QUESTIONS AND ANSWERS

AUDELS RADIOMANS GUIDE

THEORY AND PRACTICE

AUDELS RADIOMANS GUIDE

A Practical Concise Treatise Presenting in Easily Understood Form the Theoretical and Practical Information Necessary for the Proper Operation, Maintenance and Service as Applied in

MODERN RADIO PRACTICE

BY

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World Radio History

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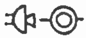
Microphone (Telephone Transmitter)	
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Piezoelectric Plate	
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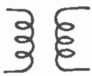
Transformer, Air Core	
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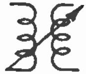
Transformer, with Variable Coupling	
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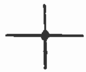
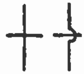
Wires, Joined	
Wires, Crossed, not Joined	
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Triode (with directly heated cathode)	
Triode (with indirectly heated cathode)	
Screen Grid Tube (with directly heated cathode)	
Screen Grid Tube (with indirectly heated cathode)	
Rectifier Tube, Full-Wave (Filamentless)	
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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

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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.

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

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

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

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

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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.

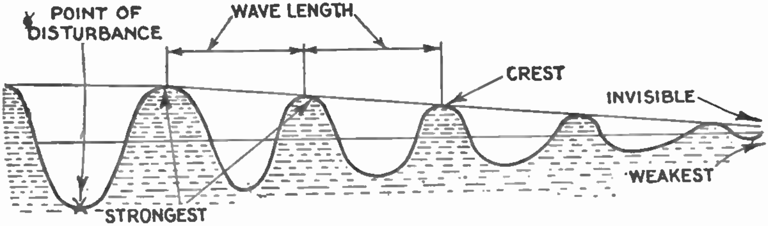

FIG. 7,181.—Sectional view of waves produced by throwing stone in still water, illustrating crest of wave, wave length and gradual weakening of the waves as they travel from the point of disturbance.

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

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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.

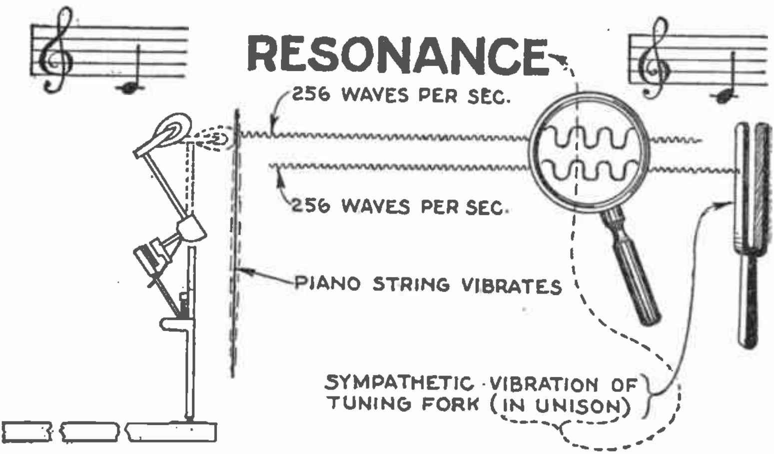

FIG. 7,182.—Sympathetic vibration of tuning fork with struck piano string when tuned to same pitch, illustrating the wave theory of radio.

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.

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Radio Definitions

A. C.—Alternating current.

A. C. C. W.—Alternating current continuous waves.

Aerial.—A device for receiving radio waves.

A. F.—Audio frequency.

Air Condenser.—A condenser in which the metal plates are separated by air, mechanical separation being provided by a small amount of solid insulating material.

Ammeter.—Instrument for measuring electric current.

Ampere.—The practical unit of electric current.

Ampere Hour.—A unit of quantity of electricity. One ampere flowing for one hour or its equivalent.

Amplifier.—An apparatus which delivers an electric current similar in form to the electric current put into it, and of greater power. The amplifiers commonly used employ electron tubes.

Amplitude.—The maximum value of any vibration during a cycle.

Antenna.—The device or part of a circuit for radiating radio waves.

Arc.—A passage of electricity through a gas which depends on the volatilization of one or both electrodes.

Arc Transmission.—The transmission of radio messages by continuous waves produced by an electric arc.

Atmosphere.—Disturbances caused in a radio receiving set by atmospheric electricity. They cause grinding or crashing sounds in the telephone receiver and at times interfere with reception.

Audion.—A three element vacuum tube.

Audio Frequency.—The term applied to currents pulsating at a frequency not over 10,000 cycles per second. Frequencies within the range of the human ear.

Battery.—Two or more electric cells connected together in one unit.

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Beats.—Periodic variations in the amplitude of two vibrations of slightly different frequencies due to the interaction of the two.

Break-in.—An arrangement whereby the transmitting key automatically disconnects the receiving set from the aerial and substitutes the transmitting set.

Broadcasting.—The transmission of information, entertainment, etc., intended for an unlimited audience.

Buzzer.—A type of electro-magnetic interrupter.

By-pass.—A condenser used for providing a low impedance path for high frequency currents across low frequency apparatus.

Capacity.—Electrical quality of a condenser or an antenna, somewhat analogous to elasticity or springiness.

Cathode Rays.—The stream of electrons or electrical particles sent out from the cathode or filament of a vacuum tube. These rays are negatively charged.

Circuit.—The wires and instruments taken collectively when connected for a given purpose.

Code, International.—The conventional arrangement of dots and dashes representing the letters of the alphabet, figures, etc., for the transmission of intelligence by radio telegraphy.

Coil Aerial.—An aerial consisting of one or more complete turns of wire.

Condenser.—An apparatus consisting of insulating material (which may be air) between two metal plates or sets of plates. The purpose of a condenser is to provide capacity.

Condenser Antenna.—An antenna consisting of two condenser plates, one of which may be a wire or set of wires elevated above the ground, and the other of which may be either the ground or another set of wires. The wire or set of wires elevated above the ground is only a part of the whole antenna.

Continuous Waves.—Radio waves which do not vary in amplitude (intensity). Continuous waves are not modulated, as modulation varies the wave amplitude.

Crystal Detector.—A device which makes incoming signals audible in the telephone receiver, employing a mineral across the contact with which more current can flow in one direction than the opposite.

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Counterpoise.—A set of metal wires or sheet forming the lower plate of a condenser antenna.

Coupler.—A device by means of which the coupling between circuits can be varied in a receiving set having more than one circuit. It usually consists of two coils of wire so arranged that one coil can slide or rotate within or near the other.

Cycle.—A complete reversal of the current in an *a.c.* circuit.

Damped Wave.—Radio waves that come in groups, the successive waves in each group decreasing in magnitude. Damped waves are produced by spark transmitting sets.

Design.—The electrical design of a circuit is the specification of particular values for the various constituent parts of that circuit.

Detector.—A device which converts radio-frequency current into pulsating current in one direction so as to make signals audible in the telephone receiver.

Dielectric.—Any material which offers a very high resistance to the passage of electric current.

Down Lead.—The wire connection from the aerial to the receiving set. (Also called "lead-in.")

Electrolyte.—The active liquid in an electric battery.

Electro-magnet.—A temporary magnet which is magnetized by the passage of an electric current through a wire wound around it.

Electrostatic.—Pertaining to an electrically charged body in which no current flows.

Electron Tube.—A combination of a filament which may be heated, a metal plate, and a metal grid which controls the flow of electrons from the filament to the plate, the whole in a vacuum. The usual type of electron tube used as a detector or amplifier greatly resembles in appearance an incandescent lamp bulb. (This is called by various names, such as "audion" "vacuum tube" "triode," "three-electrode tube.")

**Ether.*—The hypothetical medium through which radio waves are said to be propagated through space.

Fading.—Irregular variation of intensity of signals caused by actual variation of wave intensity.

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*NOTE.—Dr. Albert Einstein discards the theory of the ether usually presented by radio writers. See page 4,441.

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Farad.—A unit of electric capacity. If a steady current of one ampere flow into a condenser and the voltage across the condenser be one volt at the end of one second, the capacity of that condenser is one farad.

Feed back.—The energy returned to the grid, and the means for returning it, in a regenerative circuit.

Filament.—The hot element in a vacuum tube which emits the electrons.

Fleming Valve.—A two-element vacuum tube.

Frequency.—The number of complete reversals, or cycles per second.

Generator.—A commonly used but objectionable name for a machine which converts mechanical energy into electric energy.

Grid.—The control electrode in a three element vacuum tube.

Grid bias.—A negative pressure applied to the grid.

Grid leak.—A high resistance connecting the grid to the filament.

Ground.—An electrical connection to earth or to a large conductor which is at the earth's pressure.

Ground Wire.—The wire connection from the receiving set to ground or counterpoise.

Hard Tube.—An electron tube suitable for use as an amplifier. A tube having a higher vacuum than is necessary for a detector.

Harmonics.—Waves, the frequency of which is a multiple of the main wave of a transmitting station. Harmonics are usually objectionable; the power that goes into them is wasted.

Heaviside layer.—An assumed layer of ionized gas supposed to exist at an elevation of 25 or more miles above the earth's surface.

Henry.—The practical unit of inductance.

Heterodyne.—To produce beats with an incoming C. W. signal by supplying a locally generated frequency.

Honeycomb.—A type of winding for inductance coils which resembles a honeycomb.

NOTE.—***The Kenelly-Heaviside layer,*** first postulated in 1902 by Oliver Heaviside, English physicist, and A. E. Kenelly, and proved to exist in 1925 by other scientists, *is a conducting layer of ionized gas at a level of forty to fifty kilometers (twenty-five to thirty-one miles) above the earth's surface during the day, rising to about ninety kilometers (fifty-six miles) at night.* Its existence was pointed to be the behavior of long wave length radio waves.

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Hydrometer.—An instrument for measuring the specific gravity of liquids.

I. C. W.—Interrupted continuous waves.

Impedance.—The total opposition offered by a circuit to the passage of a current. The ratio of the voltage to the current produced by it.

Impulse.—A force acting for a very short time, such as a quick blow.

Inductance.—Electrical quality of a circuit or part of a circuit, somewhat analogous to heaviness or inertia.

Insulator.—Any substance which does not pass an electric current.

Interference.—Any electrical disturbance originating outside the receiving set which prevents clear reception of the desired signal.

Interrupter.—A device which intermittently breaks or interrupts an electric current.

Key.—A type of switch by means of which the current may be stopped and started for signaling.

Kilocycle.—1,000 cycles.

Lead-in.—Same as down lead.

Line Radio.—Transmission of a high frequency current, with its accompanying wave field, guided by a conducting line.

Loading Coil.—A coil of wire for increasing the inductance (and hence the resonance wave length) of an antenna or other circuit.

Loop aerial.—Same as coil aerial. (There is some tendency to restrict "loop aerial" to a single turn coil.)

Megohm.—The unit used to measure high resistances. One megohm equals 1,000,000 ohms.

Meter.—A unit of length 39.37 inches. The usual unit for expressing wave lengths.

Microfarad.—The unit of electrical capacity used to designate the capacity of condensers. It is one-millionth part of a farad. The higher the microfarad rating of a condenser the larger its capacity.

Microphone.—The apparatus which picks up the sound waves at a broadcasting station and produces corresponding electrical variations in the battery or transformer circuit of the transmitter.

Milli-henry.—.001 henry.

Modulation.—Variation of amplitude of the radio wave, the variation being at an audible frequency.

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Motor-generator.—A combined motor and generator by means of which a *d.c.* voltage may either be stepped up to a higher value or stepped down to a lower.

Natural frequency.—The frequency with which a coil is in tune by virtue of its inductance and distributed capacity.

Ohm.—The unit of electrical resistance. With the voltage remaining constant, the current flowing in a circuit is inversely proportional to the resistance in the circuit. In other words—the higher the resistance, the smaller the current and vice versa.

Open Antenna.—Same as condenser antenna.

Oscillator.—An electrical circuit for the generation of oscillations or high frequency currents.

Oscillations.—Very rapid vibrations.

Phase.—The time elapsed from the beginning of a cycle to a given instant.

Pitch.—An acoustic term describing the frequency of a tone.

Plate.—The positive electrode in a vacuum tube.

Potential.—Electrical pressure which determines the flow of current through a given resistance or impedance. The term *pressure* or *voltage* should be used rather than *potential.*

Potentiometer.—A high resistance (200 to 300 ohms) usually connected across the A battery and having a sliding contact making it possible to provide a fine adjustment of the plate voltage. Sometimes it is connected in a manner to provide adjustment of voltage between grid and filament. Sometimes called a stabilizer. In electrical engineering the definition of a potentiometer is entirely different.

Primary.—The first winding of a transformer or the winding on which current is impressed.

Radio frequency.—The term applied to currents pulsating at a frequency too high to be heard by the human ear. Used to identify the currents in the antenna circuit.

Reactance.—That part of the total impedance which is due to capacity and inductance.

Reactance coil.—A coil whose reactance is large compared to its resistance.

Rectifier.—A device which converts alternating current into direct or pulsating current.

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Reflex Circuit.—One in which the amplifier tubes are made to function as both radio and audio-frequency amplifiers simultaneously.

Regeneration.—Increasing amplification in a vacuum tube by returning part of the output to the grid to be re-amplified.

Regenerative Receiving Set.—A set in which an electron tube is so connected that part of the plate circuit power is fed back to the grid circuit (by a tickler or through the tube capacity), thus building up great amplification.

Relay.—An electro-magnetic switch by means of which a local power circuit is controlled.

Resistance.—That part of the total impedance which is due to dissipation of energy in the circuit.

Resonance.—Condition of a radio circuit when it gives maximum response to an impressed wave or voltage. When a circuit is in resonance it is also said to be tuned.

Resonance Transformer.—Any loose coupled tuning inductance having a primary and secondary each with a variable condenser in the circuit. Tuning the secondary circuit brings it in resonance with the primary, thus enabling signals to be heard with greatest volume.

Rheostat.—A variable resistance used to control the filament lighting current of detector and amplifier tubes.

Secondary.—The second winding of a transformer or the winding which delivers energy.

Shunt.—A by-pass or an instrument connected in parallel with another.

Signal.—Any electrical current conveying a message.

Single-circuit Receiving Set.—A set in which the detector is connected to a coil or other circuit element in the aerial circuit.

Soft Tube.—An electron tube suitable for use as a detector but unsuited for use as an amplifier because of the characteristics developed by the residual air. Sometimes called a gas tube.

Spark Transmission.—The transmission of radio messages by damped waves produced by a spark transmitting set.

Static.—Electric disturbances due to atmospheric discharges.

Super-audible.—A frequency which lies above the audible range.

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Super-heterodyne.—Use of a heterodyne to produce an intermediate frequency lower than that of the wave frequency, the intermediate frequency being in turn detected as in ordinary reception.

Super-regeneration.—A method of amplifying in which self oscillations are prevented by periodically damping the circuit.

Thermionic Emission.—The emission of a stream of negative electrons from a heated filament (cathode) in a vacuum tube.

Three-electrode Tube.—Same as electron tube.

Tickler.—A coil used to inductively feed back power from plate circuit to grid circuit in a regenerative receiving set.

Tikker.—A type of interrupter used to detect C. W. signals.

Tuning Coil.—A coil of wire for carrying the inductance (and hence the resonance wave lengths) of a circuit. Provision is made so that various numbers of turns can be connected in circuit. When used in an antenna circuit a tuning coil is also a loading coil.

Tuner.—The portion of a circuit in which tuning is done.

Two-circuit Receiving Set.—A set in which the detector is connected to a secondary circuit coupled to the aerial circuit.

Undamped waves.—Continuous waves.

Vacuum Tube.—An evacuated bulb, or one containing a rare gas and having two or more elements.

Variable Condenser.—A condenser the capacity of which can be readily varied. In its usual form it is two sets of plates which interleave but do not touch each other, one set being rotatable.

Vernier.—A term applied to condensers, rheostats, etc., having a means for providing a finer adjustment than is possible with similar apparatus not so equipped. Applied also to a variable condenser having only 3 or 5 plates.

Vibration.—Rapid to and fro motion.

Volt.—Unit of electric pressure.

Volt meter.—Instrument for measuring electric pressure.

Wave meter.—An instrument for measuring wave frequency (or wave length).

Wave Length.—The distance between successive crests of a radio wave as it passes along on its way between transmitting and receiving stations. Wave length is inversely proportional to wave frequency.

Wave Trap.—A resonant circuit used to eliminate an interfering signal.

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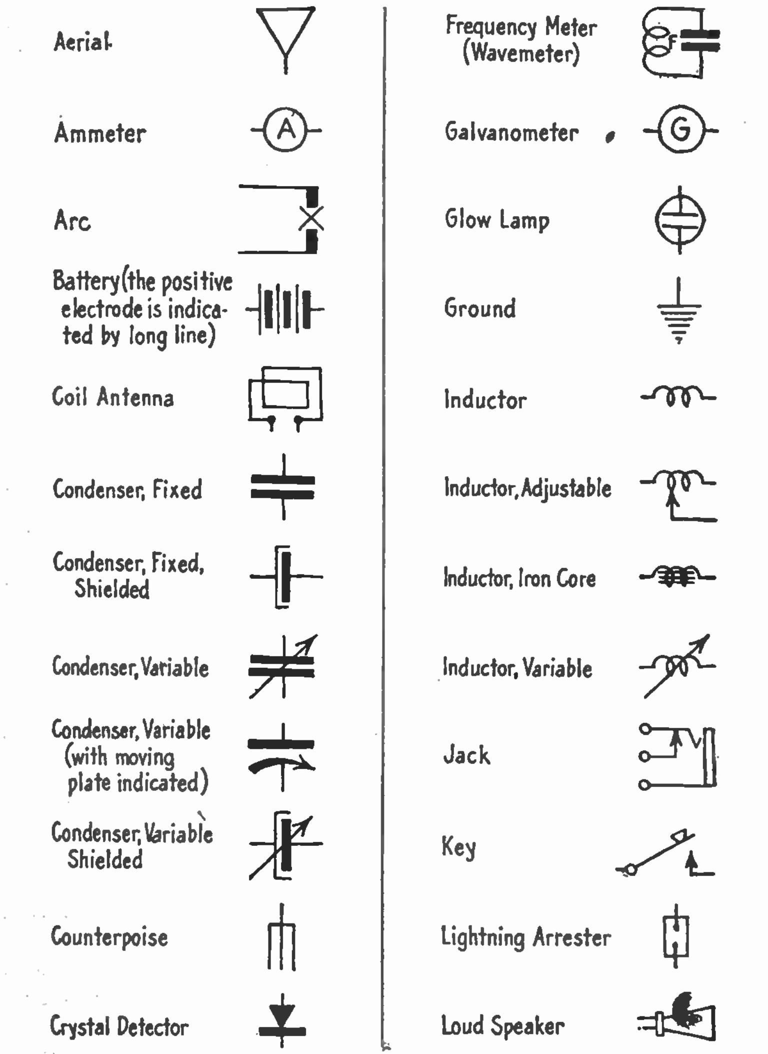
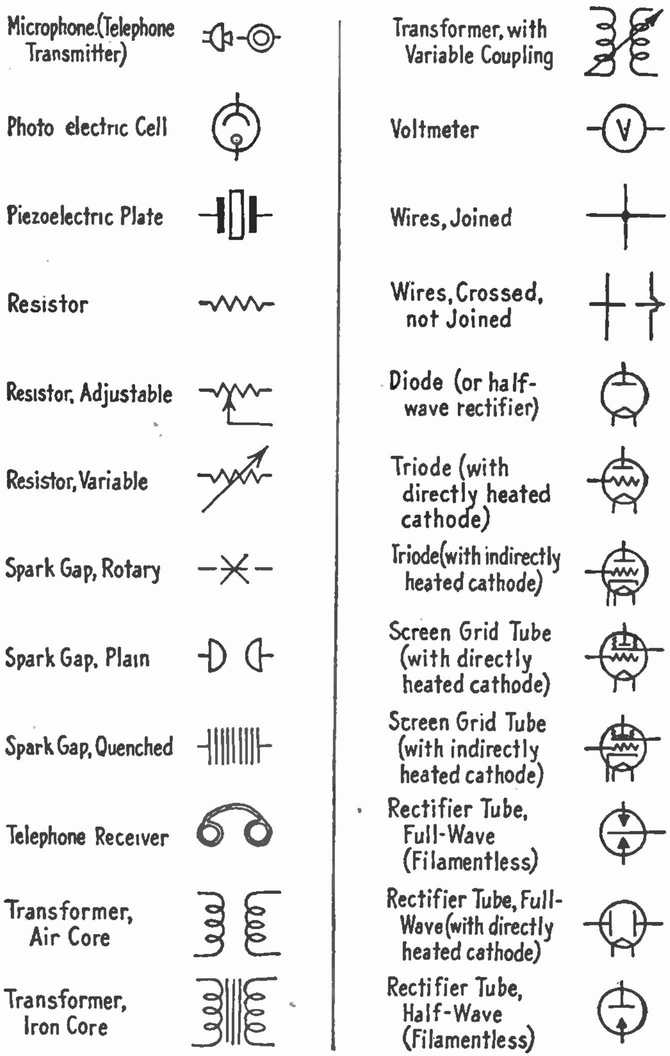


FIGS. 7,183 to 7,216o.—Chart showing various symbols used in radio diagrams.



FIGS. 7,183 to 7,216o—*Continued.*

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INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

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

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

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

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Watt.—Unit of power. Voltage multiplied by amperage.

Wired Radio.—Application of the principles of radio to communication over wires.

Essentials of Radio Communication.—Although there is a great multiplicity of "radio sets," the performance of a number of these consists of just four functions known as:

1. Reception;
2. Selection;
3. Detection;
4. Audition.

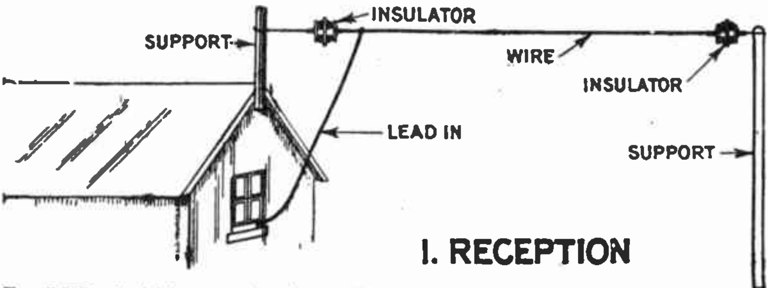

FIG. 7,217.—Aerial for reception of the radio waves.

and in those sets of greater refinement there is an additional function known as:

5. Amplification.

Reception.—The aerial is that part of the radio apparatus which receives or "catches" the radio waves and leads them to the selection part of the set. A typical aerial is shown in fig. 7,217.

Selection.—When several transmitting stations are broadcasting at the same time it is necessary to provide means for

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cutting out or making the apparatus non-responsive to all stations except the one it is desired to hear. This function is called *selection* and is accomplished by a process called *tuning.*

It is found that in a circuit containing *inductance* and *capacity*, certain combinations of these give much greater response than others to a given wave length. Hence, if each broadcasting station have a different wave length, the receiving set can be tuned to respond to any selected station by adjusting the relative amounts of inductance and capacity.

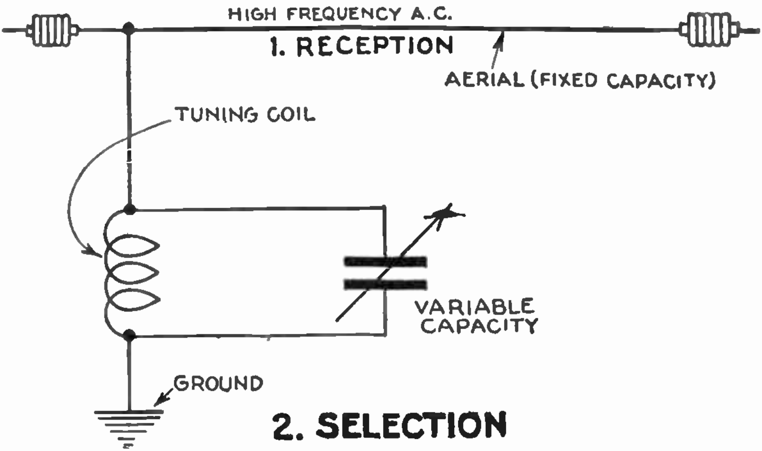

FIG. 7,218.—Aerial and tuning coil, which provide a fixed capacity and variable inductance, the essential elements in the simplest form of circuit necessary for tuning.

When the strength of the signals from the selected station is greatest, the circuit is in tune or in *resonance* with the incoming wave length, or frequency, and then only a very small impulse is required to start large current in the circuit.

In the simplest form of set the inductance is varied by means of a tuning coil and variable condenser, so that any amount of inductance relative to the capacity of the aerial may be obtained to tune to a given wave length as shown in fig. 7,218.

Detection.—This third essential function consists in *converting the alternating current in the aerial and inductance coil into a*

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pulsating uni-directional current so as to make the transmitted signals audible in the telephone receiver.

The part of the apparatus that converts the current is called a detector.

A detector is essential because the human ear is not responsive to vibrations above a few thousand per second. The detector changes the high

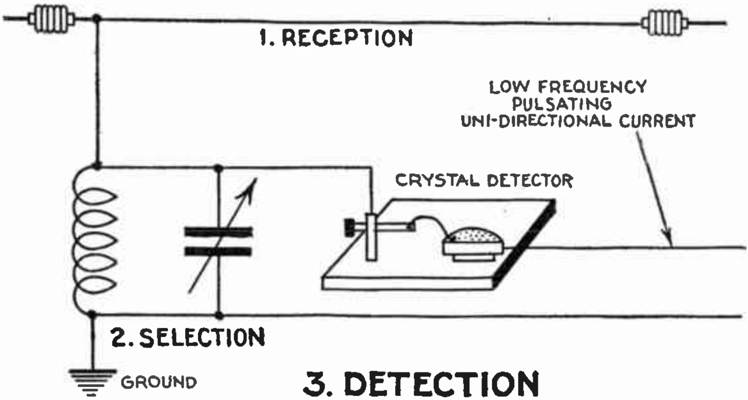

Fig. 7,219.—Addition of crystal detector to the single circuit of fig. 7,218, the essential element necessary for *detection*.

frequency currents to impulses traveling in one direction in the circuit to the number of 100 to a few thousand per second. The simplest form of detector is known as the *crystal detector*. Galena, silicon, and carborundum are the names of three of the crystals used.

The purpose of the head receivers is to change the impulses of direct (one way travel) current to sound waves which can be heard.

The essential elements of the simplest circuit for reception, selection and *detection* are shown in fig. 7,219.

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Audition.—The high frequency impulses having been rectified and reduced to audible limits by the detector it is only necessary to add telephone head receivers to change these impulses to sound waves so they can be heard.

Fig. 7,220 shows this addition to the set, for simplicity a single receiver being shown. The latter it will be seen consists essentially of an electro-magnet and a sensitive diaphragm which vibrates to produce sound waves as influenced by the low frequency pulsating uni-directional current delivered by the detector.

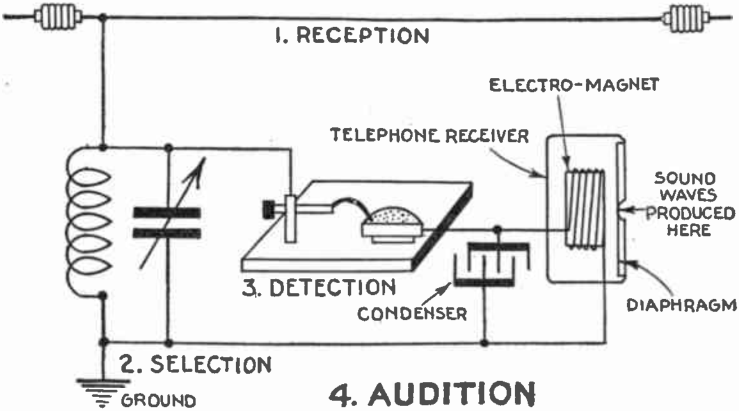

FIG. 7,220.—Addition of telephone receiver with condenser to the simple circuit of fig. 7,219, the essential element for *audition*.

The receiver is assisted in converting the pulsating uni-directional current coming from the detector by a condenser placed in circuit as shown. This condenser alternately receives and gives up charges, responsive to the state of the pulsating uni-directional current. Fig. 7,221 shows a crystal detector set as actually constructed for the four functions indicated in fig. 7,220, except that fig. 7,221 shows a *variable* inductance coil.

Summary

(Operation of simple crystal detector set shown in fig. 7,221.)

Aerial.—Converts radio waves into an alternating current of high frequency.

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Inductance Coil.—Forms, together with the aerial, a circuit which can be tuned to respond to the incoming radio wave. In this set it alone constitutes the "tuner."

Crystal Detector.—Converts the alternating current in the aerial into a pulsating uni-directional current.

Telephone Receivers.—Convert the pulsating uni-directional current into sound.

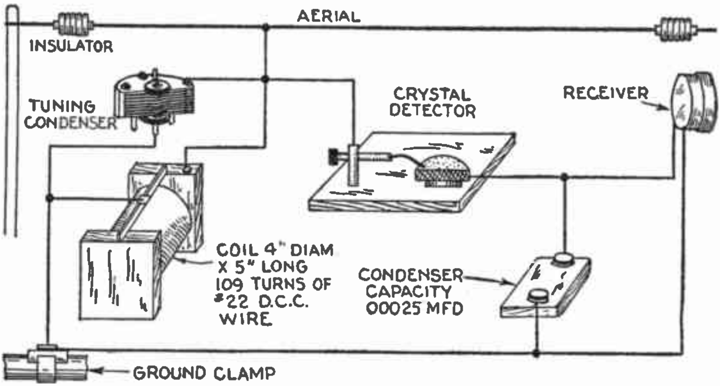

FIG. 7,221.—Small crystal detector set as actually constructed corresponding to the elementary set shown in fig. 7,220, with exception of a variable instead of a fixed inductance coil.

Amplification.—The word amplify means *to increase or enlarge;* in radio, amplification is the act or process of strengthening the radio signals, so that the more distant stations can be heard, and the sound augmented. The simplest set possessing amplification is the tuning coil set and a *vacuum tube* detector.

To understand the working of this set, the principles of the tube should be first considered.

Vacuum Tube Detector.—This device was first brought out by Dr. Lee de Forest under the trade name *Audion.* It is one of the most sensitive instruments known to science yet it does not require more than an elementary knowledge to use it in radio reception. In its simple form it consists of a glass

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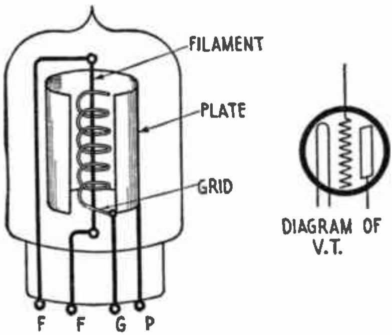
bulb, similar in shape to an electric lamp, evacuated to a high degree and containing three elements:

1. Filament;
2. Plate;
3. Grid.

as shown in figs. 7,222 and 7,223.



FIGS. 7,222 and 7,223.—View of vacuum tube showing elements and diagram of same.

The filament is a piece of high resistance wire which is heated, by current, to brilliancy, as in an electric lamp. When this filament is heated it throws off millions of little electrical units known as negative ions. Around the filament is constructed a small sheet of metal (the plate) to which the ions can go, and so return to the circuit. Ions can travel only from the hot filament to the comparatively cold plate and cannot reverse and go the other way. It is this property which is utilized when employing the vacuum tube as a detector for changing the radio waves of vibrating current into direct current impulses. It is necessary to have some means of controlling the number of ions which reach the plate and for this the "grid" is inserted.

The grid consists of a closely wound spiral or finely woven screen of wire surrounding the filament and through which the ions must pass to reach the plate. Interposed in the path from filament to plate, any electrical charge put upon it from the aerial circuit will either increase or decrease the ions reaching the plate and so varv the current through the head receivers.

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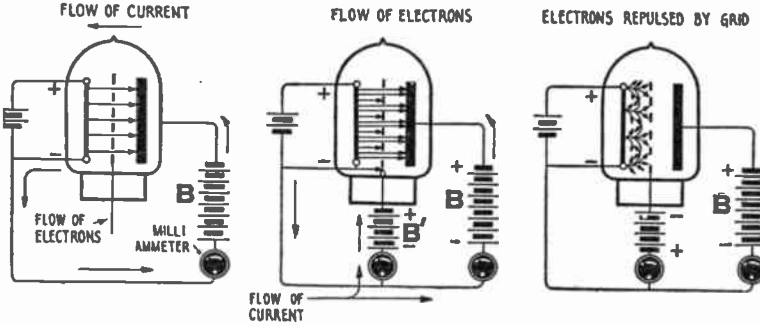
The vacuum tube is used in radio for four purposes.

1. As a detector of received radio currents. (Instead of a crystal detector.)



FIGS. 7,224 to 7,226.—Diagrams illustrating the operation of the three element vacuum tube. A plate filament circuit is secured by the electrons traveling *from the filament to the plate*, since they are attracted by the plate *positively* charged, although the current from the battery B, is arbitrarily said to flow in this circuit *from the plate* to the filament. If the grid be connected as shown above in fig. 7,225, including in this circuit a battery and a milli-ammeter, a current will flow in the grid circuit because a certain number of electrons are stopped by the positively charged grid which allows the current of the battery B′ to flow in the grid filament circuit. Now if the polarity of the grid be changed as in fig. 7,226, the flow of electrons from the filament, when the grid is negative is repulsed, for in this case the electrons are negatively charged. Accordingly, the current from the plate, having no path, is suddenly stopped. Evidently then the grid *acts as an automatic interrupter*.

2. As an amplifier of received currents. (For greatly inreasing the loudness of signals received.)

3. As a generator of alternating currents. (For radio telephony and telegraphy.)

The tube acts as a detector on account of its rectifying action; that is, the incoming high frequency alternating current is rectified or changed to a uni-directional current, one half of the alternating (the positive side) being permitted to pass through to the filament circuit, thence to the phones.

The natural amplifying property of the tube is that when properly connected, it will add current from a battery connected in one of the circuits to the signals, making them much louder when passed through head receivers or a loud speaker.

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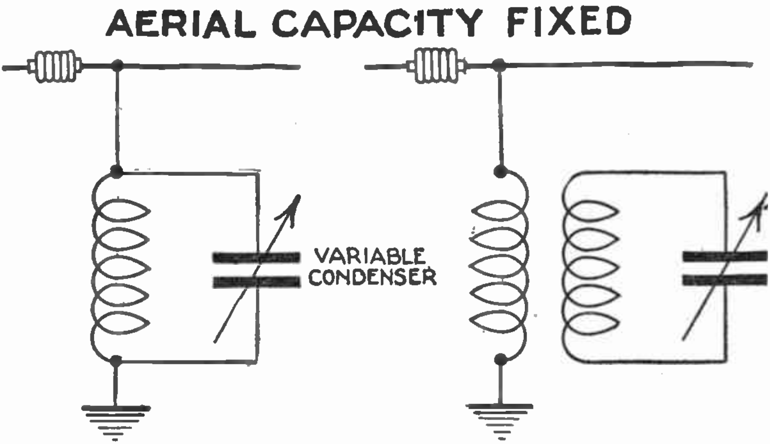
4. As a transmitter,

Direct current is converted into high frequency alternating current using large tubes to change 350, 500, 1,000 or 2,000 volt *d.c.* to *a.c.* of frequency of 50,000 to 2,000,000, per second.

For the operation of the tube, two batteries are used, known as the "A" battery and the "B" battery.



FIGS. 7,227 and 7,228.—*Tuning methods 1. Aerial capacity fixed.* Fig. 7,227, variable condenser fixed inductance coil; fig. 7,228, variable condenser with inductive coupling.

It should be noted that the amount of B battery voltage applied to the plate of the tube determines whether the tube will operate simply as a detector, or as an amplifier in addition to its function as detector.

The A battery is used to heat the filament of the vacuum tube, the amount of current drawn from the battery being controlled by a rheostat which serves to bring the filament to the proper temperature for best results; usually a 6 volt storage battery is used.

The B battery furnishes the local energy which amplifies the receiving signals so as to ncrease the loudness of tone produced in the head receivers or loud speaker. It is connected through the proper terminal to the plate circuit to create a difference of voltage between the filament and the plate.

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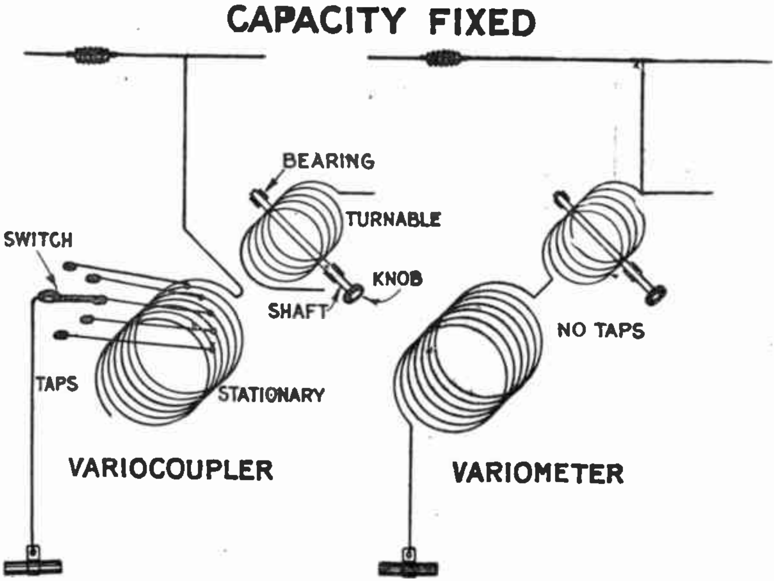
Methods of Selection.—In the simple circuits thus far shown, tuning the apparatus so that it will respond to the desired wave length is accomplished by having the capacity (that of the aerial) fixed and varying the inductance by means of a single slider tuning coil.

Selection may be accomplished in numerous other ways. The following methods (although some are old) should be noted.



FIGS. 7,229 and 7,230.—*Tuning methods 2. Capacity fixed.* Fig. 7,229, variocoupler mutual induction principle; fig. 7,230, variometer, combination of self-induction and mutual induction principles. These are old methods but show principles.

1. Capacity fixed, variable inductance.
   - *a.* One slider tuning coil;
   - *b.* Two slider tuning coil;
   - *c.* Variocoupler;
   - *d.* Variometer.
2. Capacity variable, inductance fixed.
3. Capacity and inductance variable.

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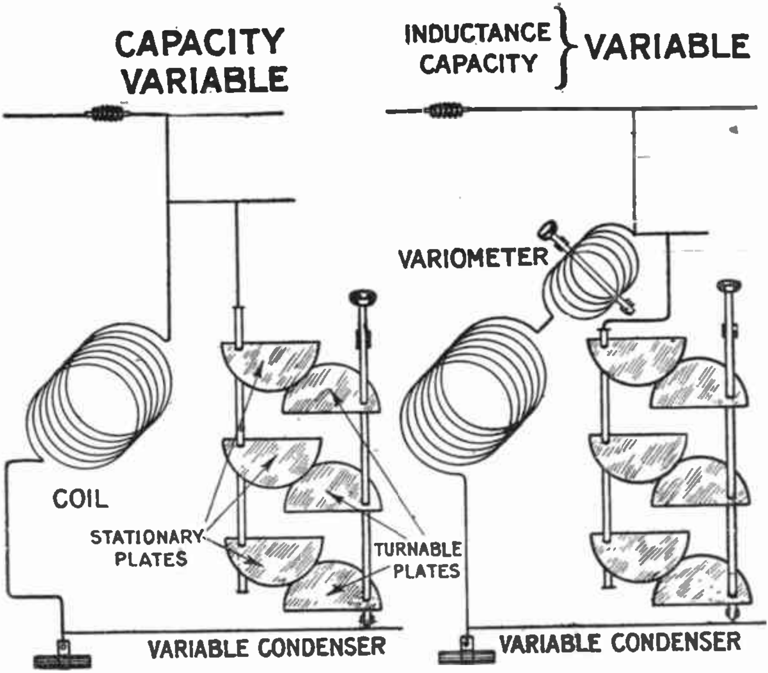
These various methods are shown in figs. 7,229 to 7,232.

