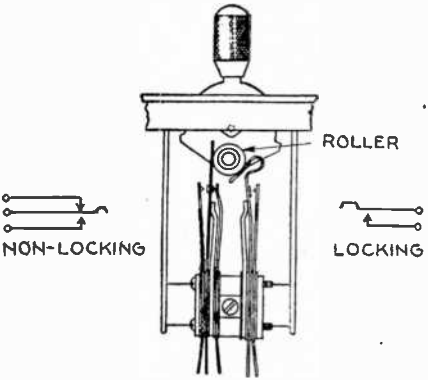


FIG. 7,541.—Face equipment of a B board section. In each section there are seven jack panels, and each jack panel has a capacity of 1,500 jacks. Each rectangle above represents a group of 100 jacks and each group is designated on the stile strip as 00, 01, 02, 03, 04,—-64—65—98—99, etc. The jacks in each group are marked from 00 to 99 inclusive so that by taking the number on the stile strip plus the jack number it indicates the particular subscriber's line associated, as 65+86, or telephone line No. 6586. The numbering is permanent for the life of the Central Office, and if a jack becomes defective, it must be disconnected and removed and a new jack put in its place.

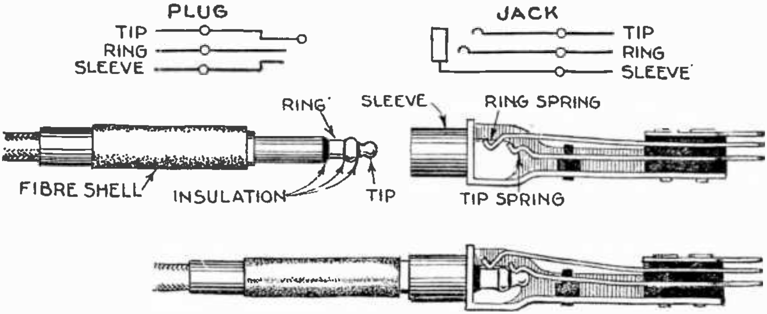
Connections to the jacks are made by means of cords, which are known as *trunks*, as shown in figs. 7,545 to 7,549.



Ques. What is the function of the B operator?

Ans. She connects a calling subscriber with a telephone within her Central Office area.

FIGS. 7,542 to 7.544.—Details of lever type key.



FIGS. 7,545 to 7,549—Jack and plug details showing how connections are made by inserting a cord plug into a jack. Each jack has three contacts known as tip, ring, and sleeve, and the cord plug has tip, ring and sleeve to correspond. Hard rubber is used for insulation of the contacts.

Incoming Trunks.—The operator completes the connection by inserting a cord plug into the jack of the desired line. When the cord is in the jack a relay associated with the cord circuit connects generator current and rings the bell of line called. The cord circuit at the B board is known as an incoming trunk.

and is connected to a jack on the A board of a distant Central Office, as shown in fig. 7,550.

The A Switchboard.—The A board in a Central Office is that part of the operating switchboard where the subscriber lines and outgoing trunks are terminated to enable the telephone operator to receive signals and calls from subscribers and to make the first connections on all calls originated by any subscriber in that particular Central Office area.

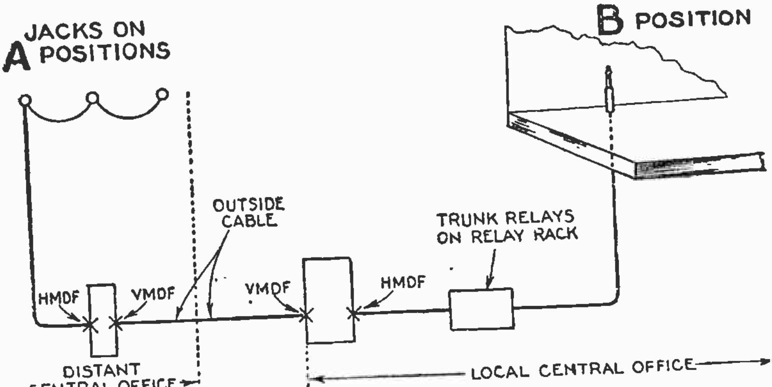


FIG. 7,550.—Diagram of trunk between A and B boards. The A board end is known as *outgoing trunk* (or O. G. T.), and is connected to a jack which is repeated on the face of the A board at every 6, 7 or 8 panels and the trunk is multipled to each jack. The B board end is terminated as a cord and is known as *incoming trunk*. There are relays associated with each trunk circuit, and these relays are generally located on relay racks in the terminal room. The incoming trunk cord is located at only one specific position of the B board.

The A board consists of sections, each of three operator positions, equipped with cords and jacks, and arranged to form a straight line, as in fig. 7,551, or a regular curve. It is similar to the B board in the construction of the wooden frame work and the design of the panels.

Answering and Trunk Jacks.—The jack equipment in the jack panel of the A board consists of the subscriber's answering jacks at the bottom, the multiple answering jacks above them,

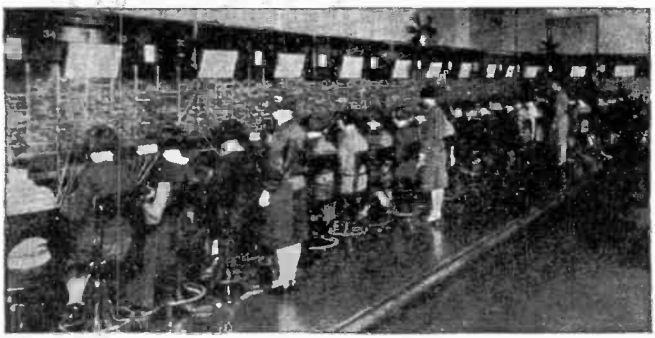


FIG. 7,551.—Typical A board in operation.

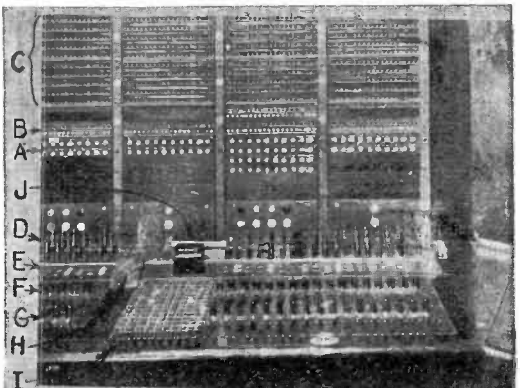
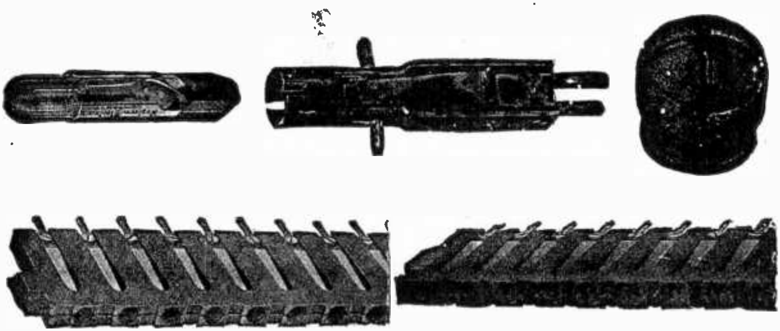


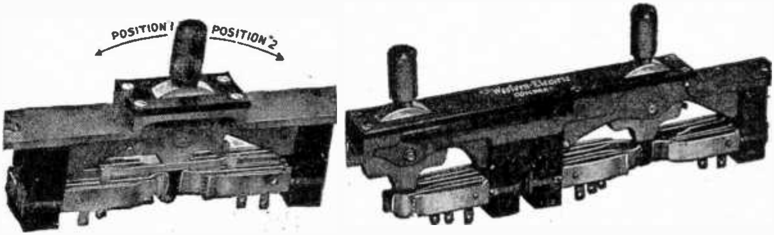
FIG. 7,552.—An A Board position. *Legend:* A, subscriber answering jacks and lamps; B, subscriber multiple answering jacks and lamps; C, outgoing trunk multiple (jacks only); D, connecting cords. There are two cords to each cord circuit, a front and a back cord. The back cord is used to answer and is inserted into the answering jack and the front cord is always inserted into the outgoing trunk jack; E, cord supervisory lamps, two to each cord circuit, one lamp for the back cord and one lamp for the front cord; F, message register key which when pressed operates a meter to register the call made by a subscriber; G, ringing and talking key. When tipped forward this key places ringing current to the front cord and when tipped backward the same key connects the operator's telephone set to the cords for talking and listening (key details shown in fig. 7,558); H, pad holder to hold a small pad on which the A operator writes the number calling and the number called with the time in case an extra charge is to be made for a connection; I, call circuit buttons. Each of these keys when pressed connects the A operator with a distant B operator. Each key represents a distant central office (B board); J, position clock, operated by electricity and shows the time in six second intervals.

and the outgoing trunk multiple jacks on top, as shown in fig. 7,552.

Each answering jack has below it a small lamp, shown in figs. 7,553 to 7,557. The answering jack and its lamp are connected to the subscriber line and cut off relays previously mentioned. The lamp lights when the receiver is removed from the hook at the telephone station associated with it.



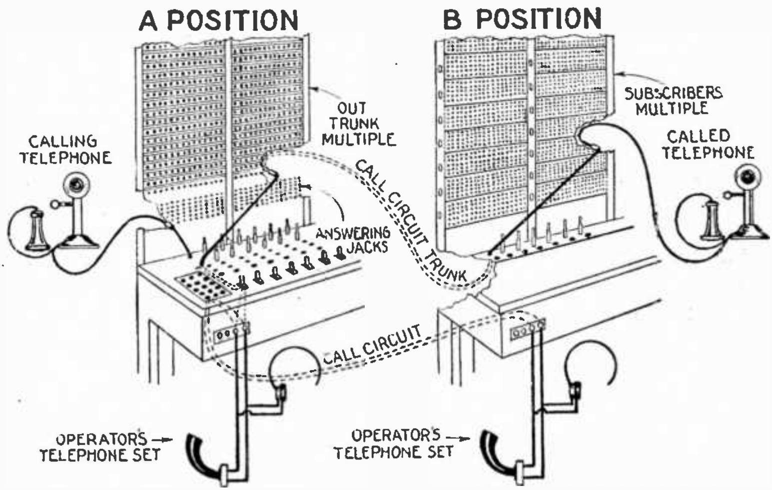
FIGS. 7,553 to 7,557.—Miniature electric lamp and parts. The lamp fig. 7,553 fits into socket, fig. 7,554, and the lamp cap fig. 7,555 fits at end of lamp socket. The glass of the lamp cap may be white opalescent, red, or green, or it may be marked with black bars or a dot. Figs. 7,556 and 7,557 shows hard rubber strips fitted with lamp sockets similar to the one of fig. 7,554.



FIGS. 7,558 and 7,559.—Switchboard keys. In order to meet the needs of every calling subscriber, the operator must perform several different acts in shifting and changing circuits and to facilitate this work, devices to simplify it as much as possible have been developed. The modern keys have greatly helped in the saving of the operator's time. By throwing the little levers a hard rubber bushing makes or breaks the contacts at the springs and throws alternating current ringing power into the line. When the finger pressure is released, the levers fly back again into normal position. The keys may be arranged to operate in the opposite direction for talking and listening purposes.

Keyboard.—On the keyboard of an A position are 17 pairs of cords, 17 keys to ring and talk, 17 register keys and 17 pairs of supervisory lamps. In addition there are a number of call-circuit keys.

Cord Circuits.—There are 17 cord circuits in each A position. Each cord circuit is composed of one pair of cords, one pair of lamps, one key to ring and talk and one register key.



Figs. 7,560 and 7,561.—Diagram of operation showing calling and called telephone and the Central Office A and B boards. The B board is assumed to be in a distant Central Office. It may, however, be located in the same Central Office as the A board in which case it serves to complete calls to subscribers in the same Central Office area.

Operation.—By referring to figs. 7,560 and 7,561 the operation for a telephone connection is made clear. Both the A and B boards are involved in every telephone connection, be it local or over a long distance.

Assume that the calling number is Stuyvesant 2997 and that the desired party has telephone number Bensonhurst 7813.

The A board will be located in the Stuyvesant central office and the B board in the Bensonhurst Central Office.

The calling party lifts the receiver off the hook and causes a lamp to light on the A board.

The A operator sees this light and inserts a back cord into the answering jack associated with the lighted lamp causing the lamp to be extinguished. The A operator says "Number please" and the calling party replies "Bensonhurst 7813." The A operator then says "Thank you," and presses a call-circuit button marked *Ben*, which connects her with the B operator who will complete the connection in the Bensonhurst Central Office.

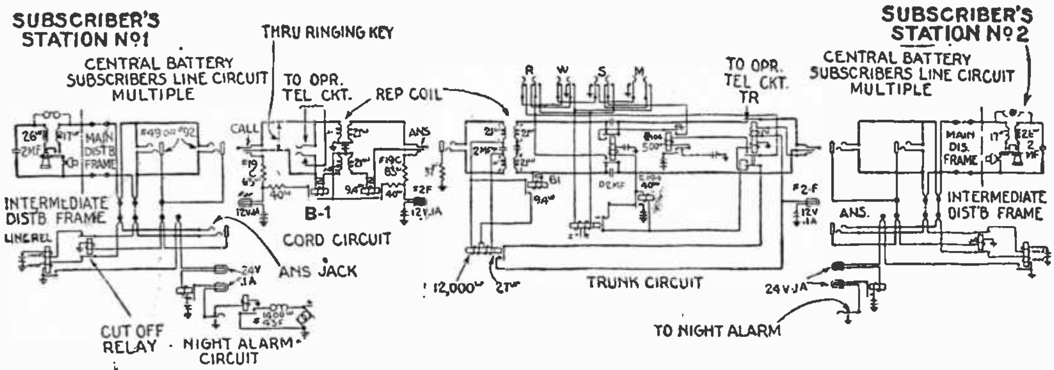
When the A operator has pressed the call circuit button she says to the B operator "Stuyvesant 7813" meaning that she is located in the Stuyvesant Central Office and desires a trunk connection to line No. 7813 in the Bensonhurst Central Office area.

The B operator assigns a trunk to the A operator, and simultaneously picks up the cord associated with the trunk she has assigned and inserts it into the jack marked 78-13. The A operator picks up the front cord of the pair she started with and inserts the plug into the outgoing trunk jack.

Before the B operator inserts the incoming trunk cord into line jack 78-13 she makes a busy test by touching the tip of the cord to the sleeve of the jack. If the line be busy at that moment, she receives a click in her head receiver, and instead of completing the connection, she inserts the cord plug into a different jack designated *busy*. This sends interrupted ground and a *busy tone* back to the A board, causing the front cord supervisory lamp to flash at the rate of sixty times per minute, which tells the A operator that the line called is busy. The calling party meanwhile hears the *busy tone* and hangs the receiver back on the hook. If he do not hang up, the A operator will advise him to do so by saying "I am sorry, but the line is busy."

If the line called be not busy, the B operator inserts the trunk cord into jack 78-13 and causes ringing current to be sent out automatically to ring the bell. When the called party answers, the ringing current is also automatically disconnected and the circuit is ready for talking

While the conversation is in progress, the cord supervisory lamps are not lighted. The instant the receiver is replaced on the hook, the corresponding cord supervisory lamp lights on the A board and the A operator disconnects,



FIGS. 7,562 to 7,565.—Typical telephone circuit showing calling subscriber line circuit, A board cord circuit, trunk circuit and called subscriber line circuit. The calling subscriber is located in the area cared for by the A board. The called subscriber is located in the area cared for by the B board. The A and B boards may or may not be in the same building and may be any distance apart.

If one end of the line should move the hook up and down slowly, the cord supervisory lamp in fig. 7,563 will flashto attract the attention of the A operator. The B board does not get this flash.

When the A operator has removed the trunk cord from the O.G.T. jack, at the end of the conversation, she causes the lamp on the B board associated with the trunk cord, to light, whereupon the B operator removes the cord from jack 78-13 and restores the trunk to normal for another connection.

The Complete Circuit.—The foregoing operation is made possible by the circuit shown in figs. 7,562 to 7,565. There are four main parts to this circuit:

1. The calling subscriber, fig. 7,562;
2. The local A board cords, fig. 7,563;
3. The trunk, which connects the local A board with the distant B board, fig. 7,564;
4. The called line at the distant end, fig. 7,565.

Making a Telephone Call.—The calling subscriber originates the call by lifting the receiver off the hook. This causes the line relay to operate and to connect ground to the line lamp, lighting it. The A operator upon seeing this light inserts the cord plug (call) into the answering jack above the lighted lamp.

The insertion of the plug into the jack causes the current to flow from the cord supervisory lamp to the *sleeve* of the cord plug, to the sleeve of the answering jack, and through the winding of the cut off relay causing this relay to operate and to extinguish the line lamp. The cord supervisory lamp does not light because it is short circuited through the contacts of relay B-1, which is operated.

After obtaining the information from the calling subscriber and also a trunk assignment from the B operator, the A operator inserts the *Ans* plug into the outgoing trunk jack. The supervisory lamp associated with this plug is now lighted since the B-1 relay of this plug has not yet operated, and will not be operated until the called party answers the telephone.

At the distant B board, the B operator takes the cord of the trunk assigned to the A operator and inserts it into the multiple jack of the line desired. If there be party lines in that Central Office, she depresses the proper party ringing key R.W.S., or M, before inserting the cord plug into the jack.

The bell at the called station now rings. The *disconnect* lamp at the B board is not lighted, and will not be lighted until the A operator disconnects.

When the called party answers, the ringing current is automatically disconnected and a path is completed for the electric current which causes the operation of the B-1 relay in the trunk, fig. 7,564. This causes the *Ans* cord supervisory lamp at the A board to be extinguished, advising the A operator that the conversation is now in progress.

At the end of the conversation the parties *hang up*, and each causes the associated B-1 supervisory relay to release and thereby light the corresponding cord lamp, advising the A operator that she may now take down the connections which she does and causes the *disconnect* lamp of the trunk to light at the distant B board. This signifies to the B operator that she may withdraw the trunk cord plug from the multiple jack, which she does, and restores the circuit to normal.

The "night alarm" shown in fig. 7,562, is used only when the switchboard is managed by a few operators, as at night.

When used, the night alarm relay, which operates when the answering lamp lights, causes the bell to ring to call the attention of the night operator who may be handling a connection at some other part of the switchboard. The bell stops ringing as soon as the operator answers the call.

Straight Forward Method.—A later development enables a trunk connection to be made in less time. This method eliminates the call circuit between the A and B operators and is termed *straight forward method.* Instead of asking for a trunk assignment from the B operator, the A operator picks out an idle trunk to the B board, and inserts the cord plug into the corresponding jack.

This causes the trunk lamp at the B position to light showing that there is a call waiting on that trunk. The B operator's telephone is then automatically connected to the same trunk and two short tone impulses are transmitted to the A operator, indicating that the B operator is ready to receive a call.

At the same time the steady trunk lamp at the B board changes to a flashing signal which aids the B operator in locating the trunk to which she is connected in case several trunk lamps are lighted at one time. The A operator then passes the number desired to the B operator who then makes the usual busy test.

If the line be idle she inserts the plug into the multiple jack, thereby extinguishing the flashing trunk lamp. The remaining operations are as previously explained for fig. 7,562.

Call Indicator Method.—On calls originated by subscribers in dialing central office areas, the connections are made by automatic switching apparatus, as explained in the next chapter.

In order to complete calls from subscribers in dial Central Office areas, the B board contains several positions which are known as *call indicator positions*. These are similar to the one shown in fig. 7,566, and differ from the regular manual positions only in the equipment of the keyboard, which contains a small metal box with a glass plate known as *call indicator* and upon which are printed five groups of digits known as:

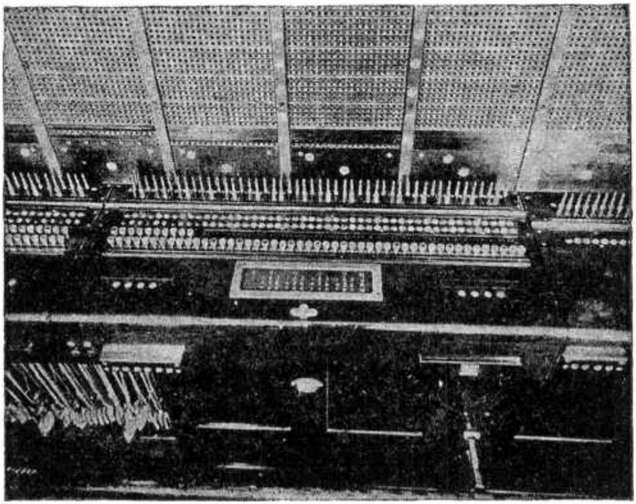


FIG. 7,566.—Typical call indicator position of a B board. The jack panels of these positions are equipped with subscriber multiple jacks like the rest of the positions on the B board. The *call indicator* box is mounted flush with the top of the keyboard.

1. Ten thousands;
2. Thousands;
3. Hundreds;
4. Tens;
5. Units.

The ten thousands group contains just 0 and 1. The other four groups have all ten digits from 0 to 9. There may also be letters for party designations. The metal box contains from 42 to 46 miniature lamps which are arranged so that each number or letter has a lamp underneath.

There is in addition at each position a control circuit composed of a number of relays. The function of the control circuit is to receive the pulses coming from the mechanical sender of a dial Central Office, as described in the next chapter.

The pulses cause the relays in the control circuit to operate in certain combinations which light the proper lamps on the *call indicator* and cause the number desired to be displayed on the glass cover. The B operator sitting at this call indicator position then takes the trunk cord over which the pulses were sent and inserts its plug into the jack corresponding to the number displayed on the glass plate, first however making the usual busy test.

When the connection has been made by the B operator the number displayed is automatically *wiped out*. The operations from this point on are the same as those explained for fig. 7,562.

Manual Private Branch Exchanges.—It is often necessary in the case of business offices, hotels, department stores and similar establishments, to have more than one telephone station and to arrange these stations so that each may call the other as well as call the Central Office to transact business. For this purpose there have been developed several types of manually operated switchboards which are located in the subscriber's premises and which are known as Private Branch Exchanges or P.B.X's.

These P.B.X.'s are connected to the telephone Central Office by means of lines called *trunks*, and have extension lines radiating to the various extension stations in the subscriber's establishment, as indicated in fig. 7,567.

The type of P.B.X. switchboard to be installed for a particular case depends upon the service requirements, such as the number of Central Office trunks, the number of extension stations and the amount of traffic to be handled.

The manual P.B.X. switchboards may be divided into two general classes:

1 Multiple. 2. Non-multiple.

In the multiple type the extension lines and the Central Office trunks are repeated along the face of the switchboard at every four panels, so that a call coming into the switchboard will simultaneously cause a lamp to be lighted at every appearance of that particular line and allow some operator, one who is not busy at that moment, to answer the call. This feature enables the switchboard to be made up of any number of operating positions up to the limiting quantity.

In the case of the non-multiple switchboards, the extension lines, and the Central Office trunks appear at only one spot on the face of the switchboard. This limiting device means that switchboards of this type are made up of a few operating positions, and are designed to fulfill a lighter demand for telephone service.

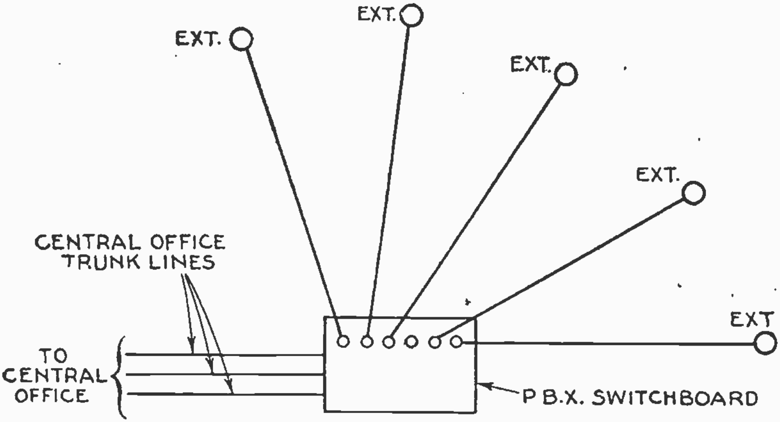


FIG. 7,567.—P. B. X. system.

Cordless Type Switchboard.—This is the smallest P.B.X. switchboard made and has keys as shown in fig. 7,568, instead of cords to make the connections. It consists of a small wooden box, the one shown being approximately 16 ins. wide by 15 ins. deep by 14 ins. high, and contains several keys, magnetic drop signals, hand generator which is used to ring the extension bells whenever the regular Central Office generator supply fails, and a telephone set.

Operation of Cordless Type Switchboard.—On connections between two extensions or between an extension and a Central Office trunk line, the two associated keys in the same horizontal row must be operated to the same up or down position, so as to bridge the two lines.

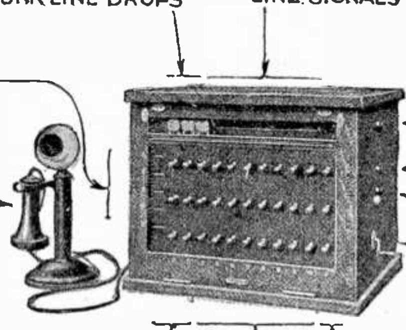


FIG. 7,568.—Cordless type P. B. X. switchboard. There are 3 rows of keys with 11 keys of the cam lever type in each row as follows: 3 keys for central office trunk lines (first 3 keys at left side), each with a trunk line drop above (details of drops shown in fig. 7,528). 7 keys for extension lines (keys 4 to 10), each with a magnetic line signal above; 1 key for the operator's line (last key at right). The keys provide for 5 simultaneous connections.

If one of the lines called be on a local extension, the ringing key in the bottom row associated with the called station must be held operated in the down position to ring the bell.

If two keys in the same horizontal row be operated to the same *up* position, two other keys in the same horizontal row may be operated in the *down* position, or vice versa, for a second connection.

Each of the five *up* and *down* positions on the horizontal row of keys has a magnetic supervisory signal mounted at the left of the keys in a vertical row. This operates as a disconnect signal when the receivers are placed on the switch hook and it may also be used to flash under the control of an extension at which the hook is being moved up and down.

Calls originated at one of the extensions are indicated by the operation of the associated magnetic line signal on the top row, which is restored to normal when the operator answers the call.

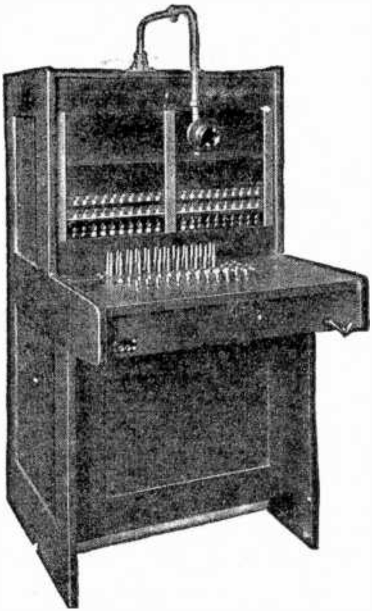


FIG. 7,569.—Cord type P. B. X. switchboard. Each extension jack and each trunk jack is equipped with a line lamp which lights when a call comes into the switchboard. The cords have supervisory lamps which light when the conversation is over and the receivers at the respective telephone stations are *hung up* to indicate to the P. B. X. operator that the connection may be taken down. The ringing key in each cord circuit has generator current from the Central Office to ring the local extension bells. If this generator supply should fail a small hand generator is equipped to furnish the necessary alternating current.

Calls coming from the Central Office are indicated at this P.B.X. by the operation of the associated trunk drop which has to be restored by hand after the call has been answered.

The necessary battery to operate this P.B.X. and the generator current to ring the extension bells is furnished over separate feeders from the Central Office. The hand generator is used to ring the extension bells only in case of failure of the Central Office supply.

Cord Type P.B.X. Switchboards.—These are equipped with cords to make the connections and have lamps and jacks similar to the Central Office switchboards. They are made in various sizes depending upon the specific needs. The one

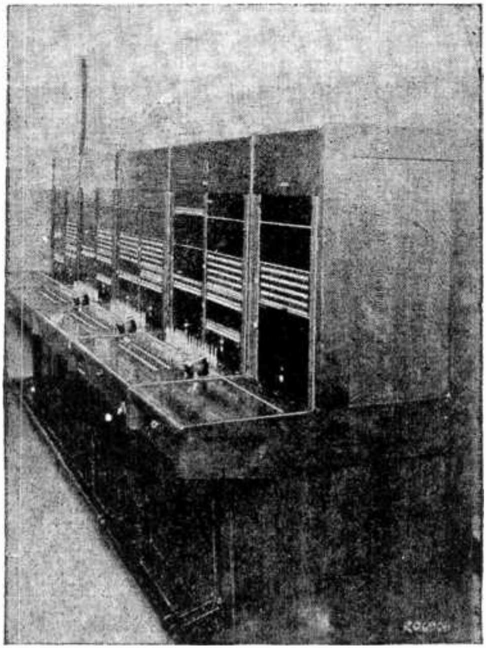


FIG. 7,570.—Multiple cord type P. B. X. switchboard of three positions. Note the dial on each position; this is made necessary since the P. B. X. is connected with trunk lines to a dial central office. The capacity of this switchboard without increasing the number of positions is approximately 500 lines.

shown in fig. 7,569 has a capacity of 80 extension lines, 15 central office trunks and 15 cord circuits (15 pairs of cords).

All the relays, resistances and retard coils of the cord and trunk circuits are mounted on a swinging gate in the rear of the switchboard.

Operation of Cord Type P.B.X. Switchboards.—The cords are arranged in pairs and are used to make all connections. There are two lamps associated with each pair of cords, and a set of listening and ringing keys. When connections are to be made between the local extensions, the back cord is inserted into the calling extension jack and the front cord into the desired extension jack.

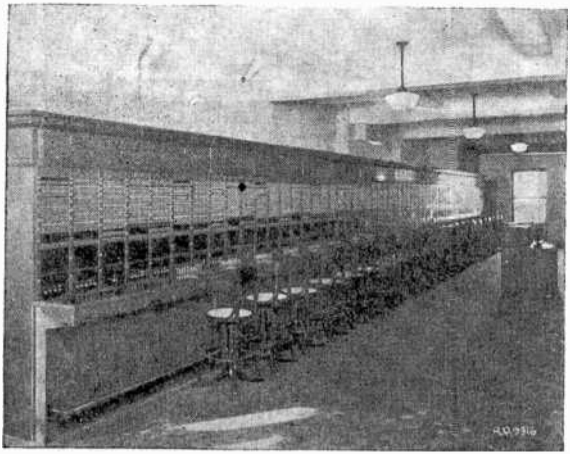


FIG. 7,571.—Large manual P. B. X switchboard.

The rear cord lamp is controlled by the switch hook of the calling extension and the front lamp by the switch hook of the called extension. On connections with central office trunks, the back cord is put up on the extension jack and the front cord on the trunk jack.

When a call comes into the switchboard, the lamp associated with the circuit lights. The operator then inserts the cord into the jack above the lamp and causes the light to be extinguished.

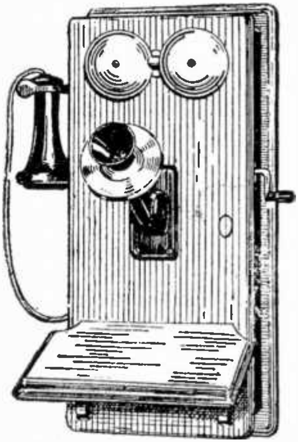
The operator, by tipping the respective key of the cord pair, can talk to the extension. By tipping the key to the *ring* position, generator current is applied to the cord, which, if inserted into an extension jack, causes the extension bell to ring. The ringing is manually controlled by the operator.

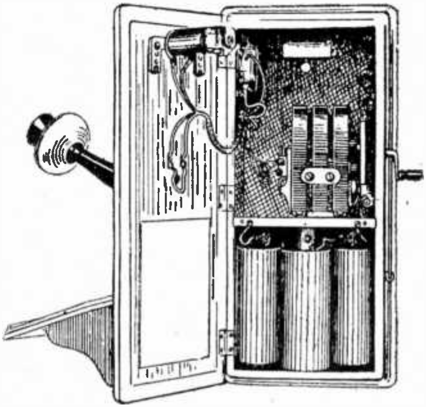
Large P.B.X. Switchboards.—Some P.B.X's have a capacity of 4,000 lines and are made up of as many as 40 operating

FIG. 7,572.—Operator's equipment showing receiver, transmitter cut in plug, etc. The chest plate transmitter equipment is shown with cords connecting it to a cut in plug and a head receiver. The horn shaped mouthpiece is made of hard rubber and can be removed. The chest transmitter is held in place by a cloth neck band, the receiver by a head receiver band and the plug is inserted in spring jacks which are connected with the operator's set.

positions. In these cases the switchboard is the same as the one used in the telephone Central Offices and requires similar main distributing frame, relay racks, and a large power plant consisting of a storage battery, charging machine, and a power board. One such P.B.X. switchboard is shown in fig. 7,571.

Operator's Telephone Set.—All telephone operators, in the central offices as well as in P.B.X's, have a head receiver and chest transmitter connected to a double plug as shown in fig. 7,572. When in use the plug is inserted into a double jack at the switchboard position in the manner indicated in figs. 7,560 and 7,561.





FIGS. 7,573 and 7,574.—Magneto set telephone; views showing case closed and open. The transmitter connections are made of stranded copper wire with a double silk insulation. These wires lead from the transmitter through the hollow arm to the inside of the door. From here one wire goes to one terminal of the battery and the other is soldered to a connector to which is already attached a wire that is carried through a slot in the back board to the primary winding of the induction coil. The set complete is made with all parts of the circuit and all wires well insulated.

Magneto System.—A magneto telephone is shown in figs. 7,573 and 7,574 which employs two or three dry cells at each telephone to supply the necessary talking battery instead of using a *common battery*.

This instrument is used in the so-called magneto telephone system where each telephone user signals or calls the telephone exchange or other telephones on the line by turning the crank of a small hand generator or magneto. This system has been made obsolete by the development of the common battery system, and is used only in small isolated plants.

Carrier Current Telephone System.—In the previous description of the telephone it was mentioned that for each conversation two wires were utilized. Where it is required to transmit telephone messages over long distances it is sometimes necessary to employ one of the long lines, or toll line, to carry more than one conversation in both directions simultaneously without interference with one another. This method is known as *Multiplex Telephony* or *Carrier Current Telephone System*.

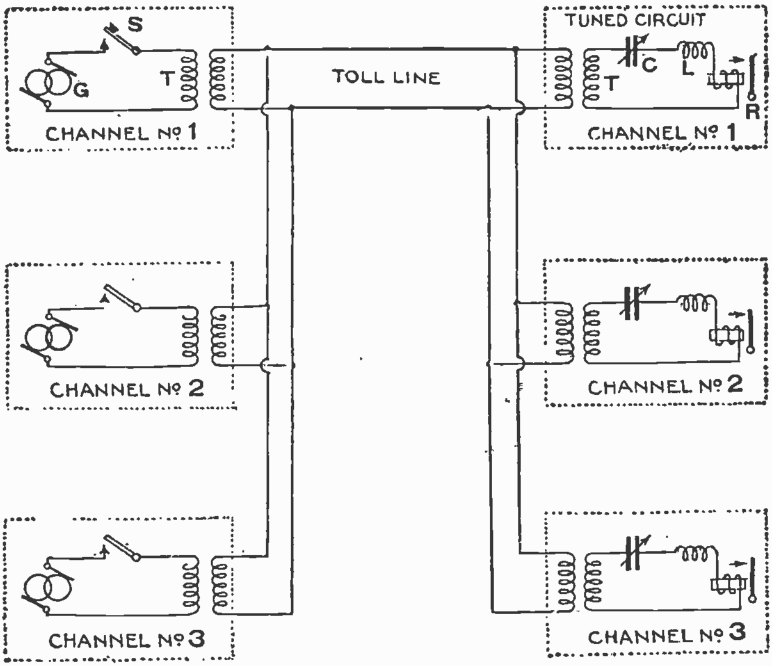


FIG. 7,575.—Simplified Multiplex circuit, *consisting of three channels*, each equipped alike and arranged to operate simultaneously over the same toll line. Each sending station is equipped with a high frequency generator G, a sending key S and a repeating coil T. Each receiving station is equipped with a repeating coil T, a variable condenser C, an inductance L, and a sounder relay R.

It is accomplished by superimposing on the same pair of wires a number of alternating currents, each of different frequency and each controlled to carry a particular telephone conversation.

The method of operation of this system is illustrated in the simple diagram, fig. 7,575.

The illustration shows three different channels, or stations, using the same toll line simultaneously. Each channel is equipped the same, except that the generator G has a different frequency for each channel. By operating the sending key S, signals of frequency G are transmitted over the toll line which are picked up at the receiving end by the tuned circuit which

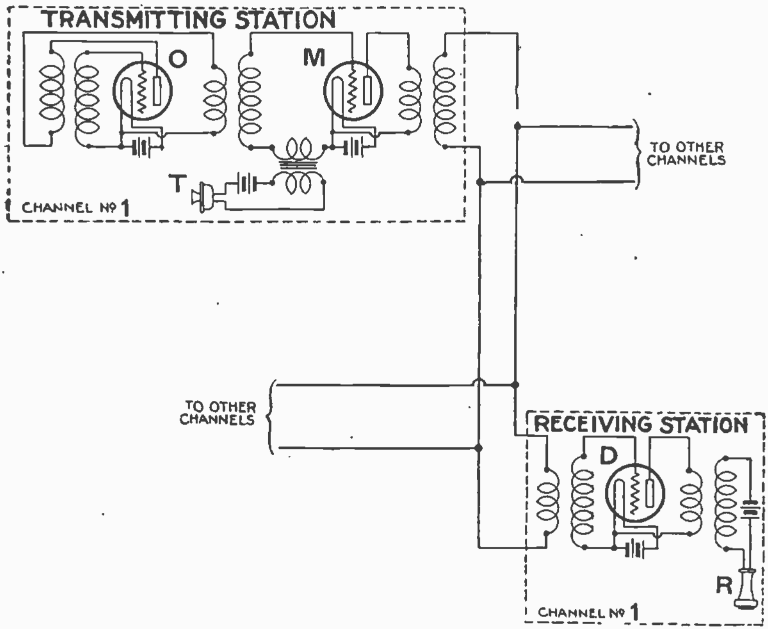


FIG. 7,576.—One channel of a carrier current telephone circuit *the transmitting station consists of:* O, vacuum tube oscillator circuit, which generates the high frequency carrier current; M, vacuum tube modulator circuit, which impresses the voice currents on the carrier current; T, transmitter. *The receiving station consists of:* D, vacuum tube demodulator circuit, which separates the voice currents from the carrier current wave; R receiver which reproduces the speech.

is adjusted in *resonance* with the frequency of G. Similar operation of the channels No. 2 and No. 3 cause signals of other frequencies to be sent over the same toll line at the same time.

At the receiving end, however, each tuned circuit, being adjusted in resonance to the respective generator frequency will pick up messages only from its own sending station. The tuned circuits are made very *selective* so that no interference results between the three messages.

The elements illustrated in fig. 7,575 are employed in the present type carrier current telephone system, except that instead of using the key to produce the messages, the ordinary subscriber transmitter is used to *modulate* the high frequency current of generator G. The generator may be a small mechanically driven alternator built as a unit with the driving motor, capable of supplying as many as twelve channels in the voice frequency range of 400 and 2,500 cycles per second; or it may be the ordinary three element vacuum tube connected as an oscillator.

The use of the vacuum tube is more desirable on account of its numerous advantages over the mechanically driven alternator. The vacuum tube has no moving parts to get out of order, takes up little room, is very easily adjusted and has a low first cost and upkeep cost.

In fig. 7,576 is shown a simple carrier telephone system employing vacuum tubes.

Operation.—The vacuum tube oscillator O operates similarly to a detector tube with *regeneration* in a radio set. When the *feed back* from

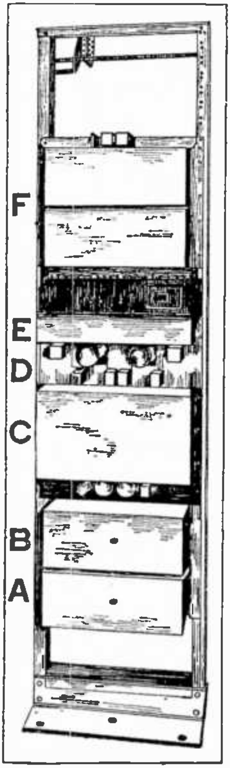


FIG. 7,577.—Typical carrier current unit A, modulator band filter; B, demodulator band filter; C, channel unit consisting of oscillator, modulator and demodulator also shown in figs. 7,578 and 7,579; D, signaling unit shown in fig. 7,580 E. adjusting unit; F, line filters.

the plate circuit exceeds a certain value the tube will cause a *howl* in the radio loud speaker. The howl is caused by *high frequency oscillations* produced by the vacuum tube. In fig. 7,576 the high frequency oscillations produced by the oscillator tube O are of constant current value, and would, of

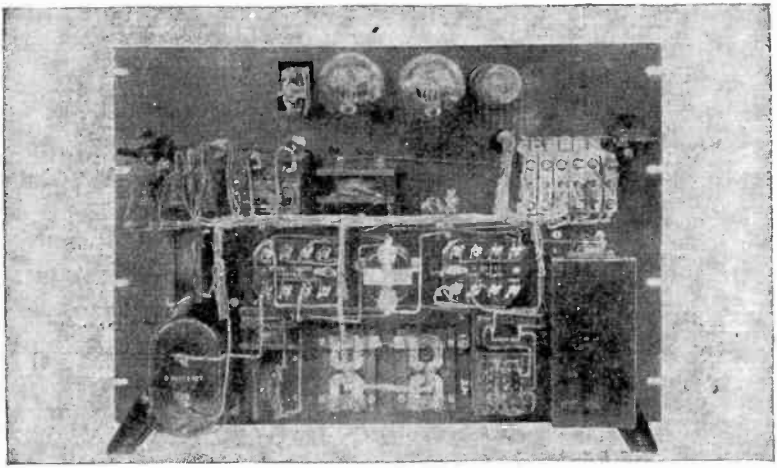


FIG. 7,578.—Front view of channel unit with cover removed consisting of oscillator, modulator and demodulator.

course, convey no information to the receiving end. It is necessary to *modulate*, or to impress upon this *carrier current* the signals, or the conversation.

This is done by using a transmitter in conjunction with another vacuum tube, designated M. The carrier wave undergoes a change as a result of this *modulation*, that is, variations are produced which correspond to the *voice* wave.

The modulated carrier current reaches the receiving set where the demodulator tube D separates the *voice* wave from the *carrier* wave. The demodulator is in reality a *detector* very much like the detector in a radio receiving set.

It must be remembered that other channels, similarly equipped, may be operating and using the same line simultaneously in both directions. However, the oscillator circuit in each channel generates a *carrier* of a different frequency and the associated receiving station is adjusted to receive only at that particular frequency. The several *carrier* currents from the various transmitting stations will not interfere with each other while traversing the common line wires.

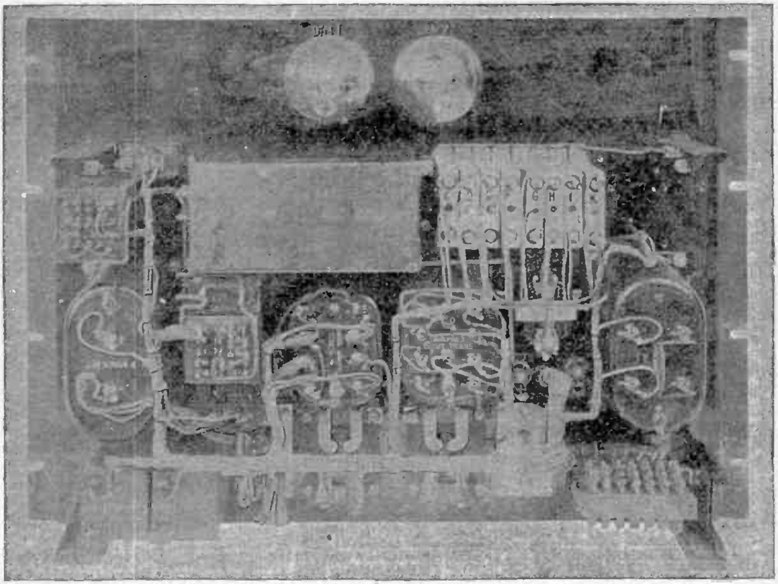


FIG. 7,579.—Rear view of channel unit with cover removed.

Commercial Current Carrier Units.—The commercial types of current carriers are made up in units which are wired and adjusted at the factory. These units are mounted on steel racks and are located in some centralized terminals, such as central offices. They may be wired to jacks which are located on the switchboard of the central office.

Each complete circuit is wired to the distributing frame where by means of cross connection wire connection may be made to a particular toll line and to the switchboard jacks when required. Fig. 7,577 shows the equipment for one circuit, both sending and receiving, with enlarged views of the units in fig. 7,578, 7,579 and 7,580.

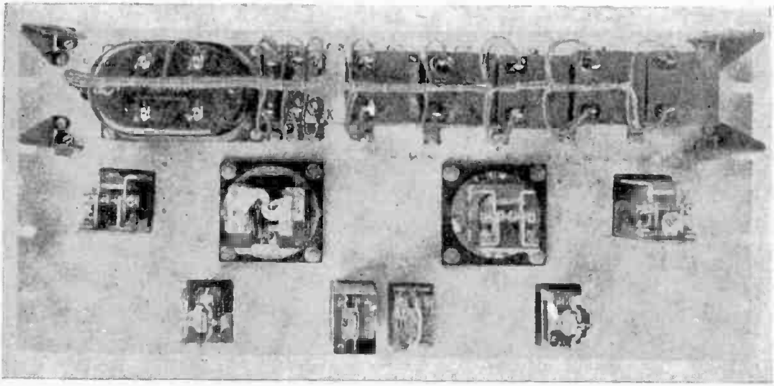


FIG. 7,580.—Front view of signaling unit. When the switchboard operator presses the ringing key at the switchboard, ringing current of 20 cycles is applied to this unit which causes by modulation spurts of the carrier current to be sent out over the toll line to the distant switchboard which is equipped with a similar unit. The signals at the receiving end are demodulated and a series of relays operate in the similar signaling unit causing the lamp associated with the toll line to light.

Ship-to-Shore Communication.—The first practical conversation between telephones on land and a ship at sea took place in the year 1922. On this occasion telephone apparatus on the S.S. America was employed while the ship was 400 miles out in the Atlantic Ocean. Before this date extensive experiments in two way conversation had been carried on between two ships and several cities in the United States.

In order to establish a conversation between a telephone station on land and one on a ship while the latter is on a voyage, *the message is transmitted by wire to a radio station located on or near the coast, thence to the ship by radio* as shown in fig. 7,581.

Likewise, conversation originated at S on the ship is sent by radio and is picked up by the radio station B.S. on land, thence it is transmitted by wire through the central offices to the telephone station L.

The system illustrated in fig. 7,581 is also used to establish telephonic communication between airplanes and land stations. This, however, has not as yet been performed on a commercial basis.

When a ship arrives at a pier, facilities are available to connect the telephone switchboard on the ship and the P.B.X. switchboard of the associated steamship company on land.

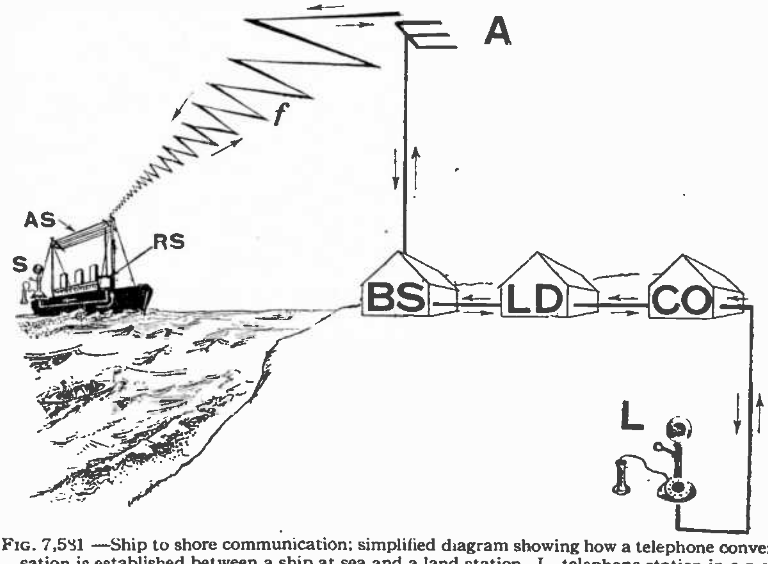


FIG. 7,581 —Ship to shore communication; simplified diagram showing how a telephone conversation is established between a ship at sea and a land station. L, telephone station in a residence or in an office; CO, local telephone central office; LD, long distance telephone exchange; BS, radio sending and receiving station on land; A, aerial on land; *f*, radio wave; AS, aerial on ship; RS, radio receiving and sending set on ship; S, telephone station on ship.

This is done by means of a portable insulated cable of several pairs of wires which is connected at one end to a terminal box on the pier, and at the other end there is a plug which may be inserted into a multi-circuit jack on the ship. The jack is connected to the telephone switchboard on the ship and the terminal box on the pier is connected to the P.B.X. switchboard on land.

TEST QUESTIONS

1. *Why is it necessary to supply a steady direct current to the telephone transmitter?*
2. *Does the receiver diaphragm vibrate at the same rate as the transmitter diaphragm?*
3. *Why is an iron diaphragm used in the receiver?*
4. *Describe the action in the receiver.*
5. *What will be the result in transmission if the carbon granules in the transmitter stick together?*
6. *What will be the effect upon the receiver if too much current be allowed to pass through the windings?*
7. *Will a bent diaphragm in the receiver cause trouble?*
8. *What will affect the sensitiveness of the receiver?*
9. *What will affect the sensitiveness of the transmitter?*
10. *Can a receiver be used as a transmitter?*
11. *What is the function of the condenser in the subscriber's bell box?*
12. *Describe the operation of the bell.*
13. *State what happens when the receiver is removed from the hook.*
14. *What is the duty of the line relay?*
15. *What is the duty of the cut-off relay?*
16. *Describe the A-board and explain its function.*
17. *Describe the B-board and explain its function.*

18. *Explain how a connection is established between the calling and called subscriber.*

19. *What is meant by "straight forward operation" of trunks?*

20. *How does the heat coil protect a telephone line?*

21. *Mention one serious trouble that will cause a large number of answering jack lamps to light on the A-board.*

22. *If a call circuit become inoperative how is the connection established between the A-board and the distant B-board?*

23. *What will happen if the ringing machine fail in a particular Central Office?*

24. *When does the A-operator take down the connection at the A position?*

25. *What indicates the end of conversation between two subscribers?*

26. *Can the A-operator talk to the calling party?*

27. *Can the A-operator talk to the called party?*

28. *Can the B-operator talk to the A-operator?*

29. *Can the B-operator talk to the called party?*

30. *When does the B-operator disconnect the trunk cord from the subscriber's multiple jack?*

31. *Who disconnects first, the A- or the B-operator?*

32. *What may cause a premature disconnection at the A or at the B-board?*

TEST QUESTIONS

Carrier System

1. *What is resonance?*
2. *What will be the effect upon transmission if one of the line wires of fig. 7,575 become grounded?*
3. *If the receiving circuit of channel No. 1 in fig. 7,575 be tuned exactly half-way between the frequency of channel No. 1 and the frequency of channel No. 2 what effect will it have upon the reception of channel No. 1?*
4. *Draw a simple diagram of a double channel two way carrier circuit.*
5. *Draw a diagram of a vacuum tube oscillator and describe its operation.*
6. *What is modulation of a carrier?*
7. *Explain how the carbon button transmitter could be used to modulate a carrier current.*

CHAPTER 186

Inter-Communicating Telephones

(Inter-Phones)

Inter-Communicating Telephones.—Inter-communicating or inter-telephones are those in which calls are made directly at each station without the aid of a P.B.X. operator, that is, each telephone has its own switchboard attached. Inter-phones are desirable in mills, factories, apartment houses, stores, office buildings, etc. Figs. 7,582 and 7,583 show two types of inter-phones.

An inter-phone system works as follows:

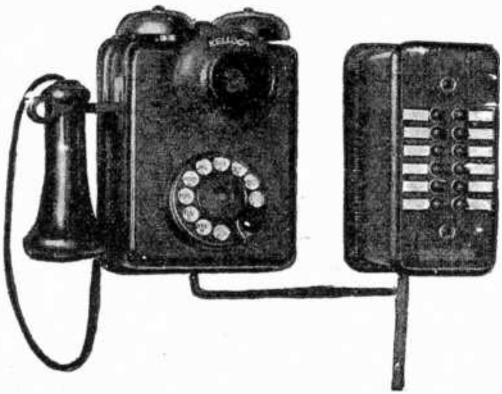


FIG. 7,582.—Kellogg 11 station automatic, wall type inter-communicating telephone.

The pressing of any of the buttons rings a particular station, and when the finger is removed from the button, it falls back on the talking circuit, connecting the system with the station desired.

When through talking with this station and another station is desired, the pressing of the other button restores to its normal position the station that has just been connected, as each button is arranged to automatically restore or release the other buttons.

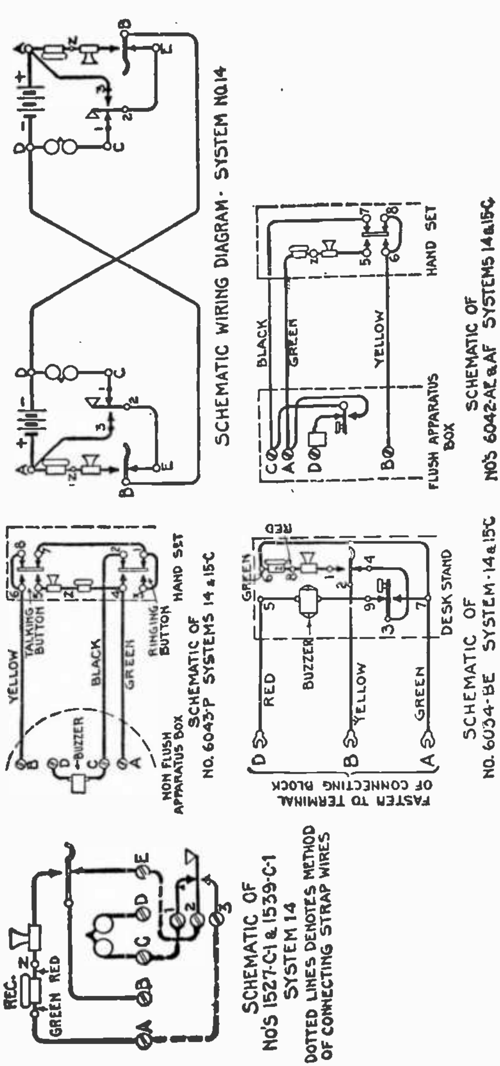
When the conversation is completed, the placing of the receiver on the hook restores whatever button may have been in use.

FIG. 7,583.—Kellogg 11 station desk inter-communicating telephone.

To meet the different conditions in home and business, various inter-phone systems have been designed, which differ in the number of instruments that can be connected, the kind of service they will give, etc.

The systems in general use are:

1. Two station; private line.
2. Code ringing; common talking.
3. Selective ringing; common talking.
4. Selective ringing; selective talking



FIGS. 7,584 to 7,588.—Schematic diagrams of Graybar two station private line inter-phone system; 7,584, wall type; 7,585, hand set, surface box type; 7,586, hand set, desk stand; 7,587, hand set, flush box type.

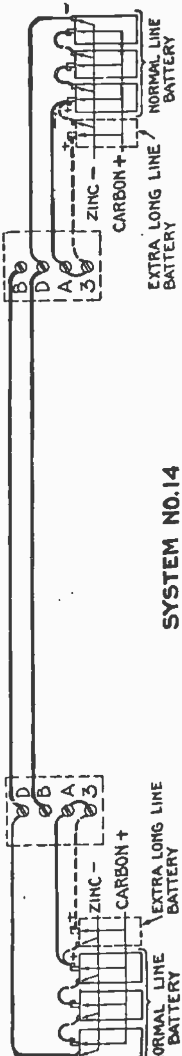


FIG. 7,589.—Diagram of connections of Graybar two station private line inter-phone system.

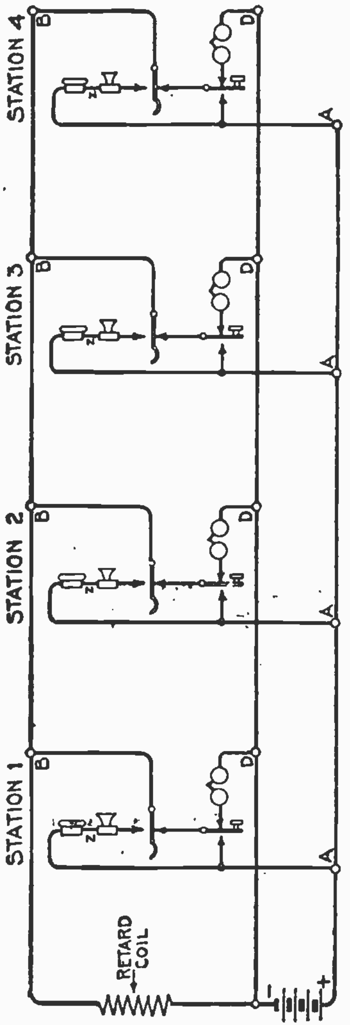


FIG. 7,590.—Wiring diagram of Graybar code ringing, common talking inter-phone system.

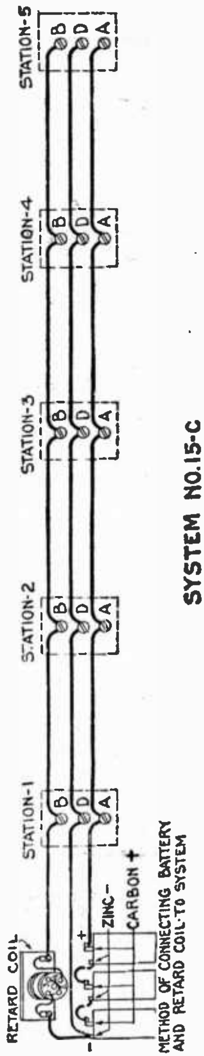


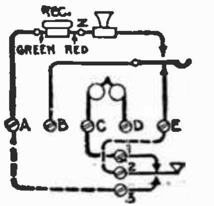
FIG. 7,591.—Diagram of connections of Graybar code ringing, common talking inter-phone system.

5. Master station; common talking.
6. Master annunciator.
7. Master annunciator; common talking.

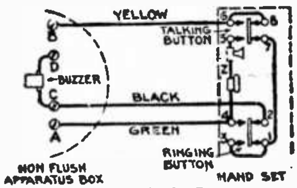
Two Station Private Line.—This system is for a small installation where the sets are distantly located from each other. Only two wires are used for connecting the inter-phones, dry cells being required at each station.

In operation, either station can ring the other by simply depressing the push button of the set. Wall, desk, or hand set inter-phones may be used interchangeably.

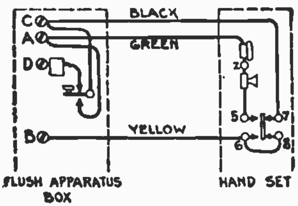
A battery of three dry cells is required at each station to furnish current for talking and ringing if the length of line be less than 750 feet. If the



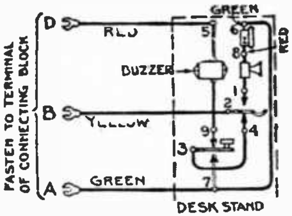
SCHEMATIC OF NO'S 1527-C-1 & 1539-C-1 SYSTEM 15-C
DOTTED LINES DENOTE METHOD OF CONNECTING STRAP WIRES FURNISHED WITH EACH SET (SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF NO. 6043-P SYSTEMS 14 & 15-C



SCHEMATIC OF NO'S 6042-AE & AF SYSTEMS 14 & 15-C

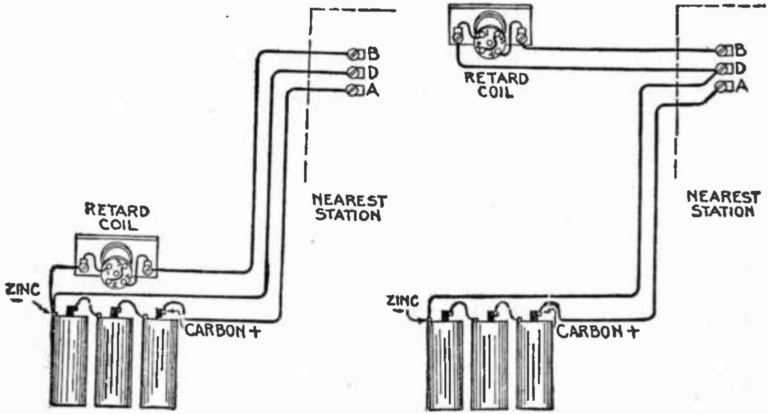


SCHEMATIC OF NO. 6034-BE SYSTEM-14 & 15-C

FIGS. 7,592 to 7,595—Schematic diagrams of Graybar code ringing, common talking inter-phone system.

length of line be increased, additional dry cells are required at each station to insure satisfactory ringing.

Code Ringing: Common Talking System.—This is a simple and inexpensive system for small residences, warehouses, stores



Figs. 7,593 and 7,597.—Method of connecting battery for Graybar code ringing, common talking inter-phone system. A retardation coil is required for this system. This coil is mounted on a small wood block and provided with two terminals. The function of the retardation coil in this system is to prevent the talking current being shunted through the battery while a conversation is being carried on. Only one battery is required to furnish current for talking and ringing. Do not use more than five Blue Bell dry cells connected in series. The retardation coil must be mounted close to the battery or at a point between the battery and the nearest station. The connections should be made as shown in fig. 7,596. Three wires should be run from the battery and coil to the nearest station as shown. In case the coil is to be mounted close to the nearest station, the connections should be made as shown in fig. 7,597.

or mercantile establishments, where only a few stations are required and the number of calls between the stations is not frequent. Requires only three line wires throughout the system for two or more stations. Only one conversation can be carried on at a time.

Each station is equipped with a push button. In operation, when the push button is depressed the bells at all the other stations ring.

If more than six stations be in service, signaling code mistakes are likely to occur, due to the possibility of misunderstood signals.

Where the initial installation comprises more than four or six stations the selective ringing common talking system should be used.

FIG. 7,598.—Graybar selective ringing common talking cradle type inter phone system. *It consists of* a hand set with a cradle type mounting having push buttons mounted in the base. The hand set is black moulded bakelite. The interphone set includes an apparatus box containing a bell and a connecting block.

Selective Ringing: Common Talking System.—This system is adapted to multi-station installation where conversation can be limited to one at a time. Any station in the system can selectively ring another station.

Each inter-phone in the system is equipped with a number of push buttons, one for each other station in the system.

In operation, by depressing the button marked with the name or number of the station wanted, the bell at that station only will ring. Wall type inter-phones for this system may be obtained in capacities of 2, 3, 4, 6 and 8 buttons, accommodating 3, 4, 5, 7 and 9 stations respectively; desk and hand set inter-phones in capacities of 4 and 8 buttons, accommodating 5 and 9 stations respectively.

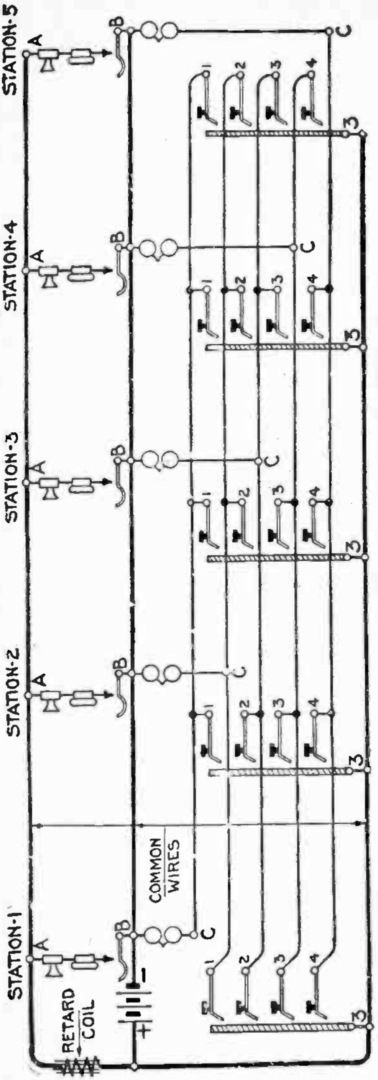


FIG. 7,599.—Wiring diagram of Graybar selective ringing, common talking inter-phone system.

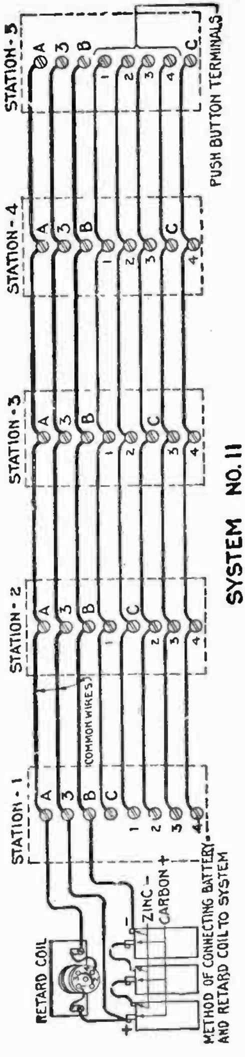
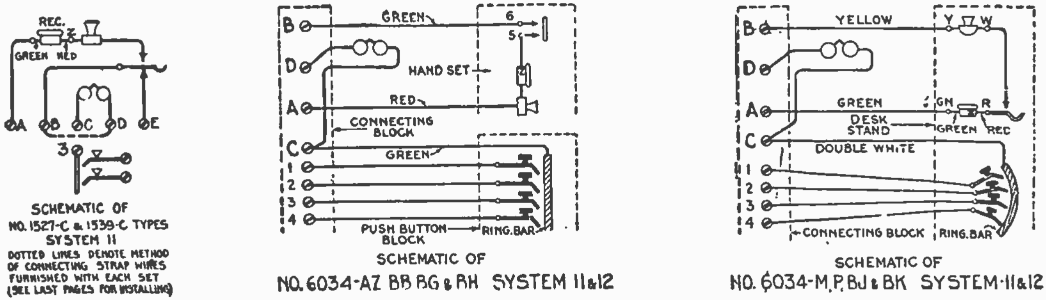
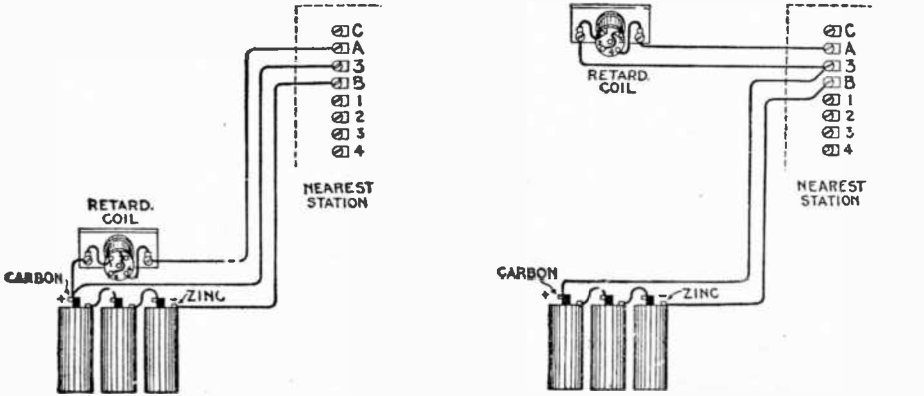


FIG. 7,600.—Diagram of connections of Graybar selective ringing, common talking inter-phone system.



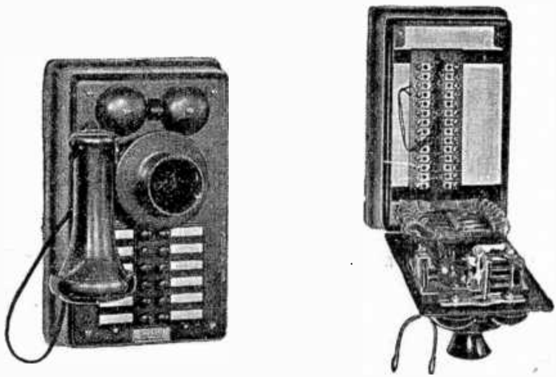
Figs. 7,601 to 7,603.—Schematic diagrams of Graybar selective ringing, common talking inter-phone system.



Figs. 7,604 and 7,605.—Method of connecting battery for Graybar selective ringing, common talking inter-phone system.

Selective Ringing: Selective Talking System.—The adaptation of this system is for service where frequently more than one conversation may take place at the same time, where connections without loss of time are necessary and where the highest grade of transmission is required.

In operation, each station can, a by pressing button, selectively ring and talk with any other station without disturbing the rest of the stations in the system and as many separate conversations can be carried on simultaneously as there are pairs of inter-phones.



FIGS. 7,606 and 7,607.—Graybar selective ringing selective talking wall inter-phone in assembled and open positions. This is an all metal phone having a hinged face plate, movable transmitter and hand receiver. The sets are finished in black enamel. The face being hinged makes it possible to easily inspect all connections and apparatus, without disturbing the installation.

For example, in a system consisting of six inter-phones, three separate conversations can be carried on at the same time. For each station in the system, one push button key is required in each inter-phone.

Inter-phones for this system are available in standard sizes of 6, 12, 16, 20 and 24 buttons.

The push button keys and their operating mechanism are mounted in a rigid metal frame. In designing this key two operations are arranged for, as follows: Each key consists of a hard rubber push button mounted on a metal plunger, which passes through a hole in a movable locking plate. When the button is completely depressed the spring makes contact

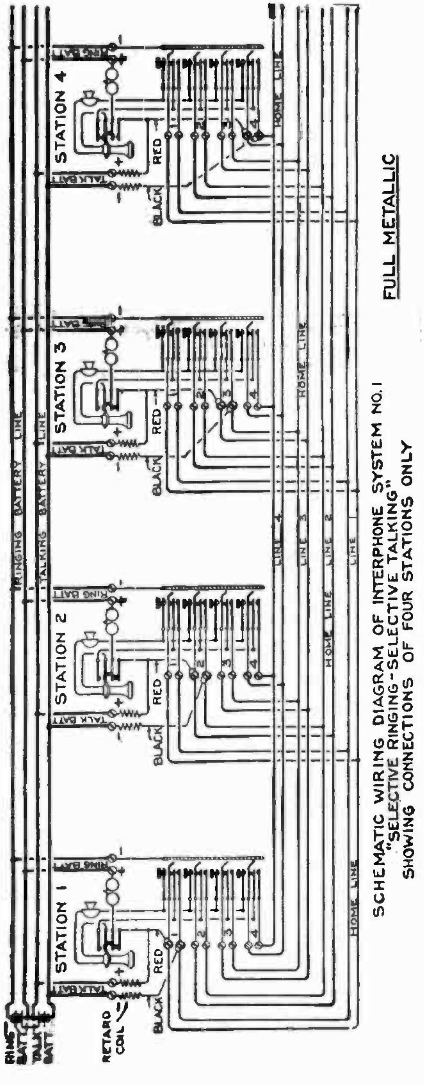


FIG. 7,603.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; *full metallic.*

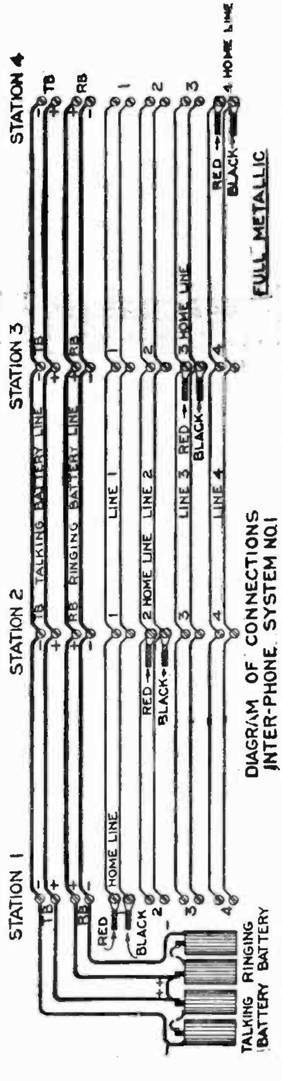


FIG. 7,609.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; *full metallic.*

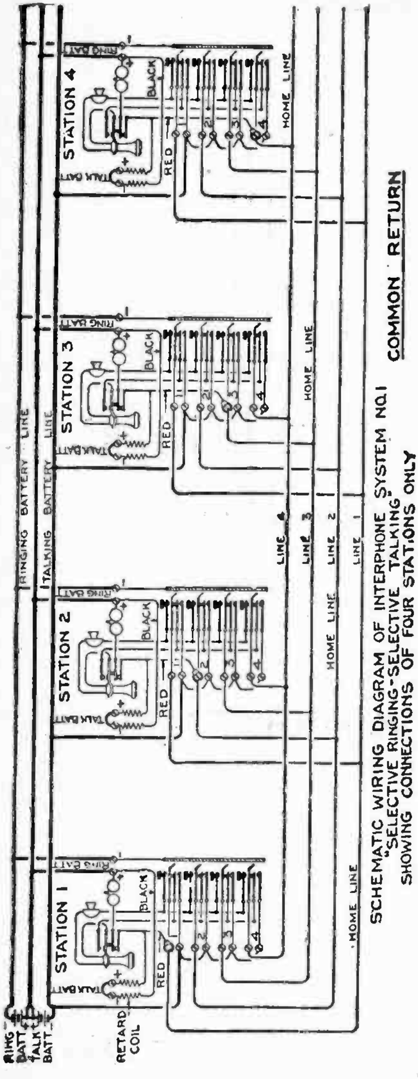


FIG. 7,610.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; *common return.*

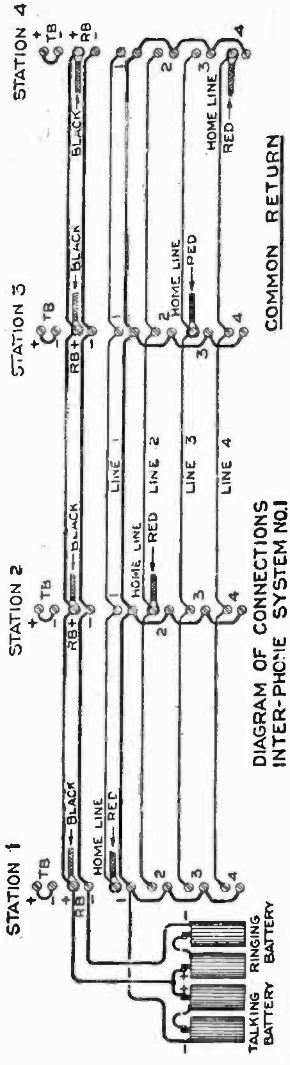
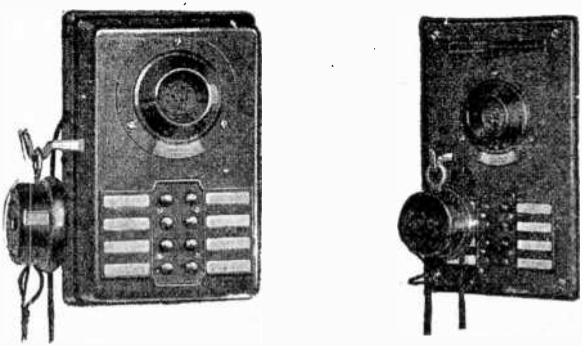


FIG. 7,611.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; *common return.*

with the ringing battery supply causing the ringing current to flow to the station to which this particular key is connected, and ringing the bell at that station.

When the pressure is released, the plunger returns to an intermediate position, breaking the ringing contact and placing the inter-phone on the line of the station called ready for conversation.

While the conversation is taking place, the plunger is automatically held in the talking position by the locking plate until the plate is actuated by depressing another button. The pressing of another button causes the locking plate to release the key so that it assumes its normal position. Talking current for the inter-phone is cut off as soon as the receiver is replaced on the switch hook.



Figs. 7,612 and 7,613.—Graybar master station common talking inter-phone system; projecting and flush wall type sets.

Master Station: Common Talking System.—It consists of one centrally located master station inter-phone to which are connected other *outlying station* inter-phones. The system provides for communication from a central point to different stations and vice versa.

The outlying stations are equipped with only one button which will ring the master station when depressed. Only one conversation can be carried on at a time.

The master station inter-phone is equipped with a number of push buttons; one for each outlying station.

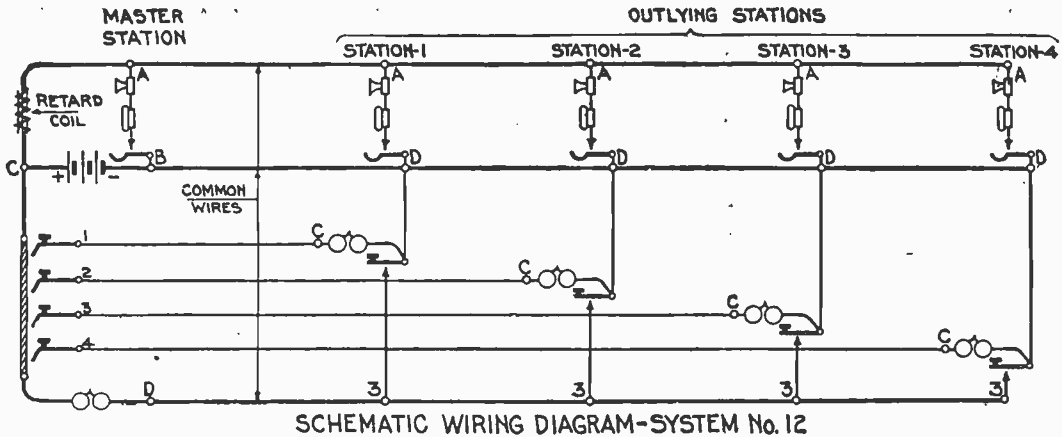


Fig. 7,614.—Wiring diagram of Graybar master station, common talking inter-phone system.

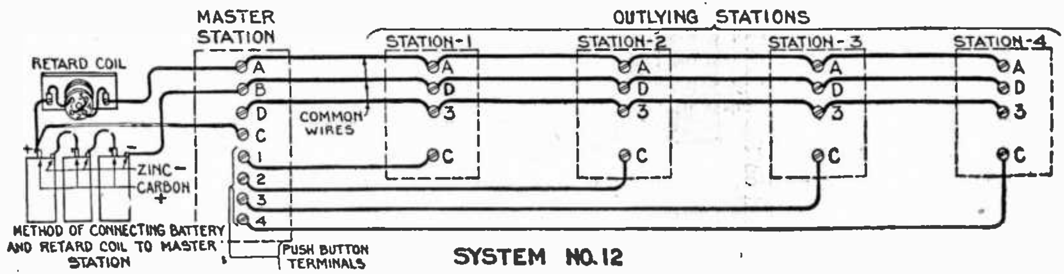
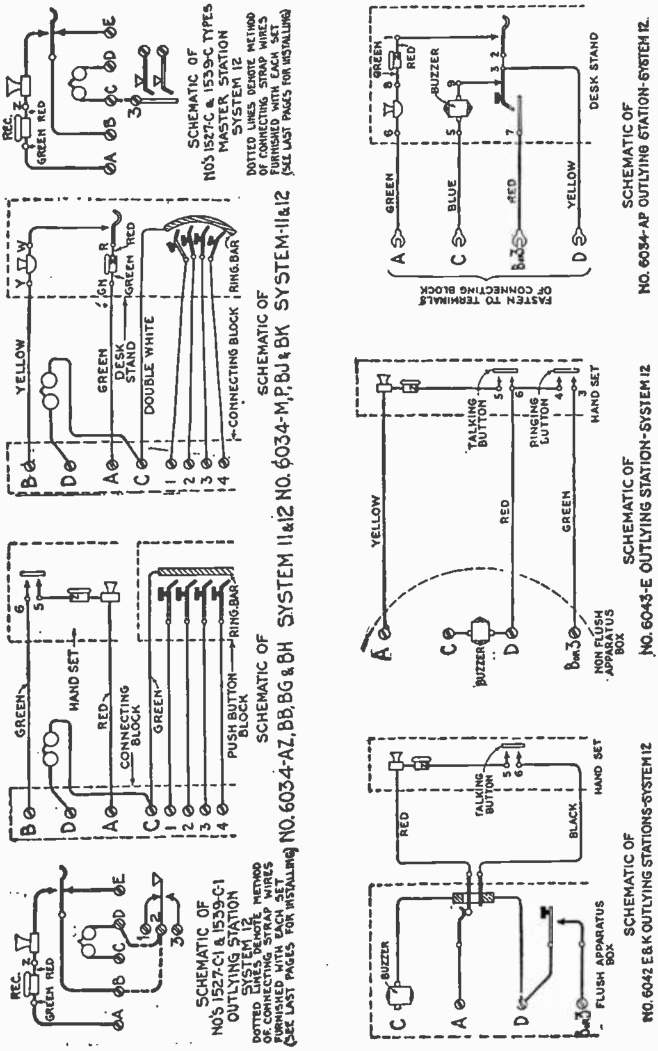


Fig. 7,615.—Diagram of connections of Graybar master station common talking inter-phone system.

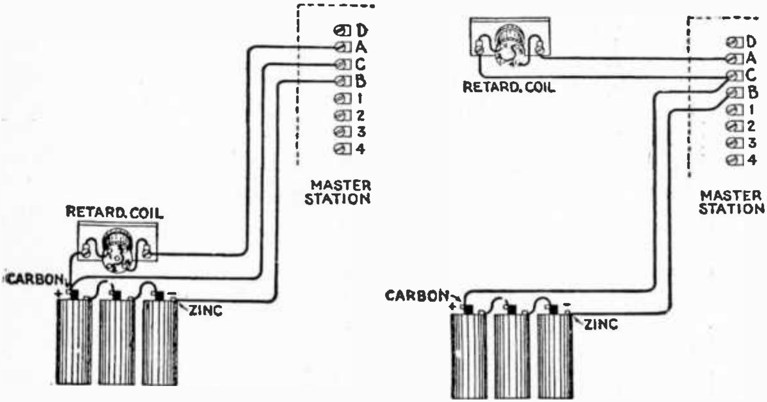


Figs. 7,616 to 7,622.—Schematic diagrams of Graybar master station, common talking inter-phone system.

In operation, when a push button is depressed marked with the name or number of the outlying station wanted, the bell at that station only will ring.

The system is adapted to one master station and from two to sixteen outlying stations.

Wall, desk and hand set inter-phones may be used for either the master or outlying stations.



FIGS. 7,623 and 7,624.—Method of connecting battery to master station for Graybar master station common talking inter-phone system. Do not use more than five Blue Bell dry cells connected in series. When using wires of No. 22 B. & S. gauge (as contained in the standard inter-phone cables recommended for this system) the wire distance between the master and the farthest outlying station should not exceed 750 ft., as this is the longest distance over which satisfactory ringing can be secured with apparatus of this system and with battery and wires of the size outlined. The retardation coil may be mounted close to the battery or at a point between the battery and the master station. The connections should be made as shown in fig. 7,623. Three wires should run from the battery and coil to the master station. In case the coil is to be mounted close to the master station, the connections should be made as shown in fig. 7,624.

Master Annunciator System.—This is a non-interfering system designed to provide for communication between a central or master station and a large number of outlying stations.

The master station can selectively ring and talk with any of the outlying stations and the outlying stations can call the master station.

The master station annunciator consists of a number of drops and jacks one for each outlying station in the system, a push button for ringing, a hand set inter-phone and a cord and plug for calling and answering.

Each outlying station inter-phone is equipped with a push button for ringing the master station and at the same time operating one of the annunciator drops, thereby registering the call.

