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

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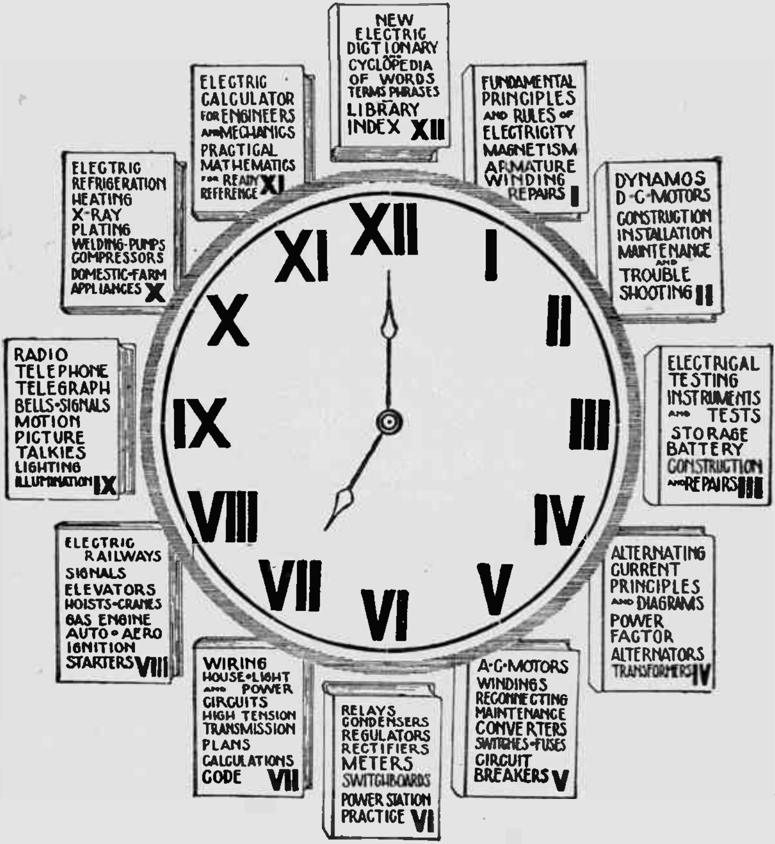

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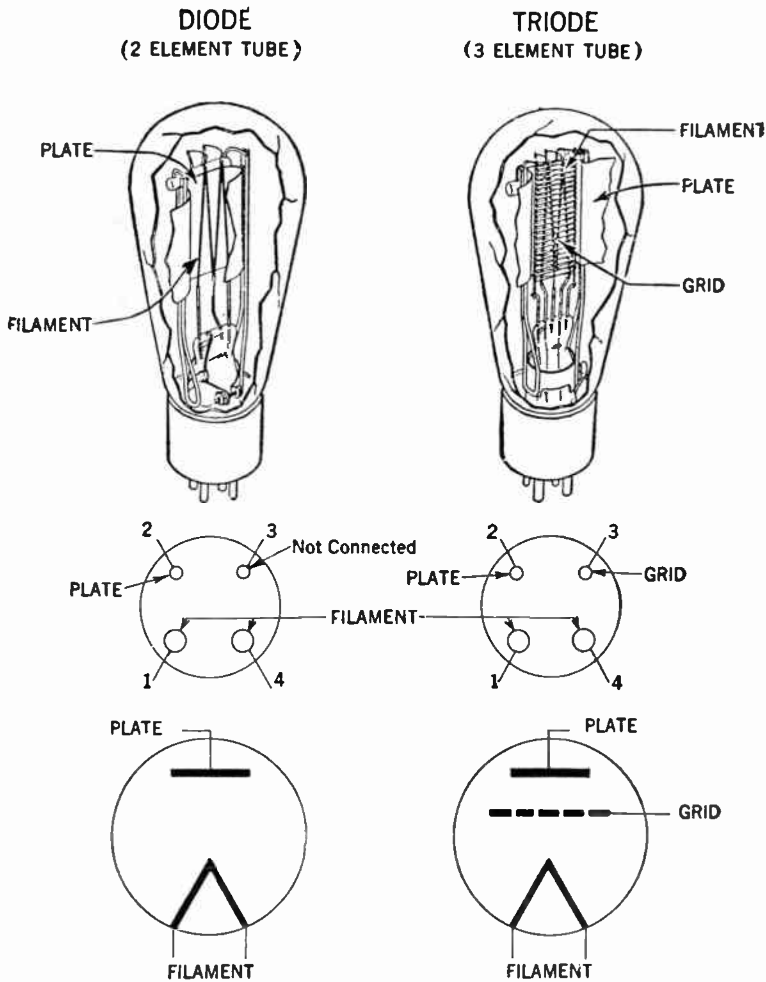

Views of two and three element vacuum tubes showing arrangement of prongs and wiring symbols

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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 electro-magnet. 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.

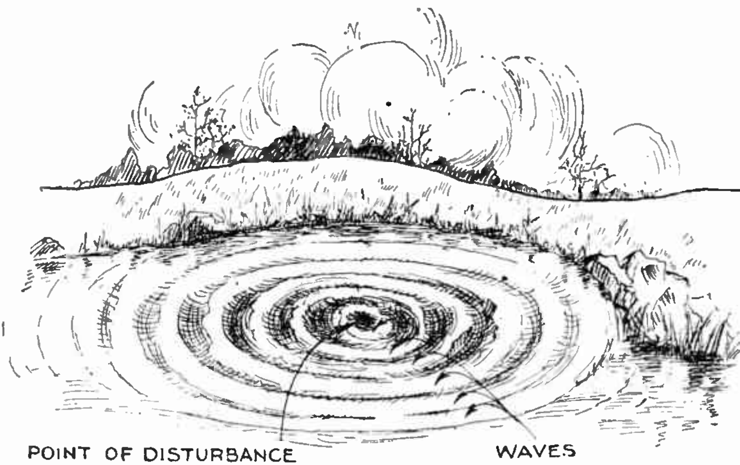

FIG. 7,180.—Effect of throwing stone in still water; production of waves which radiate or travel from the point where stone enters the water, or "point of disturbance."

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 Störmer 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.

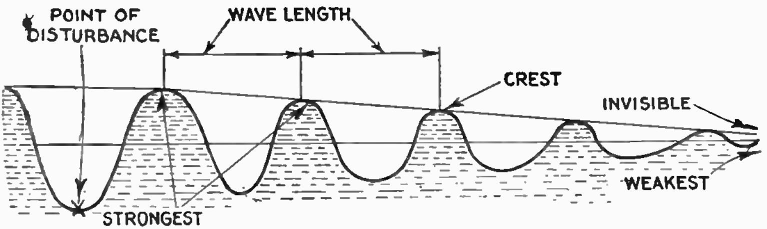

FIG. 7,181.—Sectional view of waves produced by throwing stone in still water, illustrating crest of wave, wave length and gradual weakening of the waves as they travel from the point of disturbance.

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.

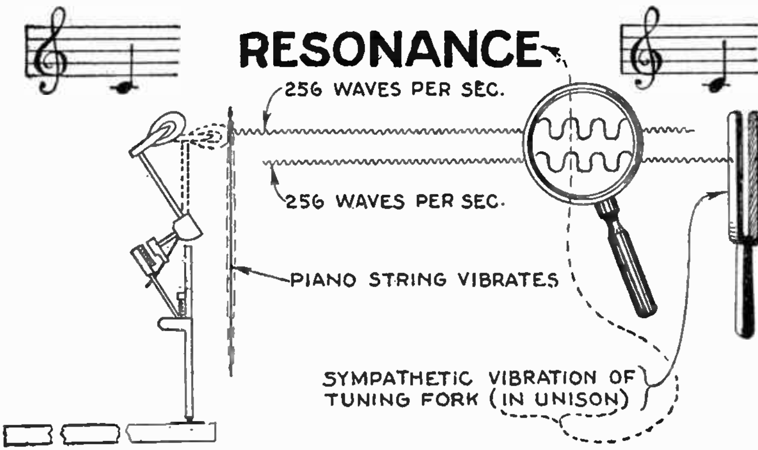

FIG. 7,182.—Sympathetic vibration of tuning fork with struck piano string when tuned to same pitch, illustrating the wave theory of radio.

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:

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

$$\text{Frequency} = \frac{300.000{,}000}{\text{wave length (in meters)}}$$

$$\text{Kilocycles} = 1000 \text{ cycles}$$

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 thermoelectric 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	— • —
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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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4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
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

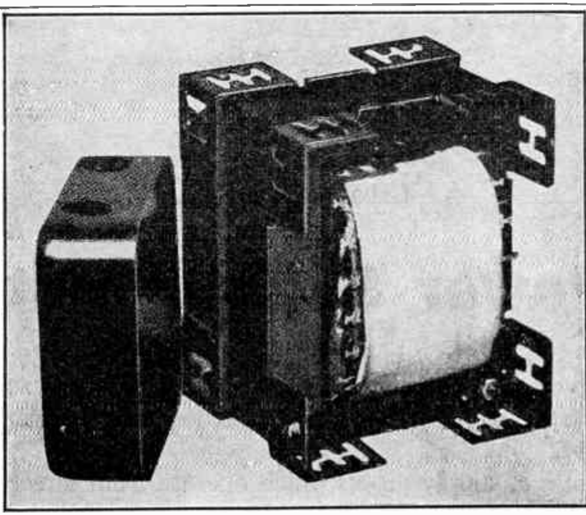


FIG. 1—Exterior view of typical power transformer.

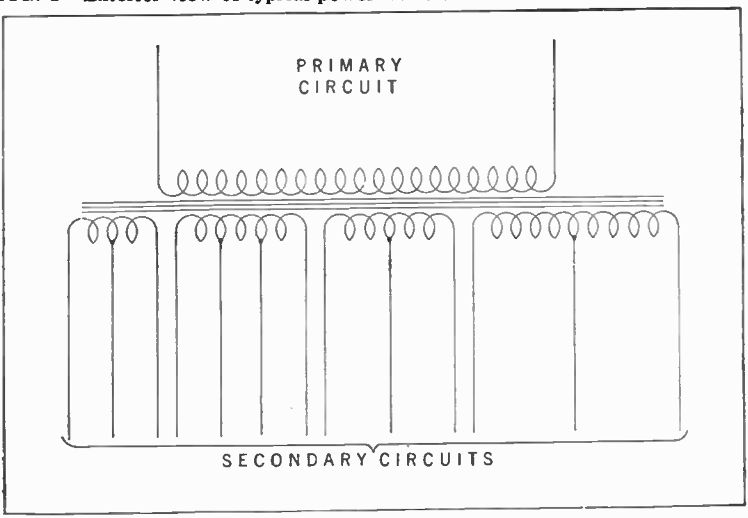


FIG. 2—Conventional diagrammatical representation of power transformer for 5 to 9 tube sets.

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.

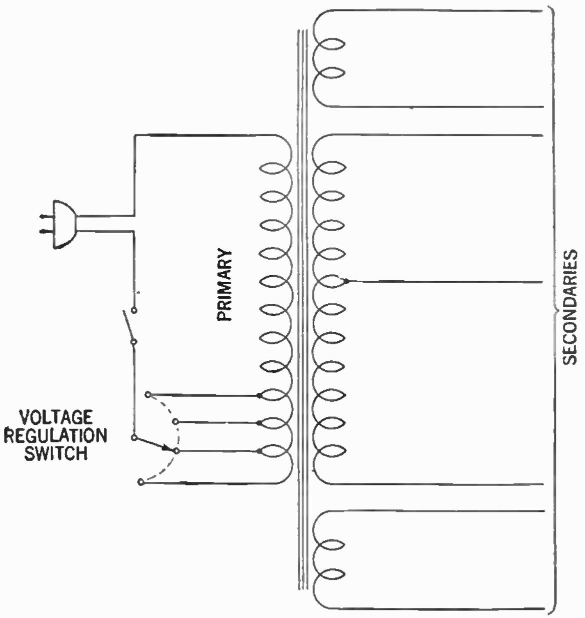


FIG. 3—Power transformer circuit showing voltage regulation switch.

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.

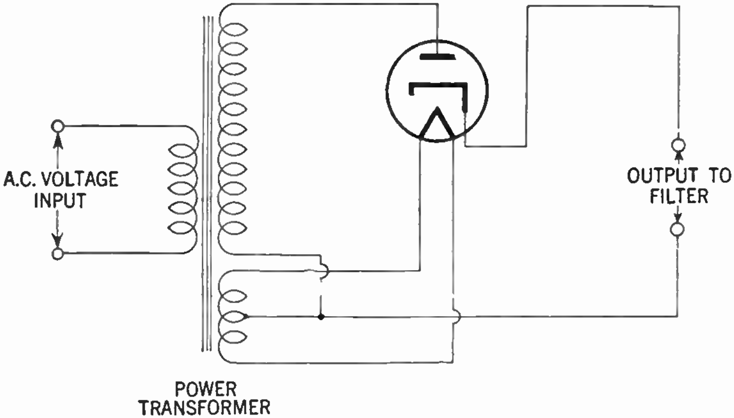


FIG. 4—Illustrates connection and rectifier tube to obtain half-wave rectification.

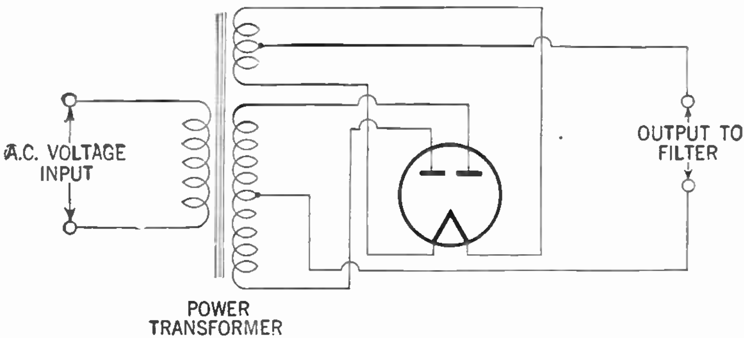


FIG. 5—Illustrates connection and rectifier tube to obtain full-wave rectification.

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 the mercury vacuum rectifier is higher than in the high vacuum type.

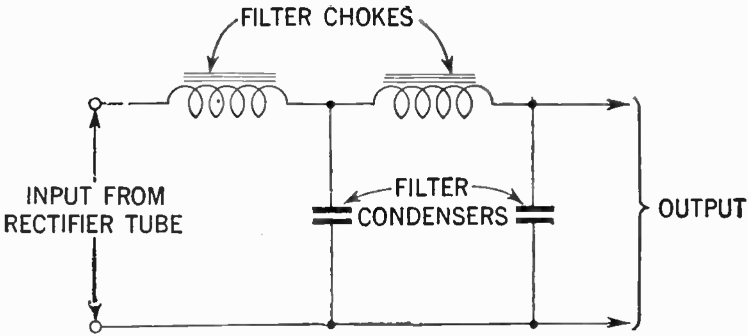


FIG. 6—Choke-input filter.

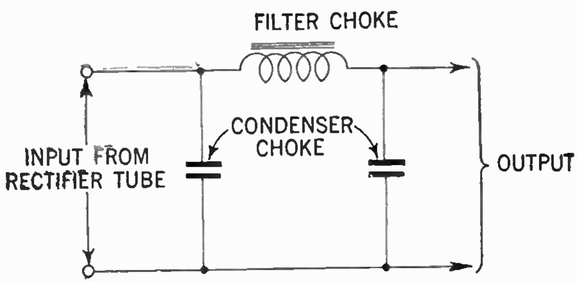


FIG. 7—Condenser-input filter.

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.

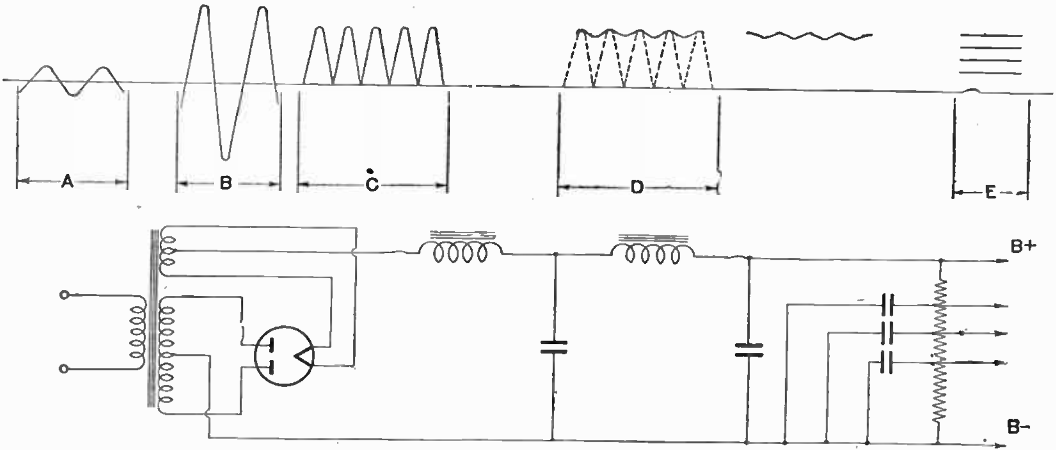


FIG. 8—Illustrates a "*B*" power supply unit of the full-wave type. The choke-input filter section is connected to the conventional voltage divider supplying plate voltages to the various tubes. The upper part of the diagram shows the approximate wave forms at various locations in the power supply unit. 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.

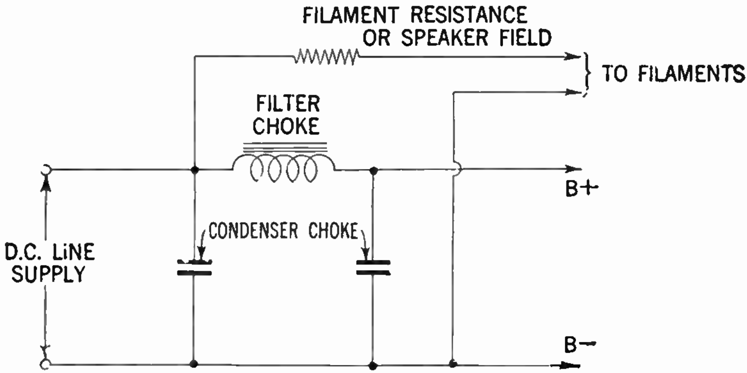


FIG. 9—Conventional filter system used on D.C. receivers.

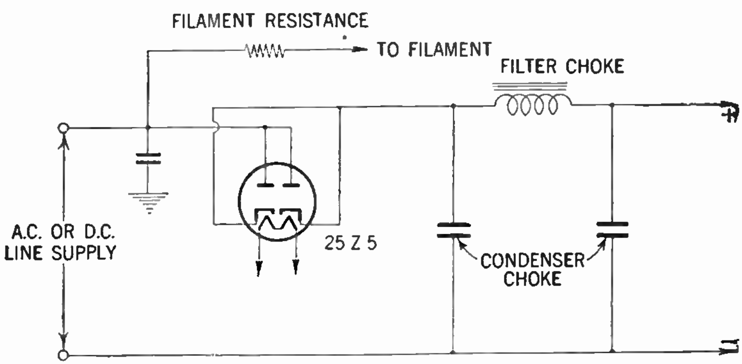


FIG. 10—Full wave rectifier tube circuit used for A.C.-D.C. receivers.

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.

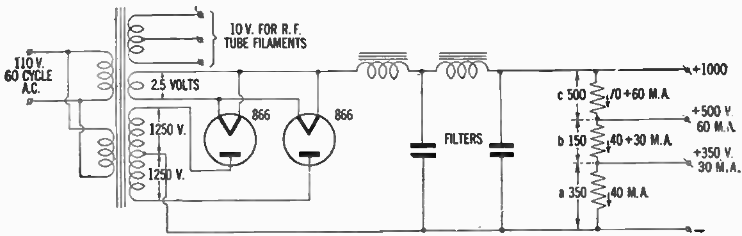


FIG. 11—Full wave rectifier circuit with conventional filters and voltage divider.

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

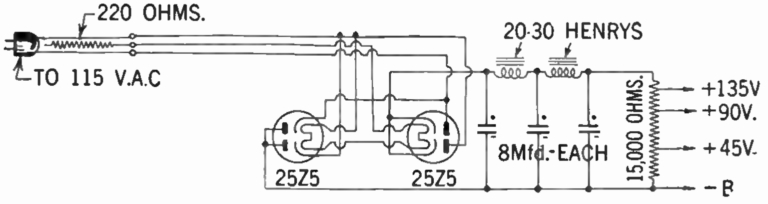
in section (a) $350\times0.04=14$ watts
in section (b) $150\times0.07=10.5$ watts
in section (c) $500\times0.13=65.0$ watts

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

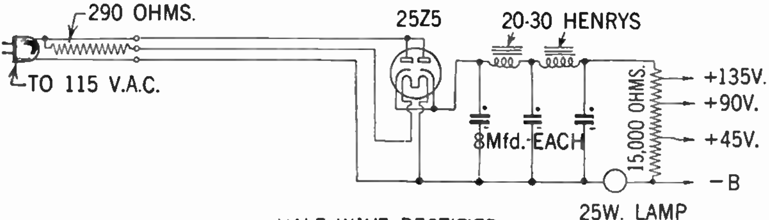
The power calculation should be done for both no-load and full-load conditions, and a resistor selected which should have a rating well above that of the higher of the two values.

In some cases it is desired to have the bleeder resistance total to a pre-determined 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.

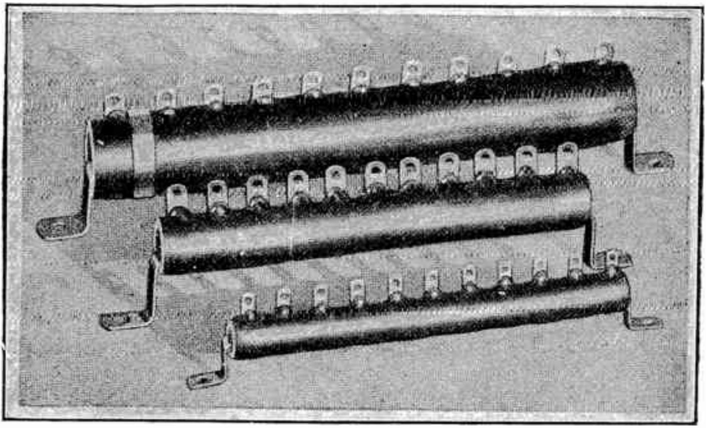


FIG. 14—Typical receiver power supply resistors.

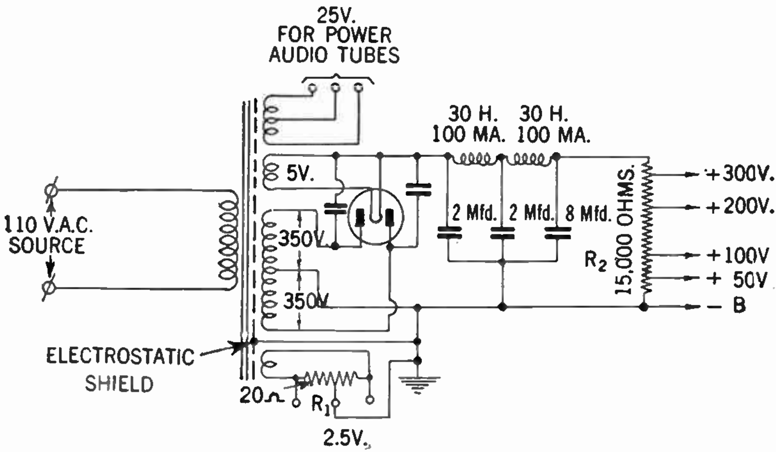


FIG. 15—Here the power transformer is used to step up the 110 volt alternating current to 350 volts on each side of the centre-top. This type of power supply will ordinarily be satisfactory for an ordinary armature receiver as well as an audio amplifier using a 47 or a pair of 45's in push-pull. The 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.

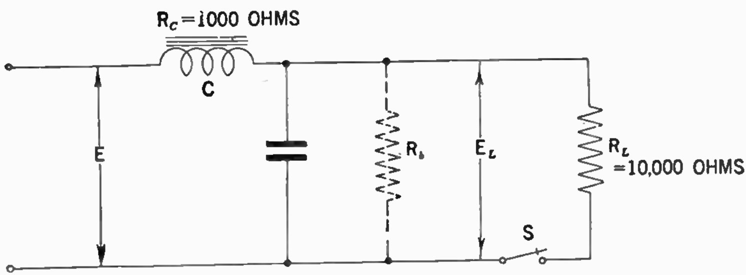


FIG. 16—Showing application of bleeder resistor across power supply.

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.

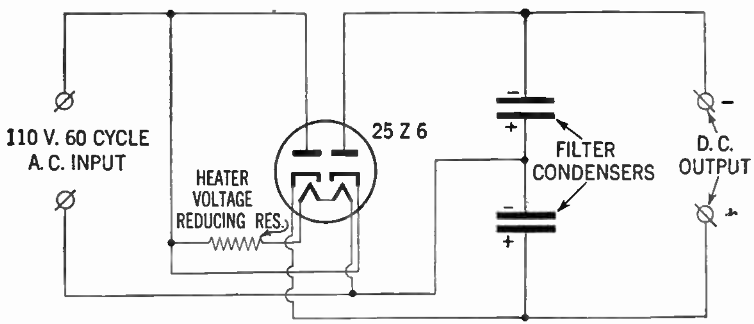


FIG. 17—Voltage doubler circuit utilizing a full-wave rectifier tube.

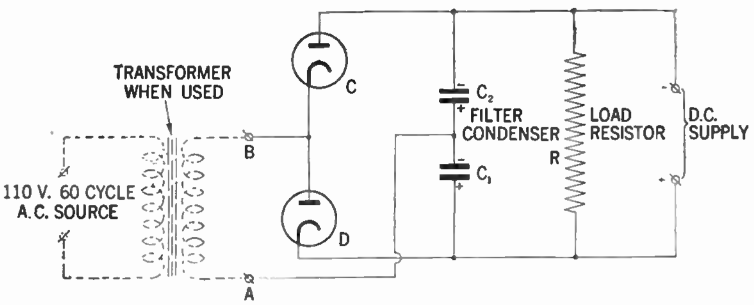


FIG. 18—Voltage doubler circuit utilizing two half-wave rectifier tubes.

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 $2 \times 1.2 = 2.4$ 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 $2 \times 0.05 = 0.1$ 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

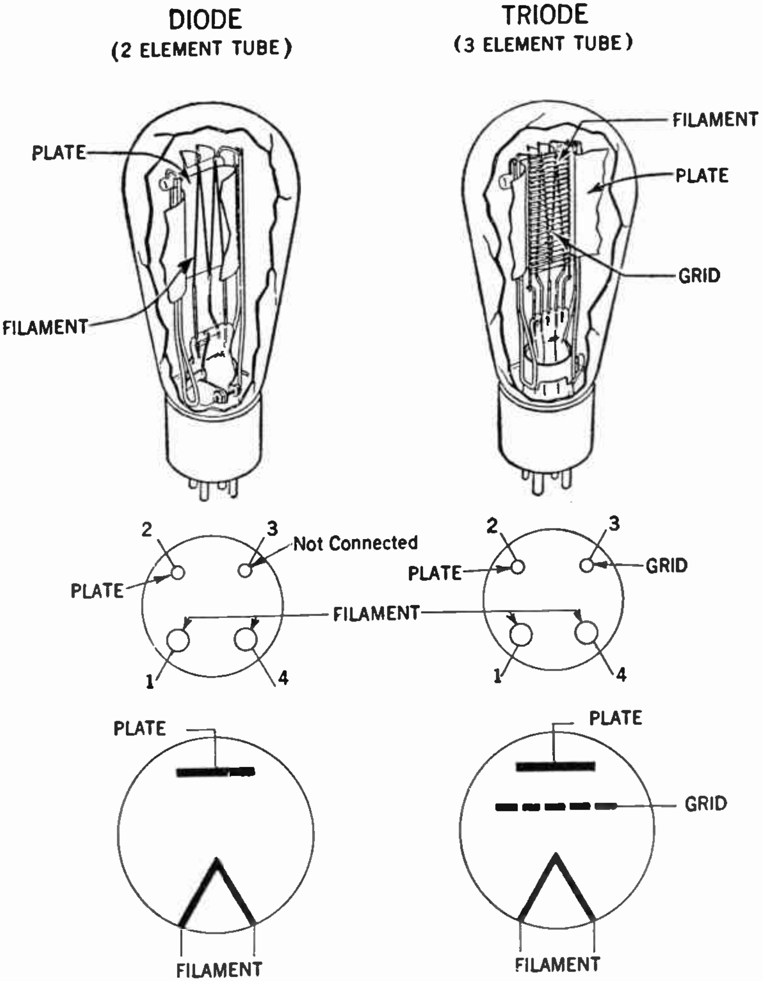
Vacuum Tubes

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.

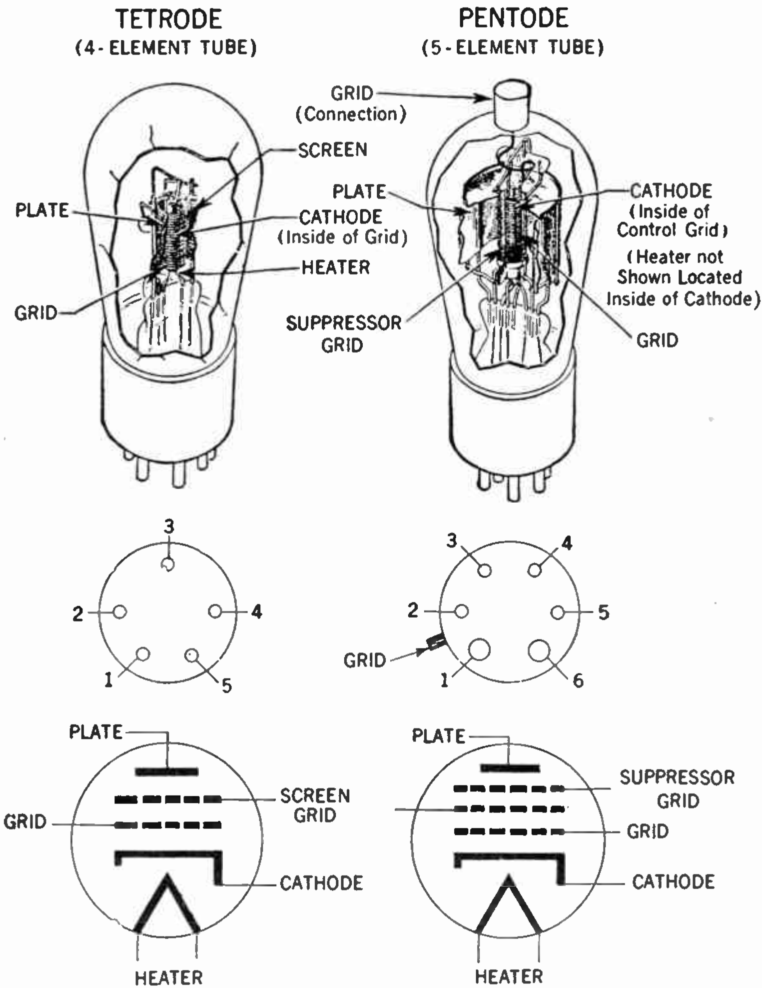
This movement of electrons may be accelerated by increasing the temperature of the conductor. Once free, most of the emitted electrons, in a vacuum tube make their way to the plate, but others return to the cathode, repelled by the cloud of negative electrons immediately surrounding the cathode. This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

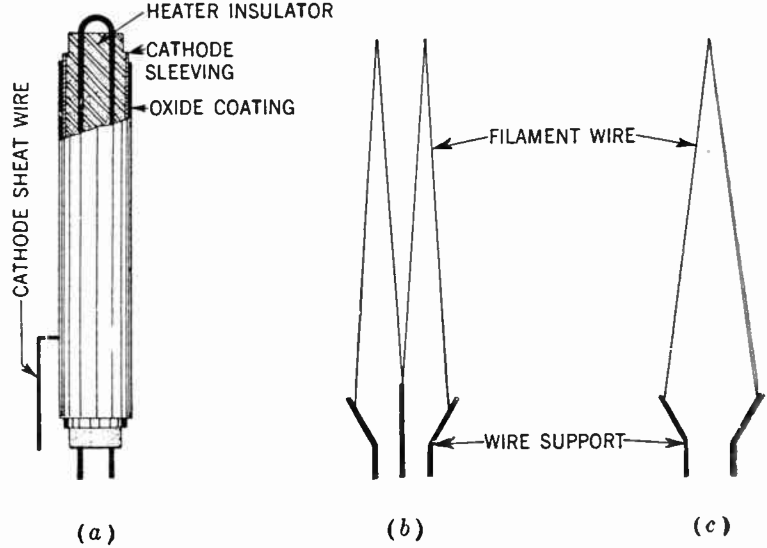


FIG. 1.—Schematic diagram of directly and indirectly heated cathodes.

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

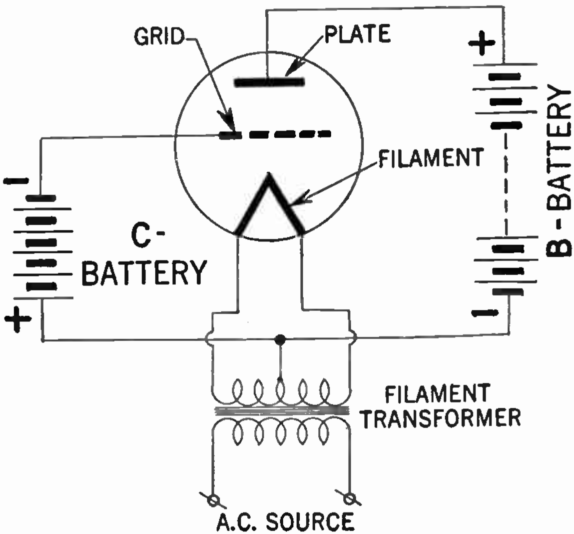


FIG. 2.—Diagram of connection to a triode employing a filament transformer.

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.

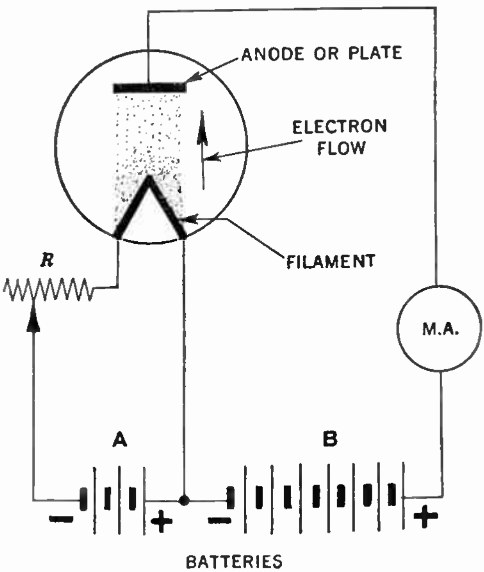


FIG. 3.—Connection diagram for a two electrode tube.

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.

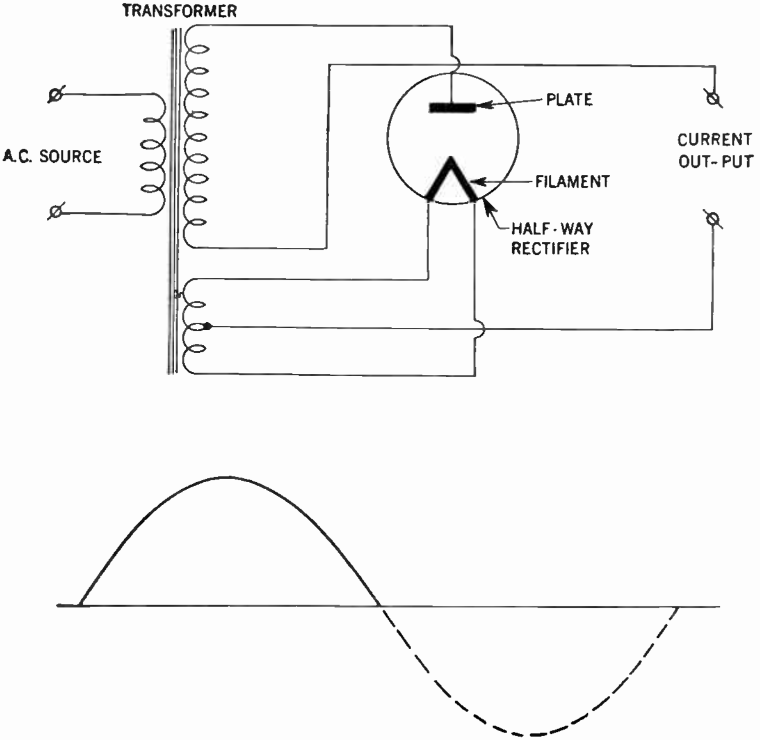


FIG. 4.—Connection diagram of the half-way rectifier. The rectified current is depicted on the upper half of the wave diagram.

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

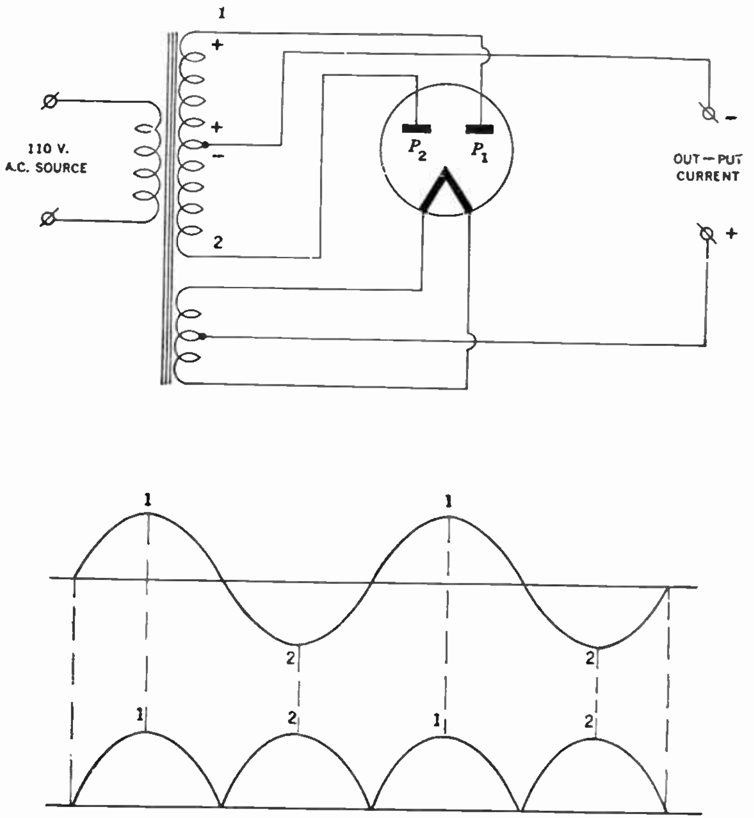


Fig. 5.—Connection diagram and depiction of the action of a full-wave rectifier tube.

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.

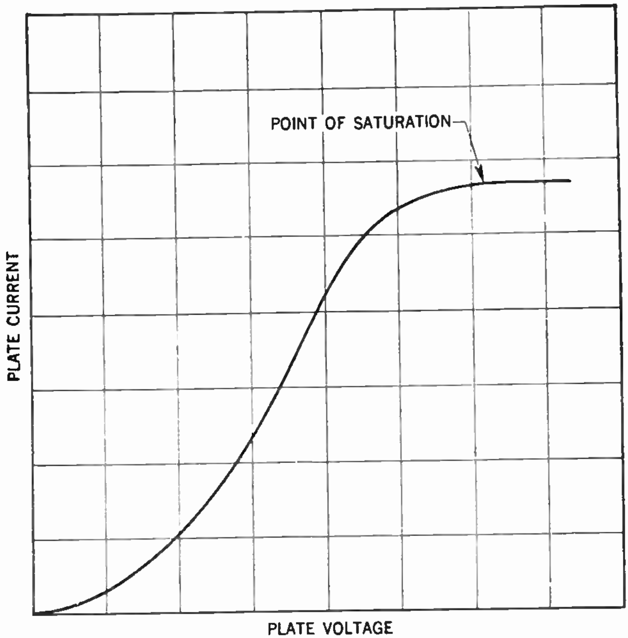


FIG. 6.—Characteristic curve of a diode.

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.

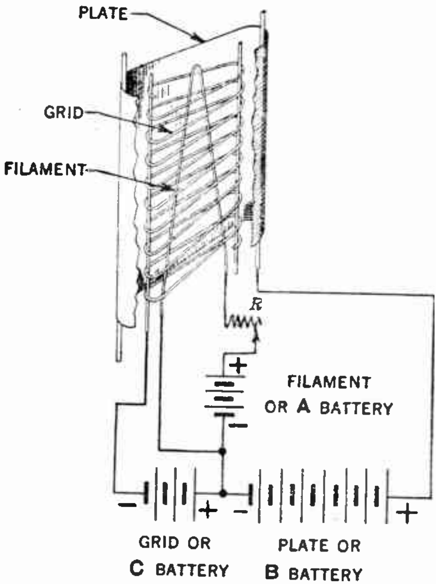


FIG. 7.—Schematic diagram showing triode connection to battery.

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.

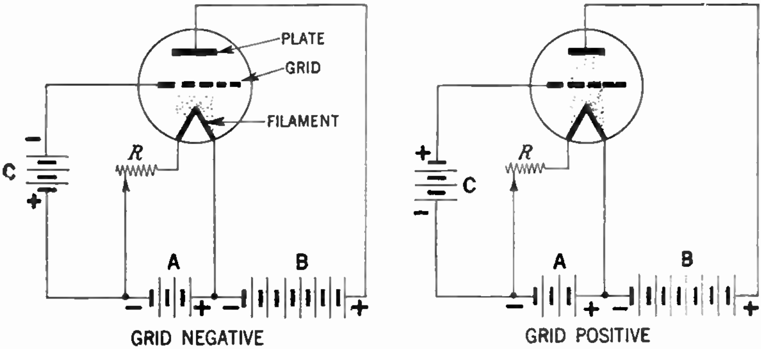


FIG. 8.—Illustrating the action of a grid in a triode vacuum tube.

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-frequency 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.

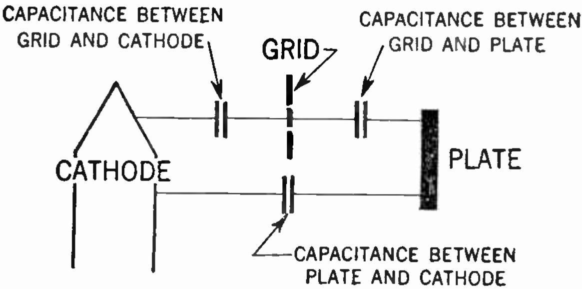


FIG. 9.—Diagram showing inter-electrode capacitances in a triode.

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.

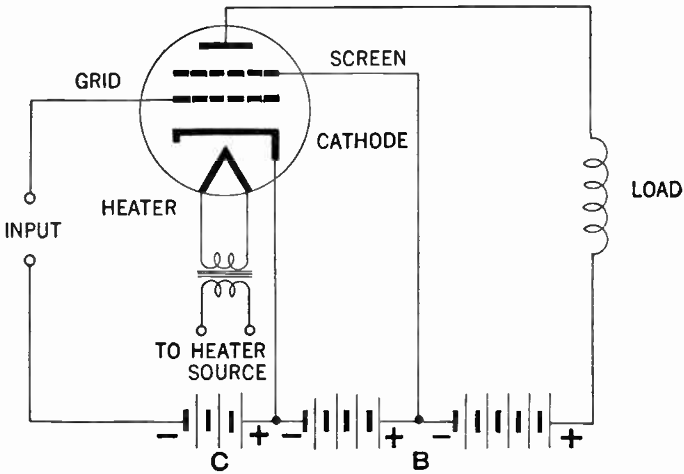


FIG. 10.—Connection of electrodes of a screen gride tube.

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.

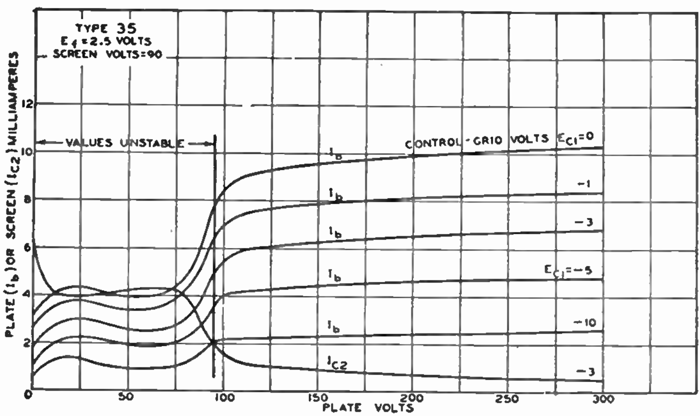


FIG. 11.—Average plate characteristics of a screen grid amplifier tube.

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%.

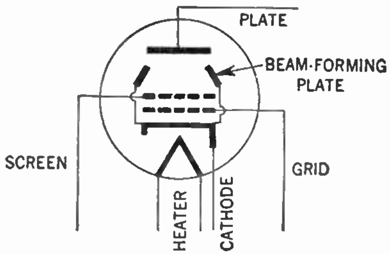


FIG. 12.—Conventional representation of beam power tube.

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*.

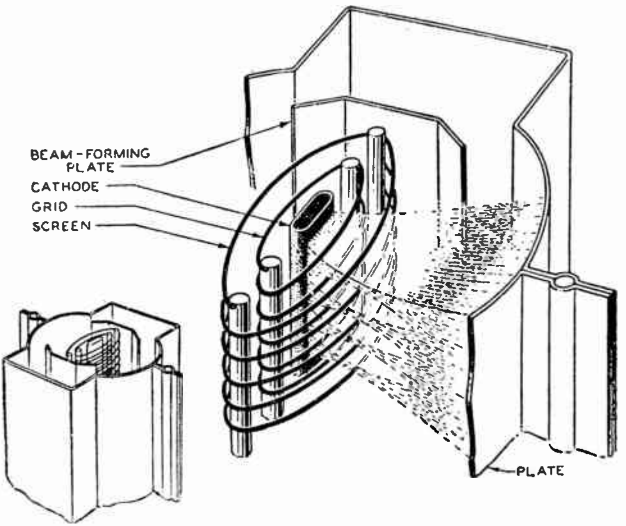


FIG. 13.—Internal structure of beam power tube.

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.

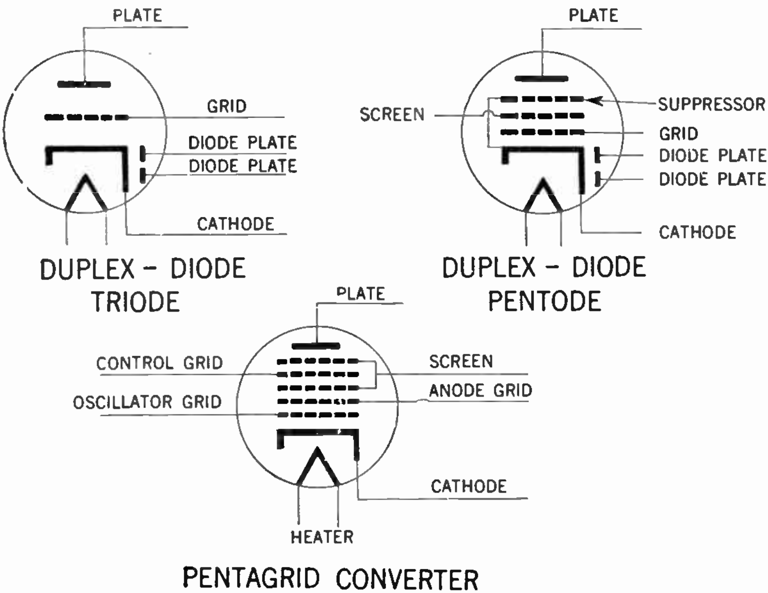
It is obvious that with this diversity of applications, this one type did not meet all requirements to the best advantage.

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:

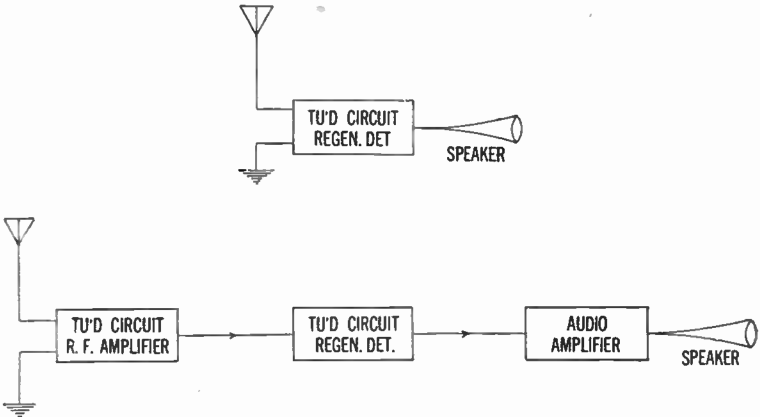
1. Regenerative
2. Tuned radio frequency regenerative
3. Super-heterodyne
4. Super-regenerative
5. Super-infra regenerative

The two last circuits are classified as short wave receivers.

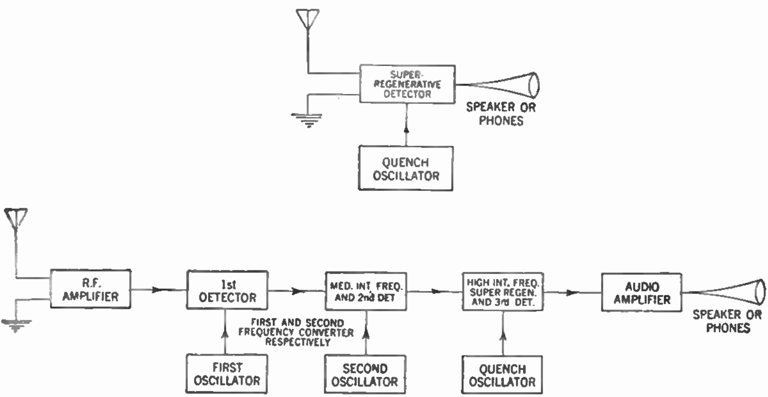
General Receiver Performance Characteristics.—The receiver performance may be divided into three groups namely:

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.

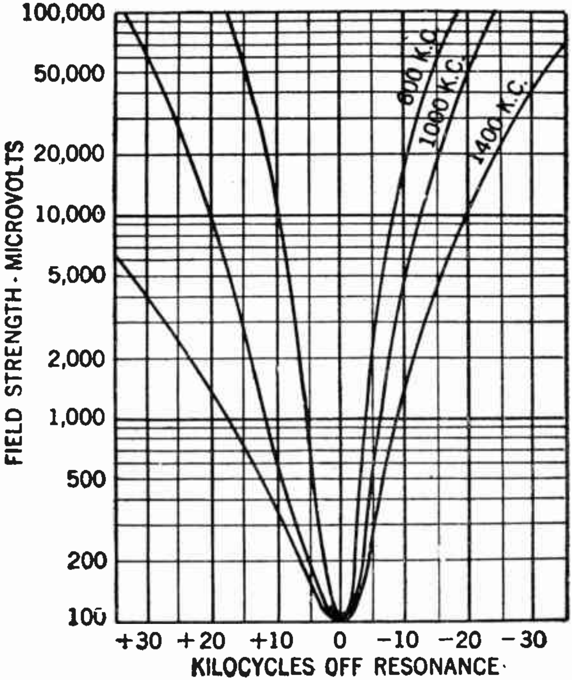


FIG. 5—A typical radio receiver selectivity curve.

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.

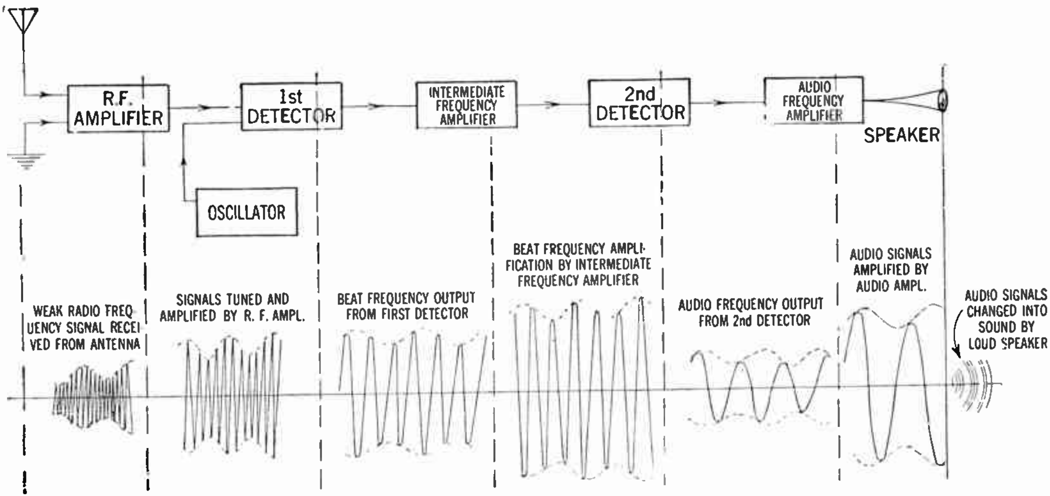


FIG. 6—Combination diagram showing arrangement of the different units of a typical super-heterodyne receiver with wave chart indicating how the radio signals are modified by each unit, that is, how the inaudible signals first picked up by the antenna undergo successive changes en route to the loud speaker.

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.

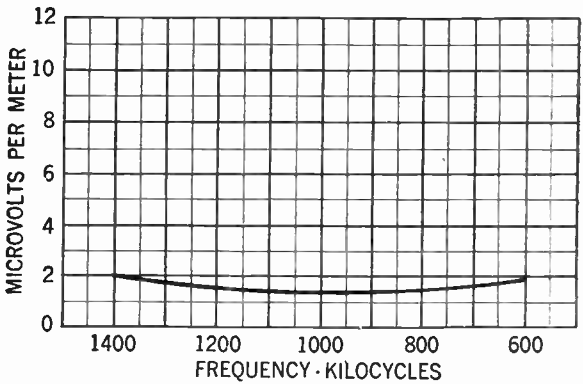


FIG. 7—Typical radio receiver, sensitivity characteristics.

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.

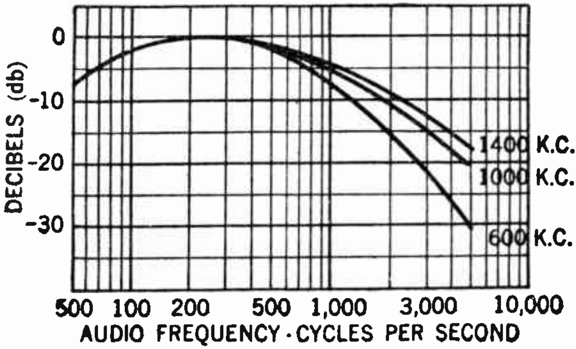


FIG. 8—Typical radio receiver, fidelity characteristics.

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.

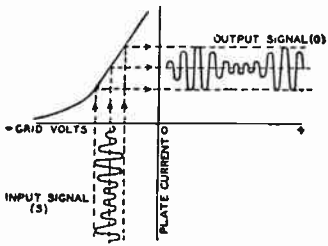


FIG. 9—A graphic illustration of method of amplification showing, by means of grid-voltage vs. plate-current characteristics, the effect of an input signal "S" applied to the grid of the tube. "O" is the resulting amplified plate-current variation.

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

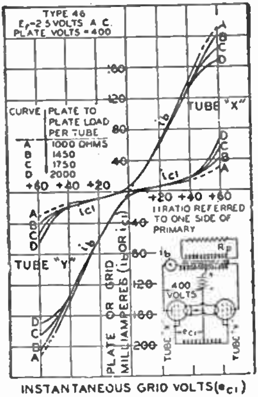


FIG. 10—Illustrates operation of tubes in class "B" circuit.

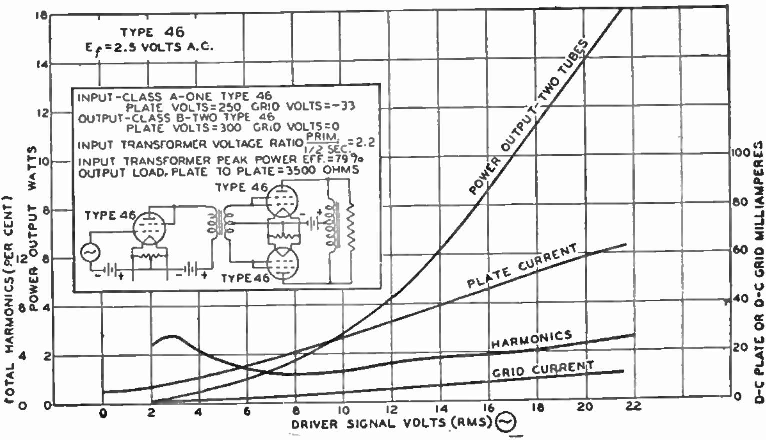


FIG. 11—Illustrates typical class "B" characteristics. An amplifier of this type generates considerable second and other harmonics. The efficiency of an amplifier of this type is higher than the previously discussed class A amplifier.

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.

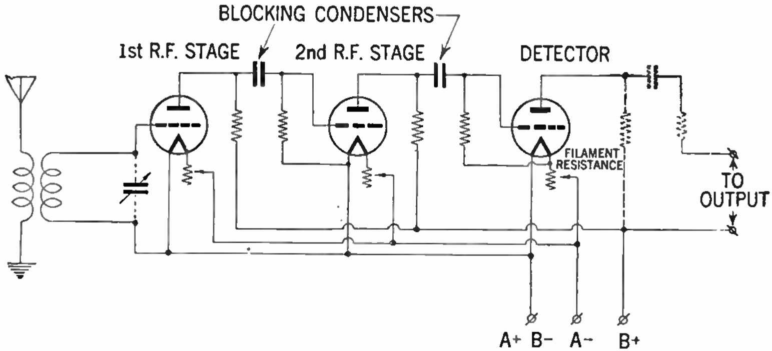


FIG. 12—Typical two stage resistance coupled radio frequency amplifier.

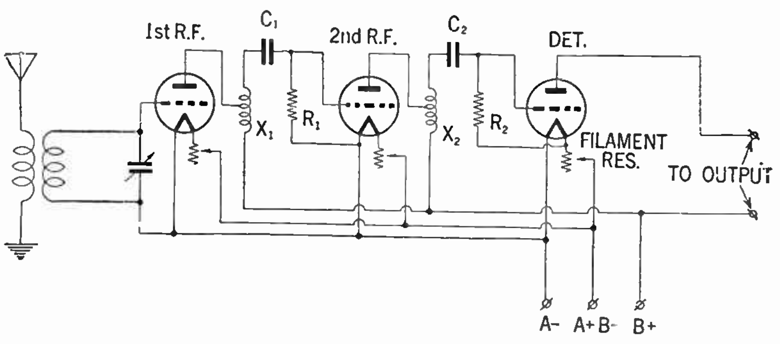


FIG. 13—Two stage impedance coupled radio frequency amplifier.

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.

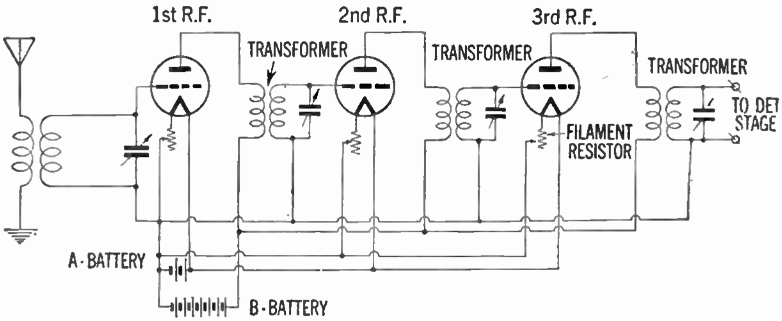


FIG. 14—Three stage radio frequency amplifier circuit.

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.

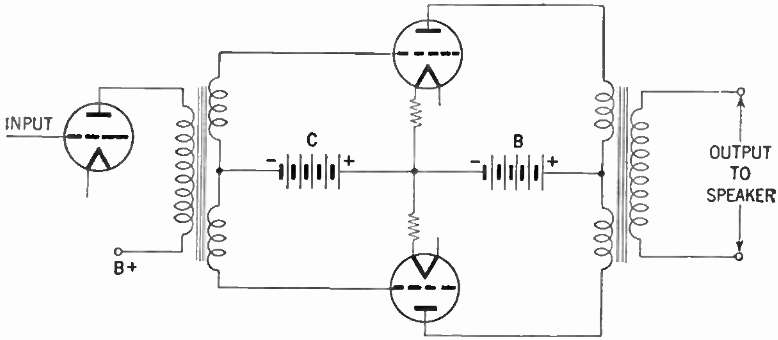


FIG. 15—Push-pull amplifier circuit. This type of amplification requires two identical tubes in each stage. The grids of the tubes are not connected together, as in the case of parallel operation, but are connected to opposite ends of a mid-tapped transformer secondary. The mid tap is used as a common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

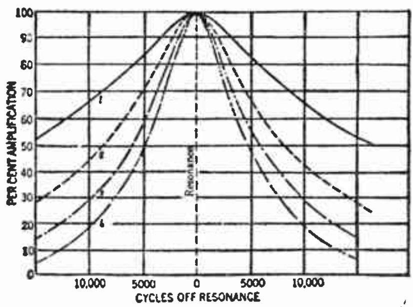


FIG. 16—Illustrates how the several stages of *r.f.* amplification increases the selectivity of a receiver by reducing the strength of undesired signals.

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.

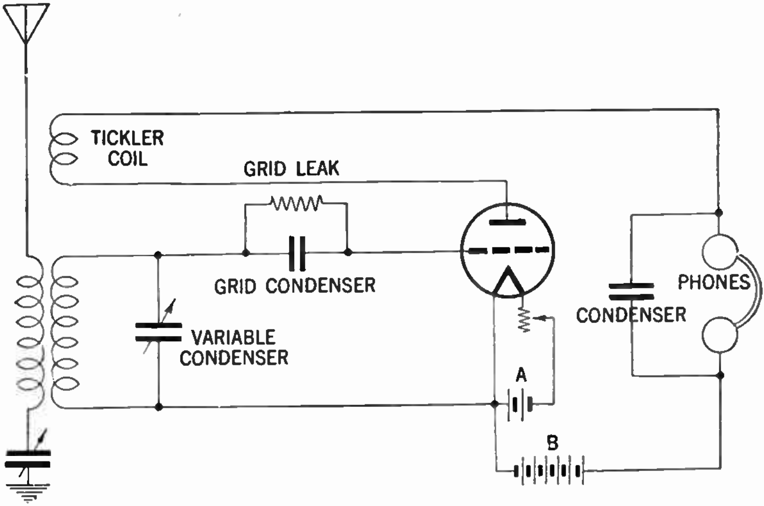
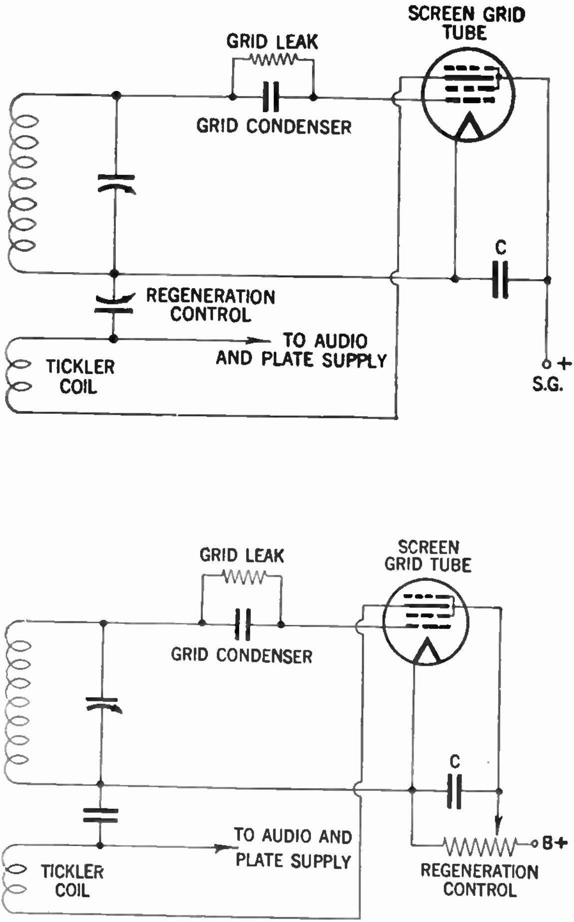


FIG. 17—Regenerative circuit. The scheme of combining a detector circuit with a separate oscillator circuit is called *heterodyning* and oscillators built exclusively for this purpose are called *heterodynes*. A circuit such as this is known as a *regenerative circuit*, and this term is applied to any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

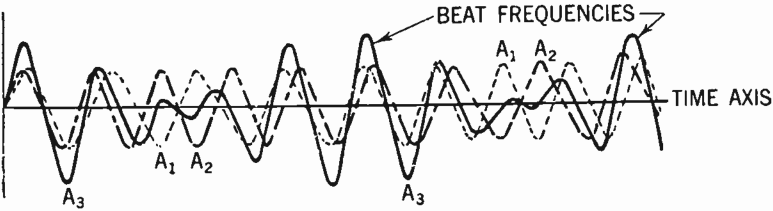


FIG. 20—Illustrates how beat frequencies are generated. With reference to curve A_1 and A_2, it may readily be observed how the frequencies are alternately in and out of phase with each other. The frequency with which these component curves are in phase with each other is equal to the difference between 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.

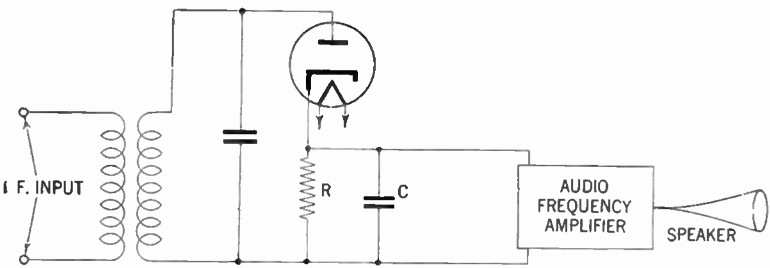


FIG. 21—Diode detector circuit.

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.

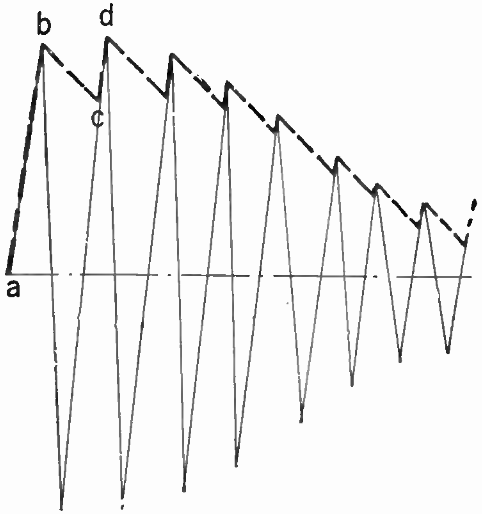


FIG. 22—Diode detector characteristics.

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.

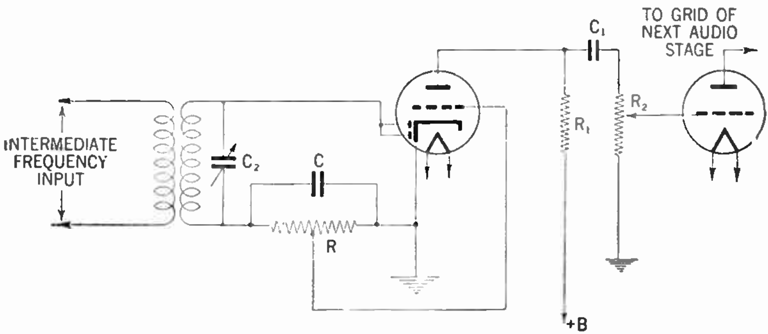


FIG. 23—Diode-biased detector circuit.

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.

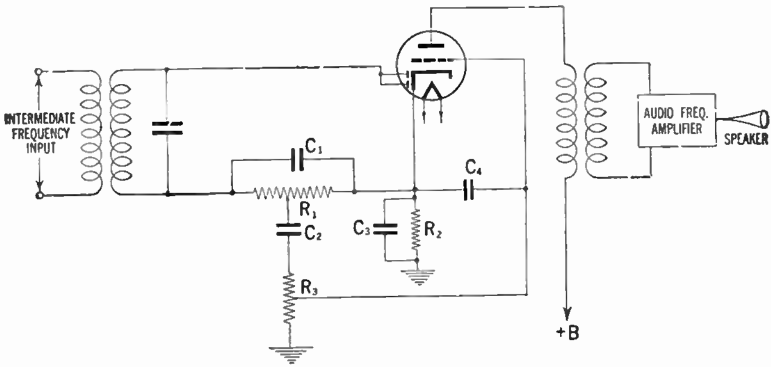


FIG. 24—A typical diode-detector circuit using a duplex-diode tube is shown above. In this circuit R_1 is the diode load resistor. A portion of the *a.f.* voltage developed across this resistor is applied to the triode grid through the volume control R_3. In a typical circuit, resistor R_1 may be tapped 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.

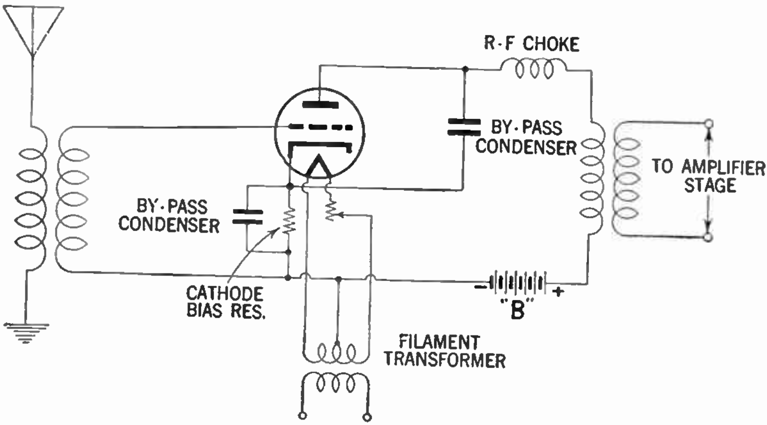


FIG. 25—Grid-biased detector circuit.

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.

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.

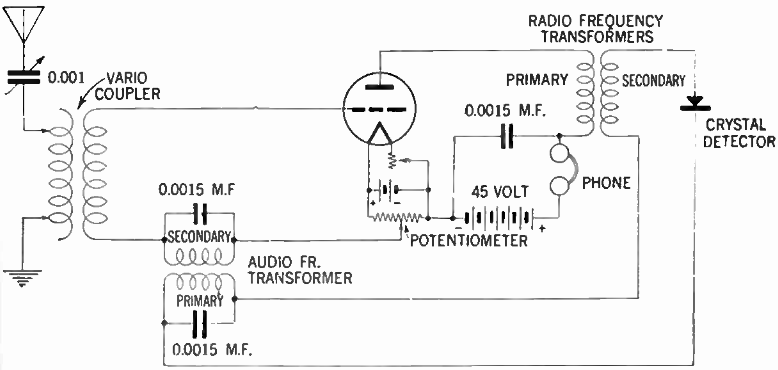


FIG. 28—Diagram showing typical reflex circuit.

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.

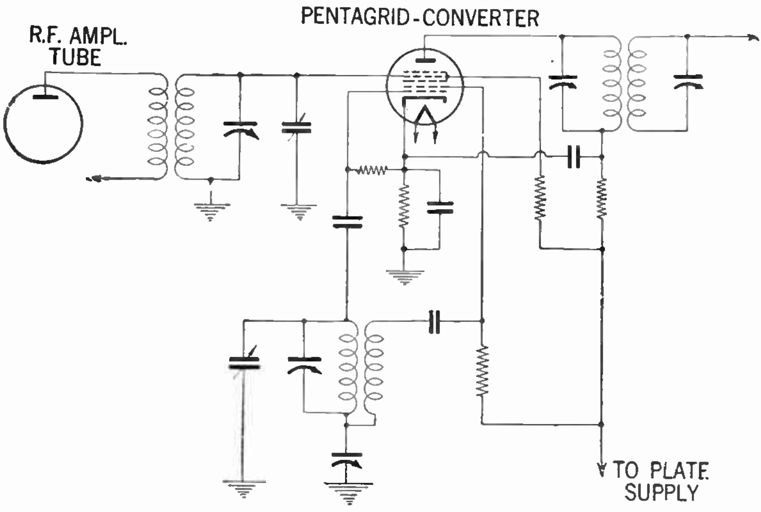


FIG. 29—Pentagrid converter tube employed as an oscillator mixer in a super-heterodyne receiver circuit.

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.

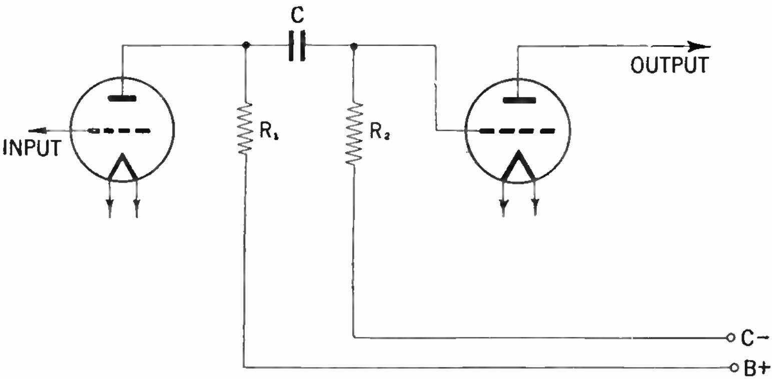


FIG. 30—Interstage coupling in a *resistance coupled* audio frequency amplifier.

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.

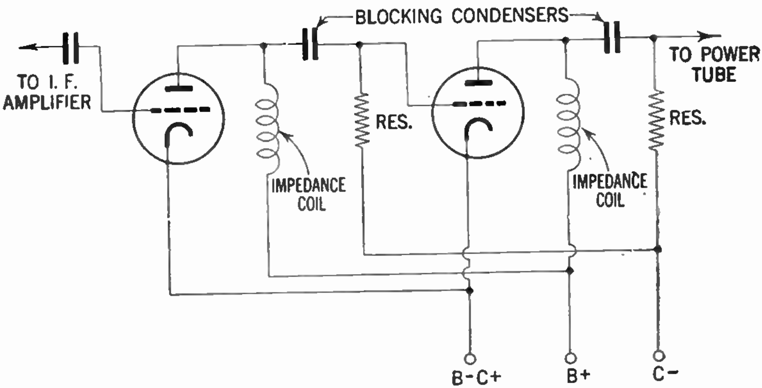


FIG. 31—Inter-stage coupling in an impedance coupled *audio frequency* amplifier.

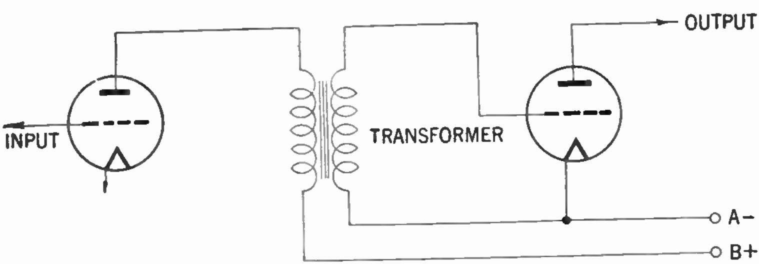


FIG. 32—Method of inter-stage connection of *transformer coupled* audio ferquency amplifier.

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.

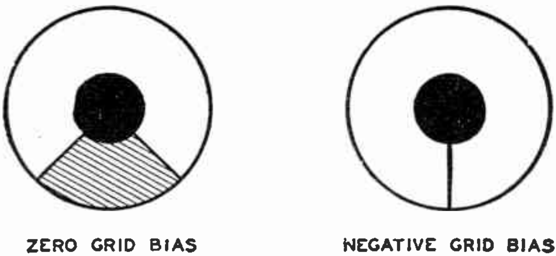


FIG. 33—Electron pattern on the 6E5 target for various grid bias.

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.

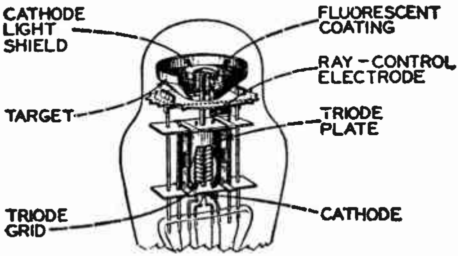


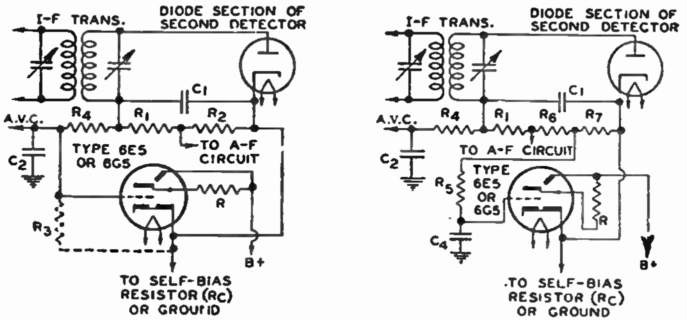
FIG. 34—Internal construction of electron ray indicator tube. (Courtesy R.C.A. Mfg. Co. Inc.)

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.)

$R = \begin{cases} 1.0 \text{ megohm for } B+ = 250 \text{ volts} \\ 0.5 \text{ megohm for } B+ = 100 \text{ volts} \end{cases}$	$R_5 = R_4$
$R_1 = 0.05$ megohm *rf* (filter)	$R_6 + R_7 = 0.2$ megohm
$R_2 = 0.2$ megohm	$C_1 = 100$ to $200\ \mu\mu f$
$R_3 =$ determined by test	$C_2 =$ *A.v.c.* filter condenser
$R_4 =$ *a.v.c.* filter resistor	$C_3 = 0.05$ to $1.0\ \mu f$
	$C_4 = C_2$

"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.

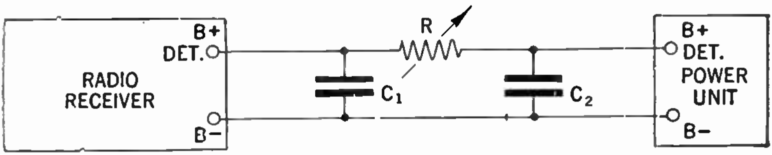


FIG. 37—A method whereby "motor boating" may be eliminated, by means of condensers and resistor connected between the receiver and "B" power supply unit as shown.

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.

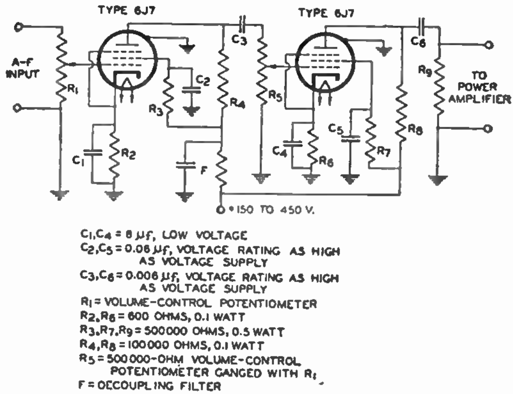


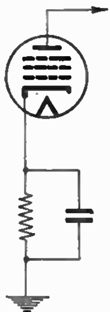
FIG. 38—Schematic circuit diagram of "Non-motor boating" resistance coupled amplifier. (Courtesy R.C.A. Mfg. Co. Inc.)

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.



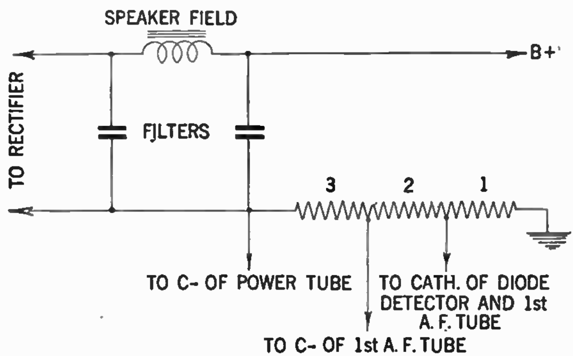


FIG. 39—Showing how grid bias may be obtained by the use of self biased by-passed resistor.

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

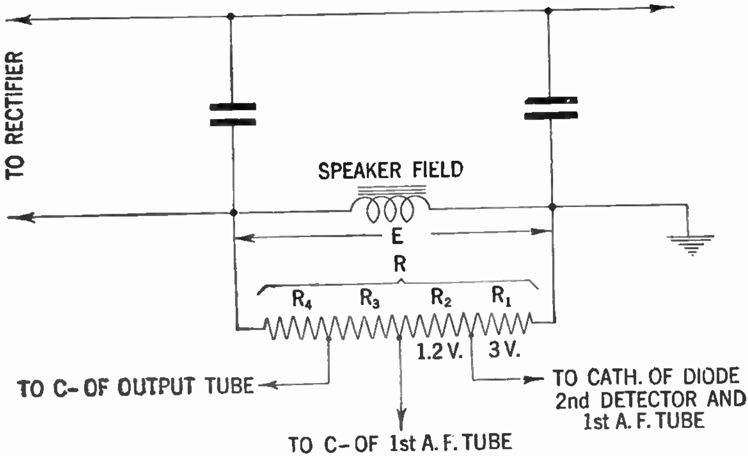
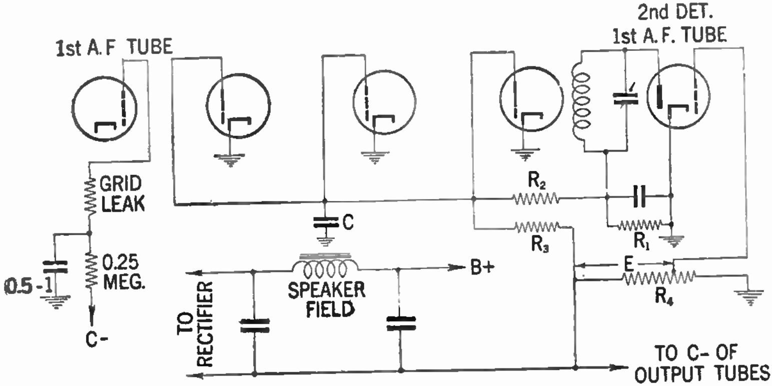


FIG. 41—Method of obtaining grid bias by utilizing voltage drop across speaker field coil.



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?*

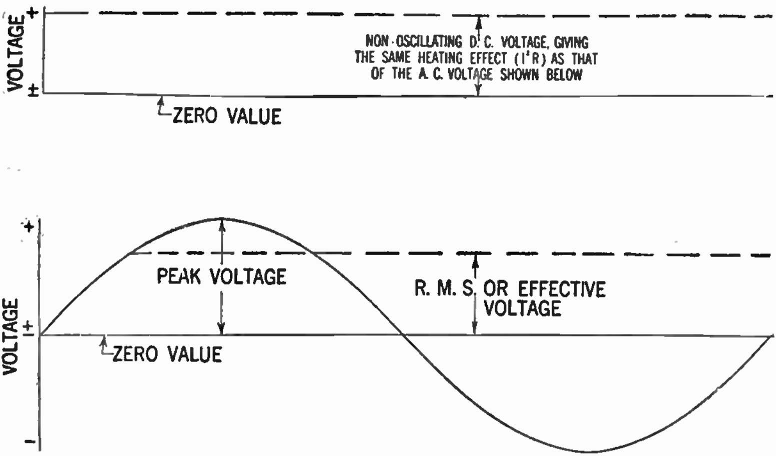


FIG. 44—Illustrating comparative values of *r.m.s.* and peak voltage in an alternating current.

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 trom $I = \frac{W}{E}$ 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

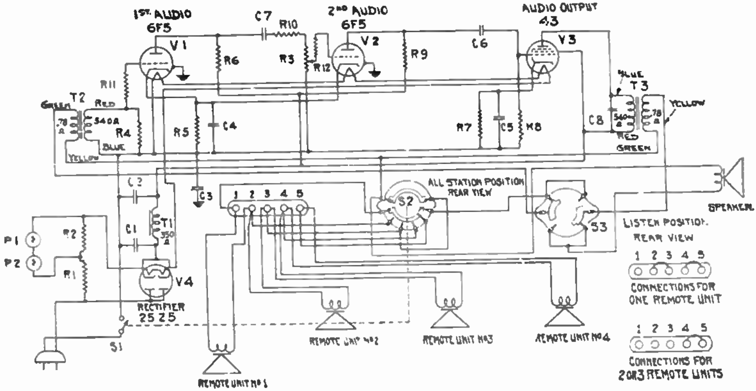


FIG. 7,318.—Schematic wiring diagram of a 4-tube Handy-phone for inter-office communication. (Model FM-41 General Electric.) The handy phone is an efficient loudspeaker phone system for use in offices, homes, hospitals or other places where voice communication between a central station and one of more 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.

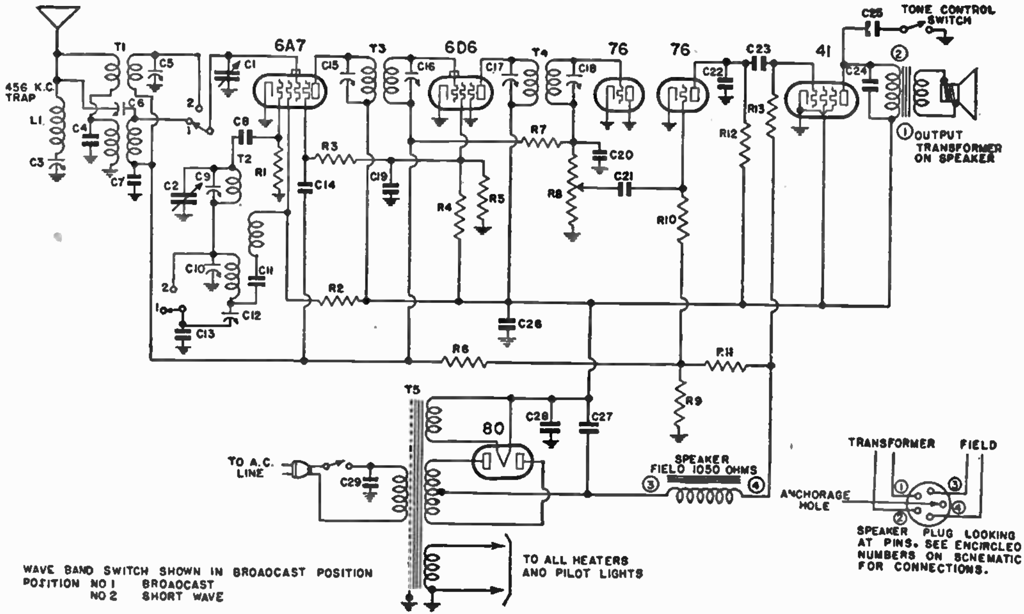
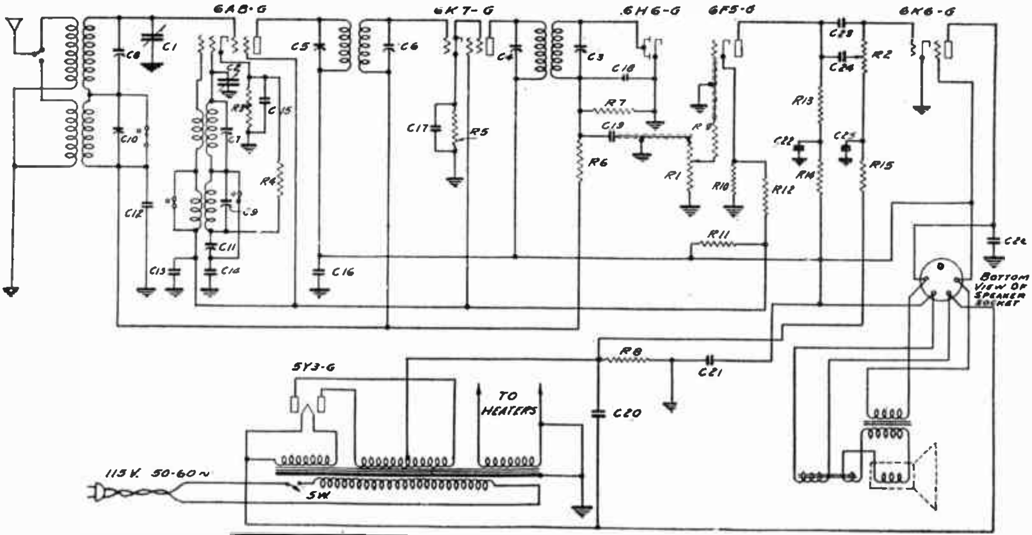


FIG. 7,319.—Schematic wiring diagram of a 6-tube *a.c.* dual-wave superheterodyne receiver. (Emerson Models, AR-171. AR-173, AR-174, AR-176, AR-180, AR-185, AT-170, AT-172, AT-181) *i.f.* peaked at 456 kilocycles. Voltage rating 105-125 volts *a.c.* Power consumption 55 watts. Frequency ranges 540 to 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				
6F6G	Audio Amplifier	6.3	126*		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.

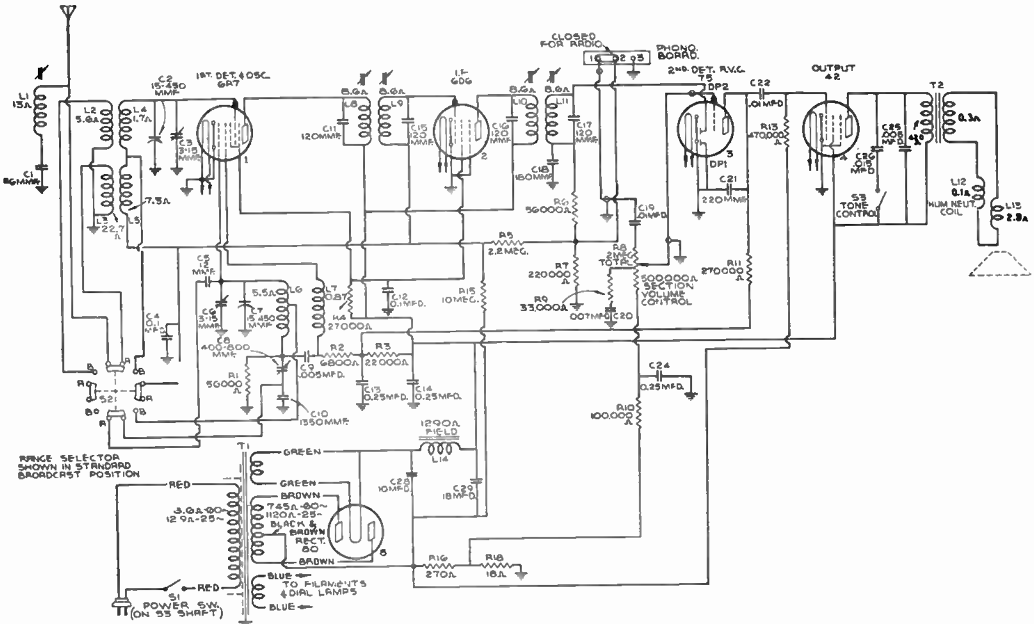


FIG. 7,321.—Circuit diagram of a 5-tube, 2-band *a.c.* superheterodyne receiver. R.C.A. Victor Mode 5T1. Its design includes magnetic-core adjusted *i.f.* transformers and wave-trap; aural-compensated volume control; two-point high frequency tone control; automatic volume control; resistance coupled 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.

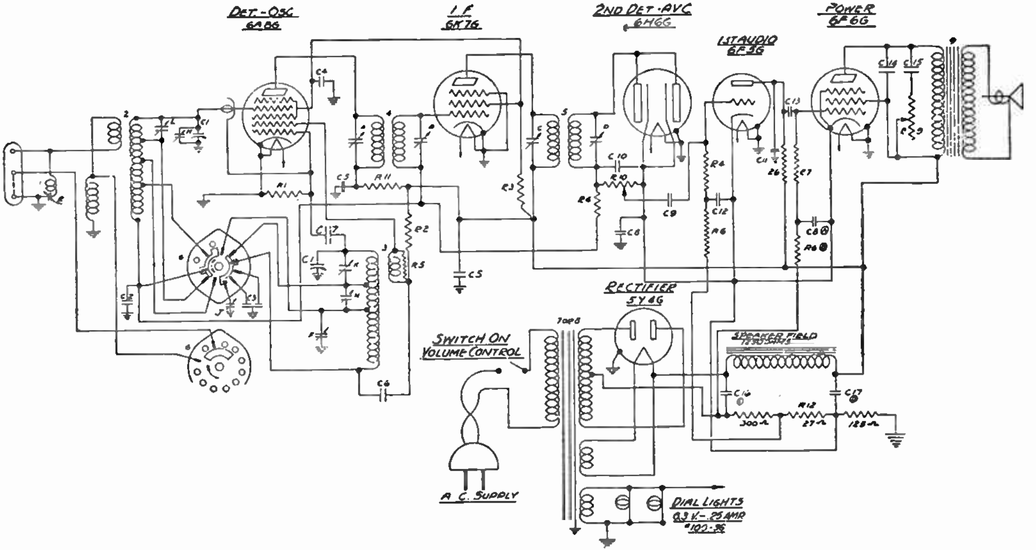


FIG. 7,322.—Schematic circuit diagram of a 6-tube superheterodyne, 3-band radio receiver. (Zenith Models, 6-S-203, 6-S-222, 6S-223, 6S-229, 6S-239, 6S-241.) *I.f.* frequency, 456 kilocycles. In locations subject to code interference adjust wave trap marked (E) for minimum interference with antenna connected and receiver operating in broadcast band. Line voltage 117 volts, *a.c.* 50 to 60 cycles. Power consumption 65 watts.

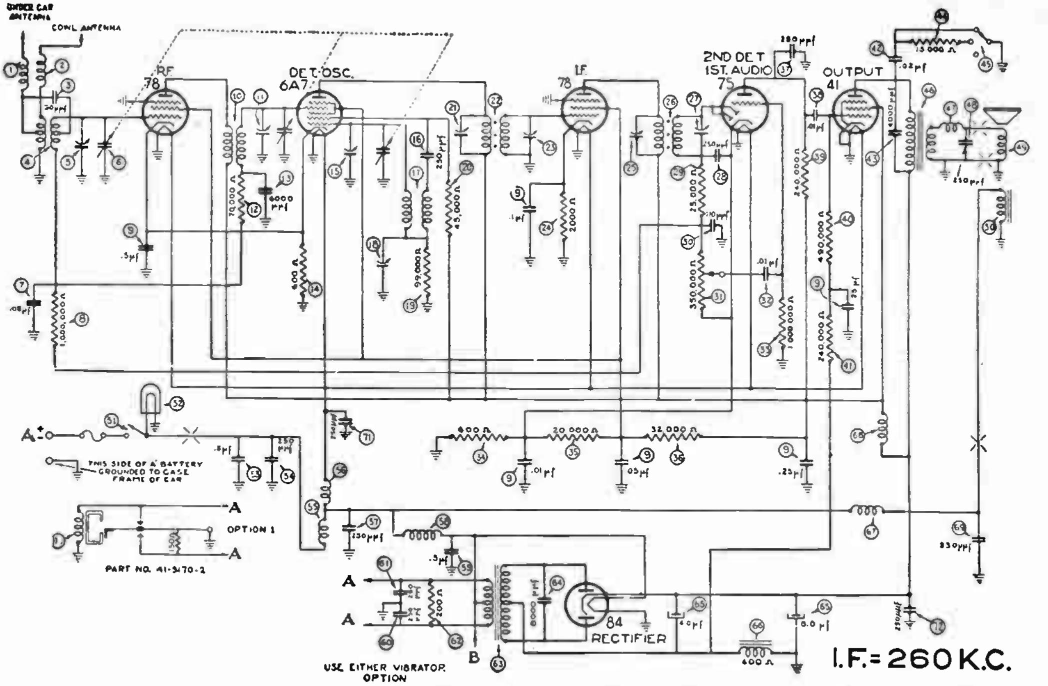


FIG. 7,323.—Schematic wiring diagram of a 6-tube automobile radio receiver. (Philco-Nash N-1434-H.) The speaker of the electrodynamic type is designed for mounting on a frame in the center above the windshield. For installation of the receiver mounting holes are provided in the left hand side of the 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.