Using a single slide tuner, as in fig. 7,221, will not give tuning sharp enough to cut out serious interference. The efficiency is increased by using two slides. The coil of fig. 7,221 is a primary induction coil (single coil) and it works on the principle of self-induction. It works on the



FIGS. 7,231 and 7,232.—*Tuning methods 3.* Fig. 7,231, capacity variable by use of variable condenser, fixed inductance; fig. 7,232, both inductance and capacity variable.

principle of self-induction as distinguished from a secondary induction coil which consists of two coils with no metal connection between, working on the principle of mutual induction; that is, use is made of the magnetic field set up to transfer the energy from one coil to the other.

The variocoupler (fig. 7,229) is an example of this method. Here tuning is accomplished by cutting out various sections of one coil and by adjusting the angular position of the second coil.

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A modification of this method is the variometer (fig. 7,230) in which there are no taps, but the coils are connected together at one end as shown.

For a small wave length range a variometer can be used with connection similar to that of a single slide tuner. With the addition of a condenser and large size variometer a very considerable range of wave length can be covered. In fig. 7,231, the tuning is done by varying the capacity and in fig. 7,232, by varying both inductance and capacity.

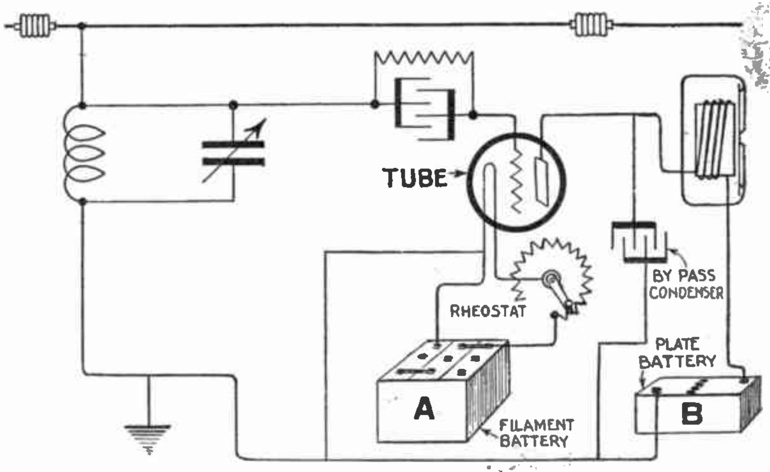

FIG. 7,233.—Simple one tube set in which the tube acts as detector and amplifier. In series with the grid element of the tube and aerial is a grid leak condenser, comprising a condenser and a high resistance in parallel as shown. The effect of this grid condenser is to render the tube a very sensitive detector. A rheostat is placed in the A, or filament battery circuit to adjust the filament current to its proper value which depends on the type of tube used. The by-pass condenser is shunted across the phone and B battery to furnish a low impedance path for the high frequency output current of the detector around the phone and B or plate battery.

Amplification with Tube Detector.—The simplest set possessing amplification is the combination of the tube and tuning coil as shown in fig. 7,233. By using another tube or several additional tubes this amplification may be carried still further, for it is merely necessary to feed the output of one tube into the grid of the next tube.

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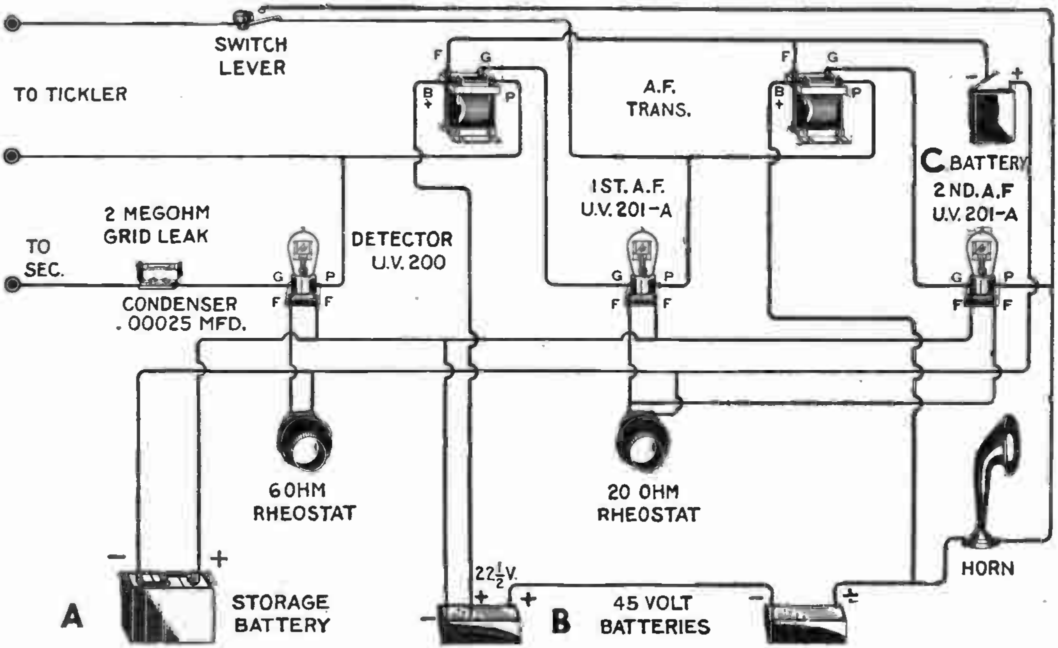

FIG. 7,234.—*Two stage audio frequency amplifier.* This two stage amplifier can be added to any single tube set. Instead of using jacks to plug in different stages of amplification, a switch is used instead. A good amplifier tube such as the UV-201A should be used and plate voltage should be about 90 volts. The addition of a C battery in this amplifier will tend to eliminate distortion so that reception will be clearer and louder.

In this way the incoming radio wave may be repeated and built up until the amplification may be as high as 50,000,000; that is, the characteristics of the incoming wave may be reproduced by an exactly similar wave of enormously greater magnitude.

Coupling of Amplifiers.—If more than one amplifier be used some apparatus must be interposed between successive tubes to obtain the maximum power output of the lower tube and if possible, at the same time obtain the maximum voltage

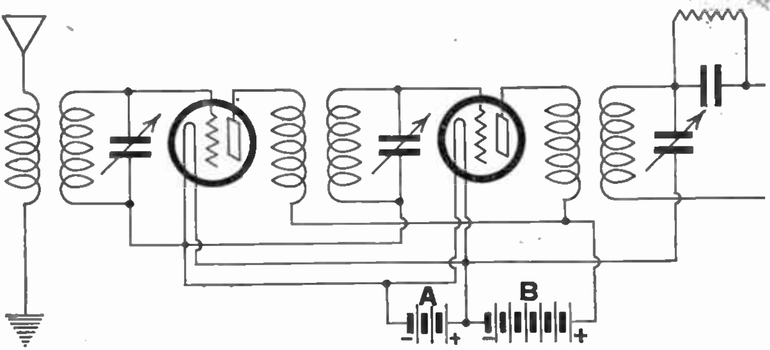

FIG. 7,235—Two stage radio frequency amplifier. Radio frequency amplifiers are used ahead of the detector on receiving sets. In order to prevent distortion in the case of weak signals several stages of amplification are used; some of these stages should be *r.f.* and some *a.f.*

charges on the grid of the upper tube. This is generally done by a transformer coupling. Fig. 7,234 shows connection for two stage amplification.

Radio Frequency Amplification.—By definition radio frequency amplification is *the amplification of the high frequency variations of voltage in the aerial circuit before reaching the detector tube.* These high frequencies are known as radio frequencies and vary from 20,000 to 300,000,000 cycles per second. Fig.

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7,235 is a circuit diagram showing a two stage radio frequency amplifier hook up.

Audio Frequency Amplification.—By definition audio frequency amplification is *the amplification of the low frequency pulsations leaving the detector tube before being fed to the loud speaker.* Fig. 7,236 shows a two stage audio frequency amplifier hook up.

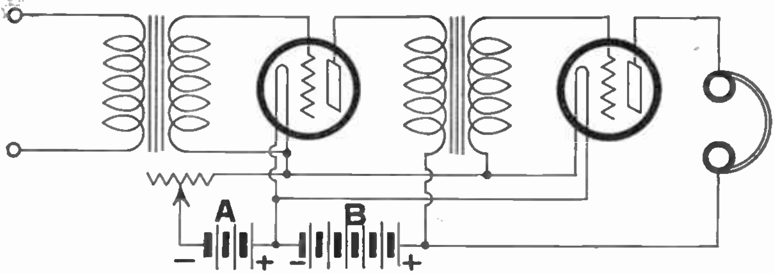

FIG. 7,236.—Two stage *audio frequency* amplifier.

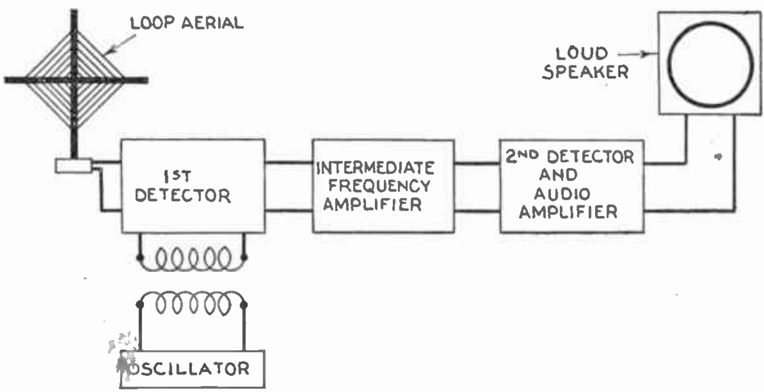

FIG. 7,237—General arrangement of super-heterodyne set showing placement of *intermediate frequency* amplifier.

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Intermediate Frequency Amplification.—By definition intermediate frequency amplification is *the amplification of the intermediate frequency pulsations*, or, frequencies from 20,000 to about 75,000 cycles per second.

Amplification at these frequencies is used in super-heterodyne receivers, the amplifier usually consisting of a *r.f.* amplifier using transformer coupling, the transformer being designed to cover very high wave lengths. An intermediate frequency amplifier hook-up is shown in fig. 7,237.

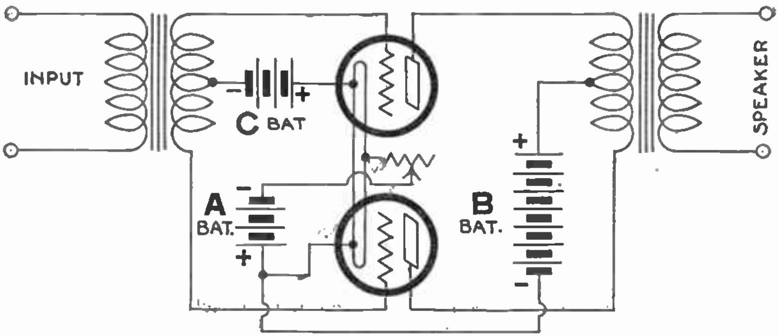

FIG. 7,238—Push pull amplification circuit. This method of amplification requires two tubes of the same type in each stage. The grids of the tubes are not connected together, as is the case in parallel operation, but are connected to opposite ends of a mid tapped transformer secondary. The mid tap is used as a common connection for making connection to the negative *bias* voltage of the grids. The grid voltage varies due to the impressed alternating voltage, which causes the grid to be alternately more and less negative. In push pull operation the grid of one tube is most negative when the grid of the other tube is least negative; therefore, as the plate current of one tube increases the plate current of the other tube decreases. To describe this action the word *push pull* was coined. The action is similar to the operation of a hand car, where one operator pushes on the cross bar as the other pulls, and vice versa. A push pull parallel stage is one in which two or more of push pull circuits are used in parallel.

Push-Pull Amplification.—By definition push-pull amplification is *a method of generating more power for the loud speaker than usually obtained by audio amplifiers*. In the last stage two tubes are thus employed and so connected as shown in fig. 7,238 that they are used alternately on the two halves of each *a.f.* cycle.

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TEST QUESTIONS

1. *What is Dr. Einstein's theory of the ether?*
2. *What happens when a stone is thrown into a pond?*
3. *What does Marconi say about radio waves?*
4. *Compare radio waves with water waves.*
5. *Draw diagram illustrating resonance.*
6. *Give definitions of radio terms.*
7. *What is the Kennelly-Heaviside layer?*
8. *Give symbols for the various pieces of radio apparatus.*
9. *What are the International Morse signals for letters of the alphabet?*
10. *Is the Morse system of signals the only one used?*
11. *What are the four essentials of radio communication?*
12. *How are radio waves received?*
13. *What is tuning?*
14. *How are radio signals made audible in the telephone receivers?*
15. *Explain audition in detail.*
16. *What is a vacuum tube?*
17. *How does a vacuum tube work?*
18. *Name three uses made of vacuum tubes in radio.*
19. *Explain use of A battery and B battery.*
20. *Explain the different methods of tuning.*
21. *How is amplification obtained with tube detector?*
22. *Draw a diagram showing two stage audio frequency amplifier circuit.*
23. *Explain the coupling of amplifiers.*

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CHAPTER 175

Vacuum Tubes

The name *vacuum tube*, which is descriptive of the fact that a high vacuum is required for operation, is widely used in America to designate what in England is familiarly known as a *valve*, a term which is roughly descriptive of the operation of the tube. There are a great many different types of vacuum

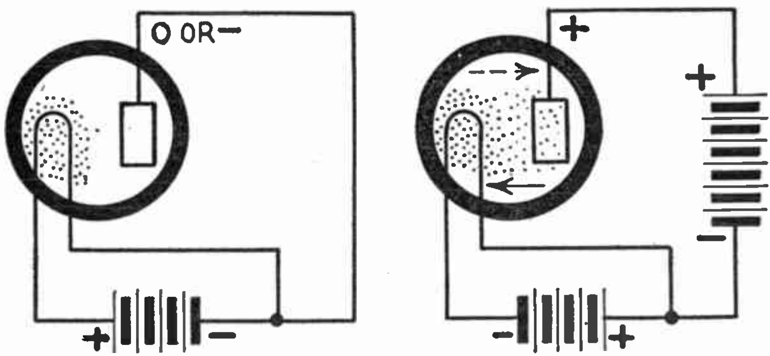

FIG. 7,239.—*How a tube works 1.* Electrons are thrown off by a heated filament. If no means be provided for drawing the emitted electrons away from the filament, they will fall back as rapidly as they are emitted and the space surrounding the filament will be filled with a constant number of electrons.

FIG. 7,240.—*How a tube works 2.* If *d.c.* voltage were applied to plate making plate + with respect to the filament, electrons would be attracted to the plate and a current would be set up as shown. The diagram shows the current flowing from plate to filament in the tube, while the electrons flow from the filament to the plate.

NOTE.—*How a tube works 3.* If either the temperature of the filament, or the voltage on the plate be varied, the flow of current will vary, but it will always flow in the same direction.

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tubes or valves, each of which has its own particular trade name, and they may be classified:

1. With respect to communication, as

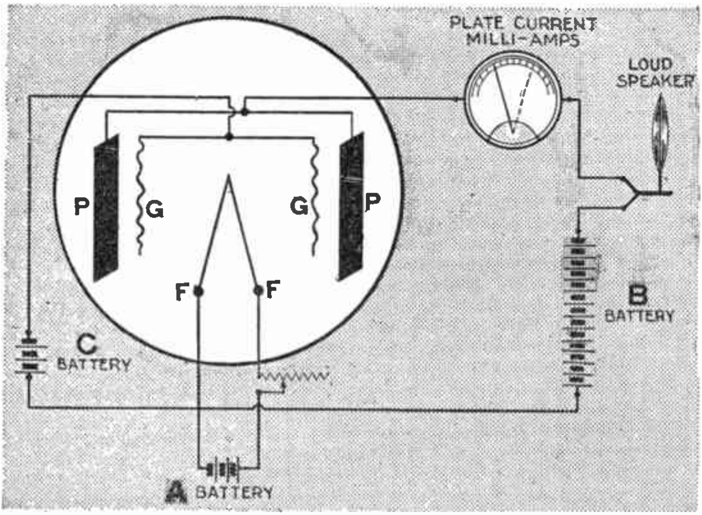

FIG. 7,241—Three element vacuum tube illustrating application of A, B, and C batteries. The work of the storage A battery is to heat the filament which gives off electrons. It has no other function in connection with a receiving set. The source of the positive electricity which is applied to the plate is the B battery and its connection to the plate is through the head phones, amplifying transformer or loud speaker, depending on the type of amplifying circuit used. The third element *or grid*, whose function is to control the flow of electrons from the filament to the plate, employs the C battery which puts a negative charge on the grid thereby acting as a governor to retard or accelerate the flow of electrons from the filament to the plate.

a. Transmitting;

b. Receiving.

2. With respect to the current, as

a. Direct {dry cell / storage battery}

b. Alternating.

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3. With respect to its use in the circuit, as

   a. Rectifier;

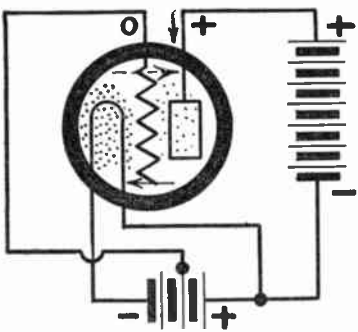
   b. Detector;

   c. Amplifier;

   d. Ballast.

4. With respect to the number of elements, as

   a. Two;



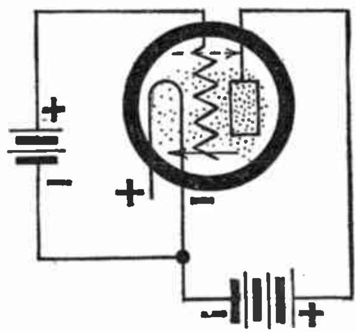


FIG. 7,242.—*How a tube works 4.* Electron flow can be controlled by a grid. If the grid be connected to the filament battery at a point half way between the filament connections as shown, so that the average difference of voltage between the grid and filament is zero, no change in the plate current will be noticed.

FIG. 7,243.—*How a tube works 5.* If the grid be kept positive with respect to the filament, the grid would aid the plate in drawing the electrons away from the filament. Since the grid is much closer to the filament than to the plate, its effect on the electron flow is relatively greater than that of the plate.

   b. Three;

   c. Four (screen grid);

   d. Five.

Electrons.—By definition an electron is *the smallest charge of negative electricity known*. When any substance is heated to

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incandescence in a vacuum, it throws off into the space surrounding it vast quantities of electrons—invisible small particles of negative electricity.

Some substances throw off electrons much more readily than others, and the hotter the substance the greater is the number of electrons emitted. The reason for this is that all matter is largely composed of these particles of negative electricity, which are always in rapid and violent motion. The increase of temperature increases the speed and violence of their motion.

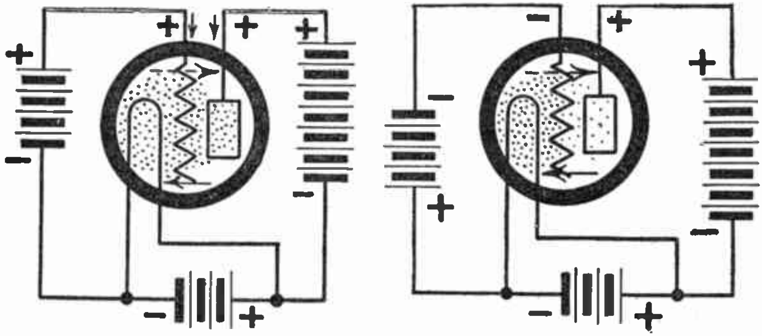

FIG. 7,244.—*How a tube works 6.* Many of the electrons which are speeded up by the positive grid *will pass between the grid wires and go to the plate,* but some of them will be collected by the grid and establish a current in the grid circuit.

FIG. 7,245—*How a tube works 7.* If the grid be kept negative with respect to the filament no current will flow in the grid circuit, and the plate current will be reduced due to action of the grid in forcing some of the electrons back to the filament, as shown.

There is always an attractive force between electrons and the substance, but when they attain a high speed, some of them overcome the attractive force and are "bumped off" only to return again unless some outside force carries them away.

Electron and Current Flow.—If a plate be placed in a tube and kept positive with respect to the filament the electrons leaving the filament and attracted by the positive plate will flow from the filament to the plate as in fig. 7,246.

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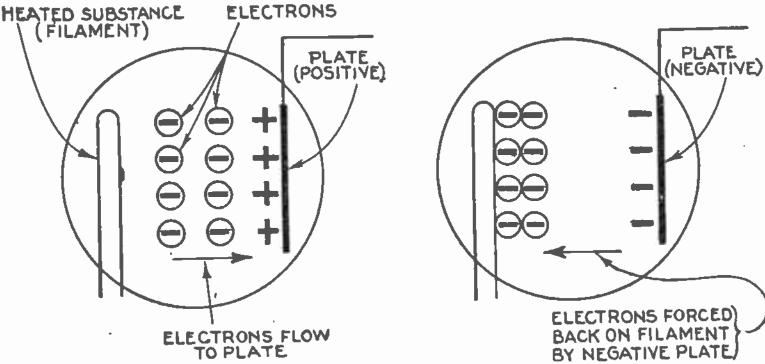
Again if the plate be kept negative with respect to the filament the electrons which tend to leave the filament will be held against it by the repulsion due to like negative charges as in fig. 7,247.

In the first instance, as stated, electrons flow from a heated substance to a positive plate. This direction of flow is contrary to the usual conception of the direction of flow of electricity, which is considered to be from positive to negative. The reason for this is that before the discovery of electrons, experimenters decided to consider that current flowed from



FIGS. 7,246 and 7,247.—Vacuum tube diagrams illustrating electron flow.

positive to negative as a sort of arbitrary rule. This rule has continued in use even though later experiments seemed to prove the contrary to be true. Therefore, current is always considered to flow from positive to negative, although the electrons actually travel in the opposite direction, as in fig. 7,246.

NOTE.—*Space charge.* According to Prof. Taylor, if the space between filament and plate were to be filled with electrons, similar to the droplets of water in a cloud, then this charge would be called a *space charge.* At any point in space in the vicinity of a negative charge the electric field is such that it tends to repel another negative charge. Thus it is seen that between the filament and plate there is an electric field due to the plate tending to pull electrons to it, while at the same time there is another electric field repelling the electrons away from the plate, due to the space charge. As a result of the repelling action of the field caused by the space charge it is evident that the resultant electric field intensity is less than that produced by the B battery alone, in the space between filament and plate. From the lessened field strength it follows that fewer electrons will move from filament to plate during each second, and consequently smaller current will flow because of it. In general, it can be stated that anything which reduces the intensity of the electric field in any region of space will decrease the current through that space.

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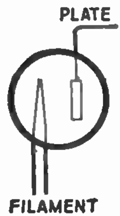

FIG. 7,248.—Two element tube consisting of filament and plate.

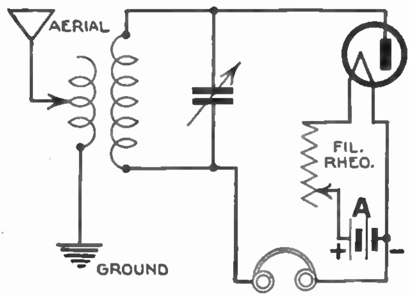

FIG. 7,249.—Two element vacuum tube used as detector.

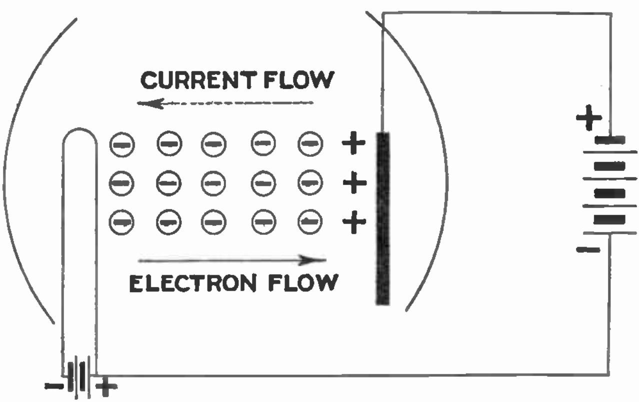

FIG. 7,250.—Vacuum tube diagram illustrating electron and current flow.

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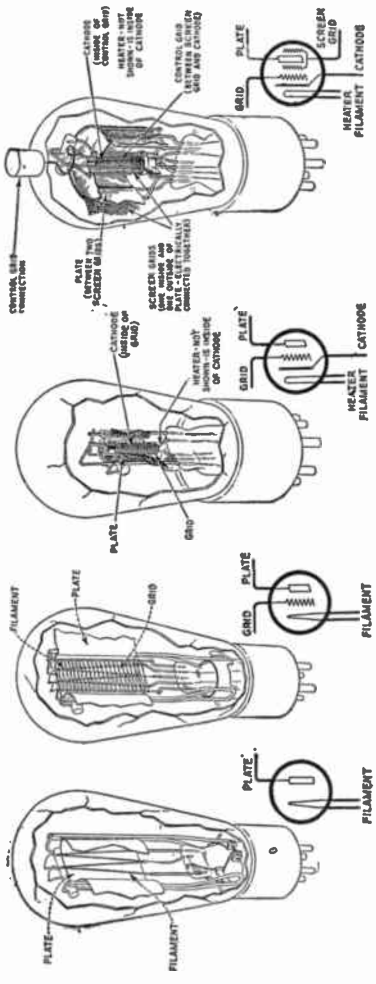
NOTE.—Assume a microscopic eye and see what is happening within the radio tube as the filament temperature rises. Electrons will be seen coming out of the filament and moving away from it, in the direction of the plate. In fact, it is probable the appearance of the electrons would be similar to a cloud of water vapor formed in a valley between two high hills. As the rays of the setting sun ceased to strike the valley, the earth would tend to cool by the process of radiation. As a consequence of this cooling of the earth and air above it, moisture would condense in the form of fog. As time went on into the evening more cooling would take place and more fog would form. After sufficient time the fog would fill the valley and perhaps reach the top of the surrounding hills. In a very similar way the microscopic eye would see a cloud of electrons first form around the filament). However, in a very short time this cloud would expand until it reaches and surrounds the plate. Now since the plate is in a region surrounded by electrons the voltage of the plate would necessarily be low. In fact, it would be lower than the voltage of the filament. As the temperature of the filament became constant, a cloud of electrons would be seen filling the tube, also coming out of the filament with the simultaneous disappearance of others as they condensed into the filament again. At this state let the temperature of the filament be raised and again observe what takes place. If this be done, what might be called an explosion of electrons from the filament will be observed. With an increase in filament temperature more electrons will probably be present when equilibrium attains than at the lower temperature. This condition is similar to the case where the temperature of a liquid is raised with the saturated vapor in contact with it. As a result of the increased temperature of the liquid the vapor density also increases.



Figs. 7,251 to 7,254.—Views of two, three, four and five element vacuum tubes.
Figs. 7,255 to 7,258.—Diagrams of two, three, four and five element vacuum tubes.

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Two Element Tube.—Formerly the two element tube was used as a detector, but now it is employed chiefly as a rectifier in power supply units. Fig. 7,249 shows a hook up with the tube used as a detector.

Three Element Tube.—This is a widely used type of tube and may be employed as a rectifier, detector, amplifier, oscillator, etc. This tube as shown in fig. 7,252 consists of *a filament, grid and plate mounted in a high vacuum.*

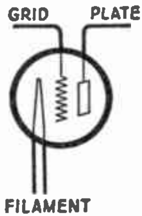

FIG. 7,259.—Three element tube consisting of filament, plate and grid.

The plate is a sheet of metal mounted so as to enclose the filament almost completely.

A free electron acts as though it were a unit of negative electricity and as such it is strongly attracted by any object having a positive or opposite charge, and will be equally strongly repelled by an object having a negative or similar charge.

Under operating conditions, the plate of the tube *is kept positive with respect to the filament and, therefore, attracts the free electrons to it.*

Neglecting the effect of the grid for the moment, it is evident that there will be a continuous flow of electrons from the filament to the plate so long as the plate is positive with respect to the filament and so long as electrons are fed to the filament as fast as they are emitted from the filament. If this were not done, the filament would soon become positive because of the lack of negative electrons, and the plate would become

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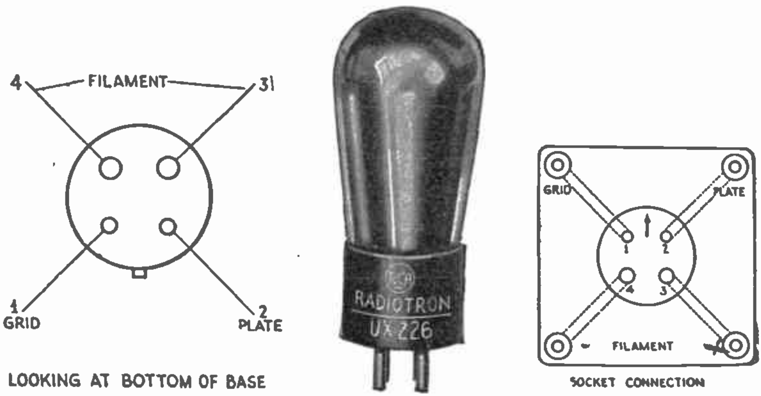
negative because of the surplus of negative charges. Under normal conditions, then, the negative terminal of a battery or dynamo is connected to the filament and the positive end is connected to the plate. The path of the electrons is then from the filament to the plate, and back through the battery or dynamo to the filament.

Since an uncontrolled flow of electricity is seldom useful, the grid is inserted in the tube *for the purpose of controlling this flow.*

If the grid be held at the same pressure as the plate, it will aid the plate in drawing electrons from the filament. If the grid be held at the same pressure as the filament, it will neither aid nor hinder the plate in drawing electrons from the filament.



Figs. 7,260 to 7,262.—RCA Radiatron UX—226 three element amplifier tube; a.c. filament. It may be used for either radio frequency or transformer coupled audio frequency amplification. It is not ordinarily suited for use as a detector or as a power output tube.

If, however, the grid be kept negative, with respect to the filament, it will tend to drive back the electrons leaving the filament, and since the grid is between the plate and the filament, it will reduce the number of electrons which eventually reach the plate.

If the grid be only slightly negative, many electrons will reach the plate through the open spaces between the grid wires, but the grid may be held sufficiently negative so that it will repel the electrons so forcibly that none is allowed to pass it, and the number reaching the plate falls to zero.

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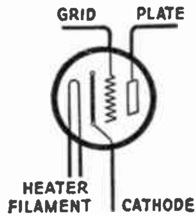
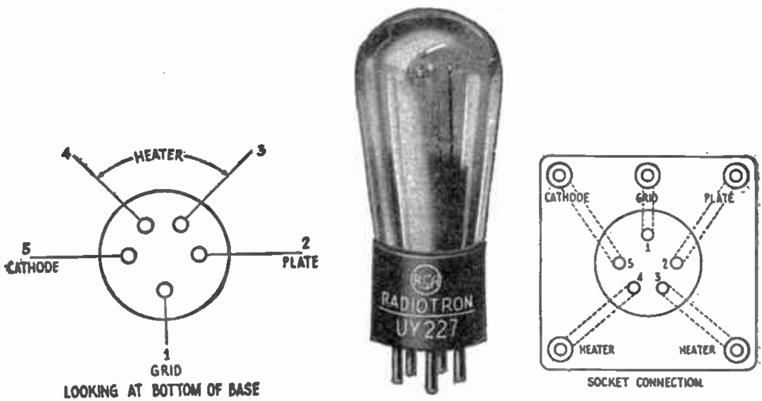


FIG. 7,263.—Four element tube consisting of heater filament, plate, grid, and cathode.

Four Element Tube.—The constantly increasing use of alternating current for lighting homes has resulted in the adaptation of the vacuum tube as an eliminator of the A battery by heating the filament of the tube by alternating current.

If the *a.c.* were applied direct to the filament of an ordinary tube, as it is employed in receiving sets, it would result in a



FIGS. 7,264 to 7,266.—RCA Radiotron UY-227 four element detector and amplifier tube. This is a general purpose tube containing a *heater element* which permits operation from alternating current. It is designed for use either as a detector or as an amplifier in *a.c.* radio sets operating from the light socket.

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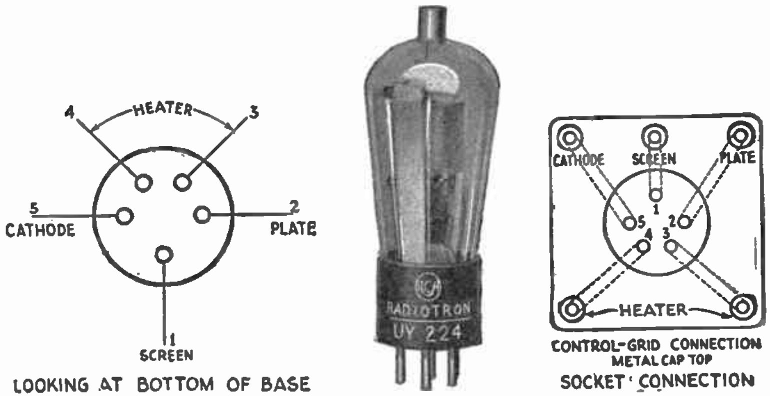
periodic variation of the voltage of the grid and plate with reference to the center of the filament.

This variation of the plate and grid voltage, would cause a corresponding variation in plate current, which would cause a disturbing noise in the head phones or loud-speaker.

To obviate noise, a fourth element is introduced in the tube, this element being *a device for heating the cathode (ordinary filament) by radiation.*



FIGS. 7,267 to 7,269.—RCA Radiotron UY-224 four element screen grid radio frequency amplifier. This screen grid amplifier tube contains a *heater element* which permits operation from alternating current. It is recommended for use primarily as a radio frequency amplifier in *carefully shielded circuits* especially designed for it. It may also be effectively used as a space charge grid tube or as a double grid tube in special circuits.

Alternating current tubes are also manufactured without the indirect heater. Such tubes have *a relatively large filament and are used in circuits in which a center tapped resistor is connected across the external filament circuit.*

The plate and grid circuits are then returned to the center tap of this resistor. These tubes are used extensively in output stages and to a lesser extent in radio and intermediate audio frequency amplifiers.

Five Element Tube.—The effectiveness of the four element screen grid tube, particularly as a power amplifier, is limited by *secondary emission.* This phenomenon is to be observed in practically all forms of electronic devices; secondary emission

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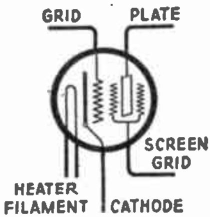

FIG. 7,270.—Five element tube consisting of heater filament, plate, grid, cathode and screen grid.

is *the emission of electrons by the anode (plate) caused by the bombardment of the original cathode ray.*

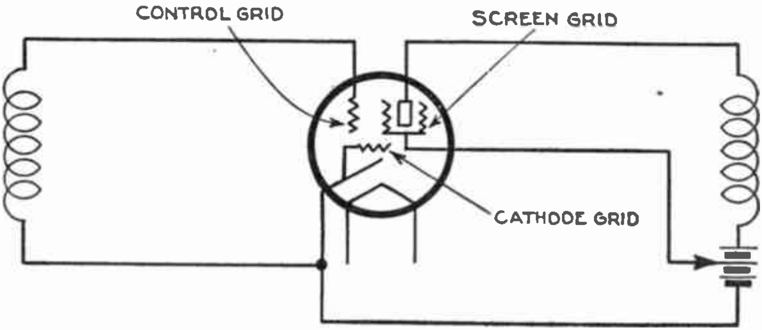

FIG. 7,271—Five element tube hook up showing how fifth element is used *to eliminate secondary emission*. If the fifth element be placed between the plate and the screen grid, and connected to the filament or some very low positive pressure as shown in the diagram, it is at a much lower voltage than the plate. This *tends to drive the secondary emission electrons back to the plate where they belong*, and prevent distortion by avoiding any subtraction from the total plate current. Thus the five element tube has the advantage of high screen grid amplification, with a large power handling capacity in addition, which makes it especially suited for power audio amplification.

As the electrons strike the plate at extremely high velocities, they knock off additional electrons. Also, the bombardment of the plate often heats it to an electron emitting temperature. In the ordinary triode, these electrons may float around for a fraction of a second and either return to the plate or join other electrons in the space charge. However, in the screen grid tube, because of the presence of another highly positive charge

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on the screen grid, many electrons leave the vicinity of the plate and travel to the screen grid. These, by taking a direction exactly opposed to that of the electrons leaving the filament, partially nullify the effect of the original electrons which form the plate current.

The reason for the five element tube is *to reduce the secondary emission,* making it possible to take full advantage of the screen grid amplification in power circuits.

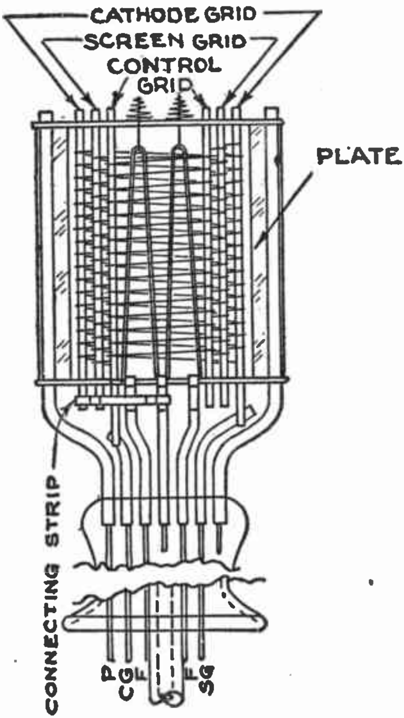

FIG. 7,272.—Interior of five element (pentode) tube showing the arrangement of the five elements. The cathode grid is connected internally to the mid-point of the filament.

FIG. 7,273.—Five element tube base showing arrangement of the prongs.

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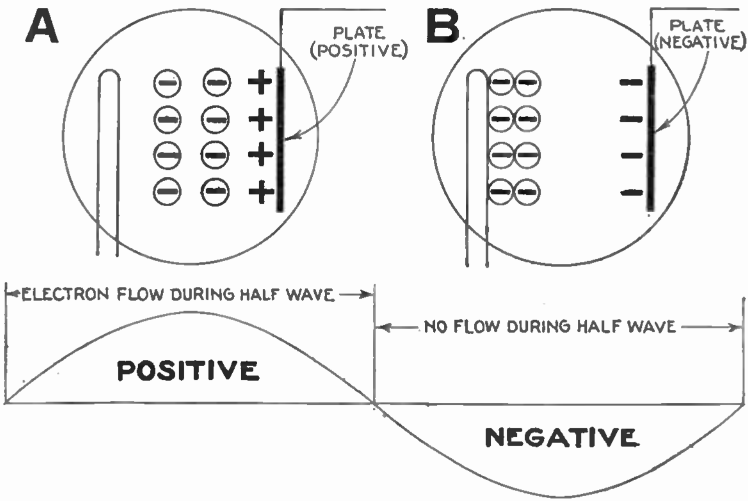
In construction, the filament, control grid and plate are the same as in the three element tube, the screen grid is used to screen the control grid from the plate and the cathode grid or fifth element is used to screen the screen grid from the plate.

The internal construction of the five element tube is shown in fig. 7,272 and its prong arrangement in fig. 7,273.



FIGS. 7,274 to 7,276.—The vacuum tube as a *half wave rectifier*.