In operation: 1. To call an outlying station, the master station operator inserts the plug into the jack corresponding to the station wanted and depresses the ringing button of the

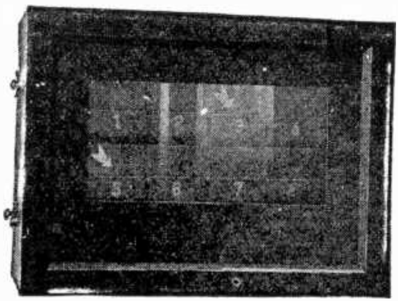
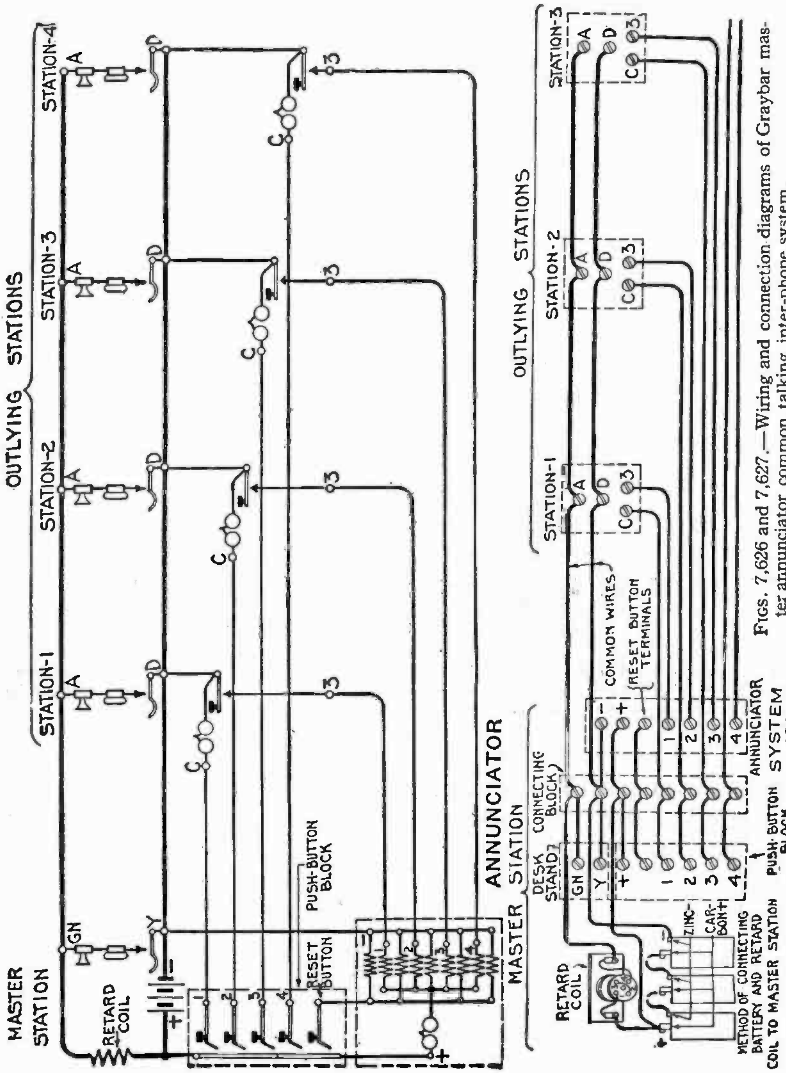


FIG. 7,6"5.—Graybar master annunciator, common talking system electric reset annunciator. The drop indicator is a white arrow which points directly at a white drop number; it can be seen from any angle. The audible signal is a new type double adjusting buzzer.

annunciator. The operator converses with the outlying station by pressing the talking lever of the hand set inter-phone; 2. The master station operator answers by inserting the answering plug into the jack corresponding to the drop operated and pressing the talking lever of the hand set.

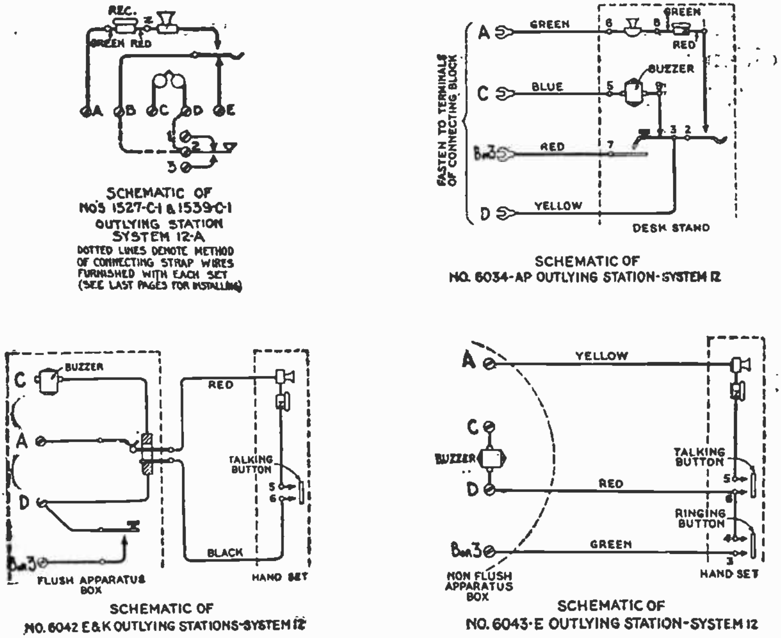
This system is only recommended for two-way service between the master annunciator and each outlying station. It is not designed for service between outlying stations, as there are no means of supervising such calls. For large installations where connections are required between stations a private branch exchange switchboard is used.



FIGS. 7,626 and 7,627.—Wiring and connection diagrams of Graybar master annunciator common talking inter-phone system.

Master Annunciator: Common Talking System.—This system meets the requirements of school service. The system consists of an annunciator for use in the principal's office for registering the calls from the class rooms, also a desk stand and a push button block for calling each class room inter-phone.

The principal's or master station equipment consists of an electric reset annunciator and a push button block with one drop and button for



Figs. 7,628 to 7,631.—Schematic diagrams of Graybar master annunciator common talking interphone system.

each class room station in the system. The push button block also contains buttons for electrically resetting the operated drops. The principal is signaled from the class room set by means of the push button on each set.

Inter-phone Apparatus.—Inter-phone systems are simple and consist essentially of the following equipment:

1. Inter-phones;
2. Batteries to furnish current for ringing and talking;
3. Wire or cable to connect inter-phones and batteries;
4. Installing material (usually furnished by the installer) for connecting and fastening inter-phones, cable (or wire) and batteries.

There are three types of inter-phones to suit different conditions:

1. Wall;
2. Desk;
3. Hand set.

These can be used interchangeably in the same system.

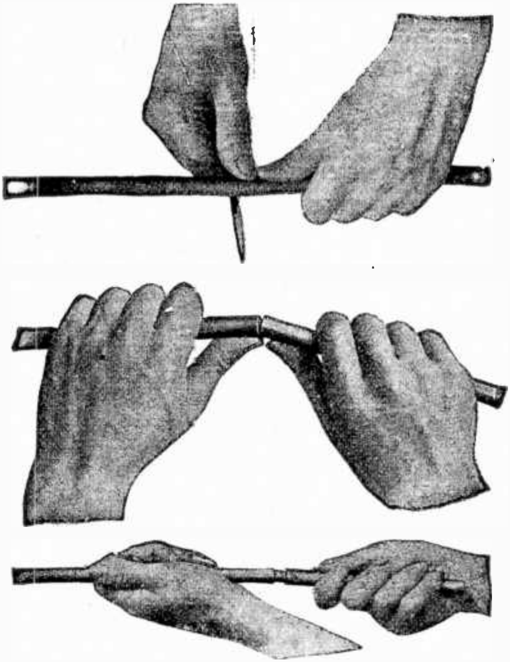
Preparing Inter-phone Cable for Connections.—After having definitely established the route of the cable, it will be necessary to open it properly and fan out the cable wires before connection can be made to the terminals of either inter-phones, cable terminals or connecting blocks.

The following procedure will serve as a guide:

The cable should be lined up parallel with the board on which the terminals are mounted, allowing a length of 4 to 6 inches of cable to extend beyond the last terminal. Mark the cable at a point about 1½ to 2 ins. before the first terminal. From this mark to the end remove the cable covering.

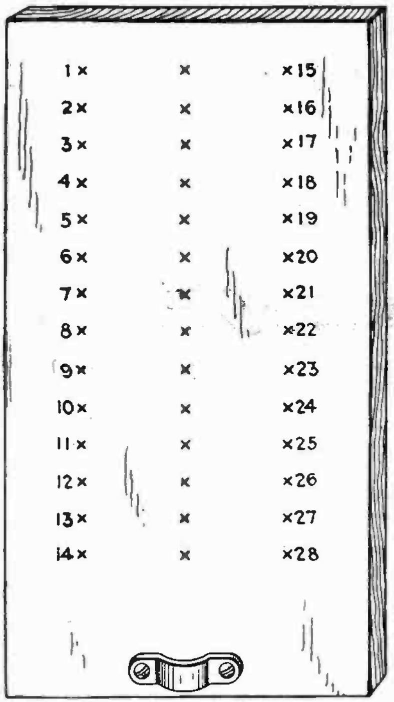
If the cable have a lead sheath, the latter can be removed as shown in figs. 7,632 to 7,634. If it have a braided covering, the latter can be removed by making a slit by means of a sharp penknife, lengthwise from the end of the cable to the marked point.

Avoid cutting the insulation of the conductors. After this cut has been made. the braiding can be peeled off easily, and removed with a pair of cutters. A wrapping of lacing twine should then be made around the cable where the braiding ends to prevent any further loosening of the insulation at that point.



FIGS. 7,632 to 7,634.—Method of preparing inter-phone cable. First make a very slight cut around the cable as in fig. 7,632 about one third through the lead. The lead sheath can then be easily broken off at this point by bending it backward and forward, as in fig. 7,633, after which it can easily be pulled free of the cable, as in fig. 7,634. In cold weather or if the cable has been bent or twisted the sheath may not come off easily. In that case, heat the end to be pulled off with a candle. This will soften the wax inside the cable and allow the lead sheath to be removed easily.

After the covering has been removed from the cable, the wires should be formed, fanned out and sewed up so that they will have the proper shape for connecting to the terminals. This is best done by the aid of a small wooden board as in fig. 7,635.



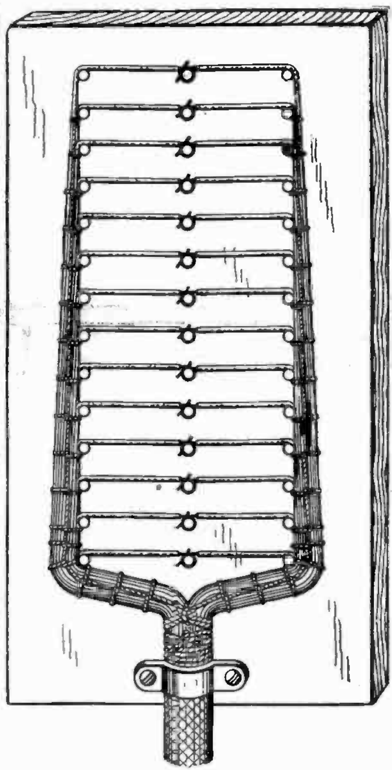


FIG. 7,635.—Board template for *fanning* and *sewing* inter-phone cable. The marking of the board depends entirely upon the location of the terminals to which the wires are to be connected. For example, the following describes a cable forming board for 24 button interphones of a two station line. Mark the board as shown each outside X mark being made at a point where a wire is to be brought to a terminal and a center X mark in the line between them. The vertical distance between the X marks will be the same as between the terminals of the apparatus. The horizontal distance between the outside X marks will be determined by the size of the block on which the terminals are mounted. Small nails are now driven in the X marks, and the end of the cable laid out flat on the board against these nails. The wires are then brought out from the cable in the order in which they should run to the terminals and twisted around the center nails as in fig. 7,636.

FIG. 7,636.—Board template with spacing nails showing inter-phone cable *fanned* and *sewed*. The lacing twine is stitched around the cable as shown in fig. 7,637.

After the cable has been prepared as shown in the illustrations the conductors should now be cut off at a point about 1 in. beyond that required to reach the terminals when the cable is in its final position. The insulation of each wire should then be removed to about 1 in. from the end. This is usually done by squeezing the insulation with a pair of flat nose pliers. If sufficient pressure be applied the insulation can then be torn off easily. Do not use a knife for cutting the insulation. A knife may nick the wire, later resulting in a break and causing trouble.

After the insulation has been removed the cable should be taken off the forming board and connected to the terminals. It is advisable to shellac the formed portion of the cable with transparent shellac, which will prevent the insulation fraying. Care should be taken to remove any piece of wire which may have fallen in among the terminals while wiring. This is often a source of trouble if not done. Every screw and lock nut should also be examined to insure tight and positive connections.

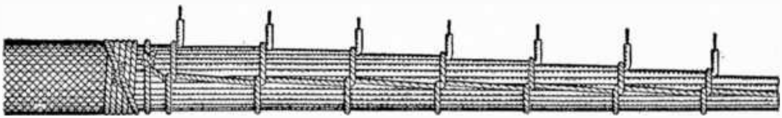


FIG. 7,637.—Detail of inter-phone cable showing lacing twine stitched around the cable to hold the wires permanently in position. Another method to secure the same result consists of drilling small holes, about ⅛ in. diameter, through the board at the outside X marks, fig. 7,635, and pushing the proper wires through these holes and then stitching the cable with lacing twine as explained before.

TEST QUESTIONS

1. *What is an inter-communicating telephone?*
2. *How does an inter-phone system work?*
3. *Name the different inter-phone systems in general use.*
4. *Describe a two station private line.*
5. *Explain the operation of the code ringing common talking system.*

6. *How does the selective ringing common talking system work?*
7. *What is the adaptation of the selective ringing selective talking system?*
8. *Draw a diagram of the selective ringing, selective talking system.*
9. *Explain the operation of the master station common talking system.*
10. *Draw a diagram of the master station common talking system.*
11. *For what service is the master station annunciator system intended?*
12. *How does the master annunciator system work?*
13. *Of what does the principal's or master station school equipment consist?*
14. *Describe the various apparatus used in inter-phone systems.*
15. *How is inter-phone cable prepared for connecting?*
16. *Describe the construction of a board template for fanning and sewing.*

CHAPTER 187

Telephone Troubles

Subscriber Line Troubles.—1. Bell does not ring; may be caused by

a. open bell;

b. open condenser;

c. open bell strap wire;

d. bell out of adjustment;

e. biasing spring too tightly drawn.

2. Can't hear; may be caused by

a. open receiver magnet;

b. open receiver cord;

c. short-circuited receiver;

d. short circuited receiver cord;

e. open secondary coil;

f. open switch hook contact;

g. receiver diaphragm missing;

h. receiver diaphragm bent.

3. Can't talk; may be caused by

a. open primary coil;

b. open switch hook contact;

c. open transmitter;

d. open transmitter cord;

e. short circuited transmitter;

f. carbon granules in transmitter *packed*.

4. Poor transmission; may be caused by

a. leakage in telephone line;

b. high resistance open in line;

c. short circuited induction coil;

d. partial short circuit in line;

e. partially demagnetized receiver.

5. Noisy connection; may be caused by

a. loose connection along the talking circuit;

b. line crossed with another line;

c. cross connection wire in Central office distributing frame;

d. defective heat coils;

e. defective jack at A board or B board;

f. defective cord connected to the line jack in the central office.

6. Can hear conversation of another circuit

a. lines crossed in cable terminal box;

b. breakdown in cable;

c. lines crossed at the distributing frame in the central office;

d. listening keys crossed on the A board.

7. Can't signal Central office operator

a. open line, one wire or both;

b. open transmitter circuit;

c. heat coil on central office distributing frame defective or missing;

d. line relay does not operate in central office;

e. dirty contacts in line relay in central office;

f. line lamp burned out on A board.

Central Office Troubles—A Board.—1. Operator can't hear on all connections

a. operator's telephone set defective;

b. operator's telephone circuit open or short circuited;

c. defective plug or cord.

2. No line lamps light

a. fuse blown in terminal room;

b. open strap wire at lamp sockets in A board jack panel.

3. No supervisory lamp on cords

a. fuse blown;

b. cord lamps burned out;

c. supervisory relay in cord circuit stuck up.

4. Position crossed (operator hears conversation with keys normal)

a. listening keys crossed.

5. Can't ring (on part of the cord circuits)

a. ringing strap broken or disconnected.

6. Can't ring (on one cord only)

a. ringing strap open at ringing key;

b. defective contacts at ringing key.

7. Operator can't hear on one cord

a. listening strap open at talking key;

b. defective contacts at talking key.

8. A position crossed with a distant Central Office B operator

a. call circuit button contacts crossed;

b. call circuit button stuck down.

9. Line lamp is not extinguished after inserting the answering cord into the answering jack

a. cut off relay does not operate;

b. line relay does not release.

10. A operator can't get distant B operator over call circuit

a. call circuit open at key;

b. call circuit open at punchings;

c. call circuit button springs not working.

Central Office Troubles—B Board.—1. No busy back on entire B board

a. lead open at beginning of line up;

b. lead open at power board.

2. B operator can't hear

a. defective telephone set;

b. open in telephone circuit;

c. open wire at grouping keys.

3. Steady guard lamp on a trunk cord

a. grounded tip side of trunk line;

b. defective (operated) relay in trunk circuit;

c. tip side of trunk crossed with another crossed cord at plug.

4. Steady guard lamp on a trunk while conversation is in progress

a. sleeve relay did not operate;

b. guard lamp relay remained operated;

c. sleeve of trunk cord open;

d. subscribers multiple jack sleeve open.

5. No guard lamp (on incoming call)

a. lamp burned out;

b. fuse blown;

c. lamp twisted in socket;

d. trunk wires open;

e. relay in trunk circuit does not operate;

f. dirty contacts in relay of trunk circuit·

g. open contacts at sleeve relay.

6. No disconnect lamp on trunk

a. supervisory relay stuck up;

b. defective lamp.

7. No busy test

a. tip side of cord open;

b. sleeve relay contacts dirty;

c. sleeve relay operated.

CHAPTER 188

The Dial Telephone

(Automatic)

A dial telephone system is somewhat different from the manual system in-so-far as the equipment is concerned, although the desired function of connecting telephone subscribers together to satisfactorily carry on a conversation is exactly the same.

In a dial central office there is considerably more equipment, a great portion of which is automatically operated and controlled, more maintenance men and less girl operators.

In a dial telephone system all calls within a specified "local" area are handled exclusively by automatic switching apparatus, there being no operators required as in the manual system. Calls to more distant points, however, are routed through a special "A" operator who, besides taking care of the connection, makes out a ticket for a "toll" charge against the calling subscriber. The special "A" board is also employed for emergency connections and assistance calls from the subscribers in the same central office area. Besides the special "A" operators, in a dial central office, there are a number of girl operators working at "cordless" B-positions.

There are two distinct types of dial systems, namely:

1. Panel.

Used for large capacity central offices in big cities.

2. Step-by-step.

Used for small central offices.

Panel Dial System.—This system derives its name from the design of the multiple banks which are arranged as *panels* and which are mounted on frames known as *selector frames*.

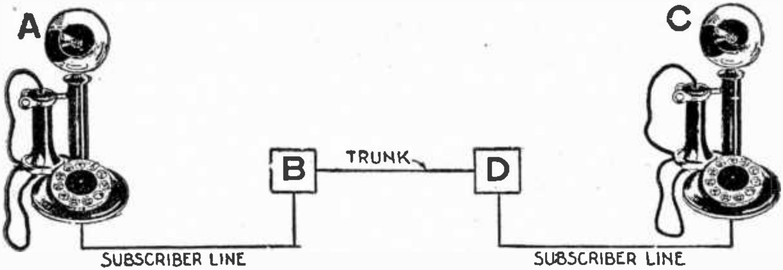
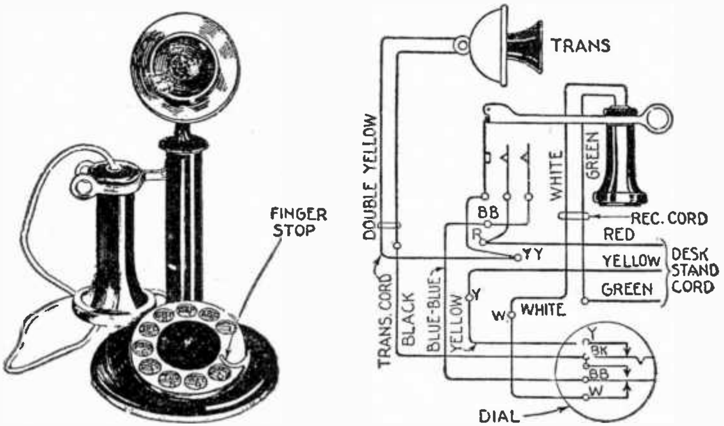


Fig. 7,628.—Simplified dial telephone system. A, telephone subscriber with number ATLantic 2357; B, Atlantic central office; D, Mayflower central office; C, telephone subscriber with number MAYflower 7348.



Figs. 7,629 and 7,630.—Telephone with dial and circuit diagram.

Consider a telephone subscriber at location A connected to a dial Central Office at B and a second telephone subscriber at C connected to a second dial Central Office at D as indicated in fig. 7,628.

The telephone station at A consists of the familiar transmitter and receiver with the bell box. In addition there is a dial mounted on the transmitter stand as shown in fig. 7,629, all wired as in fig. 7,630. The telephone station at C is equipped the same as the one at A.

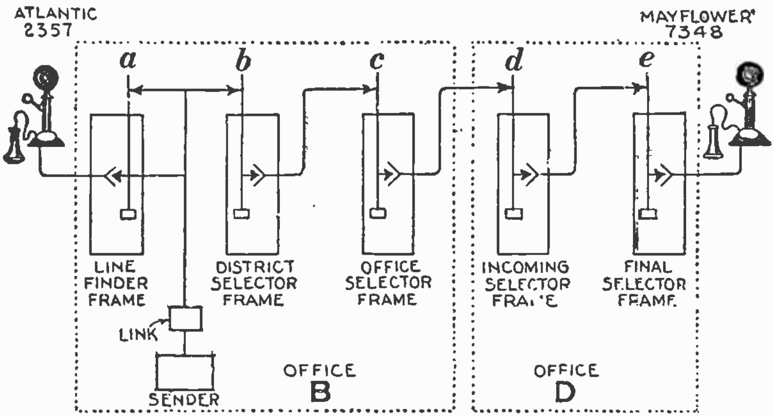


Fig. 7,631.—Panel dial system—routing of a call. a, line finder; b, district selector; c, office selector; d, incoming selector; e, final selector.

In operation: Subscriber A wishing to call C lifts the receiver off the hook and hears the dial tone, which is a sort of subdued and continuous br-r-r-r-r, sent by the *sender* at Central Office B. This means that he may proceed with the next operation, which in this case is to dial M-A-Y 7-3-4-8. By this operation the letters and the numbers are converted into different *pulses* which are received by the above mentioned sender at Central Office B where the seven different sets of pulses are *absorbed* by the sender, causing it to assume certain settings, which will direct and control the operation of various selector switches, some of which are located in Central Office B and some in the distant Central Office D, as indicated in fig. 7,631.

The sender in Central Office B, does not require that all the numbers be dialed before it can function. As soon as the three letters M-A-Y, known as the "*Central Office code*" letters have been dialed, the sender causes a so-called *district selector*, mounted on the district selector frame to operate and to move upward to find an idle trunk to another frame in the same office B which is known as the *office selector frame* and causes an idle selector on this frame to move upward and to stop at a set of terminals to which are connected wires, or *trunks*, coming from the distant office D.

When the numbers 7-3-4-8 are dialed the same sender in office B causes two different selectors in the distant office D to move upward and to locate the set of terminals corresponding to that line.

The first one of these two selectors is mounted on a frame known as the *incoming selector frame* and is determined by the first two digits dialed (in the order of dialing) namely 7 and 3, and the second selector is mounted on the final selector frame and is directed by the sender in office B in accordance with the last two numerals dialed, 4 and 8 in this case.

When the final selector in office D has, under the control of the sender in office B, connected to the called line, the incoming selector furnishes the generator current to ring the called subscriber's bell.

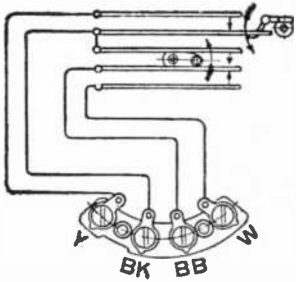
By this time the sender has performed all its work and it is accordingly disconnected from the district selector circuit of office B.

When the called party answers by lifting the receiver off the hook the ringing current is automatically removed.

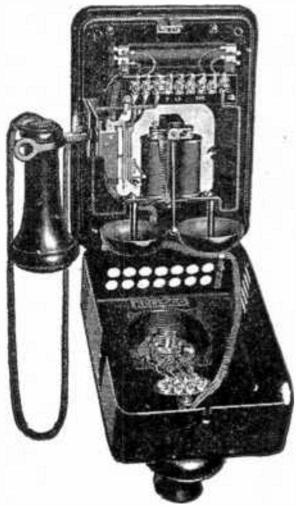
The conversation takes place and eventually it is finished and the parties hang up the telephone receivers, causing all the selectors to disconnect automatically.

The apparatus will now be described, stripped of all the circuit complications and the intricate mechanical details.

The Dial.—As shown in the accompanying illustrations, the dial is generally mounted on the telephone. It is a device consisting of a rotating disc (finger wheel), with a spring and a cam lever.



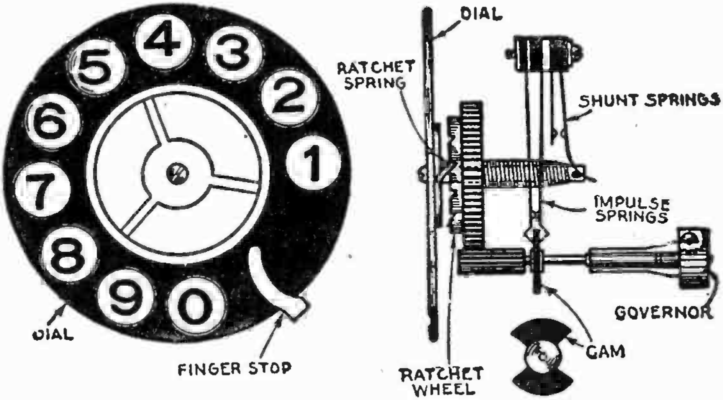
FIGS. 7,632 and 7,633.—Assembled dial and wiring diagram.



FIGS. 7,634 and 7,635.—Kellogg common battery telephone; enclosed gong wall type arranged for automatic dial. Fig. 7,635 open view showing interior construction.

Fig. 7,636.—Single central station stops.

Fig. 7,637.—Multi-central station dial showing central station letters, and numerals.



Figs. 7,638 to 7,640.—Front and side view of dial, showing the mechanism and end view of cam. ***In operation***, as the dial is rotated by the finger clockwise, a coiled spring is wound which, after removing the finger on reaching the *finger stop* causes the dial to return to its initial position. This is a ratchet which transmits the return movement to gears and a governor. The gears are in mesh with a pinion on which is a cam which is so geared that when say No. 1 is "dialed" the cam will make one half revolution, opening the impulse spring once. Similarly the impulse spring will be opened a number of times corresponding to the number dialed.

FIGS. 7,641 to 7,653.—Disassembly of dial set showing various parts; the number plates consist of a copper base coated with a vitreous white enamel. Small pins projecting from the back fit into holes in the dial frame, thereby insuring proper alignment of the number plate with regard to the finger wheel of the dial.

When a number is dialed the finger wheel is pulled around to the finger stop, and then let go. The spring now pulls the finger wheel back to its original position and in doing so the cam, which is attached to the finger wheel, causes a set of springs to separate and to come together successively opening and closing the circuit of the line, thereby generating *pulses*.

The number of pulses generated is equal to the figure under the hole into which the finger is placed. The return speed of the finger wheel is controlled by a *governor* so that when "O" is dialed the finger wheel will return to normal in one second, or 10 pulses are generated in one second.

In larger cities the plate under the holes bears certain letters of the alphabet in addition to the numbers. These letters are used for dialing the first three letters of the central office names. Figs. 7,636 and 7,637 show comparison of the single office dial and the multi office dial.

Selector Frame; Selectors.—In fig. 7,654 is shown one side of one selector frame, the opposite side being an exact duplicate of the one shown.

The framework is of iron and contains five small panels, each called *multiple banks*.

These five banks are lined up one above the other, so as to make one continuous vertical plane. Facing each side of these multiple banks, on each side of the frame, are 30 selectors arranged vertically so that they can be elevated to the highest point and then lowered to the starting point. Each selector consists of a long brass tube about ¼ in. in diameter, mounted vertically and holding *five multiple brushes* equally spaced apart so that each brush can reach the entire height of one bank.

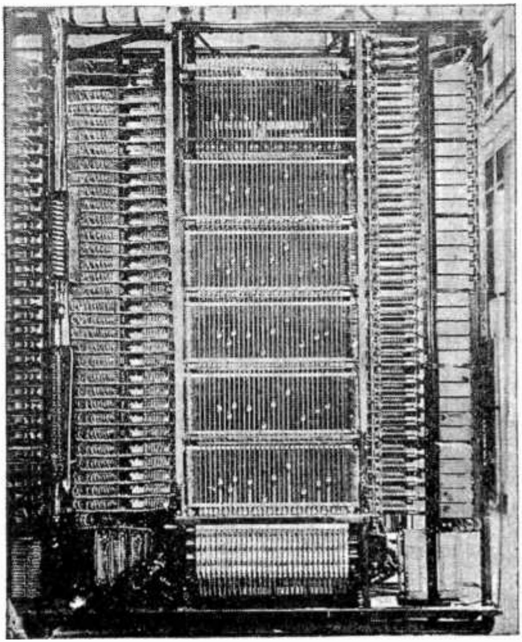


Fig. 7,654.—Panel type selector frame.

At the upper end of the selector rod is mounted a set of *commutator brushes* and at the lower end is attached a *rack* which is a flat strip of bronze with rectangular perforations, as shown in figs. 7,655 to 7,657.

Each multiple bank is built up of 300 individual brass strips running the entire length of the bank, each separated by an insulated strip. The brass strips have 30 projections on each edge so that when the whole assembly is bolted up there are formed on each side of the bank 30 sets of projections, each set composed of three vertical rows and each vertical row containing 100 terminals.

Each set of three terminals serves for one line or one trunk and is used for tip T, sleeve S, ring R (see fig. 7,661) so that there are 100 lines or trunks

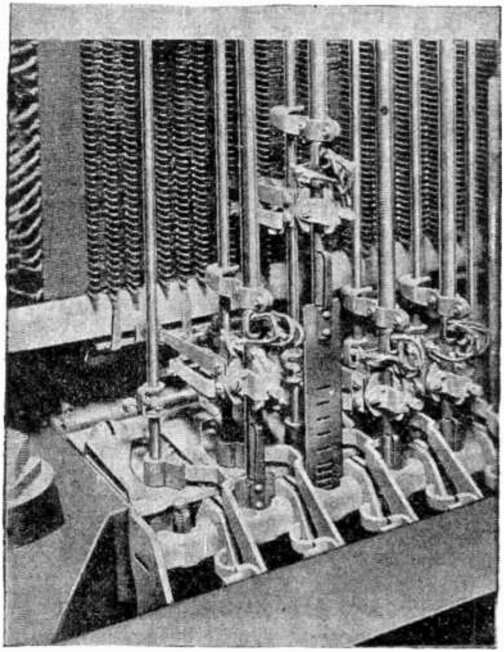


FIG. 7,655.—Lower portion of selector frame showing raised rack attached to lower end of selector rod. The rack is made of spring bronze and has 100 rectangular perforations spaced vertically corresponding to the 100 trunks (vertical) on the bank, and five rectangular perforations wider apart corresponding to tripping positions of the selector brushes. The bottom multiple brush is shown making contact with a set of terminals in the bottom bank.

arranged in a vertical column, and each line appearing 30 times on one side of the bank and 30 times on the other side.

The selectors are arranged so that there is one in front of each vertical column, and so that a particular brush of that selector can be stopped at any one of the 100 lines to make contact with the T, S, and R, projections on the multiple bank corresponding to that line.

The brush has four parallel contact springs so arranged that normally while the brush is untripped the contact springs do not touch the multiple bank contacts, or projections; but when the brush is tripped the two outer springs make contact with the T and R, lugs, respectively, on the multiple bank and the two inner springs touch the S, projection. Actually then the two inner springs on the brush serve as one.

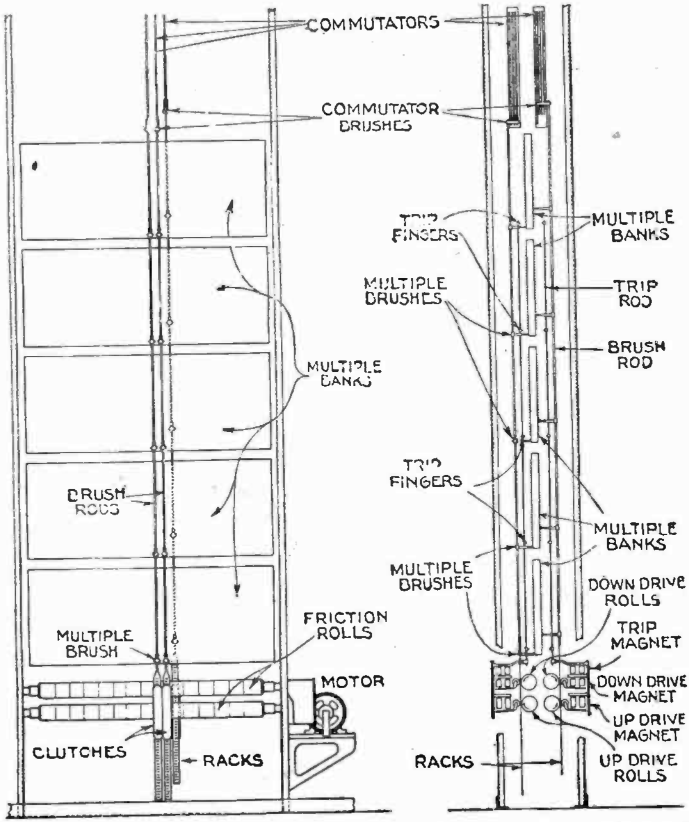
The commutator brushes at the top of the selector rod slide over brass bars moulded in hard rubber to form what is known as a *commutator* shown in fig. 7,656 and 7,657.

It was mentioned before that the lower part of the selector rod is attached to a rack which has rectangular perforations equally spaced to correspond with the 100 lines on the multiple bank, and in addition there are five other perforations a little wider apart and used in connection with the tripping of the brushes on the selector. Only one of the five brushes is tripped to make connection at one time, since all five brushes are connected in parallel and would cause a *cross* if two or more brushes were to be tripped together on one selector. As to which of the five brushes is to be tripped is determined by the sender.

The *rack* is arranged so that on one side it faces two cork rolls, revolving in opposite directions, and on the other side there are two magnetic clutches, named, *up-drive* and *down-drive* magnets, one in line with each revolving cork roller, as shown in fig. 7,656. The rolls are operated continuously by a small electric motor and a system of gears which are shown in fig. 7,658 and which are located in the lower part of the selector frame, as shown in fig. 7,656.

Operation of Selector.—Briefly, the operation is as follows: The sender causes a selector to start by energizing the up-drive magnet of the clutch which pushes the rack against the lower rotating cork roll, causing the rack to be raised. This in turn being attached to the selector rod pushes the selector upward.

As the selector rod continues in its upward movement it *reports*, so to say, back to the sender, by means of impulses from its commutator, how far upward it has progressed. When the selector rod has reached a certain height the sender immediately stops it to make arrangements to trip one of the five brushes. The brush to be tripped is the one that has to hunt in the bank where the trunk to the desired office, or where the desired line, is located. Then the selector is again started on its upward movement and



FIGS. 7,656 and 7,657.—Diagrams of assembly of selector frame and selector rods. Fig. 7,656, front view; fig. 7,657, end view.

the proper brush is tripped by a projection on the tripping rod which is rotated so that this projection gets in the way and snags the brush.

The selector continues to report to the sender through impulses received through its commutator as it moves upward to select the line, which is located in the bank where the brush has been tripped. When this line has been reached the sender stops the selector.

Provision is made that if the selector in question be hunting for an idle line in a certain group and no such idle line be available at that instant, the selector will automatically advise the calling subscriber of the busy condition by sending back the characteristic busy tone.

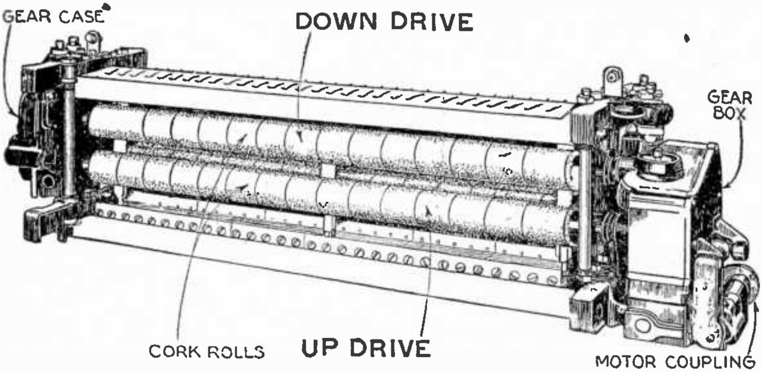
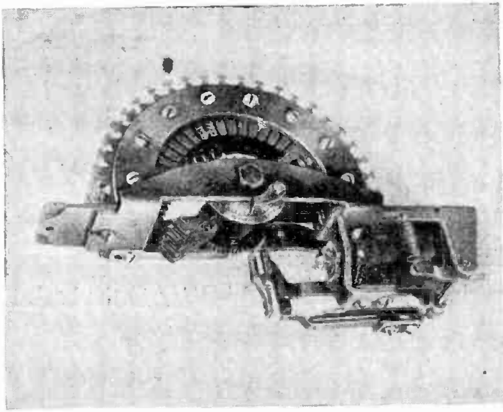


Fig. 7,658.—Cork rolls.

Sender Control of Selectors.—In the previous analysis, mention was made of the sender and its control of the operation of the various selectors. The sender is an electro-mechanical device and is the most important and complex portion of equipment of the panel type dial system.

The sender consists of a group of relays, a group of rotary switches or rotary selectors, and a group of sequence switches, all of which are mounted on frames, as shown in fig. 7,659. In the group of rotary switches, or *registers*, there is one switch for each letter and one for each digit dialed. Each one of these switches is constructed as shown in fig. 7,660 and is operated



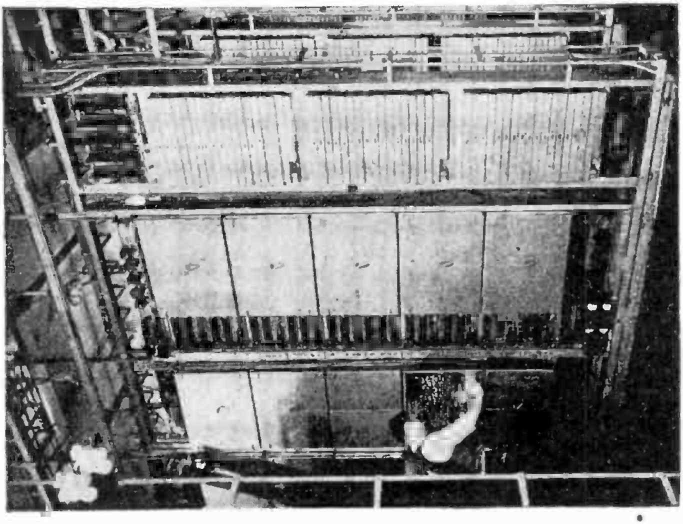


FIG. 7,659.—Group of senders on frame.

FIG. 7,660.—Rotary switch

in accordance with the pulses sent over from the dial, that is, the rotor is stepped around, one terminal or one position, with each pulse and will take a certain *setting* to correspond with the letter or numeral dialed.

When the three central office code letters have been dialed, the corresponding rotary switches in the sender take their respective setting and start a selector on the *translator selector frame* to travel upward to a certain point, and cause its brushes to make contact with certain bank terminals which are connected to *drums* of a *pulse machine*.

This pulse machine sends interrupted battery to the bank terminals of the translator frame, and these interruptions are picked up by the brushes of the translator selector which are connected to the relays in the sender circuit. These relays are known as *translator register relays*, and are operated in various combinations, according to the pulses delivered to them by the pulse machine drums. However, the circuit combinations set up by these translator register relays will determine several conditions such as

1. Whether the central office dialed is a manual or a dial office.
2. The particular brush to be tripped on the district selector frame.
3. The particular group of trunks to be selected from on the district frame.
4. The brush to be selected on the office selector frame.
5. The group of trunks to be selected from on the office frame.

As a selector is started in motion, another group of relays in the sender circuit, known as *counting relays*, receives pulses from the commutator associated with that selector, as previously explained.

The number of counting relays to be introduced is dependent directly upon the register settings. As the selector commutator brushes slide over the brass bars on the commutator, two of these counting relays are operated every time a brass bar is passed over, so that when all the counting relays for a particular setting have been operated, a circuit condition is created which causes the sequence switch in the sender to operate and to release all the counting relays that were held operated, with the result that the electricity is disconnected from the clutch magnet on the selector frame causing the selector rack to move away from the *up drive* roller. This of course means that the selector does not rise further. At this instant, the clutch pawl slips into the perforation of the rack and prevents the selector falling back to its starting position on account of its weight.

At this point, another circuit condition is created which causes the selector circuit sequence switch on the selector frame to operate and to place the selector circuit in the proper relation for the next operation, which is to cause the trip circuit to operate and the selector to start again on its upward travel.

This time one of the brushes on the selector is snagged and is brought in contact with the bank terminals. So far, the sender has accomplished what is known as *brush selection*. It is now necessary to bring that brush up to the first terminal of a desired group of trunks in that bank so that *trunk hunting* may be started.

The process of raising the selector to the first trunk of a desired group is known as *group selection* and is controlled likewise by counting relays under the control of another group of translator register relays in the manner just explained for brush selection.

When the selector has been raised to the first trunk of the desired group, *trunk hunting* takes place. This means that the selector brush makes a test on the sleeve of each trunk as it rises and every time it touches a busy trunk it receives energy to rise to the next trunk, until an idle trunk is found, when the energy to rise to the next trunk is not furnished, and the selector remains held up in that position by the pawl which slips into the rack perforation.

The operation of the sender, as outlined, applies to the control of the district selector as well as to the office selector in the home office.

The same sender directs the incoming selector and the final selector in the distant central office in a similar manner as above, except that the first two numbers dialed (the thousandths and hundredths) cause the associated registers in the sender to take certain settings and thereby throw in a certain number of counting relays to trip a particular brush on the incoming selector, and to raise the incoming selector up to a certain group of trunks. so that it can pick out an idle trunk to the final frame.

The last two digits dialed (tens and units) cause the associated registers in the sender circuit to take certain settings and thereby introduce a certain number of counting relays to trip the desired brush on the final selector and to raise the selector to the particular terminal dialed.

The last function is accomplished at two speeds; the selector is brought at high speed up to within 10 terminals, and then the rack is driven upward at low speed up to the particular terminal desired. At this instant, the counting relays cause the selector to stop. The final selector remains up in that position as the result of the pawl having engaged the rack.

At this point the talking circuit for the calling party and the ringing circuit for the called party are completed and the sender is disconnected and released.

It was mentioned above that the final selector has two *up speeds*. This is accomplished by the use of two up drive cork rolls instead of one, and a clutch with a third magnet. The commutator associated with the rising selector serves to make the transfer of the rack from the high to the low speed.

Line Finder Frame.—This frame is similar to the selector frame described, except that there are 10 banks instead of 5 and each bank has 40 sets of terminals instead of 100. On these terminals are connected the subscribers' lines, so that a total of 400 telephone lines can be accommodated by each frame.

This means that in a 10,000 line central office, there are required 25 line finder frames. The selectors, or *line finders*, on the line finder frame, are not under the control of any sender.

A line finder is sent upward by a so-called start circuit which functions when a subscriber lifts his telephone receiver off the hook.

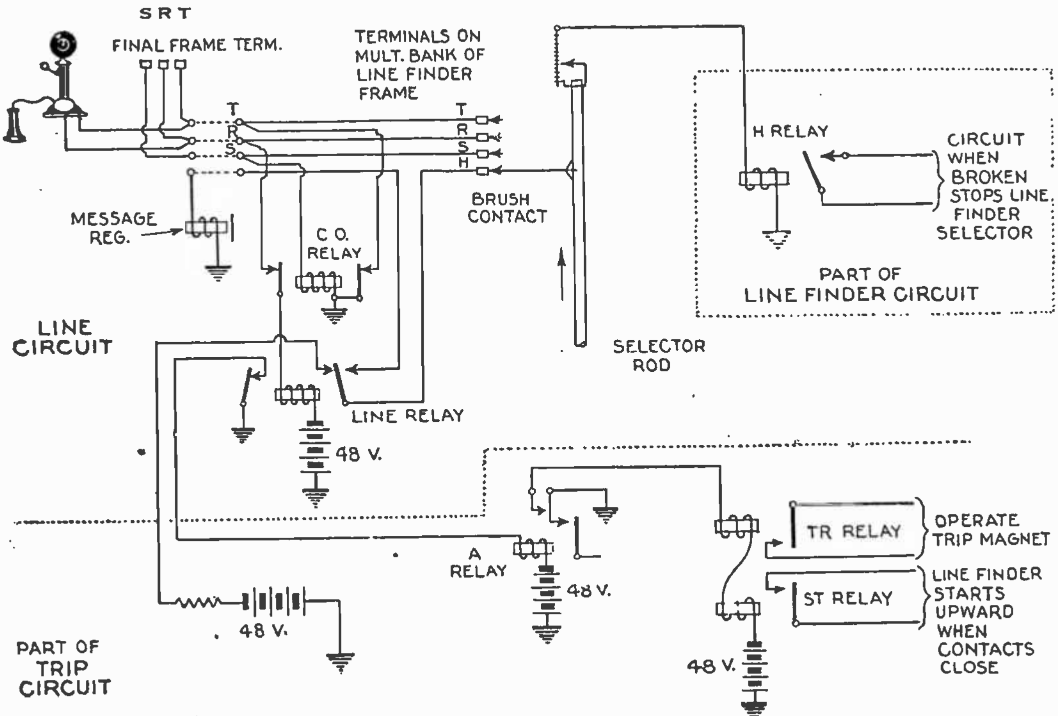


FIG. 7,661.—Line circuit.
FIG. 7,662.—Part of tripping circuit.
FIG. 7,663.—Part of line finder circuit.

Each bank of 40 lines is provided with a brush tripping circuit and an associated trip lever horizontally installed in the bottom of the bank. There are 10 brushes instead of 5 on each line finder rod, so that there is a brush capable of covering each entire bank.

All the brushes in each bank rest just below the trip lever, with the result that should the trip lever be operated and a line finder be subsequently operated, the brush in that bank will be caught and tripped, and this is exactly what happens in actual operation.

Provision is made that should two subscribers located in different banks of the same frame raise the receivers off the hooks simultaneously, only one line will be taken care of at a time, and when this line has been connected, the second line finder will start upward to connect with the second line.

The second line finder will be unable to start until after the first line finder has located the first line and has connected to it. If this feature were not provided, there would be two line finders started upward and two brushes would be tripped on each line finder; the result would be interference in the lines.

When a subscriber wishes to dial and lifts the receiver off the hook, a line finder on the frame upon which his line is terminated is automatically started upward and finds this line.

The line finder is then stopped and left with its brushes connected to the bank terminals associated with that line.

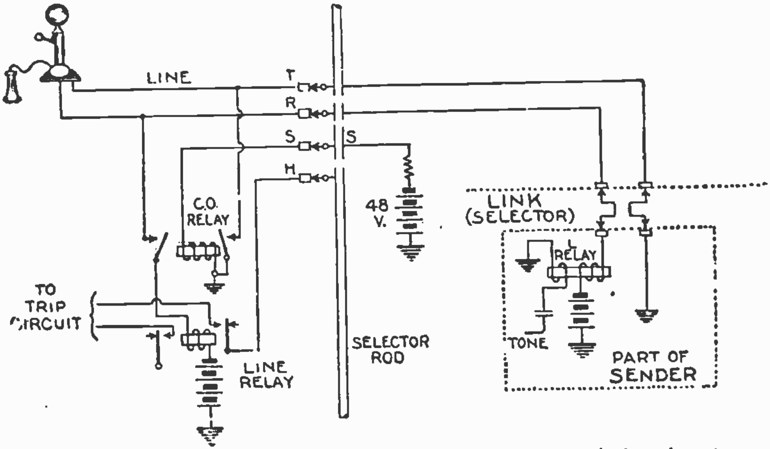
The line finder is connected to a *link* which assigns, or connects with a sender, so that at this stage of the call, the telephone has been connected to a line finder which in turn has been connected to a sender, as well as to a district selector.

The operation of the line finder with the associated simplified circuits is as follows:

The calling party of fig. 7,661 lifts the receiver off the hook, placing a short-circuit on the line and causing the operation of the line relay, which operates the A relay in the trip circuit of fig. 7,662. The A relay then operates the TR relay and the ST relay. The TR relay closes a circuit which operates the brush tripping lever in the line finder bank.

The ST relay closes a circuit which starts the associated line finder in its motion upward. After the line finder has advanced upward and its brush has been tripped, the tripping circuit is released through a segment on the commutator at the top of the line finder rod so that the tripping circuit may be used for tripping another line finder brush on another call.

The line finder now *hunts* for the line which has originated the call. The terminal H of that line is marked with *battery* from the contacts of the line relay so that when the line finder brush reaches this terminal and makes



FIGS. 7,664 and 7,665.—Line finder brushes stopped at calling line terminals and sender connected. The calling telephone receives the "dial" tone.

contact with it the H relay in the line finder circuit of fig. 7,663 operates, causing the line finder selector to stop. The CO relay is then operated and the line relay is released as shown in fig. 7,664.

The line finder is then connected by means of a link to an idle sender as shown in fig. 7,665, and the calling subscriber receives a *dial* tone which is a characteristic b-r-r-r- sound to indicate that the sender is ready to receive the dialing.

District Selector Frame.—This frame has its selectors connected to the line finders, and the contacts on the multiple banks connected to the office selector frame.

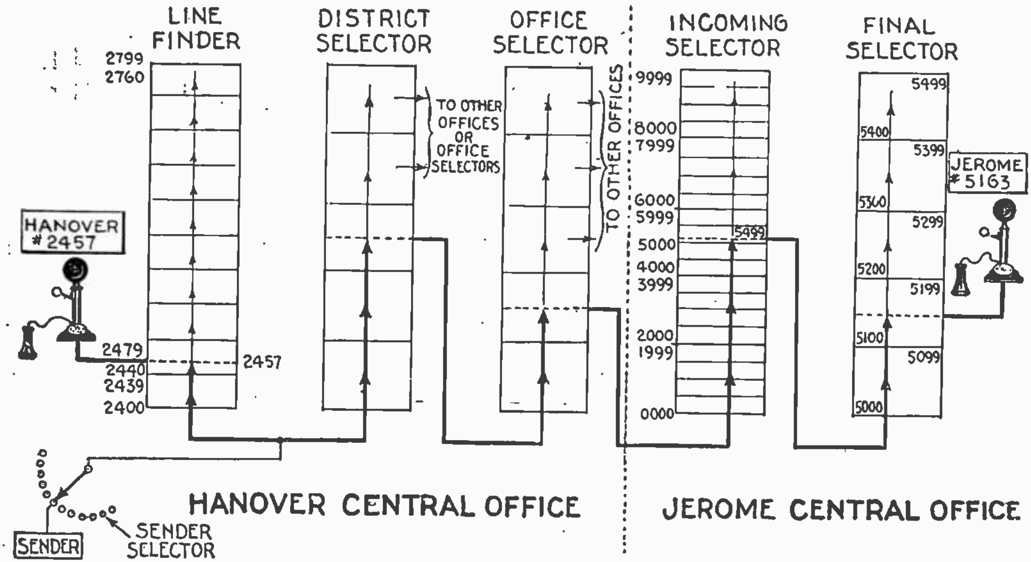


FIG. 7,666.—Panel dial system. Routing of a call.

Office Selector Frame.—The office selector frame has its selectors connected to the bank contacts on the district selector frame, and its bank contacts wired to incoming selector frames of distant offices.

Distant Central Office Incoming Selector Frame.—As previously mentioned, the trunks outgoing from the office selector frame multiple banks are cabled to the distant central office where they are terminated to selectors on the incoming selector frame, as shown in fig. 7,666.

Each incoming selector must have access to every line in the central office.

Since there are 10,000 lines in the central office, and only 500 terminal sets available on the entire five multiple banks of the incoming frame, it is necessary to introduce another selector frame before the actual subscriber line is reached. This is done by employing *final* frames, so that the incoming selector picks one of a group of trunks to certain final selectors, which in turn make the actual connection to the called line.

Final Selector Frame.—Each of the five multiple banks on the incoming frames are divided into four groups of 25 trunks each connected to final selectors on the final frame.

There are then 20 groups of trunks on each incoming frame and since there are available 500 line terminals on each final frame, the capacity of the central office will be 10,000 lines.

The terminals of the first group of trunks in the bottom bank, or *Bank O* of the incoming frame are connected to final selectors having access to the first 500 lines, or lines 0000 to 0499, the second group of terminals in the same bank of the incoming frame are connected to final selectors connecting with the next 500 lines, or lines 0500 to 0999, etc., as shown in fig. 7,666.

Ringing.—As previously mentioned, the generator current used to ring the called party is furnished through the incoming selector. An audible ringing tone is transmitted back to the calling party so that he may know that the bell at the distant end is being rung.

Message Registration.—Each subscriber's line has associated one message register, just as in the case of the manual central office system. This register is connected as shown in fig. 7,661, and is operated automatically two seconds after the called party has removed the receiver off the hook. The registers in a dial office are treated very much like those in a manual office.

Disconnection.—When the conversation is finished and the called party hangs up, all the selectors involved in the call will not be released until the calling subscriber hangs up.

Busy Back.–The final selector makes a busy test on the desired line, and if it finds the line busy the final selector, instead of applying the ringing current, will cause an interrupted busy tone to be returned to the calling party.

The Special A Board.—In a dial central office there is also an operating room with a special A-board and a "cordless" B-board. These switchboards are manually operated and perform functions somewhat different from those in a manual central office.

For special reasons, some of which are commercial and some of which are limitations imposed by the mechanical system, it is not possible to allow a subscriber to automatically connect with certain distant central offices. The scheme then is to route his call to an operator at a special A position in the central office who will care for the connection desired. This is done by the calling party by dialing "O."

The special A board framework is similar to that of the manual central office A board. Each operating position contains jacks and lamps to receive calls from the subscribers in the local area, and keys and dialing equipment to complete the calls. In addition there is in the jack panels a so-called *checking multiple* which is used by the special A operator when checking or verifying a particular telephone number from whence a long distance or toll call is being made.

This checking multiple consists of groups of brass pins, one for each subscriber number in the central office, arranged in the jack panels very much like the multiple jacks on the manual B board. The pins are insulated from each other. The special A operator when verifying the telephone number of a calling subscriber, who has called the operator for a toll connection and has declared his number to her, touches the tip of a special cord at her position to the pin on the checking multiple corresponding with the number of the calling subscriber, and if this has been given correctly the operator will hear a distinctive tone.

The Cordless B Board.—The B-board of a dial central office is known as a cordless B-board, mainly because there are no

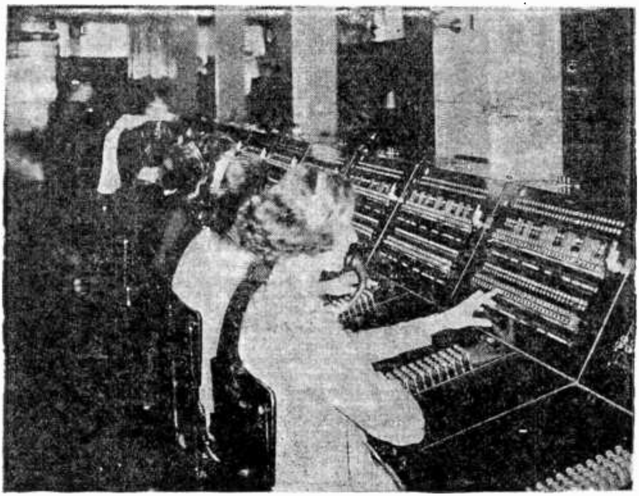


FIG. 7,667.—Cordless B board of a panel dial central office.

cords. This switchboard is used to complete connections for calls originating at manual central office areas.

The sections are constructed as shown in fig. 7,667 with a slanting top upon which are mounted keys and the lamps for approximately 60 trunks incoming from various manual central offices. These trunks are in most cases operated on *straight forward method*.

Each trunk has two lamps and two keys, as follows:

Guard lamp (Orange or White).

Busy lamp (Green).

Disconnect key (Red). Used only for call circuit trunks.

Assignment key (Green).

On each position is a set of numerical recording keys.

In operation, when a call for a subscriber in the dial central office area originates in a manual central office district, the A operator in the manual central office picks an idle trunk to the desired dial office (straight forward basis), causing the orange guard lamp to light steadily at the cordless B position. The cordless B operator then presses the associated assignment key, causing the green lamp to be lighted and to flash and the cordless B operator's telephone set to be connected to that trunk, also an idle sender is connected to the trunk and to the numerical recording keys.

The A operator at the manual office passes the desired number to the cordless B operator, over the trunk, who writes it on the numerical keys. The cordless B operator's telephone set is removed from the trunk and the orange lamp is extinguished.

The green lamp continues to flicker until selection is completed and then lights steadily until that trunk is released. The numerical keys are released as soon as the number has been recorded in the sender. The sender in turn is released as soon as it completes its function.

During conversation between the two subscribers the green lamp of the trunk remains lighted at the cordless B position. When the conversation is ended and the receiver is replaced on the hook and the A operator in the distant manual central office takes down the connection, the switches in the dial central office are released and the green light disappears. The same trunk is now ready for another call.

Step-by-Step Dial System.—The main difference between a step-by-step dial central office and a panel dial central office is in the design and operation of the automatic switching apparatus. In the *step-by-step system* the dial operates the selectors directly, each number dialed causing a different operation in the selectors and each operation occurring immediately as the dial returns to its normal position, and when the last digit is dialed the connector actually makes connection with the telephone desired.

In the *panel dial system* the dial does not operate the selectors directly. The dial pulses at each dialing operation are discharged into the sender, causing certain circuit conditions

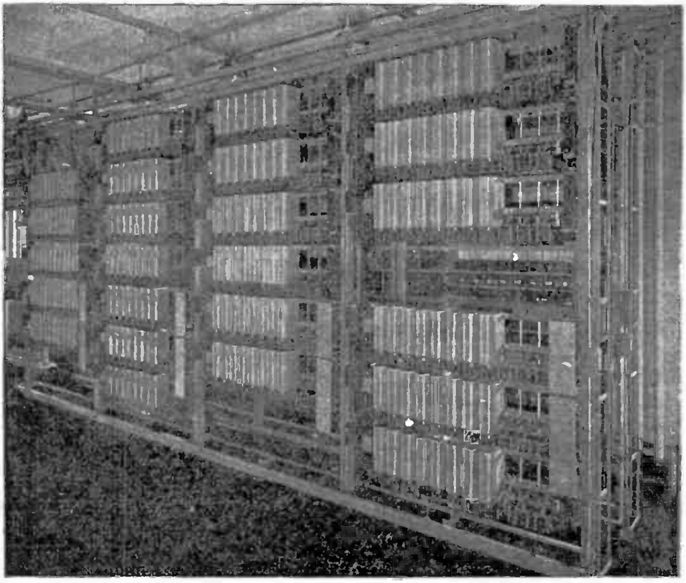


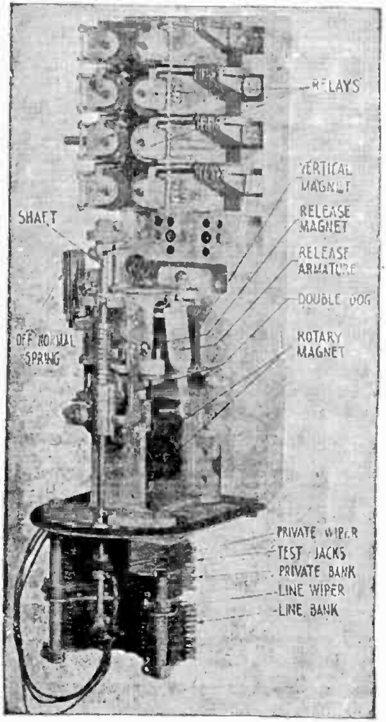
FIG. 7,668.—Step-by-step connectors mounted on switch frames.

to be set up in the sender circuit, which control the operation of all the selectors.

Theoretically, it is possible to have 10,000 lines in a step-by-step central office. However, on account of several practical limitations this system is not employed for such cases, the panel dial type being used instead.

In the most up-to-date step-by-step systems there are three distinct types of switches, namely:

1. Line finder;



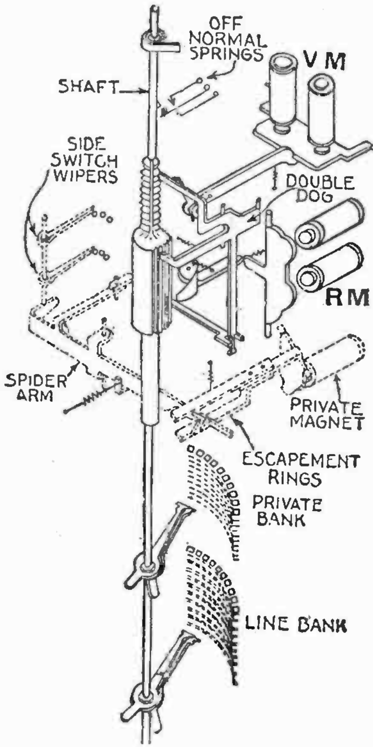


FIG. 7,669.—Step-by-step connector switch. It consists of a double bank and double wipers, or brushes, and a mechanism whereby the shaft can be lifted and rotated step-by-step. This is a two digit switch. The vertical motion is controlled by the first digit dialed and the rotary motion by the second digit.

FIG. 7,670.—Diagram of step-by-step connector switch simplified. At the lower end of the shaft are the double wipers. Further up on the shaft are vertical teeth by which the shaft is raised step-by-step by the magnet VM. Just below these teeth is a hub of rotary teeth by means of which the shaft is rotated step-by-step by the magnet RM. The coiled spring at the top of the shaft causes it to return to its initial rotary position when released, from whence it falls by gravity to its initial vertical position.

2. Selector;
3. Connector.

In the earlier systems instead of the line finder there is a line switch and master switch combination which will also be described in this chapter since many of these are still in operation.

In describing the apparatus it will be more convenient to start with the connector.

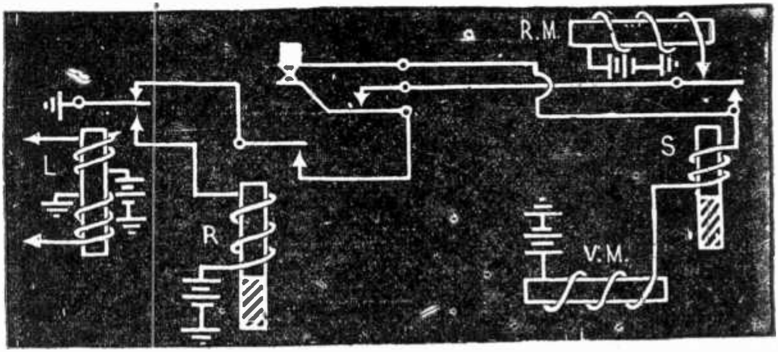


FIG. 7,771.—Step-by-step connector circuit. When this switch is first engaged the L relay and the R relay are operated. If the subscriber dials, say for example No. 46, the L relay is momentarily released and re-operated four times when the digit 4 is dialed, but the R relay remains in its initial operated position since it is a slow releasing relay. The interruptions at the L relay are transferred to the S relay which operates and remains operated since it also is a slow releasing relay, but the vertical magnet V.M. operates four times, in unison with the breaks at the L relay The vertical magnet VM causes the shaft wipers to be stepped upward to the fourth level on the multiple banks. When the wipers reach the first level, at the end of the first pulse, the off-normal springs are operated and transfer the pulsing path between the contact of the R relay and the contact at the S relay, but since relay S is slow to release, it remains up until the last pulse of the digit dialed, while the magnet VM, continues to operate and to release, thereby bringing the wipers to the fourth level. After the last pulse of the digit the S relay releases due to the long broken interval at the L relay contacts, and the pulsing circuit is then transferred from the vertical magnet V.M. to the rotary magnet R.M. When the subscriber dials the second digit which is "6", the L relay pulses six times and causes the rotary magnet to operate and to release six times, thereby stepping the wipers around to terminal No. 6 on the multiple bank. In dialing the digit 4 and 6 if the finger wheel of the dial be held off its normal position long enough for the L and R relays to release, the connector switch will be restored to normal by the release magnet (not shown) which operates when the R relay falls back and removes the double dog from the shaft, allowing the coiled spring at the top of the shaft to restore the shaft.

The Step-by-Step Connector.—In fig. 7,668 are shown several groups of connectors mounted on switch frames and in fig. 7,669 is shown one such connector with the cover removed. A simplified diagram of this switch is shown in fig. 7,670.

In order to make clear the operation of the connector a simplified diagram is shown in fig. 7,671 with the description of the pulsing circuit and the movement of the shaft carrying the wipers or brushes.

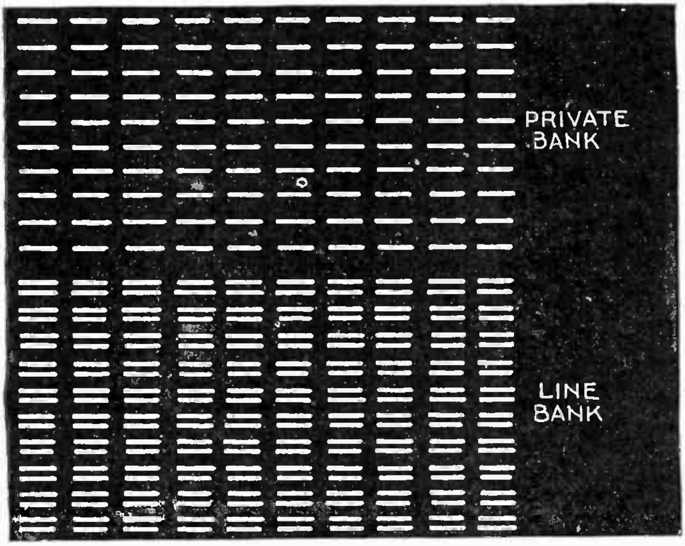


FIG. 7,672.—Diagram showing contacts of line and private banks of a 100 line system. These banks form a part of the connector switch.

The connector makes a busy test in accordance with fig. 7,673. If the line called be idle, a switching relay in the connector circuit (not shown) will operate when relay A falls back and connects ringing current to the line. When the called subscriber answers, another relay in the connector circuit (not shown) operates, causing the ringing current to be removed and the line to be connected through for talking.

While the called party is being rung, the calling subscriber hears an audible ringing tone as an indication.

The Connector Bank.—As shown in fig. 7,669 the multiple banks are bolted to the connector by bank rods which pass through bank rod holes in the banks. The bank and bank rods can be removed as a unit by removing the nuts at the top of the bank rods.

The upper or *private* bank is made up of 100 brass terminals arranged in an arc in ten levels of ten terminals each.

The terminals are insulated from each other and the adjacent levels are separated by thick insulators.

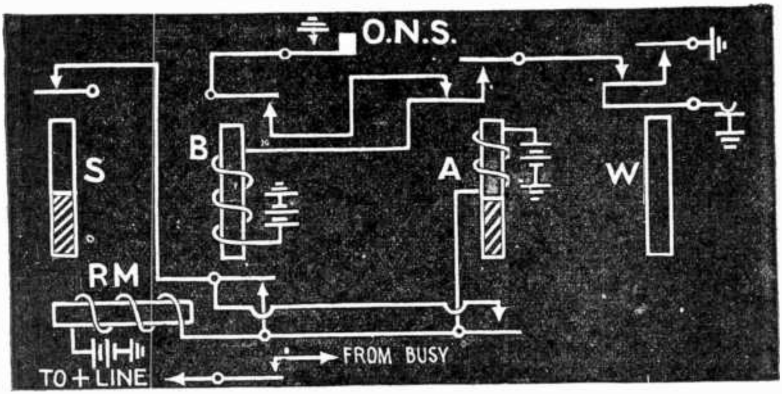


FIG. 7,673.—Busy test circuit of connector. Relay A is a slow releasing relay and has operated in parallel with the rotary magnet RM. Relay A will remain up for a moment after the last rotary impulse has been received. If the called line be busy its sleeve (private) terminal has ground connected to it and causes relay B to operate through the private wiper and front contact of relay A. After relay A has released, the B relay remains locked up through its own contact and O.N.S. springs. Relay B also opens the circuit of the rotary magnet RM, so that further dialing by the subscriber will have no effect, and connects busy tone to the tip side of the line to advise the calling subscriber that the line desired is busy.

The lower or *line* bank has 200 brass terminals arranged in vertical pairs and also mounted in an arc in ten horizontal rows or levels of ten pairs of terminals each.

The upper and lower terminal of each pair are separated by an insulator and the adjacent levels are separated by two thicker sheets of insulating material.

The terminals of each bank and the insulating material are assembled one above the other and clamped into a frame by five bolts. The terminals are double ended, the outer end forming a soldering lug for the multiple bank wiring and the inner end forming a contact over which the brushes wipe. Fig. 7,672 is a diagram of the multiple bank contacts.

The Step-by-Step Selector.—In fig. 7,674 are shown several groups of selectors and in fig. 7,675, one such switch. It will be seen that there is very little difference in the mechanical construction between this switch and the connector in fig. 7,669.

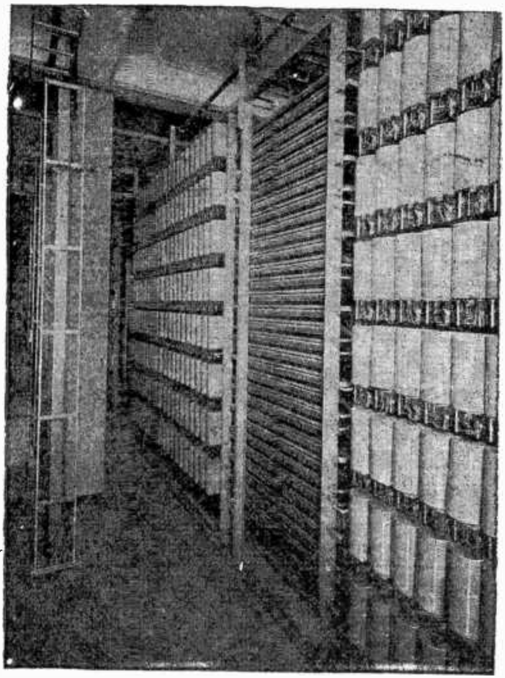


FIG. 7,674.—Groups of selectors mounted on switch frames.

The selector operates also in a similar manner to the connector except that it requires the dialing of only one digit, which raises the wipers to the

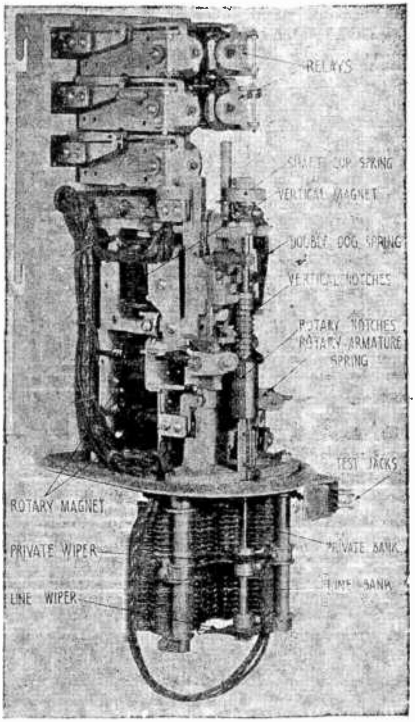


Fig. 7,675.—Step-by-step selector. It consists of a multiple bank and wipers and a mechanism similar to the connector in fig. 7,63[illegible]. This is a one digit switch. The vertical motion is controlled by the dial, and the rotary motion automatically.

level dialed. Then, without further dialing, the selector mechanism immediately starts the rotation and sweeps the wipers step-by-step over the row of bank contacts in the process of finding an idle trunk to another group of selectors or to a particular group of connectors.

The Step-by-Step Line Finder.—In fig. 7,676 are shown several groups of line finders mounted on switch frames. In construction and operation this switch is similar to the connector and selector of figs. 7,669 and 7,675, respectively, except that it has a vertical commutator at the side of the banks and an

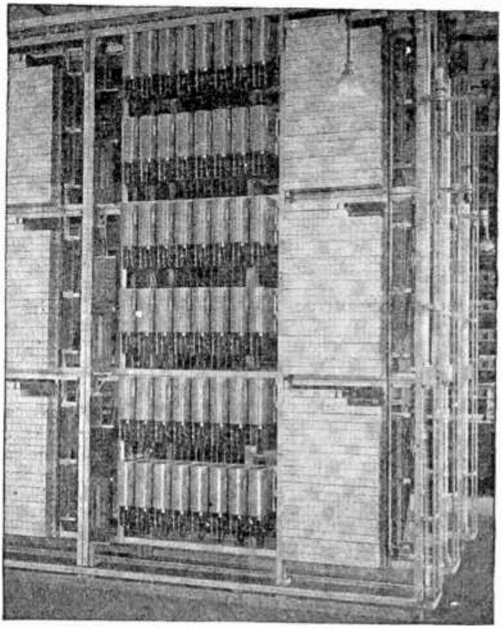


FIG. 7,676.—Groups of line finders on switch frames.

additional brush on the shaft to sweep over the contacts on the commutator so as to control the vertical movement of the wiper shaft. The line finder does not require any dialing. It is self-pulsing and is started by the lifting-off of the receiver from the switch hook.

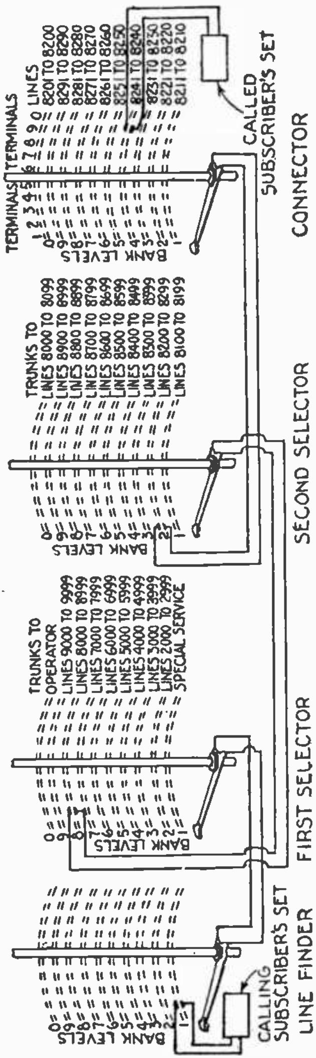


FIG. 7,677.—Progress of a step-by-step call in a four digit central office, using line finders.

The instant the receiver is removed from the hook of a subscriber line connected to the multiple banks the line relay of the subscriber line operates and closes a circuit which starts the line finder and causes it to step its wipers up to a level on the banks where the line is located and then immediately the wipers are rotated and stopped at the contacts associated with the subscriber line originating the call. All this stepping of the line finder wipers is accomplished without any dialing on the part of the calling subscriber.

Progress of a Call.—Fig. 7,677 represents in a general way all the equipment involved in a call through a step-by-step central office with four digit numbers. It will be noted that two selectors are required. If this were a three digit system only one selector would be necessary. The line dialed is No. 8,429.

When the receiver of the calling subscriber is removed from the hook, the *start circuit* functions to choose the next idle line finder. The circuit is then arranged so that the shaft of the line finder is stepped up until the commutator brush reaches the first segment which (in this case) is grounded by the operation of the group start relay. No further stepping takes place.

The stepping circuit is now transferred to the rotary magnet which operates and steps the brushes around until the sleeve brushes reach the terminal associated with the line. This terminal has had battery connected to it and causes the horizontal switching of the brushes to be arrested and the connection to be made with the calling line through the line finder brushes and to an idle first selector. Dial tone is now sent back to the calling subscriber by the selector.

It must be remembered that no dialing has been necessary so far.

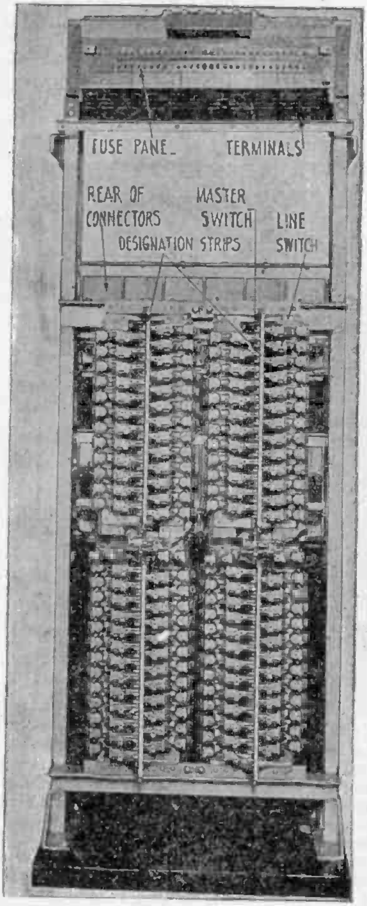
Next, the calling subscriber dials the No. 8. The first selector is actuated by eight pulses and steps the wipers to level No. 8 where it makes connection with the first idle trunk to a group of ten second selectors having access to lines 8000 to 8999.

When the next digit (No. 2) is dialed the second selector picked up is actuated by the two pulses and steps its wipers to the second level where there are trunks to a group of ten connectors having access to lines 8200 to 8299.

The subscriber now dials No. 4 and the connector picked up, steps its wipers to level 4 and when the next digit (No. 9) is dialed the connector mechanism rotates the wipers around to the 9th set of terminals which is connected to the line desired. If the line called be not busy the connector places ringing current on the line. When the party answers, this ringing current is tripped off and the line is cut through for conversation. When the parties hang up at the end of the conversation all the switches return to normal, the calling subscriber's telephone, however, controls the release of all the switches.

Line and Master Switches.—In many step-by-step central offices there is used instead of the line finder what is known as a line and master switch combination.

There is a *line switch* connected permanently to each subscribers' line in the central office. The line switches are placed on line switch frames in groups of 25, 50, 75 or 100 and each group controlled or guided, by a *master switch*. Fig. 7,678 represents a line switch frame with 100 line switches which are constructed as shown in fig. 7,680; fig. 7,682, is an enlarged view of the master switch and controlling details.



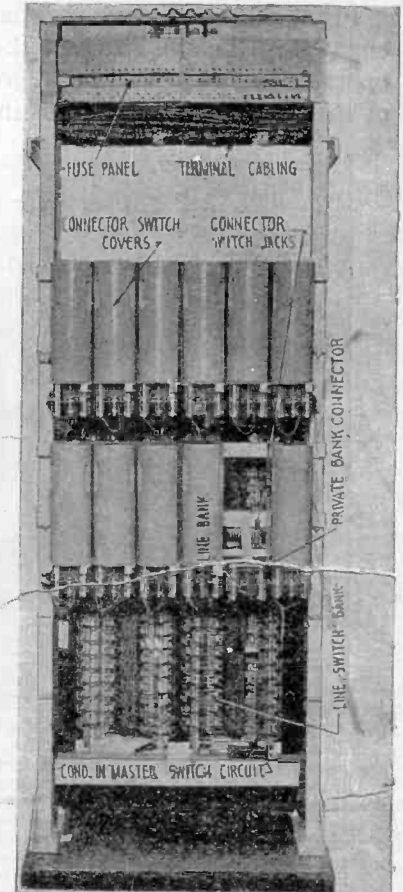


FIG. 7,678.—100 line switch board *front view*. Here are shown 100 subscribers' line switches mounted on a steel frame in four sections of 25. Two sections of 25 are mounted on each swinging shelf and each shelf of 50 is controlled by a master switch. Above the switches may be seen the power panel and terminal assembly.

FIG. 7,679.—100 line switch board *rear view*. On the rear of a line switch unit are mounted the connectors which serve that 100 lines. The incoming subscriber's lines, besides being connected to the line switches are also connected to the connector bank contacts.

Fig. 7,681 shows how the master switch bar, or guide shaft, engages in the slot at the tail end of the plungers of the unoperated line switches in that group, and misses all the plungers of the operated line switches in the same group.

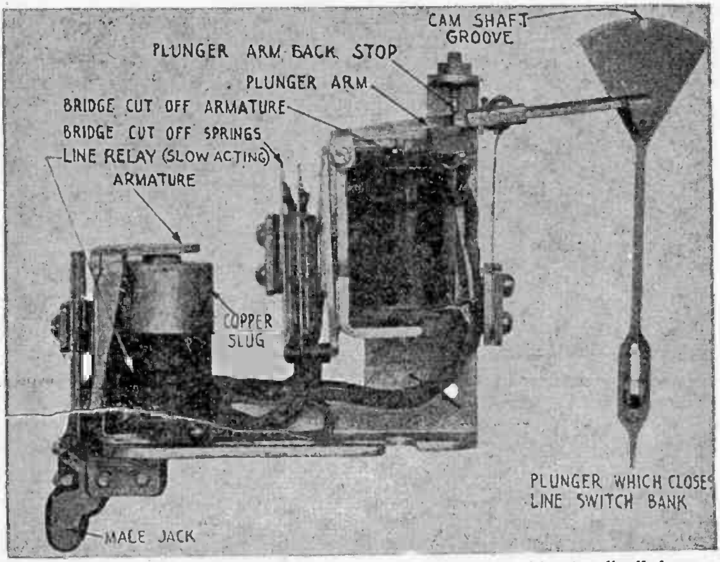


FIG. 7,680.—Line switch. ***It consists of*** a line relay and a combination "pull down coil" and "holding coil" carrying two armatures. The larger armature carries a plunger. which is pivoted so that its point may be swung by the master switch in front of a bank of contacts. The bank consists of 10 sets of contact springs with which are associated ten trunks. Line switches are mounted in groups of 25, four groups being provided for each 100 line unit. One master switch may be provided for any number of groups of line switches depending upon the trunking capacity desired, since each master switch controls ten trunks. Normally the plungers are at rest poised over bank contacts. When a subscriber removes his receiver from his telephone switch hook preparatory to making a call, a circuit is thereby closed which causes the plunger arm of his line switch to be at once pulled down, carrying its plunger out of engagement with the master shaft and thrusting it into the bank. The effect of this is to connect the subscriber's line to a trunk leading to an idle first selector switch, as shown diagrammatically in the right hand portion of fig. 7 635. The instant that one line switch thrusts its plunger into the bank, thus occupying the trunk over whose multiple all idle plungers have been poised, the master switch operates and swings the remaining idle plungers forward over the next multiple of bank contacts. If this trunk should be busy, the movement proceeds until an idle trunk is found. It is to be noted that a line switch always uses a pre-selected idle trunk instead of making a selection after a subscriber starts to call.