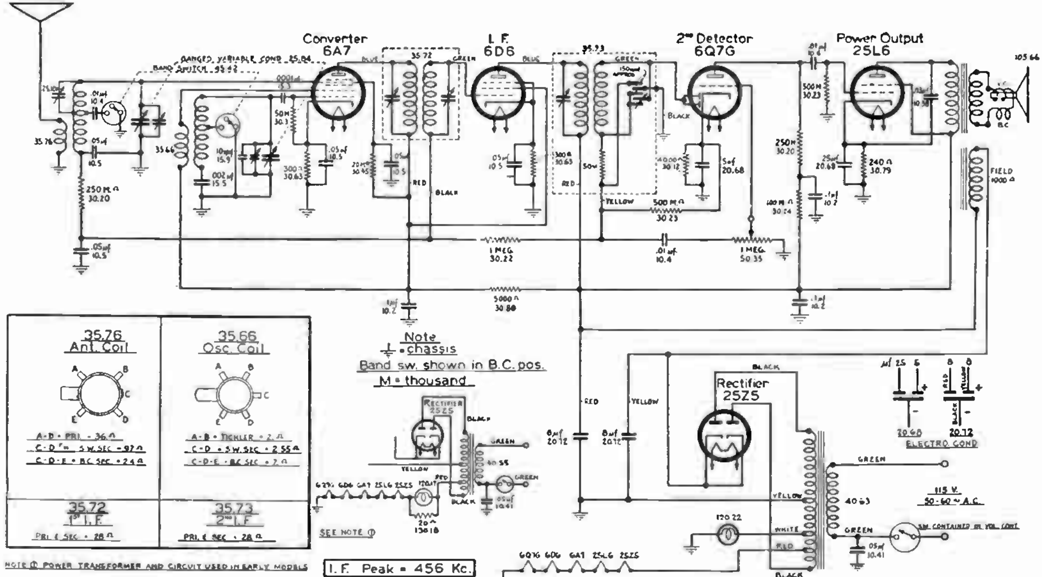


FIG. 7,324.—Circuit diagram of a 5-tube, alternating current, 115 volts, 50-60 cycle radio receiver. (Fada Model 354.)

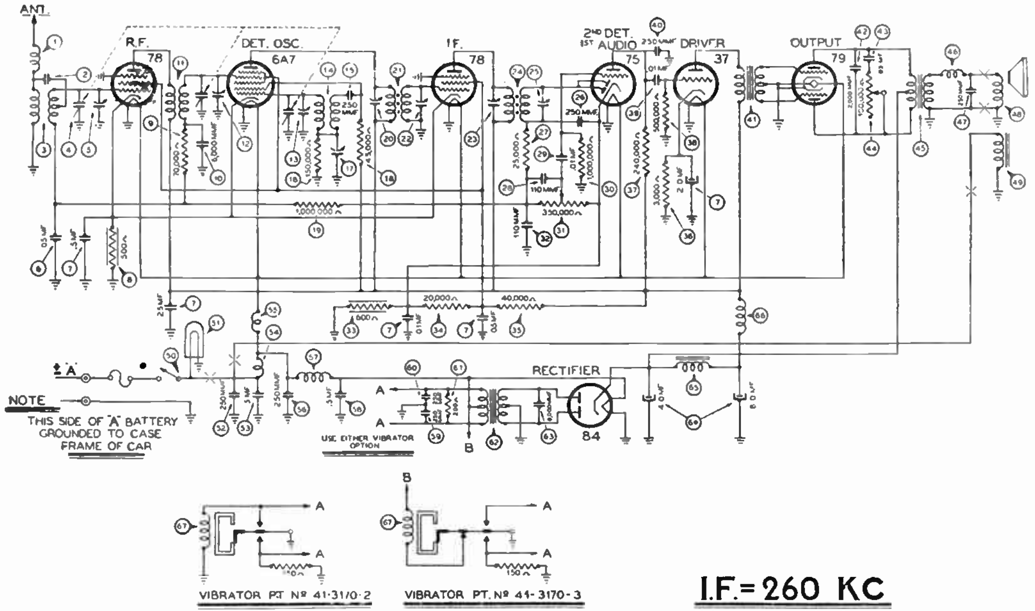


FIG. 7,325.—Circuit diagram of a 7-tube automobile radio receiver. (Philco Lincoln-Zephyr L-1424.) This receiver is equipped with an electro-dynamic speaker, which is mounted on the rear of the instrument board extension. The volume control is automatic, a specially designed input circuit to match the 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.

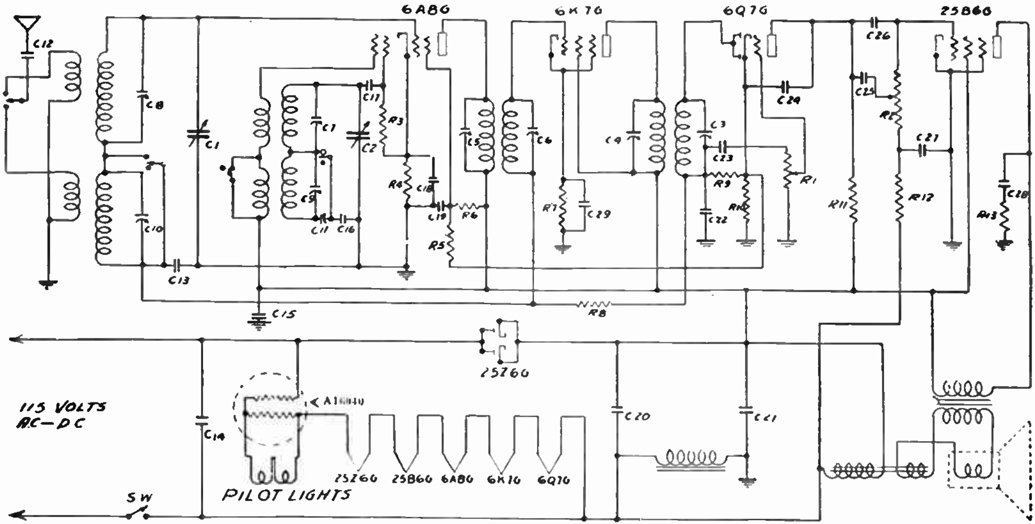


FIG. 7,326.—Schematic wiring diagram of a 6-tube 2-band *a.c.-d.c.* radio receiver. (Majestic Model-60.) The set is designed to operate on 105 to 125 volts, 50-60 cycles *a.c.* or *d.c.* *I.f.* peak 456 kilocycles "B" supply voltage B+ to chassis (ground) = 106 volts. "B" supply voltage B+ to F (line) = 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.

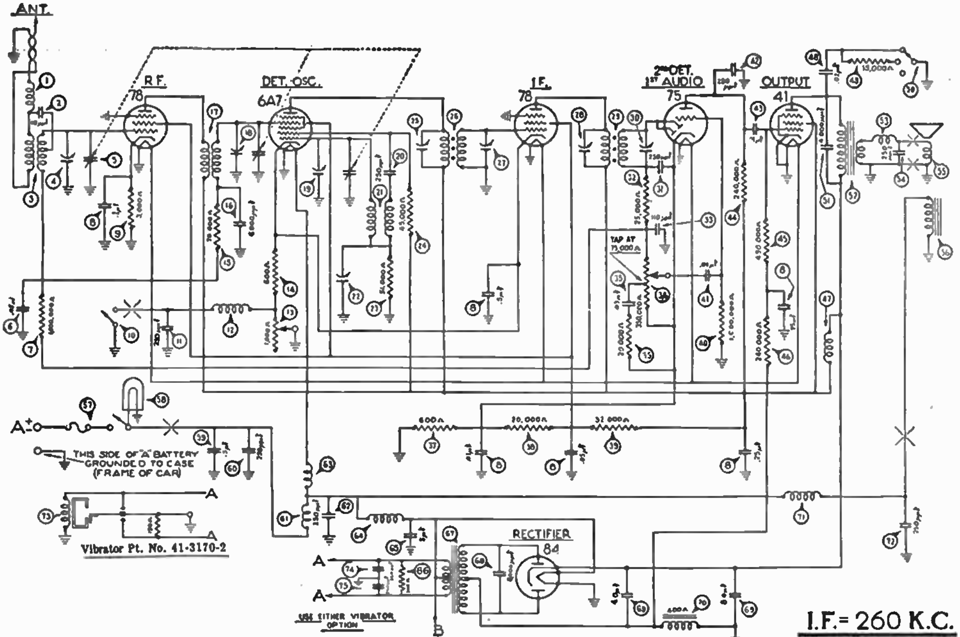


FIG. 7,327.—Circuit wiring diagram of a 6-tube automobile radio receiver. (Philco-Packard P-1432H.) The receiver is designed for installation above the steering column of the car. Special knockouts are provided in the dash for the receiver in all model 115-C and 120-C Packard cars. These plugs are easily 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.

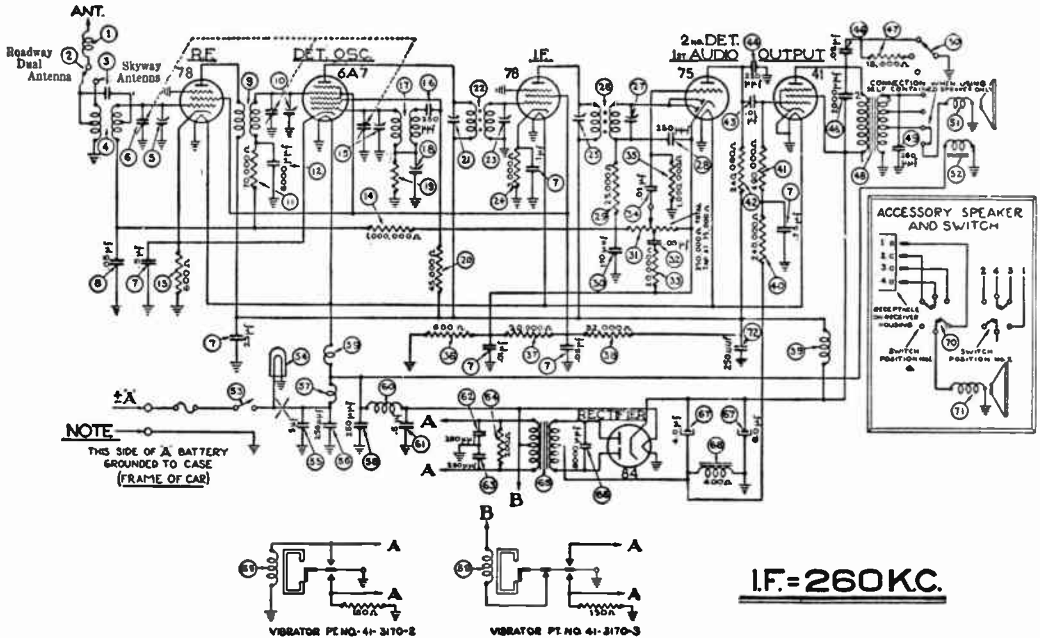


FIG. 7,328.—Schematic wiring diagram of a 6-tube superheterodyne automobile radio receiver. (Philco-Chrysler-Dodge-Plymouth-DeSoto Model C-1452.) The receiver is furnished with an electrodynamic speaker which is installed together with the receiver on the dash directly behind the steering column. Due 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.

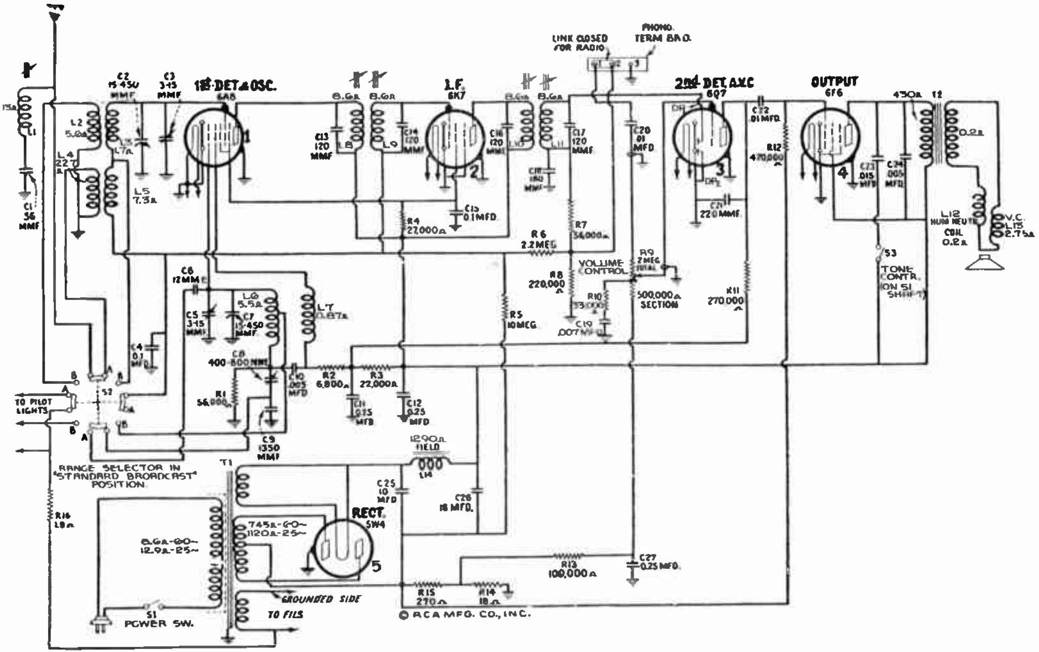


FIG. 7,329.—Circuit diagram of a 5-tube, 2-band *a.c.* superheterodyne receiver. (R.C.A. Victor 5T6, 5T7, 5T8.) Their design includes magnetic core adjusted *i.f.* transformers and wave trap; aural-compensated volume control; high-frequency tone control; resistance coupled audio system; phonograph terminal 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.

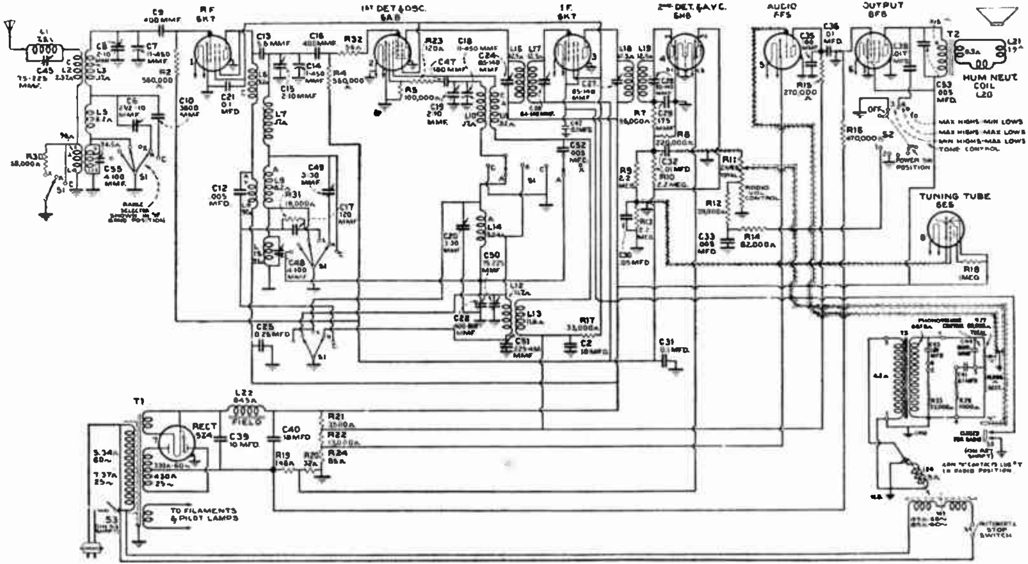


FIG. 7,330.—Circuit diagram of an 8-tube, 3-band *a.c.* superheterodyne radio-phonograph. (R.C.A. Victor 8U2.) This radio-phonograph combination consists of an 8-tube radio receiver and a manually operated phonograph combined in one cabinet. The superheterodyne circuit is used with such features of design 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.

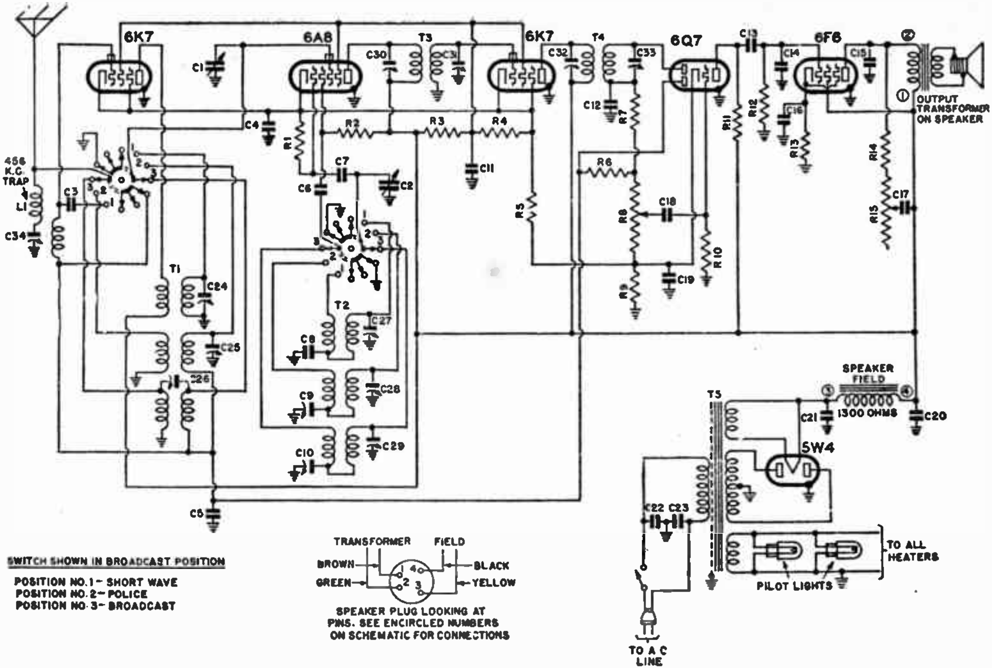


FIG. 7,331.—Circuit diagram of a 6-tube all-wave *a.c.* superheterodyne receiver. (Emerson Model S-147, S-151) *i.f.* peaked at 456 kilocycles. Voltage rating 105-125 volts. Current drain 0.55 amperes. Frequency ranges 550 to 1,750 kilocycles; 1,750 to 5,500 kilocycles; 5.7 to 18.0 megacycles.

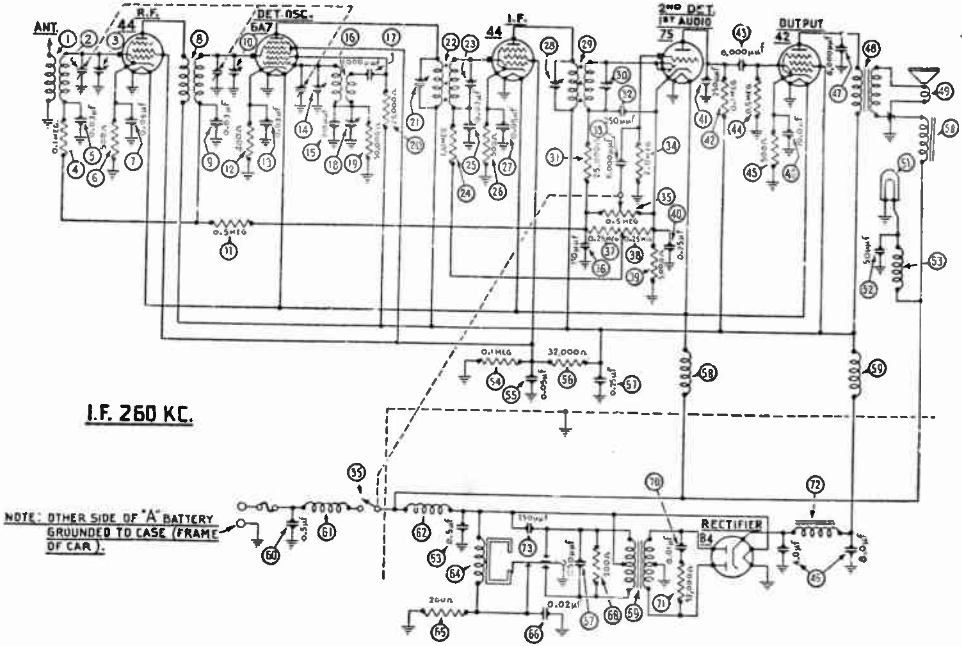


FIG. 7,332.—Circuit diagram of a 6-tube Police automobile radio receiver. (Philco Model DPV.) This model is a superheterodyne, single unit receiver designed for operation on the standard emergency police frequency as allotted by the Federal Radio Commission. The tubes are all of the 6.3 volt type especially 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.

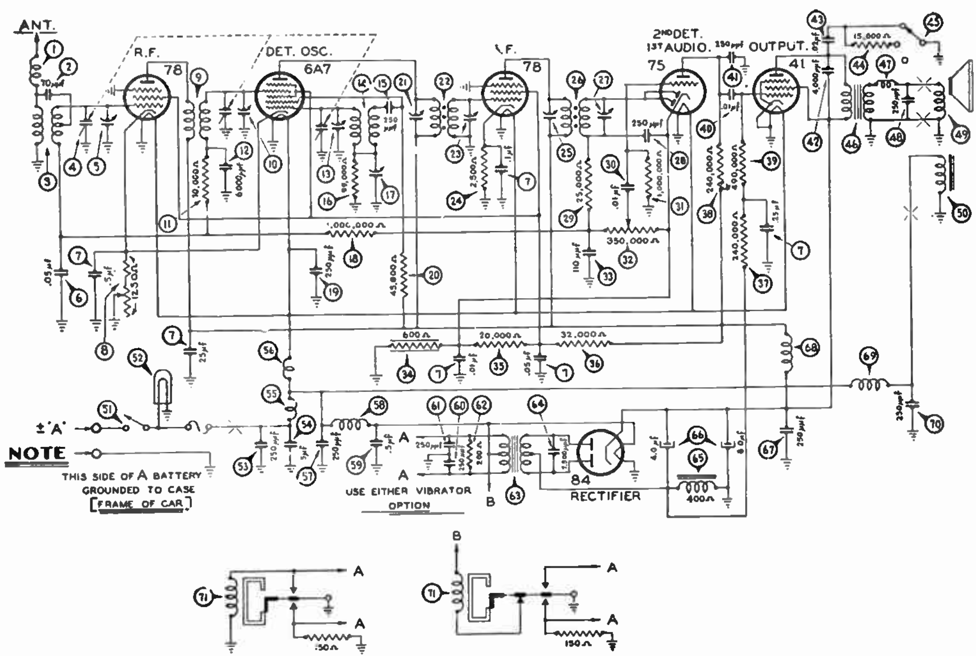


FIG. 7,333.—Circuit diagram of a 6-tube automobile radio receiver. (Ford-Philco F-1442.) The function of the vibrator (shown at 71) is to interrupt the direct current voltage produced by the storage battery, and so enabling the transforming of the current to a higher voltage by means of transformer (shown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

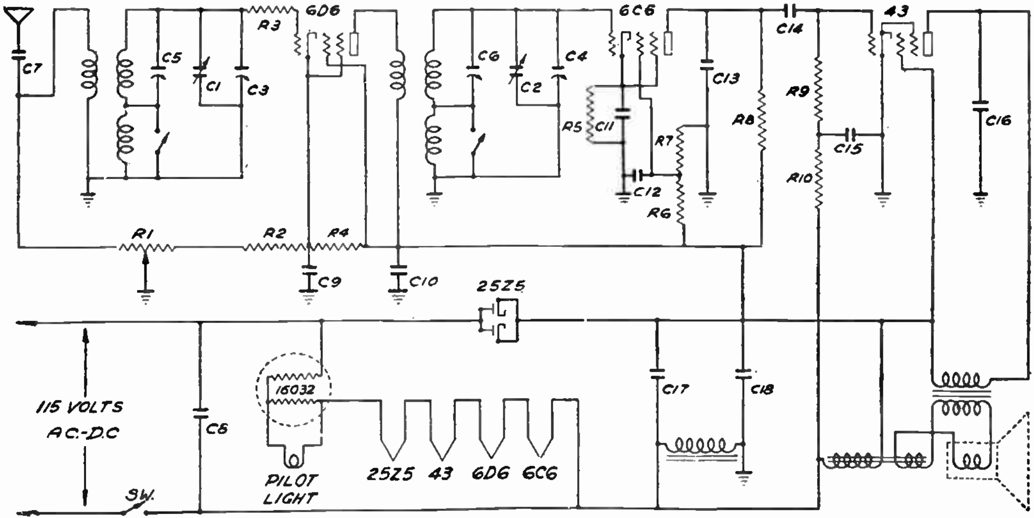


FIG. 7,334.—Schematic wiring diagram of a 5-tube, 2-band *a.c.-d.c.* radio receiver. (Majestic Model 50.) Operating voltage 105 to 125; *a.c.* or *d.c.* *I.f.* frequency 456 kilocycles. Broadcast band 540 to 1,550 kilocycles. Police band 1,550 to 4.000 kilocycles.

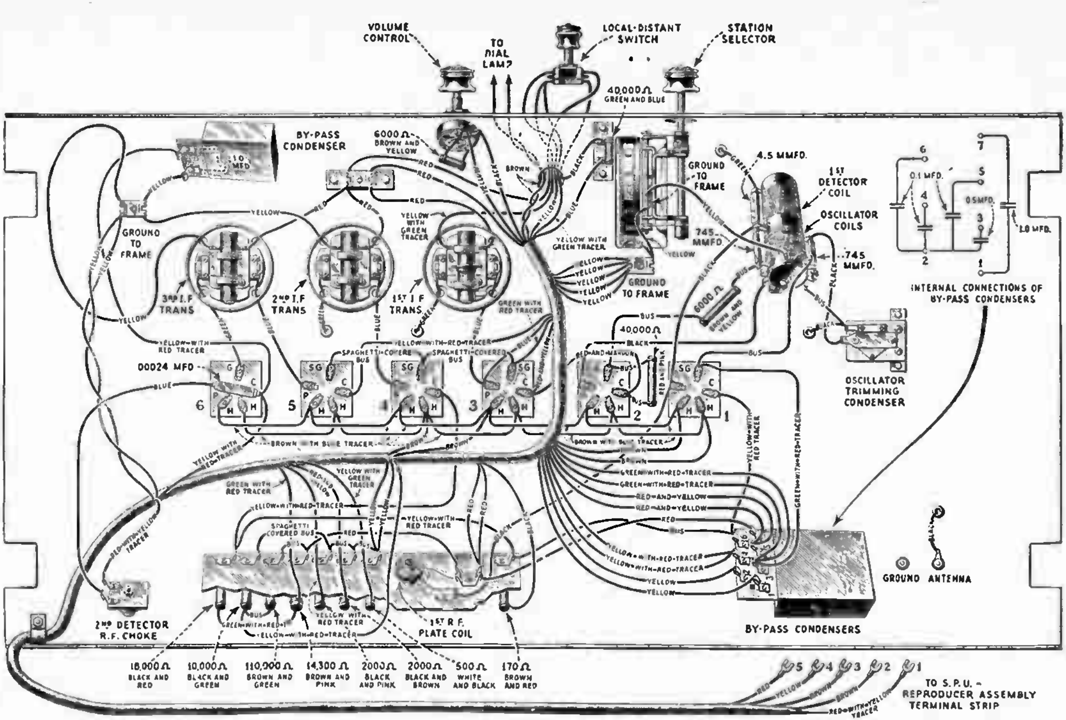


Fig. 7,339.—Pictorial wiring diagram of General Electric Model H 31 screen grid super-heterodyne receiver.

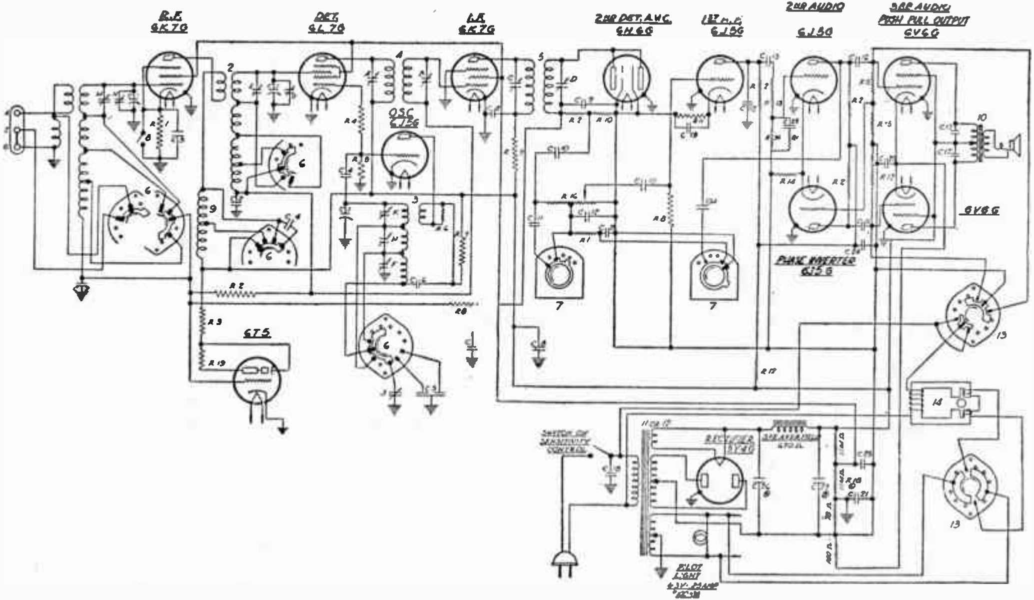


FIG. 7,335.—Schematic circuit diagram of a 12-tube superheterodyne, 3-band radio receiver. (Zenith Models 12-S-205, 12-S-232, 12-S-245, 12-S-265, 12-S-266, 12-S-267, 12-S-268.) *I.f.* frequency 456 kilocycles. Line voltage 117 volts *a.c.* 50 to 60 cycles. Power consumption 110 watts.

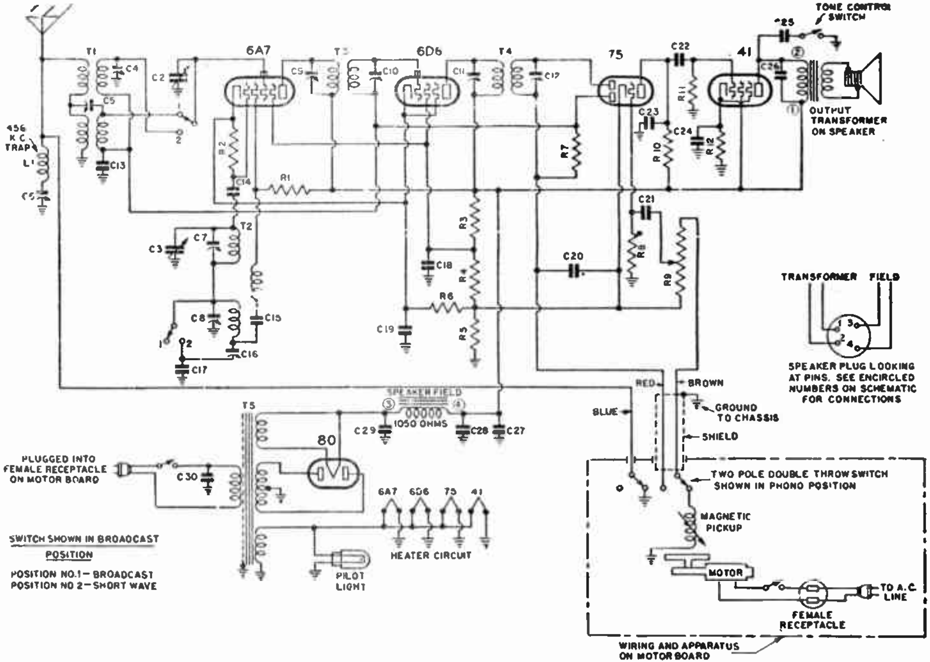


FIG. 7,336.—Circuit diagram of a 5-tube combination phonograph and dual-wave superheterodyne receiver. (Emerson Model L-143.) *I.f.* peaked at 456 kilocycles. Voltage rating 105 to 125 volts *a.c.* Current drain 0.5 amperes for receiver. Frequency range 540 to 1,750 kilocycles—2,200 to 7,500 kilocycles.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

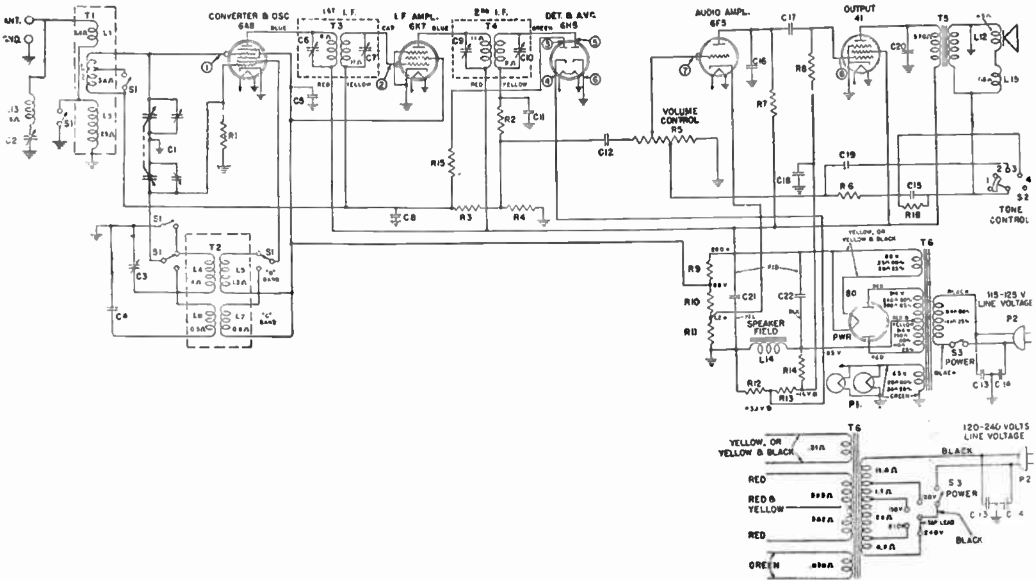


FIG. 7,337.—Schematic circuit diagram of a 6-tube, 2-band *a.c.* superheterodyne receiver. (General Electric Models F-63, F-65 and F-66.) Intermediate frequency 456 kilocycles. Tuning frequency range: Band "B," 540-1,750 kilocycles. Band "C," 2.2-7.0 megacycles. Power consumption 70 watts at 115-125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

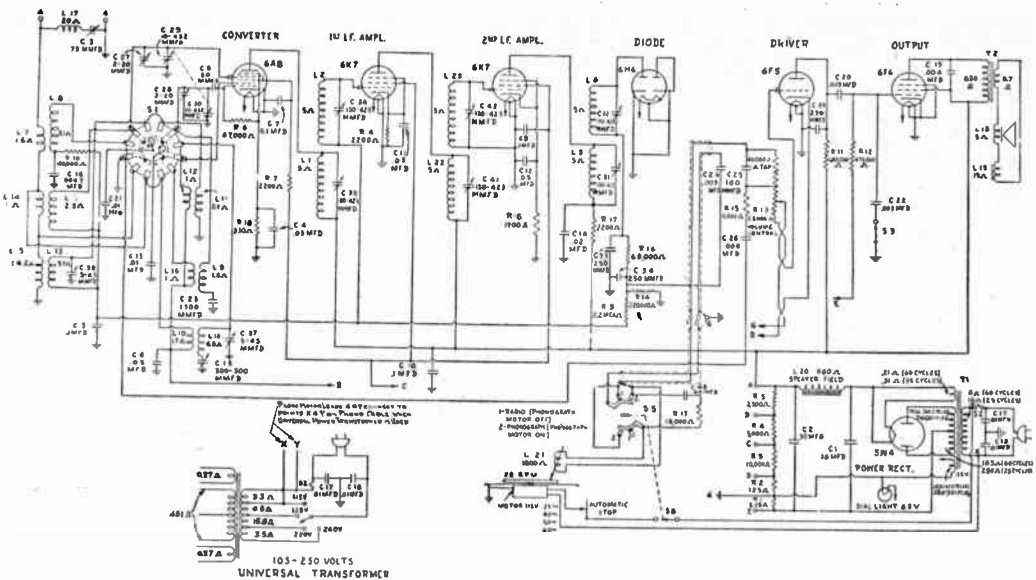


FIG. 7,338.—Schematic circuit diagram of an all-wave radio receiver and phonograph combination. 7-tube *a.c.* superheterodyne. (General Electric Model E-79.) Tuning frequency range: "Band B," 540-1,600 kilocycles. Band "C," 1,560-5,800 kilocycles. Band "D," 5.6-18.0 megacycles (5,600-18,000 kilocycles).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

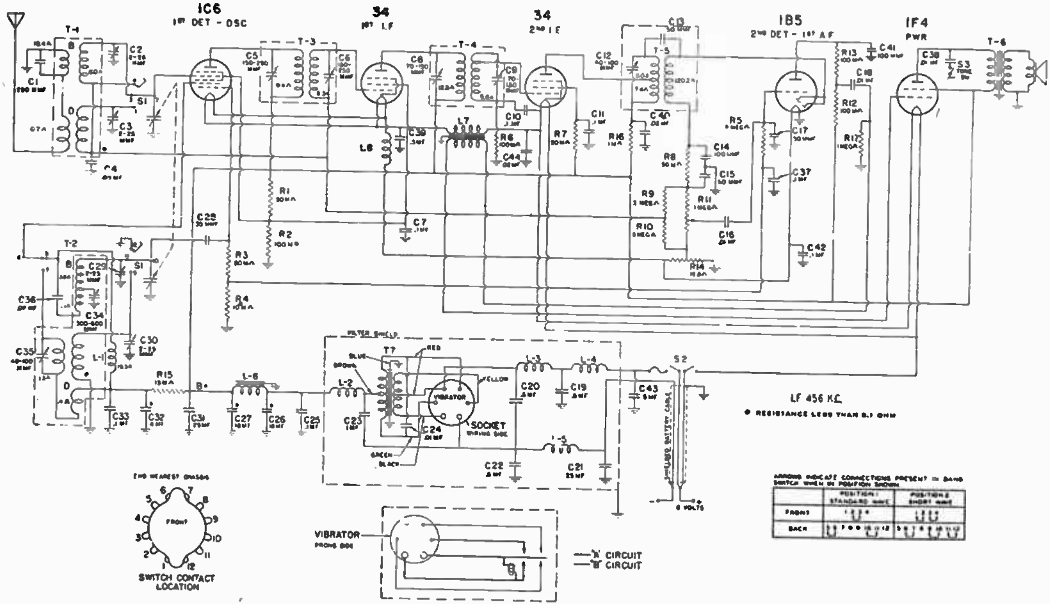


FIG. 7,339-A.—Schematic circuit diagram of a 6-volt synchronous vibrator radio receiver. 5-tube, 2-band (General Electric Models U51 and U55). Intermediate frequency 456 kilocycles. Tuning frequency range: "B" range—528-1,730 kilocycles. "D" range, 5,650-16,000 kilocycles. Power consumption 1.1 amperes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

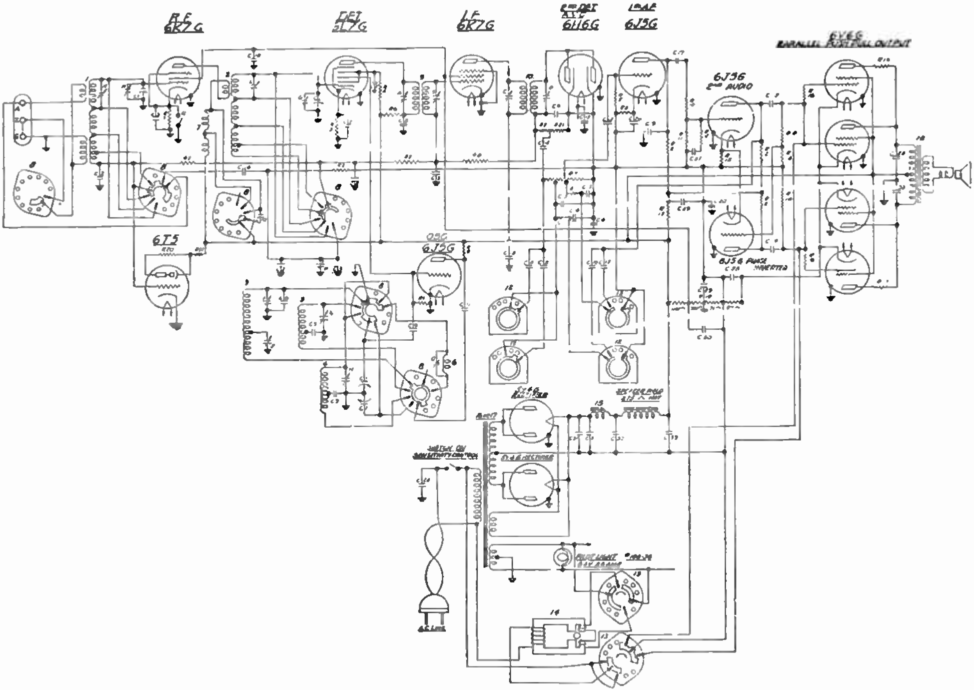


FIG. 7,339-B.—Schematic circuit diagram of a 15-tube superheterodyne 4-band radio receiver. (Zenith Models 15-U-246, 15-U-269 15-U-270, 15-U-271, 15-U-272, 15-U-273.) *I.f.* frequency 456 kilocycles. Line voltage 117 volts *a.c.* 50 to 60 cycles. Power consumption 165 watts

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 intermediate frequency.

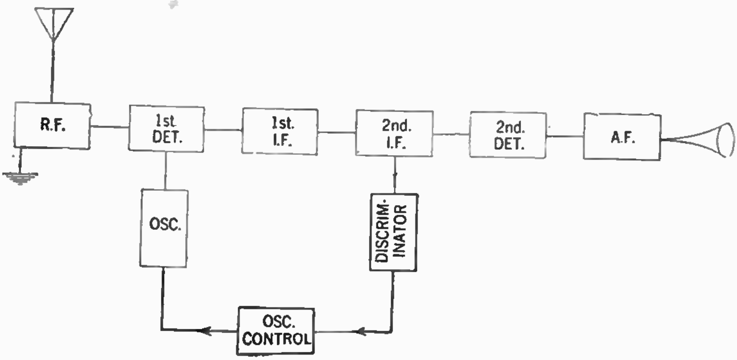


FIG. 1—Conventional block diagram of an automatic radio frequency control circuit.

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.

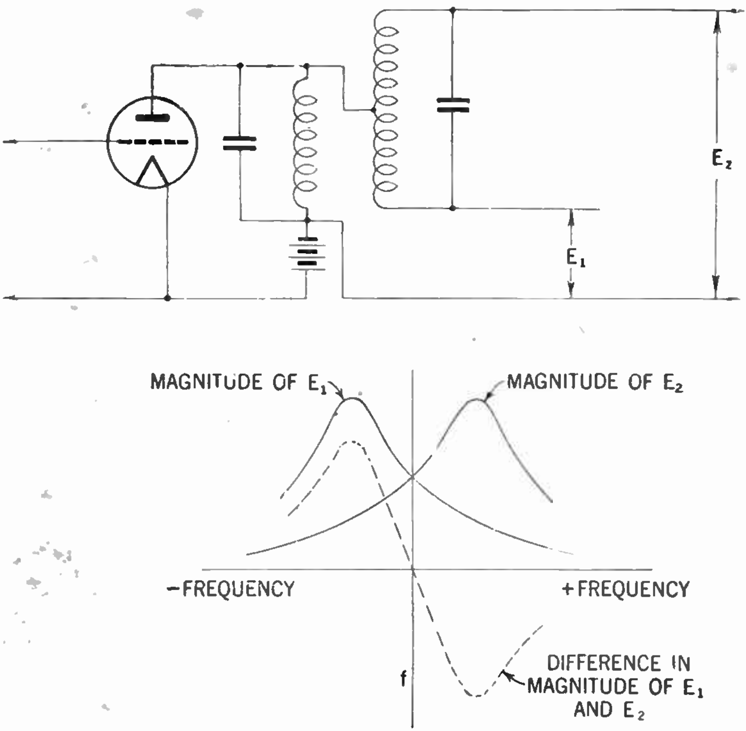


FIG. 2—Diagram and plotted curves illustrating how the potentials at either end of secondary are 180° out of phase.

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.

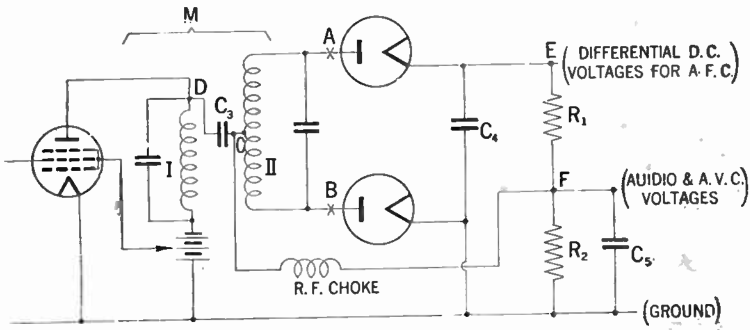


FIG. 3—Automatic radio frequency control detector diagram.

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.

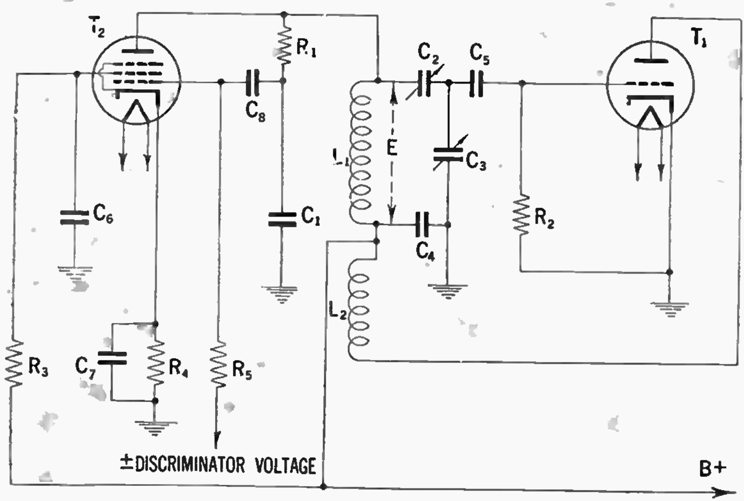


FIG. 4—Typical control circuit diagram.

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.

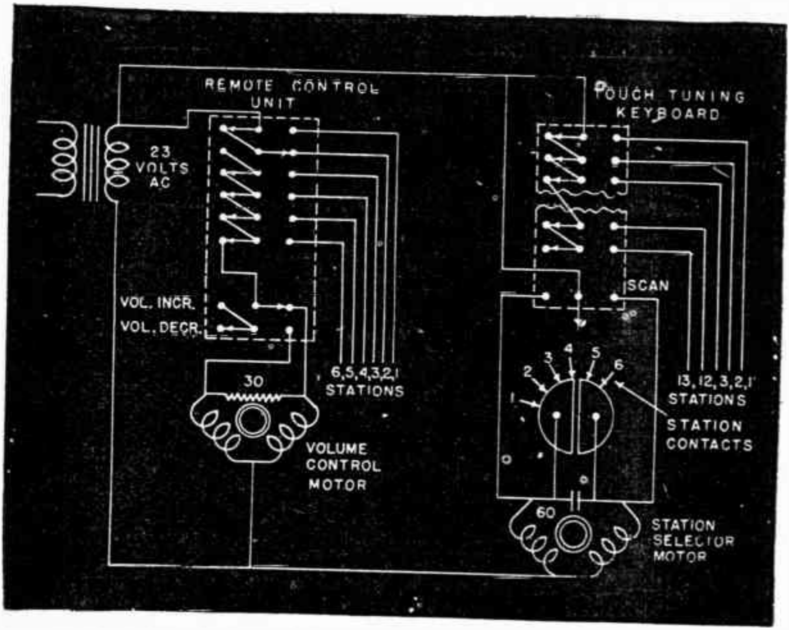


FIG. 5—Schematic wiring diagram of a General Electric push button remote control system.

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.

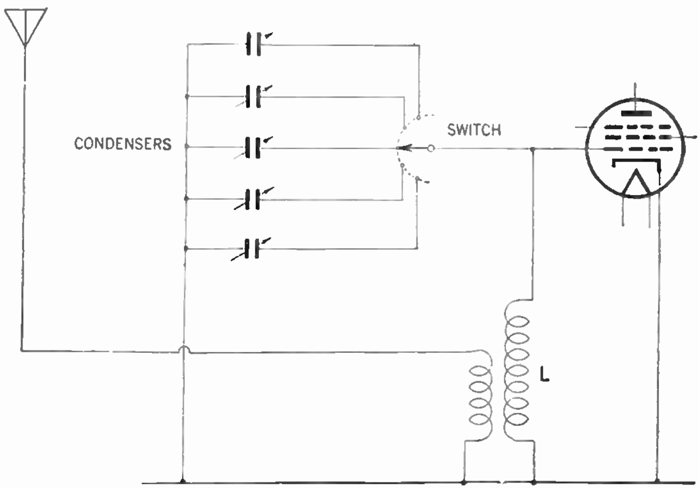


FIG. 6—Schematic diagram showing general principles of simple tuning circuits. In this system a separate pre-set condenser is provided for each station and selected by a switch, as shown.

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 superheterodyne, 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

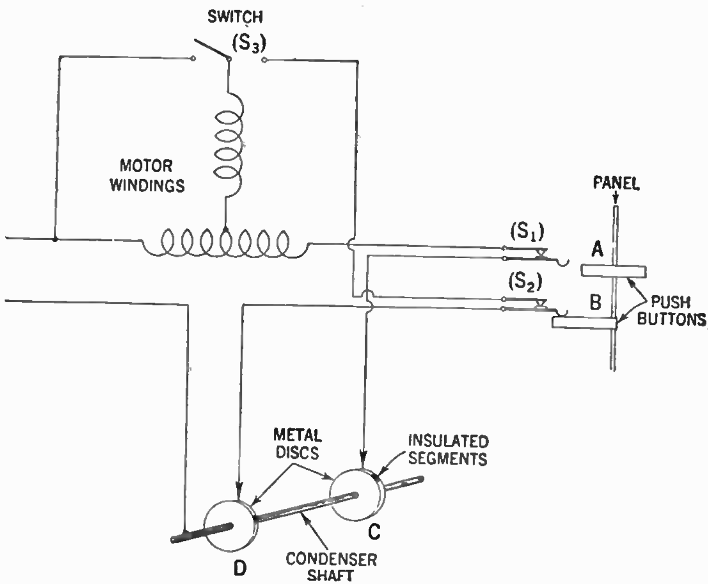


FIG. 7—Diagram illustrating a typical push button control system. The tuning condenser is driven by an electric motor which is controlled by press buttons.

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.

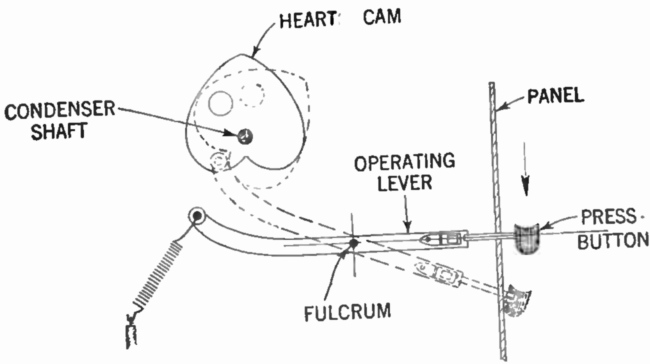


FIG. 8—Principles of control in which the tuning condenser is rotated by the pressure of a lever against a heart cam.

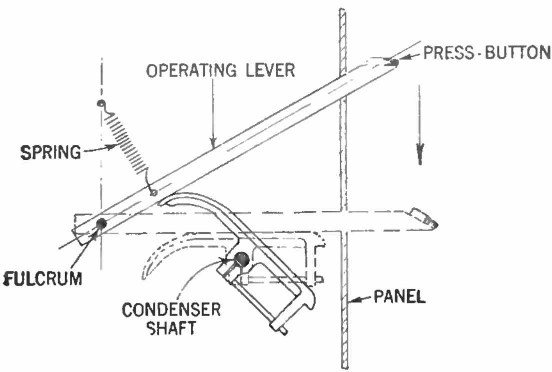


FIG. 9—Method of condenser control by lever system. When pressing the lever it contacts the rounded portion of control bar and so turns the condenser until the flat position is parallel with the lever.

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.

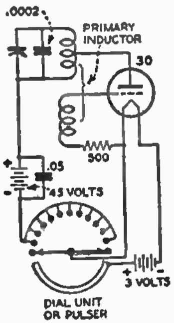
Since the control box is battery operated, the device is easily turned on while selecting a station or changing the volume. This means that the battery drain is practically nil.

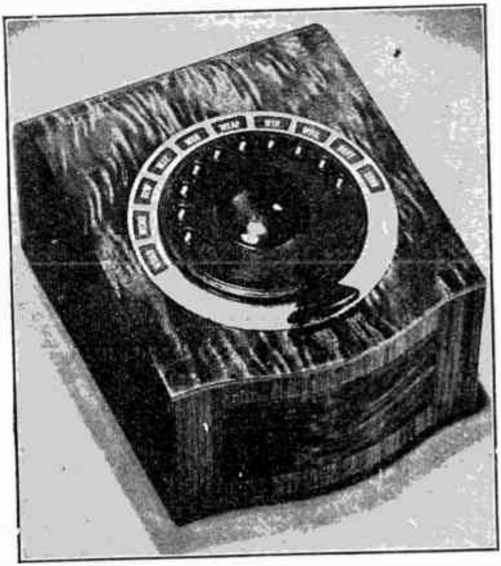
When the dial is operated, the filament circuit to the tube is closed by means of the lower switch arm and the continuous contact bar.

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.

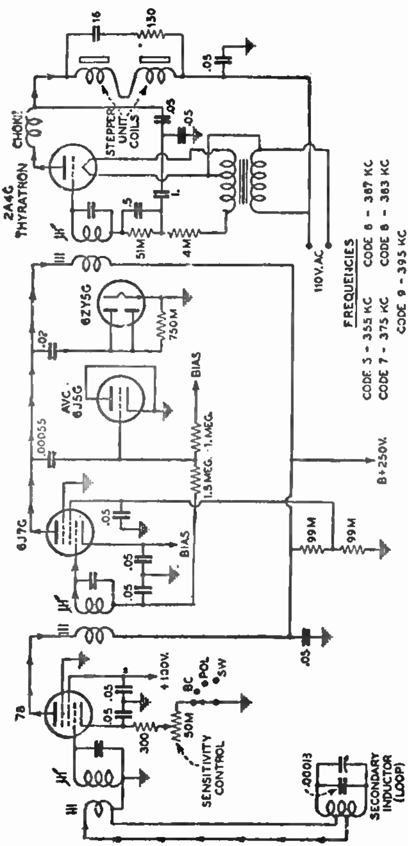


FIG. 12—Five tube stepper unit inter-connected with the high frequency part of the receiver shown in fig. 13. As previously described the receivers are equipped for five different control frequencies with range from 350 to 400 *k.c.* The purpose of the different control frequencies is to prevent interaction 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.

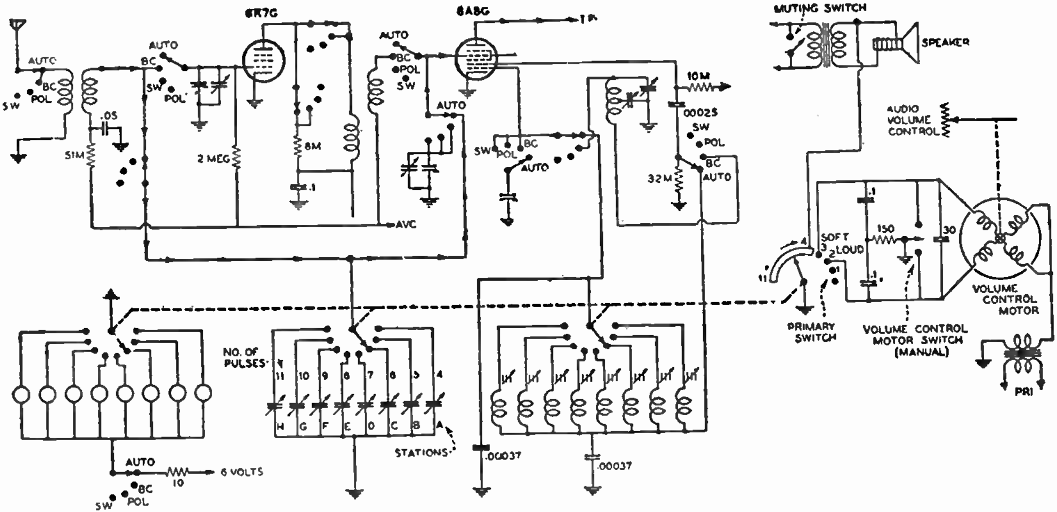


FIG. 13—Circuit diagram of high frequency part of broadcast receiver which is manipulated from a remote point by the control box. The stepper unit, fig. 12, energized by the thyratron tube switches to the desired station. Volume is also controlled remotely by means of a small motor attached to the volume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

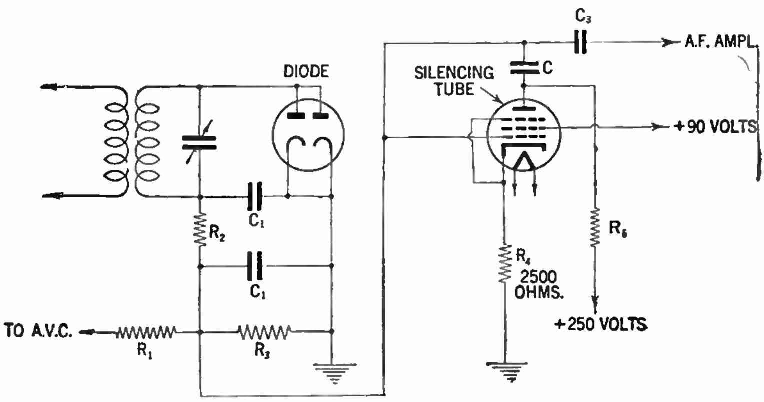


FIG. 14—Automatic tone control circuit.

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.

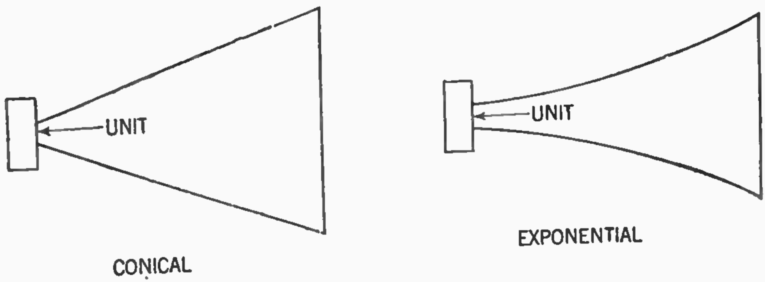
The most efficient type in common use in sound picture work has an efficiency of only about 30%.

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.

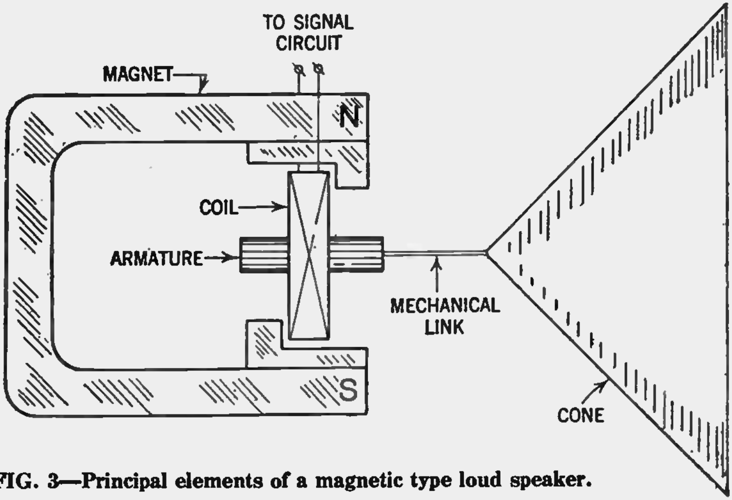


FIG. 3—Principal elements of a magnetic type loud speaker.

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.

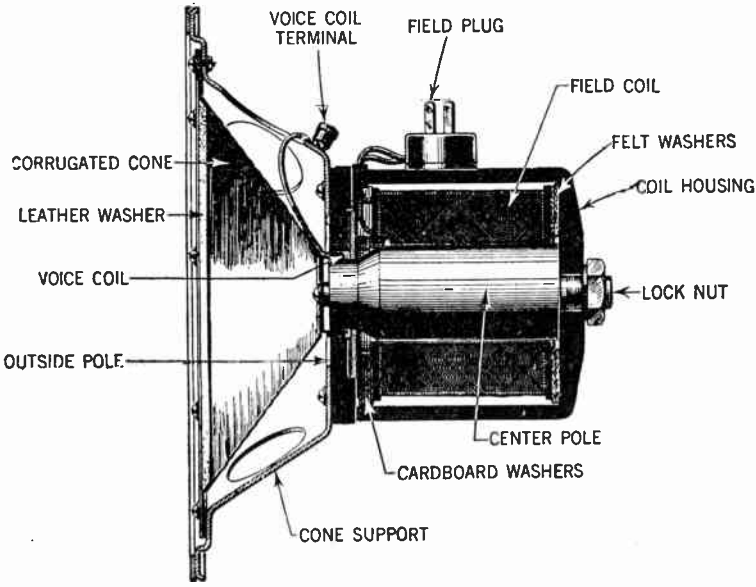


FIG. 4—Cross-section view of a dynamic type loud speaker with a moving coil driving a cone type diaphragm. Details of the various units are here clearly represented.

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.

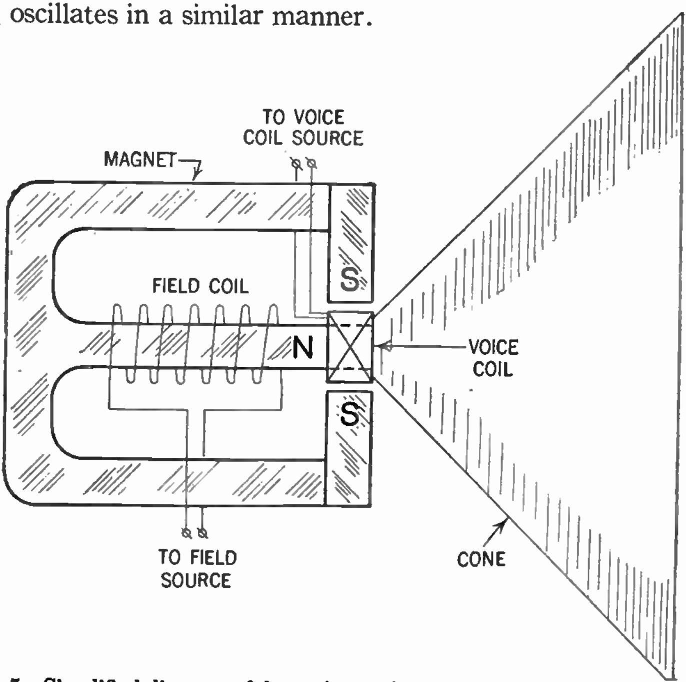


FIG. 5—Simplified diagram of dynamic speaker units shown in fig. 4.

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.

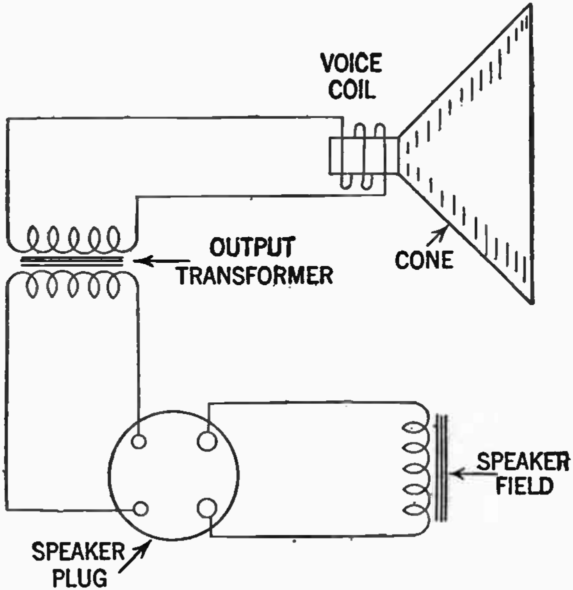


FIG. 6—When the dynamic speakers as in some commercial sets are connected by means of plug and cable to the chassis, the connections may be as shown in fig. 6 or 7; generally however, there is no set rule for these connections. The output transformer may be mounted on the receiver chassis or on the speaker 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.

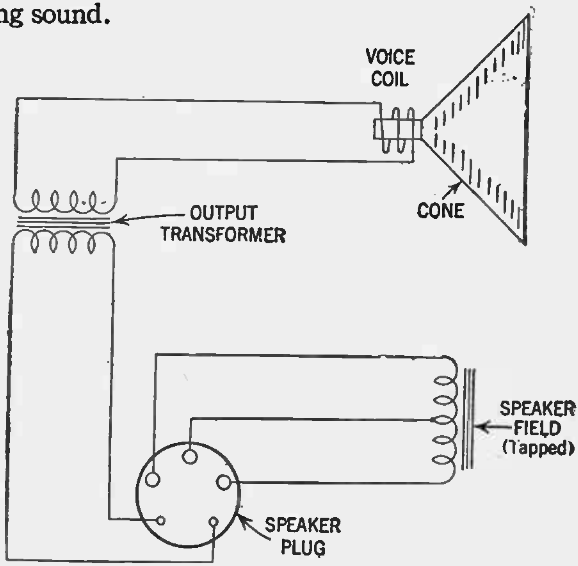


FIG. 7.—Schematic diagram of connections to speaker by means of plug-cable arrangement.

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.

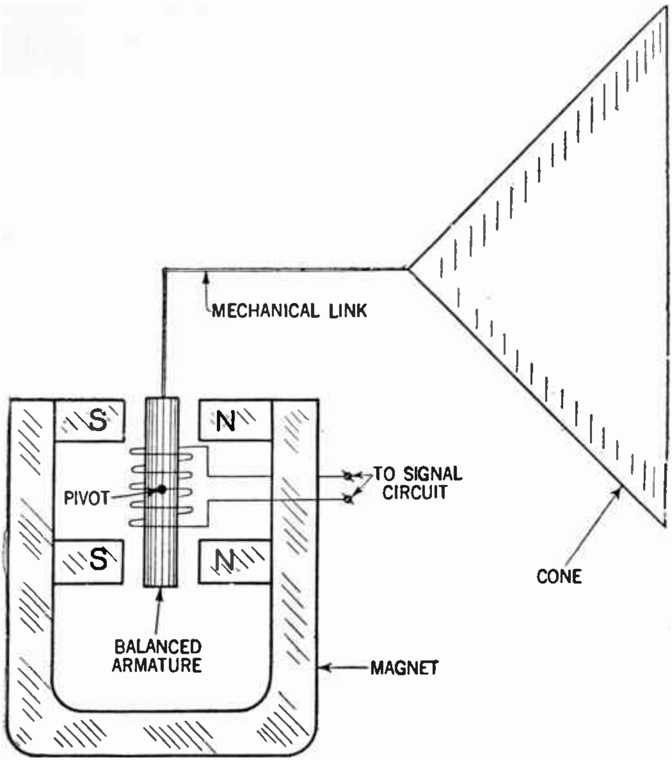


FIG. 8—Balanced armature type speaker. ***In construction*** **the balanced pivoted armature is a soft iron bar forming a core of a coil of several thousand turns of fine wire supplied with audio frequency current.** ***In operation*** **when a signal current flows through the coil, a magnetic field 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.

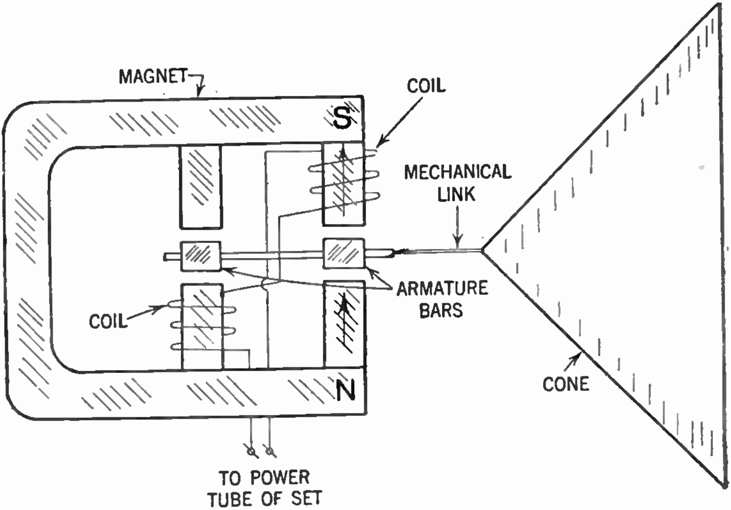


FIG. 9—View showing various units and connections for an induction type loud speaker.

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.

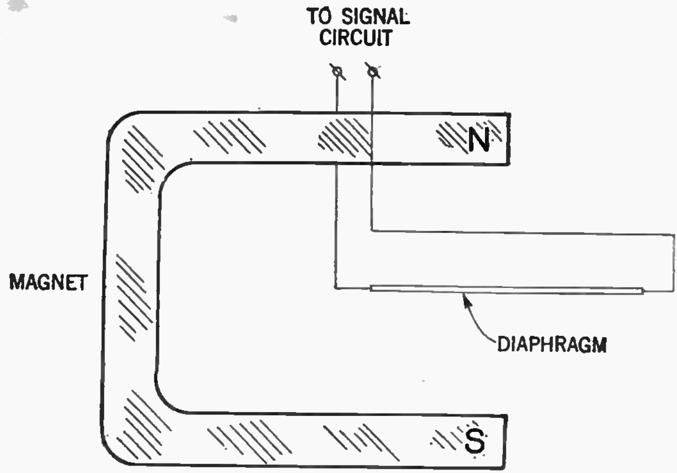


FIG. 10—Principal element of metal strip speaker. A megaphone is usually associated with this type of speaker.

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.

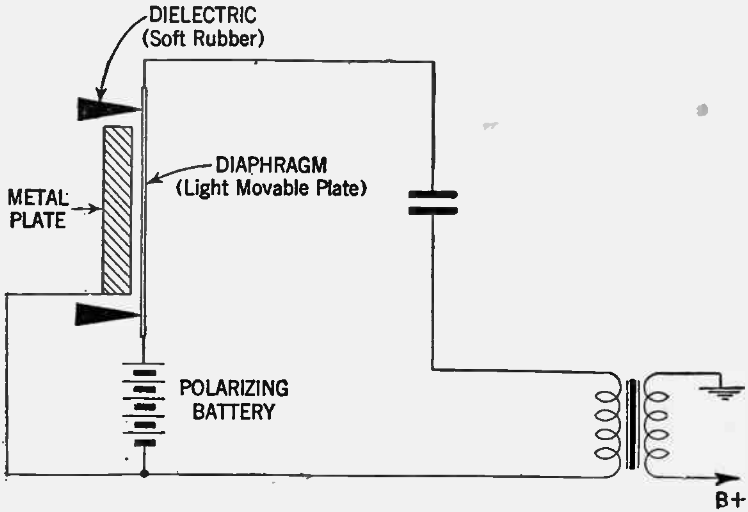


FIG. 11—Electrostatic speaker showing circuit connections. In construction, the metal plate is made rigid. The diaphragm consists of a thin layer of metal sprayed on the rubber dielectric.

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.

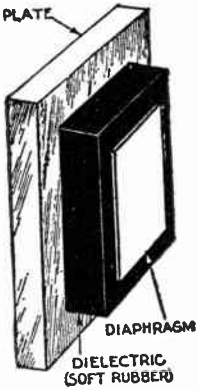
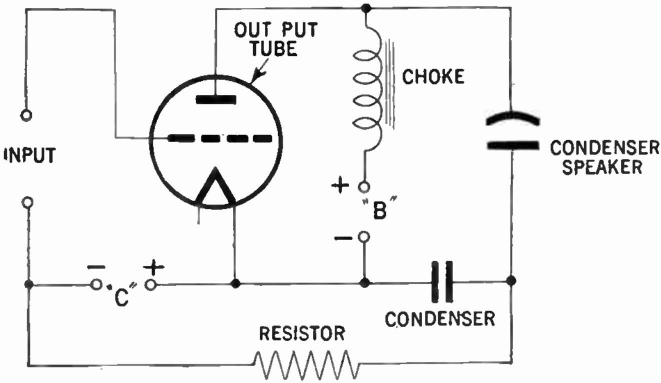
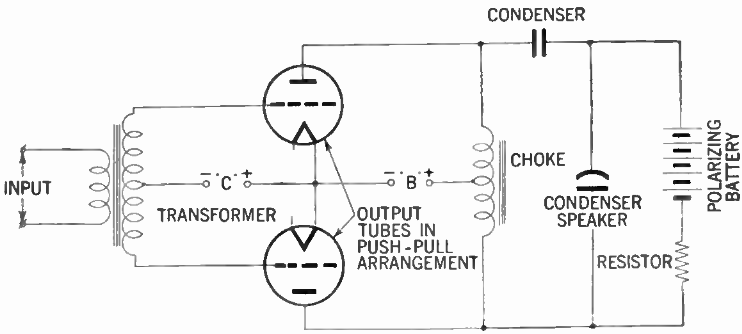


FIG. 12—Elements of an electrostatic speaker. It consists essentially of a form of condenser, hence the name as it is often called a condenser speaker.

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.

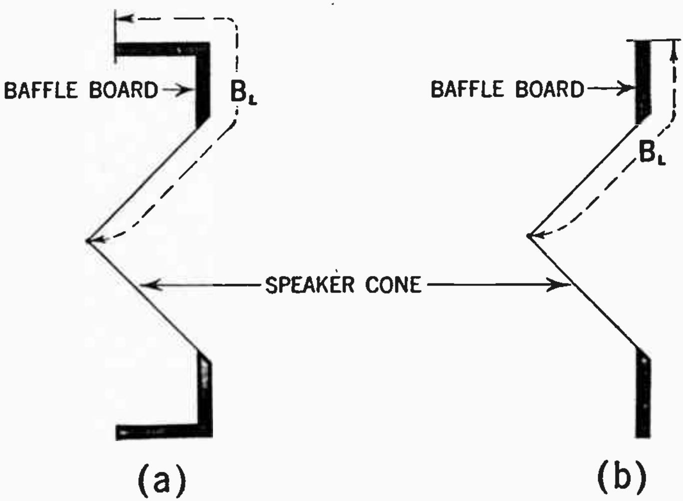


FIG. 15—Various speaker baffles; *a*, and *b*, indicates box and flat baffle types respectively. Dotted lines indicate length of baffle board in each type.

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

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

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.

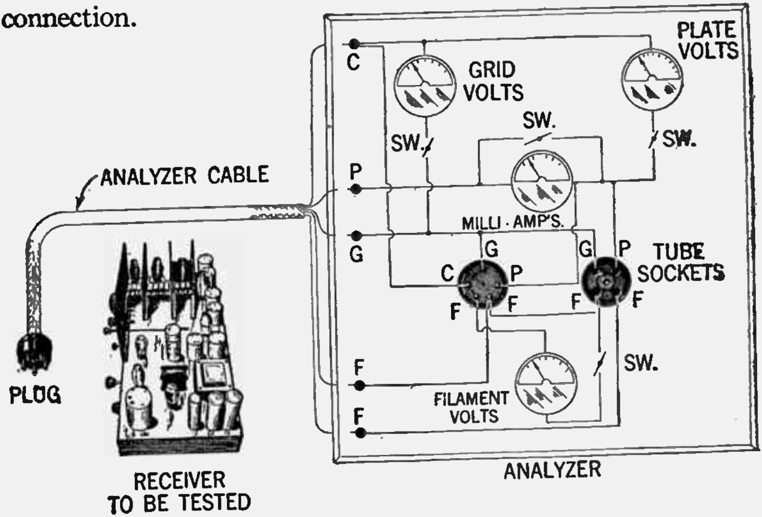


FIG. 1—Principal parts of a simple analyzer. The performance of the test is as follows: After a preliminary investigation of possible outside sources of trouble such as faulty or grounded aerials, open soldering joints, broken parts, etc., remove tube to be tested from set to proper socket in analyzer, and insert analyzer plug in place of the tube removed from set. Test the tubes one by oue, 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 before 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:

$$X_c = \frac{1{,}000{,}000}{2 \times \pi \times f \times C_{m.f}} \text{ ohms} \qquad (1)$$

When a 60 cycle current is used ($f=60$) and C is measured in microfarads, this formula then becomes:

$$C_{m.f} = \frac{2{,}650}{X_c} \qquad (2)$$

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.

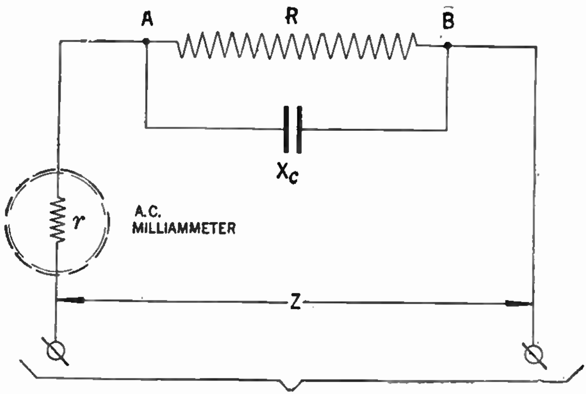


FIG. 2—Connection for measurement of capacity when capacitor is shunted by a non-inductive resistor.

The impedance Z, of the above circuit combination is obtained by the following formula:

$$Z=\sqrt{r^2+\frac{(R+2r)RX_c^2}{R^2+X_c^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

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:

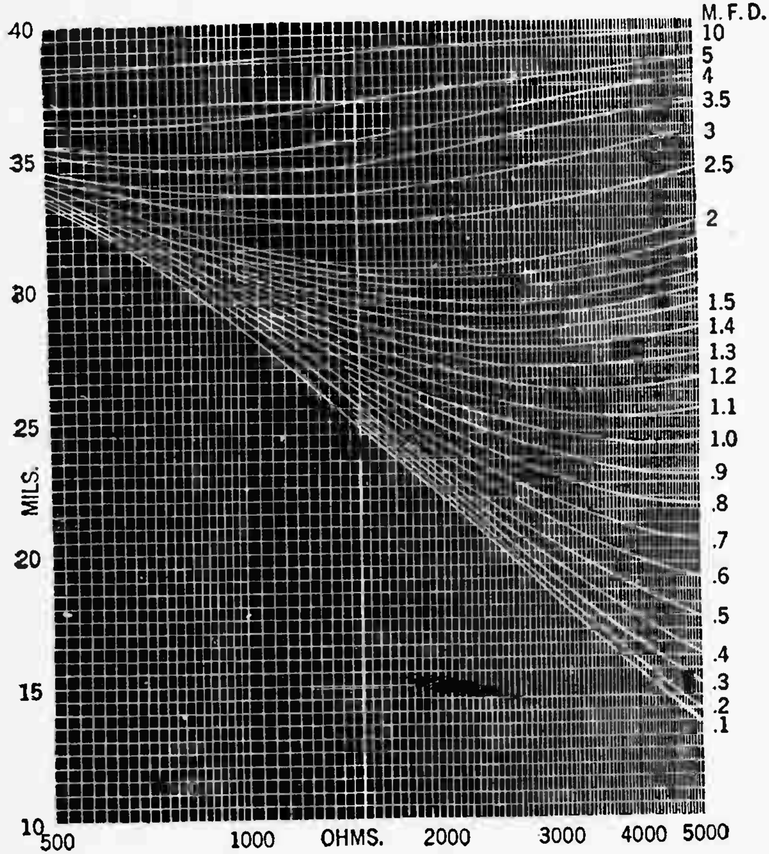


FIG. 3—Parallel resistance-capacity chart. Charts may conveniently be designed to suit individual requirements.

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:

$$X_L = 2\pi f L \text{ ohms} \quad \ldots\ldots (4)$$

or if $f = 60$ cycles, then

$$L = \frac{X_L}{377} \text{ henries} \quad \ldots\ldots (5)$$

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:

$$i = \frac{e}{\sqrt{R^2 + X_L^2}} \quad \text{.....................(6)}$$

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:

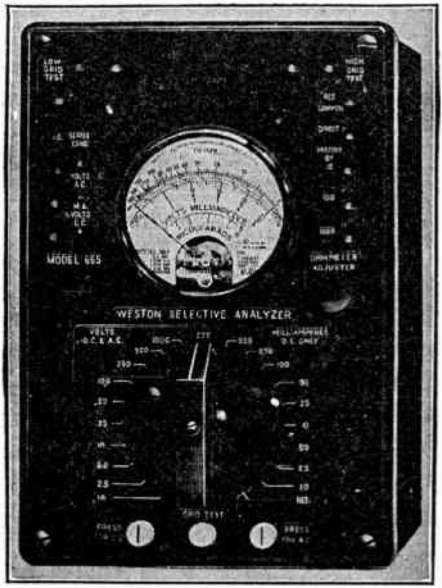


FIG. 4—Front view of Weston Model 665 selective analyzer.

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.

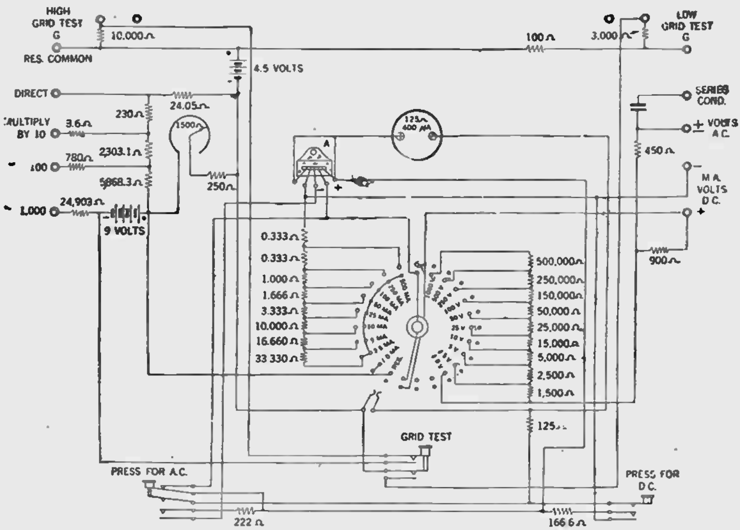


FIG. 5—Internal connection diagram of Weston Model 665 selective analyzer.

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.

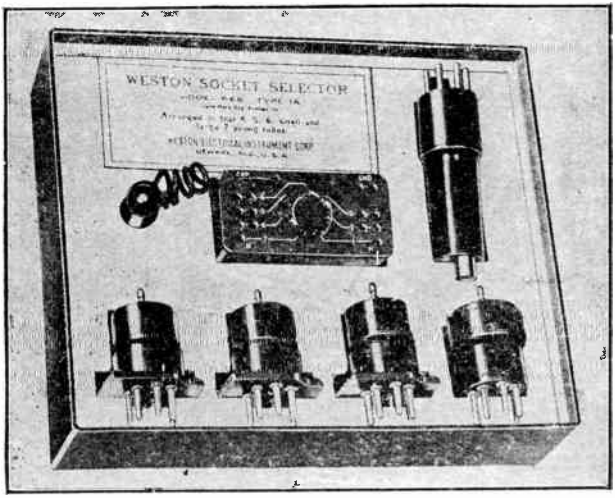


FIG. 6—Socket selector for use with Weston Model 665 analyzer.

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,

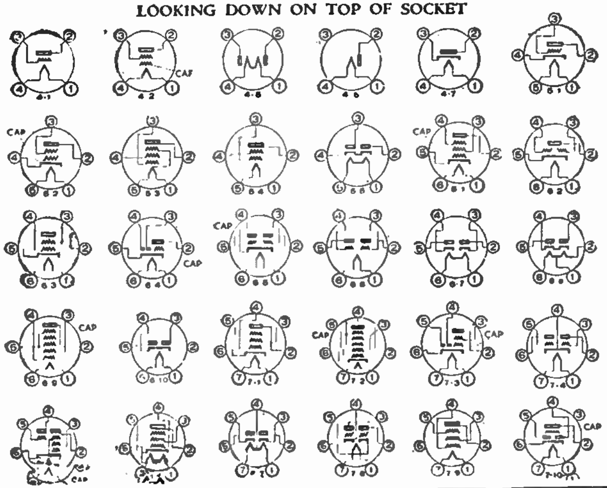
TUBE BASE CHART

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.

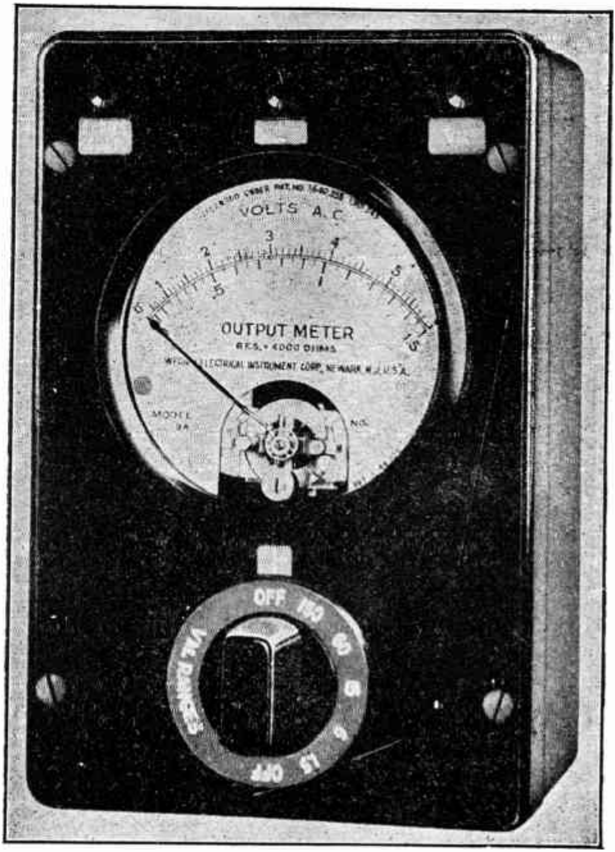


FIG. 7—Panel view of Weston Model 571 output meter.

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.

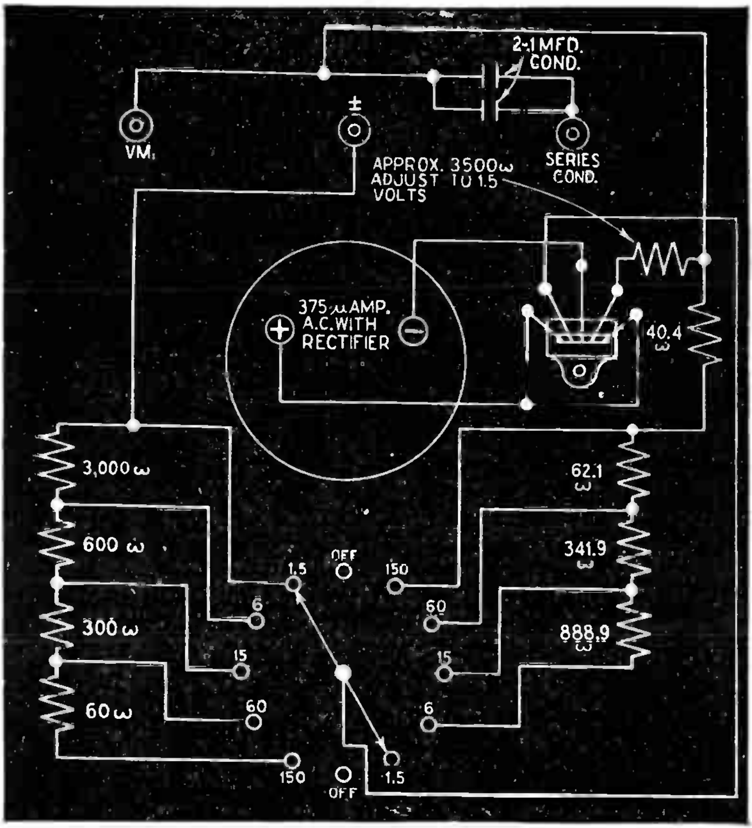


FIG. 8—Schematic wiring diagram of Weston Model 571 output meter.

Weston Model 763 Ohmmeter.—Front view and connection diagram of this instrument is shown in figs. 9 and 10 respectively.

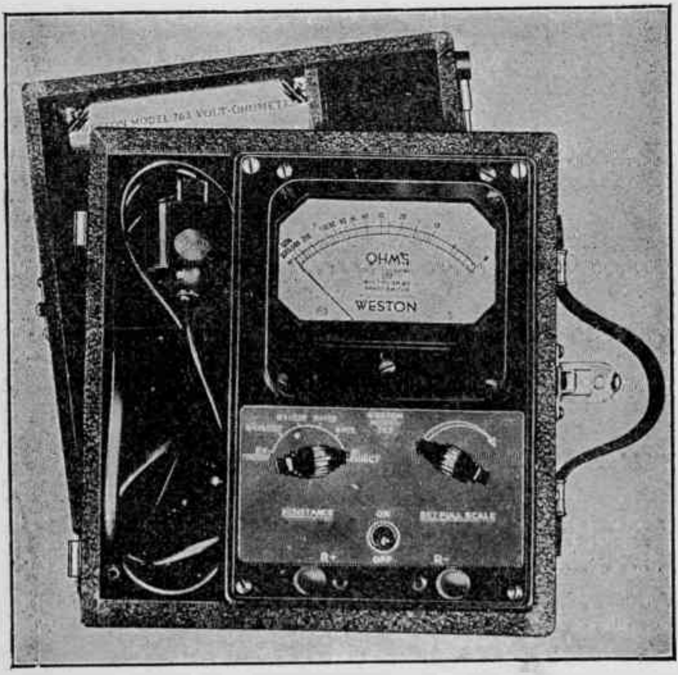


FIG. 9—Panel view of Weston Model 763 ohmmeter.

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.

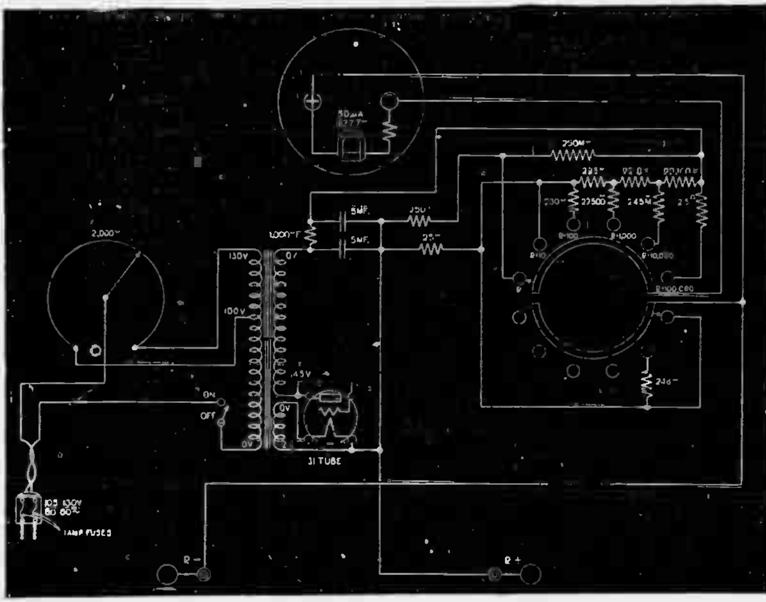


FIG. 10—Wiring diagram for internal connection of Weston Model 763 ohmmeter.

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%.

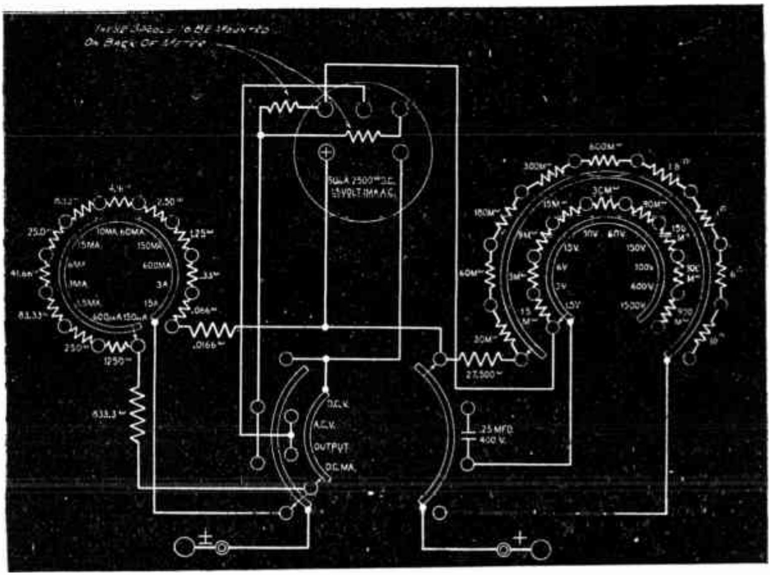


FIG. 12—Diagram showing internal connection of Weston Model 765 analyzer.

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*.

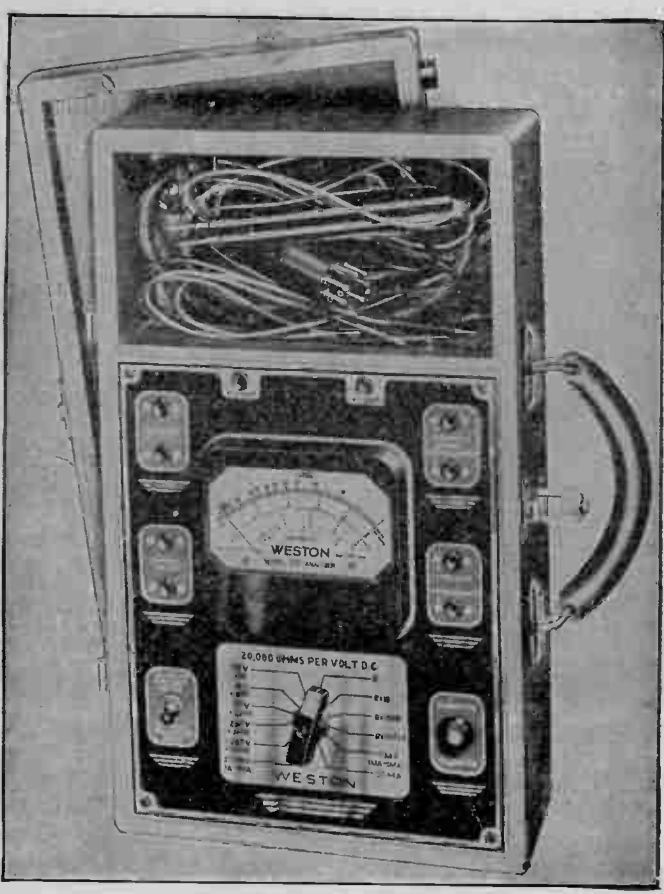


FIG. 13—Panel view of Weston Model 772 analyzer.