The Vacuum Tube as a Rectifier.—When alternating current is applied to a tube so that the plate is alternately positive and negative with respect to the filament during the *positive half of the a.c. cycle, electrons will flow from the filament to the plate as at* **A**, *fig*. 7,274.

However, when the current reverses during the negative half, no current will flow as indicated at **B**. A rectifier tube operating on this principle is called a *half-wave rectifier*.

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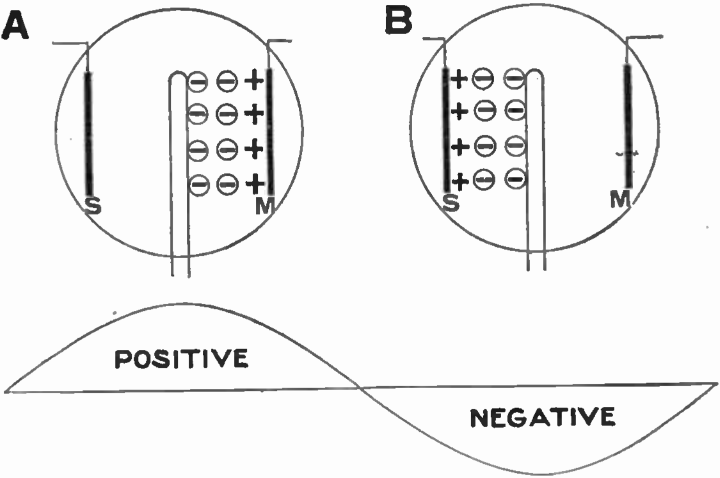

FIGS. 7,277 to 7,279.—The vacuum tube as a *full wave* rectifier. In the actual apparatus the *hook-up is such* that the plate M, is positive during the positive half of the cycle and the plate S, is positive during the negative half of the cycle.

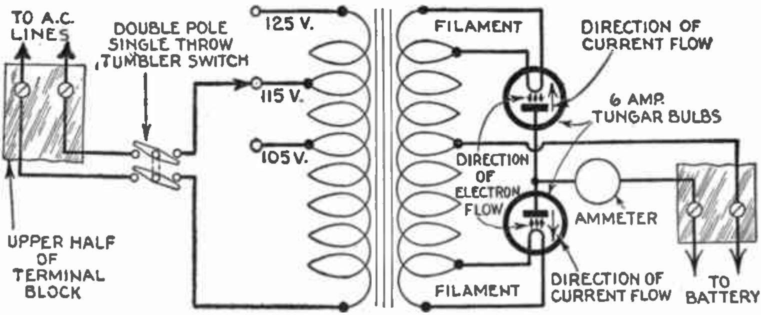

FIG. 7,280.—Wiring diagram of General Electric Tungar rectifier for charging a battery. *In operation* the ends of the secondary of the transformer are alternately + and — with respect to the center tap. Therefore, during each half cycle of alternating voltage, the plate of one or the other of the Tungar bulbs is + with respect to the filament, and a current will flow during each half cycle first through one tube and then through the other. The current always flows out of the center tap of the transformer secondary into the positive side of the storage battery, through the battery, through the ammeter, and then through one or the other of the Tungar bulbs. This current is not the steady direct current which can be obtained from a battery, but a pulsating current which flows always in the same direction. It is satisfactory for charging storage batteries but is not suitable for use where a steady direct current is required.

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By adding another plate as in fig. 7,277, *a uni-directional flow may be obtained during both halves of the cycle, in which case the tube is called a full wave rectifier.* A practical application of the principle just stated is shown in fig. 7,280.

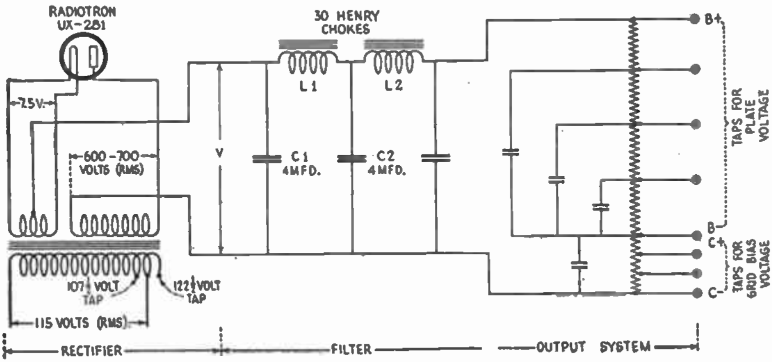

FIG. 7,281.—Typical half wave rectifier circuit.

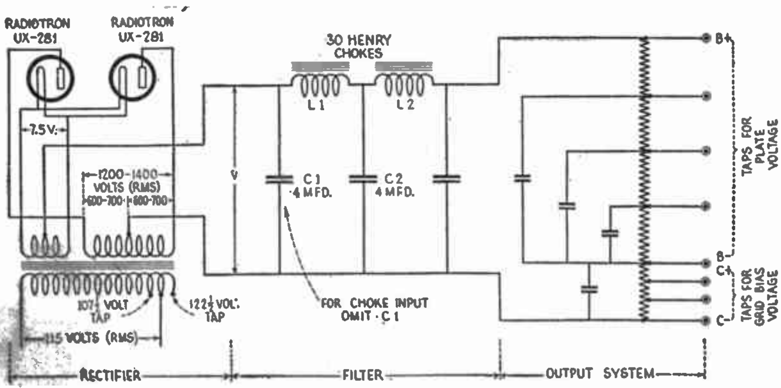

FIG. 7,282.—Typical full wave rectifier circuit.

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The Vacuum Tube as a Detector.—The three element tube can be made to act as a detector by three different methods:

1. By keeping the average grid voltage negative with respect to the filament by means of the C battery. Connect positive terminal to negative leg of the filament and negative terminal to the grid circuit.

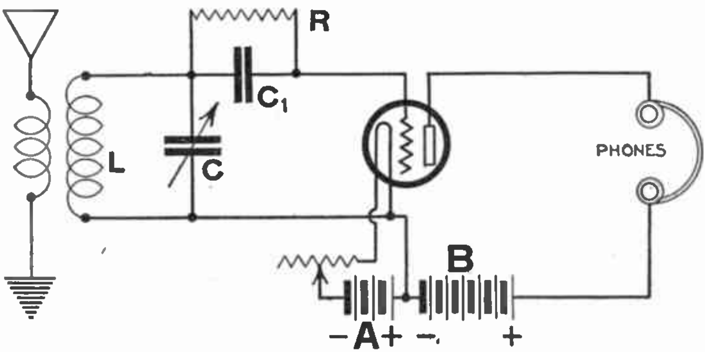

FIG. 7,283.—Circuit of grid leak and condenser detector.

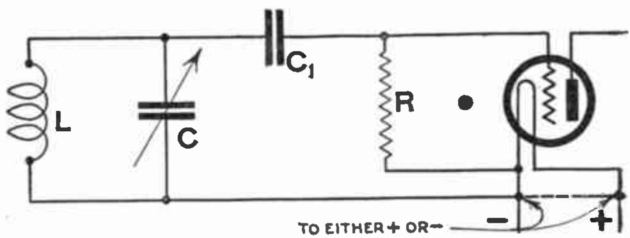

FIG. 7,284.—Circuit showing how leak may be connected from grid to filament, instead of across the grid condenser, as in fig. 7,283.

2. By keeping grid positive by aid of battery.
3. By using grid condenser and grid leak.

Figs. 7,283 and 7,284 show two hook ups for the third method.

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The first method is known as plate rectification, power detection, grid bias. In this method from 4 to 6 volts are applied to the grid of the tube to influence its operation by making it more or less negative.

The grid bias is usually negative and determines the point of the characteristic curve at which the tube will operate. In a sensitive receiver, and particularly where a tube is used as an *amplifier*, it is essential to obtain as great a change of grid current as possible. The greater the change of grid current the greater the change in plate current and hence the more powerful will be the output. By applying a negative voltage on the grid, it is possible to hold it at the point of maximum response.

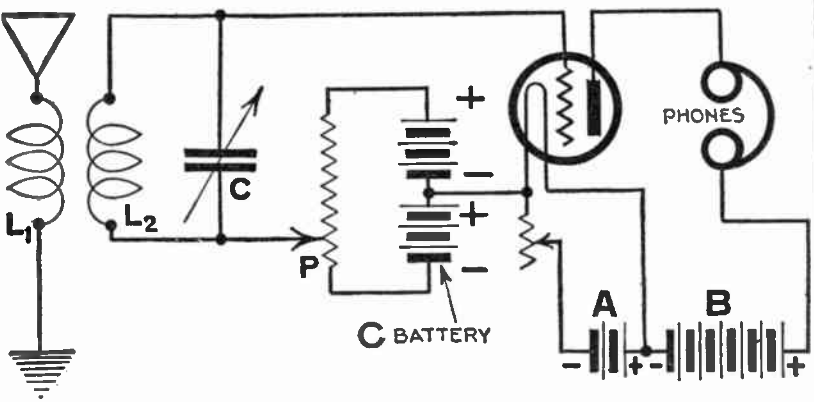

FIG. 7,285.—Detector circuit with three element tube and potentiometer control of grid bias. *In operation* the filament of the tube is heated by the A battery and the plate circuit is energized by the B battery, which maintains the plate positive. By connecting the grid return lead to the potentiometer sliding contact any desired voltage within limit of the C battery may be applied to the grid; this is called *biasing*.

A grid bias hook up is shown in fig. 7,285.

Figs. 7,283 and 7,284 show two hook ups for the third method for making a three element tube act as a detector.

This method is based upon the fact that the grid can act more or less in the same manner as the plate and attract electrons itself as soon as it becomes positive with respect to the filament.

In operation, electrons are trapped on the grid, building up a negative pressure and the high frequency voltage variations on the grid vary around

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a mean grid voltage which becomes increasingly negative. This reduces the plate current, and if the grid were insulated from the rest of the circuit, the action if continued long enough, would finally reduce the plate current to a low value and the tube would be choked or stopped. To prevent this, after a wave train has been received, it is necessary to remove the accumulated negative charge from the grid in order to restore it to the initial condition for the arrival of the next wave train.

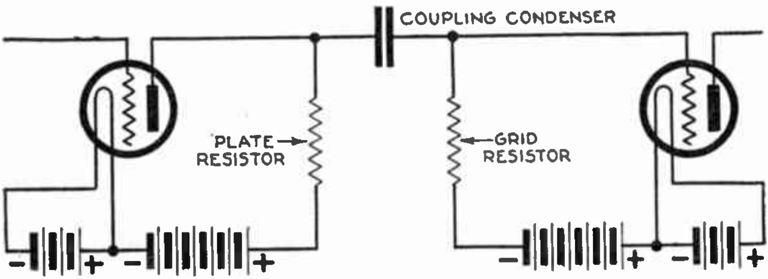

FIG. 7,286—Resistance coupled amplifier circuit

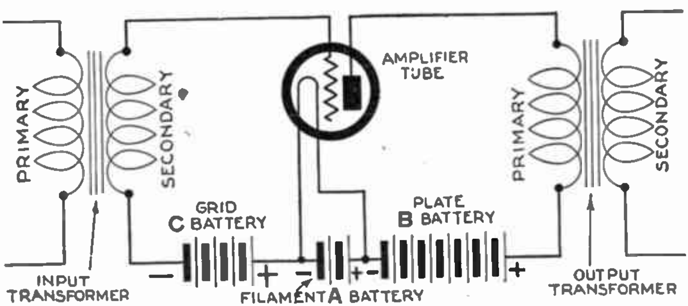

FIG. 7,287—Transformer coupled amplifier circuit.

This can be done by connecting a high resistance R, from 1 to 10 megohms, known as a *grid leak*, either across the grid condenser C, as shown in fig. 7,283, or directly between the grid and the filament as shown in fig. 7,284.

The Vacuum Tube as an Amplifier.—When a three electrode tube is used as an amplifier, *the grid is kept at a negative voltage*

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with respect to the filament. This negative grid voltage is called the *grid bias* of the tube. If an alternating voltage be added to the steady negative voltage of the grid, the relative negative voltage between the grid and the filament will vary in accordance with the alternating voltage.

Variations of the grid voltage *will cause variations in the plate current.*

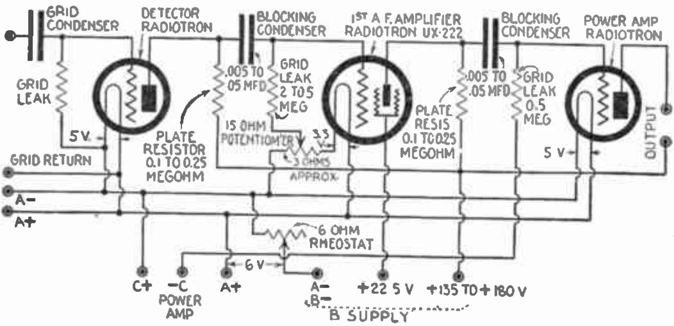

FIG. 7,288.—Typical screen grid audio amplifier circuit.

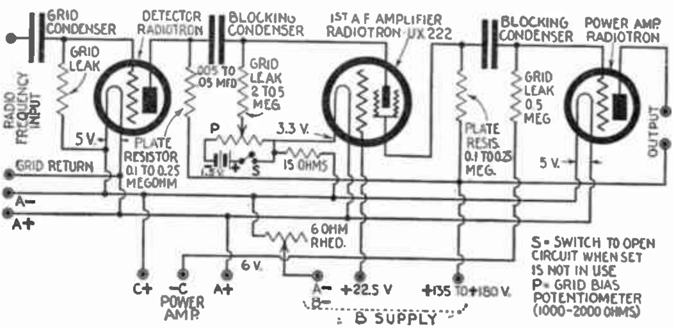

FIG. 7,289.—Typical space charge grid audio amplifier circuit.

As the grid becomes more negative the plate current decreases and as the grid voltage becomes less negative the plate current increases. If an electrical impedance, such as resistance, be placed in the plate circuit,

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between the plate and the battery, a voltage will be produced across it in proportion to the plate current.

When an alternating current is impressed on the grid, *a pulsating voltage will be produced across the resistor in the plate circuit.*

If the resistance in the plate circuit be sufficiently high, the pulsations of the voltage produced in the circuit will be greater than the alternating voltage impressed on the grid. Therefore, three electrode vacuum tubes can be used to amplify (increase) variations of voltage.

Various types of tubes are used for various purposes.

Tubes designed primarily to amplify alternating voltages, where the energy output is not important, are called voltage amplifier tubes.

Tubes designed primarily to give a large energy output are called power amplifier tubes.

TEST QUESTIONS

1. *What is the difference between a vacuum tube and a valve?*
2. *Give a classification of vacuum tubes.*
3. *What is an electron?*
4. *What is the polarity of an electron?*
5. *Explain electron and current flow.*
6. *What happens if the plate be* a, *positive, or* b, *negative, with respect to the filament?*
7. *Is the popular idea that electricity flows from positive to negative, correct?*
8. *Describe a two element tube and explain its uses.*
9. *How does a three element tube work?*

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10. *Name the various uses made of three element tubes.*
11. *What duty is performed by the grid?*
12. *Describe the four element tube.*
13. *How does the fourth element operate to eliminate noise?*
14. *What is the objection to the four element screen grid tube when used as a power amplifier?*
15. *What is secondary emission?*
16. *What is the reason for the five element tube?*
17. *Explain the operation of the vacuum tube as a rectifier.*
18. *What is the difference between a half wave rectifier and a full wave rectifier?*
19. *Draw a circuit diagram of the Tungar rectifier.*
20. *Name three methods by which the three element tube can be made to act as a detector.*
21. *Explain plate rectification.*
22. *Draw a diagram showing a grid bias hook-up.*
23. *Explain in detail how a vacuum tube is used as an amplifier.*

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CHAPTER 176

Principles of Receiver Circuits

Any electrical circuit used in connection with the reception of radio is a *receiving circuit.*

The more important receiving circuits using vacuum tubes are the

1. Regenerative
2. Super feed back
3. Tuned frequency
4. Reflex
5. Inverse duplex
6. Neutrodyne
7. Heterodyne
8. Autodyne
9. Super-heterodyne
10. Super-heterodyne with second harmonic oscillator

There are various modifications of these circuits. The basic principles governing the working of standard receiving sets has been very clearly presented by Howard M. Jenkins, and will be included in the matter following.

Feed Back Regeneration.—The amplifying properties of the three element tube can be employed to obtain what is known as *regeneration.*

Since it is possible to have greater output energy than input energy, *part of the output may be returned to the input side,* thus resulting in amplification of energy or in regeneration.

The first advance over the simple sets was the discovery that a small part of the amplified energy might be "fed back" to the grid circuit, and

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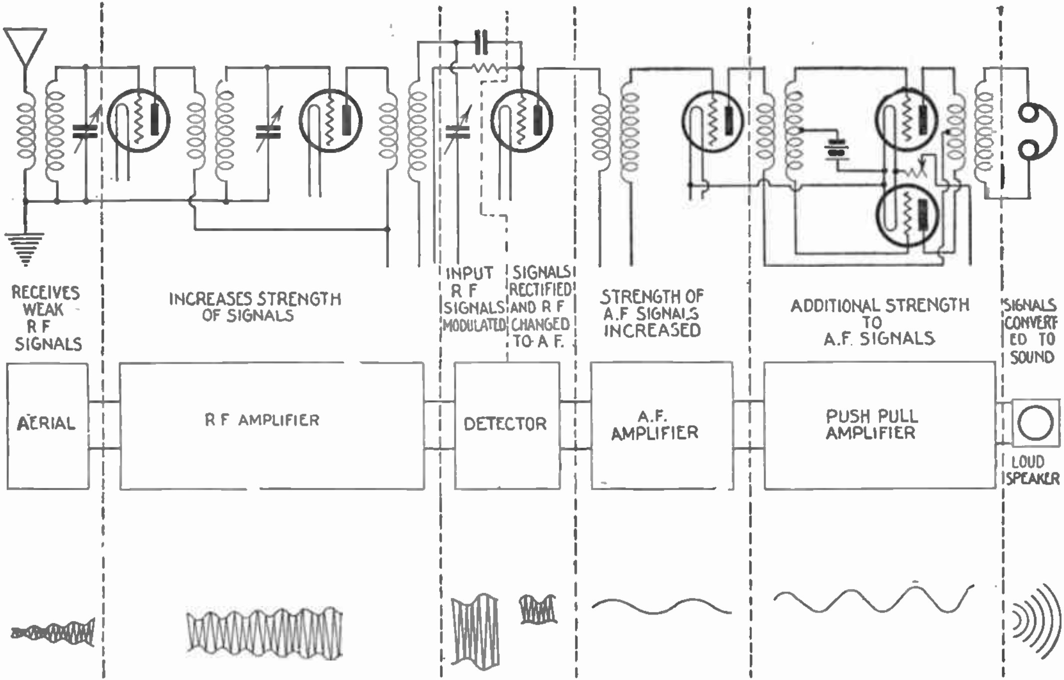
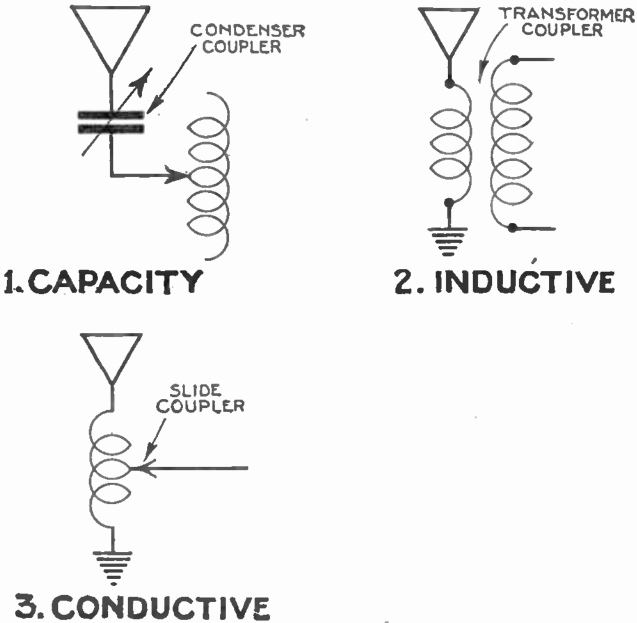


FIG. 7,290.—Combination diagram showing arrangement of the different units of a typical receiver with circuit diagram and wave chart showing how the radio waves are modified by each unit; that is, how the inaudible waves first picked up by the aerial undergo successive changes en route to the loud speaker.

combining with the incoming signal further increase the plate output. This process, if led to continue, and if the power feed back be enough to counteract all losses in the circuit, will build itself up until the circuit "oscillates" with disastrous results to the clarity of the signal. The best amount of feed back is just below this point of oscillation.



FIGS. 7,291 to 7,293.—Circuit diagrams showing various methods of coupling. Fig. 7,291, electrostatic; fig. 7,292, inductive; fig. 7,293, conductive.

There are three methods of feeding back the plate current to the grid.

1. Capacity coupling;
2. Conductive coupling;
3. Inductive coupling.

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All of these return part of the amplified energy to the grid circuit.

Super Feed Back.—With the ordinary sets there is a limit to the possible regeneration. This difficulty is overcome in the

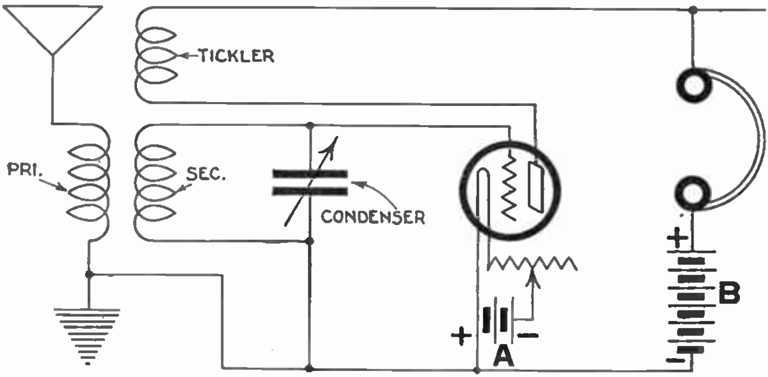

FIG. 7,294.—Diagram illustrating principle of *feed back regeneration.*

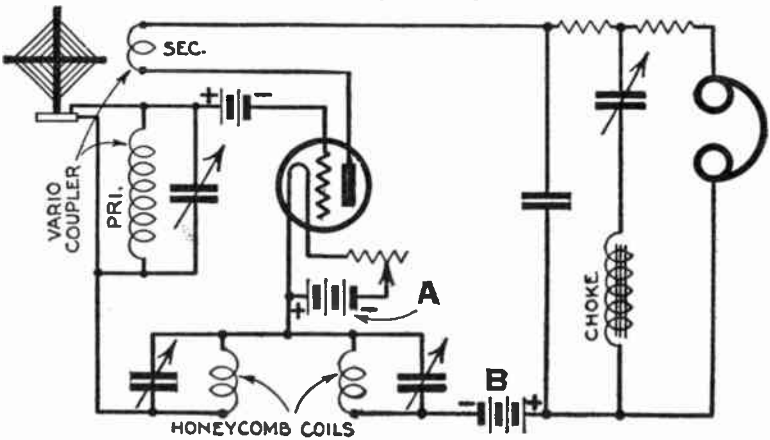

FIG. 7,295.—Diagram illustrating principle of *super feed back.*

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super-regenerative sets. These make use of the principle that by introducing into the circuit an alternator, whose frequency is above audibility, the feed back will periodically be raised and lowered about the oscillation point. By this means a tremendous feed back is possible, although the set is somewhat "critical" and difficult to adjust. The alternating current is usually produced by an electron tube oscillator, which may be a separate tube, or the detector tube itself.

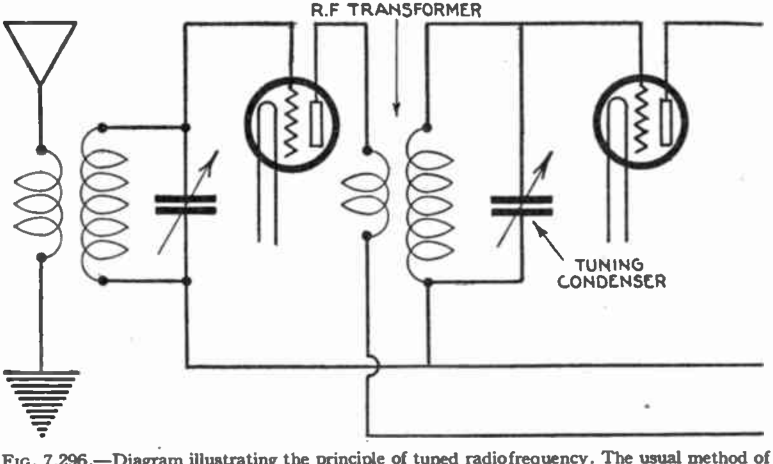

FIG. 7,296.—Diagram illustrating the principle of tuned radiofrequency. The usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer. A potentiometer is used to control oscillations, as the greatest amplification is obtained when the circuits are operated just at the point before self-oscillation starts.

Tuned Radio Frequency.—The word tuned is defined as *brought into resonance with the desired signal.* A tuned radio frequency circuit is one in which the radio frequency amplifier circuits may be tuned to the desired wave lengths by varying the inductance or the capacity or both although the usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer.

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The Reflex Principle.—The reflex idea is one of many which aim to *extract the maximum use of a tube or a group of tubes.* Briefly, the incoming wave is passed through radio frequency amplification, is then rectified by the detector, and then passed again through the same tubes as used for the radio frequency amplification, but which now functions as audio frequency amplifiers.

The current is guided through this tortuous path by inductances and condensers which, if proper values be used, are supposed to keep the current to this path.

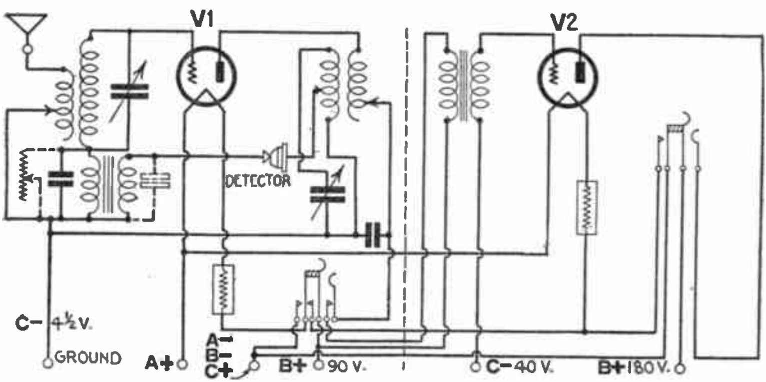

FIG. 7,297.—Wiring diagram of the Carborundum single tube reflex receiver modified with a second audio stage amplifier to provide good loud speaker volume on strong signals. V2 is the added tube arranged as a second stage of *a.f.* amplification.

The reflex circuit was invented by Marius Latour.

A typical four tube reflex set uses the second and third tubes as amplifiers simultaneously for both the radio and the audio frequency amplification.

As a result the four tubes are made to produce the effect of six. Reflexing may be accomplished in a number of different ways. In some cases all

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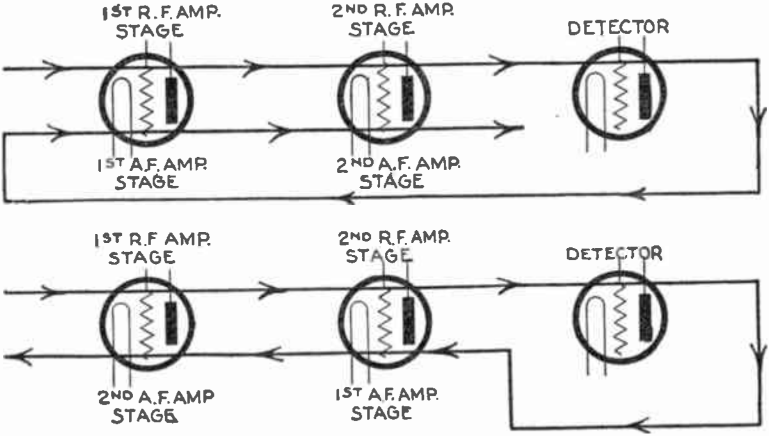
the tubes are made to work twice. In other cases, only a part of the tubes are used for dual amplification.

Inverse Duplex Principle.—A slight commercial variation of the reflex circuit produces the so called *inverse duplex*. This is essentially a reflex set, the refinement being that *the work is evenly distributed between the tubes* so that none is overloaded as in the straight reflex.



FIGS. 7,298 and 7,299.—Diagrams showing current paths in ordinary reflex circuit and in inverse duplex circuit. In the inverse duplex circuit, fig. 7,299, the incoming signal reaches the first tube where it is amplified at radio frequencies and passes to the second tube, where it is again amplified at radio frequencies. From the second radio frequency tube, it is passed to the detector tube, where it is converted to audio frequency. The current then flows back to the second radio frequency tube which is now used as an audio frequency amplifier. Thence it flows to the first radio frequency tube which acts as the second stage of audio frequency amplification.

That is, the tubes which are reflexed operate more efficiently since the relatively weak radio currents pass through the same tube as the stronger audio currents and vice-versa.

The inverse duplex circuit (invented by David Grimes), like the reflex circuit uses the tubes for double duty, the first radio frequency tube being employed also as a second audio frequency tube and the second radio frequency tube also as a first audio frequency tube.

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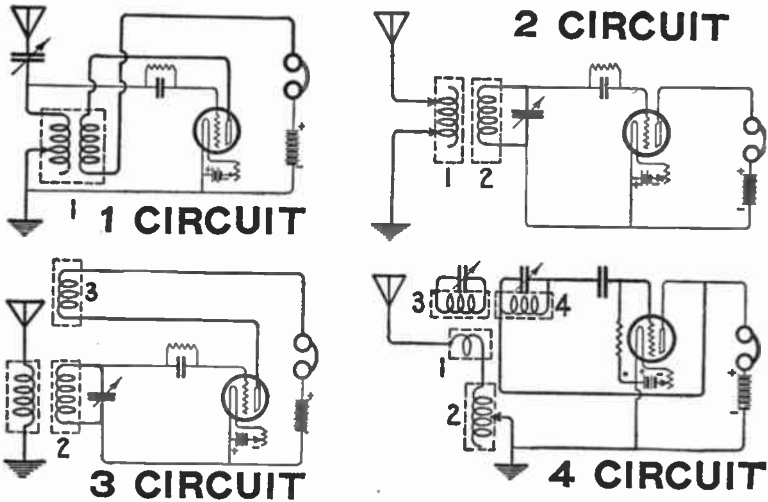
Neutrodyne Principle.—The neutrodyne circuit is the invention of L. A. Hazeltine. The typical neutrodyne receiving set uses five tubes, employing *two stages of tuned and neutralized radio frequency amplification, with detector and two audio frequency stages.*

In the neutrodyne circuit the feed back tendency of the radio frequency amplification with consequent oscillation, is eliminated. This is done by



FIGS. 7,300 to 7,303.—Diagram illustrating the designations, one circuit, two circuit, three circuit and four circuit sets.

specially designed small size neutralizing condensers placed between successive tubes. The special neutralizing condensers are called *neutrodons*. The capacity of these is very low, being approximately equal to the internal capacity of a vacuum tube. By reason of this equality, any tendency of a large amount of radio frequency current to pass back through the tube through the grid is defeated and instead is neutralized by the combination of the neutralizing capacities, the inter-element capacity of the vacuum tubes and the secondary windings of the tuned radio frequency transformers. This effect is in reality a bucking one, since the current is made to take two paths.

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Each neutralizing condenser must be adjusted so that its capacity will equal that of the vacuum tube it is connected with.

This makes possible higher ratios of radio frequency amplifications and if the transformers be of the tuned circuit type (by means of a variable condenser shunted across the secondary) the set is made very selective.

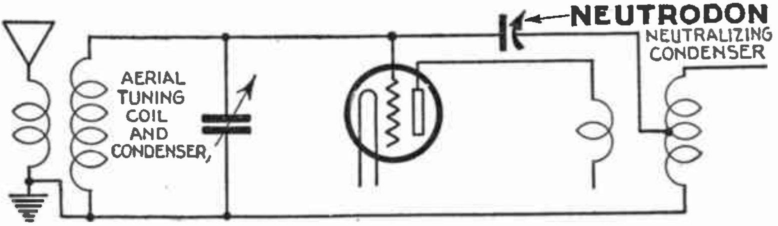

Fig. 7,304.—Diagram illustrating the *neutrodyne principle.*

Fig. 7,305.—Neutrodon variable condenser for neutralizing radio frequency circuits in neutrodyne receivers.

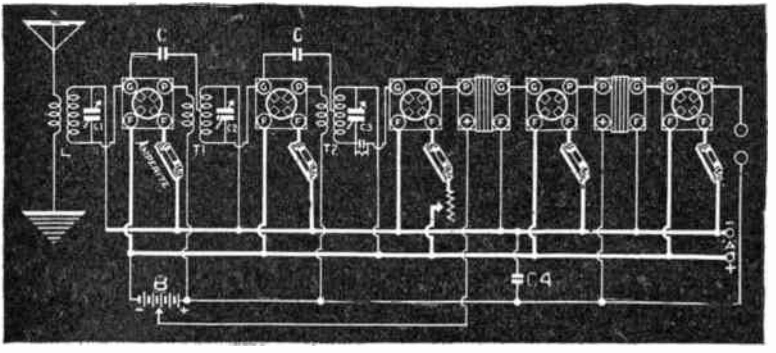

Fig. 7,306.—Five tube neutrodyne set. If properly built and adjusted the neutrodyne circuit combines ease of control with selectivity. It is excellent for both local and distant reception.

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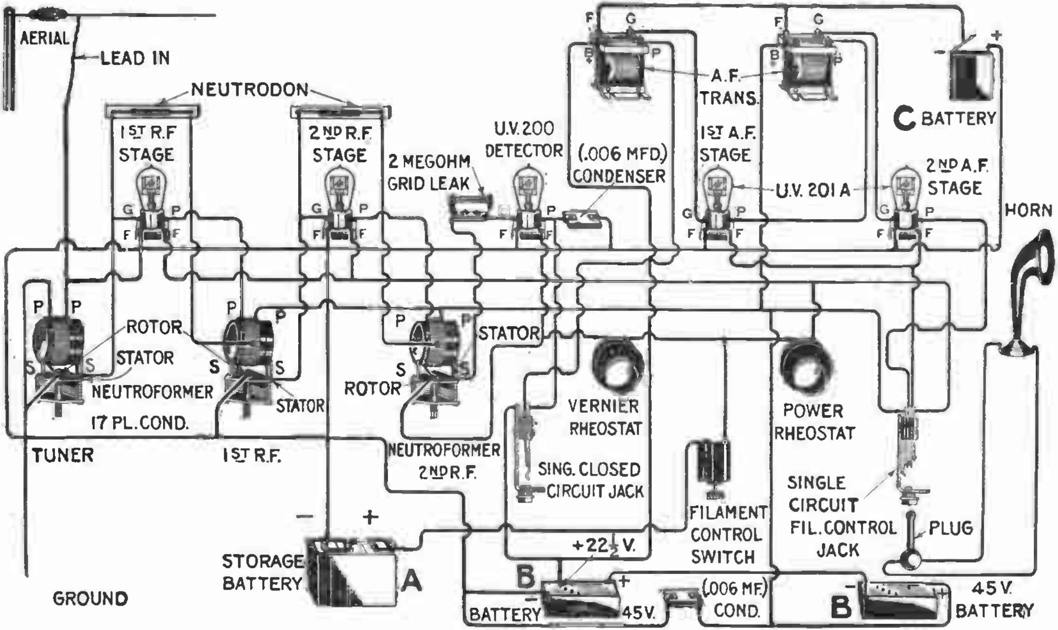

FIG. 7,307.—*Neutrodyne.*—This set embodies the principle of *tuned radio frequency*. The advantage of this over the untuned type lies in the fact that in the latter a frequency peak is reached too quickly. This limits the receiver to the wave band over which the radio frequency transformers will function. In the neutrodyne, however, the peak is so high that the receiver will function equally well on long and short wave lengths. It is also famous for its long distance reception. Either an outside aerial or a loop may be used.

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The neutrodyne principle is applied to the radio frequency alone, the subsequent amplification circuit after the detector, if any, may be straight non-regenerative amplification, or the same circuit may be made regenerative by adding a variometer; or perhaps the set may be re-flexed.

The Heterodyne and Autodyne Principles.—This is the principle of *the formation of a "beat" note by the superimposition on the incoming wave of a second wave of a slightly different frequency*, either a little higher or lower than the incoming or fundamental wave.

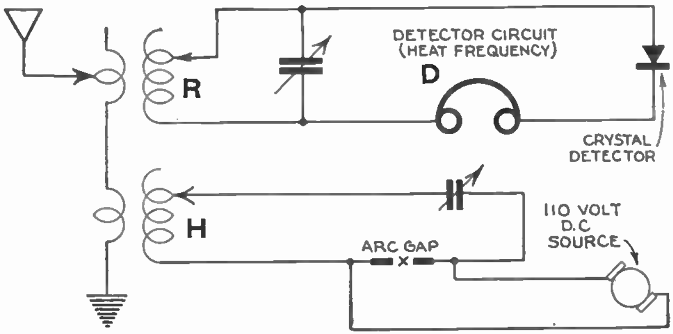

FIG. 7,308—Diagram illustrating the heterodyne principle. If R, be tuned to incoming signal wave length, and H, to a different frequency the difference is the beat frequency which will be rectified by the detector and audible in the head phones D.

This beat note will pass through the detector and be made audible in the phones in the ordinary manner. There are two advantages of this arrangement; first, the incoming wave is materially strengthened by the added wave; second, the selectivity is greatly increased, for not only is the regular resonant circuit employed but the formation of the beat note itself is a highly selective process.

The added alternating current wave may be produced by a separate electron tube oscillator, in which case the set is heterodyne, or the detector tube may be made to function as an oscillator, also in which case the set is *autodyne*.

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The beat note effect may, in fact, be present in almost any set which employs tubes, notably the regenerative circuits. Rightly understood and utilized it is of importance in all kinds of reception and is necessary for the best results in C. W. code work. However, the average amateur does not realize when his set is heterodyning and fails to diagnose and allow for this condition, which is, to him, unwanted. Familiar manifestations of the pressure of beat notes are distortion, and the whistles, squeals and howls with which every operator of a regenerative set is acquainted.

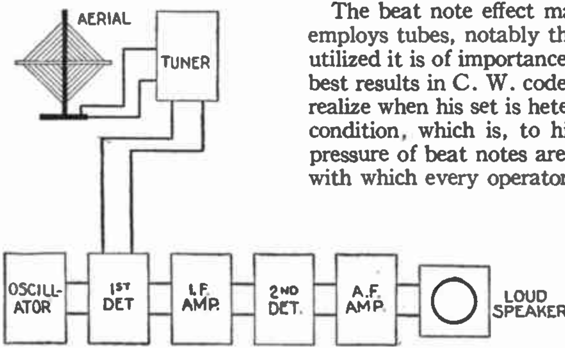

FIG. 7,309.—Block diagram showing general arrangement of super-heterodyne set.

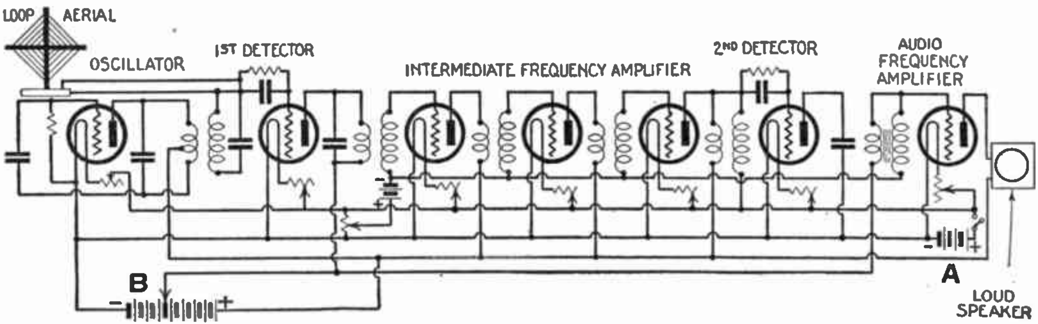

FIG. 7,310—Diagram illustrating the essentials of super-heterodyne set. This typical six tube set comprises an oscillator, first detector, two intermediate stages, second detector, and one audio frequency stage.