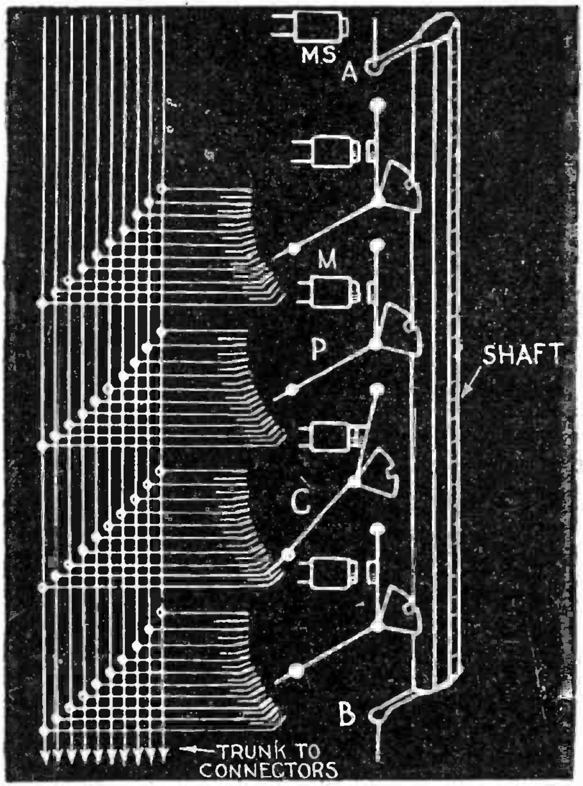


FIG. 7,681.—Diagram of line switch and connections. The switch *consists of* a magnet M, and plunger P, whose head or wing is slotted so that it may engage a projecting edge of the shaft. The shaft is pivoted at A and B, and is capable of a rotary motion of about 40 degrees under control of a master switch MS. The rotary motion causes the plungers of the various line switches to oscillate in front of the terminal of the trunks to the selector switches. Under control of the master switch the shaft comes to rest *only* opposite an idle trunk. If the shaft be holding all the plungers opposite, say the second trunk, and a subscriber remove his receiver, the corresponding plunger will *plunge in* and extend the connection to the selector associated with trunk number two. The plunger when *plunged in* is now free of the shaft as shown at C. The master switch, by means of the shaft moves the remaining plungers opposite an idle trunk, giving what is called *pre-selection of trunks*. When the subscriber who plunged in on trunk No. 2, hangs up his receiver, his plunger will come out of the bank but the slot in the wing of the plunger will not engage the shaft at this time. Hence this plunger will remain opposite trunk No. 2, until the shaft again swings in front of this

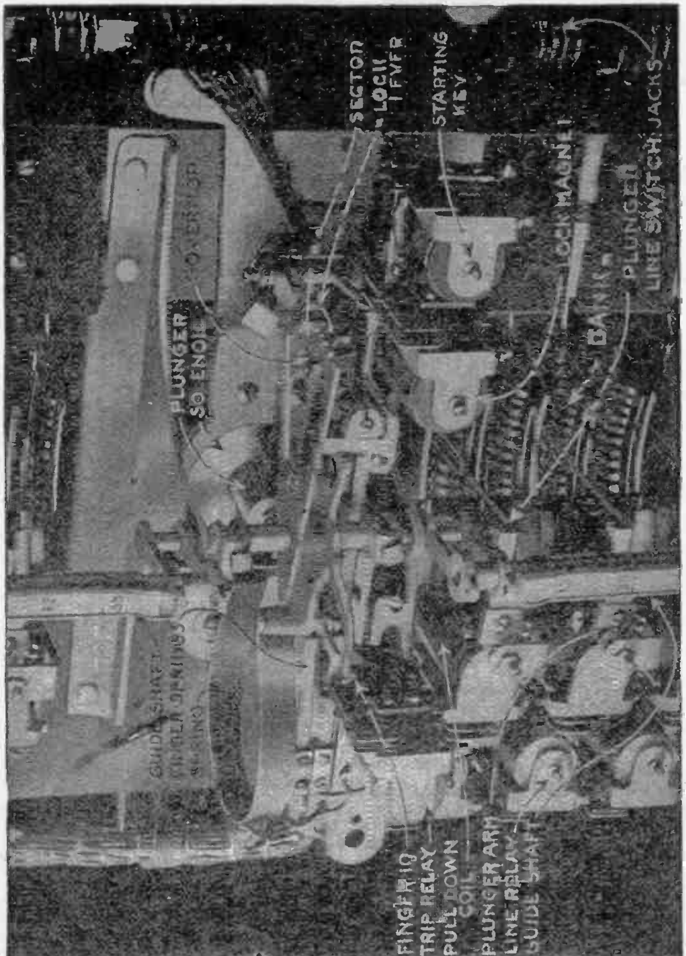


FIG. 7,682.—Master switch mechanism on line switch frame.

FIG. 7,681.—*Text continued.*
trunk and picks it up. To prevent a caller connecting on a busy trunk, a plunger must not plunge in while the master switch is seeking an idle trunk. This requirement is met by what is called the *open main battery feed*.

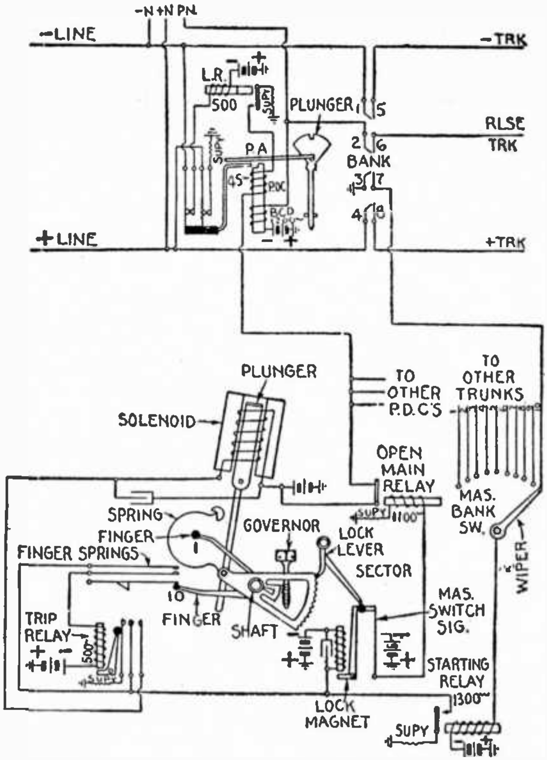
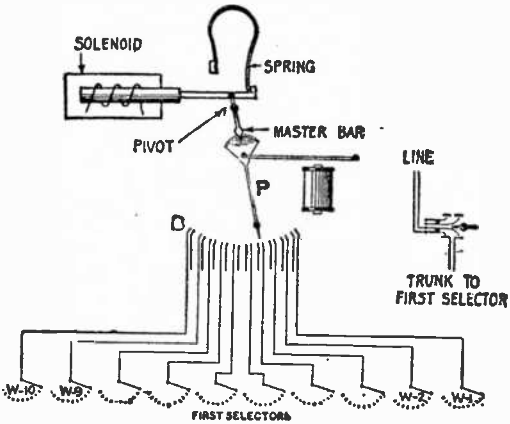


FIG. 7,683.—Line and master switch circuit. When the receiver (not shown) is taken off the hook the LR relay operates which in turn energizes the 45 ohm winding (P.D.C.) of the plunger relay and causes the plunger to be squeezed into the contacts of the line switch bank, thereby connecting the telephone with an idle trunk, or idle selector, as shown in fig. 7,685. The selector circuit then furnishes ground over the RLSE TRK lead which energizes the 1,200 ohm winding (BCD) of the plunger relay to lock the plunger in the operated position since the original operating path through the relay LR was broken upon the operation of the plunger. Ground is also sent to the master switch wiper, through line switch bank contacts 3 and 7, which causes the operation of the starting relay. The starting relay in turn operates the lock magnet relay which disengages the lock lever from the locking segment associated with the master switch and allows the guide shaft which is controlled by the U spring under tension, to rotate one notch so as to move the line switch plungers from right to left. The master switch wiper remains grounded while the associated trunk is busy, therefore, the starting relay does not release until the wiper by rotating has found a contact associated with an idle trunk. When an idle trunk is found the starting relay and the lock magnet relay release. This allows an idle line switch in the same group to operate. Each time that the lock

Line switches 1, 2, and 4, are shown unoperated, and line switch No. 3 is shown operated or plunged. The guide shaft in turn is attached to a lever which is fastened to the master switch locking segment A or at B. The latter is notched ten times at the circumference and a locking arm is pressed into the notches (one notch at a time).

The locking segment can be moved by a U spring, provided the locking arm is moved away from the notch of the locking segment, which is the case when the master switch is operated; or to be more specific, when the locking magnet is operated immediately after the plunging of a line switch.



FIGS. 7,684 and 7,685.—Master switch mechanism of line switch and diagram of trunks to first selectors. In the line switch, the notch in the head of each plunger meshes with a rocking bar or "guide shaft" as it is called. A step by step device called a master switch (seen in the upper part of the figure) is connected to each pair or to each four guide shafts and by means of them can swing the plungers back and forth, step by step over the banks of contact springs. The plungers are normally held in position by the master bar, which carries a feather fitted into the slots at the rear of the plunger. When the line switch operates, the plunger point is thrust into the bank, connecting the line to the selector trunk, and at the same time disengaging itself from the master bar. The master switch is now automatically unlocked and begins to move under the action of the curved spring until an idle trunk is reached. When the master switch reaches the end of its stroke, the solenoid is energized and this pulls the shaft back in the opposite direction against the action of the spring.

FIG. 7,683.—*Text continued.*

magnet relay operates, the master switch shaft is rotated by the U spring so as to move the line switch plungers from right to left until trunk No. 10 is reached when a circuit is closed through the finger springs (by means of the finger on the segment) which energizes the solenoid and allows the solenoid plunger to move the master switch shaft in a direction against the spring tension to give this spring energy for another cycle. This operation is repeated.

Because of the mechanical arrangement in the master switch, the locking segment moves only one tenth of its full travel or one notch at a time, which corresponds to one trunk when the position of the line plungers in the line switch bank is considered. When the locking segment has moved from position 1 to 10, in steps as outlined above, a circuit is closed which sends electric current into the solenoid, which pulls its plunger. The latter, in moving, puts more tension on the U spring by bringing its two ends closer together.

This tension is utilized in moving the locking segment from position No. 10 to the starting position No. 1 and then in succession to position No. 10 again, as outlined above. The speed of the locking segment is controlled by a small governor and a system of gears.

Operation of Line and Master Switch.—Fig. 7,683 outlines in detail the circuit operation of the line and master switch combination. The line switch bank has connected to it trunks leading to first selectors, as shown in fig. 7,684.

When the line switch plunger has operated, the calling subscriber is connected to an idle first selector which sends back *dial tone* to indicate that the switches are ready for the dialing operation. From this point on the circuits and the equipment function as outlined in fig. 7,677.

Dial Private Branch Exchanges.—The dial private branch exchanges employ step-by-step type switching apparatus, and are designed to meet the same service requirements as manual private branch exchanges.

A great many of these P. B. X.'s have a manually operated switchboard used for central office connections and certain classes of tie lines to other P. B. X.'s.

When a manually operated switchboard is used with the step-by-step switching apparatus the system is known as a *semi-mechanical P. B. X.*

The P. B. X. systems are further classified according to the line capacity and the arrangement of selectors and connectors as follows:

1. Two digit system.—100 line capacity;
2. Combined two and three digit system.—200 line capacity;
3. Three digit system.—1000 line capacity;
4. Combined three and four digit system.—over 1000 lines.

Each semi-mechanical P. B. X. consists of:

1. A manual switchboard similar to the one in fig. 7,570;

2. Line switch frames with line and master switches, similar to the one shown in fig. 7,678 with connectors as in fig. 7,679 on the rear side;

3. A selector frame with selectors of the same construction as the one shown in fig. 7,675 (when required);

4. Relay racks with relays for central office trunks, tie lines, attendant trunks, etc.;

5. Main distributing frame for terminating the central office feeder cables, house cables, extension lines and trunks;

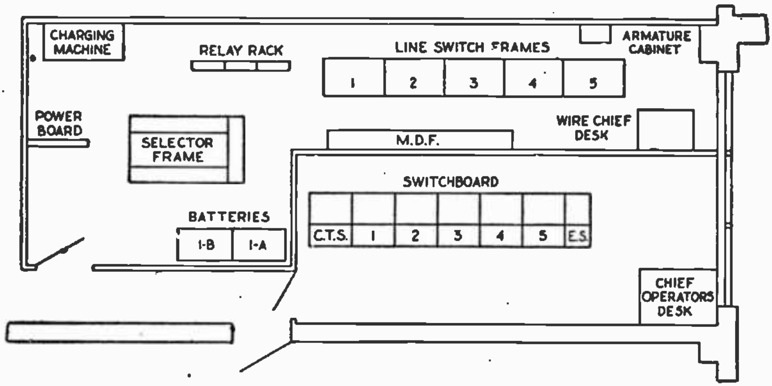


FIG. 7,686.—Typical floor plan of three digit step-by-step Private Branch Exchange.

6. A power plant consisting of a storage battery, a power board with controlling equipment and meters, a ringing machine and a charging machine;

7. Station equipment comprising the telephone instruments with dials and bells.

The apparatus is installed in the subscriber's premises in regular order, similar to fig. 7,686.

In the latest development of step-by-step P. B. X.'s the line finder has replaced the line and master switch combination as in the case of the step-by-step central office.

In operation:—Calls from extension to extension are handled with the step-by-step switching apparatus by dialing the proper number.

Calls from the central office into the P.B.X. are routed to the manual switchboard and are completed to the extensions by the operators. Calls from the extensions out to the central office may be dialed direct or they may be routed to the local P. B. X. operator who then completes the connections.

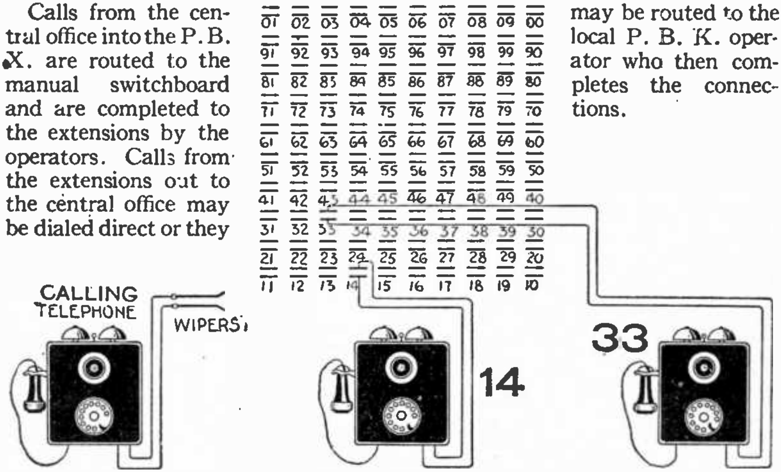


FIG. 7,687.—Diagram of line bank contacts, associated with each connector and numbering system of the telephone lines of which they are the terminals. The number of any set of terminals can be determined by noting the number of vertical and sidewise steps the wipers must be given to reach that set, remembering that ten steps are always represented by zero. Thus six vertical steps and ten rotary steps would cause the wipers to reach contact No. 60.

In the case of a small two digit system there are no selectors, the dialed connections being cared for by a so-called selector-connector, which is similar in construction to the connector and does the work of both the selector and the connector.

The selector-connectors are wired either to line finder or line and master switches.

The banks of the selector-connectors are wired to the extension telephones as shown in fig. 7,687, except that the top level or terminals 00 to 09 inclusive are wired to attendant trunks to the local P. B. X. switchboard. To dial the switchboard it is only necessary to dial "O," and to connect with an extension, two digits must be dialed.

NOTE.—In a combined three and four digit system, or a four digit system a second selector is introduced between the first selector and the connector for the four digit line groups as was explained in fig. 7,677. The first selectors may be either connected to line and master switches or to line finders as in fig. 7,677.

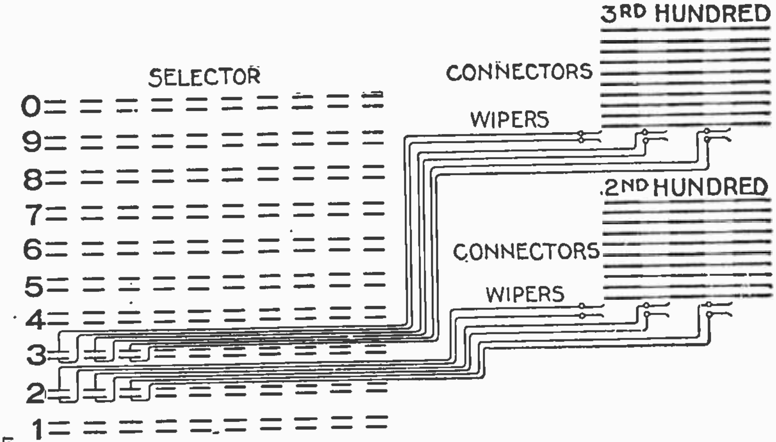


FIG. 7,688.—Diagram of a 200 line office in its simplest form. Lifting the receiver of the telephone connects the calling subscriber with an idle selector. The numbering of the telephones in this office is from 200 to 300 inclusive since the second and third levels of the selectors are used. Dialing the first figure (a 2 or 3) steps the selector up to the second or third level and thereby chooses the 200 or 300 group of lines. Immediately the vertical motion of the selector shaft is complete, the shaft and wipers automatically rotate to select an idle connector serving that 100 line group. This action is independent of the calling device. The last two figures dialed cause the connector to pick out the desired line.

In a three digit system a selector and a connector is used for each connection. The selectors may be wired either to line finders or to line and master switches.

The selectors and the connectors are wired as shown in fig. 7,688. To make connection with any extension it is necessary to dial three digits, and to reach the local P. B. X. operator it is necessary to dial "O."

TEST QUESTIONS

Panel System

1. *From what does the panel dial system derive its name?*
2. *What is the difference between the panel dial system and the step-by-step dial system?*
3. *How is the selection of a particular brush made?*
4. *What is the function of the commutator on a selector rod?*
5. *What is the duty of the "sender"?*
6. *Name the selectors controlled by dialing the central office code.*
7. *What is a "call indicator position"?*
8. *Describe the cordless B-board and explain its function.*
9. *In the automatic setting up of a complete connection, what selectors are involved?*
10. *When is the sender released from the call?*
11. *Explain the operation of a line finder?*
12. *What would happen if two line finders were started simultaneously?*
13. *What circuit receives and stores the dial impulses?*
14. *How many final selector frames are required in a central office of 6,000 lines?*
15. *How many line finder frames are required?*

TEST QUESTIONS

Step-by-step System

1. *Describe the step-by-step action of a selector.*
2. *What is the main difference between the connector and the selector?*
3. *What is the function of a line switch?*
4. *What is the function of a line finder?*
5. *What is the duty of the master switch?*
6. *Compare a line finder and a selector.*
7. *Where is terminal 35 located on the connector bank?*
8. *What causes a line switch to plunge?*
9. *When a subscriber lifts the receiver off the hook and operates the line switch, and is connected to a selector, what may cause the line switch to release and to plunge again in rapid succession?*
10. *Explain what apparatus operates and is tied up as a result of the receiver being accidentally knocked off the hook.*
11. *What switch furnishes the talking battery?*
12. *What switch furnishes the dial tone?*
13. *What switch applies the ringing current to the line?*
14. *Name the apparatus involved and describe the operation when a complete connection is set up:*
    a. *In a 2 digit system.*
    b. *In a 3 digit system.*
    c. *In a 4 digit system.*

CHAPTER 189

The Telegraph

The telegraph is *an electrical apparatus for transmitting messages between distant points.*

The simplest form of telegraph consists of

1. Key or transmitting instrument.
2. Line wire.
3. Sounder or receiver.
4. Battery or other source of electricity.

Classification.—The telegraph, like other inventions, has been considerably developed, resulting in numerous systems. A classification of these various systems, to be comprehensive, must be made from several points of view, as with respect to:

1. The kind of circuit, as

   a. Ground return;

   b. Metallic.

2. The method of operating the circuit, as

   a. Closed;

   b. Open.

3. The transmitting capacity.

a. Single Morse line;

b. Diplex.

c. Duplex { single current or differential; double current; polar; bridge; high pressure "leak"; high efficiency; city line; short line.

d. Quadruplex. { gravity battery; Jones; Field; Davis-Eaves or Postal squad; single dynamo; metallic circuit; Gerritt Smith; Western Union; British post office.

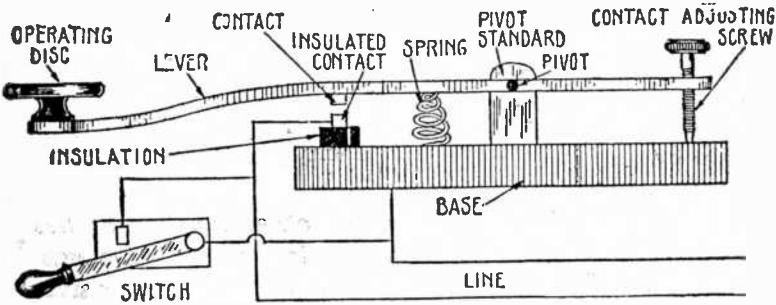


FIG. 7,689.—Elementary key. In actual construction the switch is attached to the base, but is here shown separately, in order that the connections may be more plainly seen.

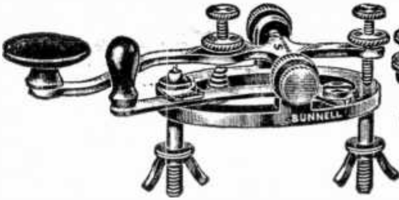
e. Multiplex { synchronous.

f. Phantoplex.

4. The method of receiving, as

a. Non-recording

b. Recording { by perforations; by printing.



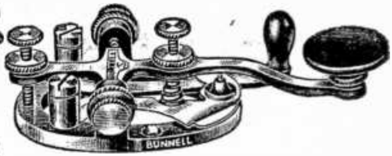


FIG. 7,691.—Bunnell key *without* legs.

FIG. 7,690.—Bunnell key *with* legs.

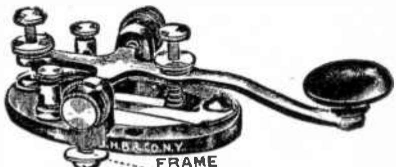
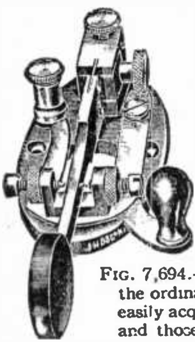


FIG. 7,692.—Fry open circuit key. *It has* a circuit closer which must be worked like an ordinary key. With circuit closer in closed position, the battery cannot be put to line or short circuited by pressing down on key lever, hence leaving a book or other heavy object on key does not waste the battery, but the relay is always in circuit ready to receive signals.

FIG. 7,693.—Bunnell open circuit key. When it is preferable to use dry cells instead of closed circuit cells this type of key is recommended. Even though a closed circuit be maintained for communication in either direction no current is being used except when key is depressed. Each individual station supplies its own current.



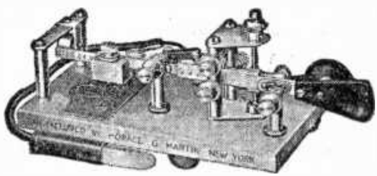


FIG. 7,694.—Bunnell double speed key. *It requires* only one-half the motions of the ordinary key, and these are made by a sidewise rocking motion of the hand, easily acquired, which guarantees that operators will not be affected with cramp, and those who are so affected will soon recover their speed.

FIG. 7,695.—Bunnell vibroplex key.

Key or Transmitting Instrument.—As shown in Fig. 7,689, a key consists essentially of *a pivoted lever provided with a contact and adjusting screw, and carried on a base having an insulated contact and a spring to keep the lever normally in the open position.* A switch is provided to close the circuit when the key is not in use.

In operating the key, its operating disc is grasped by the 1st, 2nd, and 3rd fingers; depressing the disc causes the two contacts

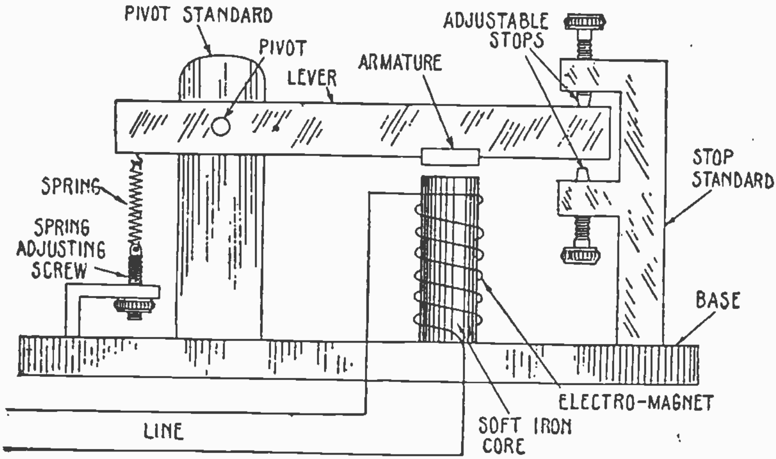
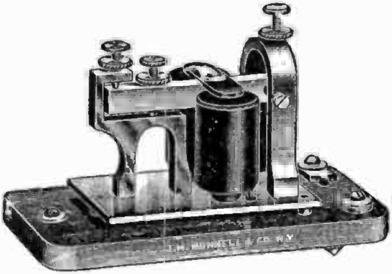


FIG. 7,696.—Elementary sounder showing essential parts.

to touch, thus closing the line circuit. When the operator ceases pressing on the disc, the spring forces the contacts apart and breaks the circuit. Closing the circuit for a short period corresponds to a "dot" and for a longer period, to a dash. The periods in which the circuit is closed are indicated audibly by a "sounder."

Figs. 7,690 to 7,695 show the actual construction and appearance of modern keys now in use.



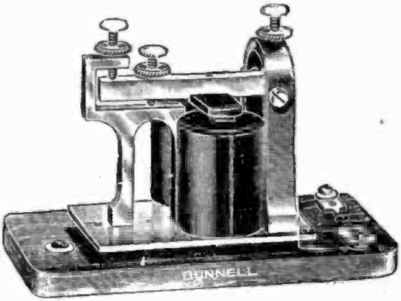


FIG. 7,697.—Bunnell aluminum lever giant sounder. Sounders wound to 4 ohms can be used on lines up to ¼ mile in length; while 20 ohm sounders will operate on main lines up to 15 miles in length, without using a relay.

FIG. 7,698.—Bunnell 1892 giant sounder with aluminum or brass lever.

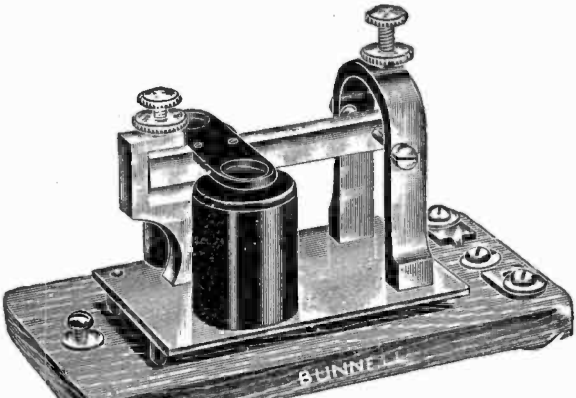


FIG. 7,699.—Ghegan alternating current sounder. *It can be used* on any 110 volt, 60 cycle *a.c.* circuit, the method of connecting depending on the resistance of the winding used. Wound with high resistance for 110 volt, 60 cycle circuit through a condenser of one-half *m.f.* capacity, which is connected in series with the sounder. By giving the lever plenty of play between stops the sounder may be connected direct to the 110 volt, 60 cycle circuit. However, the series condenser is recommended as the lever play may be adjusted to suit and the current consumption is reduced to about ten milli-amperes on closed circuit. The low resistance type is to be used in the secondary of a small socket transformer, as shown in its blue print.

Sounder.—The essential elements of a sounder or receiving instrument are shown in fig. 7,696. As here shown, a heavy pivoted lever is arranged *to vibrate between two stops and held normally against one of these stops by the action of a spring, there being an electro-magnet which when energized acts on an armature attached to the lever causing the latter to move from the upper stop to the lower stop.*

The popular name sounder is given to the receiving instrument because in operation the lever is forced against the stops with considerable rapidity. and the blows thus produced, owing to the heavy construction of the lever, are distinctly audible.

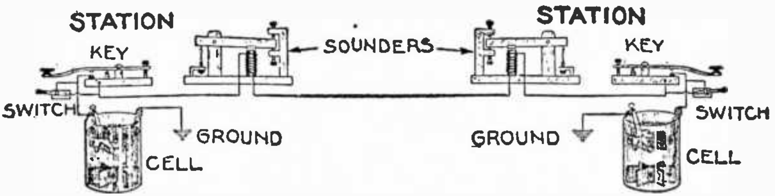


FIG. 7,700.—Elementary diagram showing a simple short line ***closed circuit*** system. It is called a closed system from the fact that the circuit is normally closed with current on the line, that is to say, when not in operation the switches are closed and current flows which energizes the magnets and holds the instrument armatures in the down position. This necessitates the use of a closed circuit cell as for example the crow foot gravity type which is capable of supplying a very weak current for a long duration of time.

Simple Short Line Circuit.—The essential apparatus required for transmitting messages a short distance consists of

1. Key. 2. Sounder. 3. Battery

at each station and may be connected up to operate on either

1. Closed circuit, or 2. Open circuit.

The closed circuit arrangement is shown in fig. 7,700.

NOTE.—An advantage of the open circuit system is that when not in use, the battery is not required to supply current to the line; another advantage is that the resistance of the sounder (or relay) is not always in the circuit, since the closing of a key cuts out the relay. On relay lines local sounders or registers are provided. In some cases a "telltale" galvanometer is placed in the main line at each station to indicate to the operator the condition of his transmitted signals, etc.

It is so called because both switches are kept closed except during operation, when the sender's switch remains closed. It would naturally be supposed that keeping the circuit closed for long intervals would exhaust the battery, but it does not because owing to the high resistance of the magnet on the sounder, very little current flows; moreover a battery designed for closed circuit is used.

The open circuit system is shown in fig. 7,701.

In this arrangement the only instruments necessary are a key with insulated contacts, a sounder, and cell at each station. One insulated contact of each key is connected to the cell, and the other insulated contact is connected in series with the sounder and the latter grounded as shown. The base of each key is connected to the line.

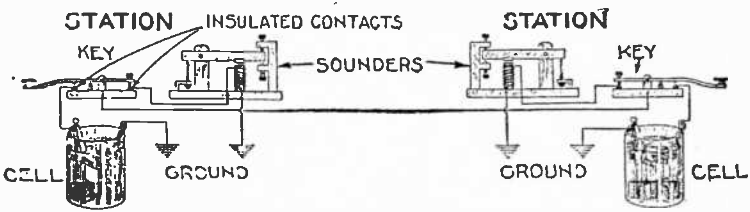


FIG. 7,701.—Elementary diagram showing a simple short line *open circuit* system. In Europe this system is in general use; it consists essentially of so arranging the apparatus that the battery shall only be placed on the line when a message is being transmitted. A main battery is necessary at each station, whereas in the *closed system*, employed in America, main batteries are required only at the terminal stations.

In operation only the battery at the sending station is available, hence twice the battery capacity is required as compared with the closed circuit system. Ordinary keys may be used by insulating the back contact of each.

Relay.—In general, a relay is *a device which opens or closes an* **auxiliary circuit** *under predetermined electrical conditions in the* **main circuit.**

The object of a relay is to act as a sort of **electrical multiplier,** that is to say, *it enables a comparatively* **weak** *current to bring into operation a* **much stronger** *current.*

In so doing it reduces considerably the battery capacity required for a line of given length.

Thus, for a given battery capacity messages can be sent over a much longer line by the aid of a relay; that is, when relays are used, a very weak current will suffice for the main line, since the moving parts of these instruments are very light they require very little energy for operation. The relay controls a comparatively strong local current to operate the sounder.

The essential parts of a relay, as shown in fig. 7,702 are

1. An electro-magnet.

Energized by the main circuit current.

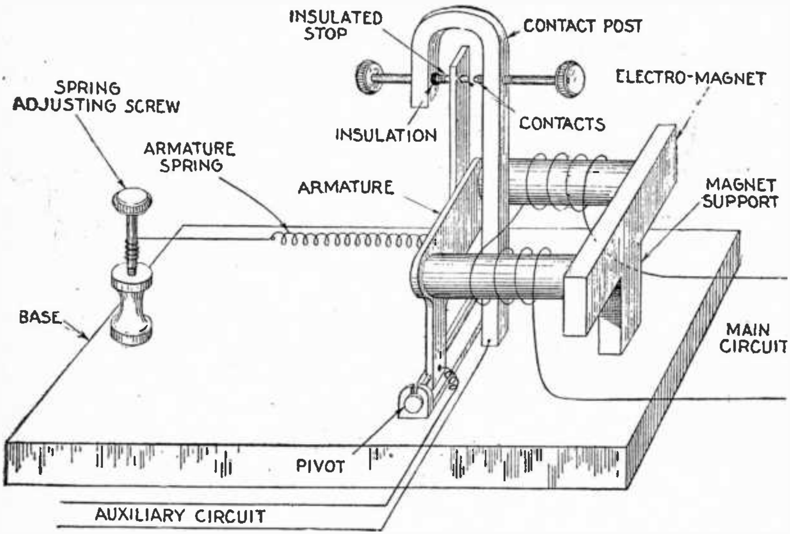


FIG. 7,702.—Elementary relay showing magnet, insulated armature contacts, insulated stop, armature spring, main and auxiliary circuit connections. *The function of a relay is to open or close an auxiliary current under predetermined electrical conditions in the main circuit,* so that *a comparatively weak current may bring into operation a much stronger current* to effect a saving in battery capacity. Note the delicate armature construction as compared with the sounder, thus requiring very little energy to operate. A relay is virtually a very delicate sounder with a contact maker at the end of the armature lever.

2. An insulated armature.

Very light in construction and pivoted so as to vibrate between a contact and an insulated stop as shown.

3. An adjustable spring.

Designed to hold armature against stop when not attracted by the magnet.

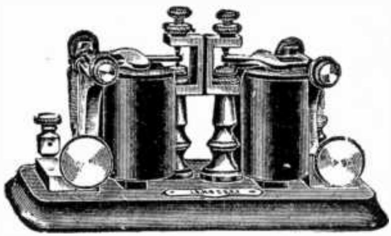


FIG. 7,703.—So called "Wheatstone" or British Post Office *polar* relay. Wound with either two or four windings according to requirements. The two winding form consists of two coils differentially connected in the same manner as the main coils of the four winding type. In the four winding instruments the first set of coils is called the main winding and the second set is called the *accelerating* and *opposing* coils respectively. The main winding consists of two coils each having the same electrical characteristics. Each coil terminates at the binding posts with the letters (U),(D), and U,D. If a jumper be connected from U to (D) and a positive current applied to (U) with its corresponding negative to D the tongue T, or commonly called the armature, will move sharply to contact stop M or marker and if the current be reversed it will move to contact stop S or spacer. Similarly in the four winding type when the opposing coil terminating at OO, and the accelerating coil AA, are connected in series, the same effect will be produced. The normal operating current through the main windings when connected in series is 5 milli-amperes and the minimum operating current is .5 milli-amperes. This instrument is especially useful on high speed automatic telegraph circuits, repeater sets, and on key worked duplex or quadruplex circuits having small operating margins.

FIG. 7,704.—Bunnell balanced double relay. *It consists* of two relays connected in series on the same base, having opposite contacts, which may be connected in series or parallel for the purpose of opening or closing a second circuit when the first or main circuit through the relays is varied or broken. As the local contacts are oppositely arranged, that is to break or make circuit under opposing conditions, one making contact on front and the other being properly adjusted, an increase or decrease in the relay circuit will cause one or the other armature to move, thus opening or closing the local or second circuit. This prevents the possibility of alarm being made inoperative by grounding or opening or by increasing or decreasing the current in the circuit.

4. Magnet leads.

Connecting the magnet winding to the main circuit.

5. Insulated armature leads.

Connecting the insulated armature and contact post with the auxiliary circuit.

Medium Distance Line with Relays.—When the length of line becomes too great to operate sounders without unduly large battery capacity the arrangement shown in fig. 7,705 is used.

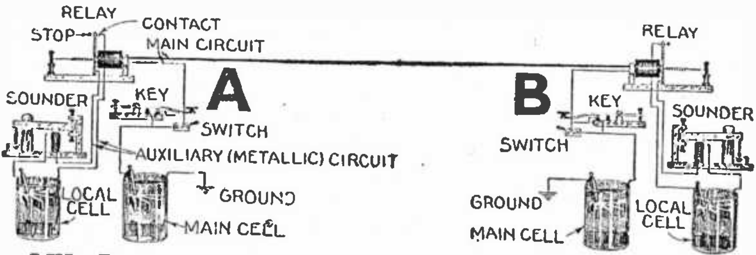
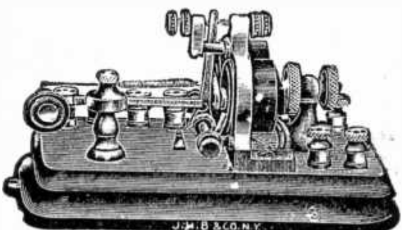


FIG. 7,705.—Elementary short line with relays, showing the main circuit and the auxiliary circuit at each station. The relay, as stated in the text *acts as a sort of multiplier*, that is to say, *it enables the comparatively weak current of the main circuit to bring into operation the much stronger current* of the auxiliary circuit to operate the sounder. On lines of moderate or long distance, as can readily be seen, a considerable saving in battery capacity is effected, by localizing the strong current necessary to operate the sounder, it being understood that considerably more energy is required to operate a sounder than a relay.



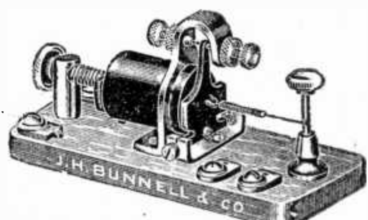


FIG. 7,706.—Smith three coil neutral relay—specially adapted to quadruplex work.

FIG. 7,707.—Bunnell single spool concentric magnet pony relay with adjustable magnet.

It consists of one main circuit and an auxiliary circuit at each station. The main circuit includes the relays, keys, and main cells all connected in series with ground return. The auxiliary circuit at each station is made up of a sounder and local cell joined in series and connected with the auxiliary circuit of the relay as shown.

When not in operation both switches are closed; this energizes the relay magnets and keeps the auxiliary circuits closed by holding the relay contacts together.

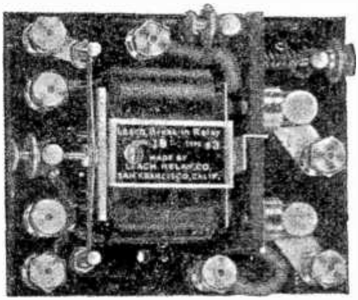


FIG. 7,708.—Bunnell *break in* relay for rapid handling of traffic working through static, cutting interference to a minimum. You hear what is going on while you are actually transmitting. The receiving operator can stop you at any time by holding his key down for a second and giving you the signal BK. You hear his dash and signal between your own dots and dashes. *It operates* on 6 volt *d.c.* and has no external resistance unit. Either a Morse Key, Bug, or Cootie key is used to operate the relay which in turn operates the transmitter.

In operation, the sender opens his switch and with the key sends the message by successively making and breaking the main circuit in proper sequence.

This causes the relay armature to move back and forth against the contact and stop, thus making and breaking the auxiliary circuit in synchronism with the movements of the key. In this way, the very weak main current is enabled to bring into action the much stronger current of the auxiliary or local circuit, thus, the movements of the delicate relay armature are reproduced by the heavy armature of the sounder.

The system shown in fig. 7,705 is suitable for lines not exceeding about 500 miles.

Repeaters.—When the length of a telegraphic circuit exceeds a certain limit, dependent upon the ratio of its insulation to its conductivity resistance, the working margin becomes so small that satisfactory signals cannot be transmitted even by the aid of increased battery capacity. This limit under existing conditions is much less in wet weather than in dry weather.

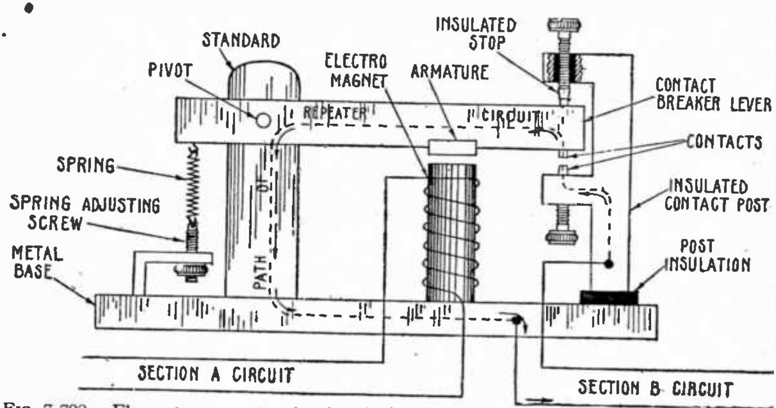
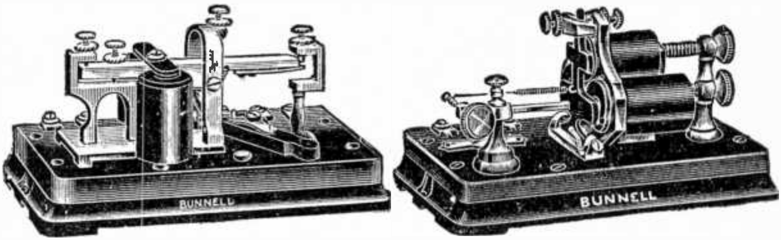


FIG. 7,709.—Elementary repeater showing the insulated parts essential for the contact maker, and path of the current through the repeater portion of the instrument. The insulated stop on the upper arm of the contact post is shown in sectional view to clearly indicate the insulation at this point. Compare this instrument with the elementary sounder fig. 7,696 and note the essential points of difference.

There is no difficulty in directly operating a telegraph of three hundred miles or less, if the line be fairly well insulated and there are not too many offices connected in the circuit. The difficulty arising from the number of offices usually settles itself, since the traffic cannot be handled without great delay when the number of offices is too great, and accordingly, it becomes necessary to employ more wire and divide the offices among them. When, however, the length of a single line increases, the difficulties with *leakage* and *retardation* increase, until the speed and certainty of signaling are largely reduced. Under such conditions it was formerly necessary to retransmit all communications at some intermediate station, but this duty is now performed by an instrument called a *repeater*.

By definition a repeater is *a sounder provided with a circuit maker for synchronously controlling a second circuit.*

That is to say, it is simply a piece of apparatus in which the sounder (or in some cases the relay), receiving the signals through one circuit, opens and closes the circuit of another line, in the manner that a relay opens and closes the auxiliary circuit of a sounder.



FIGS. 7,710 and 7,711.—Weiny-Phillips automatic repeater set consisting of transmitter fig. 7,710 and relay, fig. 7,711. The third spool of the relay is differentially wound, so that normally the windings neutralize each other and no magnetism is developed in this spool. One of the coils of the differential spool is in circuit with the front contact of the transmitter of opposite side, so that the instant the transmitter circuit is broken the corresponding coil of the differentially wound spool is opened, thereby permitting the second coil to act and hold the relay armature closed. The differential magnet being energized by the breaking instead of the closing of the auxiliary circuits enables this repeater to act quickly, and thereby very materially increases its capacity for rapid signaling.

A repeater as shown in fig. 7,709 consists essentially of *a sounder of the same construction as in fig.* 7,696, *with the exception that the contact post is insulated and is provided with an insulated stop*. This device forms *a contact maker for the repeating section of the circuit.*

As indicated by the dotted line and arrows, the path of this circuit is (when closed) through contact post, contacts, contact maker lever, pivot, standard, and out through base.

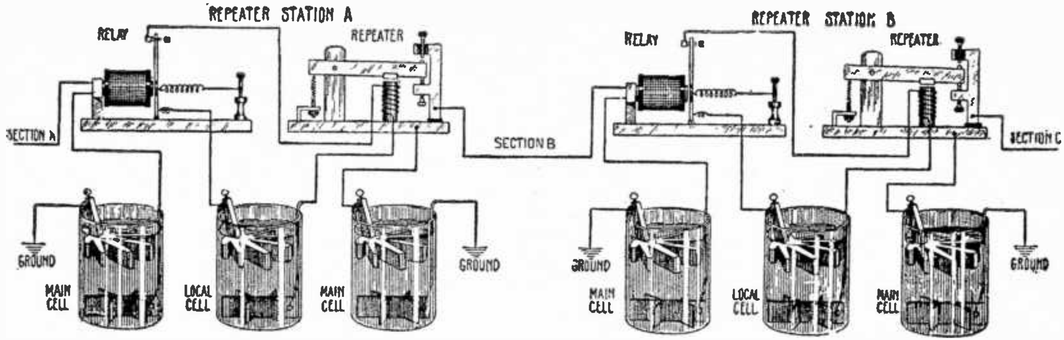


FIG. 7,712.—Elementary repeaters as connected in a circuit. *In operation*, if the home station or beginning of section A line send a message, the movements of the relay at station A will cause similar movements of the repeater, this in turn is repeated at station B, and all other stations on the line.

Long Distance Repeater Line.—To illustrate how repeaters are used on long distance lines a section of such lines showing two repeater stations is shown in fig. 7,712.

The figure illustrates how the elementary repeater shown in fig. 7,709 is connected in the circuit.

As shown, the line is divided into a number of sections, A, B, C, etc., depending upon its length, there being a repeater station joining each section to the preceding one.

The end of section A is connected to the relay main circuit, and the auxiliary circuit to the electro-magnet of the repeater.

There is a ground return on main circuit, and metallic return on auxiliary circuit, one or more cells being included in each of these circuits as shown.

The contact maker circuit of the repeater (which corresponds to the auxiliary circuit of the relay) is connected to section B and ground.

At the end of section B is another repeater station identical with the one just described, and from which section C begins, the number of repeater stations depending on the total length of the line.

An objection to the arrangement shown in fig. 7,712 is that *it will only work in one direction*. This was overcome originally by the button type repeater, and though obsolete now will be described to explain in a very simple way repeater operation.

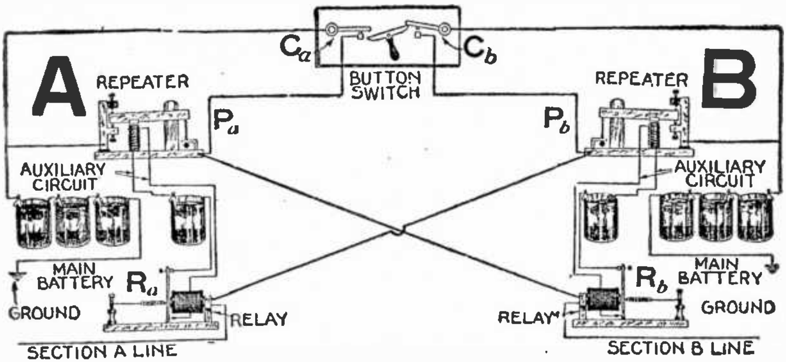


FIG. 7,713.—Diagram showing essentials of the so called button repeater, consisting of two relays, two simple repeaters, a button switch and connections as shown.

The principle of operation of the button repeater is that *the line circuit is extended by making the receiving instrument at the distant terminal of one circuit do the work of the transmitting key of the next circuit, by opening and closing the latter.*

The button repeater comprises *two relays and two simple repeaters, a "button" switch, and connections* as shown in fig. 7,713. For its operation, two local and two main sources of current supply are required.

The button switch provides means for cutting out or closing the circuit around the breaking points of each sounder, otherwise the apparatus would remain unopened.

In the operation of the button repeater if, say, section B, line be opened by the key of the operator, the armature of section B relay will open, which in turn opens section B repeater, whose circuit breaker breaks the circuit of section A. This causes the armature of section A, relay to open, followed by that of section A repeater, the circuit breaker of the latter also breaking the circuit of section A. The operator of section B line cannot now close the circuit, because it is still open in another place, viz., at the circuit breaker of section A repeater. The button switch eliminates this difficulty, for when it is swung to the left, it closes a spring contact C_a, forming a connection between the circuit breaker of section A repeater, enabling the

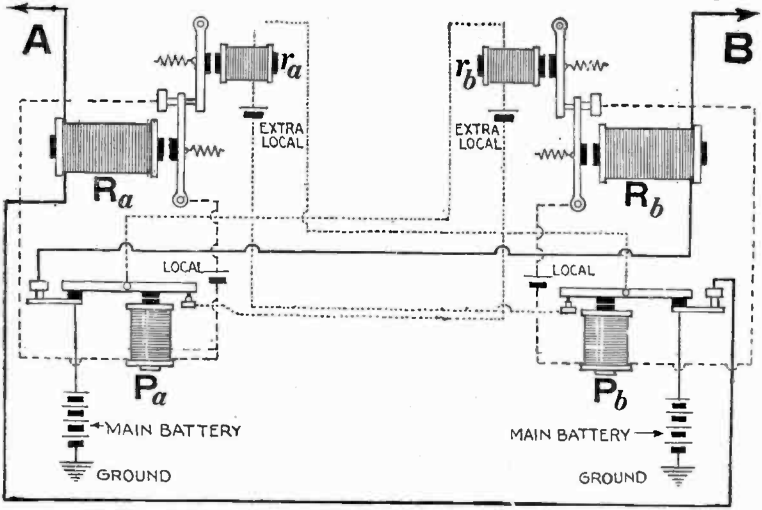


FIG. 7,714.—Milliken repeater system. The relays R_a and R_b are provided with additional or extra magnets r_a and r_b, whose levers press against the main levers in such a manner that when the working current is cut off the working winding, the spring of the extra magnet closes the local contact against the tension of its spring, so that in order that the relay open its local circuit at the local contact, it is necessary that the current be cut off its main line circuit and the current be passing through the local circuit of the extra magnet. The repeaters are provided with two contacts, one, for the local circuit of the opposite extra magnet, and the other, for the closing of the opposite main line circuit. When one of these repeaters opens, its local contact is always broken very shortly b fore the main line contact is broken, while in closing, the opposite takes place. If section A operator be sending to section B, the incoming signals will be repeated by the tongue of relay R_a. This operates repeater P_a, which in its turn repeats the signals into section B. The repetition of these outgoing signals in the relay R_a, would cause the circuit on the incoming side to open at its local contact, if the extra magnet r_b were not coincidently demagnetized by the action of the repeater P_a opening the circuit. Accordingly, the outgoing signals cannot disturb the line on the incoming side.

operator of section B to open and close its circuit, at pleasure, while his signals are repeated into section A by the action of the circuit breaker of section A repeater.

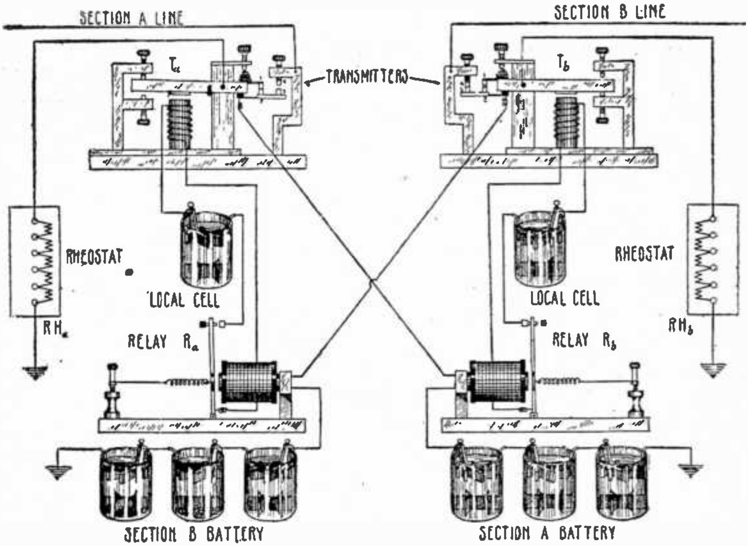


FIG. 7,715.—Diagram of Toye "repeater" or transmitter system, used extensively in the United States and Canada. It comprises two relays, two transmitters with tongue contact breakers, two rheostats and connection as shown. *In operation*, if section B send or open his key, the armature of relay R_a will open as shown, thus opening transmitter T_a lever, which causes contacts 2 and 1 to close and 4 and 3 to open. This change opens section A line, and puts in circuit with relay R_b, section A battery and rheostat RH_a, the resistance of the rheostat being adjusted so that it equals the resistance of section A line. Since this transposition of circuit maintains the current passing through relay R_b at the same strength as before the change of circuit was made, that relay remains closed and likewise also transmitter T_b, thus preserving the continuity of the line while a communication is being sent from section B to section A. Since repeater T_a connects and cuts out section A battery from section A line in response to the operation of relay R_a, relay R_b is prevented opening because section A battery when not in contact with the A line, is given a path to earth through the rheostat RH_a by way of contacts 1 and 2 of transmitter T_a, thus holding relay R_b closed until section A operator desires to "break" or begins sending to section B. In sending from section A to section B a process the reverse of the foregoing holds.

NOTE.—A *disadvantage* of the system shown in fig. 7,715 is the excessive consumption of current, moreover the adjustment of the artificial resistance must be varied to equal that of the line or lines connected through the transmitters, in order to have equal magnetic pull on the relay armatures whether the relay be in circuit with the artificial line or the main line.

The button repeater is called a *manual repeater* as distinguished from the *automatic type*.

The objectionable feature of the button repeater is that it requires the constant attendance of an operator to change the position of the button switch in accordance with the direction in which the message is passing, and consequently has been displaced by the automatic type.

The Automatic Repeater.—One of the simplest repeater systems for single telegraph working is shown in fig. 7,717.

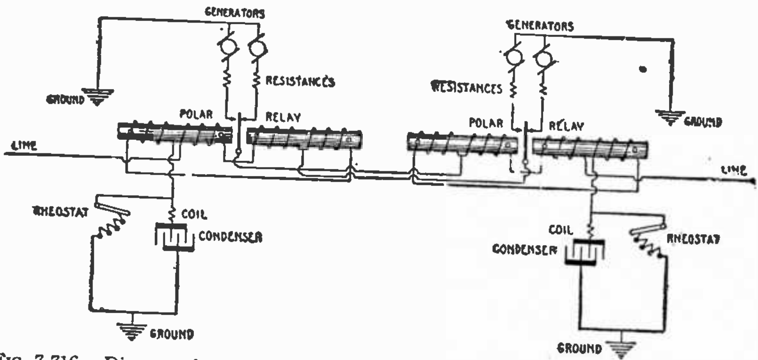


FIG. 7,716.—Diagram of the Postal telegraph repeater system. The Postal direct point duplex repeater is an arrangement by which the respective armature levers of two polar relays at the repeater office connect the positive and negative main battery currents direct to the line wires. Its principle is represented diagrammatically in the figure. The armatures of both polar relays are closed when a distant office closes the key, as shown in the diagram. This results in placing the duplex negative battery in contact with the other line. As the current passes through the coils differentially, the armature of the open line will not be affected by the impulse thereof. When the closed key is opened the positive battery is presented to the line.

This repeater consists of *a transmitter having a second lever placed above the regular armature lever in such a position that one electro-magnet is employed to work both.*

There are three distinct pairs of circuits:

1. Main. 2. Local. 3. Shunt.

In the operation of this repeater (shown in fig. 7,717) when a key on the western circuit is opened the instruments assume the positions shown in the diagram.

The armature of relay R¹, first falls back and opens the local circuit of transmitter T¹, which in turn opens the eastern circuit s¹ r¹, thus causing the armature of relay R to fall back.

This falling back of the armature of relay R, however, does not affect the local circuit of transmitter T, because before the eastern circuit was broken at s¹ r¹, the shunt around the local contacts of relay R was closed at M¹ O¹.

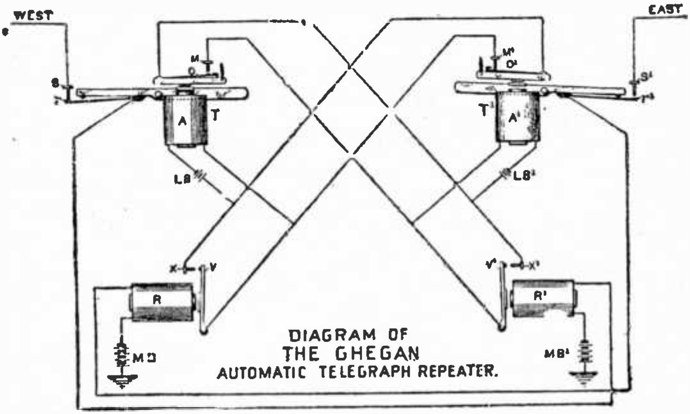


FIG. 7,717.—Diagram of Ghegan automatic repeater. Its principle of operation is based upon the fact that an armature, on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet core, the stronger the magnetism becomes. The circuits and operation are further explained in the accompanying text.

On closing the western key, the armature of relay R¹ closes the local circuit of transmitter T¹, which in turn first closes the eastern circuit at s¹ r¹, and, as already explained, after sufficient time has elapsed to permit the armature of relay R to reach its front stop, opens the shunt circuit of transmitter T at M¹ O¹.

Should east "break" when west is sending, the armature of relay R would remain on its back stop, thus breaking the local circuit of transmitter

T, on the first downward stroke of the superposed armature of transmitter T[1], and so break the western circuit at s r.

There being no extra weight or attachment of any kind to either the relay or transmitter armatures, the quickest possible action can be obtained with this repeater. As both ***relay armatures*** work in ***unison,*** it can always be seen at a glance if the signals are being ***properly repeated.***

The transmitters are provided with switches for working the lines independently or putting them together at will.

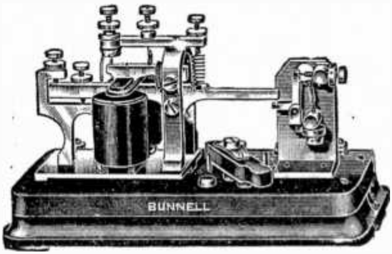
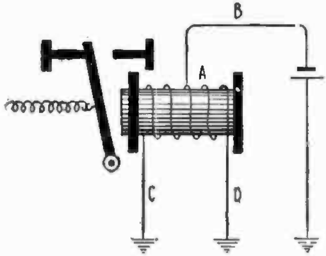
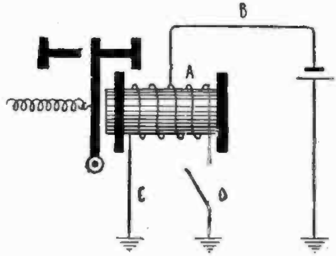


FIG. 7,718.—Ghegan automatic repeater. The second armature spring is adjusted so that on closing the local circuit of the transmitter, the regular armature must reach its front stop before the magnetism induced in it is sufficiently strong to draw the second armature from its back stop. The object of this is to allow a sufficient margin of time between the closing of the main circuit by the downward movement of the first armature and the opening of a shunt circuit by the subsequent downward movement of the second armature, to permit a relay in the main circuit to close its local contacts before the shunt circuit around them is opened. This margin of time between the closing of the main and the opening of the shunt circuit enables these repeaters to work well even on leaky lines with very sluggish relays. This transmitter has a switch for working the lines independently or putting them together at will. The fact that an armature on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet the stronger the magnetism becomes, are the novel principles utilized in this repeater.

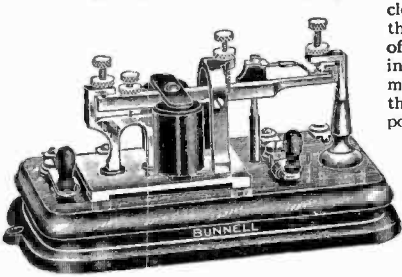
Half Repeaters or Side Line Apparatus.—When a single line and a duplex circuit are expected to repeat into each other, one half of the apparatus of any of the previously described types of single line repeaters, slightly modified, may be employed.

In order to avoid confusion with the full set, however, they are called respectively the "Half-Milliken," the "Half Weiny," the "Half-Atkinson," etc., according to the type.

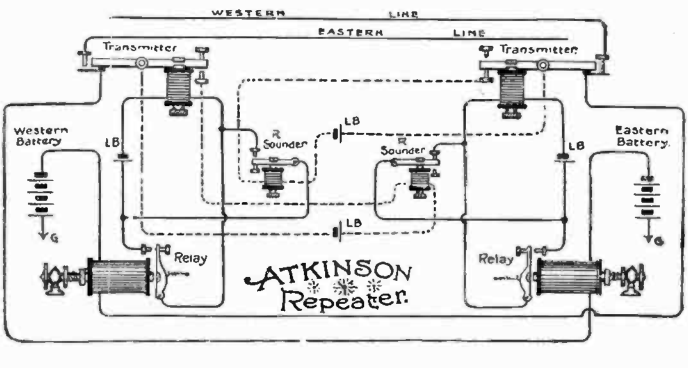




FIGS. 7,719 and 7,720.—Detail of the differentially wound third spool of relay of the Weiny-Phillips system. In fig. 7,71 , one terminal of the battery is shown grounded while the other terminal is shown connected differentially with two equal windings of the magnet. The current divides at A, half going through each coil. It may be observed that the direction of the winding of one coil is opposite to that of the other. Thus, when current flows through the wire B, the magnetization of the core due to the action of current in the coil A-C is neutralized by the presence of current in the coil A-D and as a result the core is not magnetized at all; so that the retractile spring attached to the armature holds the latter in the "open" position as shown in fig. 7,719. If, however, while the coil A-C remains closed, the coil A-D be opened, as in fig. 7,720, the core will be magnetized due to the presence of current in the coil A-C while no current exists in coil A-D, the latter no longer neutralizing the magnetic effect of the former. The armature, therefore, is attracted and held in the "closed" position as shown in fig. 7,720.



FIGS. 7,721 and 7,722.—Atkinson repeater transmitter and diagram, used by the Western Union. *The repeater set* consists of two standard relays, two Atkinson Transmitters and two repeating sounders arranged as shown in the diagram.



Diplex System.—By definition this is *a system which permits* **two messages** *to be transmitted in the* **same direction** *at the* **same time** *over a single wire.*

A principle common to the various multiplex systems is that *the receiving instrument at the home station, while free to respond to the signals of the key at the distant station, shall not respond to the signals of its associate key.*

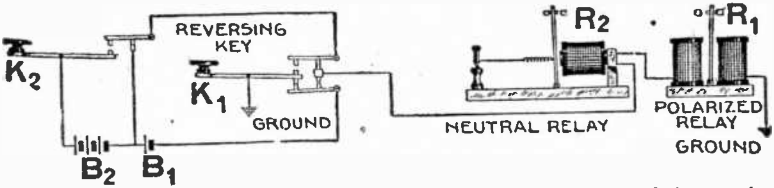


FIG. 7,723.—Elementary diplex system; diagram illustrating the principle of diplex telegraphy. *In operation,* if the sender depress key K_2, this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R , to be attracted. If now another signal be sent by the depression of key K_1, the full strength of the current traversing the neutral relay R_2, will be reversed. If the armature spring of the neutral relay R_2, be adjusted so that it cannot respond to the weak current of battery B_1, it is evident that signals may be sent by reversing the smaller battery B_1, by means of K_1, which will operate R_1, but not R_2.

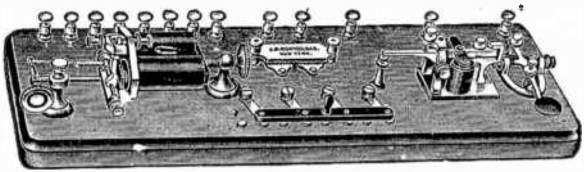


FIG. 7,724.—Bunnell open circuit automatic repeater. A relay, transmitter, key, lightning arrester and switch mounted on a polished hardwood base constitutes one instrument. Two of these make a complete repeater. When connected they can be used as an automatic open circuit repeater or as two single sets of ordinary Morse open circuit instruments, according to the position of the switch on each set.

The diagram fig. 7,723 illustrates diplex operation. If the operator depress key K_2, this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R_2 to be attracted.

If now another signal be sent by the depression of key K_1, the full strength of the current traversing the neutral relay R_2 will be reversed. If the armature spring of the neutral relay R_2 be adjusted so that it cannot respond to the weak current of battery B_1 it is evident that signals may be sent by reversing the smaller battery B_1 by means of K_1, which will operate R_1 but not R_2.

The principle and operation of polarized relays is explained in the accompanying cuts.

Duplex System.—This system is one which permits *the sending of two messages simultaneously in opposite directions over a single wire.*

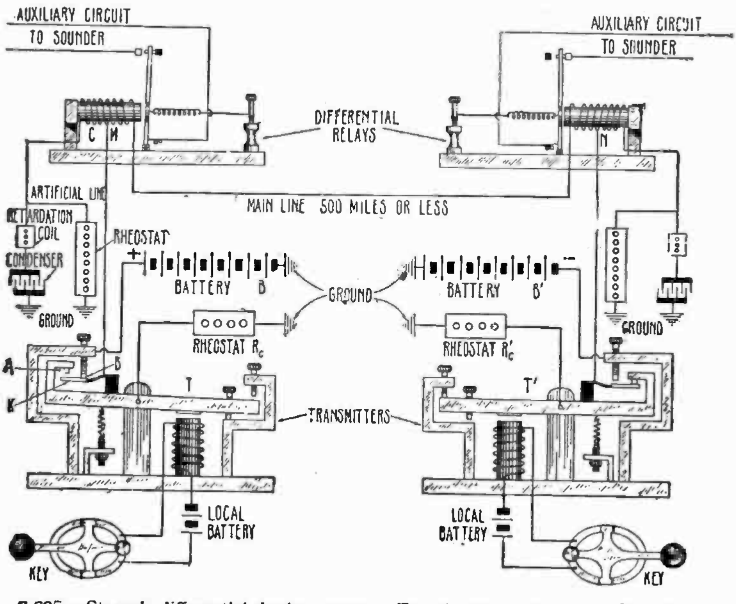


FIG. 7,725.—Stearn's differential duplex system. The circuit can be traced from the tongue contact K, to the point of division M, known as the "split." At this point one branch goes through the right portion of the relay winding to the main line, and the other through the left portion of the relay, the artificial line and to ground. When K, is in contact with B, the circuit is through battery B, to ground, and when in contact with A, it is through the transmitter lever, and rheostat R_c, to ground. The purpose of the rheostat R_c, is to divide the current passing through the relay coils equally between the main and artificial lines. When this condition is established, the current will pass through the relay with no appreciable effect upon it and the duplex is said to be "*balanced.*"

There are several systems of duplex telegraphy, namely:

1. Differential;
2. Polar {with battery; with dynamo;
3. Bridge.

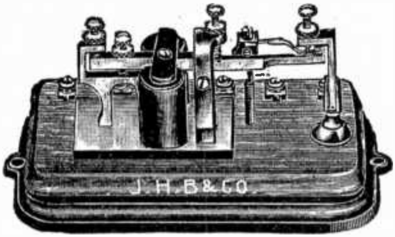


FIG. 7,726.—Bunnell shovel nose pattern single pole transmitter with circuit preserving contacts.

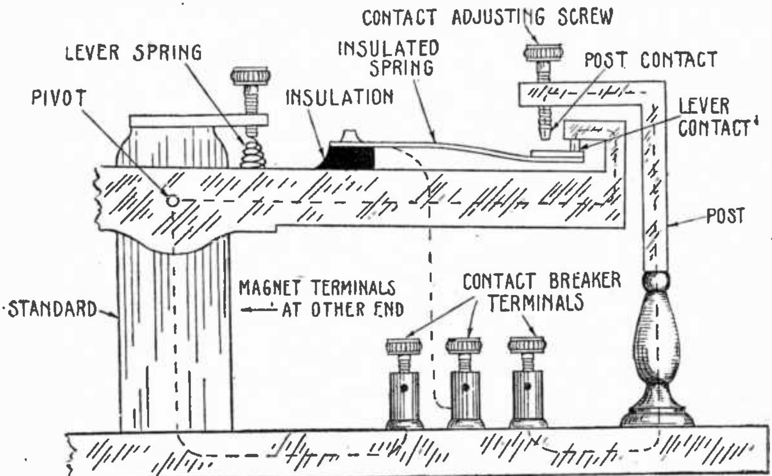


FIG. 7,727.—Detail of contact breaker end of a transmitter showing the three contacts, method of mounting the spring contact, and the circuits from the contacts to terminals. The duration of contact, or portion of the stroke of lever during which the circuit through the post contact and spring contact remains closed is regulated by the contact adjusting screw. This adjustment and other construction details are clearly shown in the illustration.

Differential Duplex System.—This method **employs** *a relay wound with two sets of coils, in each of which the current flows in a different direction.*

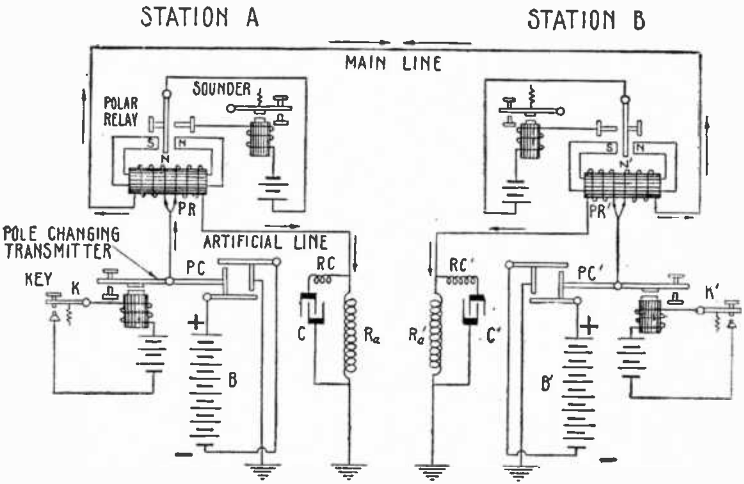


FIG. 7,728.—The battery polar duplex system. When the resistance of the main line is balanced by the resistance of a set of adjustable coils in the rheostat R_a of the artificial line, the current will divide into two equal parts at the polarized relay, and passing around the cores in different directions will neutralize each other and thus fail to magnetize the relay. This is called the *ohmic balance.* The *static balance* is effected by neutralizing the static discharge on the line by shunting the rheostat R_a, by means of an adjustable condenser C and a retarding coil RC.

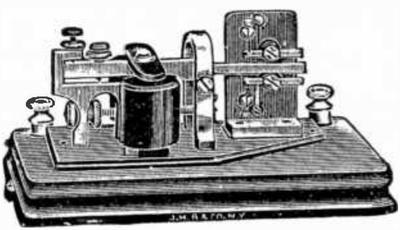


FIG. 7,729.—Bunnell W. U. battery (or gravity) pole changer for duplex or quadruplex work.

Consequently when two currents of equal intensity are passed through the relay at the same time, they neutralize each other, and the relay does not become magnetized.

Each station is provided with a differential relay, and there are two complete circuits, one including the line wire, and the other consisting of resistance coils having a resistance equivalent to that of the line and known as the *artificial line*.

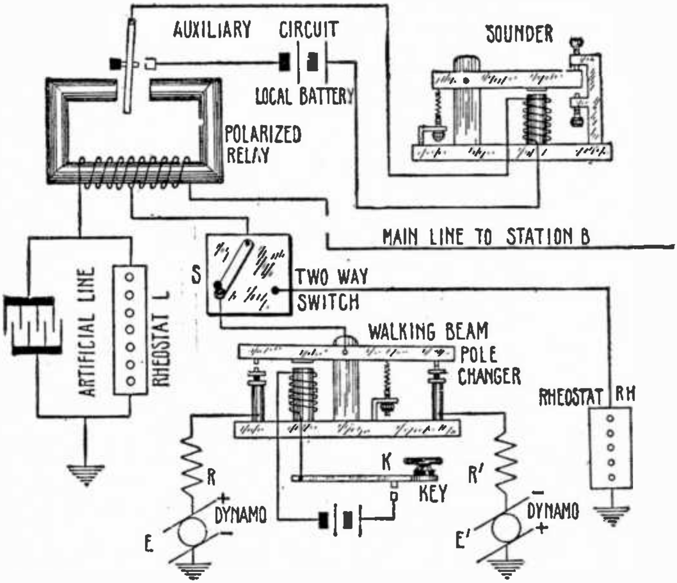


FIG. 7,730.—The dynamo polar duplex system. E. and E' are the dynamos, E for the positive and E' for the negative current. These supply their currents through resistance coils R R' either of German silver wire or of incandescent lamps. K is the key which closes the local circuit of the walking beam pole changer. The position of the lever of the pole changer determines which current is being sent to line through the pivot of the lever. The two way switch S is for changing from duplex to ground connection through a rheostat RH for the purpose of enabling the distant station to obtain a balance. From the switch the current goes to the junction of the two coils of the relay where it divides, one-half going to the main line, if the line circuit be closed at the distant station, and the other half through the artificial line to ground. The resistance in the artificial line is made equal to the resistance of the line and relay coils at the distant station. This is adjusted, not by measurement, but by trial. The operator at the distant station turns his switch to the ground position and signals are then sent by the operator at the home station.

The key and battery at each station are common to both circuits, the points of divergence being at the relay and at the ground plate.

When the key at one station which may be called the *home station* is depressed, the current flows through both sets of coils of the relay at that station without producing any magnetizing effect. Consequently, the relay and sounder at the home station remain unresponsive, but at the distant station the current will flow through only one set of coils at that station and will cause it to operate the local sounder. The same effect, of course, is produced when the key of the distant station is depressed.

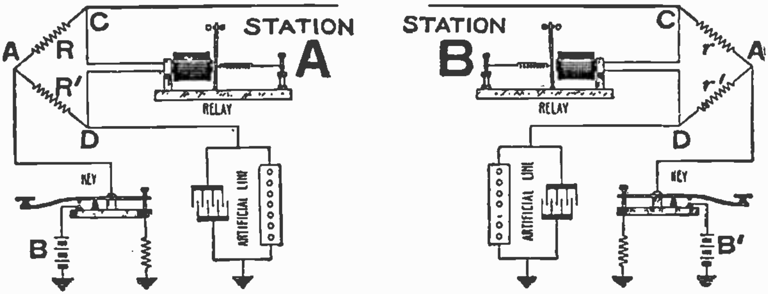


FIG. 7,731.—Diagram illustrating the operation of the bridge duplex system. In the figure, B and B', are the main line batteries, one at each station. R, R', and r, r', are the bridge resistances at each station. The various connections are clearly shown in the diagram. *In operation,* closing station A key sends out a current which divides at A. half passing over the main line to station B, and reaches earth via the apparatus at that end of the line, while the other half passes through the artificial line at station A, reaching the earth at that end of the circuit. Since the resistance between C and D, is the same as R or R', the pressures at C and D, are equal, and no current will flow through station A relay. This holds only when the resistance of station A artificial line is made equal to the resistance of the actual line to ground at the distant end. The relay at **A** is accordingly not affected when **A** sends to **B**. The same condition obtains when **B** alone sends to **A**. Signals from **A** operate the relay at **B** because the incoming signals have a joint path made up of the branches CD and CA, thus setting up a difference of pressure between the points C and D sufficient to operate the relay.

Polar Duplex System.—Each station is *provided with two batteries or dynamos, which are arranged in such a manner that the direction of the current in the line depends on whether the key is in its raised or depressed position.*

As in the case of the differential method, the current divides at the relay, which instead of being of the differential type is known as a *polarized relay*.

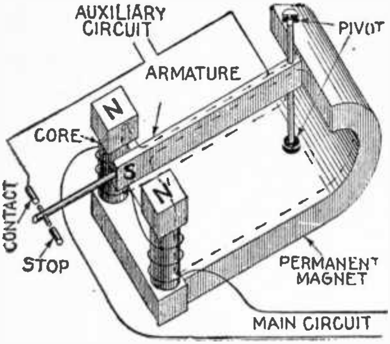


FIG. 7,732.—Elementary polarized relay. *In operation,* when no current flows through the electro magnet, the armature (having no spring), when placed midway between the poles of the electro magnet will be attracted equally by each and accordingly will approach neither. When, however, the electro magnet is energized, the magnetism thus reduced in its cores either increases or overcomes that due to the permanent magnet producing unlike poles according to the direction of the current. Thus the armature is attracted by one and repelled by the other. The magnetism of the electro magnet of the polarized relay changes in response to the reversals of the distant battery and the armature vibrates to and fro between its front and back stops in accordance with those changes.

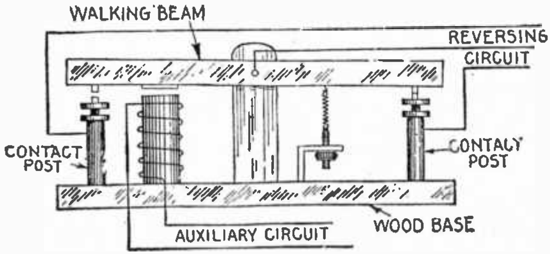
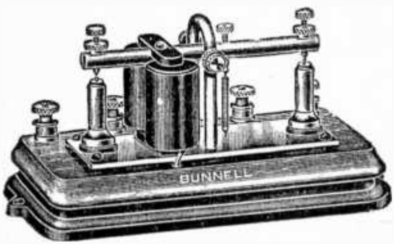


FIG. 7,733.—Essential parts of a walking beam type pole changer. As can be seen it is impossible for all three wires of the reversing circuit to be connected at any instant, that is before each reversal, the circuit is broken, thus interposing an air gap; this is an undesirable condition where dynamos are used for current supply, because their very small internal resistance would otherwise permit considerable sparking.



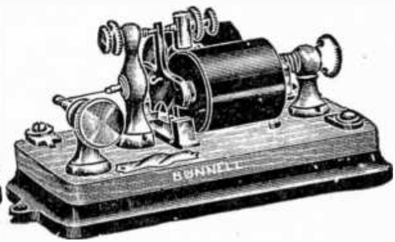


FIG. 7,734.—Standard dynamo pole changer walking beam model for duplex and quadruplex circuits.

FIG. 7,735.—Bunnell pony pole changer. Penn. R. R. pattern for dynamo work in duplex and quadruplex circuits.

Bridge Duplex System.—This method is based on the principle of the **Christie** or so-called Wheatstone bridge. It is used in the operation of submarine telegraph cables.

In this method, the relay is placed in the cross wire of a Christie bridge and the key is so arranged that connection is made with the battery before the line leading to the earth is broken. Adjustable resistance coils are placed in the arms of the bridge and a wire connects the key with one arm of the bridge, which is completed at the opposite end by a suitable arrangement.

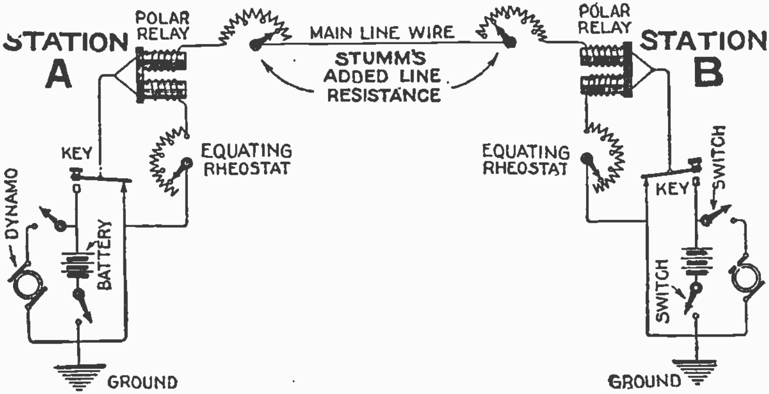


FIG. 7,736.—Frank A. Stumm's added adjustable line resistance. Necessary in duplex and all other multiplex office equipment. Formerly all balancing against wet weatner line leakage was done on the artificial line rheostat and was always very unsatisfactory and often entirely ineffectual so that quite frequently such circuits had to be abandoned until the weather resumed normality—that is, became dry. The Stumm method leaves the artificial rheostat stand unchanged at normal ohmage, *i.e.*, equal to the actual line resistance in dry weather and when the wet storm begins to cause leakage, line resistance is looped in between the relay and line sufficient to balance the artificial ohmage, and by being added to sufficiently as required maintains a steady working balance reversing the procedure as the storm recedes. This method not only secures a good and continuous working balance but also prevents heating of instrument and other office wires and cables because the resistances in the main and artificial lines remain the same in stormy wet weather as during fair and dry. In other words the actual and artificial lines have flowing in them the proper battery strength for the resistances traversed. The value of the Stumm line resistance is very great as it prevents damaging delay to tens if not hundreds of thousands of telegrams during every general rain storm which inevitably occurred under the old method of wet weather balancing. The relays used may be differential, if preferred.

If the resistances be equal, the relays will not operate when the current is transmitted, but since the earth is employed to complete the circuit, they will respond to the received current, thus enabling each operator to send and receive signals at the same time.

Quadruplex System.—This method of telegraphy **permits** *the simultaneous sending of two messages in either direction over a single wire.*

Theoretically it consists of an arrangement of two duplex systems, which differ from each other so greatly in their principles of operation that they are capable of being used in combination.

The sending apparatus consists of a reversing key and a variable current key (or equivalent), and the receiving apparatus consists of a neutral relay and a polar relay, batteries and connections.

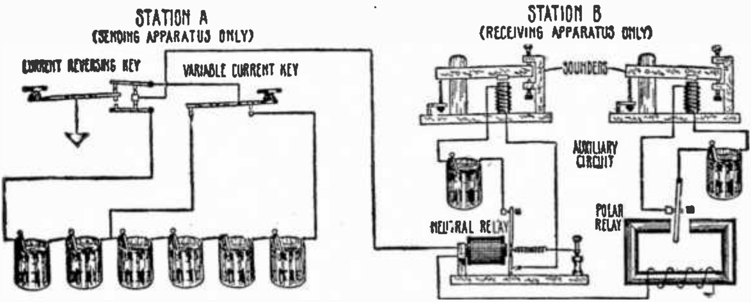


FIG. 7,737.—Elements of the quadruplex system. For simplicity, the receiving apparatus is omitted at station A and the sending apparatus at station B, the complete installation being shown in fig. 7,738. Because of the fact that a polar relay responds solely to changes in direction of the current, and a neutral relay to changes in strength of the current, it must by evident that, if the two relays be connected in series as shown, signals may be produced by the polar relay by operating the current reversing key, and with a sufficiently weak current the neutral relay will not respond; also, if the *direction* of the current be maintained constant by using the variable current key signals will be produced on the neutral relay but not on the polar. Hence, with this arrangement, two messages may be sent from station A to station B simultaneously, and by extension, if the reader imagine each station fitted with both sending and receiving apparatus, four messages may be sent at one time, thus giving quadruplex operation.

Typebar Tape Teletype Printing Telegraph System.—The teletype machine is *a simple intercommunicating machine for interchanging messages between two or more points.*

NOTE.—***The tape machine*** prints on a narrow strip of paper. ***The page machine*** prints on a wide sheet of paper usually 8½ ins. wide. ***The automatic sending machine*** provides for sending from a perforated strip which acts as a storage medium for the message.

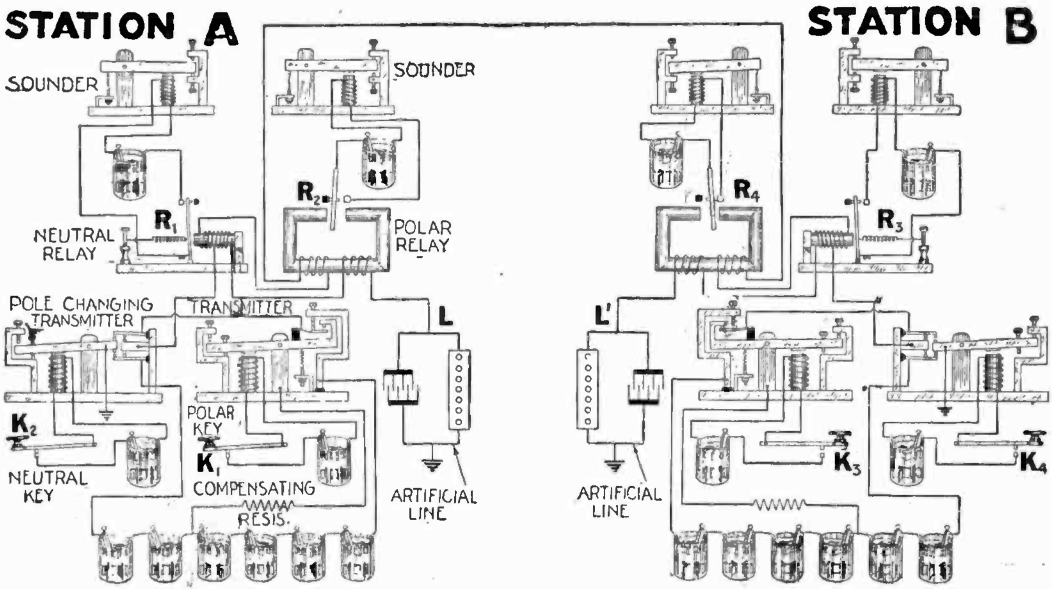


FIG. 7,738.—Quadruplex system with battery current supply. The apparatus employed in operating the polar system of the duplex is generally called the "No. 1 side of the system," or the polar side. It consists of the polar key and the polar relay at either station. The apparatus employed in operating the other system of the diplex is called the "No. 2 side of the system," or the neutral side. It consists of the neutral key and of the neutral relay. *In operation,* when none of the keys is depressed, no current flows through the line, but a comparatively feeble current flows through the artificial lines L and L', insufficient to operate the neutral relays, and to maintain the polarized relay tongues on the dead stops. Consequently, none of the sounders responds. If now K_1 be depressed, a strong positive current is sent to line at station A. This does not affect the relays at A, since it passes through them in opposite directions but on arriving at B, it tends to keep the polarized relay tongue R_4, on the dead stop, while it has sufficient power to operate the neutral relay R_3. In the same way if K_3 alone be depressed, relay R_1 alone will respond. If

Fig. 7,739 illustrates the arrangement of the standard keyboard, together with a representation of the code combinations for each character as they appear in the perforated strip used with automatic sending machines.