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,

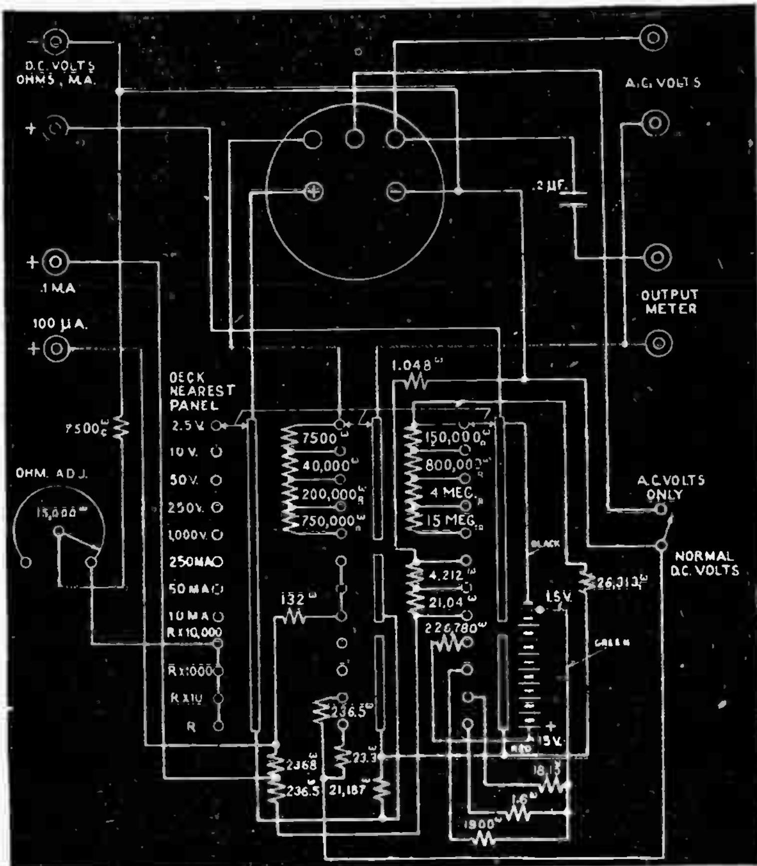


FIG. 14—Wiring diagram of Weston Model 772 analyzer.

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.

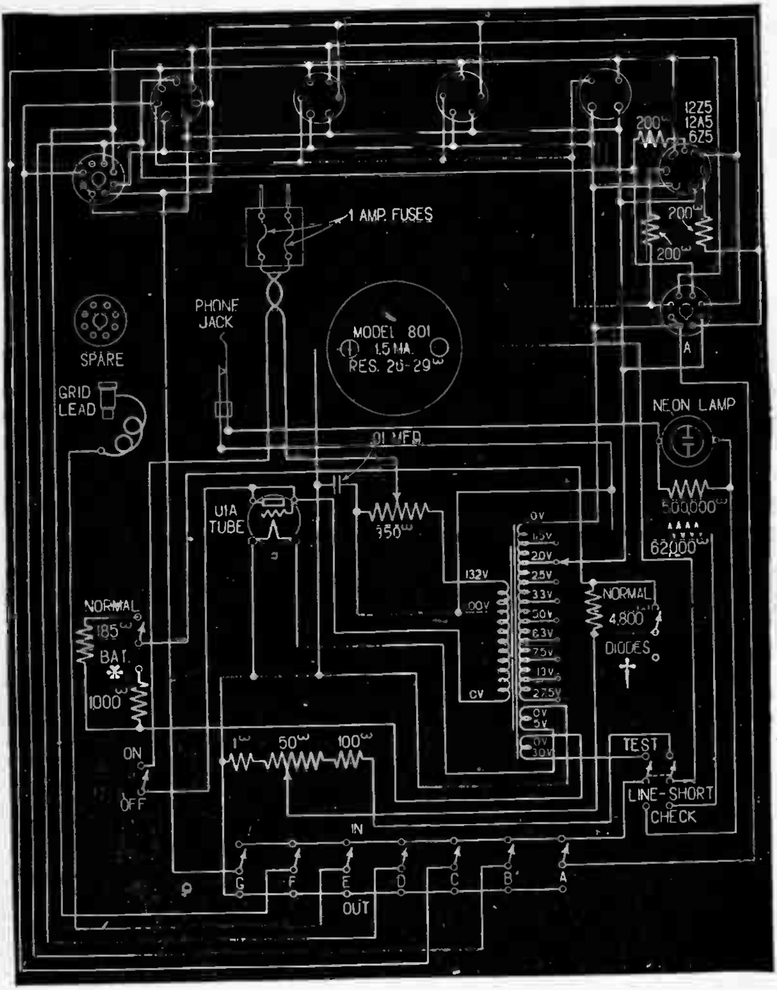


FIG. 16—Diagram of connection for Weston instruments Model 773.

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.

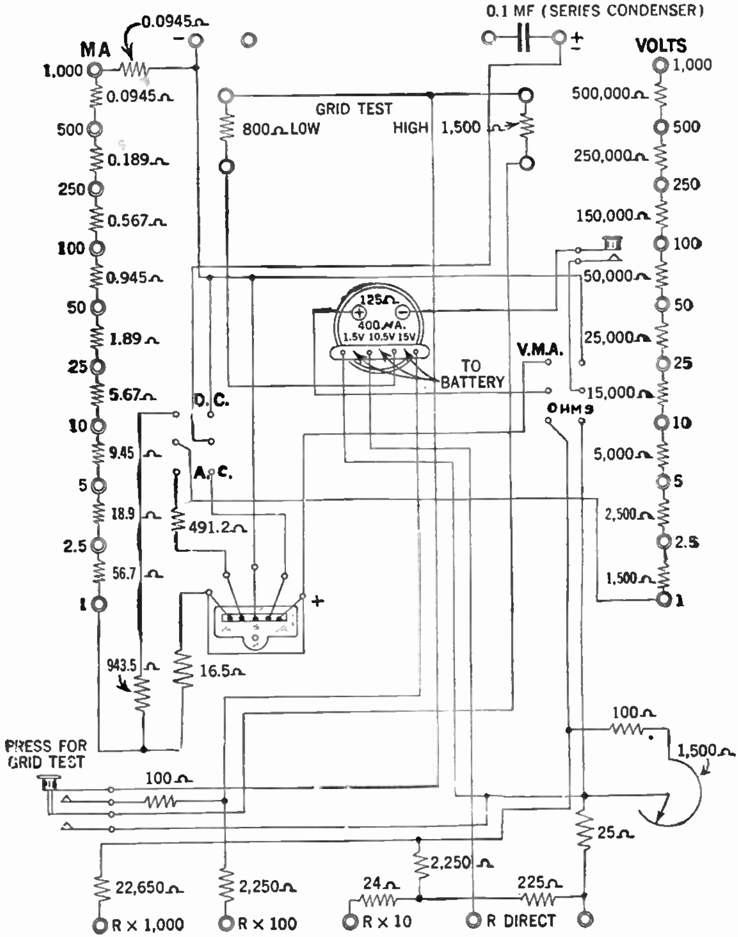


FIG. 18—Connection diagram of Weston Model 665-2 radio set analyzer.

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.

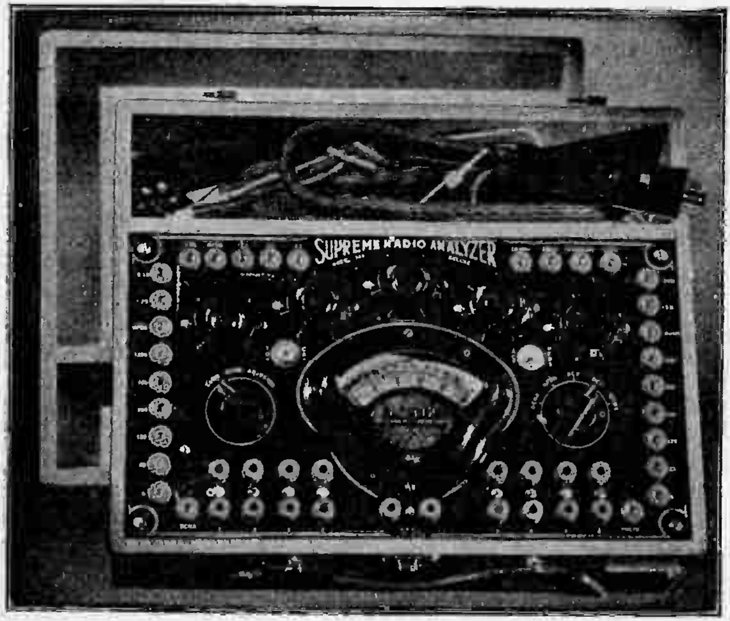


FIG. 19—Front view arrangement of Supreme Model 339 radio set analyzer.

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).

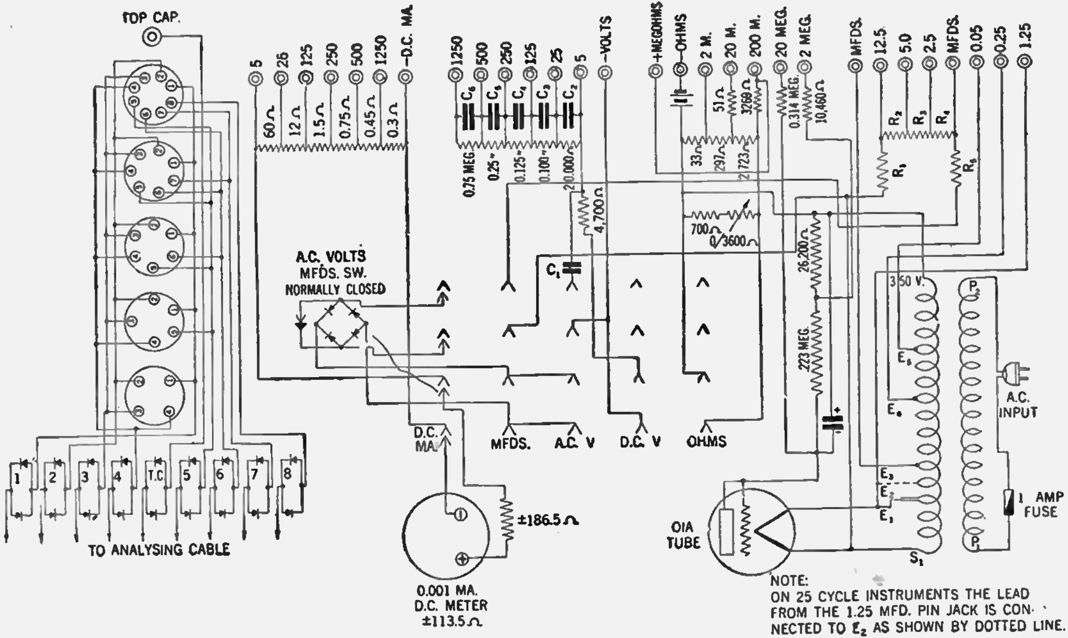


FIG. 20—Wiring arrangement and resistance values in Supreme Model 339 radio set analyzer.

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 multirange 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

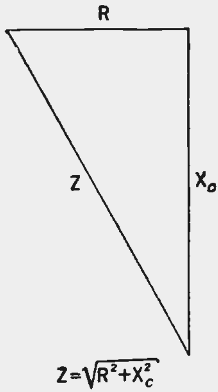


FIG. 21—Arrangement of impedance triangle in capacity measurements.

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.

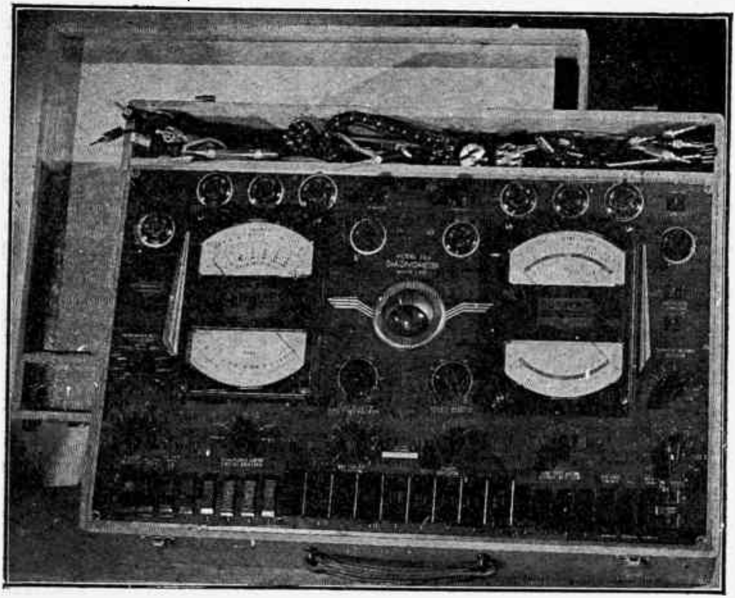


FIG. 22—Front view showing arrangement of instruments and switching devices in Supreme Model 585 diagnometer.

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.

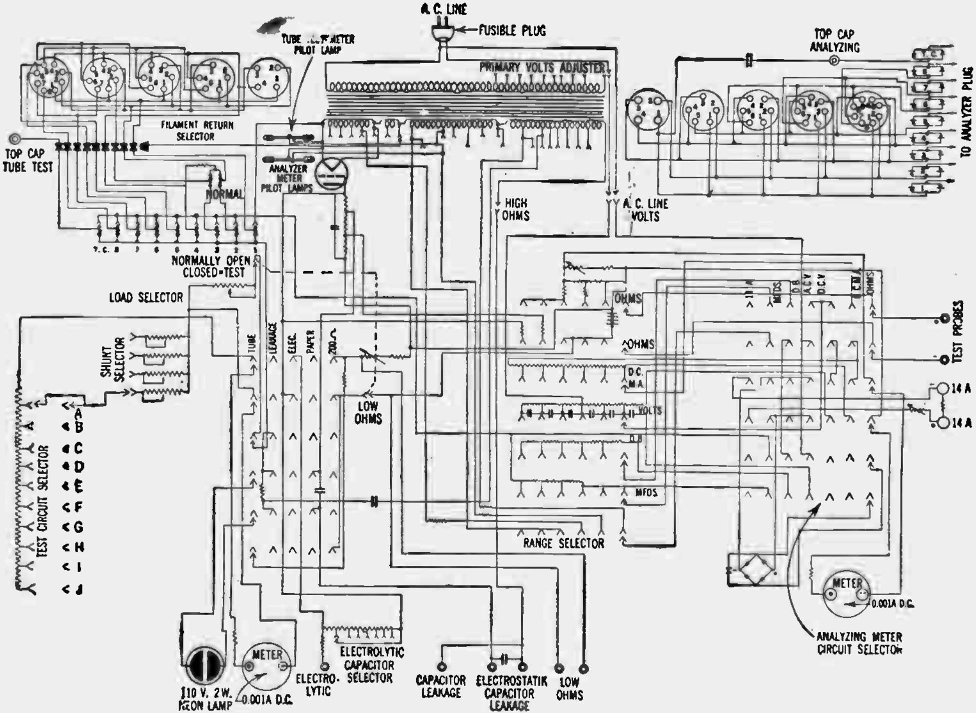


FIG. 23—Internal connection of Supreme Model 585 diagnometer.

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.

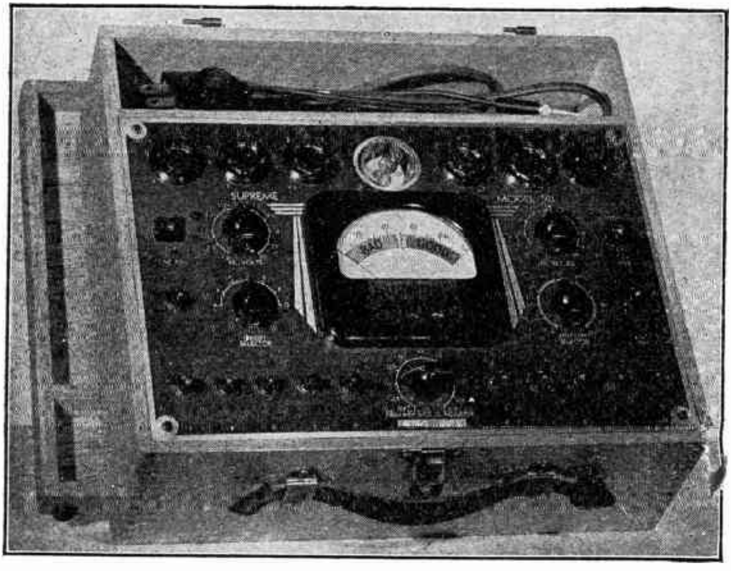


FIG. 24—Front view of Supreme Model 501 tube tester.

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.

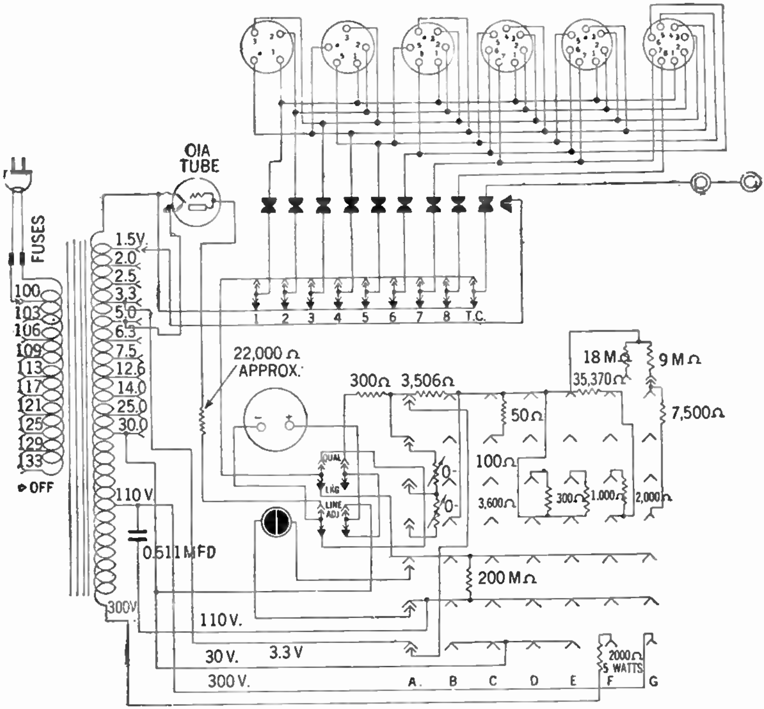


FIG. 25—Schematic wiring diagram of internal connection in Supreme Model 501 tube tester.

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

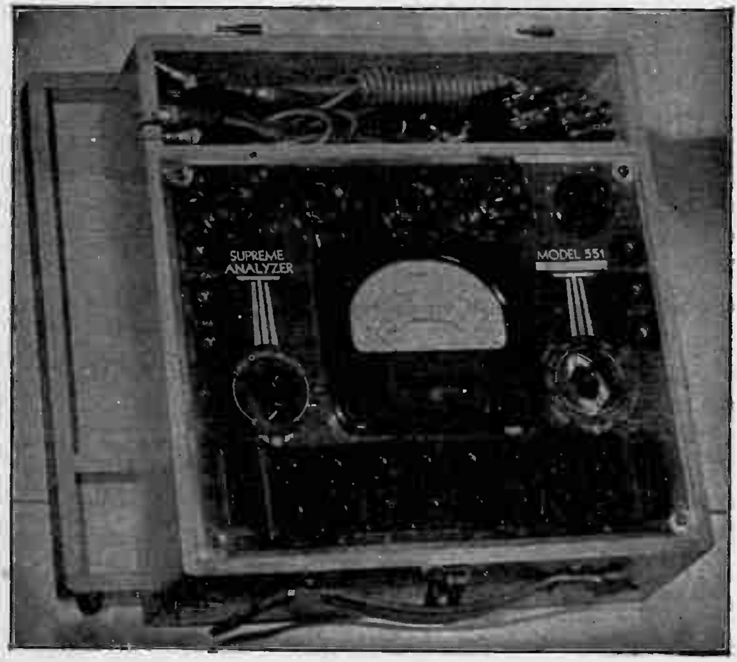
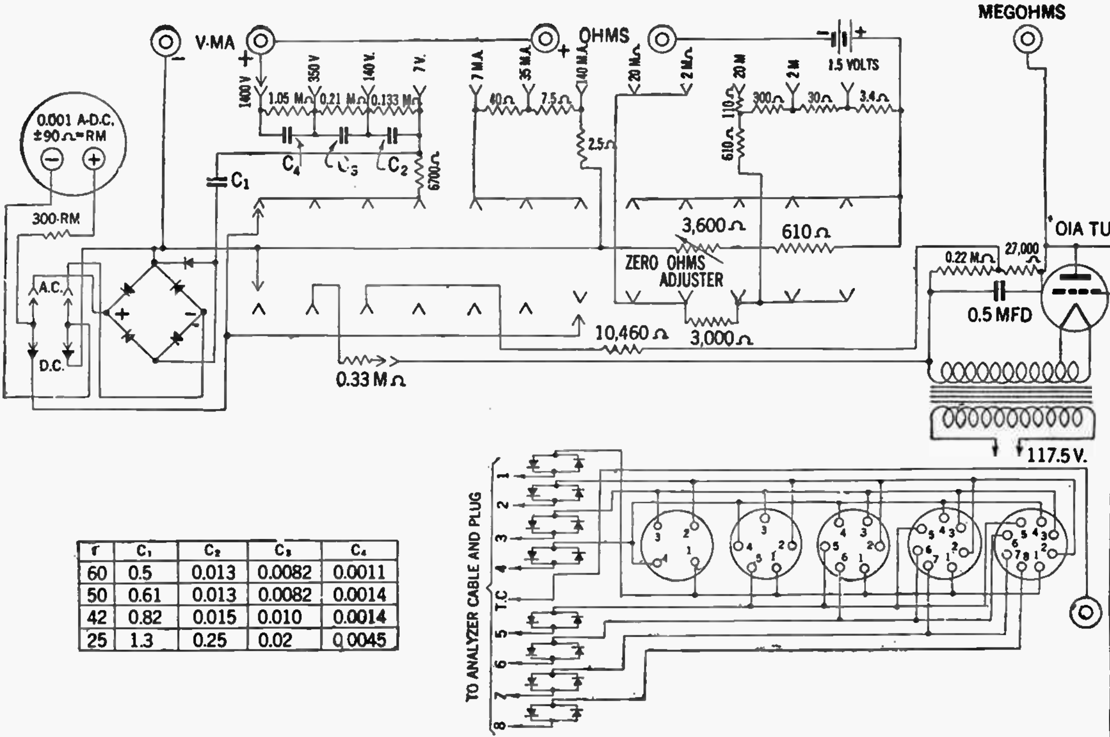


FIG. 26—Exterior view of Supreme Model 551 analyzer.



f	C1	C2	C3	C4
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.

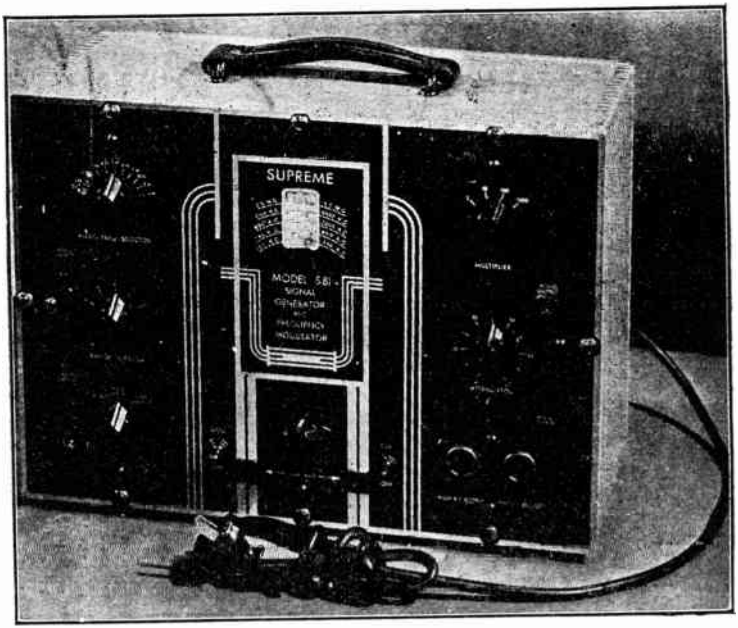


FIG. 28—Panel view of Supreme Model 581 signal generator.

Supreme Model 581 Signal Generator.—This all wave *r.f.* oscillator has a range of 130 *k.c.* to 60 *m.c.* on 5 fundamental bands and 3 harmonically related bands.

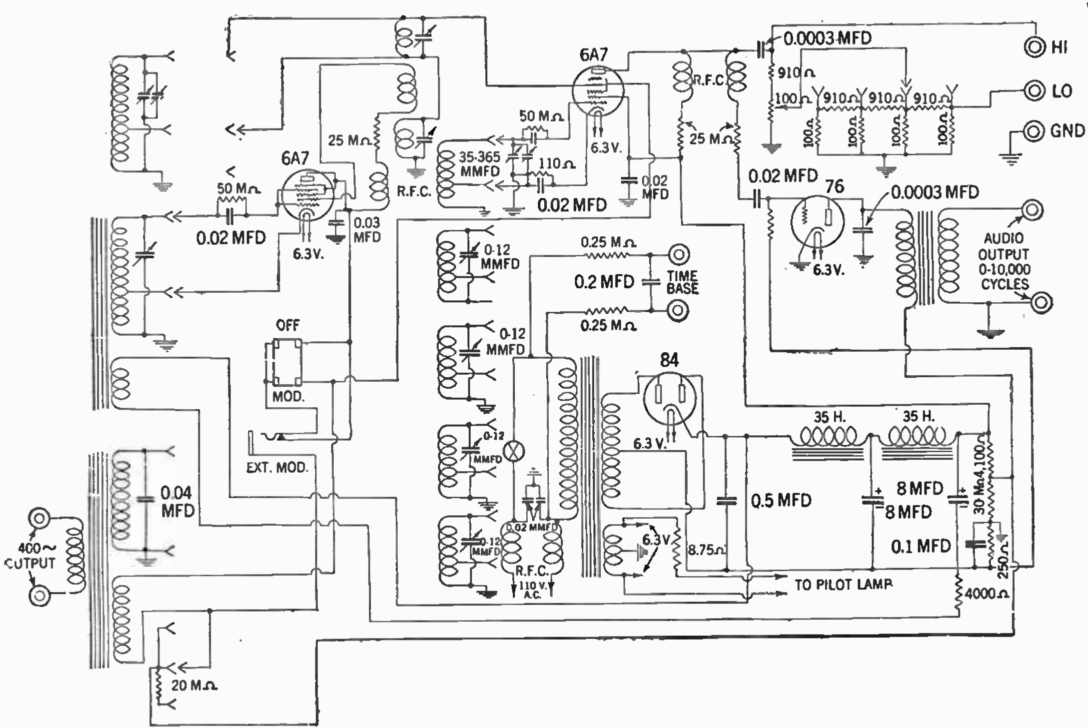


FIG. 29—Circuit diagram of Supreme Model 581 Signal generator.

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.

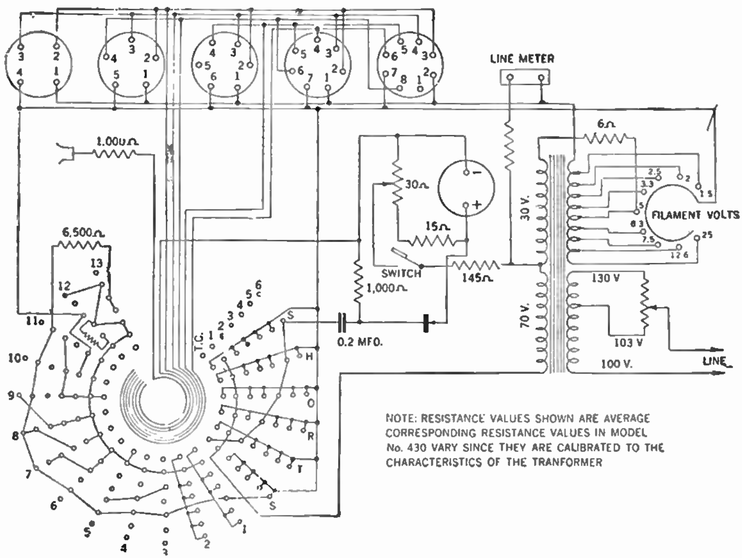


FIG. 30—Internal connection diagram of Readrite Model 430 tube tester.

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.

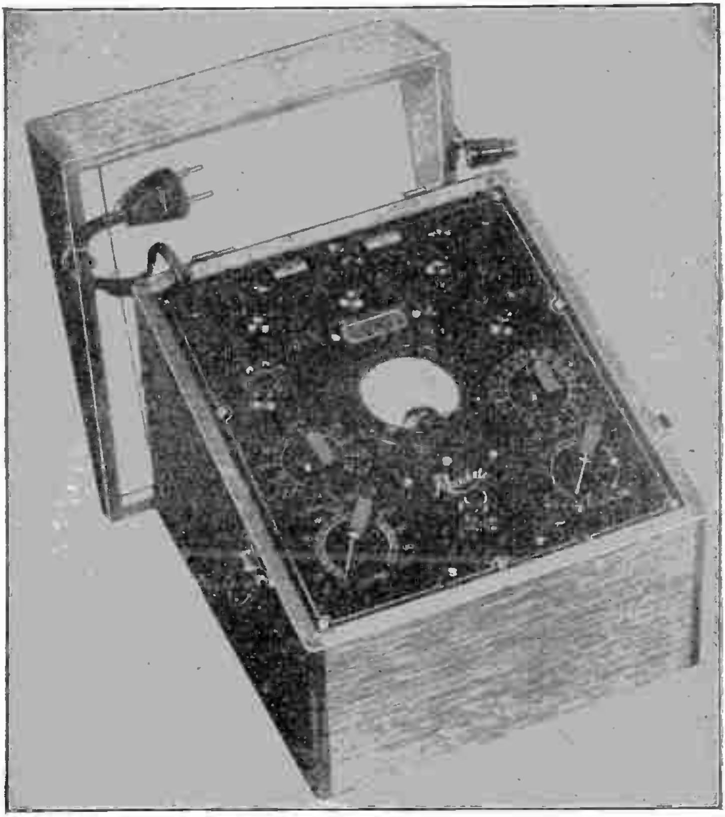


FIG. 31—Front view arrangement of devices in Readrite Model 430 tube tester.

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.

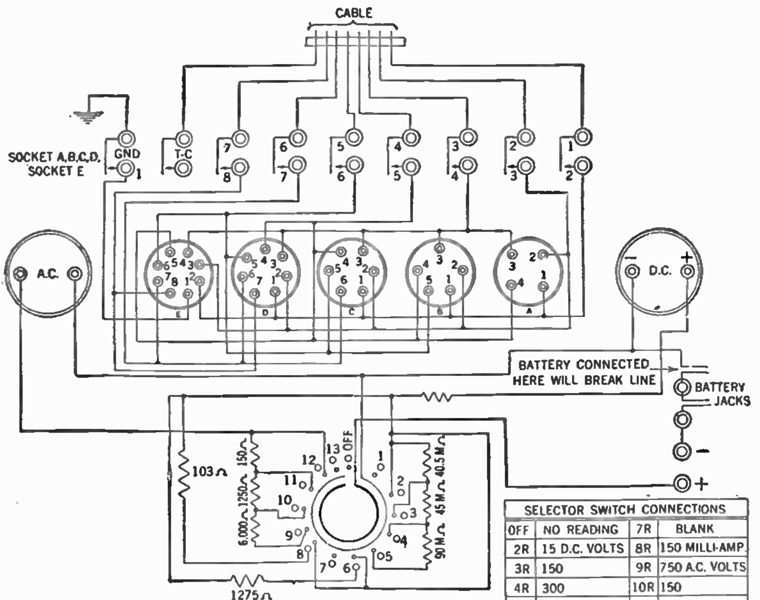
The circuit is designed on the "emission" principle in that the meter indication depends on an emission test of the tube.

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.

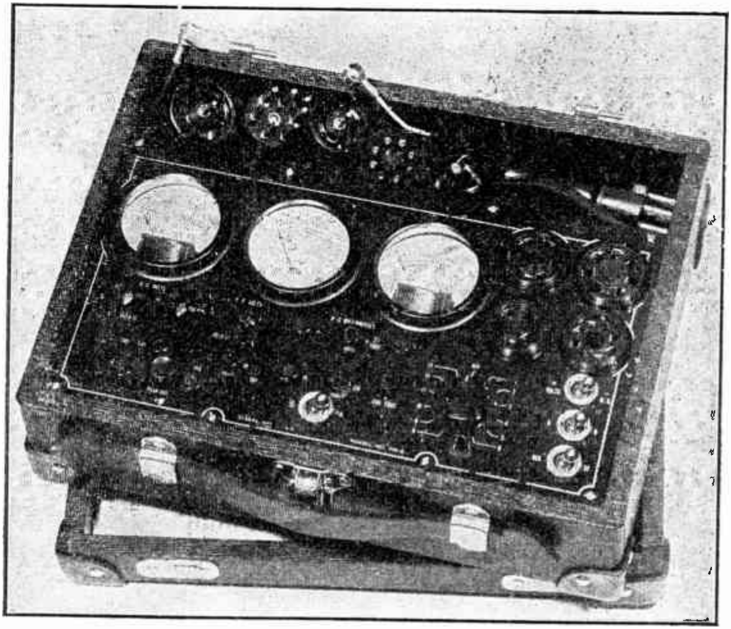
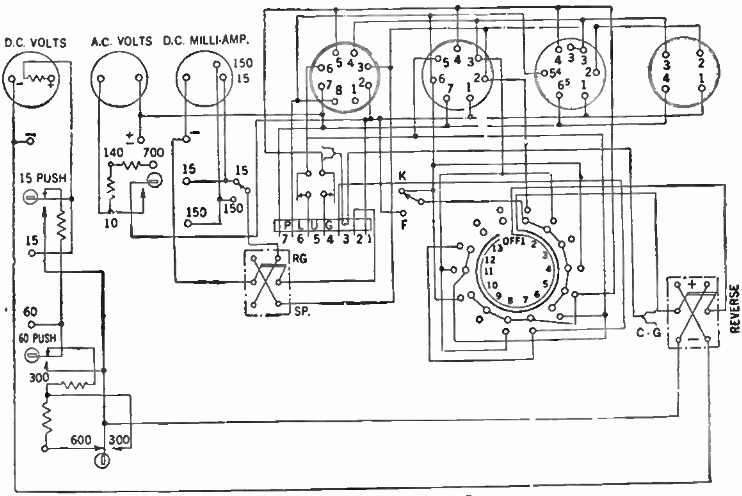


FIG. 34—Front view arrangement of Readrite Model 710-A tester.

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.

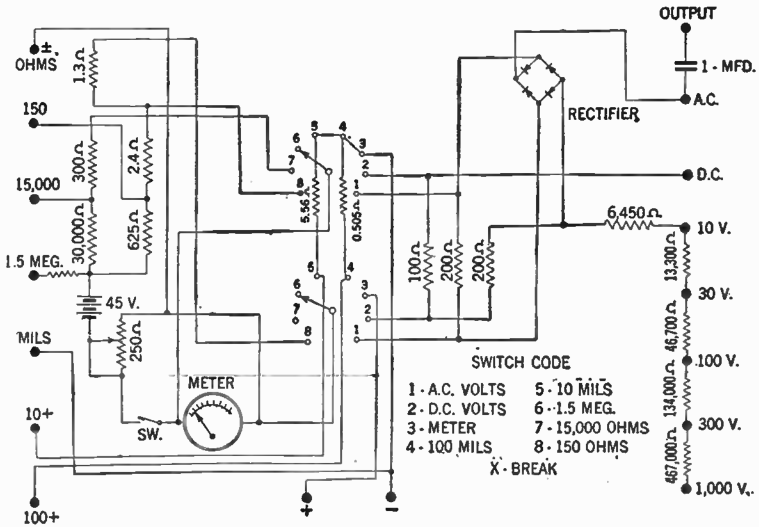


FIG. 36—Wiring diagram of Philco Model 025 radio tester.

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	"

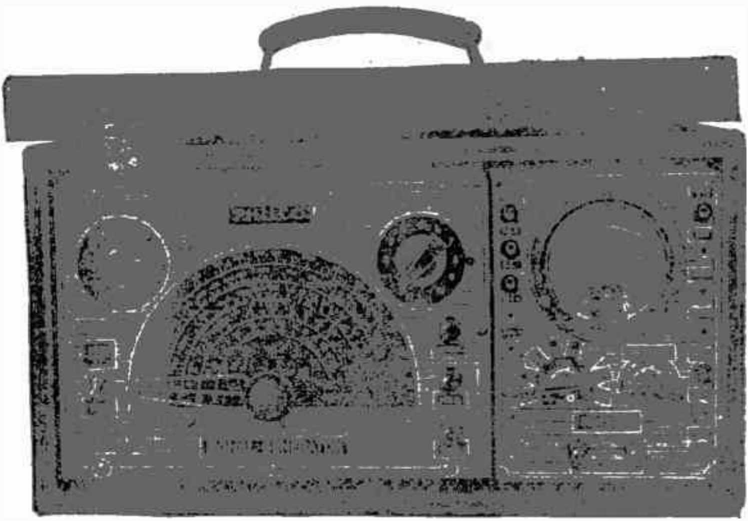


FIG. 37—Panel view of Philco Model 025 Signal generator and radio tester.

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.

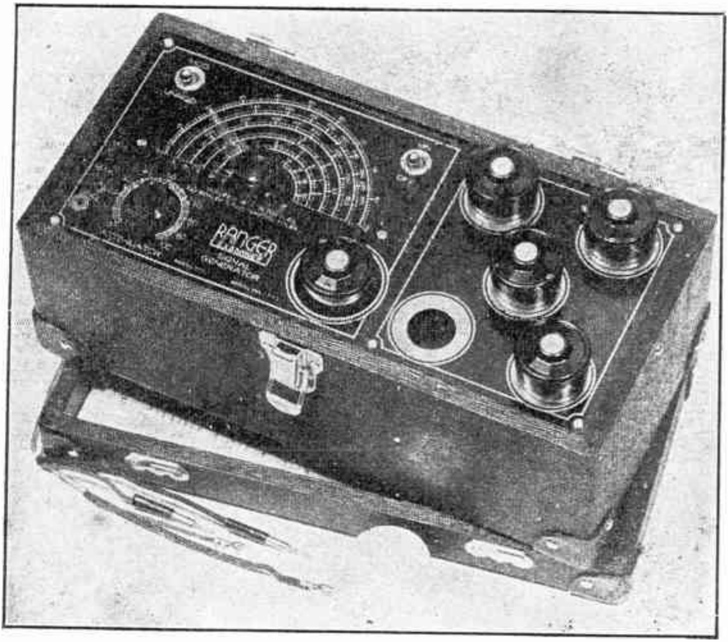


FIG. 38—Panel arrangement of Readrite Model 557 signal generator.

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.

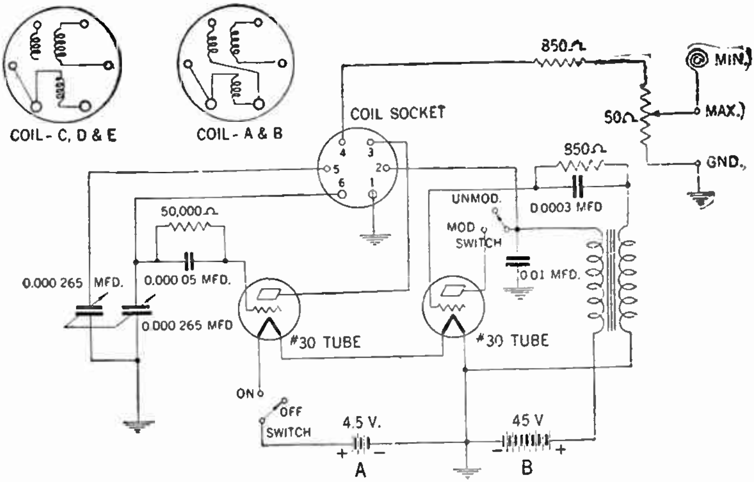


FIG. 39—Wiring diagram and coil arrangement in Readrite Model 557 signal generator.

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.

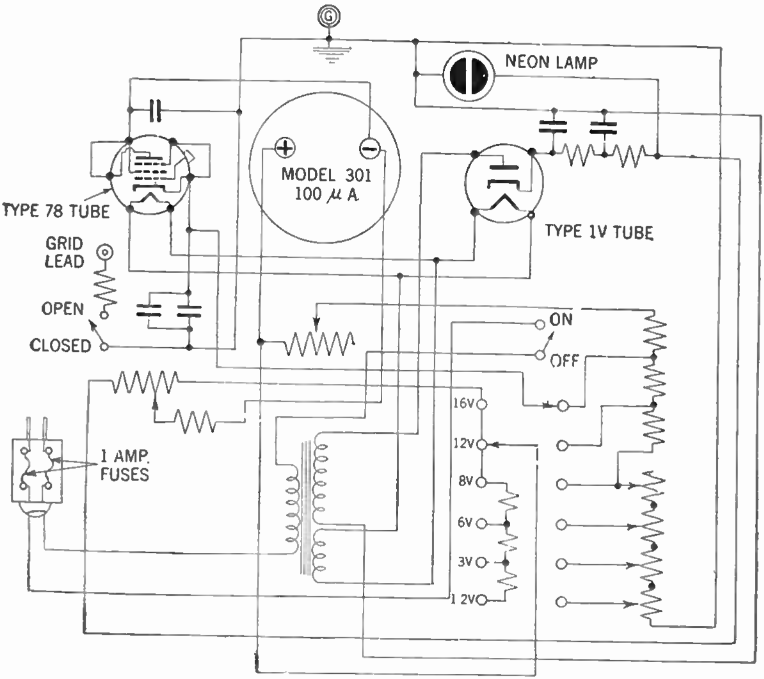


FIG. 41—Schematic wiring diagram of Weston Model 669 vacuum tube voltmeter.

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*

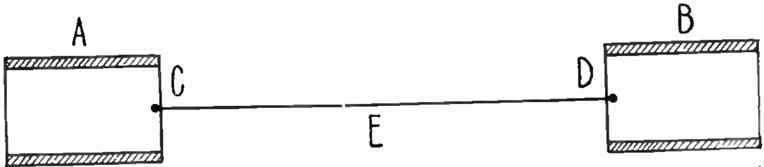
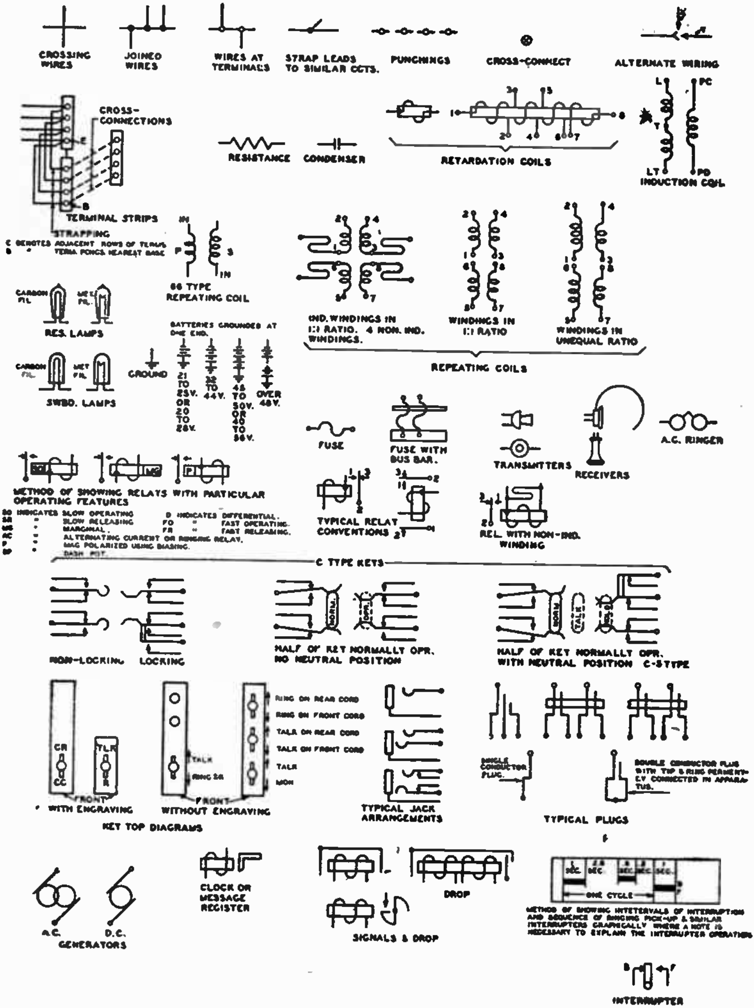


FIG. 7,413.—Diagram of simple toy telephone, consisting of two combined transmitters and receivers A and B, made of metal or wood cylinders, one end of each being covered by a membrane C and D, and the centers of which are connected by string E.

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

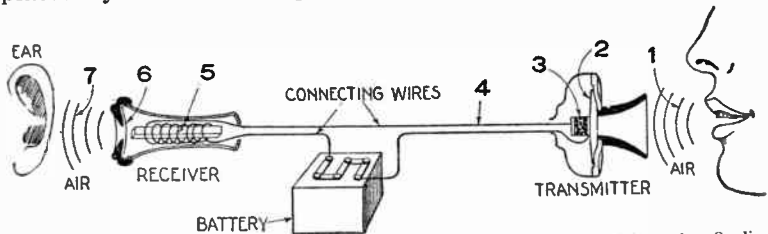


FIG. 7,478.—Electric telephone. *The parts are:* 1, air vibrations caused by voice; 2, diaphragm; 3, carbon buttons; 4, line wires; 5. electro-magnet; 6, diaphragm; 7, reproduced air vibrations representing speech.

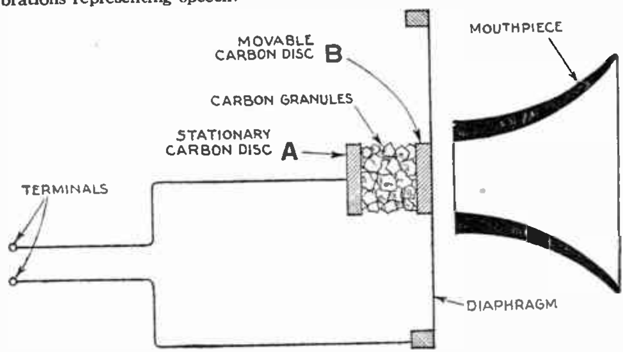


FIG. 7,479.—Simple electric telephone transmitter.

two carbon discs separated by about 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

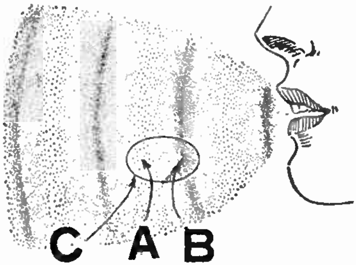


FIG. 7,480.—Microscopic view showing molecules of air at 1, in fig. 7,478. In a spoken word, or in any musical sound. the molecules dance back and forth as in fig. 7,481.

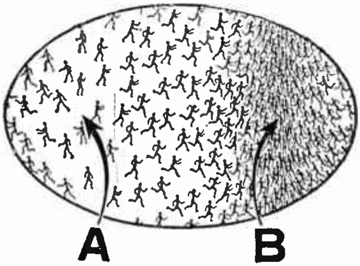
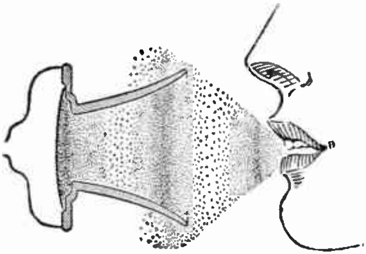


FIG. 7,481.—Enlargement of section C of fig. 7,480 with molecules represented as tiny beings rushing from A to B (fig. 7,480). First they advance, pushing against the ear drum, and then they retire and the membrane of the ear flies back. Over and over again this happens, hundreds and even thousands of 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.



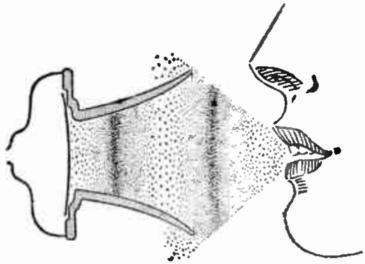
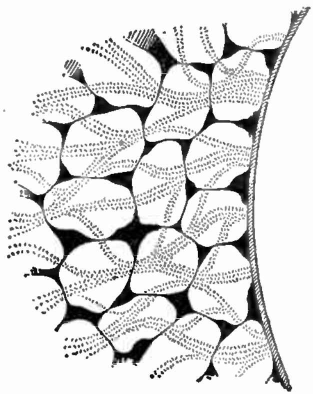
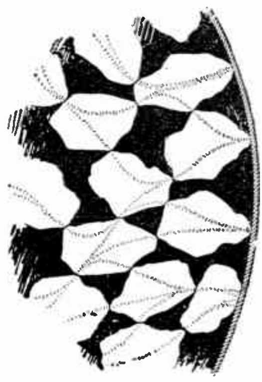


FIG. 7,482.—Effect on diaphragm caused by molecules of air which are set in motion by the voice of the speaker—they rush against the diaphragm of the transmitter and bend it in

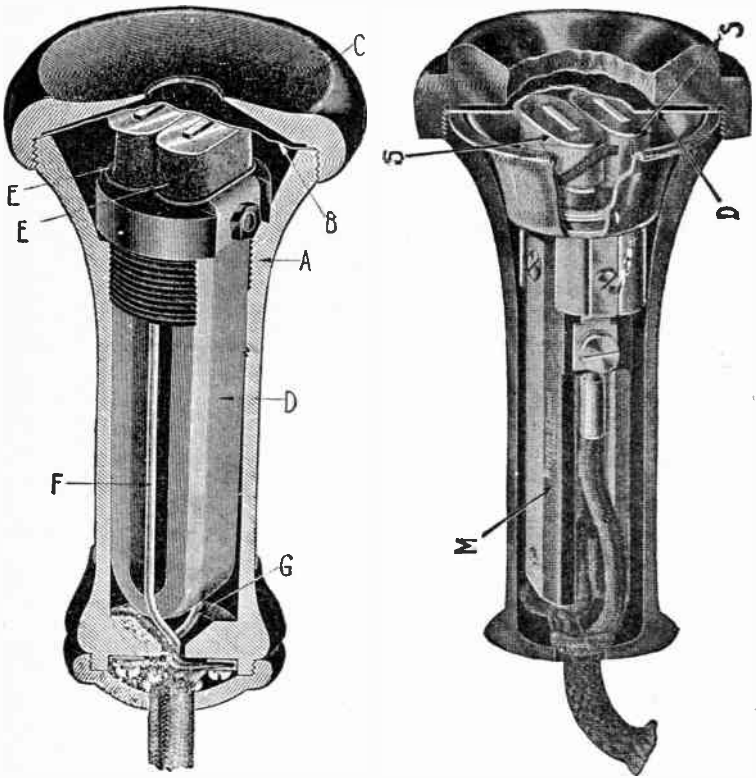
FIG. 7,483.—Effect on diaphragm when the molecules rush away—it springs back out of its bent position.



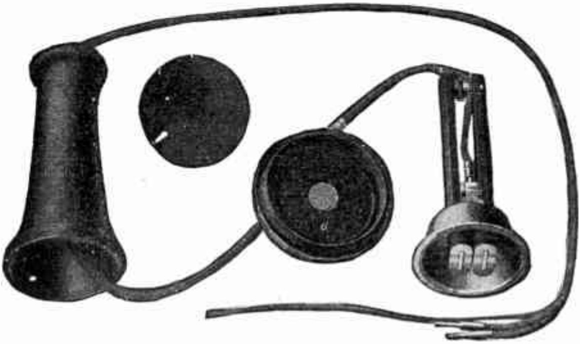


FIGS. 7,484 and 7,485.—Action of diaphragm on carbon grains. Fig. 7,484 shows carbon grains in a transmitter magnified about fifty times each way. When the diaphragm is bent in, the grains are closely packed together and many electrons can pass through, but when the diaphragm springs back, as in fig. 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.

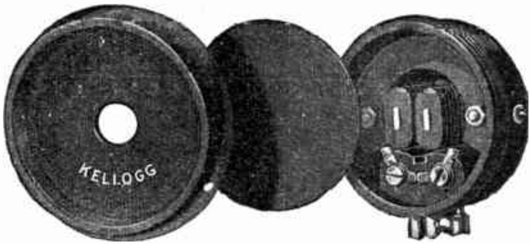
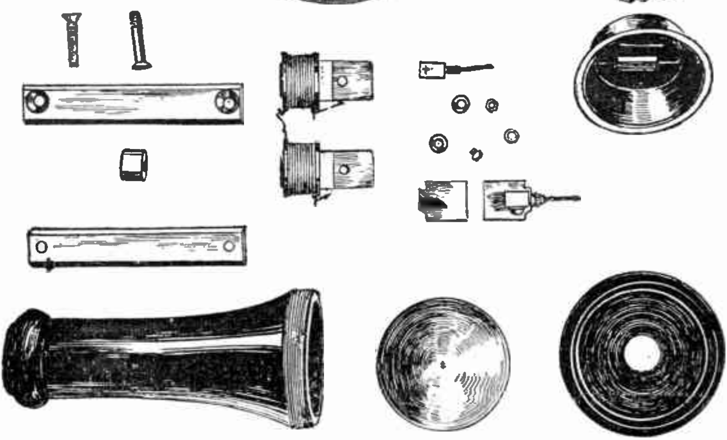
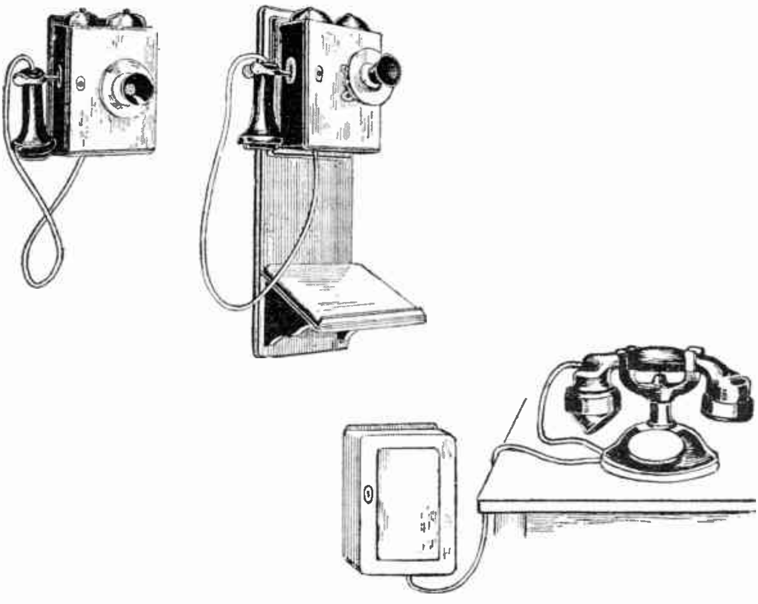


FIG. 7,490.—Kellogg operator's receiver, disassembled showing diaphragm and magnet.



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.



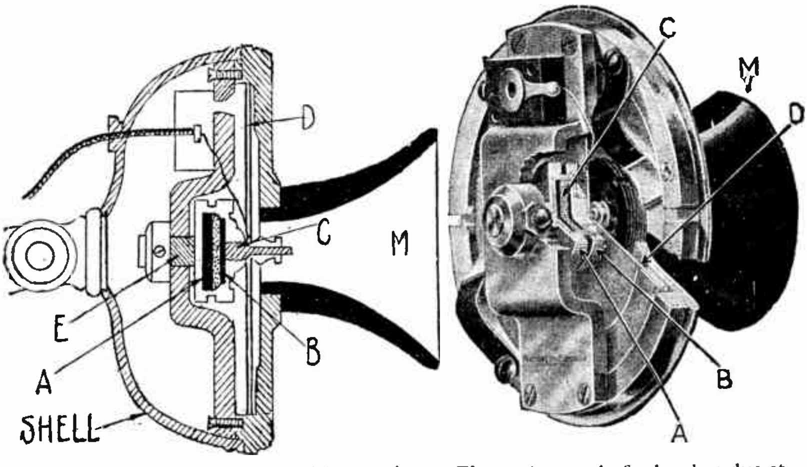
FIGS. 7,510 to 7,512.—Types of station apparatus. Fig. 7,510, wall set; fig. 7,511, wall set with writing shelf; fig. 7,512, desk stand or hand set with a separate bell box. The wall set is the smallest and lightest of these three types of instrument and is generally used where mountings on plaster walls 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.

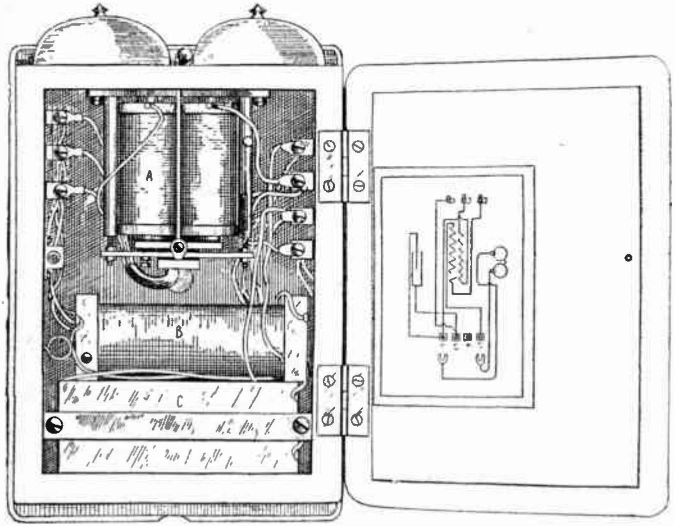
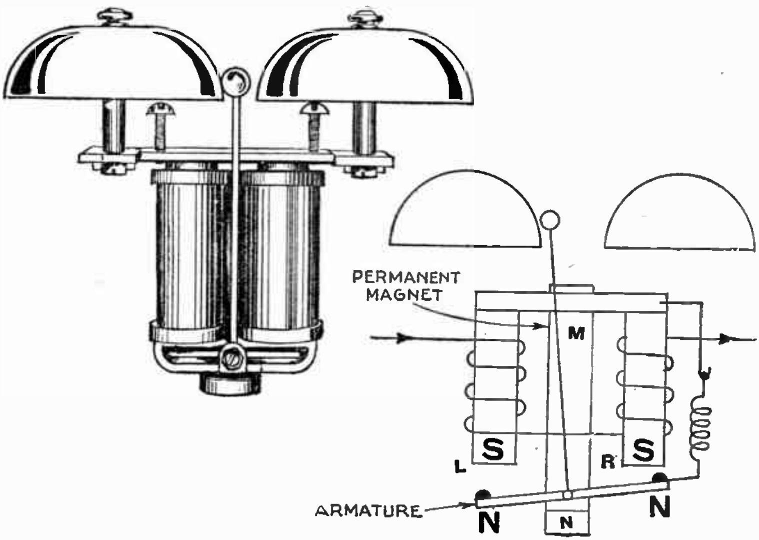


FIG. 7,515.—A typical telephone bell box with door open showing the ringer A, the induction coil B, and the condenser C.

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.

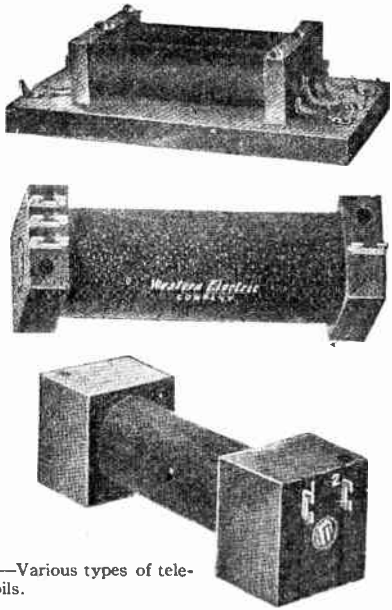


FIGS. 7,516 and 7,517.—Ringer and diagram of its operation.

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 $3\frac{1}{3}$ 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.

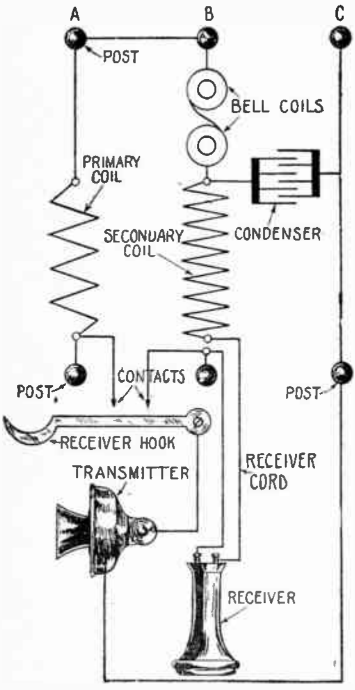


FIG. 7,522.—Diagram showing the inside connections of a telephone bell box, the binding posts of which are shown, top and bottom. Flexible wire cords connect these to the transmitter and receiver, as shown. When the receiver is off the hook the contacts there are closed by the upward spring of the hook 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.

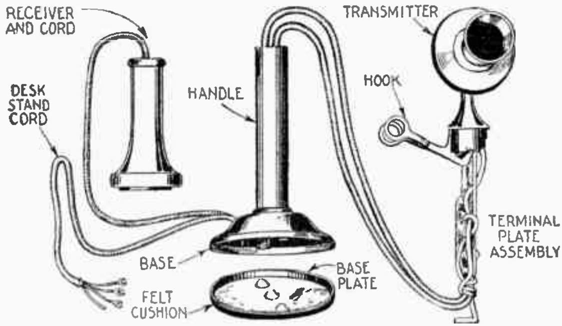


FIG. 7,523.—Desk stand parts.

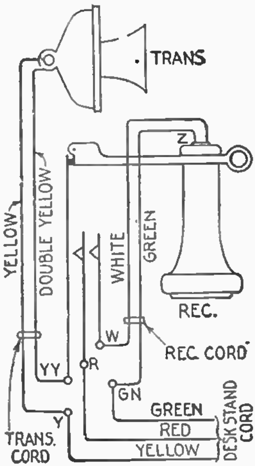


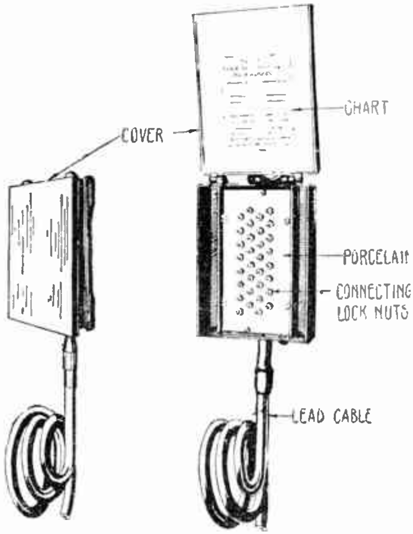
FIG. 7,524.—Wiring of desk stand.

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 electro-magnet 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.

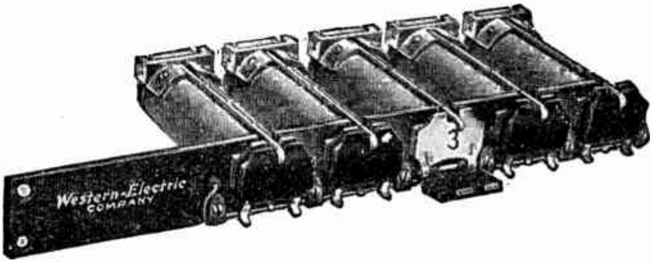


FIG. 7,528.—Mounted trunk drops. Tubular trunk drops are mounted on a metal strip each being held by two small screws underneath the drop shutter. The tubular casing of each drop is soft iron inside of which is the drop winding; the ends of the coil wires terminating at lugs which protrude from the casing 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.

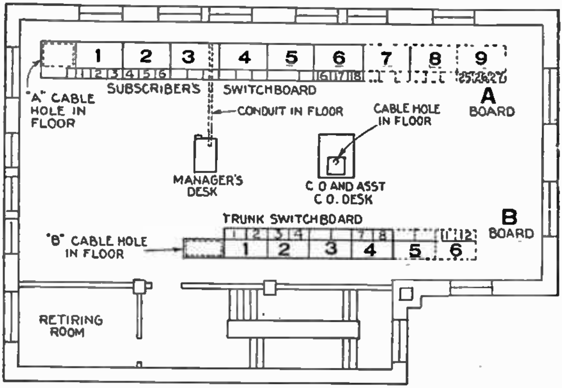


FIG. 7,529.—Typical layout of a Central Office operating room showing the A and B boards.

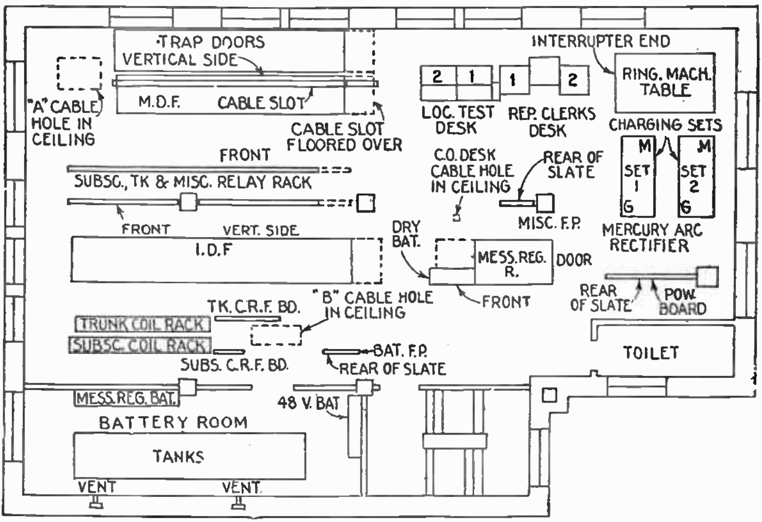


FIG. 7,530.—Typical layout of a Central office terminal room which also contains the power plant equipment.

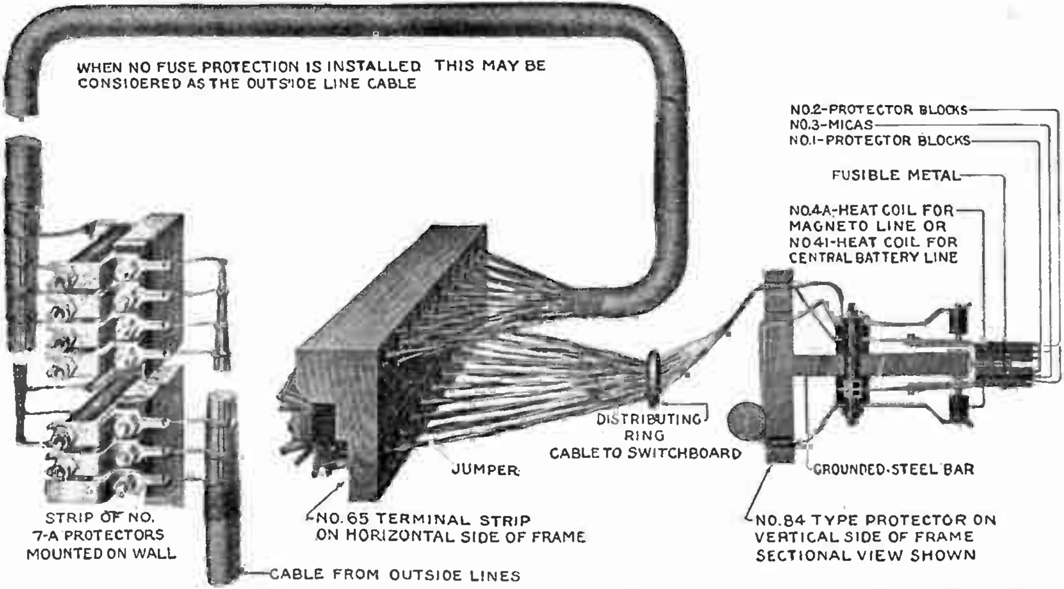
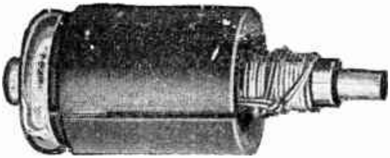
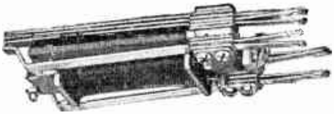


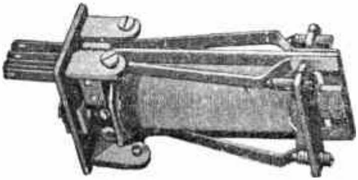
Fig. 7,531.—Typical main distributing frame and connections. All cable wires and jumper wires are in twisted pairs. The terminal strips are mounted on self supporting floor type steel frames. The heat coils, as shown in fig. 7,532, are constructed so that when heavy currents are picked up by the line 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.

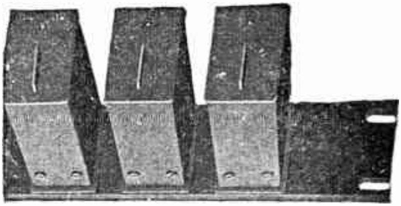
It is made up of two distinct sections namely an operating room, fig. 7,529, and a terminal room, fig. 7,530.

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.









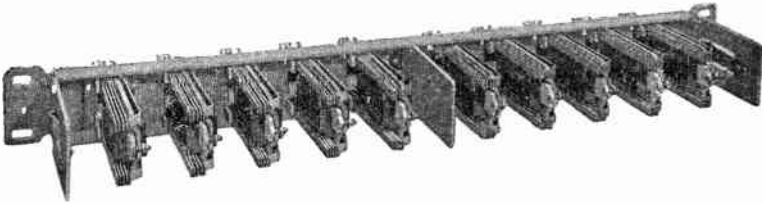


FIG. 7,532.—Heat coil, enlarged view.

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.

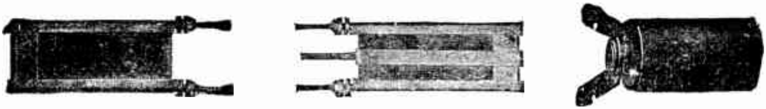
FIG. 7,536.—Relays on mounting plate.

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.

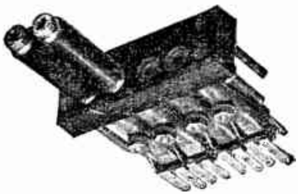


FIG. 7,540.—Jacks mounted in a hard rubber jack mounting.

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

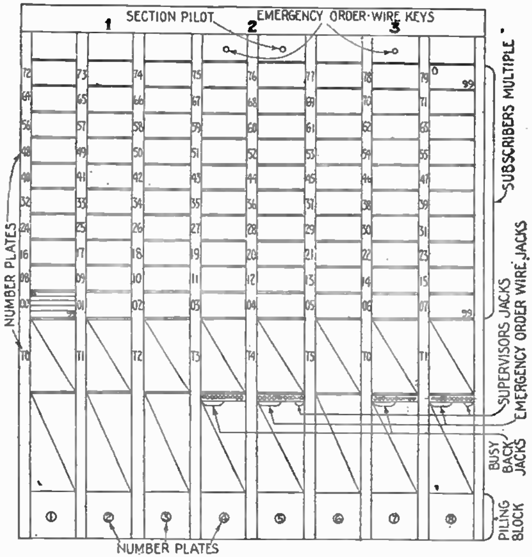
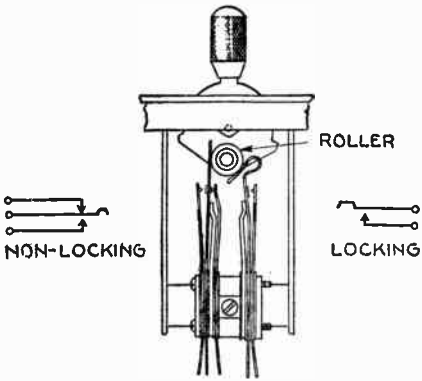


FIG. 7,541.—Face equipment of a B board section. In each section there are seven jack panels, and each jack panel has a capacity of 1,500 jacks. Each rectangle above represents a group of 100 jacks and each group is designated on the stile strip as 00, 01, 02, 03, 04,—64—65—98—99, etc. The jacks in each 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.

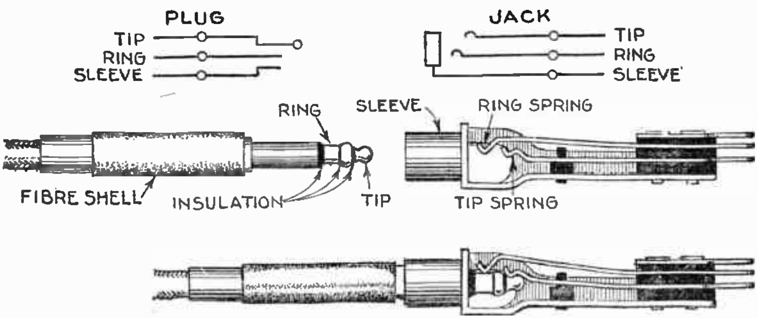
Connections to the jacks are made by means of cords, which are known as *trunks*, as shown in figs. 7,545 to 7,549.



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.

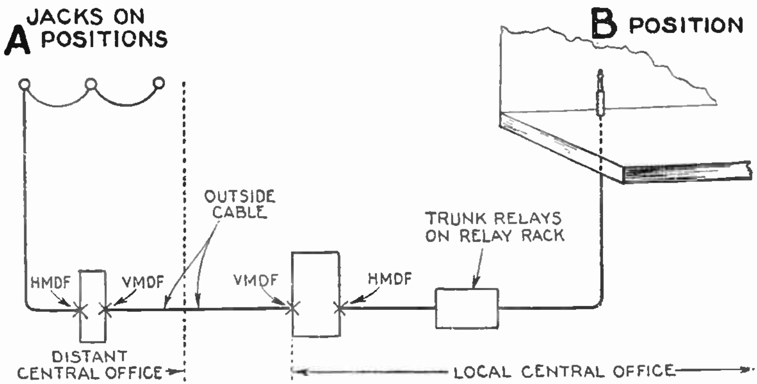


FIG. 7,550.—Diagram of trunk between A and B boards. The A board end is known as *outgoing trunk* (or O. G. T.), and is connected to a jack which is repeated on the face of the A board at every 6, 7 or 8 panels and the trunk is multipled to each jack. The B board end is terminated as a cord and is known 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.

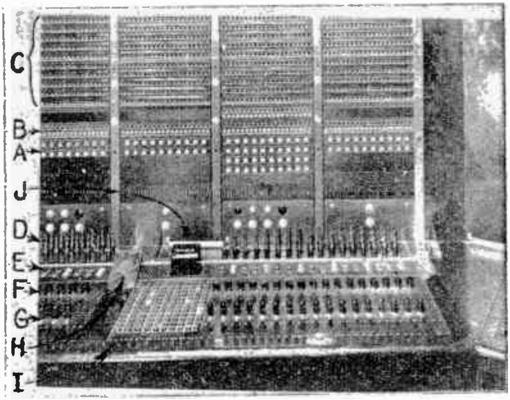
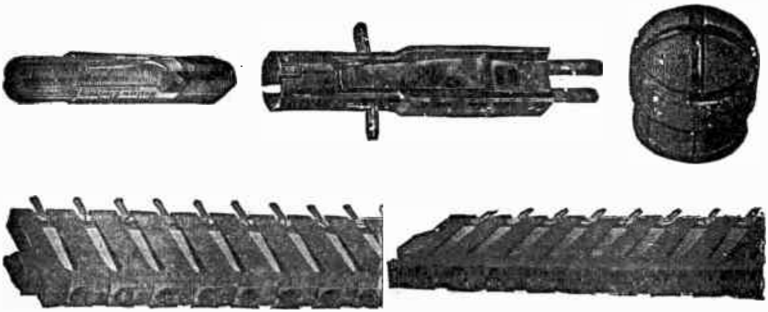


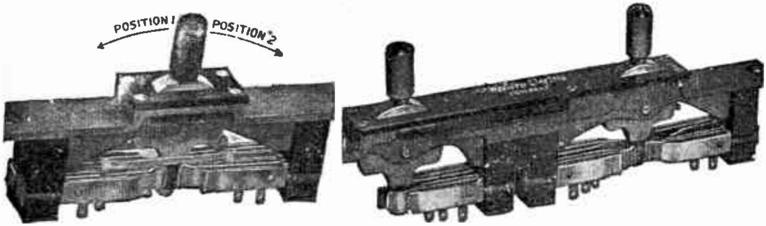
FIG. 7,552.—An A Board position. *Legend:* A, subscriber answering jacks and lamps; B, subscriber multiple answering jacks and lamps; C, outgoing trunk multiple (jacks only); D, connecting cords. There are two cords to each cord circuit, a front and a back cord. The back cord is used to answer and is 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.



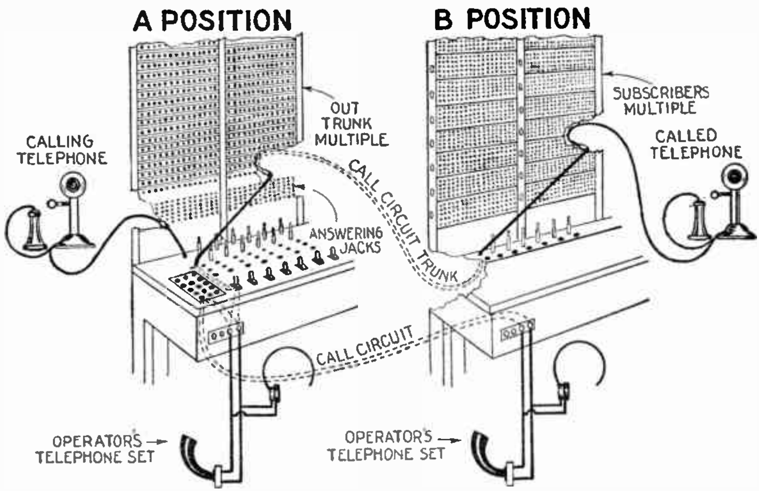
Figs. 7,553 to 7,557.—Miniature electric lamp and parts. The lamp fig. 7,553 fits into socket, fig. 7,554, and the lamp cap fig. 7,555 fits at end of lamp socket. The glass of the lamp cap may be white opalescent, red, or green, or it may be marked with black bars or a dot. Figs. 7,556 and 7,557 shows 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.

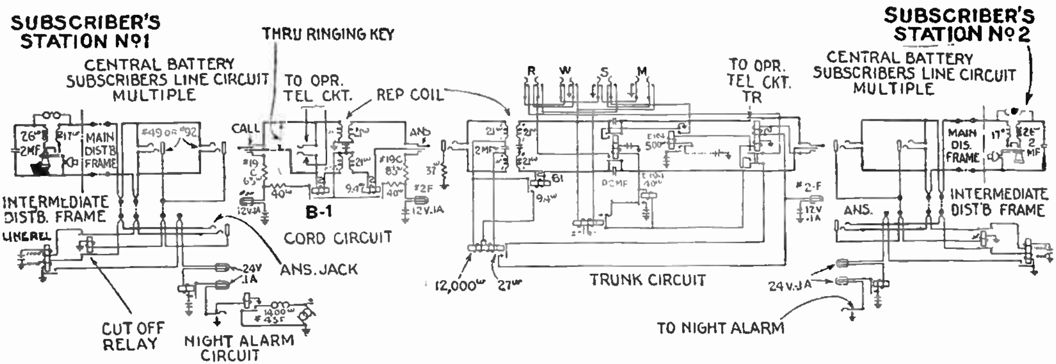
When the A operator has pressed the call circuit button she says to the B operator "Stuyvesant 7813" meaning that she is located in the Stuyvesant Central Office and desires a trunk connection to line No. 7813 in the Bensonhurst Central Office area.

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:

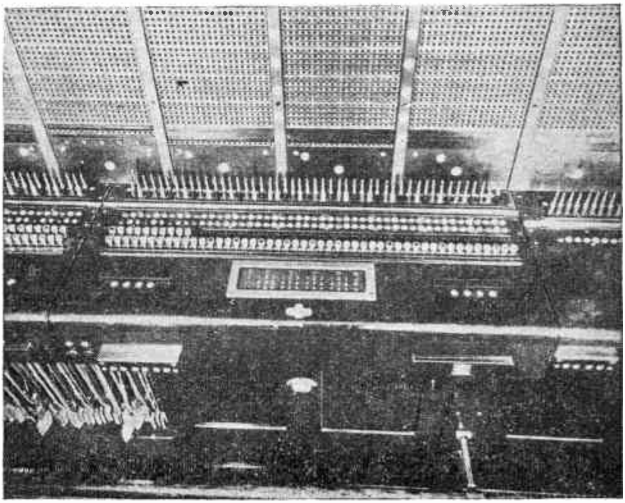


Fig. 7,566.—Typical call indicator position of a B board. The jack panels of these positions are equipped with subscriber multiple jacks like the rest of the positions on the B board. The *call indicator* box is mounted flush with the top of the keyboard.

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.

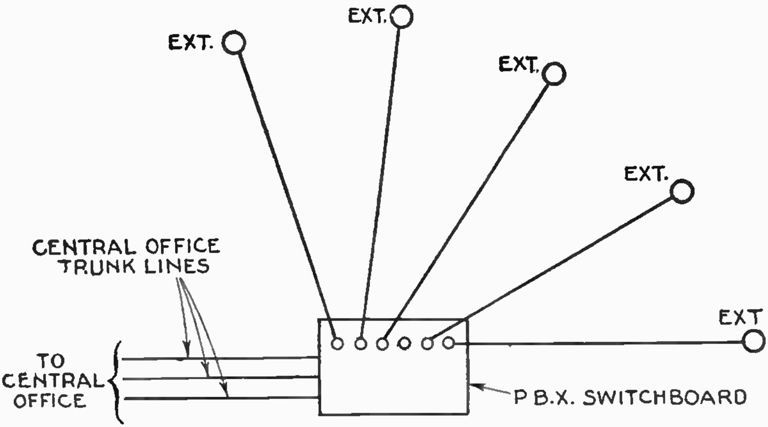


FIG. 7,567.—P. B. X. system.

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.

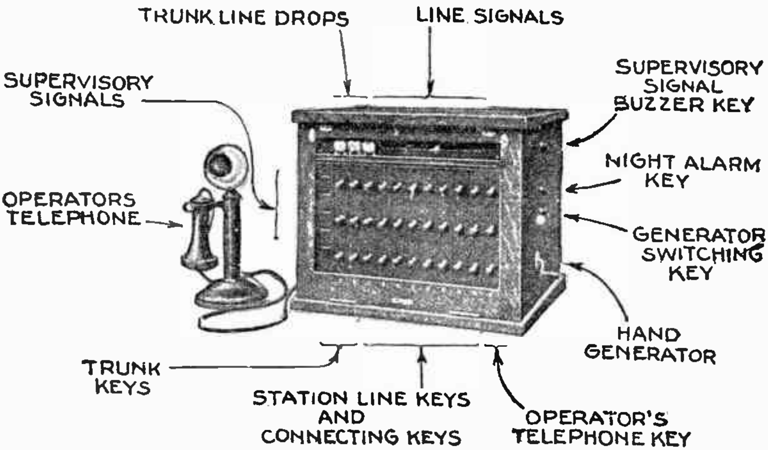


FIG. 7,568.—Cordless type P. B. X. switchboard. There are 3 rows of keys with 11 keys of the cam lever type in each row as follows: 3 keys for central office trunk lines (first 3 keys at left side), each with a trunk line drop above (details of drops shown in fig. 7,528). 7 keys for extension lines (keys 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.

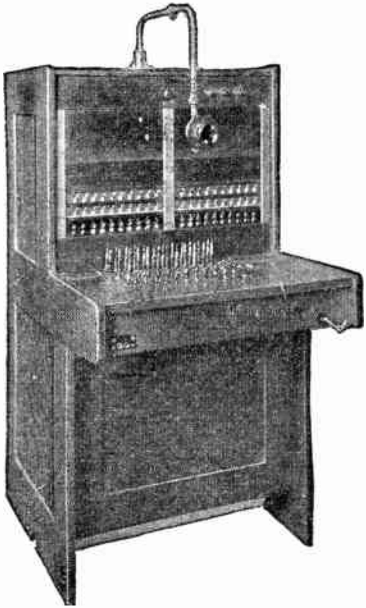


FIG. 7,569.—Cord type P. B. X. switchboard. Each extension jack and each trunk jack is equipped with a line lamp which lights when a call comes into the switchboard. The cords have supervisory lamps which light when the conversation is over and the receivers at the respective telephone stations are *hung 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

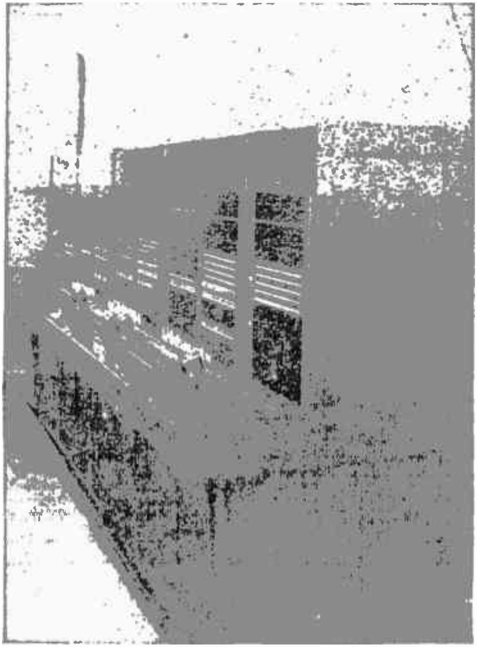


FIG. 7,570.—Multiple cord type P. B. X. switchboard of three positions. Note the dial on each position; this is made necessary since the P. B. X. is connected with trunk lines to a dial central office. The capacity of this switchboard without increasing the number of positions is approximately 500 lines.

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.

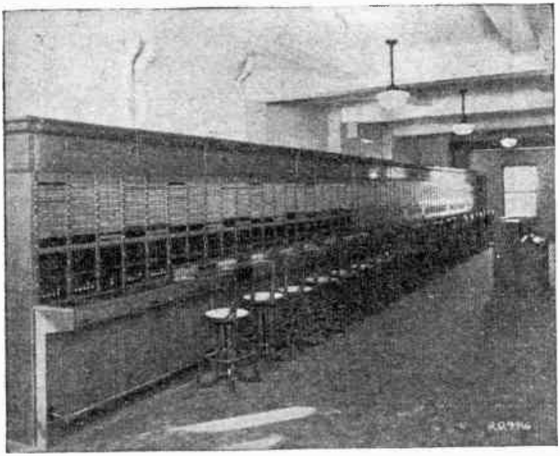


FIG. 7,571.—Large manual P. B. X switchboard.

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.

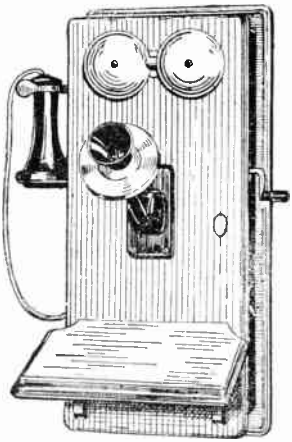
The operator, by tipping the respective key of the cord pair, can talk to the extension. By tipping the key to the *ring* position, generator current is applied to the cord, which, if inserted into an extension jack, causes the extension bell to ring. The ringing is manually controlled by the operator.

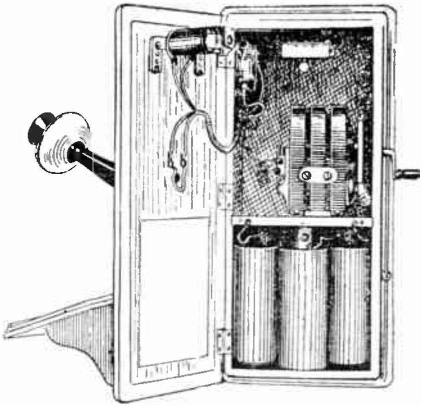
Large P.B.X. Switchboards.—Some P.B.X's have a capacity of 4,000 lines and are made up of as many as 40 operating

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*.

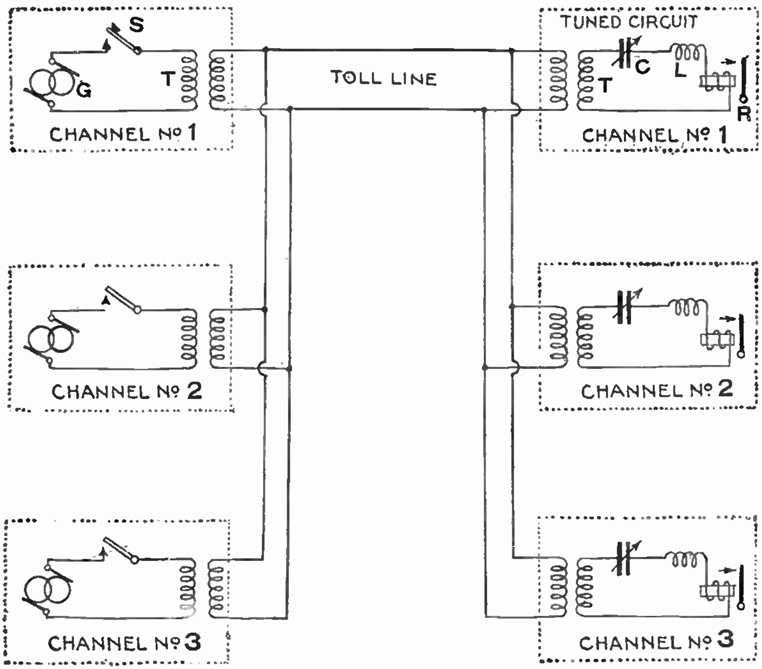


FIG. 7,575.—Simplified Multiplex circuit, *consisting of three channels*, each equipped alike and arranged to operate simultaneously over the same toll line. Each sending station is equipped with a high frequency generator G, a sending key S and a repeating coil T. Each receiving station is equipped 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

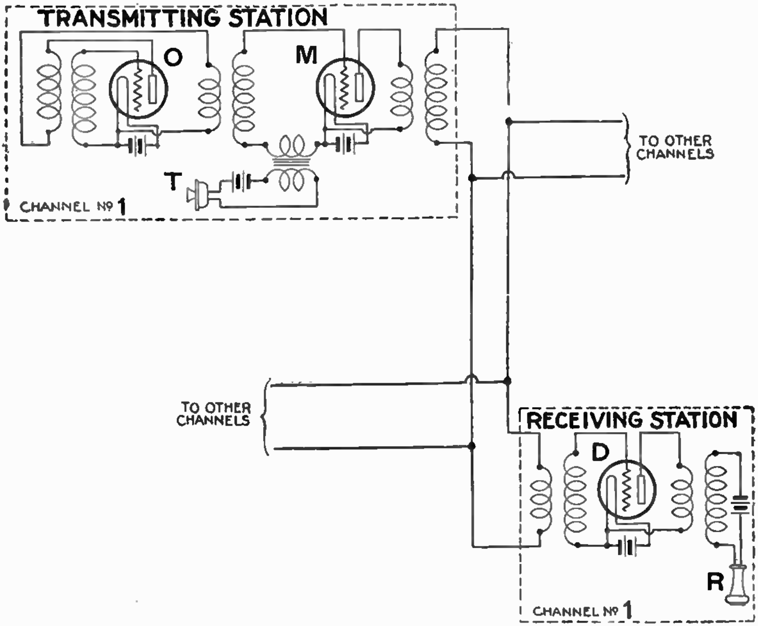


FIG. 7,576.—One channel of a carrier current telephone circuit *the transmitting station consists of:* O, vacuum tube oscillator circuit, which generates the high frequency carrier current; M, vacuum tube modulator circuit, which impresses the voice currents on the carrier current; T, transmitter. *The 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

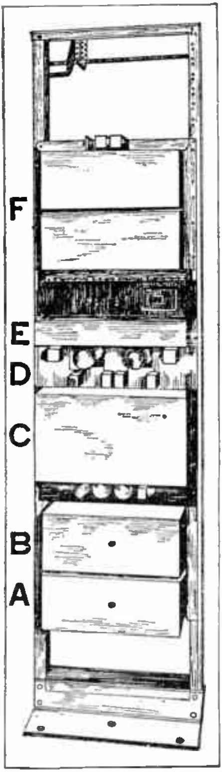


FIG. 7,577.—Typical carrier current unit A, modulator band filter; B, demodulator band filter; C, channel unit consisting of oscillator, modulator and demodulator also shown in figs. 7,578 and 7,579; D, signaling unit shown in fig. 7;580 E, adjusting unit; F, line filters.

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

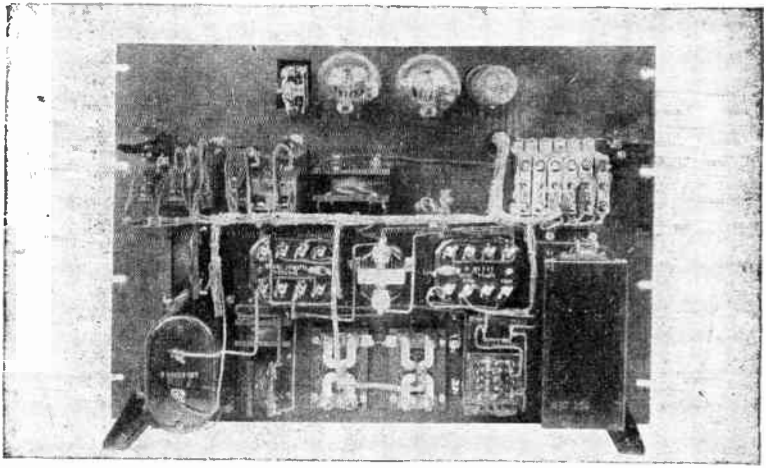


FIG. 7,578.—Front view of channel unit with cover removed consisting of oscillator, modulator and demodulator.

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.

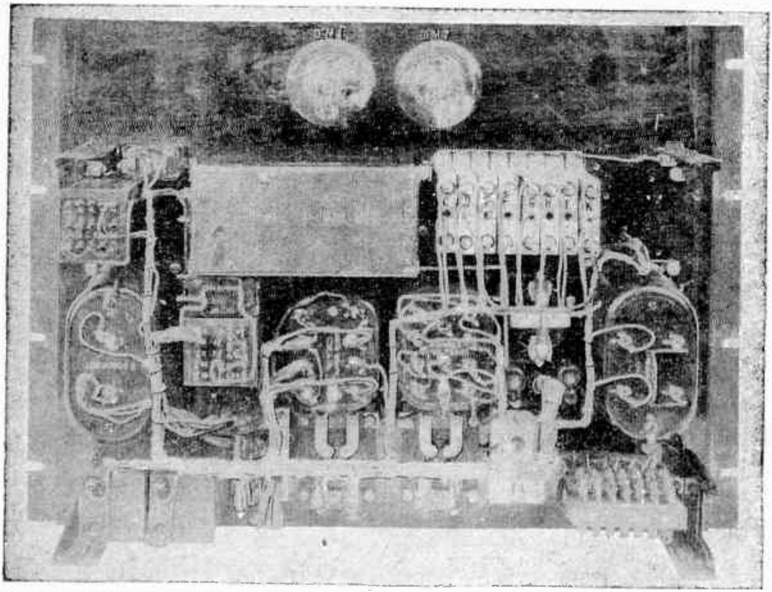


FIG. 7,579.—Rear view of channel unit with cover removed.

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.

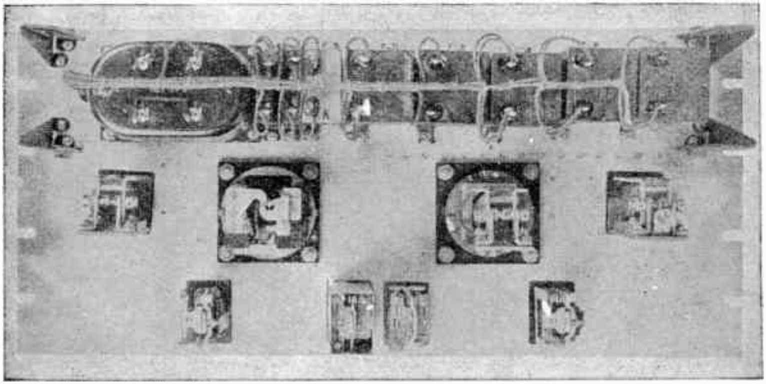


FIG. 7,580.—Front view of signaling unit. When the switchboard operator presses the ringing key at the switchboard, ringing current of 20 cycles is applied to this unit which causes by modulation spurts of the carrier current to be sent out over the toll line to the distant switchboard which is equipped 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.