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The Super-Heterodyne Principle.—The super-heterodyne circuit combines the advantages of the audio frequency and the radio frequency amplification. From a structural and

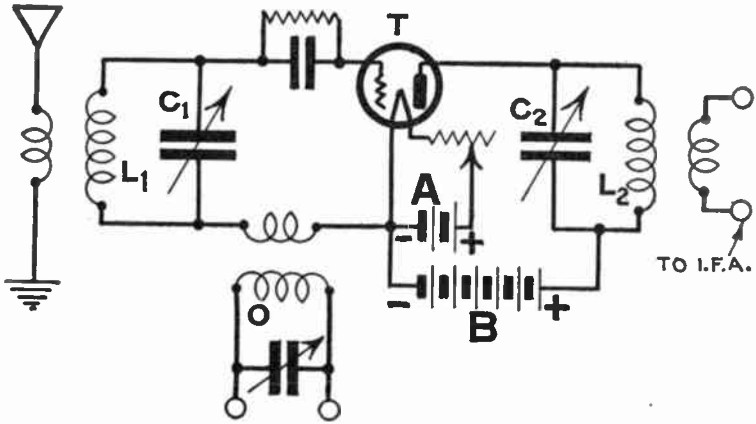
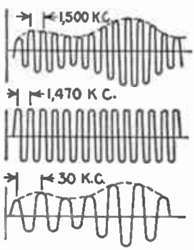


FIG. 7,311.—Frequency changing portion of super-heterodyne circuit. A vacuum tube T, is connected as a detector and has a tuned grid circuit L_1, C_1, and a tuned plate circuit L_2, C_2. Circuit O, which has a steady high frequency current flowing in it, is coupled to the grid circuit by the coils. *In operation*, a resultant or beat wave is obtained as in figs. 7,312 to 7,314.



Figs. 7,312 to 7,314.—Heterodyning of two currents. Assume that the circuit L_1, C_1 (in fig. 7,311), is tuned to an incoming signal at 1,500 kilocycles and that circuit O, is connected to an oscillator adjusted to have a frequency of 1,470 kilocycles. This gives a combination of two frequencies impressed across the grid circuit of the tube. These two frequencies combine to produce a resulting wave, as shown in 7,314, which has a frequency equal to the difference of the two waves, or 30 kilocycles. This different frequency which will be present in the plate circuit is called the intermediate frequency, and is always a lower frequency than either of the other two.

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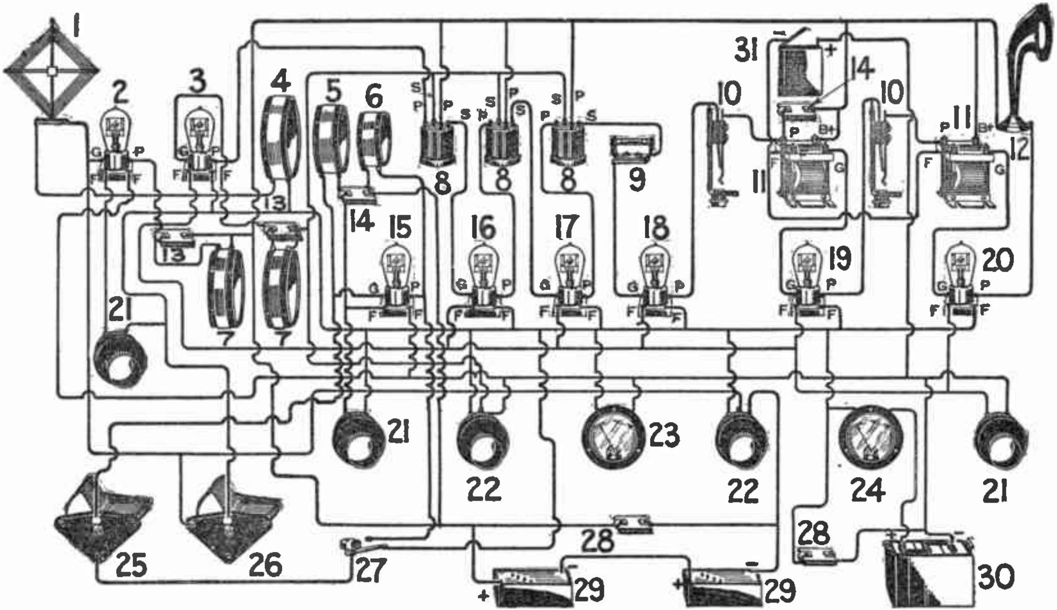

FIG. 7,315.—*Super-heterodyne.*—Trans-continental reception with this type of receiver is not uncommon. This set employs an oscillator and two detectors, three stages of radio frequency and two of audio. Tuning is accomplished by means of two variable condensers and one or two potentiometers. An outside antenna is not necessary. *List of parts:* 1, loop aerial; 2, first detector tube; 3, oscillator tube; 4, coil 4″ dia. 6 turns No. 20 D. C. C. wire; 5, coil 3¾″ dia. 20 turns No. 20, D. C. C. wire; 6, coil 2¾″ dia. 2 layers, 20 turns each; 7, 25 layers, 12 turns per layer total 300 turns; 8, radio frequency transformer; 9, 2 megohm grid leak and .00025 fixed condenser; 10, single closed circuit jack; 11, audio frequency transformer; 12, loud speaker; 13, .00025 fixed mica condensers; 14, .001 fixed mica condenser; 15, 1st radio frequency tube; 16, 2nd radio frequency tube; 17, 3rd radio frequency tube; 18, 2nd detector; 19, 1st audio frequency tube; 20, 2nd audio frequency tube; 21, rheostats;

flexibility point of view, audio frequency is the ideal, while from an electrical standpoint, radio frequency is superior. Super-heterodyne combines both of these advantages, by converting the incoming high frequency wave to a beat wave of intermediate frequency by means of superimposed oscillations.

Briefly, the super-heterodyne method of reception is one in which current is generated by *a local oscillator at a frequency which, after combining with the original signal current, will be converted into an intermediate frequency beat current.*

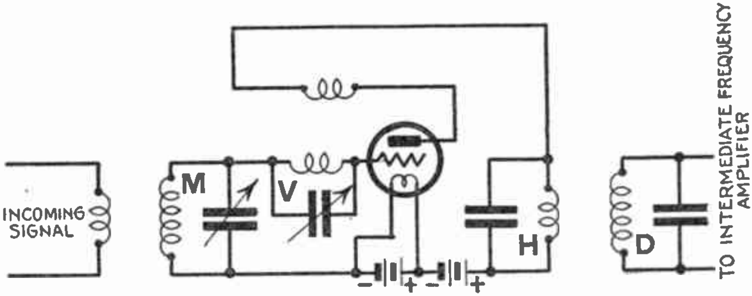

FIG. 7,316.—Diagram illustrating principle of *super-heterodyne* with second harmonic oscillator. The oscillatory circuit M, is tuned to the frequency of the incoming signal, the circuit V, is tuned to one-half the frequency of the incoming signal plus or minus one-half the intermediate frequency, and the circuits H, and D, are tuned to the intermediate frequency.

The intermediate beat current, which is low in frequency, can be amplified with minimum loss due to inter-electrode capacity, and then passed through the detector tube to be converted again, this time into an audio frequency current which is capable of reproducing the original signal wave in the phone or loud speaker.

This frequency as stated is sufficiently low to permit the use of audio frequency type amplifying transformers with their attendant advantages, and yet retain the advantage of amplification before detection. After the detector, the rectified wave may be still further amplified in the regular

FIG. 7,315.—*Text continued.*

22, 400 ohm potentiometers; 23, volt meter; 24, ammeter; 25, .001 vernier variable condenser (43 plates); 26, .0005 vernier variable condenser (23 plates); 27, switch; 28, .002 by pass condenser; 29, 45 volts B bat.; 30, 6 volts storage A bat.; 31, C bat.

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manner. This arrangement is theoretically one of the best methods for the reception of short wave lengths.

Super-Heterodyne with Second Harmonic Oscillator.—In this hook up the second harmonic oscillator is operated on the principle that *an oscillating vacuum tube circuit generates a current of fundamental frequency, and also produces other oscillations which are multiples of the fundamental frequency.*

These upper frequencies in multiples of the fundamental are called *harmonics*, several of which are strong enough to be utilized in the same way as the fundamental.

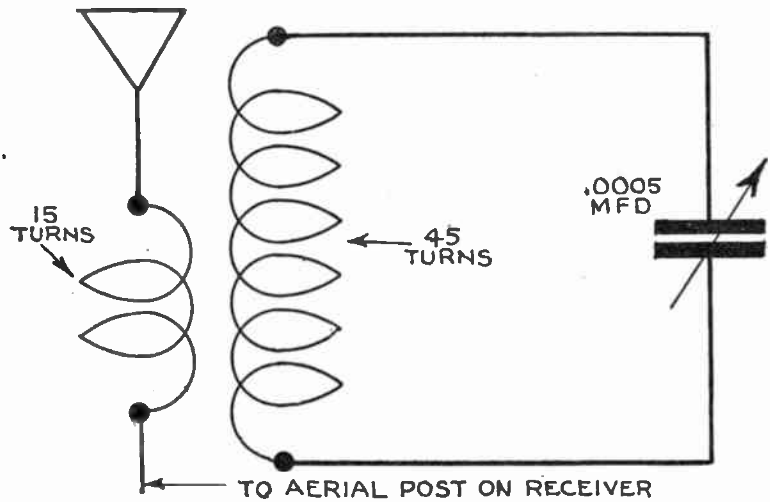

FIG. 7,317.—Super wave trap. This is a tuned oscillatory circuit and is used to eliminate interference. *It consists of* an inductance coil having a primary and a secondary winding. The variable condenser is placed in the secondary winding circuit as shown.

Another feature of the circuit is the reduction in the number of tubes accomplished by reflex action. The radio frequency tube is made to perform the double duty of amplifying both the intermediate current and the incoming signal current.

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Wave Trap.—A successful method of cutting out local interference is by means of a wave trap. The trap comprises a variable condenser placed in parallel with a coil. A switch across the coil permits switching out the trap and again receiving broadcasting from the local stations.

TEST QUESTIONS

1. *What is a receiving circuit?*
2. *Name the circuits used in radio sets.*
3. *Explain feed back regeneration.*
4. *Name three methods of feeding back the plate current to the grid.*
5. *What principle is employed to obtain super feed back?*
6. *What difficulty is encountered in super regenerative sets?*
7. *Define tuned radio frequency.*
8. *What is the usual method of tuning in a tuned radio frequency set?*
9. *Explain the reflex principle.*
10. *What use is made of the second and third tubes in a typical four tube reflex set?*
11. *State the inverse duplex principle.*
12. *How are the tubes used in the inverse duplex circuit?*
13. *How many tubes are used in a typical neutrodyne set?*
14. *How does a neutrodyne set work?*
15. *How is each neutralizing condenser adjusted?*

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16. *What name is given to a neutralizing condenser?*
17. *How is a high radio frequency amplification obtained in neutrodyne sets?*
18. *Draw a diagram of a neutrodyne set.*
19. *State the heterodyne and autodyne principles.*
20. *What is a beat note?*
21. *How does an autodyne set differ from a heterodyne set?*
22. *State, 1, the super-heterodyne principle, 2, super-heterodyne with second harmonic oscillator.*
23. *What is a wave trap?*

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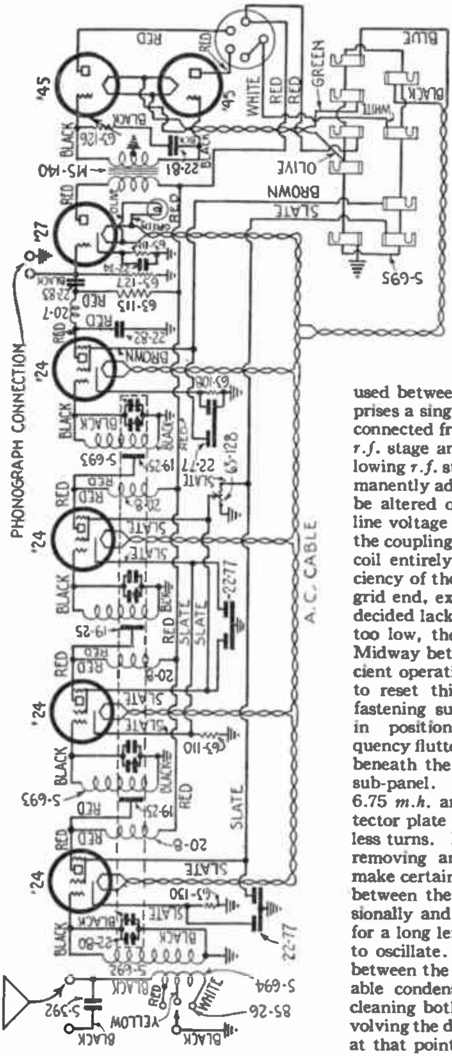

CHAPTER 177

Radio Circuit Diagrams

FIG. 7,318.—Circuit diagram of super-Zenith receiver. *The circuit comprises:* three stages of screen grid *r.f.*, a screen grid power detector, one resistance coupled stage and one stage of push pull audio amplification. A special capacity coupling is used between the *r.f.* stages. The coupling comprises a single band of bus bar wire. This band is connected from the plate terminal of the preceding *r.f.* stage and coupled to the grid coil of the following *r.f.* stage. The position of this band is permanently adjusted at the factory and should never be altered or tampered with unless the available line voltage be .xtremely low. The distance from the coupling band to the grid or top end of the *r.f.* coil entirely governs the stage coupling and efficiency of the set. If this band be too close to the grid end, excessive coupling will result, causing a decided lack of selectivity. If the band be placed too low, the result will be a lack of sensitivity. Midway between the coil winding is the most efficient operating position. If it be found necessary to reset this band, insulating cement or other fastening substance should be applied to hold it in position. Loose vibration would cause frequency flutter. The *r.f.* plate chokes are concealed beneath the *r.f.* coil base, between the base and sub-panel. These chokes have an inductance of 6.75 *m.h.* and can be distinguished from the detector plate choke by the fact that they have 150 less turns. If an occasion arise which necessitates removing an *r.f.* choke, the serviceman should make certain that the ⅛ in. spacing is maintained between the choke and the *r.f.* coil base. Occasionally and especially if the receiver remain idle for a long length of time, it may have a tendency to oscillate. This is always due to poor contact between the wipers and rotor bearings of the variable condenser gang. It may be overcome by cleaning both parts with fine sandpaper or by revolving the dial several times to remove oxidization at that point.

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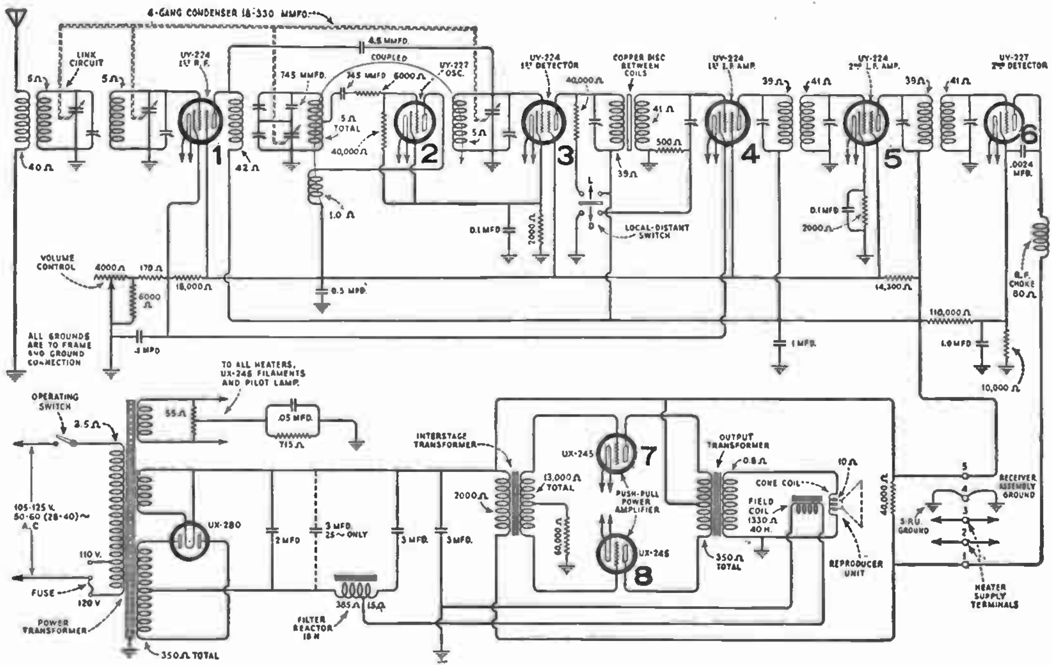

FIG. 7,319.—General Electric screen grid super-heterodyne receiver. *It comprises* a coil and condenser tuning circuit; tuned *r.f.* stage using Radiotrons UY-224, the output of this stage being coupled capacitively to the grid circuit of the first detector. The plate circuit of the *r.f.* stage has a high inductance coil, the oscillator output is coupled inductively to the grid coil of the first detector. There are two intermediate amplification stages and push pull *a.f.* stage.

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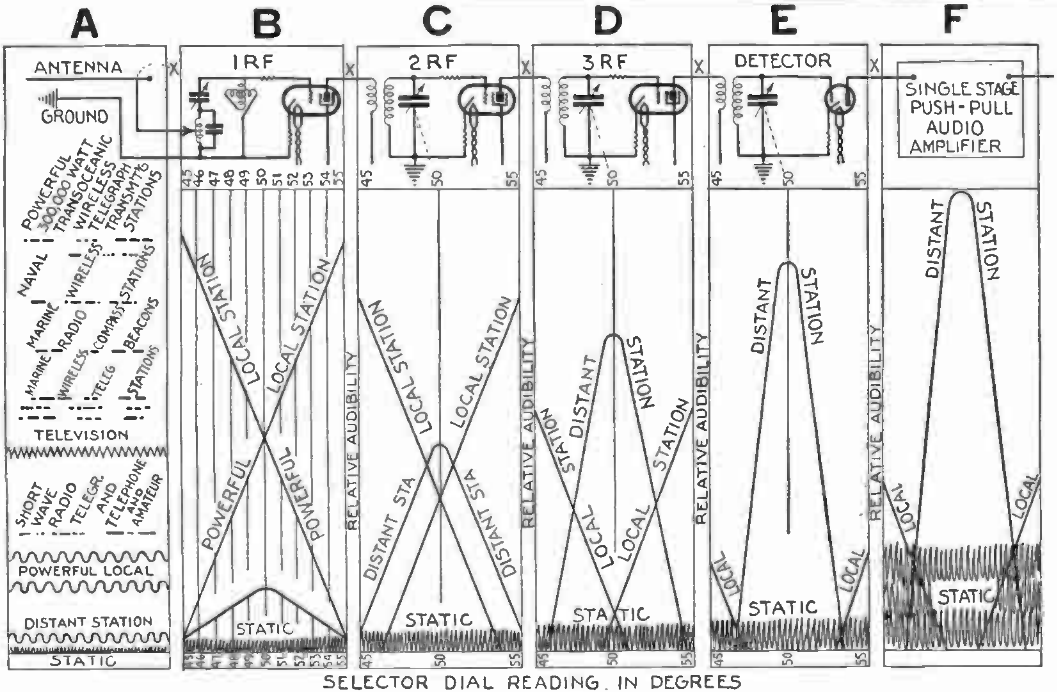

FIG. 7,320.—Diagram of Bosch model 48 receiver showing the tuning amplifying action of the various stages. The illustration is divided into six sections, lettered A to F. The graphs of these sections tend to show the type of reception which might be expected if ear phones could be connected successively in each of the receiver sections at the points marked X. The ten horizontal divisions of each graph represent the corresponding number of degrees on the tuning dial between 45 and 55. The vertical divisions represent comparative audibility.

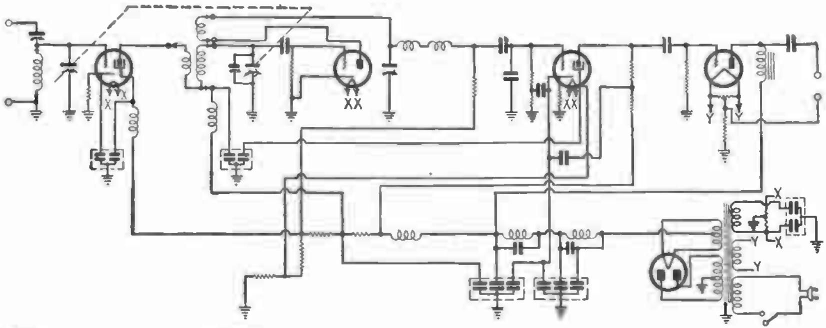

Fig. 7,321.—Silver Marshall "Bearcat" short wave receiver for use on automobiles.

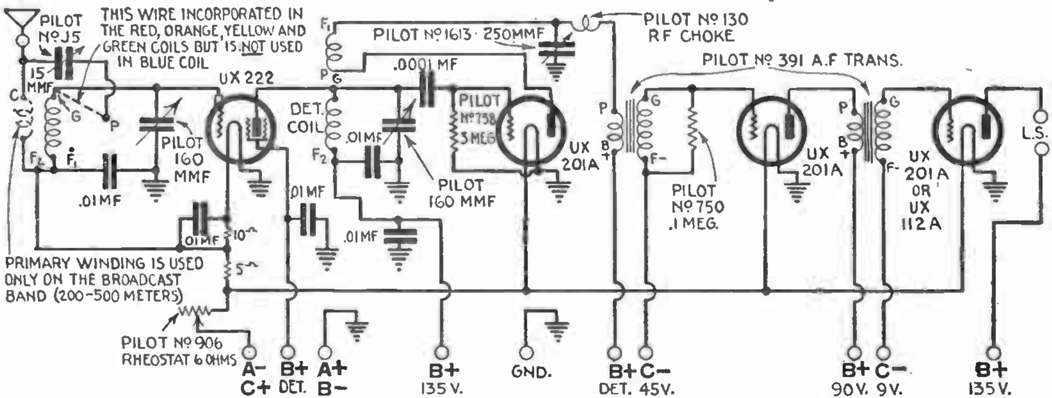

Fig. 7,322.—Schematic diagram of Super-Wasp battery model receiver for long and short waves. The various ground symbols indicate connections to the metal chassis of the receiver. *For building this set* the necessary parts are: 1 No. 705 front panel,

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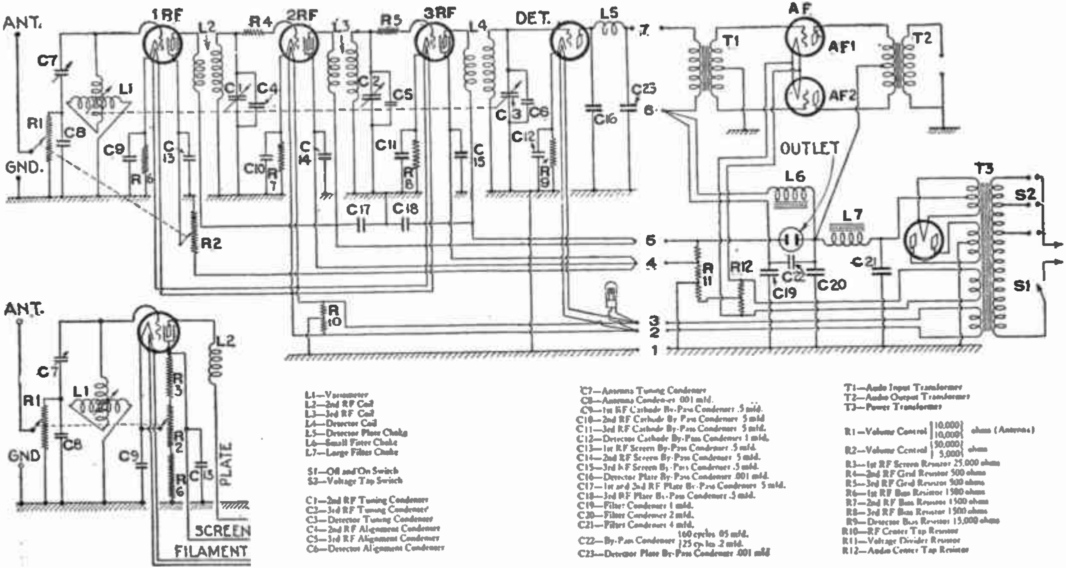


FIGS. 7,323 and 7,324.—Schematic wiring diagram Bosch model 48 receiver. In fig. 7,324 follow this portion of diagram for sets using volume control having resistances of 10,000 and 5,000 ohms.

FIG. 7,322.—*Text continued.*

7½×18×¼ ins., drilled and engraved; 1 No. 706 sub-panel, 8×17×1/16 ins. drilled with all mounting and wiring holes; 4 No. 37 metal sub-panel brackets; 2 No. 1611 .00016 mf. variable condensers; 1 No. 1613 .00025 mf. variable condenser with bakelite knob; 2 No. 1282 illuminated vernier dials; 1 No. 906 rheostat, 6 ohms; 1 No. 961 tapped resistor; 2 No. 600 special Super-Wasp shield cans; 1 No. J5 midget condenser, 5 plates; 2 No. 391 audio amplifying transformers; 2 No. 212 five prong sockets, for plug in coils; 2 No. 213 four prong sockets, for audio tubes; 2 No. 206 four prong shock proof sockets, for 222 and detector tubes; 2 pairs grid leak clips; 1 No. 758 3 megohm grid leak; 1 No. 750 100,000 ohm grid leak; 1 No. 50B fixed condenser, .0001 mf.; 5 No. 59 fixed condensers, .01 mf.; 1 No. 130 RF choke coil; 2 sets of plug in coils, 4, packages of hardware.

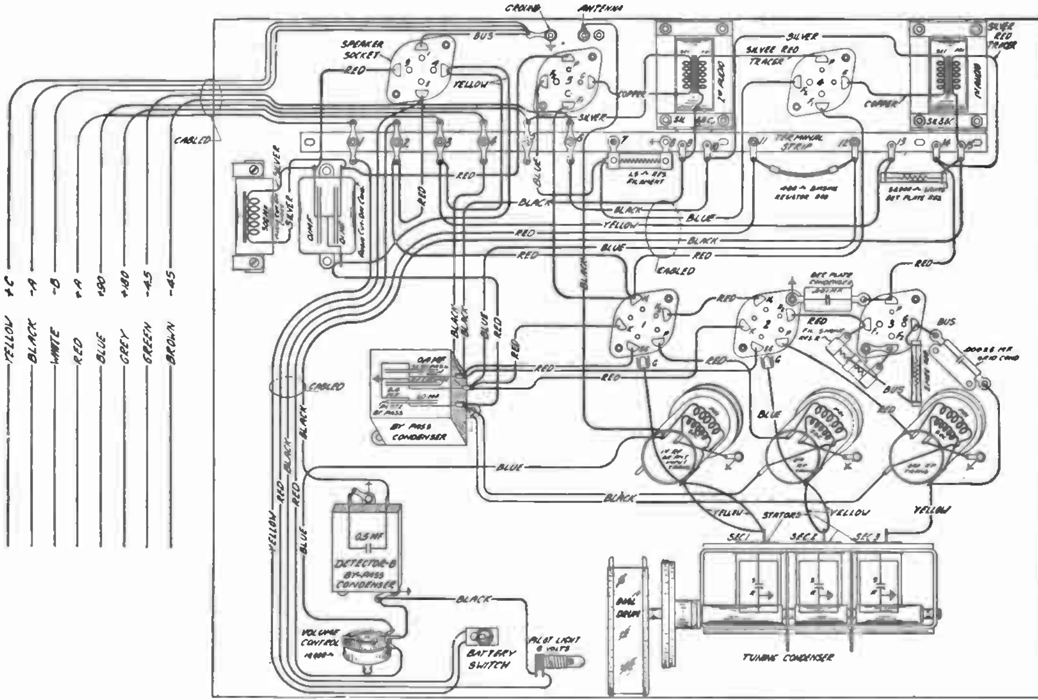
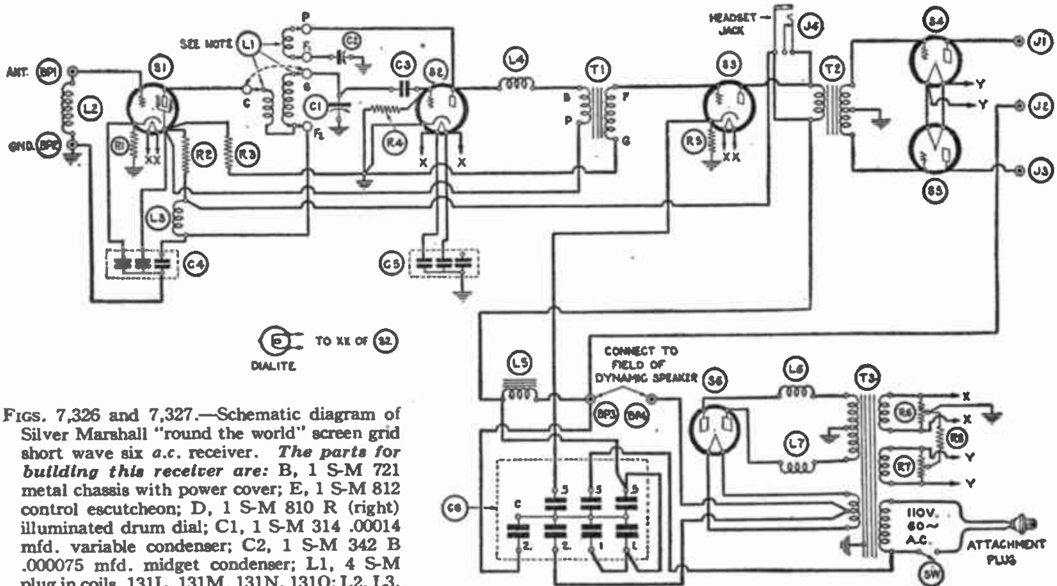


FIG. 7,325.—United States "Apex" No. 49, 5 tube battery chassis complete assembly.



FIGS. 7,326 and 7,327.—Schematic diagram of Silver Marshall "round the world" screen grid short wave six *a.c.* receiver. ***The parts for building this receiver are:*** B, 1 S-M 721 metal chassis with power cover; E, 1 S-M 812 control escutcheon; D, 1 S-M 810 R (right) illuminated drum dial; C1, 1 S-M 314 .00014 mfd. variable condenser; C2, 1 S-M 342 B .000075 mfd. midget condenser; L1, 4 S-M plug in coils, 131L, 131M, 131N, 131O; L2, L3, L4, 3 S-M 277 short wave *r.f.* chokes; L6 and L7, 2 S-M 275 *r.f.* chokes; L5, 1 S-M 338 filter choke; also the following: SH1, 1 SH2, 2 S-M 636 tube shields; T1, 1 S-M 260S audio transformer; T2, 1 S-M 270U push pull input transformer; T3, 1 S-M 336U power transformer and 1 S-M 818 hook up wire; C3, 1 Polymet .00015 mfd. small moulded condenser; C4 and C5, 2 Potter 30B by-pass condenser banks; C6, 1 Potter 674C filter condenser block; S1, 1 C-R 224 tube socket; S2, S3 and S7, 3 C-R 227 tube socket; S4 and S5, 2 C-R 245 tube socket; S6, 1 C-R 280 tube socket; R2 and R3, 2 Durham 10,000 ohm, 2 watt resistors (green); R4, 1 Durham 2 megohm, 1 watt resistor (red); R5, 1 Durham 200 ohm 1 watt resistor (white); R6 and R7, 2 Yaxley 840C 40 ohm CT resistor; J1, J2 and J3, 3 Yaxley 422 insulated tip jacks; J4, 1 Carter 2A closed circuit jack; R1, 1 Carter RU 400-400 ohm resistor; R8, 1 Ohio carhon 800 ohm 3 watt resistor (green); SW, 1 H & H 1561 rotary on and off switch; BP1, BP2, BP3 and BP4, 4 moulded binding posts; 2 KK817 brown wood knobs; 1 cord and plug, 35⁄8 × ½ in. RH machine screws; 5 1½ × 5⁄8 RH machine screws; 2 1¾ × 5⁄8 RH machine screws; 40 5⁄8 nuts; 40 No. 6 lock washers; 2 1¼ × ¼ hollow

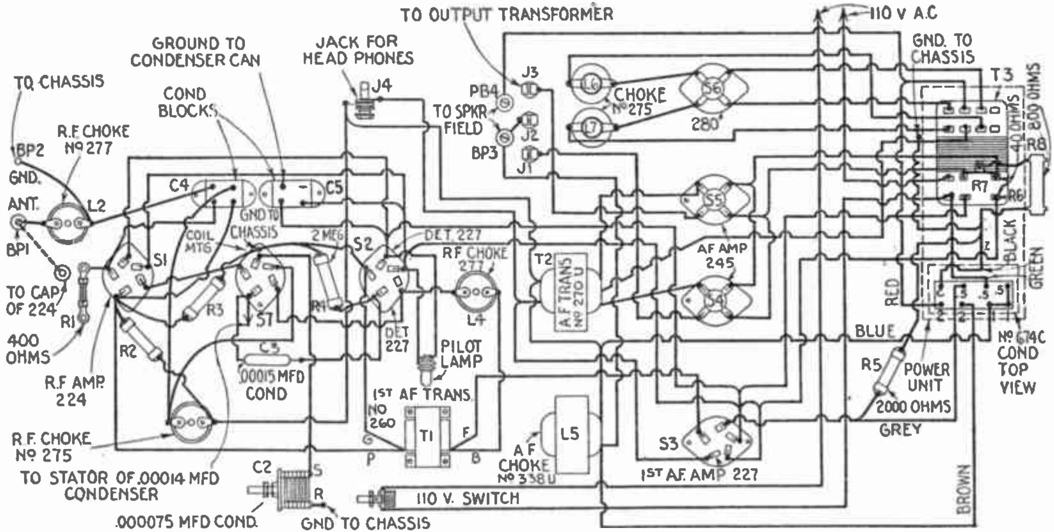


FIG. 7,328.—Bottom view of Silver-Marshall "round-the-world" screen grid short wave six *a.c.* receiver showing in detail the placing of parts and wires. ***It comprises:*** a fully *a.c.* operated screen grid short wave receiver with self contained power supply. There are four plug in coils. The receiver tunes from 16.6 to 195 meters and by means of two additional plug in coils, its range is increased up to 592 meters. It may be used with an indoor or outdoor antenna. The circuit consists of one stage of untuned *a.c.* screen grid *r.f.* amplification (224 tube) followed by a 227 tube tuned detector employing plug in coils with controllable regeneration. The detector is transformer coupled to a type 227 first audio stage which in turn feeds a 245 push pull power output stage. The power supply, operating from any 105 to 120 volt, 50 to 60 cycle *a.c.* lighting circuit, provides all A, B, and C power for the receiver, and field power for an S-M type 851 *d.c.* dynamic speaker the field of which (1900 ohms) is included in the power supply filter circuit. The receiver is provided with three controls.

FIGS. 7,326 and 7,327.—*Text continued.*
coil studs; 7 soldering lugs; 3 sets (one plain, one extruded) binding post insulated washers; 3 extruded tip jack washers; 3 plain instrument washers; 4 ft. No. 14 stranded wire; 1 grid clip.

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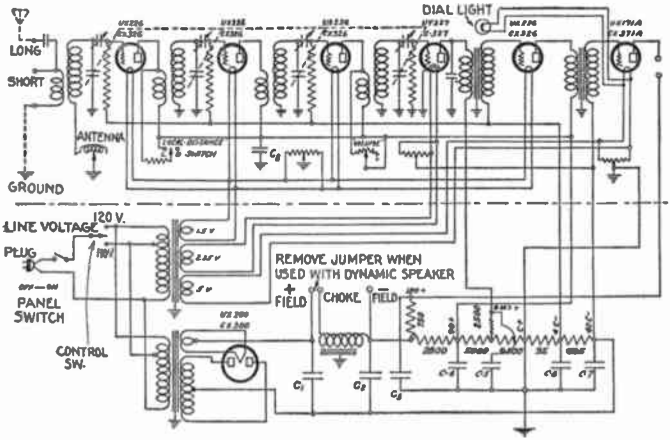

FIG. 7,329.—Wiring diagram for Grebe synchrophase *a.c.* six receiver designed to operate on 110 volt 50-60 cycle *a.c.* supply.

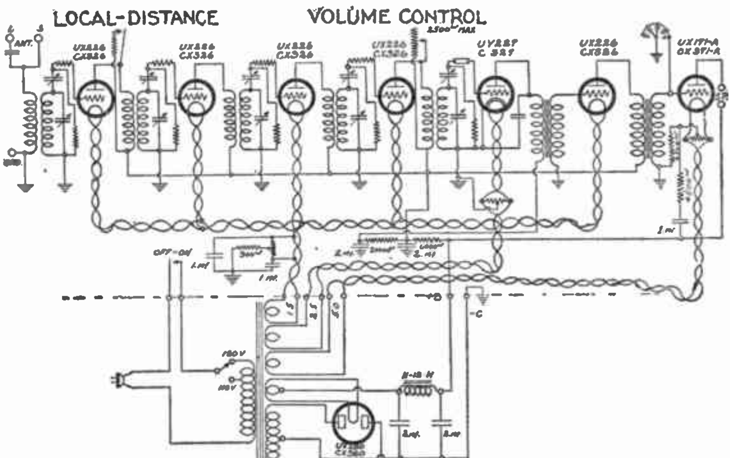

FIG. 7,330.—Wiring diagram for Grebe synchrophase *a.c.* seven receiver. It was necessary in the design of this instrument for *a.c.* operation, to include an external power unit to supply the filament, plate and grid bias voltages.

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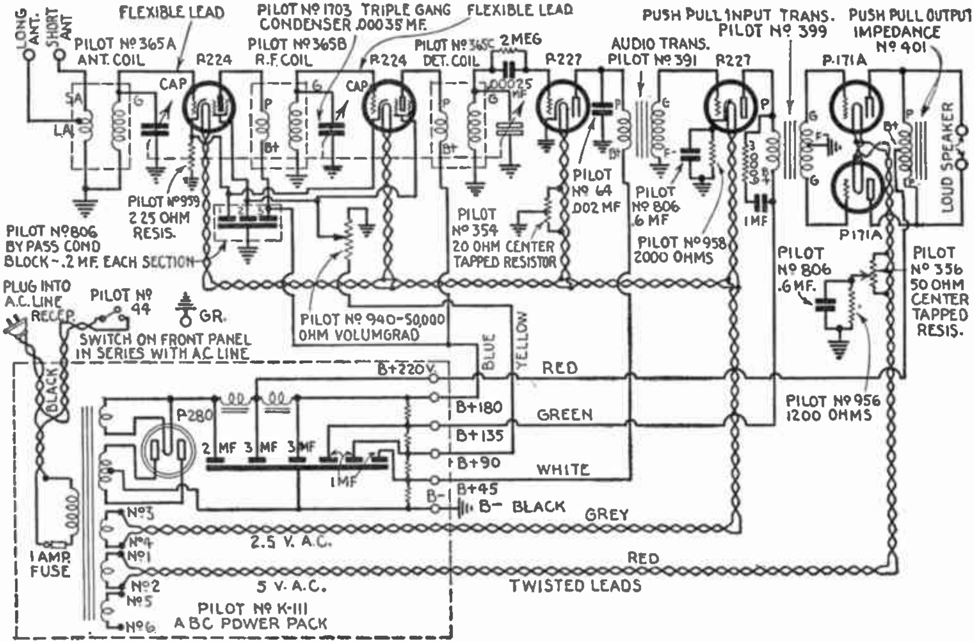

FIG. 7,331.—Pilot "P. E. 6" screen grid broadcast receiver. It is an inexpensive outfit that can be assembled and wired in a few hours. *The circuit comprises* two stages of tuned radio frequency amplification using screen grid tubes, with both the tubes and the R. F. transformers fully shielded; a non-regenerative detector, and a modern audio amplifier system of the push-pull type. Tuning is accomplished by a single illuminated vernier dial, the only other controls being a power switch and a volume knob. The set is fully *a.c.* operated, all the necessary filament, grid and plate voltages being furnished by a Pilot K-111 power pack, supplied with the K-124 kit.