In this system the Morse key and code are replaced by a keyboard similar to that of the ordinary typewriter, but the results obtained by depressing the keys on the teletype keyboard however, are quite different. By depressing the keys, various electrical signals are sent out over a wire or wires and these electrical signals cause corresponding characters to be printed on a narrow ribbon of paper, both at the home and distant stations. With the commercial typewriter, the key levers operate the type bars mechanically.

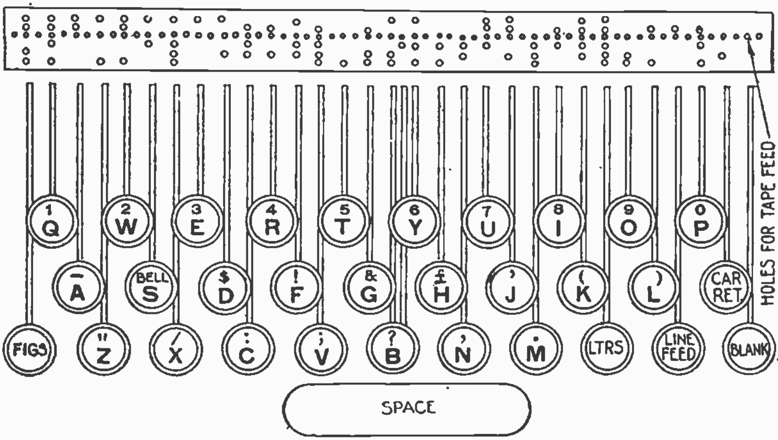


FIG. 7,739.—Teletype keyboard and corresponding code combination.

FIG. 7,738.—*Text continued.*

K_3 alone be depressed, a feeble negative current will flow to line, in a direction which will actuate R_4, but it will not have sufficient power to actuate R_3. If K_4 alone be depressed R_3 alone will similarly respond alone. The depression of any key will cause its corresponding relay to close its local circuit at the distant end of the line, regardless of the condition of the keys at that end. In practice the reversed position of neutral relay stop requires a repeater with contact on the up stroke between each neutral relay and sounder, or the equivalent secured by transposition of battery, for synchronous operation; these modifications are here omitted for simplicity.

The key levers on the teletype, however, are not connected mechanically to the type bars, but send out electrical signals which control the type bars, both at the home and distant stations.

Since the key levers are not connected mechanically to the type bars, the teletype may be divided into two units:

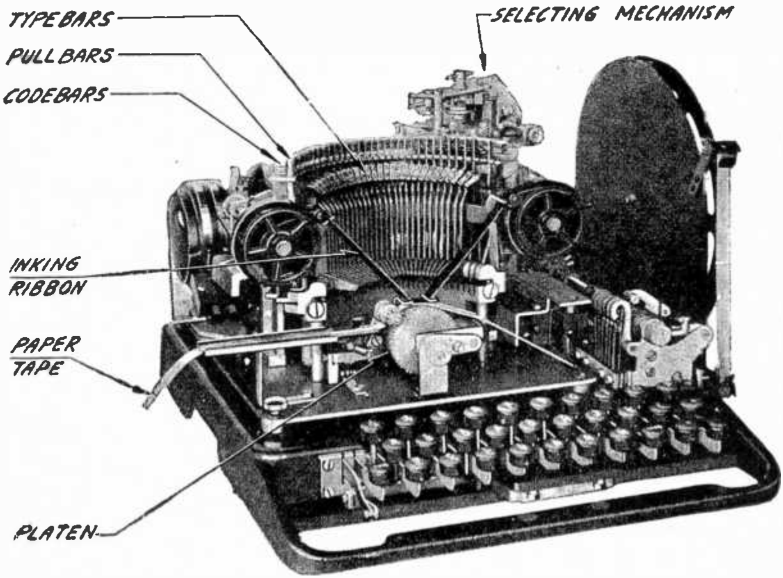
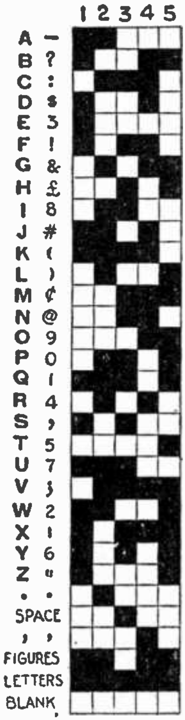


FIG. 7,740.—Teletype machine. The printing unit translates into printed characters the signals sent out by the transmitter. The various characters are on type bars which are caused to strike the paper tape as it is pulled over a narrow platen. The balance of the mechanism serves only to properly select the various type bars, move the tape forward, move and reverse the inking ribbon as on a standard typewriter, and shift the platen for upper case characters. At the bottom in the center is the platen over which the paper tape passes from right to left. Immediately above the platen is the inking ribbon. The type bars are plainly visible just back of and above the platen, arranged in a semi-circle and striking downward. Just above and back of the type bars are the code bars, five in number, and semi-circular in shape. The pull bars are just in front of the code bars and one is pulled into the notches in the code bars when the notches are lined up for that particular letter. When the selecting mechanism lines up the notches in the code bars and the proper pull bar is pulled into the notches, the operating bail is released and moves upward. The operating bail engages a notch in the pull bar pulling the latter upward, thus causing the type bar to print that particular letter.



1. Keyboard transmitter (lower portion);

2. Printing unit (upper portion).

The keyboard transmitter is the instrument *which sends out the various character signals to one or more teletypes.*

FIG. 7,741.—Teletype five unit code. ***The diagram shows*** graphically the intervals or impulses of each combination of the code. Each horizontal row represents the complete unit of time, during each of the five intervals of which current may be transmitted or omitted. The black spots represent current and the white ones no current. Thus, in the case of the letter E, current is sent during the first interval and no current during the remaining four intervals. The letter R, requires current during the second and fourth intervals and no current during the first, third and fifth intervals. Each combination of signals is preceded by a *start* and followed by a *stop* signal, the functions of which are explained in the note below.

NOTE.—***The tape machine*** is very popular for a communication service in which the individual communications are short, do not require more than one copy and need not be kept on file for any great length of time. However, if so desired, the tape can be pasted on a blank to give the appearance of a page message. ***The page machine*** is found to be very satisfactory for longer communications which are kept for future reference, for making multiple copies, and in some cases for handling special forms. From the point of view of handling telegraph traffic, the page system is not quite so efficient, because the signals controlling the operations of feeding the paper and of returning the carriage to the beginning of each line have to be transmitted over the circuit by the sending operator. These operations are not required with the tape printer. Machines for sending from a perforated strip find their use where a large volume of traffic is to be handled as in press offices. The message in the perforated strip form will pass through the sending mechanism or transmitter at a regular rate, say 360 characters per minute, but the operator in preparing the message in this form for transmittal can exceed this speed and, therefore, have a freedom of working which is found to be quite desirable. This uniform speed of transmitting over the circuit corresponds with the fastest working of most operators who are employed to prepare the perforated strip.

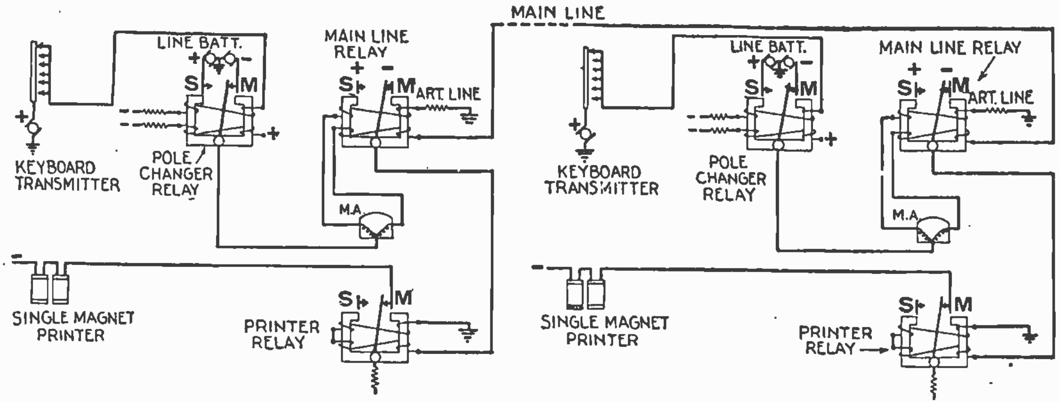


FIG. 7,742.—Two keyboard teletypes connected for duplex operation. The keyboard contacts are connected to one winding (operating winding) of the pole changer relay. Current is connected to the other winding (holding winding) in a manner that will cause the relay tongue to move to the spacing side when the keyboard contacts are open. When the keyboard contacts are closed a current of twice the value is sent through the operating winding in the opposite direction which will overcome the magnetic effect of the holding winding and cause the relay tongue to be moved to the marking side. The contacts of the pole changer relay are connected to marking and spacing battery. The tongue goes to the split of the main line relay where the circuit divides. One path of the current is through one winding of the relay to the line wire and the other path is through the second winding of the relay through the artificial line to ground. As the tongue of the main line relay responds to the distant signal it operates the printer relay, the printer relay in turn will send make-break signals to the receiving printer magnet.

One motor drives both the keyboard transmitter and printing unit. It consists of a bank of properly lettered key levers, a set of notched selector bars, a contact mechanism, and a clutch, through the medium of which the contact operating mechanism is driven.

The printing unit furnishes *a home record of the matter sent, and also serves as a receiver when another station is transmitting.*

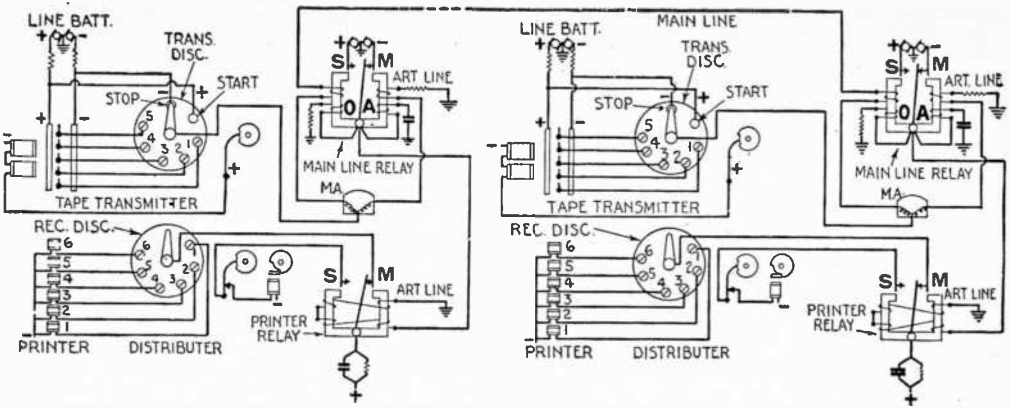


FIG. 7,743.—Theoretical circuit of two tape transmitter sets connected for duplex operation. The main line relays have in addition to the usual operating windings two auxiliary windings, O and A. These auxiliary coils in conjunction with a condenser and resistance, are connected in such a manner as to set up a steady vibration of the main line relay armature when not under the influence of the current flowing through the operating windings. With this circuit the speed of operation of the relay is greatly increased. *In operation* when the tongue reaches the spacing contact, a rush of current passes to the condenser through the accelerating winding A, in such a direction as to hold the tongue against the spacing contact. At the same time the current flows through the opposing winding O, and a resistance in series with it in such a direction as to tend to move the tongue toward the marking contact giving an opposing effect to the current in the accelerating and operating windings. The condenser charging current, however, diminishes to zero, while the current to the opposing winding increases to a steady value which will cause the tongue to move toward the marking contact when the line current diminishes at the moment of reversal. As soon as the tongue leaves the spacing contact, battery is cut off and the condenser discharges through the accelerating and opposing coils in a direction to assist the motion of the tongue, thus shortening the transit time. When the tongue reaches the marking contact, the same cycle of operation is repeated, the tongue, of course, tending to move in the reverse direction.

It is entirely mechanical with the exception of a pair of magnets which assist in translating the electrical signals sent to the teletype. Printing is effected by means of type bars which move forward and downward, instead of backward and upward as with the commercial typewriter. Ink is supplied to the paper tape by means of a ribbon in the usual way.

The signaling code employed to transmit the characters is known as *the five unit code.*

If a given unit of time be divided into five intervals, during each of which current may or may not be transmitted, it is possible to produce thirty-two different combinations of current and of no current intervals.

Duplex Teletype Printer Operation.—By use of duplex apparatus it is possible *to transmit in both directions* **simultaneously** *over a single wire.*

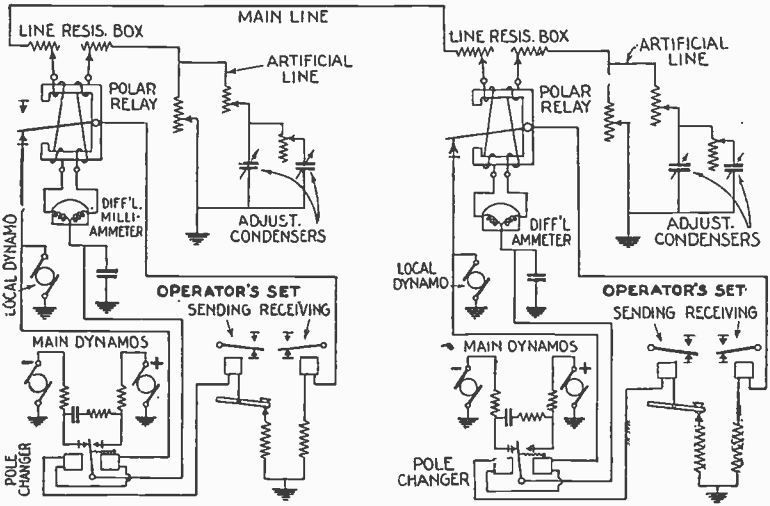


FIG. 7,744.—Teletype circuit diagram for duplex operation showing entire artificial line.

NOTE.—*Teletype unison.* The start signal and the stop signal cause the printing units to revolve in unison with the transmitter so that the character signals sent out by the transmitter may be translated into letters and other characters by the printing unit. The transmission of the start impulse allows the selector magnet armature to operate the trip mechanisms on the printing units and the selector cams start to revolve. The speed of rotation is such that when the cam shaft of the transmitter has revolved far enough to send out the first impulse, the printing unit shaft has revolved to the proper position to receive it. When the transmitter has revolved to the position to send out the second impulse, the printing unit shaft will have also rotated to the proper position to receive it. At the end of the revolution the transmission of the stop impulse attracts the selector magnet armature and the selector cams are stopped by the stop pawl.

Each printer terminal set consists of a tape transmitter, a transmitting receiving disc type distributer, a receiving printer, a main line relay, a printer relay and the artificial line apparatus. Where circuits are to be composited compositing equipment is made part of the set.

Fig. 7,742 shows two keyboard teletypes connected for duplex operation. Inasmuch as only make break signals can be sent from the keyboard contacts it is necessary to use a pole changer relay so that polar signals may be sent to the line.

The arrangement of the entire artificial line is shown in fig. 7,744.

TEST QUESTIONS

1. *Of what does the simplest form of telegraph consist?*
2. *Give a classification of telegraph systems.*
3. *What is a key?*
4. *Describe the construction of a key or transmitting instrument.*
5. *What is a sounder?*
6. *Describe the construction and operation of a sounder.*
7. *Draw a diagram showing,* a, *open circuit short line system;* b, *closed circuit short line system.*
8. *What is a relay?*
9. *Describe the construction and operation of a relay.*
10. *Name the different types of relay and describe each.*

11. *Draw a diagram of a medium distance line with relays.*
12. *Describe the operation of a medium distance line with relays.*
13. *What is a repeater?*
14. *Describe the construction and operation of a repeater.*
15. *How are repeaters used on long distance lines?*
16. *Explain the Milliken repeater system.*
17. *What is an automatic repeater?*
18. *Explain the three pairs of circuits in an automatic repeater.*
19. *What is a half repeater?*
20. *Describe the duplex system.*
21. *How does a duplex system work?*
22. *What kind of a relay is employed in the differential duplex system?*
23. *Draw a diagram of the dynamo duplex polar system.*
24. *Explain the operation of a polarized relay.*
25. *How does a walking beam pole changer work?*
26. *Upon what is the bridge duplex system based?*
27. *Describe in detail the quadruplex system.*
28. *Explain the operation of the typebar tape teletype printing telegraph system.*
29. *Explain duplex teletype printing operation.*

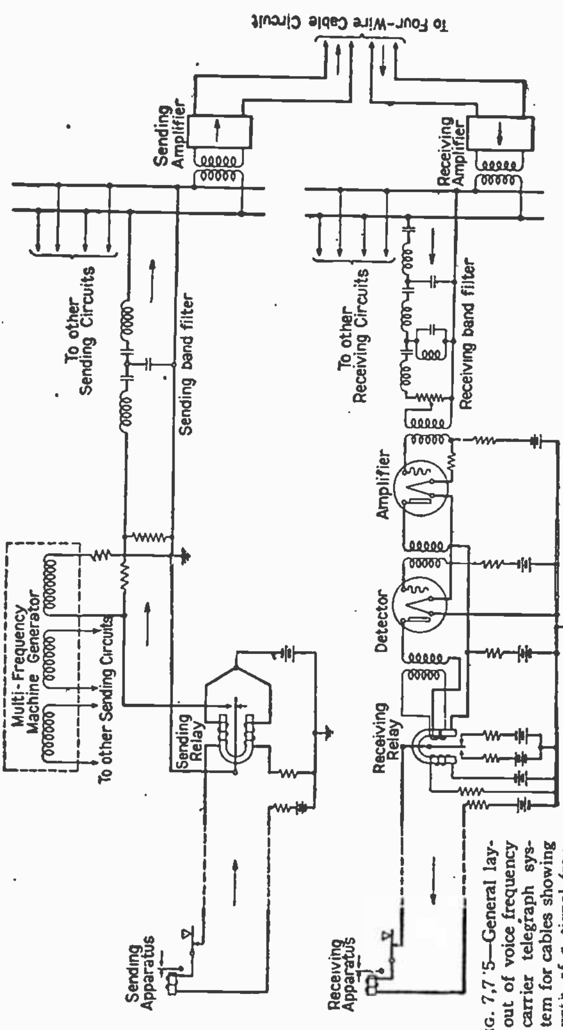


FIG. 7,745—General lay-out of voice frequency carrier telegraph system for cables showing path of a signal from the sending operator to the receiving operator on one of the ten two-way circuits.

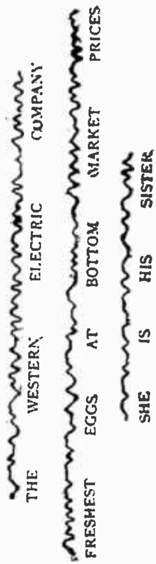


FIG. 7,746 —Test message transmitted over New York-Horta cable with a high speed siphon recorder, at a speed of 1920 letters per minute, November 14th, 1924.

CHAPTER 190

Optics

As a preliminary to taking up the study of motion pictures the student should have a general knowledge of optics.

By definition, optics is *that part of physics which deals with the property of light.*

Various explanations have been made as to: *What is light?* The most important of these are the emission or corpuscular theory, and the undulatory or wave theory.

The emission theory assumes that luminous bodies emit, in all directions, an imponderable substance which consists of molecules of an extreme degree of tenuity. These are propagated in right lines with an almost infinite velocity. Penetrating into the eye, they act on the retina and produce a sensation which is called *vision*.

The undulatory theory assumes that all bodies, as well as the celestial spaces are filled with an extremely subtle elastic medium, called the luminiferous ether, the luminosity of a body being due to an infinitely rapid vibratory motion of its molecules, which, when communicated to the ether, is propagated in all directions in the form of spherical waves, and this vibratory motion, being thus transmitted to the retina, produces the sensation called *vision*.

Definitions

Image.—The appearance of an object at a place where no object exists.

Real Image.—The image formed when the rays actually meet.

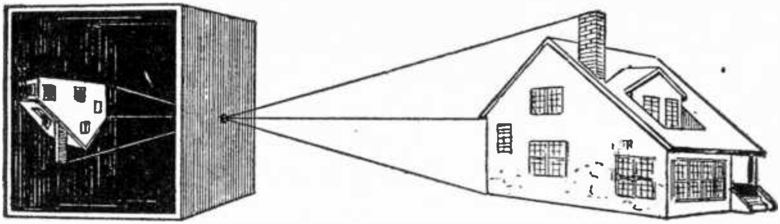
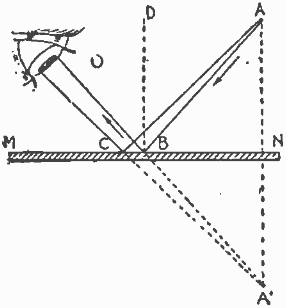


FIG. 7,747.—Image produced by small aperture showing the crossing of luminous rays at the aperture causing inversion of the image.



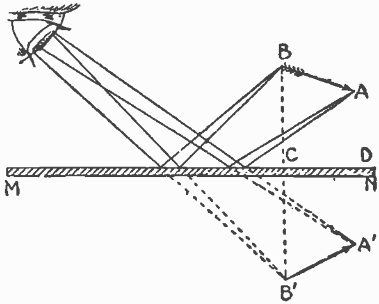


FIG. 7,748.—Formation of images by plane mirrors. The determination of the position and size of image resolves itself into investigating the images of a series of points. CASE I: *Single point* A *placed in front of a plane mirror*, as in fig. 7,748. Any ray AB, incident from this point on the mirror is reflected in the direction BO, making the angle of reflection DBO equal to the angle of incidence DBA. If a perpendicular AN, be let fall from the point A over the mirror, and if the ray OB, be prolonged below the mirror until it meets this perpendicular in the point A′, two triangles are formed. ABN and BNA′, which are equal, for they have the side BN common to both, and the angles ANB, ABN, equal to the angles A′NB, A′BN; for the angles ANB and A′NB are right angles, and the angles ABN and A′BN are each equal to the angle OBM. From the equality of these triangles, it follows that A′N is equal to AN; that is, that any ray AB, takes such a direction after being reflected, that its prolongation below the mirror cuts the perpendicular AA′ in the point A′, which is at the same distance from the mirror as the point A. This applies also to the case of any other ray from the point A, as AC. It follows, that all rays from the point A, reflected from the mirror, follow after reflection, the same direction as if they had all proceeded from the point A′. The eye is deceived, and sees the point A at A′, as if it were really situated at A′. Hence, in plane mirrors, *the image of any point is formed behind the mirror at a distance equal to that of the given point, and on the perpendicular let fall from this point on the mirror.*

FIG. 7,749.—Formation of images by plane mirrors. CASE II: *Object* AB *placed in front of the mirror*, as in fig. 7,749. The image of any object will be obtained by constructing the image of each of its points, or at least, of those which are sufficient to determine its form. Fig. 7,749 shows how the image A′B′ of any object AB is formed.

Virtual Image.—The image formed when the rays only appear to meet.

Mirror.—A polished surface which reflects objects placed before it.

Production of Images.—When luminous rays, which pass through a small aperture into a dark chamber, are received upon a screen, they form

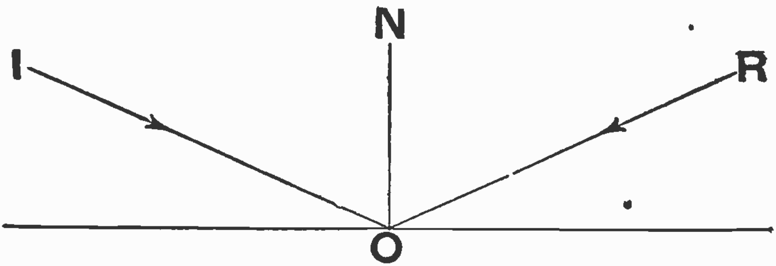


FIG. 7,750.—Angles of incidence and reflection. LAW: *The angle of reflection is equal to the angle of incidence.* The ray IO is called the incident ray; OR, reflected ray; angle ION, angle of incidence; angle NOR, angle of reflection; NO, normal or perpendicular to the reflecting surface.

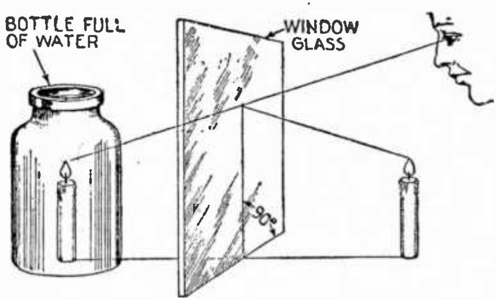
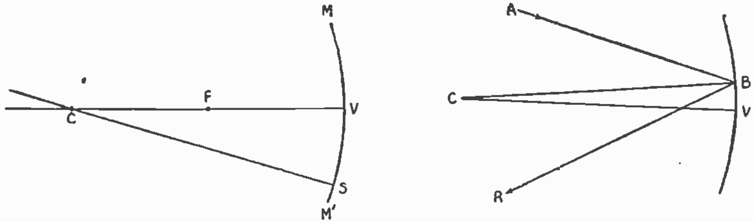


FIG. 7,751.—Position of image in a plane mirror. Let a candle be placed exactly as far in front of a pane of window glass as a bottle full of water is behind it, both objects being on a perpendicular drawn through the glass. The candle will appear to be burning inside the water. This experiment explains a large number of familiar optical illusions, such as "the figure suspended in mid-air," "bust of person without trunk," "stage ghost," etc. In the last case the illusion is produced by causing the audience to look at the actors obliquely through a sheet of very clear plate glass, the edges of which are concealed by draperies. Images of strongly illuminated figures at one side appear to the audience to be in the midst of the actors.

images of external objects as shown in fig. 7,747. These images are inverted because the luminous rays proceeding from external objects, and penetrating into the chamber, cross one another in passing the aperture as shown in fig. 7,747.



FIGS. 7,752 and 7,753.—Concave spherical mirror; explanation of fig. 7,750 V, vertex; MM', the aperture; CV, the principal axis; CS, a secondary axis; C, center of curvature; F, principal focus (midway between V and C). Any line drawn from C to the mirror will be perpendicular to the mirror at that point. This line then will always be the normal which will be used in making the angle of incidence equal to the angle of reflection. Now in fig. 7,753, if AB be an incident ray of light, the angle ABC is the *angle of incidence*. To find the direction of the reflected ray draw BR so that the angle CBR equals angle ABC, then will BR be the direction of the reflected ray.

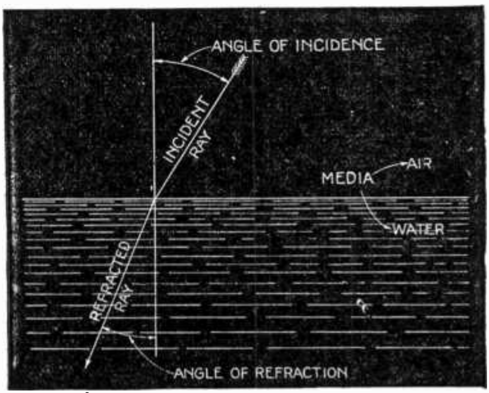


FIG. 7,754.—Diagram illustrating refraction definitions. All the light which falls on a refracting surface does not completely pass into it; one part is reflected and scattered, while the other penetrates into the medium. *According to the undulatory theory*, the most highly refracting media is that in which the velocity of propagation is least. In uncrystallized media, such as air, liquids, ordinary glass, the luminous ray is singly refracted; but in certain crystallized bodies, such as Iceland spar, selenite, etc., the incident ray gives rise to two refracted rays. The latter phenomenon is called *double refraction*.

Reflection.—The change of direction experienced by a ray of light, or of other radiant energy, when it strikes a surface and is thrown back or reflected, as shown in fig. 7,750.

Laws of Reflection.—1. *The angle of reflection is equal to the angle of incidence. 2. The incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.*

Refraction.—The change of direction which a ray of light undergoes upon entering obliquely a medium of different density from that through which it has been passing, as in fig. 7,754.

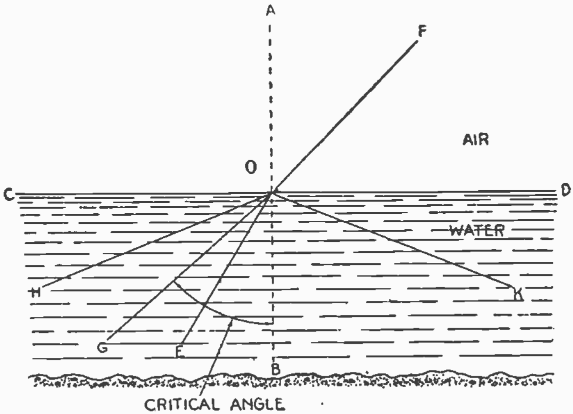


FIG. 7,755.—Diagram illustrating the critical angle or *that angle between the incident ray and the perpendicular drawn to the surface in the medium of smaller velocity at the point at which total reflection begins to occur.* In the diagram let CD be a surface separating two transparent media, the lower one being the denser of the two (as air and water). If a ray EO, strike the surface it will be bent away from the normal AOB, along the line OF, in accordance with the law of refraction sin AOF = μ sin EOB. If now the angle EOB be increased, AOF, will go on increasing until sin AOF = 1, and the refracted ray passes along OD; in this case the ray in the dense medium makes an angle BOG, with the normal such that μ sin BOG = 1, from which, sin BOG = 1 ÷ μ. This angle BOG is the *critical angle.*

Index of Refraction.—The ratio between the series of the incident and refracted angles. It varies with the media, for instance from air to glass it is $\frac{3}{2}$; from air to water, $\frac{4}{3}$, sometimes called *refractive index.*

Laws of Refraction.—1. *Light is refracted whenever it passes obliquely from one medium to another of different optical density. 2. The index of refraction for a given substance is a constant quantity whatever be the angle of* *incidence.* 3. *The refracted ray lies in the plane of the incident ray and the normal.* 4. *Light rays are bent toward the normal when they enter a more refractive medium, and from the normal when they enter a less refractive medium.*

Lenses.—A lens may be defined as, *a piece of glass or other transparent substance with one or both sides curved.* Both sides may be curved, or one curved and the other flat.

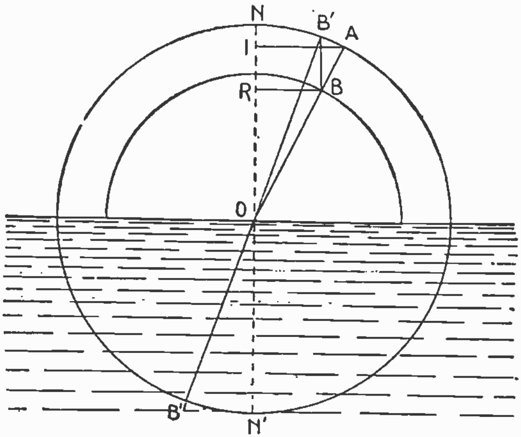


FIG. 7,756.—Construction of refracted ray. Let AO be a ray of light passing through air and entering water at O. The index is $\frac{4}{3}$. Draw two circles with centers at O and with radii whose lengths are as 4 : 3. Draw AI and BR perpendicular to the normal NN′. Since AO : BO = 4 : 3, then AI : BR = 4 : 3. Hence if AI be the sine of the angle of incidence, BR is the sine of the angle of refraction. If then, BB′ be drawn parallel with the normal, and a straight ruler be placed on the points B′ and O, the line OB′, the refracted ray may be drawn.

The **object** *of a lens is to* **change** *the direction of rays of light, and thus magnify objects, or otherwise modify vision.*

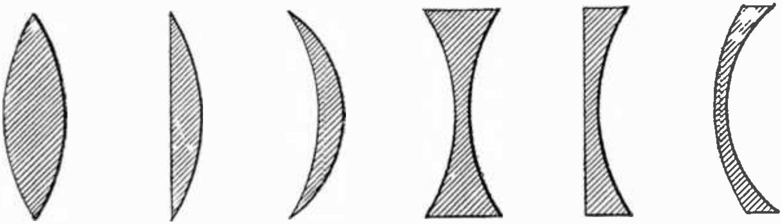
There are various kinds of lens and they may be classed as:

1. Convex.

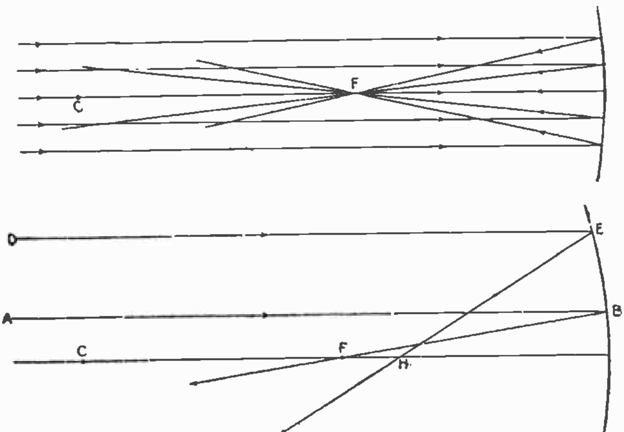
   a. double convex;
   b. plano convex;
   c. concavo convex.

2. Concave.

   a. double concave;
   b. plano concave;
   c. Convex concave.



FIGS. 7,757 to 7,762.—Various lenses. ***The first three*** are thicker at the center than at the borders, and are called *converging*; ***the second three***, which are thinner at the center are called *diverging*. In lenses whose two surfaces are spherical, the centers of these surfaces are called centers of curvature, and the right line which passes through these two centers is the principal axis. In a plano-concave or plano-convex lens, the principal axis is the perpendicular let fall from the center of curvature of the spherical face on the plane face.



FIGS. 7,763 and 7,764.—The principal focus. ***By definition***, it is *that point where all the rays* ***parallel*** *with the principal axis meet after reflection*, as, for instance, the rays from a source of light at an infinite distance from the mirror. The sun is so far distant that its rays are practically parallel. When they are reflected upon a concave mirror they are reflected to the principal focus F; forming a point of intense light and heat.

These various types of lens are illustrated in figs. 7,757 to 7,762, which give a better idea of the numerous combinations of curved and plane surfaces than is obtained by definition.

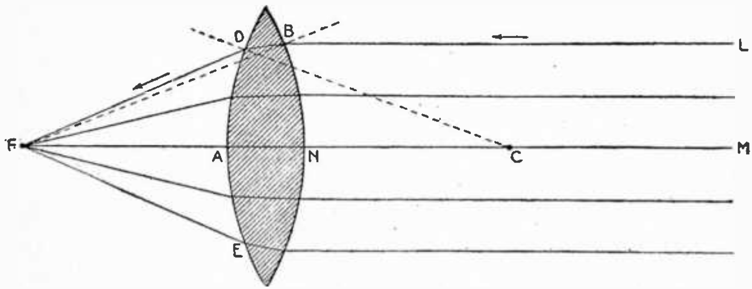


FIG. 7,765.—Principal focus in double convex lens. CASE I: *Rays from luminous sources parallel with the principal axis.*

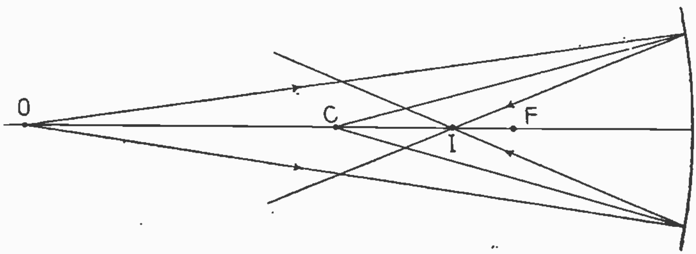


FIG. 7,766.—Conjugate foci. *By definition,* when two points are *so related that object and image may exchange places,* they are called *conjugate foci.* If a luminous object be placed at the point O, it projects divergent light rays upon the mirror. These rays will focus at a point I, a little further from the mirror than the principal focus F. If the source of light be now placed at I, the rays will pass back over the same paths and will come to a focus at O; the points I and O thus related to each other are called *conjugate foci.* Concave mirrors make divergent rays less divergent, parallel or convergent; parallel rays, convergent; convergent rays more convergent.

Foci in Double Convex Lenses.—*The focus of a lens is the point where the refracted rays, or their prolongations meet.* Double convex lenses have both real and virtual foci.

Principal Foci.—Fig. 7,765 shows the case in which the luminous rays which fall on the lens are parallel with its principal axis.

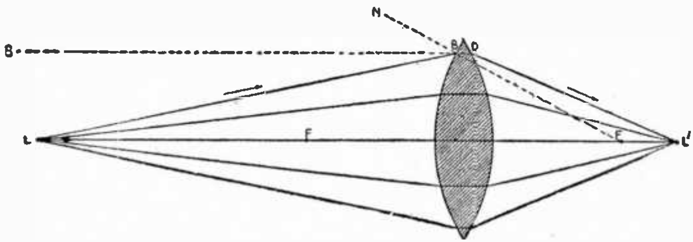


FIG. 7,767.—***Principal focus*** in double convex lenses. CASE II: *Divergent rays from luminous source.* In the figure the luminous source being at L, by comparing the path of a diverging ray LB, with that of a ray, SB, parallel with the axis, the former is found to make with the normal, an angle LBN, greater than the angle SBN, hence, after traversing the lens, the ray cuts the axis at a point L′, which is more distant than the principal focus F. As all rays from the point L intersect approximately in the same point L′, this latter is the conjugate focus of the point L. This term has the same meaning here as in the case of mirrors, and expresses the relation existing between the two points L and L′, which is of such a nature that, if the luminous point be moved to L′, the focus passes to L.

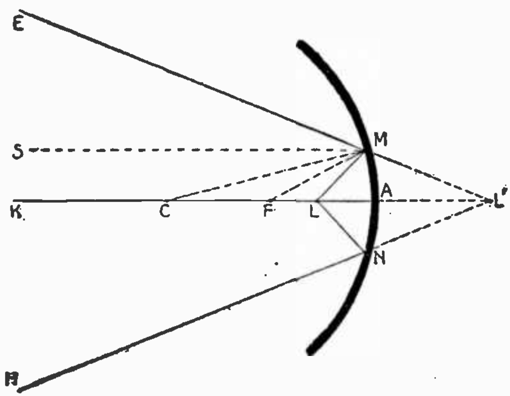


FIG. 7,768.—***The virtual focus.*** If a source of light be placed at L, between the principal focus F, and the mirror, any ray LM emitted from L, makes with the normal CM, an angle of incidence LMC, greater than FMC. The angle of reflection must be greater than CMS, and therefore the reflected ray ME diverges from the axis AK. This is also the case with all rays from the point L, and hence tnese rays do not intersect, thus forming no conjugate focus. If they be regarded as being prolonged on the other side of the mirror, their prolongations will intersect in a point L′, on the axis, giving the same effect to the eye as though the rays were emitted from the point L′, this point being called the *virtual focus.*

Fig. 7,767 shows the case in which the luminous source is outside the principal focus, but so near that all incident rays form a divergent pencil.

Virtual Foci.—A double convex lens *has a virtual focus when the luminous object is placed between the lens and the principal focus*, as shown in fig. 7,769.

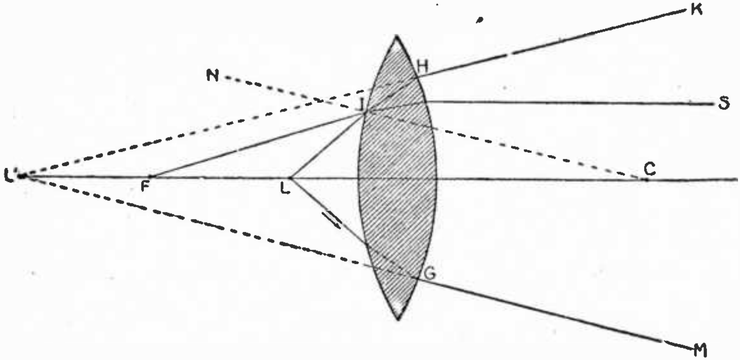
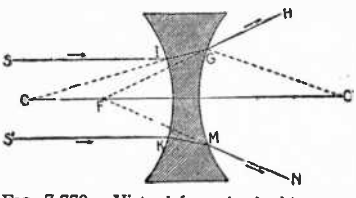


FIG. 7,769.—Virtual focus in double convex lens. In the figure, L is the position of the luminous source between the principal focus and the lens; F is the principal focus, and L', the virtual focus corresponding to the position L of the luminous source.



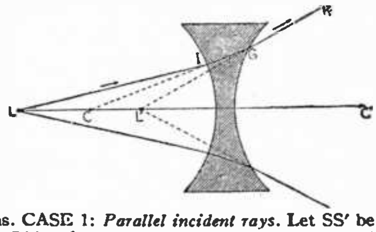


FIG. 7,770.—Virtual focus in double concave lens. CASE 1: *Parallel incident rays*. Let SS' be any pencil of ray parallel with the axis. Any ray SI is refracted at the point of incidence I, and approaches the normal CI. At the point of emergence it is also refracted, but diverges from the normal GC', so that it is twice refracted in a direction which moves it from the axis CC'. Since the same conditions obtain for every other ray, S'KMN, it follows that the rays, after traversing the lens, form a diverging pencil, GHMN. Hence, there is no real focus, but the prolongations of these rays cut one-another in a point F, which is the principal virtual focus.

FIG. 7,771.—Virtual focus in double concave lens. CASE II: *Divergent incident rays*. In this case where the rays radiate from a point L on the axis, it is found by the same construction that a virtual focus is formed at L', which is between the principal focus and the lens.

In this case the incident rays make with the normal greater angles than those made with the rays FI from the principal focus. Accordingly, when the former rays emerge, they move farther from the axis than the

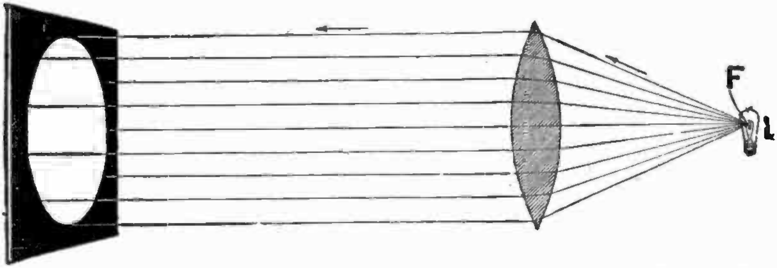


FIG. 7,772.—Effect of placing luminous source at the principal focus of a double convex lens. As the point of light comes near the lens, the convergence of the emergent rays decreases, and the conjugate focus L′ (fig. 7,7 :7) becomes more distant. When the source of light L coincides with the principal focus F, as shown above, the conjugate focus is at an infinite distance, that is to say, the emergent rays are parallel. When this condition obtains, the intensity of light decreases slowly, thus, a small lamp can illuminate a considerable distance.

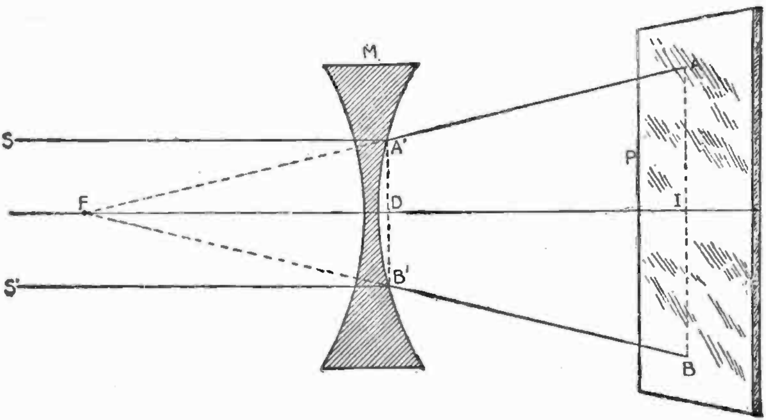


FIG. 7,773.—Experimental determination of the principal focus of a double concave lens. The face AB is covered with an opaque substance, such as lamp black, two small apertures, A and B, being left in the same principal section and at an equal distance from the axis. A pencil of sunlight is then received on the other face, and the screen P, which receives the emergent rays, is moved toward or away from the lens until A and B, the spots of light from the small apertures, are distant from each other by twice A′B′. The distance DI is then equal to the focal distance FD, because the triangles FA′B′ and FAB are similar.

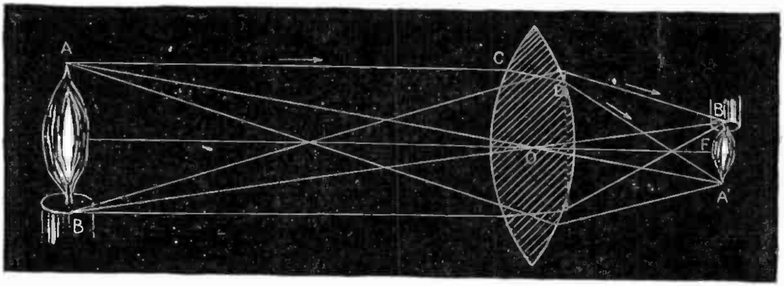


FIG. 7,774.—Formation of real image by double convex lens. Let AB be placed beyond the principal focus. If a secondary axis AA′ be drawn from the outside point A, any ray AC from this point will be twice refracted at C and D, and both turning in the same direction, approaching the secondary axis, which it cuts at A′, the other rays from the point A will intersect in the point A′ which is accordingly the conjugate focus of the point A. If the secondary axis be drawn from the point B, it will be seen that the rays from this point intersect in the point B′, and as the points between A and B have their foci between A′ and B′, a real and inverted image of AB will be formed at A′B′. To see this image it may be received on a white screen, on which it will be depicted, so the eye may be placed in the path of the rays emerging from it. Again, if A′B′ were the luminous object, its image would be formed at AB.

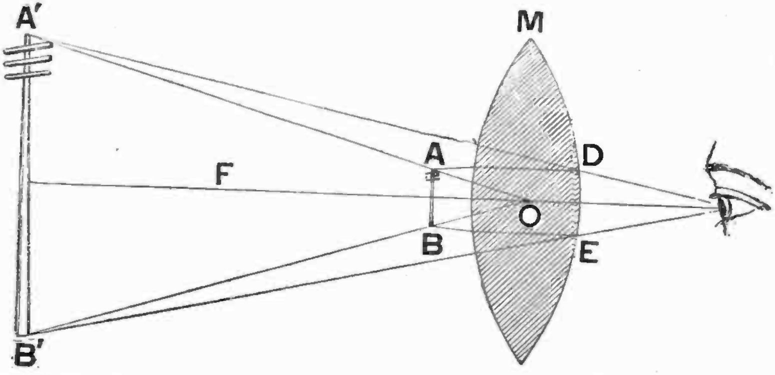


FIG. 7,775.—Formation of virtual image by double convex lens; object AB, placed between the lens and its principal focus. If a secondary axis OA′ be drawn from the point A, every ray AD, after having been twice refracted, diverges from this axis on emerging, since the point A is at a less distance than the principal focal distance, this ray, continued in an opposite direction, will cut the axis OA′ in the point A′, which is the virtual focus of the point A. Tracing the secondary axis of the point B, it will be found in the same manner, that the virtual focus of this point is formed at B′. There is, therefore, an image of AB at A′B′. This is a virtual image; it is erect and larger than the object. The magnifying power is greater in proportion as the lens is more convex, and the object nearer the principal focus.

latter, and form a diverging pencil HK, GM. These rays cannot produce a real focus, but their prolongations intersect in some point L′, on the axis, and this point is the virtual focus of the point L.

Foci in Double Concave Lenses.—In lenses of this form, *there are only virtual foci*, whatever be the distance of the object. See figs. 7,770 and 7,771.

Formation of Images by Double Convex Lenses.—In lenses as well as in mirrors, the image of an object *is the collection*

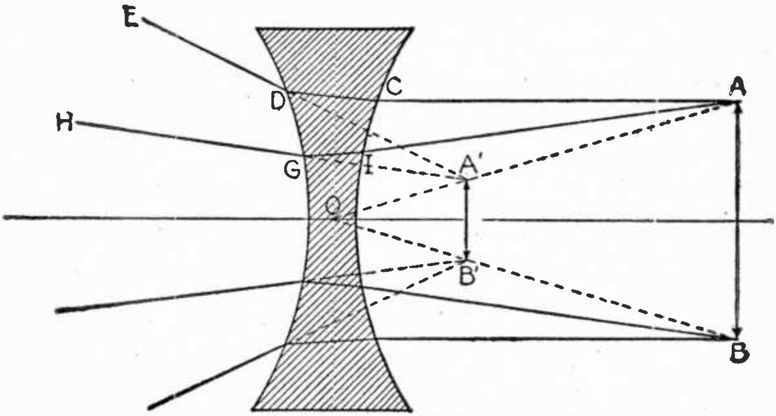


Fig. 7,776.—Formation of virtual image in double concave lens; no real image is formed with this type of lens. Let AB be an object placed in front of the lens. If the secondary axis AO be drawn from the point A, all rays AC, AI, etc., from this point are twice refracted in the same direction, diverging from the axis AO, so that the eye receiving the emergent rays DE and GH, supposes them to proceed from the point where their prolongations cut the secondary axis AO in the point A′. Similarly, drawing a secondary axis from the point B, the rays from this point form a pencil of divergent rays, the directions of which, prolonged, intersect in B′. Accordingly the eye sees at A′B′, a virtual image of AB, which is *always erect, and smaller than the object.*

of the foci of its several points. Accordingly images furnished by lenses are real or virtual in the same case as the foci, and their construction resolves itself into determining the position of a series of points.

Images are formed as follows:

1. The image formed with object *at twice the focal distance* is real, inverted, same size as the object, and at the same distance from the lens;

2. *At more than twice the focal distance*, the image is real, inverted, smaller than the object, and beyond the principal focus;

3. *At less than twice the focal distance*, the image is real, inverted, larger than the object, and more than twice the focal distance from the lens.

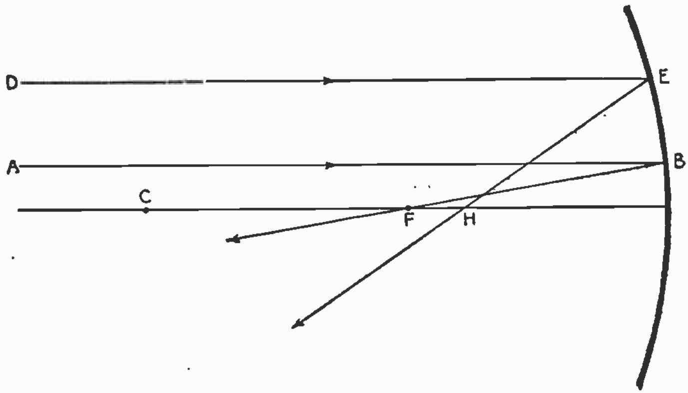


FIG. 7,777.—*Spherical aberration.* The reflected rays of concave spherical mirrors do not meet at exactly the same point. For instance, the ray AB, will be reflected to F, but DE will be reflected to H, a point closer to the mirror. This is called *spherical aberration.* It has been observed that the reflected rays only pass through a single point when the aperture of the mirror does not exceed 8 or 10 degrees.

4. When the object is at the principal focus, the rays after passing through the lens will be parallel, and no image will be formed.

5. When the object is between the principal focus and the lens the image is virtual, erect and larger than the object. In this case the rays are made less divergent but not convergent.

Formulæ Relating to Lenses.—In all these lenses the relations between the distances of the image and object, principal focus, also radii of curvature, the refractive index, etc., may be expressed by a formula.

If O be distance of the object from the lens, I the distance of the image, and F, the principal focal distance, then

$$\frac{1}{O}+\frac{1}{I}=\frac{1}{F} \qquad (1)$$

From the equation it is seen that if any two of the distances are given the other can be found. Thus solving (1),

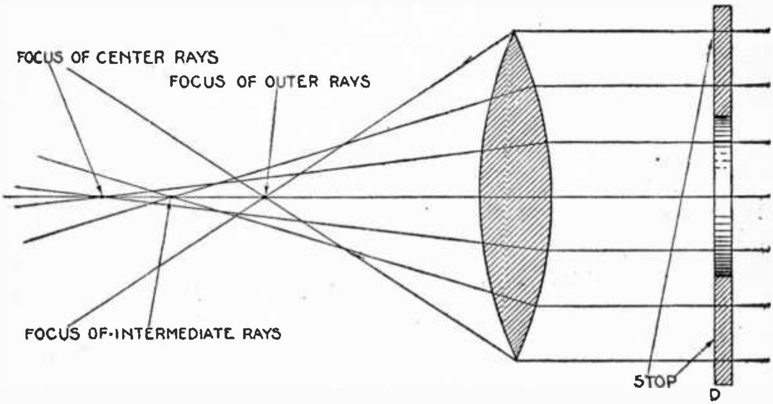


FIG. 7,778.—***Effect of spherical aberration.*** *It produces a lack of sharpness and definition of an image.* If a ground glass screen be placed exactly in the focus of a lens, the image of an object will be sharply defined in the center but indistinct at the edges, and if sharp at the edges, it will be indistinct at the center. This effect is very objectionable, especially in photographic lenses. To avoid this, a disc D with a hole in the center is placed concentric with the principal axis of the lens, thus only the central part of the lens is used.

$$\frac{1}{I}=\frac{1}{F}-\frac{1}{O} \qquad (2)$$

$$\frac{1}{O}=\frac{1}{F}-\frac{1}{O} \qquad (3)$$

Chromatic Aberration.—When white light is passed through a spherical lens, *both refraction and dispersion occur.*

This causes a separation of the white light into its various colors and causes images to have colored edges. This defect which is most observable in condensing lenses is due to the unequal refrangibility of the simple colors, and is called chromatic aberration.

Achromatic Lenses.—The color effect caused by the chromatic aberration of a simple lens greatly impairs its usefulness. *This may be overcome by combining into one lens, a convex lens of* **crown glass** *and a concave lens of* **flint glass.**

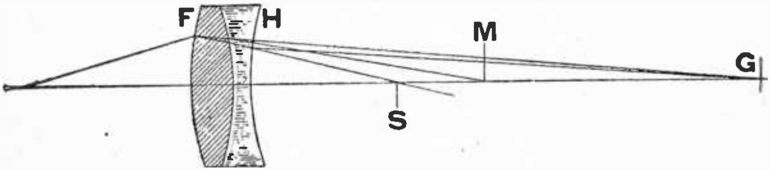


FIG. 7,779.—Achromatic lens, consisting of a combination of a double convex lens of crown glass, and a double concave lens of flint glass. Whenever it is desired to project especially good pictures upon a screen, lenses are often combined as shown in the figure. Here M indicates the line through the principal axis, at which the red rays reflected by the double convex lens would strike, and S, the line where the violet rays would be projected. The addition of the double concave lens brings the red and violet together again at G. A combination of two such lenses F H, placed the proper distance apart and the surfaces properly proportioned, may be made to combine any two of the colors of the spectrum. Accordingly even with these connected lenses there is always some coloring on the screen, although hardly noticeable.

The first lens produces both bending and dispersion; the second lens almost completely overcomes the dispersion without entirely overcoming the bending.

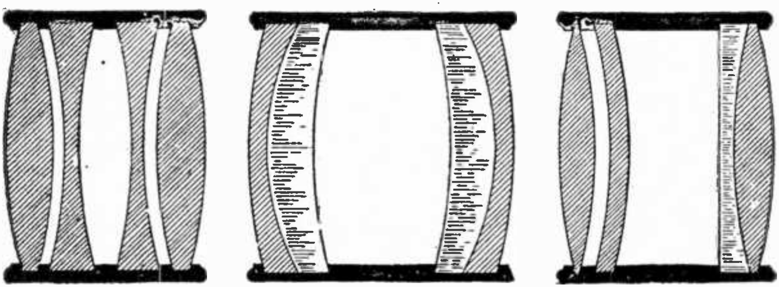
Principles of Optical Projection.—The process is almost the reverse of ordinary photography.

For instance, in photographing a scene by means of the photographic objective or lens, a reduced image is obtained on ground glass. This glass is replaced by a sensitized plate, and by the use of chemicals the image is fixed thereon.

In projection the process is reversed, that is, a transparent slide is made from the picture made with the lens, or the roll of film taken with a motion picture camera is developed and used in the projection lantern or "motion picture machine" as it is usually called.

By means of a condensed light these are strongly illuminated, and with an objective lens, an enlarged image is projected upon the screen; this screen image corresponding to the real objects photographed.

The principles of optical projection for both lantern slide and motion picture apparatus will readily be understood from the diagram fig. 7,783.



FIGS. 7,780 to 7,782.—Various achromatic lenses. FIG. 7,780 and fig 7,781 are types usually used in photography, and fig. 7,782, a combination used in motion picture and stereopticon projection.

Rules

Size of Image.—RULE: *Multiply the difference between the distance from the lens to screen and the focal length of the objective, by the size of the slide and divide the product by the focal length.*

Example.—Let L be the projection distance, 40 feet or 480 inches; S, the slide mat 3 inches; F, the focus of the lens 12 inches. The formula for size of image, is

$$d=\frac{S\,(L-F)}{F}$$

where d = size of image substituting the given data

$$d=\frac{3\,(480-12)}{12}=117 \text{ ins. or } 9\tfrac{3}{4} \text{ ft.}$$

Focal Length.—RULE: *Multiply the size of the slide or film opening by the distance from the lens to screen, and divide the product by the sum of the size of the image and the size of the slide.*

Expressed as a formula

$$F=\frac{S\times L}{d+S}$$

substituting the values previously given

$$F=\frac{3\times 480}{117+3}=\frac{1,440}{120}=12 \text{ ins.}$$

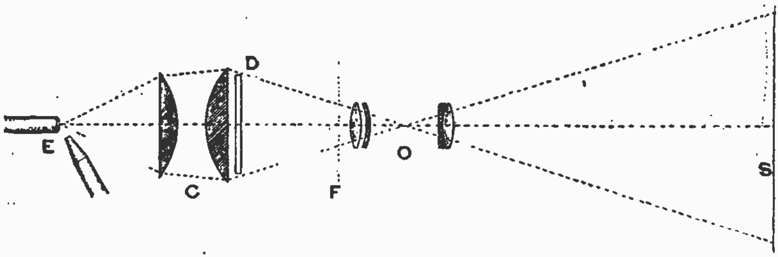


FIG. 7,783.—Diagram showing the various lenses of a motion picture machine and illustrating the principles of optical projection.

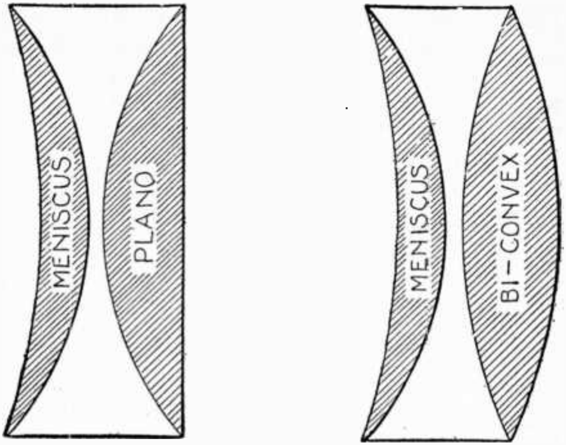
Distance from Slide to Screen.—RULE: *Multiply the sum of the size of the image and size of slide mat, by the focal length, and divide this product by the size of the slide mat.*

Expressed as a formula

$$L=\frac{F(d+S)}{S}$$

substituting the values previously given

$$L=\frac{12\,(117+3)}{3}=480 \text{ ins., or 40 ft.}$$



FIGS. 7,784 and 7,785.—Two forms of condenser. Owing to its form, the meniscus condenser will intercept and utilize a larger percentage of light rays from the arc than the plano, which means that more light will be transmitted to the film, when a meniscus condenser is used. The meniscus, however, because of being closer to the heat of the arc, is more liable to breakage. A combination consisting of one meniscus, and one bi-convex condenser is recommended.

TEST QUESTIONS

1. *Define the term optics.*
2. *Explain the emission and undulatory theories.*
3. *Give definitions of the various terms used in optics.*
4. *Explain by diagrams the formation of images by plane mirrors.*
5. *What is the law governing angles of incidence and reflection?*
6. *What is a lens?*
7. *Give a classification of lenses.*

8. *What is the focus of a lens?*
9. *Give explanation of foci in double convex lenses.*
10. *Explain with diagrams the formation of real and virtual images by double convex lens.*
11. *Explain spherical aberration.*
12. *Give the formulae relating to lenses.*
13. *What is chromatic aberration?*
14. *What is an achromatic lens?*
15. *State the principles of optical projection.*
16. *What is the rule for* a, *size of image;* b, *focal length;* c, *distance from slide to screen?*

CHAPTER 191

Motion Picture Cameras

Apparatus for taking motion pictures differs in many ways from ordinary cameras. Fig. 7,786 is a diagram showing the essential parts of a motion picture camera, from which the principles of operation are easily seen. As shown in the figure there are three compartments: 1, a front compartment U, containing a rotating shutter N, pin mechanism OP, and other parts not shown; 2, a compartment V, containing the film mechanism and magazines, and 3, a compartment on the opposite side containing mechanism communicating with the spools in the magazines, with the sprocket wheels, and the points in the first compartment.

The two magazines A,B, consisting of light boxes, fit into the back portion, and carry reels, W, X, on which the film is wound.

In operation, the roll of unexposed film L, which passes out of a small aperture H^1, at the corner of the top magazine A, around guide rollers C, D, engages by its perforations with the sprocket wheel F, to which it is kept by the roller E. The film forms a loop at H^2 and passes downward through the guide grooves made in the gate G.

Continuing, it passes out past the bottom of the gate, forming a second loop H^3, and then passes between a spring roller I, and sprocket J, under the guide roller K, and enters at H^4 the lower magazine B, when it is wound up on the bobbin X.

The sprocket wheels rotate continuously drawing the film from the supply at L, and taking it up at M.

The motion of the film in the gate G, however, is intermittent. During the period of rest, a surplus loop of film forms at H^2, which is then pulled down through the gate by the action of the pin O, engaging with the perforations.

The whole mechanism is so arranged and geared together that, *while the film is being shifted, the light is excluded from the lens, and admitted during the stationary periods.*

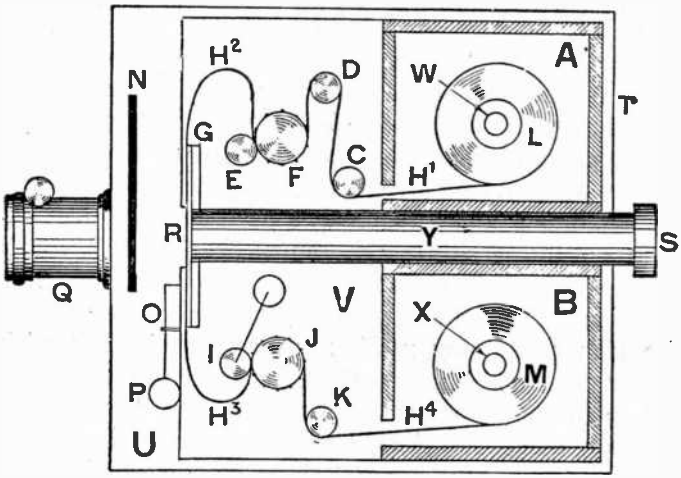


FIG. 7,786.—Diagram of motion picture camera showing the essential parts. Cameras are built for various numbers of pictures per turn of the crank; four, six, and eight are common. An eight picture camera should be run at a speed of almost one hundred turns per minute. To operate at this speed, get a watch ticking 300 ticks per minute and learn to count one, two, three; one, two, three, etc., just as fast as the watch ticks, turning the crank one revolution for every one, two, three counted; that is to say, one revolution per every three ticks of the watch

A long tube Y, extends through the center of the camera, and is provided with a detachable cap at S. This tube forms the sight hole for inspecting the image on the film, prior to exposure.

The gate G, is a kind of hinged door with an aperture in it, and its function is to keep the film flat and vertical during exposure and also to act as a channel or guide

After taking a subject, the operator presses a button, and in so doing punches a hole in the film at a point just above the gate, thus indicating the end of the subject and beginning of the next subject.

Camera Film Movement Mechanism.—The mechanism such as is used on the Bell and Howell camera is shown in fig. 7,787. It consists of two integral parts:

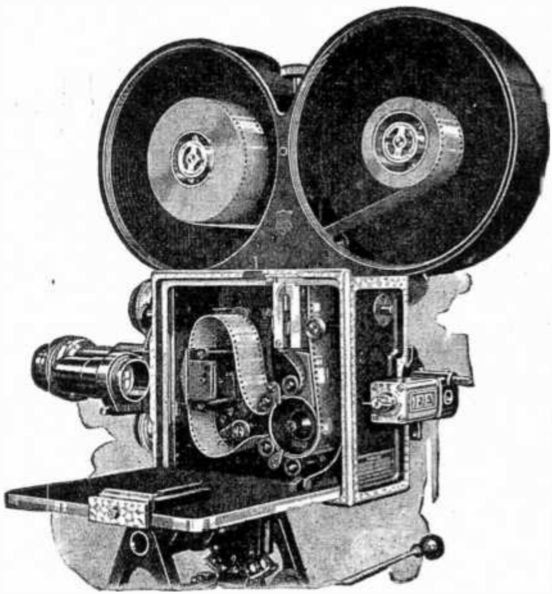


FIG. 7,787.—Bell & Howell motion picture camera; view showing camera and magazine interiors exposing film movement mechanism and threading of film.

1. Film feed and take-up sprocket;
2. Shuttle mechanism.

The film feed and take up sprocket is mounted directly to the main crank shaft by means of a lock nut and a hollow hexagon toothed washer.

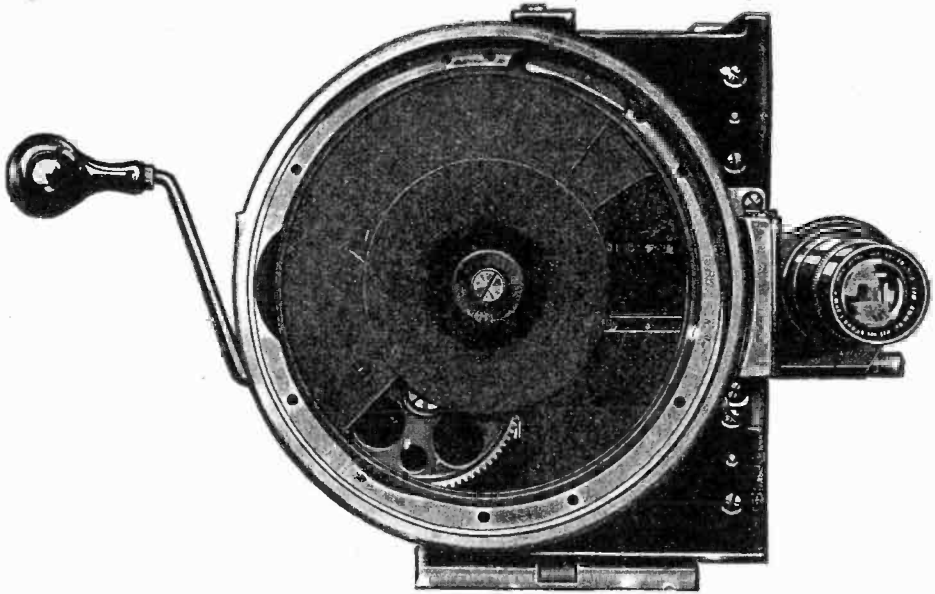


FIG. 7,788.—Bell & Howell camera. Front view with turret plate removed showing shutter, photographing aperture and part of brake mechanism.

This sprocket performs the double service of continuously drawing the unexposed film from the forward compartment of the magazine and delivering the exposed film to the rear compartment, where it is automatically rewound. Two sets of film guide rollers, upper and lower respectively, keep the film in proper engagement with the sprocket.

The shuttle mechanism comprises four distinct mechanical elements:

1. The shuttle bar carrying the engaging pins which impart the feeding motion to the film.

2. The register leaf forming the guideway for the film before the aperture.

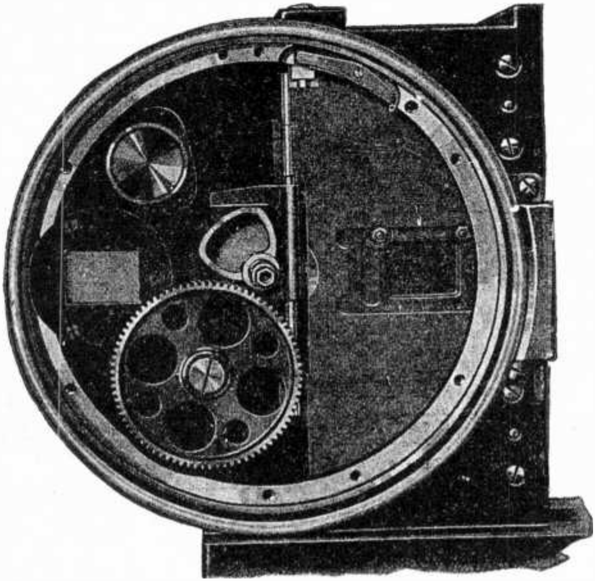


FIG. 7,789.—Bell & Howell camera. Front view with turret plate and shutter removed showing focusing and photographing apertures; shuttle operating cam, part of brake mechanism and opening for mounting focusing magnifier above focusing aperture.

3. The pilot register pins which cause the accurate register of the film before the exposing aperture. These pins are mounted above and in fixed relation to the aperture plate. Their specific function is to prevent inaccurate spacing, since an error in spacing to an infinitesimal degree causes unsteadiness on the screen in the projection of the picture.

4. The aperture plate against which the film is brought to register before the exposing aperture. This plate is mounted to the register leaf mounting

and is in fixed relation thereto. The opening in the aperture plate definitely extablishes the marginal limits of the picture. Its rearward surface forms the seat against which the film is held in contact by the register leaf during exposure, thereby accurately locating the film at the focal plane.

The film movement mechanism thus described provides for the free travel of the film from the magazine through the camera and back to the magazine.

TEST QUESTIONS

1. *Draw a diagram illustrating the essential parts of a motion picture camera.*
2. *How does a motion picture camera work?*
3. *Describe the camera film movement in detail.*
4. *Of what does the shuttle mechanism consist?*
5. *How does the shuttle mechanism work?*

CHAPTER 192

Motion Picture Projectors

The function of a moving picture machine or *projector* is *to project motion pictures upon a screen.* The machine not only projects pictures on the screen, but is usually provided with apparatus for reproducing *synchronized sound*.

The projector proper consists essentially of:

1. An optical system, comprising

   a. Source of light;

   b. Lens { condenser; objective.

2. Intermittent film feed-system, comprising

   a. Upper reel;
   b. Upper steady feed sprocket;
   c. Steady drum;
   d. Film gate;
   e. Intermittent sprocket;
   f. Intermittent movement;
   g. Shutter;
   h. Lower steady feed sprocket;
   i. Lower reel;
   j. Lower reel drive;
   k. Operating crank and drive;
   l. Numerous presser rollers.

Besides these various essential parts, safety devices such as, fire shutter, fire valves, film shields, etc., are provided.

How a Projector Works.—The elementary diagram fig. 7,790 has been prepared to show in a very clear manner the operation of a projector. If the reader imagine the crank A, turned

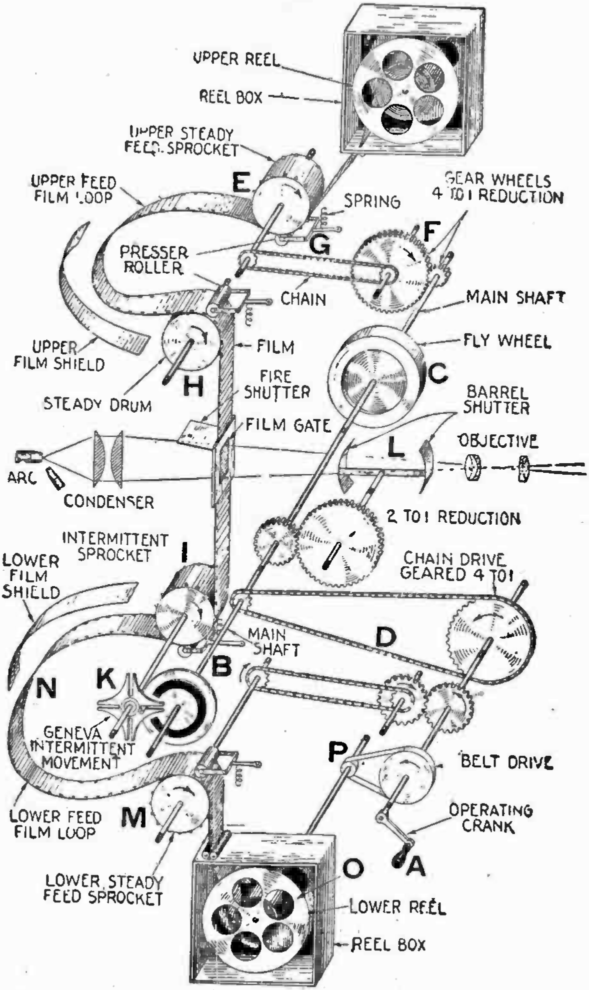


FIG. 7,7?0.—Elementary moving picture machine without case showing essential parts arranged to illustrate plainly the motion system.

counter clockwise he will have no difficulty in tracing the movements of the various parts.

The diagram does not represent any particular machine but is intended to give a clear idea of how the film is fed across the film gate intermittently and the synchronous operation of the shutter whereby the light is cut off from the screen during each movement of the film, with alternate "on" intervals while the film is at rest.

The operation of the projector is briefly as follows:

By turning crank A, in fig. 7,790, counter clockwise, the main shaft B, is driven through the 4 to 1 reduction chain drive D, a steady turning motion being caused by the fly wheel C, this in turn operates the upper steady feed sprocket E, through the 4 to 1 reduction gear F, thus the teeth of E sprocket which mesh with the perforations in the film, feed the film at a constant rate, the film being held against E by pressure roller G. A film loop or length of loose film is thus maintained between E and the steady drum H.

The film is fed past the film gate intermittently by the intermittent sprocket I, operated by the Geneva movement K, the latter producing a quick quarter turn of I, followed by a relatively long rest during which the main shaft B, makes one revolution.

The barrel shutter L, by a 2 to 1 gear with the main shaft and proper timing, operates to cut off the light rays from the screen during each movement of the intermittent sprocket I, and to admit the light during the intervals that I remains stationary. The synchronous operation of the intermittent sprocket and the shutter is very clearly shown in the diagram.

A lower steady feed sprocket M, which operates at the same speed as the upper sprocket E, maintains a lower feed film loop N, and feeds the film to the lower reel O. Because of the increasing diameter of the roll of film due to winding the film on reel O, the velocity of rotation of O must be allowed to vary; this is accomplished by means of the belt drive P, the belt permitting slippage below the maximum speed. *It should be carefully noted* that the total revolutions made by each of the three sprockets E, I, and M, is the same, the only difference being that the *motion of* E *and* M *is constant while that of* I *is intermittent.*

The object of the upper and lower feed loops is to lessen the inertia of the film by reducing the length of film subject to the sudden intermittent motion

The film gate guides the film so as to prevent any lateral motion, flattens the film and by frictional resistance prevents the momentum of the film causing any up and down vibration.

The Intermittent Movement.—Various devices have been introduced for producing the intermittent movement necessary in projecting motion pictures. The movement consists essentially of an intermittent sprocket and intermittent gear.

The sprocket is a cylinder with teeth at each end, or for very light construction, it may consist of two hubs provided with teeth and properly

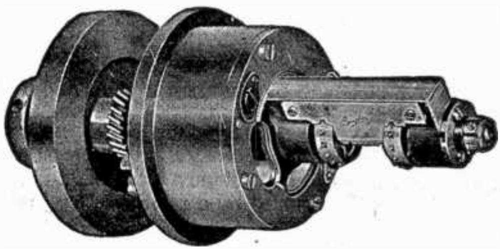
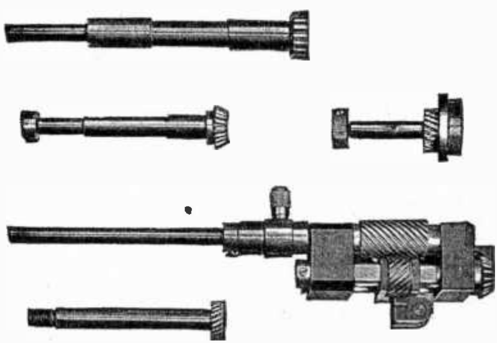


Fig. 7,791.—Simplex Geneva type intermittent movement.



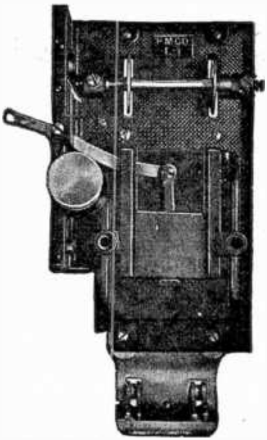
Figs. 7,792 to 7,796.—Simplex gears. The bevel and intermediate gears are made of formica, which material absorbs noise and damps the ring of metal gears.

spaced on a shaft to take the film. The teeth mesh with perforations in the film and thus secure a positive movement.

Of the various intermittent movements, the Geneva is extensively used and easily understood. Its operation is shown progressively in figs. 7,799 to 7,804.

The nature of the motion is as follows:

1. Begins slowly (fig. 7,800),



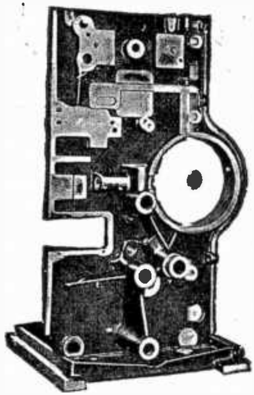


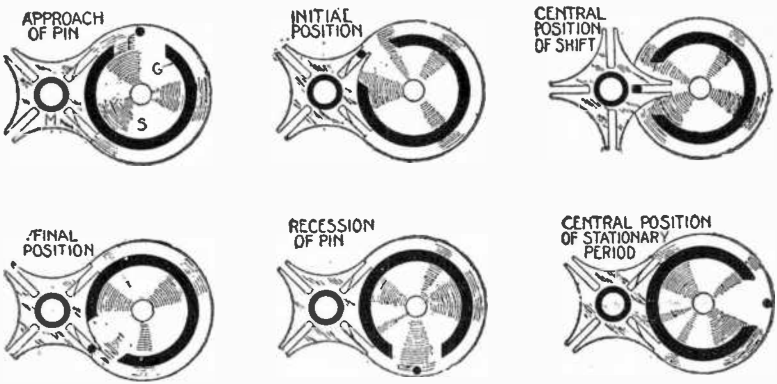
Fig. 7,797.—Simplex film trap. It has a felt runner type of tension shoe. The film guide may be removed from the mechanism by giving it a slight upward thrust; this permits ease and free access to all parts of the trap and door for the purpose of cleaning away emulsion, dust or dirt. Film trap is equipped with a slide in mask which eliminates the projection of the sound track to the screen. By slipping this mask in or out as desired, silent, sound on disc, or sound on film prints may be properly projected at will. A gate locking device also forms part of this assembly. This assures the projectionist that once the gate is closed it will remain locked in position during the projection of pictures. The gate may be released by a slight pressure of the finger when pressing on the opening device to which the lock is attached. The fire shutter is of the gravity type.

Fig. 7,798.—Simplex center frame.

2. Accelerates to a maximum at the mid position (fig. 7,801) and

3. Gradually slows down to zero (fig. 7,802).

Light for Projectors.—Both arc and incandescent lamps are used to produce illumination for motion picture projection.



FIGS. 7,799 to 7,804.—Operation of Geneva movement shown progressively. *It consists of* a maltese cross M, and a disc S, provided with a pin F, and circular guide G. *In operation*, the pin disc S, is in continuous motion and the pin is so located that it enters one slot of the cross M and carries it along with it, thus causing one-quarter revolution. The circular guide G, is cut away sufficiently to allow the cross to make a quarter revolution, but when it registers with the cross it holds the latter securely until the pin rotates around to the next slot.

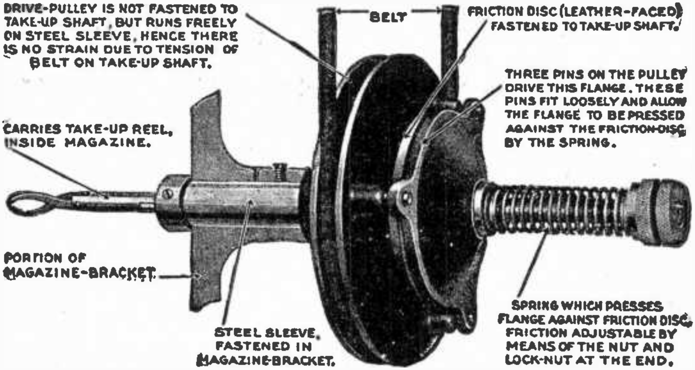
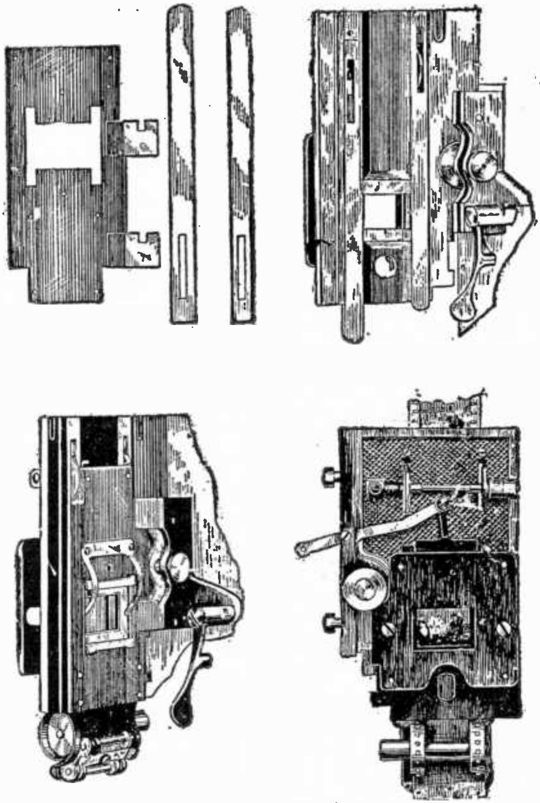


FIG. 7,805.—Simplex take-up device. *It is driven* from the main driving gear, thus balancing the entire mechanism and equalizing the strain on the main driving shaft. The unit is adjustable for any desired tension. Two grooved pulleys are furnished permitting the use of reels with either 2 in. or 5 in. hubs.



Figs. 7,806 to 7,811.—Construction details of Simplex film gate. It is made of machine steel; the lugs securing the gate to the holder being electrically welded. Fig. 7,806 represents milled surfaces. The film trap shoes (figs. 7,807, 7,810), are of steel ground on both sides and beveled (fig. 7,807) to permit sliding into the dovetail slots (fig. 7,806). The lateral guide rollers (fig. 7,810 and 7,811) are of steel hardened and ground; the film cannot pass the guide rollers unless it be set between the two. If it should not be, it automatically rights itself. The distance between the rollers is adjustable by a set collar (fig. 7,811). The gate (fig. 7,810) is opened for threading by a light inward pressure on a thimble (fig. 7,811), and is closed by releasing the film trap door trip lever (fig. 7,810). Thus, in threading, there are only two operations: one to open, and one to close the gate. The intermittent sprocket tension shoe is made of ten pieces of hardened tool steel. The two inside shoes are offset and do not touch the film. The cooling plate (fig. 7,811) is made of two pieces of sheet steel separated ¼ inch, which arrests the heat by radiation and protects the fire shutter and aperture side of the film trap. The air space between the film trap is ½ inch.