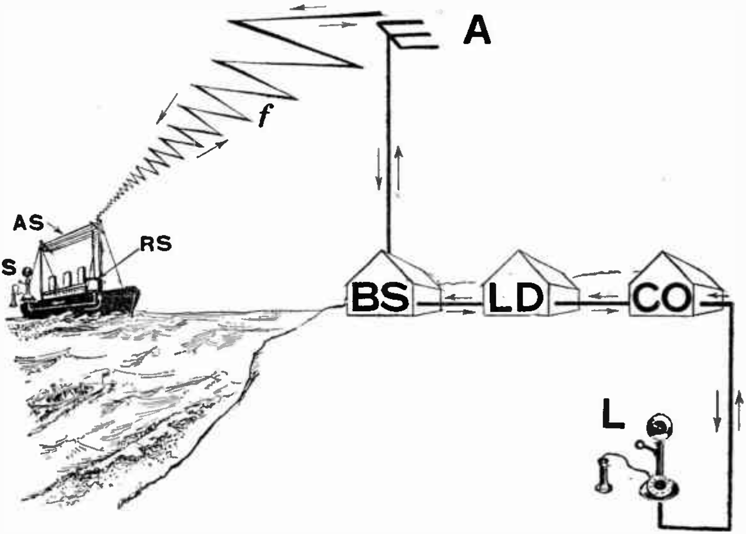


FIG. 7,581.—Ship to shore communication; simplified diagram showing how a telephone conversation is established between a ship at sea and a land station. L, telephone station in a residence or in an office; CO, local telephone central office; LD, long distance telephone exchange; BS, radio sending and 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:

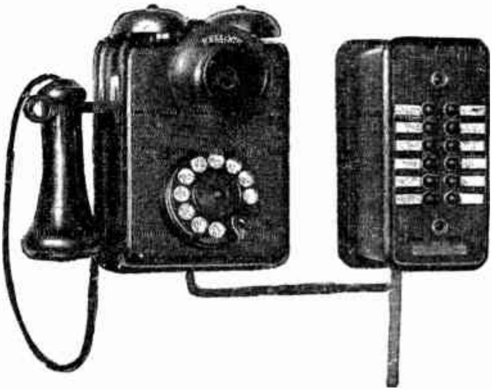


FIG. 7,582.—Kellogg 11 station automatic, wall type inter-communicating telephone.

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.

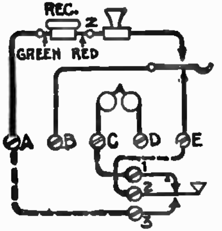
When the conversation is completed, the placing of the receiver on the hook restores whatever button may have been in use.

FIG. 7,583.—Kellogg 11 station desk inter-communicating telephone.

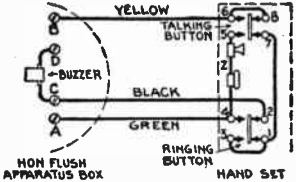
To meet the different conditions in home and business, various inter-phone systems have been designed, which differ in the number of instruments that can be connected, the kind of service they will give, etc.

The systems in general use are:

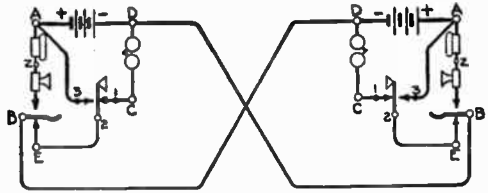
1. Two station; private line.
2. Code ringing; common talking.
3. Selective ringing; common talking.
4. Selective ringing; selective talking



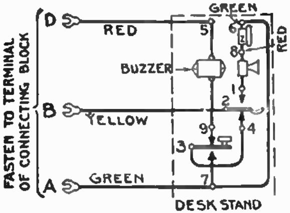
SCHEMATIC OF
NO'S 1527-C-1 & 1539-C-1
SYSTEM 14
DOTTED LINES DENOTES METHOD
OF CONNECTING STRAP WIRES



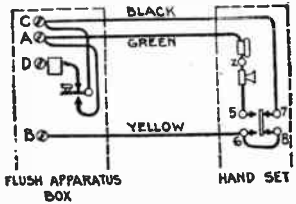
SCHEMATIC OF
NO. 6043-P SYSTEMS 14 & 15-C



SCHEMATIC WIRING DIAGRAM - SYSTEM NO.14



SCHEMATIC OF
NO. 6034-BE SYSTEM-14 & 15-C



SCHEMATIC OF
NO'S 6042-AE & AF SYSTEMS 14 & 15-C

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.

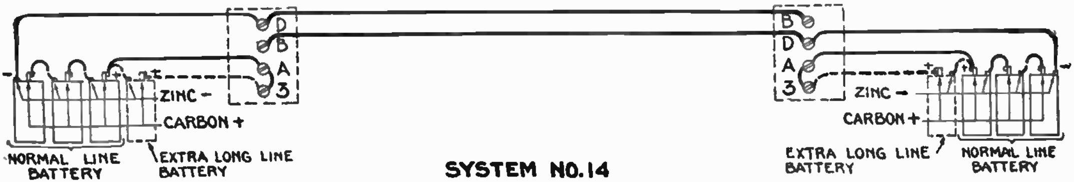
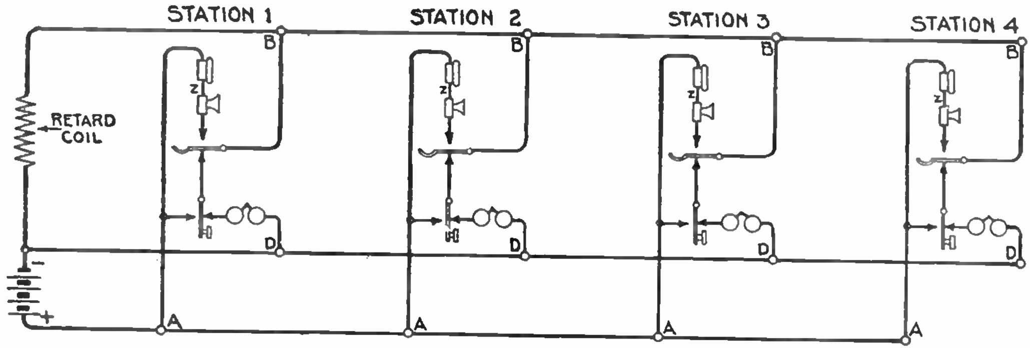
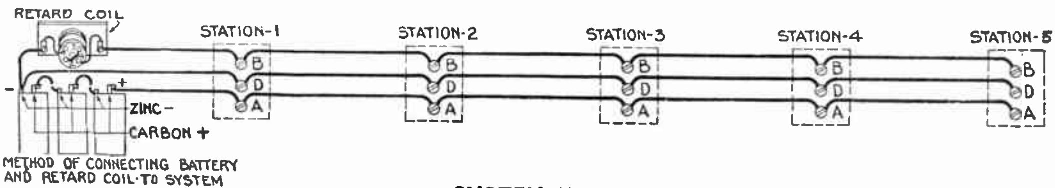


FIG. 7,589.—Diagram of connections of Graybar two station private line inter-phone system.



SCHEMATIC WIRING DIAGRAM - SYSTEM No. 15-C

FIG. 7,590.—Wiring diagram of Graybar code ringing, common talking inter-phone system.



SYSTEM NO.15-C

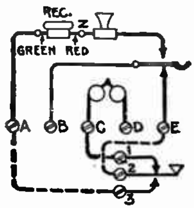
FIG. 7,591.—Diagram of connections of Graybar code ringing, common talking inter-phone system.

5. Master station; common talking.
6. Master annunciator.
7. Master annunciator; common talking.

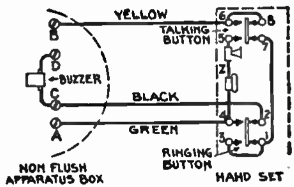
Two Station Private Line.—This system is for a small installation where the sets are distantly located from each other. Only two wires are used for connecting the inter-phones, dry cells being required at each station.

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.

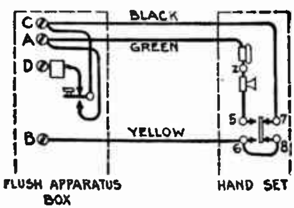
A battery of three dry cells is required at each station to furnish current for talking and ringing if the length of line be less than 750 feet. If the



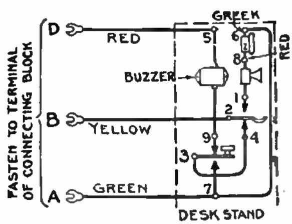
SCHEMATIC OF
NO'S 1527-C-1 & 1539-C-1
SYSTEM 15-C
DOTTED LINES DENOTE METHOD OF CONNECTING STRAP WIRES FURNISHED WITH EACH SET (SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF
NO. 6043-P SYSTEMS 14 & 15-C



SCHEMATIC OF
NO'S 6042-AE & AF SYSTEMS 14 & 15-C

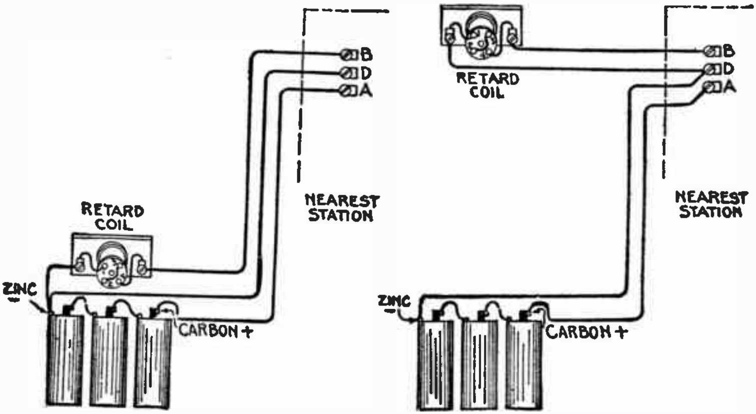


SCHEMATIC OF
NO. 6034-BE SYSTEM-14 & 15-C

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. 7,596 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.

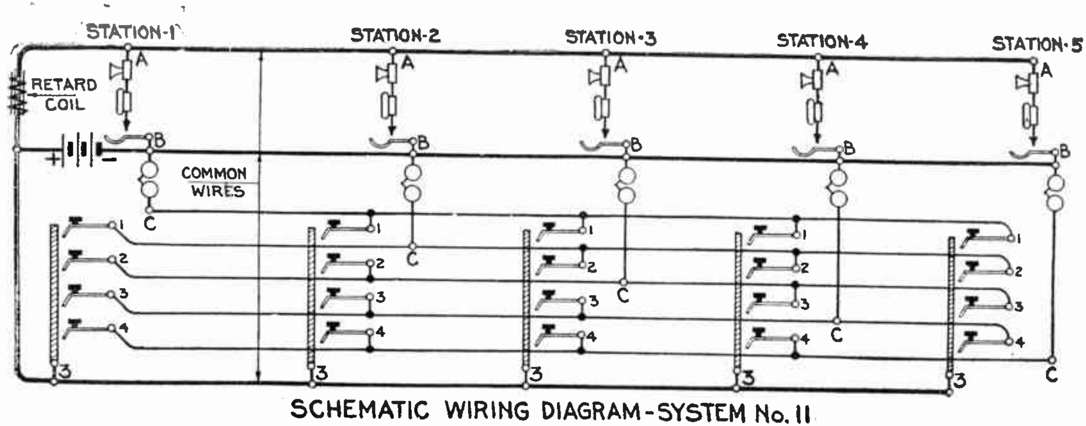


FIG. 7,599.—Wiring diagram of Graybar selective ringing, common talking inter-phone system.

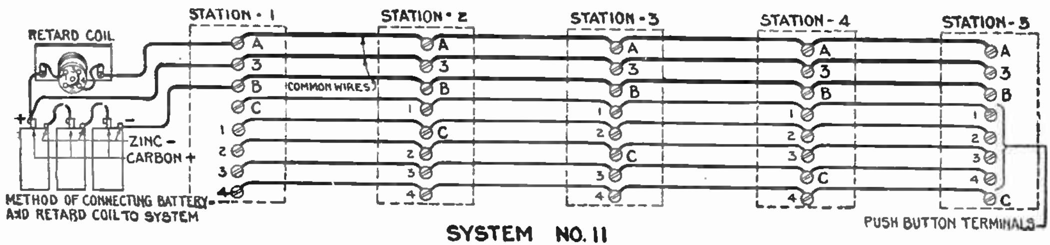
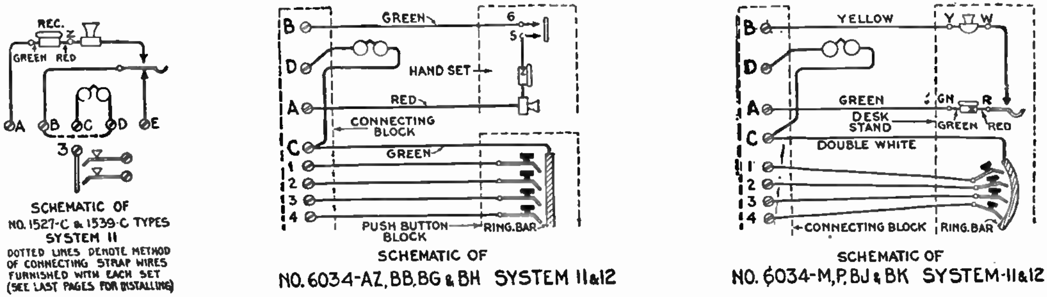
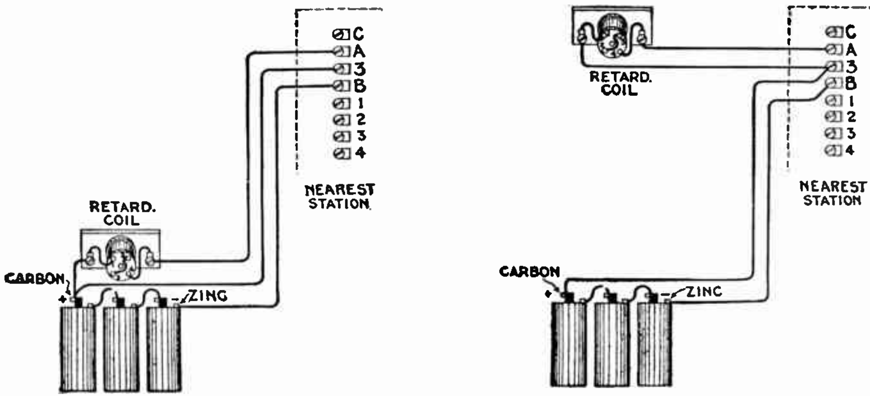


FIG. 7,600.—Diagram of connections of Graybar selective ringing, common talking inter-phone system.



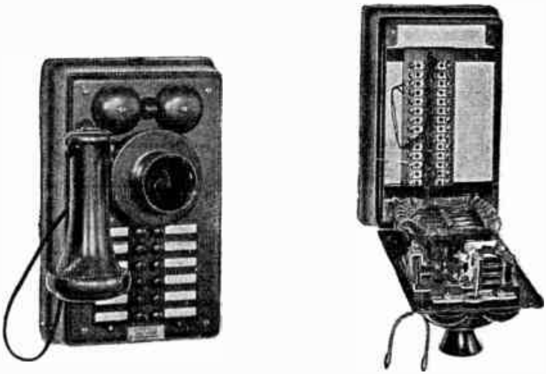
FIGS. 7,601 to 7,603.—Schematic diagrams of Graybar selective ringing, common talking inter-phone system.



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

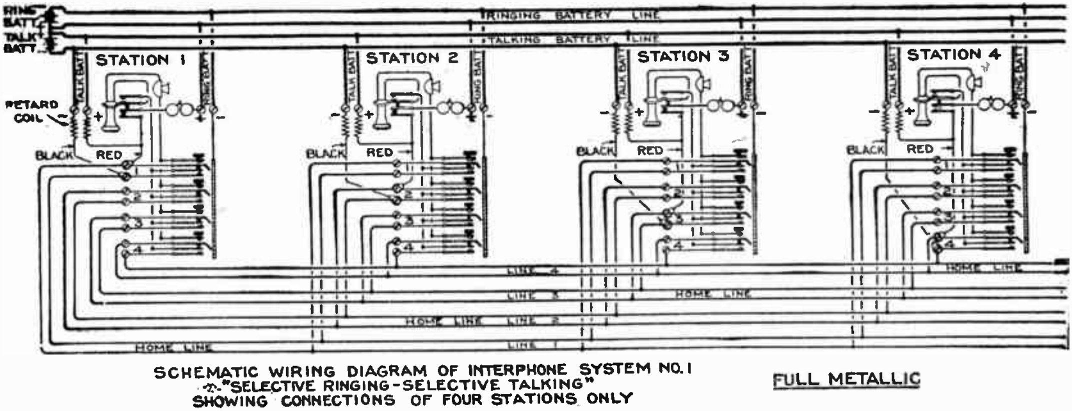


FIG. 7,608.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; *full metallic.*

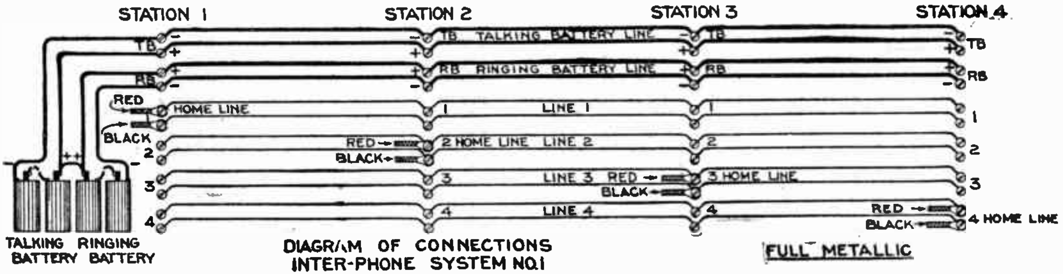


FIG. 7,609.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; *full metallic.*

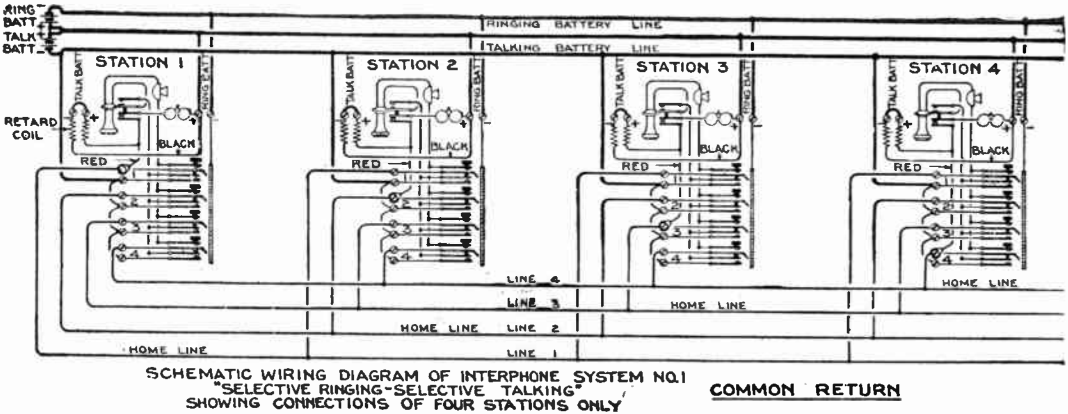


FIG. 7,610.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; *common return.*

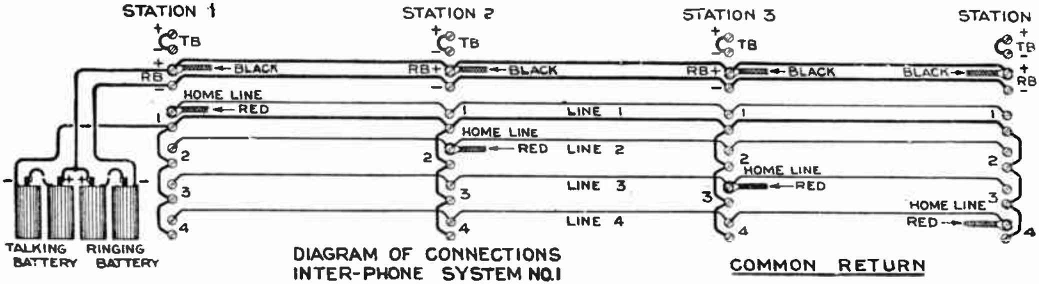
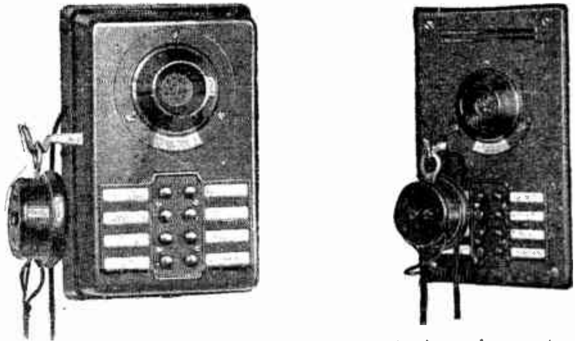


FIG. 7,611.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; *common return.*

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.

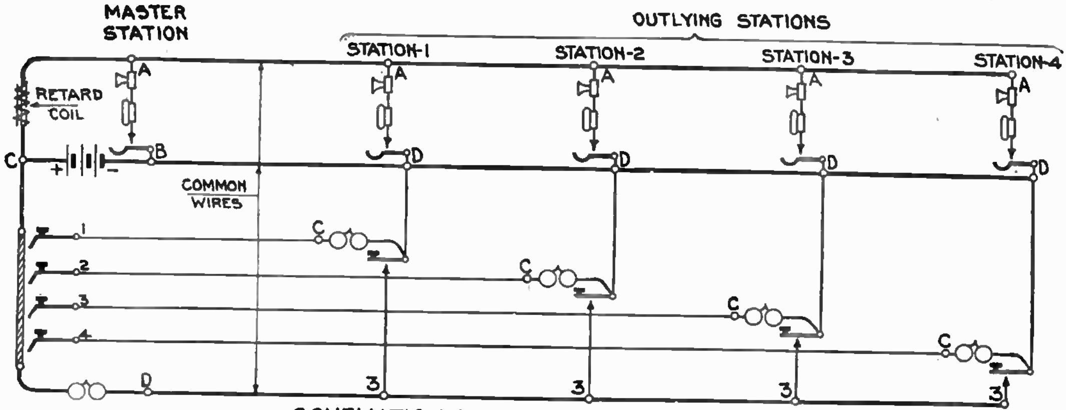


Figs. 7,612 and 7,613.—Graybar master station common talking inter-phone system; projecting and flush wall type sets.

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.



SCHEMATIC WIRING DIAGRAM-SYSTEM No. 12

FIG. 7,614.—Wiring diagram of Graybar master station, common talking inter-phone system.

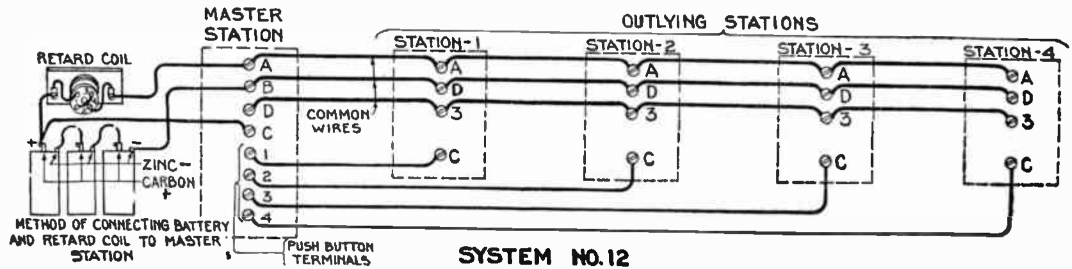
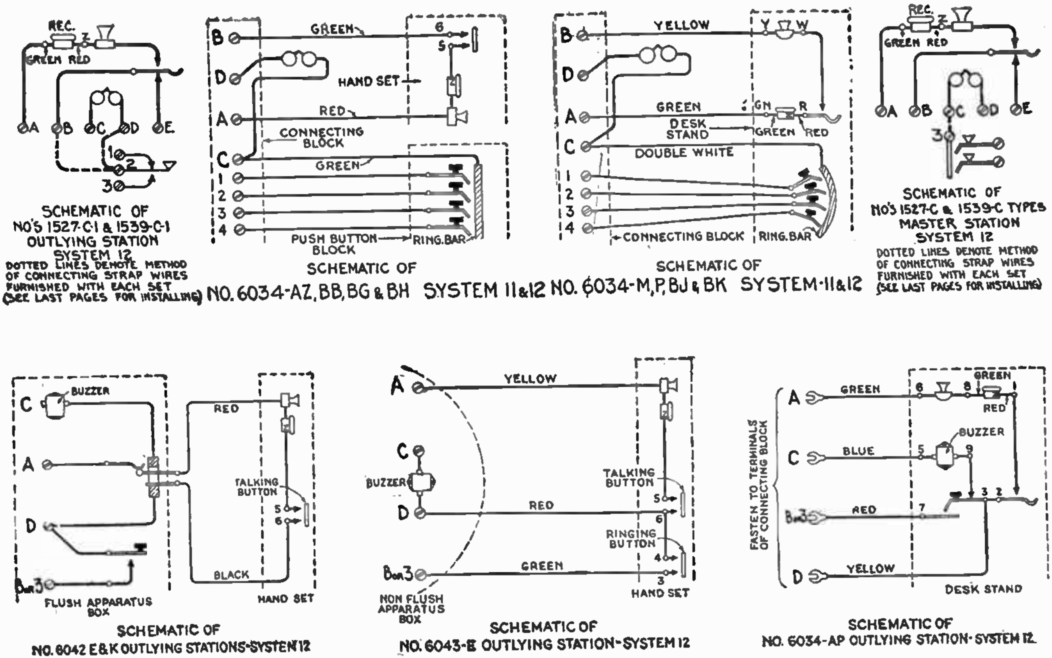


FIG. 7,615.—Diagram of connections of Graybar master station common talking inter-phone system.

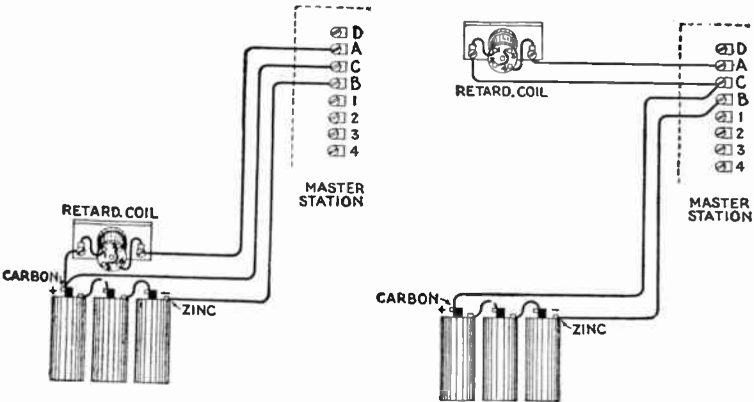


FIGS. 7,616 to 7,622.—Schematic diagrams of Graybar master station, common talking inter-phone system.

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

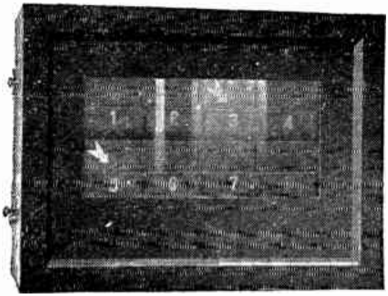
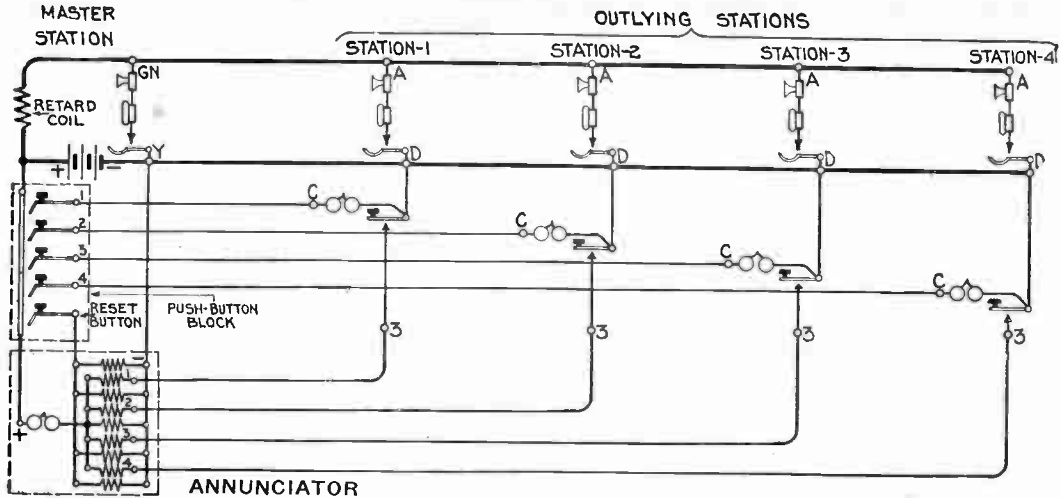
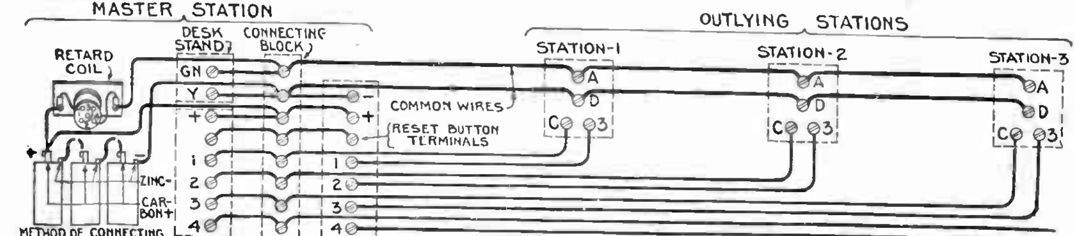


FIG. 7,625.—Graybar master annunciator, common talking system electric reset annunciator. The drop indicator is a white arrow which points directly at a white drop number; it can be seen from any angle. The audible signal is a new type double adjusting buzzer.

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.

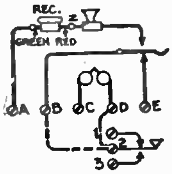




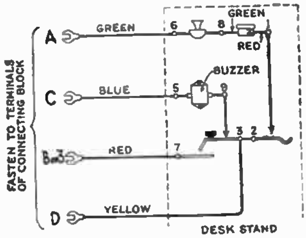
Figs. 7,626 and 7,627.—Wiring and connection diagrams of Graybar master annunciator common talking inter-phone system.

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.

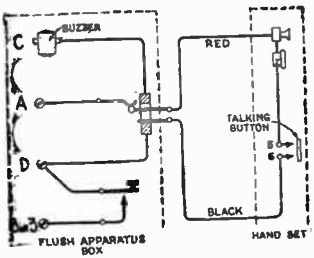
The principal's or master station equipment consists of an electric reset annunciator and a push button block with one drop and button for



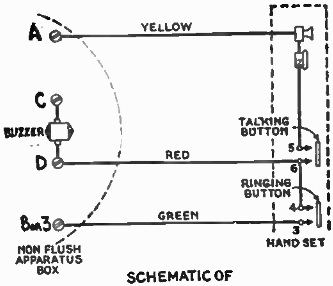
SCHEMATIC OF
NO'S 1527-C-1 & 1539-C-1
OUTLYING STATION
SYSTEM 12-A
DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP WIRES
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF
NO. 6034-AP OUTLYING STATION-SYSTEM 12



SCHEMATIC OF
NO. 6042 E & K OUTLYING STATIONS-SYSTEM 12



SCHEMATIC OF
NO. 6043-E OUTLYING STATION-SYSTEM 12

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.

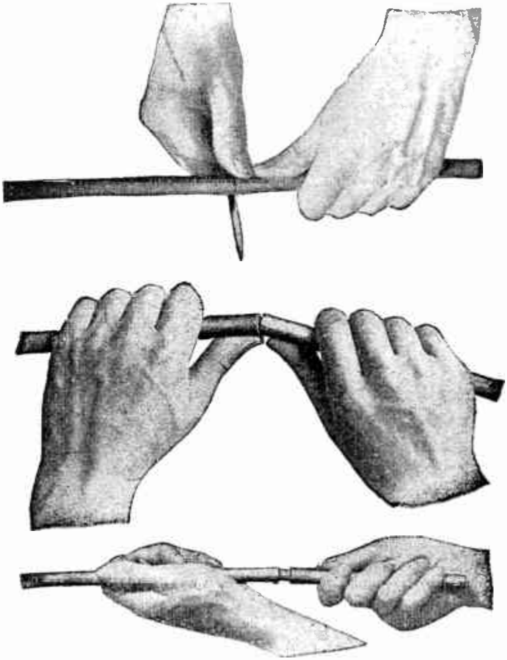
Preparing Inter-phone Cable for Connections.—After having definitely established the route of the cable, it will be necessary to open it properly and fan out the cable wires before connection can be made to the terminals of either inter-phones, cable terminals or connecting blocks.

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.

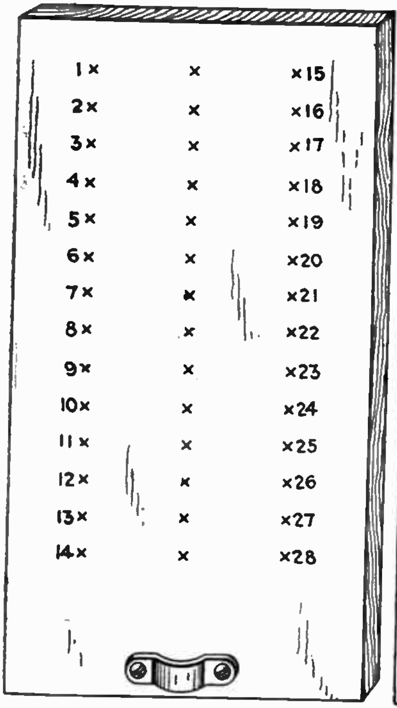
If the cable have a lead sheath, the latter can be removed as shown in figs. 7,632 to 7,634. If it have a braided covering, the latter can be removed by making a slit by means of a sharp penknife, lengthwise from the end of the cable to the marked point.

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.



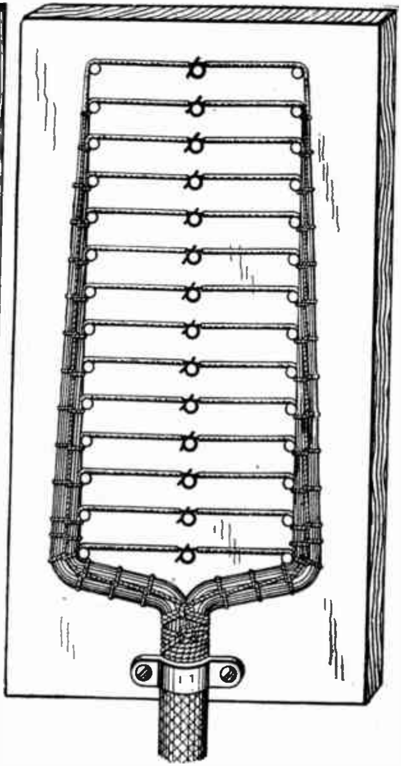


FIG. 7,635.—Board template for *fanning* and *sewing* inter-phone cable. The marking of the board depends entirely upon the location of the terminals to which the wires are to be connected. For example, the following describes a cable forming board for 24 button interphones of a two station line. Mark 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.

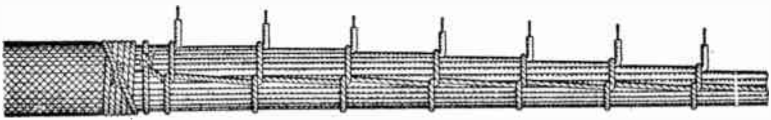


FIG. 7,637.—Detail of inter-phone cable showing lacing twine stitched around the cable to hold the wires permanently in position. Another method to secure the same result consists of drilling small holes, about ⅛ in. diameter, through the board at the outside X marks, fig. 7,635, and pushing the proper 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*.

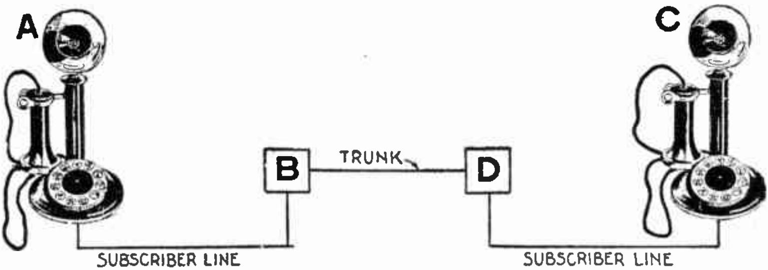
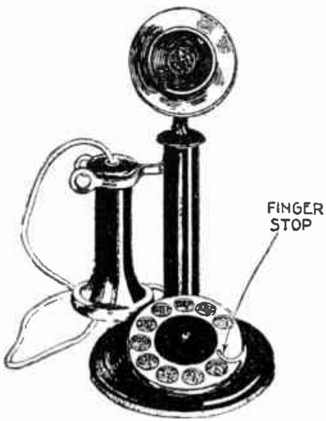
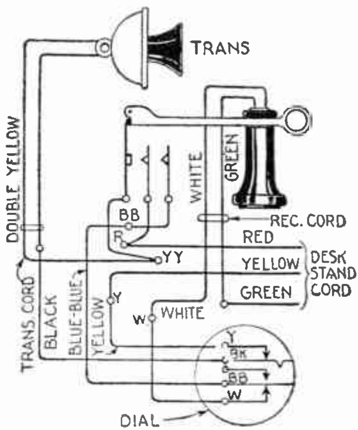


FIG. 7,628.—Simplified dial telephone system. A, telephone subscriber with number ATLantic 2357; B, Atlantic central office; D, Mayflower central office; C, telephone subscriber with number MAYflower 7348.





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.

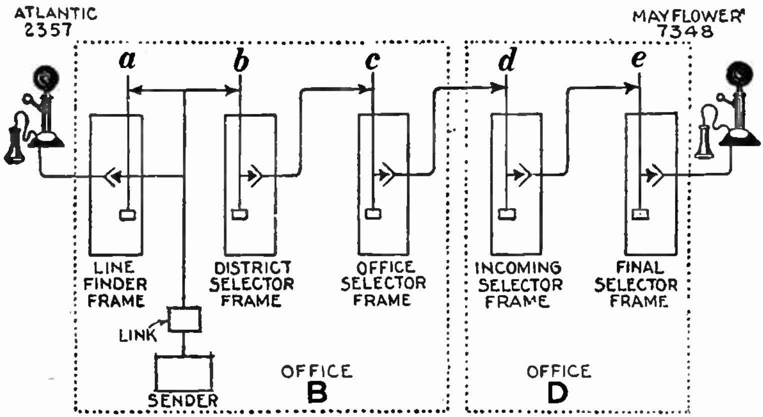


FIG. 7,631.—Panel dial system—routing of a call. a, line finder; b, district selector; c, office selector; d, incoming selector; e, final selector.

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.

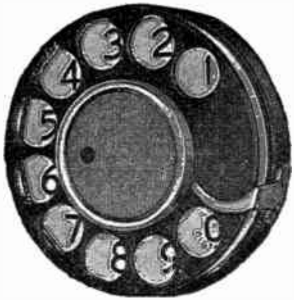
By this time the sender has performed all its work and it is accordingly disconnected from the district selector circuit of office B.

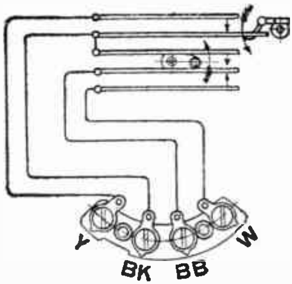
When the called party answers by lifting the receiver off the hook the ringing current is automatically removed.

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.



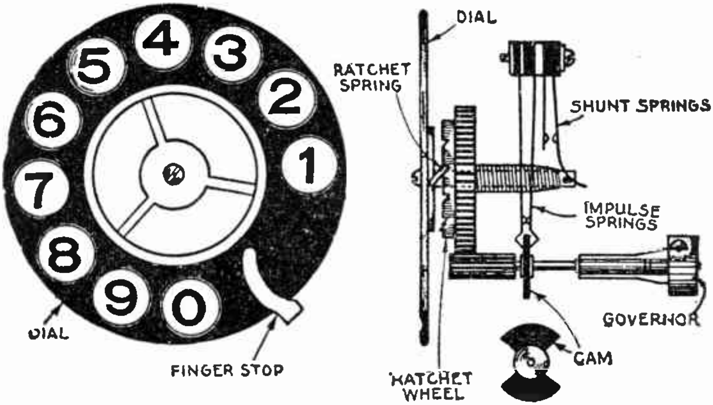


FIGS. 7,632 and 7,633.—Assembled dial and wiring diagram.

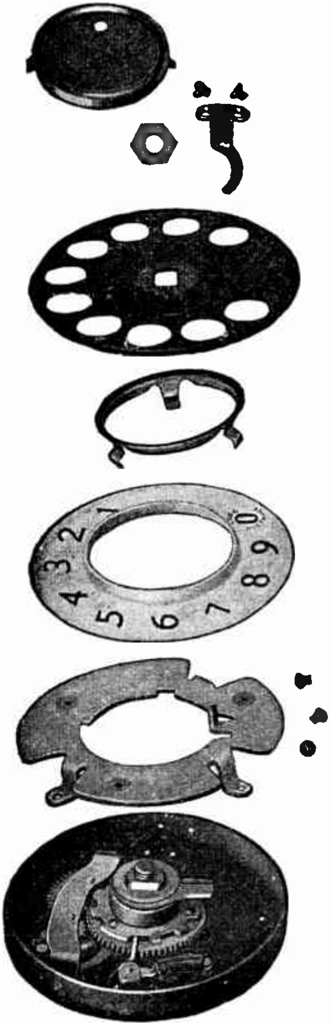
FIGS. 7,634 and 7,635.—Kellogg common battery telephone; enclosed gong wall type arranged for automatic dial. Fig. 7,635 open view showing interior construction.

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.

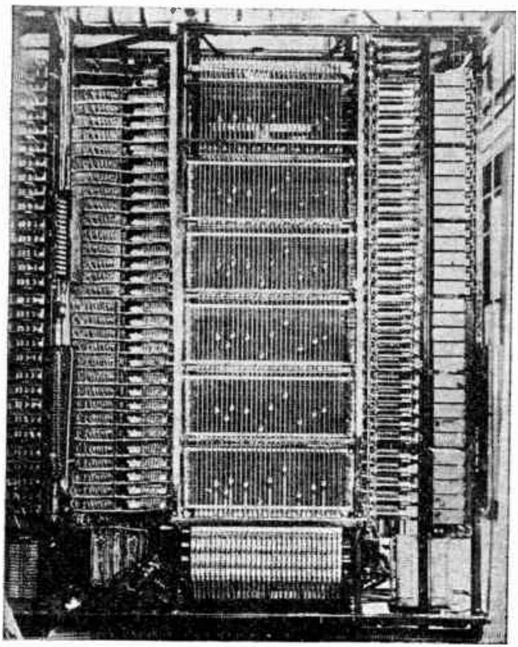


FIG. 7,654.—Panel type selector frame.

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

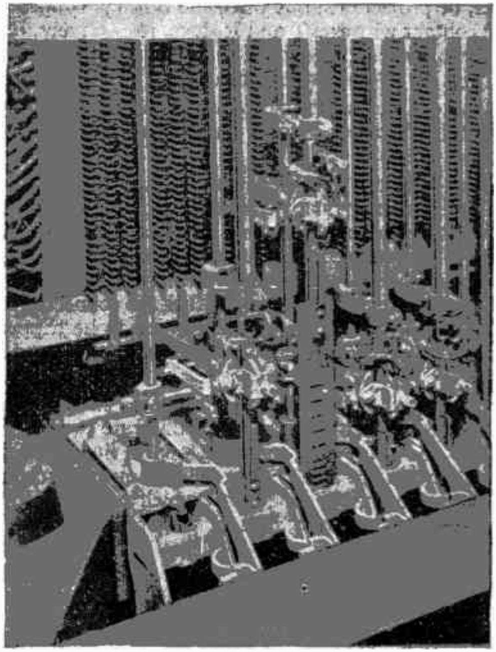


Fig. 7,655.—Lower portion of selector frame showing raised rack attached to lower end of selector rod. The rack is made of spring bronze and has 100 rectangular perforations spaced vertically corresponding to the 100 trunks (vertical) on the bank, and five rectangular perforations wider apart corresponding 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.

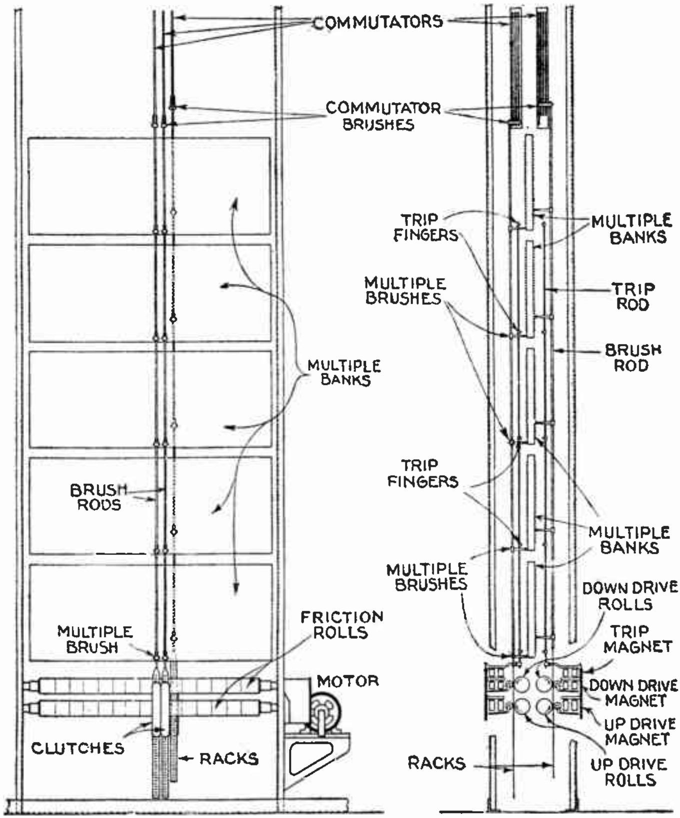
The commutator brushes at the top of the selector rod slide over brass bars moulded in hard rubber to form what is known as a *commutator* shown in fig. 7,656 and 7,657.

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.

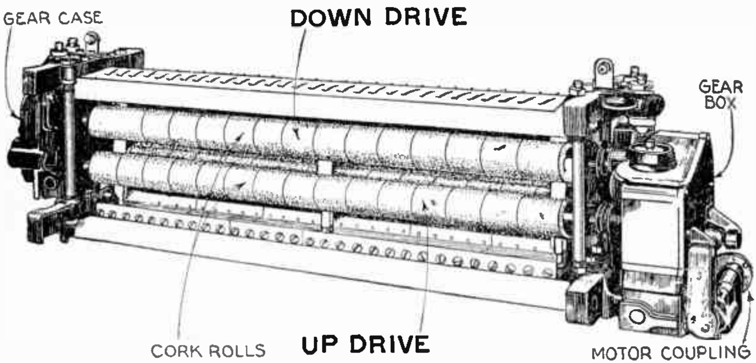
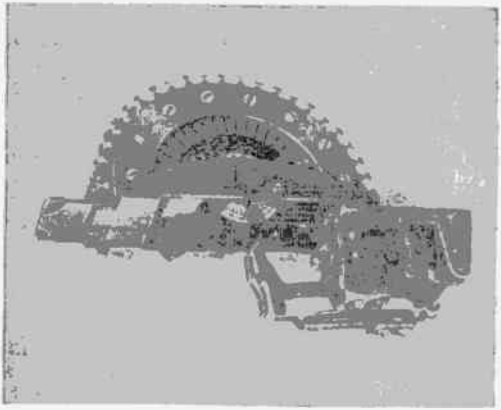


FIG. 7,658.—Cork rolls.

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



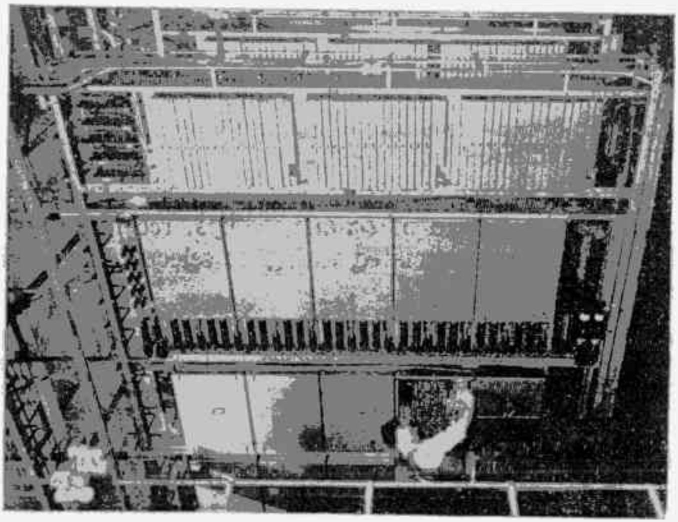


Fig. 7,669.—Group of senders on frame.

Fig. 7,668.—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.

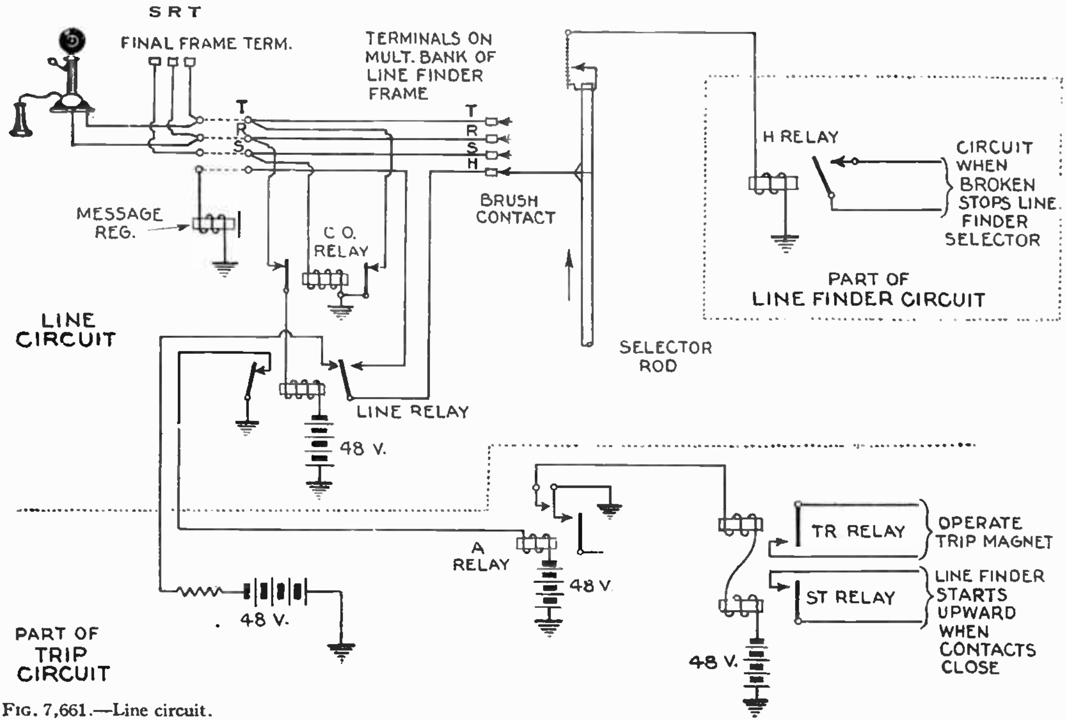


FIG. 7,661.—Line circuit.
FIG. 7,662.—Part of tripping circuit.
FIG. 7,663.—Part of line finder circuit.

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.

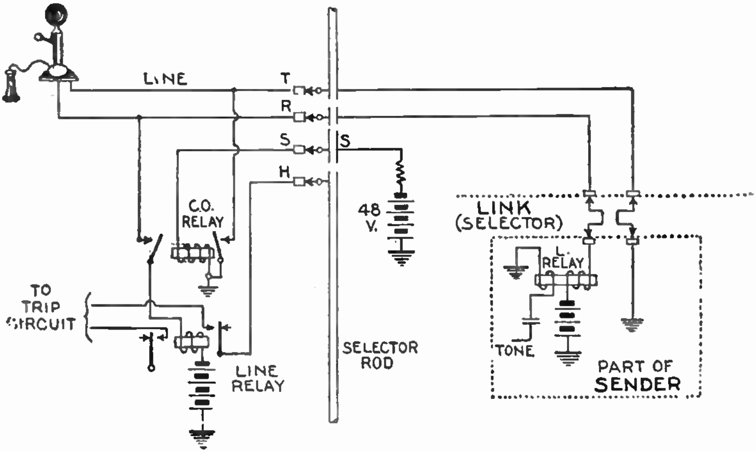
The line finder is connected to a *link* which assigns, or connects with a sender, so that at this stage of the call, the telephone has been connected to a line finder which in turn has been connected to a sender, as well as to a district selector.

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.

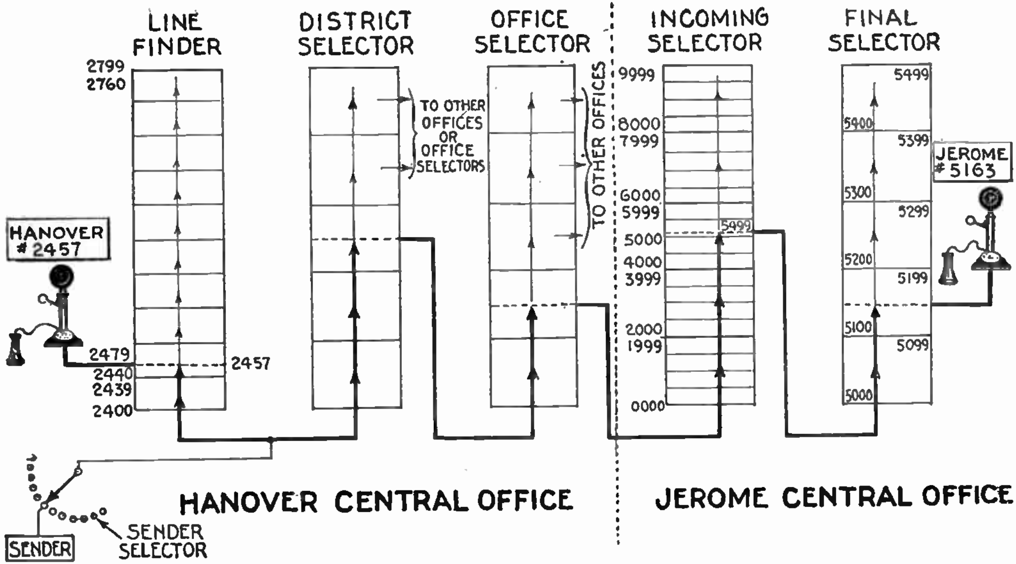


FIG. 7,666.—Panel dial system. Routing of a call.

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

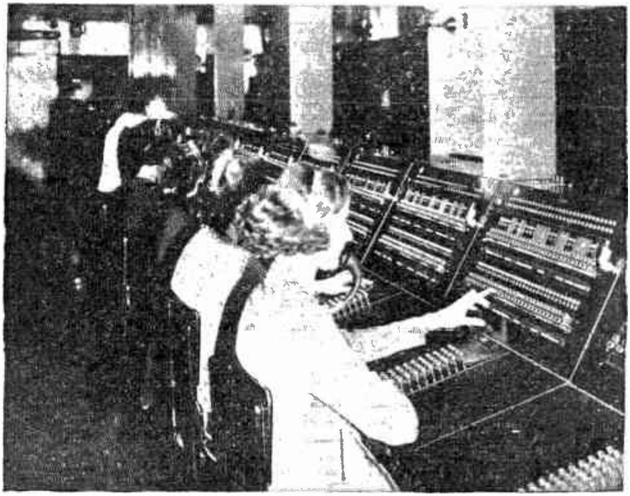


FIG. 7,667.—Cordless B board of a panel dial central office.

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

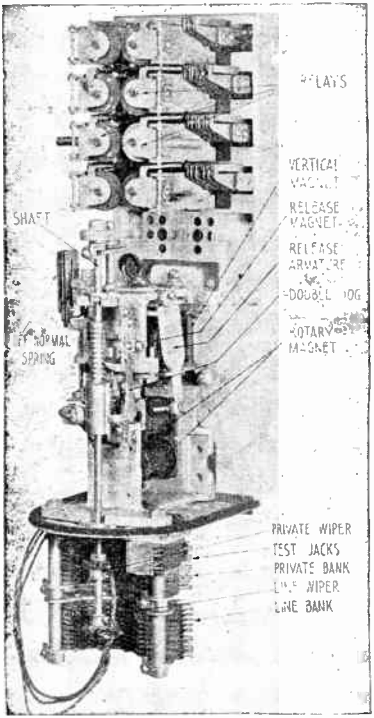
FIG. 7,668.—Step-by-step connectors mounted on switch frames.

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;



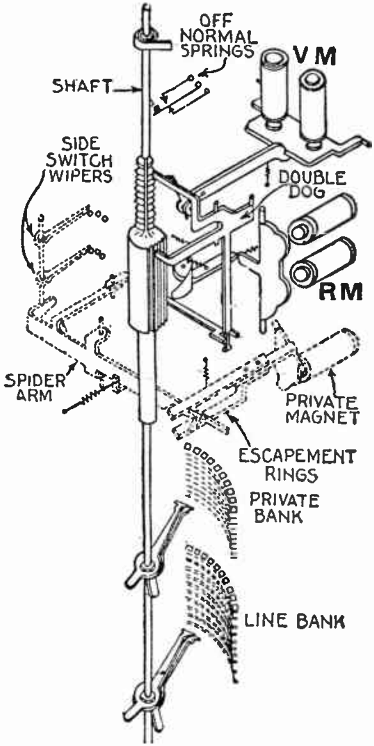


FIG. 7,669.—Step-by-step connector switch. It consists of a double bank and double wipers, or brushes, and a mechanism whereby the shaft can be lifted and rotated step-by-step. This is a two digit switch. The vertical motion is controlled by the first digit dialed and the rotary motion by the second 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.

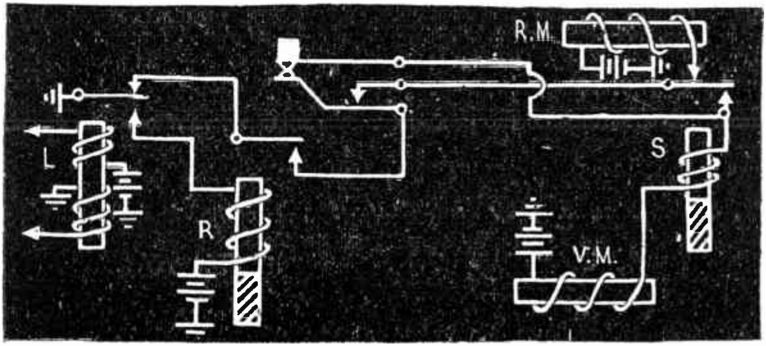


FIG. 7,671.—Step-by-step connector circuit. When this switch is first engaged the L relay and the R relay are operated. If the subscriber dials, say for example No. 46, the L relay is momentarily released and re-operated four times when the digit 4 is dialed, but the R relay remains in its initial operated 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 VM, 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 VM, to the rotary magnet RM. 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.

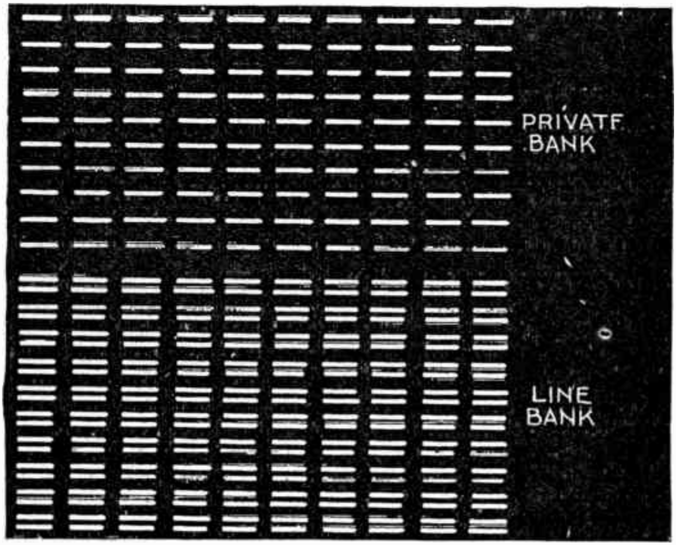


FIG. 7,672.—Diagram showing contacts of line and private banks of a 100 line system. These banks form a part of the connector switch.

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.

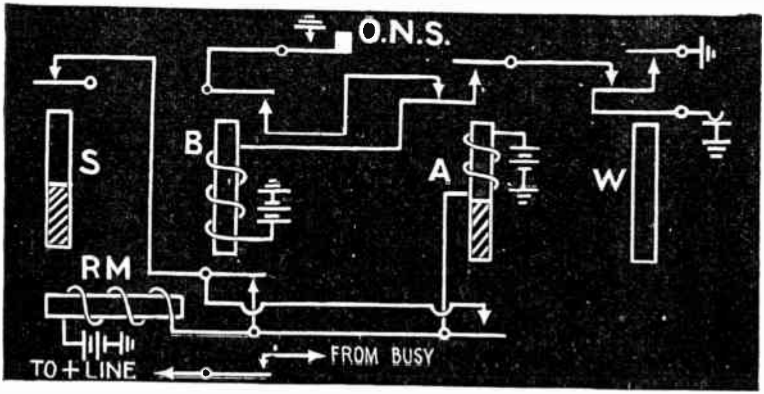


FIG. 7,673.—Busy test circuit of connector. Relay A is a slow releasing relay and has operated in parallel with the rotary magnet RM. Relay A will remain up for a moment after the last rotary impulse has been received. If the called line be busy its sleeve (private) terminal has ground connected to it 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.

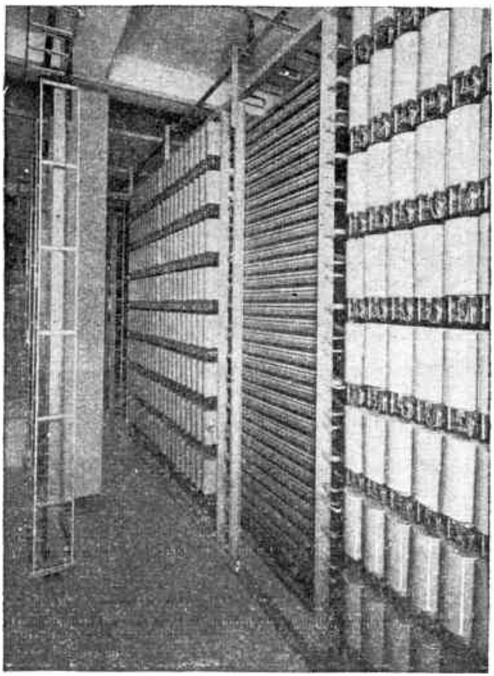


FIG. 7,674.—Groups of selectors mounted on switch frames.

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

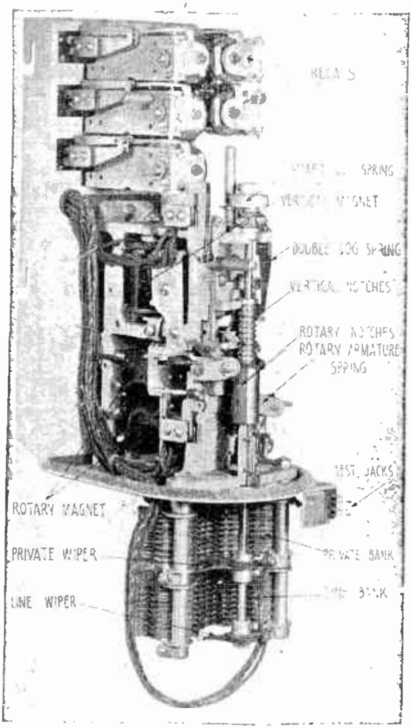


FIG. 7,675.—Step-by-step selector. It consists of a multiple bank and wipers and a mechanism similar to the connector in fig. 7,669. This is a one digit switch. The vertical motion is controlled by the dial, and the rotary motion automatically.

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

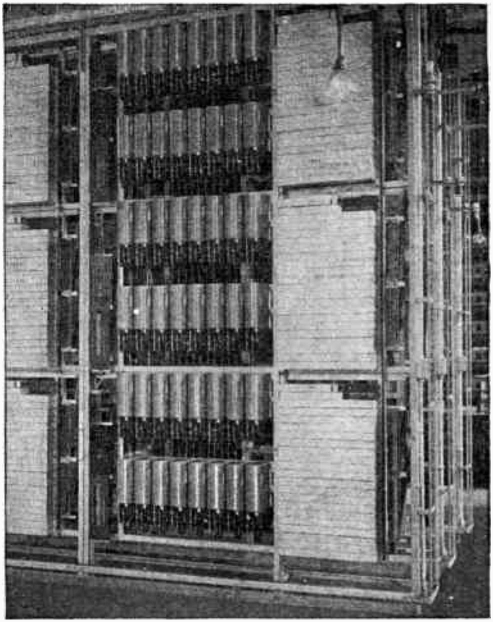


Fig. 7,676.—Groups of line finders on switch frames.

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.

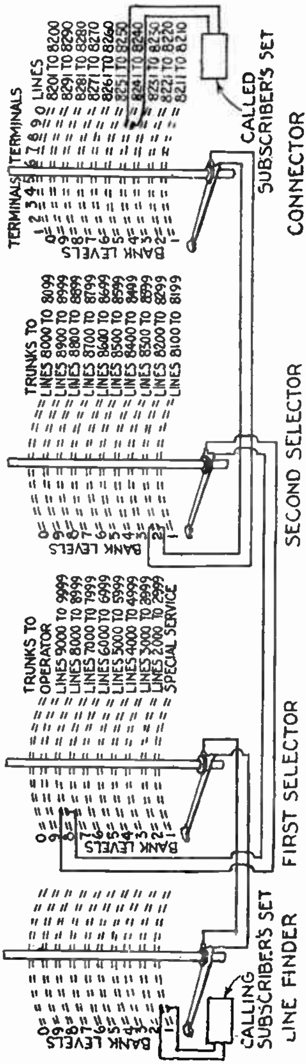


FIG. 7,677.—Progress of a step-by-step call in a four digit central office, using line finders.

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.

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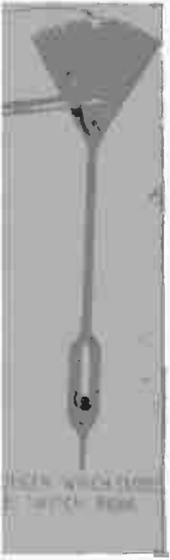
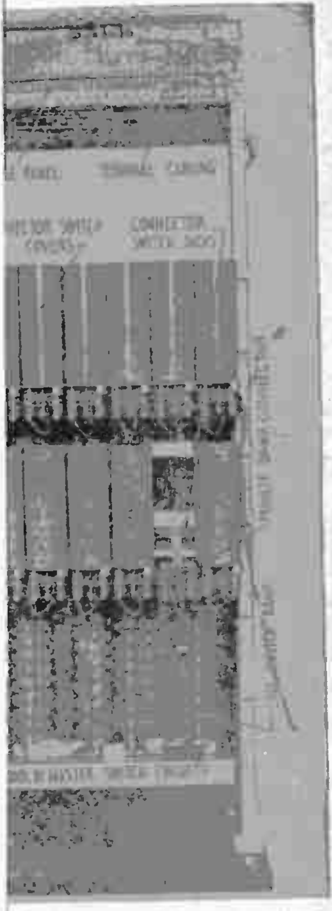


ation "pull down coil" arries a plunger, which t of a bank of contacts. iated ten trunks. Line for each 100 line unit, ine switches depending s ten trunks. Normally er removes his receiver is thereby closed which carrying its plunger out. The effect of this is to r switch, as shown dia- t one line switch thrusts le all idle plungers have plungers forward over he movement proceeds uses a pre-selected idle



shown 100 subscribers' line switches o sections of 25 are mounted on each master switch. Above the switches

ear of a line switch unit are mounted ming subscriber's lines, besides being connector bank contacts.

Fig. 7,681 shows how the master switch bar
engages in the slot at the tail end of the plu
operated line switches in that group, and misse
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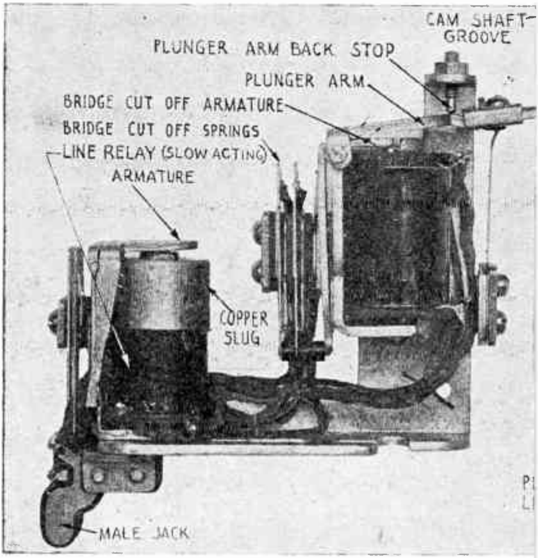
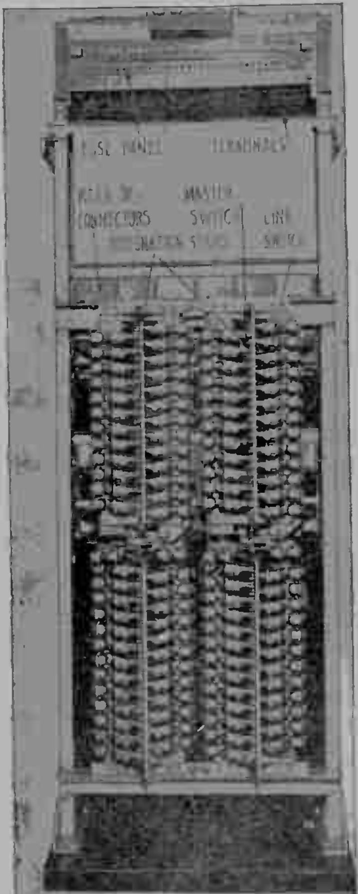


FIG. 7,680.—Line switch. ***It consists of*** a line relay and a combi and "holding coil" carrying two armatures. The larger armature is pivoted so that its point may be swung by the master switch in fro The bank consists of 10 sets of contact springs with which are asso switches are mounted in groups of 25, four groups being provided One master switch may be provided for any number of groups of upon the trunking capacity desired, since each master switch contr the plungers are at rest poised over bank contacts. When a subscri from his telephone switch hook preparatory to making a call, a circui causes the plunger arm of his line switch to be at once pulled down, of engagement with the master shaft and thrusting it into the bank connect the subscriber's line to a trunk leading to an idle first select grammatically in the right hand portion of fig. 7 685. The instant th its plunger into the bank, thus occupying the trunk over whose multi been poised, the master switch operates and swings the remaining id the next multiple of bank contacts. If this trunk should be busy, until an idle trunk is found. It is to be noted that a line switch alwa trunk instead of making a selection after a subscriber starts to call.



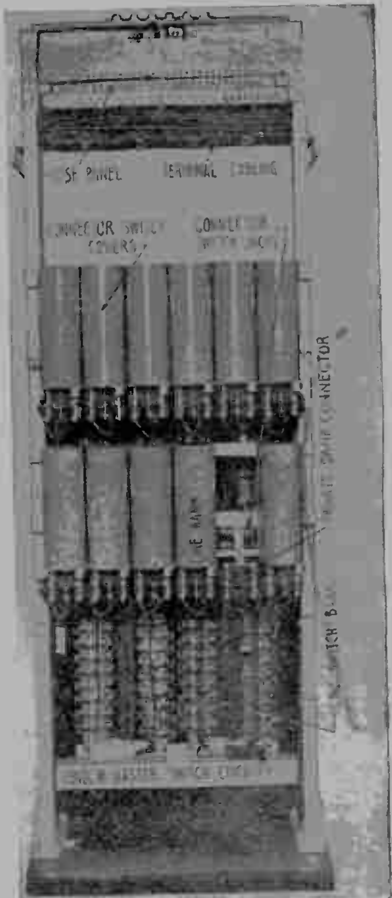


FIG. 7,678.—100 line switch board *front view*. Here are shown 100 subscribers' line switches mounted on a steel frame in four sections of 25. Two sections of 25 are mounted on each swinging shelf and each shelf of 50 is controlled by a master switch. Above the switches may be seen the power panel and 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.

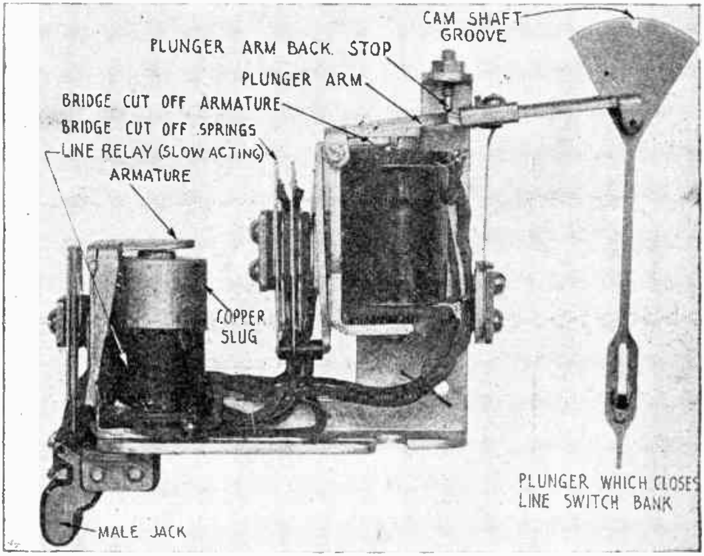


FIG. 7,680.—Line switch. *It consists of* a line relay and a combination "pull down coil" and "holding coil" carrying two armatures. The larger armature carries a plunger. which is pivoted so that its point may be swung by the master switch in front of a bank of contacts. The bank consists of 10 sets 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. 7 685 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.

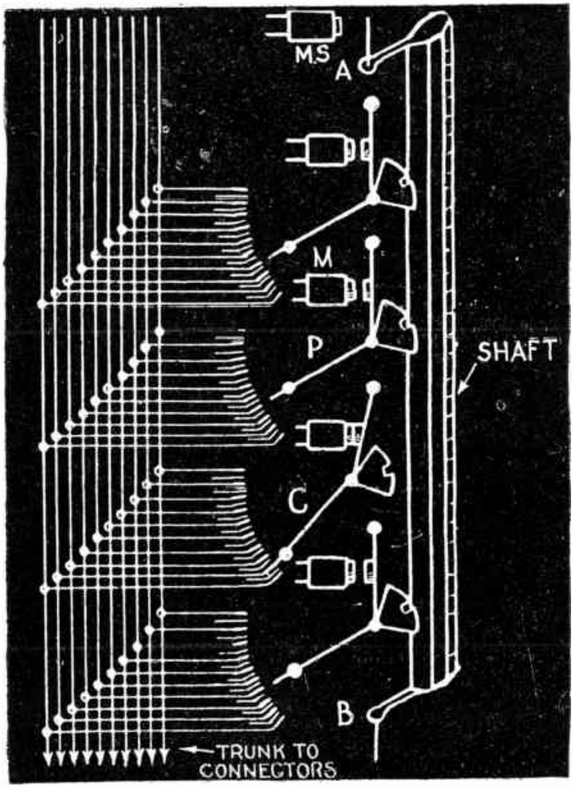


FIG. 7,681.—Diagram of line switch and connections. The switch ***consists of*** a magnet M, and plunger P, whose head or wing is slotted so that it may engage a projecting edge of the shaft. The shaft is pivoted at A and B, and is capable of a rotary motion of about 40 degrees under control of a master 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

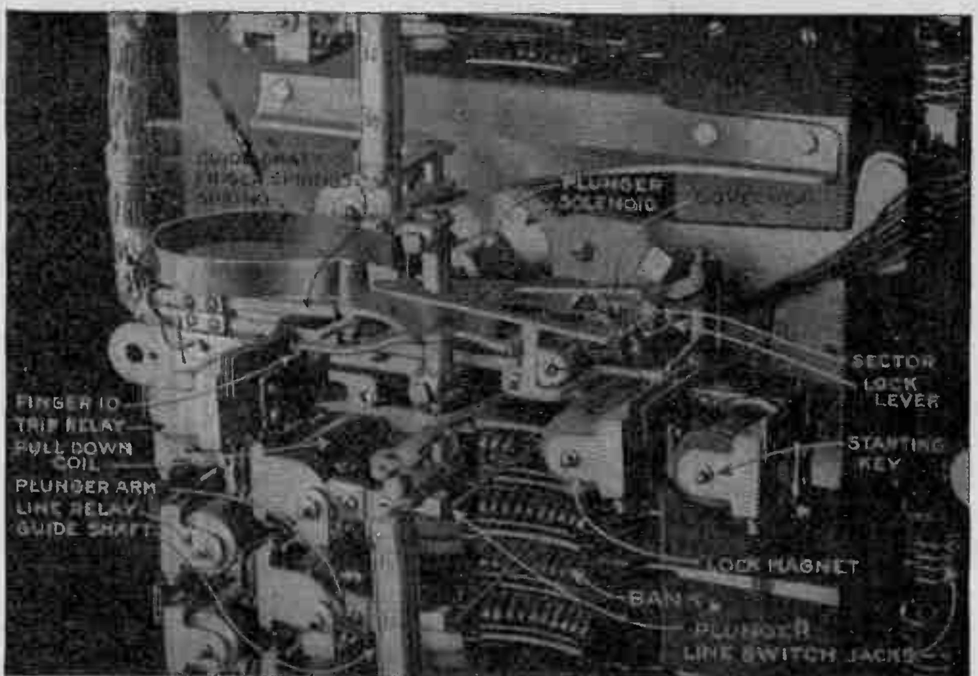


FIG. 7,682.—Master switch mechanism on line switch frame.

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***.

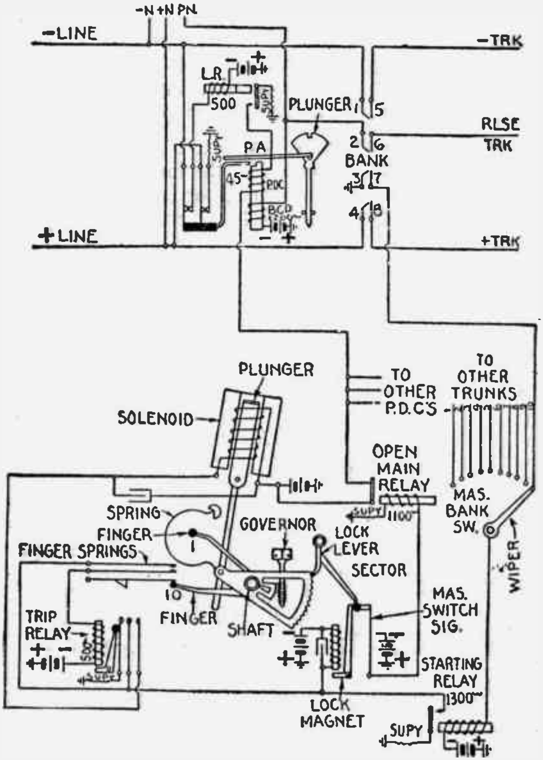
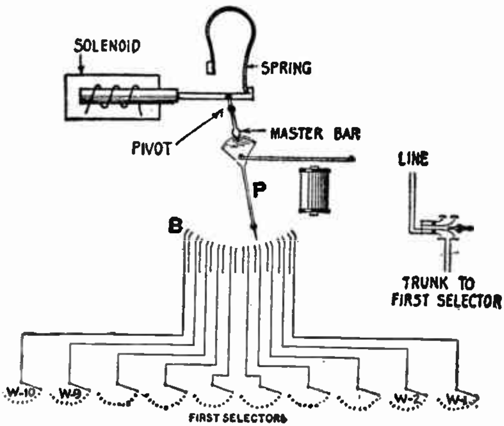


FIG. 7,683.—Line and master switch circuit. When the receiver (not shown) is taken off the hook the LR relay operates which in turn energizes the 45 ohm winding (P.D.C.) of the plunger relay and causes the plunger to be squeezed into the contacts of the line switch bank, thereby connecting the telephone 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 uulocked 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;

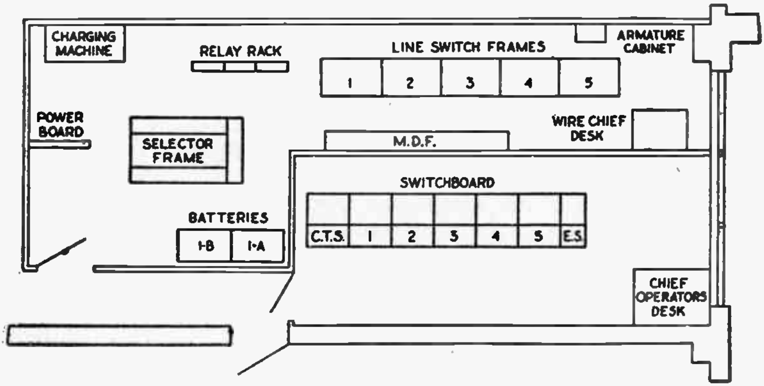


FIG. 7,686.—Typical floor plan of three digit step-by-step Private Branch Exchange.

6. A power plant consisting of a storage battery, a power board with controlling equipment and meters, a ringing machine and a charging machine;

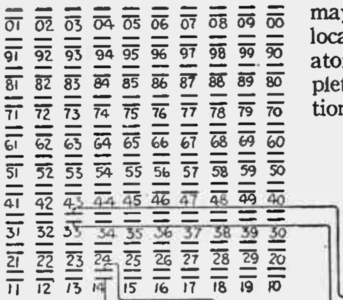
7. Station equipment comprising the telephone instruments with dials and bells.

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. K. operator who then completes the connections.



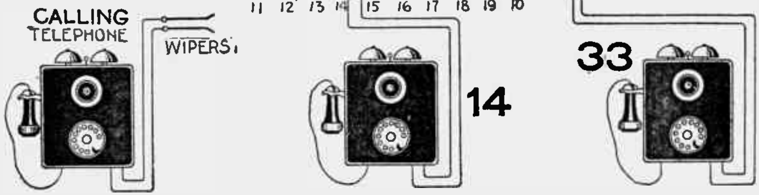


FIG. 7,687.—Diagram of line bank contacts, associated with each connector and numbering system of the telephone lines of which they are the terminals. The number of any set of terminals can be determined by noting the number of vertical and sidewise steps the wipers must be given to reach that set, remembering 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.

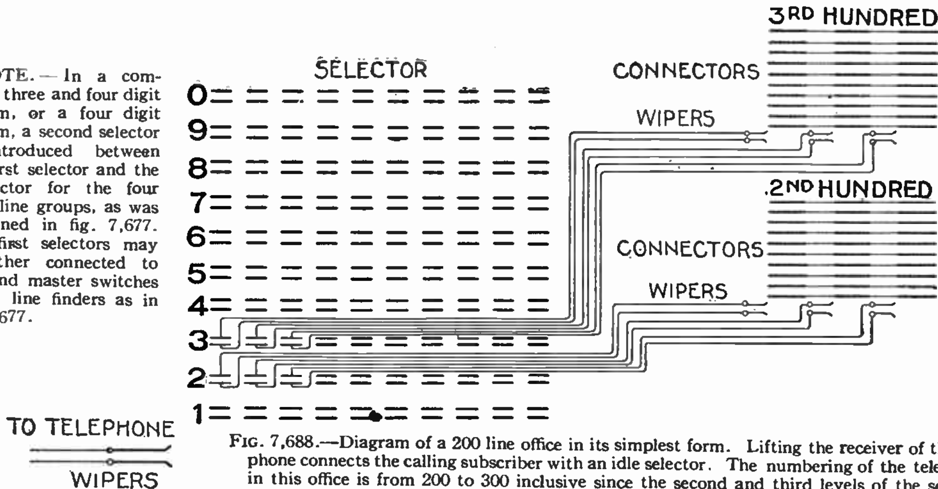


FIG. 7,688.—Diagram of a 200 line office in its simplest form. Lifting the receiver of the telephone connects the calling subscriber with an idle selector. The numbering of the telephones in this office is from 200 to 300 inclusive since the second and third levels of the selectors are used. Dialing 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.

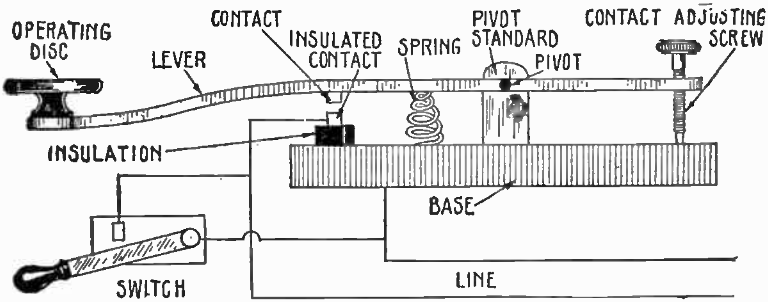


FIG. 7,689.—Elementary key. In actual construction the switch is attached to the base, but is here shown separately, in order that the connections may be more plainly seen.

e. Multiplex {synchronous.

f. Phantoplex.

4. The method of receiving, as

a. Non-recording

b. Recording
- by perforations;
- by printing.

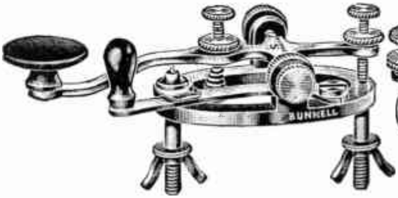
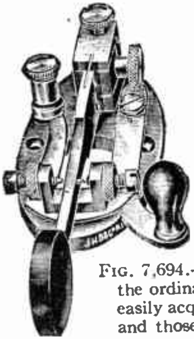


FIG. 7,691.—Bunnell key *without* legs.

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.



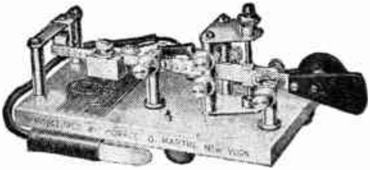


FIG. 7,694.—Bunnell double speed key. *It requires* only one-half the motions of the ordinary key, and these are made by a sidewise rocking motion of the hand, easily acquired, which guarantees that operators will not be affected with cramp, and those who are so affected will soon recover their speed.

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

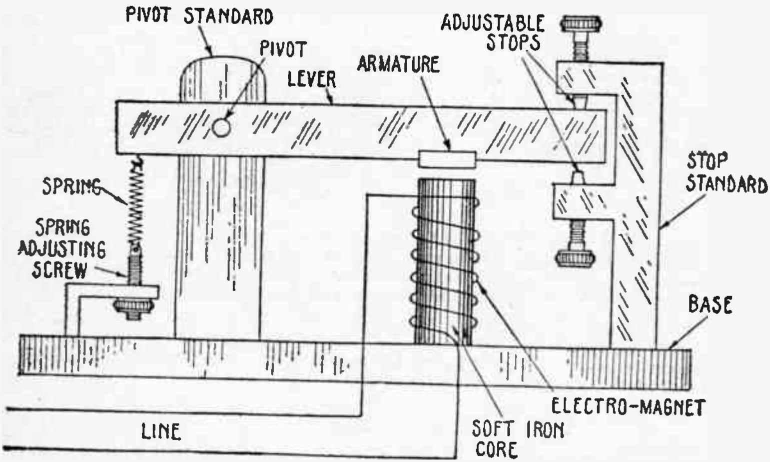
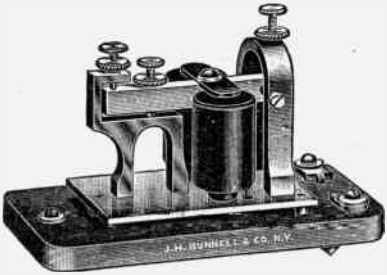


FIG. 7,696.—Elementary sounder showing essential parts.

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.



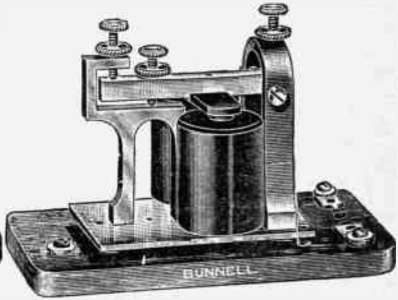


FIG. 7,697.—Bunnell aluminum lever giant sounder. Sounders wound to 4 ohms can be used on lines up to ¼ mile in length; while 20 ohm sounders will operate on main lines up to 15 miles in length, without using a relay.

FIG. 7,698.—Bunnell 1892 giant sounder with aluminum or brass lever.

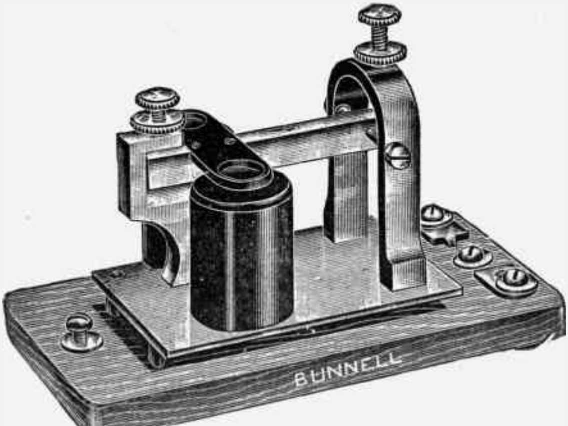


FIG. 7,699.—Ghegan alternating current sounder. *It can be used* on any 110 volt, 60 cycle *a.c.* circuit, the method of connecting depending on the resistance of the winding used. Wound with high resistance for 110 volt, 60 cycle circuit through a condenser of one-half *m.f.* capacity, which is connected 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.

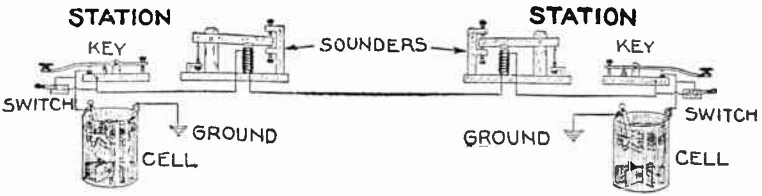


FIG. 7,700.—Elementary diagram showing a simple short line ***closed circuit*** system. It is called a closed system from the fact that the circuit is normally closed with current on the line, that is to say, when not in operation the switches are closed and current flows which energizes the magnets 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.

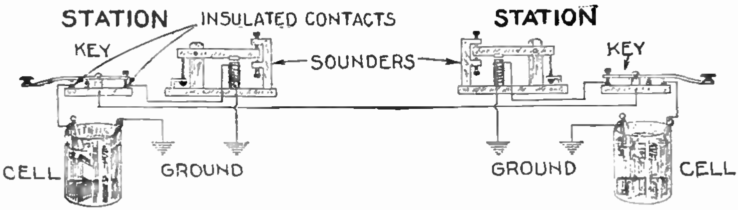


FIG. 7,701.—Elementary diagram showing a simple short line *open circuit* system. In Europe this system is in general use; it consists essentially of so arranging the apparatus that the battery shall only be placed on the line when a message is being transmitted. A main battery is necessary at each station, 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.

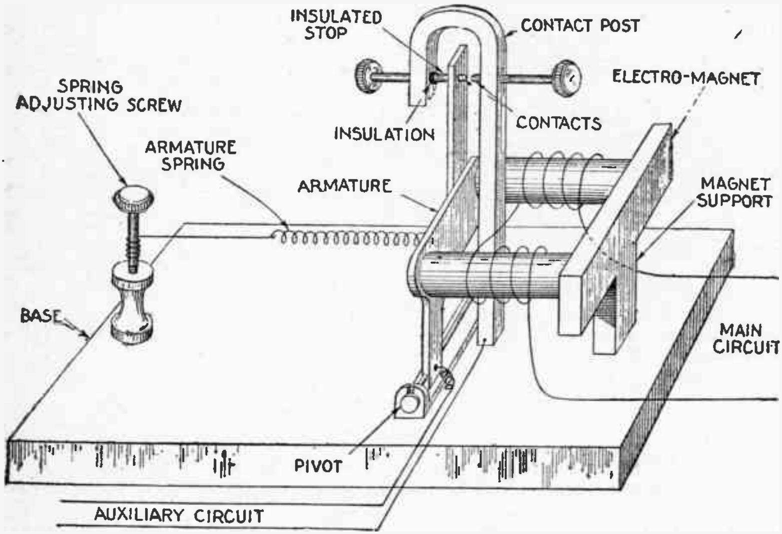


FIG. 7,702.—Elementary relay showing magnet, insulated armature contacts, insulated stop, armature spring, main and auxiliary circuit connections. *The function of a relay is to open or close an auxiliary current under predetermined electrical conditions in the main circuit,* so that *a comparatively 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.

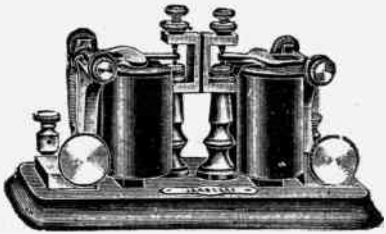


FIG. 7,703.—So called "Wheatstone" or British Post Office *polar* relay. Wound with either two or four windings according to requirements. The two winding form consists of two coils differentially connected in the same manner as the main coils of the four winding type. In the four winding instruments 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.

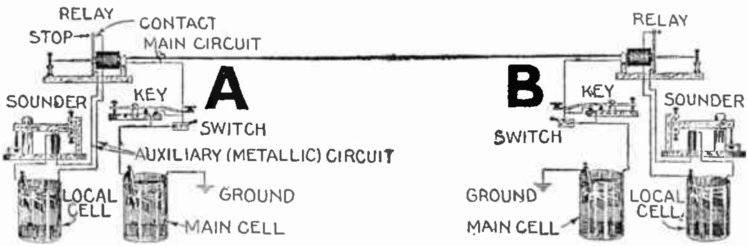
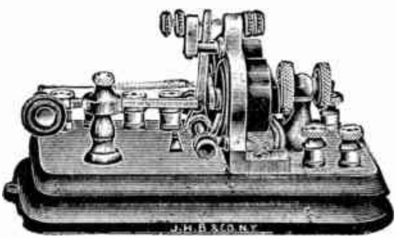


FIG. 7,705.—Elementary short line with relays, showing the main circuit and the auxiliary circuit at each station. The relay, as stated in the text *acts as a sort of multiplier*, that is to say, *it enables the comparatively weak current of the main circuit to bring into operation the much stronger 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.



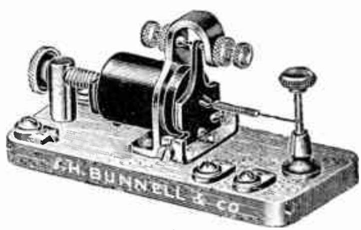


FIG. 7,706.—Smith three coil neutral relay—specially adapted to quadruplex work.

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.

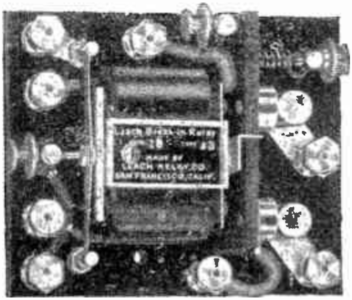


FIG. 7,708.—Bunnell *break in* relay for rapid handling of traffic working through static, cutting interference to a minimum. You hear what is going on while you are actually transmitting. The receiving operator can stop you at any time by holding his key down for a second and giving you the signal BK. 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.

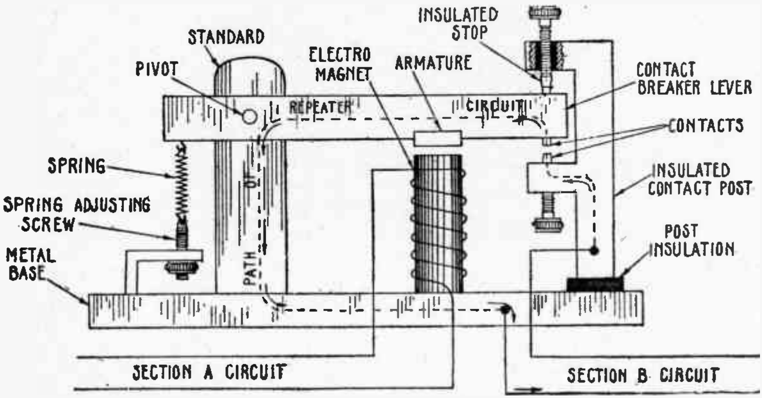
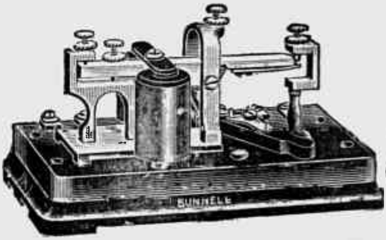


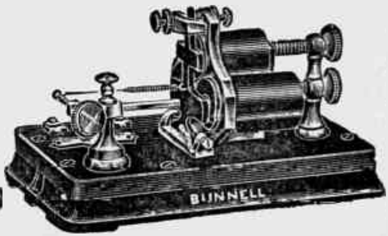
FIG. 7,709.—Elementary repeater showing the insulated parts essential for the contact maker, and path of the current through the repeater portion of the instrument. The insulated stop on the upper arm of the contact post is shown in sectional view to clearly indicate the insulation at this point. Compare 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.