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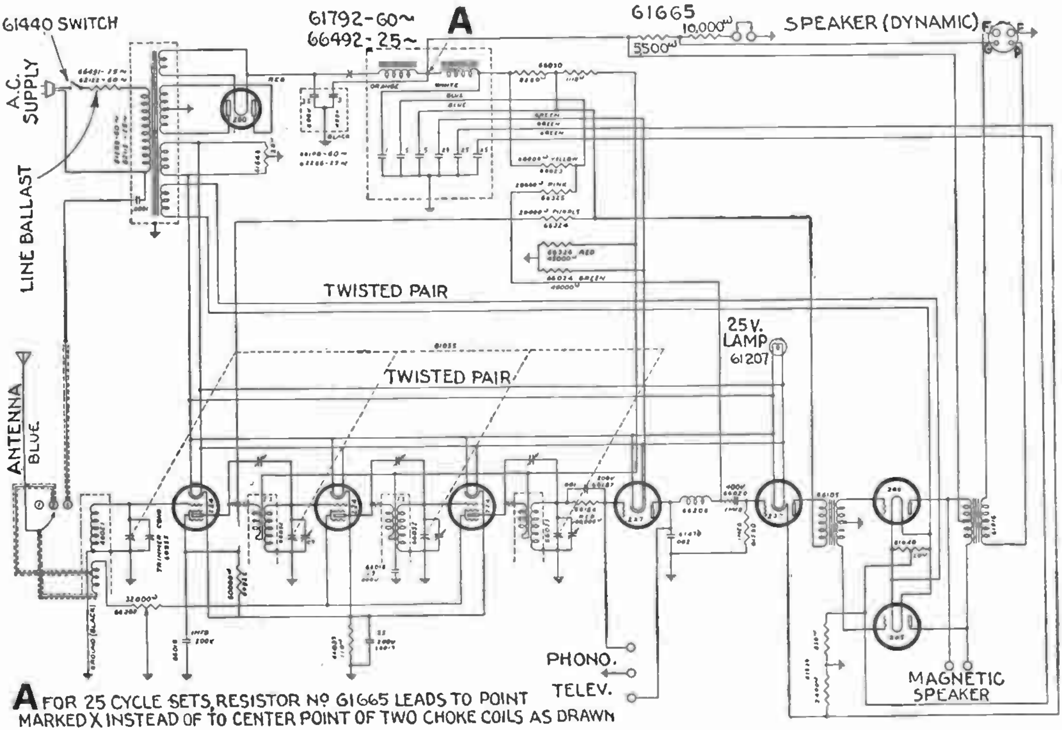

FIG. 7,332.—Circuit diagram for Stewart-Warner 950 screen grid receiver. *It employs* a combination of inductive and capacitative coupling in the R. F. stages, thus producing a flat sensitivity curve over the entire broadcast band; the inductive coupling being most effective at the lower frequencies, and the capacitative at the higher frequencies.

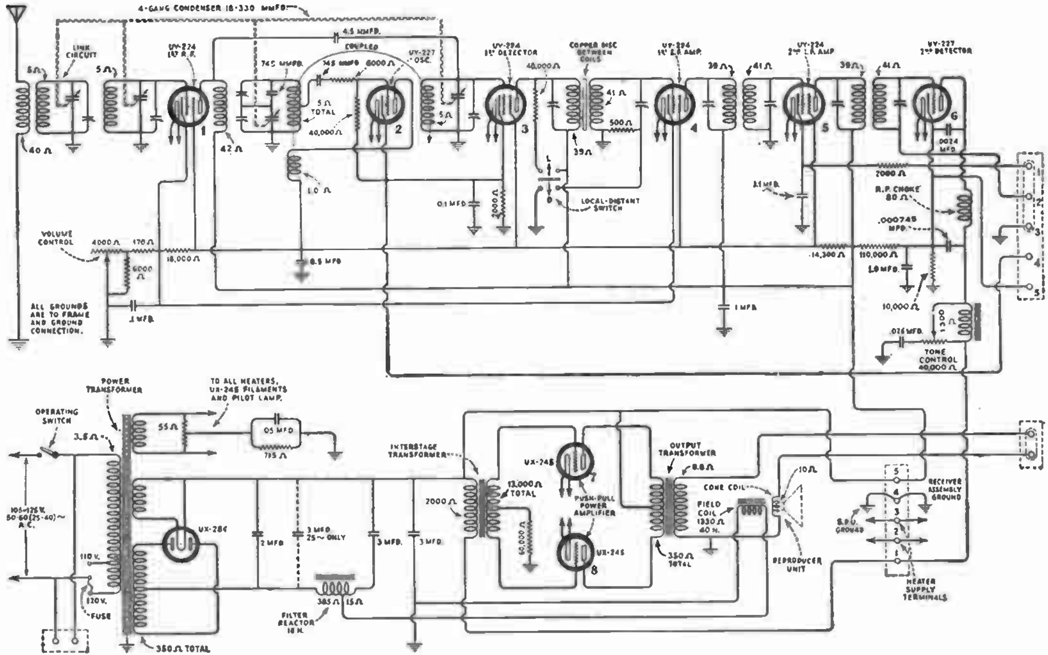

FIG. 7,333.—Circuit diagram of RCA *a.c.* screen grid super-heterodyne Radiola 82. Voltage 105-125; frequency 50-60 or 25-40; power consumption 120 watts, 1 stage *r.f.*; 2 intermediate stages; 1st stage (push pull) *a.f.* *The tone control* consists of a 40,000 ohm potentiometer in series with a .025 *mfd.* fixed condenser. This arrangement is shunted around a choke placed in the second detector plate circuit. With the resistor arm at the extreme "high" position, the reactor is shorted and the full amount of the resistance is placed in series with the condenser, thus giving the normal fidelity of the receiver. As the potentiometer arm is

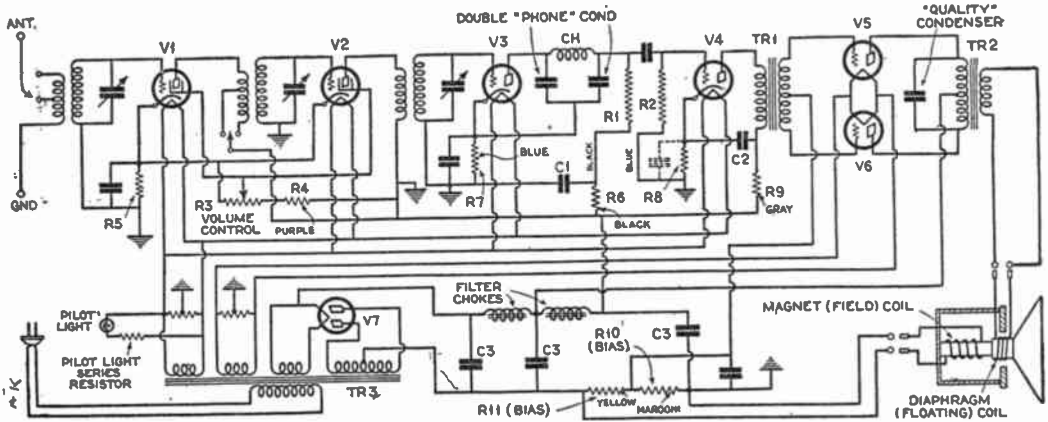

Fig. 7,334.—Atwater Kent Model 55 six tube (and rectifier) *a.c.* receiver. This model does not require a long aerial. Two aerial posts are provided on the set marked "long antenna and short antenna." The long aerial post will give greater selectivity and should be used if the aerial be 30 ft. or more in length. The short aerial post should be used if a very short (inside) aerial be employed. If extreme selectivity be desired use a short aerial connected to the long aerial post. Indoor aerials for Model 55 should be erected as far as possible away from grounded metal, such as pipes, electric wiring, etc. Ground connection *must* be used with Model 55. This set will also not operate (as some *a.c.* sets do) with either aerial post connected to the ground. The two *a.f.* output tubes used in the audio stage should be matched on a tube tester, otherwise the set may hum. Do not use any other model of Atwater Kent speaker with Model 55, than the type F-4 or F-4C. Do not remove speaker plug from socket when set is in operation. The set should be operated with the local distance switch in the local position when receiving nearby stations. Failure to do this may result in overloading of the detector tube, which will be evidenced by a decrease of output volume at the resonant point on the tuning dial, as well as a slight ragged type of distortion on strong stations.

Fig. 7,333—*Text continued.*

moved toward the extreme "low" position, the choke and condenser both become effective, and thus reduce the high frequency output of the receiver. The amount of this reduction is dependent on the position of the potentiometer arm, operated by the tone control knob.

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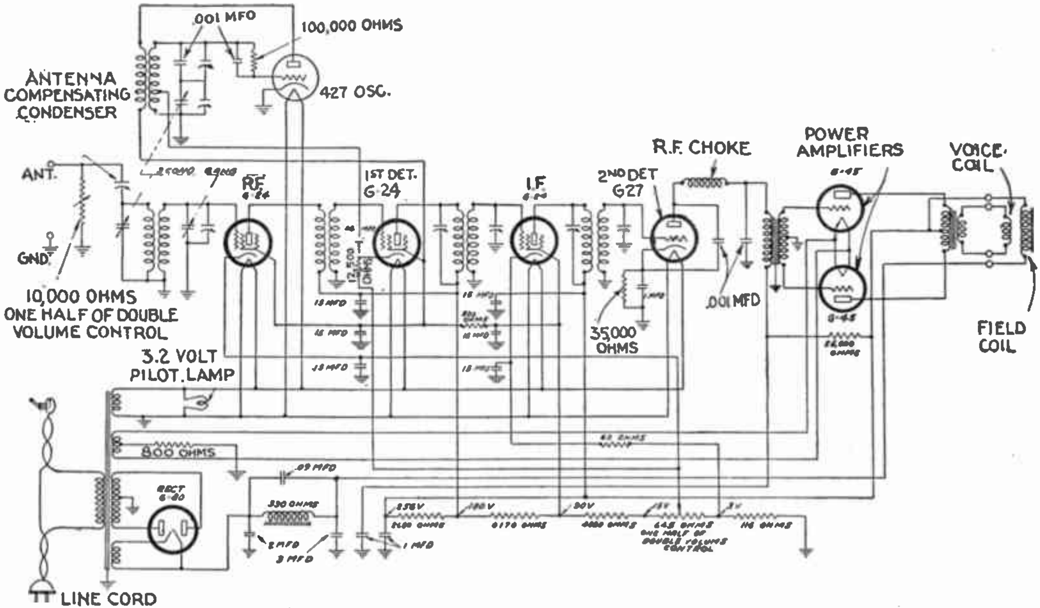

FIG. 7,335.—Schematic diagram of Majestic screen grid super-heterodyne receiver. The set comprises a rectifier, an oscillator circuit, aerial compensating condenser, first and second detectors, one *r.f.* and one *i.f.* amplification stage, *r.f.* choke, power amplifiers and speaker.

World Radio History

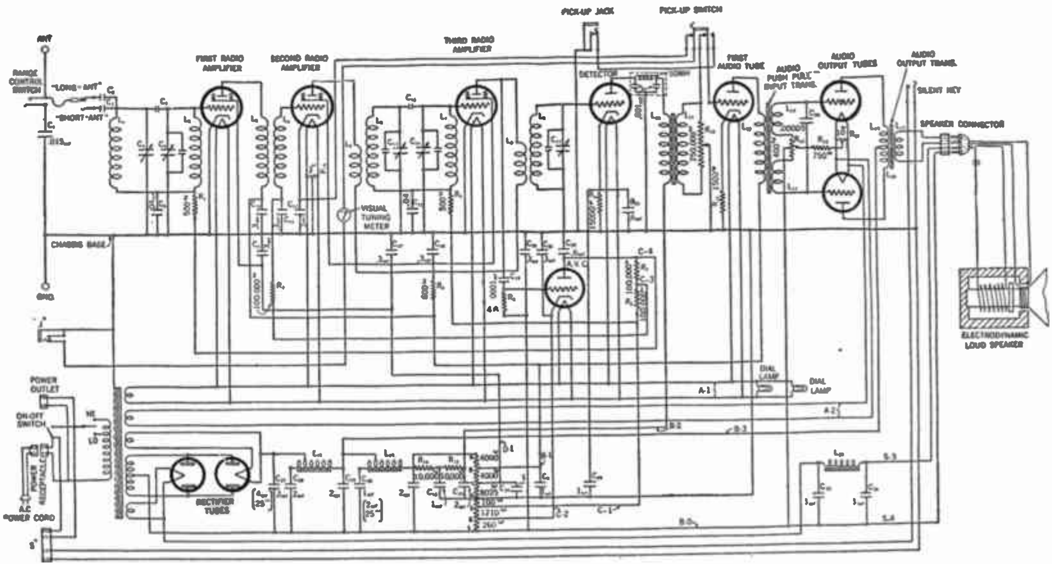

FIG. 7,336.—Schematic diagram of Stromberg-Carlson No. 12 receiver. It employs three UY-224 screen grid tubes. The radio amplifier comprises five tuned circuits as well as a broad band inter-stage coupling transformer. Four of these tuned circuits are used in two "Bi-resonators" while the fifth is used to couple the radio amplifier to the detector. An automatic volume control circuit is employed, using a UY-227 tube. The detector also uses a UY-227 tube, and is coupled to the first audio (UY-227) tube by means of a low ratio transformer. This first audio tube is coupled to the push pull UX-245 output tubes by a special large transformer. One UX-280 rectifier tube supplies the *d.c.* to the tubes, and another UX-280 supplies rectified current to the speaker field.

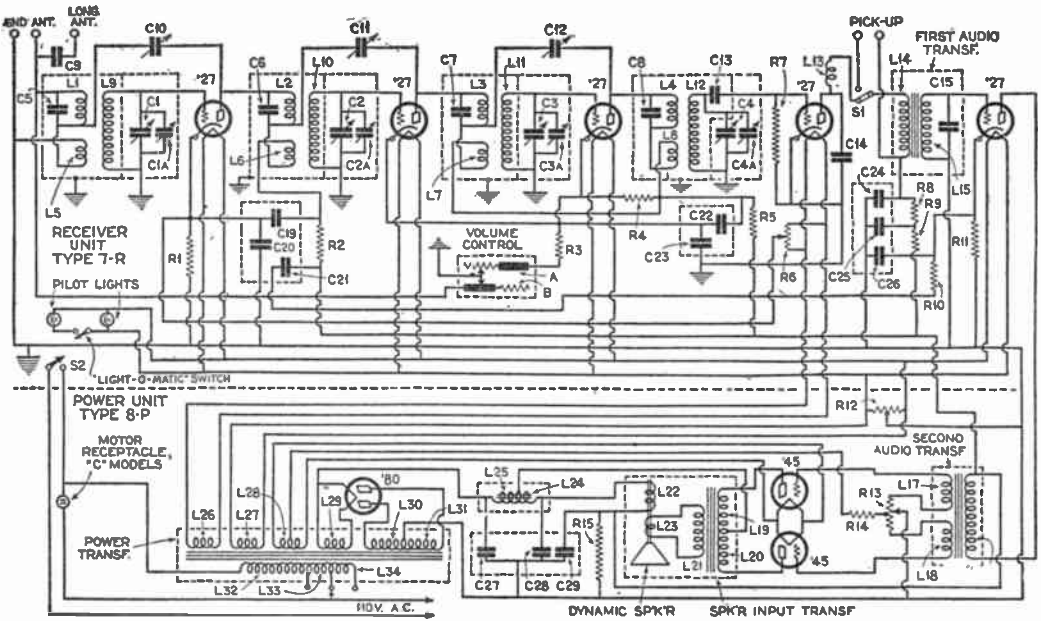

FIG. 7,337.—Wiring diagram of Edison R-4, R-5 and C-4 receivers. L1, L2, L3 and L4 are low frequency primaries, resonated to approximately 450 kilocycles by means of the condensers C5, C6, C7 and C8; L5, L6, L7 and L8 are high frequency primaries, not shunted by any condenser; L9, L10, L11 and L12 are secondaries tuned by the variable condenser sections C1, C2, C3 and C4, which are shunted by the trimming capacities C1A, C2A, C3A and C4A. Stabilization of the *r.f.* amplifier is accomplished by the use of grid circuit neutralization; that is, the employment of neutralizing condensers, C10, C11 and C12 connected from the plate of each *r.f.* amplifying tube to a coil tightly coupled to the secondary of the input transformer of that tube. These coils in the diagram are L5, L6 and L7, which are at the same time the high frequency primaries of the

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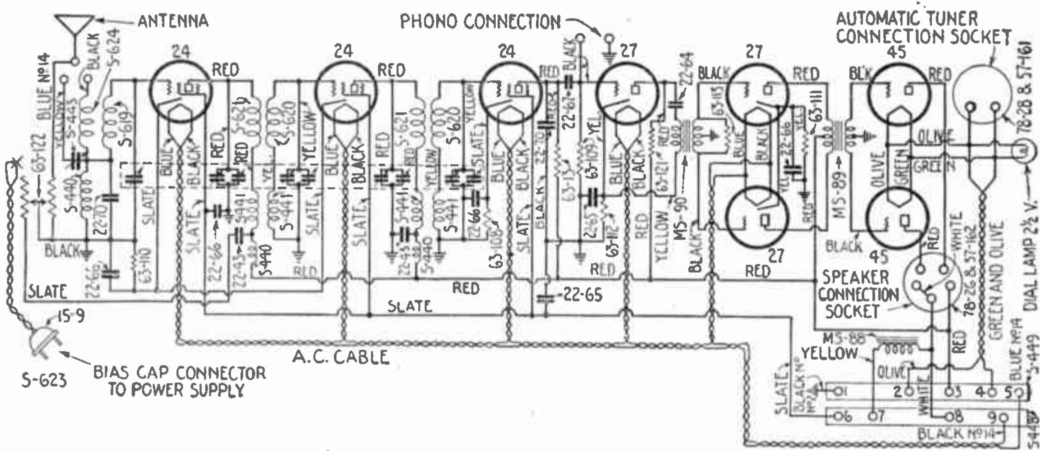

FIG. 7,338.—Circuit diagram of Zenith "70" series *a.c.* receiver. ***The circuit consists of*** two stages of tuned plate, tuned grid, screen grid radio frequency amplification, a screen grid power detector, one stage of resistance coupled audio amplification using a 27 tube, a second stage of push pull using two 27 tubes, and a third or power stage using two 45's in push pull. The electrolytic condenser, the voltage divider and the by-pass condenser for the grid bias of the third stage audio are placed in the power unit. The separate unit type condensers have been incorporated in this pack. A cover has been placed over both the terminal strips on the chassis and the fuse clip on the power pack. All possible wiring has been cabled. All cabled wire has a definite color code. The double volume control has been adopted as standard. Provision has been made to use a short aerial.

FIG. 7,337.—*Text continued.*

first, second and third *r.f.* transformers. Substantial resonance of the first *r.f.* input circuit to the resonant frequency of the second and third *r.f.* and detector input circuits is maintained by holding the effective aerial-ground capacity to a value less than 100 micromicrofarads. Self bias of the first *r.f.* amplifying tube is secured by the use of resistor R1, by-passed by the capacity C20. Isolation of the *r.f.* component of the plate current of this tube is accomplished by the use of resistor R2, and capacity C19. Self bias of the second and third *r.f.* amplifying tubes in common is effected by the resistor R3, and the section A, of the volume control by-passed by the capacity C23. Isolation of the *r.f.* components of the plate currents of those two tubes in common results from the use of the resistor R5 and the capacity C22.

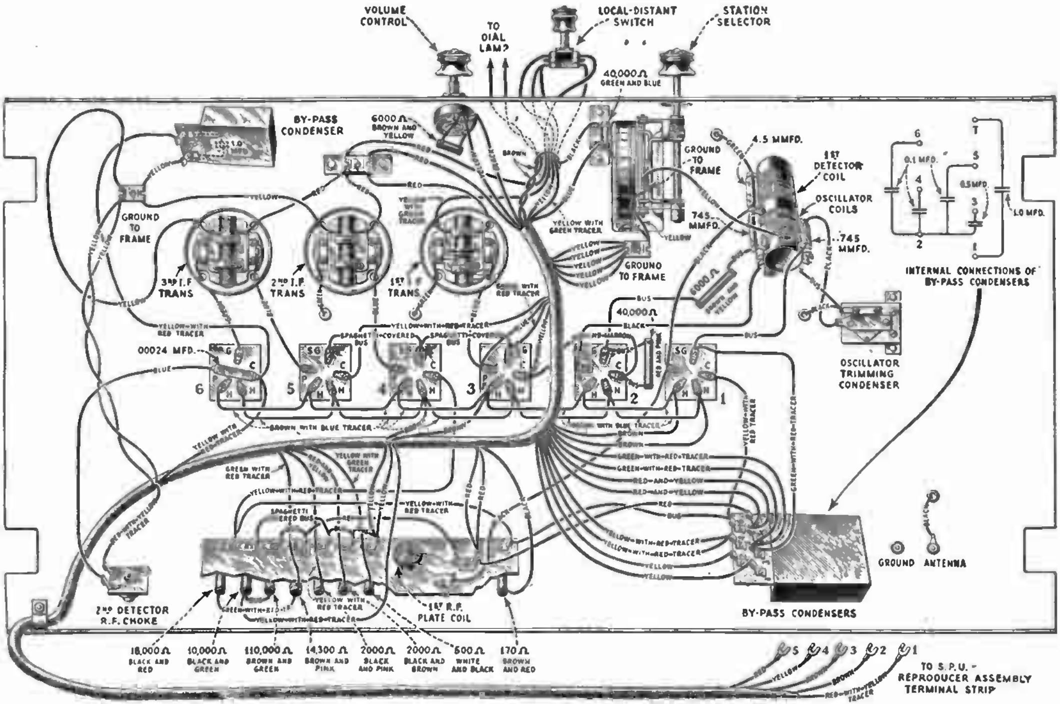

FIG. 7,339.—Pictorial wiring diagram of General Electric Model H 31 screen grid super-heterodyne receiver.

CHAPTER 178

Short Waves

Short waves permit broadcasting to much greater distances than with the longer waves regularly used, and in order to extend the broadcasting range some of the leading stations simultaneously transmit their programs on long and short waves.

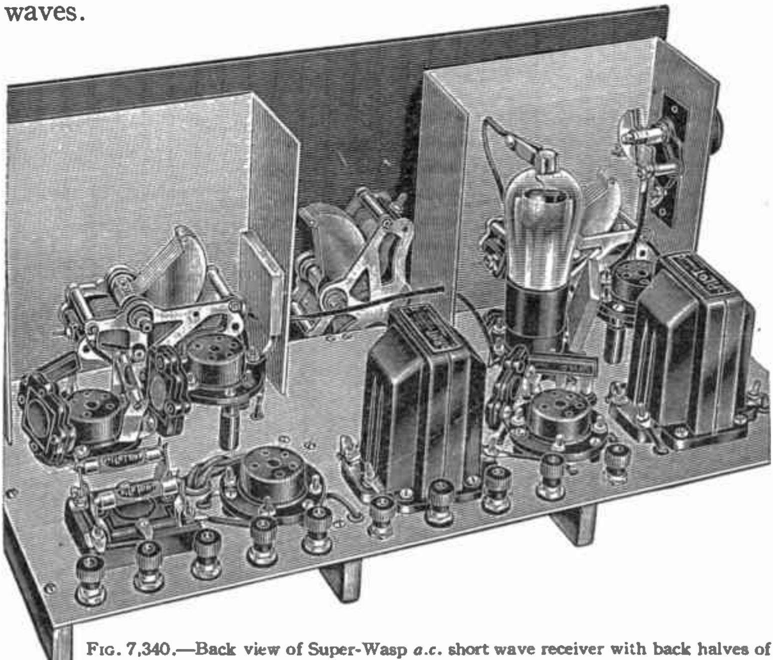

FIG. 7,340.—Back view of Super-Wasp *a.c.* short wave receiver with back halves of the shield cans removed.

By definition, a short wave is *any wave of a length less than 200 meters*.

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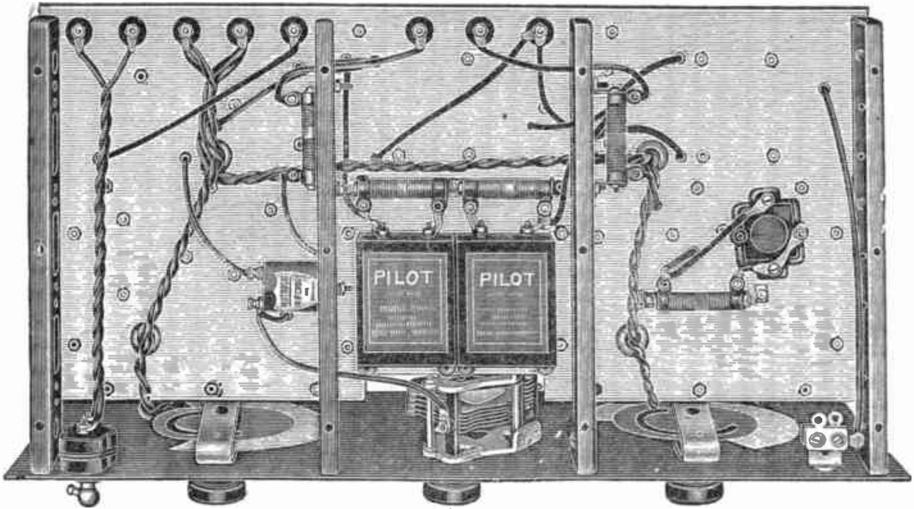

FIG. 7,341.—Under view of Super-Wasp *a.c.* short wave receiver show'ng arrangement of parts.

Wave Length and Frequency.—Since the electric strain and flux lines move with the velocity of light, 186,300 miles per second, or 300,000,000 meters per second, the distance between two successive maxima of electric strain directed in the same direction, or, wave length = 300,000,000 ÷ number of waves per second. As usually expressed,

$$\text{wave length} = \frac{300{,}000{,}000}{\text{wave frequency in cycles per sec.}} \quad \ldots\ldots\ldots\ldots (1)$$

From the formula it is seen that *the shorter the wave length the higher the frequency.*

Examples.—What are the frequencies for wave lengths of 10 and 200 meters? From formula 1

$$\text{wave frequency} = \frac{300{,}000{,}000}{\text{wave length}} \qquad (2)$$

substituting 10 in formula 2

$$\text{wave frequency} = \frac{300{,}000{,}000}{10} = 30{,}000{,}000 \text{ cycles or } 30{,}000 \text{ kilocycles}$$

substituting 200 in formula 2

$$\text{wave frequency} = \frac{300{,}000{,}000}{200} = 1{,}500{,}000 \text{ cycles or } 1{,}500 \text{ kilocycles}$$

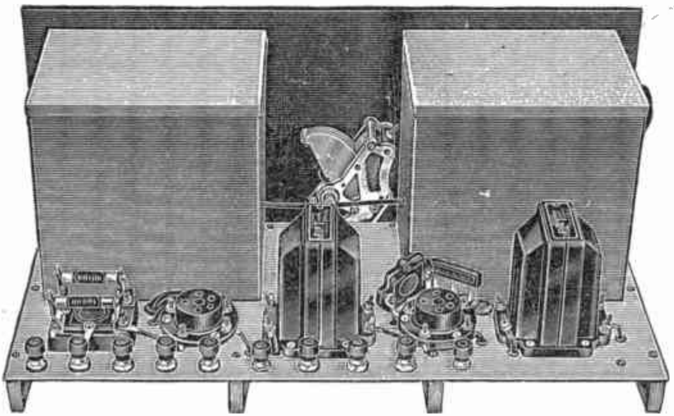

FIG. 7,342.—Back view of completed Super-Wasp *a.c.* short wave receiver showing shield cans in place.

that is, for a 10 meter wave, the frequency is (30,000 ÷ 1,500) or 20 greater than for a 200 meter wave.

High Frequency Reception.—The requirements of receivers for short waves are different than for ordinary receivers on account of the high frequency of the short waves.

With short waves the inductance and capacity effects between wires and coils are very marked.

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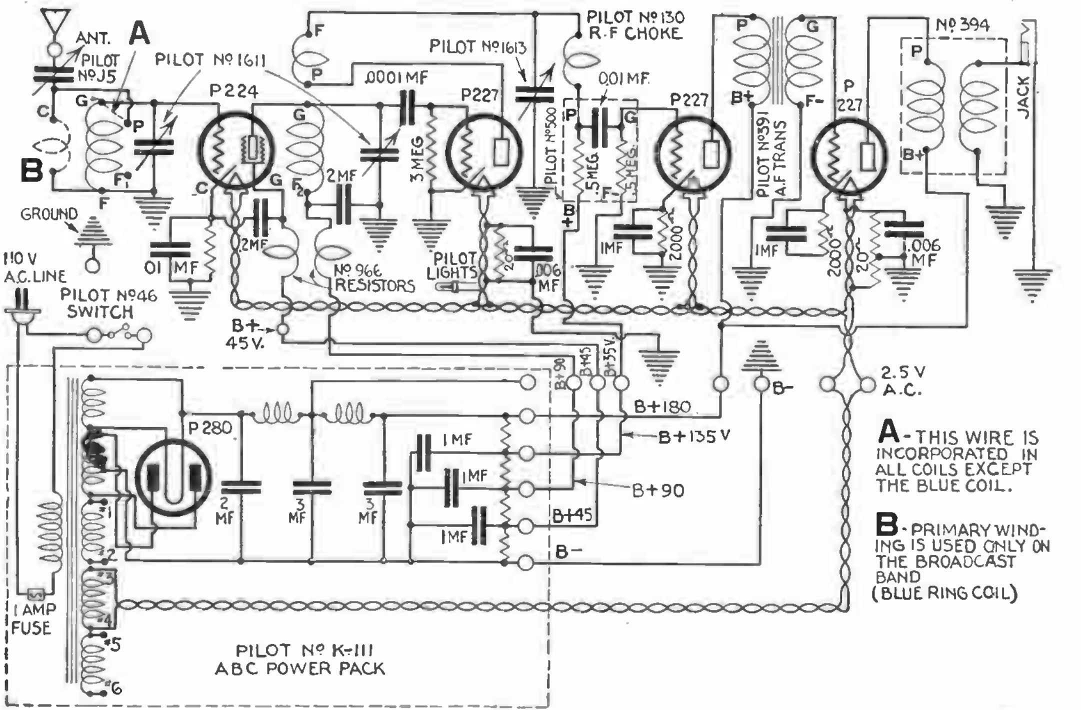

FIG. 7,343.—Complete wiring diagram of Super-Wasp a.c. short wave receiver.

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All wires from grids and plates of tubes should be kept short and well separated. Unless care be exercised in wiring the variable condensers, troublesome hand capacity effects are liable to result. This makes tuning very difficult, and is manifested by a change in the tuning of the set whenever the hand is brought near the tuning dial.

The wire from the grid of the tube to the tuning coil and condenser should always be connected to the stator plates of the tuning condenser, and the rotor plates should go to the grid return circuit.

Complex circuits using multi-stage amplifiers are usually either unstable or have too many operating controls to be of value.

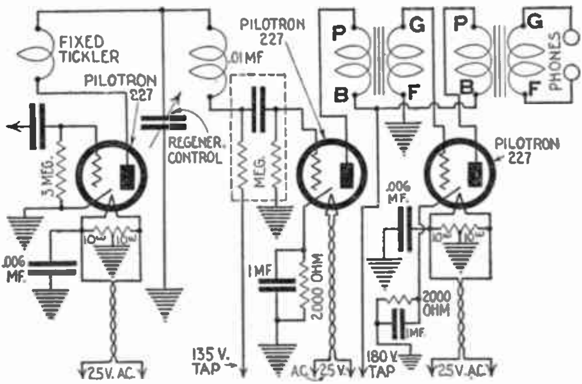

FIG. 7,344.—Audio amplifier system of Super-Wasp *a.c.* short wave receiver. The first stage is *resistance coupled*, the second stage *transformer coupled*. The amplification system consists of a detector working directly into a high resistance high capacity coupling unit, onto the grid of the first audio tube. This audio stage is then coupled to the last audio tube through a standard transformer with the primary phase arranged for negative howl tendency. A tube with the standard electrical amplification characteristics of the 227 is used in all three positions. The use of this first resistance stage reduced the residual hum much more than the reduction in audio amplification. It was found that a net gain in hum reduction resulted from the use of the resistance coupling in the first stage. The resistance units did not act like *a.c.* pick up coils, as did the transformer windings in this location.

Short Wave Receivers.—These usually consist of *a stage of radio frequency amplification followed by a regenerative detector*, either with or without one or two stages of ordinary transformer coupled audio frequency amplification. The use of a

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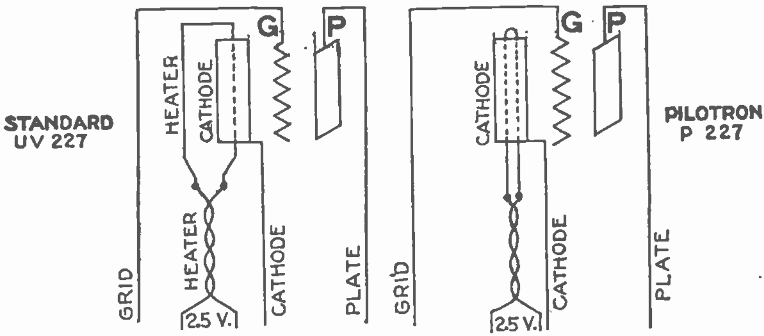
stage of tuned screen grid radio frequency amplification increases the sensitivity greatly.

The nature of the power supply and of the audio amplifier system is of little consideration. The success of the receiver depends mostly upon the apparatus that precedes the audio amplifier.



FIGS. 7,345 and 7,346.—Modification of tubes to avoid hum in Super-Wasp *a.c.* short wave receiver. In the ordinary tube, fig. 7,345, it is apparent that at one instant the bottom of the filament will be positive while the top is negative, shortly followed by a reversal of the heating current which makes the bottom of the filament negative with the top positive. The electronic field within the cathode is thus rapidly twisted back and forth during each alternation of the heating current. A noticeable hum results. Now the construction shown in fig. 7,346 is purposely designed to avoid this. The heating filament is doubled back on itself within the cathode cylinder after the fashion of a hairpin. In this arrangement, the electronic field is neutralized at every point and no upheavals take place on the reversals of the heating current.

Most owners of short wave receivers do not fully appreciate the fact that the entire success of their outfits depends on how smoothly and easily they can control the regenerative action of the detector tube.

Many carefully built receivers using the most expensive parts do not produce more than a few weak local broadcasting stations and possibly a dozen loud telegraph stations, simply because the detectors collapse into oscillation with a pronounced "plop."

Many carelessly assembled sets using parts retrieved from the junk box bring in phone stations from all over the world, because the regenerative action has precision control.

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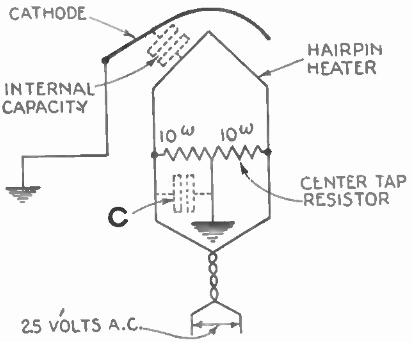
On account of the very great difference in frequency in the range of short waves it would not be practical to provide a tuning system for the full range that would be satisfactory, hence the receiver is designed for the particular *wave band* desired or is provided with removable coils, called plug in coils, or condensers or both.

These can be changed for each of the many narrow wave bands into which popular short wave transmission is now divided. These are, the



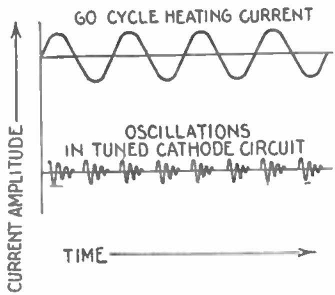


FIG. 7,347.—Method used in Super-Wasp *a.c.* short wave receiver to kill the little oscillating circuits in the tube circuit by addition of a by-pass condenser C. The capacity of the oscillating system is the internal capacity of the cathode-heater combination. The inductance is that of the leads combined with that of the center-tapped resistance. This resistance unit actually has enough inductance to be troublesome at the very short waves. The cure consists in merely adding a .006 *m.f.* condenser across one side of this center tapped inductance, so as to kill the resonant combination.

FIG. 7,348.—Diagram showing how 60 cycle *a.c.* creates oscillation in the tuned cathode circuit of Super-Wasp *a.c.* short wave receiver.

160 meter, 80 meter, 40 meter and 20 meter amateur bands and the broadcast short wave bands at 50, 25 and 20 meters. Most short wave sets are now built with a non-removable variable tuning condenser and a number of removable plug in coils which are wound for tuning to the various wave bands.

Simplest Short Wave Receiver.—In building any short wave receiver it is important to consider problems which, in the ordinary broadcast band from 550 to 1,500 kilo cycles were

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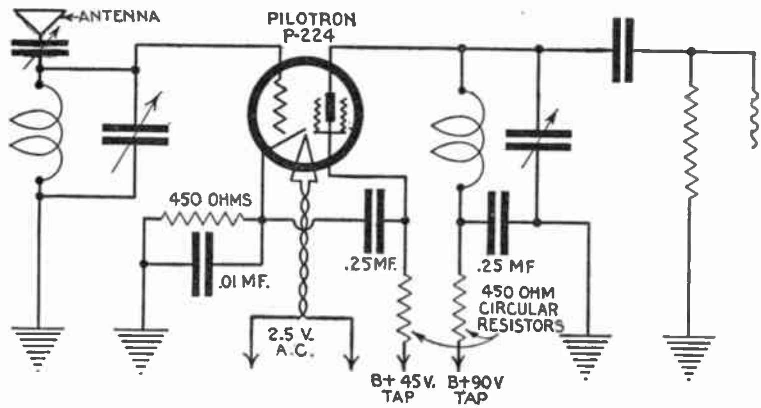

FIG. 7,349.—Super-Wasp diagram showing method of choking the screen grid leads. The chokes are cylindrically wound resistors, and perform the function of choking the plate and screen grid leads. They are indicated in the diagram as 450 ohm resistors.