In the old type arc, light is produced by passing an electric current across an air gap between two carbon electrodes, thereby heating the tip of one of the carbons, the positive, to bright incandescence. The resulting, slightly concave, bright spot constitutes the principal light source.

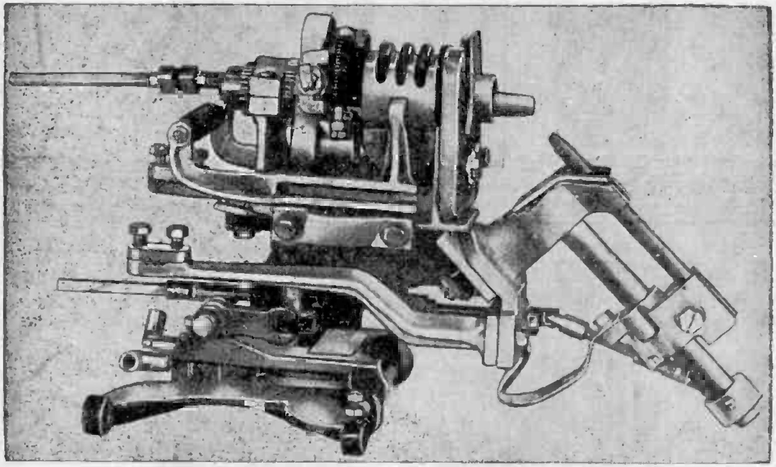
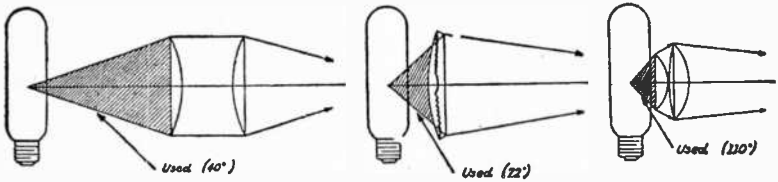


FIG. 7,912 —Hall and Connolly high intensity arc burner. *It consists* essentially of a combination tilting and swiveling stand upon which, but electrically insulated therefrom, is mounted an upright bracket casting carrying the lamp frame proper. The lamp frame carries a long spline shaft and a threaded shaft along which ride the positive carbon holder carriage with its rotating gears and carbon clamp. The threaded shaft advances the carbon carriage at the same time that the carbon holder and clamp are being revolved in the carriage. At the front of the lamp frame is a locating V recess in which rests loosely a half round carbon contact of ample surface and weight. In this contact the carbon slides and rotates under pressure from another contact resting on top of the carbon held down by a spring and lever. The carbon carriage is provided with a quick release from the worm drive for quick retrimming of the carbon. The length of travel of the carriage is sufficient to give 22 minutes of continuous burning at normal amperage. The positive carbon contacts are shaded from the heat of the arc flame by means of insulated, laminated shields made of heat resisting non-corrosive metal. The negative carbon unit consists of a pivoted self-aligning carbon clamp carriage sliding on two substantial rods or guides, the upper ends of which are rigidly attached to the guide head casting, which in turn is attached to, but properly insulated from, the same bracket casting carrying the positive unit. The guide head casting has a V recess into which the carbon is held and slides under tension of a tungsten spring located underneath the pivoted carbon holder carriage. The pivoted carbon holder and the V shaped guide head insure constant and correct alignment with the positive carbon and at the same time give to the copper coated negative a good wiping contact. Feeding motion is imparted to the negative carbon through a connecting rod coupled to a nut traveling on a long threaded shaft located on the back of the burner away from the direct heat of the arc.

In the high intensity arc, light is similarly produced by passing a heavy current across an air gap between two electrodes, but the position and composition of these electrodes are different.



FIGS. 7,813 to 7,815.—Comparison of arc and incandescent lights. The crater of the arc emits light only forward. With such a distribution the 10 in. or 12. focus plano condensers and a 1½ in. diameter projection lens collect and utilize practically all of the light. The incandescent lamp emits light very nearly equally in all directions. Obviously, if the incandescent lamp be simply substituted for the arc, only a small portion of the total light emitted will be used as in fig. 7,813. Accordingly, in order to intercept more light, a much shorter focus condenser must be used. At first, a single piece corrugated condenser was used as in fig. 7,814 and later a triple lens aspheric condenser as in fig. 7,815. Such condensers pick up a solid angle of light of about 110°, as against 40° for the old plano condensers. In order to utilize the light which is given off to the rear of the lamp, a spherical mirror is placed behind the bulb, and so adjusted as to reflect an image of the filament coils back between the coils themselves. Thus instead of the 60° picked up in the arc system, we are utilizing the equivalent of 220° of solid angle. It is very important that the spherical mirror be accurately adjusted, in order to secure the best results.

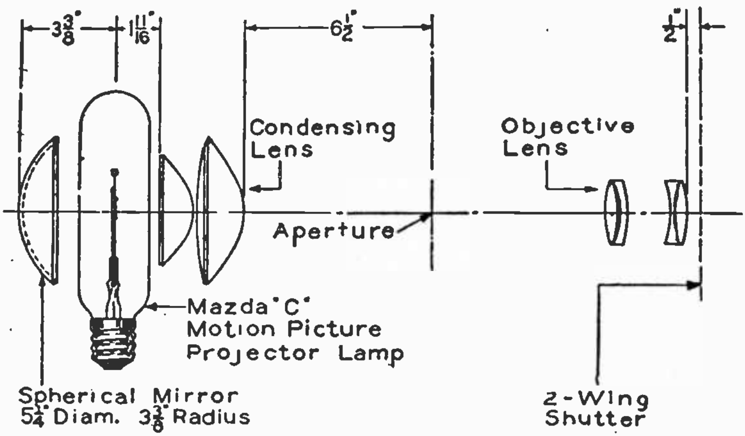
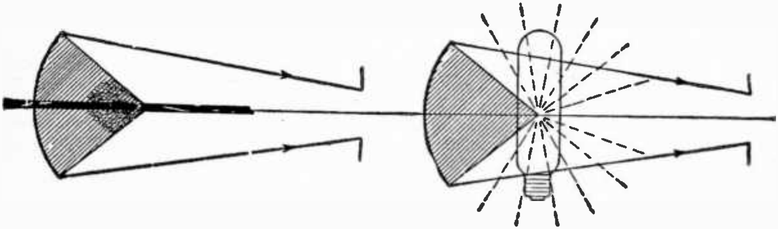


FIG. 7,816.—Optical train with incandescent lamp using Bausch & Lomb Cinephor condenser.

The positive is made up of rare earths, the principal one of which is cerium fluoride, and this rod of luminescent, arc sustaining material is encased in a thin shell of carbon. The negative consists of a copper coated heavy carbon shell surrounding a flame sustaining core. *The negative electrode* is positioned at an angle varying from 20 to 45 degrees according to the service for which the particular burner is intended

The current in passing across the air gap is concentrated in the core of the positive, causing great current density at this point. The core burns away more rapidly at first than the carbon shell, thus forming a cup shaped cavity more than ⅜ of an inch in depth, tapering down from about ¾ the



FIGS. 7,817 and 7,818.—The standard arc lamp reflector, when used with an incandescent lamp, redirects but a small part of the available light through the condenser. Good results with incandescent lamp projection necessitate not only the proper equipment, but also very accurate adjustment of the various elements of the optical system.

diameter of the shell at the rim to about the diameter of the core at the bottom. In this cup or crater the luminescent gases from the core are generated and superheated, giving rise to tremendous temperature. *These gases are the light source* in the high intensity arc. This method of producing light is made possible by using sufficient current density, a special positive electrode of suitable structure and composition, by placing the negative electrode so that the arc stream is projected against the face of the crater to confine the positive gases, and revolving the positive carbon in order to prevent the rim of the crater burning away unevenly and letting the gases escape too rapidly.

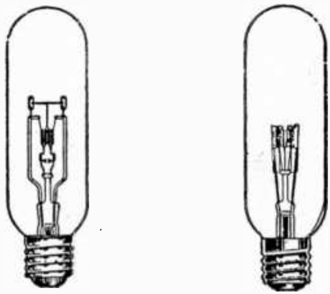
The brightness of the old type arc is about 140 candle power per square millimeter of crater surface.

The brightness of the new high intensity arc may be forced to well above 900 candle power per square millimeter of crater surface

Fig. 7,812 shows the gear and mounting of a high intensity arc lamp.

The construction and operation of a modern projector is shown in fig. 7,821.

Referring to illustration, the pedestal, carriage, adjustable support and base, constitute a single symmetrical unit. The stand rests on six leveling points and the projector is not attached to the floor or fastened to the building.



Figs. 7,819 and 7,820.—Comparison of Mazda lamps. Fig. 7,819 shows a 28-32 volt, 900 watt, and fig. 7,820 a 1,000 watt Mazda projection lamp. The lower voltage lamp, on account of the shorter length of filament and its lesser liability to squirm when heated, has the desirable factor of greater filament concentration. *Reason for low voltage:* It is characteristic of tungsten filament that the higher the voltage, the smaller in diameter the wire must be, and the more it will squirm when it is heated and cooled. If 110 volt lamps were used the filament could not be concentrated into so small an area nor could it be run at quite so high a temperature. The greatest filament concentration possible, with the low voltage high current lamp is, therefore, the prime reason for its use. The useful size of light source is limited by the optics of the projector. The lens system will pick up light from a limited area and any light outside of this area is of no avail.

The underslung motor table O, is close to the base and the motor is accessible for oiling or regulating. It can be raised or lowered on its supporting rod by loosening two wing screws. The position of the motor on the stand is an important factor in eliminating vibration.

To tilt the projector, release locking handle A, attached to rear adjustable support, by turning it to the left, loosen pedestal adjustment locking nuts B and C, and pedestal adjustment hand wheel D, can then be turned with either hand to give desired angle. Micrometer adjustment can be made by means of the hand wheel, and compression springs E, on rear adjustable support make this extremely comfortable. When A, B, and C, are again locked, the projector is held rigidly in the proper position.

The lamp house can be placed in position for slides by loosening knobs F and G, firmly grasping slide over arm handle H, and drawing it to the left for the correct placing. Lamp house carriage K, turns on lamp house pivot

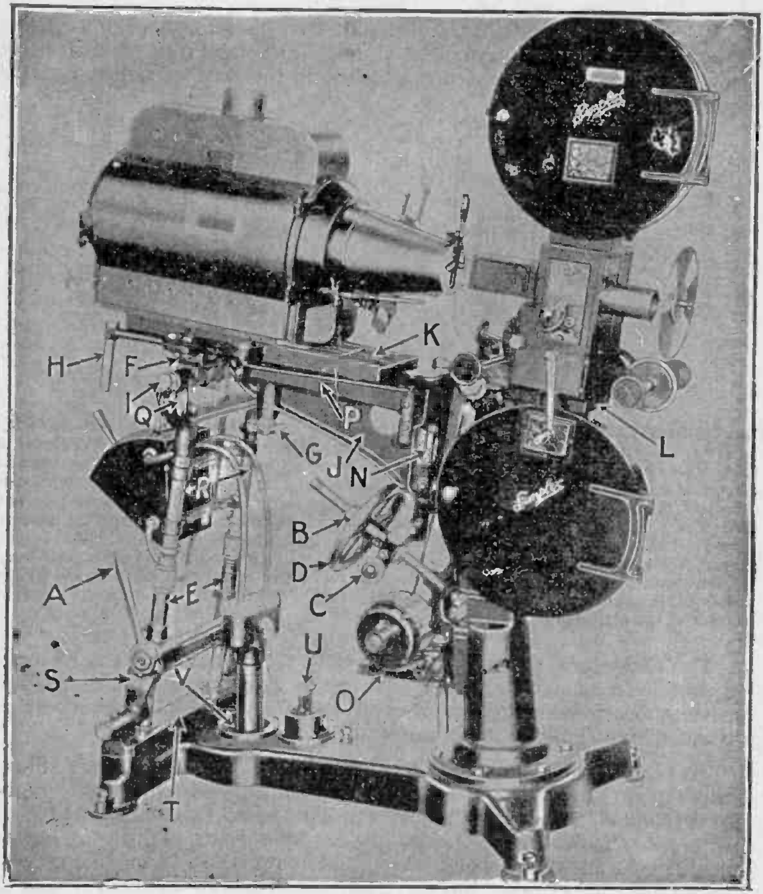


FIG. 7,821.—Model M, Simplex projector.

N, and at G, and slides over lamp house carriage rod I, and rear adjustable support. When F and G, are again locked, lamp house carriage K, is held rigidly in position.

The rear adjustable support consists of an upper fork Q, two rods R, and a lower fork S, swings on the pivot casting T. When the locking handle A, operates, it releases a powerful friction lock, and support rods R, are free to slip through the lower fork S. When the locking handle A, is released, the adjustable support ceases to act and hangs idle from the swinging table. When locked the rods and two forks constitute a structure that firmly connects the swinging table to the base. The 100 ampere switch and switch box are attached to the rear adjustable support. There is a foot motor switch U, for starting and stopping the projector and the 4 in. opening V, is provided in the base for installing a condulet.

TEST QUESTIONS

1. *What is the function of a motion picture machine or projector?*

2. *Of what does a motion picture projector consist?*

3. *Draw an elementary diagram illustrating how a projector works.*

4. *Describe the construction of the intermittent movement.*

5. *What is the nature of the motion due to the intermittent movement?*

6. *What is a take up device?*

7. *Give construction details of the film gate.*

8. *How does a high intensity arc burner work?*

9. *Give comparison of arc and incandescent lights.*

CHAPTER 193

Projector Operation

In the operation of projectors it should be noted especially that for continued perfect service cleaning and oiling are essential. The projection lens, the condensing lenses, and the mirror reflector should be thoroughly cleaned frequently. Oiling instructions should be carefully followed. The aperture plate and film gate collect a gummy substance especially from fresh film. This must be cleaned off to maintain the necessarily smooth surface for the film to ride upon.

Oiling.—Selecting the Super Simplex projector for illustration it will be noted in fig. 7,822 that all the bearings in the frame are reached by means of oil tubes A.

There is one bearing C, which has a direct oil hole on the side of the apparatus for lubricating the rear bearing of the shutter shaft. Do not overlook this hole in oiling.

The one oil tube which is not immediately visible is that which carries oil directly into the intermittent case and there is no wick in this particular tube. The method of oiling this is explained in fig. 7,822.

There are other minor oil holes which should receive oil occasionally, two which provide lubrication to the bearings of the film gate opening shaft, one which provides lubrication to the rear bearing of the frame shaft and two which provide lubrication to the bearing of the shutter adjusting shaft. The latter oil holes will be found under the framing lamp assembly. The only other oil hole on the mechanism is the one supplying oil to the outer bearing of the intermittent sprocket which is oiled through the ball oil cap D, fig.

7,823, in the same manner as in the old type Simplex mechanism with double bearing movement.

Of course, a small drop of oil should occasionally be placed on all slipping and sliding parts in order that they may work freely at all times and also on the gear teeth so that the mechanism may operate smoothly.

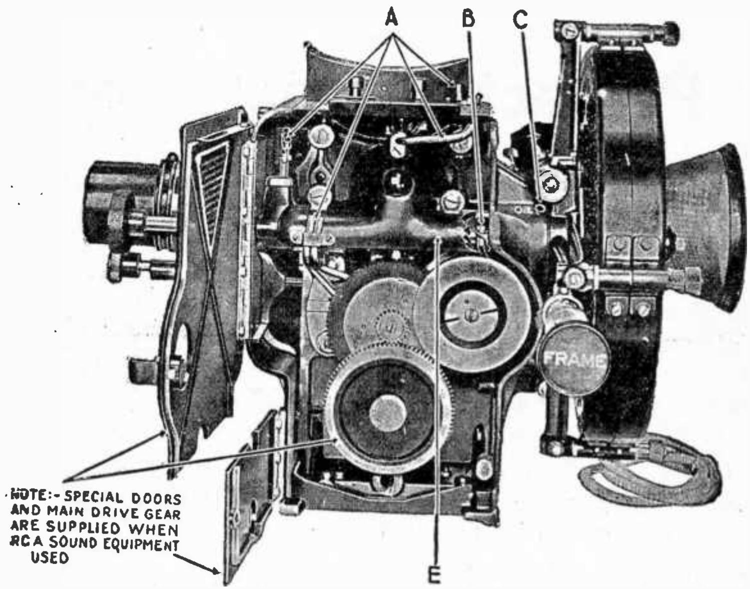


FIG. 7,822.—*Super-Simplex oiling system.* Oil intermittent casing as follows: Set the framing handle to the position which brings the red line on the oil sight to a horizontal position; in the shutter shaft support casting E, just above the fly wheel of the intermittent movement, will be found a window or hole milled through the casting through which can be seen a portion of the shutter shaft. Just in front of the shutter shaft is the oil tube B, leading to the intermittent casing. This oil tube can be reached in one position only; this position is obtained by moving the framing handle as before directed. Enough oil should be inserted through this tube to bring the level in the oil case up to the red sight line, and no more, when machine is level; use judgment when projector is not level.

Sound Aperture and Picture Centering Device.—The Super Simplex projector is supplied with the vertical sliding aperture plate in which are two standard apertures, one having the standard dimensions for straight silent film projection, .906 × .6795, and the other having standard dimensions for sound film projection .800 × .6795, or the proportional aperture, .800 × .607 for the projection of sound film to give a screen picture

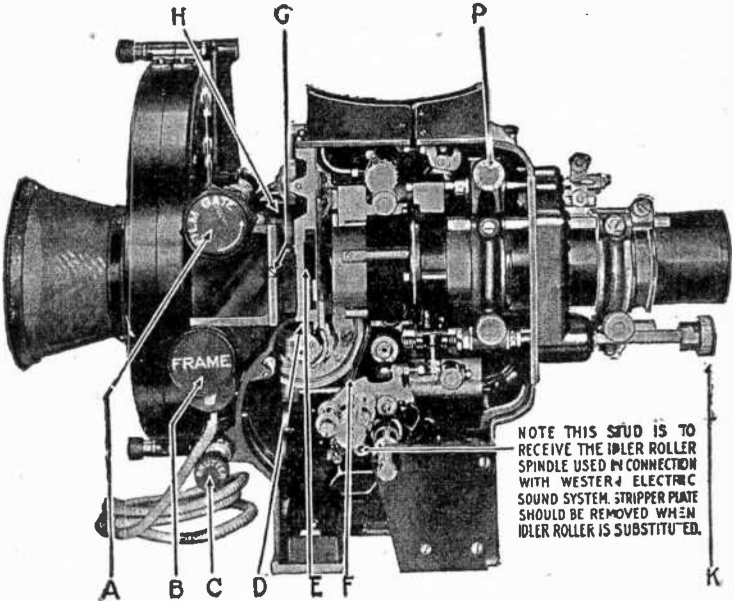


FIG. 7,823.—Super-Simplex projector; view showing aperture plate, outer bearing of intermittent sprocket, etc.

of the same dimensions as obtained with the standard silent projection aperture.

With the use of this latter aperture it is necessary to change to shorter focal length lenses and this can be done in the Super Simplex as is explained under Method of Mounting Lenses.

Aperture Plate.—This plate E, fig. 7,823, slides vertically behind the film tracks on the film trap. In its upper position it carries the standard silent film aperture. When slipped into the lower position it carries the standard sound film aperture or the standard proportional aperture, depending on which was ordered with the projector.

When using the standard sound film aperture or the proportional aperture it is obvious that the lens mount with relation to the center of the aperture is off center, due to the masking of the sound track, and, therefore, throws the picture to one side on the screen.

On the front and top of the lens mount, outside of the mechanism, fig. 7,824, will be found a lever A, which may be thrown laterally from left to right. In the position shown the lens is accurately centered on the standard or proportional sound film aperture, and thrown over to the left position it will be centered for the standard silent or disc aperture.

Stops B, are provided on this adjustment so that the length of its throw may be pre-determined in order that the lens may also come into the correct relation with the projection apertures and the projected picture; these stops fetch up against the stationary stop shaft C.

Just within the glass door of the mechanism in the upper right hand corner, see P, figs. 7,823 and 7,826, will be found a lens holder lock screw. This screw is attached to a clamp provided in order that the lens centering lever may, if desired, be locked in fixed position and also to apply a slight tension that eliminates vibration of the lens centering unit.

Revolving Shutter.—The construction of this detail is shown in fig. 7,825. The method of setting the shutter is explained in the illustration.

Eye Shield.—This device, which protects the projectionist's eyes from the bright rays from the spot at the aperture, is enclosed and the colored glass therein may be removed for cleaning by loosening screw G, in fig. 7,823.

This eye shield together with the framing and threading lamp are attached by means of screws to the front section of the shutter guard. A slot H, fig. 7,823, is provided in the eye shield assembly just behind the aperture, so that change over devices using an aperture cut off may be readily adapted.

Threading and Framing Lamp.—This lamp shown at D, fig. 7,824, directs a strong beam of light up behind the eye shield to the aperture and by this means it is possible for the projectionist to place the film in frame readily while threading the projector.

A small switch F, is provided by means of which the lamp may be thrown on or off at will. The framing lamp assembly is connected by armored cable to any convenient source of 110 volt supply.

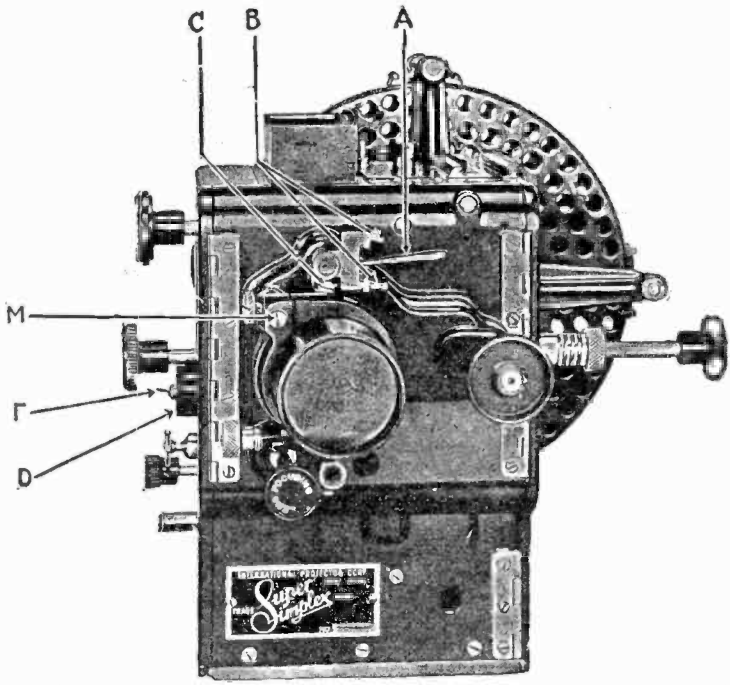


FIG. 7,824.—Super-Simplex projector; view showing adjusting lever, threading and framing lamp, etc. *To replace lamp:* Loosen screws which hold switch assembly and lamp socket in lacquered barrel: the entire assembly may then be removed and lamp readily replaced

Gate Opening, Framing and Shutter Adjusting Knobs.—These knobs are plainly visible on the projector and very little need be said with regard to their operation. These knobs are shown in figs. 7,823 and 7,826 and explained in fig. 7,826.

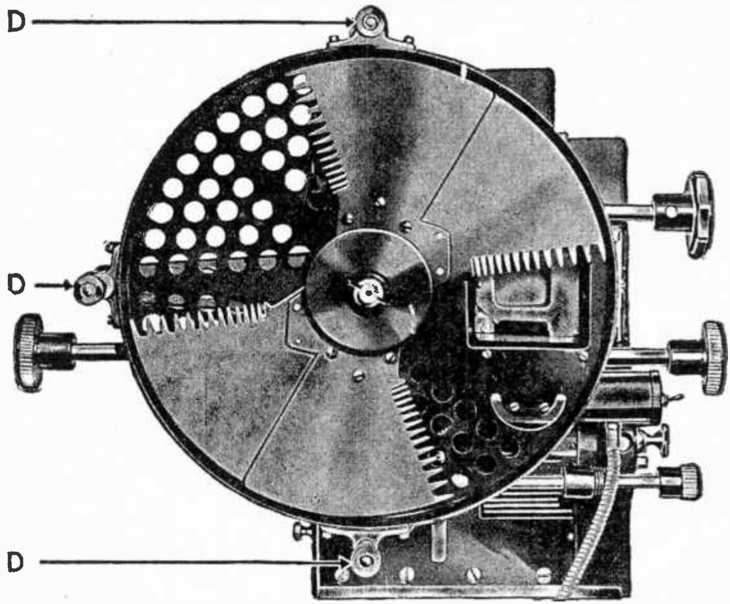


FIG. 7,825.—Super-Simplex projector; view showing revolving shutter. *To set:* Bring the intermittent sprocket from rest down two teeth, using the lower end of the film shoes as a guide; then set the center of the shutter on the optical axis, locking it in this position. Care should be taken to see that the throw of the shutter adjusting screw C, fig. 7,823, is set centrally in order that the shutter may be adjusted in both directions if it be not set at exactly the proper position on the shaft. The entire shutter may be exposed by removing the front shutter guard. This is accomplished by removing the three nuts and washers D. fig. 7,825, and slipping the front shutter guard from its supporting studs.

Lens Mount.—This device will support any type S of M.P. standard lenses. The lenses are held firmly in place by means of two lens clamps, one within the projector mechanism G, fig. 7,826, and one H, on the outside on front of the mechanism.

Half size Ross lenses may be accommodated but it will be found that in many focal lengths the large barrel diameter K, fig. 7,827, is several thousandths of an inch below the American standard, and where this discrepancy

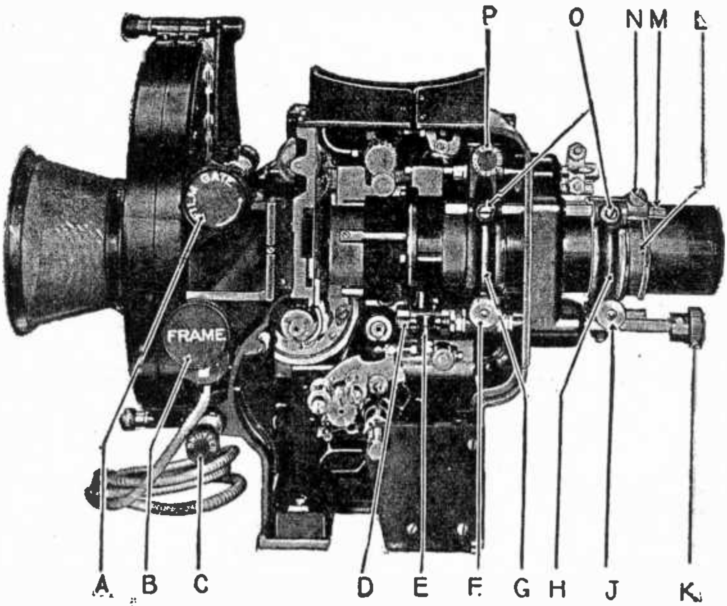
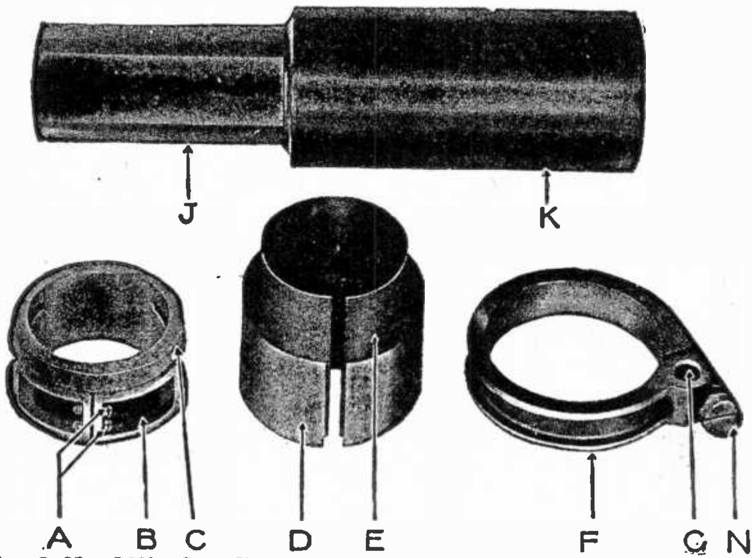


FIG. 7,826.—Super-Simplex projector view showing gate opening, framing and shutter adjusting, knobs, lens mount, etc. The film gate knob A, (also A, fig. 7,823) controls both the film gate latch and the gate opening device, and it is turned about a quarter turn to the left as indicated by the arrow thereon to open the gate. When the gate is opened, upon being released by lever F, (fig. 7,823) it both closes and latches readily. When the gate is closed, it should be closed gently and a slight pressure of the finger given it in order to make sure that it latches property. The framing handle B, (also B, fig. 7,823) is so mounted upon the shaft that when the word *frame* is read in a horizontal position, as indicated, the framing device is centrally located, allowing approximately the same throw to right and left for framing purposes. The shutter adjusting knob C, (also C, fig. 7,823) is connected through the gear train and shafts to the shutter shaft and turning it in either direction will revolve the shutter shaft to the right or left respectively, so that the shutter may be accurately set with the projector in operation after it has been temporarily set and locked on the shutter side. Care should be taken to see that an equal amount of throw is allowed in the shutter adjusting mechanism when the shutter is locked upon the shaft. The lens focusing knob K, (also K, fig. 7,823) projects out through the front of the mechanism and is of the micrometer type. One complete turn of this knob moves the lens mount forward or backward approximately .040 ins., depending upon the direction of its rotation.

is discovered it will be necessary sometimes to use shims similar to that shown at D, fig. 7,829, in the front clamp H, fig. 7,826.

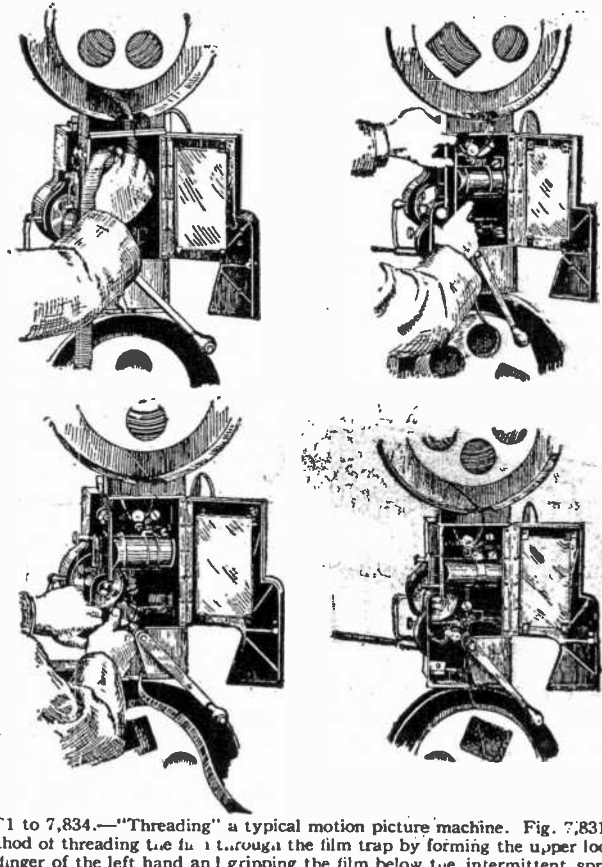
Method of Mounting Lenses.—This operation should be done as follows: Set the focusing nut E, fig. 7,826, centrally on the focusing thread D, by turning the focusing knob K. Loosen the lens clamp screws F and J, fig. 7,826. Slip the rear lens adapter B, fig. 7,828 (if one be necessary), over the rear combination lens without clamping it on the barrel, as shown in



Figs. 7,827 to 7,83? .—Super-Simplex lens adapter parts.

fig. 7,835. Slip the lens in through the front of the lens mount and bring it into approximate focus by sliding it back and forth in the mount.

When in focus, slightly tighten the front lens clamp screw J, fig. 7,826, so that the lens will not slip. Slip the rear lens adapter B, fig. 7,835, along the



FIGS. 7,831 to 7,834.—"Threading" a typical motion picture machine. Fig. 7,831 illustrates the method of threading the film through the film trap by forming the upper loop with the second finger of the left hand and gripping the film below the intermittent sprocket with the first finger. Fig. 7,832 illustrates how the film is threaded through the film trap by forming the upper loop with the second finger of the left hand and gripping the film below the intermittent sprocket with the first and third fingers of the right hand and closing the film trap gate by tripping the film trip lever with second finger. Fig. 7,833 illustrates the method of forming the lower loop, threading the film over the lower feed sprocket and closing the lower feed sprocket roll arm by a downward pressure with the first finger of the right hand. The film is then inserted through the fire valve by means of the slot in the base of the mechanism and is then fastened on to the lower reel so as to rewind to the right. Fig. 7,834 shows the machine completely threaded from the top reel to the feed sprocket through the film trap and on to the lower feed sprocket and the take up reel.

lens until it centers in the rear lens clamp G, fig. 7,826. Loosen the front lens clamp screw J, fig. 7,826, and carefully remove the lens. Tighten the clamp screws A, fig. 7,828, so that adapter will then be tightly clamped on the rear lens combination. The lens is then permanently assembled for future use and may be accurately focused by the focusing knob in the regular way.

Threading the Film.—The operation of threading the film is an important one and is shown progressively in figs. 7,831 to 7,834.

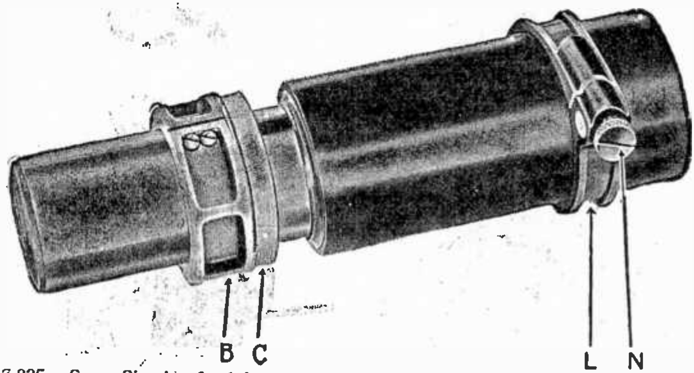
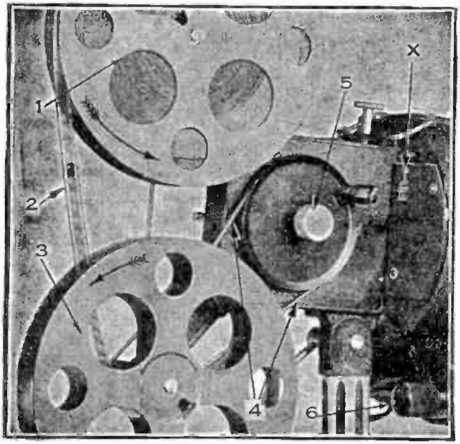


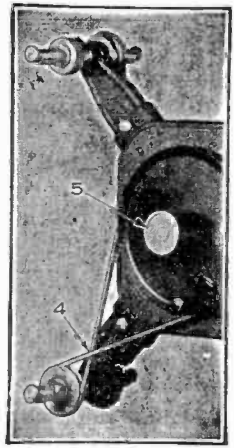
FIG. 7,835.—Super-Simplex fixed focus clamp. In theatres where proportional size aperture plates or effect masks are used, it is necessary to quickly change lenses from one focal length to another, and it is essential that each and every lens used in this connection he absolutely in focus without adjustment on the part of the projectionist when the change is made. Where it is desired to change lenses quickly from one focal length to another this is taken care of by means of an auxiliary lens clamp L, (also L, fig. 7,8 6) which clamps to the lens proper by means of screw N.. After the lens is sharply focused, this auxiliary lens clamp is slipped over the front end of the lens barrel and brought tightly against the front lens clamp as shown at L, in fig. 7,826.

Starting the Projector.—After the projector has been properly oiled, film properly threaded, framed and adjustments made, the following directions (which relate especially to the Superior projector) should be observed:

1. Strike arc by adjusting carbon holders and throwing knife switch.

2. Especially on new equipment the star and cam should be eased off before starting. Instead of accomplishing this by turning the fly wheel as formerly, it is now done by an adjusting knob located at the front end of the direct motor drive shaft. A slight turn of this knob will serve to ease off the star and cam and thus allow easy starting, and also save much wear on these vital parts.





FIGS. 7,836 and 7,837.—Rewinding film on Victor Cine projector. ***Instructions:*** Place the full reel 1 on the left shaft of the upper reel arm so that the film 2 comes off the reel from the front and is attached to hub of empty reel 3 as shown. When rewinding by hand loosen clutch knob 5 by turning to right. If rewinding by motor, rewind belt 4 must be crossed as in fig. 7,837 and clutch 5 tightened by turning firmly to right. A film may be rewound while another is showing. This is a great convenience when the same film is to be shown more than once during any one exhibition. When rewinding by motor it is not necessary that the lamp remain lighted. Remove plug 6 to disconnect lamp current. Incorrect rewinding on the Victor Cine projector is impossible because of an automatic clutch in the take up shaft which prevents revolving of the spool in incorrect direction. If a new film before projection has been wound on the reel incorrectly, inside out, it must be rewound twice, so that the starting end is on the outside.

3. Engage motor by pulling or pushing the motor switch located at the rear of the cradle and under the lamp house. This can be done from either side.

4. Variation in speed is accomplished by turning speed knobs, located on either side to the left or right as occasion requires. Changing speed should be done slowly rather than abruptly.

5. Crank handle should always be close at hand in case of an emergency. Should any trouble develop with transmission continue running of projector by means of hand crank, immediately disengaging the motor.

Operating Hints.—The following suggestions in the form of "dont's" will be found of value to the projectionist:

1. Don't operate machine with mechanism doors open or unlocked.

2. Don't start machine until complete threading course has been checked up.

3. Don't lift up fire shutter while film is in mechanism and lamp house dowser is open.

4. Don't start machine until picture is in frame.

5. Don't use force in driving pins or removing shafts.

6. In removing intermittent sprocket be careful not to strike it against sides of machine.

7. Don't fail to examine and test machine before starting each show. It will save trouble and is required by regulations in some cities.

8. Don't start machine with a jerk, but increase the speed after the machine is in motion.

9. Don't have too much tension on pad or film guide. This causes undue wear on the star wheel and intermittent sprocket, and may injure the film.

10. Don't let film trap slam after threading, as the film may be thrown off sprocket and ruined when machine starts. Place finger against film trap and let it close easily.

11. Don't use steel to scrape the emulsion off the film trap and tension springs. Use edges of a coin or piece of copper or other soft metal.

12. Don't force the machine when it seems stiff. It may need oil or an obstruction may have found its way into the working parts.

13. Don't forget to re-time or set the shutter after removing the intermittent case from the machine.

14. Don't use graphite in any part of the mechanism. It will not only ruin the gears, but will eventually destroy the bearings and entire mechanism.

15. Don't use alcohol, benzine, kerosene or turpentine as a lubricant. Either Simplex oil or oil of a similar quality is the only machine lubricant recommended.

16. Don't use oils "that clean as well as lubricate." Any oil that is powerful enough to eat rust will also eat any of the bearings and shafts.

17. Don't fail to give mechanism a kerosene bath at least once a month.

18. Don't try to put enough oil into mechanism at one oiling to last a week, but use less oil and use it oftener.

19. Don't forget any of the oil holes. They are there for a purpose and every one of them is important. Locate each one of them on the instruction plates.

20. Don t fail to oil machine every time before using, particularly the intermittent movement—"the heart of the mechanism."

21. Don't put vaseline, grease or packing of any kind into the intermittent casing.

22. Don't allow oil to touch friction discs of speed control, if of fibre type.

23. Don't fail to keep leather friction disc well oiled.

24. Don't use oil on the arc lamp, as it quickly burns off and causes lamp to bind. For the arc lamp, use graphite for lubrication.

25. Don't fail to keep lenses and condensers clean at all times.

26. Don't use a rough cloth or waste to clean these optical units. A piece of chamois, linen or soft cloth moistened with ammonia will give the best results, and remove all dirt as well as giving a high polish. Use equal parts of ammonia and water.

27. Don't fail to examine all electrical connections on lamp, rheostat or motor. For any electrical device to be efficient all connections must be firmly tightened.

28. Don't allow water or any dampness to penetrate the rheostat or motor.

29. Don't fail to keep the commutator and brushes on the motor perfectly clean.

30. Don't allow the brushes to wear down too low or commutator will become pitted and the motor will lose speed and be ruined.

31. Don't hold the idler pulley to slow up on titles, as this imposes a strain on the motor. Use the speed control.

32. Don't fail to oil the armature shaft frequently.

33. Don't neglect the arc lamp connections. High amperage eventually chars the asbestos lead nearest the lamp and efficiency requires that a new connection be made every week.

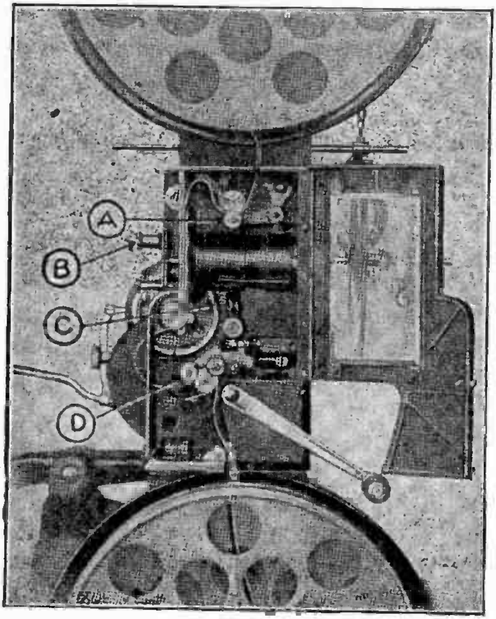


FIG. 7,838.—Threading the Simplex projector First see that a loose length of approximately five feet of film is left hanging from the loaded reel, which reel is placed into the upper magazine in such a position that the film will feed into the mechanism from the top of the reel, and with the dull or emulsion side of the film facing the lamphouse. The five foot length of film is necessary to provide sufficient length for threading, forming of loops, and still leave enough to make several turns around the lower empty reel to insure its security. Now feed the edge of the film into the slotted section of the magazine roller valve, and fasten the door of the magazine. Then open up guide rollers A and D as well as the film gate. The film gate is opened by pushing against plunger B until gate is fully opened, when it automatically locks itself into open position. Now pass the upper section of loose film under the upper feed sprocket, making sure that sprocket teeth engage accurately with film sprocket holes. This is ascertained by passing finger lightly over engaged teeth, and making sure that teeth protrude through sprocket holes. Then close roller A and pass remainder of film over top of gate and see that both edges of film are squarely between the two circular film guides. Now with the index finger of left hand raise the loose film so that a loop as here shown will be formed. Then, making sure that film is squarely located upon film tracks, bring the film around under side of intermittent sprocket, and while holding index finger of left hand in the upper loop, maintaining a slight upward pressure against the loop, trip the catch marked C with the index finger of the right hand, which operation will close and lock the gate in operating position.

NOTE.—*Warning.*—When catch C in fig. 7,838 is released there is a tendency for the gate, released of its confinement, to shoot suddenly toward film, so it is advisable to retard this sudden momentum by a slight pressure of the hand against it.

34. Don't use oil or grease on lamp joints or rods. Use a little powdered graphite at the joints.

35. Don't allow carbon dust or other dirt to accumulate in the lamp-house. A small pair of hand bellows will blow out all dust.

36. Don't have any loose contacts or burnt asbestos leads on the lamp. Burnt or broken leads mean trouble while machine is in use.

37. Don't try to get good results with poor carbons.

38. Don't try to get good results with dirty or pitted carbon jaws.

39. Don't remove pins from intermittent sprocket without proper support for sprocket.

40. Don't attempt delicate intermittent repairs without proper tools.

41. Don't adjust take up tension spring too tightly. Too much tension wears sprockets and damages film.

42. Don't run machine with magazine doors open.

43. Don't allow cold air draught from fan or other sources to blow into lamp house. Such draught will invariably result in condenser breakage.

44. Don't put foreign or home made attachments of any kind upon machine without consulting the builders.

45. Don't screw up condenser rings and holders too much.

46. Don't fail to wash sprocket teeth at least twice a week with stiff bristled tooth brush dipped in kerosene.

47. Don't fail to keep aperture plate clean.

48. Don't fail to keep film loops as small as possible. Large loops are noisy and unnecessary.

49. Don't fail to close lamp house dowser if film breaks.

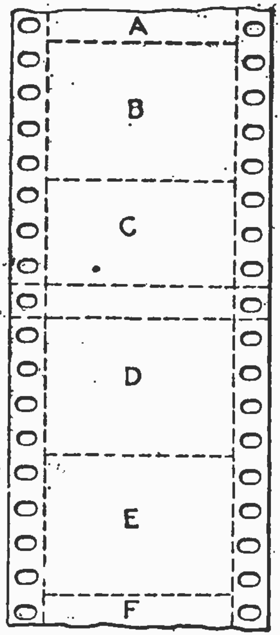
50. Don't fail to match "O" marks when replacing gears.

NOTE.—***After making sure*** that the film is safely confined between the sides of the intermittent guides, form the lower loop as in fig. 7,838 and place film over the lower sprocket teeth, making sure of its engagement with the teeth; then close down roller D and feed film edgewise into lower magazine slot. A sufficient length of film is left, the end of which is fastened into reel clip of the empty reel in the lower magazine and the slack between the reel and the lower sprocket is taken up by making several turns with the empty reel, thus tightening up the film, which is now ready for action.

NOTE.—***Before running machine*** it is necessary that all doors of the mechanism be closed and locked, as the Simplex is so designed that the film is best safeguarded against fire or damage when the mechanism is entirely enclosed.

51. Don't fail to remove oil box complete when adjusting intermittent sprocket.

52. Don't fail to keep pad rollers adjusted to one thickness of film.



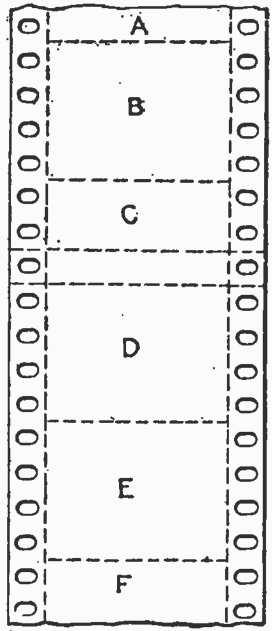


Fig. 7,839.—Splice in frame. The picture C has four holes at the side, just as have the pictures A, B, D, E, etc., and when that film is passed through the film gate and intermittent mechanism, the framing will be preserved, because mechanically the film is the same in distribution of pictures and of sprocket holes as though no splice had been made. The difference is found in the "jump" of the pictures when one or more pictures have been omitted, but the "frame" will not be disturbed as the splice passes.

Fig. 7,840.—Splice out of frame. The picture C has but three holes at the side. Hence, when the picture B is pulled out of the film window and C is pulled in, the intermittent sprocket pulling down four holes will pull into the film window the three-quarter picture C, and also the top quarter of the whole picture D. At the next shift, the intermittent sprocket pulls down another four holes, pulling into the film window the remaining three-quarters of D, and the top quarter of E, etc. This continues until the operator notices the screen and frames with his lever. This is called a splice "out of frame" because the splice throws the picture out of frame in passing.

53. Don't bend the intermittent guide apron. To do so may result in serious film damage.

54. Don't forget to oil the take up spindle.

55. Don't fail to oil the pad rollers.

56. Don't fail to see that all pad rollers are turning when machine is in action. .

How to Splice Film.—Cut one end on the line between pictures and cut the other end with a quarter picture on; thus in cutting a film there will be three quarters of a picture cut out, a picture and three quarters, etc. Moisten the gelatine on the quarter picture and scrape it clean, also scrape the celluloid side of the other end clean. Spread cement on the cleaned quarter picture space and fit it on the back of the other end, sticking the two ends together with the picture lines matching and the sprocket holes matching. Cut either through a sprocket hole or midway between sprocket holes straight across the film.

TEST QUESTIONS

1. *What are the two principal requirements for maintaining a projector in perfect condition?*
2. *Give full directions for oiling.*
3. *Describe the picture centering device.*
4. *How does the aperture plate work?*
5. *Explain method of setting revolving shutter.*
6. *How is the eye shield arranged?*
7. *What is the object of the threading and framing lamp?*
8. *Explain the manipulation of the gate opening, framing and shutter adjusting knobs.*

9. *How are lenses mounted?*
10. *Describe in detail the operation of threading a typical motion picture machine.*
11. *Describe how the projector is started.*
12. *Describe the operation of rewinding the film.*
13. *Give 56 operating hints.*
14. *Explain in detail how to splice film.*

CHAPTER 194

Physics of Sound

Production of Sound.—When air is set in vibration by any means, sound is produced provided that the frequency of vibration is such that it is audible. If a violin string in tension be plucked, as in fig. 7.841, it springs back into position, but due

FIG. 7,841.—Sound produced by vibration of violin string.

to its weight and speed, it goes beyond its normal position, oscillates back and forth through its normal position, and gradually comes to rest. These vibrations produce sound.

As the string moves forward it pushes air before it and compresses it, also air rushes in to fill the space left behind the moving string. In this way the air is set into vibration. Since air is an elastic medium, the disturbed portion transmits its motion to the surrounding air so that the disturbance is propagated in all directions from the source of disturbance.

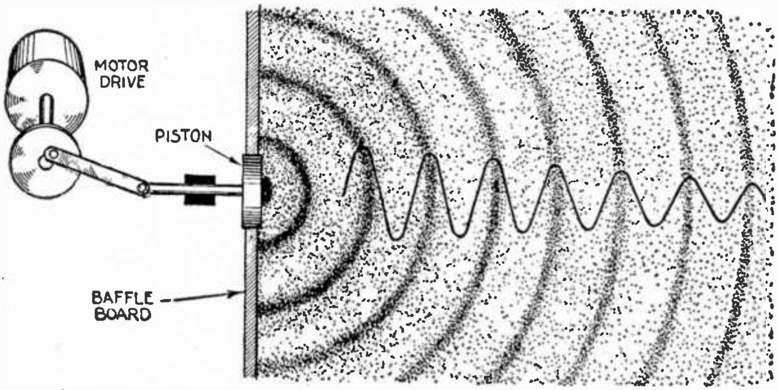


FIG. 7.842.—Generation of sound waves by the rapid oscillation of a light piston. *As the piston oscillates* the air in front of the piston is compressed when it is driven forward, and the surrounding air expands to fill up the space left by the retreating piston when it is drawn back. Thus a series of compressions and rarefactions (expansion) of the air is the result as the piston is driven back and forth. Due to the elasticity of air, these areas of compression and rarefaction do not remain stationary but move outward in all directions, as shown.

If the string be connected in some way to a diaphragm such as the stretched drum head of a banjo, the motion is transmitted to the drum. The drum, having a large area exposed to the air, sets a greater volume of air in motion and a much louder sound is produced.

If a light piston several inches in diameter, surrounded by a suitable baffle board several feet across, be set in rapid oscillating motion (vibration), as in fig. 7,842, by some external means, sound is produced.

Propagation of Sound.—If the atmospheric pressure could be measured at many points along a line in the direction in which the sound is moving, it would be found that the pressure along the line at any one instant varied in a manner similar to that shown by the wavy line of fig. 7,842.

To illustrate if extremely sensitive pressure gauges could be set up at several points in the direction in which the sound is moving it would be found that the pressure varied as indicated in fig. 7,843.

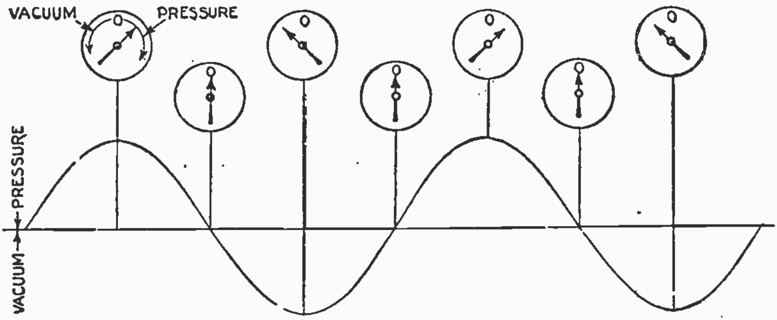


FIG. 7,843.—Diagram illustrating pressure variations due to sound waves. *It should be noted* that the type gauges shown, register pressure *above* atmospheric when the pointer moves to the right of the vertical, and *vacuum* or pressure *below* atmospheric when it moves to the left of the vertical.

Again, if a pressure gauge be set up at one point and the eye could follow the rapid vibrations of the points it would be found that the pressure varied at regular intervals and in equal amounts above and below the average atmospheric pressure. The eye, of course, cannot see such rapid vibrations, but it *can* see wave motion in water, however, which is very similar to sound waves with the exception that water waves travel on a plane surface, while sound waves travel in all directions.

In the case of water as a medium for wave propagation, if a pebble be dropped into a still pool, as in fig. 7,844, and starting at the point where the pebble is dropped, waves will travel outward in concentric circles, becoming lower and lower as they get farther from the starting point, until they are so small as not to be perceptible, or until they strike some obstructing object.

FIG. 7,844.—Effect of throwing a stone into still water; it produces waves which travel outwardly in expanding, concentric circles from the point where the stone enters the water or *point of disturbance.*

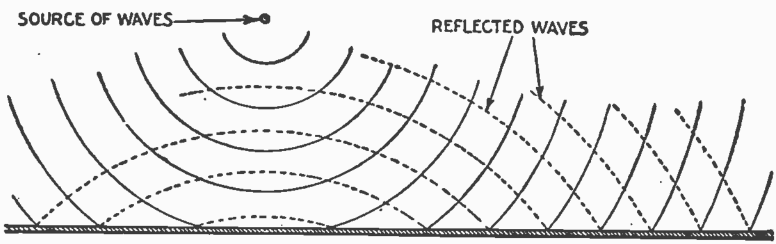


FIG. 7,845.—Reflection of waves from a plane surface.

If the pond be small it will be noticed that the waves which strike the shore will be reflected back. If the waves strike a shore that is parallel with the waves, they will be reflected back in expanding circles, as in fig. 7,845.

If the waves strike a hollow or concave shore line as in fig. 7,846 the reflected waves will tend to converge (focus) to a point.

Comparing water and air as media for wave propagation, water waves travel in *expanding circles* and air waves in *expanding spheres*.

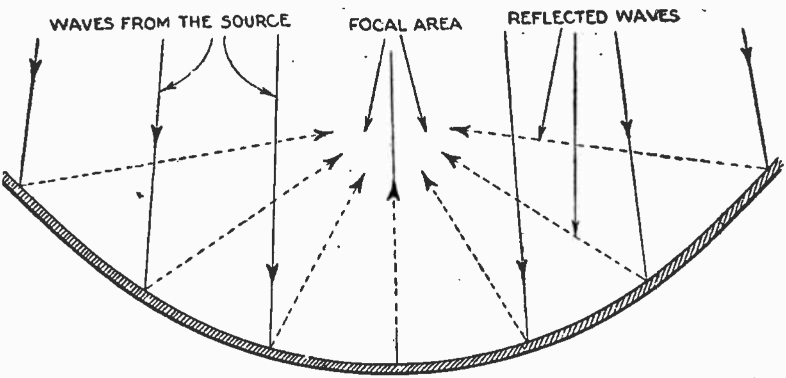


FIG. 7,846.—Reflection of waves from a curved surface. The solid lines show the direction of the original waves and the dotted lines show the direction and focusing of the reflected waves. Focusing of waves results in their reinforcement, which may cause them to build up to considerable proportion at one point.

Sound waves are reflected in a manner similar to water waves, causing echo and reverberation. If the sound waves focus at a point, loud and dead spots are produced.

Wave motion has certain definite characteristics and these characteristics determine:

1. Loudness;
2. Pitch;
3. Tone.

Loudness.—By definition, loudness is ***relatively high intensity of sound.*** Loudness (or amplitude) is determined by the amount of difference in pressure between the maximum compression and the maximum rarefaction. This corresponds in water waves to the vertical height of the crest above the trough of the wave. Loudness is illustrated in fig. 7,847.

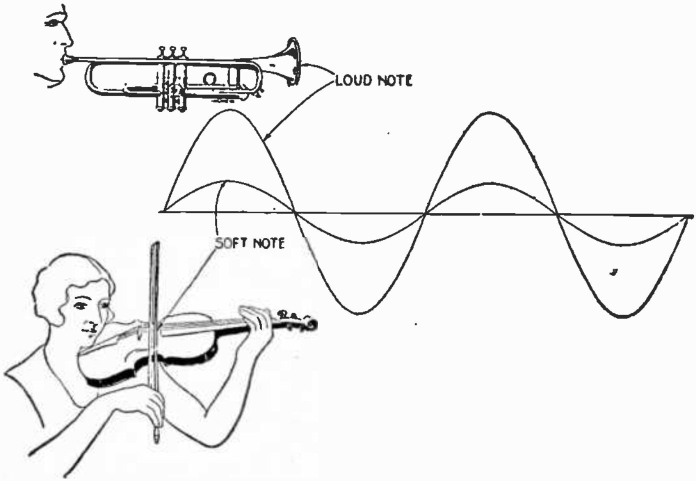


FIG. 7,847.—Properties of wave motion illustrating what causes loudness of tone.

Pitch or Frequency.—*Any one of a series of variations, starting at one condition and returning once to the same condition is called a cycle.* Observe some point on the surface of the water in which waves exist and it will be noticed that at this point the water will rise and fall at regular intervals. At the time at which the wave is at its maximum height the water begins to drop, and continues until a trough is formed, when it rises again to its maximum height. Accordingly, all the variations of height which one point on the surface of the water goes through in the formation of a wave, is a *cycle* of wave motion.

The number of cycles a wave goes through in a definite interval of time is called the frequency. Therefore the number of times

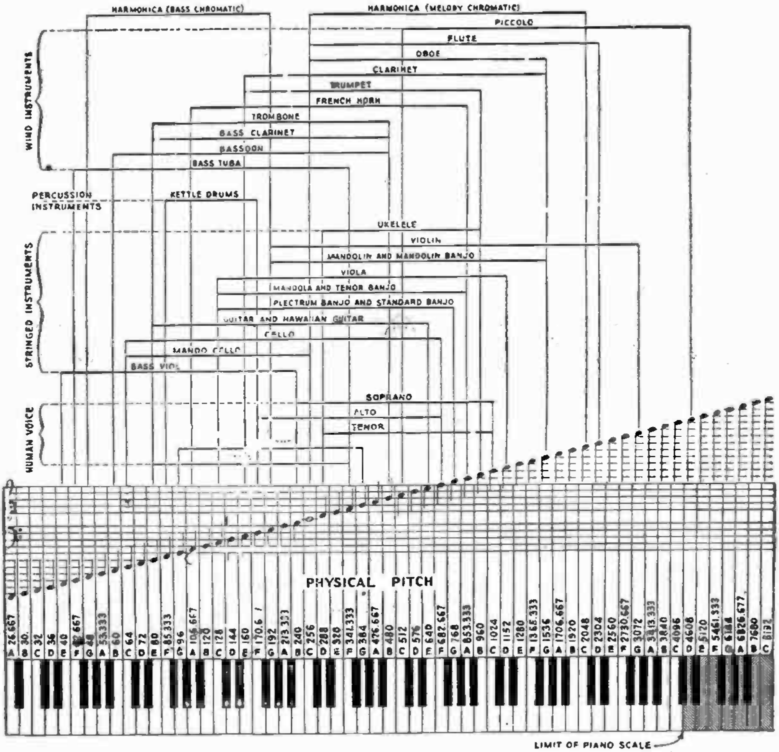


FIG. 7,843.—Musical pitch chart for piano, voice and various instruments. This chart represents the relation between the musical scale and the piano keyboard, giving the frequency of each note in terms of complete vibrations, or cycles, according to the standard used in scientific work such as the scientific scale based on middle C at a frequency of 256 cycles. The piano keyboard covers nearly the entire range of musical notes and extends from 26.667 cycles to 4,096 cycles. The piccolo reaches two notes beyond the highest note of the piano. The extreme organ range, not shown on the chart, is from 16 cycles to 16,384 cycles, scientific or physical pitch, as it is usually called. Music seldom utilizes the full keyboard of the the piano, the extremely high notes and extremely low notes being seldom used. Therefore a reproducing device which reproduces all frequencies from 50 to 4,000 cycles would be satisfactory in reproducing musical notes.

the water rises or falls, at any point in one minute would be called the frequency of the waves per minute, expressed as the *number of cycles per minute*.

In sound, the number of waves per minute is large, and it is more convenient to speak of the frequency of sound waves as the number of waves per second, or, more commonly, as the number of cycles per second. Thus, a sound which is produced by 256 waves a second is called a sound of a frequency of 256 cycles.

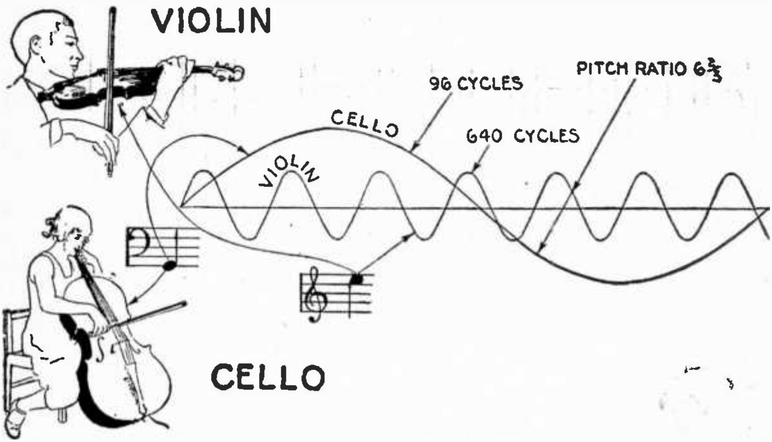


FIG. 7,849.—Properties of wave motion illustrating *pitch*.

When speaking of sound, cycles always mean cycles per second.

Considered from the standpoint of traveling waves, frequency is determined by the number of complete waves passing a certain point in one second, and this, of course, is equal to the number of vibrations per second generated at the source.

Fig. 7,848 is a chart showing pitch frequencies corresponding to the various keys of the piano and range of the human voice and various instruments.

Tone.—By definition tone is *sound in relation to volume, quality*, duration and pitch; specifically, in acoustics, a sound that may be employed in music, having a definite pitch and due to vibration of a sounding body; opposed to sound as mere noise.

By common usage in music, tone generally means the *timbre* or *quality of sound*.

A pure note of a given pitch always sounds the same, and the frequency of this note is termed its *fundamental* or *pitch frequency*. However, notes of the same pitch from two different kinds of instruments do not give the same sound impression. This difference is due to the presence of *overtones*, sometimes called *harmonics*.

Consider again the case of a taut string which is plucked to set it in vibration.

If the string be plucked at its exact center, it will vibrate as a whole and give a very nearly pure note; but if it be plucked at some other point, say one-third of the length from one end, it will vibrate as three parts as well as a whole, and a change of tone will be noticed. If the string be plucked indiscriminately, various tones will be heard, all of the same pitch.

Hollow cavities built into the bodies of the various musical instruments give them their characteristic tones, because the air chambers, called resonance chambers, strengthen overtones of certain frequencies and give a very pronounced tone to the instruments.

Other instruments have built into them means of suppressing certain overtones, which help to give them their characteristic sounds. The frequency of an overtone is always some multiple of the pitch frequency; that is, the second overtone has twice the frequency of the pitch note, and the third overtone, three times the frequency, etc.

Overtones of twenty times the frequency of the pitch note are present in the sounds of some musical instruments, but overtones of this order are important only when the pitch note is low, because the frequency of the twentieth overtone of even a moderately high note would be beyond the ability of the human ear to detect.

Overtones give character and brilliance to music, and their presence in reproduced sound is necessary if naturalness is to be attained.

The combined result of all the partial or overtones gives the quality or timbre of the tone, that is the peculiar characteristic sound as of a voice or instrument. A great variety of tone is found in the orchestra as exemplified by the strings, wood wind, brass and reed choirs. See figs. 7,850 to 7,853.

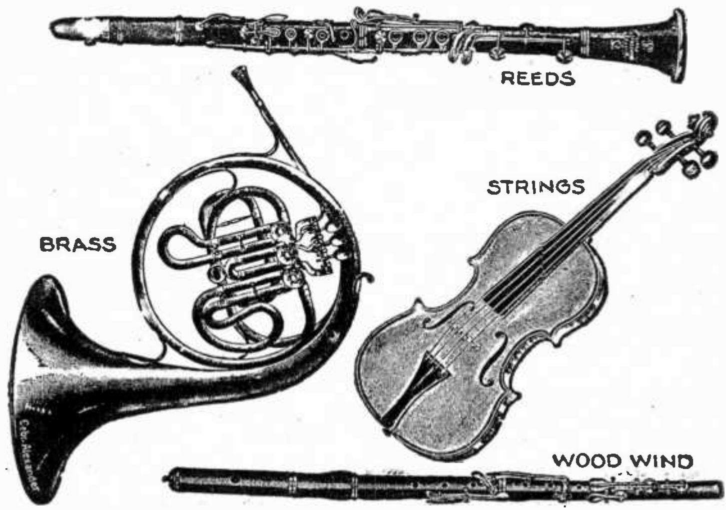


FIG. 7,850 to 7,853.—Familiar instruments of the orchestra illustrating the great variety of tone produced by the various "choirs" to which these instruments belong. It is because of this great variety of tone that the orchestra is the finest medium for musical expression. *It should be noted* that even the best organs represent a very poor attempt to imitate the orchestra—it cannot be done. Such impossible instruments as the cornet, saxophone, etc. are not employed in any legitimate orchestra.

A reproducing device which reproduces frequencies from 50 to 6,000 cycles will cover very well all the notes and overtones necessary for naturalness and distinctiveness.

In singing, the range of notes covered is approximately from 64 to 1,200 cycles, extreme limits. but this range cannot be covered by one person's voice. The frequency of 1,200 cycles does not represent the highest frequency used in singing, because overtones of several times the frequency of the note are always present in the human voice. The presence of the overtones gives the pleasing quality to songs. This quality of the singing voice is called *timbre*. The timbre of the voice transmits the emotions of joy, sadness, etc., from the performer to the audience, and therefore is very important in the enjoyment of vocal music.

Wave Length.—By definition the wave length (of a water wave for instance) is *the distance between the crest of one wave and the crest of the next wave*. This distance remains the same as long as the wave continues, even though the wave becomes so small as to be hardly perceptible.

Frequency in wave motion is related to wave length.

All waves produced do not have the same wave length. A small pebble dropped into a pond will produce a wave of short length, but a large stone will produce a wave of correspondingly longer length. In sound the wave length is dependent upon the frequency of the source. Similarly, in sound the wave length of a sound wave is *the distance between the point of maximum compression of one wave to the point of maximum compression of the next wave*.

Sound travels at different speeds in different substances, thus it travels at a much higher speed in water and steel than in air.

NOTE.—*Voicing* is the art of obtaining a particular quality of tone in an organ pipe and of procuring uniform strength and quality throughout the entire stop. Voicing is one of the most delicate and artistic parts of the organ builder's art, and it is seldom, if ever, that a voicer is good at both flue and reed voicing.

NOTE.—*Percussion instruments* such as drums and the various accessory traps produce the greatest pressures that are used in music. Although the fundamental frequency of the notes which they emit is fairly low, the notes are particularly rich in tones of higher frequency, which may extend as high as 10,000 cycles. Although these higher tones die out rather rapidly, they are essential to good definition.

NOTE.—*The organ, piano and harp* have the greatest compass and cover a frequency range from about 16 to 4,000 cycles. All three of these instruments are characterized by a rather prominent first overtone, so that their effective range extends as high as 8,000 or 9,000 cycles.

NOTE.—*According to Prout* "the *cornet* is a vulgar instrument whereas the *trumpet* is a noble instrument." The only excuse for a cornet is that it is easier to play than a trumpet. Non-musical instruments, such as the cornet and saxophone, if they must be heard, should be confined to 2nd and 3rd rate taxi-dance halls in order that cultured and discriminating ears may not be profaned.

In the latter medium it travels about 1,100 ft. per second. An illustration of the fact that time is required for sound to travel from one place to another is shown by a steam whistle at a distance of several hundred yards. If it be observed when blown, it will be noticed that the "steam"* can be seen coming from the whistle a considerable length of time before the sound of the whistle is heard. Sounds of all frequencies, or pitches, travel at the same speed. The speed at which sound travels divided by the frequency gives the wave length of the sound wave.

A knowledge of wave length is necessary for the proper construction and location of baffle boards and horns in theatres.

Speech.—The sounds of speech are divided into two classes, vowels and consonants. The vowel sounds are used in the pronunciation of the letters *a*, *e*, *i*, *o*, *u*, and sometimes *y*, in the formation of words.

These letters are also used in combination to indicate other vowel sounds. The pitch frequencies of the vowel sounds in male voices range from 110 cycles to 140 cycles. For female voices the range is from 230 to 270 cycles. The characteristic frequencies, or overtones of the vowel sounds, however, reach frequencies of 3,300 cycles. So important are these overtones that the pitch frequency can be entirely eliminated without noticeably changing the sound sensation produced on the human ear. The full range of frequencies used in vowel sounds is from 110 cycles to 4,800 cycles.

The pitch frequency of the vowel sounds are produced when air is blown through the vocal cords.

The vocal cords are two muscular ledges in the air passage of the throat. When these muscles are taut there is a narrow slit between them, which sets the air passing through into oscillation. The sound produced by the vocal cords is changed by the cavities of the mouth.

The shapes of the cavities continuously change as a person speaks, making it possible for him to produce a wide variety of sounds, all of very nearly the same pitch frequency.

*NOTE.—*The white cloud* seen issuing from a steam whistle usually called "steam," is not steam but a fog of minute liquid particles produced by *condensation*. The term is misused above simply for convenience. Steam is invisible.

Consonant sounds are usually produced without the aid of the vocal cords.

Most of these sounds are produced by the lips and teeth, as in the pronunciation of *th*, *s*, and *f*. The range of frequencies covered by consonant sounds is from 200 to 8,000 cycles, but most consonant sounds have frequencies of less than 6,000 cycles.

Hearing.—The actual mechanism of hearing is not very well understood, but certain facts regarding the ability of the ear to register sounds of various frequencies has been determined very accurately.

The range of frequencies which the average person can hear is from about 20 cycles to 17,000 cycles, but a comparatively large amount of sound energy is required before the ear can detect sound of extremely low or extremely high frequencies.

The ear is most sensitive to frequencies between 500 cycles and 7,000 cycles; also, the ear is most sensitive to changes of pitch and changes of intensity of sound in this same band of frequencies.

NOTE.—*Woman's speech* in general is more difficult to interpret than man's. This may be due in part to the fact that woman's speech has only one half as many tones as man's, so that the membrane of hearing is not disturbed in as many places. It may be inferred therefore that the nerve fibres do not carry as much data to the brain for interpretation. The greatest differences occur in the case of the more difficult consonant sounds. In woman's speech these sounds are not only fainter but require a higher frequency range for interpretation. A range of from 3,000 to 6,000 cycles for man's voice corresponds roughly to a range of from 5,000 to 8,000 cycles for woman's voice. Since the ear is less sensitive in the latter range and the sounds are initially fainter, their difficulty of interpretation is greater.

NOTE.—When sounds containing a number of tones are increased in loudness, the lower tones in the sound deafen the auditor to the higher tones. This deafening or masking effect becomes very marked when the sound pressure of the lower tones is greater than twenty sensation units. In the case of speech, this effect impairs the interpretation of the higher pitched sounds. The best loudness for the interpretation of speech corresponds to a sound pressure between 0 and 20 sensation units. If the sound pressure be less than this, the fainter sounds are inaudible. If the sound pressure be greater, the masking effects impair the interpretation of these sounds.

TEST QUESTIONS

1. *How is sound produced?*
2. *Explain the propagation of sound.*
3. *Draw a diagram illustrating pressure variations due to sound waves.*
4. *What is the effect of throwing a stone into still water?*
5. *How are sound waves reflected?*
6. *What are the characteristics of wave motion?*
7. *Upon what does loudness depend?*
8. *Define pitch or frequency.*
9. *How are sound cycles measured?*
10. *What is tone in music?*
11. *What is the effect of overtones or harmonics?*
12. *Why are hollow cavities built into the bodies of various musical instruments?*
13. *What is the range in cycles of the human voice?*
14. *Define the term wave length.*
15. *What is voicing?*
16. *What musical instruments produce the greatest pressures?*
17. *What is the difference between a cornet and a trumpet?*
18. *Into what two classes are the sounds of speech divided?*
19. *Why is woman's speech more difficult to interpret than man's?*

CHAPTER 195

Synchronized Sound

In order to reproduce in a theatre the pictorial record of events accompanied by the sound associated with those events, it is, of course, necessary to add equipment to that installed to produce only the silent motion picture.

Methods of Recording Sound.—There are two basic methods of sound recording:

1. Cutting a groove in a wax disc;
2. Making a photographic impression on film.

Formerly in making disc records the original sound energy of the source was used to actuate the stylus or cutting point the same as in making an ordinary phonograph record.

The present method used by all up to date record producers employs electricity. The sound energy is first converted into electrical energy, amplified in vacuum tube amplifiers, and the electrical energy is then used to actuate the mechanism which cuts the impression on the record. With this method no sacrifice in faithfulness is necessary to obtain the desired volume, with the result that extremely faithful reproductions are now possible from disc.

The methods of recording on wax discs by different producers are very similar although there are slight differences in the apparatus used.

There are two fundamentally different methods of recording on film as by:

1. Variable area;
2. Variable density.

Variable area recording is used by Photophone and variable density by Western Electric and Movietone.

Picking Up and Converting Sound Energy.—The first step in recording, the *picking up* of the sound energy and converting it into electrical energy is essentially the same in all modern recording systems. This is done by means of a sensitive microphone. The RCA Photophone, the Western Electric and Fox Movietone all use a condenser microphone similar to those used in radio broadcasting.

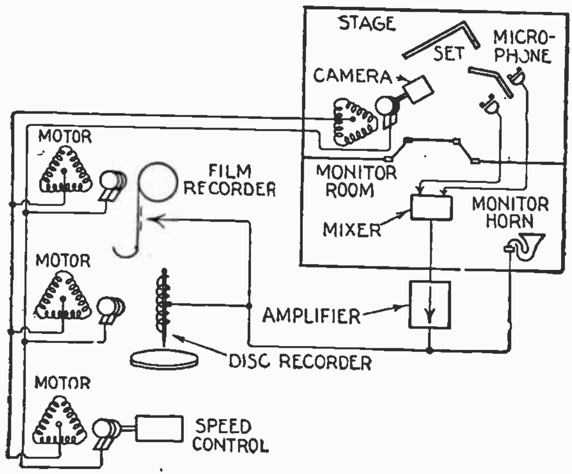


FIG. 7,854.—Studio sound recording system in its simplest form. The essential parts of such a system consist of microphone pick ups on the stage, a mixer and volume control in the monitor room, system and monitor amplifiers, recording machines, and a synchronous motor system for synchronizing the recorders with the cameras.

When a condenser microphone is acted upon by sound waves the diaphragm moves in and out at the frequency of the sound waves. A pressure of 180 volts *d.c.* is impressed across the plates and a resistor of 20 to 50 million ohms resistance is in series with one of the leads. As the diaphragm is moved in and out by the action of the sound waves, the alternating current set up flows through the resistor and produces an alternating voltage across it. This alternating voltage is impressed on the grid of the first tube of a vacuum tube amplifier. The amplified signals are then used to operate the recording device.

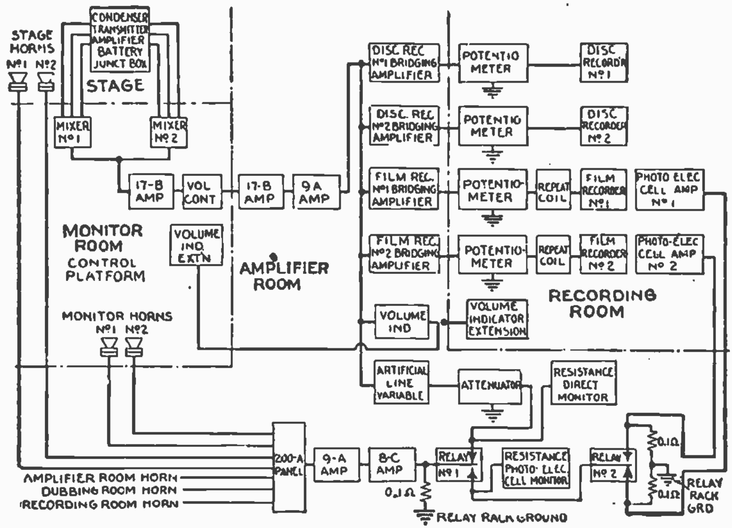


Fig. 7,855.—One complete recording channel.

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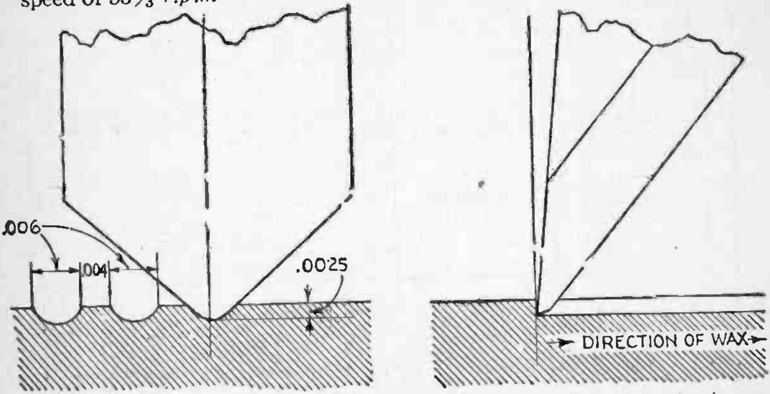
*NOTE.—***Method of making wax record duplicates.**—The wax is coated with a fine powder of conducting material. It is then electro-plated so as to give a metallic negative record called a *master*. This master is again electro-plated after the surface has been suitably treated to permit an easy removal of the resultant positive plate. This positive is commonly called an *original*. From the positive another negative is made, a metal mold called a *stamper*. From it duplicate originals can be plated to make duplicate stampers. These successive plating processes involve no measurable injury to the quality of the record. By the custom of making a number of duplicates, the master is protected from accidents and wear to which it would be subject if used to make the finished record. The stampers are used to press the final product, and as many as a thousand records can be made with one stamper. The material from which the records are made is called *record stock*. This material must have a hard surface to resist wear, and must contain enough abrasive, or wear producing material, to grind the needle quickly to a good fit. At the beginning of a run of a new needle the pressure on the record is very great because of the small area of the needle point. However, after a minute's wear the needle pressure is reduced to 50,000 lbs. per sq. inch.

Disc Recording.—The amplifier just described actuates a vibrating armature which has attached to it a sapphire stylus or cutting point.

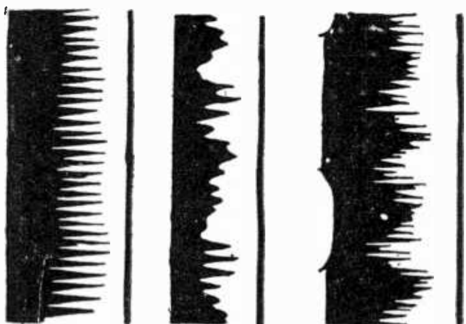
This stylus is placed on the surface of a rotating plate and cuts a wavy groove in its surface. This plate, while usually referred to as a wax plate, is in reality made of an insoluble soap. The plate is rotated at a constant speed of 33⅓ *r.p.m*



Figs. 7,856 and 7,857.—Recorder stylus. The shape of the groove varies somewhat in commercial practice. The groove and stylus here shown is that most commonly used with Western Electric apparatus. The groove is approximately .006 in. wide and .0025 in. deep. The pitch of the groove is between .010 in. and .011 in. so that the space between grooves is about .004 in. Thus the maximum safe amplitude is about .002 in. If this occur at 250 cycles the corresponding amplitude at 5,000 cycles, assuming constant absolute intensity of sound over this range, would be .0001 in. It is important that a smooth groove be cut as any roughness in the walls introduces extraneous noise in the reproduced sound. To insure a truly smooth groove the surface of the wax must be shaved to a high polish. The texture of the wax must be fine and homogeneous which requires not only that the wax composition be correct, but that it be operated at the proper temperature. Fig. 7,856 a radial section through the wax; fig. 7,857 a section looking from stylus point to the center of the disc.

Synchronizing Sound on Disc.—After making a wax disc, it is rotated at a uniform speed of 33⅓ *r.p.m.* and is driven by a synchronous motor. The camera is driven so as to have a film speed of 90 ft. per min. by another synchronous motor operating from the same power supply as the motor which drives the wax disc. The recording disc and the camera are started at the same time, and after they get up to speed they are operated simultaneously. Since both are driven by synchronous motors they will always have the same relative speed. Therefore, the sound and picture will always be in synchronism when produced if the film and disc be both started at the proper start position, and there be no mishap such as the needle of the pick up jumping the groove, or the film breaking and not being properly patched.

Should the film break, it is necessary to have the same number of frames in the patched film as it had originally, if the sound and picture are to remain in synchronism. The addition of blank film to replace parts of the film which were torn results in disagreeable breaks in the picture.



FIGS. 7,858 to 7,860.—Details of "sound track" with *variable area* method of recording. The juncture of the opaque and transparent parts of the sound track form a wavy line which is practically an exact representation of the sound pressures of the original sound waves.

Variable Area Method of Recording on Film.—The system consists essentially of:

1. A source of light;

2. A mirror;

Which is vibrated by the amplified sound currents.

3. A suitable optical system for concentrating the light into a very fine beam.

The intensity of the light is kept at constant value, but the area of the sensitized film which is affected by the light is varied.

The elements of the system are shown in fig. 7,861.

A beam of light from an incandescent lamp is focused on the mirror. The vibration of the mirror sends the light across the exposed moving film through a suitable optical system containing lenses and a narrow slit. The mirror needs to move only a little to sweep the light beam comparatively large distances at the film.

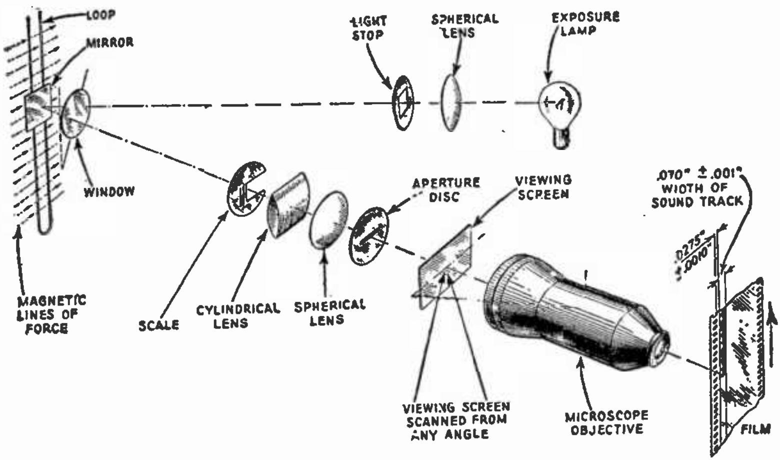


FIG. 7,861.—Elements of *variable area* method of recording on film. *In operation,* when the mirror is at rest only one half of the sound track is exposed. The other half of the light beam is cut off by a screen. When the mirror is moved to its extreme position in one direction, the light beam is shifted off to the screen so that the beam covers the entire sound track. When moved in the other direction to its extreme position, the beam moves over so that it is cut off entirely by the screen and strikes no part of the sound track. When referring to the extreme position which the mirror moves it is not meant that this extreme is the maximum movement which can be obtained by the mirror, but only the maximum position to which it should ever move when recording. When the film moves through the recorder it is exposed to this fine line of light which varies in length as the mirror vibrates in response to the sound currents flowing through the loop supporting it. When the film is developed the part of the film which was exposed to the light beam will be opaque while the remainder of the sound track will be transparent, as shown in figs. 7,858 to 7,860.

The light from the lamp is focused through a condensing lens on to the mirror of the galvanometer. The light stop between the lens and the mirror cuts off the fringe of distorted light so as to give a clear cut beam of light.

The galvanometer window is tilted at a slight angle to keep the light reflected from its surface from entering the optical system. The reflected light from the mirror passes through the cylindrical lens, which condenses the light in one direction only. It then passes through a spherical condensing lens which reduces the beam size still more.