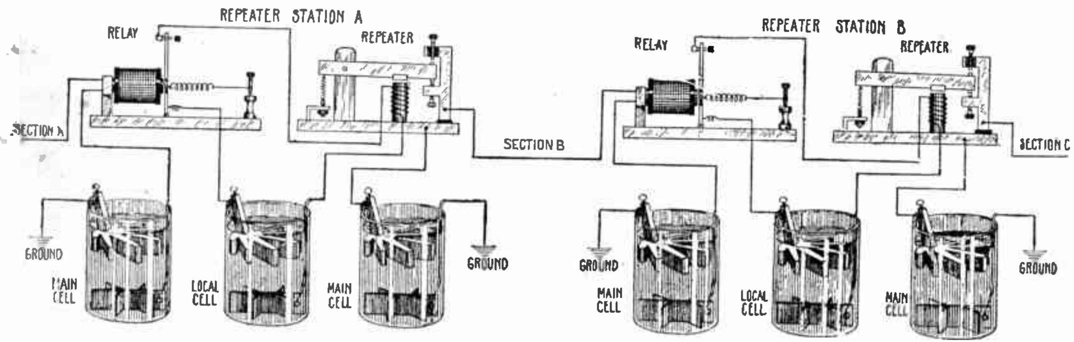


FIG. 7,712.—Elementary repeaters as connected in a circuit. ***In operation,*** if the home station or beginning of section A line send a message, the movements of the relay at station A will cause similar movements of the repeater, this in turn is repeated at station B, and all other stations on the 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.

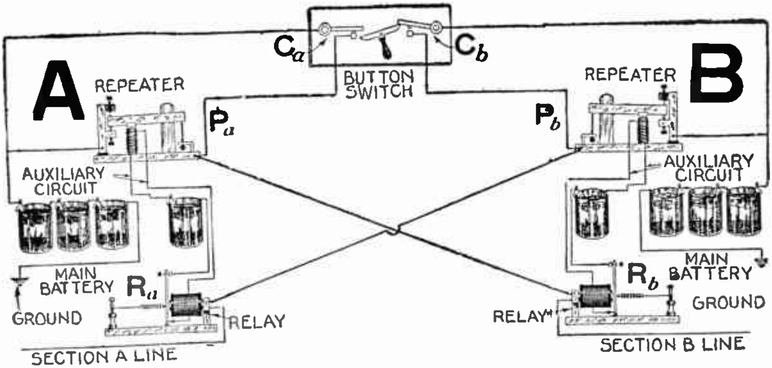


FIG. 7,713.—Diagram showing essentials of the so called button repeater, consisting of two relays, two simple repeaters, a button switch and connections as shown.

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

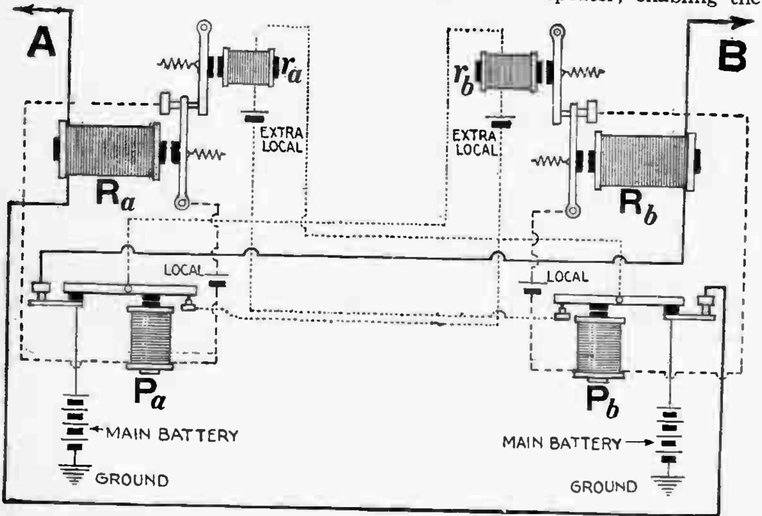


FIG. 7,714.—Milliken repeater system. The relays R_a and R_b are provided with additional or extra magnets r_a and r_b, whose levers press against the main levers in such a manner that when the working current is cut off the working winding, the spring of the extra magnet closes the local contact against 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.

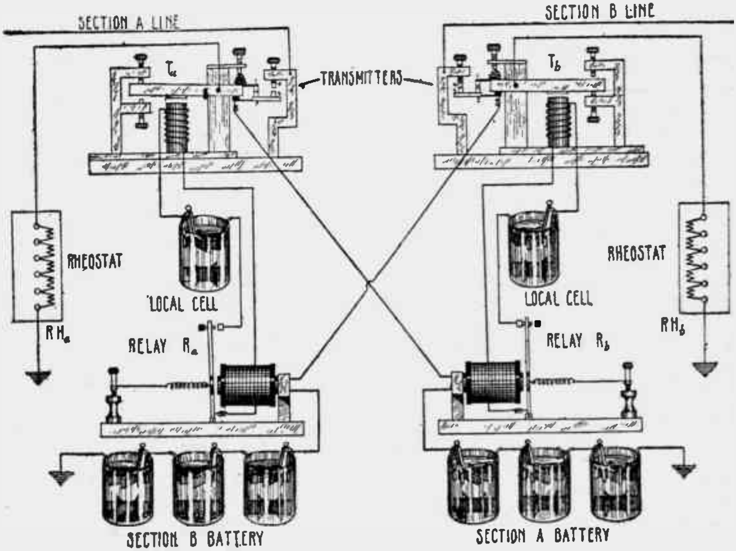


FIG. 7,715.—Diagram of Toye "repeater" or transmitter system, used extensively in the United States and Canada. It comprises two relays, two transmitters with tongue contact breakers, two rheostats and connection as shown. *In operation*, if section B send or open his key, the armature of relay R_a will 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.

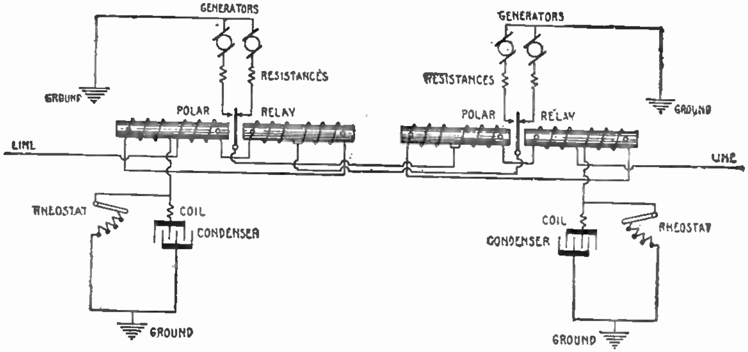


FIG. 7,716.—Diagram of the Postal telegraph repeater system. The Postal direct point duplex repeater is an arrangement by which the respective armature levers of two polar relays at the repeater office connect the positive and negative main battery currents direct to the line wires. Its principle is 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 R^1, first falls back and opens the local circuit of transmitter T^1, which in turn opens the eastern circuit s^1 r^1, 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 s^1 r^1, the shunt around the local contacts of relay R was closed at M^1 O^1.

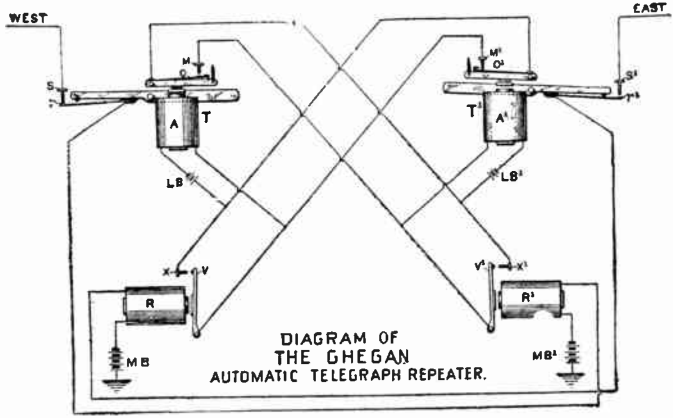


FIG. 7,717.—Diagram of Ghegan automatic repeater. Its principle of operation is based upon the fact that an armature, on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet core, the stronger the magnetism becomes. The circuits and operation are further explained in the accompanying text.

On closing the western key, the armature of relay R^1 closes the local circuit of transmitter T^1, which in turn first closes the eastern circuit at s^1 r^1, 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 M^1 O^1.

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.

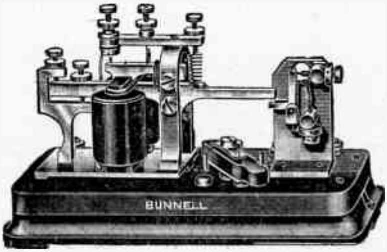
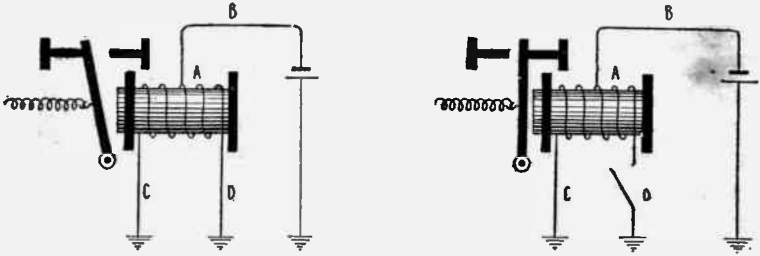


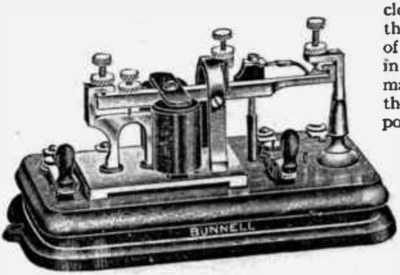
FIG. 7,718.—Ghegan automatic repeater. The second armature spring is adjusted so that on closing the local circuit of the transmitter, the regular armature must reach its front stop before the magnetism induced in it is sufficiently strong to draw the second armature from its back stop. The object of 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.

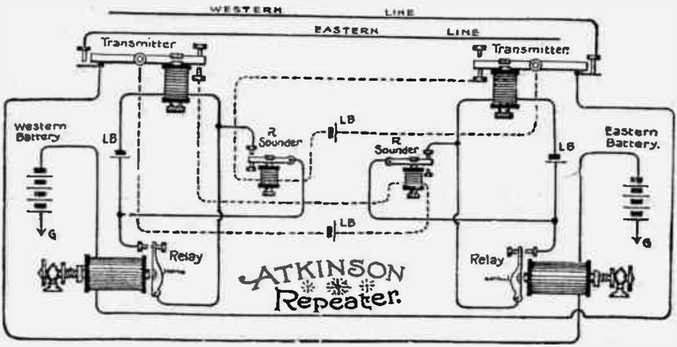
In order to avoid confusion with the full set, however, they are called respectively the "Half-Milliken," the "Half Weiny," the "Half-Atkinson," etc., according to the type.



FIGS. 7,719 and 7,720.—Detail of the differentially wound third spool of relay of the Weiny-Phillips system. In fig. 7,719, 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.*

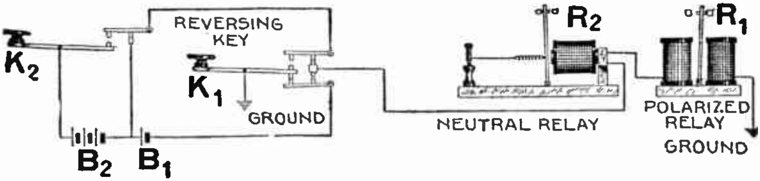


FIG. 7,723.—Elementary diplex system; diagram illustrating the principle of diplex telegraphy. *In operation,* if the sender depress key K_2, this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R_2, to be attracted. If now another signal be sent 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.

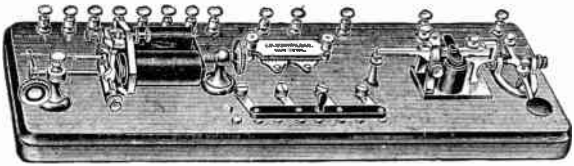


FIG. 7,724.—Bunnell open circuit automatic repeater. A relay, transmitter, key, lightning arrester and switch mounted on a polished hardwood base constitutes one instrument. Two of these make a complete repeater. When connected they can be used as an automatic open circuit repeater or as two single sets 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.*

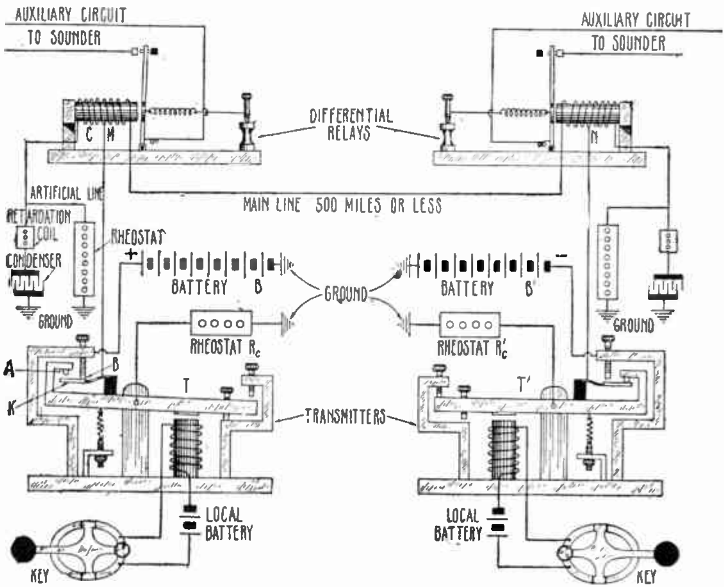


FIG. 7,725.—Stearn's differential duplex system. The circuit can be traced from the tongue contact K, to the point of division M, known as the "split." At this point one branch goes through the right portion of the relay winding to the main line, and the other through the left portion of the relay, the 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.

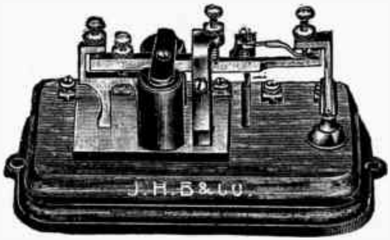


FIG. 7,726.—Bunnell shovel nose pattern single pole transmitter with circuit preserving contacts.

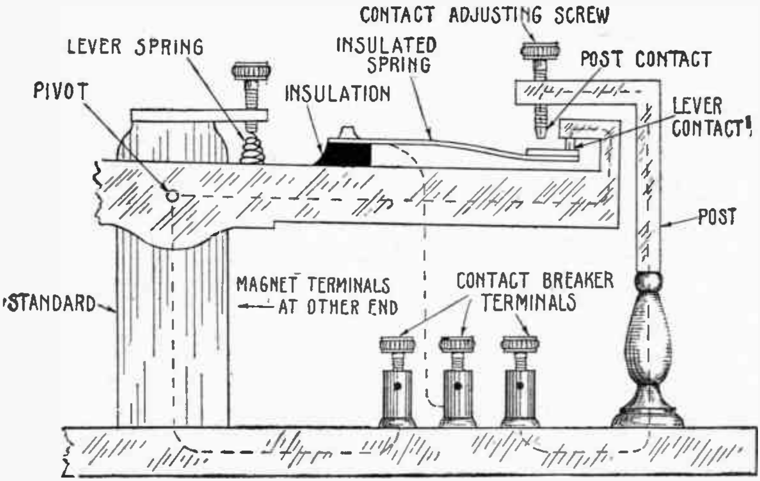


FIG. 7,727.—Detail of contact breaker end of a transmitter showing the three contacts, method of mounting the spring contact, and the circuits from the contacts to terminals. The duration of contact, or portion of the stroke of lever during which the circuit through the post contact and spring contact 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.*

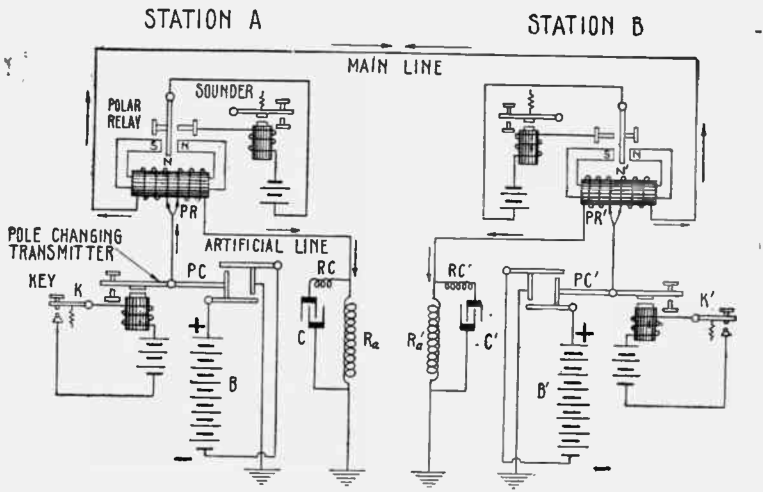


FIG. 7,728.—The battery polar duplex system. When the resistance of the main line is balanced by the resistance of a set of adjustable coils in the rheostat R_a of the artificial line, the current will divide into two equal parts at the polarized relay, and passing around the cores in different directions 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.

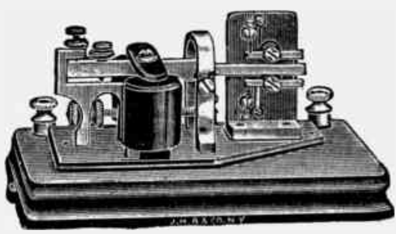


FIG. 7,729.—Bunnell W. U. battery (or gravity) pole changer for duplex or quadruplex work.

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*.

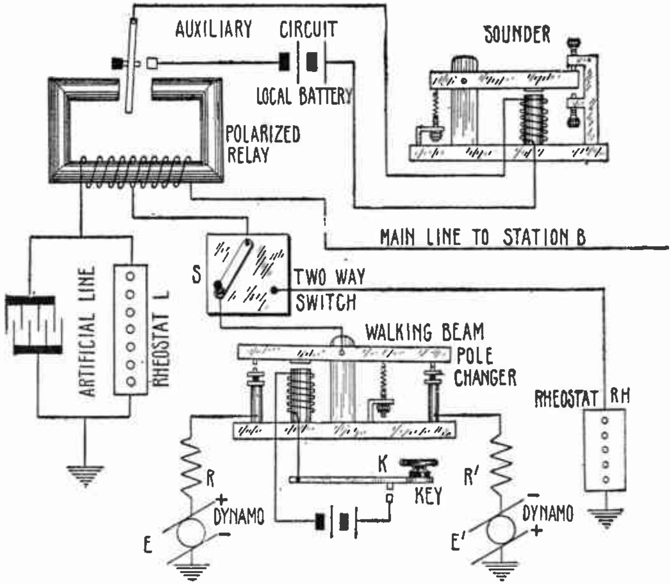


FIG. 7,730.—The dynamo polar duplex system. E. and E′ are the dynamos, E for the positive and E′ for the negative current. These supply their currents through resistance coils R R′ either of German silver wire or of incandescent lamps. K is the key which closes the local circuit of the walking beam pole 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.

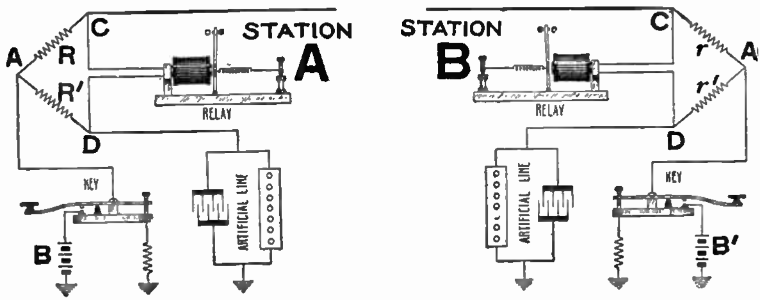


FIG. 7,731.—Diagram illustrating the operation of the bridge duplex system. In the figure, B and B', are the main line batteries, one at each station. R, R', and *r*, *r'*, are the bridge resistances at each station. The various connections are clearly shown in the diagram. ***In operation***, closing 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 tne differential method, the current divides at the relay, which instead of being of the differential type is known as a *polarized relay*.

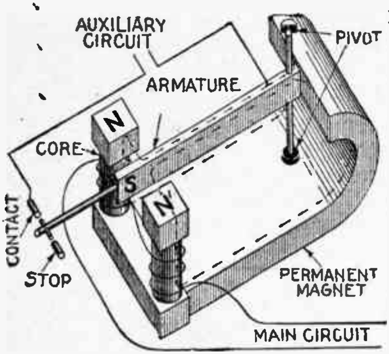


FIG. 7,732.—Elementary polarized relay. *In operation,* when no current flows through the electro magnet, the armature (having no spring), when placed midway between the poles of the electro magnet will be attracted equally by each and accordingly will approach neither. When, however, the electro magnet 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.

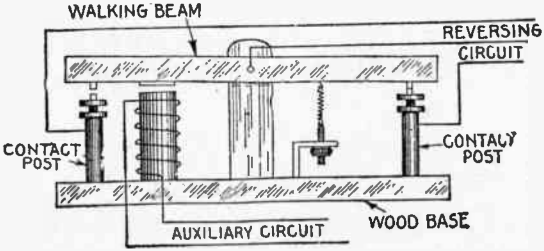
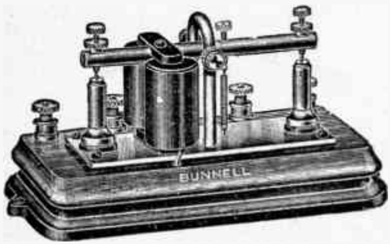


FIG. 7,733.—Essential parts of a walking beam type pole changer. As can be seen it is impossible for all three wires of the reversing circuit to be connected at any instant, that is before each reversal, the circuit is broken, thus interposing an air gap; this is an undesirable condition where dynamos are used for current supply, because their very small internal resistance would otherwise permit considerable sparking.



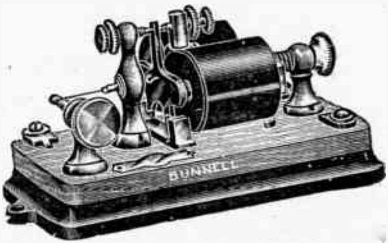


FIG. 7,734.—Standard dynamo pole changer walking beam model for duplex and quadruplex circuits.
FIG. 7,735.—Bunnell pony pole changer. Penn. R. R. pattern for dynamo work in duplex and quadruplex circuits.

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.

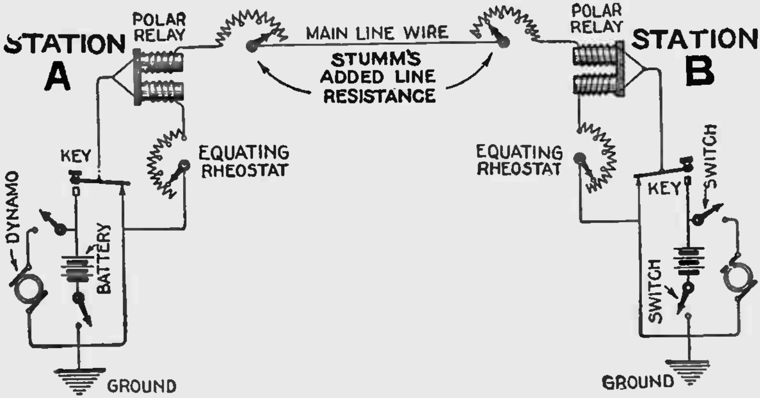


FIG. 7,736.—Frank A. Stumm's added adjustable line resistance. Necessary in duplex and all other multiplex office equipment. Formerly all balancing against wet weather line leakage was done on the artificial line rheostat and was always very unsatisfactory and often entirely ineffectual so that quite 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.

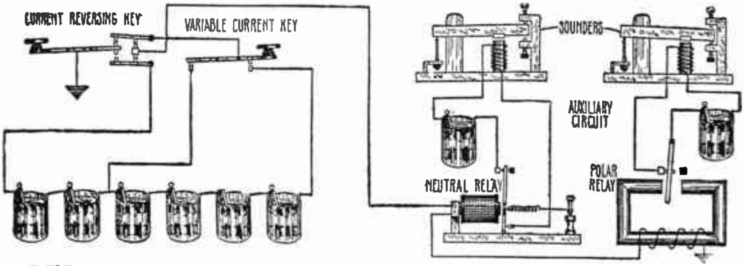


FIG. 7,737.—Elements of the quadruplex system. For simplicity, the receiving apparatus is omitted at station A and the sending apparatus at station B, the complete installation being shown in fig. 7,738. Because of the fact that a polar relay responds solely to changes in direction of the current, and 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.

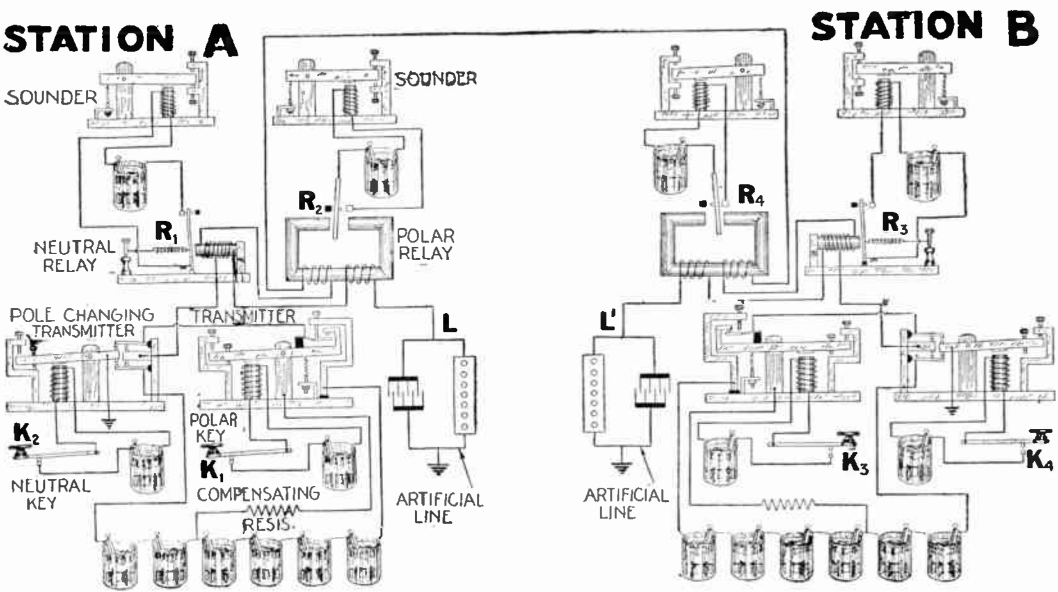


FIG. 7,738.—Quadrupiex system with battery current supply. The apparatus employed in operating the polar system of the duplex is generally called the "No. 1 side of the system," or the polar side. It consists of the polar key and the polar relay at either station. The apparatus employed in operating 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.

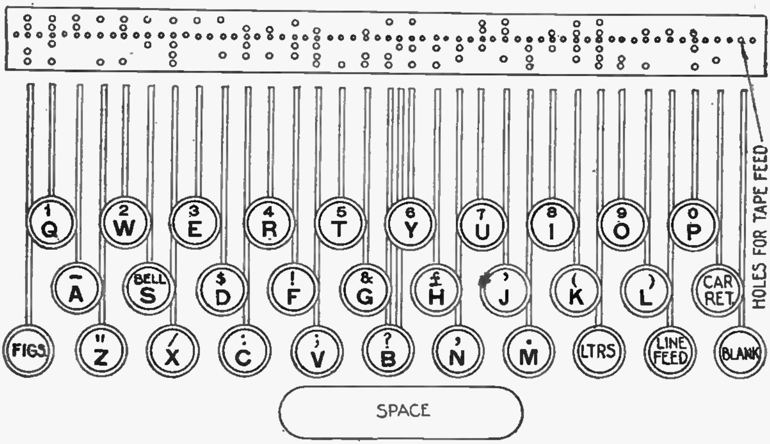


FIG. 7,739.—Teletype keyboard and corresponding code combination.

FIG. 7,738.—*Text continued.*

K_2 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_2. If K_4 alone be depressed R_2 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:

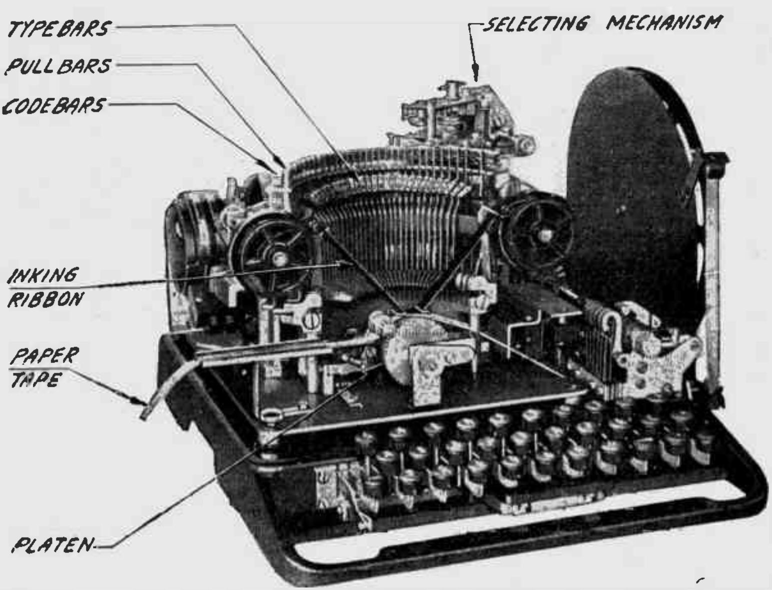
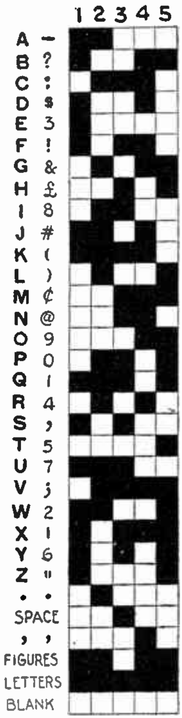


FIG. 7,740.—Teletype machine. The printing unit translates into printed characters the signals sent out by the transmitter. The various characters are on type bars which are caused to strike the paper tape as it is pulled over a narrow platen. The balance of the mechanism serves only to properly select 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.

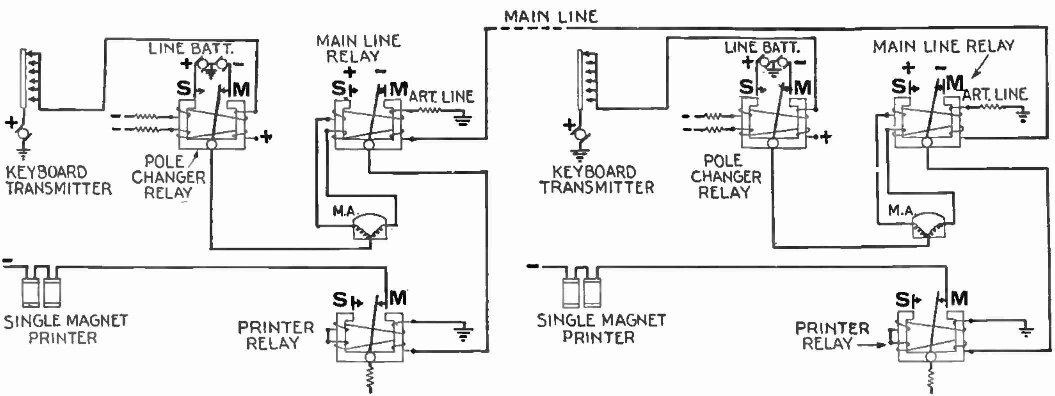


FIG. 7,742.—Two keyboard teletypes connected for duplex operation. The keyboard contacts are connected to one winding (operating winding) of the pole changer relay. Current is connected to the other winding (holding winding) in a manner that will cause the relay tongue to move to the spacing side when 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.*

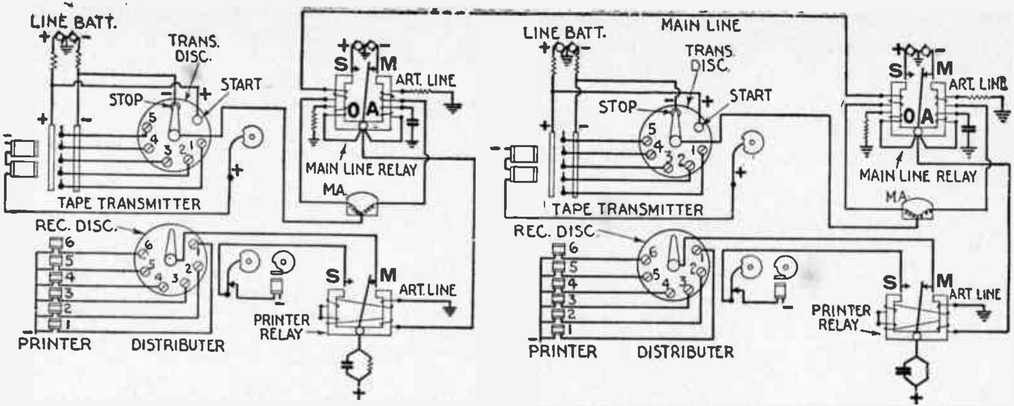


FIG. 7,743.—Theoretical circuit of two tape transmitter sets connected for duplex operation. The main line relays have in addition to the usual operating windings two auxiliary windings, O and A. These auxiliary coils in conjunction with a condenser and resistance, are connected in such a manner as to 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.*

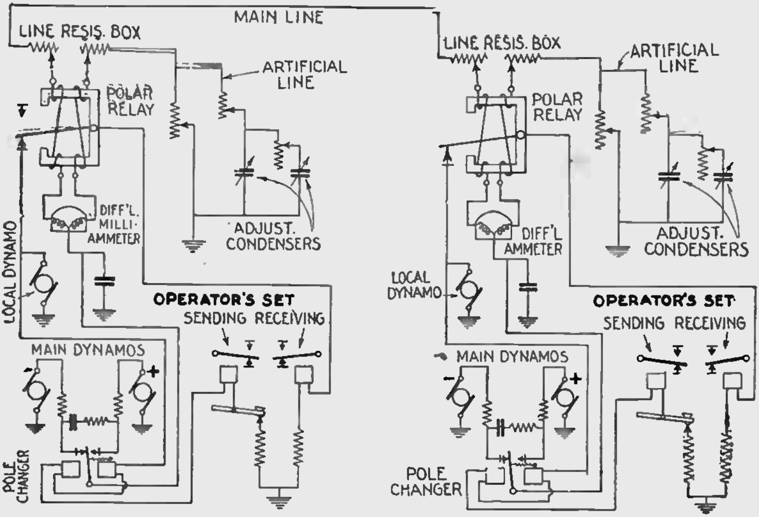


FIG. 7,744.—Teletype circuit diagram for duplex operation showing entire artificial line.

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.*

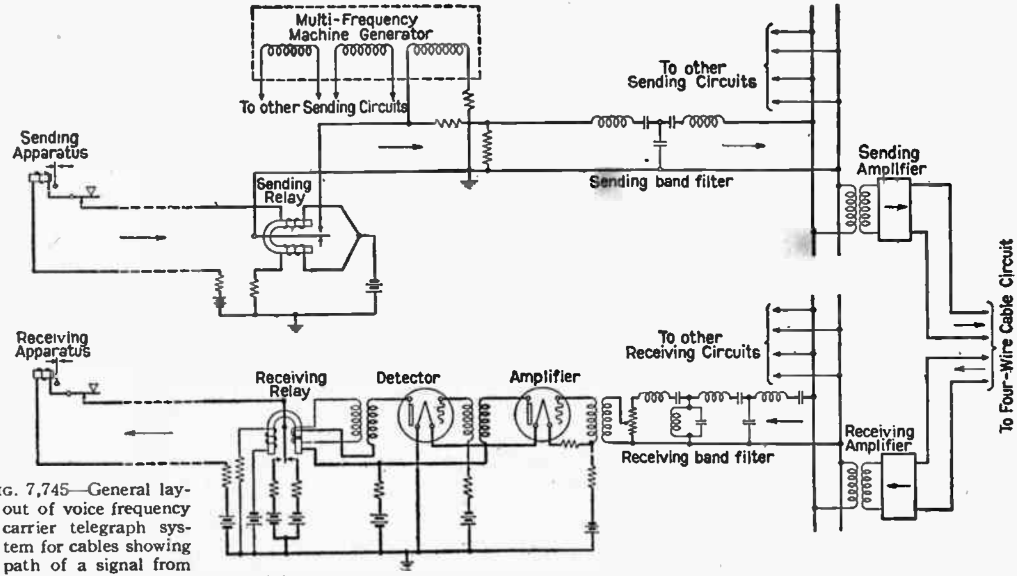


FIG. 7,745—General lay-out of voice frequency carrier telegraph system for cables showing path of a signal from the sending operator to the receiving operator on one of the ten two-way circuits.

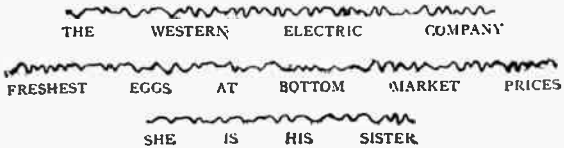


FIG. 7,746.—Test message transmitted over New York-Horta cable with a high speed siphon recorder, at a speed of 1920 letters per minute, November 14th, 1924.

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.

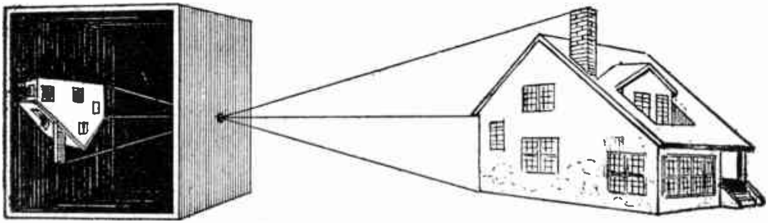
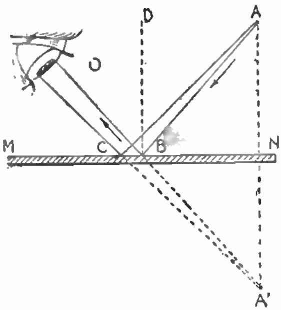


FIG. 7,747.—Image produced by small aperture showing the crossing of luminous rays at the aperture causing inversion of the image.



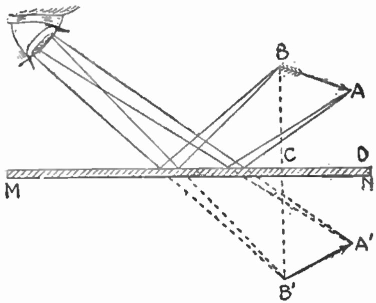


FIG. 7,748.—Formation of images by plane mirrors. The determination of the position and size of image resolves itself into investigating the images of a series of points. CASE I: *Single point* A *placed in front of a plane mirror*, as in fig. 7,748. Any ray AB, incident from this point on the mirror 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

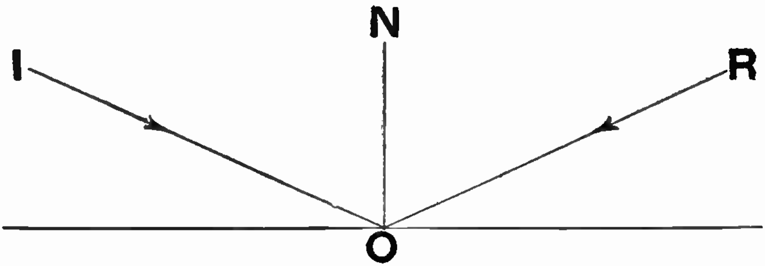


FIG. 7,750.—Angles of incidence and reflection. LAW: *The angle of reflection is equal to the angle of incidence.* The ray IO is called the incident ray; OR, reflected ray; angle ION, angle of incidence; angle NOR, angle of reflection; NO, normal or perpendicular to the reflecting surface.

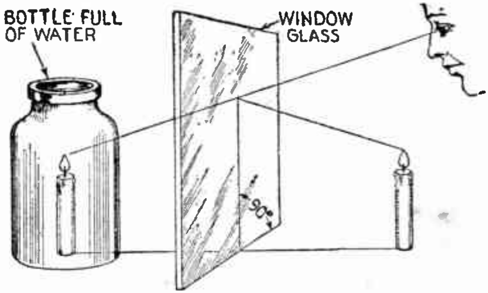
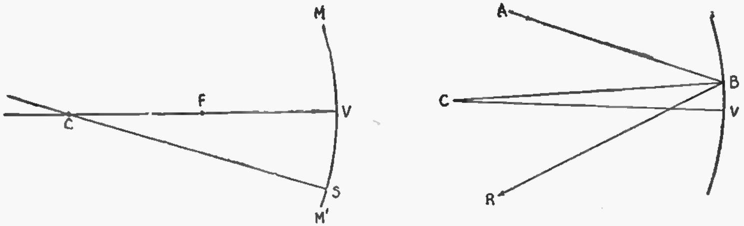


FIG. 7,751.—Position of image in a plane mirror. Let a candle be placed exactly as far in front of a pane of window glass as a bottle full of water is behind it, both objects being on a perpendicular drawn through the glass. The candle will appear to be burning inside the water. This experiment explains 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.

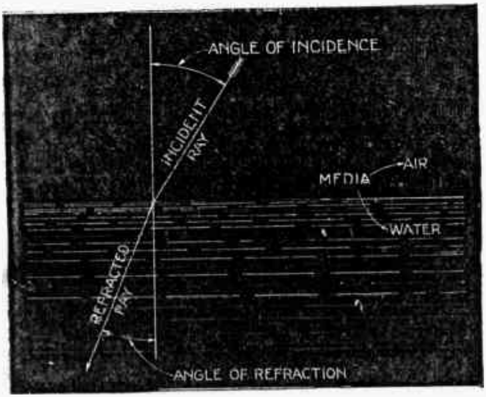


FIG. 7,754.—Diagram illustrating refraction definitions. All the light which falls on a refracting surface does not completely pass into it; one part is reflected and scattered, while the other penetrates into the medium. ***According to the undulatory theory,*** the most highly refracting media is that 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.

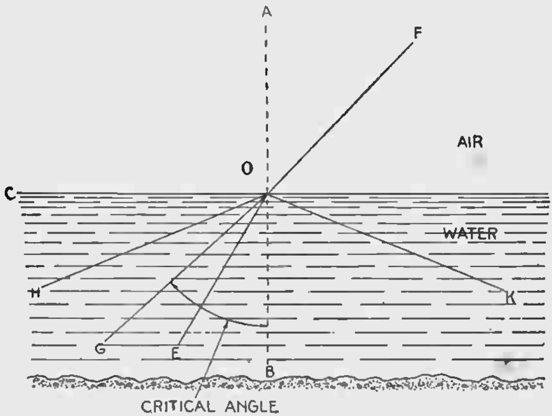


FIG. 7,755.—Diagram illustrating the critical angle or *that angle between the incident ray and the perpendicular drawn to the surface in the medium of smaller velocity at the point at which total reflection begins to occur.* In the diagram let CD be a surface separating two transparent media, the lower 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.

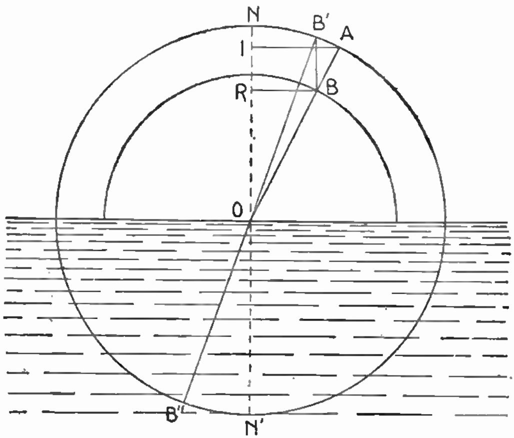


FIG. 7,756.—Construction of refracted ray. Let AO be a ray of light passing through air and entering water at O. The index is $\frac{4}{3}$. Draw two circles with centers at O and with radii whose lengths are as 4 : 3. Draw AI and BR perpendicular to the normal NN'. Since AO : BO = 4 : 3, then AI : BR = 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.

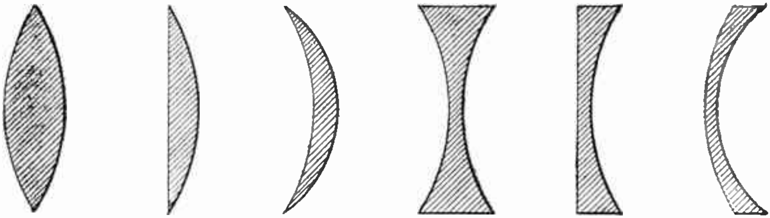
   a. double convex;
   b. plano convex;
   c. concavo convex.

2. Concave.

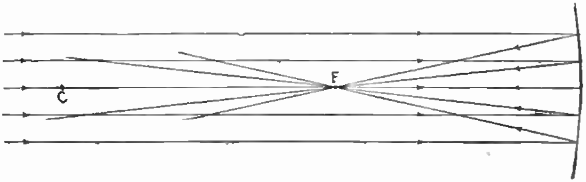
a. double concave;

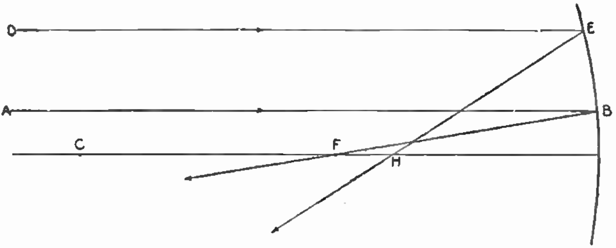
b. plano concave;

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.

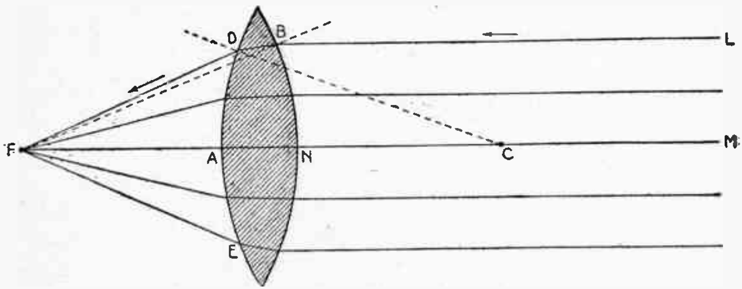


FIG. 7,765.—Principal focus in double convex lens. CASE I: *Rays from luminous sources parallel with the principal axis.*

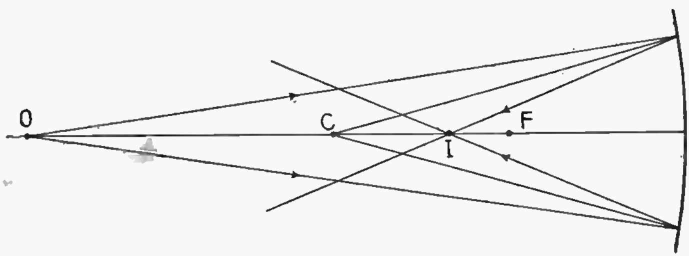


FIG. 7,766.—Conjugate foci. ***By definition,*** when two points are *so related that object and image may exchange places*, they are called *conjugate foci*. If a luminous object be placed at the point O, it projects divergent light rays upon the mirror. These rays will focus at a point I, a little 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.

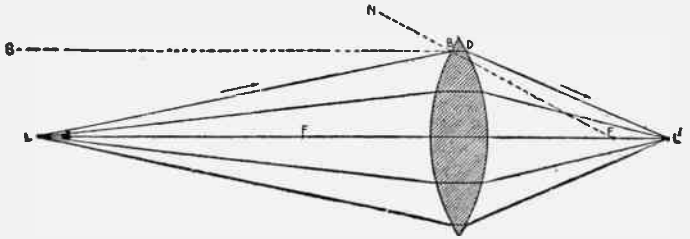


FIG. 7,767.—***Principal focus*** in double convex lenses. CASE II: ***Divergent rays from luminous source.*** In the figure the luminous source being at L, by comparing the path of a diverging ray LB, with that of a ray, SB, parallel with the axis, the former is found to make with the normal, an angle 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.

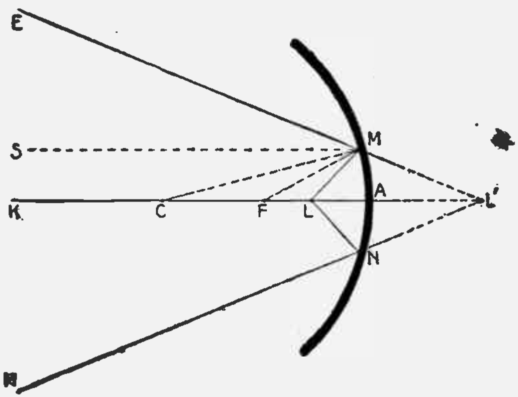


FIG. 7,768.—***The virtual focus.*** If a source of light be placed at L, between the principal focus F, and the mirror, any ray LM emitted from L, makes with the normal CM, an angle of incidence LMC, greater than FMC. The angle of reflection must be greater than CMS, and therefore the reflected ray ME diverges from the axis AK. This is also the case with all rays from the point L, and hence these 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.

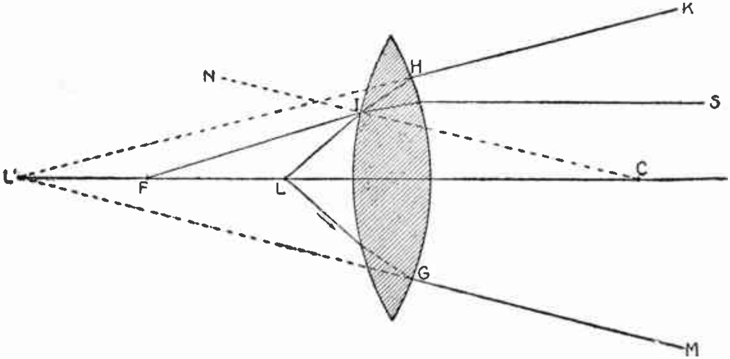
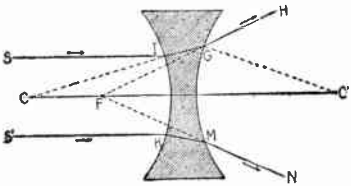


FIG. 7,769.—Virtual focus in double convex lens. In the figure, L is the position of the luminous source between the principal focus and the lens; F is the principal focus, and L', the virtual focus corresponding to the position L of the luminous source.



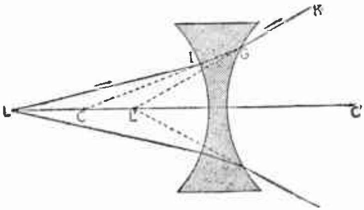


FIG. 7,770.—Virtual focus in double concave lens. CASE 1: *Parallel incident rays*. Let SS' be any pencil of ray parallel with the axis. Any ray SI is refracted at the point of incidence I, and approaches the normal CI. At the point of emergence it is also refracted, but diverges from the normal GC', 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

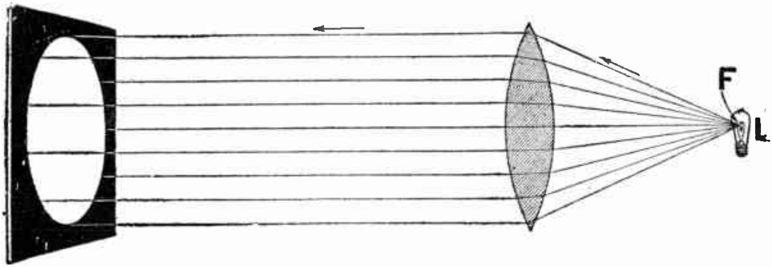


FIG. 7,772.—Effect of placing luminous source at the principal focus of a double convex lens. As the point of light comes near the lens, the convergence of the emergent rays decreases, and the conjugate focus L′ (fig. 7,767) becomes more distant. When the source of light L coincides with the principal 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.

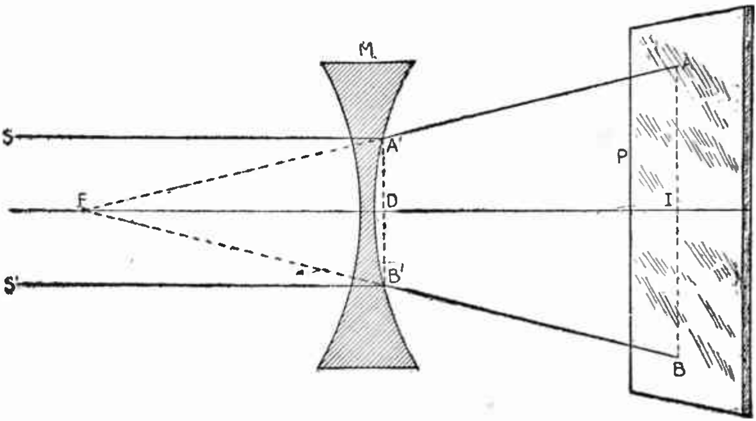


FIG. 7,773.—Experimental determination of the principal focus of a double concave lens. The face AB is covered with an opaque substance, such as lamp black, two small apertures, A and B, being left in the same principal section and at an equal distance from the axis. A pencil of sunlight is then received 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.

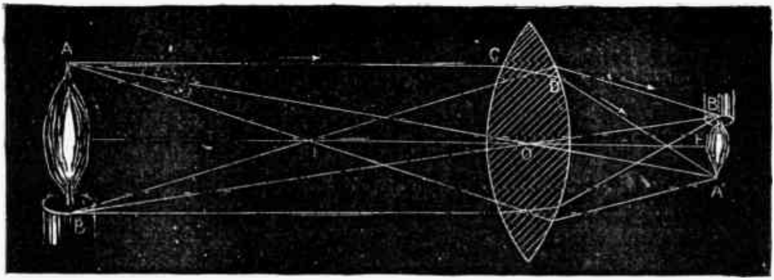


FIG. 7,774.—Formation of real image by double convex lens. Let AB be placed beyond the principal focus. If a secondary axis AA′ be drawn from the outside point A, any ray AC from this point will be twice refracted at C and D, and both turning in the same direction, approaching the secondary axis, which 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.

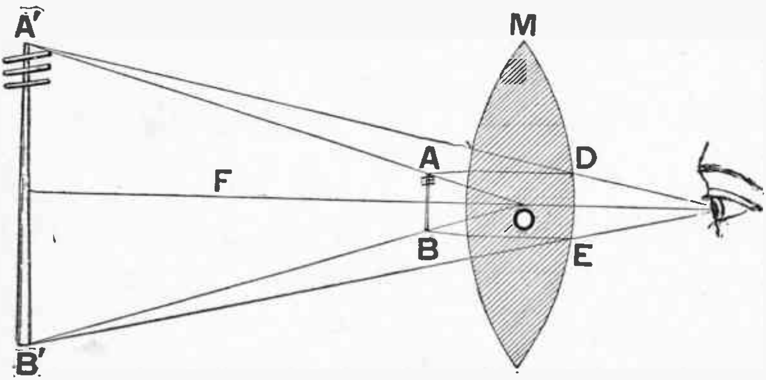


FIG. 7,775.—Formation of virtual image by double convex lens; object AB, placed between the lens and its principal focus. If a secondary axis OA′ be drawn from the point A, every ray AD, after having been twice refracted, diverges from this axis on emerging, since the point A is at a less distance than 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*

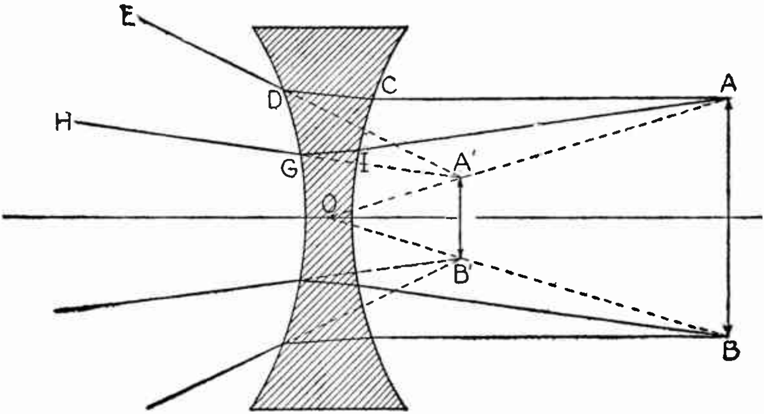


FIG. 7,776.—Formation of virtual image in double concave lens; no real image is formed with this type of lens. Let AB be an object placed in front of the lens. If the secondary axis AO be drawn from the point A, all rays AC, AI, etc., from this point are twice refracted in the same direction, diverging 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.

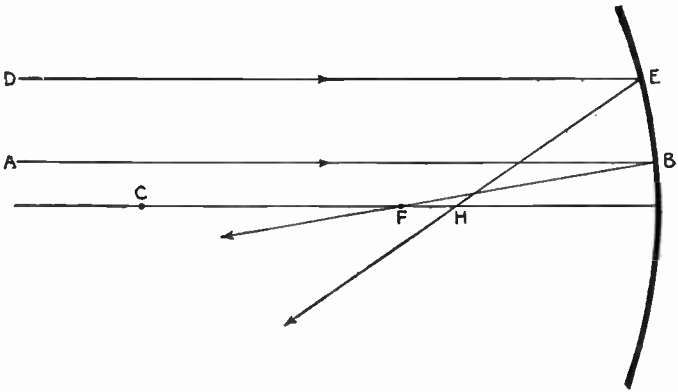


FIG. 7,777.—***Spherical aberration.*** The reflected rays of concave spherical mirrors do not meet at exactly the same point. For instance, the ray AB, will be reflected to F, but DE will be reflected to H, a point closer to the mirror. This is called *spherical aberration*.It has been observed that 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),

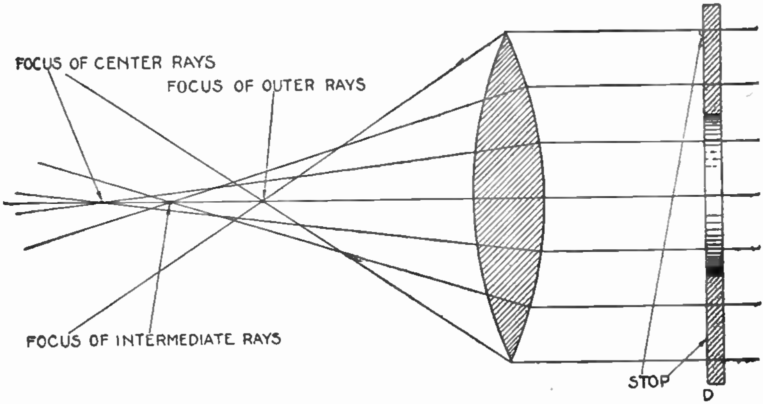


FIG. 7,778.—***Effect of spherical aberration.*** *It produces a lack of sharpness and definition of an image.* If a ground glass screen be placed exactly in the focus of a lens, the image of an object will be sharply defined in the center but indistinct at the edges, and if sharp at the edges, it will 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.**

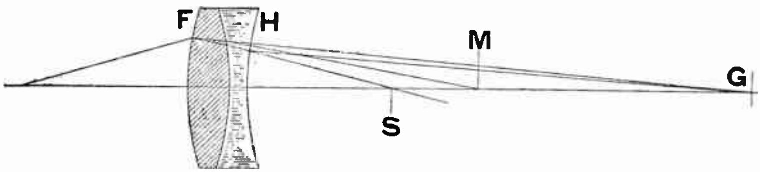


FIG. 7,779.—Achromatic lens, consisting of a combination of a double convex lens of crown glass, and a double concave lens of flint glass. Whenever it is desired to project especially good pictures upon a screen, lenses are often combined as shown in the figure. Here M indicates the line through the 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.

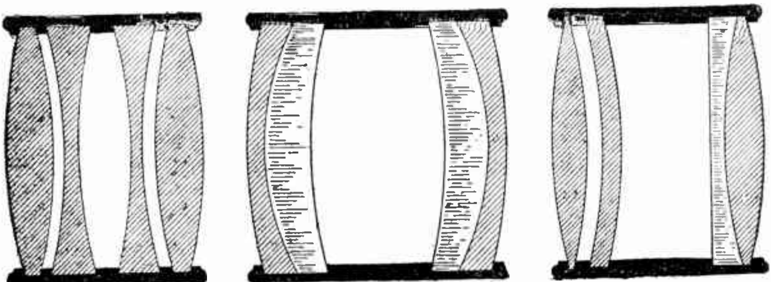
Principles of Optical Projection.—The process is almost the reverse of ordinary photography.

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

$$F = \frac{3 \times 480}{117+3} = \frac{1,440}{120} = 12 \text{ ins.}$$

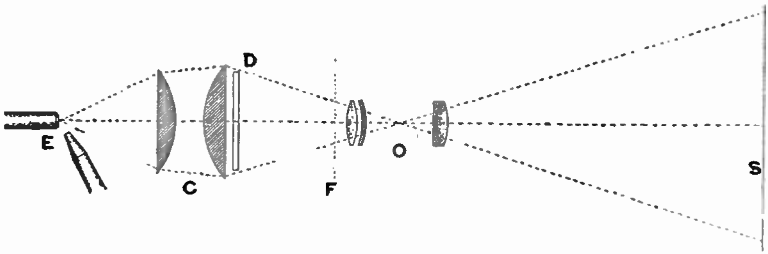


FIG. 7,783.—Diagram showing the various lenses of a motion picture machine and illustrating the principles of optical projection.

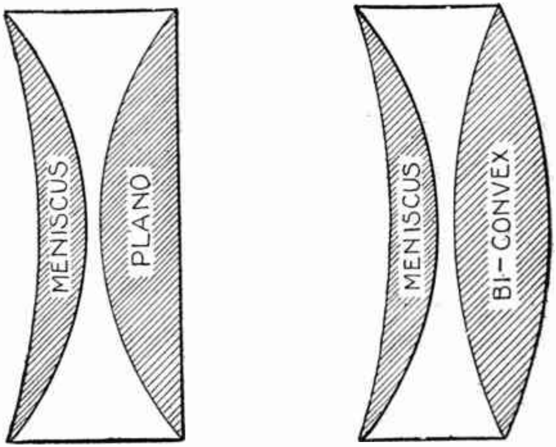
Distance from Slide to Screen.—RULE: *Multiply the sum of the size of the image and size of slide mat, by the focal length, and divide this product by the size of the slide mat.*

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

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. 7,786, it springs back into position, but due

Fig. 7,786.—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.

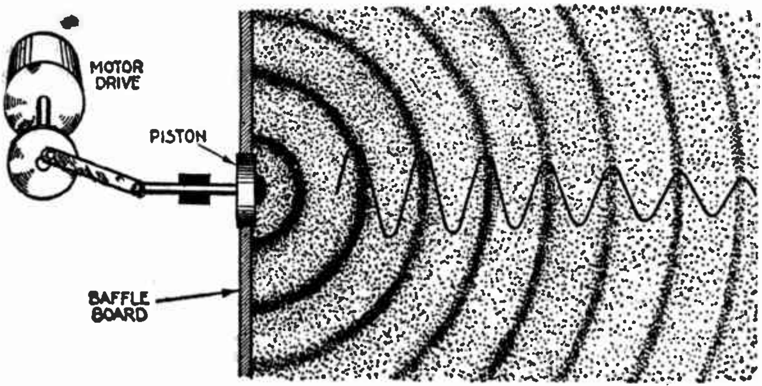


FIG. 7,787.—Generation of sound waves by the rapid oscillation of a light piston. ***As the piston oscillates*** the air in front of the piston is compressed when it is driven forward, and the surrounding air expands to fill up the space left by the retreating piston when it is drawn back. Thus a series 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. 7,787, 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. 7,787.

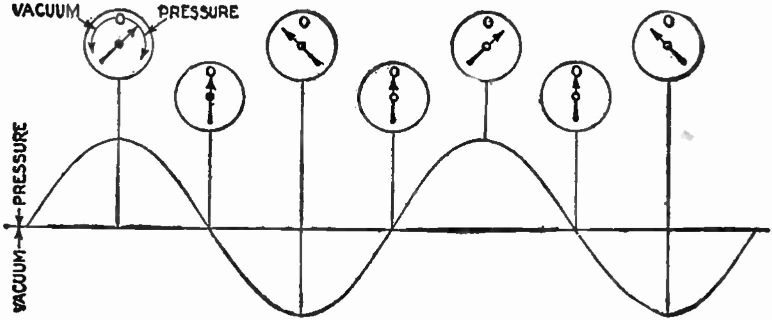


FIG. 7,788.—Diagram illustrating pressure variations due to sound waves. ***It should be noted*** that the type gauges shown, register pressure *above* atmospheric when the pointer moves to the right of the vertical, and *vacuum* or pressure *below* atmospheric when it moves to the left of the vertical.

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. 7,788.

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. 7,789, 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. 7,789.—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*.

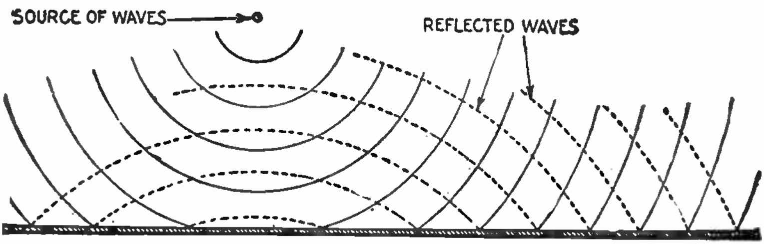


FIG. 7,790.—Reflection of waves from a plane surface.

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. 7,790.

If the waves strike a hollow or concave shore line as in fig. 7,791 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*.

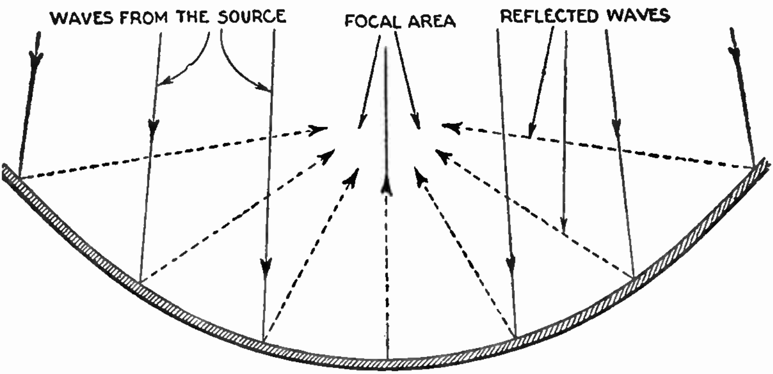


FIG. 7,791.—Reflection of waves from a curved surface. The solid lines show the direction of the original waves and the dotted lines show the direction and focusing of the reflected waves. Focusing of waves results in their reinforcement, which may cause them to build up to considerable proportion at 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. 7,792.

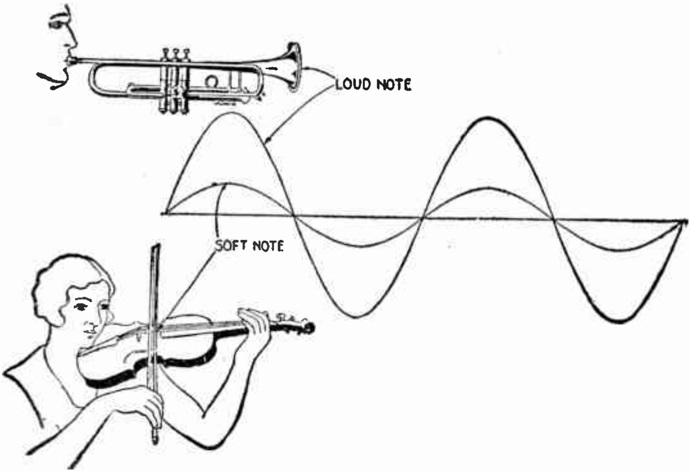


FIG. 7,792.—Properties of wave motion illustrating what causes loudness of tone.

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

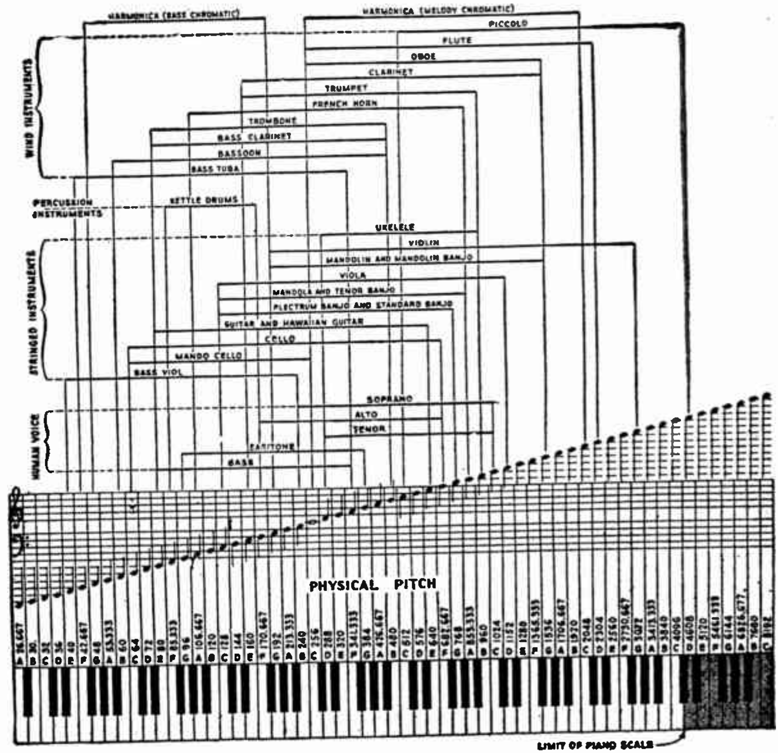


FIG. 7,793.—Musical pitch chart for piano, voice and various instruments. This chart represents the relation between the musical scale and the piano keyboard, giving the frequency of each note in terms of complete vibrations, or cycles, according to the standard used in scientific work such as the scientific 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 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.

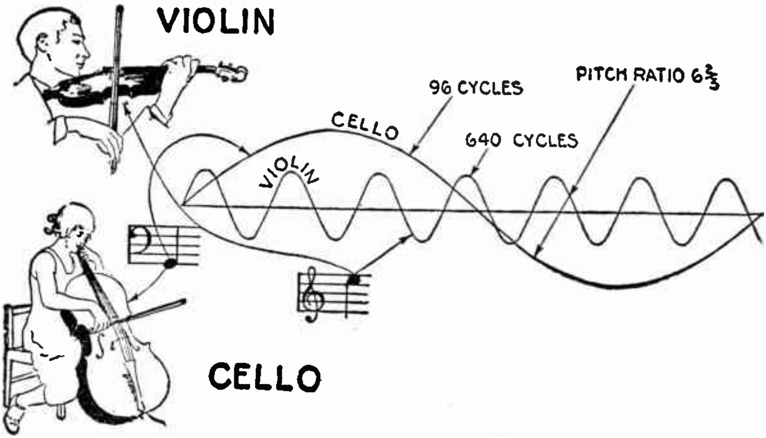


FIG. 7,794.—Properties of wave motion illustrating *pitch.*

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. 7,793 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.

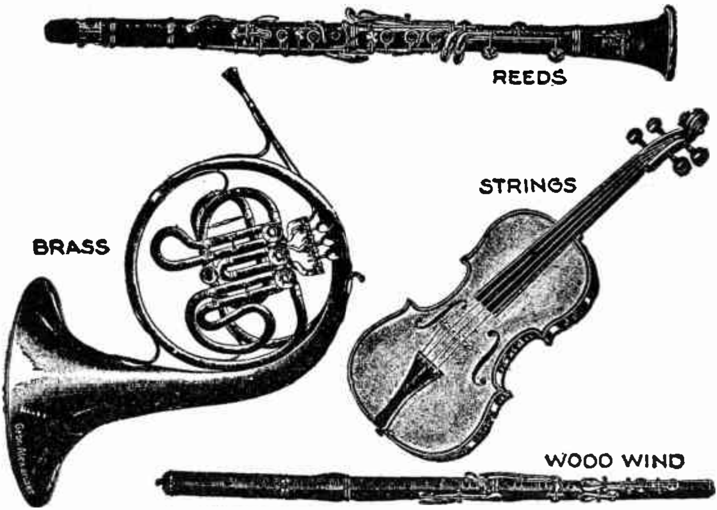
Hollow cavities built into the bodies of the various musical instruments give them their characteristic tones, because the air chambers, called resonance chambers, strengthen overtones of certain frequencies and give a very pronounced tone to the instruments.

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. 7,795 to 7,798.



FIGS 7,795 to 7,798.—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 orhcestra.

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 flute 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.

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*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 192

Principles of Photographic Sound Recording

General.—All systems employed for the reproduction of sound from films are fundamentally similar, irrespective of trade name or manufacture.

There are two principal methods used in the reproduction of sound, namely:

1. The wax record or disc method;
2. The photoelectric cell method.

With the wax or disc method the speech or music is picked up by an electrical reproducer that gives out a minute electric current whose variations correspond to the sound. This small current passes through amplifiers and is converted into sound by means of loudspeakers.

The film used with the record is synchronized with the sound, and is similar to an ordinary film, except that one frame in the beginning is specially marked to give the starting point.

The photoelectric cell method, usually termed "*sound on film method*," employs a photoelectric cell and exciting lamp to convert the photographed sound, from the motion picture film into electrical impulses. It is this latter method which is universally used at present in sound on film reproduction.

According to *E. W. Kellogg*, prominent authority on sound recording with the *R.C.A.* (*Victor Division of The Radio Corporation of America*), the sound on film recording is principally as follows:

The Sound Track.—Principally a photographic sound record is designed to be used with a lamp and a photoelectric cell which has the property of passing an electric current which is in proportion to the intensity of the light which strikes its cathode plate.

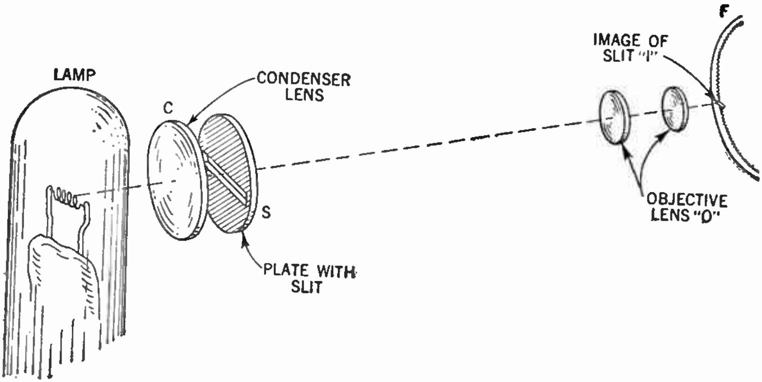


Fig. 1.—Schematic diagram of a reproducing optical system.

The sound track must provide the means for producing fluctuations in the light transmitted to the photoelectric cell, which corresponds with adequate fidelity to the variations in sound pressure which originally reached the microphone. In the case of a 35 mm motion picture film a space has been provided for the sound track by narrowing the picture while in the case of 16 mm film the space has been provided by omitting one row of sprocket holes.

For sound reproduction the film is carried past an optical system such as that illustrated in fig. 1. Light from the lamp is restricted by a narrow slit at S, an image of which is produced on the film at F, by the objective lens O. The condensing lens C, which is of such focal length as to provide an image of the lamp filament within the aperture of lens O, causes the slit to appear illuminated throughout its length. The photoelectric cell is placed back of the film so as to receive as much of the light reaching the film at I, as is not obstructed by the developed silver in the track.

It is usual to speak of the image of the slit on the film as a "line of light" and ideally it should be a line for perfect reproduction, but in order to pass a reasonable quantity of light to the photoelectric cell, it is given a width of the order of .001 in. while its length is normally about .084 in. for 35 mm systems, and .071 in. for 16 mm systems.

The mechanical requirements are that the film shall move at the correct uniform rate through this light beam, in a direction at right angles to the slit image. that it be maintained in the plane of sharp focus, and shall not have any sidewise motion or weaving beyond certain small limits or tolerances.

A part of the light which strikes the film at F, is absorbed by the silver in the emulsion at that point. and the remainder passes through to the photoelectric cell, the electrical output of which is amplified and applied to loudspeakers.

As the film carrying the sound track passes through this light beam, it absorbs varying amounts of the incident light. The light modulated in this manner determines the sound waves radiated from the loudspeakers.

The photoelectric cell current depends on the total quantity of light reaching the cathode. If the correct fraction of the light be absorbed by the silver image, the desired result is achieved whether it is absorbed by a uniform gray deposit on the entire track width, or by rendering certain portions of the track completely black.

It is in this manner two types of track is obtained as illustrated in figs. 2 and 3, one of which is termed as the "variable density" system, and is composed of various shades of gray (the density of the silver deposit being uniform across the track) the second type is known as the "variable width" or "variable area" system, the track being divided into essentially black and white areas. The boundary between these areas is a picture of the sound wave.

It is obvious that the recording of a variable area track requires that the length of the illuminated portion of the slit shall be varied from instant to instant in accordance with the sound pressure in the original sound, while the variable density recording requires that means be provided for varying the intensity of the exposed light, the illumination at any instant being uniform throughout the slit length.

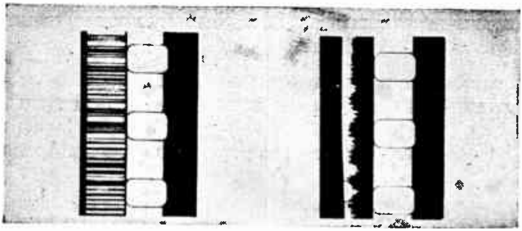


Fig. 2.—Typical *variable-density* sound track.

Fig. 3.—Typical *variable-area* sound track.

Sound consists in variations of air pressure above and below the average atmospheric pressure. The electric currents which are produced by the microphone and are used for transmission of the sound, may be alternating, but the exposing light cannot reverse sign but must consist of a certain mean value of light on which the fluctuations are superimposed.

Similarly, the light which reaches the photoelectric cell consists in a steady value on which fluctuations are superimposed, and the same is true of the current from the photoelectric cell. The maximum light which can reach the photoelectric cell is that which would pass through clear film. The sound track must cut the average light to 50% or less of this maximum, thus permitting upward and downward variations between zero and 100%.

Recording Variable-Density Tracks.—Making a variable-density record calls for either employing a lamp whose brightness can be varied at audio frequency, or employing some optical device by which various fractions of the lamp output can be absorbed or diverted. Even under optimum conditions it has not been found possible to change the brightness of incandescent filaments with the required rapidity for sound recording; hence all variable-intensity light source recording has been done with lamps of the gas-discharge type.

Mercury lamps were among the first to be used, but under the conditions which give the extreme high brilliancy of which mercury arcs are capable, the luminosity does not fall rapidly enough when the current decreases for satisfactory modulation, while at low pressures or intensities the advantage of mercury vapor over other gases is not great.

The most successful glow lamp is known as the "*Aeolight*" and was developed by the *Theodore Case Laboratories at Auburn, N. Y.* It has been widely used in *Fox Movietone* newsreel equipment, and employs a hot cathode and a mixture of permanent gases, thus is much less affected by external temperature than any mercury vapor lamp.

Nitrobenzol has the property of rotating the plane of polarization of light through an angle which increases with the strength of a transverse electric field. If a cell of nitrobenzol is placed between crossed polarizing prisms, no light is transmitted until an electric field is applied to the nitrobenzol, and the amount of light increases with the sine of the angle or rotation up to the point of 90° rotation.

The *Caroius Cell*, or *Kerr Cell* as this device is called, is one of the fastest known means of modulating light, so there is no question about getting adequate high frequency response. However, the high voltage required, the discoloration of the liquid, geometrical limitations which restrict the amount of transmitted light, and most of all, the non-linearity of the characteristic, have contributed to the abandonment of the *Kerr Cell* as a sound recording device.

Starting with a constant source of light such as an incandescent lamp, the exposure of the film may be modulated by either varying the size of an opening through which the light must pass, or by employing a reflecting galvanometer. The manner of employing a reflecting galvanometer for making variable density records can best be explained after description of the variable area recording system.

The variable sized aperture method is represented by the *Western Electric "Light Valve."* Fig. 4 shows the general optical arrangements, with the valve or variable width slit indicated at V. The condensing lens system concentrates light on the valve, and the light which passes through the opening is focused on the film at I, by objective lens O.

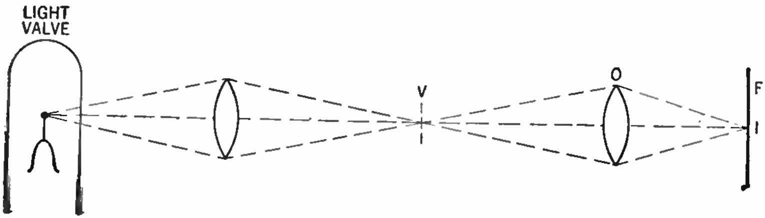


FIG. 4.—General optical arrangement for *light-valve* recording.

The variable sized slit is a narrow opening between the edges of two stretched metal ribbons which carry the recording current in one direction through the upper ribbon and back through the lower ribbon. A strong magnetic field is provided, parallel to the optical axis, and the audio currents cause the ribbons to approach and recede from each other, thus widening and narrowing the slit between. Fig. 5 illustrates the arrangement of ribbons and magnet pole pieces. In order that the ribbons may not actually hit they are slightly displaced axially, so that they are in different planes.

The slit is sharply focused on the film. It will be noted that the image on the film varies in width in accordance with the movements of the ribbons. Thus the variations in exposure are produced by changes in the time during which the film is passing through the illuminated spot, and not by variations in the intensity within the spot. The difference between varying the intensity and varying the time of exposure must be taken into account in any complete analysis of the performance of variable density systems.

Modulation for Variable Area Recording.—Variable area recording systems may be considered to be an outgrowth of the *Duddell* oscillograph in which a tiny galvanometer swings a spot of light back and forth across a moving film and traces a picture of the wave shapes of the electric currents sent through the galvanometer. Fig. 6 shows the essential optical arrangements of the oscillograph.

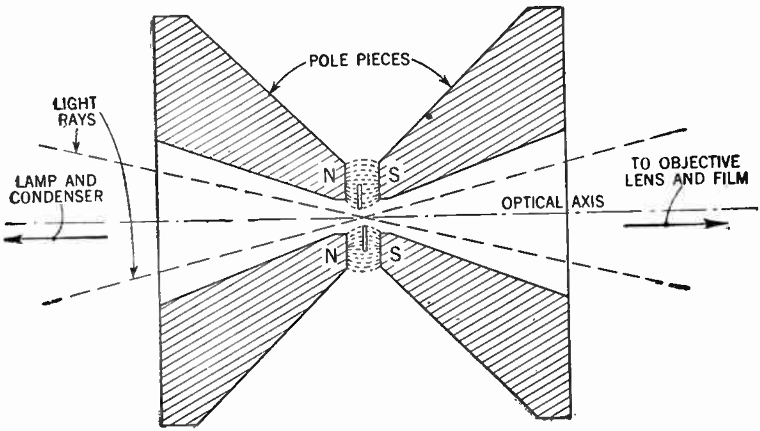


FIG. 5.—Showing light valve ribbon and pole piece arrangement with section at right angles to ribbons.

The cylindrical lens near the film serves to make the light spot smaller and more intense, and serves to confine the light reaching the film to a narrow line, so that a mask with a very narrow slit is not necessary. In the oscillograph, care is taken to make the light spot small in both directions so as to trace a sharp line as shown at A, in fig. 7. This is done by making the light source itself small.

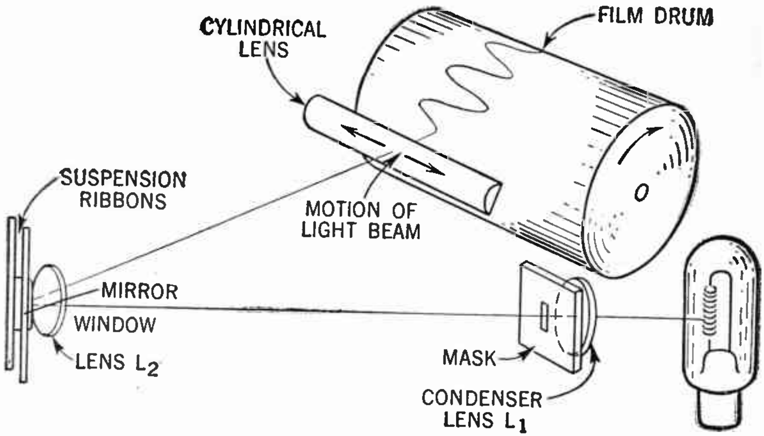


FIG. 6.—Illustrating optical system of Duddell oscillograph.

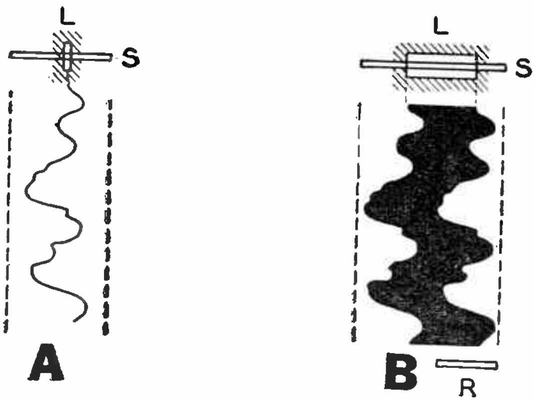


FIG. 7.—Illustrating evolution of *variable-area* sound track from oscillograph. In figure A, represents standard oscillograph recording; B, recording by oscillograph with wide light spot L, light spots; R, light spot by which sound would be reproduced from track B; S, s its close to film or equivalent effect produced by short focus cylindrical lenses.

By using a larger light source, we can elongate the light spot on the film until its length exceeds its total amplitude of travel. The oscillograph would then make a record like that shown at B, in fig. 7, in which the wave shape trace has been broadened to a black stripe, whose edges are pictures of the wave shape. Such an oscillogram can be used as a variable width sound record by simply scanning either edge by itself.

The optical system used in variable area sound recording, illustrated in fig. 8, is essentially the same as that of the oscillograph except that instead of throwing the light spot from the galvanometer directly on the film, it is projected on a slit plate of mask M, in which there is a narrow slit S, and the slit is imaged on the film in reduced dimensions by an objective lens O.

If a film were pulled through the device, directly behind the slit, as shown dotted at F′ we would obtain a large record of the wave shape. Since the purpose of the recording optical system shown in fig. 8 is to produce a track like that shown at fig. 10A, only one end of the light spot falls within the slit length, the other end being masked off.

The ordinary oscillograph has been developed to produce rather large scale traces of wave shapes. The sound track requires that the wave trace be of microscopic dimensions. The system in which the modulated light is thrown on a slit of convenient size and then a reduced image of the slit formed on the film, lends itself to production of small scale images of finer quality than could readily be obtained by the direct system, particularly since lenses of extraordinarily high resolving power have been developed for microscope objectives.

The arrangement in which the light spot moves parallel to the slit has now been abandoned in favor of one in which it moves transversely to the slit. This is illustrated in fig. 9.

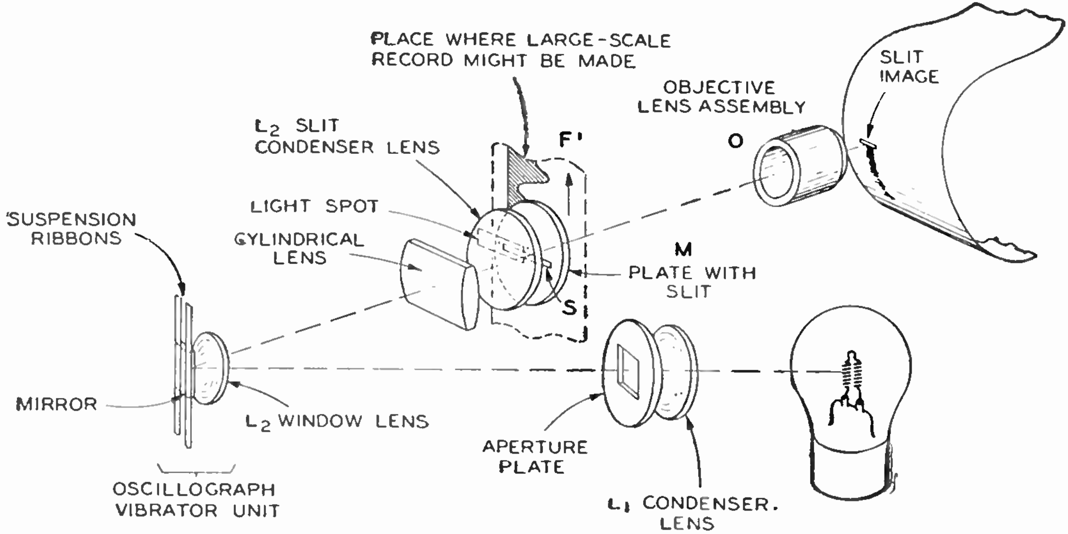


FIG. 8.—Illustrating original photophone *variable-area* recording system.

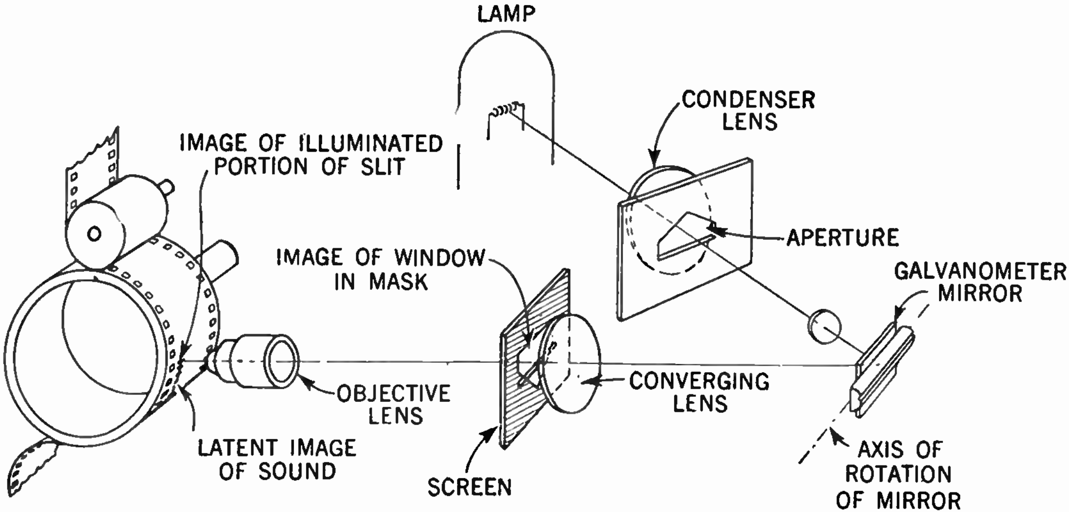


FIG. 9.—Showing elements of optical recording system.

The present arrangement offers advantages on the score of sensitivity, since by throwing on the plane of the slit a triangle whose edge makes an acute angle of intersection with the slit, a smaller movement of the galvanometer suffices to change the length of the illuminated portion of the slit from zero to 100%.

Another important advantage is that the system becomes readily adaptable in making various types of track. This is illustrated in fig. 10. With a single sloping edge intersecting the slit, we can get the original unilateral track, fig. 10 B.

If the light spot is a triangle with the vortex normally at the middle of the slit, we get a symmetrical track, fig. 10 C. Two triangles, one on each side, with vertices pointed in opposite directions, produce a push-pull track, figs. 10 D or E. If the triangles are so positioned that their vertices cross the slit simultaneously, we can produce a Class B, push-pull track, fig. 10 F. Push-pull and Class B tracks are discussed in the following section.

In all cases the triangular opening does not stop at the base of the triangle, but an additional rectangular area is provided, adjacent to the base of the triangle. This prevents a very objectionable distortion which would otherwise occur whenever, because of overload, the base of the triangle crosses the slit. By putting in a mask which produces a black triangle on a white background, we can make a direct positive ready to play back without resorting to a printing operation. This is illustrated at G, fig. 10, as applied to a Class B track.

If the light source (in this case a single horizontal helix) be uniform in brightness from top to bottom, a horizontal edge suitably located between the condenser and the galvanometer casts a shadow on the plane of the slit which varies at uniform rate from zero to 100% brightness. The movements of the galvanometer move this graded shadow or penumbra up and down, and the intensity of the slit image on the film varies in accordance with the galvanometer deflection. This provides for making variable density records.

Push-Pull Tracks.—If the track be divided into two equal strips and the light is modulated oppositely on the two sides

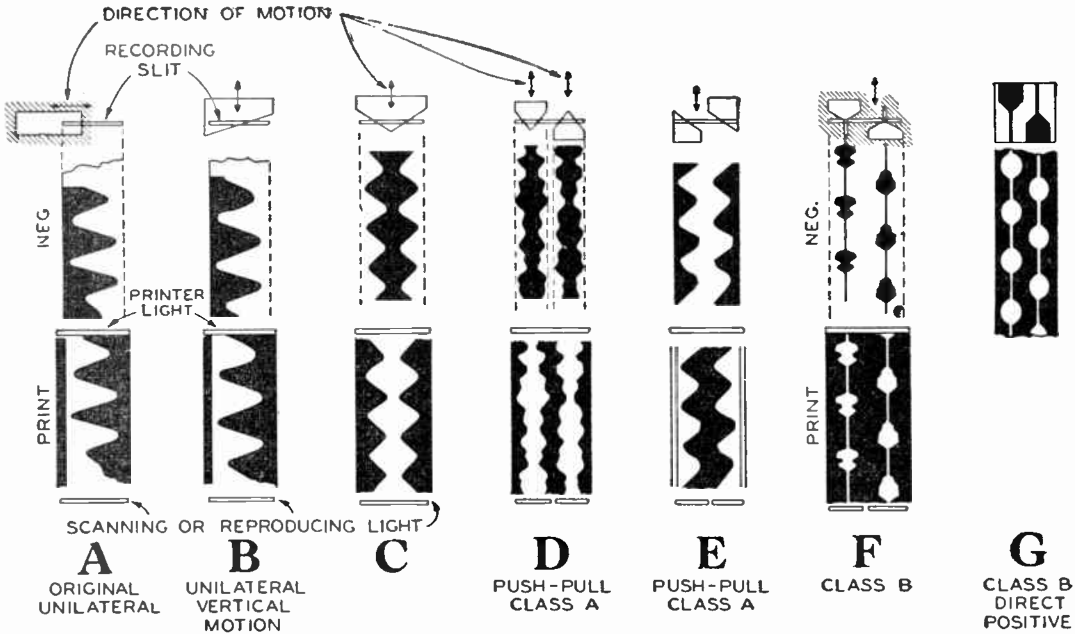


FIG. 10.—Illustrating various types of *variable-area* sound tracks.

of the middle, it may be reproduced by a system in which the light that passes through the film is picked up by two photoelectric cells, which are oppositely connected as shown in fig. 11. Several types of distortion are substantially reduced by applying a push-pull system, especially those which produce even harmonics and rectification effects.

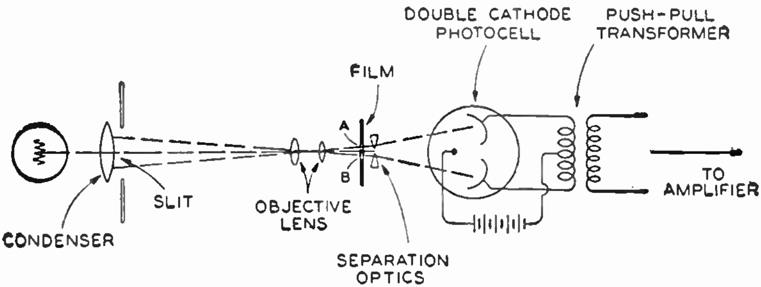


FIG. 11.—Simplified circuit showing arrangements for reproducing push-pull track. It should be noted that commercial circuits are adapted to switching between push-pull and standard, and to adjusting photoelectric cell voltages to give balance.