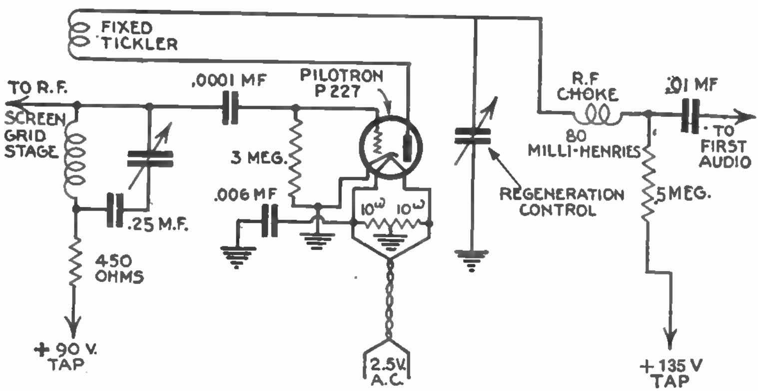

FIG. 7,350.—Detail of *a.c.* Super-Wasp detector circuit showing method of subduing *squawking*. There appears to be a highly critical condition existing in the grid circuit at the starting point of oscillation. Just as the grid tends to change from the slight positive bias, which it normally has, to the negative value which the rectification gives it, it undergoes an oscillatory condition which causes a bad *squawk* when the plate voltage is fed through a transformer. However, when the plate voltage is supplied through a high resistance, such as the .5 megohm, as here shown, the effective plate voltage drops when this condition occurs and this decline stops the oscillation or *squawk*.

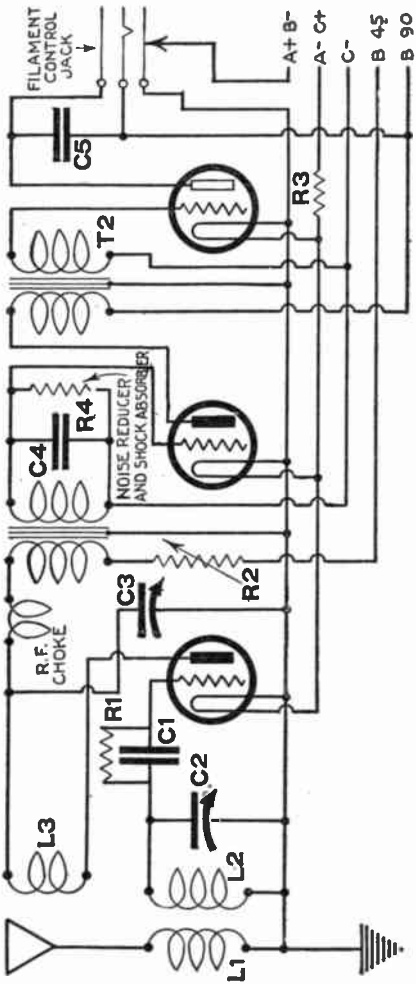

FIG. 7,351.—Typical hook-up of a good regenerative short wave receiver.

considered relatively unimportant; to see that the capacities of the coil windings themselves be carefully kept down at all times.

The minimum capacity of the condenser is important; so it is imperative under such conditions to use the appropriate type of variable condenser.

The grid and plate capacities of the tube also play an important part, and it is, therefore, essential that the grid and plate leads shall be as short as possible, and as far away from one another as they can be placed. Moreover, the radio frequency currents *must* be confined to those circuits in which they belong. Blocking condensers should be used profusely but intelligently. It must be borne in mind that these by-pass or coupling condensers should have as little leakage as possible, in order to conserve the weak radio frequency current.

NOTE.—The short wave radio set builder can obtain the necessary parts for building the short wave Super-Wasp set from the manufacturer, The Pilot Radio and Tube Corp., Brooklyn, N. Y.

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The short wave receiver must be shielded against hand capacities and between the relative stages.

For shielding against hand capacities, a plain aluminum panel, for mounting the condensers and control dials, is sufficient. It is not imperative that the balance of the circuit be placed in an aluminum container although it is quite advantageous for mechanical reasons.

In the case of copper shields, the corners must be evenly soldered; aluminum should have large overlaps. Short wave interference unless these precautions are carefully observed, will get through. The coils must be kept as far away as possible from the shields themselves. The shields should not be of thin material, but of a thickness sufficient to shield one

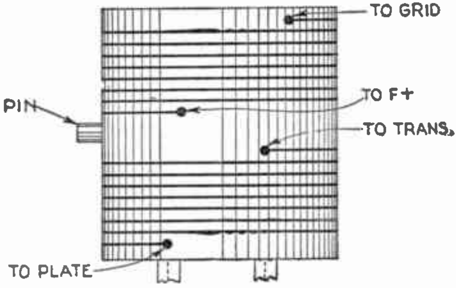

FIG. 7,352.—How plug in coils are made.

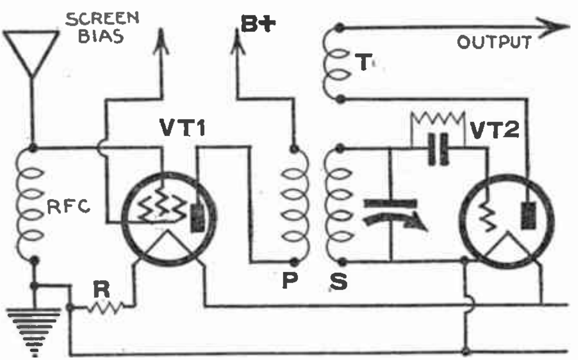

FIG. 7,353.—Connection of radio frequency stage with screen grid tube, ahead of regenerative detector.

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stage effectively from the other. With copper, a thickness of 30 mils (.03 in.) seems to be quite reasonable. In the case of aluminum, a thicker or substantial piece of metal should be used, with an overlap of half an inch wherever possible.

A very simple diagram showing a single control super-heterodyne, is fig. 7,353.

The output circuit is from the filament of VT2, and the output. The secondary of the three circuit arrangement is made to oscillate at a frequency differing from that of the incoming wave by a value corresponding to the frequency of the intermediate stage. If the intermediate stage be a broadcast receiver tuned to 1,000 kilocycles, the difference between the oscillator frequency and that of the incoming wave should be 1,000 kilocycles.

Short Wave Receiver Reference Table

C1—.0001 mf. mica fixed condenser.

C2—.000015 mf. midget variable condenser, 7 plate.

C3—.000015 mf. midget variable condenser, 7 plate.

C4—.0005 mf. mica fixed condenser.

C5—.0005 mf. mica fixed condenser.

R1—10 megohm grid leak (noiseless).

R2—0-50,000 ohm Bradleyohm.

R3—Rheostat or amperite.

R4—1/10 megohm grid leak.

L1—Two turns bell wire around coil socket base.

L2—Grid coil on plug in tube base.

L3—Tickler on plug in tube base.

	L2		L3	
Wave Band	Turns	Wire Gauge	Turns	Wire Gauge
80	37	28	25	30
40	16	22	20	30
20	7	22	10	30
10	3	20	5	30
5	1	20	3	30

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How to Tune Short Wave Receivers.—The short wave beginner is usually surprised to begin picking up broadcast stations which he cannot find in the short wave list. What he hears is the *harmonics* of stations broadcasting on the medium waves between 200 and 550 meters. These are often a nuisance, for they may be poorly modulated, and they are easily mistaken for a foreign station, and sometimes they interfere with wanted foreign stations. The last named trouble is one which will have to be dealt with as short wave broadcasting becomes more general; but at the present time the experimenter will find these harmonics useful for the calibration of the dials.

Each harmonic has a definite wave, just as much so as the broadcast station's fundamental carrier wave. A harmonic must have exactly twice, three times, five times, nine times, etc., the frequency of the fundamental (corresponding respectively to ½, ⅓, ⅕, 1/9, and so on) wave length. Many of these harmonics can be heard with any short wave receiver. When one of them is picked up, and the station identified, it is only a matter of division to determine the exact wave to which the receiver is tuned. By checking up a number of these harmonics, and the few known short wave broadcasters, it is a very simple matter to draw up a calibration curve for each coil of any short wave set.

Take a sheet of paper for each coil, and number each from top to bottom with figures corresponding to those on the tuning dial or dials, usually 0 to 100. (These numbers do not correspond to the settings of the regeneration dial.)

Start with any one, or pair, of the coils covering a certain wave band; and tune in the first station picked up. If it be a regular short wave station, mark down its known wave exactly opposite the figure on the chart which corresponds to the dial setting. If the station be one which is not known to have a short wave transmitter, then a harmonic has been heard.

Look up the authorized wave length of the station and divide it by the number which will bring the result nearest to the wave length to which the coil should be tuned. For example, if the coil be rated by the manufacturer as covering from 30 to 55 meters, and the condenser setting is low, then it is probable that the wave length must be between 30 and 40 meters.

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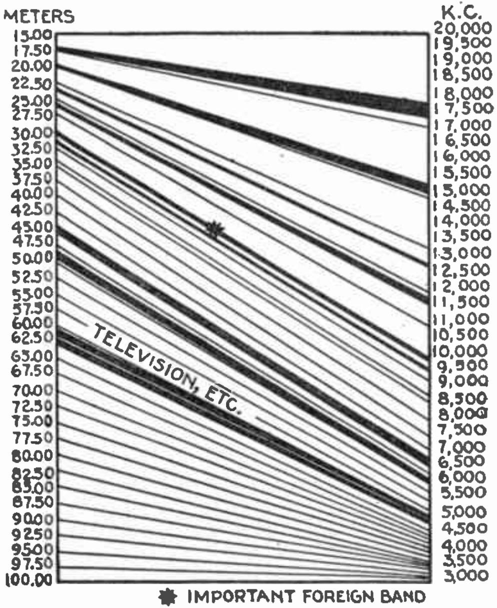

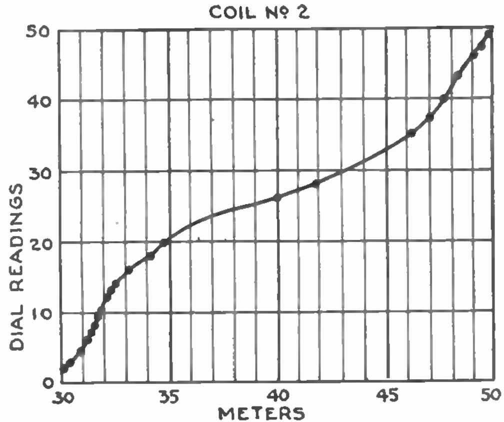

Fig. 7,354.—Short wave broadcast channels. The bold black bands show the channels. Note how they crowd at the lower end of the meter scale.

Fig. 7,355.—Calibration chart for coil plotted from the log table on page 4,544.

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COIL No. TWO

Range 30 to 55 Meters (Approximately)

Dial Reading	Wave-length	Stations Heard
0		
1		
2	30.01	WRVA (9th Harmonic—fundamental 270.1 meters)
3	30.50	NRH, Heredia, Costa Rica, 10-11 p. m. daily
4	30.85	WBT (9th Harmonic—fundamental 277.6 meters)
—5		
6	31.04	KQV (7th Harmonic) 7LO, Nairobi 11-2 p. m. daily
7	31.26	W3XAU — PCJ — VPD — KIXR
8	31.38	........Konigswusterhausen (Berlin) Germany
9	31.48	W2XAF — OXY, Lyngby, Denmark, 2-3 p. m.
—10	31.80	XDA, Mexico City, Mexico
11		
12	32.10	CGA, Drummondville, Canada
13	32.20	WSAI (7th Harmonic—fundamental 225.4 meters)
14	32.40	GBK, Rugby, England (transatlantic phone)
—15		
16	33.26	GBS, Rugby, England (transatlantic phone)
17		
18	34.23	KSTP (6th Harmonic—fundamental 205.4 meters)
19		
—20	34.68	W2XAC, HKCJ
21		
22		
23		
24		
—25		
26	40.00	WWRL (5th Harmonic—fundamental 199.9 meters)
27		
28	41.80	KSTP (5th Harmonic—fundamental 205.4 meters)
29		
—30	AMATEUR PHONE BAND	
31		
32		VRY, Georgetown, British Guiana (Wed. and Sun., 7:15-9 p. m.)
33		Code (Mobile services)
34		
—35	46.12	WHAP (5th Harmonic—fundamental 230.6 meters)
36		
37	46.92	WOR (9th Harmonic—fundamental 422.3 meters)
38		
39		
—40	47.59	WLBL (7th Harmonic—fundamental 333.1 meters)
41		
42		
43	48.35	HKT, Bogota, Columbia, 10-11:30 p. m.
44		
—45		
46	49.02	W2XE, New York
47	49.40	W8XAL, Cincinnati
48		
49	49.80	W9XF
—50	49.98	HRB, Honduras, Mon., Wed., Fri., 9-12 p. m.

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If the station heard be working on a fundamental of 274.9 meters (1,080 kilocycles) it will be seen that dividing this by nine gives 30.54 meters (9.720 kilocycles) and this is the wave length of the ninth harmonic, which is being heard.

The odd harmonics are usually of much greater strength than the even harmonics.

Mark the wave length found, 30.54, on the proper sheet opposite the condenser dial reading. It is necessary to carry the wave length out to two places; for a tenth of a meter covers considerable room on a short wave dial.

Go up slightly on the dial and find a harmonic of a broadcast station which is known to be working on 215.7 meters (1,390 kilocycles). Since the seventh harmonic of this station is 30.81 meters (7,730 kilocycles) set down this figure opposite the second dial reading. In this manner, the dial is calibrated from top to bottom on the chart; calibrate the other coils in a similar way until it is determined where any given wave may be tuned in on the receiver. Stations may thus be found right where they should be expected.

Tuning Problems.—The great sharpness of tuning on short waves should be considered; compare it with the broadcast band. In the United States and Canada exactly 96 broadcast channels are in use, one every ten kilocycles from 550 to 1,500 kilocycles inclusive. This gives one channel to a division on the dial, and each station therefore corresponds to a different reading.

It is not necessary to discuss the relation of kilocycles to meters here (see fig. 7,354) except to say that the frequency increases more and more rapidly as the wave length becomes shorter. Between 15 and 80 meters (the effective short wave broadcast band) there is more than 1,600 kilocycles separation, or sixteen times the width of the upper broadcast band. The average short wave set covers this with three or perhaps four coils and as many revolutions of the tuning dial, from 0 to 100.

If stations were operated on channels 10 kilocycles wide, as in ordinary broadcasting, 300 to 400 of them would be covered in one turn of the dial. On the smaller coils, the number is even greater. The station, therefore, covers only a small part of the space between two numbers on the dial.

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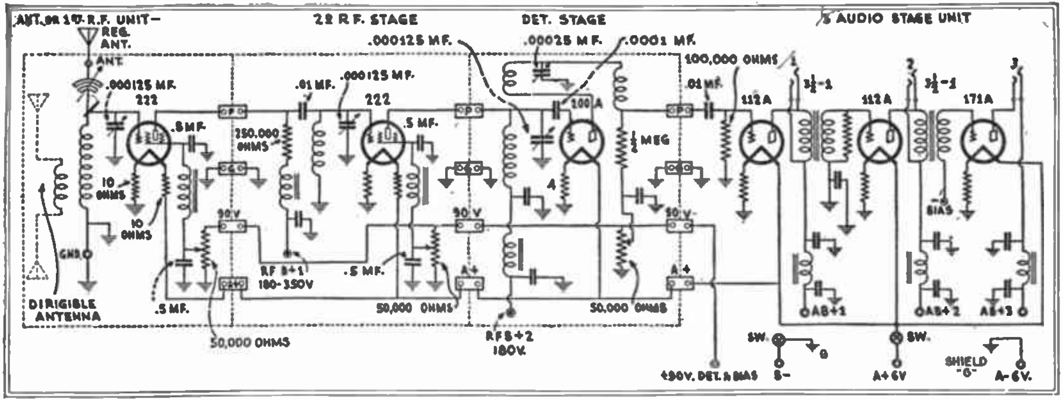

FIG. 7,356.—Wiring diagram of Leutz short wave receiver. It is of the unit construction giving a flexible arrangement and providing double shielding. For example, if desired, the detector unit and audio unit would be used together as a complete receiver. To that combination, one tuned radio stage can be added and later still another tuned radio stage added again. For average purposes the following set up is suggested, one tuned radio stage, detector stage and audio unit. For extreme distance work and where maximum volume is desired, the full combination is required consisting of first radio stage, second radio stage, detector stage and audio unit. Due to obvious technical limitations, the power output stage of the audio unit is not push pull. Two power tubes in push pull combination require a certain high signal input voltage in order to secure full output. The required signal voltage is not always available on short wave signals in which case the complete signal would be entirely lost. By having three cascade stages of audio amplification, sufficient volume is still available and the amplifier is sensitive even to the very weak signals. The detector unit is arranged to use any of the standard superdetector tubes such as the 200A, 240, etc. The tuned inductance has two windings, one for the detector grid circuit and the other for the plate regenerative amplification circuit, the coupling between the two being fixed. For the first *r.f.* one stage unit tuned inductance is required and it has two windings. The first winding tunes the grid circuit of the tube which is capacitively coupled to the antenna circuit. The second winding may or may not be used as desired. It is provided to enable using a dirigible type aerial and suitable binding posts are provided to connect such an antenna. For maximum sensitivity a second tuned radio stage should be added. In the Leutz short wave set, this stage is added by connecting same between the antenna stage and detector stage. No internal connections need he disturbed. In all the tuned stages, vernier condenser adjustments are provided where required. Individual filament resistors are also available so that each tube can be regulated to its maximum operating point of efficiency.

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If the dials be operated in the manner usual in medium wave tuning, many *noises* will be passed over, which are really stations that would give good loud speaker strength if properly tuned in. The proper procedure, therefore, in operating a short wave set, is to calibrate the receiver in the method illustrated, and make notations where certain desired stations should fall on the dials. Note when these stations may be expected to operate; and tune for them at the proper times, on the proper dial readings.

Pick up the signals by the *beat note* method; that is, set the detector tube oscillating, and pick up the carrier wave, or *squeal*. After the carrier is found, keep the wave length or tuning dial set in the exact center of the squeal; and turn the regeneration dial back past the point of oscillation. Then, very slowly, move it up again until the best reception is obtained.

The third point is how to determine what stations to tune for.

At the present time, all short wave broadcast stations are of an experimental nature, and their wave lengths, as well as schedules, are subject to sudden changes without notice. Since distance means little or nothing in short wave reception, the carrier wave in its longer path is more subject to atmospheric conditions than the nearby medium wave broadcasts.

Stations which can be heard with great volume at one season of the year are often unheard at another, regardless of the power which they use. The short waves, also, are peculiarly affected by sunlight; some being reduced in strength, and others greatly increased in volume on the arrival of darkness. Since reception is world wide, means of communication are slow, and no universal language is yet in use, no accurate list of stations can be compiled.

It may be said that reception of short wave broadcasts directly from overseas is not so difficult as may be imagined; it is a commonplace occurrence.

It is possible to pick up programs in Siamese, Russian, German, Spanish, French and many other languages, in addition to English.

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TEST QUESTIONS

1. *What is a short wave?*
2. *What is the advantage of snort waves?*
3. *Explain the relation between wave length and frequency.*
4. *Give formula for wave length.*
5. *How does the frequency vary for the different wave lengths?*
6. *What are the requirements of sets for highest frequency reception?*
7. *What makes tuning difficult when the hand is brought near the tuning dial?*
8. *Of what does a short wave receiver usually consist?*
9. *Upon what does the success of the receiver mostly depend?*
10. *Why is tuning difficult on some short wave receivers?*
11. *What is a wave band?*
12. *Explain why "plug in" coils are used?*
13. *How are most short wave sets usually built?*
14. *Give directions for building a simple short wave receiver.*
15. *Draw a diagram of a single control super-heterodyne set.*

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CHAPTER 179

Aerials

By definition an aerial is *a wire system suspended in the air and insulated at the ends for receiving electro-magnetic waves.*

Strictly speaking an *aerial* is the wire system at the receiving end as distinguished from an *antenna* or wire system at the transmitting end.

Aerials may be classified:

1. According to the number of wires as

   a. Single wire;

   b. Multi-wire.

2. According to location, as

   a. Outside;

   b. Inside;

   c. Underground.

3. According to shape, as

   a. Inverted L;

   b. Tee (T);

   c. Cage;

   d. Fan;

   e. Umbrella;

   f. Loop {solenoid, spiral, pancake,

etc.

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The simplest type of aerial consists of a single wire of suitable length with its ends connected to elevated insulators as in fig. 7,357.

At the end nearest the radio set a *lead in* connects the aerial to the set. This arrangement is known as an inverted L aerial; when connected at the center it is called a T aerial, the distinction being shown in figs. 7,358 and 7,359. Various other types of outside aerials are shown in figs. 7,360 to 7,369.

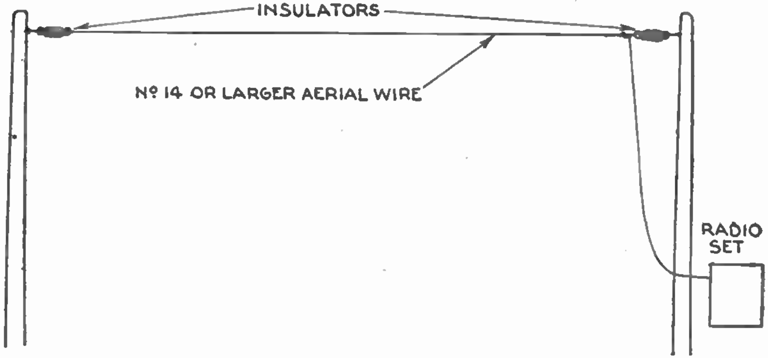
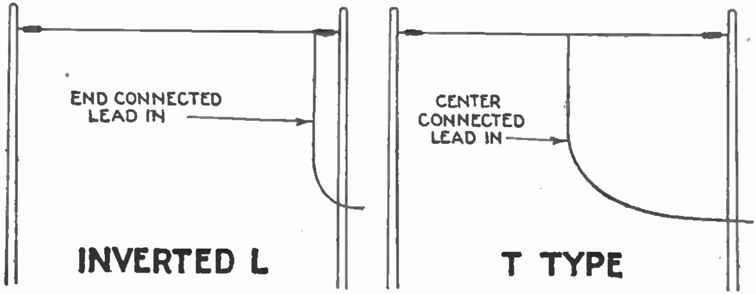


FIG. 7,357.—Single wire outside inverted L aerial; end connected lead in.



FIGS. 7,358 and 7,359.—Inverted L and T aerials. The lead in is usually connected at the end, but where an extra long aerial is desired it is connected at the center.

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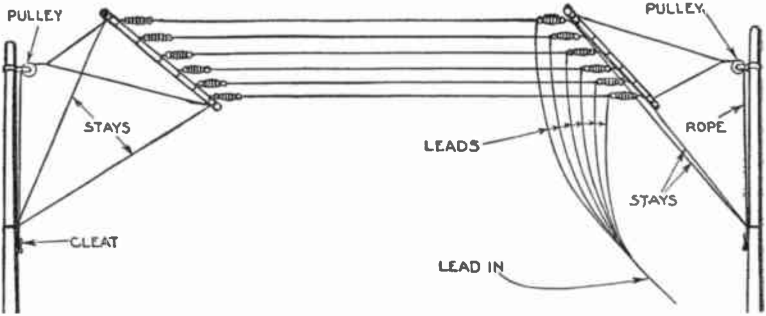

FIG. 7,360.—Multi-wire inverted L (flat top) outside aerial. Where the distance between supports is limited, the necessary length of aerial may be obtained by running two or more lengths of wire parallel as shown.

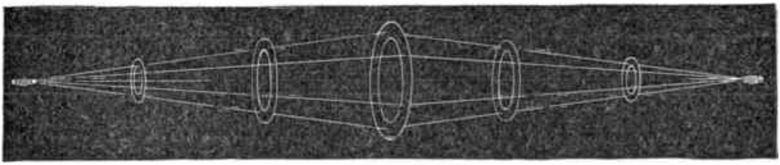

FIG. 7,361.—Cage antenna. A type frequently employed at transmitting stations.

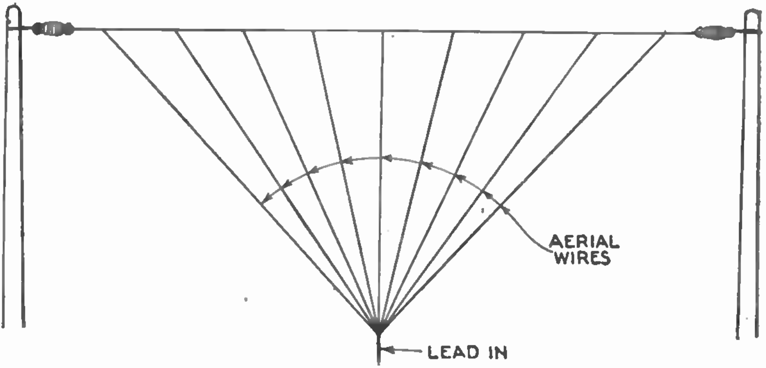

FIG. 7,362.—Fan aerial.

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The loop aerial is used without a ground connection being connected to the radio set so as to form a closed circuit.

The loop acts as an inductance coil whereas the other aerials act as one plate of a condenser with the ground or *counterpoise* as the other.

Electro-magnetic waves on reaching the aerial set up an alternating voltage between the wires forming the upper plate of the condenser and the ground or lower plate of the condenser.

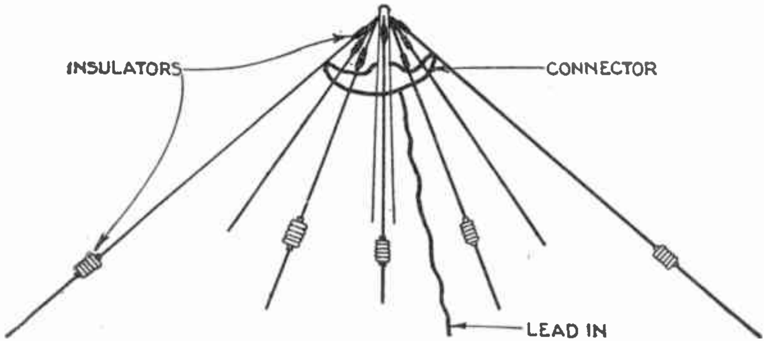
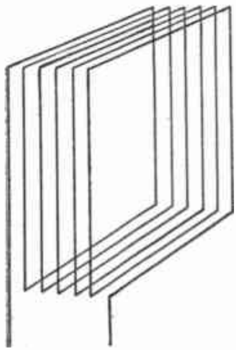


FIG. 7,363.—Umbrella aerial. The radial wires connect at the top with a vertical lead in.



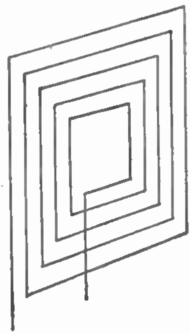


FIG. 7,364.—Inside loop aerial of the solenoid type.
FIG. 7,365.—Inside loop aerial of the pancake type.

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This action takes place through electrostatic induction. In the *loop aerial*, electro-magnetic induction sets up an induced voltage thus causing alternating current to flow to the detector.

Counterpoise.—In places where it is difficult to obtain a good ground because of dry soil a *counterpoise* is used.

This consists of a second aerial suspended on supports about one foot above the ground and insulated from the latter. The counterpoise should run parallel with and preferably underneath the main aerial, though if necessary it may be offset to one side. Fig. 7,367 shows the essentials.

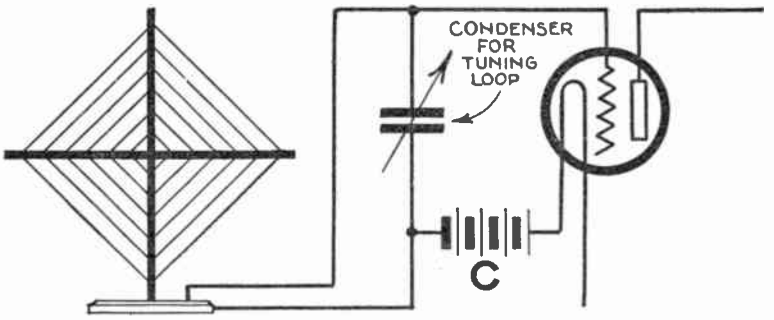

FIG. 7,366—Method of connecting a loop aerial. Since loop aerials are not very efficient, they should only be used with sensitive sets such as super-heterodyne.

Length of Aerial.—For best results make the aerial *as short as will permit reception from the desired stations*. A 30 foot wire is considered a short aerial.

In congested districts a short aerial should be used. The selectivity of the set depends largely on the length of aerial, some sets having two or more aerials of different lengths.

Location of Aerial.—The best location of the aerial *depends on local conditions*, each installation presenting its own problems.

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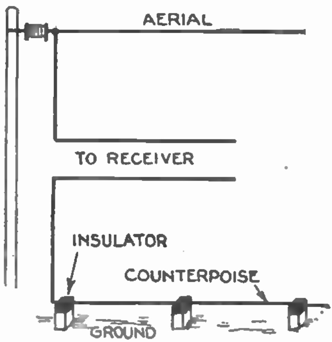
In general when satisfactory reception is not obtained, the trouble may be rectified *by changing the direction of the aerial;* if possible place the aerial at right angles to its former position.

Installation.—Erect the aerial *as far from other wires as possible.*

The insulation should be of the best quality. The wire should be sufficiently taut to prevent undue vibration or swinging. Do not place an aerial under or above power wires; select a direction as nearly as possible at right angles to other wires.

There should be a good soldered connection of the lead in to the aerial.



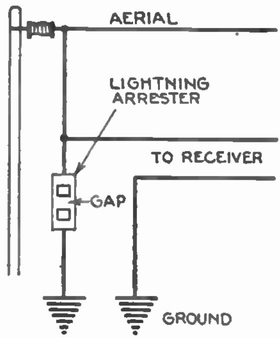


FIG. 7,367.—Counterpoise and connection. The counterpoise forms one plate of a condenser of which the main aerial is the other plate.

FIG. 7,368.—Method of connecting lightning arrester to aerial circuit.

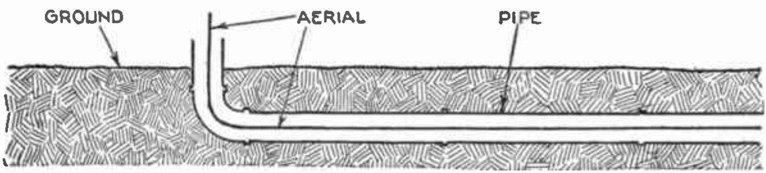


FIG. 7,369.—Rogers underground aerial. The aerial wire is placed inside a pipe. This type aerial is not affected much by conditions of the atmosphere.

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Lightning Arrester.—The preferred location of the lightning arrester is *outside the building at the point where the lead in wire enters the building.*

One terminal of the arrester is connected to the aerial and the other to ground. The lightning arrester interposes a very small air gap between the aerial and the ground and across which any sudden high voltage impressed on the aerial as happens during a thunder storm will readily discharge across the gap without injuring the radio apparatus.

TEST QUESTIONS

1. *What is an aerial?*
2. *What is the difference between an aerial and an antenna?*
3. *Give classification of aerials.*
4. *Of what does the simplest type aerial consist?*
5. *What is the construction of a loop aerial?*
6. *What is the action of electro-magnetic waves on reaching the aerial?*
7. *What causes alternating current to flow in an aerial to the detector?*
8. *What is a counterpoise?*
9. *How should a counterpoise be run with respect to aerials?*
10. *What should be the length of an aerial for best results?*
11. *How long should an aerial be in congested districts?*
12. *Upon what does the selectivity of a set largely depend?*
13. *How is the best location of an aerial determined?*
14. *In what direction should an aerial be run?*

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15. *How should an aerial be located with respect to other wires?*
16. *Why should an aerial be strung taut?*
17. *How should the lead in be connected to the aerial?*
18. *What is the preferred location for the lightning arrester?*
19. *How is the lightning arrester connected?*
20. *What does a lightning arrester interpose in tne circuit?*
21. *Where does the air gap circuit terminate?*
22. *What happens in a thunderstorm?*
23. *Explain the operation of the lightning arrester.*

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CHAPTER 180

Loud Speakers

By definition a loud speaker is *a device designed to convert the amplified audio frequency currents into sound waves.* In other words a loud speaker *changes varying electric currents into sound waves.*

In order to do this the construction of the loud speaker must be such 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 sets into vibration a large volume of air which produces the sound.

The efficiency of a loud speaker depends on how near these sound waves approach a true reproduction of the sound waves broadcast at the transmitting station.

It is hardly necessary to state that the efficiency of most loud speakers is very low and even that of the best is far from perfect.

Classification of Speakers.—That part of a loud speaker which changes the varying currents of the audio frequency amplifier into mechanical vibrations, is called the *driving unit* or *motor*, and with respect to the principle involved in the operation of the driving unit, speakers may be classed as:

1. Magnetic;
2. Balanced armature;
3. "Dynamic" or moving coil;
4. Induction;

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5. Metal strip;
6. Electro-static or condenser;
7. Piezo-electric.

Speakers which use a permanent magnet are called *magnetic* speakers; those using an electro-magnet are generally known as *dynamic* speakers.

Magnetic Speakers.—In this type *a bipolar permanent magnet is used.* On each pole of the magnet is mounted a coil of

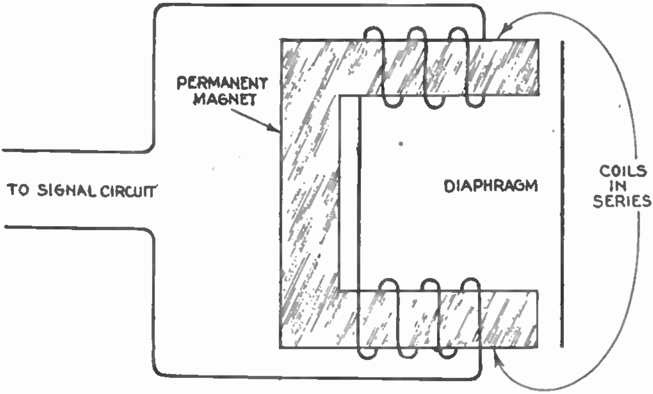

FIG. 7,370.—Magnetic type speaker consisting of a combined permanent and electro-magnet and diaphragm. The latter is of magnetic metal and the magnetic lines of force pass through it from pole to pole. If the diaphragm become saturated *it will not respond perfectly to variations of the magnetic strength and distortion will result.*

wire having a large number of turns, the two coils being connected in series, as shown in fig. 7,370.

The speaker is connected as indicated and in operation the varying currents coming from the plate circuit of the last tube varies the resultant magnetization (of coils and permanent magnets) accordingly causing the diaphragm to vibrate and produce sound waves.

Balanced Armature Speaker.—This speaker does not chatter easily on loud signals and responds well to weak signals. The

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essentials of construction are shown in fig. 7,371. It has an armature pivoted at its center between the poles of a permanent magnet and provided with a coil through which the signal current flows as shown, 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 of the armature are communicated to the diaphragm by means of the link connection.

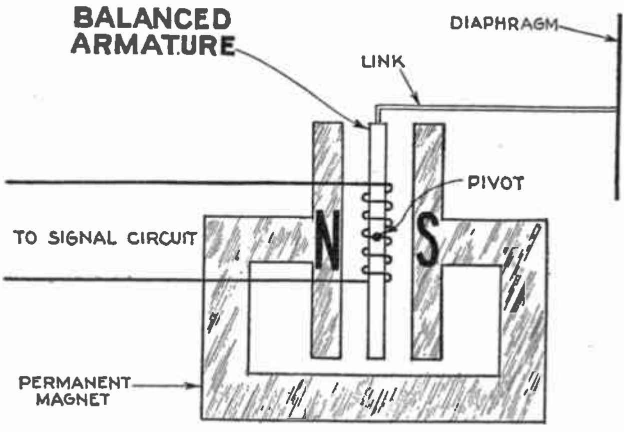

FIG. 7,371.—Balanced armature type speaker. *In construction* the balanced pivoted armature is a soft iron bar forming a core of a coil of several thousand turns of fine wire supplied with audio frequency currency. *In operation* when a signal current flows through the coil, a magnetic field is produced, 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.

Dynamic Speakers.—The *moving coil principle is here employed*. In this arrangement the signal current flows through the moving coil which is placed around the middle pole of a three pole magnet and the reaction between the two causes

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the moving coil to vibrate corresponding to variations of the signal current. The diaphragm being mechanically connected to the moving coil vibrates similarly. The essential elements are shown in fig. 7,372.

Induction Speakers.—The operation of this type speaker depends upon *the production of eddy currents in the diaphragm by a varying magnetic field.*

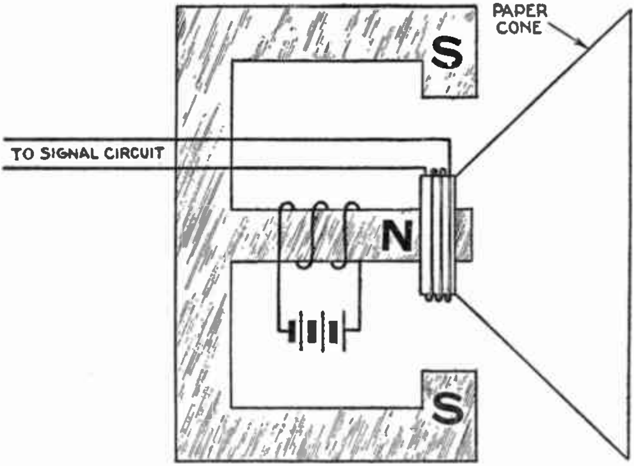

FIG. 7,372.—Dynamic or moving coil speaker. *In construction* the coil is very small and light. It vibrates betweer the armature magnetic field between two concentric magnetic poles. The coil is usually attached to a paper cone, or in the case of a horn to a non-magnetic diaphragm. The moving coil has about 100 turns of about No. 34 wire on a thin insulated shell.

As shown in fig. 7,373, the diaphragm is placed between two sets of concentric coils Direct current is applied to the two sets of coils in opposite directions producing a radial field. The signal current is also passed through the coils which causes the steady field due to the *d.c.* 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. Loud speakers of this type are extra powerful and therefore suitable for halls.

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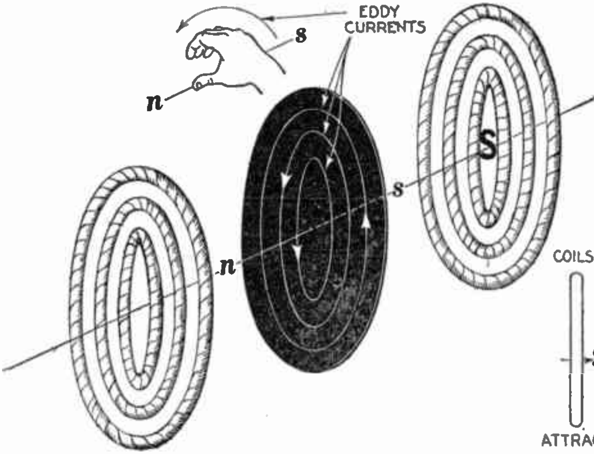
Metal Strip Speaker.—This speaker is a type of the magnetic class in which *a metal strip is suspended between the poles of a permanent or electro-magnet and the signal current passed through the strip*, as shown in fig. 7,375.

The reaction between the steady field of the magnet and varying field of the strip causes the latter to vibrate. The metal strip being the diaphragm the sound waves are produced direct without any drive gear.



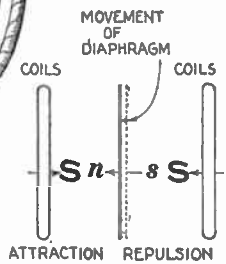


FIG. 7,373.—Induction speaker. In this speaker the diaphragm is made of a non-magnetic metal-aluminum. An auxiliary source of current is required to supply the steady magnetic field.

FIG. 7,374.—Side view of induction speaker. Since the *d.c.* supplied to the coils is passed through the two sets of coils in opposite directions like poles SS, will he produced on their sides facing the diaphragm and unlike poles *ns* on the faces of the diaphragm. These polarities are easily determined by the right hand rule as shown in fig. 7,373. At the instant shown the diaphragm is moved to the left by attraction due to unlike poles S,*n*, and repulsion due to like poles *s*S.

Electrostatic or Condenser Speakers.—Speakers of this type consist essentially of three elements:

1. Plate; 2. Dielectric; 3. Diaphragm.

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The dielectric is placed between the plate and diaphragm and the assembly forms a condenser, as shown in fig. 7,376, hence the name. Its adaptation as a speaker is shown in fig, 7,377.