The beam from this lens is focused on the slit in the aperture plate, this slit being .003 of an inch wide. The light which passes through the aperture plate slit is focused on the film through a microscope objective lens system. This objective reduces the size of the beam by a 4 to 1 ratio in both directions so that the resultant beam on the film is .070 of an inch long by .00075 of an inch wide.

FIG. 7,862.—Film showing sound track with *variable density* method of recording.

Variable Density Method of Recording a Film.—There are two different methods of variable density recording, as with:

1. Variable intensity light,

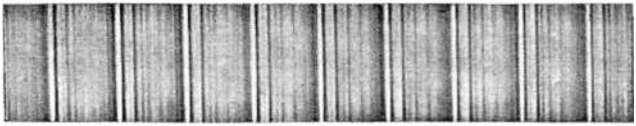
   Called "aeolight" and used by Fox Movietone.

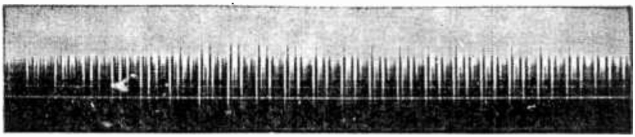
2. Light valve.

In the variable intensity light method, the light varies in intensity with the amplified sound currents and shines through a narrow slit on to the moving film, which is kept running at a constant speed of 90 ft. per minute.

The slit is cut into a small quartz block held in contact with the moving film. This quartz block is coated with silver to make it opaque, and the slit is engraved in the metal to the desired size.

When the film is developed after being exposed to the variable intensity light, the sound track will be made up of lines of varying density extending across the sound track as shown in fig. 7,863.





FIGS. 7,863 and 7,864.—Comparison of sound tracks showing difference between the variable density, fig. 7,863, and fig. 7,864, variable area methods of recording.

The spacing of these lines at each point depends on the pitch of the sound which was recorded at that moment.

The difference in density of the lines depends on the loudness of the sound, that is, the greater the contrast between light and dark lines, the louder the sound.

The light valve method is used in the Western Electric system. The light valve in this case varies the amount of light by the opening and closing of a slit. This slit is the space between two taut sides of a loop of wire suspended in a magnetic field. As the sound current passes through the loop, the loop opens and closes passing varying amounts of light through it. This light is then focused with lenses on the moving film so as to form lines of varying density when the film is developed. The light valve is shown in fig. 7,865.

When the valve is interposed between a light source and a photographic film it virtually forms a camera shutter of unconventional design. With this system, recording in the studio is carried out on a film separate from that which receives the picture. This practice permits the use of two machines to make duplicate sound records, an insurance which is well worth its cost. The practice of separate negatives for sound and picture also permits the picture negative to be developed and printed according to well established technique, and allows the necessary latitude in developing the sound record. The recording machine is shown in fig. 7,866.

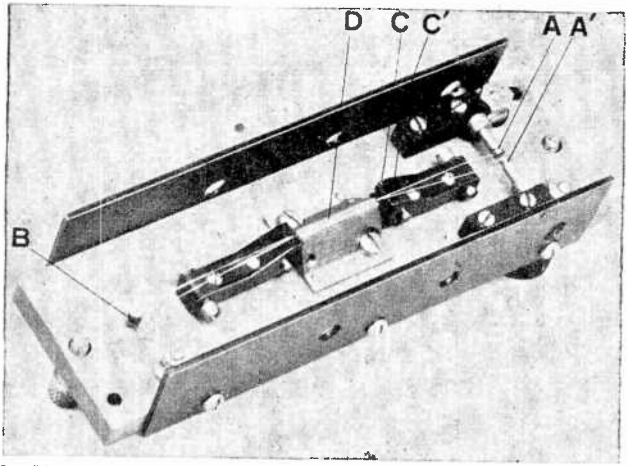


FIG. 7,865.—Light valve for variable density film recording. ***It consists of*** a loop of duralumin tape suspended in a plane at right angles to a magnetic field. When the assembly of magnet and armature is complete, the two sides of the loop constitute a slit, .002 by .256 in., its sides lying in a plane at right angles to the lines of force and approximately centered in the air gap. The ends of the loop are connected to the output terminals of the recording amplifier. If the magnet be energized and the amplifier supplies an alternating current, the loop opens and closes in accordance with the current alternations. When one side of the wave opens the valve to .004 in. and the other side closes it completely, full modulation of the aperture is accomplished. A.A', windlasses; B, spring held pulley; C, C' insulated pincers; D, armature.

Synchronizing Sound on Film.—As just mentioned the sound film is usually run on a separate machine from the camera for practical reasons, and the two films must be so synchronized that when they are printed together they will be in synchronism throughout the length of the film. This is accomplished by running the camera and the recorder at exactly the same speed. They are both driven by synchronous motors connected to the same power supply, and this keeps them always in synchronism.

Some kind of marking is required so that the picture and sound track can be lined up for printing. This is sometimes taken care of by marking the

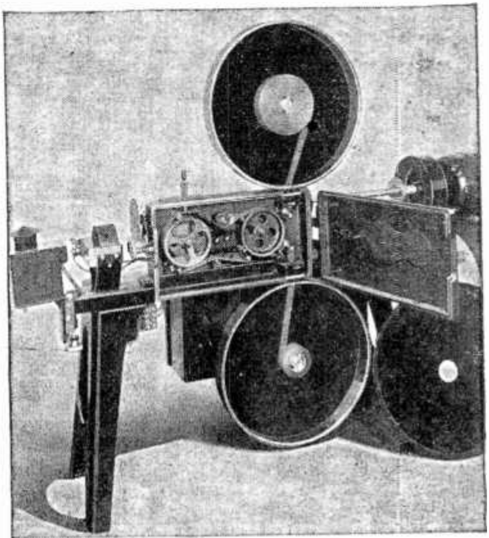


FIG. 7,866.—Studio recording machine with the door of the exposure chamber open. The left hand sprocket engages twenty perforations and is driven through a mechanical filter. The recording machine is driven by a motor synchronously with the camera. Lest there be any variation in the velocity of the film past the line of exposure, the sprocket which carries the film at that point is driven through a mechanical filter which holds the instantaneous velocity constant to one part in one thousand. In the recording machine a photoelectric cell is mounted inside the left hand sprocket which carries the film past the line of exposure. Fresh film transmits some four per cent of the light falling on it, and modulation of this light during the record is appreciated by the cell inside the sprocket. This cell is connected to a preliminary amplifier mounted below the exposure chamber, and with suitable further amplification the operator may hear from the loud-speaker the record as it is actually being made on the film.

film by means of a small marker lamp which shines on the film outside of the sprocket holes. Since the sound head of the projector is 19 frames from the picture in the frame, it is necessary to displace the sound track by 19 frames when they are printed together.

The advantages of sound on film is that, if the projector be properly threaded, the sound will always be in synchronism with the film. The breaking of the film does not interfere with the synchronous action, so that a blank patch is not necessary.

Synchronous Reproduction of Recorded Sound.—The first step in synchronous reproduction is *to generate a small electric current whose variations correspond to the sound waves forming*

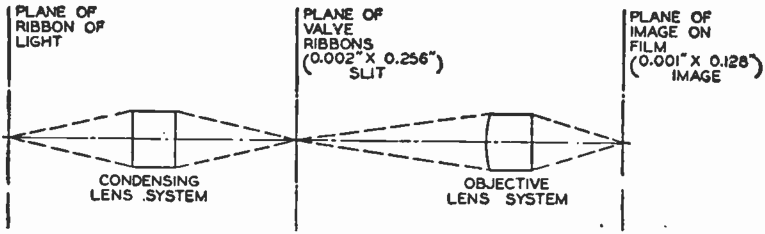


FIG. 7,867.—Optical system for studio recording. At the left is a light source, a ribbon filament projection lamp, which is focused on the plane of the valve. The light passed by the valve is then focused with a two to one reduction on the photographic film at the right A simple achromat is used to form the image of the filament at the valve plane, but a more complicated lens, designed to exacting specifications by Bausch and Lomb, is required for focusing the valve on the film. The undisturbed valve opening appears on the film as a line .001 by .128 in., its length at right angles to the direction of film travel. The width of this line varies with the sound currents supplied to the valve, so that the film receives exposure to light of fixed intensity during the varying time required for a given point to traverse the varying aperture of the slit.

the voice or music that was recorded. Depending upon which of the two general methods of recording was used, this current is obtained either from an electrical reproducer playing on a disc record, or from a film reproducing attachment through which the film passes on leaving the projector head.

The disc records employed are similar to the best types of phonograph record except that they are much larger and run at about half standard speed; this enables each record to play throughout a whole reel. The film used with the disc record, called a *synchronized film*, is similar to an ordinary film, except that one frame at the beginning is specially marked to give the starting point.

With the film method, the sound record consists of *a band about ⅛ in. wide, called the sound track, which runs down one side of the film* and having photographed on it *microscopic lines* as previously described and shown in fig. 7,862.

Such a film is called a sound film, and is otherwise similar to an ordinary film. After leaving the lower sprocket of the projector head, the sound film enters the reproducing attachment, as in fig. 7,868 where it passes over a sprocket that moves it along at constant speed.

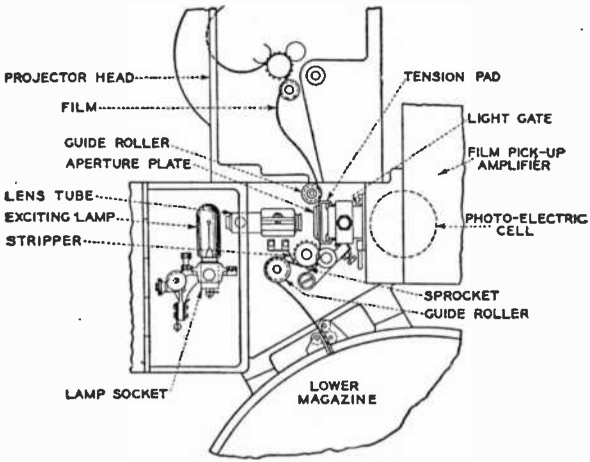
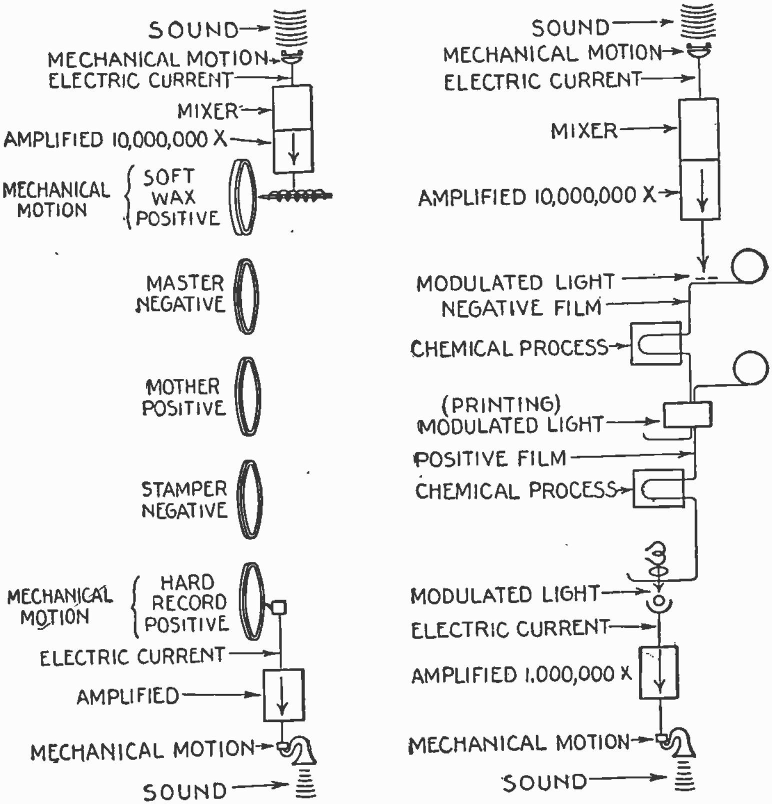


FIG. 7,868.—Detail of motion picture projector head and *sound head* for reproducing sound from film.

A narrow bright beam of light from a high intensity exciting lamp is focused on the sound track of the film through a system of lenses and an aperture plate. The light which has passed through the moving film will then vary in intensity according to the variations of the lines recorded on the sound track. This light falls on a photo-electric cell, which produces a small electric current whose variations correspond to the light, and therefore to the sound which was recorded.



FIGS. 7,869 and 7,870.—Recording and reproducing sound, showing intermediate processes. Beginning as sound waves, mechanical motion is imparted to the diaphragm of the condenser transmitter. This mechanical motion is in turn translated into a minute electric current. After being amplified the power of this current modulates a light to which film is exposed. The resultant latent image is treated chemically and when developed, again modulates a light to produce the positive. After development this positive, when run through a projector, modulates a beam of light, thereby controlling a minute electric current. After amplification the resultant power is sufficient to impart mechanical motion to a loud speaker diaphragm, thereby producing a very close approximation to the original sound. Beginning as sound, fourteen changes of condition must be passed through before the sound is reformed. The same number of changes occur in recording on disc.

Amplification.—The small current from the electrical reproducer or the photo-electric cell passes along to one or more vacuum tube amplifiers.

Sound Projectors.—The current from the amplifiers *is converted into sound by means of sound projectors consisting of re-*

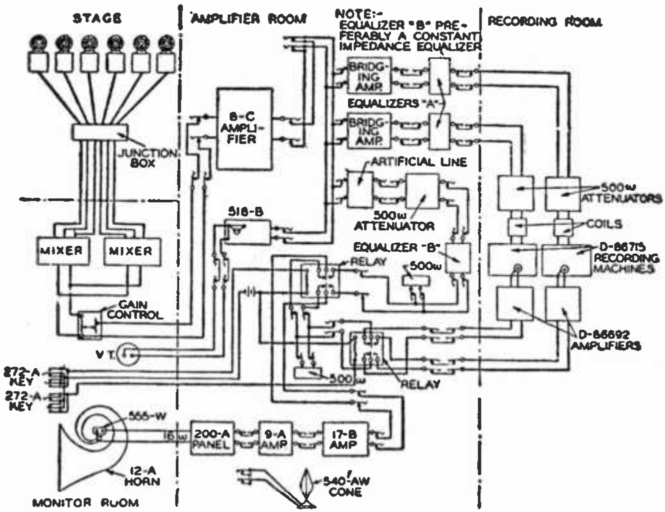


Fig. 7,871.—Schematic diagram of a studio equipment for sound recording. Provision is made for combining if desired the contributions of several microphones on the set. This combination is under the control of the mixer operator in the monitoring room, viewing the set through a double window in the studio wall. The mixer controls also the gain of the amplifiers for the recording machines. The diagram shows relays which permit the mixer to connect the horn circuit either directly to the recording amplifier or to one or the other of the monitoring photo-electric cells in the film recorders. The direct connection is used in preparing the sound pick up in the studio; the program is rehearsed until satisfactory arrangement of microphones and of amplifier gain is effected. The electrical characteristic of this direct monitoring circuit is so designed that the sound quality heard in the horns shall be the same as the quality to be expected in the reproduction of the positive print in the theatre.

ceivers and horns located at the screen, as shown in figs. 7,872 and 7,873.

The number of horns used, and their exact location depends on the size and acoustic properties of the house. Usually a special type of screen is employed, which reflects light well and enables a good picture to be obtained and is transvocent for sound waves.

The horns are placed immediately behind the screen so that a perfect illusion that the voice or music is coming from the speakers and artists seen on the screen is obtained in all parts of the house.

Obviously if the sound be not coming directly from the screen, the illusion is lost.

The horns used in all these systems can be mounted in such a manner that they are removable whenever the stage is used for purposes other than pictures. This can be done either by flying them or by mounting them on towers that are easily and quickly removable.

TEST QUESTIONS

1. *Name two methods of recording sound.*
2. *Describe the two methods of recording sound on film.*
3. *How is sound energy picked up?*
4. *Describe the method of making wax record duplicates.*
5. *Explain disc recording.*
6. *How is sound synchronized on disc?*
7. *Define the term sound track.*
8. *What are the two methods of recording on film?*
9. *Describe in detail the variable area method of film recording.*

10. *Make a sketch illustrating the elements of the variable area method of recording on film.*
11. *Explain in full the variable density method of recording on film.*
12. *What is the comparison of sound tracks made by the two methods?*
13. *Of what does a light valve consist?*
14. *How is sound synchronized on film?*
15. *What are the advantages of sound on film?*
16. *What is the first step in synchronous reproduction of recorded sound?*
17. *Describe in full the method of reproducing recorded synchronized sound.*
18. *Draw a diagram showing all the apparatus used in reproducing synchronized recorded sound.*

CHAPTER 196

Sound Reproducing Equipment

In theatres in which motion pictures accompanied by synchronized speech or music are presented, there must be in addition to the sound box or disc turntable, additional apparatus to amplify the current, to effect its conversion into sound and so to direct the sound into the theater auditorium, as to create the illusion that it emanates from, rather than merely accompanies, the picture.

When a theater is being prepared for presenting sound pictures, the film projectors in use are ordinarily retained but each is fitted with a new motor and driving mechanism; it is provided with a turntable and electric pick up for disc records, and with analogous equipment for film records, or both.

Typical installation layouts for sound pictures are shown in figs. 7,872 and 7,873. A layout consists of:

1. Film and disc.

These are reproducing attachments, by means of which, small electric currents are generated with variations corresponding to the sound waves produced in recording.

2. Vacuum tube amplifiers.

These greatly magnify the electric currents.

3. Sound projectors.

These consist of receivers and horns which convert the electric energy into sound.

Disc Record Pick Up.—The pick up used for disc records, is in some ways similar to the reproducer of an ordinary acoustic

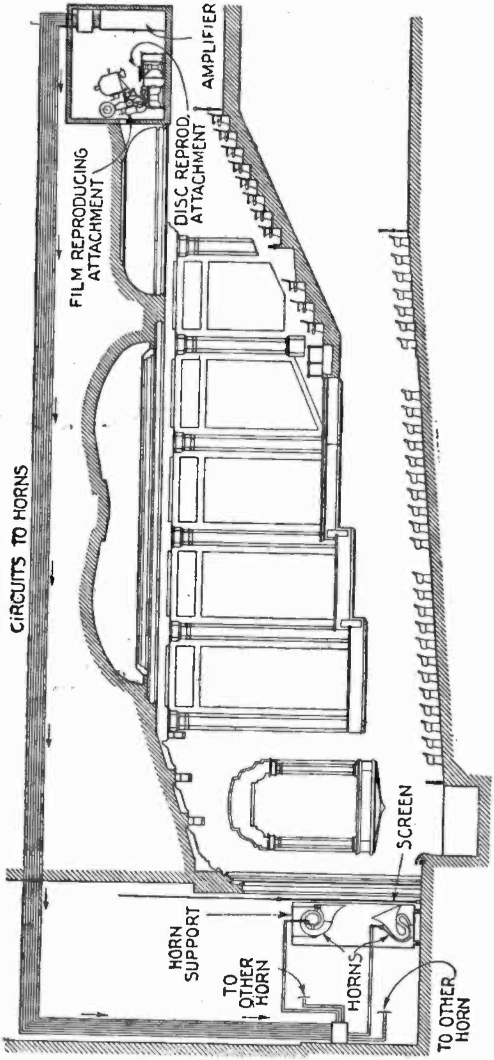


FIG. 7,872.—General installation layout of sound reproducing equipment.

phonograph, with a needle holder connected to a clamped diaphragm of highly tempered spring steel. To the diaphragm there is fastened an armature made of a special high permeability alloy, so arranged that as the diaphragm and the armature vibrate, the flux in the air gap of a permanent magnet varies correspondingly; in appropriately placed coils, currents are induced which are the electric representation of the wave groove which moves past the needle.

Although this instrument delivers energy at a comparatively low level, it has a nearly uniform response over a wide range of frequencies. That result has been secured largely by preventing distortion which would arise from resonance in any part of the system; the members have been designed with

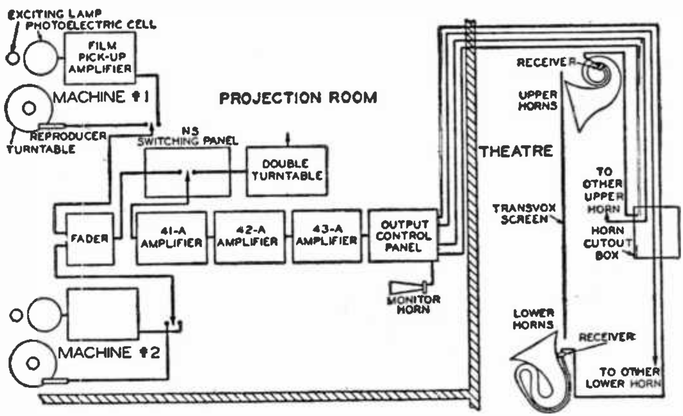


FIG. 7,873.—Layout of a typical theatre for presenting sound pictures. The amplifier is built in three units, of which the first consists of three low power tubes connected in tandem, resistance coupled, with the filaments heated by a twelve volt battery. In the second unit there are two medium power tubes with a push-pull connection, whose filaments are heated by low voltage alternating current. Two similar tubes in this unit act as a full wave rectifier, and supply rectified *a.c.* for the plate circuits of the amplifier tubes in the first and second units. The third unit has a single stage of high power push-pull amplifier tubes and push-pull rectifier tubes; like the second, it operates entirely on *a.c.* The three units can be arranged to meet any conditions. In small theatres only the first two are required, and in larger houses the high power unit, the third is used as well. For unusual conditions two or more of the high power units may be operated in parallel from the output of the second unit to give a greater volume of sound.

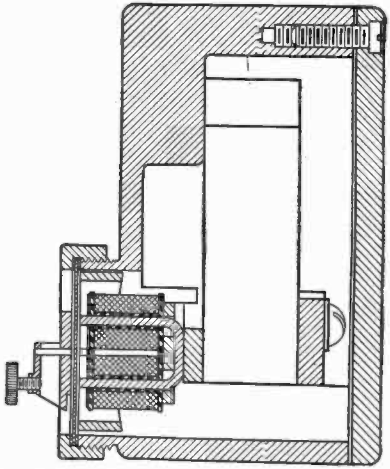


FIG. 7,874.—Reproducer for disc record.

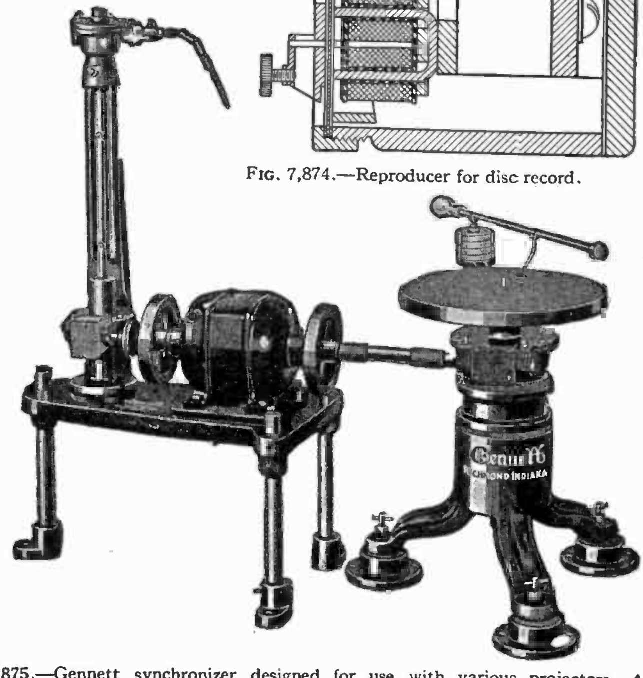


FIG. 7,875.—Gennett synchronizer designed for use with various projectors. *A.c.* synchronous motor drive which insures constant speed of the disc so that when the disc is synchronized with the film it remains in synchronism. Upright arm is adjustable for height of various types of projectors. Synchronizer may be used to play 33⅓ *r.p.m.* records for intermission music and non-synchronous films.

natural periods beyond the range of frequencies to be transmitted, and the magnet chamber back of the diaphragm is filled with a heavy oil to damp free vibration.

The films used with the disc records, called synchronized films, differ from ordinary films only in that one frame at the beginning of each is marked to give the starting point.

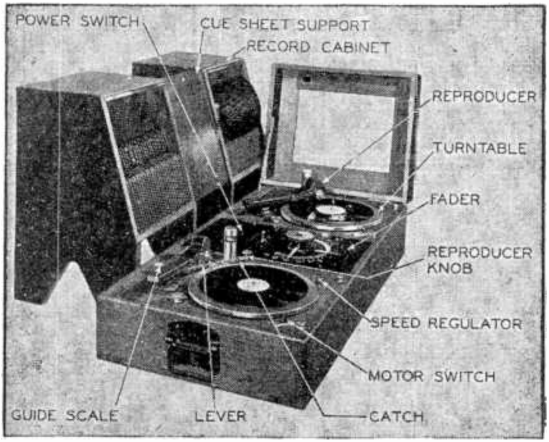


FIG. 7,876.—Non-synchronous double turntable cabinet for disc reproducing where records are not synchronized with the film. Each turntable is provided with a pick up and means for locating it accurately upon a record, and a fader to make possible continuous playing. The same amplifier and loud speakers are used as for the syncnronized speech and music.

Photo-electric Cell.—This is a device which varies in electrical resistance *in proportion to the amount of light falling upon it.* Manufacturers of photo-electric cells used for sound pictures make use of the fact that when light falls upon the surface of a metal, electrons are emitted from its surface. Although all metals emit electrons when subjected to light, only a few of them are affected by ordinary or visible light. The number of electrons emitted *is directly proportional to the amount of*

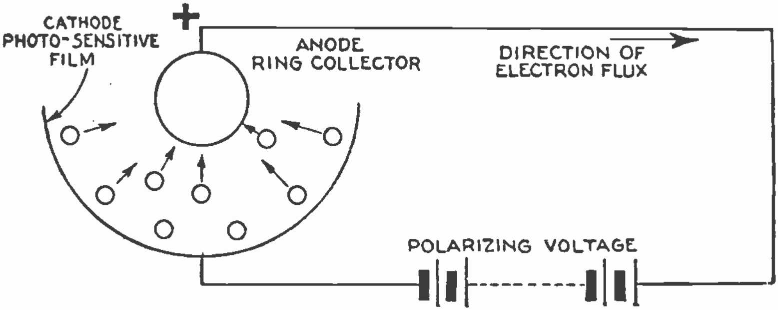
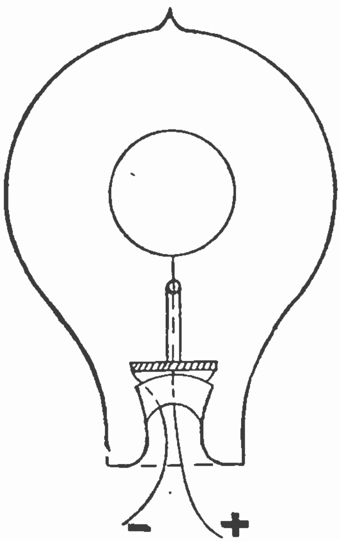


FIG. 7,877.—Circuit diagram of photo-electric cell. *In operation* wherever light flux falls upon the photo-sensitive film a cloud of electrons is emitted and if there be an electric field, called the *polarizing voltage* applied as shown, a current will be caused to flow as each electron flows from the photo-sensitive surface to the collector and deposits its charge thereon. This amount of current is, of course, directly proportional to the number of electrons emitted, which, in turn, depends upon the quality of the photo-sensitive film.



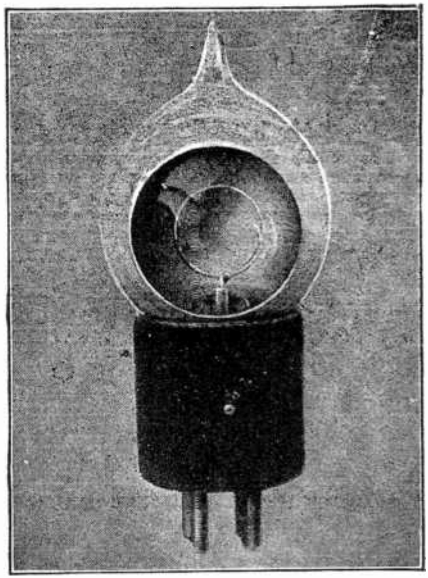


FIG. 7,878 and 7,879.—Jenkins type SR1 photo-electric cell. It is gas filled and suitable for sound moving picture work relay operation; also for television direct pick up work when the ionization voltage is properly chosen.

light falling on the surface of the metal; that is, if a certain amount of light fall upon the surface of the metal, a definite number of electrons will be emitted, and if the amount of light falling on the surface be doubled, the number of electrons emitted will also be doubled.

In order to make use of this fact some method of collecting the electrons emitted is necessary. To obtain this end a plate coated with the active metal is placed within a vacuum tube and an electrical connection is made from it to the outside of the tube. Another conductor set in the proximity of the plate is also placed within the tube and has a lead brought out for electrical connection.

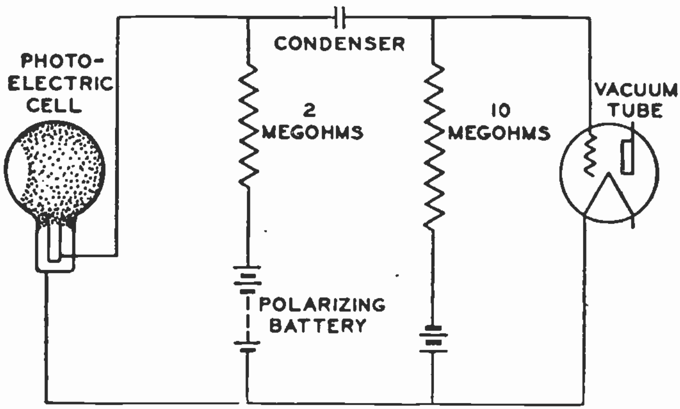


FIG. 7,830.—Photo-electric cell. The characteristic of this device is that *when it is polarized by a proper voltage and is used within proper limits the current through it is proportional to the incident light.*

The plate or metallic surface coated with the active metal is called the *cathode*, and the other conductor is called the *anode*.

If the cathode be connected to the negative side and the anode to the positive side of some source of *d.c.* voltage, such as a battery, the anode will collect the electrons emitted from the cathode.

Since the number of electrons emitted depends upon the amount of light falling on the cathode, the number of electrons collected by the anode will vary with the amount of light falling on the cathode.

The electrons collected by the anode do not remain there, but flow off immediately in the form of an electric current through the external circuit and return to the cathode. Therefore, a varying amount of light falling or

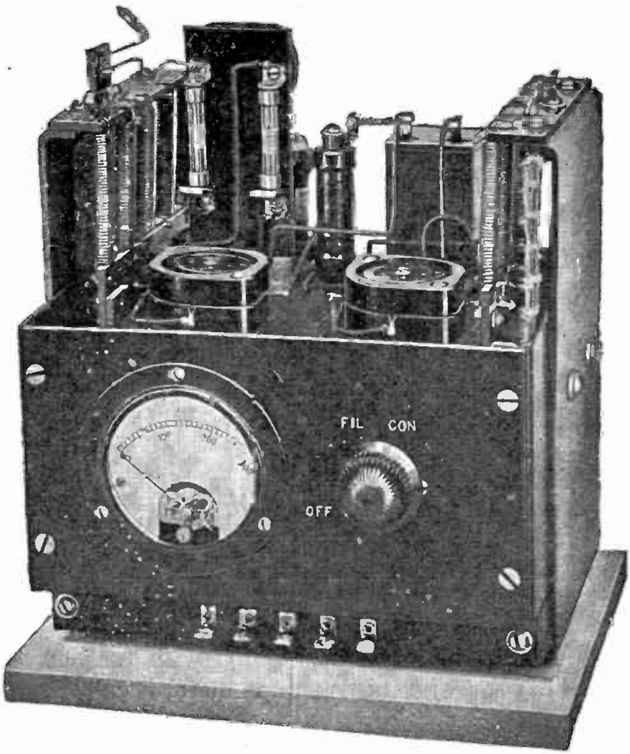


FIG. 7,881.—Photo-electric cell amplifier for projector. ***In construction*** the cell and amplifier are enclosed in a heavy metal box made fast to the frame of the projector, and the frame is carefully grounded. As a further precaution, the amplifier is supported within the enclosing box by a rather elaborate flexible suspension, lest vibration of the vacuum tubes introduce noise components into the current. The amplifier brings up the energy level to about that obtained from the magnet coils of the reproducer for disc records.

the cathode will cause a varying current in the external circuit. A photo-electric cell of the type used is shown in fig. 7,878 and the circuit in fig. 7,880.

When polarized by a proper voltage, the cell passes a current proportional, within limiting values, to the intensity of the light falling upon it.

The polarizing voltage is supplied to the cell through such a high resistance that in operation there is obtained from the cell a voltage across the resistance proportional to the incident light. The voltage bears therefore at any time an inverse relation to the density of that part of the sound track then between the exciting lamp and the cell.

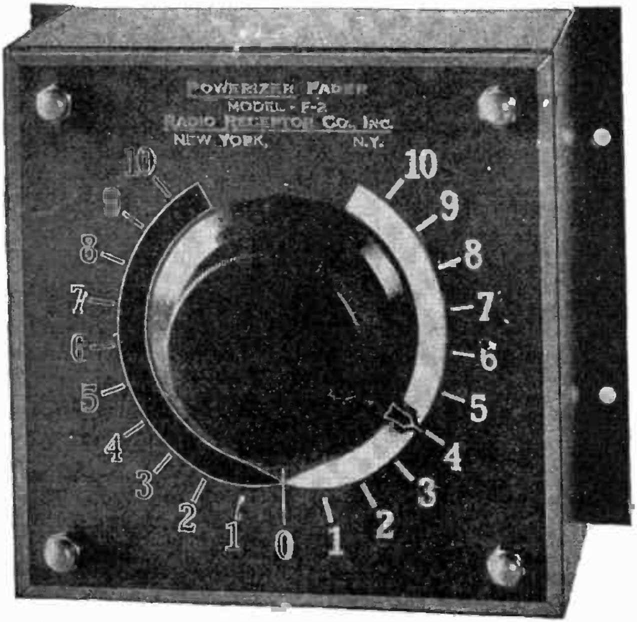
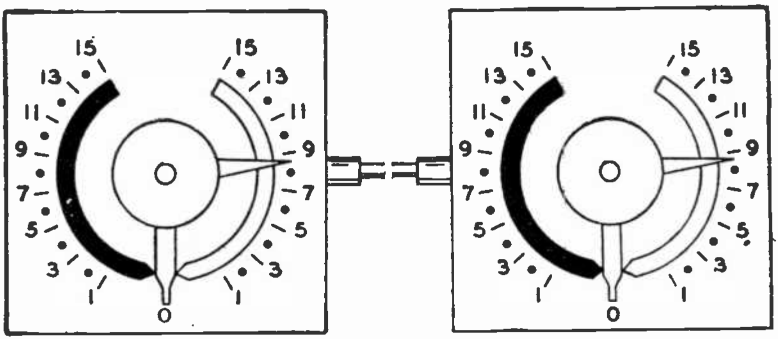


FIG. 7,882.—"Powerizer" fader for small theatres. *It is* of the potentiometer type with suitable resistance wire and resistance taps mounted on one unit, easily removable from the interior of the case. Connections are easily accessible and the entire unit may be wired in accordance with the Underwriters' Code. The entire unit is enclosed in a heavy steel case with two sets of markings, one in red, and one in white, to indicate its operation on either projector. The gain, per tap, is approximately in logarithmical increment.

Photo-electric Cell Amplifier.—The photo-electric cell circuit is inherently one of high impedance. In such a circuit local interference, or static, is readily picked up, and since the energy level is low, the current so acquired may be appreciable in comparison with the sound currents themselves. In addition the shunting effect of the capacity between the conductors is noticeable, particularly at the higher frequencies. Hence a vacuum tube amplifier, as shown in fig. 7,881, which serves both to increase the energy and to make that energy available across a low impedance circuit, is closely associated with the cell upon the projector itself.



FIGS. 7,883 and 7,8^4.—Fader showing master and auxiliary positions. Since in ordinary pictures, in order to run a continuous program, it is necessary to use two projectors alternately. As the picture from one machine is faded imperceptibly into that on the other so the sound record may be faded from one machine to the other without the audience being aware that a change has been made. At the end of each record or sound film the music overlaps the beginning of the next and a device called a fader is employed in making the transition. All that is necessary is to turn the fader knob when the incoming machine is started. This fader is in fact a double potentiometer. In the upper or normal operating range the change in volume in moving from one step to the next is hardly more than perceptible whereas in the lower range used only in fading the steps are large and the volume decreases to zero in one machine and builds up on the other very rapidly. By choosing the proper step in the upper range any volume of sound within reasonable limits can be obtained and the level obtained from different sound records equalized. The fader is ordinarily installed with one or more auxiliary dials and handles interconnected so that it may be operated from any projector position. In connection with the fader there is provided a switch for changing from the film to the disc input system and also a key for switching a spare projector in place of either of the regular machines.

The Fader.—As with ordinary motion pictures, two projectors must be used alternately to present a continuous program. At the end of a record, the music or speech coming from one machine must be blended imperceptibly into that from the other just as the picture from one reel is faded into that of the next.

At the end of each sound film or disc the music overlaps that at the beginning of the next; a device called a fader is used to make the transition.

By definition a fader is simply *a double potentiometer.*

As the starting projector goes into operation, the fader knob is turned and the current delivered to the amplifiers is changed quickly until it comes entirely from the new record. Ordinarily the fader is installed with auxiliary dials and handles, so that the operator can control it from any position around the projectors.

In its lower range, used in changing between projectors, the steps are rather large, whereas in the upper range the volume changes in scarcely perceptible steps. The fader thereby fills another use; it makes possible any volume of sound desired, within reasonable limits, by choice of the proper step in the upper range, and thereby permits equalizing the level of sound obtained from different records. There is provided as well a switch for changing from film to disc records, and the reverse, and a key for connecting a spare projector in place of either of the regular machines. Figs. 7,883 and 7,884 show a fader with master and auxiliary positions.

Main Amplifiers.—After passing through the fader, the sound currents go to the main amplifier, where their energy is raised to a level adequate for the loud speakers of the particular theatre.

A potentiometer is provided on the amplifier, but after it has once been adjusted at the time of installation it is ordinarily not changed; necessary adjustments in energy level are made on the fader instead.

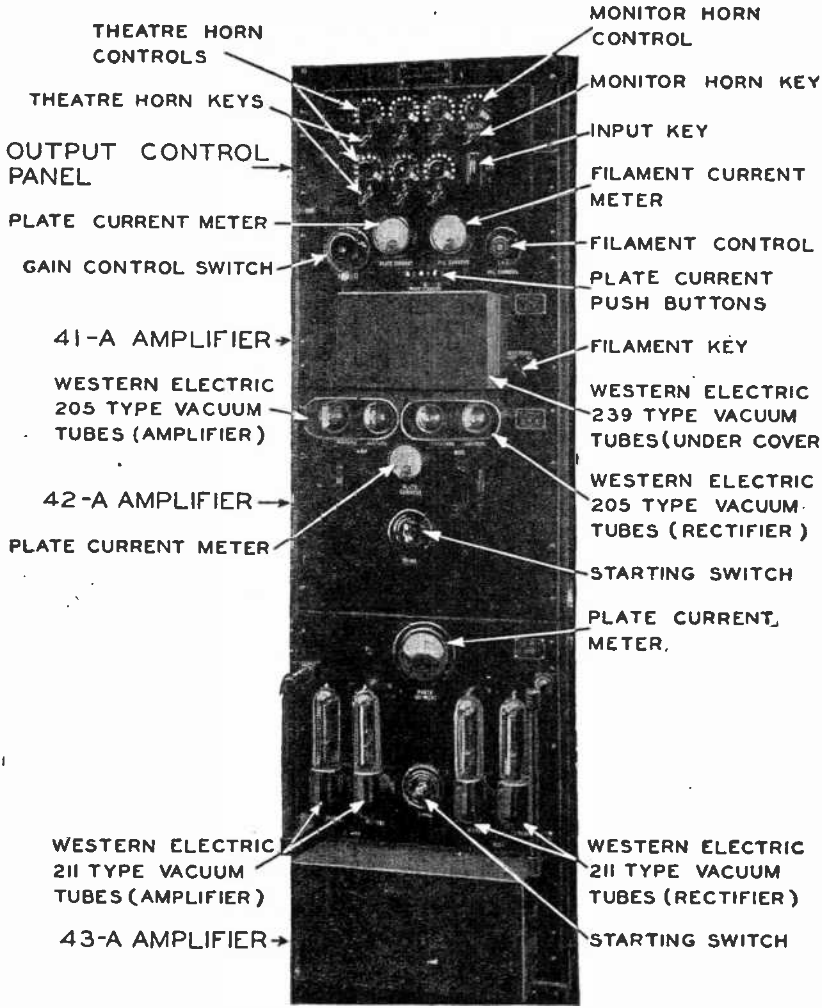


FIG. 7,885.—Typical amplifier panel. This combination is capable of an energy amplification of about 100,000,000 times and is so designed that all frequencies in the range from 40 to

Amplifier Panel.—Following the amplifier there is an output control panel consisting of an auto-transformer having a large number of taps which are multipled to a number of dial switches. To the switches are connected the loud speaking receivers, so that the impedance of the amplifier output can be matched to the desired number of horns. Thereby is secured the most efficient use of the power available, and adjustment of the relative volumes of the individual horns is made possible at any time.

The Horns.—A theatre installation ordinarily contains four horns. They are mounted behind a transvocent screen, on which the pictures are shown, so that the sound may seem to come directly from the picture.

Two horns are mounted at the line of the stage and pointed upward toward the balconies and two are mounted at the upper edge of the screen, or above it, and directed downward. One or more Western Electric receivers are used with each of the horns.

A horn is ordinarily fitted with one receiver, but for outdoor use or other special requirements, it may be fitted with two, four or nine by a throat.

The maximum electrical input to a horn for continuous safe operation is approximately five watts per receiver. To disperse the sound waves over a large angle, more horns are needed than for a comparatively small angle.

FIG. 7,885.—*Text continued.*

10,000 cycles are amplified practically equally. A potentiometer is provided on the amplifier but while its handle is readily accessible it is ordinarily not used after having once been set at the time of installation to give proper results in the particular theatre. Necessary adjustments are made on the fader. The amplifier shown consists of three units. The first consists of three low power tubes in tandem, resistance coupled, and requiring a 12 volt battery delivering ¼ ampere to heat their filaments. The second consists of a single stage of two medium power tubes, connected in push pull arrangement with filaments heated by low voltage *a.c.* Two similar tubes in this unit operate as a full wave rectifier and supply rectified *a.c.* for the plate circuits of the amplifier tubes of both the first and second units. The third unit has a single stage of high power push pull amplifier tubes and push pull rectifier tubes and also operates entirely on *a.c.* These three types are capable of arrangement into combinations to meet the particular need. For small theatres only No. 1 and No. 2 are required. In the larger houses the high power unit No. 3 is added, while to meet exceptional conditions two or more of the high power amplifiers may be operated in parallel from the output of No. 2.

This directive characteristic of the horns is important, since it is responsible for the illusion that the sound comes directly from the mouth of the horn, that is, from the screen.

When the horn is replaced by a loud speaker of otherwise identical characteristics which radiates its sound over a very wide angle, the sound seems to come from a point some distance behind the screen, so that the illusion of coming from the picture is destroyed.

TEST QUESTIONS

1. *Describe a typical installation for reproducing sound pictures.*
2. *What is the construction of a disc record pick up?*
3. *Draw a diagram showing layout of a typical theatre for presenting sound pictures.*
4. *What is a photo-electric cell and how does it work?*
5. *Describe in detail the construction of photo-electric cells.*
6. *What is the construction of a photo-electric cell amplifier used at the projector?*
7. *What is a fader and how does it work?*
8. *Draw diagrams showing fader in master and auxiliary positions.*
9. *Where do the sound currents go after passing through the fader?*
10. *Describe the amplifier panel.*
11. *Draw diagrams illustrating recording and reproducing sound, showing intermediate processes.*
12. *How are the horns mounted?*

CHAPTER 197

Sound Apparatus Operation

As explained in the chapter on Synchronized Sound there are two general methods of recording sound:

1. Disc recording;
2. Sound on film.

In the sections following, a few operating hints will be given which will be found helpful for the projectionist in reproducing the recorded sound.

1.—Sound on Disc Operation

The revolving support upon which a sound disc is placed is called a *turntable*.

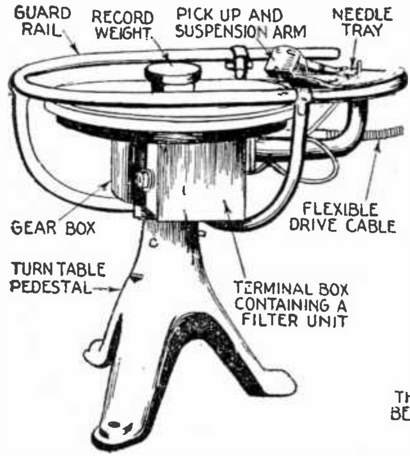
The following brief description of the Pacent disc system will show in general how disc systems work.

One motor drives both the projector and turntable through a gear box. A safety coupling between motor and gear box insures smooth and even running. Inside the gear box are gears that give the two drive shafts their proper speeds. The projector shaft terminates in a flexible coupling which takes care of possible misalignment developed during use. A pinion drives the projector head.

The turntable is driven from the gear box through a flexible coupling which eliminates possible vibrations reaching the tone arm. To further insulate the tone arm, it is mounted on a hub insulated by special cushions.

Pick up units are mounted in such a way that they can be easily replaced should trouble develop. To serve the operator a monitor speaker is mounted in the booth and the control of this speaker does not affect the volume or quality of the reproduction in the auditorium. It is up to the chief operator to decide whether he wants the speaker on or off.

The records used for this work are similar to standard phonograph records but larger and run at lower speed.



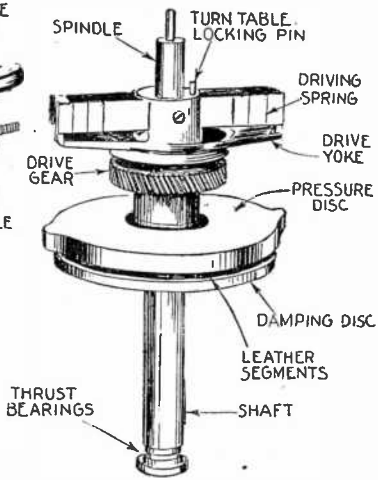


FIG. 7,885.—Typical synchronous turntable showing construction.

FIG. 7'837.—Viscous damping device of synchronous turntable. ***In construction*** a felt washer bears against one side of the fly wheel and introduces friction, or drag, and prevents any back lash in the gears, which might be caused by slight changes of motor speed, causing a *wow*. The pressure of the felt washer against the fly wheel can be adjusted by means of an adjusting screw, which is locked into position by means of a lock nut. The pressure on the washer should be adjusted to the lowest value that will just prevent *wows*.

The pick up needle travels from inside of records toward the periphery. An arrow indicates location of needle at start for proper synchronization.

The film is the same as standard film except that one frame is marked *start* and film number.

This frame is also marked with number O at the edge and every sixteenth frame is marked with the length in feet from the starting frame. The correct speed of the synchronized film is 90 ft. per minute and the equipment automatically regulates itself to have that speed constant during run. The projector machine and the turntable are mechanically connected so that no slipping which might result in improper synchronization is possible.

The general construction of a synchronous turntable is shown in fig. 7,886.

In order to avoid "wows" caused by sudden small variations in the speed

FIG. 7,888.—Pacent disc reproducer showing method of inserting needle. If during a reel the sound suddenly die down, hold the pick up down in the groove, with the right hand and at the same time bear slight pressure on pick up head toward center of turntable. What happens when the sound dies down is that the armature inside of the pick up freezes against one pole piece. A light pressure will free the armature and the pick up will give good results again. Of course this pick up is only to be used during that reel and immediately after change-over replace pick up. To prevent this freezing happening, when inserting the needle always hold needle with thumb on needle point and apply a slight force to right side of pick up working from front of pick up then tighten up the turn screw and by holding of needle no force will be applied to armature during the tightening.

of the driving motor, a viscous damping device is incorporated in the turntable mechanism, as shown in fig. 7,887.

Synchronizing Sound on Disc.—To synchronize a sound disc with the picture requires that *the film and disc both start at definite reference points.* One frame of the film is always

FIG. 7,889.—Method of setting disc at starting point on Western Electric reproducer set. 1. Hold record with both hands and lay it on turntable so that starting arrow is at about the place where needle comes. Wipe off record lightly with cleaner provided; 2, pick up forward end of reproducer unit between thumb and forefinger of left hand so that tips of thumb and finger project about ½ in. below bottom of unit; 3, move unit over until needle point is above starting groove and rest tips of thumb and forefinger on record surface so as to hold needle point just off record; 4, place right hand with fingers resting lightly on underside of turntable, near edge, and thumb on top of record, near edge, hold turntable steady and by moving thumb turn record so that starting arrow comes exactly below needle point; 5, lower needle down gently into starting groove at this point by slowly opening thumb and forefinger between which it is held. Do not push point into groove by sliding it sideways across uncut record surface, but lower it straight down. When it is in place rest fingers lightly on top of reproducer and gently press it toward each side to make sure needle point is in groove; 6, put record clamp over center pin of turntable and press it down in record firmly, but not too heavily.

marked in some way to indicate the frame which should be *in frame* when the film is threaded in the projector. After the film has been threaded as indicated, place the record on the turntable, and set record as explained in fig. 7,889. Motor must never be turned when adjusting record on turntable.

2.—Sound on Film Operation

In reproducing sound on film there are a few requirements of primary importance:

1. The light which shines through the film must be steady.

2. The beam of light must be as thin as the beam used in recording, and exactly as wide as the sound track.

3. The speed of the film passing the light beam must be the same as the film speed of recording and *must be constant.*

Variations in speed would cause variations of pitch which would be recognized as "wows."

4. The sound track of the film must be clean.

A dirty sound track would cause extraneous variations of the transmitted light and produce a grating noise in the loud speakers.

Variable Density and Variable Area Reproduction.—Although the sound tracks of the variable area and variable density recordings do not look alike, *the variations of the light transmitted through them are the same.* Therefore, reproducing equipment which is suitable for reproducing from one type of recording is equally capable of reproducing from the other.

All producers of standard sound recordings on film use the same width of sound track, and use a light beam of approximately the same thickness.

Sound Head.—The apparatus through which the film travels to produce the sound is called a sound head. In general, it consists of a housing containing:

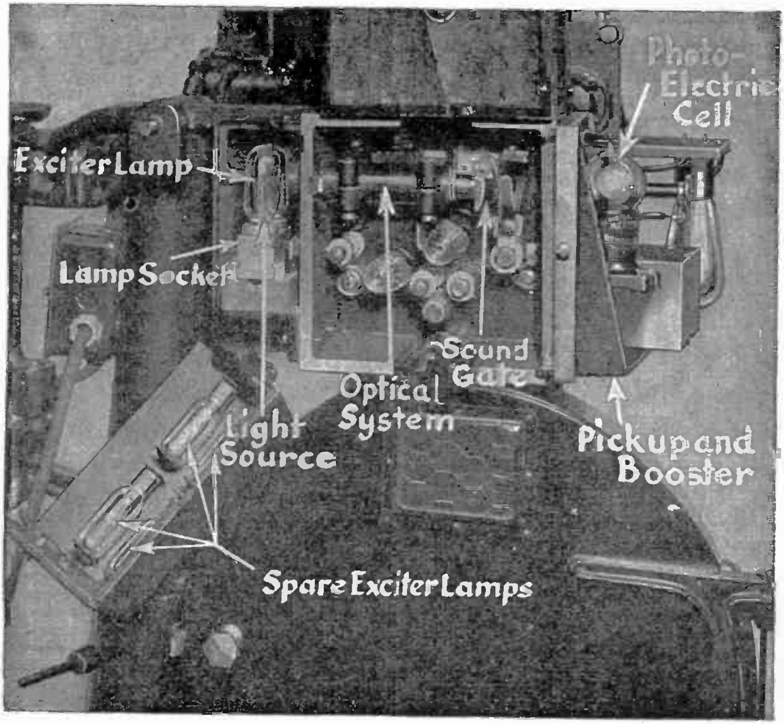


FIG. 7,890.—Pacent sound head showing light source, optical system and pick up system. *The filter system* consists of two fly wheel members, spring driven from the same shaft but through a gear system of a slightly different ratio for each fly wheel. As a result, these fly wheels, during the operation of the machine, revolve at a slightly different rate of speed though the relative speed is low, normally. These wheels are placed fairly close together in line with the axis of each and there is inserted between them, at right angles to the axis, a leather washer which contacts the sides of both wheels and in that way forms a frictional contact. To one of the fly wheels is connected the constant speed sprocket, the other is used as an impulse filter. In its operation, any variation in the speed of the fly wheel to which is connected the constant speed sprocket will change the relative speed between both wheels and will bring about a corresponding change in friction.

1. An exciter lamp assembly.

   In separate compartment.

2. An optical system.

   For focusing the light on the film.

3. A sound gate.

   For guiding the film past the beam of light.

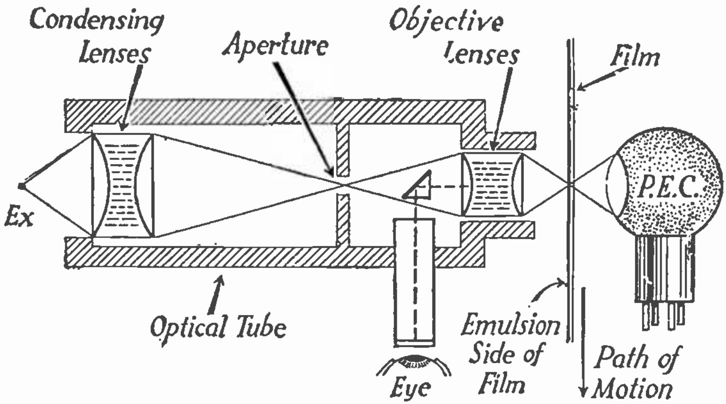


FIG. 7,891.—Diagram of the light source, optical system and pick up system in the Pacent sound head. Ex is the light source or exciter lamp. The optical system immediately at the right comprises a series of suitable lenses encased in a lens barrel or optical tube, and, following this, is the sound gate (not shown) over which the film rides before contact with the constant speed sprocket. *In operation* the light, modulated by the impressions on the film, falls upon the window of the sensitive photo-electric cell. This light sensitive cell, converts the varying intensity of the light beam into electrical impulses which are amplified by the booster, voltage amplifier, power amplifier and thence to the loud speakers.

4. A viscous damping device.

   To insure constant speed of the film.

5. A photo-electric cell and its transformer.

   For translating the light variations into electrical variations.

A typical sound head is shown in fig. 7,890 and the manner in which it works in fig. 7,891.

Viscous Damping Device or Filter System.—The importance of having the film move at a constant rate of speed when passing the sound gate is well known, and need not be discussed further here. The sprocket which pulls the film through the sound gate is called the *constant speed sprocket* because it is driven through a device known as viscous damping device or filter system whose duty it is to keep the speed constant, that is to remove any unevenness of drive which might be imparted by the motor or due to gear back lash. Two examples of sound head are shown in figs. 7,890 and 7,893.

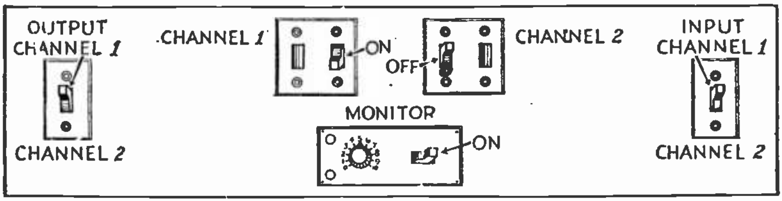


Fig. 7,892.—Pacent amplifier cabinet showing how switches should be set for operation. *In starting:* 1, set the fader at zero. 2, throw on main switch for channel *one* on amplifier cabinet; throw on input and output switches for channel *one* on same cabinet; throw on exciter lamp switch; throw on filament supply switch for booster unit; throw on speaker field switch—if current supply be other than 50 or 60 cycles *a.c.*, throw on switch for power supply unit for amplifier and power pack.

Threading the Film.—To set up a sound film ready for operation the following instructions will be found useful.

1. See that the fader is at zero and that film pick up circuits are connected to it.

2. On projector head, place aperture sound track mask in position.

3. On projector, place framing lever in central position.

Move projector mechanism by turning the hand wheel so that shutter cut off blade is uppermost, lens is open and intermittent has just ceased moving. Thread projector mechanism with film in usual manner except as follows:

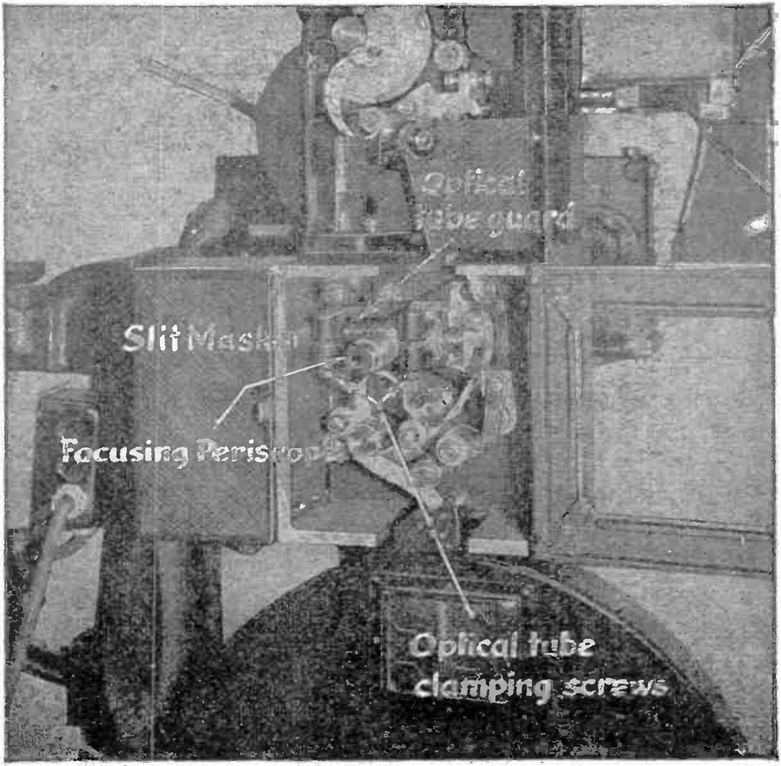


FIG. 7,893—Pacent sound head showing threading of film. Note periscope in position for focusing test. After threading the film through the projector head in the ordinary manner it should be lead through the outlet in the lower part of the projector head into the opening in the upper part of the sound head thence over sound gate and around constant speed sprocket and over take up sprocket to rewind magazine. Film should be made taut between take up sprocket in projector head over sound gate and around constant speed sprocket, then released one hole. Caution is advised at this point to make sure that the lower normal running loop as shown in fig. 7,894 is large enough to prevent breaking film.

a. For Simplex, be sure that loop between intermittent sprocket and lower sprocket of head, is such that film just comes in line with edge of head, as shown in fig. 7,895.

b. For Motiograph, allow a tight *two finger* loop between intermittent sprocket and lower sprocket of head.

c. For Powers, thread above automatic loop setter and allow a *two finger* loop.

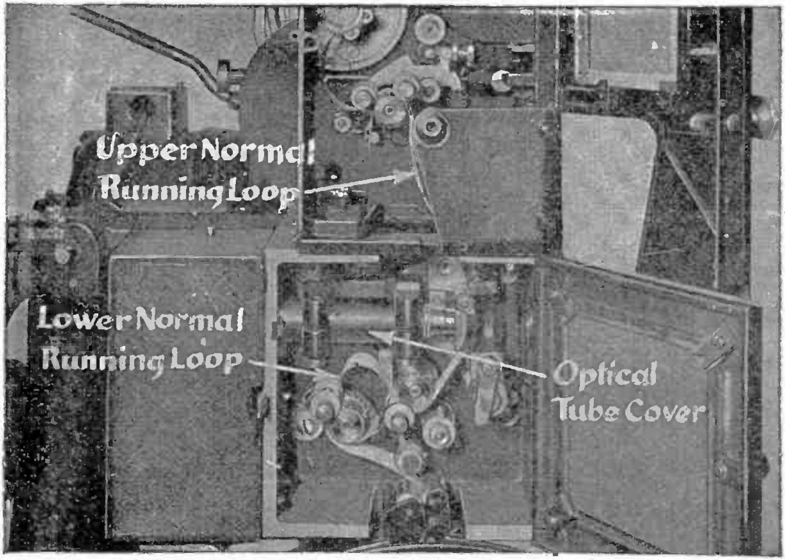


FIG. 7,894.—Pacent projector head and sound head showing proper size for lower normal running loop between constant speed sprocket and take up sprocket.

d. If using a type of projector head other than one of the three makes just mentioned, allow a length of film equal to 19⅓ frames, or 14½″ between center of picture aperture in the projector head, and center of light gate aperture in the reproducing machine. In other words, if the frame centered at projector aperture be called No. 1, then, counting downward along film, middle of light gate aperture should be ⅓ of a frame past center of No. 20. This gives perfect synchronism between sound and picture with all makes of heads, and is basis of rules for threading just given.

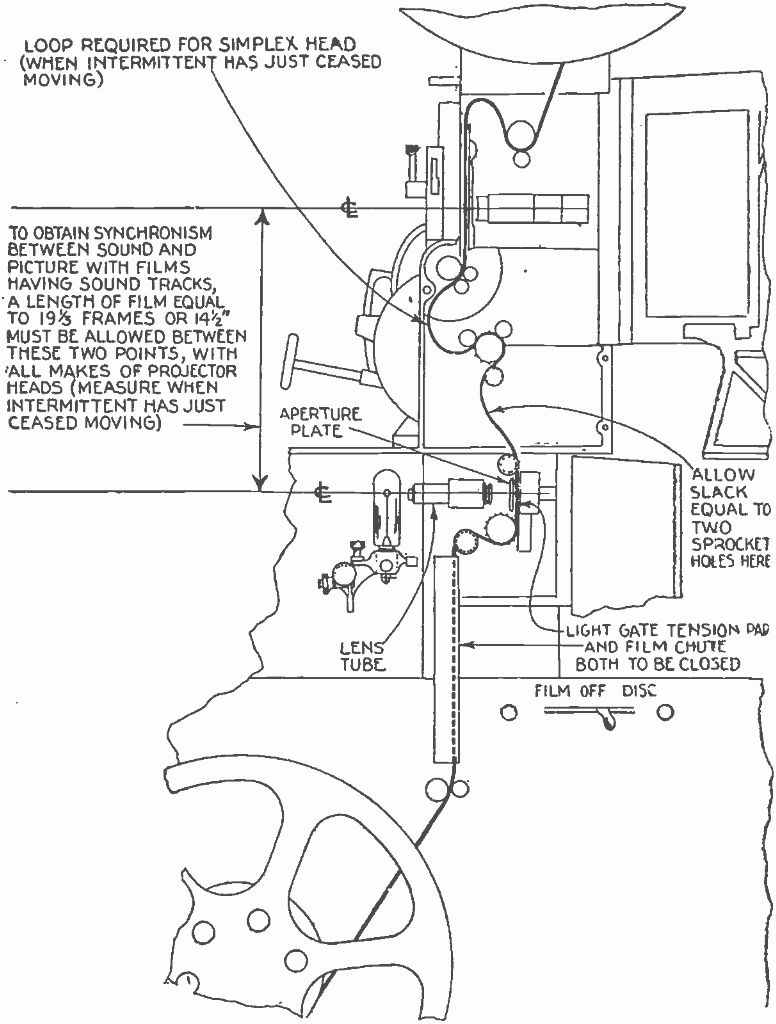


Fig. 7,895.—Threading projector and Western Electric reproducer set (sound head) for film reproduction.

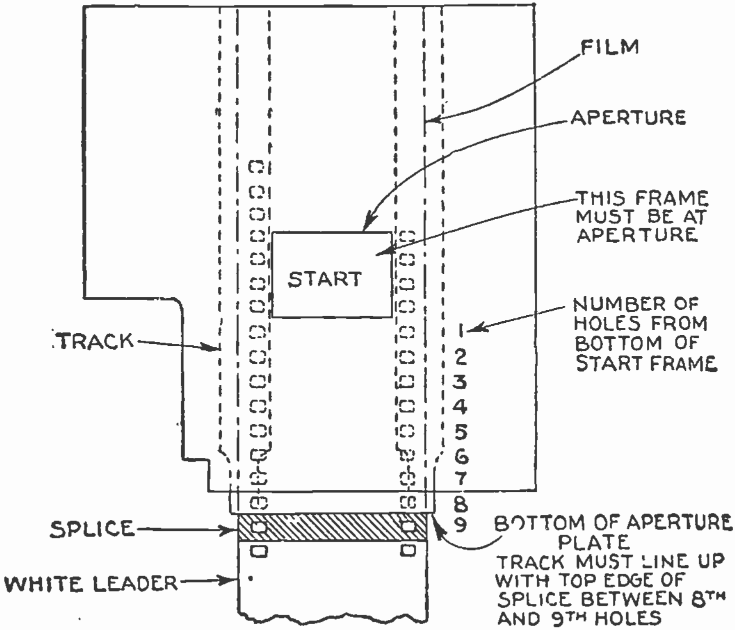


FIG. 7,896.—Setting up record and film for disc reproduction on Simplex and Motiograph heads. 1, set fader at zero; 2, see that reproducer is in its rest. Put in new needle; 3, select film and record to be used, and be sure to check number on record against number on film. Mark record on label to show number of times used, counting this run; 4, on projector, place framing lever in central position. Move projector mechanism by turning hand wheel so that shutter cut off blade is uppermost, lens is open, and intermittent has just ceased moving. Thread projector and reproducing mechanism with film in same manner as for film reproduction, placing frame marked *start* directly in front of aperture. On simplex and Motiograph, this step is easier if it be remembered that when a frame is in front of the aperture the lower edge of the aperture plate track will be between the *eighth* and *ninth* sprocket holes from the lower edge of the frame. Therefore, splice a white leader on the ninth hole from the *start* frame, and then when splice is lined up with the lower edge of the aperture plate track, start frame will be at the aperture, as shown. On Powers, the gate is open when threading, so that there is no difficulty; 5, set up record on turntable as in fig. 7,889 In doing this, following method must be strictly observed so as to avoid risk of imperfect synchronism or damage to records. Motor must never be turned when adjusting record on turntable; 5^a, hold record with both hands and lay it on turntable so that starting arrow is at about the place where needle comes. Wipe off record lightly with cleaner provided; 5^b, pick up forward end of reproducer unit between thumb and forefinger of left hand so that tips of thumb and finger project about ⅛" below bottom of unit; 5^c, move unit over until needle point is above starting groove and rest tips of thumb and forefinger on record surface so as to hold needle point just off record; 5^d, place right hand with fingers resting lightly on underside of turntable, near edge, and

4. Thread film through film reproducing mechanism exactly as shown in fig. 7,895.

In doing this, allow for *slack*, between lower sprocket of projector head and sprocket of film reproducing mechanism, a length of film equal to *approximately two sprocket tooth intervals.*

5. After film has been properly located on reproducing machine sprocket, do not forget to *release tension pad*, so that it bears on film and holds it close up against aperture plate in front of lens tube, as shown in fig. 7,895.

Door cannot be shut unless tension pad is released. Also close the film chute cover so as to have the film completely enclosed in case of fire.

6. On synchronized feature pictures, by starting and stopping motor with starting switch run off as much film as necessary to bring end of "Part No" leader approximately up to projector aperture. Avoid doing this to excess, as it tends to burn up the switch contacts.

Splicing Film for Disc Reproduction.—Vitaphone film has 16 frames per foot, and each foot is numbered. Beginning with O, at the starting mark, the 16th frame after the starting mark is marked No. 1. The 16th frame after No. 1 is marked No. 2, and so on throughout the print. There are, therefore, 15 frames without numbers between each pair of numbers.

FIG. 7,896.—*Text continued.*

thumb on top of record, near edge, hold turntable steady and by moving thumb turn record so that starting arrow comes exactly below needle point; 5ᵉ, lower needle down gently into starting groove at this point by slowly opening thumb and forefinger between which it is held. Do not push point into groove by sliding it sideways across uncut record surface, but lower it straight down. When it is in place rest fingers lightly on top of reproducer and gently press it toward each side to make sure needle point is in groove; 5ᶠ, put record clamp over center pin of turntable and press it down on record firmly, but not too heavily; 6, turn over mechanism by hand wheel until turntable and record have revolved about half a turn. See that needle tracks properly on record and film travels free; 7, on synchronized feature pictures, by starting and stopping motor with starting switch run off as much film as necessary to bring end of *part No.* leader approximately up to projector aperture. Avoid doing this to excess, as it tends to burn up the switch contacts.

By this system, the position of every single frame in the reel is indicated.

In synchronized features there are in addition other numbers on the margin of the film which indicate the scene numbers of the picture.

These numbers can be distinguished from the footage numbers, because they have a dash at each side, as for instance –286–, the footage numbers themselves being simply 286, without the dash at either end.

In cases where the scene and footage numbers conflict, the footage number is omitted, but is counted, and reference will have to be made to the next footage number in sequence.

If a footage number do not appear at each 16th frame, continue counting until the next number is reached, when there should be 31 frames between the two footage numbers.

With the numbering system described, it is easy to ascertain whether or not a print has the proper number of frames, by examining each splice and counting the footage numbers on each side. The two numbers should be consecutive and there should be 15 frames without numbers between them.

In case of a break in a film, make a patch by inserting black leader.

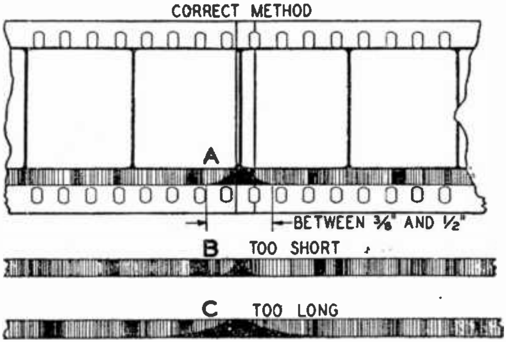
Be sure that the number of frames of black leader inserted is exactly the same as the number of frames taken out of the film, plus the frames used for the patches. After putting in the black leader, be sure to check up and see that the numbers follow in sequence and that there are exactly 15 frames without numbers between each pair of footage numbers.

If any numbered frames be missing, or if the missing portion be more than one foot, both sides of the break to the next number will have to be checked, and after making the splice, do not forget the intervening numbered frames.

Splicing Film for Film Reproduction.—In case film carrying a sound track become broken, cut out as few frames as possible when making the splice. A break in the sound track is usually even more noticeable to the audience than a break in the picture. However, do not go to the extreme of saving weak film that will cause trouble later.

A plain splice, no matter how carefully made, will cause a click to be heard from the sound projectors as it passes through the film reproducing attachment, because the two edges and the overlap disturb the uniformity of the sound track and produce the same effect as though noises had actually been recorded on the track.

In dealing with film of this type, therefore, first make a splice in the usual manner and then paint over this splice in black, as shown at A, in figs. 7,897 to 7,899.



FIGS. 7,897 to 7,899.—Method of splicing film with film track.

The painted mark on the sound track should be roughly triangular in shape with a blunted apex and between 3/8 inch and 1/2 inch wide at the base.

If the splice be painted in this manner, it will be almost inaudible when passing through the reproducing attachment, as the change in the light intensity which it causes will be at a frequency below the audible range.

If the mark be made too short, as shown at B, the click will be very pronounced; if it be made too long, as at C, there will not be a click but there will be a noticeable pause in the sound owing to so much of the sound track being obliterated.

For opaquing splices, the use of Zapon concentrated black lacquer No. 2002-2 is recommended. It is made by the Zapon Company, Stamford, Conn. When a thinner is necessary, Zapon thinner No. 20 is recommended. The lacquer should be applied to the shiny or celluloid side of the film and not to the emulsion side. It dries almost instantly, adheres tightly, and is much more satisfactory than India ink or other substances. If for any reason it should become necessary to remove it, a rag soaked in lacquer thinner will be effective.

Splices in the negative in making up subjects sent out by the producers are taken care of in the printing and may be observed bv the triangular marks along the sound track near changes of scene.

TEST QUESTIONS

1. *What is a turntable?*
2. *Describe how a typical disc system works.*
3. *What kind of records are used in the disc system?*
4. *What is a viscous damping device?*
5. *How is the film marked in sound recording?*
6. *How is sound synchronized on a disc?*
7. *Give method of setting disc at starting point on Western Electric reproducer set.*
8. *What are the requirements for reproducing sound on film?*
9. *Is reproducing equipment suitable for reproducing from both variable density and variable area sound tracks?*
10. *Of what does a sound head consist?*
11. *How does a sound head operate?*
12. *Describe the operation of a viscous damping device or filter system.*
13. *Explain in full the method of threading sound film.*
14. *Describe the splicing of film for disc reproduction.*
15. *Describe the splicing of film for film reproduction.*

CHAPTER 198

Sound Picture Speed Control

In all types of projectors equipped with sound heads or reproducers, there are two essential requirements.

1. The sound must be in synchronism with the film.
2. The apparatus must be run at a pre-determined constant speed.

The first requirement needs no explanation.

In regard to the second requirement it should be noted that musical pitch varies directly with frequency or rate of vibration.

The faster the record is rotated, or sound track is run, the higher the pitch of the sound given out.

In order, therefore, that the reproduced music may be of the same pitch as that recorded, *the record must run at an assigned speed*, and to keep the pitch from varying during the playing of the record, this speed must be prevented changing. To attain these ends, the speed of the driving motor must be accurately controlled.

A good musical ear will detect sudden changes in pitch produced by a change in speed of only one half of one per cent.

To make sure, therefore, that a discernible change in pitch never arises, speed regulation better than one half of one per cent is required at all times. As further allowances seemed desirable to provide a suitable factor of safety, a regulation of two tenths of one per cent was agreed upon.

The interlocking of the motor system employs a principle known for many years in the electrical power field. It consists of *connecting the stators and wire wound rotors of polyphase slip ring induction motors with similar electrical impedance characteristics, in parallel, and the placing of an alternating voltage across the stator.* Each motor acts as a transformer.

The rotors of all driving motors are brought into the same electrical

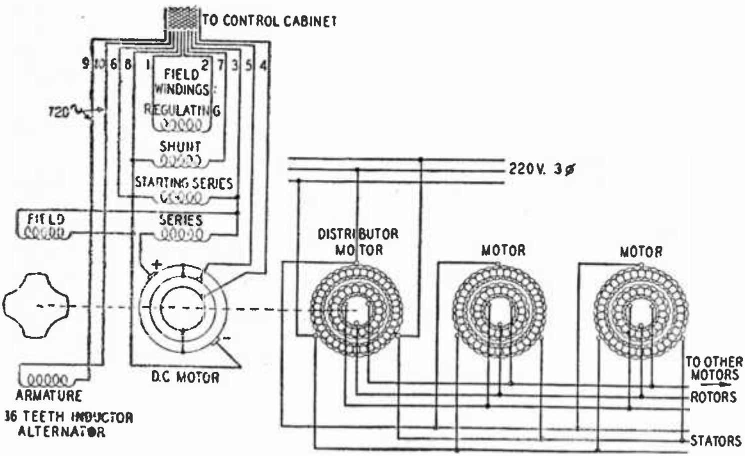


FIG. 7,900.—Diagram of motor system.

phase relation as is presented by the distributer motor. This system gives a strong interlocking action between all motors.

Mechanical rotation of the distributer rotor produces a corresponding rotation of all other interlocked rotors. Hence, if the rotor on the distributer be driven at a constant speed, all interlocked motors are likewise driven at the same speed independently of the power supply frequency and the actual number of revolutions from start to stop is exactly the same for all motors.

The system may be thought of as a long shaft as in fig. 7,901, with all loads geared directly thereto. The shaft is then driven by the distributer motor at a constant speed and all loads will then run in synchronism and likewise have the same number of revolutions from start to finish.

This feature of having the same number of revolutions from start is an important one. It permits the marking for synchronization of the sound film and picture film while stationary, while still having complete synchronization throughout, and is also important in the transferring of the sound record from one film or disc record to another film or disc in a dubbing process.

In the sound picture system a few comparatively simple electric circuits *act as a governor to correct the slightest change in speed of the driving motor.*

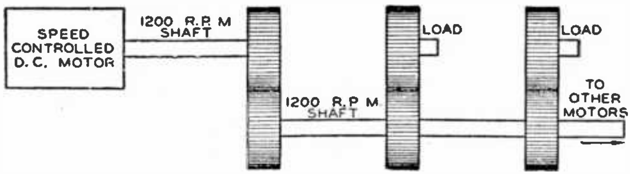


FIG. 7,901.—Mechanical analogy of motor system.

To make clear the principles involved, the electrical governing apparatus may be compared to the familiar steam engine governor shown in fig. 7,902. In this comparison the electrical governing apparatus may be split up into three parts corresponding to those of the fly ball governor. One part will substitute for the driving link (not shown in fig. 7,902) between the engine and the governor spindle, another for the fly balls themselves and their connecting levers, and a third for the steam valve that changes the torque of the engine.

The driving link for the electrical system is a 720 cycle alternator coupled to the main driving motor of the projector unit. The governing circuit proper is a special bridge circuit shown in fig. 7,903.

One arm of the bridge has a fixed inductance and condenser in series, which are adjusted to tune the circuit to 720 cycles. At this frequency the impedance of this arm is a resistance only and the impedance of the arm D, is made a resistance of the same value. At 720 cycles the ratio of these two arms, therefore, is unity, as is that of the other two arms, made up of the primary of a transformer divided at its half tap. The small alternator, connected across the transformer, thus becomes the source of power for the bridge. This arrangement makes an extremely sensitive analogy to the fly ball governor and lever system. The voltage

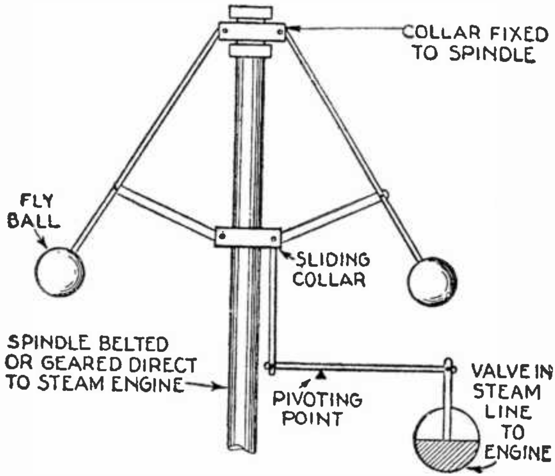


FIG. 7,902.—Familiar fly ball steam engine governor showing how sensitivity may be changed by moving the pivoting point to the left or right.

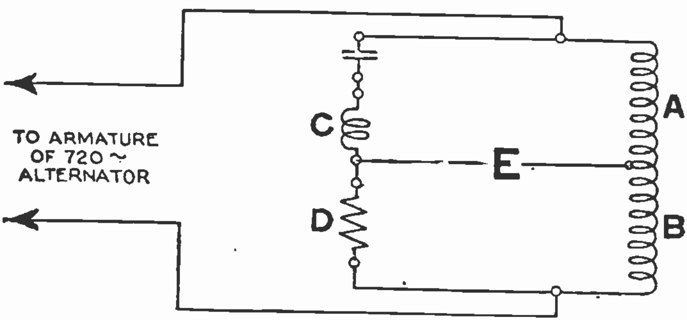


FIG. 7,903.—Sound picture governing circuit proper. Voltage E, shifts 180° in phase as the speed changes from any value below 1,200 *r.p.m.* to any value above it.

E, from the mid point of the coils A, and B, to the junction of arms C and D, which is zero at 720 cycles, shifts its phase 180° as the speed changes from any frequency below 720 cycles to any above it. Below 720 cycles the current in C, is leading due to the predominance of the condenser and above 720 it is lagging due to the predominance of the inductance. Instead, therefore, of a gradual change as the speed changes from its desired value there is an abrupt one which furnishes a basis for accurate speed control.

Acting as the steam valve to control the speed of the motor is an impedance coil with three legs, as shown in fig. 7,905.

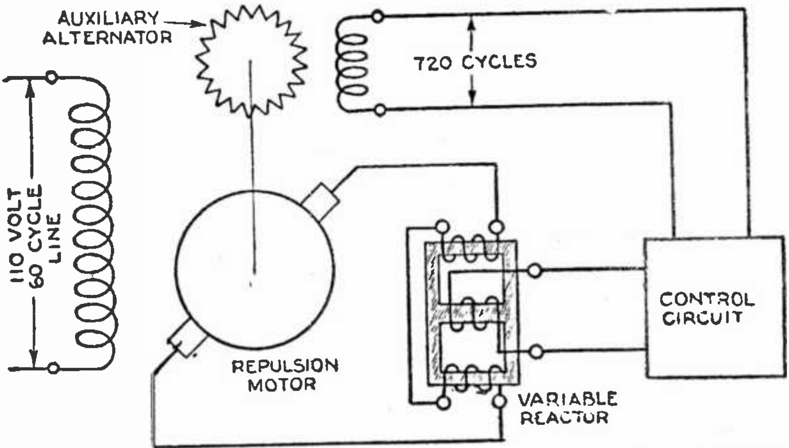


Fig. 7,904.—Torque control for driving motor. This is obtained by a three legged inductance coil, the impedance of which is changed by direct current flowing around the middle leg.

The two outer legs L_1 and L_2, are connected to the motor armature and serve as the impedance controlling the speed.

The middle leg G, carries a direct current winding. As the current in this winding increases the magnetic flux in the two outer branches increases to saturation and their impedance decreases. The torque of the motor varies inversely with the reactance of the coils, L_1 and L_2, and as a result the greater the direct current flowing into the coil G, the higher will be the torque of the motor.

The link between the bridge and the three legged inductance is a vacuum tube circuit.

. This circuit causes more direct current to flow as the motor speed tends to fall. This complete circuit, shown in fig. 7,905, includes the detector tube V_4, and two tubes V_1 and V_2, which supply current for the middle winding of the impedance coil. Tube V_3 is a rectifier to supply excitation for the 720 cycle alternator and grid biasing voltage for V_1, V_2 and V_4.

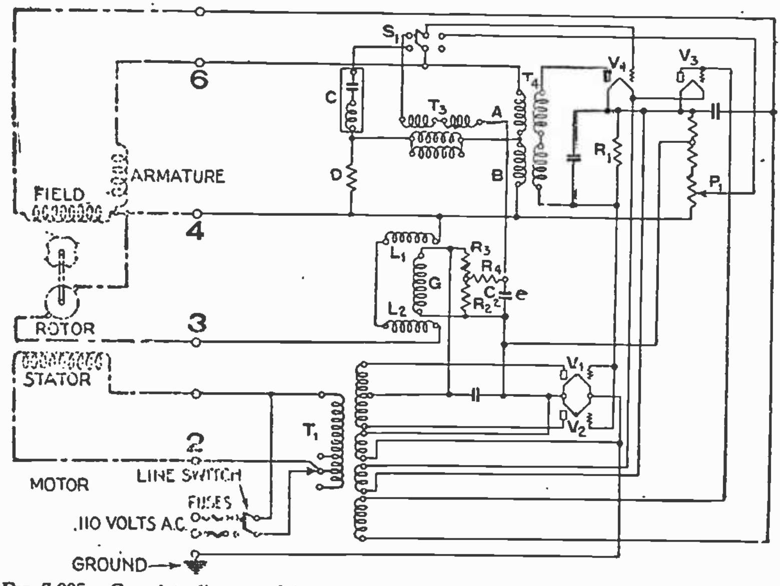


FIG. 7,905.—Complete diagram of the governing circuit showing the three legged reactance coil in the center. Switch S_1, is normally thrown to the left.

Plate voltage for V_4 comes from the alternator through the transformer T_4, and its phase is fixed. Grid voltage for this tube is from the bridge output circuit E, the phase of which shifts 180° as the alternator speed changes from below to above 1200 *r.p.m.* This 180° shift of phase changes the voltage of the grid relative to the plate from negative to positive or vice versa, and thereby causes a relatively large change in the plate current, which, flowing through R_1, causes a correspondingly large change in the grid voltage of tubes V_1 and V_2, and thus in the direct current to the impedance coil.