Push-pull systems have been widely used for making original recordings where the utmost in quality is justified even at the cost of greater complication in the recording and reproducing equipment. Many of the push-pull systems which have been used in recording studios employ double width track. This results in an improvement in the ratio of useful sound to ground noise.

Mention has already been made of the Class B track, illustrated in fig. 10. The left side of the track carries only the negative halves of the waves, and the right hand side the positive halves. Careful adjustments are required in which the characteristics of the film emulsion and developer have to be taken into account in order to balance and adjust the system so that no distortion occurs at the point of transition between positive and negative half cycles. A hairline extension of the vertex of the triangle makes the adjustment for transition less critical.

The Class B track is inherently the least affected by ground noise of any of the known types of photographic sound record. For this reason it is finding much use for making original recordings (for subsequent re-recording to standard track). The ground noise advantage of the Class B track is carried still farther if it is recorded as a direct positive.

A modification known as the A-B, variable area track has been used to a limited extent, in which the masks are so shaped that very low amplitudes are recorded Class A, while higher amplitudes are recorded Class B. The A-B system is somewhat less critical to adjustment, but does not go as far in the reduction of ground noise as the Class B system.

Ground Noise Reduction.—While there are various sources of background noise (such as photoelectric cell hiss, fluctuations in the brightness of the reproducing lamp, and hum resulting from circuit causes) which are not caused by the film itself, these can, in a well-designed system, be made very small compared with the noise which is caused by the moving film.

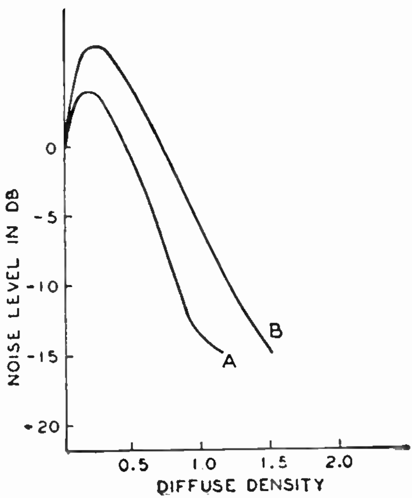


FIG. 12.—Illustrating relation between density and noise owing to graininess.

It is obviously important that fluctuations in the sources of illumination used for recording and printing shall be prevented, and that all causes of non-uniformity in development be minimized. However, when all these are done there are still variations in the opacity of exposed film. These variations are usually referred to as "graininess."

Graininess gives rise in the sound reproducing system, to a soft hiss. Although graininess is caused by imperfect distribution of the film grains rather than a matter of light obstruction by the individual grains, it is generally true that whatever results in fine grains also gives reduced graininess, as shown in fig. 12.

The absolute level of noise resulting from graininess increases at first with the silver deposit and reaches a maximum when approximately half of the light is absorbed. Thereafter it falls continuously because there is less light to modulate. Hence in variable density systems graininess noise is reduced by making the sound track as dark as is compatible with providing the required useful light modulation.

The remainder of the film ground noise results from dirt and abrasions on the film surface. Dust particles which settle on the film while it is wet cause specks that are very difficult to remove.

For this reason, modern laboratories do all of their film handling in an atmosphere which is as nearly dust free as modern air conditioning can make it. Developing, fixing, and washing baths are continuously filtered and checked for condition.

In properly designed cameras, sound recorders, printers and projectors, all possible precautions are taken to avoid danger of scratching the film, especially within the area of the sound track and picture, but release prints in their circulation from one theater to another inevitably receive some damage.

Probably the greatest cause of ground noise (of the type caused by film abrasion) is slippage between layers of film in take-up magazines. Since projection booths are rarely dust free, particles of dirt collect on the film and are then rolled in, and cause scratches when there is any slippage.

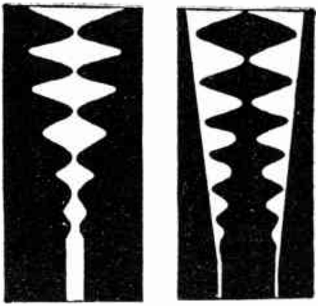
It is practically impossible to scratch a clear spot in a dark film, but the least scratch in a clear area has the effect of a black spot. There is, therefore, in variable area recording, much to gain by avoiding any unnecessary clear area in the prints. This is accomplished by providing a maximum of clear area in the negative.

Specks in the clear areas of negatives, print out as holes in the dark areas of the prints, but since the sound negatives can usually be fairly well guarded from abuse, the noise attributable to the negative is, in general, much less than that which results from scratches and dirt in the release prints after some use. Moreover, if the specks on the negative are very small they will not print through as perfectly clear spots in the print, but will be partly fogged in.

In variable density recordings, the noise from scratches and dirt is minimized by the same measure as was just described as helpful with respect to graininess noise, namely, by reducing the average exposure of the negative during periods of low modulation, which results in a thin negative and a correspondingly dark print.

It is obvious that at full modulation, a variable area track should transmit on the average approximately 50% of the maximum light, but when the amplitude of the recorded waves falls, a narrower clear area will suffice. It is during times of low modulation that ground noise is most objectionable.

Ground noise reduction systems used for variable area recording provide for marking off the unused portion of a sound track area. This may be done by biasing the galvanometer, giving a track such as shown in fig. 13 A, or by use of a shutter whose vanes cut off a portion of the recording beam during periods of low modulation, as shown in fig. 13 B. It will be seen in the figure, that the shutter vanes move relatively slowly in and out, following the envelope of the waves recorded by the glavanometer.



A
BIAS
PRINT

B
SHUTTER
PRINT

Fig. 13.—Illustrating sound tracks with ground noise reduction.

Current for actuating the shutter for biasing the galvanometer (*i.e.*, shifting the mean position about which it vibrates) is obtained by applying the audio frequency voltages to a rectifier and then filtering the rectified current so that at no time does it change rapidly enough to contribute audible noise in the reproduced sound. The design of the filtering system involves a compromise between clipping the tops of the waves in the case of a quick increase in sound amplitude and moving the shutter fast enough so that the motion itself becomes audible.

It is likewise essential that the shutter return to the low modulation position with reasonable rapidity upon the cessation of audio sound; otherwise a certain amount of ground noise becomes audible at the ends of the sounds. It is inevitable in designs of this kind that some differences of opinion would exist as to the optimum. and that considerable variations in design constants will be found in commercial use.

In variable density systems ground noise reduction takes the form of making the print darker at times of low modulation. In light valve systems this is accomplished by bringing the ribbons of the light valves closer together by means of a biasing current, while in the penumbra system of variable density recording, using the galvanometer, a separate electromagnetic device similar to the shutter used for variable area recording moves the vane, the shadow of whose edge constitutes the penumbra.

Monitoring.—Provision must be made to inform the recordist quickly and continuously of the amplitude of the recording as related to the overload point of the sound track. In variable area systems this is usually accomplished by throwing a light spot on a screen, the motion of the light spot produced by the vibrations of the galvanometer being a direct indication of the amplitude.

The system is arranged so that the monitoring card will show bias as well as vibration amplitudes, or else will show the combination or over-all excursions in both directions from the mid-track position. Marks on the card indicate the correct position of the edge of the light spot for zero modulation and maximum permissible modulation.

Card monitoring can be used with the penumbra system of variable density recording, but in general variable density monitoring is done by the photoelectric cell. A portion of the modulated light passing through the recording slit is reflected to a photoelectric cell, the output of which is amplified, rectified, and indicated by meter. In order to adjust bias, it is also necessary to be able to measure the continuous or average photoelectric cell current; separate provision is made for indicating this.

Inasmuch as the diversion for monitoring purposes of any material fraction of the useful modulated light increases the difficulties of providing adequate exposure, a special reflector was developed for use in the RCA variable density system, which is practically 100% transparent for blue and violet light, but reflects over 60% of the red light, to which cesium photoelectric cells are sensitive, but which plays no part in exposing the recording film.

Importance of Constant Speed.—Experienced engineers in the field of recorded sound recognize the importance of minimizing speed fluctuations both in recording and in reproducing.

Propelling the film through the recording or reproducing light beam on a sprocket is almost sure to give rise to measurable disturbance at the tooth frequency or 96 cycles per second. A number of recorders operating in this manner have, however, given a creditable result. In this connection it should be noted that conditions for direct sprocket drive is always more favorable in the case of a recorder, because this involves new film, whereas printers and reproducers must work with film of various degrees of age and shrinkage.

A preferable arrangement for both recording and reproduction employs a smooth drum on which the film is carried past the optical system. Flywheels are employed to oppose speed changes. Numerous damping systems have also been employed to prevent such oscillations.

Weaving and Track Placement.—In drum type machines dependence is placed on flanged rollers for guiding the film to the correct position on the drum. A rubber-tired pressure roller is usually employed to prevent slipping on the drum. The pressure roller not infrequently causes instability in the film position resulting in sidewise "*weaving*." With proper design this does not need to occur.

It is customary to utilize a standardized "buzz truck" to check reproducers for track placement and weaving. The area normally scanned by a correctly located reproducing beam of standard size is clear, while on either side, tones are recorded.

If adjustment be correct these tones are not heard in reproduction. If there be weaving they are heard intermittently. Test films for checking reproducers in other ways are also employed.

Sprocket Hole Modulation.—In the foregoing reference has been made of speed fluctuations resulting from sprocket tooth action. Aside from the speed effect the misfortune that the sound track is close to the sprocket holes gives rise to a 96 cycle hum owing to the fact that there is freer circulation of the developer opposite the sprocket than between, and consequently the film receives more development and is darker.

Sixteen-Millimeter Recording.—Only painstaking developments have made it possible to satisfactorily record the high frequencies on a 16 mm film.

Sixteen millimeter film travels only 40% of the speed of 35 mm film. This means that the waves must be compressed longitudinally and only with the utmost refinement can reasonable good high frequency response be obtained from 16 mm film.

Actually the standard obtained from a 16 mm film will be considerably lower than that which may be expected from a 35 mm film.

Packing the waves into a shorter length of track increases the tendency to cross-modulation. The methods of control of cross-modulation are (or should be) essentially the same as in the case of 35 mm tracks, except that the modulated high-frequency wave has usually been taken as 4,000 or 6,000 cycles instead of 9,000 cycles.

The problem of constant speed is also rendered much more difficult by the low average speed of the 16 mm film.

In the most successful large-scale production of 16 mm prints, it is common to employ some compression when making the negative. to improve intelligibility, and low-pass filters are employed to eliminate some of the higher frequency components which could scarcely be successfully recorded if present.

Contact printing is at present the general method, but excellent results have been obtained with optical reduction printing.

TEST QUESTIONS

1. *What are the two principal methods used in the reproduction of sound?*
2. *What is the principal difference between the disc method and the photoelectric cell method as used in the reproduction of sound?*
3. *Which of the foregoing methods is commonly employed in sound on film reproduction?*
4. *How is sound energy picked up?*
5. *What is meant by the term "sound track"?*
6. *What are the two methods of sound recording on film?*
7. *Describe in detail the variable area method of sound on film recording.*
8. *Make a sketch illustrating the elements of the variable area method of recording sound on film.*
9. *Explain in full the variable density method of recording sound on film.*
10. *What is the comparison of sound tracks made by the two methods?*
11. *Of what does a photoelectric cell consist?*
12. *What are the advantages of sound on film?*
13. *What is the cause of "ground noise" and how can this be minimized in sound on film reproduction?*
14. *What is the function of the flywheel as employed in motion picture projectors?*

CHAPTER 193

Projection Room Layout

General.—The modern projection room, designed for greatest operating efficiency, is usually divided into four distinct units, as indicated in fig. 1. They are:

1. Projection room proper;
2. Rewind room;
3. Power equipment room;
4. Lavatory.

It is of the utmost importance that the projection room conforms with the recommendations of the S.M.P.E. (Society of Motion Picture Engineers) in regards to spacing of projectors (angles and distances) that it be thoroughly fireproof so as to confine fire within its own walls, that it be structurally sound, and that the electrical equipment be installed in accordance with the present requirements of the *National Electrical Code* in addition to *Local Ordinances and Regulations*.

Projection Room Proper

Location.—In the design of the theatre, the location of the projection room is of prime importance in securing the finest possible screen image. Experience has shown that the projection room should be so located that the vertical projection angle approaches as nearly as possible the ideal angle of zero degrees and should never exceed 14°. Placing the projectors equidistant on each side of the theatre centerline and five feet apart is essential.

Dimensions.—The height of the projection room should never be less than eight feet and the width and depth will vary with the amount of equipment installed and by whether the film rewinding and storing is to be incorporated in a separate room or in the projection room proper. If a separate rewind room be provided, the width of the projection room should be eight feet for one projector plus six feet for each additional projector, spotlight, stereopticon or effect machine. Thus, the average projection room containing two projectors and one stereopticon will be 20 feet wide. A depth of 10 feet will be adequate.

It is sometimes impractical to provide a separate rewind room and it then becomes necessary to allow more space in the projection room proper for this purpose. If the film rewinding and storing facilities are provided for at the right or left side of the projectors, the projection room should be 16 feet wide for one projector plus six feet for each additional projector, spotlight, stereopticon or effect machine. The depth of the room will still remain 10 feet.

It may be advantageous to provide the film rewinding and storage facilities at the rear of the projectors in which case the projection room should be calculated the same as if a separate rewind room was provided but the depth of the room should be a minimum of 12 feet instead of 10 feet.

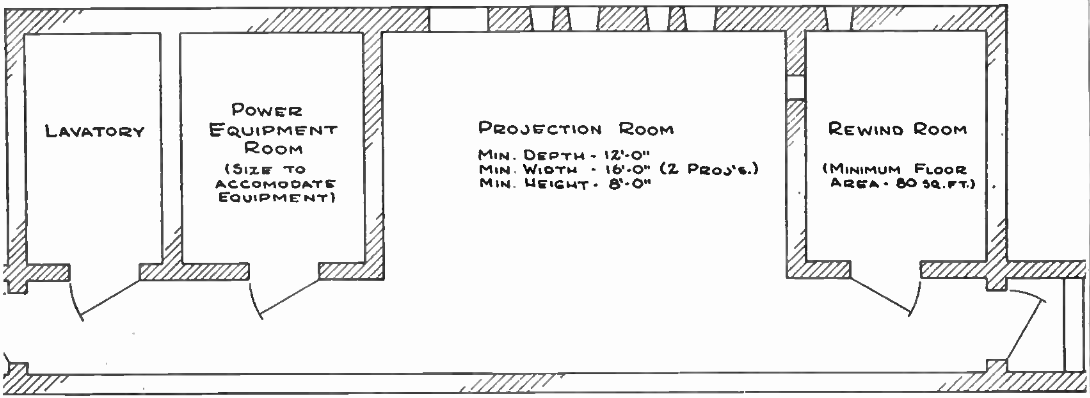


FIG. 1.—Showing floor plan of modern projection room.

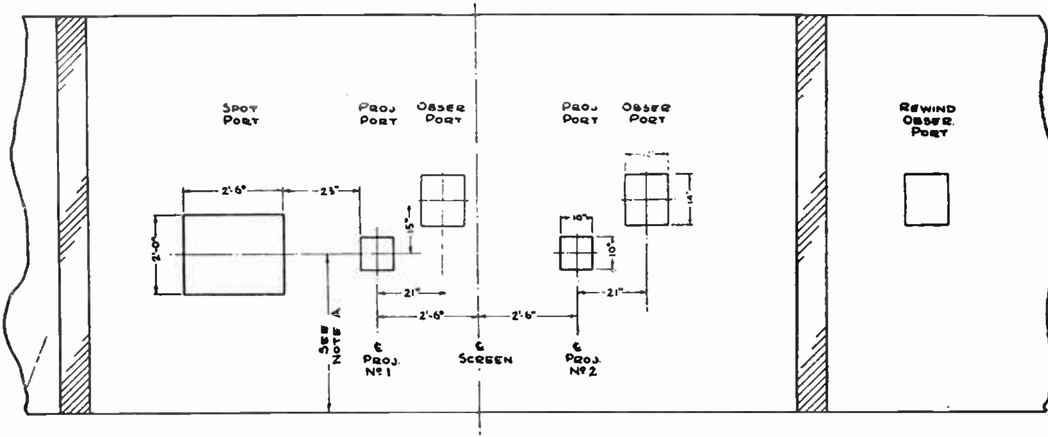
Floor Construction.—It is important that the floor of the projection room be constructed to provide for a minimum strength of 200 lbs. per sq. ft. plus the dead weight of the construction proper. A very satisfactory floor consists of (1) a reinforced concrete floor slab four inches thick; (2) a tamped cinder fill not less than four inches thick and (3) a troweled cement finish two inches thick. The cinder fill and cement finish are provided to accommodate concealed conduit.

Wall Construction.—Brick, tile or plaster blocks, finished on the inside with three-quarter inch of cement or acoustical plaster, form a satisfactory projection room wall. The core of the wall should be at least four inches thick and all electrical conduit should be concealed in the wall. The ceiling should be constructed of four-inch concrete slabs, or pre-cast concrete, or of three-inch plaster blocks supported by a steel structure and be finished on the inside with three-quarter inch cement or acoustical plaster.

Doors.—A door at each end of the projection room not less than two feet six inches wide and six feet eight inches high of the approved fire-door type, self-closing and swinging outwardly will provide the necessary means of egress and ingress and at the same time satisfactorily protect the balance of the theatre.

Windows.—It is desirable to provide one or more windows in the rear wall of the projection room if this wall is an exterior wall of the theatre. The window frame must be of steel construction and the glass of the shatter-proof type.

The reduction of noise transmission to the auditorium may be accomplished by the use of fireproof acoustical material on the walls starting four feet above the floor and on the ceiling.



NOTES A DIMENSION FROM FINISHED FLOOR TO ℄ OF PROJECTION AND SPOTLIGHT PORTS VARIES WITH THE ANGLE OF PROJECTION.

B ALL OBSERVATION PORTS ARE CONSTRUCTED WITH A GREATER WIDTH THAN HEIGHT TO PERMIT A MUCH CLEARER VIEW OF THE SCREEN.

C IF NO REWIND ROOM IS PROVIDED AND THE SIDE OF THE PROJECTION ROOM IS TO BE USED FOR REWINDING, INCREASE THE WIDTH OF THE ROOM BY 8 FEET. IF THE REWIND FACILITIES ARE PLACED AT THE REAR OF THE PROJECTION ROOM, INCREASE THE DEPTH OF THE ROOM BY 2 FEET.

FIG. 2.—Illustrating front wall plan layout.

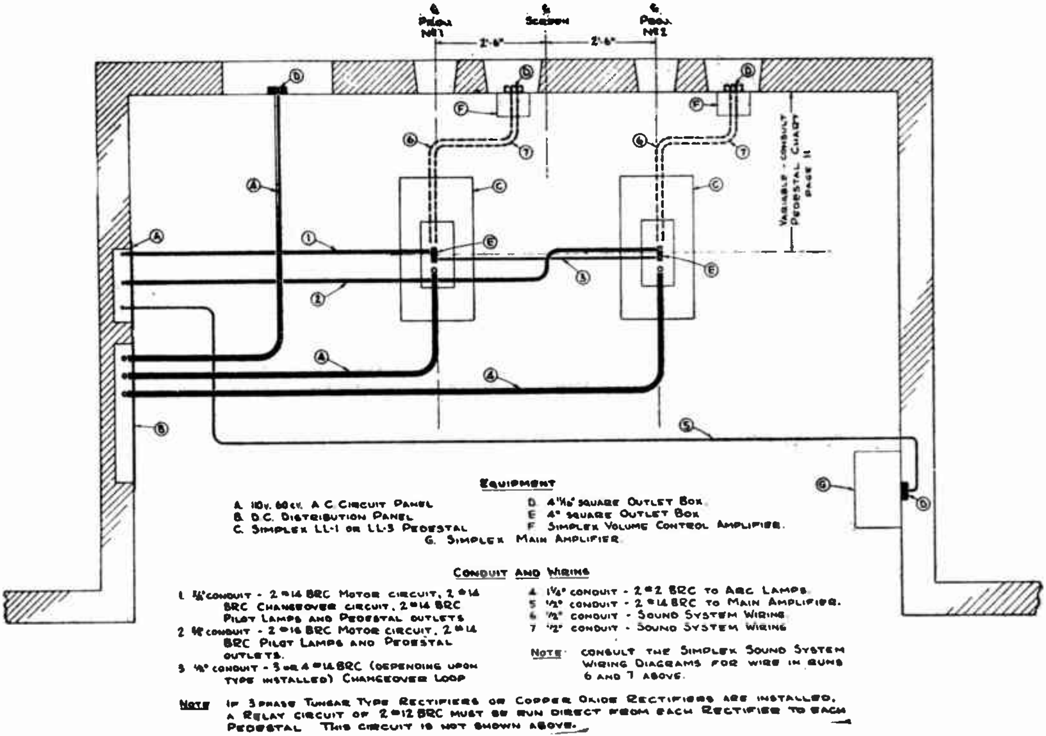


FIG. 3.—Showing floor plan conduit layout and wiring. NOTE.—The electrical wiring, construction and fire control devices shall be in accordance with the latest requirements of the *National Electrical Code* in addition to *Local Ordinances and Regulations.*

Portholes.—All porthole openings must be covered by gravity type shutters sliding in metal frames and constructed of not less than number 10 gauge iron. The drop shutter should overlap the openings at least one inch all around and should be connected to a system that will operate automatically in case of fire or other emergency. Fusible links above each shutter and over each piece of equipment assures immediate system reaction to fire. Large porthole shutters should be counterweighted to facilitate manual operation.

Lighting.—Generous consideration should be given to the problem of lighting the projection room. Indirect or semi-indirect ceiling fixtures should be provided for general illumination, and individual ceiling fixtures or reel lights should be provided at the operating side of each piece of equipment.

All lights should be shaded to prevent light from entering the auditorium through the portholes. It is advantageous to provide convenience outlets along the base of the wall for the use of the projectionist.

Ventilation.—Two separate ventilation systems are necessary in the projection room. One for ventilation of the room proper and the other for ventilation of the carbon arc equipment. Each piece of equipment of the carbon arc type should be connected by a flue to a common duct which runs directly to the outside air. An exhaust fan connected to this system should provide a movement of not less than 15 cubic feet of air through each arc lamp per minute.

The general projection room ventilation system consists of at least two fresh air intakes, one at each end of the room along the floor line and a separate exhaust system entirely independent of any other system in the theatre. This latter system terminates in at least two ceiling grilles and is operated by a blower having a capacity of not less than 200 cubic feet of air per minute.

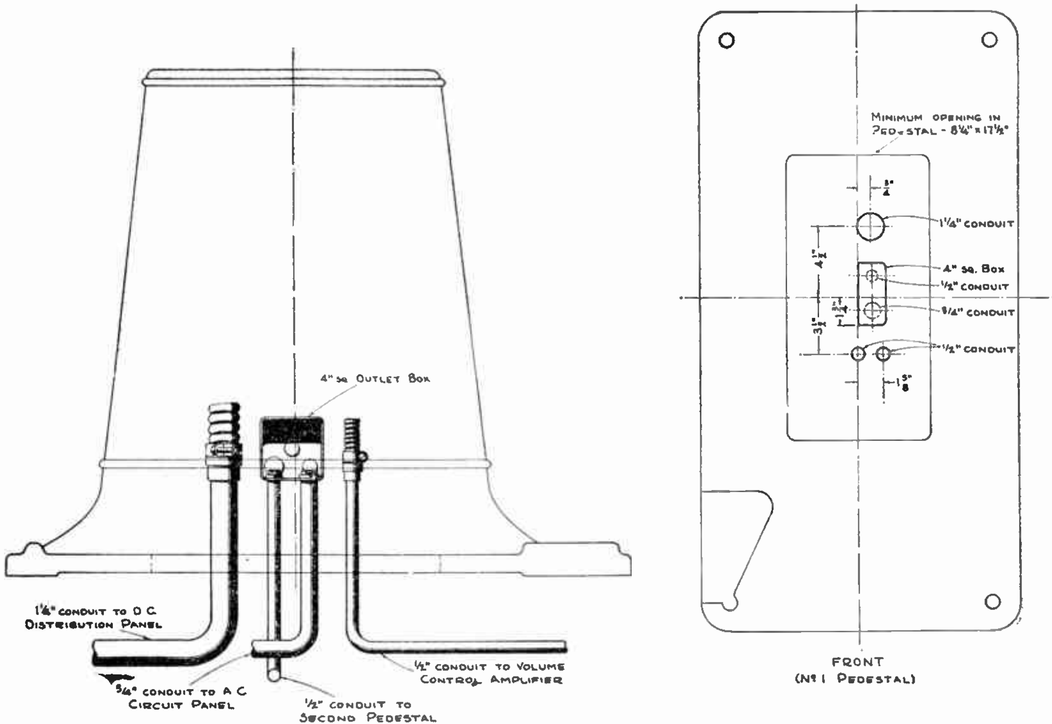
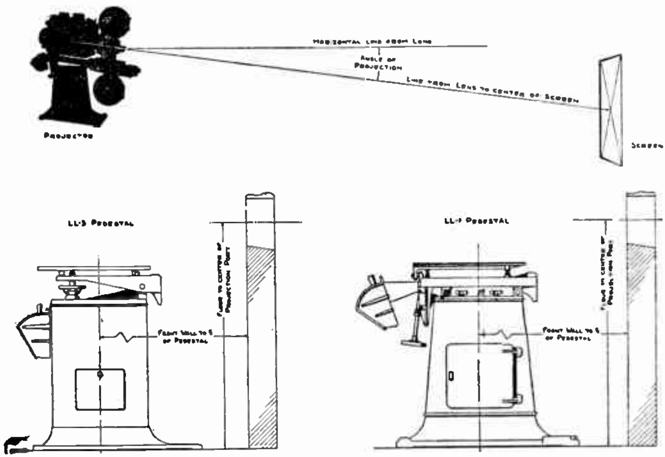


Fig. 4.—Showing projector pedestal conduit layout.



DETERMINE THE ANGLE OF PROJECTION FROM AN ACCURATE ELEVATION VIEW OF THE THEATRE. USE TABLE UNDER THE SELECTED PEDESTAL TO FIND THE PROPER LOCATION OF THE PEDESTAL AND PROJECTION PORT.

	LL-3 PEDESTAL			LL-1 PEDESTAL	
ANGLE OF PROJECTION	FLOOR TO CENTER OF PORT	WALL TO CENTER LINE OF PEDESTAL	SPOT PORT	FLOOR TO CENTER OF PORT	WALL TO CENTER LINE OF PEDESTAL
-3	50 "	45 3/4"	48 "	49 15/16"	44 "
-2	49 1/4"	45 3/4"	48 "	49 3/16"	44 "
-1	48 1/2"	45 3/4"	48 "	48 9/16"	44 "
0	48 "	45 3/4"	48 "	48 "	44 "
1	47 1/4"	45 3/4"	47 1/2"	47 1/4"	44 "
2	46 5/8"	45 3/4"	47 "	46 13/16"	44 "
3	46 1/8"	45 3/4"	46 1/2"	46 1/8"	44 "
4	45 1/2"	45 3/4"	46 "	45 9/16"	44 "
5	44 7/8"	45 3/4"	45 3/8"	45 "	44 "
6	44 1/4"	45 3/4"	44 3/4"	44 5/16"	44 "
7	43 5/8"	45 3/4"	44 1/4"	43 11/16"	44 "
8	43 "	45 3/4"	43 3/4"	43 1/8"	44 "
9	42 3/8"	45 3/4"	43 1/8"	42 1/2"	44 "
10	41 3/4"	45 3/4"	42 1/2"	41 15/16"	44 "
11	41 1/4"	45 3/4"	42 "	41 3/8"	44 "
12	40 5/8"	45 3/4"	41 1/2"	40 3/4"	44 "
13	40 "	45 3/4"	41 "	40 1/4"	44 "
14	39 3/8"	45 3/4"	40 1/2"	39 5/8"	44 "
15	38 3/4"	45 3/4"	39 3/4"	39 "	44 "
16	38 1/8"	45 3/4"	39 "	38 9/16"	44 3/8"
17	37 1/2"	45 3/4"	38 3/8"	37 1/2"	44 3/4"
18	36 7/8"	45 3/4"	37 3/4"	36 15/16"	45 1/4"
19	36 1/8"	46 1/4"	37 1/8"	36 "	45 5/8"
20	35 3/8"	46 5/8"	36 1/2"	35 1/4"	46 "
21	34 5/8"	47 "	35 3/4"	33 "	50 1/4"
22	33 7/8"	47 1/4"	35 "	32 1/8"	50 3/4"
23	33 "	47 5/8"	34 1/8"	31 1/4"	51 1/8"
24	32 1/8"	50 1/4"	33 1/4"	30 3/8"	51 1/2"
25	31 1/4"	50 1/2"	32 1/2"	29 7/16"	51 3/4"
26	30 1/2"	51 "	31 3/4"	28 1/2"	52 1/8"
27	29 1/2"	51 1/4"	31 "	27 1/2"	52 1/2"
28	28 3/4"	51 1/2"	30 "	26 1/2"	52 3/4"
29	27 3/4"	51 3/4"	30 "	25 1/2"	53 1/8"
30	26 7/8"	52	30 "	24 1/2"	53 3/8"

FIG. 5.—Showing typical pedestal chart. The angle of projection may be determined by an accurate elevation view of the theatre. Use table under the selected pedestal to find the proper location of the pedestal and projection port.

Decorating.—The appearance of the projection room may be greatly enhanced by painting the walls olive green from the floor to the point where the acoustical material starts. The acoustical material should be painted a dull buff color and the ceiling white. In many localities it is permissible to cover the floor with a good grade of battleship linoleum cemented in place.

Inter-Communication.—Two-way telephone communication between the manager's office and the projection room is a definite necessity in modern theatre operation. Provisions should be made to locate the projection room telephone at a point on the front wall to permit the projectionist to continue observing the screen while using the communication system. In many instances, it may be desirable to have additional stations located at such points as the rear of the auditorium or on the stage.

Rewind Room.—The separate rewind room should be a miniature of the projection room proper with respect to construction. It must provide not less than 80 square feet of floor space for film rewinding and storage facilities. One observation porthole should be provided in such a position that the projectionist may view the screen while in the rewind room.

An additional observation porthole should be provided in the wall separating the rewind room from the projection room proper and should consist of a fixed steel frame and a polished plate wire glass window having an area of not more than 200 square inches. The horizontal centerline of this porthole should be located five feet above the floor line.

The rewind room may be connected to the same fresh air and exhaust system that supplies the projection room. Painting and general lighting conform with the projection room proper. Recommended auxiliary lighting consists of either a reel light or fixed wall bracket fixture over the rewind table

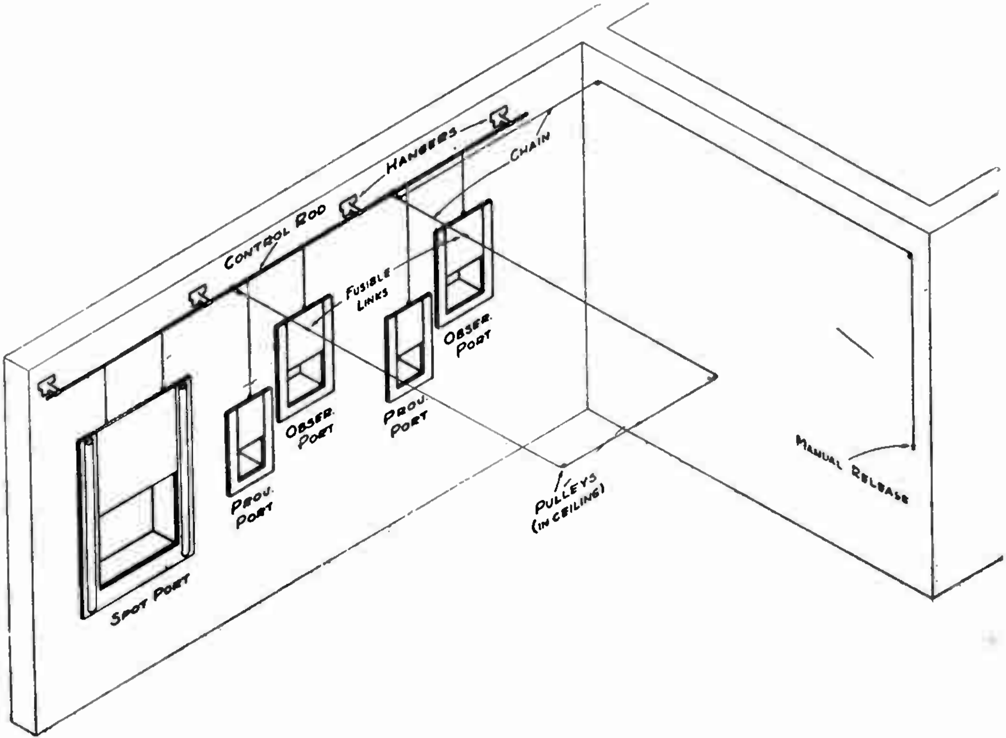


FIG. 6.—Showing wiring arrangement for porthole shutter system.

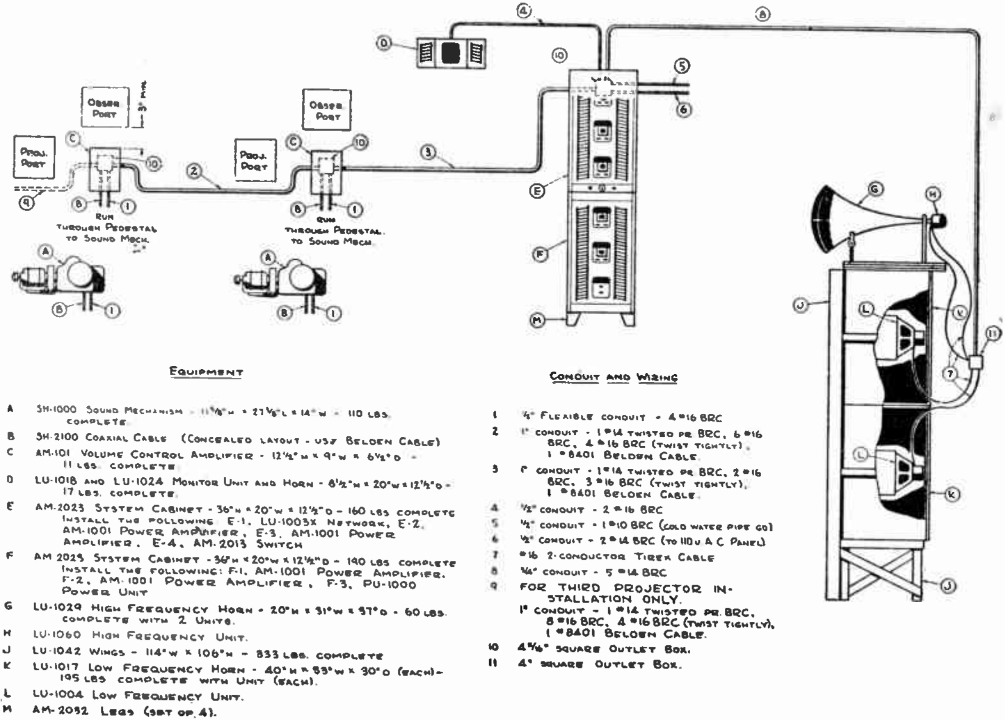


FIG. 7.—Showing conduit layout and wiring of apparatus for a *Simplex* four star sound system type B-60.

Power Equipment Room.—The construction of the power equipment room conforms with that of the projection room proper. The size of the room must be governed by the quantity and kind of equipment installed. It is advisable to allow space for possible future needs.

The power equipment room should be well lighted and convenience outlets provided along the base of the wall. It should be ventilated by the general projection room ventilation system and painted to match the other rooms.

Lavatory.—A clean, neat, well equipped lavatory is a definite asset to the efficient operation of the projection room. Modern sanitary facilities, a good wash basin with running water and a flush type medicine cabinet in a tiled floor room not only aid the appearance of the projection room but reflect the generous consideration given to the convenience of the projectionist.

TEST QUESTIONS

1. *In how many distinct units is the modern projection room usually divided?*
2. *What is the maximum vertical projection angle between the projector lens and screen?*
3. *How should the projectors be placed with respect to the centerline of the projection room and screen?*
4. *What dimensions should a well planned projection room have?*
5. *Give the specifications for satisfactory floor construction.*
6. *What constitutes a satisfactory projection room wall?*

7. *What type of doors should be provided in a projection room?*
8. *What is the requirements as to window construction in the projection room?*
9. *Give the operation and construction principles of porthole shutters.*
10. *Why is projection room ventilation important?*
11. *Give a complete description of the ventilation system installed in a projection room.*
12. *From where must air for ventilation be obtained?*
13. *What should be the minimum capacity in cubic feet per minute of an exhaust fan connected to an arc lamp ventilation duct?*
14. *What colors should the floor, walls and ceiling have in a projection room?*
15. *Why is it necessary to provide a two-way telephone communication system between the projection room and the manager's office?*
16. *What is the recommended minimum size of the film rewinding room?*
17. *Why is the projection room lighting important?*

CHAPTER 194

Projector Operation

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. 1 has been prepared to show in a very clear manner the operation of a projector. If the reader imagines the crank A, turned counter clockwise he will have no difficulty in tracing the movements of the various parts.

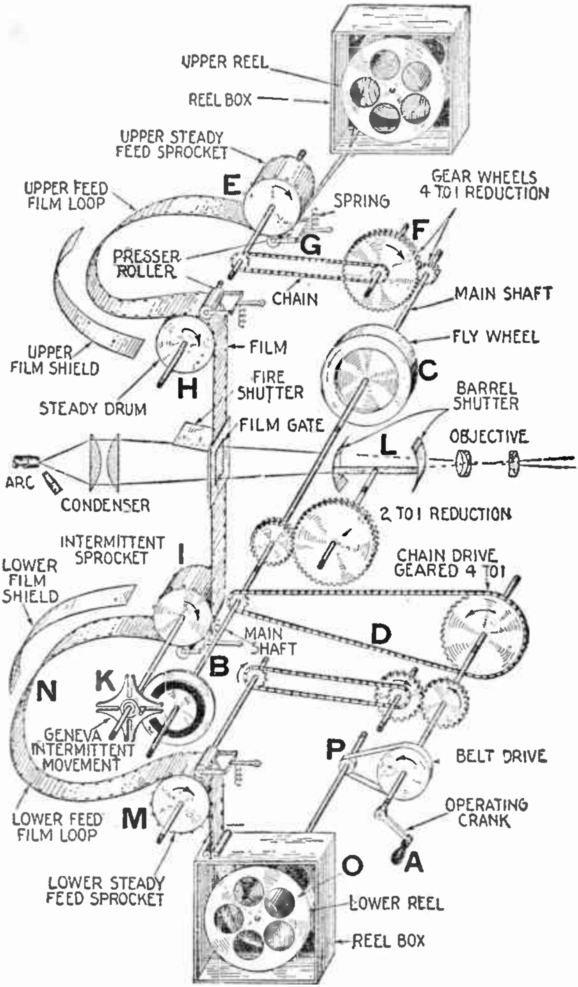


FIG. 1.—Elementary moving picture machine without case showing essential parts arranged to illustrate plainly the motion system.

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. 1, 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 an down vibration.

A sound motion picture film contains two types of record; one, a series of instantaneous photographs taken in rapid succession of a moving subject and the other, a record of the sounds associated with or appropriate to the motion of that subject. Fig. 2 represents a short section of such a film. The large rectangles in the center represent the individual photographs, the

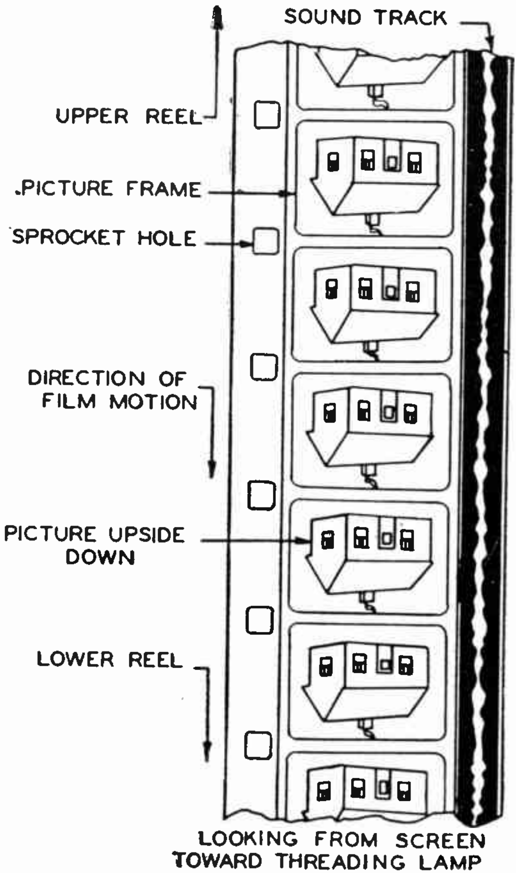


Fig. 2.—Showing components of a 16 mm sound motion picture film.

dark band at the right edge represents the sound track, and the wavy white line in the middle of the dark band represents the sound record.

When such a film is shown, the photographs are projected on a screen in the order they were taken and at the same rate. The sound is reproduced through an amplifier and a loud speaker and is synchronized with the action in the picture. The effect of the rapid presentation of a large number of slightly different pictures in proper sequence gives the illusion of a continuously moving picture and the simultaneous reproduction of appropriate sounds strengthens the realism.

Formation of Images.—The projection of motion pictures on a screen is based on the principle of the formation of an image by a convex lens. This principle is illustrated in fig. 3. Let AB represent any lighted subject, for example an illuminated film. Some of the rays of light from A are intercepted by the lens and are brought together at point A1 on the opposite side of the lens.

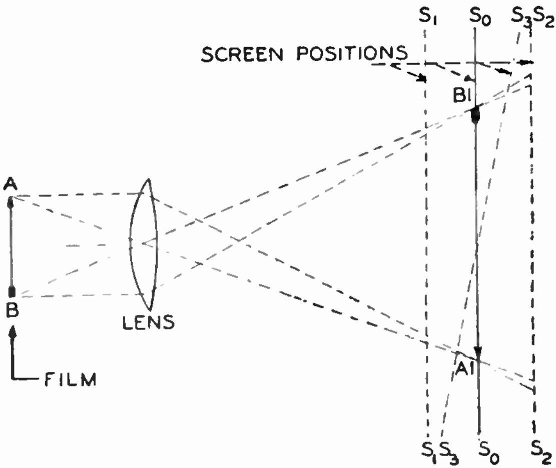


Fig. 3.—Illustrating formation of an image on the screen.

For simplicity, only two rays are shown, one passing through the edge of the lens and the other through its center. Point

A1 is the image of point A. In a similar manner, point B1 is the image of point B in the object. Every point in the object is represented by a point in the image.

For a given distance between the lens and the film there is only one screen distance at which the picture will be sharp. Light rays from a point in the film meet at a point on the screen in the plane S_0-S_0. If the screen is either nearer to the projector, as S_1-S_1, or farther from it, as S_2-S_2, these rays do not all strike the screen at the same point and therefore produce a blur.

But for any screen distance there is a corresponding film-to-lens distance which will give a sharp picture. In practice, it is usual to choose the screen distance to give the desired sized picture and then to move the lens in or out until the picture is sharpest. This is done by rotating the projector lens-barrel.

The screen should be at right angles to the lens axis. Tipping the screen as indicated at S_3-S_3, results in a picture which is out of focus at the top and at the bottom, although it may be sharp at the middle. Fig. 3 also shows that the rays cross as they pass through the lens; therefore, the image on the screen is inverted with respect to the film. In other words, the picture on the film should be upside down.

Projection of Motion Pictures.—In a motion picture projector each frame of the film is projected in the same manner as the single object in fig. 3. It is not held long, however, but is merely flashed on the screen for a small fraction of a second. It is immediately followed by the next frame on the film, which is shown for an equally brief interval.

In sound motion picture projection, 24 frames are shown every second, but this does not imply that each frame is held on the screen 1/24 of a second. The actual time is about ½ of this, for the screen is darkened twice per frame, once while the film is moving forward and again while a frame is being held stationary in the projector. If the light were not cut off while the film is in motion, the picture on the screen would be streaked and blurred; and if it were not cut off at least once while each frame is still, an annoying flicker would result.

The light is cut off by means of a two-segment shutter placed between the source of light and the film aperture. This shutter revolves once for each frame, or for each complete cycle of the intermittent film forwarding mechanism. The segment that interrupts the light beam while the film is in motion is known as the "pull-down" blade and the other as the "anti-flicker" blade.

Motion Picture Projector.—Fig. 4 shows a functional diagram of a typical sound-film projection system.

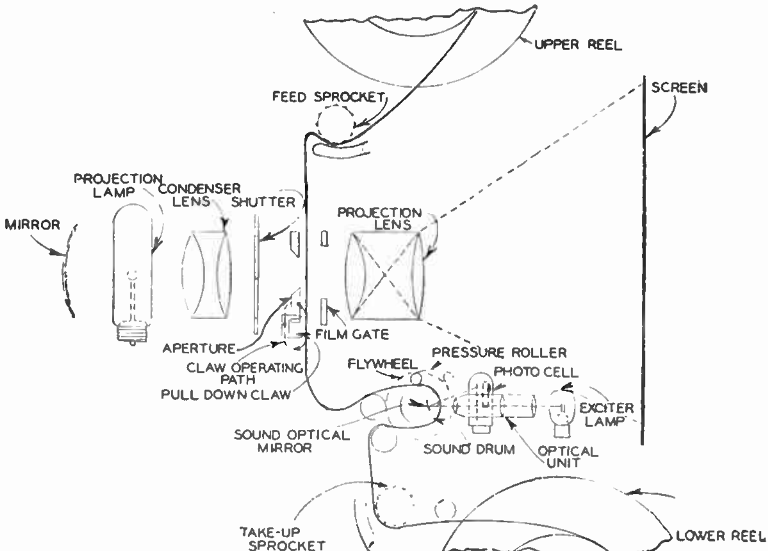


FIG. 4.—Schematic diagram giving the principal parts and film path in a modern projector.

1. The reflector on the left of the projection lamp increases the utilization of the light from the lamp by reflecting much of the back radiation into the spaces between the heated filaments of the lamp and, therefore, in the direction of the film.

2. The condenser lens concentrates the light on the aperture. The shutter, already discussed, is placed between the condenser and the aperture, where it not only darkens the screen when required, but also protects the film against the heat from the lamp.

3. The aperture is a rectangular opening in a metal plate. Its purpose is to limit the illumination to that portion of the film which is occupied by the picture.

4. The upper reel holds the film to be run through the projector.

5. The feed sprocket, turning at constant speed, unwinds the film from the upper reel and maintains a loop of film above the film gate.

6. The film gate holds the film flat against the aperture and keeps the picture in focus. It consists of a mounting for the projection lens and of a flat pressure shoe with a rectangular opening somewhat larger than the aperture. The shoe holds the film against the aperture plate and maintains a constant pressure on the film. The film gate assembly is hinged to the frame of the projector so that it can be swung away from the aperture.

7. The pull down claw pulls the film into position in front of the aperture intermittently at the rate of 24 frames per second. Each time the claw moves down, it advances the film one frame. During this motion the pull down blade of the shutter cuts off the light from the screen. While the claw moves back up, one frame of the film is held stationary in the aperture and is projected on the screen, except as it is interrupted once by the passage of the anti-flicker blade across the light beam.

8. The projection lens forms on the screen an enlarged image of the strongly illuminated frame at the aperture, as has already been explained.

9. The lower reel receives the film that has passed through the projector. This reel is driven by a friction clutch, whose slippage between the reel and its drive mechanism is controlled by the weight of film on the reel in order to maintain an even tension on the film regardless of the diameter of the roll of film on the reel.

10. The take up sprocket, like the feed sprocket, turns with a uniform velocity and, therefore, helps to keep the film moving at a constant speed. In addition, it serves to maintain a loop of film of proper length below the film gate. Without this loop, the film would not pass the aperture intermittently.

Sound Optical System.—The sound optical system is also outlined in fig. 4.

1. Between the film gate and the take up sprocket, the film first passes over a guide roller and then around the sound drum, which is coupled to a damped flywheel or rotary stabilizer. This stabilizer forces the film to move at a uniform speed, which is essential for good sound reproduction.

2. A pressure roller and an idler roller insure that the film wraps around the drum sufficiently to prevent the film from slipping on the drum and to maintain a constant distance between the sound track and the sound optical unit.

3. The optical unit concentrates the light from the exciter lamp into a line about .001 inch wide. This line is slightly longer than the width of the sound track. The optical unit is adjusted so that the line comes to a sharp focus at the emulsion side of the film and so that its center coincides with the center of the sound track. The point on the sound track where this line is focused is the scanning point. This portion of the film overhangs the back edge of the sound drum.

4. The light that passes through the sound track falls on the sound optical mirror whence it is reflected into the photocell mounted directly behind the optical unit.

Scanning and Sound Reproduction.—The right hand margin of fig. 2 illustrates a typical sound track of the variable width type.

The black areas are opaque, the white transparent. The width of the transparent area may vary from nothing up to the limits of the opaque band, depending on the instantaneous strength of the sound recorded. It is the variation in the width of the transparent area from point to point along the track that is of importance. When this variation does not exist, no sound has been recorded on the film and none can be produced from it.

When a sound track of variable width passes the scanning point, light from the exciter lamp goes through the film only where it is transparent. Since the width of the scanning line is constant, the amount of light going through the sound track at any point is directly proportional to the width of the transparent area at that point (that is, to the utilized portion of the scanning line). This width varies continuously as the film moves past the scanning point. Therefore, the amount of light that goes through and ultimately reaches the photocell varies in the same manner.

The variations in the light that enters the photocell are converted into equivalent variations in the current in the associated circuit. One element of that circuit is a high resistance which is connected between the control grid and the cathode of the first tube in the audio amplifier. The voltage drop caused by the varying current through this resistor is the input signal to the amplifier, and this signal varies in precisely the same manner as the record on the sound track. After the signal has been amplified sufficiently, the loudspeaker converts it into sound.

The sound associated with an individual frame is not recorded on the sound track directly opposite that frame, but at a point 26 frames farther ahead. This displacement of the sound track relative to the picture is necessitated by the requirement that, for proper synchronization of sound and picture, the sound record must pass the scanning point when the picture is at the aperture. (This 26-frame displacement between sound and picture is a standard for 16 mm sound film approved by the *Society of Motion Picture Engineers.*)

Any light varying at an audio-frequency rate will give rise to sounds in the loudspeaker if such light enters the photocell. Thus if the photocell is exposed to the light from a lamp operated from a 60 cycle line, a 120 cycle tone will issue from the loudspeaker, for the intensity of that light varies at a rate twice that of the frequency of the lamp current. It is clear from this fact that the exciter lamp cannot be operated with 60 cycle current, for if it were, a loud 120 cycle tone would result. The lamp can, however, be operated with alternating current of a superaudible frequency, which is done in most equipment.

The Amplifier.—The circuit diagram of an amplifier manufactured by the *Radio Corporation of America*, is given in fig. 5. The amplifier has provision for two sources of signals; a photocell and a high impedance microphone or phonograph pickup. Either may be selected with switch S-2 which is labeled *MIC-FILM* on the amplifier panel.

When the switch is in the MIC position, the load on the photocell is so small compared to the required value that the photocell is virtually short-circuited. When the switch is in the FILM, or open position, the microphone is out of the circuit and R-1 is connected across the photocell. R-1 has sufficient resistance, 560,000 ohms, to cause an adequate signal voltage to be impressed on the grid of the 6J7 tube (V-1) when the varying photocell current flows through it.

The photocell must have a *d.c.* voltage applied in series with itself and its load if any current is to flow. This voltage is derived from the grid of the 6F6 oscillator tube (V-7). To make certain that this voltage does not contain any ripple, it is well filtered by a high resistance R-23 and a large condenser C-15. In addition, a voltage regulating resistor R-2 minimizes the variations in the photocell voltage due to variations in the plate supply voltage.

The volume is controlled with a potentiometer in the grid circuit of the second tube (V-2) and the tone with a center tapped potentiometer connected in a compensation network in the grid circuit of the third tube (V-3). This control provides a range of tone balance between high and low frequencies which is adequate to correct for the variations in sound charac-

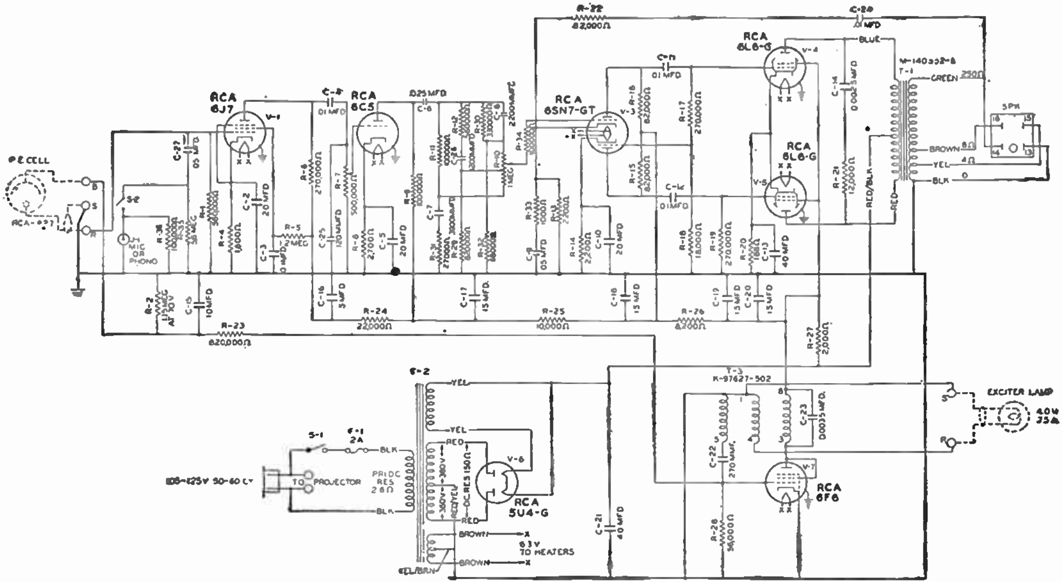


FIG. 5.—Schematic diagram showing the amplifier circuit of a typical sound on film projector. *Courtesy Radio Corporation of America.*

teristics and reproducing conditions usually encountered. The third tube (V-3) in the circuit is a typical phase inverter. which provides a balanced input voltage to the push-pull output tubes (V-4) and (V-5).

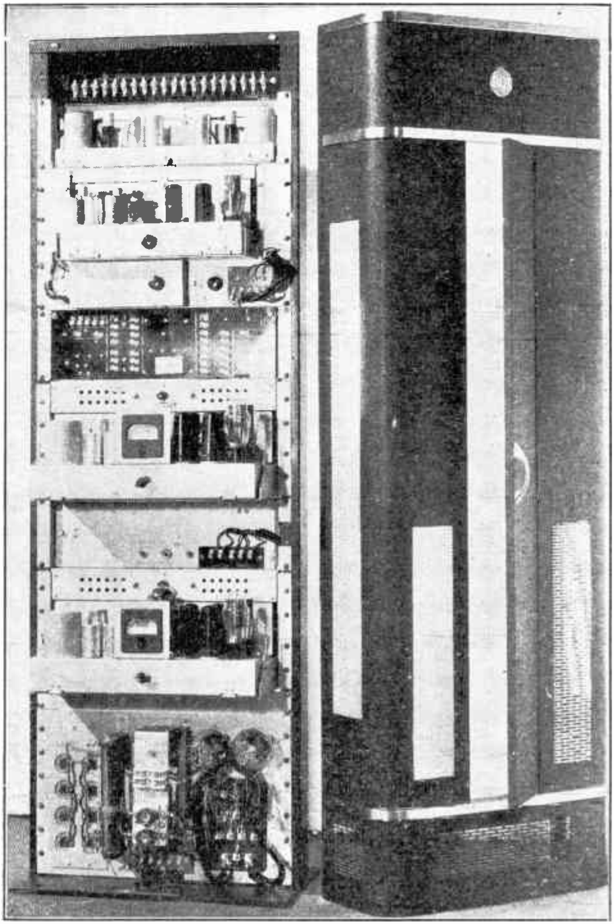


FIG. 6.—Showing rear view of typical amplifier panel. *Courtesy Radio Corporation of America.*

Inverse feedback from the secondary of the output transformer to the cathode of the phase inverter tube is employed to reduce distortion to a negligible value. The values of capacitors C-24 and C-9 are such as to provide appropriate tone equalization of the sound output.

The 6F6 (V-7) is a high frequency oscillator which serves two distinct purposes in the circuit: to supply current for the filament of the exciter lamp and high *d.c.* voltage for the photocell circuit. The frequency generated is about 28 *kc.* and is determined by the capacity of condenser C-23 and the inductance of the coil connected in shunt with this condenser. The high frequency current for the exciter lamp is obtained from the winding between terminals 1 and 4.

Loudspeaker.—The loudspeaker is of the dynamic type, with a permanent magnet field, a voice coil impedance of 8 ohms, and a cone diameter of 10 inches.

The speaker cone is provided with a cap over the central pole piece to keep dust and iron particles out of the spaces between the voice coil and the pole faces. The speaker is fed from the push-pull output stage of the amplifier through a step-down transformer and a 50-foot speaker cable.

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. *Of how many types of record does a sound motion picture film consist?*
5. *Upon what principles is the formation of an image upon the screen based?*

6. *How many picture frames per second is projected upon the screen?*

7. *What is the function of the take-up sprocket and feed sprocket in a projector?*

8. *How is an alternating current converted into a direct current in the amplifier?*

9. *What is the function of the photoelectric cell?*

10. *What means are employed to control the sound volume in an amplifying system?*

11. *From where does the photoelectric cell derive its voltage?*

12. *What is the function of the loudspeaker in motion picture sound system?*

CHAPTER 195

Motion Picture Projection

General.—The proper and successful projection of film depends primarily upon the following factors:

1. Modern projection apparatus correctly installed;
2. Properly trained technical personnel.

All preparation and expenditure of money involved in the creation of the film when it finally arrives at the theatre has now been reduced to so much film footage.

The film is now in the hands of the projectionist with whom lies the responsibility of transferring the material to the screen, through the medium of projectors and a source of light. Motion pictures are an illusion and are intended to convey realism to the screen.

Handling of Film.—Upon the arrival of the release print, the normal procedure in first-run theatres is a careful inspection and measurement of the entire film-footage. During the past several years the exchanges have been doubling up the reels of features for shipment, which duty is handled by the personnel in the exchange. In other words, the composite film is delivered to them on spools from the laboratory; they in turn mount the A and B sections on 2,000-foot reels.

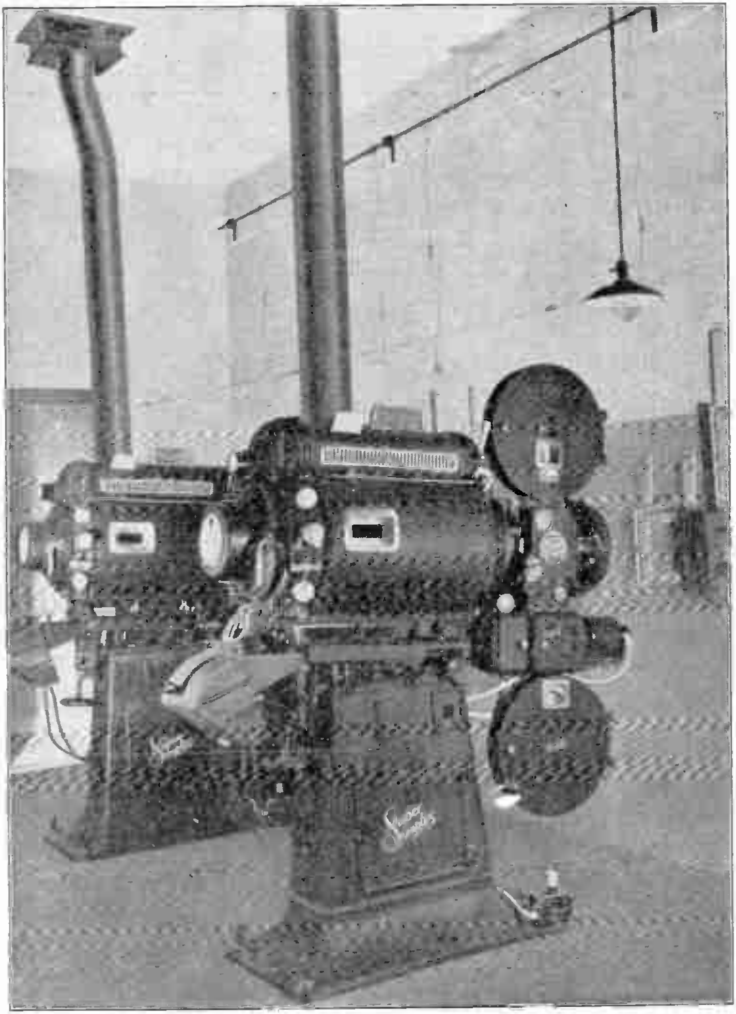


FIG. 1.—Illustrating projector installation in typical projection room. NOTE: Ventilation stack arrangement.

Importance of Correct Splicing.—The three most important factors in making good splices are:

1. Expert workmanship;
2. Good film cement;
3. Proper tools.

Preparatory to the actual splicing, the film should be cut one end on the line between pictures and 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. Scrape the emulsion from the stub end exactly to the center of the frame line and no further. The line at the end of the scraping must be straight and at 90° angle to the length of the film. It is important that the film be scraped to the proper depth so as to remove all the emulsion and also to slightly roughen the celluloid beneath.

If the emulsion be not properly removed the splice will not be secure. Also if the scraping is too deep, the film will be weakened.

The back of the film or the celluloid side must also be scraped slightly to remove dirt and oil and the celluloid should be roughened slightly.

The importance of good splicing cement cannot be overemphasized. The cement should not be exposed to air, since it will evaporate and absorb moisture at a rapid rate, thus destroying its strength.

It should be noted that cement is *brushed on—never rubbed on.* A small brush is used and the brush is passed across the film only once. If more than one stroke of the brush be laid on, the film will be weakened.

After joining the two ends, a heavy even pressure should be applied for at least five or six seconds. Insufficient pressure or uneven pressure will result in a weak and unsatisfactory splice.

Mechanical splicers cut the film ends perfectly square and also cut the stub end at exactly the correct length. It applies sufficient and evenly distributed pressure and automatically matches the sprocket holes perfectly. Too often, however, mechanical splicers are allowed to become worn and out of alignment with the result that inaccurate splices are made.

It is of the utmost importance that the splicing operators fully realize the importance of properly "blooping" out splices. Too often the splicing cement is allowed to become thick and slow-drying and as rewinding proceeds, deposits from wet applications are smeared on the track over several wraps.

This necessitates cleaning with a lacquer remover, and invariably the faulty splices have to be removed. Under no circumstances should the shipping reels be used because they are for the most part badly bent and warped. Most of the best theatres are equipped with cast aluminum reels, upon which the film material is mounted for the duration of the engagement.

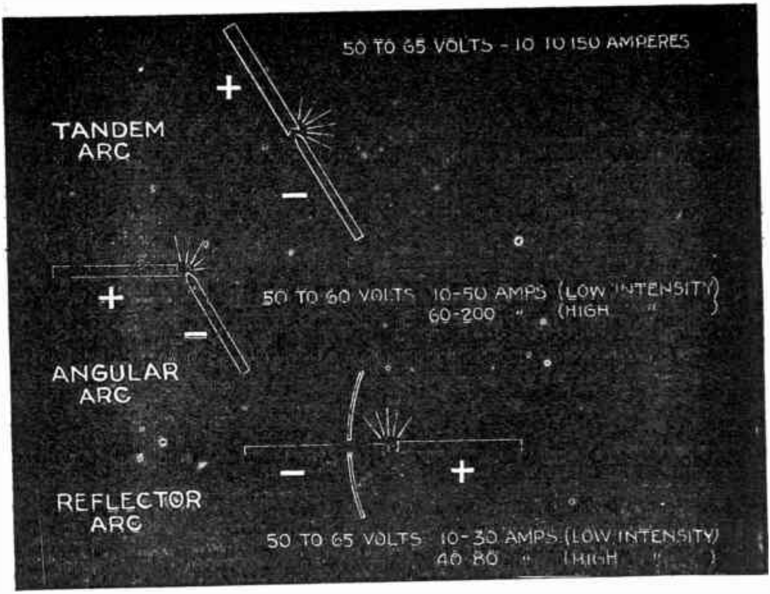
Rehearsals.—It was the practice of first-run theaters in the early days of sound to conduct complete rehearsals before the opening of new pictures. The chief projectionist checked the volume from the auditorium, cues were made, and a general knowledge was acquired of the complete show.

Today, unfortunately, this practice is not usually followed, with the result that the new shows are opened without the crew's having any accurate knowledge of the volume required. They depend solely upon booth monitoring.

Projection Room Routine.—This will vary from theatre to theatre. Irrespective of this, however, there are certain duties which must be performed daily. Of great importance are the inspection and cleaning of the following units:

1. Projector mechanism;
2. Upper and lower magazine valve assemblies;
3. Optical systems;
4. Lamp houses, contacts and all component parts;
5. Take-ups and belts. Proper oiling with manufacturer's specified lubricant. Many projectors have been ruined by inferior oils;
6. Inspection of sound system;
7. Inspection of generators or rectifiers. Motor switches must be replaced at regular intervals. A failure here may cause interruption of the performance.

Light Sources.—The success of the presentation depends largely upon technical conditions often beyond the control of the projectionist. The equipment in many theatres is inadequate, particularly with respect to the available light.



Figs. 2 to 4.—Various projector arcs. Fig. 2, tandem arc; fig. 3, angular arc; fig. 4, reflector arc.

Light sources may be divided into three categories, namely:

1. Condenser type high-intensity arcs (used in the largest type of theatres);
2. The Suprex type arcs (used in intermediate size theatres);
3. The one *kw. a.c.* or *d.c.* types (used in small theatres).

Due to its yellow color and low intrinsic brilliancy, the low-intensity arc is being rapidly replaced by an intermediate type of non-rotating high-intensity arc having a color value approximating the white light of the rotating and non-rotating high-intensity arcs.

The reflected screen light depends upon the character of the source, *the optical system, the reflectivity of the screen* and *the efficiency of operation.* Upon the projectionist falls the task of co-ordinating these elements into a single smoothly-operating whole.

Type of Current Used.—The current used depends upon the type of equipment employed and may be either alternating or direct current.

When direct current is employed as an arc source various converting units are used (since most localities supply only alternating current). These units fall into four classes, namely:

1. High voltage motor generators with proper ballast resistance inserted in the circuit to reduce the generator output voltage to that required at the arc.

2. Low voltage motor generator sets with constant voltage characteristics. These are usually made of a capacity sufficient to supply two lamps and with individual ballast resistances, connected to the generator in parallel.

3. Motor generator sets with falling volt-ampere characteristics and a no-load voltage near that of the arc. These machines require no ballast resistance but do require a separate generator for each lamp.

4. Rectifiers with falling volt-ampere characteristics which similarly require no ballast resistance. but require a separate unit for each lamp.

Carbons and Their Combinations.—Carbons are generally classified by trade names, by their length and by their diameters. Carbon diameters are quite frequently given in millimeters (mm). If it be remembered that one millimeter equals .03937 of an inch, it is comparatively easy to convert one measurement into the other. Thus, for example, an 8 mm carbon would be $8 \times .03937 = .31496$ or $\frac{5}{16}$ of an inch in diameter approximately.

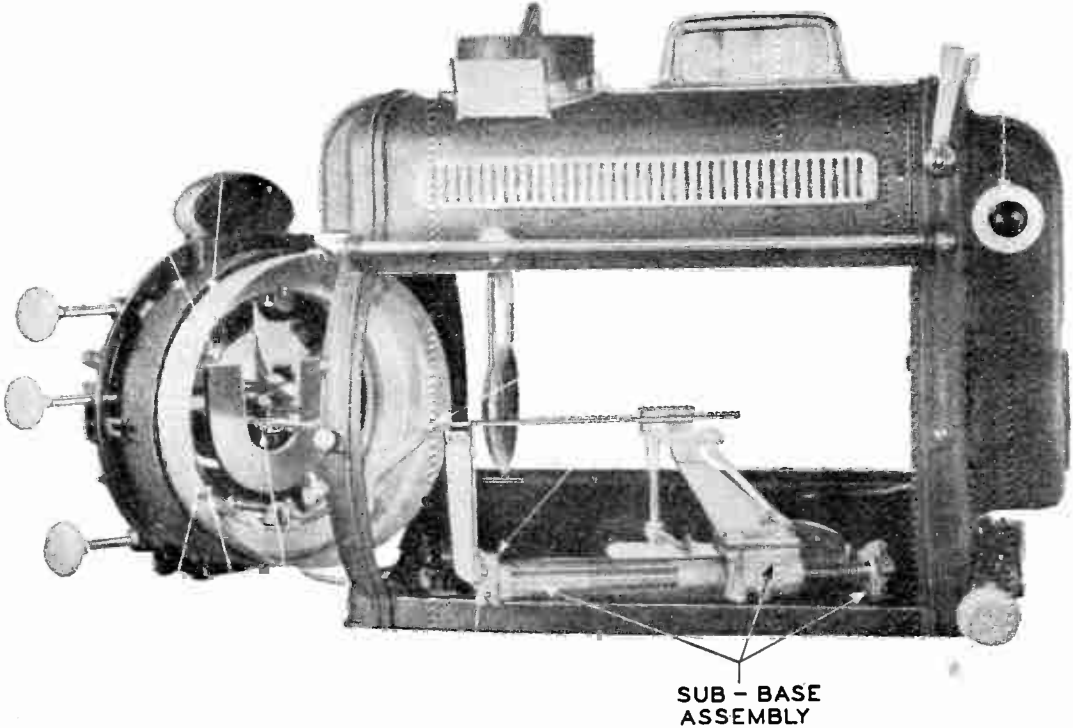


FIG. 5. Showing construction of typical *Peerless* high intensity lamp.

It is of the utmost importance that carbons be stored in a warm, dry place several days before they are to be used. Tables giving the best carbon combinations for a certain projector are usually supplied by the manufacturer in addition to current and voltage ranges. The following table serves to illustrate the carbon combinations of the *Suprex* type:

Table of Carbon Combinations
Arc Voltages and Amperages

Amperage Range	Arc Voltage Range	Copper Coated "HI" Carbons
40–42	27–28	7 mm positive 6 mm negative (Orotip "C")
42–50	31–40	7 mm positive 6 mm negative
56–65	31–40	8 mm positive 7 mm negative
70	40	8 mm positive 7 mm negative } Special

ELECTRICAL DIAGRAM

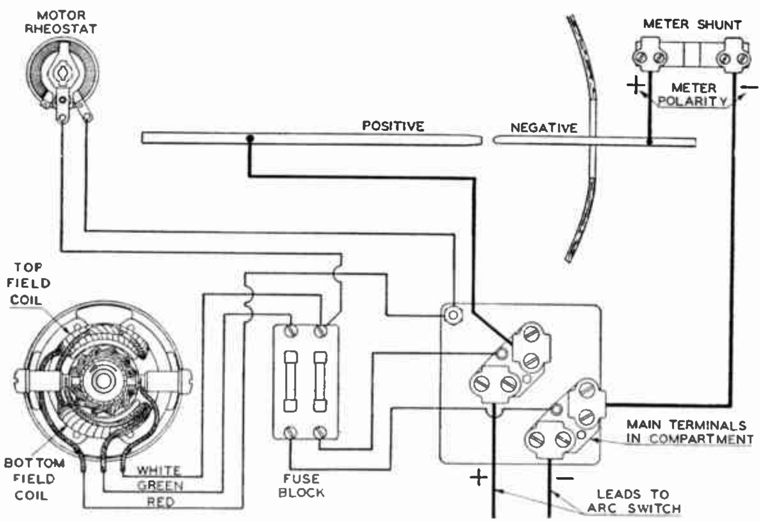


FIG. 6.—Wiring diagram showing electrical connection and control apparatus for typical high intensity lamp.

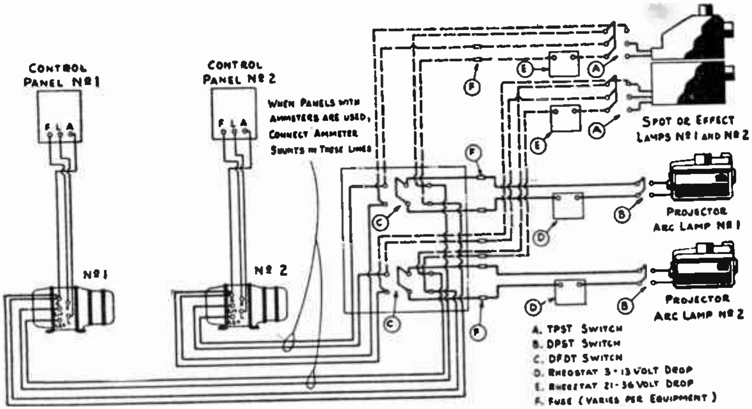


FIG. 7.—Wiring diagram showing connections between motor generators and lamps. The double pole, double throw switches will permit power supply to lamps alternately from motor generator set No. 1 or No. 2.

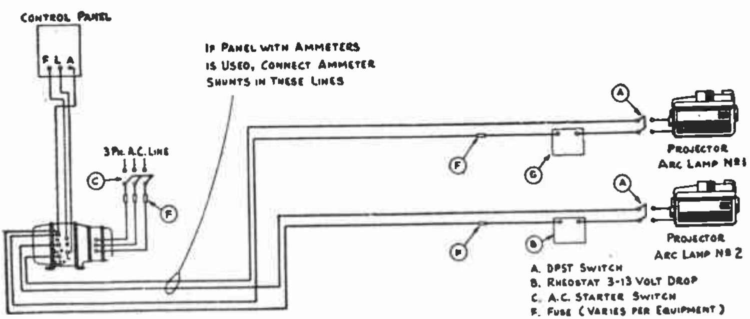


FIG. 8.—Wiring diagram showing connections between motor generator and lamps, with only one motor generator set used as power supply.

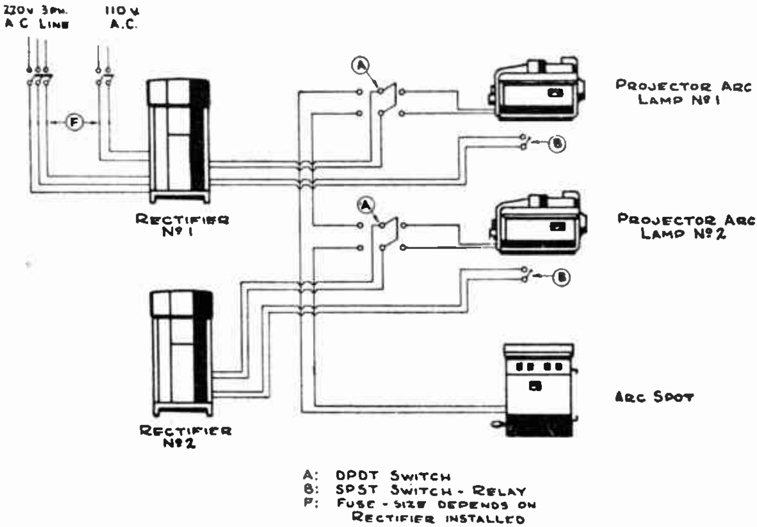


FIG. 9.—Wiring diagram showing connections between rectifiers and lamps. NOTE.—*A.C.* wiring for rectifier No. 2 will be similar to that of rectifier No. 1 shown in full.

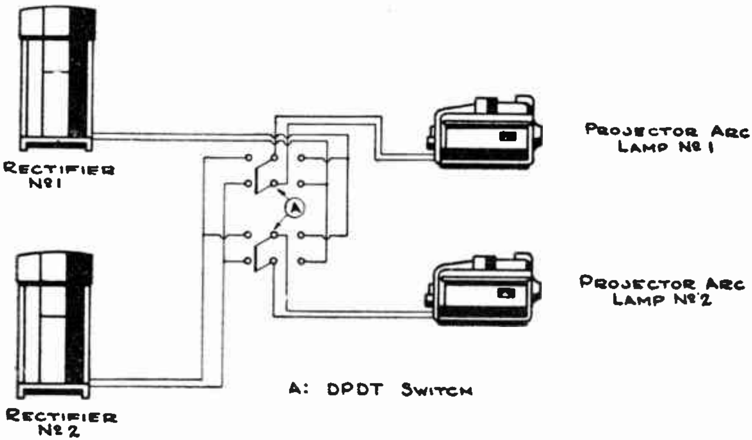


FIG. 10.—Wiring diagrams showing connections between rectifiers and lamps. NOTE.—*A.C.* wiring and relay circuits (not shown) will be similar to that shown for rectifier No. 1, fig. 9.

The Influence of Dense Print and Smoke.—Dense prints are now quite common and it is also becoming the practice to increase the auditorium illumination. Smoking is permitted in many theaters, tending to decrease reflectivity of the screen.

The projectionist in the large theaters using the *Suprex* equipment instead of the high-intensity condenser arcs will often increase the arc wattage beyond the rated capacity of the carbon trim in an attempt to increase the brightness of the picture. He then encounters a disproportionate increase in carbon-burning rate, often beyond the feed rate of the arc control mechanism. Operation then becomes critical and efforts at manual control prevent the arc from establishing itself on a stable basis.

There has been a tendency to increase the picture size without adding to the illuminations, whereupon a reduction in brightness and contrast results. Graininess is also noticeable, and all these factors lessen the value of the front rows of seats.

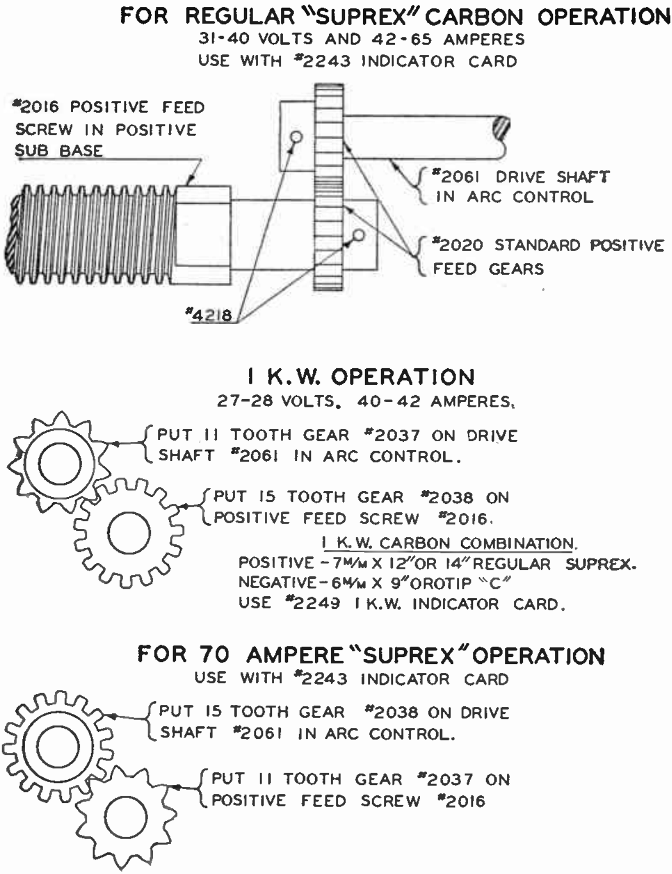
Operating Difficulties with Rotating High-Intensity Lamps. These may be due to pitted or burned contact brushes, loose and dirty lead connections, excessive voltage at the arc.

The carbon manufacturers' specifications should be rigidly followed. The lamp house should be ventilated, if possible, with a separate exhaust fan, and dampers put into the stack in such a manner as to control the travel of air without impeding the passage of waste materials of arc combustion.

Floating Carbon Principle.—A great many lamps employ a single mechanism to commonly control the feeding of both the positive and the negative carbon. Other lamps of more recent manufacture, however, are built with separate mechanisms for feeding each carbon, permitting greater flexibility in the choice of carbon and currents.

A lamp mechanism permitting a change of the original carbon sizes and current is shown in figs. 11 to 13. This change may be accomplished in the projection booth by simply changing two gears as illustrated.

Reflector to Aperture Distance.—This will vary, depending upon the lamp used. The optical diagram of a Peerless Magnarc high intensity lamp is shown in fig. 14. Here the



Figs. 11 to 13.—Diagrams showing method of adjustment if it be desired to change the original carbon sizes and current. This may be accomplished by simply changing two gears as indicated.

operating distance from the rear surface of the reflector when measured through the hole in its center to the projector aperture should be approximately 34 inches.

To obtain this dimension it may be necessary on certain projectors using rear shutters to remove and discard the small metal light cones mounted on the rear half of the projector shutter housing.

Formation of Carbide Tips on Negative.—Under certain conditions a reddish carbide tip will form on the end of the negative carbon. This carbide tip is a non-conductor and if particularly heavy may cause difficulty in striking the arc.

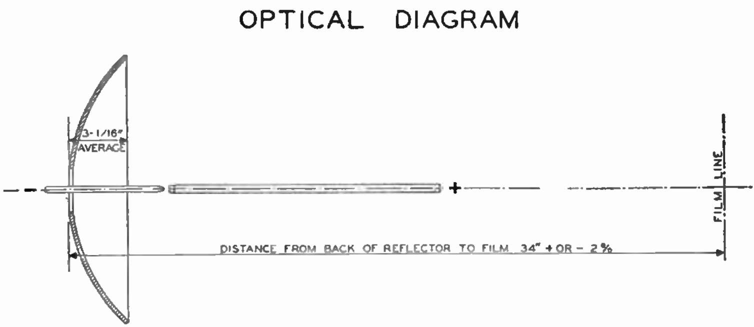


FIG. 14.—Optical diagram, showing reflector to aperture distance when using *Peerless Magnarc* lamp.

If no arc occurs, the projector switch should be opened and the end of the carbon dampened which causes rapid disintegration of the carbide tip or with a file remove the formation from the tip of the negative carbon.

When the arc is not lit for intervals of fifteen or twenty minutes, this carbide tip will disintegrate itself due to the current no longer emanating from the end of the negative carbon but rather from the sides thereof just back of the carbide tip. This condition results in higher arc voltage and consequently increased motor speed. When such a condition occurs, it is not advisable to readjust the arc control rheostat for this increased voltage but rather to remove the carbide tip when the end of the reel is reached.

Current Surges.—At infrequent intervals during normal operations, a relatively sudden increase of current may be noted as registered by the ammeter. Generally the cause can be traceable to the development of small cracks in the shell of the positive carbon or overloading the carbon combination used.

When such cracks occur they permit a leakage of gas from the crater, rarefying the gas, which condition in turn reduces the normal resistance across the arc.

During such periods the crater will become rather shallow and the rim of it burns to a pronounced rounded edge.

The only remedy, under the circumstances, is to allow the cracked area of the carbon to burn away or retrim at the first opportunity.

Importance of Draft Control.—The *Suprex* and the one-kilowatt types of the high-intensity lamp are operated at a small arc voltage and current. Hence they are sensitive to drafts. Modern lamp houses are designed to have sufficient ventilation under ordinary conditions, but close control of the amount of air passing through the lamp houses into the stack is essential for trouble-free operation.

Abnormal draft is caused by excessive ventilation of the projection room, back-draft from certain types of rear shutters having cooling fins, and down-drafts from chimneys lacking forced-draft ventilation. Excessive draft, unless very strong, does not usually cause flickering, but it does cause a movement of the arc flame, which becomes noticeable on the screen.

The non-rotating high intensity arc, when properly burned, is almost rectangular in form, with the point of the tail flame directly above and not far behind the positive crater. If the tail flame wavers and is driven toward the front of the lamp house in an intermittent manner, excessive draft is usually indicated.

If it is not possible to control the draft with the stack damper, it may be necessary to restrict the ventilation entering the lamp house; or, if the trouble is caused by fins on the rear shutters, the fins may be removed. However, this procedure is not recommended, as the fins were installed to dissipate heat from the film and the film-trap assembly.

It is suggested that the arc be protected by means of a heat-proof glass shield placed directly behind the rear shutters. It should be remembered, however, that adequate ventilation is necessary to protect the lamp house, and drafts should be restricted only to the point at which the arc will burn satisfactorily.

Maintenance of Rectangular Arc Shape.—In order to maintain a rectangular arc shape, it is necessary that the carbons be properly positioned by raising and lowering the negative carbon until the gases are seen to escape from the top of the positive crater. For higher currents, the negative carbon tip should be slightly below the centerline of the positive, and in order to let the gases escape from the top of the crater, it may be necessary to allow the top of the positive crater to burn back as much as .32 inch.

Anything that disturbs the normal position or function of the arc, such as some types of carbon savers, or by burning the carbons too short, may result in screen discoloration, light reduction, or change in light distribution.

When to Strike the Arc.—The optical system of the non-rotating high intensity lamp is designed by the manufacturer to deliver the maximum amount of light, and the arc should be operated in a given position with respect to the mirror. Moving the positive crater toward the mirror .10 inch from its proper distance will result in a decrease in screen illumination of approximately 40% when using a 7 mm positive carbon.

In order to avoid noticeable screen color difference, the arc should be struck three or four minutes before the change-over period and the position of the image of the positive crater should be adjusted before, not after, the change-over. In many theaters where false economy prevails, projectionists are instructed never to strike the arc on the incoming projector until the last minute. With this procedure, screen results are bound to suffer.

Illumination Trouble.—When illumination trouble occurs, it is necessary to locate it with a minimum of delay. Unfortunately, it is often difficult to determine immediately whether or not the carbons are at fault, and some projectionists keep a few trims in a dry place to be used as a check. Later if trouble occurs, carbons being currently used are checked against these reserves. If the trouble persists, one may look elsewhere for it, such as in the current supply or in the condition of the draft. Rarely are the carbons found to be at fault.

Miscellaneous Projection Pointers.—With the releasing of productions on fine grain stock, hopes were entertained that some of the lighting problems would be lessened. Experience in this respect has been, to say the least, very disappointing. The greater brilliance and contrast are readily apparent, but the stock used so far has a tendency to buckle. The phenomenon is very curious; it comes and it goes. A print may be used for a few days without trouble; then, for no apparent reason, the picture on the screen begins to weave in and out of focus. In other words, the photographic image will be out of focus.

The modern projector is designed to be adaptable to all types of theaters. There are, however, many mechanisms now in use, particularly in circuit theatres, that should have been discarded years ago. Worn film-tracks and hooked sprockets are found in many of them, which are the causes of film damage in alarming proportions. Many projectionists have adopted the practice of speeding up their electric rewinds beyond the limits set by the manufacturers. This causes many fine scratches on the surface of the film, commonly called "rain" and should not be tolerated.

Another source of annoyance is the all too often apparent neglect of the most important part of the equipment, namely, the screen, which is allowed to become dirty and discolored. There are many methods of so-called resurfacing, few of which have proved satisfactory. The best procedure is to try to keep the surface and perforations free from dust and dirt. When discoloration takes place, the screen should be replaced. The difference in cost between the ordinary resurfacing job and a new screen is not comparatively great.

Picture distortion and keystoning is another source of annoyance. Squaring the picture image by aperture-plate correction improves the general appearance, but the situation is a serious handicap to good projection. It is unfortunate that such conditions prevail in many of our first-run theatres.

Several years ago the *Research Council of the Academy of Motion Picture Arts & Sciences* recommended the standard leader and the placing of dots in the upper right hand corner of the composition for change-over cues. This practice was adopted by all the large producing companies, and provides a successful means of properly changing from one reel to another.

Yet there are still some projectionists who deliberately deface the ends of reels with cues of their own design, such as punch marks or crosses scratched into the emulsion, all tending to impair the print and detract the audience's attention from the subject being reproduced upon the screen. True, the laboratories do not provide standard cues on many short subjects, such as newsreels and trailers, and it is necessary that some sort of cue be provided. A small inexpensive cue-marker consisting of a template and a hardened steel scriber is recommended, for scribing a small circle at the upper right-hand corner of the film image, at exactly the spot where the standard dots would appear.

Conservation is an all-important factor and replacement parts will not always be obtainable. It is, therefore, urgent that equipment should be properly checked and adjusted. There is no reason why an intermittent sprocket should not last at least three years, provided it is of the manufacturer's specifications and the tension pads and shoes are properly adjusted.

Excessive tension not only shortens the life of the sprockets, but also causes undue wear throughout the entire projector mechanism. One method of increasing the life of tension pads and shoes is to have them ground perfectly true and then chromium-plated. This also eliminates the tendency of new (or "green") film to stick while being projected.

Projection may be termed the bottle neck of the industry, and there is much that can be done in the projection room to assist in placing upon the screen high-quality pictures reflecting the great amount of labor, art and expense that went into the making of the production in the studio.

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.

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.

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.

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.

TEST QUESTIONS

1. *What is the film capacity in feet of a standard film reel?*
2. *What is the correct procedure in splicing of film?*
3. *Describe the application of film cement to the splice.*
4. *What takes place if cement be exposed to air?*
5. *Why is machine splicing preferred to that of hand splicing?*
6. *What is the result when insufficient and uneven pressure is applied to the splice?*
7. *Describe the daily projection room routine commonly adhered to in modern theaters.*
8. *Name three types of light sources employed in projectors.*
9. *What methods are generally employed in converting the conventional 60 cycle alternating current to direct current for use in projector lamps?*
10. *How are carbons classified?*
11. *Why is it necessary to store carbons in a dry location?*
12. *Describe the influence of dense smoke upon the reflectivity of the screen.*
13. *What should be done to prevent operating difficulties when using rotating high-intensity lamps?*
14. *Describe the floating carbon principles employed in modern projector lamps.*

15. *What should be done when carbide tips form on the negative carbon during operation of the lamp?*

16. *What is the most common cause of current surges as indicated by the ammeter during normal operation of lamps?*

17. *When should the arc be struck?*

18. *What are the methods commonly used to control excessive drafts in high intensity lamps?*

19. *What is the effect of an increase in picture size without a corresponding increase in illumination?*

CHAPTER 196

Various Sound Projector Systems

General.—The following may serve as a brief outline of the essential elements common to all *sound reproduction units and their method of operation.*

It may be said at the outset that there is nothing complicated about this, yet extreme care must be observed to see that all necessary adjustments are accurately made inasmuch as each of the various elements has a definite relation to the other and only by the proper combination of settings can the entire assembly be made to reproduce properly all that is recorded in the sound track on the film.

The exciter lamp furnishes illumination to a slit mounted directly behind the condenser lens in the optical system and the image of this slit is projected by the small short focal length objective lens mounted in front of the optical system to the sound track on the film. The line of light thus projected to the film is known as the *scanning beam*. It naturally follows that all of the elements comprising this system must be in accurate alignment and adjustment in order that the best possible results may be obtained.

The sound track passing through the scanning beam continually varies the amount of light falling on the photoelectric cell, thus varying the current in the photoelectric cell circuit feeding the amplifier. These minute currents are then greatly amplified, first by a voltage amplifier, and then still further by a power amplifier, both of which are usually incorporated in one unit. The greatly amplified current is then passed to the voice coil of the loud speaking units and there changed to mechanical energy which moves the cone of the loud speaker reproducing audible sound waves.

Acoustical Considerations

The acoustic properties of an auditorium are determined principally by the shape of the auditorium, the material used on the walls and ceiling, the decorative drapes on the walls, the type of seats and carpeting and the final positioning of the stage horns.

When reverberation and reflections are encountered special considerations apply.

Reverberation.—When the contours of the walls and ceiling are such that there is no concentration of sound but reflections from many surfaces, due to the non-absorption qualities of the surfaces, the multiple reflections result in a general mass of sound known as *reverberation*. It may be recognized by the persistence of sound after the source has stopped.

Reverberation will occur when sound strikes the wall of an auditorium unless that wall has been treated with sound absorbing material.

Such material may consist of thick drapes, of special plaster, or anything that a great number of very narrow air channels into which the sound vibration penetrates, and is lost by reason of friction between the particles of air and the extremely narrow passages in which they must move.

In auditoriums where reverberation is present the stage horns should be set so that direct sound is projected into the seating area, and does not strike any reflective surfaces.

Reflection.—In auditoriums having large reflective surfaces, such as flat or curved walls, large ceiling domes, etc., reflected sound may be concentrated in certain areas within the seating section of the auditorium. Such a condition, depending upon the source of the reflected sound, is known as *side wall*, *ceiling* or *back-wall "slap."* These may be eliminated or greatly modified if the following procedure be employed:

Side Wall Slap.—To eliminate side wall slap, the two upper outside cells of the high frequency horn may be plugged with wool yarn. Do not pack tight. The yarn should be in a loosely formed cone.

Ceiling Slap.—Tilting the high frequency horn downward so that the direct sound is projected into the seating area and does not strike the ceiling, will generally eliminate this condition.

Back Wall Slap.—This condition is generally the most difficult to clear, especially in theaters with high balconies or large unbroken back wall areas as direct sound may be reflected from the back-wall to the seating area. Under these conditions the following adjustments are suggested:

1. If possible, the high frequency horn should be tilted downward so that the direct sound is just heard in the last row of seats, in which case the audience and seats will usually absorb the sound and avoid reflections.

2. If the conditions still exist, the entire loudspeaker system should be moved off center on the stage and adjusted to give proper distribution. This change alters the reflection pattern and back-wall slap may not be noticeable.

3. Another method of altering the reflection pattern is to angle the loudspeaker system with respect to the screen. The amount of rotation necessary for effective results depends upon the size and shape of the auditorium and the nature of the surfaces.

The Simplex Projector*

(**Installation Procedure**)

1. General.—An exterior view of a Simplex type E-7 sound projector is shown in fig. 1. The projectionist is urged to read these instructions carefully and thoroughly, to consult them frequently and to operate his projector in accordance with them. It is only through careful and systematic maintenance of the mechanism that continued high quality sound reproduction is obtained.

2. *Mounting.*—Mounting holes are aligned and positioned exactly as in earlier models of Simplex mechanisms. The projector is mounted on the pedestal or sound head in accordance with the requirements of the latter.

Warning.—Wherever the design of the sound head requires that the projector be shimmed to line up the drive shaft hole in its base casting with a "floating" shaft in the sound drive, place the shims as close as possible to the projector mounting holes. Otherwise extremely slight warping of the heavy base plate of the projector may occur when the mounting bolts are tightened and may impair the perfect factory alignment of the moving parts.

3. *Threading Lamp Wiring.*—The threading lamp, a standard type S-6, 6 watt, 120 volt, candelabra base, is wired through the shielded cable provided to any convenient source of 110 volts, *a.c.* or *d.c.*

4. *Framing Lamp Wiring.*—The framing lamp 3 watt, 6-8 volt bayonet base. Mazda No. 55 is wired to any convenient source of 6 volts, *a.c.* or *d.c.*, such as dry cells or a bell-ringing transformer.

5. *Lubrication.*—Using Simplex oil only, lubricate the mechanism in the following manner:

Fill the reservoir of the one-shot oiling system (see A, fig. 2) until the oil level is just below the top of the viewing glass. Next depress the pump handle A, fig. 4, pushing it down a few times until the back pressure causes it to rise slowly when released, instead of abruptly. The pumping action does not take place when the level is pushed down, but when the

*NOTE.—The Simplex projector is manufactured by the *International Projector Corporation* and is distributed by the *National Theatre Supply*, 90 Gold St., New York City, N. Y.