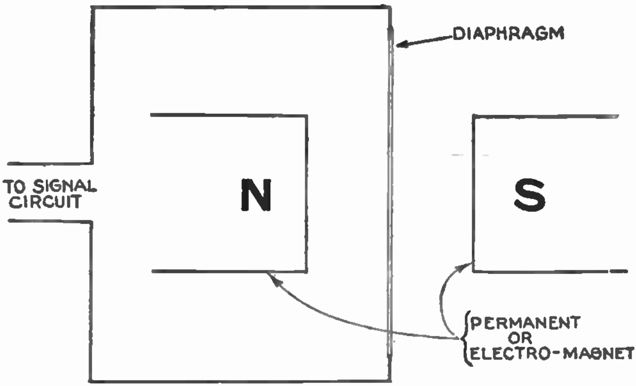

FIG. 7,375.—Metal strip speaker. A megaphone is used with this type speaker.

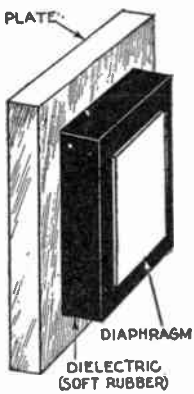

FIG. 7,376.—Elements of an electrostatic speaker. It is simply a form of condenser, hence the name as it is sometimes called a *condenser speaker*.

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In the operation of a condenser any difference in voltage on the two metal elements (plate and diaphragm in fig. 7,374) produces attraction between them, thus compressing the dielectric which in this case is rubber. To keep the speaker normally in this condition, the plate and diaphragm are placed in a battery circuit. The signal current is superimposed on the battery current.

In operation the signal current varies the voltage in the circuit which in turn varies the attraction between the plate and condenser; the rubber which is in compression acts as a restoring force to displace the diaphragm

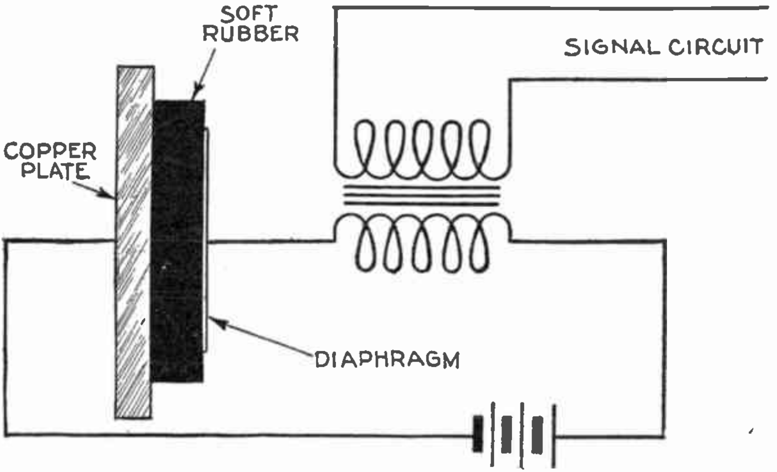

FIG. 7,377.—Electrostatic or condenser speaker showing circuit connections. *In construction,* the copper plate is made rigid. The diaphragm consists of a thin layer of metal sprayed on the rubber dielectric.

outward when the signal current is in such a direction as to reduce the attraction between the plate and diaphragm.

Piezo-electric Speakers.—This type of speaker depends for its action on *the property of a crystal of expanding and contracting in accordance with the electric strains to which it is subjected.* This principle as applied to a speaker is shown in the diagram fig. 7,378.

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In operation the variations in the applied signal voltage will cause the crystal to expand and contract and these mechanical vibrations may by suitable means be communicated to a diaphragm.

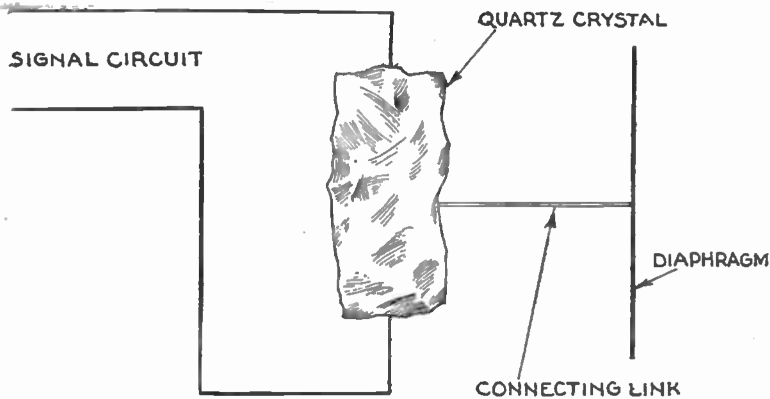

FIG. 7,378.—Piezo-electric speaker operating on the property of a crystal expanding and contracting with varying electric strains.

TEST QUESTIONS

1. *What is a loud speaker?*
2. *How does a loud speaker work?*
3. *Give a classification of loud speakers.*
4. *How does a magnetic speaker work?*
5. *What is the construction of a balanced armature speaker?*
6. *Explain the operation of dynamic speakers.*
7. *What is the basic principle on which induction speakers operate?*
8. *Describe the metal strip speaker.*
9. *How does an electrostatic or condenser speaker operate?*
10. *Upon what does a piezo-electric speaker depend for its operation?*

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CHAPTER 181

Radio Instruments

For radio use, a volt meter should draw as small a current as is possible if it is to be left in circuit to show the voltage across the filament of a vacuum tube whenever it is in operation.

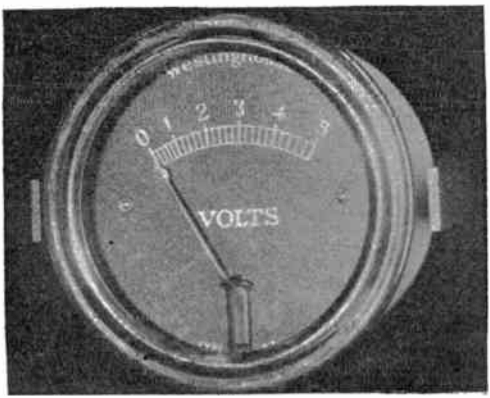

FIG. 7,379.—Westinghouse two inch diameter, 0-5 volt meter.

Unless the volt meter draw a small current, it cannot be placed across the vacuum tube filaments for the moment of adjustment of the rheostat, and then be removed from the circuit, without causing the filaments to have excessive voltage when the volt meter switch is opened.

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Inefficient ammeters are undesirable for filament adjustment, since they have a relatively high voltage drop and the A battery must be replaced, or recharged, much sooner.

The most efficient polarized vane ammeters have a nearly complete circuit of non-residual iron in the form of a yoke with less residual magnetism than is found with instruments using merely a stubby core of less expensive iron. The result is a highly efficient instrument consuming only one tenth or even one fiftieth the energy required to operate other moving vane instruments.

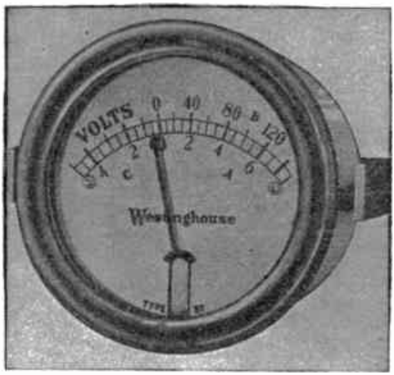

Fig. 7,380.—Westinghouse triple scale volt meter, 5-0-7.5 and 0-150 volts.

A vacuum tube set taking from three to five volts for filaments can be served better by a combination filament volt meter and plate battery tester than by a filament ammeter.

This combination instrument is more expensive than the ammeter, but it is worth more. Tungsten and tungsten alloy filaments can be adjusted better with a volt meter than with an ammeter because of the great change of resistance of that material and the corresponding slow change of current with a given change of applied voltage.

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Volt Meter Combinations.—Several ranges of combination volt meters have been developed, which should cover the requirements of all radio sets.

They will indicate filament voltage and B battery voltage, and in some cases A battery and C battery voltage also. These have 100° scales. A triple scale volt meter is shown in fig. 7,380.

Switching Schemes.—Some switching device should be used to connect the volt meter across the different batteries one at

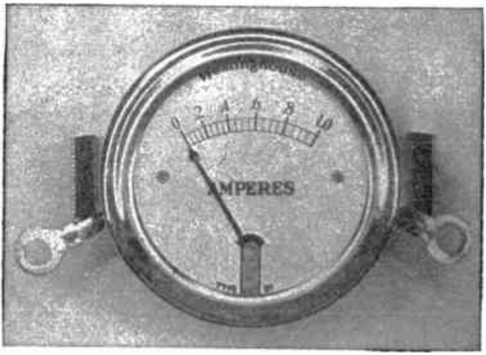

FIG. 7,381.—**Westinghouse low loss ammeter, 0-1.0 amperes.**

a time. There are a number of inexpensive dial switches on the market which are suitable for this purpose.

A switch should be chosen with sufficient movement of the blade so that adjacent active contacts will not be short circuited. If contact buttons be close together, then only every other contact should be used. Thus any five position switch could be used to show the voltage of three different circuits, such as filament volts, B battery volts, and C battery volts.

The high range requires an additional series resistance to reduce the higher voltage so that the instrument current is the same and will give the same deflection on 150 volts as on 7.5 volts. This resistance is

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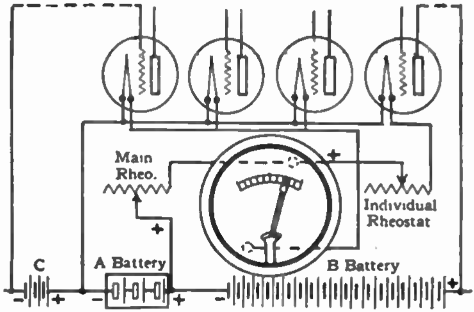

FIG. 7,382.—Ammeter connections for a radio set with four dry cell tubes. Having the individually adjusted filament in series with the main rheostat, but not in the ammeter circuit, prevents it ever having more than normal current.

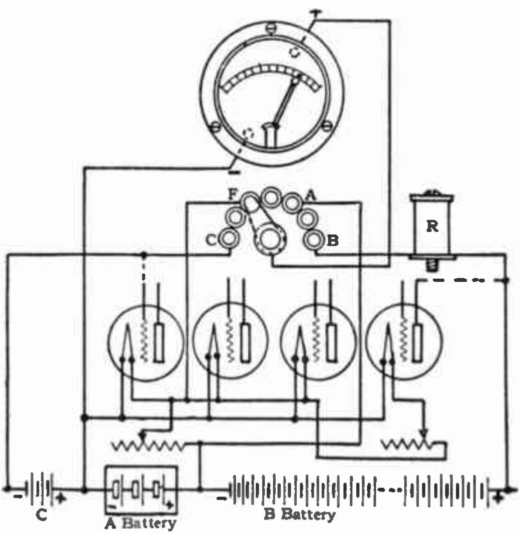

FIG. 7,383.—Dial switch control for multi-range volt meter; C, C battery volts to left; F, filament volts, lower right; A, A battery volts, lower right; B, B battery volts, upper right.

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supplied on a spool external to the volt meter proper so that it may be inserted in the circuit between the high voltage and the contact button on the switch for that voltage. With a seven contact switch, four values may be read from this one volt meter, including A battery volts.

In all cases the minus (common) of the volt meter should be connected to the minus bus bar of the filaments, as shown in fig. 7,383, then•F, A, and B, will be plus, causing deflection of the volt meter pointer to the right, and C, will be minus, causing deflection to the left of zero. The switch should never be left on B, or C, except while taking readings.

Several switching schemes have been worked out for the control of the volt meter for uses such as with radio sets.

Fig. 7,384, shows how a standard radio jack may be used with a metal plug and a double range volt meter to control the *on* and *off* of the set

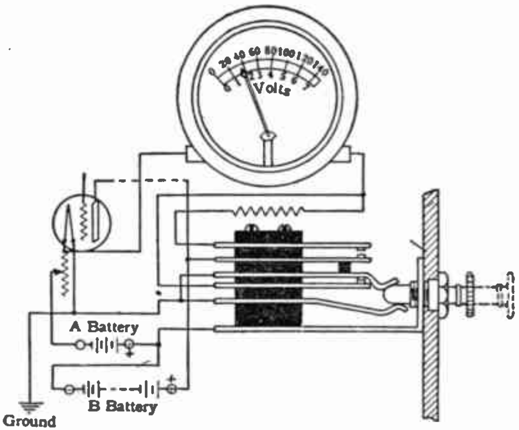

FIG. 7,384.—Volt meter and tube control with a standard jack. 1, plug removed, rheostat off = set off, A battery ready to charge; 2, plug in normal, rheostat on = set operating, volt meter showing filament voltage; 3, plug pressed entirely in, rheostat on or off = volt meter indicates B battery voltage; 4, plug released, returns to normal. The switch is a standard radio jack plus a metal plug whose shank is ¼ in. in diameter, approximately 1 in. long and has a hemispherical end. The main frame of the jack is connected to +A and −B. The two prongs which usually receive the plug are connected together and to the plus bar of all filaments, +F. The common of the volt meter is connected to the minus bus bar of the main filaments. The ground G, may be connected either to +A, or to +F. The contact between the main prongs is connected to the plus terminal of the low range of the volt meter. The two upper contacts are connected in the high voltage, B, circuit with the multiplier resistance somewhere between +B. and the plus of the low range of the volt meter.

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as well as the indication of filament volts and B battery volts. This arrangement is ideal for radio sets having dry cells for A battery. The common of the volt meter is connected to the minus bus bar of the main filaments.

If one vacuum tube be used with an individual filament rheostat, the extra filament and rheostat should be in series with each other across the positive and negative bus bars of the main filaments. Then the voltage of the individually controlled filament would never be greater than that applied to the main lot, and this is shown by the volt meter.

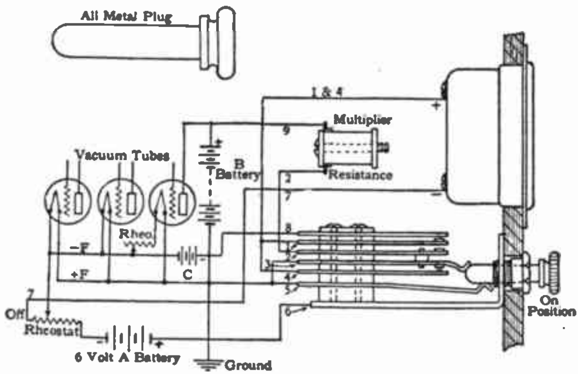

FIG. 7,385 and 7,386.—Volt meter control switch and lock with special jack. 1, plug removed, rheostat off =set locked off, A battery ready to charge; 2, plug inserted, rheostat off =volt meter indicates storage battery voltage; 3, plug inserted, rheostat on =set in operation, volt meter indicates filament voltage, lower right; 4, plug pressed slightly, volt meter indicates B battery voltage, upper right; 5, plug pressed entirely in =volt meter indicates C battery voltage, lower left; 6, plug released, returns to normal; 7, plug removed, =set locked off.

In operation of the hook up shown in fig. 7,384 when the metal plug is inserted in the jack, the vacuum tube filaments immediately light up, if the rheostat is on, and the volt meter shows the voltage applied to the filaments. The filament rheostat is advanced as the dry cells age, so as to keep proper voltage on filaments. When the metal plug is pressed in so as to lift one prong and break the circuit between the volt meter and the plus of the filament, the pointer returns to the zero of the scale. As the pressure on the head of the plug is increased, the upper contacts close and the volt meter indicates B, battery voltage. When the operator's finger is withdrawn, the plug returns to its natural position with instrument indicating filament volts. The jack will not remain in the B battery

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position. Thus all danger of accidentally exhausting the B battery is avoided. When the plug is removed, the filament circuit is open and hence all flow of current stopped.

If the A, battery be of the storage cell type, the rheostat may be turned off when the plug is removed, so that both sides of the storage battery are disconnected from the set.

In this case −B should be connected to G and to + F, and not to + A. With such an arrangement, the storage battery may be charged with a rectifier, even though this rectifier does not have a transformer with an insulated secondary winding.

An ideal arrangement for multi-tube sets having storage A batteries is shown in figs. 7,385 and 7,386.

This scheme gives every combination of circuits and every combination of volt meter readings that can be desired. This switch is similar to that shown in fig. 7,384, with an additional top contact for C battery indication. The contact below this goes to the plus of the low range of the triple scale volt meter. The contact below this one goes through the multiplier resistance to +B. Also +F, −B, and G, are together. The plus of the C battery goes to −A, or to −F. In this case the minus common of the high resistance volt meter goes to the *off* end of the main or low resistance rheostat.

When the rheostat is off this is equivalent to −A, but when rheostat is on this is equivalent to −F, since the drop in the rheostat due to the small current of the volt meter is negligible, but the drop in the rheostat due to the filament current is not negligible. The functioning of this switch is much the same as for fig. 7,384, except that the C battery circuit is added. As the plug is pressed in it first disconnects the positive terminal of the volt meter from the filament circuit, then connects it through the multiplier resistance to the B, battery circuit. Then with further pressure, the plug forces the upper contacts together and the minus of the C, battery is connected to the normally plus terminal of the volt meter. This causes the volt meter pointer to deflect to the left of zero on the C, scale. Meanwhile the multiplier resistance current from +B, is shunted through the low resistance of the C battery, and thence to −B, without passing through the volt meter. Thus it is seen that the volt meter indicates C battery voltage without any appreciable error due to the current through the multiplier.

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The triple scale volt meters: 5-0-7.5 and 0-150; also 6.5-0-10 and 0-100 volts, are ideal for the switching arrangement just mentioned.

With this arrangement, every operation is logical. No harm can be done the volt meter or the batteries. The scale readings cannot be mistaken, for normal position of plug is always filament volts if set be operating; pressure with deflection to right is always B, volts; greater pressure and deflection to left is always C, volts; release always results in return to normal.

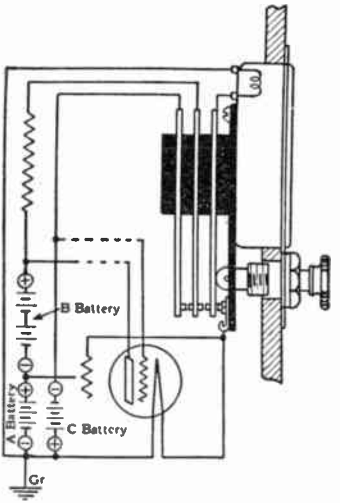

FIG. 7,387.—Push switch scheme, with special contactors mounted on back of volt meter, for indicating filament, B battery and C battery volts. The contacts do not act as a battery switch but merely control the volt meter. To give best results, the *common* of the volt meter is connected to the minus of the filaments. This is preferably the plus of the C battery and the minus of the A battery. The minus of the B battery may be connected to either the plus or minus of the A battery. The B reading would include that of the A battery in the first case, but not in the second. The contacts of the switch shown may be made from standard jack contacts or may be made much smaller to go on the back of a small volt meter. The contact in the insulating base passes to the positive side of the vacuum tube filaments and also through the filament rheostat to the plus of the A battery. The first spring contact, normally pressing on the stationary contact, is connected to the plus of the low range of the volt meter. The next spring contact, normally not touching contacts at either side, is connected through the volt meter multiplier resistor to the plus of the B battery. The last contact is connected directly to the minus of the C battery.

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Thus one switch unit and one volt meter serve for all desired functions and do away with all guess work as to condition of A, B, or C batteries, and filament voltage. Removal of the plug protects the filaments from being harmed by children turning on the rheostat to the extreme position.

These general ideas may be modified in many ways. The standard jack construction may be followed only in part. The shank of the plug may have a pin in it passing through a slot in the switch head, so that the plug may be twisted after insertion, so that it will not slip out and accidentally break the circuit. The round metal plug may be replaced by a flat key with different side grooves or ridges, with corresponding openings in the different jack heads. Such a construction would be a lock against tampering.

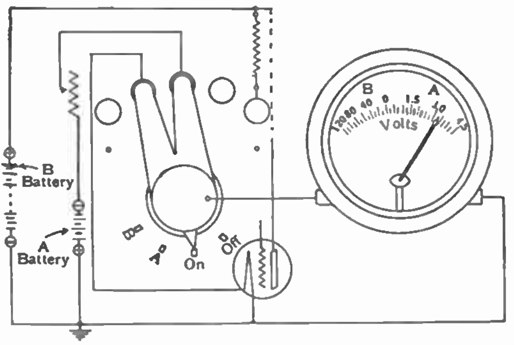

FIG. 7,388.—Filament and volt meter control with a double blade switch, with off, filament, A battery and B battery voltage positions. When the double blade switch is in the *off* position, one finger is in an inactive position, while the other finger is on a button contact leading to the negative side of the filaments. In the next position, *on*, the fingers bridge this negative filament button and a button contact leading through the filament rheostat to the negative end of the A battery. This turns on the filament current and causes the volt meter to show filament voltage on the A, scale, one side of zero. In the next position, A, the double blade is active only through the rheostat to the A battery, the filament being cut off. This position causes the volt meter to show the A battery voltage, on the same A, scale. This is necessary in order to know when the filament battery is completely charged or discharged. The drop in the rheostat due to the small volt meter current is negligible, and hence introduces no error. In the next position B, the blade touches a contact leading through the volt meter multiplier resistor to the plus of the B, battery. This setting causes the volt meter pointer to deflect in the opposite direction and show the B, battery voltage on the B, scale. The switch should not he left in the B, position for any great length of time. A spring may he provided to move the switch blade away from this last contact when the knob is released by the operator. Merely the insulated knob and a pointer may appear on the outside of the panel, with *off*, *on*, A and B, engraved thereon. This scheme has the advantage that the A and B, readings cannot be confused and that the switch controls the *on* and *off* of the vacuum tube set as well as the functioning of the volt meter.

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Another push switch scheme for indicating filament, B battery and C battery volts on the triple scale double range volt meters, is shown in fig. 7,387.

In operation (fig. 7,387), the volt meter will normally show filament volts whenever the rheostat is on. A slight pressure on the button breaks the contact to the plus of the filament and makes the contact to show B battery volts. A greater pressure on the button throws the three spring contacts together and causes the low range of the volt meter to be connected across the C battery. The current through the multiplier continues to flow, not through the volt meter but through the C battery, and A battery to −B. Thus the volt meter pointer deflects to left of zero and shows

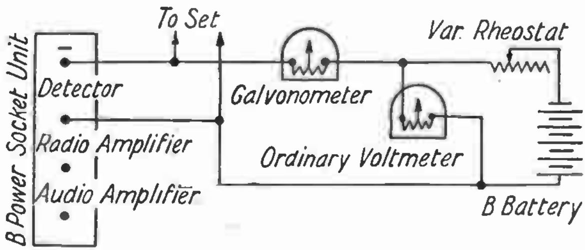

FIG. 7,389.—Potentiometer method of obtaining correct readings of B power unit voltages with galvanometer and ordinary volt meter.

C battery volts on the C, scale. When the button is released the springs return to normal and the volt meter to filament volts. The vacuum tube set is turned on or off by the rheostat.

A switching arrangement which can be made up of standard parts is shown in fig. 7,388.

Milli-Ammeters.—These instruments are provided with fine wire coils of many turns. Those marked in milli-amperes range from 0-10 to 0-100, and are for use in plate circuits of vacuum tubes, and for other purposes where a few volts drop is not harmful.

The 0-10 milli-ammeter may have its terminals connected to a standard plug and thence inserted into any jack intended for head phones or loud

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speaker, so as to measure the vacuum tube plate current in that circuit. The voltage drop in the milli-ammeter is much less than that in any head phone or loud speaker, and hence this drop is no detriment for such uses.

A combination instrument is made with a scale of from 0-10 milli-amperes at from 0-25 volts with arrows at 17.5 and 22.5 volts, representing empty and full B battery block.

With an external multiplier, this same instrument reads from 0-100 volts so as to show total voltage of four or less blocks of B batteries in a set. This instrument may be used to advantage on a B, battery eliminator, placing the 100 volt range clear across the main condenser, and tapping off, where the multiplier joins the low range resistor, to feed the detector at approximately one quarter total voltage. In such a case the volt meter readings will be correct only when the detector plate current is small compared with 10 milli-amperes. A bridging condenser should be used to keep this lowered voltage constant while the set is operating. Thus this one instrument serves not only as a milli-ammeter and as a double range volt meter, but also as a 10,000 ohm potentiometer with tap at 2,500 ohms for voltage reduction.

Double Range Ammeters.—These instruments are particularly good for double duty rectifiers.

The minus common of the ammeter is connected to the minus (anode) of the rectifier. Two other terminals are supplied, one for 0-5 amperes for A battery charging, and the other for 0-1 ampere for B battery charging.

The usual number of plus terminals for 2, 6, 12, 22.5, 45, and 90 volt batteries should be supplied on the rectifier as usual. Other double ranges are supplied such as: 0-1.5 and 0-7.5, also 0-2 and 0-10 amperes.

TEST QUESTIONS

1. *What is the requirement of a volt meter for radio instruments?*
2. *Why is it necessary that a volt meter draw a very small current?*
3. *Why are inefficient ammeters especially undesirable?*

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4. *Name an efficient type of ammeter.*
5. *What is the advantage of a combination instrument?*
6. *Name some volt meter combinations.*
7. *What kind of a switching device should be used?*
8. *How should a switch be selected?*
9. *Draw a diagram for radio connections with four dry cell tubes.*
10. *Draw a diagram showing dial switch and control for multi-range volt meter.*
11. *Describe the method of volt meter and tube control with a standard jack.*
12. *Why is a volt meter control switch and lock arranged with special jack?*
13. *Describe an ideal arrangement for multi-tube sets.*
14. *What are the advantages of triple scale volt meters?*
15. *Draw a diagram showing filament and volt meter control with a double blade switch.*
16. *How are milli-ammeters constructed?*
17. *What is the range of a milli-ammeter scale?*
18. *On what circuits is a milli-ammeter used?*
19. *How is a 0-10 milli-ammeter connected?*
20. *How does the voltage drop in a milli-ammeter compare with that in a head phone or loud speaker?*
21. *Explain the use of a bridging condenser.*
22. *What is the advantage of a double range ammeter?*
23. *How is a double range ammeter connected?*

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CHAPTER 182

Broadcasting Stations

(Transmitting Apparatus)

The essential elements of a transmitting station consist of:

1. Source of energy.

Such as a storage battery, *d.c.* or *a.c.* supply, steam engine, or any other source from which energy might be obtained.

2. Oscillator, or high frequency alternator.

The device for converting the available energy into the form of high frequency currents.

3. Controlling device.

Such as key, which makes and breaks a circuit, or modulator which varies the amplitudes of the high frequency current in accordance with sound waves which it is desired to send out.

4. Antenna.

The device for radiating the energy due to the high frequency current into space in the form of electro-magnetic waves.

The Vacuum Tube as an Oscillator.—A vacuum tube may be used as a generator of high frequency voltages, and when so used it is called an *oscillator*. When the vacuum tube is

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used as an oscillator the A, B and C batteries form the source of energy and the tube is connected to the oscillatory circuit, so that there is coupling between the grid circuit and the oscillatory circuit and also between the plate circuit and the oscillatory circuit, as illustrated in fig. 7,390.

From the explanation of the diagram, it is seen that by associating the battery source of energy and the oscillatory circuit with the vacuum tube in such a way as to provide suitable coupling between the plate circuit and the oscillatory circuit, and between the grid circuit and the oscillatory

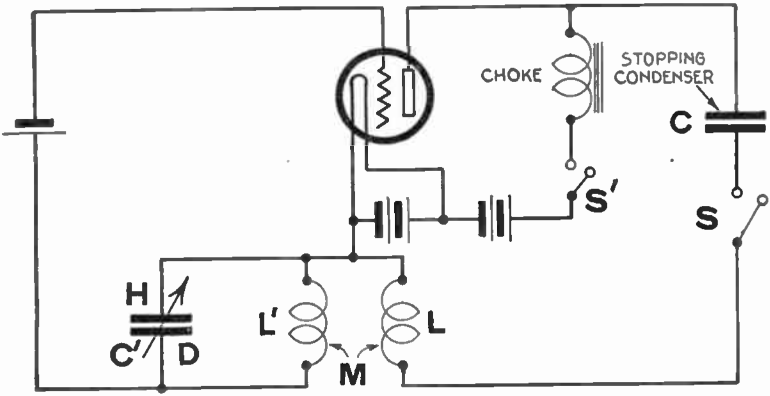

FIG. 7,390.—Modified Hartley type oscillator. *In operation* with switch S open and S', closed, the B battery sends a steady current through the choke coil and the internal plate circuit. Condenser C, prevents this *d.c.* flowing through coil L, when S is closed, thus preventing discharge of B battery through coil L, and also making the reactance of the circuit LC, to *r.f.* currents low. When S, is closed a surge in current takes place via condenser C and coil L, which is absorbed from the internal plate circuit. Since the choke maintains the battery current steady, the variable current through coil L induces a voltage in coil L'. Assuming the induced voltage is such as to cause a surge of current down through coil L', the condenser C' would be charged with the plate D positive. The voltage across this condenser would then be in opposition to the original grid bias, and would, consequently make the grid less negative than before. This decrease in negative grid voltage would effect an increase in the internal plate current. Because of the choke coil in the battery circuit the increased current must flow down through the coil L, and up through the condenser C, which in turn would induce a voltage in the coil L', causing a surge of current up through this coil and charging the condenser C' with the plate H, positive. Now, the voltage across the condenser C', aids the original grid bias and results in an increased negative grid voltage and therefore the current from plate to filament is decreased again, with the resulting surge of current down through C, and up through L, which induces a voltage in L', and so the cycle is repeated indefinitely.

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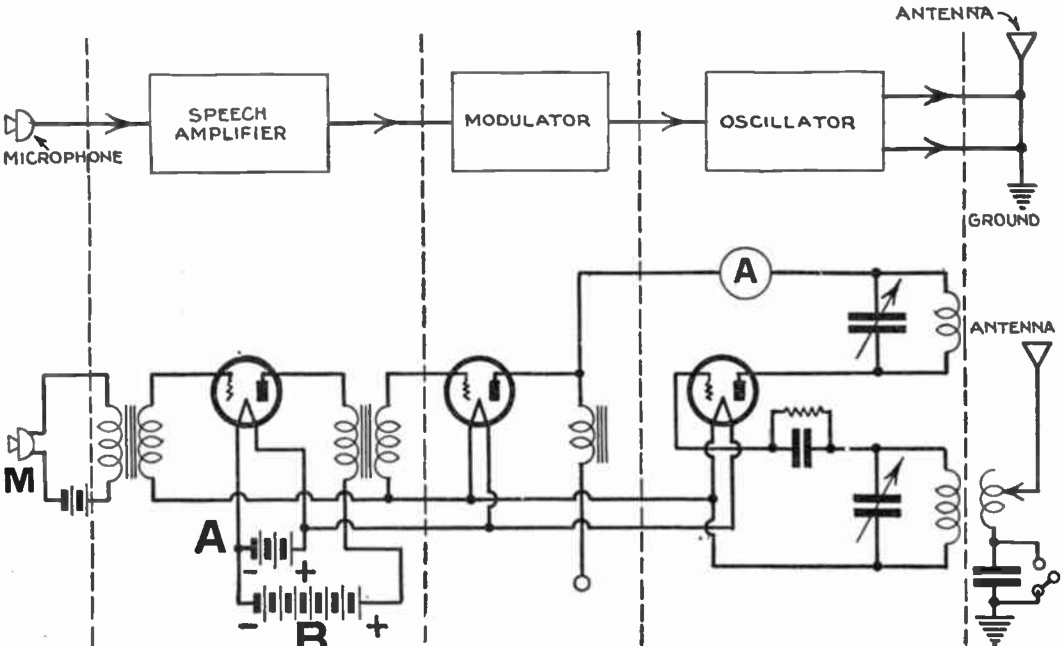

FIG. 7,391.—Arrangement of elements of radio transmitting station.

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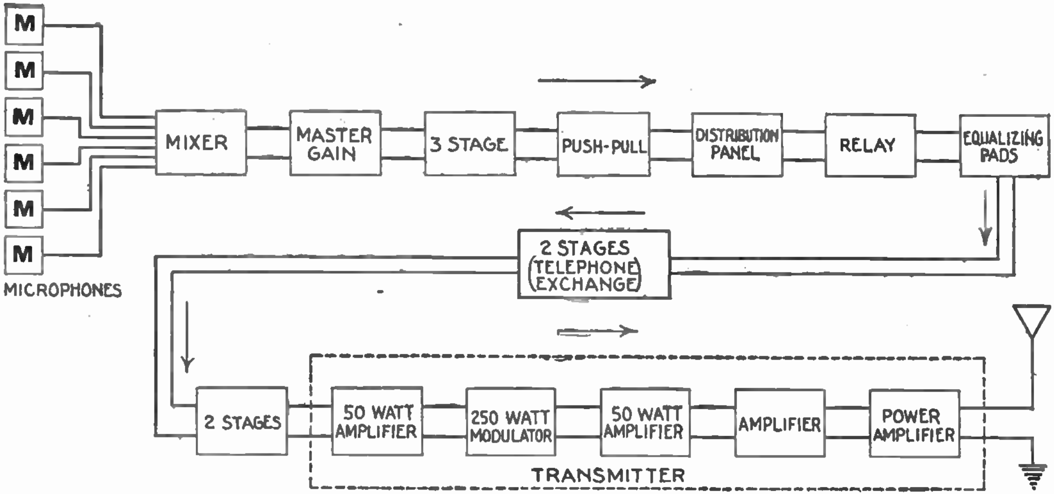

FIG. 7,392.—Arrangement of elements of Hollywood broadcasting station KNX. The most interesting units are the mixer, the master gain, and the equalizing pads; the latter are merely circuit elements designed to match the relay signal output to the telephone line. The amplifier consists of three stages, using 250 watt tubes, and the power amplifier of two 10 *kw.* tubes. Plate modulation is used, the modulator being capacity coupled to the 50 watt *r.f.* amplifier.

circuit, there is produced sustained oscillations, thus some of the available battery energy is converted into the form of high frequency currents.

Because of the amplifying action of the vacuum tube, the alternating voltage across the grid condenser C′, during a given cycle would result in an increased alternating voltage across the coil L, in the plate circuit, and consequently with sufficiently close coupling between L and L′, the voltage induced in coil L′ would be greater than that which previously existed across the condenser C′. For this reason the amplitude of each cycle would be greater than that of the preceding cycle, and the oscillations of the plate current would continue to increase until the instantaneous values of plate current varied between some maximum and some minimum determined by the coupling and the constants of the circuit. The form of this oscillating plate current is shown in fig. 7,394.

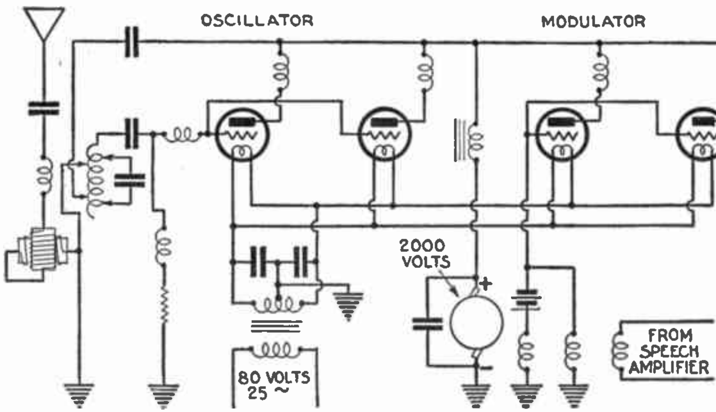

FIG. 7,393—Circuit diagram of a broadcasting station.

Broadcasting Station Circuits.—One example of a transmitting circuit is shown in fig. 7,393. The oscillator used in this circuit contains two tubes in parallel and is of the Meisner type. The modulator also employs two tubes in parallel, and modulation is effected by means of variation of the input power (Heising system).

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The general arrangement of the various units comprising the apparatus of a large transmitting station is clearly shown in the circuit sequence diagram of Hollywood Station KNX, as shown in fig. 7,392.

By means of the master gain controls the sound level is kept down within reasonable limits. The speech currents are mixed, amplified twice, and then sent through the equalizing pads, over the telephone wires, amplified again in the telephone exchange, and yet again at the station before entering the modulator. The monitoring is done here, and the needle of the meter is not allowed to swing past the red mark on either side of zero. All equipment is, of course, in duplicate as an emergency measure.

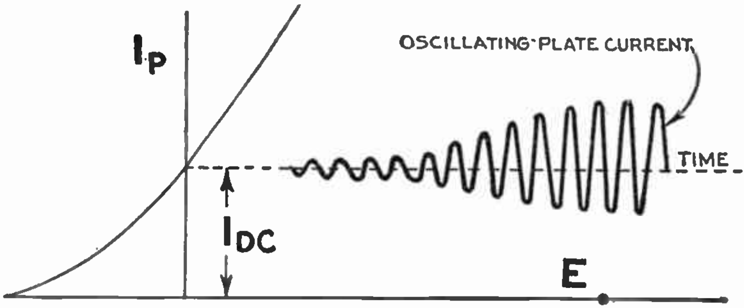

FIG. 7,394.—Diagram showing form of the oscillating plate current.

TEST QUESTIONS

1. *What other name is given to a broadcasting station?*
2. *Name the essential elements of a transmitting station.*
3. *Is an aerial or an antenna used at a broadcasting station?*
4. *Describe an oscillator.*
5. *Draw a diagram showing the various circuits of a broadcasting station.*

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CHAPTER 183

Radio Troubles

The service man, in order to intelligently cope with the various faults liable to develop in radio sets should be provided with a compact portable *testing set* of which there are a number of good ones available.

The author has selected for illustration in this chapter a test set known as a *Diagnometer*, Model 400 B, made by the Supreme Instrument Corp. It comprises equipment for testing as follows:

1. Tube tester
2. Modulated radiator
3. Resonance indicator
4. Neutralizer
5. Analyzer
6. Continuity tester
7. Rejuvenator
8. External use of meters

The first step in servicing should be a preliminary inspection of the operating characteristics of the radio, and as this can best be done by actually tuning the radio to signals, if the radio be not completely inoperative, it is advisable to put the *modulated radiator* in operation. After a preliminary examination of the radio, the next step should be the testing of the tubes used in the radio, which is also accomplished with the *modulated radiator* circuits, preferably powered through the *power plant*.