The bridge circuit makes a very sensitive governing device, but with it alone some permanent change in speed would be required to compensate for each change in load or line voltage. Something else must be added if the speed is to be constant for all conditions. Also some dashpot equivalent must be used to prevent the speed oscillations mentioned.

These two functions are accomplished by a network composed of R_2, R_3, R_4 and C_2, properly connected to the other circuits. Current flowing in the plate circuit of V_1 and V_2, to the coil of G, flows also through R_2 and R_3. The drop across C_2 which after a short preliminary period is the same as that through R_2, feeds back a voltage to the grid circuit of V_4, and thereby causes the additional regulation required. To slow down the action of this feed back, however, R_4 in series with C_2, is connected in parallel with R_2 as shown.

The feed back voltage is that across C_2, and this rises or falls slowly as the condenser must be charged or discharged through the high resistance R_4.

By these means, in the comparatively simple and compact electrical circuit shown in fig. 7,904, a governor is provided, similar in its functioning to the fly ball governor of fig. 7,902, that will control the speed of the driving motor under all ordinary conditions to within the required two-tenths per cent.

The switch S_1, was added to the circuit so that, when the picture projection machine was used for ordinary silent motion pictures, when such close speed regulation is not required, it could be thrown to the right and hand regulation obtained by the potentiometer P_1. This is needed to vary operating speed of the projector to meet a definite time schedule for showing the picture. When the schedule permits, however, accurate speed regulation is preferred since it enables a leader to keep his orchestra in better step with the picture.

TEST QUESTIONS

1. *What are the two essential requirements of projectors equipped with sound heads?*

2. *Why must a disc run at a pre-determined constant speed?*

3. *What principle is employed in the interlocking of the motor system?*

4. *Describe in full detail the method of obtaining constant speed.*

5. *Give a complete diagram of governor circuit.*

CHAPTER 199

How to Run the Show

Preliminary Considerations.—Before giving in detail the steps to be followed in running the show, some general points will be touched on. Before any public showing, all presentations should be rehearsed as covered in the section on Rehearsing.

The fader must always be kept at zero when the house is empty, except when testing with all theatre horns turned off, or when voice or music is actually being reproduced, with the motor up to speed, as covered in detail in these instructions. This is necessary:

1. To avoid the record surface noise or film noise being noticed.
2. To prevent the possibility of noises being heard from the horns at times when the pick up equipment is being handled.
3. To preclude the voice or music being heard in distorted form when the motor is speeding up or slowing down, in case it has to be stopped during a reel from film breakage or other cause.
4. When making a change over as described in detail in the instructions which follow, move the fader as smoothly as possible, and if a complete change over cannot be made in one movement, stop at zero for a fresh grip. Be careful not to over shoot the setting and then have to come back to it.

If the installation include disc pick up, always keep the reproducer in the rest except when a record is set up.

Under no circumstances is it permissible to run pictures with synchronized voice or music at any other speed than 90 ft. per minute.

When running such pictures the motor control box regulating switch must *always* be set at "Reg" and *never* at "Var." Any adjustment in the timing of the program by speeding up numbers or slowing them down must therefore be done elsewhere than in the synchronized reels.

A member of the staff appointed by the manager should remain in the theatre all through the performance so that the operator may have immediate and proper notification in case any part of the show is not coming over as it should.

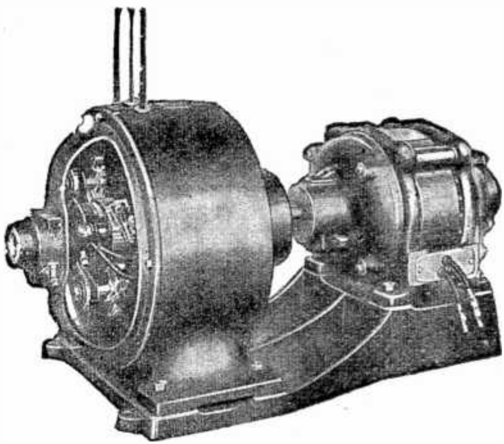


FIG. 7,906.—General Electric *a.c.* to *d.c.* motor dynamo *compensarc*. For use when the source of power is *a.c.* The equipment operates from an *a.c.* circuit and delivers *d.c.* of proper voltage to the projection arc. Sixty per cent of the moving picture theatres are located so that only *a.c.* is obtainable. The motor in this set, being a standard induction motor, can be obtained for any commercial lighting or power circuit whether single, two or three phase.

The observer should be competent to judge quality of reproduction, synchronism, etc. He should be within reach of the observer's telephone and given responsibility of notifying the operator immediately anything goes wrong. He should also keep the operator informed as to how well the house is filled, so that the latter can adjust the volume if necessary.

Never make the monitor horn so loud that it can be heard outside the projection room.

Keep the volume up just enough to follow the sound after the numbers have started, and make it a little louder before cues.

Do not cut synchronized film or sound film except in case of breakage.

If it be found desirable to eliminate bows at the end of the film, use the douser. If there be insufficient leader to permit proper threading of the film at starting, more blank leader may be added, provided of course, it is added *before* the "start" mark. Leader must always be so added if it be found that the voice or music begins before the motor is fully up to speed.

If the machine be equipped with a safety device which stops the motor when the film has run through, then, with disc reproduction, in case the record do not end until some time after the finish of the film, this ending will be spoiled through the safety device shutting down the equipment, unless sufficient blank film be added at the end to prevent this device operating until the music is finished.

Check this point during rehearsal and before running show make sure these blank lengths have been added to any reels that require them.

With subjects using disc reproduction a broken film is a more serious interruption than with ordinary subjects, on account of the need for synchronism between record and film, and with film reproduction, a break is also specially objectionable because it cuts off the music as well as the picture. Therefore, examine all synchronized films and sound films with extra care while rewinding, so as to catch tears before they develop into breaks. For this reason, rewind by hand and not by motor.

In film reproduction make especially sure that the film has been put in as good condition as possible and that the mechanism is clean. Oil or grease from the projector or film pick up mechanism is particularly liable to get on the first few feet of film. Keep emergency films in containers unless they have to be used.

Synchronized films and sound films come treated ready for immediate use, and require no different care from ordinary films, except as just noted.

Keep all records in envelopes they come in, when not in use. Put each record in its envelope with the playing side next the felt, and facing you. Keep the records in correct order for the next show.

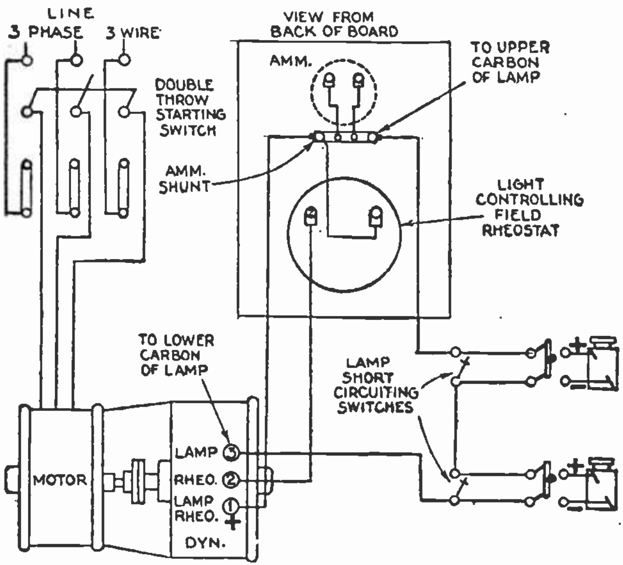


FIG. 7,907.—General Electric motor dynamo *compensarc* wiring diagram. ***In operation*** the current can be varied over a wide range by means of the field rheostat as the operator sees fit. The first arc is struck in the usual manner. The second lamp being short circuited by means of the switch. When ready to change over to the second lamp the carbons are brought together until they touch. The short circuiting switch is then opened. To shut off the first lamp the carbons are gradually brought together and the short circuiting switch closed. Two picture machines and a spotlight can be used, if only two of the arcs be used at the same time for change over and only one burn continuously. Since no steadying resistance is used the dynamo has been designed to operate over a wide range of load with approximately the same operating efficiency, whether one or two of the lamps be burning.

Synchronized Subjects.—The process of running synchronized subjects, using either film or disc reproduction is as follows:

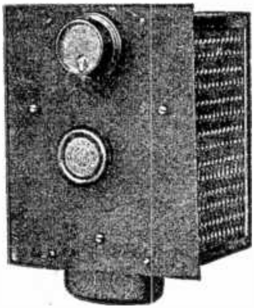
1. Follow out starting and testing procedure, and set up first two synchronized numbers on the two machines to be used, exactly as described in preceding sections.

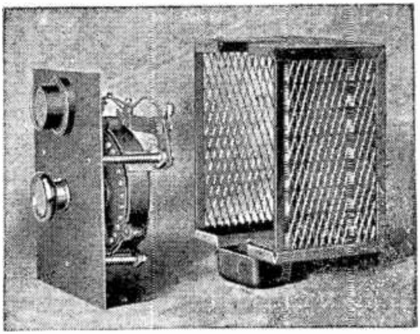
2. Strike arc on first projector in usual manner.

3. When lamp is in operating condition and show is ready to proceed, start motor of first projector.

4. When motor is up to speed open douser.

5. Bring fader up slowly so that it reaches correct setting just before voice or music begins. This needs rehearsal.





FIGS. 7,908 to 7,910.—General Electric control panel with ammeter and field rheostat for motor dynamo *compensarc*.

The motor used in the Western Electric equipment takes four or five seconds to speed up, because of heavy fly wheel required. Never move fader from zero before motor has reached full speed, as this will completely spoil beginning of speech or music. If sound begin before motor has finished speeding up, add leader to film as required.

6. For synchronized feature pictures, keep track of operation by listening to monitor and by watching screen for cues.

Do not make monitor so loud it can be heard outside projection room. At cue SM, as given on cue sheet, start motor on second machine. At cue CO, operate change over so as to switch picture from outgoing projector to incoming. As soon as voice or music from outgoing machine is finished, bring fader of this machine to zero, and then up to proper setting for incoming machine in time to catch first note of music. This needs rehearsal. Stop outgoing machine, kill arc and set up third film and also third record, with disc method.

7. For synchronized subjects other than feature pictures, keep track of operation by listening to monitor and watching pictures.

As soon as last note of music or last word is heard, bring fader to zero, then fade out picture as soon as subject matter requires. Start second machine in same manner as already described for first machine. Proper instant for starting second machine so as to get right time interval between end of first subject and beginning of second, must be determined by rehearsal. Never stop motor on any machine before fader has been brought to zero or switched to incoming machine, as otherwise end of speech or music will be spoiled. Stop outgoing machine, kill arc, and set up for third subject.

8. Continue process of switching from one machine to the other until show is completed.

9. When synchronized presentations are finished shut down amplifier and power equipment as covered in previous sections. Put away films and records.

10. When using film pick up, after running each reel, wipe off with a rag the light aperture and film tracks of aperture plate and tension pad in reproducing attachment, so as to guard against possibility of dirt accumulating and obstructing light beam or scratching film.

Non-synchronized Subjects.—When films without synchronized accompaniment are being used, and it is not desired to operate at the standard synchronized speed of 90 ft. per minute, throw the regulating switch on the motor control box to the VAR, position and turn the control knob to regulate the speed as desired. The motor is started and stopped by the foot switch used in synchronized operation.

Use of Tilting Mechanism.—If the house have both a front and a back screen, change the projection angle, in going from one screen to the other, by turning the tilting hand wheel.

Upper and lower stop nuts are provided to check the movement of the hand wheel when the correct angle is reached. Be sure to loosen the tilting clamp before turning the hand wheel, and also to tighten it again when the angle has been changed.

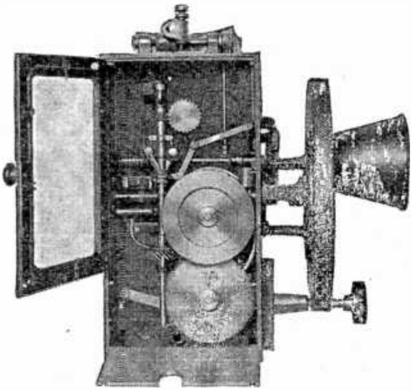


Fig. 7,911.—Superior projector. Head mechanism, *gear side* showing new rear shutter, new framing device and special gear for attaching sound reproducer equipment. *Timing Shutter;* since the shutter must operate in exact synchronism with the intermittent movement it is necessary that they should be in proper relation. To accomplish this turn the fly wheel in the direction it revolves until the intermittent sprocket starts to move, after which set the lower edge of the larger wing of shutter about one eighth of an inch above centre of the aperture plate opening. If travel ghost, streaks or a blurry effect be apparent the shutter is out of time and should be adjusted until these conditions are eliminated.

If for any reason it be desired to change the tilt of the machine by a large amount, first see that the tilting clamp is tight, then loosen the two tilting stud set-screws, which grip the tilting rod. Hold the rear of the lamp house bracket in one hand, loosen the tilting clamp with the other, and tilt the machine as desired. Then tighten clamp and set-screws. See instructions on page 4,841.

Use of Foot Brake.—When the foot switch is pressed down lightly, it turns off the starting switch and stops the machine.

If it be pressed down more heavily, against the resistance of the spring, it applies a brake to the motor fly wheel. However, *this braking feature is not to be used as a regular practice*, as this is not necessary and would cause excessive wear. *It is only to be used in emergencies*, such as film breakage, when a quick stop is necessary to avoid damage.

Rehearsing.—In order to give a satisfactory performance with synchronized presentations, adequate rehearsal is necessary to cover the various points which will be listed.

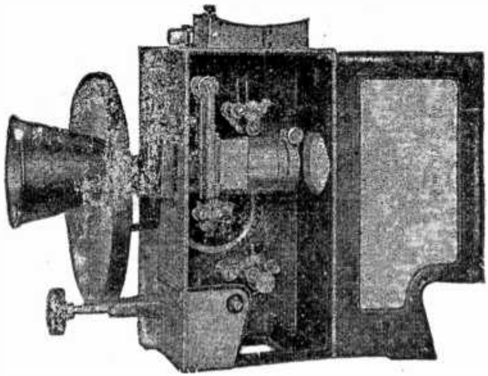


FIG. 7,912.—Superior projector. Head mechanism, *film side* showing new rear shutter, new framing device, mask on aperture to cut off sound track in connection with sound film.

The house manager should be present at these rehearsals with an observer at the telephone set. The subjects should be run off in the same way as for an actual performance. Time spent in careful rehearsing will be amply repaid in the perfection of the show, and the actual presence and interest of the house manager is indispensable. Light effects and any special features of the forthcoming show should be considered and tried out in conjunction with the rehearsal procedure described here.

Note that, as previously mentioned, adjustments in the timing of numbers must be confined to parts of the program other than the synchronized reels; the latter must always be run at standard speed, with the regulating switch on the motor control box set at REG.

The points to check are as follows:

1. On first reel of each synchronized feature picture and on first of each group of short subjects shown, determine how soon after starting motor fader should be brought up to its full setting.

It should be brought up slowly, taking two or three seconds, and should reach this point just before the voice or music begins Add blank leader if necessary.

2. For remaining reels of a feature, determine how soon after change over fader should be brought up to its full setting.

Usually this will be immediately after change over.

3. For short subjects, determine how soon after end of voice or music accompanying each subject the picture should be faded out.

On second and following subjects, determine when motor of incoming machine should be started to allow proper time interval between subjects, and when fader should be brought up to its setting to catch incoming music.

4. If using a safety device that stops motor when film has run through, see whether there be any reels where the film terminates before the end of the record is reached, and add blank film at end as required.

5. As previously mentioned, in houses where the upper horns are of the 12-A type and the lower horns of the 13-A type, and where an output control panel is used, with a separate control for each horn, three different types of combinations or settings of the upper and lower horns are used, and designated respectively by the letters A, B and C.

The A, setting is for vocal and instrumental solos or speech and uses upper horns only or upper horns with some lower horn.

The B, setting adds more lower horn to bring out effect of orchestral accompaniment.

The C, setting is for orchestra alone and carries further result mentioned for the B, setting.

After setting up the record or film as directed, adjust the horns for an A, B, or C, setting as required for the particular subject being shown.

Inasmuch as the settings are determined by careful tests of the house, they should be followed without change. Other settings may throw the system out of balance electrically and overload it or distort sound.

6. As a matter of convenience, and in order to give the theatres the benefit of the opinion of the recording and engineering staffs, recommended fader and horn settings are frequently marked on records or films or given on cue sheets sent out with them.

Amplifiers are so adjusted that with a full house, and fader setting recommended, correct full house volume is obtained. With house only partially filled, fader should be brought down one or two steps.

7. Determine horn settings and empty house fader setting for each number, bearing in mind any recommendations marked on or accompanying record or film.

Do this with care and in particular do not permit too high a volume. Synchronized scores to feature pictures should be run at a volume appropriate to incidental music. Never make the volume so loud that it causes the needles to oscillate on the amplifier plate current meters. If this happen, it is a sure sign of overloading and poor quality.

Speakers talking at a distance or in conversational tones should be reproduced with less volume than those speaking close or obviously talking loudly. Instrumental solos should have less volume than full orchestras (not accompanying), bands, etc. In news reels, street noises, locomotive whistles, etc., should be loud to give correct illusion.

8. In certain records effect may be improved by bringing fader up or down a step at certain points in the picture, as just mentioned.

Even the horn settings may occasionally be changed during a number as record changes from light or vocal effects, which are best reproduced by upper horns, to heavier orchestra music for which lower horns are brought out. However, discretion must be used in not making too great or too frequent changes in horn and fader settings; each record is made under skilled musical and technical direction in such a manner that when it is reproduced the effect desired by composer, artist and conductor will be obtained without any need for frequently changing settings while playing. If they be changed too much, therefore, proper effect will not be obtained.

9. Having rehearsed show and determined all settings, curtain cues, etc., record them in the form of a cue card posted in the booth.

10. In communicating with the operator by means of the telephone set it will be found handy to use the buzzer with the following code:

One buzz........................Fader up one step.

Two buzzes......................Fader down one step.

Three buzzes....................Answer over telephone.

TEST QUESTIONS

1. *What fader setting should be used when the theatre is empty?*
2. *What is the proper film speed for pictures with synchronized sound?*
3. *How should the motor control box regulating switch be set?*
4. *How can the operator tell whether the sound is coming over properly?*

5. *What should be done in the case of broken films?*
6. *Draw a diagram of a motor dynamo compensarc.*
7. *Describe the process of running synchronized subjects using either film or disc reproduction.*
8. *What is the procedure in running non-synchronized subjects?*
9. *Explain the use of the tilting mechanism.*
10. *How is the foot brake used?*
11. *Describe the method of rehearsing.*
12. *What is the buzzer signal code?*

CHAPTER 200

Troubles During the Show

The projectionist should become familiar with the instructions given herein so that troubles may be quickly located and remedied thus continuing a programme with the minimum of interruption.

Whenever the sound is not coming over as it should, the fader can be employed to cut it out until the trouble has been located and remedied. It is much better to do this than to continue the sound accompaniment when it is obviously bad. If the fader be properly handled all kinds of trouble may happen and be remedied by the projectionist without the audience noticing anything seriously amiss.

Emergency Equipment.—Whenever trouble occurs, use the emergency equipment or emergency set up if one be provided and endeavor to locate and remedy the difficulty, if possible, by following the instructions given here. If unable to cope with the trouble notify the manufacturer of equipment to send a service man.

Fuses.—The installation has fuses at the following points:

Motor control box—Two 10 amp. plug fuses on *a.c.*
Two 15 amp. plug fuses on *d.c.*

Battery panels.

Box for film dry batteries—1 amp. midget fuses.

Horn cut out box (back stage)—3 amp. plug fuses.

46-A or 46-B amplifier (if used)—Two 3 amp. plug fuses.

KS-5321 motor generator (used on *d.c.* only)—

Generator—Two 10 amp. cartridge fuses.

Motor (115 V.)—Two 20 amp. cartridge fuses.

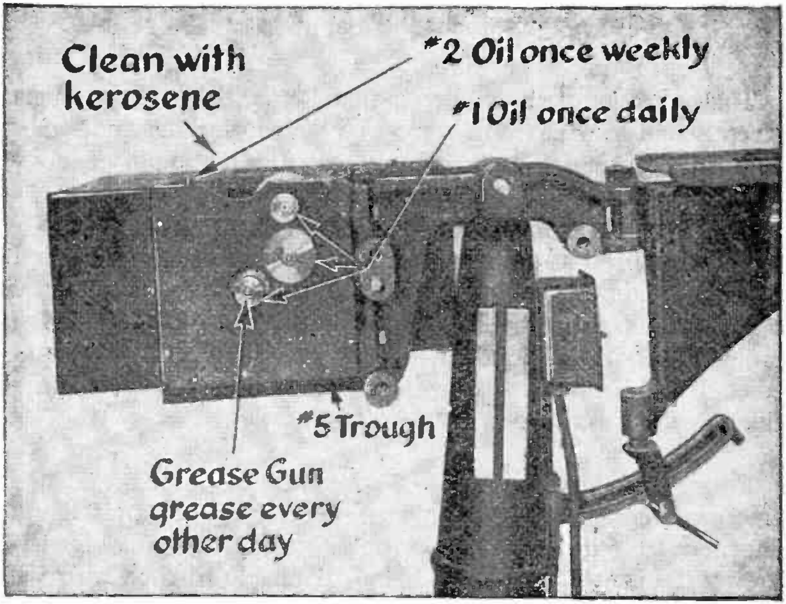


FIG. 7,913.—Pacent film head with oiling and greasing indications.

Motor (230V.)—Two 10 amp. cartridge fuses.

Volt meter—Two ½ amp. midget type fuses.

Battery charger (used on *a.c.* only)—Three 5 amp. plug fuses.

If one of the fuses burn out, replace it by a new fuse of the same type, as covered in the instructions which follow, but if it blow a second time, do not renew it until the cause of the trouble has been found and remedied.

Before removing the rear cover of any piece of amplifier equipment, be sure to turn off the power and keep it off until the cover is replaced. Also switch off the power on the battery switching and charging panel before replacing any fuses.

Testing Equipment for Faults.—If all conditions appear normal, and still no sound be heard from the horns, and no relief be afforded by any of the procedures that will be described, the indications are that a break or short circuit exists somewhere in the sound circuit. In this case listen in with the head set along this circuit, starting at the disc or film pick up with a record playing, and working on toward the horns until the location of the fault is shown by coming to a spot beyond which nothing is heard.

Be sure to use very little gain, as otherwise the head set will be overloaded and possibly damaged, and the quality will be spoiled. Use the same method to locate the source of noise or bad quality

Use a battery and buzzer to test lines for opens or shorts, but never to test amplifier or reproducer circuits, as this may upset the magnetic characteristics of the coils.

On some amplifiers two or more tubes are operated with their filaments in series; if one tube burn out, the others will then be extinguished. If two or more tubes go dark at once, therefore, it should be realized that only one has burnt out. This tube may be located by inspection, or the replacing tube can be tried in each socket in turn.

1.—Troubles Occurring while Testing

1. Charger not functioning (*a.c.* supply only).

a. On charger used with *a.c.* supply, if a rectifier bulb do not light, its filament may be burned out. Also a fuse on battery panel may have blown. Clean tube socket. If tube still do not light, replace it by one of spares supplied.

b. If tubes light but charger do not give output, a fuse inside charger may have blown

2. Motor does not start.

a. Is line switch on?

b. Fuse may have blown in motor control box.

3. Reading on motor control box meter not within specified limits.

a. If reading be too high, on *a.c.* or too low, on *d.c.* it indicates excessive friction at some point in mechanism. If this be not attended to immediately a bearing may freeze, rendering a projector temporarily useless. Stop machine and oil all bearings immediately abnormal reading is noted on meter, particularly any bearing that seems unduly hot. If trouble persist, notify manufacturer to send service man.

4. Motor does not maintain regulated speed.

a. Notify service man at once.

5. Unsteady pitch in reproducing (flutter).

a. With film reproduction, there may be dirt on the sprocket in the film compartment of the attachment. If this cause do not exist, notify service man at once.

6. Reproducer not tracking properly.

a. This occurs when needle jumps from groove. See that reproducer is not dragging on record, and that it is not hitting anything or otherwise being hindered from free movement. Put in new needle. Try new record. The swivel base on which the reproducer swings is mounted on a bracket, which in turn is clamped to the base by a bolt. See that the bracket is level and that the bolt has not loosened and allowed it to turn.

7. Excessive or insufficient plate current.

a. If this be noticed on testing the amplifiers, replace the tube showing this condition by a spare. When two or more tubes on an amplifier all show low plate current at the same time, try replacing the rectifier tubes on that amplifier (the 41-A amplifier uses the rectifier tubes o ı the 42-A amplifier). This may also be a sign of defective condensers (see paragraph *f* under heading, Volume falls off or ceases).

8. No sound from one horn.

a. Fuse may have blown in cut out box back stage.

b. If fuse in cut out box has not blown, replace receiver.

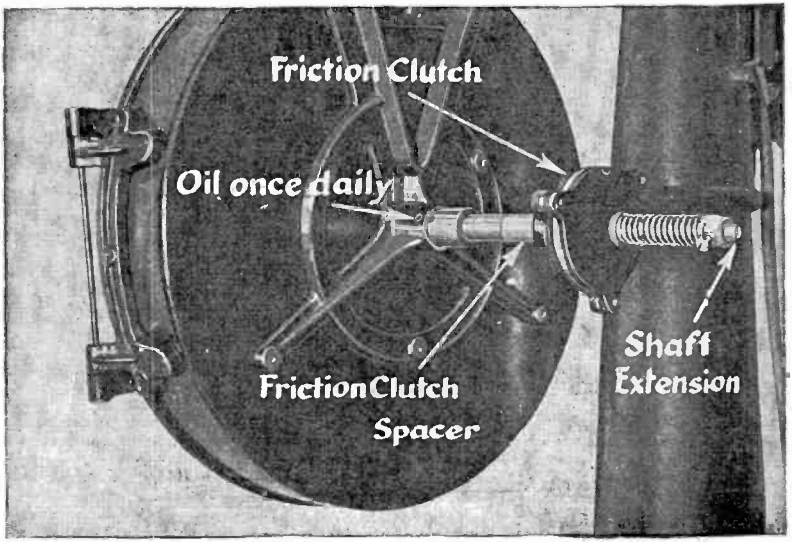


Fig. 7,914.—Pacent friction clutch spacer with oiling indications.

9. Volume falls off or ceases.

a. If system be a double one, having emergency amplifier equipment, cut in emergency amplifiers by means of key on system transfer panel. If this clear trouble, continue use of emergency amplifiers until a service man repairs or replaces defective regular amplifier, unless trouble can be cleared as will now be described.

b. One of amplifier tubes may be burnt out. If so, replace with a new tube of same type.

c. One horn may have short in line or winding through which sound current passes, thereby causing others to receive no power. Turn off all horns by means of keys on output control panel, or if these be not provided, then by means of switches in horn cut out box back stage, and then try to locate

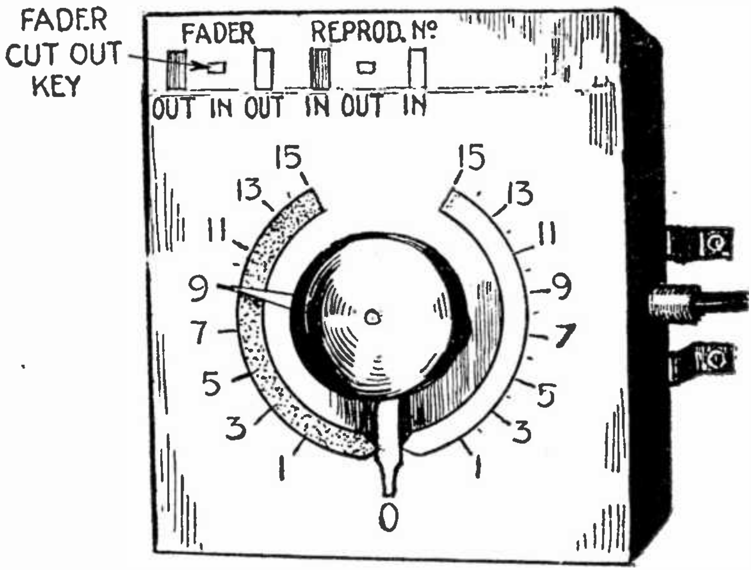


FIG. 7,915.—Western Electric fader.

bad receiver by turning horns on and off one at a time. They should all give volume except bad one. If defective receiver be found, replace.

d. Possibly fuses in horn supply circuit on battery panel have blown.

e. Check reproducers by switching from one to the other on fader. If one be bad, replace. If neither give any sound, check fader and circuit by means of head set, or as follows:

f. In systems using 41, 42 and 43 type amplifiers, left hand key at top of fader, called fader cut out key, fig. 7,915, can be used to cut out either side of fader circuit. If this key be thrown to left (red) for example, reproducing equipment on red machine will be connected direct to amplifiers without going through red side of fader. Similarly when key is thrown to right (white) side, white machine is connected direct to amplifiers. To check whether trouble be due to defect in fader, try using cut out key in this manner. If this eliminate trouble, use cut out key for change overs, instead of fader until service man can repair or replace latter. Regulate volume by means of gain control on 41-A amplifier.

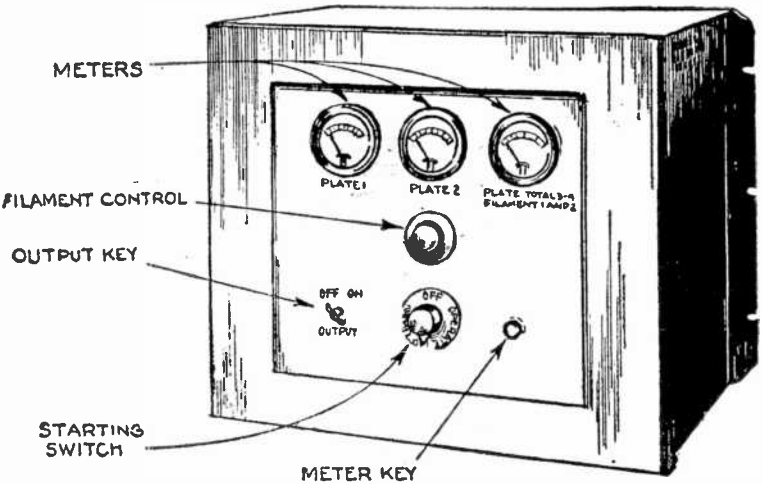


FIG. 7,916.—Western Electric type 46-B amplifier.

g. With film reproduction, exciting lamp may be out of focus or burnt out, or opening in photo-electric cell may be out of line with opening leading to film compartment. Position cell properly.

h. If system use one or more 43 type amplifiers, and plate current reading on one of these amplifiers is very low or is zero, probably a condenser has failed. A further indication of this is that plates of rectifier tubes of amplifier affected may begin to get red hot. Turn off power on this amplifier, by means of amplifier starting switch. Locate defective condenser as follows:

Remove front cover of amplifier. The condensers are connected in parallel in two groups, the first group containing C-2 to C-10 inclusive and the second group C-11 to C-19 inclusive. Unsolder connection coming from behind panel to lower terminal of C-2. Turn amplifier starting switch to *plate*. If plate meter reading be now normal, it shows bad condenser is in C-2 to C-10 group. Shut off switch. Restore connection on C-2 and unsolder connection between C-2 and C-3. Turn on switch. If meter reading be still normal, it shows C-2 is good and bad condenser is in C-3 to C-10 group. Restore connection on C-3 and unsolder connection between C-3 and C-4; test again with switch and meter, and so on until a condenser be found which when connected causes meter reading to fall. This will be the bad condenser. Cut it out by connecting together directly the lower terminals of the two adjoining condensers, instead of making the connection through the lower terminal of the defective condenser.

If in the first place when the connection coming from behind the panel is unsoldered from the lower terminal of C-2, this does not bring the meter reading back to normal, it shows that the defective condenser is in the C-11 to C-19 group. Then restore connection on C-2, unsolder connection between C-11 and C-12, and test for defective condenser as already described for C-2 to C-10 group.

i. If all fuses be in good condition and all current and voltage readings normal, probably there is a ground, open circuit or short circuit somewhere in the system. Try to locate fault with head set. Possibly a loose or grounded connection may be found which can be readily repaired.

If system have no emergency amplifiers and includes one 43-A amplifier and this is found to be defective, disconnect its *input* and *output* terminals (accessible by removing the back cover) and run system off 500 ohm *output* terminals of 42-A amplifier. If system use two 43-A amplifiers and one is found to be defective disconnect its *input* and *output* terminals. When cutting out an amplifier as just described the loss of power can be partly compensated for by running the fader higher, or raising the gain control dial on the 41-A amplifier one or two steps. Be careful not to impair quality by raising fader or gain so much as to overload amplifiers.

10. Poor quality or noisy output.

a. See paragraph *a* under previous heading "Volume falls off or ceases."

b. One of amplifier or rectifier tubes may be burnt out. Replace with spare of same type. For amplifier use, this must be a new tube.

c. A receiver may be defective. Test horns one by one as described in paragraph *c* under previous heading.

d. Film may be scratched or dirty.

e. A reproducer may be defective. Test reproducers as described in paragraph *e* under previous heading.

f. Fader may be defective. Check as described in paragraph *f* under previous heading.

g. One of amplifier tubes may be defective. Take a new tube and try it in place of each tube in turn until the noisy one is located.

h. Storage batteries may be dirty on top. See that they are kept clean. Storage batteries may have been put in use too soon after charging while

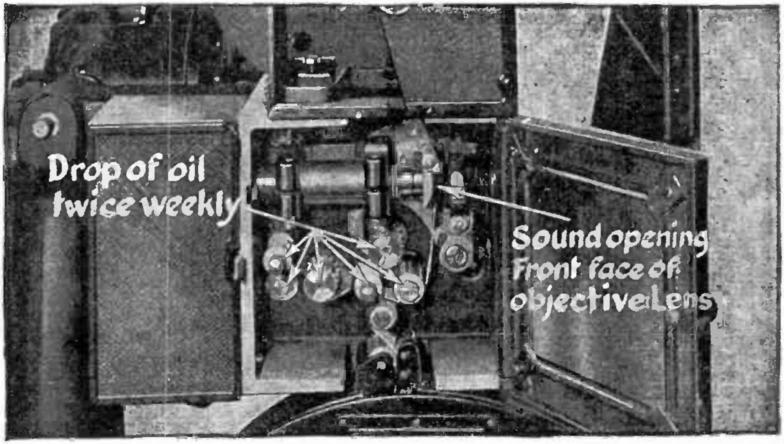


FIG. 7,917.—Pacent optical chamber with oiling indications.

still gassing. About half an hour is required for gassing to cease completely. Storage battery connections may be loose. Keep them tight.

i. There may be poor ground or loose connection at some point in system. Examine connections and tighten any found loose. If trouble be still unsolved, use head set, and if a defective 43-A amplifier be found, cut it out as described in paragraph *i* under previous heading.

11. Observer's equipment not functioning.

a. If not loud enough to enable observer and operator to hear each other, or if buzzer be weak or inoperative, make sure that switch on box is pulled out, and that batteries are in good condition. Replace batteries (open battery box by loosening screw in cover). If trouble be not here, check line for shorts or opens.

12. Film breaks (Film reproduction).

a. As synchronism between pictures and sound is inherent in the film, no loss of synchronism is occasioned by a break. Therefore, deal with a broken sound film the same as with an ordinary film in the same circumstances, but in making splice be sure to follow directions given for Splicing Film.

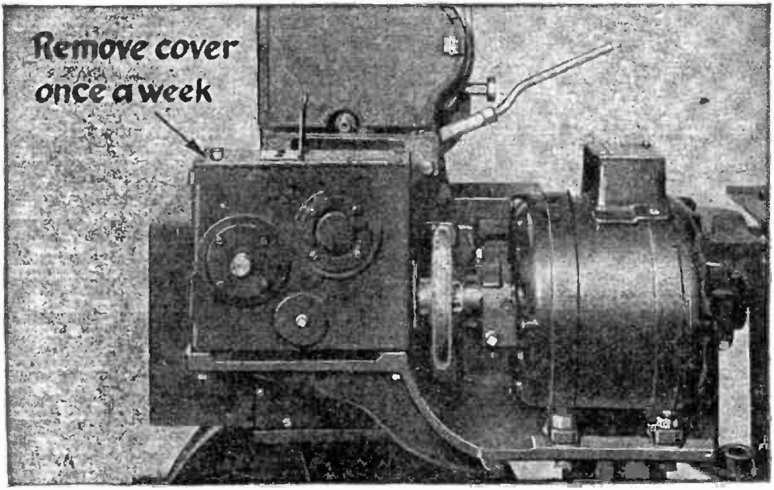


FIG. 7,918.—Pacent gear box with removable cover.

13. Film breaks (Disc reproduction).

a. Douse light, turn fader to zero and stop motor. The next step, as specified below, will depend on whether the break is above the intermittent or below it, and whether the sound only consists of a musical accompaniment and incidental effects, or whether there be speech, close ups, etc., which make synchronism very important.

b. Splice broken films.

14. Break below intermittent—all cases.

a. Run down film needed for winding around take up by means of hand wheel. Do not disturb film at aperture plate, or record and reproducer. Continue run, bringing fader to regular setting as soon as full speed is reached. Synchronism will usually be maintained under these conditions. However, since audience will lose some of the subject, it is generally better in the case of short subjects not to wait for re-starting as just described, but to continue performance immediately by showing next subject, which is set up on other machine. In the meantime broken film can be repaired and shown again at conclusion of number which is running on other machine. If break be near end of reel it may not be worth while returning to subject.

15. Break above intermittent—with speech or other sound accompaniment where exact synchronism is essential.

a. In this case it is not possible to continue on broken film without losing synchronism, and there is therefore no option except to continue program with next reel, which is set up on other machine, or else cut out sound for remainder of this reel.

16. Break above intermittent—with music or other sound accompaniment where exact synchronism is not essential.

Rethread and continue as previously described for break below intermittent. Synchronism is usually lost under these conditions, but this can be tolerated in an emergency, unless there be a direct cue in record, such as a knock, voice or cheers. In such a case, pass over cue with fader on zero.

17. Needle jumps groove.

a. If the needle jump back the sound will repeat, and may keep on repeating at every revolution of the record. If the needle jump forward, the sound will be ahead of the picture. The procedure will depend on the character of the film and on where the jump occurs. Any record on which the needle has jumped must never be used again, and the reproducer should be checked as soon as possible, when covered under "Troubles occurring while Testing—Reproducer not Tracking Properly." Bring fader to zero as soon as jump is noticed; the next procedure will depend on circumstances as follows:

With speech or other sound accompaniment where exact synchronism is essential. In this case it is not possible to continue without losing synchronism, and there is therefore no option except to continue program with next reel, which is set up on other machine, or else cut out sound for remainder of this reel.

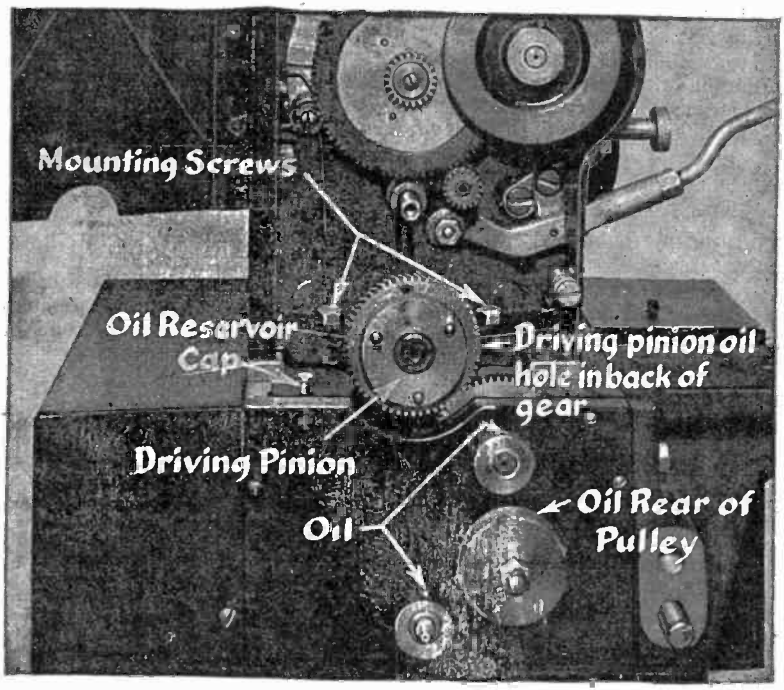


FIG. 7,919.—Pacent driving pinion with oiling indications.

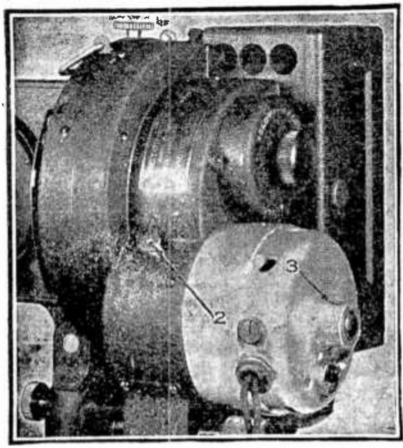
With music or other sound accompaniment where exact synchronism is not essential. Keep projector running, and look over reproducer quickly to see if there be any visible cause for jump, such as reproducer body dragging on record or reproducer hitting something that prevents it moving freely. If so, remove obstacle or change reproducer. This of course involves loss of accompaniment for remainder of reel.

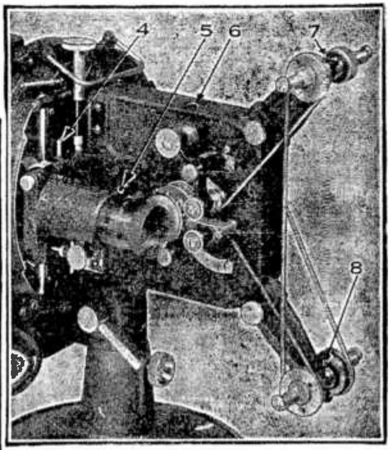
If no cause for trouble be evident, then, if needle jumped back, change needle, move reproducer over to a position two or three grooves ahead of where it was when it jumped, and restore fader to its regular setting. If needle jumped forward and if it now seem to be tracking properly, restore fader to regular setting.

Synchronism is lost when record is continued after needle has jumped, so in such cases if there be any direct cues in picture, such as knocks, voices, cheers, etc., fader must be put down to zero when passing over them.

18. Quality goes bad or noisy and volume falls off or ceases.

See recommendations already made under these headings in previous section "Troubles Occurring while Testing."





FIGS. 7,920 and 7,921.—Victor Ciné projector with oiling indications. In fig. 7,920, locate and oil. 1, main bearing oil tube; 2, front motor bearing tube. Slide cover aside to expose hole; 3, rear motor bearing; in fig. 7,921, locate and oil; 4. cam bearing tube; 5. gear shaft (directly behind lens mount), 6. sprocket shaft tube; 7. upper reel shaft; 8. lower reel shaft; 9. rewind pulley hub.

TEST QUESTIONS

1. *When sound is not coming over properly, what should be done?*
2. *What may be said of the emergency equipment?*
3. *Where should fuses be installed?*
4. *Describe the method of testing the equipment for faults.*
5. *Give a list of eighteen troubles occurring while testing and explain in full the various remedies to be applied.*

CHAPTER 201

Technicolor

Technicolor.—This is a process for photographing pictures *in their natural colors*. The process as described by Cameron is briefly as follows:

An especially sensitized negative is run through a camera which photographs simultaneous pairs of pictures; one member of the pair recording all the warm tones of the original scene, the other member of the pair recording all the cold tones of the original scene. These color records appear on the negative in black and white, that is to say, in varying densities of black silver, just like any other negative.

The color records are transferred from the negative to a positive by the usual photographic procedure. These positives are then colored with dyes, one with warm colored dye and the other with cold colored dye. These two, when superimposed, recreate the original scene in both its warm and cold tones.

Needless to say the actual camera filters and the actual pigments used in the positive process are very carefully selected and balanced to give brilliant primary colors as well as the softer intermediate tones.

The original technicolor process resulted in a positive film which had the two companion images on opposite sides of the film. This naturally required special attention on the part of the operator to make sure that what ordinarily is the celluloid side of the film was not being rubbed or abraded in any way in his machine; since such abrasion would be affecting one of the emulsions of the technicolor film. Furthermore, to show the images of the two sides of the film to maximum advantage, it was desirable that the projection lens be racked forward slightly. The added emulsion also caused a slight increase in thickness of the film which gave it a flexibility somewhat different from ordinary film and also made it desirable to have film gate tension on the projector somewhat looser than normal. These differences are characteristic of all double coated stock.

For the past year technicolor release prints have been made by a new and improved process wherein both images are embedded in one emulsion so that the resultant film is mechanically like a black and white film. The advantages of this improvement will be obvious to the projectionist. What corresponds to the emulsion in this new film is a very hard and glassy looking gelatin so that the appearance of the film in the hand is a little different from black and white and care must be taken to distinguish the celluloid side from the gelatin side. To assist the operator, all technicolor prints have a little red tab at the side of the picture. When holding the film in the hand with the little tab at the left of the picture the gelatin side is then facing you. When splicing this film, care must be exercised to see that the especially hard gelatin is entirely scraped away where the patch is to be made.

TEST QUESTIONS

1. *What is technicolor?*
2. *How do color records appear on the negative?*
3. *How are color records transferred from the negative to a positive?*
4. *Describe the original technicolor process.*
5. *Explain the new and improved process.*

CHAPTER 202

Booth Wiring for Projectors

Kinebooth Wiring 1

In the preparation of this chapter the author has had the able assistance of Mr. Alvin Seiler, Director of Engineering of the National Theatre Supply Co., New York City.

To become a good booth wireman, it is necessary to have a thorough knowledge of the various items of apparatus and equipment to be installed in the booth and to be familiar with the functions thereof, so that the wiring can be properly installed to meet the requirements of the various pieces of apparatus. Since all the apparatus has been described in other chapters, it is unnecessary to go into that part of the subject here.

The simple elements comprising the light projector system are:

1. The light source.
2. The lens system;
3. The screen or reflecting surface.

The simple process employed is to introduce an object of

NOTE.—Because of the many instances in which a misnomer has been applied to designate the room in which motion picture projectors, stereopticon projectors, effect projectors, spotlights, and auxiliary apparatus and equipment are located, the word *kinebooth* has been adopted and accepted by architects and engineers to define that particular section of a building.—*Seiler*.

NOTE.—*To aid those* operating *series* arcs, the author includes such arrangement in this Chapter, although the present practice is to wire the arcs in *multiple*. See Chapter 204 for additional *multiple arc diagrams*.

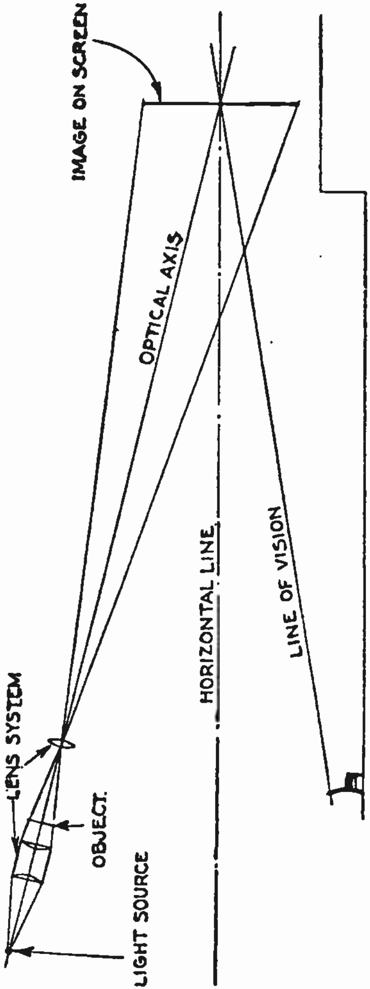


FIG. 7,922.—Diagram illustrating proper placement of projector and screen.

variable density ranging from opaque to transparent (or opaque and transparent for black and white projection, or color mediums as desired), between the light source and the lens system projecting the image against a screen or reflecting surface.

The ideal and most efficient plan of location of the apparatus comprising the simple elements would be to place the projector slightly above the horizontal and to have the audience seated slightly below the horizontal, as shown in fig. 7,922. As structural building conditions do not always permit the ideal arrangement, this and many other factors naturally govern the results to be obtained from a light projector system just described. The following are some of the primary factors:

1. Quality and intensity of light at source.

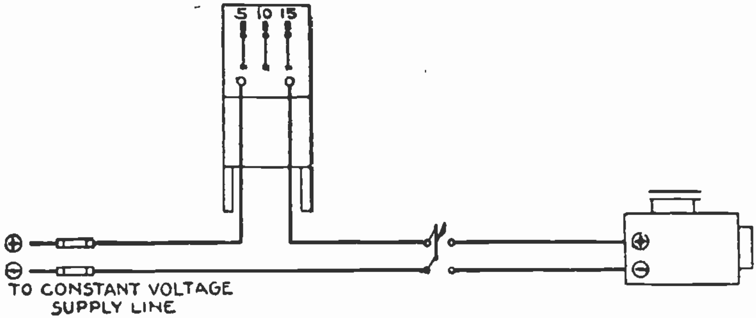


FIG. 7,923.—Hertner wiring diagram showing method of connecting type AA, and A ballast rheostats.

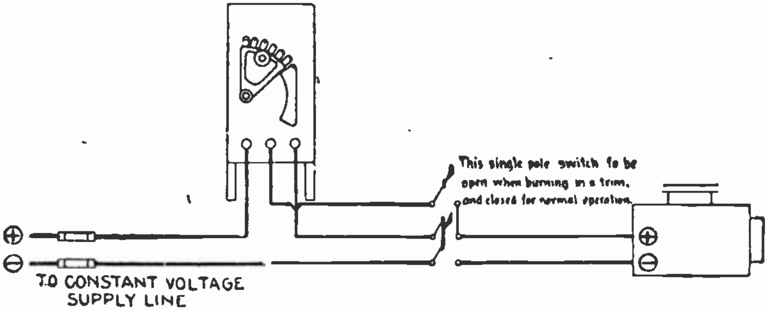


FIG. 7,924.—Hertner wiring diagram showing method of connecting types G and H ballast rheostats.

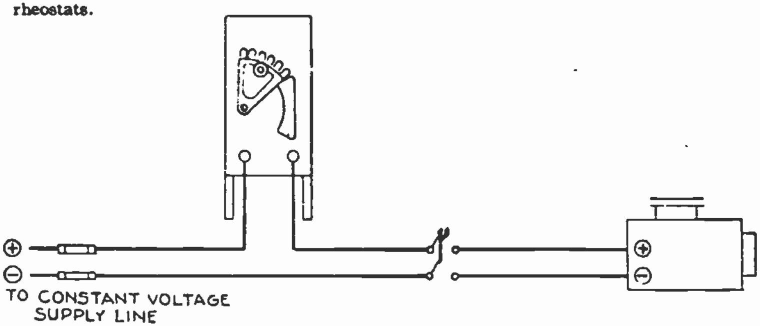


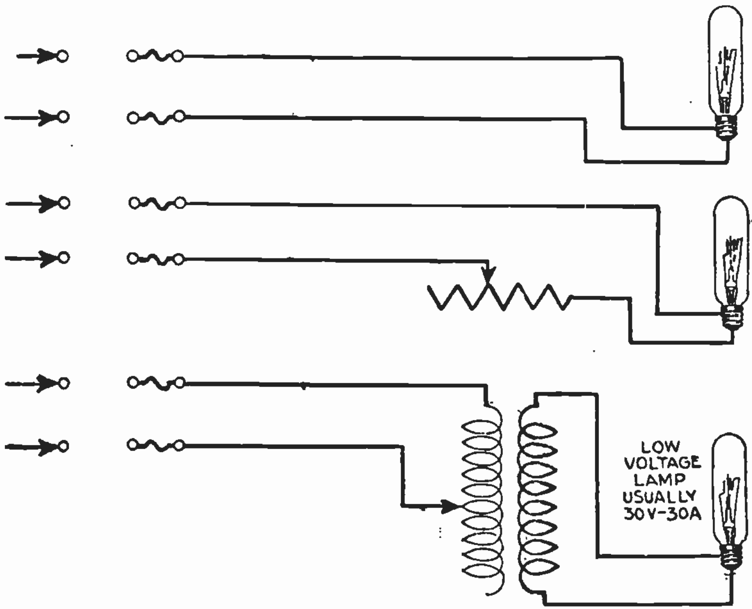
FIG. 7 925.—Hertner wiring diagram showing method of connecting types B, C and D, ballast rheostats.

2. The lens system;

3. The light reflecting and distributing properties of the screen surface.

4. The angle of the axis of the projected light beam.

Careful study and analysis must be made of all conditions surrounding the simple elements, such as distance, angle, area of the screen, size of auditorium, etc., before selecting the projector apparatus.



FIGS. 7,926 to 7,928.—Methods of connecting incandescent lamp source. Fig. 7,926, fixed control; fig. 7,927, variable control resistor type; fig. 7,928, variable control transformer type.

With the many auxiliary devices introduced to refine and elaborate the simple process of the light projector system, it is quite evident that the use of electricity plays an important part and the installation of correct and adequate wiring is most essential. Each application presents distinct and individual problems and no fixed rule or plan of wiring can be given.

Booth wiring in general is usually divided into five sections:

1. Projector wiring for projector light source

   a. A.c. wiring;

   b. A.c.—d.c. wiring;

   c. D.c. wiring.

2. Light wiring;
3. Power wiring;
4. Sound system wiring;

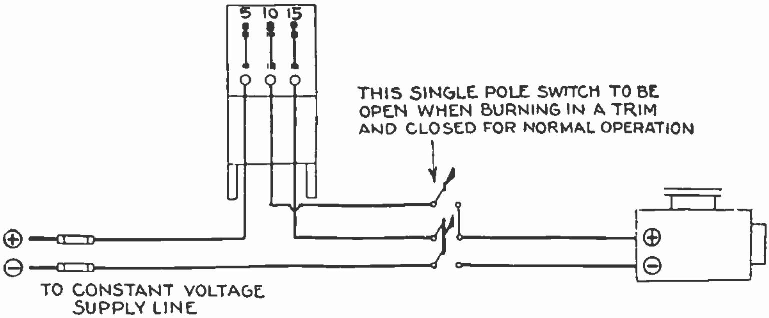


FIG. 7,929.—Hertner wiring diagram showing method of connecting types J, K and L, ballast rheostats.

5. Signal system such as phones, buzzers, indicators, etc.

This chapter treats only of projector wiring, the sound system wiring being presented in Chapter 203. Considerable information on theatre wiring in general being given in Chapter 204 in question and answer form.

A. C. Wiring.—Where incandescent lamps are employed as the light source the connections for each projection unit are made as shown in figs. 7,926 to 7,928.

When two or more projector units are installed, the wiring shown in these diagrams is done in respective multiples and

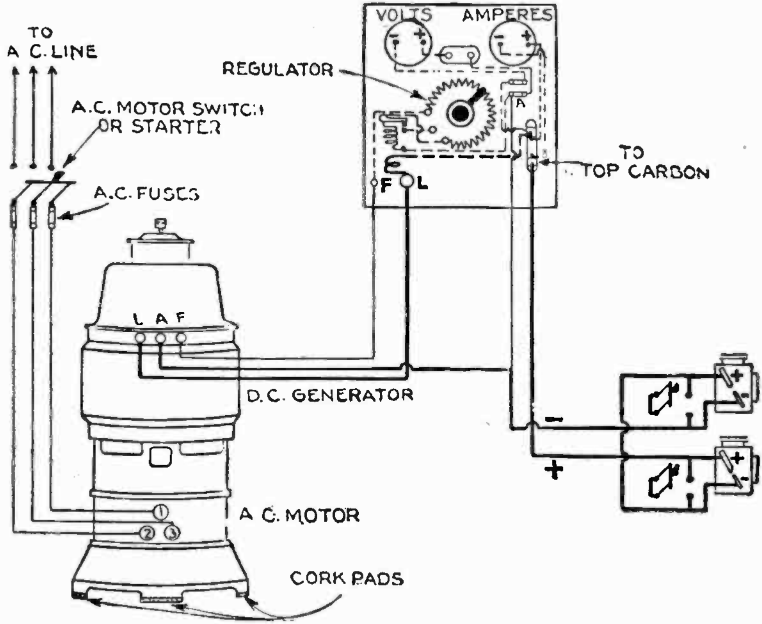


FIG. 7,930.—Wiring diagram of double arc three phase transverter with control panel. Transverter should be on a floor that is free from vibration. It is not necessary to bolt it down. Set the machine on the four cork pads which are provided for this purpose. *Wiring.* Make connection from the *a.c.* line service to the starting switch and from the starting switch to motor terminals as shown. On two or three phase equipment close the switch and make sure that the armature rotates in the direction indicated by the arrow on the top cap. If the armature rotate in the wrong direction, it must be corrected by reversing the leads to one phase of the motor terminals. Single phase equipment will always start in the proper direction when connections are made according to the diagram. *Caution.* Do not change connections inside of transverter unit to correct direction of rotation or polarity. The machines are all checked up complete with their equipment when tested. The motor must be connected to proper side of the line and connections to panel must be made correctly to bring polarity of the instruments and lamp carbons correct. *Fuses.* Fuse the *a.c.* motor side of these machines only. The *d.c.* generator circuit does not require fuses or switches other than on wiring print accompanying the machine. The *a.c.* fuses at the *a.c.* motor starting switch must be of large enough capacity to carry the maximum load of the machine. Fuse according to voltage of line service. *Wiring to lamps.* Use wire of size proper for capacity of machine to connect from L and A, on the transverter to panel board, and lamps. No. 14 or No. 12 size wire may be used to connect F, on transverter to the F, on the field regulator in panel board.

distribution to the units is made from the *a.c.* panel board preferably located in the kinebooth. Miscellaneous branch circuits may also be taken from the panel board thus comprising a simple wiring system.

Incandescent projector lamps are adaptable only to installations where a small picture is desired and the distance to the screen is short, rarely in excess of fifty feet.

These installations are usually made in small schools and auditoriums

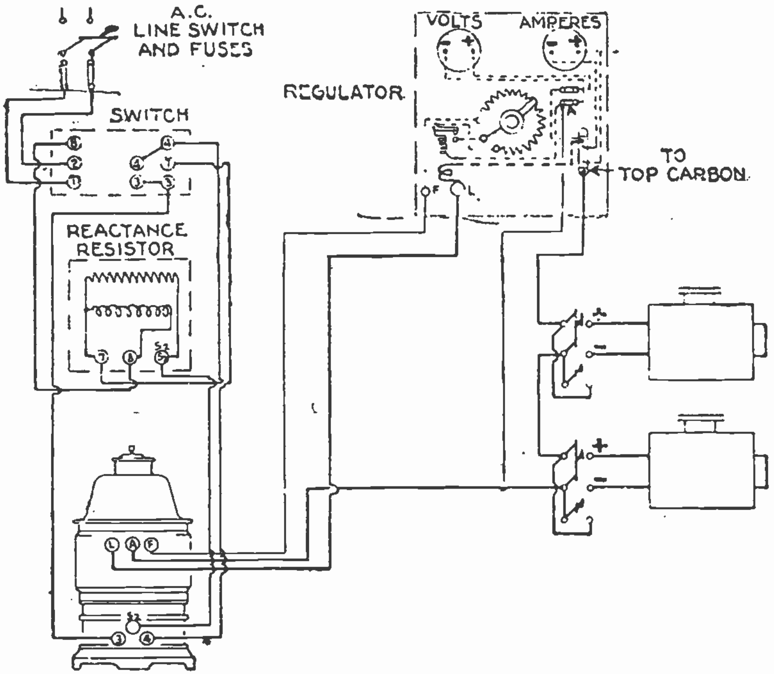


FIG. 7,931.—Wiring diagram of double arc *single phase* series arc transverter with control panel. To start throw the handle of the switch to the position marked *start*. Hold there until unit comes up to speed, then throw over to position marked *run*. The starting time is approximately 20 to 30 seconds.

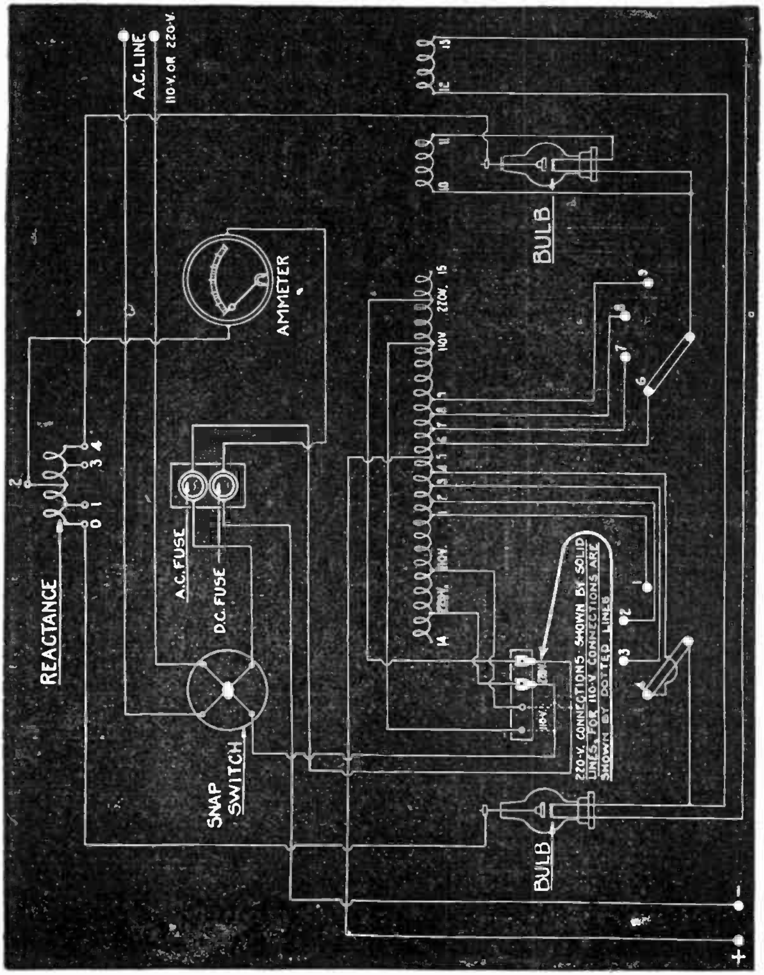


FIG. 7,932.—Wiring diagram of Forest M. P. 15 rectifier.

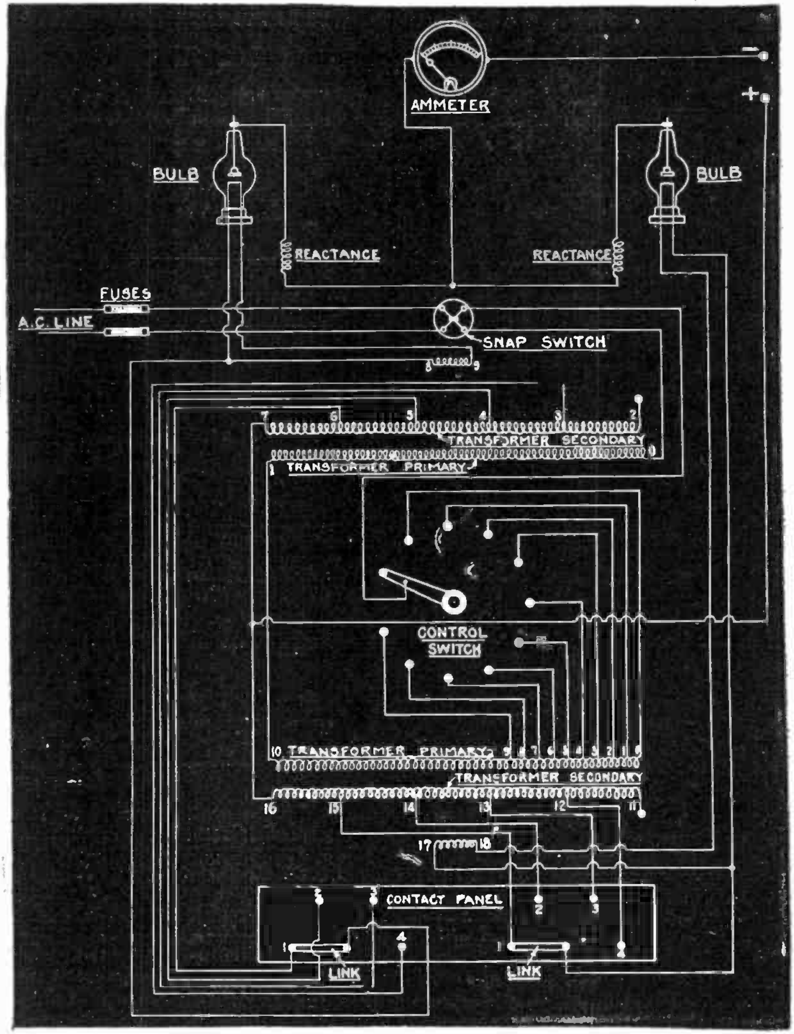


FIG. 7,933.—Wiring diagram of Forest M. P. 30 rectifier.

and the commercial use in small theatres is being abandoned. When incandescent lamps are operated on *d.c.* circuits, connections as shown in figs. 7,926 and 7,927 are used.

A. C.—D. C. Wiring.—As the size of the picture and the distance to the screen increases, greater demand is made on the light source. The next step is to employ an arc lamp. Alternating current at the arc results in an unsteady and flickering light. Direct current at the arc results in a steady light and as the temperature at the positive carbon is greater than at the

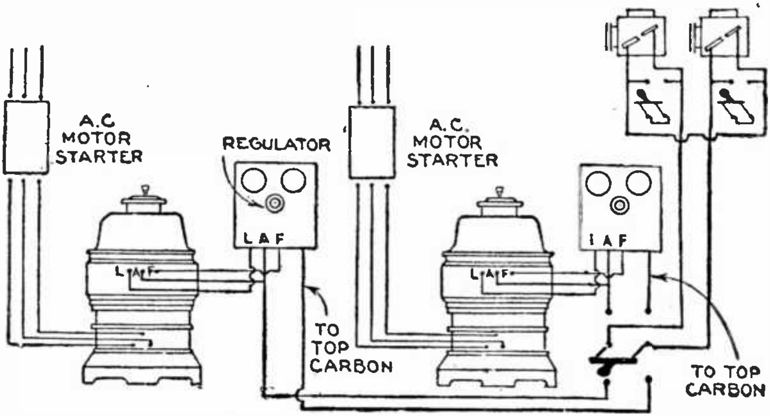


FIG. 7,934.—Wiring diagram for two double arc transverters connected for emergency use.

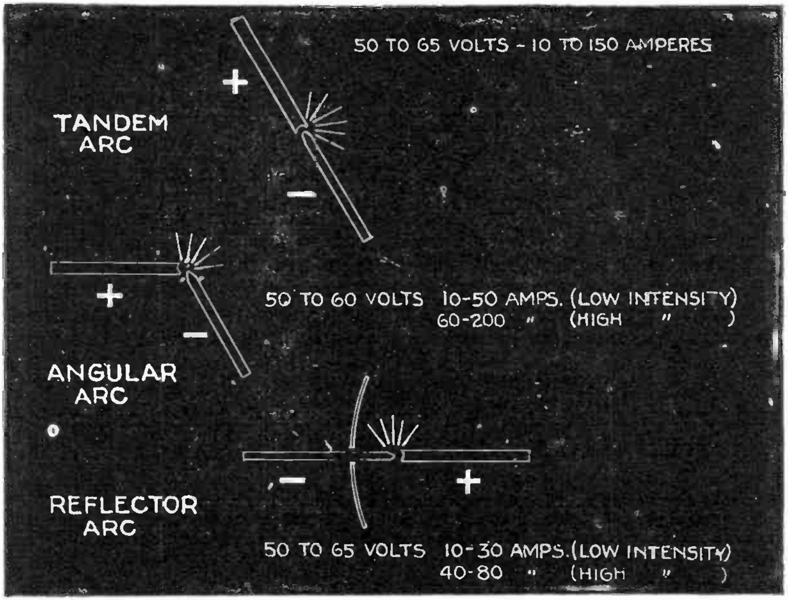
negative carbon, the light is generated at a concentrated point which is an advantage to the optical or lens system.

When the *d.c.* demand is low, an *a.c.* to *d.c.* rectifier with ballast characteristics is sometimes employed for each projector unit. This wiring diagram is shown in fig. 7,932.

When two or more projector units are installed, the wiring is done in multiples as previously described, and the *a.c.* distribution system remains the same.

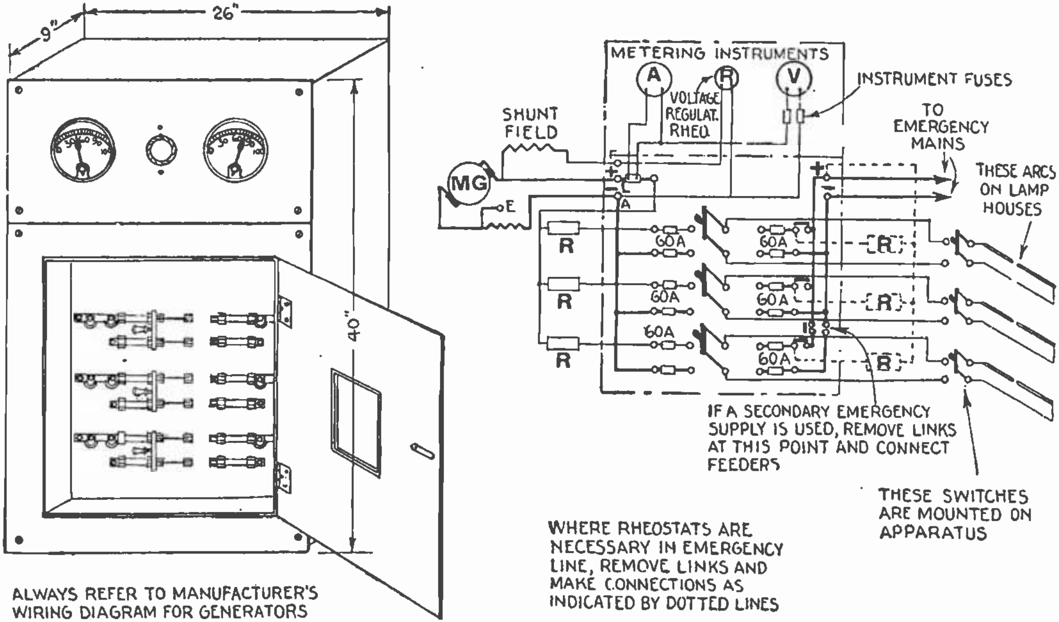
D. C. Wiring.—To meet the various requirements at the light source, several types of arc lamps have been designed. The standard types are:

1. Tandem arc. 2. Angular arc. 3. Reflector arc.

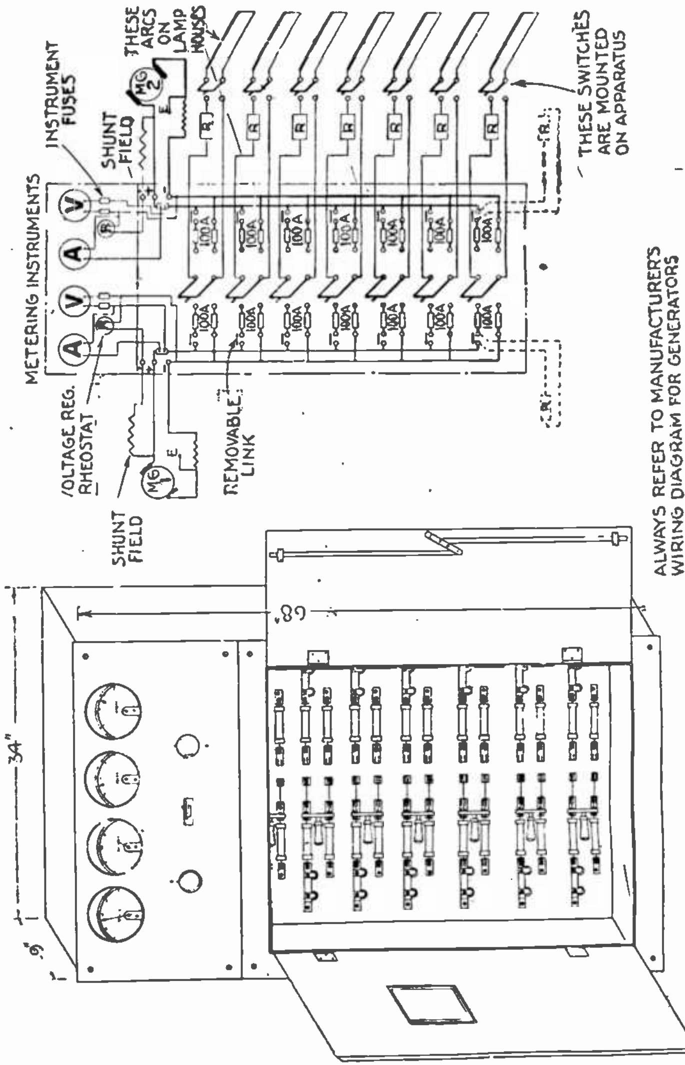


Figs. 7,935 to 7,937 —Various projector arcs. Fig. 7,935, tandem arc; fig. 7,936, angular arc; fig. 7,937, reflector arc.

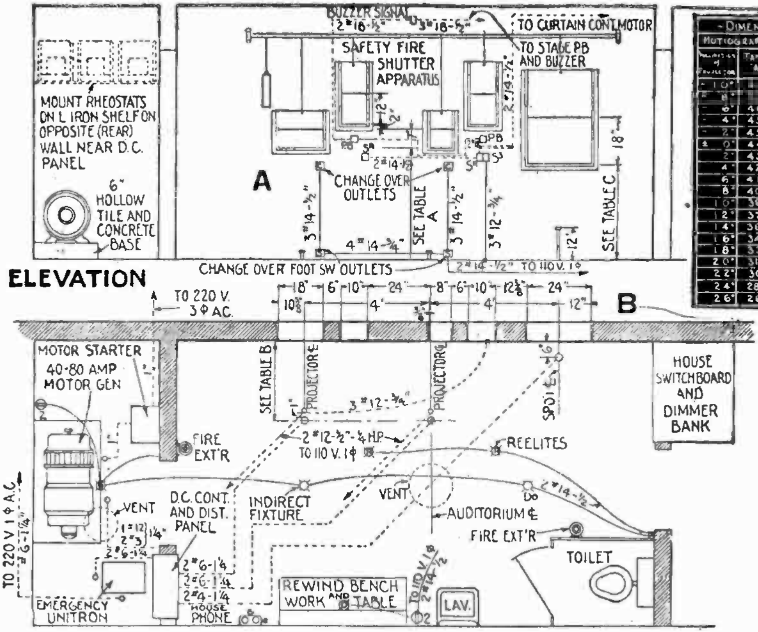
As conditions further increase the demand at the light source and by the grouping of several projectors the *d.c.* demand continually rises. Due to the special characteristics and requirements made on the *d.c.* supply, an independent system is desirable. Special generating apparatus has been designed which, of course, requires independent control and distribution.



FIGS. 7,938 and 7,939.—National *d.c.* control cabinet and wiring diagram, type SG-63.



FIGS. 7,940 and 7,941.—National *d.c.* control cabinet wiring diagram, type DG-107.



- DIMENSION TABLES -

MOTIOGRAPH F & H			SPOT
[illegible]	TABLE "A"	TABLE "B"	TABLE "C"
-10°	[illegible]	35 [illegible]	50
-8°	[illegible]	34 [illegible]	49
-6°	46 [illegible]	33	48
-4°	45 [illegible]	31 [illegible]	47
-2°	45 [illegible]	30	46
0°	44 ¼	28 [illegible]	45
2°	43 [illegible]	30	44
4°	42 [illegible]	31 [illegible]	43
6°	41 [illegible]	33	42
8°	40 [illegible]	34 [illegible]	41
10°	38 [illegible]	35 [illegible]	40
12°	37 [illegible]	37 [illegible]	39
14°	36 [illegible]	38 [illegible]	38
16°	34 [illegible]	[illegible]	37
18°	33 [illegible]	[illegible]	36
20°	31 [illegible]	42 [illegible]	35
22°	30	[illegible]	34
24°	28 [illegible]	44 [illegible]	33
26°	26 [illegible]	45 [illegible]	32

FIGS. 7,942 and 7,943.—Typical kinebooth layout for motiograph machines, types F and G, and Brenkert spot C-4 or equal. *Note A.*—Cut both projection apertures 1_"x_". If stereopticon attachment is to be used on both machines. *Note B.*—Flare each side of all apertures to line with side of proscenium arch, and slope bottom to line with foot. *Note C.*—Dimensions in table C are based on ¢ of spot lens being 43" from floor (O inclination). If this distance be more or less, add or deduct from table. ***Note D.***—Information on the layout is to convey data regarding projection equipment only. Dimensions are based on the use of two motiograph type **F** or **H**, projectors and one spotlight (Brenkert C-4 or equal) generator and wire sizes are figured for low amperage reflector arc lamps on the projectors, and with not over 50 amp. on the spotlight.

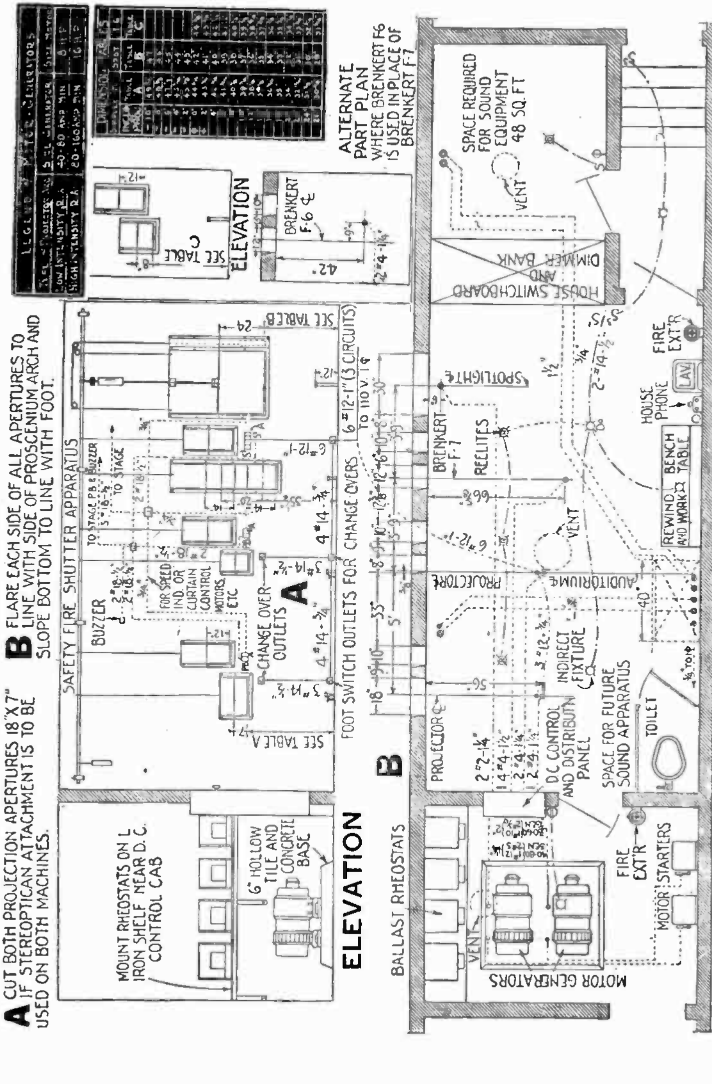
The wall space available in the kinebooth being limited, it is desirable to lay out the wiring system as compact and efficient as possible. This can be effectively accomplished by combining the control and distribution in one cabinet as shown in figs. 7,938 to 7,941.

Location.—After a thorough analysis of the requirements is made, a complete detailed drawing showing the exact location of each piece of apparatus should be prepared. This drawing serves as a guide to the wireman on the job and as a check against the electrical and structural requirements of the kinebooth. Figs. 7,942 and 7,943 is an example of a small kinebooth plan designed for installation of two motion picture projectors (without sound equipment), one small spotlight, one motor generator, one *a.c.* to *d.c.* rectifier for emergency use, etc.

Figs. 7,944 to 7,947 is a plan designed for installation of two motion picture projectors (with sound equipment), one double lamp house dissolving lantern slide and effect projector, one heavy duty spotlight, two motor generators, switchboards, dimmer bank, etc.,

Auxiliary Equipment.—There is usually a considerable amount of auxiliary equipment installed such as, rewind apparatus, film renovating machine, inspection and rewind table, carbon racks, film vaults, supply cabinets, fire extinguishers, etc., some of which occupy wall space and careful consideration should be given to the location of these items so that electrical outlets can be provided where needed and that the wall space is properly allocated.

Light Wiring.—This section covers the wiring for small motors, general lighting, reelite inspection lamp, plug receptacles, etc., where the demand is under 1500 watts per circuit and it is good practice to provide a separate regulator type of



Figs. 7,944 to 7,947.—Typical kinebooth layout for Simplex model M machines. Brenkert F7 effect (or F6 slide projector) and Brenkert C3 or equal spotlight.

panel board to take care of the kinebooth requirements only and not to connect these circuits to any panel board outside of the kinebooth. Always provide a liberal number of spare circuits for future requirements.

Power Wiring.—This section covers the wiring necessary for all motors one *h.p.* and above, such as motor generators, ventilating equipment, heavy duty curtain control, etc. This is done in the standard practice of wiring; feeders and branches are run from the power distribution switchboard to the line switches thence to starters and motors.

The control should be located in the kinebooth and as wall space is limited, remote control starters should be used in almost all instances. It is good practice to provide the feeders and branch circuits in double the size of rated requirements as in many instances a change in equipment in the kinebooth places unusual demands on the wiring system.

Sound Wiring.—This section is covered in Chapter 203.

Signal System.—A complete signal and communication system should be installed in every kinebooth. An inter-communicating telephone system is most essential. This should connect with the stage, dressing rooms, orchestra leader, ticket booth, manager's office, etc.

It is also desirable to supplement this with a signal system of buzzers, drops or pilot lights between the stage director, stage electrician, orchestra leader, etc., as a means of conveying cue signals to control the operation of the various apparatus. This wiring should be done in multi-conductor lead covered cable with sufficient spare conductors provided for future requirements.

Conclusion.—From past experience it has been observed that in the advancement made in design and application of various types of light projector apparatus, continued increase has been made on the demand for electric current not only in load requirements but in electric current of various characteristics. The introduction of sound with the motion picture has brought with it a sensitive and complex system of wiring. Satisfactory operation of all the combined equipment depends on the proper supply of electricity at points of demand. Therefore, the electrical wiring should be installed in the best manner possible with materials of highest quality.

Tight connections, well soldered joints, good insulation, shielding and guarding of conductors are all very important. Many responsibilities are placed on the electrical contractor and wireman. It is advisable to consult with a reliable and experienced engineer and be guided by one person in directing the installation of the wiring and equipment.

TEST QUESTIONS

1. *Name the simple elements of the projector system.*
2. *Mention five provisions of kinebooth wiring.*
3. *What is the proper placement of a projector?*
4. *Name the various controls for incandescent lamp source.*
5. *What are the conditions requiring* a.c.-d.c. *wiring?*
6. *How are ballast rheostats connected?*
7. *Name three kinds of arc.*
8. *Describe light and power wiring.*
9. *Draw a diagram of double arc, single phase, series arc transverter with control panel.*
10. *Draw a diagram of a multiple arc three phase transverter with control and distribution panel.*

CHAPTER 203

Booth Wiring for Sound

Kinebooth Wiring 2

To illustrate the method of wiring sound reproducing apparatus the RCA Photophone system is here presented.

Generally speaking, RCA Photophone sound reproducing equipment is divided into two general classes:

1. Equipment with power supply for amplifier racks furnished by motor-dynamo sets.

2. Equipment with power supply obtained wholly, or in part from vacuum tube high voltage rectifiers.

These equipments are known respectively as SPU (socket power unit) and MG (motor dynamo) equipment. Representatives of these two classifications are the PC-10 equipment and the PG-13 equipment which will be described in more detail in the following paragraphs.