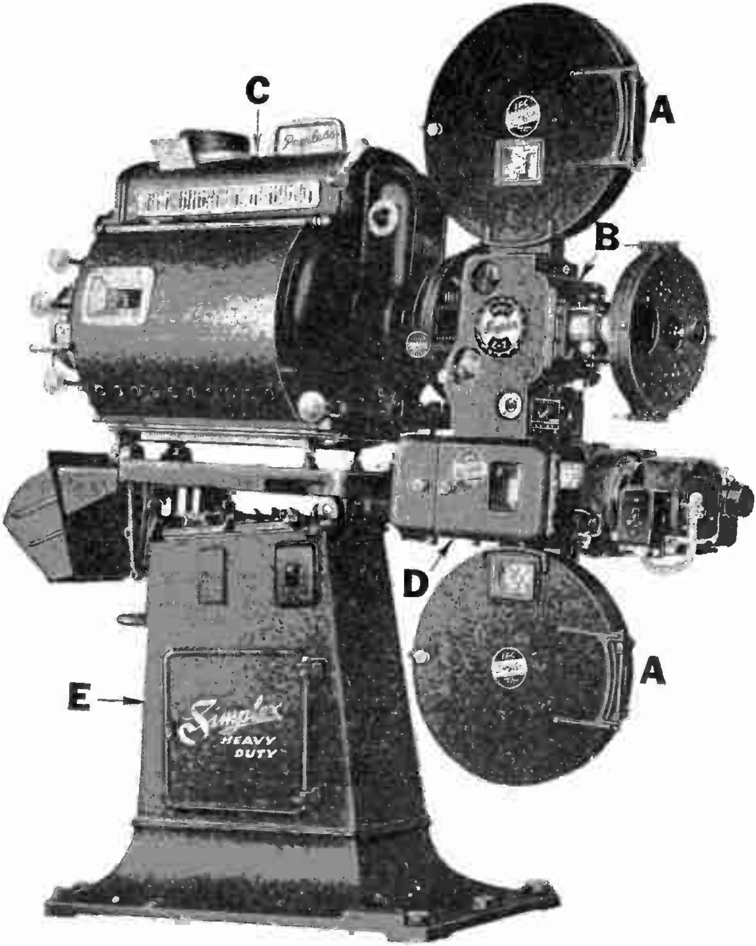


FIG. 1.—View of Simplex E-7 projector. In the figure A, represents film magazines; B, mechanism; C, arc lamp; D, sound head; E, pedestal.

spring pushes it back up. Hence, when it rises slowly the back pressure has become great enough to oppose the spring action, indicating that all parts served by the automatic system are satisfactorily oiled.

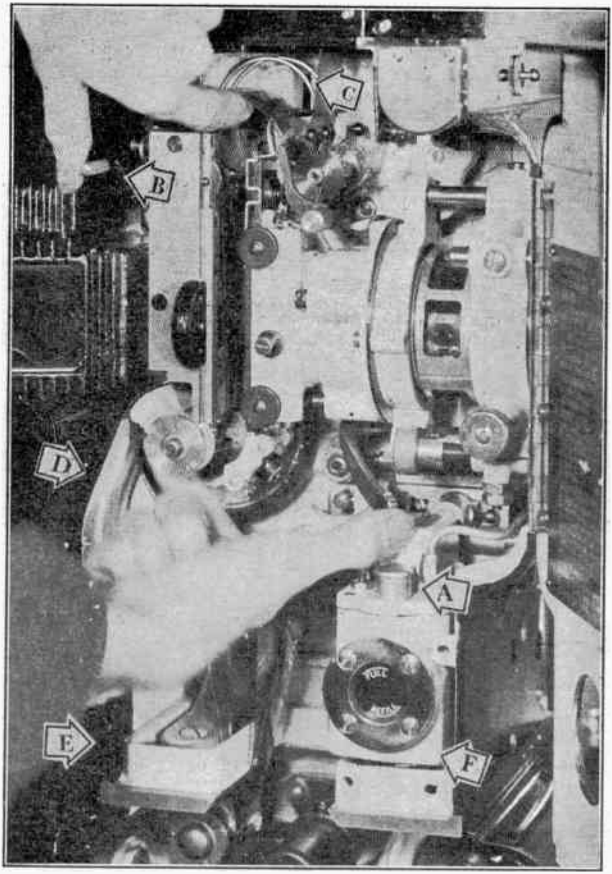


FIG. 2.—View of Simplex projector mechanism. In the figure A, represents reservoir of one-shot oiling system; B, fire shutter-lift lever; C, automatic fire shutter trip lever; D, drum cover; E, drum cover attaching screw; F, drain screw for oil reservoir.

Fill the intermittent movement with oil from either the drive side or the operating side, until the oil level rises in the oil cup just short of overflowing.*

Warning.—*Do not* fill the intermittent movement of the E-7 while the mechanism is in operation. The movement should be filled with Simplex oil to the indicated level on the sight glasses, only while the mechanism is at rest.

Provision is made in this movement to eject any surplus lubricant over and above the predetermined amount. When the projector is in operation the oil in the oil well is splashed and pumped all around the internal structure of the movement. Thus any lubricant added at this time will only raise the oil level and be ejected when the mechanism comes to rest, unnecessarily messing up the equipment and causing the projectionist to believe he has an improperly oil sealed movement.

Apply a few drops of Simplex oil (*not grease*) to each individual gear on the drive side of the mechanism and a drop or two to the governor, A. fig. 3, which can be reached with an oil spout of moderate length. This is done *only* when the projector is motionless, *never* while it is running.

Wipe away any oil that may have been spilled in the film compartment. Wipe away any excess oil that was placed on sprockets, idlers and so on just before shipment to prevent rusting under the unfavorable climatic conditions sometimes encountered in transportation.

6. Inserting the Lens.—Turn the interior focusing knob B, fig. 4. until the lens collar is in half-way focusing position, with equal focusing leeway at either side. Insert the lens (or the lens in its adapter) in the lens collars, making sure the front end of the lens or adapter clears the front shutter.

7. Preparing the Focus.—Remove the spot sight box as in Section 13. Strike the arc, and focus the lens as accurately as possible by hand, opening and closing the fire shutter momentarily to check the effect on the screen. (The projector is not running and there is no film threaded in). Make absolutely certain that the lens barrel not only clears the front shutter, but that there is sufficient clearance to allow the lens to be brought forward into focus after the film has been threaded. Lock the lens in the collars by means of the interior L, fig. 4, and exterior lens collar locking knob C, fig. 4.

*NOTE.—If the intermittent is oiled from the operating side, and the can used does not permit accurate control, excess oil will flow into the film compartment, and must be wiped away to avoid soiling the film; while if lubrication is applied at the driving side of the intermittent, an accidental excess will only add to the lubrication of the gears, and will do no harm. Therefore, if the oil can is one that will not permit filling the oil cup with *no* chance of overflow, it is recommended that the intermittent be lubricated from the drive side only.

Replace spot sight box. Start the projector, and line up the aperture image on the screen, using the lateral and vertical adjustments provided by whatever pedestal is installed. The projector is running; there is still *no* film threaded.

8. Threading.—Operating the gate and fire shutter lift levers as in fig. B, fig. 2, thread projector as in fig. 4, leaving loops as there indicated.

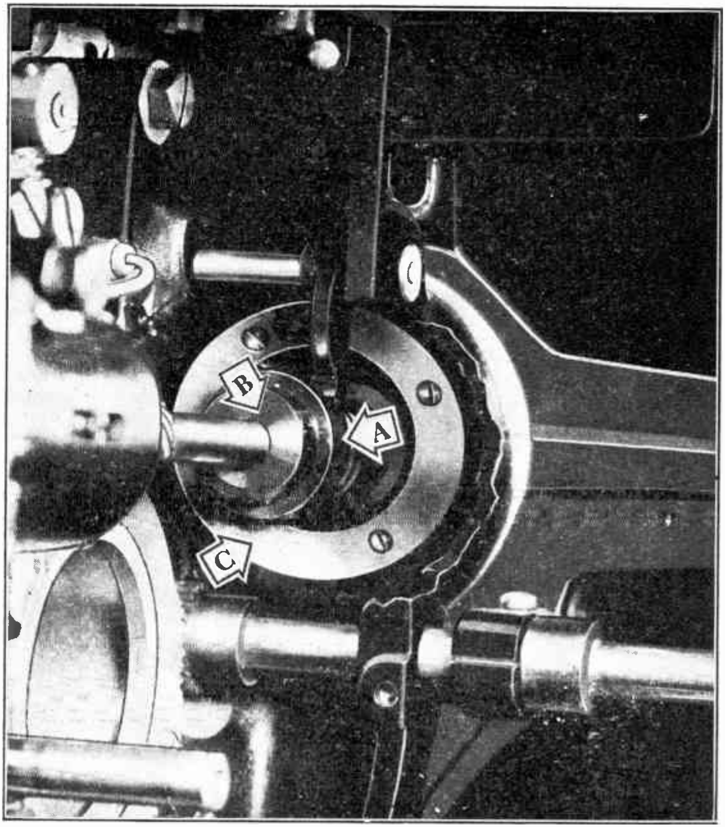


Fig. 3.—Simplex projector mechanism. In the figure A, represents governor flange; B, governor stop collar; C, governor ring.

Threading in frame is facilitated by pressing forward on the fire-shutter lift lever shown against upper thumb in fig. 2, which simultaneously lifts the fire shutter and lowers the framing lamp behind the aperture, lighting that lamp in the process.

Warning.—Be careful not to make the upper loop too large or the excess film may trip the fire shutter, which is designed to be tripped by piled-up film in case of a break. If the upper loop is made too large the projector will have to be stopped, and the loop shortened, before the performance can proceed. Fire shutter trip may be readily removed and replaced at will by simply pinching the two sides together and pulling from or inserting in receiving holes in cross bar.

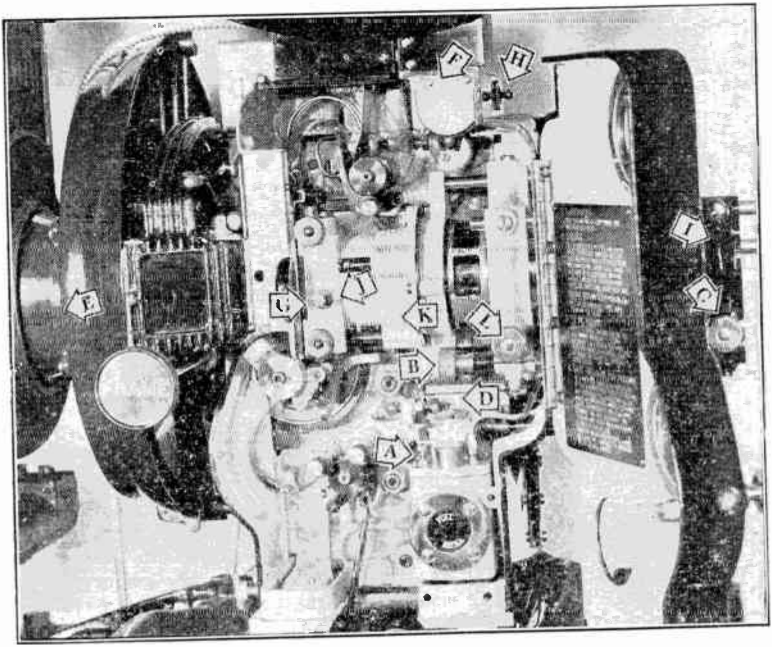


Fig. 4.—Simplex projector mechanism. In the photograph A, represents one-shot oil system pump handle; B, interior focusing knob; C, exterior lens collar locking knob; D, shutter adjusting slide locking screw; E, air deflector slide; F, threading lamp shield fastening screw; G, long tension pad adjusting screw; H, threading lamp switch; I, exterior lens collar; J, long tension pad adjusting screw lock nut; K, sliding film shield; L, interior lens collar locking knob.

9. Completing Installation Adjustments.—Thread a film showing titles. Start the projector and sharpen the focus, using either the interior focusing knob B, or the exterior focusing knob M, fig. 4, which will be found at the front of the mechanism on the operating side.

Check the shutter adjustment by observing the screen. The projector leaves the factory with shutter set perfectly, but they may have been disturbed in the course of installation.

If travel ghost is seen, release the locking screw of the shutter adjusting knob slide, which will be found inside the mechanism, just under the lens barrel. Operate the shutter adjusting knob until all travel ghost is completely cleared, and tighten down the locking screw D, fig. 4.

Routine Operation

10. Lubrication.—While the projector is new, the pump of the automatic oiling system is operated, as explained in Section 5, about every two hours that the projector is actually running. As time goes on, the intervals of lubrication are gradually lengthened until, when the mechanism is completely broken in; the automatic system is used only once about every *four* hours of actual running time, which schedule is continued through the life of the projector.

The intermittent oil viewing ports are observed from time to time, and the intermittent reservoir is refilled as described in Section 5, whenever the ports show that more oil is needed. It is always advisable to oil the intermittent from the driving side, rather than from the operating side as the sight glasses are readily discernible from this side.

The gears and governor are oiled, as in Section 5, at least once a day while the mechanism is new, but this lubrication is also applied less frequently as the machine breaks in, when it will be needed only twice a week. Gears and governor are *never* oiled while the projector is running

11. Cleaning.—Owing to the white-enamelled interior, illuminated by the threading lamp, and to the ease with which component parts can be removed (see removing instructions under *Maintenance* on the pages that follow) the mechanism is easily kept in spotless condition. All foreign matter that may impair the image, soil the film, or cause undue wear to moving parts, can readily be seen, is easily reached, and should be removed at once.

12. Pad Tension Adjustment.—The Simplex E-7 includes provisions by which the film pad tension can readily be adjusted, even while the projector is running, to compensate for the use of new, worn or oily film. The detailed instructions given in Section 40 should be consulted and used from time to time as the conditions of operation require.

Maintenance

13. Removing the Spot Sight Box.—This is removed from the operating side. It pulls out—merely open the door of the projector and draw the spot sight box toward you.

14. Removing the Rear Shutter Guard.—The rear shutter guard is built in two vertical sections, or halves, each of which can be taken off separately.

To take off the half at the operating side, take out the machine screw seen at the bottom of the shutter guard, when facing it from the operating side. Take out the corresponding screw at the top of the guard. Going now to the drive side of the projector, two machine screws will be seen facing you at the bottom of the guard. The one nearest the mechanism is taken out. The corresponding screw at the top of the guard is taken out. The operating side half of the guard can then be lifted off.

To take out the drive side half, remove *both* machine screws facing you at the bottom of the drive side of the guard, and *both* machine screws at the top of the drive side. Take out the nickel-plated hexagon bolt just above the drive side framing knob. The drive side half of the shutter guard can then be lifted out.

15. Removing the Front Shutter Guard.—At the top of the guard take out *one* machine screw—the one at the very top, and furthest to the front. Take out the corresponding screw at the bottom, the one furthest toward the bottom and furthest front. At the drive side remove the machine screw furthest toward the drive side. The front half of the guard can then be drawn off.

If the rear half of the guard is to be removed, loosen the shutter hub clamping screws and draw the front shutter off its shaft. At the top of the guard take out the topmost screw—the one corresponding to and just behind the screw that was removed to take off the front half of the guard. Proceed similarly at the bottom and at the drive side, again removing three screws in all. The rear half of the guard can then be drawn off the shutter guard support rods.

When the front shutter is replaced, it must be "timed" as described in Section 20.

16. Removing the Film Gate.—Put the gate in half-open position, by operating the gate-opening lever. Take off the knurled thumb screws at the top and bottom of the gate. Draw the gate toward you.

To replace it, again operate the lever to half-open position. Push sliding shield in lens mount forward. Engage the hole in the bottom of the gate with the lower stud, and slip the gate home, and replace the knurled thumb screws.

17. Removing the Film Trap.—Remove spot sight box (Section 13). Hold up the fire shutter by means of lift lever and remove the rear retaining screw with a thin screwdriver, as in B, fig. 5. Next remove the front retaining screw—the one indicated by the left forefinger in A, fig. 5. Lift the fire shutter again and draw the trap toward you.

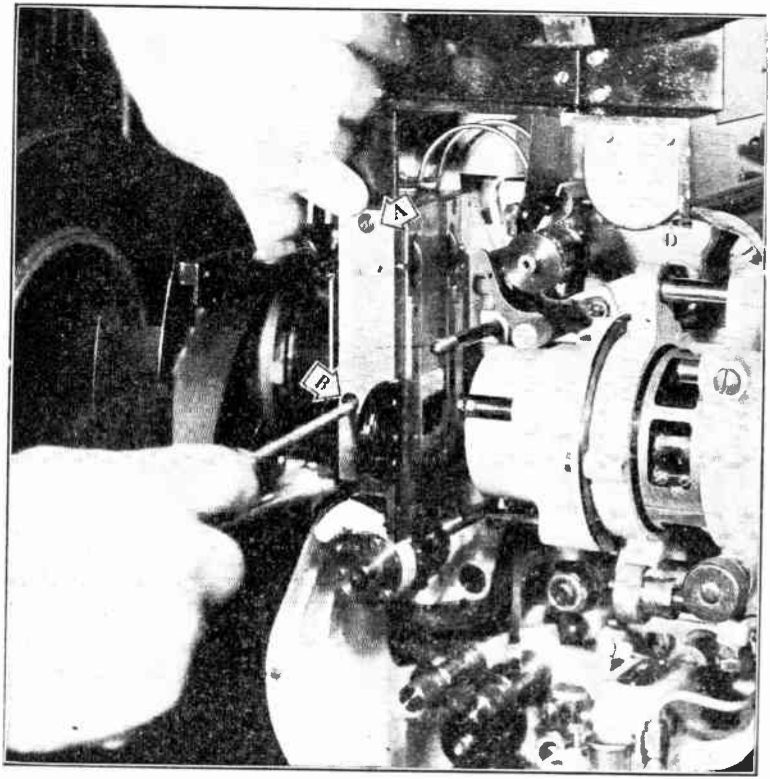


FIG. 5.—Simplex projector mechanism. In the figure A, represent film trap fastening screw (upper); B, film trap fastening screw (lower).

18. ***Taking Out the Intermittent Movement.***—Remove spot sight box, film gate and film trap (Sections 13, 16 and 17). Next remove right back drum cover D, fig. 2, just below the film trap. This casting is held by three knurled thumb screws, E, fig. 2, two along the bottom edge and one at the inner edge, half-way up. When these thumb screws have been loosened, draw the casting toward you.

At the drive side, loosen the flywheel clamping screw located at the side of the center flange of the flywheel hub.

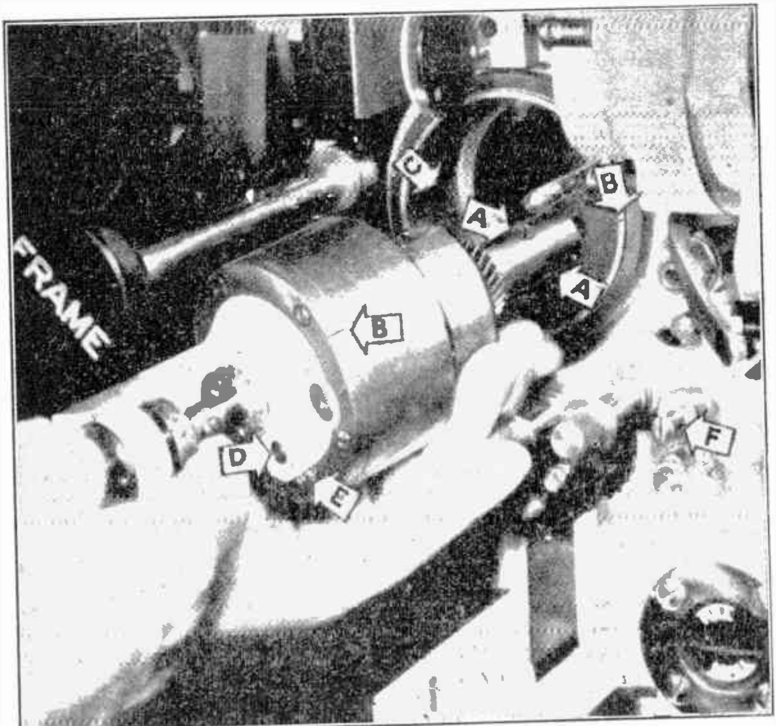


FIG. 6.—Simplex projector mechanism. In the figure A, represents flywheel gear fastening screw; B, intermittent guide lines; C, synchronizing cam; D, cam end play adjustment stud; E, cam end play adjusting locking screw; F, lower sprocket pad roller arm stud and fastening screw.

Warning.—Do *not* loosen the two shaft screws shown at A, in fig. 6, which are accessible through holes in the hub, but only the screw shown at A, in fig. 10. Remove the flywheel by withdrawing it from the shaft. Refer to fig. 7 and loosen the three screws holding the wedge shape retaining clamps shown at A, one of which is in contact with the screwdriver. Loosen all three screws until the clamps swing freely. The third screw, hidden in fig. 7 behind the intermediate gear, may be exposed by operating the fram-

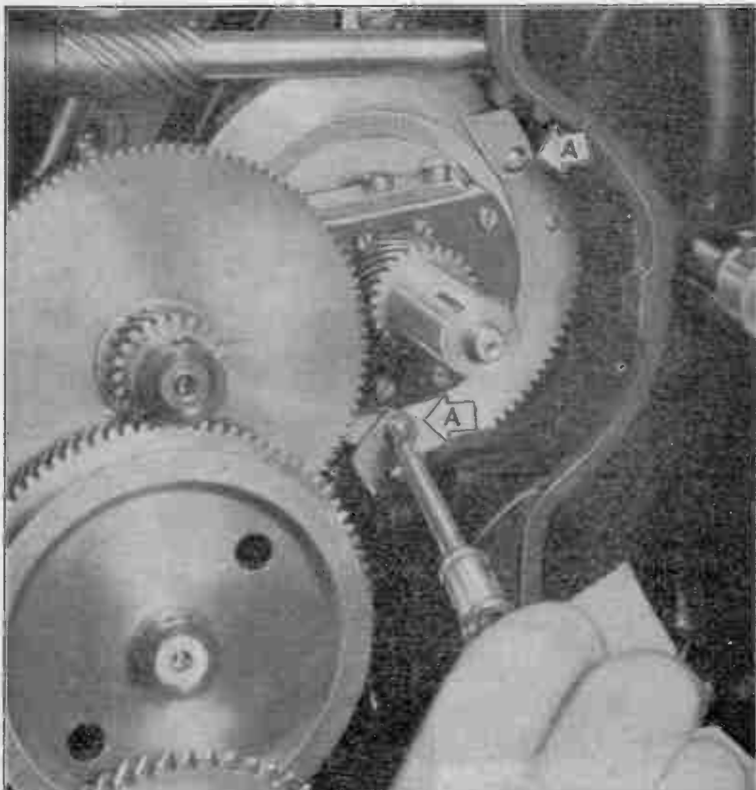


Fig. 7.—Simplex projector mechanism. In the figure A, represents intermittent retaining clamps.

ing knob. Swing the three clamps clear of the movement and tighten the screws lightly to prevent the clamps from dropping back into their previous position. It is not necessary to remove any gears on the drive side. Returning to the operating side, open the film gate with the gate opening lever, lift the fire shutter and draw the movement toward you, as in fig. 6.

19. Inserting an Intermittent Movement.—Make sure the case of the movement is clean, and that the surface of the synchronizing cam into which it fits C, fig. 6, is also clean. Oil both lightly as a precaution against rust.

The procedure to be followed will differ slightly, according to whether the movement to be installed is a new one, or one that has been taken out of the same machine and merely is being replaced.

In the case of a new intermittent, take off its flywheel as in Section 18. Slide the movement into place from the operating side, lining up the guide lines B, fig. 6, so the guide line on the movement and the guide line on the framing cam coincide perfectly. Push the movement home when the small dowel pin in the framing cam will match up with the hole in the movement provided to receive it. Be careful to see that flywheel gear and large micarta gear are properly meshed while performing this operation.

A movement that has just been taken from the mechanism and is to be replaced is slid part way (not all the way) into the synchronizing cam. Line up the guide lines roughly, deferring accurate alignment until later. At the drive side look for an "O" mark on the intermittent gear hub, just outside the gear, and a corresponding "O" mark or dot on the micarta gear that meshes with the intermittent gear. Rotate both gears until the teeth indicated by these "O" marks are in contact with each other. Now push the movement all the way into the synchronizing cam. Leaving the gears at the drive side properly meshed, as indicated by the "O" marks, return to the operating side and rotate the movement in the synchronizing cam until the guide lines are perfectly matched and push the movement home.

Whether the movement is a new one or an old one, it is now set properly in the synchronizing cam, and ready to be locked in place. This is done by means of the wedge-shaped clamps on the driving side, all three of which are swung down into the slots provided for them on the intermittent casing. Their holding screws are then tightened down. The flywheel is replaced on the intermittent shaft, the key in the flywheel fitting into the guide groove on the shaft. The flywheel clamping screws A, fig. 10, are tightened evenly. The rear casting of the housing, the film gate, film trap and spot sight box are replaced.

In the case of a new movement it is still necessary to "time" the shutters; if an old movement has been replaced with proper reference to the "O" mark, as explained previously, retiming the shutters will not be required, but it is best to check shutter timing in any case.

20. Timing the Shutters.—Loosen shutter adjusting slide fastening screw. Turn the shutter adjusting knob at the front of the projector, under the exterior lens collar, until the shutter synchronizing device lock screw D, fig. 4, is in approximately central position in its slot. Remove aperture plate.

Loosen the lens collar locking knob C, fig. 4, and remove the lens and air deflector slide E, fig. 4. Loosen both clamp screws on both front and rear shutters, leaving those shutters free to turn on their shafts. Remove the spot sight box.

Insert the shutter aligning barrel in the lens holder with the knurled screw toward the front shutter. Lock it in place with the lens collar locking screws. Insert the shutter aligning shaft in the aligning barrel with the grooves toward the front shutter, lifting the fire shutter out of the way and being careful not to strike the aligning shaft against either front or rear shutter blades.

Line up the narrow groove in the shaft—the one nearest the front of the shaft, with the front of the aligning barrel. When this is properly done, and the knurled screw is tightened down, the lower end of that screw will enter the wider of the two grooves on the shaft, holding the shaft in place but leaving it free to rotate even when the knurled screw has been turned as far as it will go. Rotate the shaft until its flat extensions face downward. Set movement in its locked position by turning motor flywheel or knob on end of motor shaft, *not by shutter shaft knob.*

Take the intermittent indicator and hold it vertically, with the diamond-shaped end upward. Slip the diamond over the axis of the intermittent sprocket shaft, which protrudes beyond the double bearing arm.

Turn the mechanisms over by hand in the normal direction, very slowly, watching the lower end of the intermittent indicator. Stop when the indicator just begins to move.

Grasp the rear shutter by its hub clamp and turn it until the edge of one blade (either blade, they are identical) comes up against the flat extension of the shutter aligning rod. Be sure the shutter is free so as not to turn the mechanism. While turning the shutter hub, push it toward the projector to assure that it will remain clear of the rear of the shutter guard. Lock the shutter in this position.

Turn the front shutter assembly similarly until the edge of either blade comes up against the flat extension of the aligning shaft, making sure the shutter remains centered with reference to its guard, so it will not rub. Lock the front shutter in position.

Remove the shutter aligning devices from the lens holder; remove the intermittent indicator.

Replace the aperture plate, spot sight box and lens, and refocus the lens as in Sections 6, 7 and 9.

A slight adjustment may be necessary (see Section 9) to remove any travel ghost that may remain.

21. Changing the Intermittent Sprocket.—The sound drive should first be disengaged, and the projector turned over by the front shutter knob to note the "feel" of the mechanism for comparison when the job is completed. The same test is repeated after the new sprocket has been installed, to determine whether the intermittent movement is then set properly.

The next step is removal of the film gate and film trap (Sections 16 and 17) and of the housing casting just under the film trap (first paragraph of Section 18).

The screw under the right hand oil sight of the movement is then taken out, and the oil drained into absorbing material. Any oil that reaches any part of the mechanism is carefully wiped away.

The four other screws in the same circumference are then removed, after which the double bearing sprocket arm can be drawn out. This must be done with extreme care to avoid striking the star wheel as it leaves the intermittent casing. The gasket between the arm and casing must be preserved undamaged, or replaced with a new one.

The fastening screw in the sprocket hub is then removed, and the star wheel with its shaft is drawn out of the double bearing arm. Lift the sprocket out of the arm, replace it with a new one. Slide the star wheel shaft back into position.

This is done very gently, with a slight twisting motion; no tools are used to drive the shaft. If the fit be snug, the shaft may be lubricated with a drop of Simplex oil. When the screw holes are lined up the fastening screw is replaced in the sprocket hub, but before it is tightened down, sprocket and star are pressed toward each other until there is *no* perceptible end play, but rotation is still perfectly free. Replace gasket.

The double bearing arm is now held in the left hand, the fingers of the right hand resting against the sprocket. In this way, and with due care to avoid striking the star, the star wheel is brought gently against the cam. The left hand now rotates the double bearing arm carefully until a locating hole in its casting engages a corresponding locating pin in the frame of the movement. Pin and hole are kept in approximate contact while the fingers of the right hand rotate the sprocket very slowly until they feel the star engage the cam radius. The double bearing arm is then gently brought home—locating pin and hole, star and cam, engaging simultaneously. Patience and care are essential; a single hasty motion may damage the star or cam and make satisfactory performance impossible.

With the arm in place, the five screws are restored; loosely at first. Then all are tightened down to draw the arm firmly against the intermittent casing. They are loosened again to allow the arm to shift downward of its own weight and again made up tight.

The projector is now again turned over by the front shutter knob to determine whether there is the slightest trace of binding between star and cam; comparison being made with the "feel" of the project or as it was before the sprocket was changed. Unless the action is absolutely perfect the five screws are loosened, the arm moved slightly, and the screws made up tight again. This process is repeated as many times as necessary until the star and cam action has been brought to perfection. The slightest hint of compromise at this point is not permissible.

The intermittent reservoir is then re-oiled, using clean Simplex oil from a clean can; gate, trap and housing casting are restored, and the sound drive is re-engaged.

Only men experienced in this work should undertake it. Otherwise the intermittent movement should be taken out as in Section 18, and returned to the manufacturer or to an authorized service station.

22. Replacing the Upper Feed Sprocket.—Take out the spot sight box, gate and film trap (Sections 13, 16 and 17). With a short screwdriver, reach through the hole in the upper sprocket shoe and remove the fastening screw from the sprocket hub. The gear and shaft can then be drawn out from the driving side.

Caution.—There is a thrust washer on the shaft, between the gear and the main frame, which is needed for proper spacing and must not be lost. The sprocket is lifted clear and the shaft is slid back into place through the hub of the new sprocket. The fastening screw is replaced; while this screw is being tightened down gear and sprocket are pressed toward each other to leave approximately .002 inch end play. Gate, trap and sight box are replaced.

23. Replacing the Lower Feed Sprocket.—Remove the housing casting below the film trap (first paragraph of Section 18). With a short screwdriver loosen the screw that holds the lower stripper stud in the main frame casting; tilt the stripper out of the way. Remove the fastening screw in the sprocket hub, and draw the sprocket off the shaft. The new sprocket should be slipped all the way in, leaving only approximately .002

inch end play, and the fastening screw made tight with the sprocket in this position. The shaft may be pushed in from the non-operating side through a hole in the large main drive gear. The stripper is tilted back into place, care being taken that it just clears the sprocket hub and its fastening screw. The stripper stud holding screw in the main frame casting is tightened down, and the housing casting replaced.

24. Replacing the Upper Feed Sprocket Shoe.—Do not attempt to take the shoe off the arm on which it mounts—the entire arm must be removed from the mechanism. The stud on which the arm rides is loosened with a screwdriver and drawn out with pliers. The arm can then be removed.

The shoe is mounted in the arm by means of a shoe stud and two browned machine screws. One screw holds the shoe stud, the other holds the shoe itself. Take both screws out of the arm, being careful not to lose the washer on the shoe screw.

The shoe and its stud will now come off. Slip the stud through the new shoe and replace it in the arm. Replace and tighten down the stud holding screw, pressing on the stud at the same time to remove end play. When this screw is tight the shoe should be free to rotate on its stud, but with *no* end play at all. The shoe locking screw (with its washer) is now replaced, but is *not* tightened down.

The arm and arm stud are now replaced in the mechanism, aligned so the shoe rides properly on the sprocket, and locked in place.

The shoe is then rotated on its own stud until the inner curvature of the shoe parallels the curve of the sprocket, and the shoe holding screw is then tightened down.

Above and a trifle left of the arm stud will be seen a hexagonal bolt and lock nut. These are adjusted to leave exactly two thicknesses of film clearance (approximately .015 in.) between sprocket and shoe, and the lock nut is tightened down in that adjustment.

25. Replacing the Lower Sprocket Pad Roller.—Loosen the lower sprocket and roller arm stud screw F, fig. 6, and draw screw and stud toward you. The pad roller arm can then be taken out. Loosen the holding screw of the shaft of the roller to be removed, after which the shaft, with its roller can be drawn out of the arm. Insert the shaft in the new roller and replace it in the arm. Allow the roller .005 inch play, and tighten down its shaft holding screw. Replace the arm in the mechanism and restore the arm stud and holding screw. In tightening this screw, press inward on the screwdriver to remove all end play from the arm.

At the top right of the arm will be seen a hexagonal bolt and lock nut. Adjust these for exactly two film thicknesses (approximately .015 in.) clearance between the sprocket and the *left* roller, regardless of which roller was changed. Lock the hexagonal nut in that adjustment.

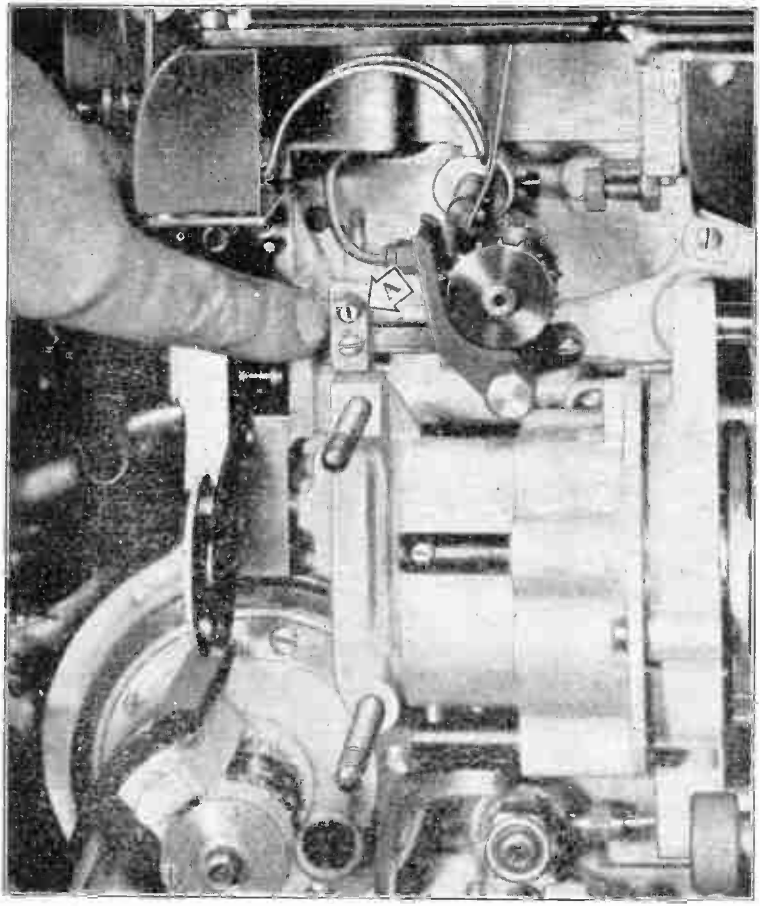


FIG. 8.—Simplex projector mechanism. In the figure A. represents film gate guide rod adjusting screw.

26. *Adjusting Gate Play.*—Remove gate. Loosen the gate guide rod adjusting screw locking screw B, fig. 8, and release the gate guide rod adjusting screw A, fig. 8. Work the gate opening lever back and forth while adjusting gate guide rod adjusting screw until the desired degree of friction is obtained; then tighten the locking screw and replace gate.

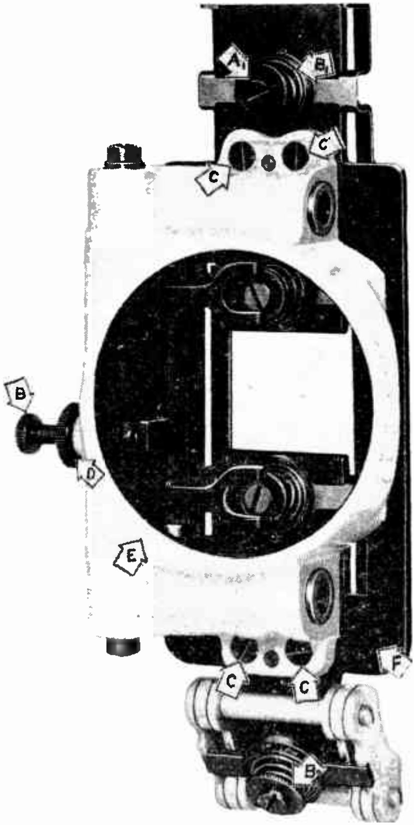


FIG. 9.—Simplex projector system. In the figure A_1, represents top tension pad adjusting nut retaining screw; A_2, intermittent tension shoe adjusting nut retaining screw; B, long tension pad adjusting screw; B_1, top tension pad adjusting nut; B_2, intermittent tension shoe adjusting nut; C, gate casting fastening screws; D, long tension pad adjusting screw lock nut; E, gate casting; F, gate plate.

27. Replacing the Threading Lamp Bulb.—Take out the two screws in the face of the threading lamp shield F, fig. 4. The 120 volt bulb, a standard 6 watt, candelabra base type, can then be unscrewed and replaced.

Warning.—The bulb cover is held only by the shield; unless supported by hand it will drop when the shield screws are taken out.

28. Replacing the Framing Lamp Bulb.—Take out the spot sight box (Section 13) and hold it upside down. Pressing on a nickel-plated stud that will be found near the rear of the spot sight box will lower the framing lamp within easy reach. The bulb is a Mazda No. 55, 6-8 volt bayonet base type.

29. Replacing the Main Drive Gear.—Remove the lower housing casting on the drive side. Take out the collar fastening screw in the main gear shaft, slip off the collar and draw the gear L, fig. 10, toward you.

Lubricate the new gear with a drop of Simplex oil. When installing it, rotate the lower feed sprocket until its gear meshes with the new main drive gear; then restore the collar, holding screw and housing casting.

30. Replacing the Intermediate Drive Gear Assembly.—Take off the intermittent flywheel as in Section 18, second paragraph, and the main drive gear as in Section 29. Take out the collar fastening screw in the intermediate gear shaft, slip off the collar, and draw the gear assembly, K, fig. 10, toward you. Lubricate the new assembly with a drop of Simplex oil on each gear. In installing it, after meshing all gears properly, make sure there is *no* end play. Restore the collar and fastening screw, the main drive gear and the intermittent flywheel. Retime the shutters as in Section 20.

31. Replacing the Lower Sprocket Driven Gear and Shaft.—Take off the main drive gear as in Section 29. At the operating side of the mechanism loosen the holding screw in the lower sprocket hub as in Section 23. The gear G, fig. 11, and shaft can now be drawn out from the driving side. Lubricate the new gear and shaft with a drop or two of Simplex oil.

32. Replacing the Upper Sprocket Driven Gear.—Proceed as in Section 22, taking out gear C, fig. 10, and shaft from the driving side. Lubricate the new gear and shaft with a drop of Simplex oil.

33. Replacing Oblique Shaft or Gears Mounted Thereon.—Remove the nickel plated cap located just behind the magazine screws at B in fig. 10 at the top of the mechanism. This may be done by inserting a screwdriver beneath the cap and prying it up. It is held in place by a circular spring. Remove the lower cover plate on the drive side of the mechanism. Remove the main drive gear by removing the screw which holds the retaining collar in place. Remove the intermittent flywheel as instructed in Section 18. Remove the intermediate drive gear by removing screw and collar which holds it in place. Disconnect the lower oil tube connector from the distributing block. The loop in this tube permits it to be bent downward slightly and away from the lower gear on the oblique shaft.

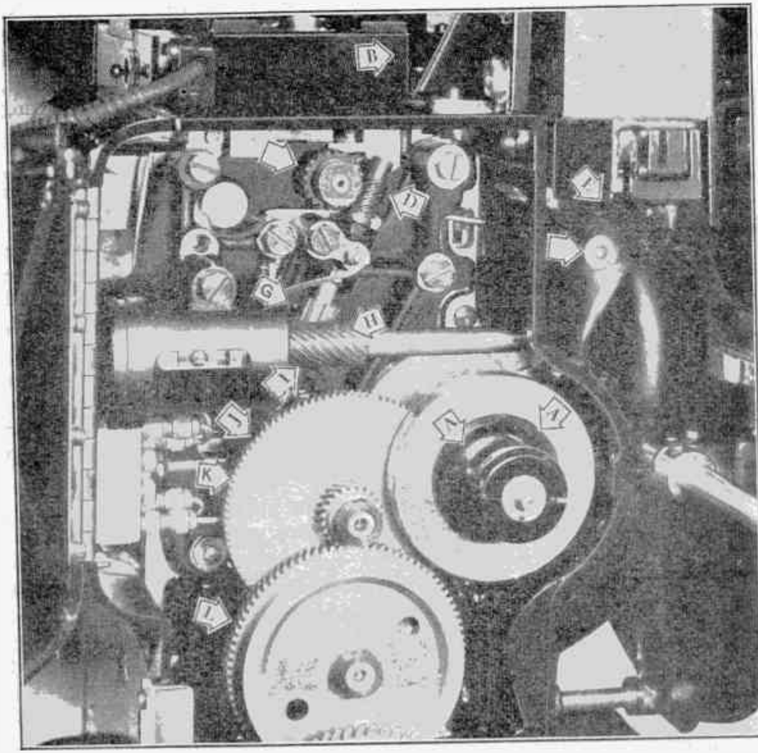


FIG. 10.—Simplex projector system. In the figure A, represents intermittent flywheel clamping screws; B, nickel plated cap covering hole through which oblique shaft may be removed; C, upper sprocket shaft driven gear; D, upper sprocket driving gear; E, fire shutter raising lever adjusting bushing lock screw; F, fire shutter raising lever adjusting bushing; G, shutter gear driving gear; H, shutter gear Woodruff key; I, shutter shaft gear; J, lower gear on an oblique drive shaft; K, intermittent drive gear assembly; L, main drive gear.

Remove screw which holds the lower gear J, in fig. 10, to the oblique shaft and slip the gear downward and off the shaft. Remove key from shaft. Loosen the three retaining screws on the middle gear. Slip the shaft upward slowly until the key in the middle gear is visible and carefully remove with a pair of long nose pliers. The shaft may now be removed entirely by withdrawing it through the hole in the top of the mechanism.

The reassembly is made in the reverse manner. At this time care must be taken to line up the key slot in the middle gear with the key slot in the shaft and insert the key before the shaft is pushed downward to its final position. Before tightening the three retaining screws of the middle gear, it should be located centrally, with respect to its mesh with the mating shutter shaft gear.

If necessary to replace sprocket driving gear D, fig. 10, on oblique shaft, remove shaft entirely, carefully remove pin from old gear and replace with new one, driving pin in carefully.

34. Replacing the Shutter Gear.—Before undertaking the work in the projection room read the following instructions through and make sure there is room enough in front of the mechanism to perform the required operation. If there is not, the projector must be removed from the pedestal, and the work done on a table or bench.

The following parts are removed in the order given: Front shutter shaft knob. Front half of front shutter guard, shutter and rear half of the guard (Section 15). Shutter adjusting knob holding screw and shutter adjusting knob. Drive side door stop slide screw, disconnecting the stop slide from the door.

Remove the two nickel-plated screws at the top of the front shutter ball bearing housing, and draw the housing toward you, removing it from the mechanism. Loosen the exterior lens collar holding screws and draw off the exterior lens collar.

Take out all screws that face you when looking at the front of the mechanism ***except*** for the following: hinge screws; two small screws at the top just left of the threading lamp toggle switch; three black machine screws placed close together toward the drive side of the base casting. None of these are disturbed. All others, seven in all, are taken out.

Both doors are then opened, and the entire front of the housing with the doors and the front shutter spider, is drawn forward and removed.

The front bearing casting (it surrounds the shutter shaft just behind the front shutter) is now removed by taking out the four screws that hold it. Turn framing handle on non-operating side counter-clockwise as far as it will go. Force back spring retaining collar sleeve and draw pin out of retaining collar being careful not to release spring suddenly. Draw off synchronizing spring.

At the non-operating side, take out the sliding sleeve guide screw A, fig. 11. Push the sliding sleeve C, fig. 11, forward in the sliding sleeve support casting B, fig. 11, until it protrudes slightly at the front.

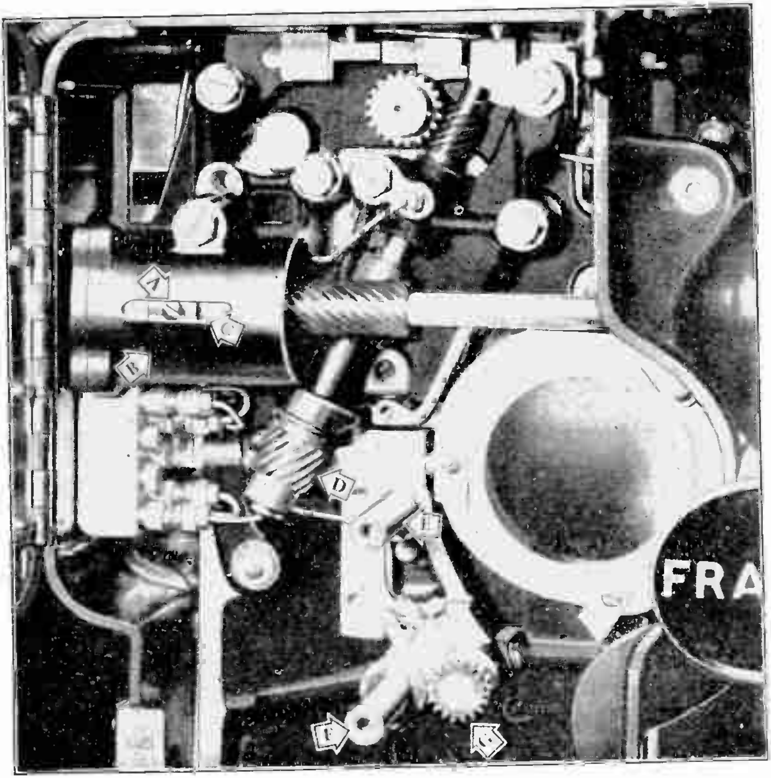


Fig. 11.—Simplex projector system. In the figure A, represents sliding sleeve guide screw; B, shutter gear sliding sleeve support casting; C, shutter gear sliding sleeve; D, lower gear on oblique drive shaft; E, intermediate drive gear stud; F, main drive gear stud; G, lower sprocket driven gear.

Grasping the sliding sleeve where it protrudes from its support casting, rotate it clockwise ¼ turn. Rotate the shutter shaft until the keyway to the rear of the shutter gear points upward. The sliding sleeve can now be drawn out and removed, and will take the shutter gear assembly with it.

Caution.—There is a Woodruff key, H, fig. 10, a wedge-shaped piece of metal, driving the shutter gear, which fits into the keyway in the shutter shaft. In drawing out the sliding sleeve make sure this key (which drives the shutter gear) is not lost. The remainder of the work is done on the shutter gear assembly, and not at the projector.

Take out the three screws that hold the ball bearing retaining plate and remove that plate. Remove the shutter gear I, fig. 10, ball bearing and lock nut assembly from the sliding sleeve.

Remove the lock nut fastening screw and take the lock nut off the gear. Slip the gear out of the ball bearing.

The new gear is installed by reversal of the foregoing procedures, with the following precautions:

Be sure to re-stake the fastening screw in the ball bearing lock nut.

The Woodruff key must be properly seated in the shutter shaft when the sliding sleeve assembly is replaced.

The sliding sleeve assembly must slip *freely* on the shutter shaft, but with *no* perceptible play.

Do not replace the front of the housing until the shutter shaft has been found to run smoothly. If it does not rotate freely the front bearing casting may have to be reseated by loosening its four screws, shifting it slightly, reseating the screws and trying the shaft again. It may prove necessary to repeat this procedure until perfect alignment is attained. Re-time the shutters as in Section 20.

35. Replacing the Main or Intermediate Gear Studs.—Remove the gear as described in Section 29 or 30. On the operating side, remove the self-locking stud retaining nut on the intermediate gear stud, or the film protecting stud nut on the main drive gear stud, with a suitable wrench. The studs may be prevented from turning by inserting a straight pin punch in the oil hole on the lower side. The stud E or F, in fig. 11, may now be drawn out from the driving side.

When replacing a stud, the cross hole at the end for the gear retaining collar screw should be vertical and the oil grooves should always be on the *lower* half of the stud surface. Before replacing a gear on the stud, oil the bearing surface with clean Simplex oil.

In the case of the removal of the intermediate drive gear assembly stud, time the shutters as in Section 20.

36. Replacing the Gate Top Tension Pad.—Take out the gate, Section 16, and remove the small screw at the center of the retaining screw, A1, fig. 9. Remove the round knurled nut B1, fig. 9 (the pad tension adjusting nut), and the spiral spring. Slip off the tension pad. Slip on the new one; restore the spring, knurled nut and adjusting screw. Adjust the new pad tension as in Section 39.

37. Replacing the Intermittent Sprocket Shoe.—Take out the gate (Section 16) and remove the small screw at the center of the bottom spiral spring—the sprocket shoe tension retaining screw A2, fig. 9. Remove the knurled nut (the sprocket shoe tension adjusting nut B2, fig. 9) and the spiral spring. Slip off the shoe and replace, restoring the spring, knurled nut and adjusting screw. Adjust the new shoe tension as in Section 39.

38. Replacing the Long Tension Pad.—Remove the four gate casting holding screws C, fig. 9. Separate the gate plate F, fig. 9 (which is located by two dowel pins), from the casting, and proceed as in Section 36.

39. Replacing the Long Tension Pad (Upper Pad).—Remove the gate as in Section 16, and set the upper pad adjusting screw for very light tension—just enough to hold the film flat against the runners and no more. Replace and remove the gate as often as necessary, testing the tension until the correct adjustment is obtained, which is then made permanent with the round knurled locking nut.

Intermittent Sprocket Shoe Tension.—Proceed exactly as for the upper tension pad. Tension should also be the same; just enough to hold the film to the base of the sprocket teeth, and no more.

Restore the gate, and remove all pressure at the center pad by backing off completely the adjusting screw B, fig. 9, and round locking nut D, fig. 9 shown at the side of the gate in G, fig. 4, and B, fig. 9 Run film, being careful to use a reel that has no camera jump in it, and watching the screen, tighten the tension by turning the external adjusting screw clockwise until the picture is steady.

Warning.—Make sure there is *no* excess tension, which will shorten the life of the runners, pressure pads, sprockets, star and cam, and tear sprocket holes in the film itself. Lock the correct adjustment with the round knurled nut.

In operation, the external long pad adjusting screw and locking nut may be used to compensate for difference between new, used or oily film, without first removing the gate as previously described. All that is needed is to back off the round knurled locking nut, and reset the adjusting screw, being careful *always* to use the minimum tension necessary for a steady picture. The correct adjustment is then made permanent with the locking nut.

It is very essential, in all adjustments made during operation, to be very careful to distinguish between projected unsteadiness and camera jump, and to avoid increasing the tension dangerously in an impossible attempt to cure the latter.

40. Reducing Intermittent Noise.—To cure imperfect adjustment of the intermittent movement, one symptom of which is noise, run the projector with no film threaded, and while the machine is in operation press against the flywheel shaft where it protrudes beyond the flywheel clamp.

If the noise disappears or is reduced in intensity, loosen the flywheel shaft screws (not the clamping screws). The shaft screws are shown in A, fig. 6, with the instructions *not* to loosen them when removing the intermittent.

Those screws having now been loosened slightly, pull or pry the flywheel shaft toward you (toward the non-operating side of the mechanism) the smallest possible fraction of an inch, and again tighten down the screws. Start the projector again; if there be any noise left again press against the end of the flywheel shaft as before. If this reduces the intensity of the remaining noise, repeat the process.

It is important *not* to try to take out all noise at once by moving the flywheel shaft over a longer distance, but to repeat the same procedure a number of times, and to stop it as soon as the shaft has reached the position in which the noise disappears or resists further treatment of this type.

If pressing on the end of the flywheel shaft does *not* reduce noise, or if there is still noise left after the foregoing described process has been followed to the limit of its usefulness, remove the drum cover as in the first paragraph of Section 18. Loosen the cam end play adjustment locking screw E, fig. 6, using the framing knob to bring the screw to the most convenient position. Run the projector without film and press inward on the cam end play adjustment stud D, fig. 6, until the noise disappears. Holding the stud in this position, stop the projector, and make the adjustment permanent by tightening down the locking screw.

If there be still noise left after these procedures, take out the screw under the right hand oil sight of the movement, draining the oil into rags or other absorbing material, and wiping away carefully any oil that reaches any part of the mechanism.

Loosen the four other screws in the same circumference and restore. without tightening the screw that was taken out. The double bearing arm is thus allowed to shift downward of its own weight. The five screws are then tightened. the intermittent re-oiled, and the projector is run again. Also see Section 21.

If there still be serious noise in the action of the movement the trouble is beyond ordinary projection room repair, and the movement should be sent for adjustment to the manufacturer or to an authorized service station.

41. Adjusting the Governor Stop Collar.—If the governor stop collar B, fig. 3, has for any reason been disturbed. loosen its holding screws and slide it toward the governor until it just touches the governor flange. Allow it to rest against the flange with *no* pressure, and tighten down the holding screws.

42. Adjustment of Fire Shutter.—Remove spot sight box (Section 13). Look down between the rear of the mechanism and the rear shutter guard to locate the fire shutter lift pin fastening screw. It is a black screw, the lowest that can be seen. Loosen it.

At the non-operating side of the mechanism. look in past the governor to locate the fire shutter lifting pin—a steel pin about ⅛ inch in diameter which engages the slot that raises the fire shutter. Lift this pin as high as possible, making sure it remains in its slot; hold it in that position and retighten the fastening screw.

Run the projector without film, and try to push the fire shutter down by hand without using too much force. If it can be made to drop, this adjustment was not perfectly carried out, and must be repeated.

43. Adjustment If Fire Shutter Jams.—Remove the spot sight box (Section 13). Note that just above the top of the fire shutter on the film trap there is a small stud or boss on the film trap casting. The top of the fire shutter, in raised position, should *not* quite touch this boss, but should clear it by about 1/32 inch. Loosen the fire shutter raising lever adjusting bushing lock screw E, fig. 10, about ¼ turn, no more. Do not take out this screw. Now, adjust the shutter height by turning the fire shutter raising lever adjusting bushing F. fig. 10. Turning this bushing clockwise raises the shutter, turning it counter-clockwise lowers the shutter. Tighten down the lock screw when the proper adjustment is obtained.

Readjust the fire shutter lifting pin in Section 42 and replace spot sight box.

44. Adjustment If Fire Shutter Interferes with Light Beam.—If this occurs, repeat the process described in Section 43. making certain the final adjustment leaves the top of the shutter no more than 1/32 inch below the bottom of the excrescence or stud mentioned.

45. Adjustment If Automatic Fire Shutter Fails to Trip.—The fire shutter trip C, fig. 2, should be operated manually from time to time to make sure the shutter works properly.

If it does not, take out the spot sight box and the film trap (Sections 13 and 17). Remove the shutter lever guard holding screw and take off the shutter lever guard. The parts of the shutter mechanism can then be cleaned with kerosene to remove gummed oil or other obstructions.

Warning.—The shutter lever guard should never be taken off unnecessarily.

46. Removing the Fire Shutter Mechanism.—Take out the spot sight box (Section 13) the film trap (Section 17) and the fire shutter lever guard (Section 45). The two black pivot pins are then pried out, after which the fire shutter can be drawn off. In replacing the shutter, check the fire shutter lift pin (Section 42) and make certain it is properly re-located in the slot that raises the shutter.

The Simplex Sound Head

Description.—The SH-1000 is a film propulsion mechanism for the reproduction of sound from 35 mm sound film by the photoelectric cell method. A motor assembly is required to drive the mechanism.

The sound mechanism is attached to the sound head support arm of the projector pedestal. The motor assembly, including motor and flywheel, flywheel guard and hand brake on a bracket, is attached to the front of the sound mechanism and drives the projector mechanism and the constant speed sound and hold-back sprockets in the mechanism through a reduction gear box.

The gear box may be removed as a unit. The hand brake, which engages the flywheel is provided to stop the mechanism in case of film breakage. The take-up is driven from the mechanism. Although belt drive is standard, chain drive may be used if desired.

Scanning System.—At the rear of the mechanism is the scanning system. It is assembled on a bracket attached to the sound mechanism by a special vibrationless mounting. The well known rotary stabilizer maintains constant film speed past the scanning beam. A prefocused exciter lamp (4 amp., 9 volt) on an adjustable bracket provides an intense source of light to illuminate the .0012 in. slit in the optical system.

Light from the optical system passes through the film sound track, and is reflected to the photoelectric cell by an adjustable lens mirror. The vertically mounted photoelectric cell and wiring are shielded from oil leakage and static pick-up.

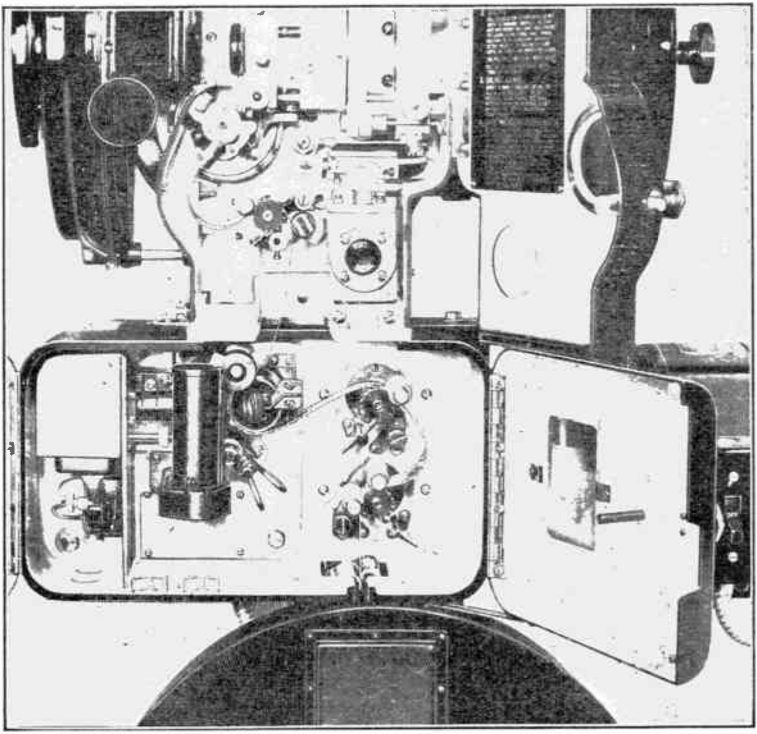


FIG. 12.—Showing operating side of Simplex sound head. The sound mechanism is equipped with a rotary stabilizer feature insuring uniform film motion essential to perfect sound reproduction. It also includes a pre-heated exciter lamp which guarantees instantaneous sound changeover. The vertical photoelectric cell is easily adaptahle to sterephonic and push-pull recordings if this form of sound reproduction is universally accepted.

The photoelectric cell output is coupled to the volume control amplifier by a fixed length of low capacity coaxial cable. The photoelectric cell polarizing potential is obtained from a voltage divider in the volume control amplifier, and the exciter lamp supply from the PU-1000 power unit.

The Drive Motor.—A motor operating on a 100-130-volt, 60-cycle *a.c.* supply is considered standard, although a 105-125-volt *d.c.* motor may be used as an extra. A 5-ampere fusetron is recommended for each motor circuit. If fusetrons are not available, a 20-ampere fuse may be used temporarily.

Scanner System Adjustment.—The main frame assembly is furnished with the exciter lamp bracket, lens tube and reflector lens, mounted and adjusted ready for use. It is recommended, however, that the adjustments be checked, using a 9,000-cycle film and volume indicator to make sure that the maximum response is obtained.

Before proceeding with the adjustment, it is necessary that the exciter lamp, the photoelectric cell and lenses be carefully cleaned with lens tissue, and all parts of the sound mechanism cleaned with soft cloth.

Exciter Lamp Bracket Adjustment.—The vertical and lateral adjustment may be accomplished by loosening the screws provided for this purpose. After the adjustments have been completed, be sure that all screws are tight. Maximum response is obtained when the filament of the exciter lamp is exactly centered horizontally and vertically on the lense tube slit.

Lens Tube Adjustment.—To focus the lens tube two methods of adjustment may be used They are known as the response test and the flicker test and may be performed as follows:

1. Response Test.—Thread the machine with a 9,000-cycle test film, run the machine, and adjust the lens tube for focus until maximum response is obtained on a volume indicator, or aurally.

2. Flicker Test.—Thread the machine with a 9,000-cycle test film, place a white card between the film and reflector lens, and turn the motor hand wheel slowly. The film frequency lines make a definite flicker of light on the card. The tube is focused when the lines are stationary. If they move downward on the card, the lens tube should be close to the film—while if they move upward the tube should be farther from the film.

Reflector Lens Adjustment.—If properly adjusted the spot of light on the photoelectric cell should be about 7/16 in. in diameter, and centered on the anode of the cell. To position the spot of light loosen the clamping screw at the top of the lens holder, and carefully rotate the lens until the spot is centered on the anode. To change the size of the spot, move the lens in or out of the bracket as required. If further movement is required, loosen the two lens holder mounting screws, and adjust as necessary.

These adjustments are more readily performed if the photoelectric cell is removed and a piece of transparent paper substituted. A still more convenient method is to remove the glass envelope and cathode from an old photoelectric cell and substitute a transparent paper cathode which may be attached to the cathode support wires. With either of these methods the spot can be accurately centered and adjusted for size.

Threading Film in Sound Mechanism.—The film should be threaded in the projector mechanism in accordance with the instructions given therein. The sound mechanism should be threaded in accordance with fig. 13. Make sure that the lateral guide roller is closed after film is threaded. If the mechanism door does not close, the lateral guide roller is open. Pull the lateral guide roller assembly outward, after the threading is completed, until it is in firm contact with the knurled adjusting nut. In some instances the assembly may be pushed inward as it is closed and may not return to its proper position due to friction.

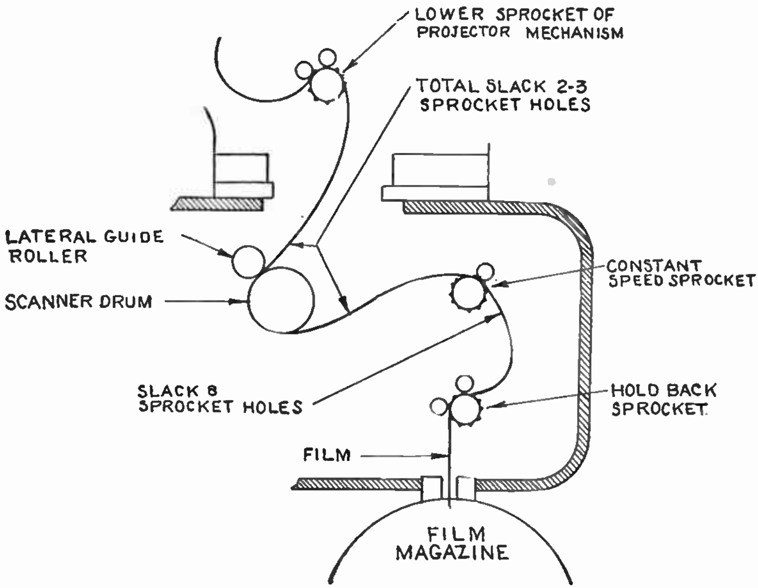


FIG. 13.—Illustrating threading of film in sound mechanism.

Amplifier Circuits

Volume Control Amplifier.—The volume control amplifier, fig. 14, is of a two-stage, resistance coupled inverse feed-back type using two 6J7 tubes. The maximum gain is 46 db., input impedance 250,000 ohms output impedance 10,000 ohms. It contains the main system volume control, consisting of a potentiometer having nineteen 2 db. steps. which regulates the volume by varying the signal voltage applied to the grid of the second tube.

An adjustable resistor (R_3) having a range of 6 db. is provided in the cathode adjustment circuit of the first tube of the amplifier for equalization of the photoelectric cell output by adjustment of the gain of the amplifier.

Plate and filament supply are obtained from the power amplifier, and a voltage divider in the volume control amplifier provide photoelectric cell polarizing potential.

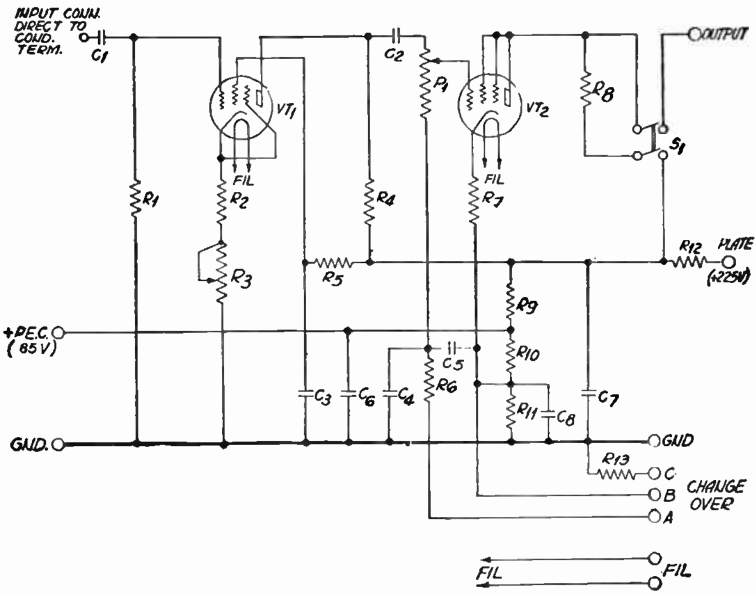


Fig. 14.—Schematic connection diagram of volume control amplifier.

Volume Control.—The main volume control should be adjusted as required to compensate for the variations in prints, size of audience. etc.

In establishing normal operating level initially for a specific auditorium, set the volume control on step 9, run a standard recording such as the *Academy Test Reel*, and adjust the gain control in the power amplifier as required to obtain adequate volume level in the auditorium.

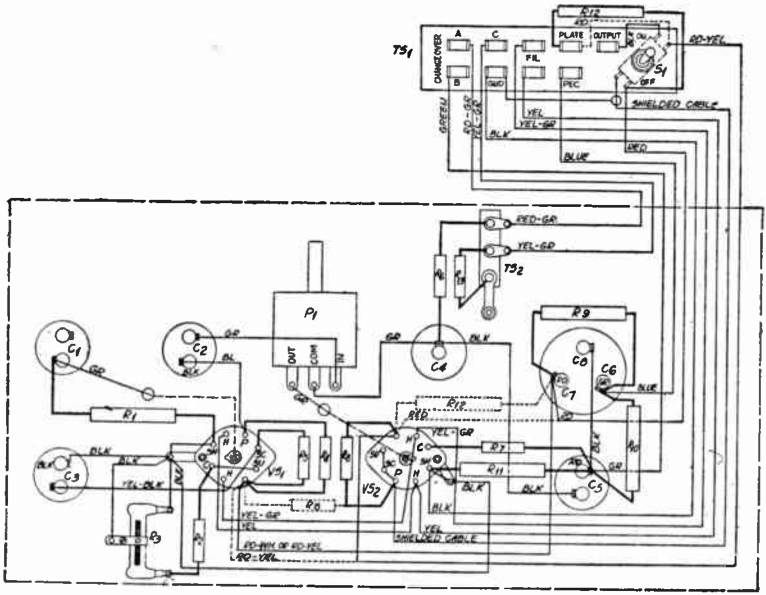


FIG. 15.—Showing wiring diagram of volume control amplifier (bottom view).

Power Amplifier.—The AM-1001 power amplifier is of the resistance coupled, push-pull type and is operated from the usual 105 to 125 *a.c.* 60-cycle supply. The maximum gain is 60 db. input impedance 10,000 ohms, output impedance 12 or 24 ohms. The output is 15 watts, maximum noise level −35 db.

A schematic diagram of the power amplifier to which the volume control amplifier delivers its speech output and also from which it obtains its filament and plate operating voltages is shown in fig. 16. The power transformer and rectifier arrangement is of the conventional type, except that the filters use condensers only and have no choke coil.

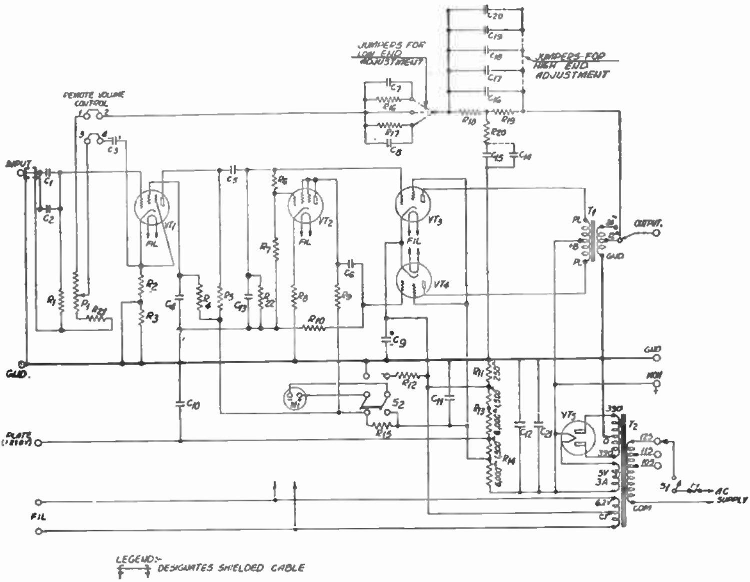


Fig. 16. Schematic connection diagram of power amplifier.

Switching Circuits.—A typical change-over switching arrangement is shown in fig. 17. The change-over is made at either machine by depressing the switch button on the front of either amplifier, there being two sets of amplifiers in a system. In depressing the switch the sound and exciter lamp are being transferred at the same time. An electronic type of sound change-over is here employed.

In the *ON* amplifier the second tube has normal bias, whereas in the *OFF* amplifier the bias of this tube is increased beyond cut-off and the amplifier is inoperative. There is no switching in the sound circuit and the change-over is instantaneous and noiseless. The exciter lamp change-over provides for pre-heating of the stand-by lamp on *a.c.* to eliminate thermal lag in the filament. The pilot lamp indicates the machine in use.

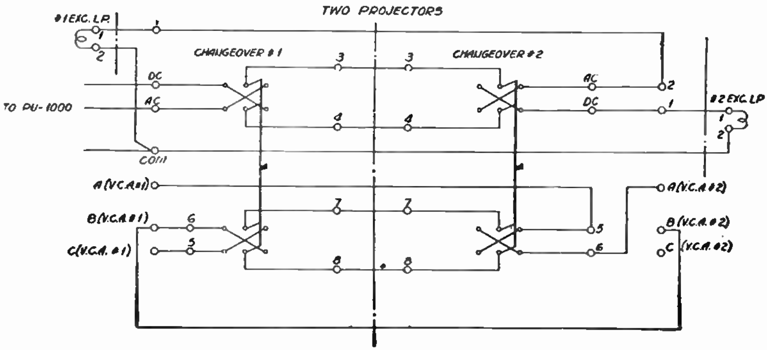


FIG. 17.—Showing changeover sound and exciter lamp wiring arrangement.

Amplifier Selector Switch Wiring.—A three-position amplifier selector switch as illustrated in fig. 18 is employed when two or more amplifiers are operated in parallel.

In the mid-position of the switches all system amplifiers are connected in parallel. In the left position amplifier No. 1 operates and No. 2 is disconnected. In the right position amplifier No. 2 operates and amplifier No. 1 is disconnected.

Inoperative amplifier (output, external heater, plate circuit and warping circuits) may, therefore, be disconnected and the system operated on the remaining amplifier. Only one warping circuit is used at a time. The input is not disconnected in order that the inoperative amplifier may be tested and serviced while the system is operating.

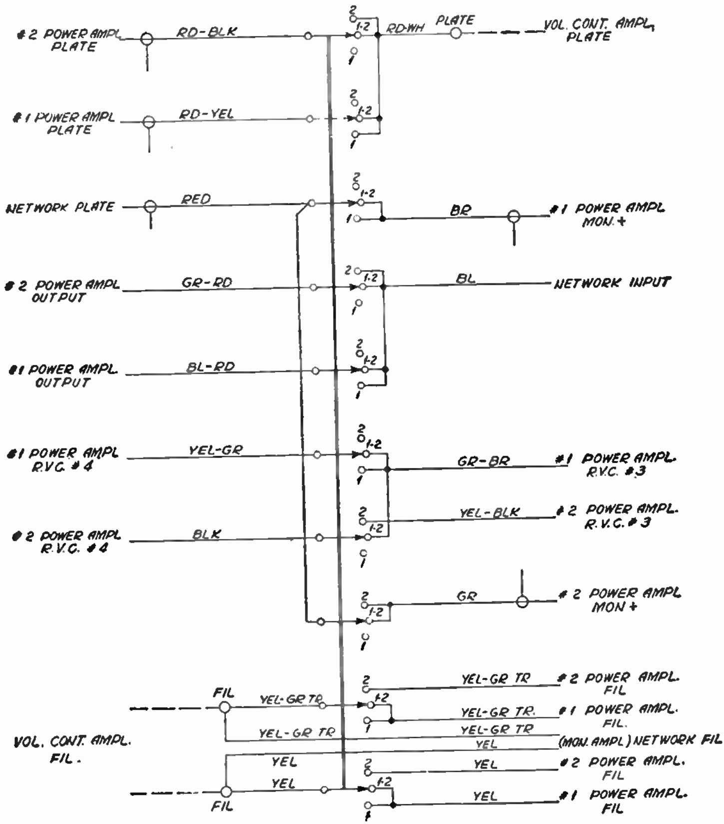


Fig. 18.—Schematic diagram of amplifier switching arrangement.

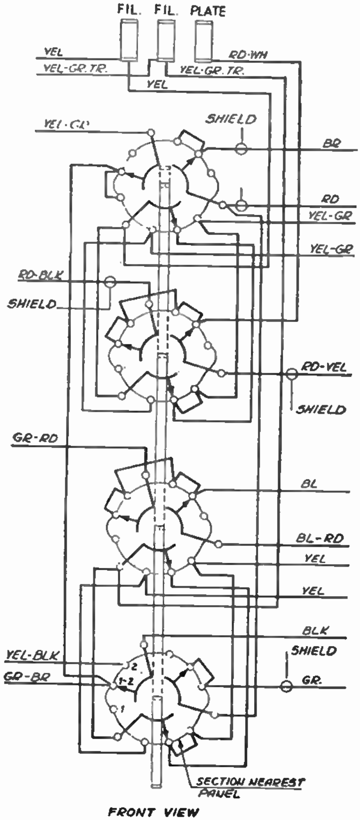


FIG. 19.—Cabinet wiring diagram of amplifier switching arrangement

The Western Electric Sound Projector*

A front view of the machine is given in fig. 20 showing the film, lamp and photocell compartments. The film path is perhaps as simple as has been offered to the theater industry and approaches a straight vertical line from the holdback sprocket in the projector head to the lower magazine with no free loops to be set. The film is under a tension of approximately 300 grams from the lower sprocket in the projector to the sound sprocket in the reproducer.

The threading operation is both quick and simple. The film is passed under the upper filter arm roller, over the scanner drum, and over the lower filter arm roller. Before engaging the sound sprocket the film is pulled down until the arrow and line on the filter arm assembly are in approximate registry. The film is then engaged around and under the sound sprocket and over the idler roller which guides it into the fire trap of the lower film magazine.

The Film Filtering Mechanism.—This consists of a solid flywheel mounted on the scanner shaft which supplies the inertia elements, two filter arms and rollers connected together by a spring which furnish the compliance element where rates of flutter below 10 cycles are concerned, and a viscous dashpot connected to the lower arm, which provides the damping element. Above 10 cycles the attenuation of disturbing frequencies by the film compliance gradually exceeds that furnished by the spring. While the filter parts are simple, an explanation of how they function involves a rather complicated electrical analogy.

It is sufficient here to state that the upper filter arm, which is not directly damped by the dashpot, supplies an attenuation of the order of

*NOTE.—The projector herein described is commonly known as the *Century* type and is manufactured by the *Century Projector Corporation*, New York, N. Y. The amplifying equipment and certain other parts, however, are manufactured by the *Western Electric Company*.

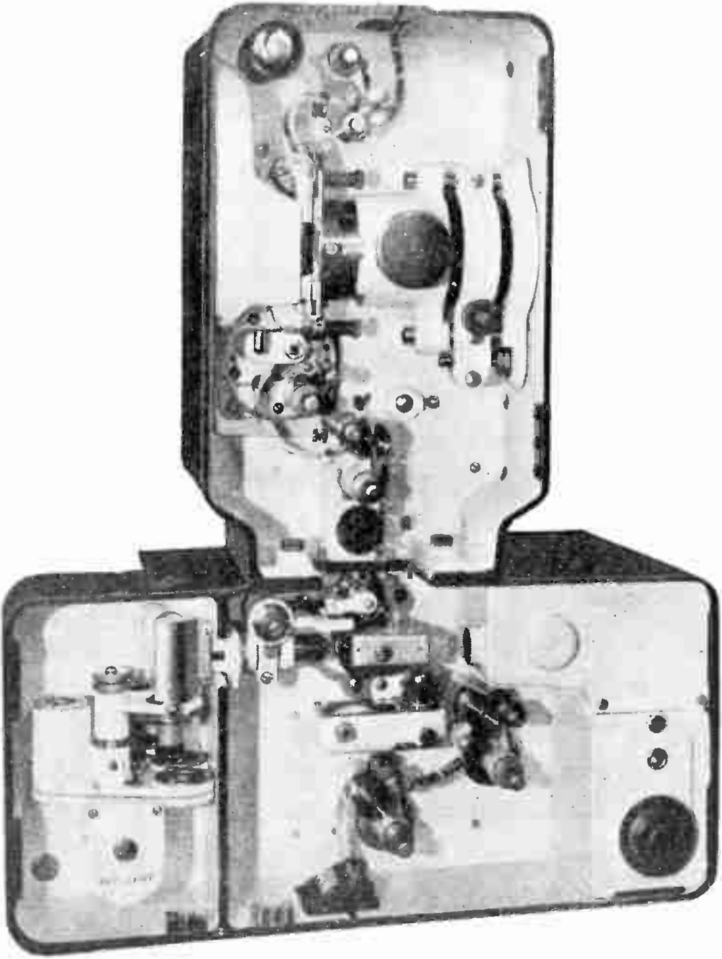


FIG. 20.—The new Westrex Master sound reproducer is here shown (from the operator's side) assembled with *Century* mechanism. Note particularly the Hydro-Flutter Suppressor which is mounted midway between the scanning drum and the sound sprocket. This unit, in combination with other features of the new design reduces "*flutter*" to .80%. *Courtesy Western Electric Company*

12 db. per octave against disturbances arising in the projector head. This permits the elimination of the free loop between picture and sound head with a reasonable factor of safety. A further factor of safety against slow rates of disturbances occurring in either the projector head or take-up magazine has been provided by the use of a new sprocket tooth with a relatively wide base.

In the present film path where the film operates between two sprockets under a relatively fixed tension, is it desirable that the tension beyond the two sprockets be maintained at either a greater or lesser value than that existing between the sprockets. The tension of the film on the incoming side of the upper sprocket, which is in the projector, is substantially zero, so that the requirement is met at this point.

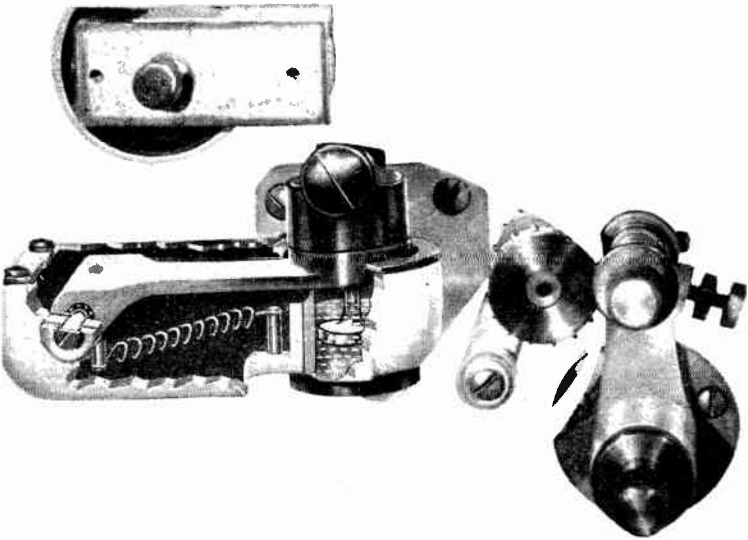


FIG. 21.—Close-up view of the film filtering mechanism. Essentially the device consists of a pivoted, fluid-damped lever arm which makes contact with the film loop between the sound sprocket and scanning through a ball bearing pad roller. It takes up any slack in the loop, however slight, and conversely responds when the loop tightens. This action results in the application of a precisely constant driving force to the scanning drum and hence, practically flutter-free operation. *Courtesy Western Electric Company.*

The film leaving the lower, or sound sprocket, is at substantially the same tension as the take-up. As long as the take-up tension is maintained at a higher value than that in the filtered path, the holdback sprocket can be eliminated with reasonable safety. In the event the take-up tension approaches the same value as that in the filtered film path the variations in take-up tension may cause the film to travel between the limits of free play between the tooth and sprocket hole. The effect is, of course, attenuated by the belt action of the film on the sprocket and on the lower idler roller.

To minimize the amount of disturbance that might occur from this source, a new sprocket tooth has been developed which more nearly fits the sprocket hole, with due consideration for film shrinkage, etc.

The Scanner Assembly.—This consists of a scanner drum, shaft and flywheel and mounts in the main frame as a unit. The filter arm assembly also mounts as a unit and consists of two arms and rollers mounted on cone pivots operating in ball races to produce a minimum of bearing friction and lateral play.

The upper roller is provided with a lateral adjustment to provide means for aligning the sound track with respect to the principal axis of the optical system. The dashpot is easily removed for inspection. The liquid used in the dashpot has been chosen for its small viscosity change with temperature to insure a sufficiently uniform damping characteristic.

The Optical System.—This consists of a flexibly mounted lamp bracket which takes the theater prefocused base 7½-amp., 10-volt exciter lamp, the Bausch and Lomb 41-87-35 objective, a collective lens, and a photocell. The collective lens images the aperture of the objective lens onto the cathode of the photocell and gives approximately a uniform area of variable-intensity illumination on the cathode with modulation of the light beam.

The Photo-Electric Cell.—This is flexibly mounted and is coaxially coupled to a remotely-located photocell amplifier.

The photo-electric cell mounting plate is so designed that it is interchangeable with a two-stage photo-electric cell amplifier, should that arrangement be preferred to the coaxial cable coupling.

The Driving Mechanism.—This is somewhat different from current practice and contains some interesting features, particularly when considered from the standpoint of ease of assembly and alignment. With the exception of the scanner assembly, the sound sprocket shaft is the only one that is mounted in the main frame casting. This shaft is driven by the motor through double vee-belts.

Since the motor is flexibly mounted, the vee-belts provide a coupling that transmits very little motor vibration to the film drive mechanism. Double belts are used to minimize the effect of belt irregularities on the machine's performance. The belt drive also simplifies the motor alignment problem. Different motor speeds are accommodated by a change of pulleys. If synchronous interlock operation is desired, the vee-belts are replaced by a silent chain drive.

Also mounted on the sprocket shaft are the silent chain sprocket for driving the projector head and a gear to couple with the take-up pulley shaft. The take-up pulley and its driven gear are located by means of a stub shaft on a spider that centers on the sprocket shaft and is locked by two screws to bosses on the main frame. An idler to tension the projector drive chain is also mounted on the spider. The take-up belt tension is adjusted by loosening two screws and rotating the spider.

Performance.—Fig. 22 shows a chart of flutter as measured on a pre-production model of the reproducer. It will be observed that the total integrated flutter from 2-200 cycles does not exceed ±.09%, while no discrete disturbance between 2½ and 200 cycles is greater than ±.05%. Occasional irregular disturbances in the bands between 0-1 and 1-2½ cycles reach as high as ±.06 and ±.08%, respectively. This results from the fact that full advantage of the new sprocket tooth could not be taken because a few laboratories still release on film that does not have standard positive perforations.

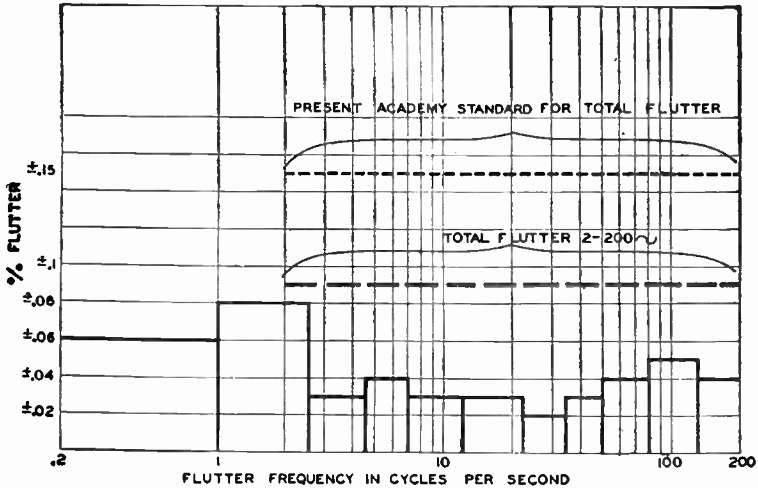


FIG. 22.—Flutter performance chart.

The type of film path and filter system used in this reproducer is substantially identical with that used in several designs of studio recorders and re-recorders. Tests set up to simulate operation under adverse conditions indicate that little or no effect was discernible in the reproduced sound.

Film weave in this system appears to be negligible. In one test. sprocket eccentricity to the extent of 18 mils was introduced and while the filter arms were set into considerable motion. only a very small increase in measured flutter was found. A piano recording was reproduced under this condition and listeners were unable to detect the effect of the sprocket eccentricity. The photo-electric cell network and coaxial cable, pick up no machine noise, that is audible under any normal condition of operation.

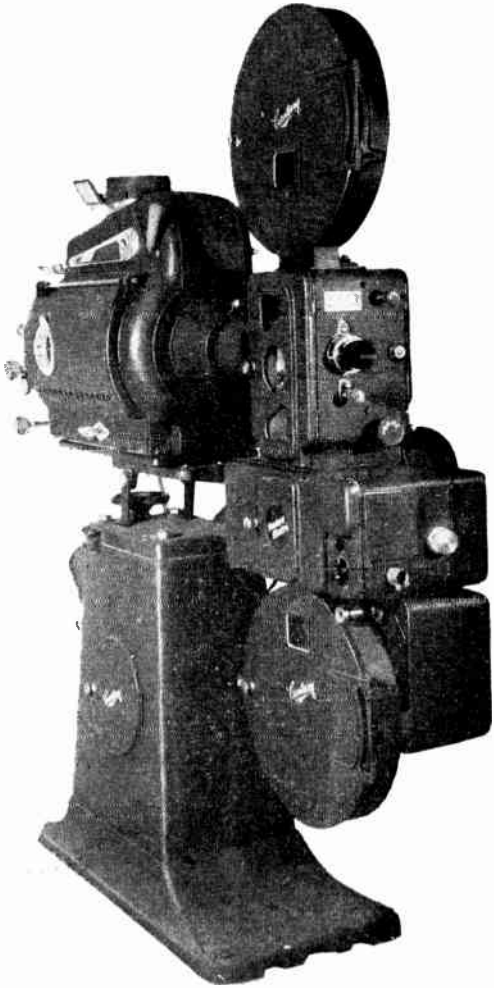


FIG. 23.—The new Westrex Master Sound reproducer is here shown assembled with the *Century* mechanism and base. The equipment may be used, however, with any standard mechanism. *Courtesy Western Electric Company.*

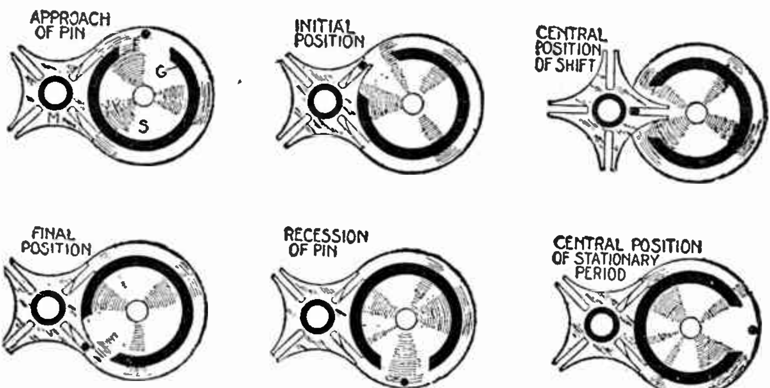
Installation Procedure

General.—An exterior view of a *Century* projector is shown in fig. 23. This projector is adaptable to all types of sound heads.

It is suggested that a careful study be made of this mechanism in order to become familiar with all its features. Careful, systematic maintenance of the mechanism is essential to obtain continued high quality sound reproduction.

The mechanism has two slow speed shafts (the feed and take-up sprocket shafts) which have been designed with oil-less type bearings. In shafts such as these, ball bearings are not used because of the slow speed of rotation. Oil reservoirs are provided on each bearing to supply the necessary lubrication.

Working Principles of the Intermittent Movement.—Various devices have been introduced for producing the intermittent movement necessary in projecting motion pictures. 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 spaced on a shaft to take the film.



Figs. 24 to 29.—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.

The teeth mesh with perforations in the film and thus secure a positive movement.

Of the various intermittent movements the *Geneva* is exclusively used, and its working principles remain the same. Its operation is shown progressively in figs. 24 to 29.

The nature of the motion is as follows:

1. Begins slowly (fig. 25);
2. Accelerates to a maximum at the mid-position (fig. 26);
3. Gradually slows down to zero (fig. 27).

A photographic view of the intermittent movement employed in the *Century* type projector is shown in fig. 30.

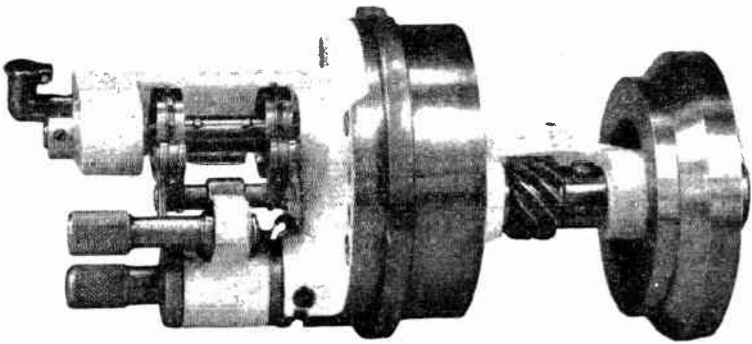


FIG 30.—Intermittent movement. *Courtesy Century Projector Corporation.*

Mounting the Projector.—In addition to the two tapped holes usually provided for holding a projector, there are four other holes located in the base which may be used for additional support. Sound heads designed for this additional support will have corresponding holes.

In older types of sound heads it may be possible to re-drill the sound head and add spacers, thus taking advantage of greater stability between the sound head and the projector.

The height of the optical center above the mounting surface of the sound head is standard as well as the position of the aperture with respect to the mounting holes. This projector can, therefore, replace the Simplex type projectors with no adjustments necessary in lamphouse or sound head.

Referring to fig. 31, which shows the construction of the main drive shaft and gear, No. 1 is the main drive shaft; No. 2 is the main drive gear; No. 3 is the shaft and coupling device to the sound head; No. 4 is the set screws clamping together the main shaft, main drive gear and coupling shaft from the sound head. The main drive shaft is designed for a 7/16 inch coupling shaft. The end of the main drive shaft is provided for coupling

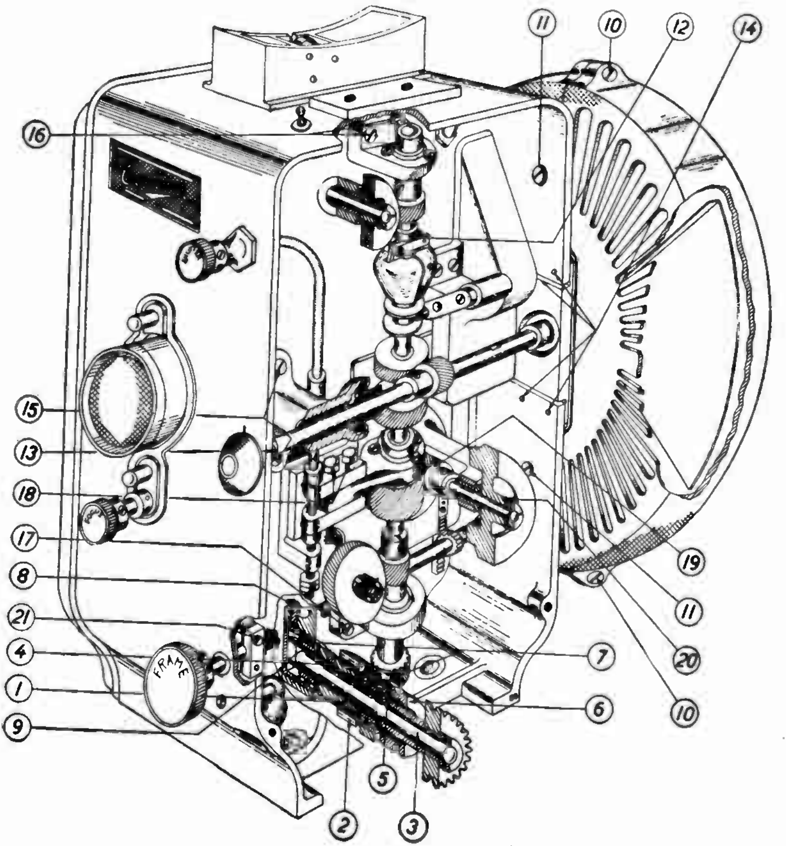


Fig. 31.—Showing driving side of Model "C" *Century* projector.

to a pinion drive such as is used on Simplex type projectors. When used in this type of drive the set screws No. 5 clamps the pulley No. 6 around the end of the split main drive shaft. This in turn clamps the outside of the pinion as well as the set screws clamping between the teeth of the pinion. The whole assembly including the sound head coupling rotates on the ball bearings No. 7.

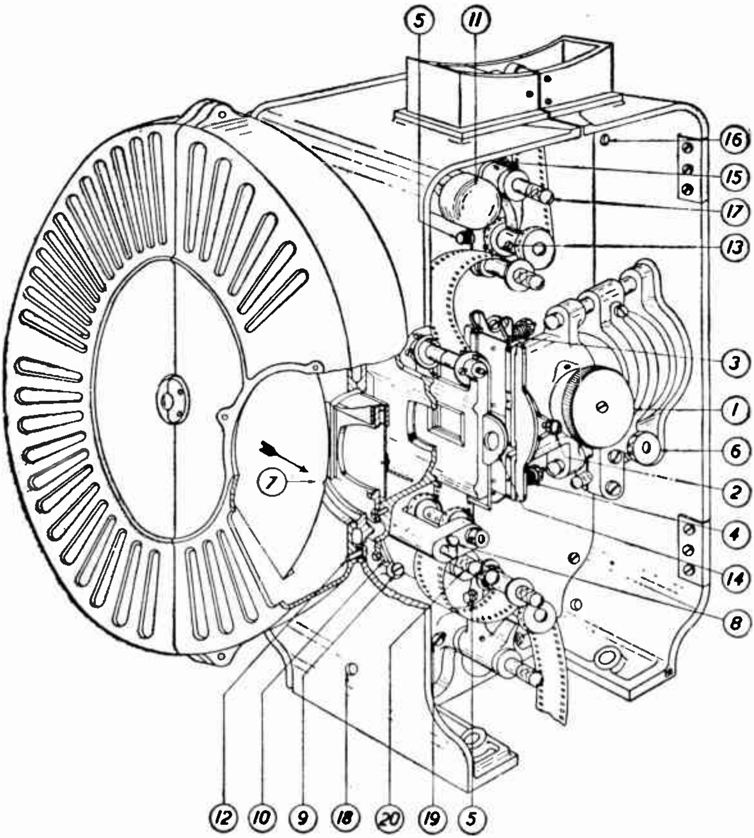


FIG. 32.—Operating side of Model "C" *Century* projector.

Operating Instructions

The Gate.—The large nickel plated knob No. 1, fig. 32, in the center of the projector on the operating side opens and closes the gate. To open the gate, give it a half turn to the right. The gate will open and the knob will remain in that position automatically locking the gate in open position.