Type PG-13 Equipment.—This is the motor-dynamo operated equipment consisting of an amplifier with a motor generator set for power supply, two sound heads, two synchronous discs, one booth monitor and one stage speaker with directional baffle. Ordinarily, it is intended that this equipment be completely installed in the projection room, with the exception of the stage speakers, of course.

All power for the type PG-13 equipment is supplied by a three unit motor dynamo set. One dynamo is 600 volts, and supplies all plate and photo-cell polarizing voltages.

The second dynamo delivers the current at 12 volts for the exciter lamps, tube filaments, monitor speaker field and stage speaker field. The

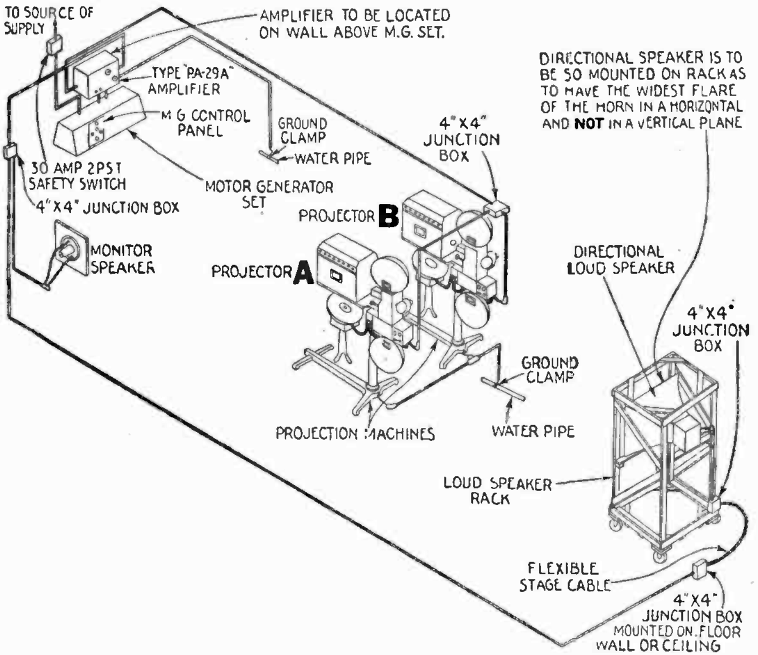


Fig. 7,943.—General layout of a typical RCA type PG-13 installation showing inter-apparatus conduit runs.

12 volt machine is excited from the 600 volt machine. For standard equipment the motor is a 115 volt, single phase, 60 cycle machine. Whenever necessary, a 110 volt *d.c.* motor and *d.c.* projector motors are supplied.

The dynamo set is enclosed in a metal cage approximately 48 ins. by 18 ins. by 30 ins. high. This cage is made so that the front and back are removable by taking out about one half dozen thumb screws. The motor dynamo set is mounted on a separate base and is not mechanically connected to the cage base.

Type PG-13 Control Panel.—This is built on to the motor dynamo set and is an integral part of it. This panel is mounted at the middle of the motor dynamo set and stands approximately 1 ft. off the floor, flush with the metal cage.

The controls on this panel consist of field rheostats, starting switch and two meters. The meters indicate the two voltages which are controlled by the field rheostats. The rheostats are built in tandem with a single knob similar to that used on broadcast apparatus. The knob is pushed in to turn one rheostat, and is pulled out to turn the other.

Turning on the starting switch puts the dynamo set in operation, and consequently places the whole set in operating condition. The dynamo set itself is mounted on a felt base, which is fire proofed. This is provided to eliminate noise due to vibration of the machine.

Type PG-13 Amplifiers and Tone Control.—The amplifier unit consisting of voltage and power amplifiers, is built into a single unit somewhat similar in its general appearance to the socket power unit amplifier.

The voltage amplifier is made up with a combination of transformer, resistance and impedance coupling. It consists of three stages using UX-112A tubes.

The power amplifier consists of four UX-250 tubes operating in parallel push-pull.

In addition to the amplifier proper, there is a separate filter unit for filtering the plate supply and polarizing voltages. The entire amplifier is contained in a cabinet which measures approximately 22 ins. by 22 ins. by 10 ins. deep. This cabinet is designed for mounting on the wall. In addition to the amplifier and filter units, the amplifier cabinet contains a volume control and compensating unit.

The relay type of fader is used and the amplifier cabinet is provided with pilot lights to indicate which projector is in operation. The amplifier has practically the same input terminal connections as the type PG-10. The output circuit of the amplifier has been designed to operate a single stage loud-speaker and a dynamic monitor, although, by making the

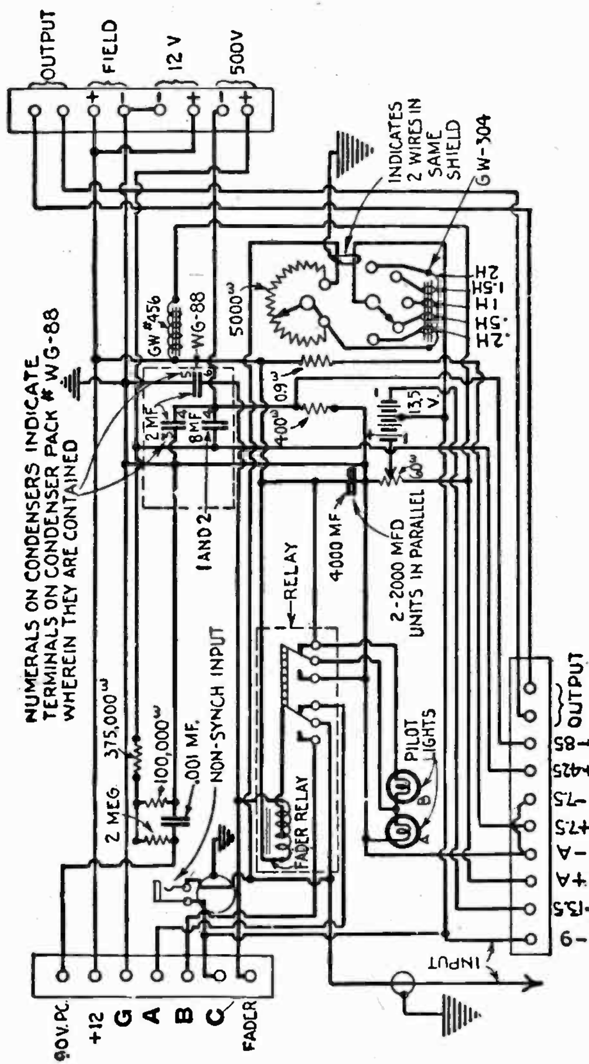


FIG. 7,949.—Wiring diagram of RCA type PG-13 sound equipment filter unit.

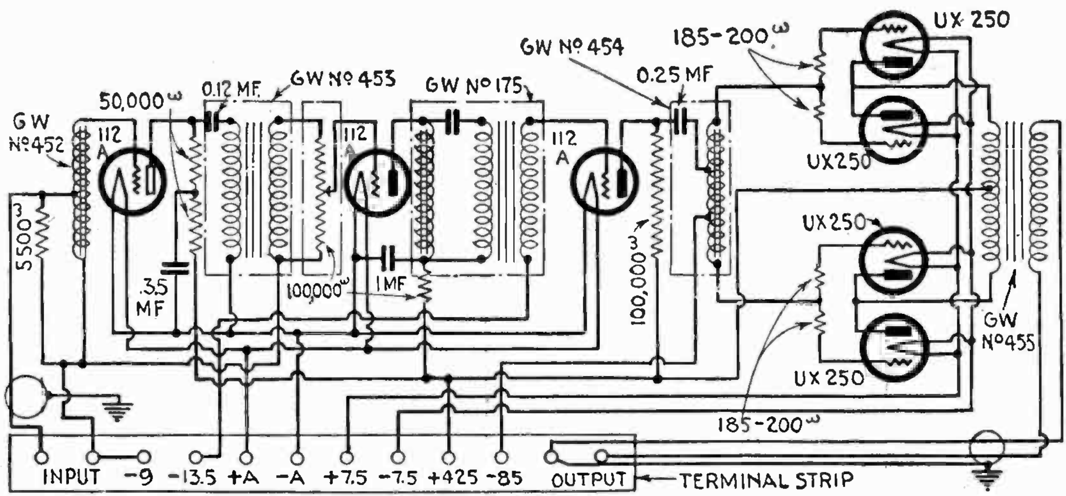


FIG. 7,950.—Wiring diagram of RCA type PG-13 sound equipment amplifier unit.

proper connections, two or four loud speakers may also be used. A phonograph input jack has been provided for the use of a non-synchronous phonograph.

Wiring for Filter Unit.—Fig. 7,949 illustrates the wiring of the filter unit used on the type PG-13 equipment. Three terminal boards are provided.

The one in the upper right hand corner provides for the connection of the filter unit to the motor dynamo set which supplies all power to the type PG-13 equipment, and also for the connection of all loud speakers.

The terminal board in the lower left hand corner provides terminals for the power supply from the filter unit to the voltage and power amplifier, and the terminal board in the upper left hand corner provides the terminals for the power supply to the sound heads, and for the incoming signals from the projectors.

The two lower terminals on the upper right hand terminal board are marked + and — 500 volts respectively. These terminals are connected direct to the 600 volt dynamo in the motor dynamo set.

The next two terminals above are marked + and — 12 volts respectively, and are wired to the 15 volt dynamo. The two binding posts marked + and — field, are for external connections to the fields of the monitor and stage speakers. The two upper terminals labelled *output*, supply the sound currents to the monitor and the stage speaker voice coils.

The binding posts on the terminal board at the lower left-hand corner of the diagram are connected to corresponding binding posts in the voltage and power amplifier illustrated in fig. 7,950. The terminals marked + and — A, are connected to the filaments of the UX-112A radiotrons and the terminals marked + and — 7.5, are connected to the filaments of the UX-250 tubes. The terminals marked — 9, and — 13.5, are the grid bias connections for the UX-112A radiotrons.

The terminal marked —85, is the grid bias connection for the UX-250 tubes while the terminal marked +425, supplies plate voltage to all tubes. The two terminals labelled *output* are connected from the output of the power amplifier to the output terminals on the upper right hand terminal board and are merely for the transfer of connections from power amplifier to speakers.

On the upper left hand terminal board, the binding post marked 90 volts, is the power line to the projector photo-cell circuit. The binding post marked +12, is the exciter lamp current supply to the projector sound heads. Terminals A, B and C, are connected to the output circuit of the two projectors, C, being a common lead.

The binding post marked *fader* is connected to three way switches on the projectors which operate the fader relay. The terminal marked G. is a common ground and furnishes the return circuit for the photo-cell, exciter lamp, and fader control circuits.

The fader relay is illustrated in fig. 7,949 and is connected so as to transfer the amplifier input from one projector to the other.

It is operated by means of the three way control switches on the projector. The group of resistors and condensers shown above the fader relay are used for the purpose of protecting the equipment in the case of a defective photo-cell or some other defect in the projector's photo-cell circuits.

These resistors also act as a filter to give the desired output characteristic to this circuit.

The condenser block shown to the right of the relay is made up of two 2000 microfarad electrolytic condensers and is used to smooth the ripple in the 15 volt dynamo supply. Below this condenser is the potentiometer connected across the filament of the UX-112A's which is used for hum elimination.

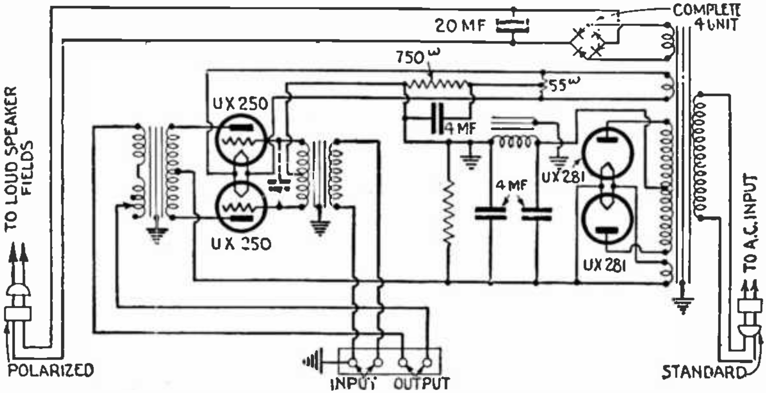


FIG. 7,951.—Wiring diagram for power amplifier. *Note:* Capacitor pack (3-4 mf. cond. 1-20 mf.). New SPU-62 includes 50 mmf. condenser across secondary of input transformer, also large radiating plates for Rectox.

The power amplifier illustrated in fig. 7,951 is used in all Photophone SPU equipment.

The larger the equipment the more power amplifier units are used. An examination of fig. 7,951 will show that its grid, plate and filament voltages are totally derived from its own power unit which is connected to any 100 volt 60 cycle *a.c.* supply.

As most 60 cycle *a.c.* supplies are of 110 volts a rheostat is incorporated on the power amplifier panel to reduce the line voltage to 100. A volt meter is also incorporated on the amplifier panel so that the operator may see when he has the proper line voltage adjustment. The amplifier stage in this SPU is a conventional push pull amplifier stage utilizing two Radiotrons UX-250.

Field supply for the loud speakers is obtained from a high current Rectox rectifier.

The schematic inter-apparatus wiring diagram is shown in fig. 7,952 and gives a general idea of the layout of the equipment. In the case of a *d.c.* installation, a small motor dynamo set or rotary converter is used to supply the necessary *a.c.* for the SPU's.

Wiring for C Batteries.—The C, batteries for all UX-112A tubes are connected at their positive end to the movable arm

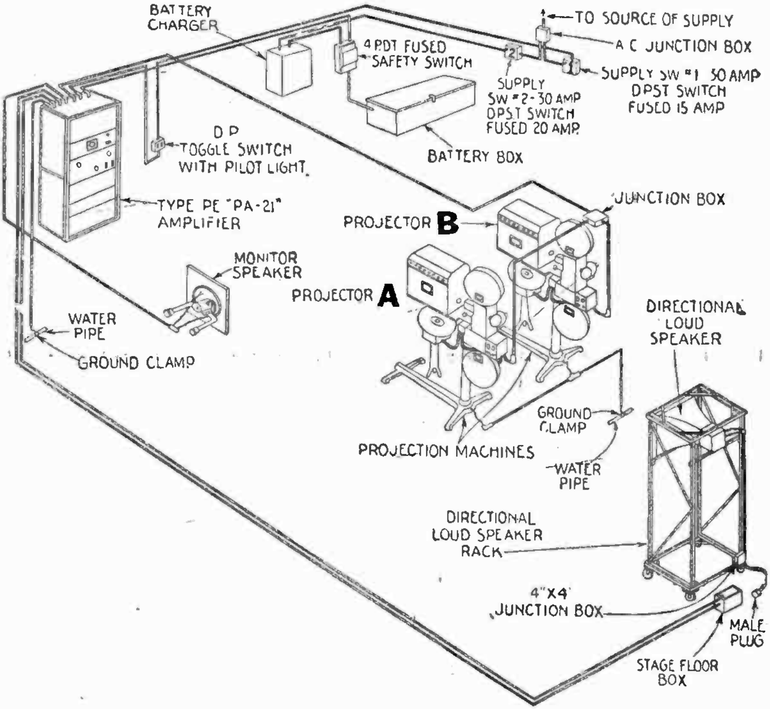


FIG. 7,952.—General layout of a typical RCA type PG-10 installation showing inter-apparatus run for directional loud speaker type installation. Exact location of RCA equipment to be determined by installation man; the directional loud speaker is to be mounted on rack so as to have the widest flare of the baffle in a horizontal and *not* in a vertical plane; stage floor box to be used on portable loud speaker rack installations only.

of the potentiometer. Proper taps are taken off the battery to give the correct C voltages. The 400 ohm resistor shown above the C battery furnishes by means of plate current RI drop, the grid bias for the UX-250 tubes. The 0.9 resistor to the right of the 400 ohm resistor is used as a fixed filament rheostat to give the proper voltage at the filament of the UX-112A tubes. To the right of this group of resistors, the C battery, and the condenser just mentioned are located and compensator, consisting of a tapped inductor and a variable resistor, which is connected in the circuit in such a fashion as to enable the operator to vary the tone quality of the output from the speakers to compensate for the ill effects of poor recording.

The condenser block and reactor shown above and to the right are connected so as to filter out the commutator ripple of the two dynamos and thereby eliminate any incident noise.

Voltage and Power Amplifier Circuits.—In fig. 7,950 is illustrated the voltage and power amplifier circuits of the PG-13 equipment. This unit is mounted on a steel base similar to that of the filter unit and is located within the same cabinet in the upper shelf. Three radiotrons UX-112A and four radiotrons UX-250 are used in this amplifier as previously stated.

The UX-112A's are connected in single stage cascade amplifying circuits while the radiotrons UX-250 are in a parallel push pull circuit.

The terminal board at the lower left hand corner of the diagram is connected to a corresponding terminal board in the filter unit as mentioned above. The first tube is coupled through an auto-transformer to the sound input from the projectors.

The plate circuit of the first tube is resistance coupled to the first interstage transformer which has a volume control connected across the secondary, this volume control thereby operating in the grid circuit of the second UX-112A.

The plate circuit of the second UX-112A is impedance coupled to the second inter-stage transformer and the third tube is resistance coupled to a push pull auto-transformer in the grid circuit of the radiotrons UX-250.

It may be seen that all tubes receive their plate supply from the +425 voltage terminal, having the voltage reduced to proper values by series plate resistors.

General Layout of Equipment.—Fig. 7,948 shows the general layout of a typical PG-13 installation and gives some idea of the layout of the equipment, although it must be understood that wide variations sometimes occur in practice due to the limitations of the construction of different theatres, and unusual power supplies, such as *d.c.* 25 cycle, *a.c.*, etc.

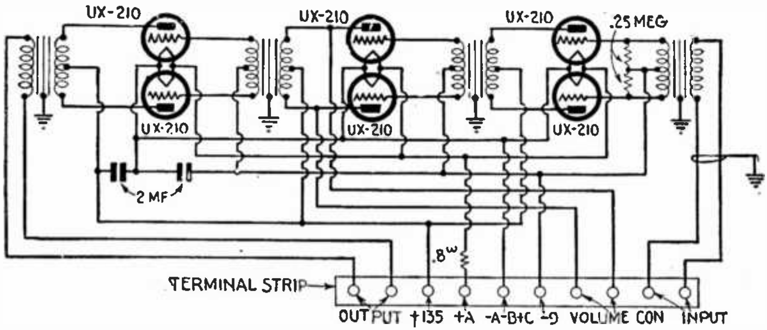


Fig. 7,953.—Wiring diagram for voltage amplifier.

Sound heads are provided for Powers, Simplex or Motiograph projectors. In general these sound heads are much the same as the sound heads used with SPU equipment but differ in that what is called an impedance type sound gate, is used.

In Photophone equipment type PG-1, 2, 3, 4, 6, 7, 8, and 10 equipment, the film is driven through the sound head by means of the constant speed sprocket which is driven through a viscous damping device.

This viscous damping device is a mechanical filter constructed with the purpose in view of eliminating the effects of mechanical vibration due to gear back lash, etc. This mechanical filter makes use of the cushioning effect of a spring drive damped by means of a grease lubricated friction device.

In the type PG-13 equipment another type of mechanical filter is used, consisting of a free running fly wheel which is friction-driven by the film itself as it leaves the sound gate.

Any tendency for speed variation to be introduced into the motion of the film is effectively damped out by the inertia of the fly wheel. A sprocket driven at constant speed is located below the impedance roller and pulls the film through the sound gate and past the roller. The film is held in tension at the gate by means of springs.

Optical System.—The optical system used is similar to that used in other Photophone sound heads. The exciter lamp assembly, however, is entirely different from those used in other Photophone sound heads. Only one lamp will be put in position at a time and this is carried on an easily removable base so that the lamp can be set up and focused, then the entire assembly laid aside for emergency use while another exciter lamp is set up focused and left installed for routine operation. The UX-868 photo cell is used. The sound head contains an exciter lamp, ammeter and rheostat, together with the film disc transfer switch.

Type PG-10 Amplifier.—The type PG-10 equipment contains an amplifier rack containing a battery operated voltage amplifier and the necessary B, C and photo-cell polarizing batteries. This rack also contains a socket power unit operated power amplifier which derives voltages for grid, filament, and plate from a self contained power supply unit.

Two heavy duty storage batteries are used to supply the filament current of the voltage amplifier tubes and exciter lamps. Tungar rectifiers are used to charge the storage batteries. Two sound heads, two synchronous disc attachments, one booth monitor loud speaker and from one to four stage loud speakers with directional baffles complete the equipment.

The voltage amplifier used in all RCA Photophone SPU equipment except the PG-10 is shown in fig. 7,953.

As may be seen from examination of fig. 7,953, the voltage amplifier is a conventional push pull amplifier of three stages with transformer coupled input and transformer coupled output. The tubes are operated at a plate voltage of +135 and a grid voltage of −9. The necessary filament voltage is obtained from a 12 volt storage battery mentioned previously. The 0.8 ohm resistor in the positive filament lead reduces the battery voltage to the proper value to light the tubes.

In fig. 7,953, the volume control is shown as a variable resistor connected across the plates of the second stage tubes, which permits of a remote volume control that operates without loss of quality.

The two *mfd*. condensers by pass the radio frequency currents around the B and C, batteries. The voltage amplifier is mounted on a steel base, all tubes operating in the vertical position. The type PG-10 voltage amplifier is similar in all respects with the exception that it uses UX-112A tubes and a grid circuit volume control instead of the plate circuit volume control. The grid circuit volume control does not permit a remote volume control and is therefore mounted directly on the amplifier rack. This amplifier is described rather than that of the PG-10 since the differences are very slight and this voltage amplifier in itself is representative of all other Photophone SPU equipment. The output of the voltage amplifier is sent to the amplifier shown in fig. 7,951.

TEST QUESTIONS

1. *Draw a general layout of a typical sound system wiring installation.*
2. *Describe the amplifiers and tone control.*
3. *How is the wiring installed for the filter units?*
4. *How is a fader relay connected?*
5. *Describe the wiring for C batteries.*
6. *How are the voltage and power amplifier circuits installed?*
7. *Describe the general layout of equipment.*

CHAPTER 204

Questions and Answers

(For Wiremen and Operators)

The following questions and answers relating to the various branches of theatre wiring give the code requirements and other valuable information:

Ques.—How many amperes are allowed on footlights, proscenium and side lights?

Ans.—15 amperes on a branch circuit fuse.

Ques.—What size wire is used for stage and gallery pockets?

Ans.—Minimum size wire for arc pockets; No. 6 B & S gauge; minimum size wire for incandescent pockets: No. 12 B & S gauge.

Ques.—Why must conduits and gas pipes be securely fastened in outlet boxes?

Ans.—To insure an effective ground. If a gas pipe be insecurely fastened to outlet box and should current pass over the conduit system, a hole might be burned in the gas pipe at the point of loose contact, causing a gas fire.

Ques.—What is the code ruling on dimmers?

Ans.—Dimmers must be wired so that they are dead when their respective circuit switches are open.

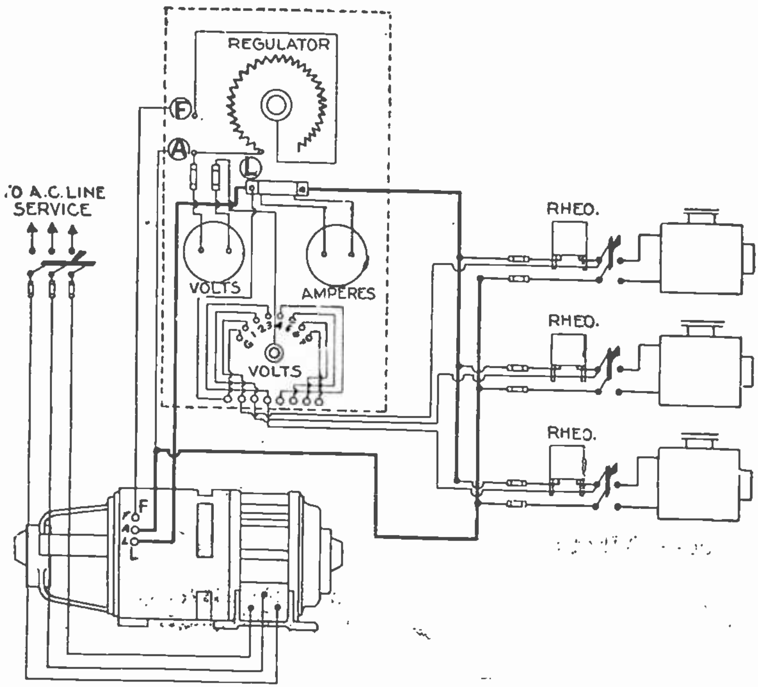


FIG. 7,954.—Wiring diagram of three phase multiple arc transverter.

Ques.—Festooned lighting on stage enclosed in lanterns, what is the code ruling?

Ans.—Joints should be staggered and metal lamp guards must be used.

Ques.—Where two services are installed in a theatre, what capacity on each service?

Ans.—One service shall be of sufficient capacity to supply current for the entire equipment of the theatre. The other of sufficient capacity to supply the emergency system.

Ques.—What is the difference between professional and non-professional moving picture machines?

Ans.—The professional type machine must be enclosed in an approved booth. In charge of a qualified attendant. Use an electric arc as the source of illumination. The non-professional type machine is so constructed that it is not possible to use full sized commerical film An incandescent lamp must be used as the source of illumination. The machine

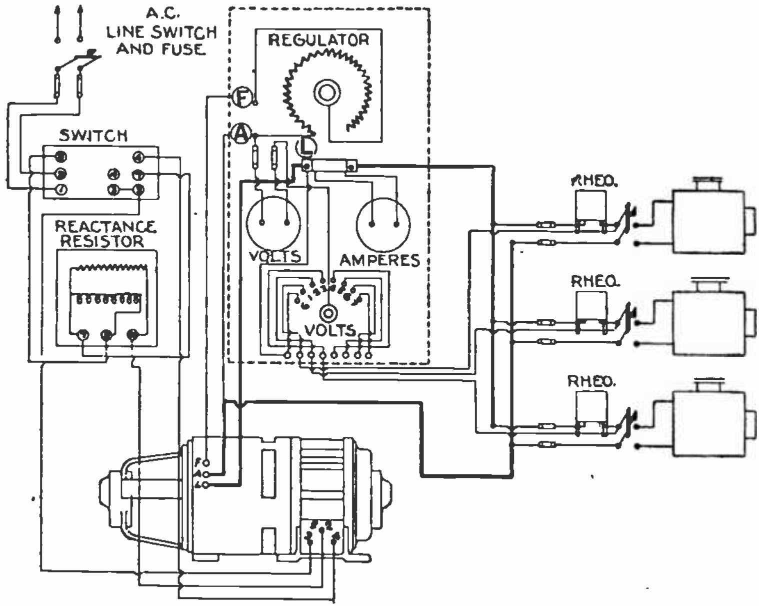


FIG. 7,955.—Wiring diagram of single phase (split phase starting) multiple arc set.

should be marked "For use with slow burning film only." Machines using slow burning film only are approved for use without booth.

Ques.—How must a motion picture booth be ventilated?

Ans.—By means of a vent pipe having a cross sectional area of not less than 78 sq. ins. and this vent should lead to the outside of the building or to a special non-combustible flue. Draft in vent pipe must be maintained by an exhaust fan having a capacity of 50 cu. ft. of air per minute, connected on emergency service, controlled outside booth.

Ques.—What precautions and requirements must be observed in the installations of storage batteries? Give reasons for these requirements.

Ans.—Storage battery rooms must be ventilated. Because of the danger from gas fumes when charging. Wiring should be exposed and painted with P. B. or similar compound. The wiring being exposed to the air reduces the possibility of corrosion of the insulation and conductors by acid fumes. Storage batteries should be mounted on non-absorptive insulators. This reduces current leakage. Metal liable to corrosion should not be used in the cell connections. Because metal that has been eaten away having lost its area, the carrying capacity is reduced.

Ques.—How should 0, 00, 200,000 *cm*. size conductors be supported in vertical conduit?

Ans.—0 size 100 ft.; 00 size 80 ft.; 200,000 *cm*. size 80 ft.

Ques.—What may happen to a conductor which is heavily overfused?

Ans.—In case of excessive load the wire would become hot, this would constitute a fire hazard. The effectiveness of the insulation would be impaired.

Ques.—Give the code ruling on wiring a dressing room.

Ans.—Approved conduit or armored cable must be used to wire dressing rooms. Pendants for lights must be made of approved reinforced cord or armored cable, lamps must be protected by approved guards locked in place.

Ques.—What services are required to be installed in a theatre?

Ans.—Two separate and distinct services. One for the emergency lights. One for general lighting and power.

Ques.—Give the allowable carrying capacities of at least five different sizes of wire with which you are familiar.

Ans.—No. 18, 3 amp.; No. 14, 15 amp.; No. 12, 20 amp.; No. 6, 50 amp.; No. 1, 100 amp.; No. 00, 150 amp.

Ques.—What are the insulation resistances of a building between conductors and ground of 25, 100, 400 amperes?

Ans.—Up to 25 amperes, 800,000 ohms; up to 100 amperes, 200,000 ohms; up to 400 amperes, 50,000 ohms.

Ques.—How should lights on scenery be installed?

Ans.—Fixtures should be wired internally. The fixture stem carried through to the back of the scenery and the end bushed. Fixtures should be fastened securely in place on scenery.

Ques.—On portable bunches, how should they be installed?

Ans.—Substantial metal should be employed in their manufacture. The wiring should not be exposed. Where the cable passes through the metal an approved bushing must be used. The cable must be anchored in such a manner that no strain will be brought to bear on the connections. Bunches must be kept clear of inflammable materials. Standards should not be grounded.

Ques.—How should lamp be installed in scene dock?

Ans.—Lamps installed in scene docks should be so located and guarded as to be free from mechanical injury. Lamp guards must be used.

Ques.—How should a motor generator be installed in a motion picture booth?

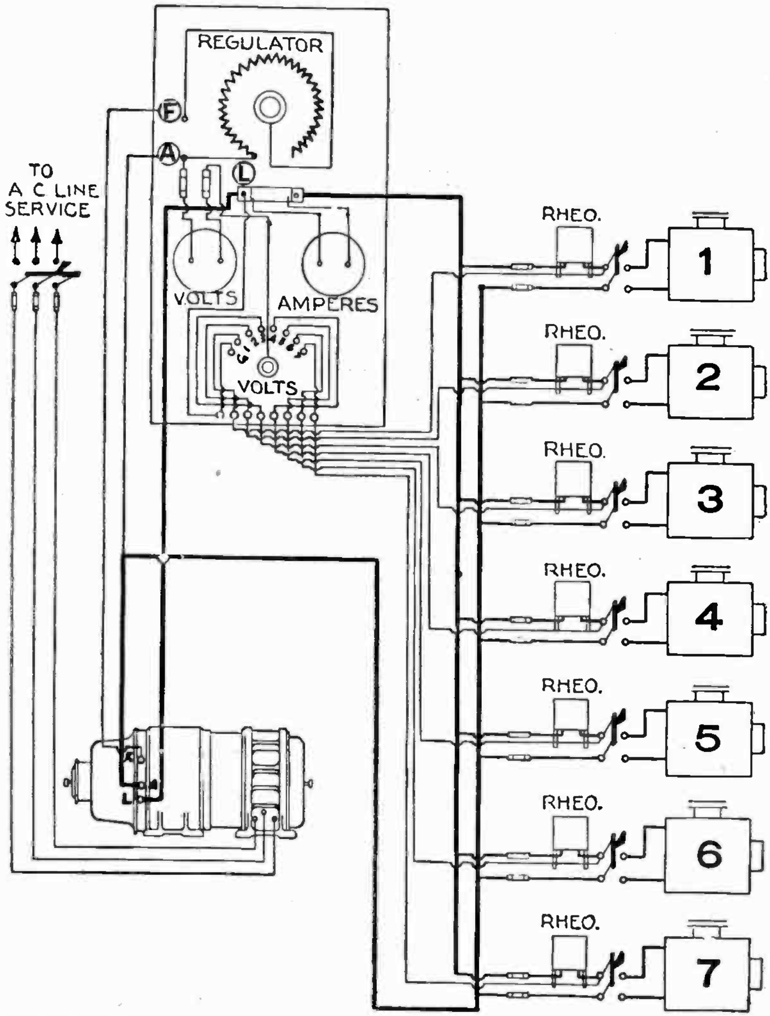


FIG. 7,956.—Wiring diagram of three phase multiple arc set showing control panel with volt meter selector switch.

Ans.—Of the totally enclosed type, conductors brought in conduit to box incorporated on motor frame, motor generator so located that it will not be in the way of M. P. operator. Properly grounded, and a disconnecting switch within sight of motor.

Ques.—What size wire is used for motion picture machine?

Ans.—The minimum No. 4 B & S gauge. Wires should be of sufficient carrying capacity for the current rating of the projector.

Ques.—How must emergency light be installed?

Ans.—On emergency service controlled from the front of the theatre.

Ques.—In stage flues and dampers how can same be controlled?

Ans.—If electrically controlled, on a closed circuit, by two single pole switches each in box with a self closing door, without a lock or latch. One at the electrician's station, the other at a place designated by the commissioner. The release device should be designed to operate at the voltage of the circuit on which it is installed.

Ques.—Why is a single phase 3 wire system used for lighting even in cases where it is necessary to introduce a 2 phase service to a building because of its power load?

Ans.—Because of the voltage fluctuation when starting motors. If trouble develop on power service, lighting service will not be interfered with.

Ques.—Where border lights are installed what kind of wire should be used?

Ans.—Slow burning wire for circuit wiring. Border light cable where flexibility is required.

Ques.—If a tap of No. 14 B & S gauge wire had to be taken off a main of No. 10 gauge wire, when would it be permissible to omit fuses where the wire size changed?

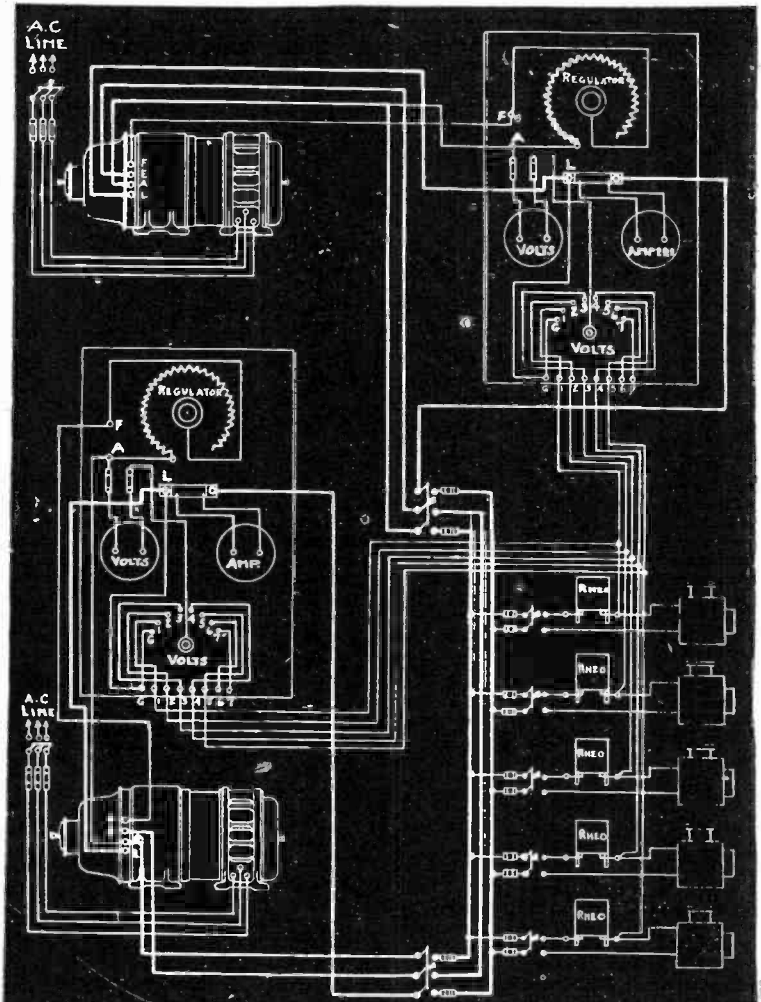


FIG. 7,957.—Wiring diagram showing installation of two multiple arc units in parallel and control panel.

Ans.—Fuses may be omitted where an extremely short tap from a No. 10 main is connected by No. 14 wire to a cut out or wherever the fuse in the larger wire will protect the smaller wire.

Ques.—Give in detail how to wire a moving picture booth for current for two standard moving picture machines, one motor generator set and 3-60 watt lamps. Give sketch.

Ans.—All conductors should be installed in rigid conduit. Run set of feeds to motor of motor generator set as per requirements of motor, from the output side of motor generator set run 2 No. 00 B & S gauge conductors to a distribution panel, from the panel 2 No. 4 B & S gauge conductors to each MP. M. outlet. Run 2 No. 14 B & S gauge wires to booth for lighting fed from emergency panel. Run 2 No. 12 wires to exhaust fan outlet fed from emergency panel. Run 2 No. 14 B & S gauge wires from distribution panel to each drive motor outlet. All motors, motor generator set, and other electrical apparatus well grounded. At distribution panel 1 switch for each motion picture machine, and 1 switch for each drive motor. Exhaust fan switch located outside booth. Lighting switch in booth.

Ques.—What is the Code ruling on portable plugging boxes?

Ans.—Live parts enclosed. Each receptacle should have a current carrying capacity of 30 amps. and be protected by fuses enclosed in a fireproof box with self closing doors. Bus bar capacity equal to total capacity of outlets. Master cable connected by lugs to box.

Ques.—How should a curtain motor be installed?

Ans.—With all live parts totally enclosed. Chain, gears, etc., clear of scenery wires brought in conduit, direct to box on motor frame. Drip pan, frame grounded. Switch at motor which will disconnect all wires from same.

Ques.—State all the rules that you can recall covering the installation of curtain motors on the stage of a theatre.

Ans.—Gears, chains, and all moving parts of motor guarded so they cannot come in contact with scenery. A switch incorporated in the motor unit itself. Type motor totally enclosed. Should be located overhead if possible. Connections at motor totally enclosed. A switch should be in circuit to disconnect all live wires from same. Should be grounded.

Ques.—How should dimmers in theatre wiring be wired with respect to the balance of the circuit of which they form a part?

Ans.—Half the lights of each border, foots, etc., should be on one side of 3 wire circuit and the other half on the other side. As one switch controls each individual border light, etc., and this switch is double pole each side being on a live leg of different polarity the balance will be absolute. The dimmer is placed in series with each outside line.

Draw a diagram of a break down switch connecting street service and a private plant.

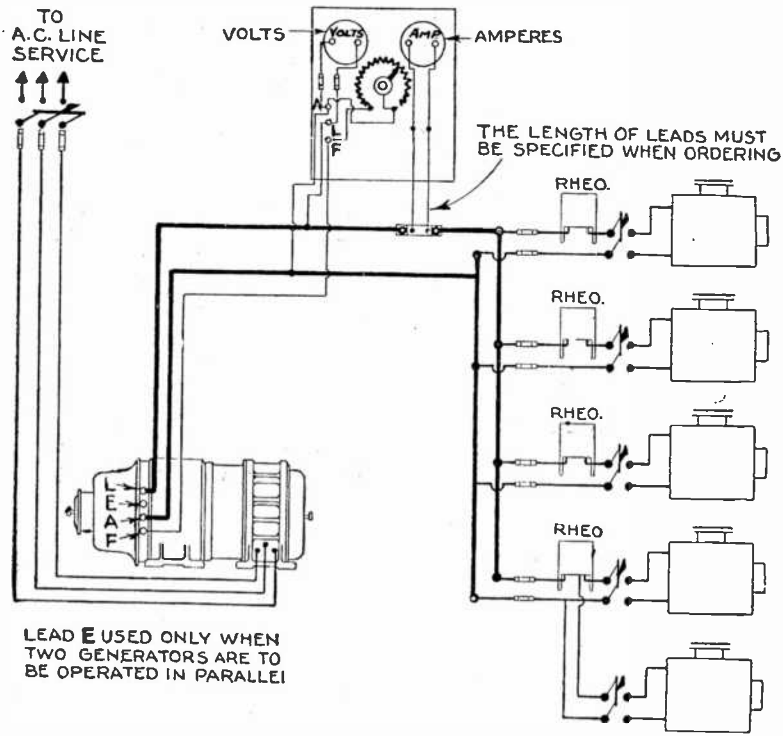


Fig. 7,953.—Wiring diagram of multiple arc transverter, three phase motor.

Ques.—What rules cover the service for motion picture house or theatre?

Ans.—Two distinct services. If one service to building the emergency service shall be hooked up ahead of the main fuse on street side of general service, and only one set of fuses between service fuses and outlets.

Ques.—How must motors of 550 volts be installed?

Ans.—Motors of this type are to be installed in power house, sub-station, etc., or in a room especially designed for the purpose. Switch at motor. Frame effectively grounded. Leads carried in conduit direct to box on motor frame. No live part exposed, and must be provided with drip pan.

Ques.—How should motor and rheostats be installed in film storage vault?

Ans.—This is forbidden.

Ques.—Name all the reasons you can that would cause excessive sparking at the brushes of a compound wound motor.

Ans.—*a*, Loose shunt field connection; *b*, bad condition of commutator; *c*, bad condition of brushes; *d*, open circuit in armature; *e*, bad adjustment of brushes; *f*, overload.

Ques.—How would you wire a moving picture booth for the machine and for lighting? Draw diagram of connections, give wire size and names of various appliances.

Ans.—Principal parts of projector are: drive motor; automatic shutter; auto. arc feed; intermittent movement; enclosed switch for arc; enclosed switch for motor; all wiring in rigid conduit; 3 No. 1 B & S gauge conductors installed as feeders, to a distribution panel in the booth. From this distribution panel 2 No. 4 B & S gauge wires to each M.P. machine outlet, also 2 No. 14 B & S gauge wires to each drive motor outlet. Individual switch for each moving picture machine and drive motor in panel. Two No. 12 B & S gauge wires feeding exhaust fan outlet, fed from emergency panel. Exhaust fan switch outside booth. Two No. 14 B & S gauge wires for lighting circuit fed from emergency panel switch in booth.

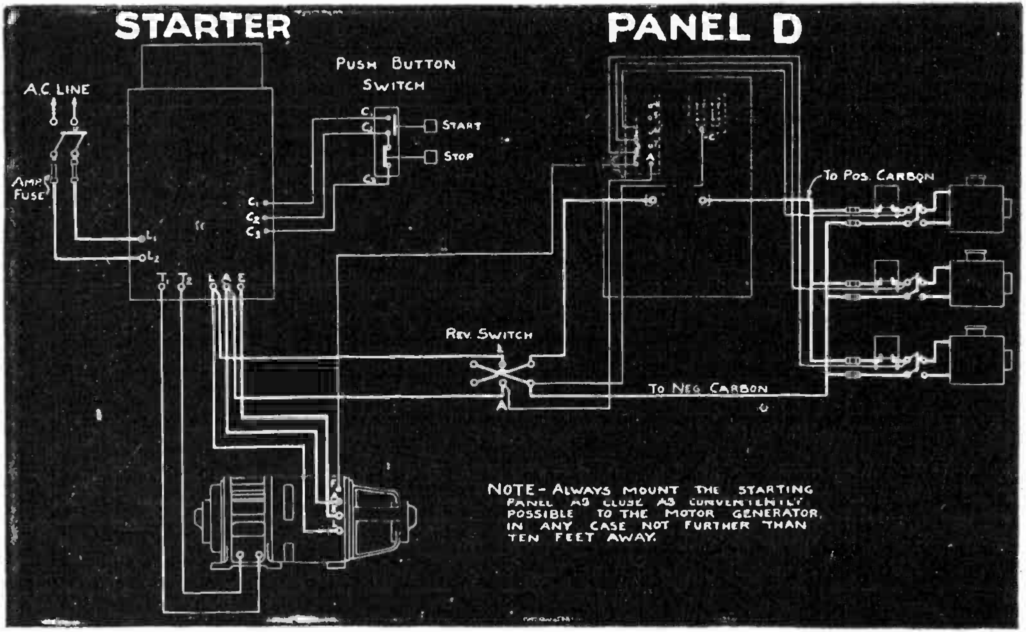


FIG. 7 959.—External wiring diagram of Hertner single phase transverter starter and panel D. The push button station, panel D, and the reversing switch can be located wherever desired. ***Wiring Instructions.*** Connect L-1 and L-2, in the starter to the *a.c.* line. Connect T-1 and T-2, in the starter to the *a.c.* motor. Connect L, A and E, in the starter to L, A and E, on the dynamo. Connect F in the panel D, to F, on the motor dynamo. Connect L and A, in the starter to the center posts of the reversing switch. Connect C-1, C-2 and C-3, to the push button station which can be located at any desired point Connect one jaw post of the reversing switch to the negative lamp bus. Connect the other jaw post of the reversing switch to L, in the panel D. Connect the C terminal in the panel D, to the positive lamp bus. Connect the C terminal in the panel D,

FIG. 7,959.—*Text continued.*
to the jaw post of the reversing switch to which the negative lamp bus has been connected. Connect the A, terminal in the panel D, to the hinge post of the reversing switch to which the A, lead from the starter has been connected. All connections are now complete and after the dash pot has been fitted with oil and replaced on the relay the unit should start when the starting push button is pressed. In making connections be sure that the wire sizes used are not smaller than noted on the diagram. ***Fuses.*** The *a.c.* fuses directly ahead of the starter must be of large enough capacity to carry the maximum load of the machine. ***Operating instructions.*** When the start button is pressed the unit will immediately start and with the reversing switch closed to one side, the meter will read properly or the needle will go off the scale past the zero point. In other words the polarity will be reversed. If this be the case it is only necessary to throw the reversing switch to the other position so that the meters will read properly. When the meter reads properly the polarity to the lamps will be correct. This motor dynamo will supply current at approximately constant voltage up to the capacity of the machine. The unit is designed to carry the high ampere load for such time as is required to burn in carbons or warm them up preparatory to a change over. The field regulator in the panel provides a means of adjusting the voltage of the dynamo to the correct operating voltage. ***Starter operation.*** As soon as the start button is pressed the four pole *a.c.* contactor will close. This connects the dynamo to the *a.c.* line and will permit the unit to start. At the same time the push button is pressed the dash pot relay is energized and this relay should close after the unit has come up to running speed. When the dash pot relay closes, the coil to the two pole *a.c.* contactor is energized, and as this contactor closes, the circuit to both the four pole contactor and the dash pot relay is opened so that only the *a.c.* motor is connected to the *a.c.* line. If the two pole contactor close too soon, further adjustment should be made on the dash pot relay by closing the oil inlet valves and turning down the plunger.

Ques.—In general, what are the principles governing the installation of electric heaters?

Ans.—Should not be located in dusty or linty places. Heating devices must have name plates as a guide to installation thereof. Smoothing irons must have an approved stand. Pilot or indicating lamps are advisable. A heater consuming over 250 watts must be fed by heater cord. Heaters of 6 amp. may be used on branch circuits. Heaters over 10 amps. must have an indicating switch. Switches must disconnect all ungrounded wires from circuit. Key sockets should not be used. Ground wires to heaters must be bolted securely to same, soldering is not acceptable.

Ques.—In wire for special electrical effects, what is the code ruling?

Ans.—Screened and so constructed that sparks cannot come in contact with inflammable material.

Ques.—What size ground wire should be used for: *a*, 0 to 100 amp.; *b*, 101 to 200 amp.; *c*, 201 to 500 amp.; *d*, over 500 amp.?

Ans.—The following size wires B & S gauge: *a*, No. 10; *b*, No. 6; *c*, No. 4; *d*, No. 2.

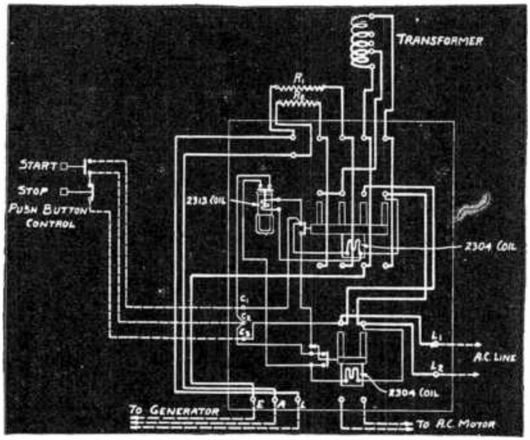


FIG. 7,960.—Back of board diagram of Hertner single phase starter 3 wire control, timing relay.

Ques.—How would you change the direction of 3 phase *a.c.* induction motor?

Ans.—By interchanging any two of the motor lead connections.

Ques.—What are emergency lights in a theatre as described in the Electrical Code?

Ans.—Exit lights, light in corridors, stairways, lobbies, and all other lights normally kept lighted during the performance.

CHAPTER 205

Electronic Television

(Questions and Answers)

What is television?

Television is vision obtained of a distant object by means of various devices identified as the transmitting and receiving apparatus. The problem of television broadly is that of: 1, converting light signals into electrical signals; 2, transmitting the electrical signals to a distant station; 3, converting the transmitted electrical signals back into light signals.

How is light converted into electrical energy?

By means of various light sensitive tubes generally known as *photo-electric tubes* or *cells*.* The cathode or light sensitive surface of such a tube consists of a certain amount of a light sensitive element such as rubidium, lithium, potassium, sodium or caesium.

When the cathode is illuminated, photo electrons or current is emitted—the emission varies in degree with the amount of light on the photo-sensitive surface of the tube. Figs. 1 and 2 shows two types of photo electric generators for converting light into electrical energy.

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*For a detailed treatment on the various kinds of photo-electric tubes, and their practical employment in industrial applications, the reader is advised to study our book on *Electronic Devices* and Their Application.

When was the first television system constructed?

In 1875 it was first proposed to imitate the human eye by a mosaic consisting of a large number of selenium photocells arranged as shown in fig. 3. The selenium cells constitute the transmitter (pick-up camera) and a group of lamps each one

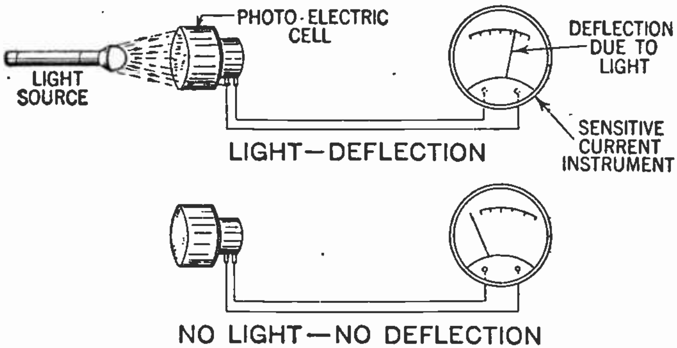


FIG. 1—Illustrating how variations in light on the photo-electric cell causes deflection of the needle on a galvanometer or other sensitive current measuring device.

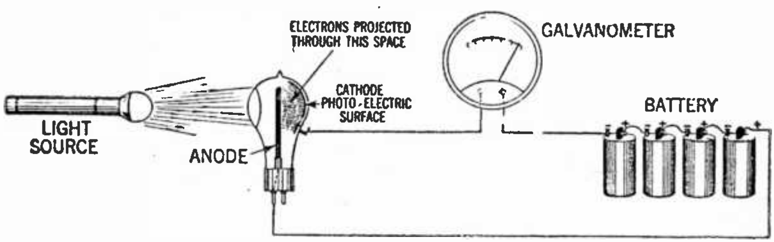


FIG. 2—To increase the amount of deflection (efficiency of light conversion) various methods of current amplification similar to that associated with current amplification in radio circuits is employed.

connected through an amplifier to its similarly positioned electro-magnet which opens a shutter connecting a light, which makes up the receiver (distant) end.

When the light-image to be transmitted is focused on the mosaic of photocells, an electric current will flow through the

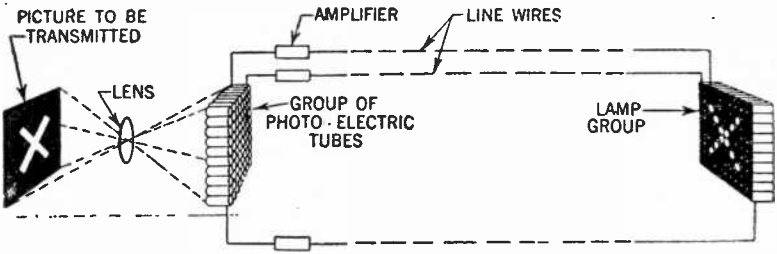


FIG. 3—Diagram of an early television system. At the transmitting end light is converted into electrical energy which when amplified will energize a magnetic shutter or similar device at the receiving end causing a reproduction of the picture. Each photo-electric cell must be individually converted to its correspondingly remotely located light element. In the case under consideration therefore, approximately 80 wires will be necessary.

circuits, connecting those of the photocells with the lamps resulting in a reproduction of the subject, which will appear as an illuminated picture.

In a system of this kind, the amount of detail that can be transmitted is obviously limited by the actual dimensions of the individual photo-elements in the pick-up area.

A television system of this nature was actually tried tentatively and used to transmit images of simple letters and figures. However, as the number of details increases so will also the number of electrical circuits and hence the obvious impracticability of the system.

What is the difference between a film motion picture and a television picture?

The main difference between the two is that in the former the reflected light from the subject is converted into a film record, and transmission from the film record to the viewing screen is effected through the agency of light, whereas in television transmission reflected light from the subject is converted into electrical impulses which are transmitted either by radio or through special cables from the point at which the subject is located to a point remotely located, and then re-converted into light images which appears upon the viewing screen. The reproduced image may originate from a subject or from a film record of the subject.

Mechanical vs. Electronic Television Systems.—Although in this section attention has been concentrated towards the *electronic* methods of television, or that system in which the electron ray tube is utilized as the scanning medium, other methods of scanning should not be entirely discarded.

In mechanical systems, the scanning process generally is accomplished by means of various modications of the Nipkow disc. See fig. 4. Here a light source is projected through a film to be televised, and according to the difference in the density of the film so that a fluctuating amount of light is applied to the photo-electric cell.

The rotating scanning disc is arranged so that it scans completely the film or object to be televised a certain number of times per second.

In this manner the light fluctuations of the unit areas of the film are accurately impressed on the photo-electric cell located on the other side of the scanning disc. This light is here converted into electrified impulses which after passing through suitable amplifiers are sent out through an antenna to a similarly equipped receiver.

A simple diagrammatical explanation of the previously discussed apparatus is shown in fig. 5. Here the light is projected

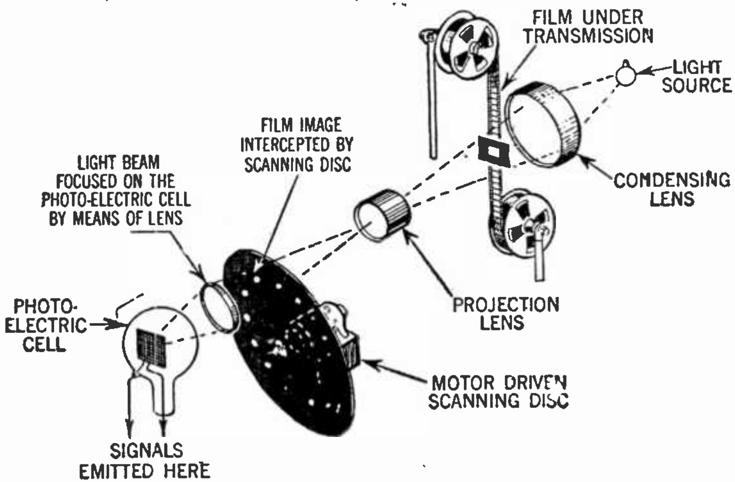


FIG. 4—Simplified view of a mechanical transmitting system.

through a scanner on the object to be transmitted, then reflected back to the photo-electric cell and is converted into electrical energy and transmitted.

The signals at the receiver are converted back into light and passed back through the scanner and on to the screen.

As the scanner rotates at exactly the same speed at both the transmitting and receiving ends, the light fluctuations are in the same position and sequence, and in this manner making it possible for the picture to be reproduced at the receiving end.

Other systems cmploys as scanning elements, a series of concave mirrors mounted as shown in fig. 6. In this system the synchronous performance is attained by reflection of some of the light into a small fixed mirror which is arranged in such a way so as to reflect it again on to a photo-electric cell, which functions to regulate the current in a circuit connected as a control of an alternating current motor. In this manner the speed of the receiving motor is kept exactly in step with that of the transmitting motor.

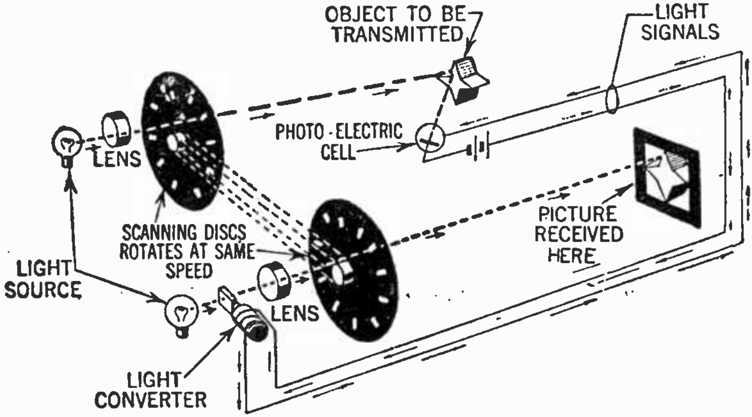


FIG. 5—Simplified view of complete mechanical television system consisting of transmitter and receiver.

Light Control.—In mechanical systems one of the most important problems is that of the light source. An ordinary tungsten lamp for example may be perfectly suitable, but when it comes to the matter of the rapid and accurate control of its brilliance in conformity with the television signals, it fails completely and must therefore be eliminated from consideration.

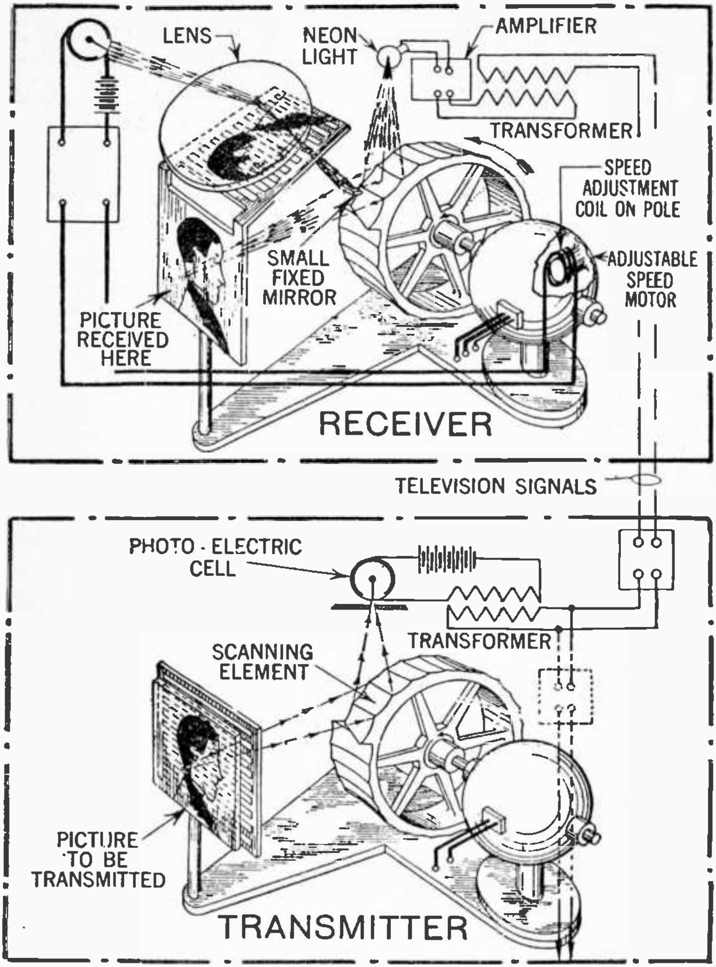


FIG. 6—Simplified view of a mechanical television system.

In the various mechanical television systems, a decided advantage is apparent when the important consideration of picture size is taken into account. In the cathode ray tube systems, the picture size is limited by the dimension of the tube face diameter, and it is mainly due to this very important setback in the electronic system, that an intense research still continues in various European countries, and from which a system may yet be developed which has all the inherent requirements which a successful television system must possess.

Summing up the points in favor of the electronic television system as compared to that of the mechanical systems, it is found that:

1. No high speed vibrating or rotating mechanical parts are required, and it is hence noiseless in operation.

2. Higher picture details are possible than in the mechanical system.

3. Circuit changes may easily be accomplished, permitting changes in scanning and picture aspect ratio.

Some of the disadvantages of the electronic television system are:

1. Picture size limited by dimension of the tube face.

2. Circuits of high potentials are necessary—safety precautions are therefore necessary.

3. Complicated circuits and a large number of tubes which are subject to renewal—increasing the operating cost.

What are the parts necessary for an electronic television receiver?

The fundamental units that make up a modern television receiver are shown in fig. 7, and consists of the following: 1. Sound receiver. 2. Vision receiver. 3. Line frequency oscillator.

4. Picture frequency oscillator. 5. Spot intensity oscillator. 6. High voltage supply unit. 7. The cathode ray tube.

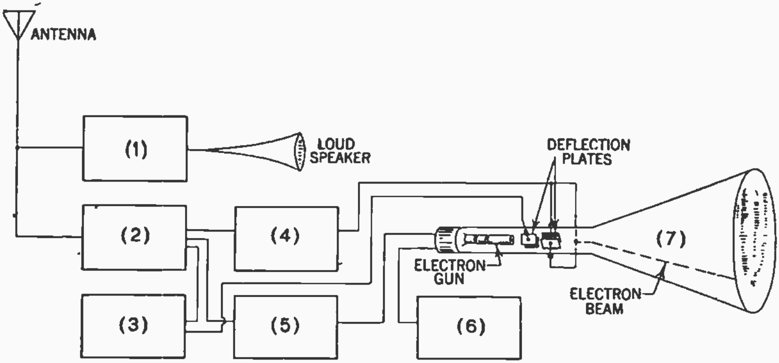


FIG. 7—Block diagram indicating fundamental unit that makes up a television receiver.

Why is it necessary to employ so many tubes in a television receiver?

The large number of tubes with a corresponding circuit complicity is unavoidable when it is considered that:

1. A set of tubes must be provided to pick up the picture signals (if ordinary tubes be employed for this purpose it may take at least a dozen to bring in and adequately amplify these signals for television reception).

2. A set of tubes complete and separate from the vision must be employed to reproduce the sound accompanying the picture.

3. In addition, several special oscillator amplifiers and filtering circuits are necessary, requiring numerous tubes as well as other components.

Where does the first step in the television of a picture take place?

The first step takes place in the television camera, sometimes identified as the *iconoscope**.

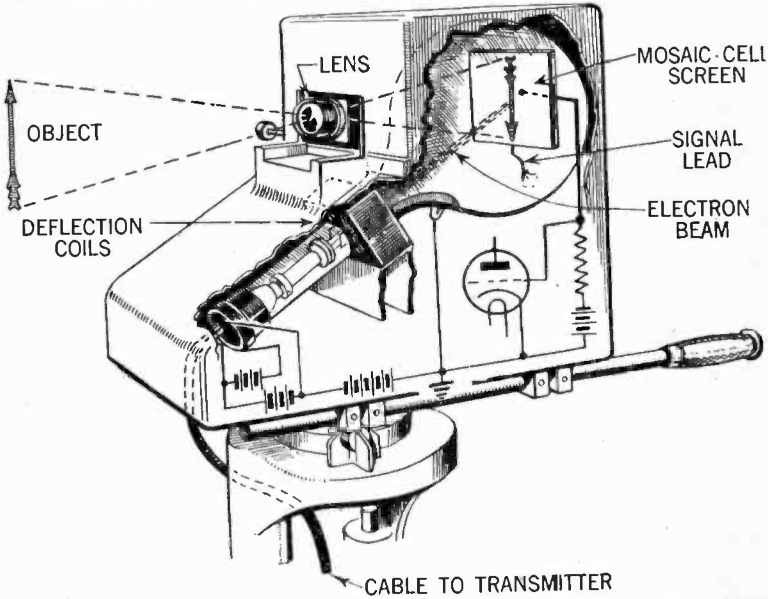


FIG. 8—Internal view of television pick-up camera, converting light impulses of the object to be transmitted to electrical signals which are sent out from the antenna, and picked up by the television receiver. This apparatus in television actually corresponds to the microphone in regular broadcast. Roughly it consists of a lens arrangement similar to that of the ordinary camera which is formed on the scene to be televised. The image is projected upon the screen of a special cathode ray tube which is mounted in the camera as illustrated.

*The name *Iconoscope* relates to a type of television transmitting tube invented by Dr. V. K. Zworykin of the Radio Corporation of America. The word *iconoscope*, taken from the Greek word "*icon*" meaning "image" and "scope" meaning observation.

Define the principle transmitting and receiving apparatus utilized by the R.C.A. electronic television system.

This system employs the *Iconoscope*—a specially designed cathode ray tube for translating the visual image into electrical

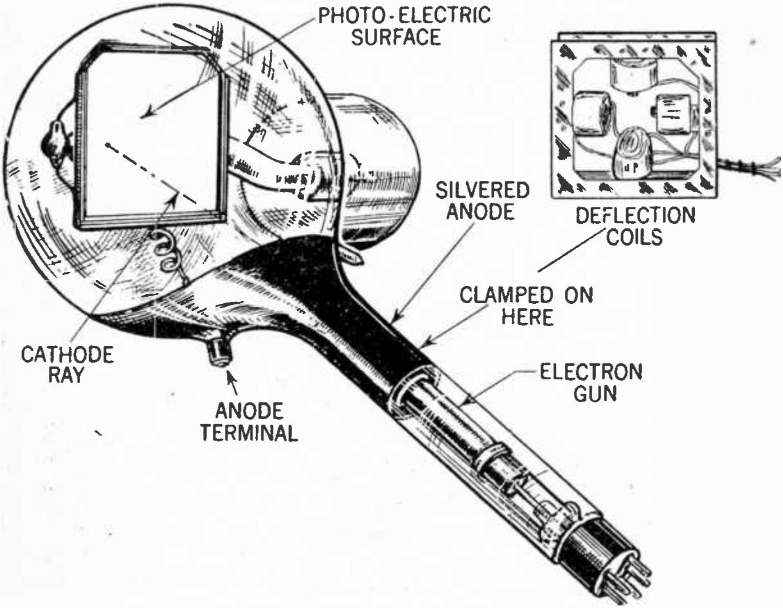


FIG. 9—Iconoscope (transmitting tube) used in the television pick-up camera.

impulses, and the *Kinescope* for transforming the electrical impulses back into the variations of light intensity to reproduce the image.

What are the parts and function of the iconoscope?

The iconoscope shown in fig. 9 consists of an *electron gun* and a large rectangular plate of thin mica enclosed in a highly evacuated glass envelope. The *main characteristics* of this mica plate is that the front side consists of a very large number of small photo-sensitive spots, which are so closley spaced that it gives the screen a *mosaic* appearance.

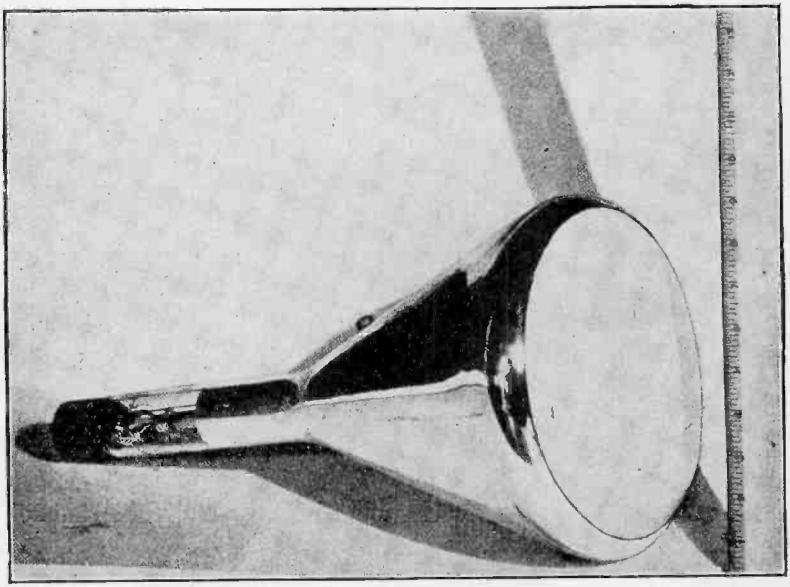


FIG. 10—The kinescope.

The electron gun when energized, produces a fine beam of electrons which is focused to a small spot on the mosaic. The horizontal and vertical movements of this beam constitute what is known as *scanning* on the mosaic screen. The other side of the mica is covered with a conductive film which is connected to a signal lead.

When the televised scene is projected on this screen photoemission takes place from each of the very large number of spots, as if there were a waste number of minute photocells, each of them shunted by an electrical condenser which couples it to a common signal lead. Now, at time of illumination of the mosaic, the condensers are positively charged with respect to their equilibrium potential, due to the emission of photoelectrons. This positive charge is in direct proportion to the received light.

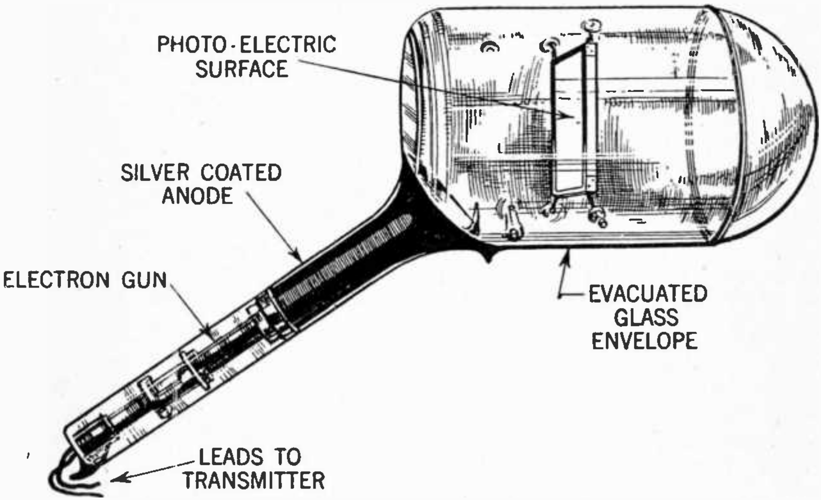


FIG. 11—Another type of cathode ray transmitting tube.

The electron beam as it scans the mosaic from left to right, neutralizes the elements over which it passes and thus releases the charges, which in turn induces current impulses in the signal lead. It is this train of current impulses which constitutes the picture signal, generated by the aforementioned action of the iconoscope, and are transmitted as television signals.

What are the principal parts of a cathode ray tube used in the reception of electronic television?

With reference to fig. 12 it consists essentially of five component parts. 1. A glass envelope, sealed for maintenance of high vacuum. 2. A cathode from which the electrons are emitted. 3. A device for concentrating controlling and focusing the electron beam. 4. An arrangement (either internal or external) for deflection of the beam. 5. A fluorescent screen on which the received image is reproduced.

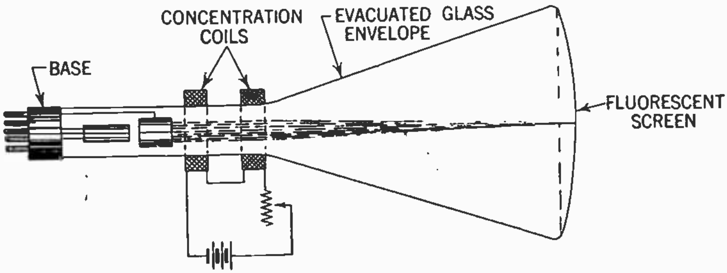


FIG. 12—Cathode ray tube with external concentration coils. The concentration coils generally consists of one or more solenoid of wire placed as shown for focusing the ray. For a practical utilization of this form of ray concentration, however, it is necessary that the position of the coils be definitely fixed and the current through them suitably controlled.

What are the classifications of cathode ray tubes used in electronic television reception?

Cathode ray receiving tubes may be classified: 1. According to the size and type of screen. 2. Focusing and deflection method. One of the fundamental requirements for any cathode ray tube is that the screen be of such diameter that the picture may be easily recognized at a nominal distance from the apparatus. The screen should in addition be clear and of a pleasing color and sensitivity.

Describe the cathode of the cathode ray tube.

The cathode is of a tubular form with a flat emitting surface covered with a preparation of barium oxide. Only the flat end, facing the fluorescent screen is covered with the electron emitting material. A tungsten heater, non-inductive wound, and insulated with a heat resisting material, is located inside the circular cathode.

What is the purpose of the first anode?

The purpose of the first anode is to stop the beam in the same manner as that of an optical stop in a lens and also to create an axially symmetric electro-static field which would start the initially divergent electrons of the beams toward the axis.

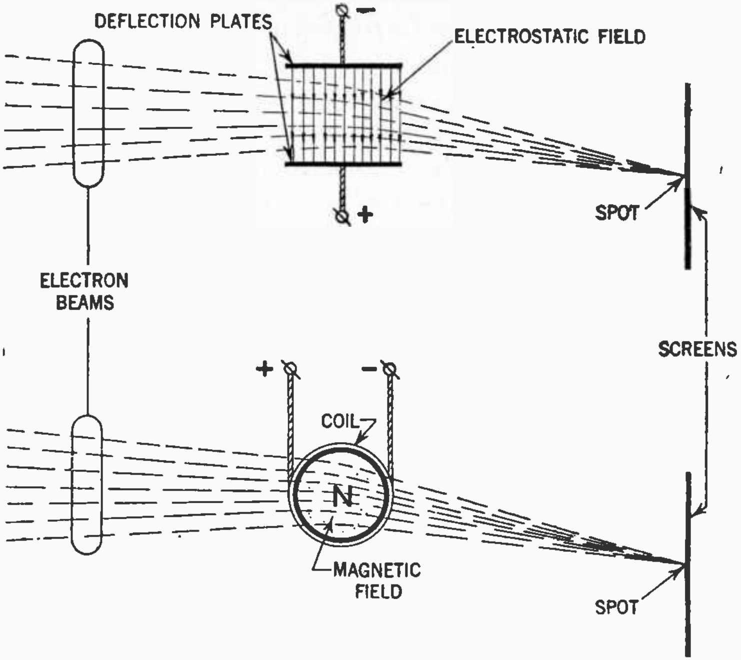
The fluorescent spot on the screen can be brought to a minimum diameter by adjustment of the voltage on the first anode. The voltage on the first anode for best focus is usually ¼ or ⅕ of that on the second anode.

Describe the Electron Gun in a cathode ray tube.

The electron gun is identified as that device which controls and focuses the electron beam and consists of a *grid sleeve* and a *first anode*. Sometimes it includes another electrode, usually called screen grid. This electrode however is not essentially necessary for operation of the tube.

The grid sleeve is of tubular form with a disc parallel to the flat emitting surface of the cathode. A circular hole in the center of the disc is coaxial with the cathode sleeve space.

The first anode cylinder coaxial with the rest of the system is usually mounted by means of insulators on the grid sleeve. It carries diaphragms or aperture discs on the inside for stopping



FIGS. 13 and 14—Indicating how an electron beam may be deflected either electrostatically or electromagnetically. When the former method is used deflection plates are placed at certain points along the tube; in the later deflection method the beam is deflected by means of a special coil or coils placed around the neck of the tube.

or limiting the beam angle and for limiting the penetration of electro-static fields.

What is the method used for focusing the electron beam in a cathode ray tube?

There are at present two in general use—the electron lens and the magnetically focused. In the former special focusing electrodes are interposed between the cathode and the anode, each one having a critical potential and thus a symmetrical radial electro-static field, which re-deflects any diverging electrons into the jet and thus brings about focusing.

In electron tubes of the magnetically focused kind a reconcentration of the diverging electrons are produced by magnetic focusing coils placed at certain points around the tube. This arrangement permits accurate focusing.

How is the electron beam deflected to produce the picture on the fluorescent screen of the cathode ray tube?

The beam is generally deflected electro-magnetically by means of two deflection coils placed along the stem of the tube with their axes perpendicular to the beam to be directed.

The amount of deflection is in direct proportion to the current passed through the coils. The direction of movement is the same as that of a wire suspended in the same field would take if it carried a current flowing in the same direction as that of the current in the beam. However, although an electromagnetically deflected beam is more practical on account of the utilization of externally located coils, electro-static deflection is sometimes employed. When this type is used, two sets of deflection plates are placed at right angles to each other in the neck of the tube, and the deflection accomplished in the usual manner by changing the potentials of the plates.

When for example the voltages are applied to one pair of plates the focused beam will move across the screen in one direction and when applied to the other the spot will move at right angles to its previous direction.

How are the signals from a television transmitter picked up and applied to the sound and sight receivers?

With reference to fig. 15 on the *sound side* the signals are amplified, rectified and applied to the loudspeaker in the usual manner. On the *picture side* the signals are amplified and applied to the cathode ray tube. Also transmitted and recorded are the synchronizing signals which keep the cathode ray tube beam in step with the transmitter.

What is meant by scanning of a picture?

Scanning is the process of an orderly dissection of a televised picture into minute elemental areas of varying light intensities, each element occurring at both the transmitter and receiver end in a logical order, which when reconstructed, will give a complete picture.

What are the fundamental principles of scanning?

Considering the transmission system shown on page 5,005 in which a number of selenium cells constitute the transmitter, it is found that if a practical translating device such as the photoelectric cell be utilized, the electrical response would simply be proportional to the total illumination from the object reaching the cell. In other words, it would be a single effect, and there now arises the problem of converting this into a number of separate effects presented so rapidly one after the other, that the eye must be deceived or persuaded into believing that they all exist at once.

This is fulfilled by the process known as *scanning*, which consists of transmitting the picture point by point. In this way it

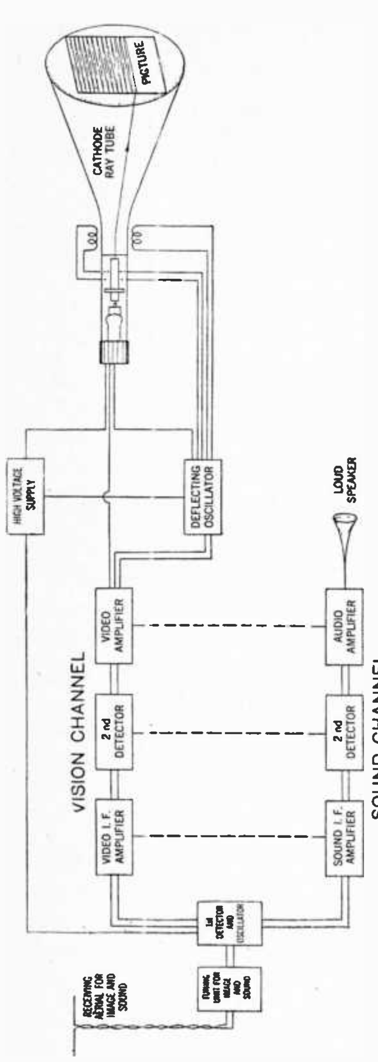


FIG. 15—Block diagram showing the general process involved in picking up simultaneous sound and vision signals.

becomes possible to transmit the image over a single communication channel and use a point-by-point method of reconstruction at the receiving end.

Following this idea further, let it be assumed that a picture is to be transmitted and it is impossible to send it in a single operation. Now, if the picture be broken up into different pieces and the light reflected from each piece be made to fall on a photo-electric cell in very rapid succession, it would be found that the electric response of the cell from instant to instant would vary, according to the light and shade of the different parts in the order in which they were examined.

Again, following this idea still further, if the picture be broken up into an infinite number of elements and the light from each element be made to fall in rapid succession on the cell, there would be obtained an electrical variation of current which represents a complete copy of every detail of the picture in the order and sequence in which the elements were examined.

These elements have then to be transmitted over the communication channel in their approximate sequence, and converted at the receiving end into corresponding variations of light.

In order to re-construct the picture it will be necessary that these light impulses of varying strength, be presented to the eye; 1, in a very rapid succession; 2, in their proper sequence; and 3, in their appropriate relative position to each other.

Television then has an analogy in the well known process in printing where half-tone blocks are employed. If any printed half-tone illustration is examined under a sufficiently strong magnifying glass, it will be found to consist of a large number of minute dots, corresponding to what is known as a screen. It will likewise be found that the greater number of dots per unit area, the better is the quality and detail of the picture.

In television, however, the picture is normally broken up into a series of lines as shown in fig. 16 instead of dots as employed in the printing process.

The underlying principle is very similar and the resemblance is strengthened by the fact that each line may vary in brightness from point to point in its length, thus approximating very closely the idea of dots. As shown in fig. 16, where (a) shows the picture in its normal appearance, and (b) shows what its appearance would have been if it were divided into 30 equal horizontal strips, 1, 2, and 3, etc.

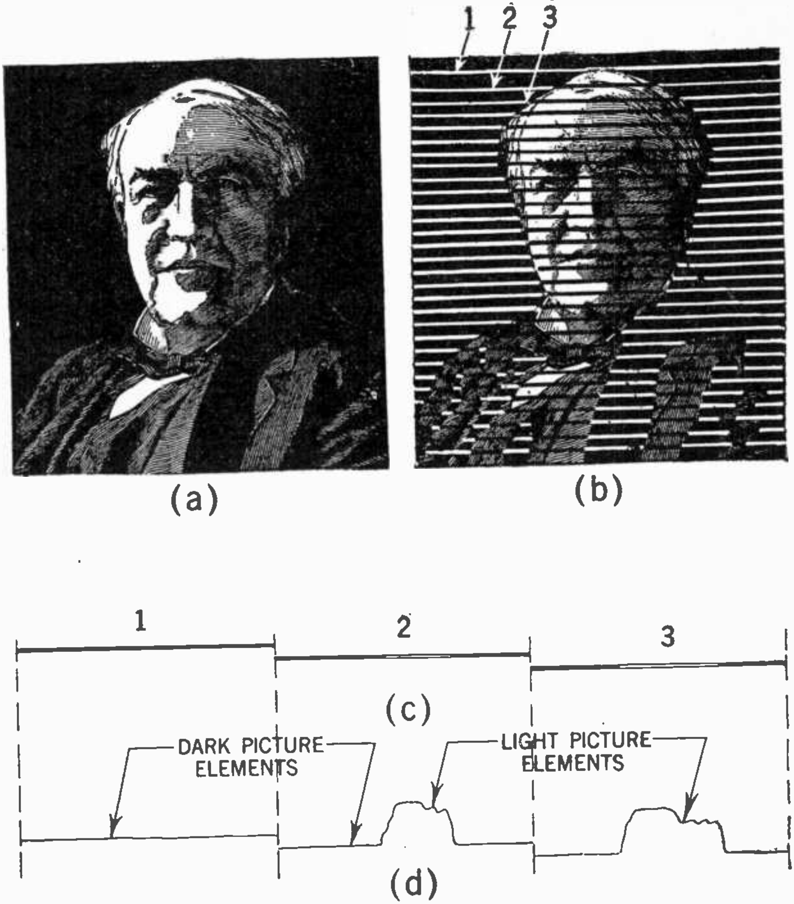


FIG. 16—Showing fundamental scanning principles.

Assume further that instead of keeping these strips parallel or side by side as in fig. 16 they are placed, while still parallel, end to end as in fig. 16 (c) of the diagram. This gives a fairly clear impression of the sequence of changes of light and shade which the scanning element would encounter, as it moved downward first over strip 1, then over strip 2, then over strip 3, etc. Finally, assume that we have some form of device sensitive in its response to light and shade and giving in fact, electrical current impulses according to the degree of light which it encounters. Then as the scanning elements move along the strips 1, 2, 3, etc. in turn, the current in this device will vary as shown in fig. 16 (d).

From the previous discussion it is evident that these current variations can now be used to *modulate* a communication channel in the same manner as has been previously considered.

The apparatus now employed for the accomplishment of transforming a certain train of light impression to a corresponding amount of electric current variations is the photo-electric screen which may be defined as a great multiplicity of minute photo electric cells.

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