To close the gate, push the center of the knob with the thumb or hand and the gate will close automatically. In the closed position the gate is locked and cannot be opened except by turning the knob as directed.

The gate is mounted at the rear of the lens holder on a sliding tube. This type of construction assures accurate alignment of the gate with the film trap and prevents displacement of the gate due to accidental bending.

To remove the gate for inspection, open the gate as previously described and loosen the holding screw No. 2, fig. 32. The gate can now be pulled straight toward the trap. This will disengage the two supporting studs which hold the gate in the lens tube.

The gate pads are long and heavy and are designed to give uniform pressure against the film over their entire surface.

The lever design assures that exactly equal pressure is applied to both sides of the film which has been found so necessary in the elimination of picture jump and weave. The combination of the tension springs, levers and pads has been designed so that there is minimum disturbance of the pads as slices go through the projector.

The tension of the pads is adjustable over a wide range through tension springs No. 3 and No. 4, fig. 32. After a little experimenting, the best operating pressure will be found for any condition of film. It is suggested that until these optimum values are found that the adjustment nuts be in about mid-position. A safety feature on the adjustment will be found in the stops provided. so that the tension adjustment nuts cannot be tightened so far as to lock the film in the gate. It is desirable to operate with as little tension as possible on both the upper and lower pads and still maintain a steady picture. The lighter the tension, the less wear on sprockets, shoes, pads, etc.

Pad Rollers.—The upper and lower pad roller arms are opened by pushing the roller knobs toward the rear of the projector. The pressure pads on the intermittent sprocket are opened by pushing the knob downward.

The upper and lower pad rollers in open position provide for automatically setting the loops above and below the gate. The lower pad roller also provides a means of measuring the correct distance on the film between the picture aperture and the sound aperture, thus assuring exact synchronization of sound and picture.

Although there are no tension springs showing on the pad rollers each has a scientifically designed tension device built into the pad roller arm providing just the right amount of tension for optimum performance. Each pad roller arm has a positive stop in closed position, which prevents undue mutilation of the film. These stops are adjustable.

The upper and lower pad rollers should be adjusted so that there is a clearance of two thicknesses of film between the pad roller and the sprocket. This clearance is adjusted by means of the stop screw No. 5, shown in fig. 32.

The intermittent sprocket pad assembly is adjusted by loosening the set screw No. 7, fig. 33, and turning the shaft. The pad assembly should be turned so that the pads just make contact with the intermittent sprocket with little or no pressure being applied. When film is threaded through the intermittent it will depress the pad shoes by an amount corresponding to the thickness of the film. This will be the correct amount of tension for best operation.

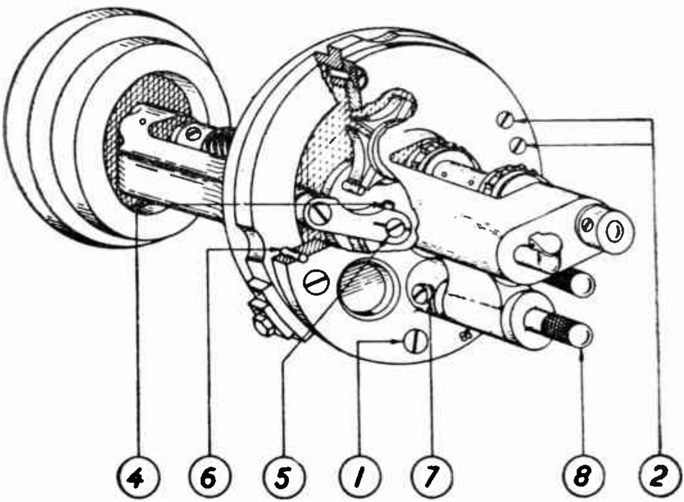


Fig. 33.—Intermittent movement of Model "C" *Century* projector.

Installing the Lens.—The lens holder is designed for half size lenses including the latest F2 lens recently developed. (No change in the shutters has to be made for this high speed operation.) With the proper adapters the holder will fit any projection lens. Care should be taken that the front of the lens is towards the screen, otherwise the quality of the picture will not be satisfactory.

The lens focusing knob should be turned so that the lens clamp is in the center of its full length of travel. Insert the lens into the holder and clamp it lightly in place with lens clamp knob No. 6, fig. 32. If the focus is not good, when the picture is projected, the lens may be shifted back and forth until a fair focus is obtained. The lens clamp is tightened and the final accurate focusing done with the focusing knob which extends through the projector case toward the front.

Timing the Shutters.—Each projector has been set up and run in the factory so that when it is received, the shutters should be in time. However, it is well to check this point as follows:

The spot sight aperture is located in the fixed shutter guard on the operating side of the projector. The red glass in the aperture is removable by pressing it in with the thumb and pushing it upward. After the red glass has been removed it will be noted that an indicator across the aperture is used for timing the shutters.

When the projector is turned slowly by hand it will be observed that the shutter blade has been notched at the edge of No. 7, fig. 32. This is the blade which is used in timing the shutter with the intermittent sprocket.

Turn the projector slowly by hand and observe the intermittent sprocket. When the sprocket has advanced two teeth from its stationary position, stop the projector. This alignment must be done very accurately. If the shutter be in time with the intermittent the notch on the shutter blade will line up exactly with the indicator across the spot sight aperture. If this condition cannot be obtained, then the shutter should be loosened from the shutter shaft and rotated until this condition is obtained and the shutter locked in position.

Before changing any of the foregoing settings be sure that the timing of the shutter cannot be corrected by adjusting the shutter timing knob on the front of the mechanism. If the shutters are moved on their shafts be sure that the shutter timing adjustment is set in the center of its full length of travel before locking them to their shafts.

After timing the shutter as previously explained, the final adjustment may be made with the projector running. Any travel ghost which may be present can be eliminated by adjusting the shutter adjustment knob.

An easy and very satisfactory way of checking the shutter timing is to proceed as follows:

It will be noted that the hub of the flywheel on the intermittent movement is slotted. Turn the projector until this slot is parallel with the shutter shaft, at the same time the intermittent sprocket is moving. In this position the notch in the shutter blade should be directly opposite the wire indicator which is across the spot sight aperture.

Oiling of Projector.—Do not oil ball bearings. Place a drop of oil on each gear daily. An excessive amount of oil does no more good than just enough. Any excess of oil will be thrown off the gears and will eventually make the inside of the projector look very dirty if it is not cleaned away.

Put a drop of oil into the oil cups on the upper and lower sprocket shafts.

The intermittent should be filled with oil through the oil cup No. 8, fig. 32, on the operating side of the projector, so that the oil gauge will show about half full. If by chance too much oil be put into the intermittent, it will run out of the vent hole on the outer bearing near the flywheel. Otherwise no damage will result in running the intermittent too full of oil. To remove any excess oil from inside the intermittent, the bottom screw shown in No. 1, fig. 33, can be removed and as much oil as is necessary drained out. A clean cloth should be placed under this screw, before it is removed, to catch the oil and prevent it from running down into the sound head. Replace the screw and refill the case if necessary.

It is better not to add oil to the intermittent while the projector is running unless this seems desirable in case of emergency. The intermittent cam acts as an oil pump so that while it is running the oil pumps from the bottom of the case and supplies the cam, star-wheel and bearings with a constant supply of fresh oil. There may, therefore, be no indication of oil level in the gauge glass while the projector is running.

Oil the projector before running. Oil can snouts have a defect which causes them to get caught in the gears if this work be done with the projector running.

The following oiling routine is suggested: *Once each day* put a drop of oil on each gear. *Once each week* check the oil level in the intermittent and put a drop or two of oil in the oil cups on the sprocket shafts.

Threading the Projector.—Open the gate, the upper and lower pad roller arms and the intermittent sprocket pad. Thread the film through the fire trap in the upper magazine; under the upper sprocket; over the upper pad roller; through the gate; under the intermittent sprocket; around the lower pad roller; over the lower sprocket and down to the sound head, as shown in fig. 32.

Light the framing lamp by operating the pilot light switch on the top of the projector case. Place the film in the gate with the intermittent sprocket engaged with the film so that it is in frame. Close the intermittent pad assembly. Close the gate. The film may be observed in the gate through the observation hole provided in the gate holder tube. The film is now engaged with the upper sprocket with a tight loop. Close the upper pad roller.

A check of the proper framing may be made by observing the sprocket holes below the film trap shoes. With a frame line at the bottom of the trap shoes, the upper side of the sprocket hole of the upper hole next to the frame line will come exactly even with the bottom of the trap shoe.

The film is now engaged with the lower sprocket with a tight loop. Close the lower pad roller. With the film properly threaded through the sound head to the lower magazine, the projector is ready to run.

Framing.—The framing of the picture on the screen may be changed by turning the framing knob on the front of the projector. The degree of clamping of the framing shaft may be changed by tightening or loosening the screw No. 2, fig. 31, on the framing clamp.

Maintenance.—Other than keeping the projector properly oiled and cleaned, the maintenance of this projector should be minimum. There are several new and important improvements which should be noted and taken advantage of in the regular maintenance routine. Do not use benzine or other cleaning fluids on the gears or shafts where excess amounts might enter the sealed ball bearings.

Practically all the operating units of the machine are easily removed and replaced. Most of the removable parts are located by dowel pins making the replacement comparatively easy.

Included are the following: The main drive shaft; the vertical shaft assembly complete; the shutter shaft complete; the film trap; the film gate; the upper and lower sprocket shafts; the upper and lower pad roller arms; the intermittent movement, and the intermittent sprocket pad assembly.

Spare parts including complete assemblies of the foregoing may be kept in the booth at all times and replacement quickly made in case of an emergency.

Removal and Replacement of Parts

Removing the Intermittent.—Take off the flywheel of the intermittent on the driving side of the projector by taking out the screw No. 20, fig. 31, which holds it and slips it off the cam shaft. Frame the intermittent carriage all the way in its down position. Remove the film gate. On the operating side of the projector, loosen the four screws holding the intermittent shown in No. 9, fig. 32. Turn the intermittent about an eighth turn in a clockwise direction until the cut-outs in the intermittent cover are even with the holding screws. Pull the intermittent straight out of its carriage. Care should be taken not to hit the intermittent sprocket against anything which would damage the teeth.

Installing a New Intermittent Movement.—Refer to fig. 34. Set the shutter adjustment mid-way of its full travel, open the film gate to maximum stop. Move the intermittent carriage to its down position. Remove the flywheel of the new movement by taking out the holding screw and slipping it off the cam shaft. Loosen the intermittent stop screw A.

Remove the red glass from the spot sight aperture. Rotate the mechanism by hand until the notch in the shutter blade is even with the bottom of the spot sight aperture.

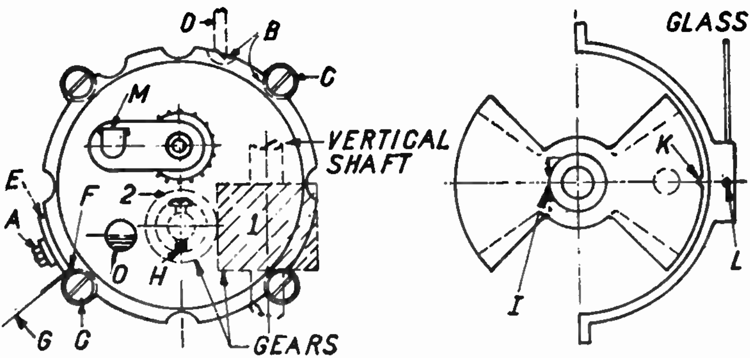


Fig. 34.—Details of intermittent movement Model "C" *Century* projector.

Take the movement in your hands and rotate the gear on the cam shaft until the sprocket advances exactly two teeth. Be careful not to move the gear from this position.

Insert intermittent with cut-outs B, matching the locking screw C, and lower end of film trap shoe D. Turn the movement counter-clockwise so that the intermittent gear 2, meshes with its driving gear 1, on the vertical shaft. Continue turning the movement until these two gears press lightly together with no backlash or play. Tighten any two opposite screws C. Push the stop plate E, tight against the stop F. and tighten screw A. Now loosen the two C screws which were previously tightened and turn the movement clockwise until there is a space of 3/64 (.046) of an inch between stop plate E and its stop F. Hold the movement in this position or insert a 3/64 inch spacer between stop plate E. and stop F, and tighten all four screws. Note: A dime is approximately 3/64 in. thick.

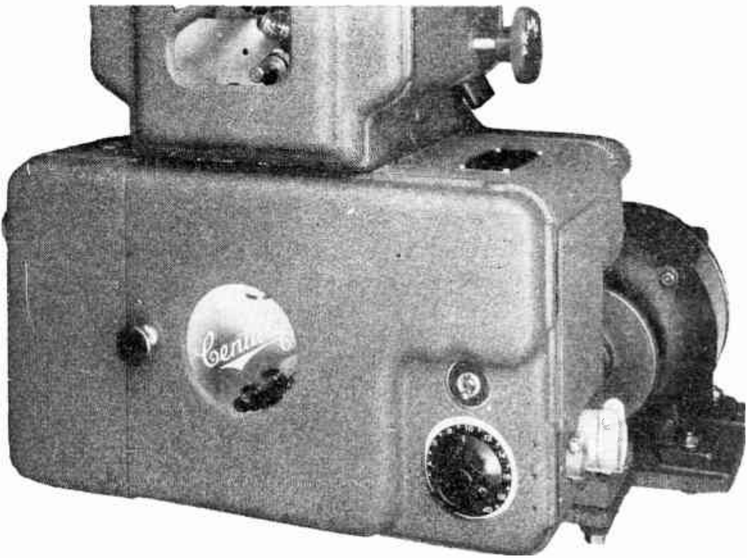


FIG. 35.—Photograph showing exterior view of *Century* sound reproducer with driving motor. Projecting through the front casing may be seen the volume control and the sound change-over switch.

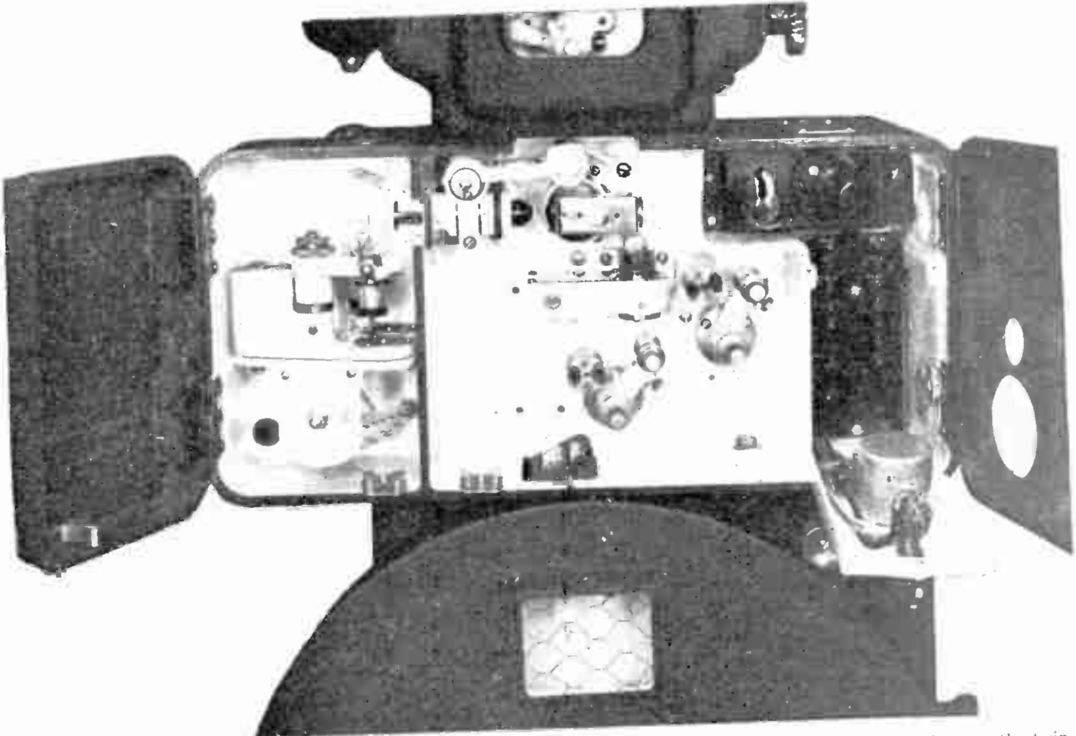


FIG. 36.—Photograph showing operating side of *Century* sound reproducer (film not shown). At the left may be seen the twin-exciter lamp compartment and at the extreme right the pre-amplifier terminals. The film alignment control, the hydroflutter suppressor mechanism and the equilight diffuser will be seen in the center compartment.

Loosen screws A, push stop plate E tight against its stop F, and tighten screw A. Replace the flywheel on the cam shaft. A slight amount of backlash should now be present between gears 2 and 1. Put oil in movement M, check oil level at red line O, before running. Check the timing of the shutters. Loosen shutter hub screws I, so that shutters turn on shaft. Turn the projector by hand so that flywheel screw H is in line with the vertical shaft, line up notches K with wire L, being careful not to shift projector gears, tighten screws I, replace guard.

If slight travel ghost is present with projection of picture, it may be removed by turning shutter adjusting knob right or left.

Changing the Intermittent Sprocket.—Remove the intermittent movement from the projector in accordance with the instructions previously given. Drain the oil from the case by removing the oil drain screw shown in No. 1, fig. 33. Do not attempt to save this oil to be replaced in the movement. Always use clean, fresh oil. Remove the other four screws in the cover. Under the heads of all these screws will be found copper washers. Save these washers for re-assembly.

Loosen the two set screws No. 2, fig. 33. Hold the case of the intermittent with one hand and the cover with the other hand and carefully pull them apart. Extreme care must be used in this operation in order that the star or cam should not be damaged.

Push the two taper pins out of the hub of the sprocket, using a tool made for this purpose. If such a tool be not available, place the hub of the sprocket into a V-bloc and very lightly tap out the two pins. These pins should never be removed except in one of the two ways indicated. Loosen the two screws in the collar on the outside end of the star wheel shaft and remove the collar. The star wheel and shaft can now be pulled out allowing the sprocket to be removed.

All these operations should be carried out with extreme care. It is not necessary to use force in removing any of the units. If any difficulty be encountered, the complete movement should be returned for repairs.

Adjustment of the Cam-Shaft Thrust Bearing.—While the intermittent is disassembled, the end play of the cam-shaft should be checked and if found to be excessive it should be adjusted. It will be noted that at the end of the cam-shaft there is a thrust bearing No. 5, fig. 33. By loosening the locking screw No. 4, fig. 33, the thrust bearing may be tightened or loosened by screwing it in or out. It should be adjusted so that there is no perceptible end play in the cam-shaft and yet not tight enough to cause the cam-shaft to drag or bind. Tighten the locking screw No. 4, fig. 33.

The end play of the cam-shaft may also be adjusted after the movement is assembled by removing the large plug screw in the center of the movement case. This will expose the end of the thrust bearing No. 5, fig. 33. A screwdriver slot is provided in the end of this bearing so that it may be tightened or loosened. The same adjustment will apply as previously described.

To Assemble the Intermittent.—Insert the star-wheel shaft into the bearings of the cover and make sure that it turns smoothly in its operating

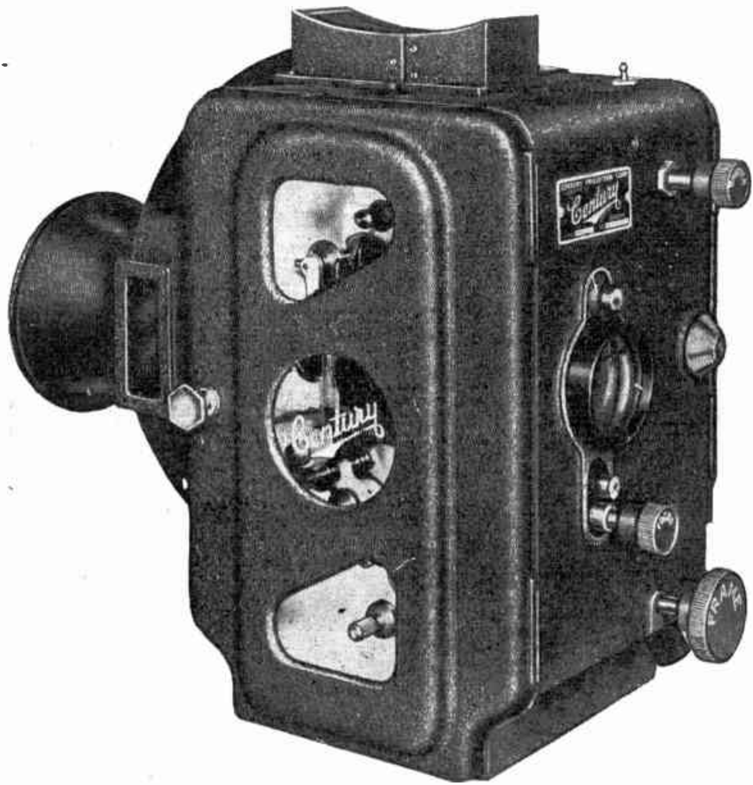


FIG. 37.—Exterior view of *Century* projector mechanism.

position. Pull the shaft almost out of the inner bearing and place the sprocket in position. Push the shaft all the way through until it is in place with the holes in the shaft lined up with the holes in the sprocket. These are tapered holes so care should be taken that the tapers line up properly.

Push the two pins into place with the tool which was used to remove them, but not too tight. Replace the collar at the outer end of the shaft. Hold the star-wheel with the thumb and the collar with the first or second finger and gently squeeze the two together. Tighten the two set screws in

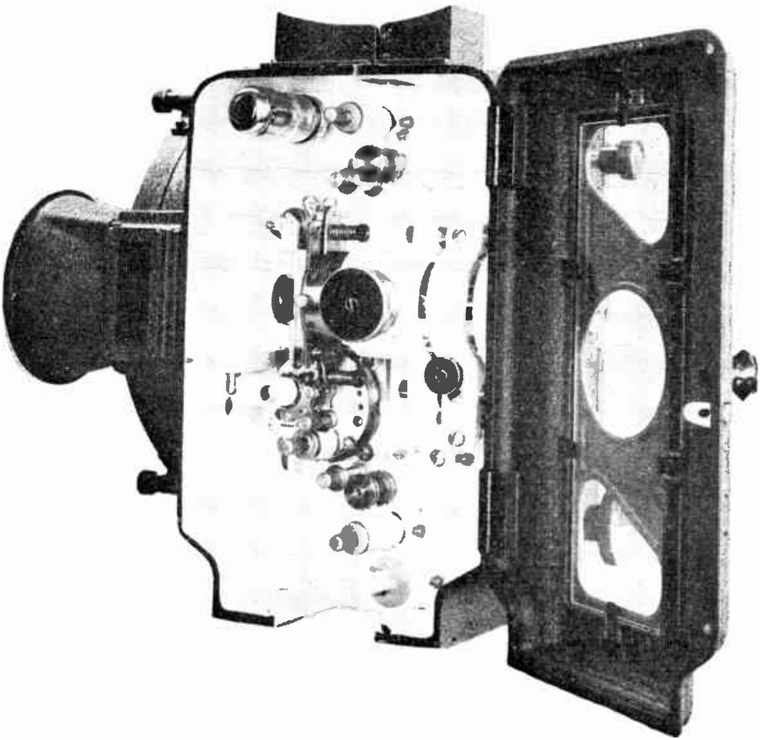


FIG. 38.—Photograph showing operating side of *Century* projector mechanism.

the collar. The star-wheel and sprocket should rotate without binding and with no drag; at the same time there should be no perceptible end play in the shaft. Replace the gasket.

Hold the case of the intermittent in the right hand with the cam-pin in the down position (out of engagement with the star-wheel) and hold the cover in the left hand with the star-wheel rotated so that the radius of the star will match the radius of the cam, when the two are put together. Carefully place the locating hole over the locating pin No. 6, fig. 33. Move the cover so that the star-wheel radius is slightly above the cam ring and

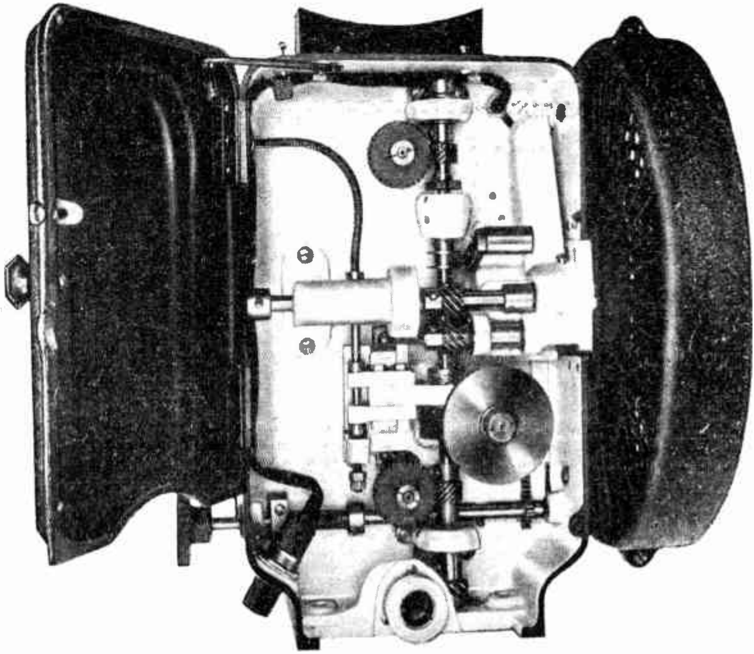


Fig. 39.—Photograph showing driving side of *Century* single shutter projector mechanism. The horizontal shaft is that of the shutter. The gears through which the vertical shaft drives the lower sprocket, intermittent movement and upper sprocket are clearly seen. These shafts are provided with ball bearings.

push the cover and case together slowly all the way. Then gently lower the cover until the star and cam meet. Replace all the holding screws. If the job has been done correctly, it is now possible to rotate the cam by the flywheel and advance the intermittent sprocket.

The case should now be filled to the proper operating level with oil by means of the oil cup provided for that purpose in the end of the star-wheel outer bearing. Revolve the flywheel a number of times, making sure that there are no binds and that the cam pin is moving in and out of the star-wheel satisfactorily. Do not force the cam pin into the star-wheel by turning the flywheel. It is well to check the intermittent sprocket for any looseness when the sprocket and star-wheel are in locked position. If any play be found, it can be adjusted by lightly loosening the screws around the cover and tightening or loosening the two set screws No. 2, fig. 33. Loosening the upper screw and tightening the lower one a fraction of a turn will tighten the star-wheel against the cam. This operation is a most delicate one and should never be performed with the projector running.

As soon as everything has been checked and the intermittent is in good running condition, it may be replaced in the projector. It has been found desirable to run-in the intermittent for a little while after changing the sprocket or star-wheel by mounting the intermittent in a holder and running it at normal speed with a belt drive to the flywheel.

Removing and Adjusting the Film Trap.—Remove the heat shield by taking out the two screws just above and in back of the film trap. Take out the three screws holding the film trap. One of these will be exposed when the heat shield is removed. The film trap can now be removed by pulling it straight out.

Note that there are two guiding pins which keep the film trap accurately in line and at right angles to the optical center line. These pins hold the trap in vertical alignment when it is moved backward and forward for adjusting the film trap shoes in the proper position to the intermittent sprocket. The film trap is set at the factory and will not require adjustment unless the trap is removed to renew the shoes or the studio guides.

If new shoes be installed, they should be lined up with the sprocket as follows:

Loosen the two screws holding the film trap. Make two wraps of film around the intermittent sprocket. Place a straight edge against the face of the shoes and let it extend down to the sprocket. The film trap should now be moved forward or backward until the straight edge comes into contact with the film which is around the sprocket. Tighten the film trap holding screws.

Replace or Reverse the Film Trap Shoes or Studio Guides.—Remove the film trap. Take out the four screws holding the studio guides. This will allow the studio guides and the film trap shoes to be removed. The film trap shoes may be reversed from right to left giving double life.

The studio guides may be reversed from right to left as well as turning them over from inside to outside. This provides for four times normal wear.

After the changes have been made, the film trap should be replaced and adjusted as instructed under "Removing and Adjusting the Film Trap."

Replacing the Gate Knob.—Loosen the two set screws, one on top and one below the knob assembly, on the lens tube and gate mounting. Pull the gate knob straight out.

The new gate knob should be turned in its hub, to the right, until it locks in the first stop. The gate tube should be moved to its gate open position. The knob assembly should then be inserted into its holder, with the oil hole up, so that the gate tube and the recesses in the gate knob hub coincide with the holding set screws. Tighten the holding set screws above and below the knob assembly.

To Replace the Gate Knob Spring.—Open gate to fullest open position. Remove the screws at the center of the gate knob. Remove the gate knob by pulling it straight off. Remove old spring. Insert new spring so that the inner end engages in the hole at the bottom of the recess in the gate knob.

Hold the knob so that the slot is in 90° position to the cross-pin in the gate knob shaft. Engage the outer end of the spring into the nearest hole in the knob. Holding the knob, securely on the shaft, but not engaged with the cross pin, rotate it to the right one and a quarter turns and push the knob into engagement with the cross pin. Replace the screw at the center of the knob and tighten securely.

If less knob tension be desired, proceed as previously, except when engaging the knob with the spring. Hold the knob so the slot is parallel to the cross pin and then engage the outer end of the spring into the nearest hole in the knob. Holding the knob securely as instructed, rotate it to the right one turn and push the knob into engagement with the cross pin. Replace the screw at the center of the knob.

Replacing the Film Gate Pads.—Remove the gate. There is one screw holding each of the four film pads. The screw should be removed from the pad being replaced and the new pad screwed into place. After replacing all the pads they should be inspected to make sure they are free to move in and out.

To Replace the Pilot Light.—Unscrew the pilot light shield shown in No. 11, fig. 32, and remove it. Unscrew the pilot light from its socket and replace it with a 110-volt 7.5-watt G. E. candelabra base Mazda lamp.

Removing the Shutter Guards.—The shutter guard on the driving side of the projector is removed by taking out the two screws No. 10, fig. 31, which hold it to the fixed shutter guard. One of these screws is at the top of the guard and the other is at the bottom.

The shutter guard on the operating side of the projector is removed as follows:

On the driving side of the projector there are two holding screws No. 11, fig. 31, for the shutter guard. These should be removed. On the operating side of the projector the large screw just below the heat shield No. 12, fig. 32, should be removed. The shutter guard can then be removed.

To Replace the Upper or Lower Sprocket.—Open the pad roller arm. Take out the screw No. 13, fig. 32, at the center of the sprocket hub and pull the sprocket off the shaft. It will be noted that the screw holding the sprocket goes all the way through the sprocket and clamps the sprocket to the shaft. This feature prevents the shaft from bending under the strain of the set screw. Both the upper and lower sprockets are reversible.

When the new sprocket is installed, the sprocket drive gear should be held tightly against its bearing and the sprocket held firmly against its bearing. The holding screw should now be tightened. This will take out the end play of the shaft.

To Take Out the Aperture Plate.—Pull out the aperture retaining plate shown in No. 14, fig. 32, which is behind the aperture plate. This frees the aperture plate so that it can move a little toward the rear and then it can be pulled directly out of its holder.

It will be noted that the aperture plate is held in position by its specially designed shape. The four corners are carefully fitted into the film trap and keep the aperture plate accurately located.

Setting the Height of the Fire Shutter.—At the top of the governor which is on the vertical shaft there is a set screw No. 12, fig. 31, which locks the governor to the shaft. Loosen this screw and the governor may be raised or lowered; this will raise or lower the fire shutter. When the proper shutter height is obtained the set screw should be firmly tightened. The height of the shutter should be adjusted so that it does not come into the light beam with the projector running and yet not high enough to touch the top of the heat shield.

To Clean the Threading Reflector.—Take out the heat shield and wipe the threading reflector with a soft cloth. If the reflector be very dirty, it should be polished with a good metal polish.

Removing the Upper or Lower Pad Rollers.—Loosen the retaining screw in the pad roller arm and pull the shaft and roller straight out of the arm. When the roller is replaced, the shaft should be adjusted so that the roller turns freely, but has very little end play.

To Remove the Upper Pad Roller Arm Complete.—Loosen the retaining screw No. 15, fig. 32, with a screwdriver through a hole No. 16, fig. 32, in the front of the projector case. The complete pad roller arm will then pull straight out.

Installing the Pad Roller Arm.—Insert the pad roller arm stud into its hole in the main frame. Loosen the adjusting screw No. 5, fig. 32, and back it out of contact with its stop. Rotate the arm into firm contact with the sprocket by means of the stud knob No. 17. fig. 32, and tighten the screw No. 15, fig. 32. Adjust the adjusting screw No. 5 until it comes into contact with its stop. Place two layers of film between the sprocket and the pad roller. Adjust the adjusting screw until the pad roller holds the film lightly in place. Lock the adjusting screw with its lock nut.

To Replace the Lower Pad Roller Arm Complete.—The procedure is the same as with the upper pad roller arm except that the screwdriver is inserted through a hole No. 18, fig. 32, in the projector case at the back of the projector to loosen set screw No. 19. fig. 32.

Installation of the lower pad roller arm is made in the same manner as the upper roller arm explained previously.

To Replace the Intermittent Pad Shoe Assembly Complete.—Loosen holding screw No. 7, fig. 33. The complete pad assembly will now pull straight out.

To install a new pad assembly push firmly into the holding hole and turn the pads so that they just make contact with the intermittent sprocket with little or no pressure being applied. When film is threaded through the intermittent it will depress the pad shoes by an amount corresponding to the thickness of the film. This will be the correct amount of tension for best operation.

Removing the Shutter Shaft Complete.—Open the driving side door and loosen the screw No. 13, fig. 31, holding the shutter knob. The knob will then slip off the end of the shutter shaft. Take off the driving side shutter guard. Take out the four screws holding the rear bearing bracket of the shutter shaft No. 14, fig. 31. Take out the two screws holding the front bearing bracket of the shutter shaft No. 15, fig. 31. This bearing is dowel pinned in position. Holding the shutter shaft in both hands, disengage from the dowel pins and remove the shutter shaft complete including the shutter. Replacing the shutter shaft reverses the procedure.

The two screws No. 15, fig. 31, in the front bearing bracket are tightened first. It will be noted that the ball bearings are self-aligning. Before tightening the four screws No. 14, fig. 31, in the rear bearing bracket the gear mesh should be adjusted between the shutter shaft gear and the driving gear on the vertical shaft. These two gears should be meshed close enough to prevent an excessive amount of backlash, but not sufficiently close to cause binding.

Removing the Vertical Shaft Complete.—Remove the shutter shaft complete as previously explained. Remove the intermittent movement. See "Removing the Intermittent." Take out the two screws in the upper bearing bracket No. 16, fig. 31. Take out the two screws in the lower bearing bracket No. 17, fig. 31. Take out the two bolts in the intermittent drive gear bracket No. 18, fig. 31. Disengage this bracket from its holder. The upper and lower bearing brackets are dowel pinned in position. Holding the vertical shaft with both hands, disengage the brackets from the dowel pins and remove the vertical shaft. To put in a new vertical shaft, reverse this procedure.

Removing the Main Drive Shaft and Gear.—Refer to fig. 31. Remove the two set screws No. 4. This will allow the removal of the main drive shaft No. 1, by pulling it straight out. The main drive gear No. 2 can now be removed from the projector.

To assemble the main drive shaft and gear, proceed as follows:

If the main drive shaft ball bearing retainer No. 9 be not out, remove it by loosening the retainer holding screw No. 8 and push it out. Insert the outer ball bearing in its place. Working from the non-operating side of the projector push the main drive shaft through the outer ball bearing; put on the steel and then the fibre washers. Put on the main drive gear and then the fibre and steel washers. Insert the inner ball bearing from the operating side of the projector. Insert the main ball bearing retainer. Push the retainer firmly into place and tighten the retainer holding screw. There should be no end play in this shaft after the assembly is complete.

Removing the Film Gate Support and Lens Holder.—Take the lens out of the holder. By means of the focusing knob move the lens clamp all the way forward. Remove the focusing knob by removing the screw which holds it and pull the knob straight off the focusing shaft. Close the gate. Take out the two screws which will be exposed on the back side of the holder. Open the gate. The lens holder and film gate are located by means of dowel pins. The holder may now be removed from the projector. To replace the holder in position, reverse this operation.

INCLINATION OF PROJECTION	POSITION OF WALL OPENING	OVERALL HEIGHT
−5°	51 1/16	74 9/16
−4°	50 9/16	74 5/32
−3°	49 13/16	74 1/8
−2°	49 3/16	74 1/32
−1°	48 5/8	73 13/16
0°	48	73 5/8
+1°	47 3/8	73 5/16
+2°	46 3/4	73 1/8
3°	46 1/8	73 1/16
4°	45 1/2	73
5°	44 15/16	72 25/32
6°	44 5/16	72 9/16
7°	43 3/4	72 5/16
8°	43 1/8	72 1/16
9°	42 9/16	71 13/16
10°	42	71 9/16
11°	41 3/8	71 5/16
12°	40 13/16	71 1/32
13°	40 5/16	70 3/4
14°	39 3/16	70 7/16
15°	39 1/16	70 5/32
16°	38 1/2	69 27/32
17°	37 15/16	69 9/16
18°	37 3/8	69 1/4
19°	36 13/16	68 29/32
20°	36 1/8	68 5/8
21°	35 5/8	68 1/4
22°	35 1/8	67 7/8
23°	34 9/16	67 19/32
24°	33 15/16	67 5/16
25°	33 3/8	66 15/16
26°	32 13/16	66 5/8
27°	32 1/4	66 1/4
28°	31 11/16	65 15/16
29°	31 1/8	65 19/32
30°	30 3/4	64 7/8

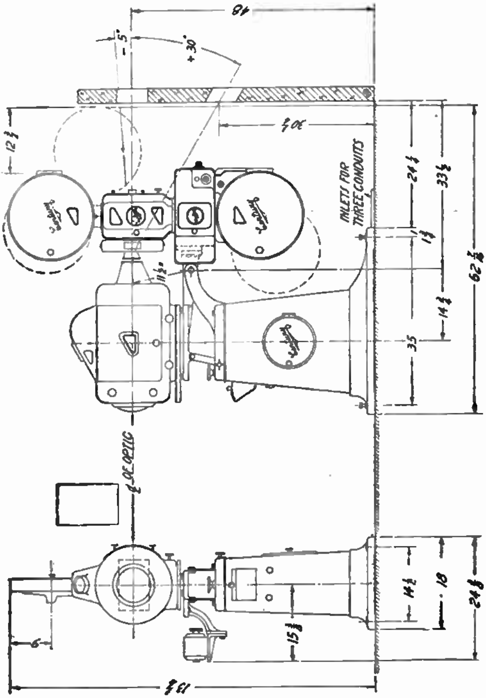


FIG. 40.—Showing installation chart for *Century* type "C" sound on film projector.

The Amplifier System

General.—By definition, an amplifier is a device for increasing the power associated with a phenomenon without appreciably altering its quality, through control by the amplifier input of a larger amount of power supplied by a local source to the amplifier output.

An electro-communication type of amplifier is defined as a device which by enabling a received wave to control a local source of power, is capable of delivering an enlarged copy of the wave.

A schematic circuit diagram associated with the Westrex master sound system having an output of 50 watts, is shown in figs. 41 to 44.

The rectifier is designed for supplying the direct current and *a.c.* vacuum tube heater currents to the (a) amplifier units; (b) the exciter lamp and (c) the photoelectric tube.

It consists of one R_3 power supply (exciter lamp supply) and one R_2 power supply (plate and filament supply) mounted one above the other in a cabinet. A double pole single throw switch is provided for the *a.c.* supply line. The lower pole of this switch controls the "*hot*" side of the R_2 power supply, and the upper pole controls the R_3 power supply. The common side of the *a.c.* supply line is connected directly to the common *a.c.* terminal of the R_3 power supply and by an internal strap to the common *a.c.* terminal of the R_2 power supply. The rectifier is designed for wall mounting.

The R_3 power supply consists of a power transformer and a bridge type selenium rectifier stack and associated filter. Two one ohm slide wire resistors are provided for adjusting the current to each of the two exciter lamps on early systems and on later systems low voltage taps are provided on the transformer T_1.

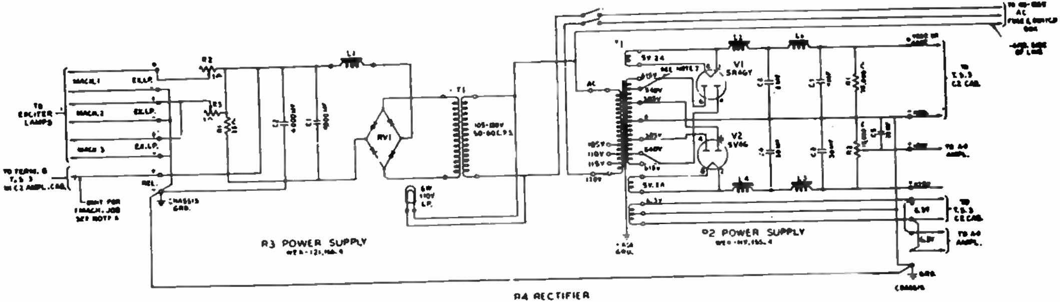


FIG. 11. Schematic circuit arrangement of power rectifier unit for Westrex Master Sound System. *Courtesy Western Electric Company.*

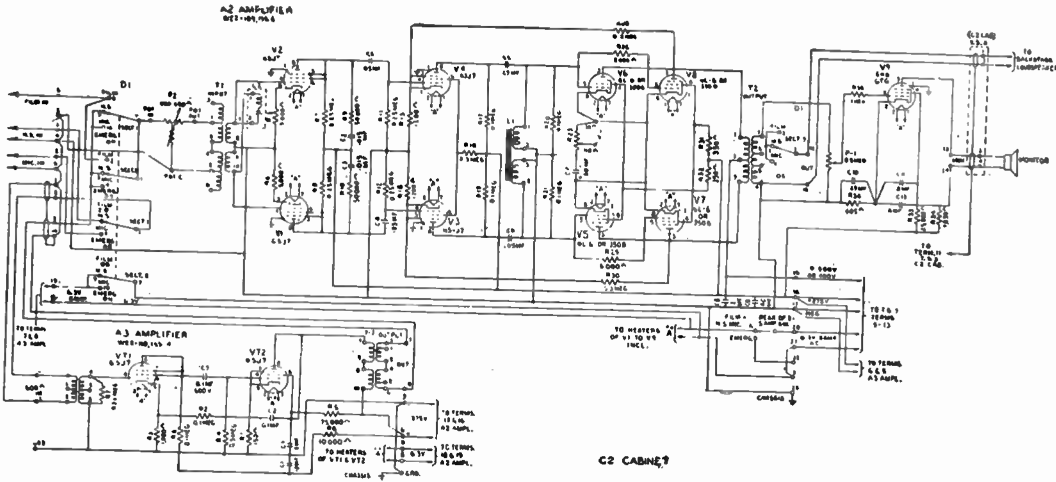
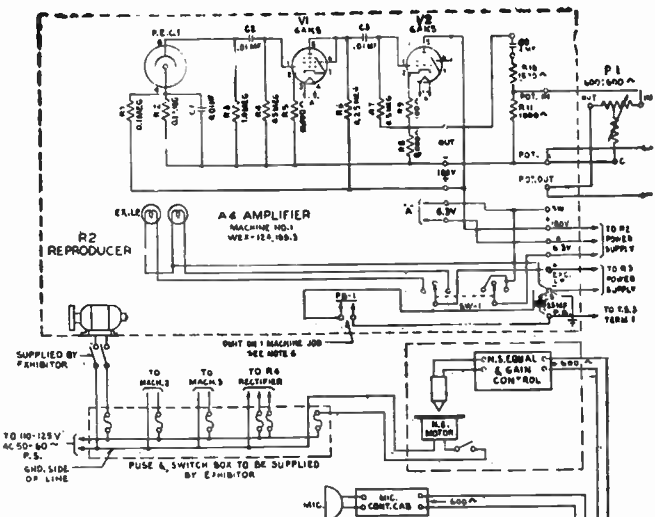


FIG. 42.—Schematic wiring diagram showing main amplifier for Westrex Master Sound System. NOTE.—For connection of wires connected to terminals marked 1, 3, 4, 5 and 6 see corresponding markings on terminals shown in fig. 44. *Courtesy Western Electric Company.*



NOTES.

1. FOR 50 WATT OPERATION, STRAP R23 OF THE A2 AMPL. TO OBTAIN 110. OHMS, CONNECT PLATE LEADS TO T2 IN R2 POWER SUPPLY FOR HIGH VOLTAGE OPERATION AND USE WE-350B VACUUM TUBES AS V5, V6, V7 AND V8 OF THE A2 AMPL. FOR 40 WATT OPERATION, REMOVE STRAP ON R23 OF THE A2 AMPL. TO OBTAIN 130 OHMS, CONNECT PLATE LEADS TO T1 IN R2 POWER SUPPLY FOR LOW VOLTAGE OPERATION AND USE 6L6 VACUUM TUBES AS V5, V6, V7 AND V8 OF THE A2 AMPL.
2. FOR 2 MACHINE OPERATION ELIMINATE REPRODUCER 3 AND R2 REL-2 AND WIRING SHOWN AS – – – – – AND STRAP TERMS. 8-9 AND TERMS. 12-13 OF T.S.1 AS INDICATED BY WIRING SHOWN AS –•–•–
3. FOR EMERGENCY OPERATION INSTALL ONE ADDITIONAL A2 AMPL., REMOVE STRAPS FROM TERMS. 21-23 OF BOTH AMPLS. AND STRAP TERMS OF "EMERGENCY" AMPL. TO TERMS. OF "REGULAR" AMPL. AS FOLLOWS:

"REG." AMPL. TERMINALS	STRAP TO "EMERG." AMPL. TERMINALS
1-17, INCLUSIVE	SAME
18	19
19	18
20	OPEN
21	20
22	23
23	22
OPEN	21
ALL OTHERS	SAME

WHEN SO STRAPPED THE SELECTOR SWITCH OF ONE AMPL. MUST BE SET TO EMERGENCY FOR THE FILAMENTS OF THE OTHER AMPL. TO BE ON. SETTING THE SELECTOR SWITCH OF BOTH AMPLS. TO EMERGENCY TURNS OFF THE FILAMENTS OF BOTH AMPLS., BUT LEAVES THE A3 AMPL. FILAMENTS ON.

4. N.S. REPRODUCER AND MICROPHONE FURNISHED ONLY WHEN ORDERED SEPARATELY.
5. SPEECH CONDUCTORS MARKED "C" BETWEEN C2 CAB. AND A4 AMPL. MUST CONNECT TO POT. C TERMINAL IN R2 REPRODUCER.
6. ON SINGLE MACH. INSTALLATIONS THE REL. CHASSIS, INCL. TERM. STRIPS T.S.1 & 2 IS NOT FURNISHED WITH THE C2 CAB. & THE PUSHBUTTON WIRING (TERMS 1-6) ON T.S.3 OF C2 CAB. IS OMITTED. IN SUCH CASES EXTERNAL WIRING SHOWN CONNECTED TO TERMS. 1&2 OF T.S.1 & TERMS. 3 TO 6 OF T.S.2 SHOULD BE ROUTED TO CORRESPONDING TERMS. OF T.S.3 IN C2 CAB. TERM. 2 OF T.S.3 SHOULD BE GROUNDED TO TERM. 11 OF T.S.3 IN C2 CAB.
7. FOR 480V OPERATION USE 615V TAP
   FOR 400V OPERATION USE 540V TAP

FIG. 43.—Schematic diagram of pre-amplifier for Westrex Master Sound System. NOTE.—For associated wiring of complete unit see figs. 41 to 44. *Courtesy Western Electric Company.*

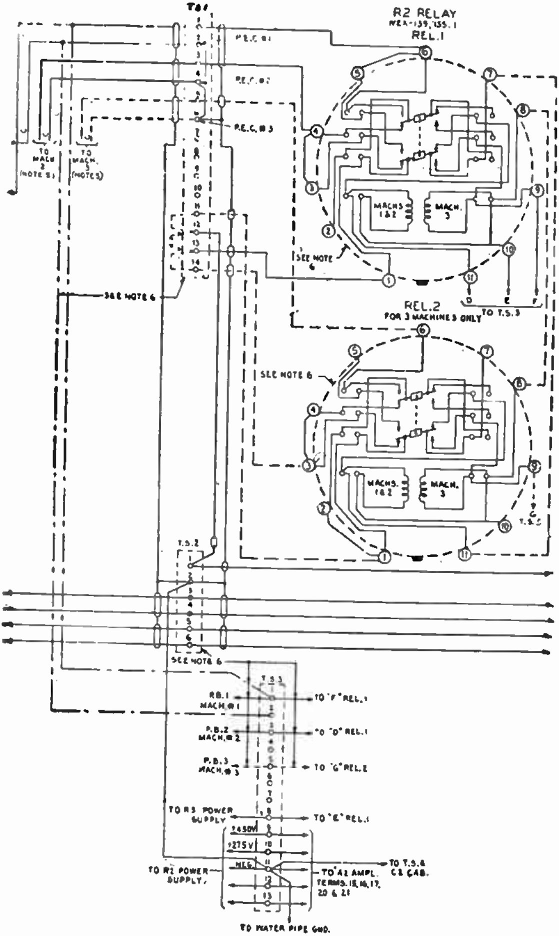


FIG. 44.—Schematic diagram of relay system associated with Westrex Master Sound System. NOTE.—For connection of wires marked 1, 3, 4, 5 and 6 see corresponding markings on terminals shown in fig. 43. *Courtesy Western Electric Company.*

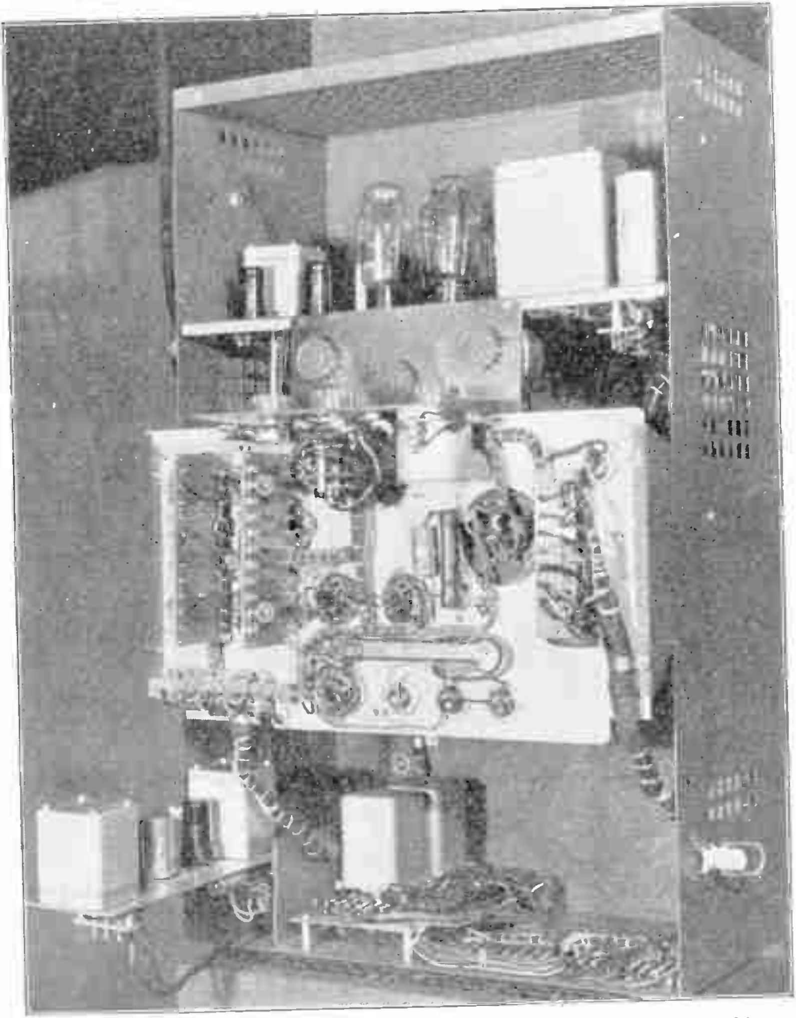


FIG. 45.—Photograph showing cabinet wiring of two-rack amplifier used in Westrex Master Sound System. 50-watt output. NOTE.—Rectifier unit located underneath amplifier not shown. *Courtesy Western Electric Company.*

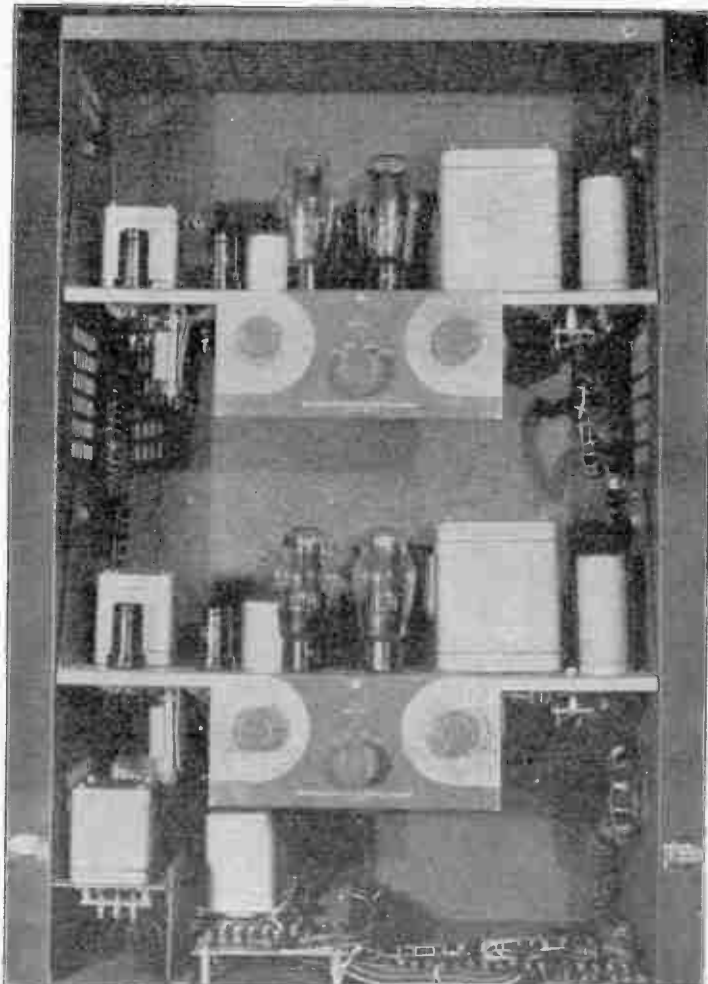


FIG. 46.—Photograph showing cabinet wiring of single-rack amplifier as used in Westrex Master Sound System, 40-watt output. NOTE.—Rectifier unit located underneath amplifier not shown. *Courtesy Western Electric Company.*

TEST QUESTIONS

1. *What is the function of the exciter lamp in a motion picture projector?*
2. *How is the film marked in sound recording?*
3. *What are the main components in a typical sound-on-film projector?*
4. *How are the acoustic properties of an auditorium determined?*
5. *What is reverberation?*
6. *When is reverberation likely to occur in an auditorium?*
7. *What type of material absorbs sound?*
8. *How should stage horns be set in an auditorium where reverberation is present?*
9. *What type of oil should be used to lubricate a Simplex projector?*
10. *What operations are necessary to prepare the focus in a Simplex projector?*
11. *Describe the film threading operation in a Simplex projector.*
12. *How may the film gate be removed in a Simplex projector?*
13. *What precautions must be observed in removing and reinserting the intermittent movement in a Simplex projector?*
14. *Describe a step-by-step procedure in replacing the shutter gear in a Simplex projector.*

15. *How is the fire shutter adjustment made in a Simplex projector?*
16. *Of what does a Simplex sound head consist?*
17. *What precautions are taken to protect the drive motor against overload in a Simplex projector?*
18. *Describe the procedure in making lens tube and reflector lens adjustments in a Simplex projector*
19. *How many stages does a Simplex volume control amplifier have?*
20. *Draw a wiring diagram showing the connections of an amplifier selector switch used when two or more amplifiers are connected in parallel.*
21. *Describe the film filtering mechanism as employed in a Century projector.*
22. *What are the essential features of the driving mechanism in a Century projector?*
23. *Draw diagrams showing the principles in operation of the Geneva intermittent movement.*
24. *Describe the necessary adjustments for timing the shutters in a Century projector.*
25. *Describe the film threading operation in a Century projector.*
26. *Describe the operations necessary to replace the intermittent movement in a Century projector.*
27. *How may the upper and lower sprocket be replaced in a Century projector?*

CHAPTERS 197 TO 204

Questions and Answers

(For Wiremen and Operators)

General.—Any installation of electrical wiring and associated equipment throughout the United States is governed by the requirements of the *National Electrical Code.*

In addition to the *National Electrical Code* requirements, existing local *Codes* should also be considered. They may be obtained from the local *Municipal Authorities.* In territories outside the jurisdiction of municipalities, *State* and *County,* authorities should be consulted.

The following questions and answers relating to the various branches of *theatre* and *motion picture* house wiring, gives certain Code requirements and other useful information:

Ques.—How shall lamps be installed in film vaults?

Ans.—In film storage vaults lamps shall be installed on rigid fixtures and enclosed in vapor-tight globes. Lamps shall be controlled by a double pole switch located outside the vault. This double-pole switch shall disconnect from the source of supply all conductors terminating in any outlet box in the vault, and no conductors other than those controlled by the double pole switch shall terminate or pass through any outlet box in the vault. Electric motors or portable lamps shall not be placed in the vault.

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.—When shall an emergency lighting system be provided in a theatre or motion picture house?

Ans.—An emergency lighting system shall be provided where the seating capacity of the auditorium exceeds 100 persons. Emergency lighting shall include all required exit lights and all other lights specified as necessary to provide sufficient illumination to enable persons to see their way out of the building.

Ques.—What type of current supply shall be employed in an emergency lighting system?

Ans.—The current supply shall be such that in event of emergency within the building or group of buildings concerned, emergency lighting shall be available. Service may comprise:

a. One service and a storage battery of sufficient capacity to supply and maintain at not less than 91% full voltage the total load of the circuits carrying lights for emergency illumination for a period of at least ½ hour. Automobile batteries, or lead batteries of other than the sealed, glass-jar type, are not considered suitable.

b. One service and a generator set, driven by some form of prime mover and of capacity sufficient to supply circuits carrying emergency illumination load, with suitable means for automatically starting the generator on failure of the normal service.

c. Services as widely separated, electrically and physically, as the available facilities allow.

d. Connection on supply side of the main service if sufficiently separated from main service to prevent simultaneous interruption of supply through an occurrence within the building or group of buildings served.

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.—What type of portable lamps shall be provided in a theatre or motion picture house?

Ans.—For portable lamps, composition or metal sheathed porcelain unswitched lamp holders shall be used. The cord shall carry the male end of a pin plug connector or equivalent, the female end being of such design or so hung that the connection will readily break apart at any position of the cord. The connector shall be kept at least one foot from the floor. The lampholder shall be provided with a guard, hook and handle. The provisions of this section shall not apply to portable lamps used as properties in a motion picture set on a studio stage or similar location.

Ques.—What type of flexible cord shall be used in portable lamps?

Ans.—Types S, SO, or ST cord shall be used on portable lamps and equipment, except that portable lamps used as stage properties in a motion-picture set on a studio stage or similar location may be used with any approved type of cord with which they may be equipped.

Ques.—What are the specifications with respect to motors and generators installed in theatres or motion picture houses?

Ans.—If motors or generators having brushes or sliding contacts are used, they shall meet one of the following conditions:

a. Be of the totally-enclosed, enclosed-fan-cooled, or enclosed-pipe-ventilated types.

b. Be enclosed in separate rooms or housings built of non-combustible materials so constructed as to exclude flyings or lint, and properly ventilated from a source of clean air.

c. Have brush or sliding-contact end of motor enclosed by solid metal covers.

d. Have brushes or sliding contacts enclosed in substantial, tight metal housings.

e. Have the upper half of brush or sliding-contact end of the motor enclosed by a wire screen or perforated metal and the lower half enclosed by solid metal covers.

f. Have wire screens or perforated metal placed at the commutator or brush ends. No dimension of any opening in the wire screen or perforated metal shall exceed .05 inch, regardless of the shape of the openings and of the material used.

Ques.—What are the requirements with respect to exposed live parts of electrical equipment?

Ans.—Live parts shall be enclosed to prevent accidental contact by persons or objects. Rheostats shall be enclosed and externally operative.

Ques.—What are the requirements as to grounding of equipment in theatre or motion picture houses?

Ans.—All metal raceways, cable armor and the exposed metal frames of all equipment and enclosures shall be grounded. except pendent and portable lamps operating at not more than 150 volts to ground.

Ques.—What are the requirements as to the enclosure of the professional type motion picture projector?

Ans.—The professional type of projector, such as is commonly used in theatres and motion picture houses, shall be located in an approved enclosure. The professional projector employs a 35 mm film which is 1 3/8 inches wide and has on each edge 5.4 perforations per inch.

Ques.—What are the requirements as to the enclosure of the non-professional or miniature type motion picture projector?

Ans.—Projectors of the non-professional or miniature type, if employing only approved slow-burning (cellulose acetate or equivalent) film, may be operated without a booth.

Ques.—What are the specifications with respect to a 35 mm motor driven projector?

Ans.—Motor driven projectors shall be approved for the purpose as an assembly or shall comply with all of the following conditions:

a. An approved projector shall be used.

b. An approved projector lamp shall be used.

c. Motors shall be so designed or guarded as to prevent ignition of film by sparks or arcs.

d. Projectors shall be in charge of a qualified operator.

Ques.—What conductor sizes are required for operation of 35 mm projectors?

Ans.—Conductors supplying outlets for projectors of the professional type shall not be smaller than No. 8 and shall be of sufficient size for the projector employed.

Ques.—What are the specifications as to conductor insulation in 35 mm projectors?

Ans.—Asbestos covered conductors type AA or other types of insulated conductors having a maximum operating temperature of 200°C. (392°F.) shall be used on all lamps or other equipment when the ambient temperature at the conductors as installed will exceed 50°C. (122°F.).

Ques.—What type of lamp guards shall be employed in projection rooms or booths?

Ans.—Incandescent lamps in projection rooms or booths shall be provided with an approved lamp guard unless otherwise protected by non-combustible shades or other enclosures.

Ques.—What are the requirements as to location of electrical equipment in connection with 35 mm motion picture projectors?

Ans.—Motor generator sets, transformers, rectifiers, rheostats, and similar equipment, for the supply or control of current to arc lamps on projectors shall, if practicable, be located in separate rooms. If placed in the projector room, they shall be so located or guarded that arcs or sparks cannot come in contact with film and motor-generator sets shall have the commutator end or ends protected as previously described.

Ques.—May switches, overcurrent devices and other electrical devices be installed in projector rooms?

Ans.—No switches, overcurrent devices or other equipment not normally required or used for projectors, sound reproduction, flood or other special effect lamps or other equipment shall be installed in such booths or rooms, except remote-control switches for the control of auditorium lights or a switch for the motor operating the curtain at the motion picture screen.

Ques.—What are the recommendations as to provisions for ventilation in projection rooms?

Ans.—It is recommended that the authority having jurisdiction over the construction and ventilation of rooms for professional type projectors refer to the standards of the *National Board of Fire Underwriters*.

Ques.—What are the requirements as to construction of professional type projectors and equipment?

Ans.—Equipment and projectors of the professional type shall comply with the following:

a. Approved Type: Projectors and enclosures for arc or incandescent lamps, rectifiers, transformers, rheostats and similar equipment, shall be of an approved type.

b. Name Plate: Projectors and other equipment as set forth in paragraph *a.* of this section, shall be marked with the name or trademark of the maker and with the voltage and current for which they are designed.

Ques.—What are the requirements as to construction of non-professional type projectors?

Ans.—Projectors of the non-professional type shall comply with the following:

a. Approved Type: Projectors, lamp enclosures and current-controlling devices and similar devices shall be approved as component parts of the projector equipment.

b. Name-Plate: Projectors shall be marked with name or trademark of the maker, with the current and voltage for which they are designed, and for projectors of this type using the standard 35 mm film, with the wording, "For use with slow-burning films only."

c. Source of Illumination: The source of illumination shall be a lamp of a type approved for stereopticon use or for motion-picture projection.

d. Film to Be Marked: The slow-burning (cellulose acetate or equivalent) film shall have a permanent distinctive marker for its entire length identifying the manufacturer and the slow-burning character of the film stock.

Ques.—What are the requirements as to stage switchboard employed in theatres or motion picture houses?

Ans.—Stage switchboards shall be of the dead-front type.

Ques.—How are exposed live parts on stage switchboards protected?

Ans.—Stage switchboards having exposed live parts on the back of such boards shall be enclosed by the building walls, wire mesh grills, or by other approved methods. The entrance to this enclosure shall be by means of a self-closing door.

Ques.—What are the requirements as to control and overcurrent protection of receptacle circuits?

Ans.—Means shall be provided at the stage switchboard for the control and individual overcurrent protection of branch circuits to stage and gallery receptacles used for portable stage equipment.

Ques.—What means are employed to protect stage switchboards from falling objects?

Ans.—Stage switchboards shall be provided with a metal hood extending the full length of the board to protect all equipment on the board from falling objects, unless the switchboard is recessed in the building construction or is of the completely enclosed, dead-front and dead-rear type.

Ques.—What are the requirements as to the installation of dimmers in a theatre or motion picture house?

Ans.—Dimmers shall conform with the following:

a. Disconnection from Supply: If dimmers are installed in ungrounded conductors, each dimmer shall have overcurrent protection not greater than 125% of the dimmer rating, and shall be disconnected from all ungrounded conductors when the master or individual switch or circuit-breaker supplying such dimmer is in the open position.

b. Resistance or Reactor Type Dimmers: Resistance or series reactor type dimmers may be placed in either leg of the circuit.

It is recommended that resistance or reactor type dimmers be placed in the grounded neutral conductor of the circuit provided they do not open the circuit.

c. Auto-Transformer Type Dimmers: An auto-transformer type of dimmer shall be energized by a circuit operating at not more than 150 volts between conductors and the grounded conductor shall be common to both the input and the output of the auto-transformer.

Ques.—What are the requirements as to circuit loads in theatre lighting?

Ans.—Footlights, border lights, and proscenium side lights shall be so arranged that no branch circuit supplying such equipment will carry a load exceeding 15 amperes.

Ques.—What type of receptacles are required for installation to arc and incandescent lamps?

Ans.—Receptacles intended for the connection of arc lamps shall have not less than 35 amperes capacity and shall be supplied by conductors not smaller than No. 6. Receptacles intended for the connection of incandescent lamps shall have not less than 15 amperes capacity and shall be supplied by conductors not smaller than No. 12. Plugs for arc and incandescent receptacles shall not be interchangeable.

Ques.—How should lamps be installed in scene docks?

Ans.—Lamps installed in scene docks shall be so located and guarded as to be free from mechanical injury and provide an air space of not less than two inches between such lamps and any combustible material.

Ques.—What are the requirements with respect to stage flue damper controls?

Ans.—If stage flue dampers are released by an electrical device, the circuit operating the latter shall be normally closed and shall be controlled by at least two externally-operative switches, one switch being placed at the electrician's station and the other where designated by the inspection authority. The device shall be designed for the full voltage of the circuit to which it is connected, no resistance being inserted. It shall be located in the loft above the scenery and shall be enclosed in a suitable iron box having a tight, self-closing door.

Ques.—How shall portable stage equipment arc lamps be installed?

Ans.—Arc lamp frames and standards shall be so installed and guarded as to prevent their becoming grounded.

Ques.—What are the requirements for wiring of lights on scenery?

Ans.—Brackets on scenery shall be wired internally and the fixture stem shall be carried through to the back of the scenery where a bushing shall be placed on the end of the stem, except that externally wired brackets or other fixtures may be used when wired with type P or other cords designed for hard usage which shall extend through scenery and without joint or splice in canopy of fixture back and terminate in an approved type stage connector located within 18 inches of the fixture. Fixtures shall be securely fastened in place.

Ques.—What is the Code ruling as to festoon wiring?

Ans.—Joints in festoon wiring shall be staggered where practicable. Lamps enclosed in lanterns or similar devices of combustible material shall be equipped with approved guards.

Ques.—What are the requirements as to special effect devices?

Ans.—Electrical devices used for simulating lightning, waterfalls, and the like, shall be so constructed and located that flames, sparks or hot particles cannot come in contact with combustible material.

Ques.—How shall flexible conductors be connected to receptacles or electrical devices?

Ans.—Connectors for flexible conductors shall be so constructed that tension on the cord or cable will not be transmitted to the connections. The female half of the connector shall be attached to the live end of the cord or cable.

Ques.—What are the requirements as to conductors for portable equipments?

Ans.—Flexible conductors used to supply portable stage equipment shall be types K, S, SO or ST, except that reinforced cord may be used to supply stand lamps if the cord is not liable to severe mechanical injury and is protected by an overcurrent protection rated at not over 15 amperes.

Ques.—Is it permissible to install pendants in dressing rooms?

Ans.—Neither lamp pendants or receptacles shall be installed in dressing rooms.

The use of flat irons, curling irons, electric heaters or other electrical appliances, whose operating temperatures might ignite combustible material, should not be permitted in such rooms.

Ques.—What are the requirements as to lamp guards in theatre dressing rooms?

Ans.—All incandescent lamps in dressing rooms, if less than eight feet from the floor, shall be equipped with open-end guards riveted to the outlet box cover or otherwise sealed or locked in place.

Ques.—How shall theatre footlights be installed?

Ans.—If metal trough construction is employed for footlights, the trough containing the circuit conductors shall be made of sheet metal not lighter than No. 20 USS gauge (.0359 inch in thickness) treated to prevent oxidation. Lampholder terminals shall be kept at least ½ inch from the metal of the trough. The circuit conductors shall be soldered to the lampholder terminals.

Ques.—What are the requirements as to the construction and installation of arc lamps in theatres and motion picture houses?

Ans.—Arc lamps shall comply with the following:

a. General: Portable arc lamps shall be substantially constructed entirely of metal not less than No. 20 USS gauge (.0359 inch) except where approved insulating material is necessary. The design shall be such as to provide proper ventilation while retaining sparks, and to prevent carbons or other live parts of lamp from making contact with metal of hood.

b. Hoods: Hoods for other than lens lamps shall have the front opening equipped with a self-closing hinged door frame carrying either wire gauze or glass. Hoods for lens lamps may have a stationary front, and a solid door on either back or side.

c. Insulation: Mica shall be used for the insulation of the lamp frame

d. Switch: The switch on the standard shall be of such design that accidental contact with any live part will be impossible.

e. Rheostats: Rheostats shall be enclosed in a substantial properly ventilated metal case affording a clearance of at least one inch between case and resistance element. If the rheostat is mounted on the standard, a clearance of three inches above the floor shall be maintained. Asbestos-covered type AA conductors shall be used between the rheostat and the lamp.

f. Terminals: If stranded conductors are used, they shall be connected to lamp, rheostat and switch terminals by means of approved lugs or connectors; provided that approved pressure connectors shall be used at arc lamp terminals.

Ques.—What are the requirements as to construction and installation of portable plugging boxes?

Ans.—Portable plugging boxes shall conform with the following:

a. Enclosure: The construction shall be such that no current carrying part will be exposed.

b. Receptacles and Overcurrent Protection: Each receptacle shall have a current-carrying capacity of not less than 30 amperes, and shall be protected by overcurrent devices installed in an approved enclosure equipped with self-closing doors.

c. Busbars and Terminals: Busbars shall have a current-carrying capacity equal to the sum of the ampere ratings of all receptacles. Lugs shall be provided for the connection of the master cable.

Ques.—How are portable stage switchboards supplied?

Ans.—Portable switchboards shall be supplied only from outlets especially provided for this purpose. Such outlets shall consist of externally operative, enclosed fused switches or circuit-breakers mounted on the stage wall or at the switchboard in locations readily accessible from the stage floor.

Ques.—What type of overcurrent protection shall be employed for portable stage switchboards?

Ans.—Circuits from portable switchboards directly supplying equipment containing incandescent lamps of the medium base or smaller types shall be protected by overcurrent devices having a rating or setting of not more than 15 amperes. Other circuits shall be provided with overcurrent devices with a rating or setting not higher than the current required for the connected load.

Ques.—What are the general requirements as to construction and installation of portable stage switchboards?

Ans.—Portable switchboards for use on stages shall comply with the following:

a. Enclosure: Portable switchboards shall be placed within an enclosure of substantial construction which may be so arranged that the enclosure is open during operation. Enclosures of wood shall be completely lined with sheet metal of not less than No. 24 USS gauge (.0239 inch) and if not of corrosion-resistant type shall be well galvanized, enamelled, or otherwise properly coated to prevent corrosion.

b. Live Parts: Except as provided for dimmer face plates in paragraph *e*, there shall be no exposed live parts within the enclosure.

c. Switches and Circuit-Breakers: All switches and circuit-breakers shall be of the externally-operative, enclosed type.

d. Circuit Protection: Overcurrent devices shall be provided in each ungrounded conductor of every circuit supplied through the switchboard. Enclosures shall be provided for all overcurrent devices in addition to the switchboard enclosure.

e. Dimmers: The terminals of dimmers shall be provided with enclosures, and dimmer face plates shall be so arranged that accidental contact cannot be readily made with face-plate contacts.

f. Interior Conductors: All conductors within the switchboard enclosure shall be stranded and, except for cables feeding to or from AA or other types approved for a maximum operating temperature of 200° C. (392°F.). Each conductor shall have a current-carrying capacity at least equal to the rating of the circuit-breaker, switch or cutout which it supplies. except for conductors for incandescent lamp circuits having overcurrent protection not exceeding 15 amperes. Conductors shall be enclosed in metal troughs or securely fastened in position and shall be bushed where they pass through metal.

g. Pilot Light: A pilot light shall be provided within the enclosure and shall be so connected to the circuit supplying the board that the opening of the master switch will not cut off the supply to the lamp. This lamp shall be an independent circuit having overcurrent protection of a rating or setting of not more than 15 amperes.

h. Supply Connections: The supply to a portable switchboard shall be by means of flexible cord (types K or S) terminating within the switchboard enclosure of in an externally-operative fused master switch or circuit-breaker. The supply cable shall have sufficient current-carrying capacity to carry the total load on the switchboard and shall be protected by overcurrent devices.

i. Cable Arrangement: Cables shall be protected by bushings where they pass through enclosures and shall be so arranged that tension on the cable will not be transmitted to the connections.

j. Terminals: Terminals to which stage cables are connected shall be so located as to permit convenient access to the terminals. At terminals not provided with approved pressure connectors the following construction shall be employed:

1. For conductors of No. 10 or larger, solder lugs shall be used.

2. For conductors smaller than No. 10, the strands shall be soldered together when connected to clamps or binding screws not specifically approved as pressure connectors.

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.

*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

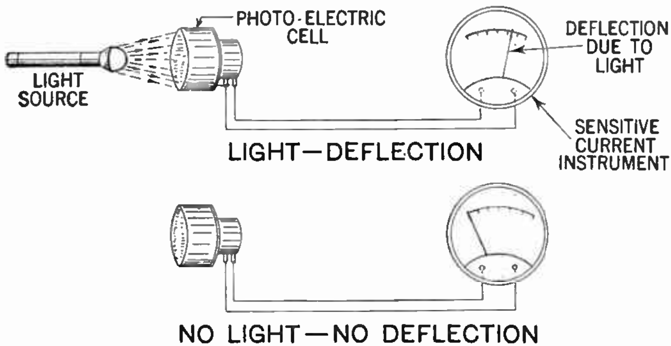


FIG. 1—Illustrating how variations in light on the photo-electric cell causes deflection of the needle on a galvanometer or other sensitive current measuring device.

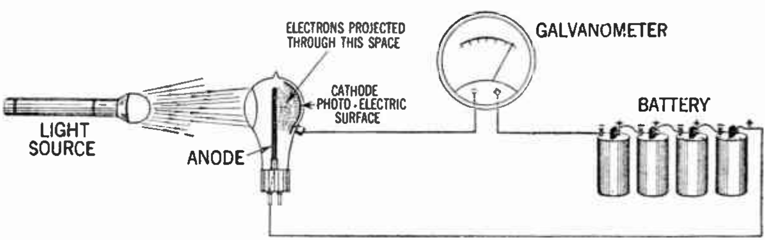


FIG. 2—To increase the amount of deflection (efficiency of light conversion) various methods of current amplification similar to that associated with current amplification in radio circuits is employed.

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

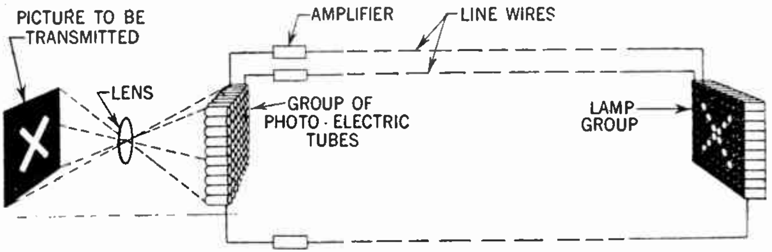


FIG. 3—Diagram of an early television system. At the transmitting end light is converted into electrical energy which when amplified will energize a magnetic shutter or similar device at the receiving end causing a reproduction of the picture. Each photo-electric cell must be individually converted to 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

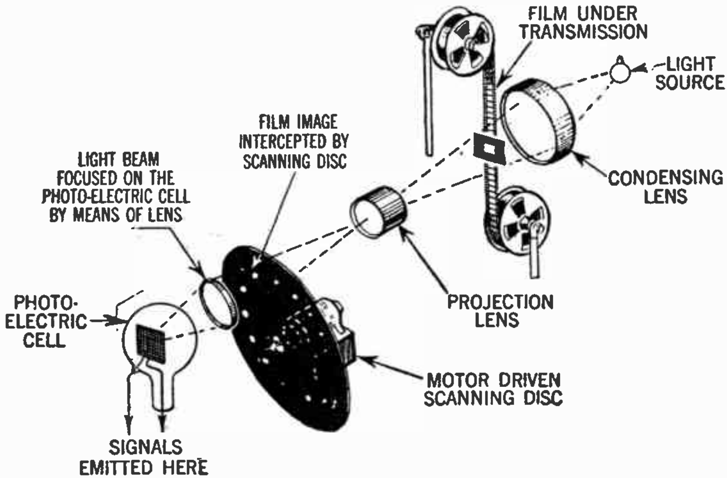


FIG. 4—Simplified view of a mechanical transmitting system.

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 employs 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.

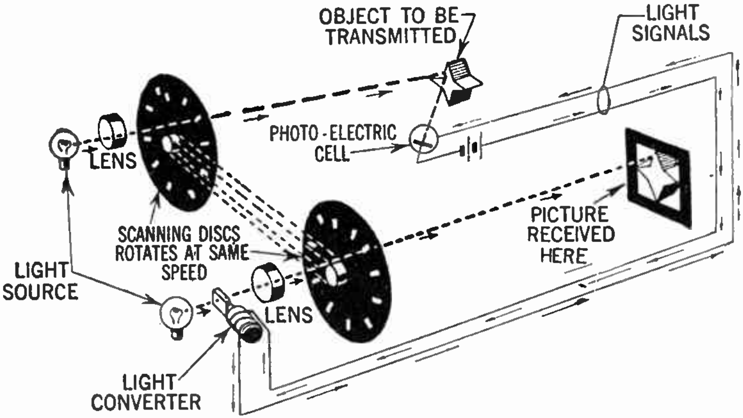


FIG. 5—Simplified view of complete mechanical television system consisting of transmitter and receiver.

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.

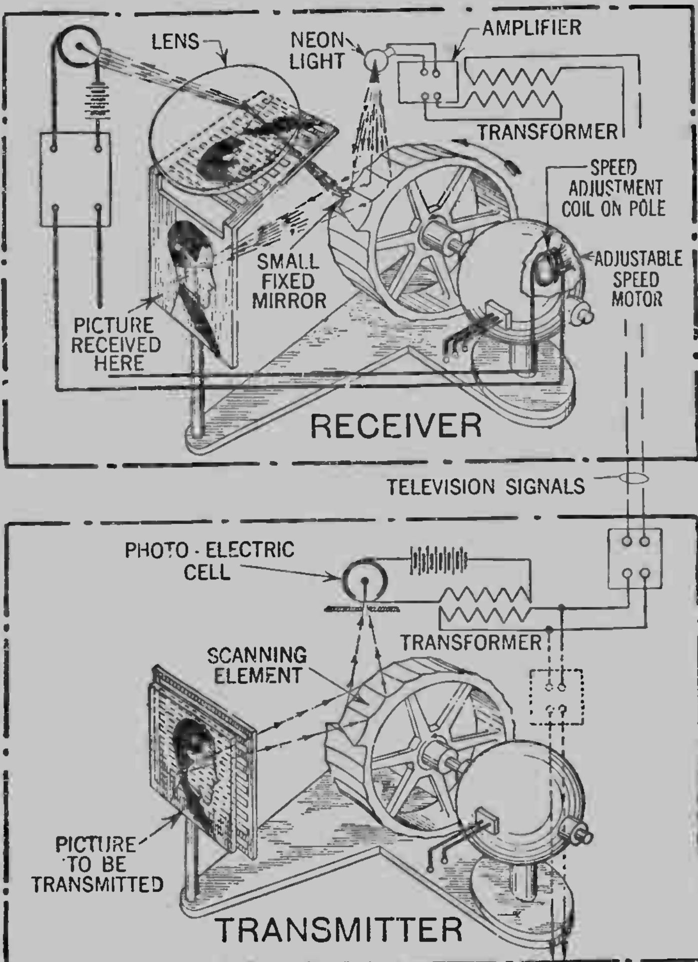


FIG. 6—Simplified view of a mechanical television system.

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.

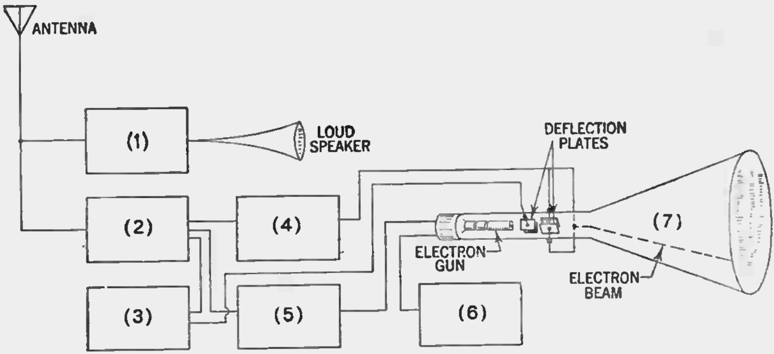


FIG. 7—Block diagram indicating fundamental unit that makes up a television receiver.

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**.

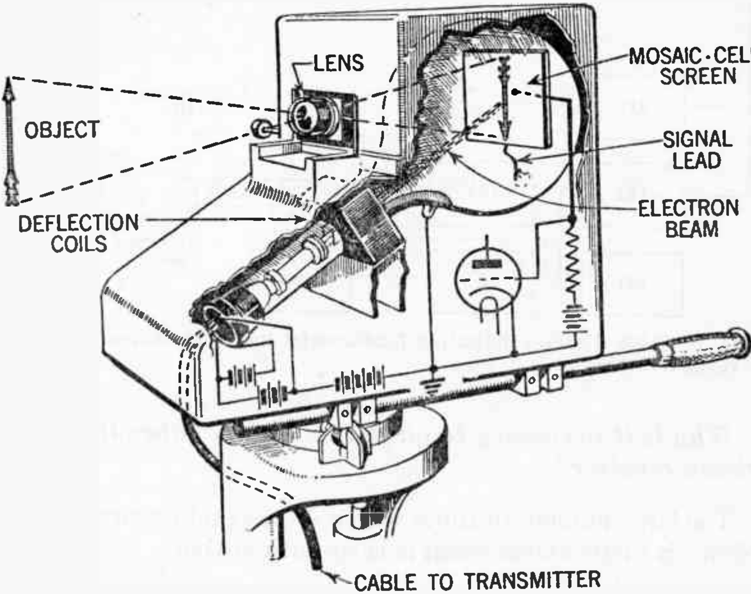


FIG. 8—Internal view of television pick-up camera, converting light impulses of the object to be transmitted to electrical signals which are sent out from the antenna, and picked up by the television receiver. This apparatus in television actually corresponds to the microphone in regular broadcast. Roughly 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

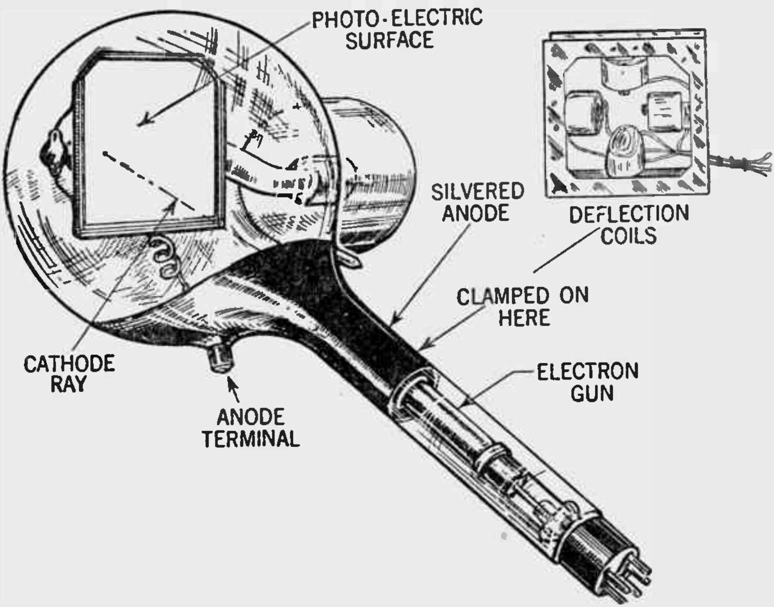


FIG. 9—Iconoscope (transmitting tube) used in the television pick-up camera.

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.

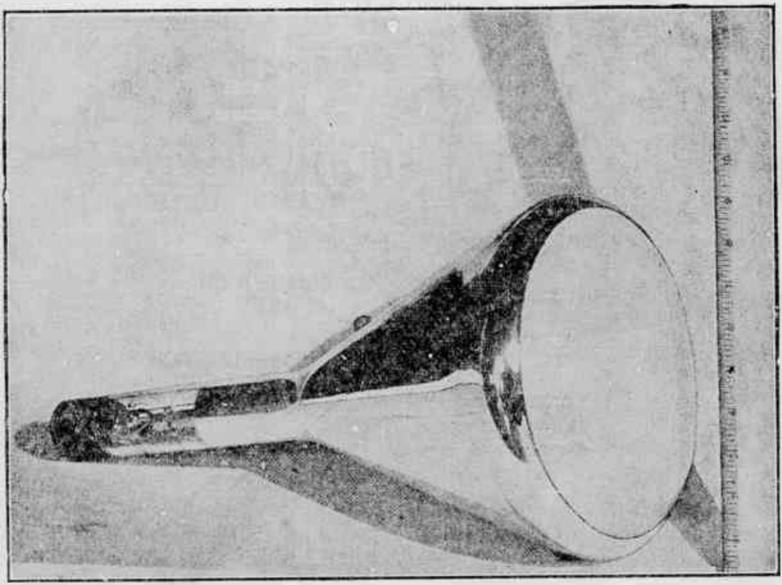


FIG. 10—The kinescope.

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.

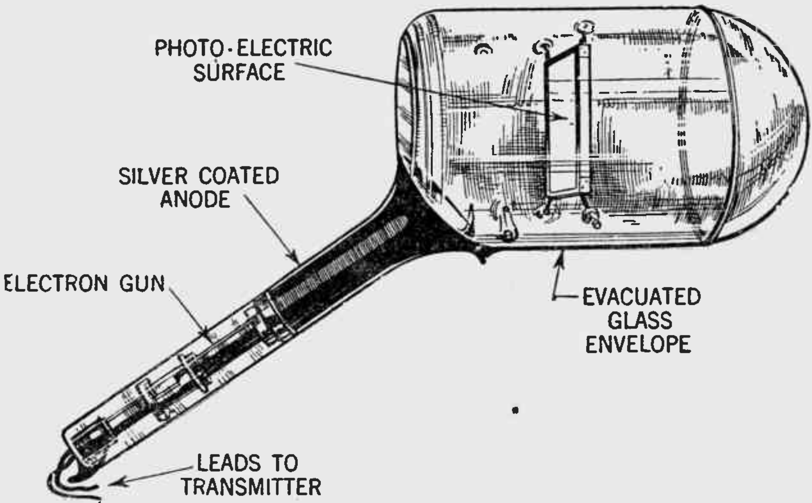


FIG. 11—Another type of cathode ray transmitting tube.

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.

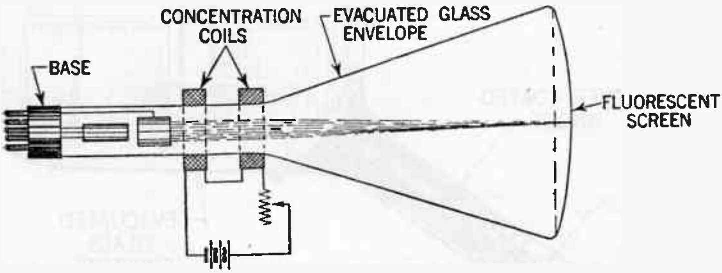


FIG. 12—Cathode ray tube with external concentration coils. The concentration coils generally consists of one or more solenoid of wire placed as shown for focusing the ray. For a practical utilization of this form of ray concentration, however, it is necessary that the position of the coils be definitely 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.

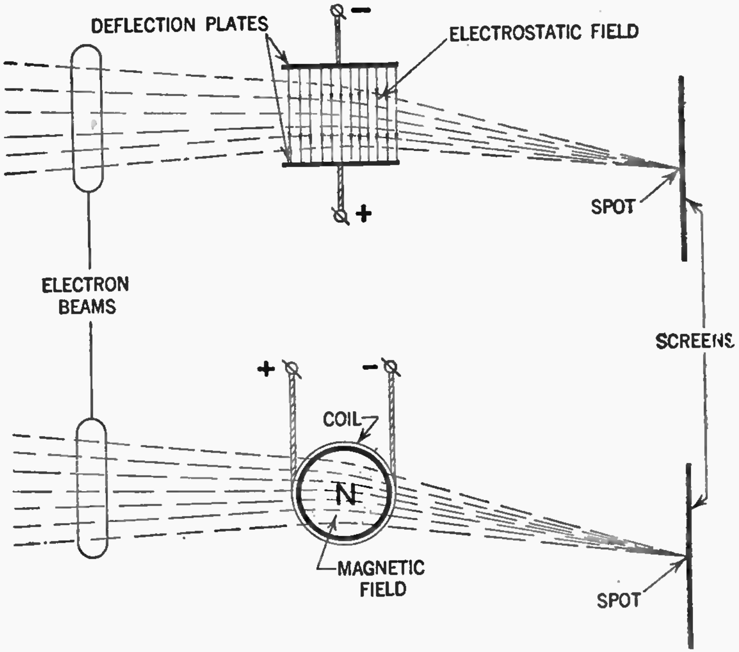
The fluorescent spot on the screen can be brought to a minimum diameter by adjustment of the voltage on the first anode. The voltage on the first anode for best focus is usually ¼ or ⅕ of that on the second anode.

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 photo-electric 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

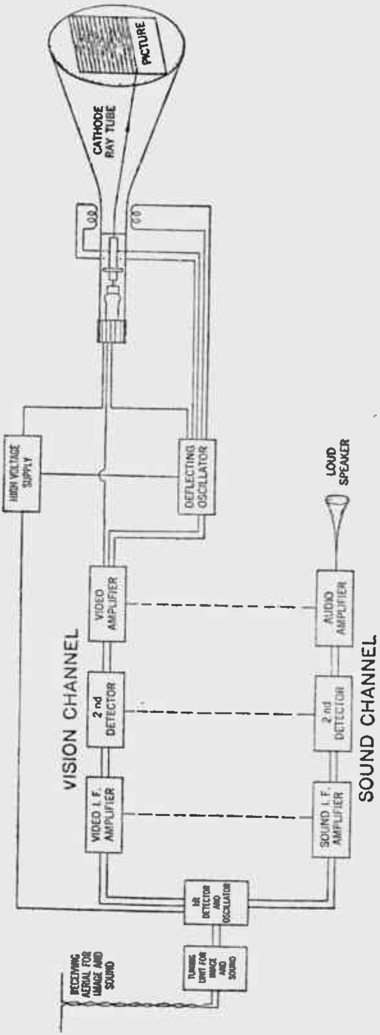


FIG. 15—Block diagram showing the general process involved in picking up simultaneous sound and vision signals.

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.

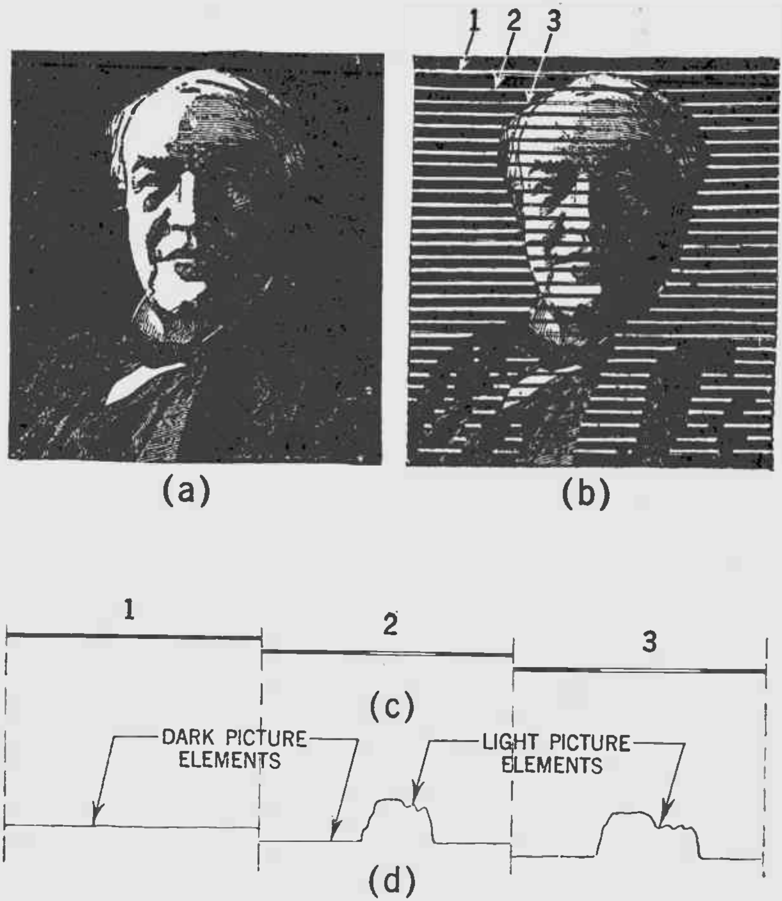
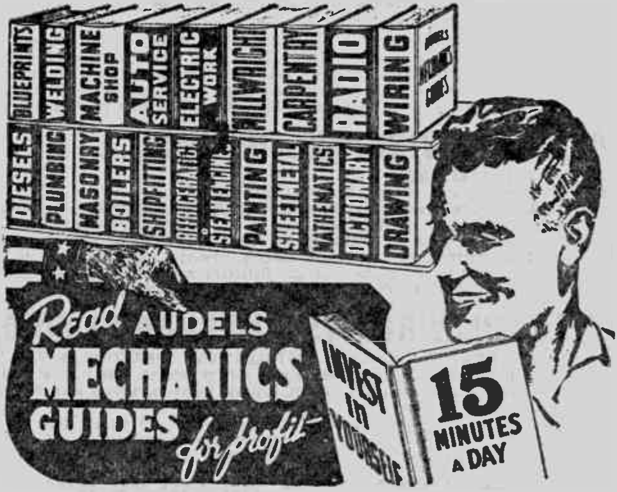


FIG. 16—Showing fundamental scanning principles.

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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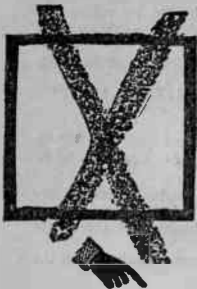

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