Putting the Power Plant in Operation.—Where alternating current power, of the voltage and frequency for which the testing set is designed, is available, the following procedure puts the *power plant* in operation for powering the *modulated*

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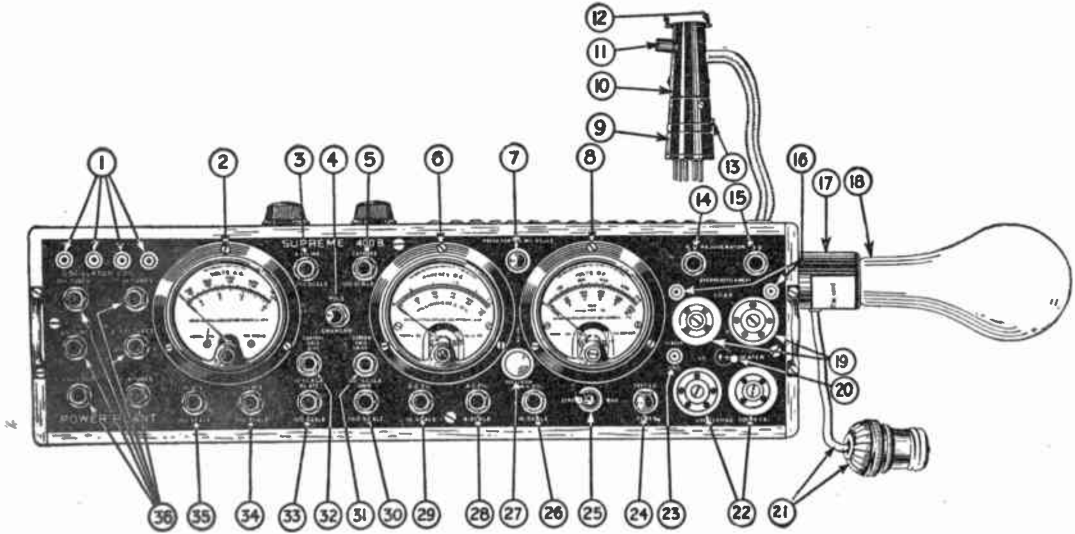

FIG. 7,395.—Supreme *diagnometer* showing front panel markings. ***The markings are:***

1. Oscillator coil pin jacks marked B.P.G.F.;
2. *A.c.* volt meter, 4 scales 750/150/16/4/0;
3. *A.c.* line jack, for connecting 150 volt scale of *a.c.* volt meter 2, across *a.c.* supply line 21;
4. Pole changer push button switch for reversing connections to the *d.c.* volt meter 8, when the needle backs off scale during *d.c.* filament 29, or cathode 5, analysis;
5. Cathode bias jack, for indicating cathode biases on the 100 volt scale of the *d.c.* volt meter 8, when analyzing from UY sockets with the UX heater switch 20, in the heater position;
6. *D.c.* milli ammeter, the 125 mil. scale of which is in the common plate circuit of the 4 sockets 19 and 22. The 2½ ampere scale is available externally only;

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FIG. 7,395.—*Text continued.*

7. Milli ammeter switch for opening a shunt for the 25 milli ampere scale range 6;
8. *D.c.* volt meter, 4 scales, 750/250/100/10/0;
9. Analyzer adapter for UY sockets;
10. Universal analyzer plug. This plug should be removed from any radio tube socket before connecting the *diagnometer* to the *a.c.* supply line 21;
11. Control grid contact lug on the analyzer plug 10;
12. Top heater tube filament contacts on the analyzer plug 10;
13. Adapter release on the analyzer plug 10;
14. Jack for rejuvenating 5 volt tubes of thoriated filament types;
15. Jack for rejuvenating 3 volt tubes of thoriated filament types;
16. Overhead (top) heater tube filament pin jacks;
17. Polarized series socket adapter for 100 watt Mazda protective lamp;
18. 100-watt Mazda lamp;
19. Load sockets used when analyzing from radio tube sockets;
20. UX heater switch. To be left in *heater* position when analyzing from radio sockets which utilize tubes having independent cathodes. For all other tube socket analysis, leave the switch in the UX position;
21. *A.c.* power supply cord and plug. To be detached when analyzer plug 10, is to be inserted in any radio tube socket;
22. *Tube testing sockets* used when the testing set employs any tube while connected to an *a.c.* power supply system;
23. Screen grid jack for connecting to the control grid contact on top of any screen grid tube placed in any of the testing set tube sockets;
24. Switch to be depressed when testing screen grid tubes and the second plate of full wave rectifying tubes placed in either *tube testing socket* 22;
25. Switch for applying either of two grid voltages to the grid of any tube placed in a tube testing socket 22;
26. *A.c.* filament jack for connecting 16 volt scale of *a.c.* volt meter 2, across the filament contacts of the analyzer plug 10;
27. Push button switch for shunting G and F of the oscillator coil pin jacks 1, to *stop oscillation* of any amplifier tube used in a *tube testing* socket 22;
28. *A.c.* filament jack for connecting the 4 volt scale of the *a.c.* volt meter 2, across the filament contacts of the analyzer plug 10;
29. *D.c.* filament jack for connecting the 10 volt scale of the *d.c.* volt meter 8, across the filament contacts of the analyzer plug 10;
30. Grid jack for connecting the 100 volt scale of the *d.c.* volt meter 8, across the grid and cathode contacts of the analyzer plug 10, for indicating negative grid bias;
31. Screen grid jack for connecting the 100 scale of the *d.c.* volt meter 8, across the grid and cathode contacts of the analyzer plug for indicating positive screen grid bias;
32. Control grid jack for connecting the 10 volt scale of the *d.c.* volt meter 8, across the control grid contact lug 11, and the cathode contact of the analyzer plug 10, for indicating negative control grid bias;
33. Plate jack for connecting the 100 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10 for indicating positive plate voltages below 100 volts;
34. Plate jack for connecting the 250 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10, for indicating positive plate voltages between 100 and 250 volts;

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radiator for a test of the tuning characteristics of a radio, for the testing of tubes, and for other purposes:

1. Remove the oscillator coil from its pin jack position.
2. Open all switches on the panel of the testing set.
3. Clear the analyzing plug and all jacks of the testing set from contact with any electrical conductors which might short circuit any of the jack

FIG. 7,396.—Supreme radio diagnometer in carrying case which provides adequate space for all tools that may be required as well as spare tubes and parts. Illustration shows oscillator coil in position and swinging tube shelf that provides accessibility and protection to tubes. Instrument can be used in carrying case or removed, as desired.

FIG. 7,395.—*Text continued.*

35. Plate jack for connecting the 750 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10, for indicating positive plate voltages between 250 and 750 volts;

36. Power plant jacks for applying a filament voltage which corresponds to the filament rating of any tube placed in either of the *tube testing sockets* 22, when the testing set is connected with the supply cord 21, to an *a.c.* supply system.

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switches, or which might be grounded or directly connected to the common alternating current system. This will avoid the possibility of shunting power supply around the protective resistor.

4. Remove the prescribed protective resistor from its series socket of the *a.c.* connector cord.

5. Connect the testing set to a convenient *a.c.* supply socket, using the *a.c.* connector cord with its series socket vacant.

6. Close the *a.c.* line switch. If the *a.c.* volt meter show any reading, the series socket is shorted, and the deficiency must be corrected before proceeding with any test.

7. If the *a.c.* volt meter show no reading, replace the protective resistor in its series socket of the *a.c.* supply connector cord. The *a.c.* line voltage should then be indicated on the *a.c.* volt meter. This switch may remain closed so that line voltage fluctuations may be observed. A shorted tube, or other short circuit within the circuits upplied with the *power plant* will be indicated by a radical drop of the volt meter reading.

Putting the Modulated Radiator in Operation.—With the *power plant* in operation, the following steps complete the set up of the *modulated radiator* for a check up of the pick up characteristics of a radio, for tube testing, and for other purposes:

1. Insert the oscillator coil, with its label to the front, in its prescribed position.

2. Throw the UX heater switch to its heater position.

3. Place a good oscillating tube in one of the tube testing sockets. Use a clip pin plug lead for connecting the top control grid contact to the screen grid pin jack on the instrument pane'

4. Throw the biasing toggle switch to the position for maximum oscillation.

5. Leave the ammeter milli-ammeter scale switch in position for readings on the highest available scale of the meter.

6. Close the *power plant* switch, the voltage marking of which corresponds to the filament specification of the tube which has been placed in one of the tube testing sockets.

7. When using screen grid tubes, close the test S. G. tubes switch momentarily for obtaining plate readings of the tube.

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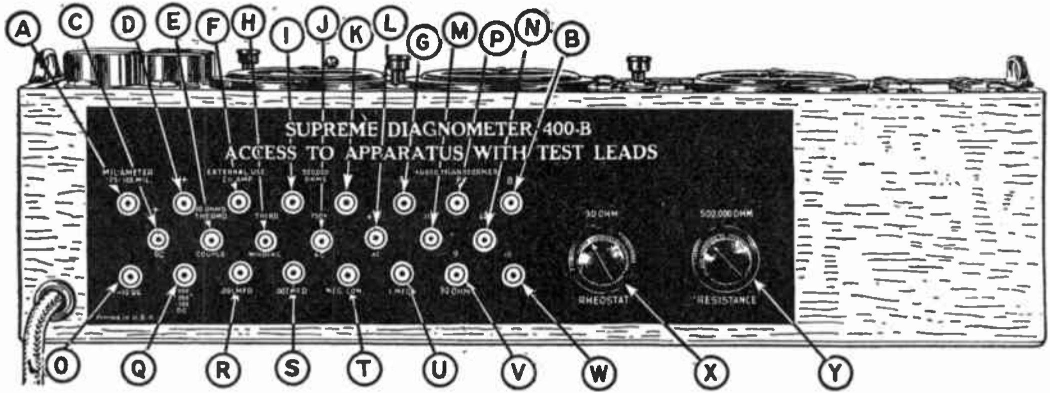

FIG. 7,397—Supreme *diagnometer* showing rear panel markings for external connections.

The markings of the diagnometer (fig. 7,397) are:

A. Connects to negative side of 125 mil. scale of *d.c.* milli-ammeter 6. Positive side connects to D. 25 mil. scale available by depressing milli-ammeter switch 7.

B. Connects to one side of primary circuit of audio transformer. Other side of primary connects to P;

C. Common positive connection for all scales of *d.c.* volt meter 8. Negative connections available at O and Q when a corresponding jack 29, 33, 34 or 35 is closed;

D. Common positive connection to *d.c.* milli-ammeter 6. Negative 125 scale available at A, without closing any switch or jack. Negative 25 mil. connection completed at A, by depressing milli-ammeter switch 7. Negative connection to 2½ ampere scale of *d.c.* milli-ammeter 6, completed at F, without closing any switch or jack.

E. One side of 30 ohm rheostat X, and thermo couple heater unit of *d.c.* volt meter 8. Other side of 30 ohm rheostat available at V. Rheostat should not be used as a filament control with a battery hook up of the testing set;

F. Negative connection to 2½ ampere scale of *d.c.* ammeter 6. Positive connection completed at D, without closing any switch or jack;

G. One side of secondary winding of audio transformer which is completed at T;

H. One side of third (low impedance secondary) winding of audio transformer. The other side is completed at E;

8. The plate current, which includes whatever additional current which may be induced by the oscillatory circuit, will then be indicated on the milli-ammeter.

9. If the current reading do not exceed the next lower scale limit, the milli-ammeter scale switch should be closed to the position for readings on the next lower scale. Observe the value of the current.

10. Close the oscillation switch and observe the plate current reading with the tube not in an oscillating condition. The audible strength of the radiated signal will generally be in proportion to the difference in the current readings obtained.

Operating Modulated Radiator with Batteries.—Where alternating current power supply of the voltage and frequency for which the testing set is designed is not available, the oscillatory

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FIG. 7,397.—*Text continued.*

I. One side of 500,000 ohm variable resistor Y. The other side is completed at K, the resistor heing independent of all other circuits;

J. One side of 750 volt scale range of *a.c.* volt meter 2. The other side is completed at L, without closing any panel switch or jack;

K. One side of 500,000 ohm variable resistor. The other side is available at I;

L. Common connection for all scales of *a.c.* volt meter 2. The other side of the 4 and 16 volt scale ranges is available at U, when a corresponding panel jack 28, or 26, is closed. The other side of the 150 volt scale range is available at D, when the *a.c.* line panel jack 3, is closed. The other side of the 750 volt scale range is available at J, without closing any panel switch or jack;

M. One side of thermo couple heater unit. The other side is available at E;

N. To be connected to C, for closing thermo couple heater unit to 1 mil. movement of *d.c.* volt meter 8;

O. Connects to negative side of 10-scale of *d.c.* volt meter when panel jack 29, is closed for completing the positive meter connection to C;

P. One side of audio transformer primary. The other side terminates at B;

Q. Connects to negative side of 100, 250 and 750 volt scale ranges of *d.c.* volt meter 8, when a corresponding panel jack 33, 34 or 35, is closed for completing the positive meter connection to C;

R. One side of 0.001 mfd. fixed condenser. The other side connects to T;

S. One side of 0.002 mfd. fixed condenser. The other side connects to T;

T. Common connection of each condenser terminating at R, S, and U; also connects to filament end of audio transformer secondary;

U. One side of 1 mfd. fixed condenser. The other side connects to T;

V. One side of 30 ohm rheostat X. The other side connects to E;

W. Connects directly to V;

X. Control knob of 30 ohm rheostat available at E and V;

Y. Control knob of 500,000 ohm variable resistor available at I and K.

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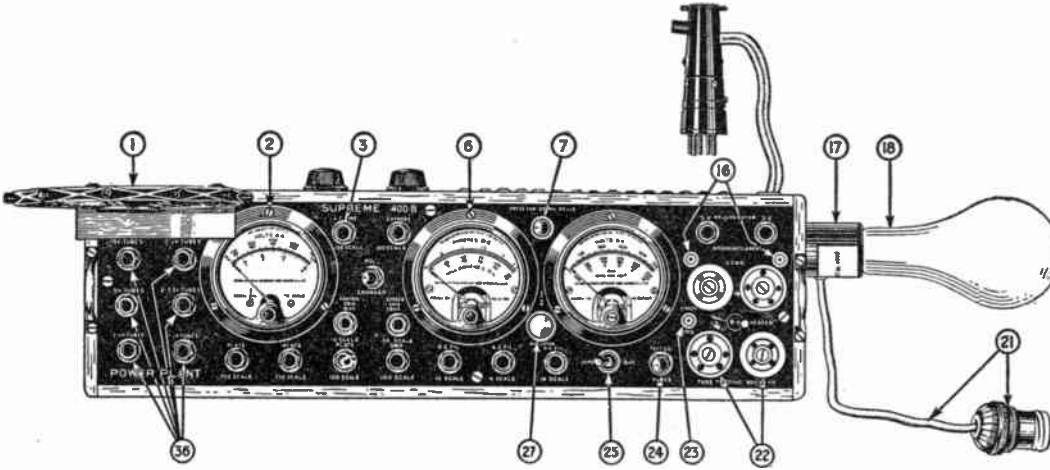

FIG. 7,398.—Supreme oscillator operation modulated with *a.c.* supply.

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common *a.c.* supply system.

B. Insert the polarized series socket adapter 17, without the 100 watt Mazda lamp 18, in the receptacle on the end of the tray;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3. If the *a.c.* volt meter 2, show a reading, the series socket adapter 17, is shunted and the deficiency must be corrected before proceeding with any test;

E. If the *a.c.* volt meter 2, show no reading, place the 100 watt Mazda lamp 18, in the series socket adapter 17. The *a.c.* supply voltage should then be indicated on the *a.c.* volt meter 2. No device other than the prescribed 100 watt lamp 18, should be used in the series socket adapter 17. A lower resistance would endanger the milli-ammeter;

F. Insert the oscillator coil with its label to the front, in the prescribed position 1;

G. Place an amplifier tube of any type, except a screen grid or top heater, on one of the tube testing sockets 22;

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circuits of the *modulated radiator* may be powered with batteries, the hook up procedure being as follows:

1. Connect the common positive (*d.c.*) external pin jack of the testing set to the positive terminal of a battery the voltage of which is regulated to meet the filament voltage specification of the tube to be placed in either of the tube testing sockets.

2. Connect the −10 *d.c.* external pin jack to the negative terminal of the filament supply battery.

3. Connect the external milli-ammeter positive pin jack to the positive terminal of a 45 volt B battery.

4. Join the negative terminal of the 45 volt B battery to the positive terminal of the filament battery.

5. Close the *d.c.* Fil. switch of the testing set for observing the filament voltage.

6. Insert the oscillator coil in its prescribed position.

7. Place a tube in one of the tube testing sockets.

Using the Modulated Radiator for Tube Testing.—Tube testing is probably the most important phase of radio servicing, and every test or analysis of any radio should be preceded by a test of the tubes used in the radio with whatever replacements and rearrangements of the tubes may be required for the best

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FIG. 7,398.—*Text continued.*

H. Remove the jack plunger from the *a.c.* line jack 3, and insert it in the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube which has been placed in the tube testing socket 22;

I. If the tube be generating oscillations, modulated *r.f.* signals should now be radiated at about five different frequencies within the broadcast band. These signals may be *tuned in* with any operative radio for synchronizing, neutralizing, or other purposes;

J. The harmonic frequencies may be changed somewhat by changing the position of the *zero bias* toggle switch 25;

K. If it be desired to increase the pickup strength of the signals, the oscillator coil intermediate winding, which terminates at two pin jacks on the back of the coil, may be coupled with test leads to the pickup circuits of a radio under test;

L. If the oscillator signals be too strong and broad, their strength may be reduced and the tuning *sharpened* by changing the position of the jack plunger to a power plant jack of a voltage marking lower than the filament rating of the tube.

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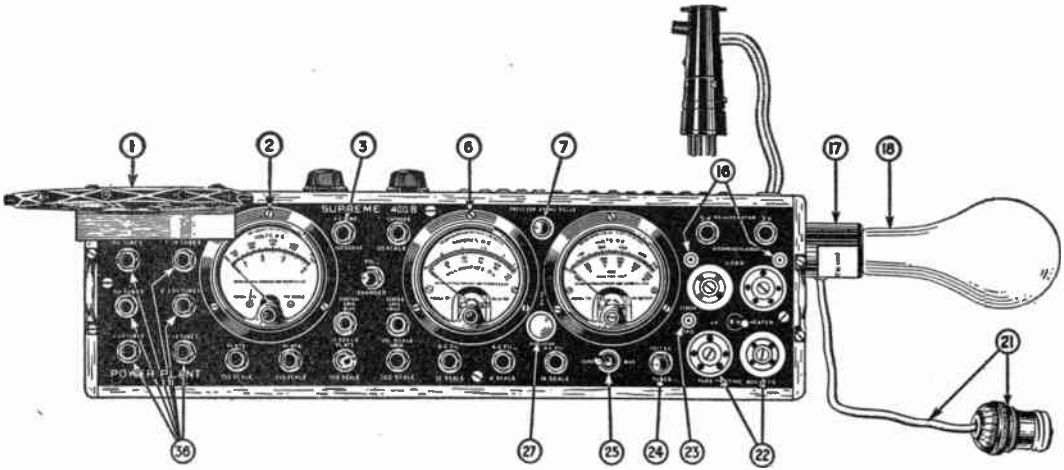

FIG. 7.399.—Supreme tube testing with *a.c.* supply. **PART 1.**—Except screen grid, rectifier, and top heater tubes.

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in one of the tube testing sockets 22.

operation of the radio. With the *modulated radiator* in operation, the following procedure is necessary to accomplish tube testing:

1. If the *radiator* be powered with alternating current, close the *a.c.* line switch and observe the line voltage reading on the *a.c.* volt meter. All tube testing tables are graduated on line voltage readings; and on the use of a 45 volt B battery where alternating current supply is not available.

2. Place the tube to be tested in one of the tube testing sockets.

3. Throw the biasing toggle switch to its zero position.

4. Leave the milli-ammeter scale switch in position for readings on the highest available scale of the milli-ammeter.

5. If utilizing *a.c.* power supply, close the *power plant* switch the voltage markings of which correspond to the filament specifications of the tube which has been placed in one of the tube testing sockets.

6. When testing screen grid tubes close the test S. G. tubes switch momentarily for obtaining the proper plate readings of the tube.

7. The plate current, which includes whatever additional current which may be induced by the oscillating circuit, will then be indicated on the milli-ammeter.

8. If the current reading do not exceed the next lower scale limit, the milli-ammeter scale switch should be closed to the position for readings on the next lower scale. Observe the value of the current.

FIG. 7,399.—*Text continued.*

G. Throw the biasing toggle switch 25, to its *zero* position;

H. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;

I. As the tube attains its operating temperature, the plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will be indicated on the 125 scale of the *d.c.* milli-ammeter 6. If the plate current reading 6, is less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale;

J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;

K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;

L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio;

M. The four plate current readings obtained may be compared with the tube testing tables, which indicate average relationships in tube characteristics.

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9. Except when testing rectifier tubes, close the oscillation switch and observe the plate current reading with the tube not in an oscillating condition.

10. Except when testing rectifier tubes the biasing switch may be thrown to its bias position, repeating the two preceding steps.

11. Compare the readings obtained with the readings shown in tube testing tables.

12. Repeat above routine for each tube to be tested.

If there be a radical difference between the values of plate current in each of the plate circuits of a full wave rectifier of

FIG. 7,400.—Supreme tube checker; portable model for either counter or portable use, with lid mounted on slip hinges, handle and detachable cord. It provides the *following features:* 1, tests pentode tubes and the new 2 volt 30 series tubes; 2, tests screen grid tubes with voltage closely approaching operating conditions; 3, full size 3½ in. meter, full bakelite case; 4, double scale meter, both scales calibrated; 5, large size transformer; 6, correct filament voltages applied to every type tube; 7, off and on switch.

NOTE.—*Screen grid tube testing with a.c. supply, fig. 7,399.*

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in one of the tube testing sockets 22, with its top control grid contact connected with a short clip pin plug lead to the *screen grid* 23, panel pin jack.

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the filament type, the tube may not perform as efficiently as it would were both plate current values normal.

If it be desired to test both plates of full wave rectifying tubes of the filament type, depress the test S. G. tubes for obtaining a reading on the second plate.

Setting up the Rejuvenator.—Where alternating current power supply is available and it is desirable to rejuvenate tubes of the thoriated filament type, the following procedure should be followed for rejuvenating tubes in the sockets of the testing set:

1. Put the *power plant* in operation, but close no switches in the *power plant*.

2. Place a tube to be rejuvenated in the UX tube testing socket. A tube to be rejuvenated may also be placed in the UX load socket by closing the *d.c.* Fil. switch and throwing the UX to Heater switch to the UX position.

NOTE—*Continued.*

G. Throw the biasing toggle switch 25, to its *zero* position;

H. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;

I. After the tube attains its operating temperature, depress the *test screen grid tubes* push button switch 24. The plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will then be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6.

If the plate current reading 6, in fig. 7,399, be less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale.

J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;

K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;

L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio;

M. The four plate current readings obtained may be compared with tube testing tables which indicate average relationships in tube characteristics.

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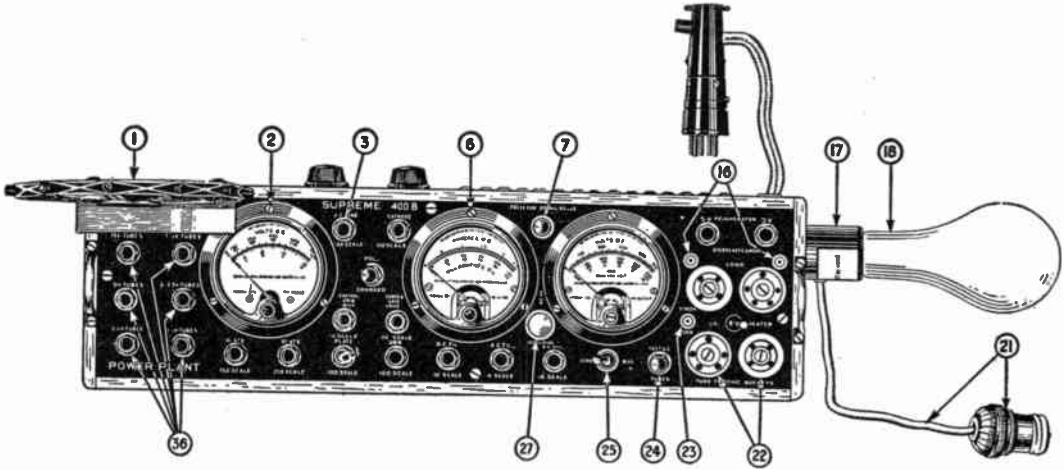

FIG. 7,401—Supreme tube testing with *a.c.* supply. ***PART 2. Rectifier (thermionic) tubes.***

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show inaccurate readings;

C. Connect supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in the UX tube testing socket 22;

3. Completely close the *rejuvenator* switch.

4. After 15 seconds place the *rejuvenator* switch in its semi-closed (notched) position.

5. After 10 or 15 minutes, take a test reading of the tubes which have

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FIG. 7,401—*Text continued.*

G. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;

H. The current of one plate will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6;

I. When testing a full wave rectifier tube, depress the *test screen grid tubes* push button switch 24, for obtaining the plate current reading of the other plate;

J. The plate current readings obtained may be compared with tube testing tables, which indicate average relationships in tube characteristics.

NOTE.—*Overhead* (*top*) *heater tubes* (fig. 7,401).

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18 in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in the UX tube testing socket 22, with its overhead (top) heater contacts connected with short clip-pin plug leads to the *overhead filament* 16, panel pin jacks;

G. Throw the biasing toggle switch 25, to its *zero* position;

H. Close the 3-3.3 *V tubes* power plant jack 36;

I. As the tube attains its operating temperature, the plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will then be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6. If the plate current reading 6, be less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale 6;

J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;

K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in the plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;

L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio.

M. The four plate current readings obtained may be compared with tube testing tables, which indicate average relationships in tube characteristics.

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been subjected to the rejuvenating process to ascertain the progress of the rejuvenation.

6. If tubes be restored no further rejuvenation is necessary. If not, the process should be repeated until the tube emission is restored or until it is clearly apparent that the tube is worn out or exhausted and will not respond to rejuvenation.

As many as 12 tubes may be rejuvenated at one time by utilizing the tube sockets of a *d.c.* radio, the filament contacts of which are wired in parallel. An improvised bank of sockets may be utilized for connecting the filaments together.

The following procedure should be followed in utilizing the tube sockets of a *d.c.* radio for holding the tubes during rejuvenation:

1. Disconnect the ground lead from the radio.

2. Disconnect the battery or other power supply leads from the radio.

3. Turn all manually controlled rheostats to their full On positions so as to remove rheostat resistances from filament circuits of the radio.

4. Shunt out all automatic filament control devices.

5. Remove one of the tubes from the radio, and insert the analyzer plug in the vacant socket.

6. Fill all other tube sockets of the radio with tubes to be rejuvenated, the total number of tubes not to exceed 12.

7. Close the *d.c.* Fil. switch so as to combine the *analyzer* circuits with the *rejuvenator* circuits.

8. Repeat steps through 6 of the preceding paragraph.

It must be remembered that only tubes of the thoriated filament type which have been paralyzed or over loaded can be restored by rejuvenation. Worn out or exhausted tubes of this type, or tubes of any other type of filament cannot be rejuvenated.

Tube Socket Analyzing.—As the fundamental operating characteristics are practically the same for all radios, for the

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purposes of analysis, the circuits of a radio fall into two classifications, namely: the tube socket circuits which are always directly supplied with voltages from the radio power supply system, and may always be subjected to tube socket analysis, and the input (pick-up) and output (audible reproducer) circuits, which may or may not be directly connected to the radio power supply system, and may require the use of some method of testing other than that afforded by tube socket analysis.

The electrical characteristics of the circuits not amenable to tube socket analysis may be determined by their reaction to the *modulated radiator* with the radio in operation. The location of defects in these circuits will be discussed along with the instructions for the use of the *continuity tester*.

If properly connected, each filament, plate, grid and cathode circuit of a radio terminates at a tube socket.

In other words, the radio is built to fit the tube, which is the heart of radio circuits; and the tube circuits constitute the arteries, veins, and nerves of the radio, centering at the tube sockets at which most of the needed information as to the operating characteristics of a radio may be ascertained.

At one time it appeared probable that all tubes would be built on standard UX bases, but the advent of the indirect heater type introduced the UY base. The later appearance of the screen grid tubes introduced another tube element with its contact at the top of the tube. The newer types of radios will probably be built with relatively fewer UX sockets. Until a standard socket arrangement is adopted for all tubes and radios, adapters will be necessary for the interchanging of tubes and sockets. A familiarity with the use of adapters is essential for tube socket analyzing.

Analyzing Adapters.—The diagnometer is provided with a plug which requires the use of only one adapter for analytical tests on all radios, including screen grid types and overhead heater filament types, employing UX or UY tube sockets. No tube base adapter is required for placing any UX or UY tube in the sockets of this model.

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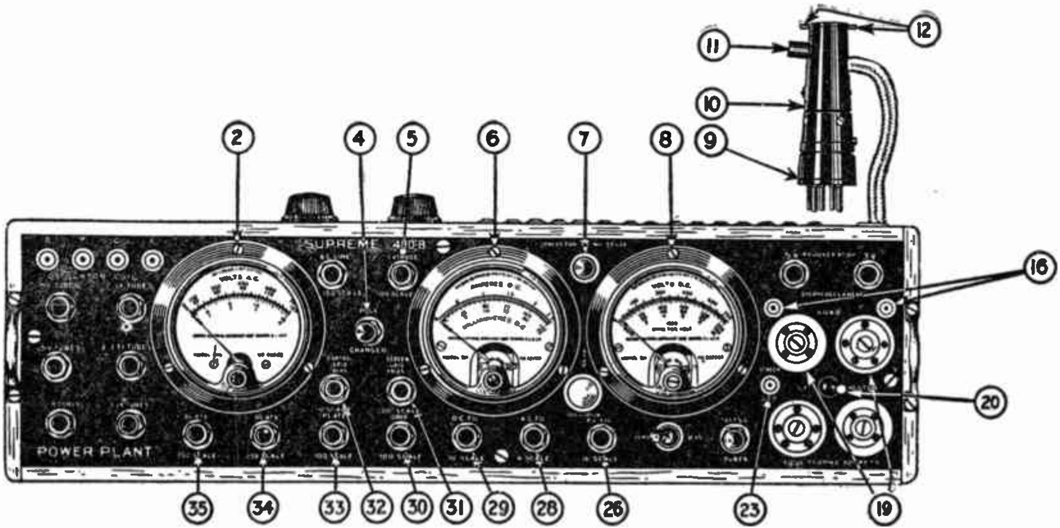

FIG. 7,402—Supreme analyzing radio tube sockets. ***PART 1—Triode tubes, UX and UY sockets.***

A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the *diagnometer;*

B. With the radio to be analyzed turned *off* remove a tube from the radio and place the tube in the *load socket* 19, which will accommodate the tube without an adapter;

C. Throw the *U X heater* switch 20, to the *U X* position for UX tubes and to the *heater* position for UY tubes;

D. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket;

E. Turn the radio *on* and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the *press for* 25 *mil. scale* milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the *d.c.*

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FIG. 7,402.—*Text continued.*

milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;

F. If it be desired to continue the analysis on the same socket, insert the jack plunger in the *a.c.* filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the *a.c.* volt meter 2, scale which corresponds to the closed jack 26 or 28;

G. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

H. The negative grid voltage should be indicated on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the grid jack 30. If the grid of the radio tube socket being analyzed be resistance coupled to the preceding stage, a more accurate reading of the applied grid voltage will be indicated by connecting a test lead between the grid contact of the unoccupied *load socket* 19, and the *grid return* which is usually the grounded chassis of the radio;

I. A negative cathode bias applied to a UY radio tube socket under analysis should be indicated directly on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the cathode jack 5. If the *d.c.* volt meter 8, needle backs off scale, depressing the pole changer push button switch 4, affords a direct reading of positive cathode biasing.

NOTE.—*Screen grid tube socket analysis* (fig. 7,402).

A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the diagnometer;

B. With the radio to be analyzed turned *off* remove a tube from the radio and place the tube in the *load socket* 19, which will accommodate the tube without an adapter;

C. Connect the top control grid contact of the tube with a short clip pin plug lead to the *screen grid* pin jack 23, on the panel;

D. Throw the *UX-heater* switch 20, to the *UX* position for UX tubes and to the *heater* position for UY tubes;

E. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket.

F. Connect the control grid contact lug 11, of the analyzer plug 10, to the control grid clip of the radio tube socket;

G. Turn the radio *on* and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the *press for* 25 *mil. scale* milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the *d.c.* milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;

H. If it be desired to continue the analysis on the same socket, insert the plunger in the *a.c.* filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the *a.c.* volt meter 2, scale which corresponds to the closed jack 26, or 28. If the filament of the radio tube socket be supplied with a direct current voltage, the *d.c.* filament jack 29, should be used instead of an *a.c.* filament jack 26, or 28, for indicating the *d.c.* filament voltage on the 10 scale of the *d.c.* volt meter 8;

I. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

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A snap catch is employed on this plug to prevent the separation of the adapter from the plug when inserted in a tube socket. Special pin plug clip leads are used for testing screen grid tubes and for testing overhead heater filament tubes.

A pole changer switch must be used in connection with the adapter. Grid and plate voltages should be read with the pole changer in its normal position and re-read with the pole changer depressed. Unless no reading is obtained in either case, the lowest reading obtained should be used as the correct reading. The pole changer switch should be depressed when the *d.c.* volt meter backs off scale when attempting to read *d.c.* filament voltages.

The adapter should be used for placing UX tubes in the load socket when analyzing *a.c.* radios, and when analyzing *d.c.* radios in which the negative filament terminals are adjacent to the plate terminals. Leave the pole changer switch in its normal position for reading the filament voltages.

Voltage Tests, Circuits Unloaded.—*No load* filament, plate and grid voltage tests may be made with all tubes removed from the sockets of parallel filament radios where all of the voltages are supplied from batteries. *No load* readings may be compared with the *load* readings for ascertaining the extent of battery exhaustion. On all other radios, except those employing series filaments, *no load* filament and plate voltage readings should be taken with only one of the tubes out of the circuits.

No load grid readings need not be undertaken except where a C battery is used. In battery types of radios where no C voltage is employed, continuity of the grid circuit may be determined by changing the position of the pole changer switch so as to read the filament voltage across the grid circuit with the *grid* switch closed.

NOTE.—*Continued.*

J. The negative control grid bias should be indicated on the 10 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the control grid jack 32;

K. The positive screen grid bias should be indicated on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the screen grid jack 31;

L. A negative cathode bias applied to a UY radio tube socket under analysis should be indicated directly on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the cathode jack 5. If the *d.c.* volt meter 8, needle back off scale, depressing the pole changer push button switch 4, affords a direct reading of positive cathode biasing.

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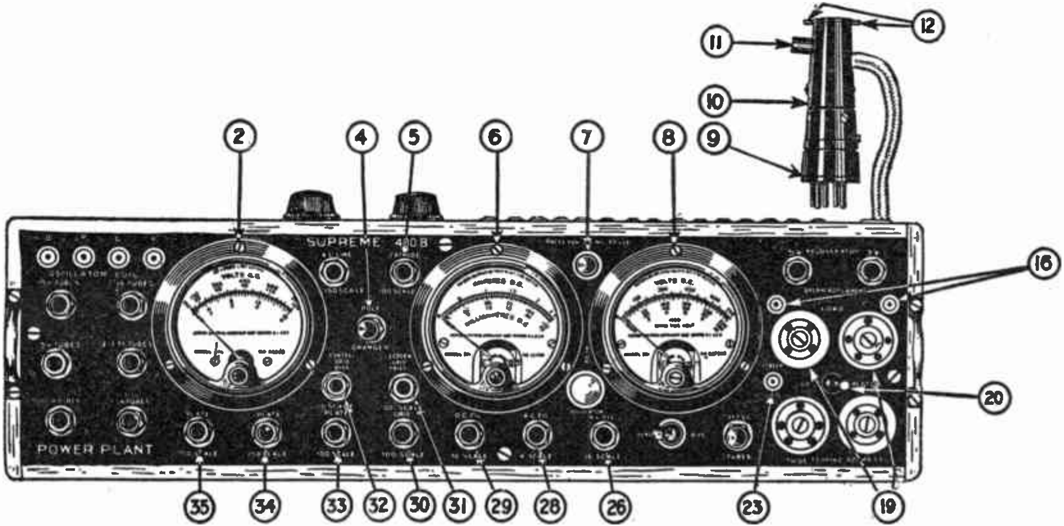

FIG. 7,403—Supreme analyzing radio tube sockets. ***PART 2—Triode tubes, UX and UY d.c. filament.***

A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the diagnometer;

B. With the radio to be analyzed turned *off*, remove a tube from the radio and place the tube in the *load socket* 19, which will accommodate the tube without an adapter;

C. Throw the *UX heater* switch 20, to the *UX* position. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket;

D. Insert the jack plunger in the *d.c.* filament jack 29;

E. Turn the radio *on*. If the *d.c.* volt meter 8, needle backs off scale, depress the pole changer push button switch 4, while adjusting the radio filament controls, if any, for an indication on the 10 scale of the *d.c.* volt meter 8, of the rated filament voltage of the tube. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6 during the analysis. If the reading be less than 25 milli-amperes, the *press for* 25 *mil. scale* milli-ammeter switch 7, may be depressed for a more

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All grid and plate *no load* readings, where these voltages are supplied with batteries, should be read with the battery switch open, first with the testing set pole changer switch in its normal position, and then read with the pole changer switch depressed. The lowest reading of value will

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FIG. 7,403.—*Text continued.*

exact reading on the 25 mil. scale of the meter. If the tube be good, a normal reading on the *d.c.* milli-ammeter 6, will generally indicate continuity of all radio circuits terminating at the socket being analyzed;

F. If it be desired to continue the analysis on the same socket, insert the jack plunger in a plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

G. Insert the jack plunger in the grid jack 30, for observing the negative grid voltage which will be the lower of two separate readings indicated on the 100 scale of the *d.c.* volt meter 8, the two readings corresponding to the two positions of the pole changer switch 4. The reading of the lower value will not include the filament voltage.

NOTE.—***Top heater tube socket analysis*** (fig. 7,403).

A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the diagnometer;

B. With the radio to be analyzed turned *off* remove a tube from the radio and place the tube in the UX *load socket* 19;

C. Connect the top heater contacts of the tube with short clip pin plug leads to the *overhead filament* pin jacks 16, on the panel;

D. Throw the *UX-heater* switch 20, to the *heater* position;

E. Insert the analyzer plug 10, without the adapter 9, into the radio tube socket;

F. Connect the top heater tube filament contacts 12, of the analyzer plug 10, to the *trolley* filament contacts of the radio tube socket;

G. Turn the radio *on* and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the *press for 25 mil. scale* milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the *d.c.* milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;

H. If it be desired to continue the analysis on the same socket, insert the jack plunger in the *a.c.* filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the *a.c.* volt meter 2, scale which corresponds to the closed jack 26, or 28;

I. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

J. The negative grid voltage should be indicated on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the grid jack 30. If the grid of the radio tube socket being analyzed is resistance coupled to the preceding stage, a more accurate reading of the applied grid voltage will be indicated by connecting a test lead between the grid contact of the unoccupied *load socket* 19, and the *grid return* which is usually the grounded chassis of the radio.

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not include the filament voltage and should be recorded as the correct grid or plate voltage respectively.

Load Tests.—The load test of any device is the most reliable test. A comparison of the *load* test of any electrical device with its *no load* test is a fairly reliable index to the internal resistance of the device.

When a tube is placed in the *load socket* during analysis with the radio in operation, the current drawn by the tube will be shown on the milli-ammeter. This reading may be compared with the tables published by tube manufacturers.

If there be a radical departure from the specified current reading it indicates a defective tube, or improper relation between the B and C voltage of the radio. The latter is not an unusual trouble where socket power devices are attached to radios originally designed for battery operation. Wherever this trouble is encountered, the B voltage should be adjusted to the proper value for the C voltage used. Otherwise the tubes will be subjected to strenuous usage, and the reproduction will not be satisfactory in quality.

When taking voltage readings, it may be noticed that the milli-ammeter may show a slight deflection, indicating the load of the volt meter, which, with the 1000 *ohm per volt* volt meter, will be 1 milli-ampere at full scale volt meter deflection. All load readings taken with the testing set will be accurate within about 2%, this slight variation being accounted for by the losses encountered in the analyzing cord leads.

Setting up the Analyzer.—The following procedure constitutes the preliminary procedure for putting the *analyzer* circuits in operation:

1. Remove the oscillator coil from its prescribed operating position.

2. Open all switches.

3. Disconnect the *a.c.* supply cord and clear all jacks from contact with any electrical conductor which might be grounded or directly connected to the common alternating current supply system, thereby avoiding any possibility of electrical harm to the testing set or to the radio.

4. Open the power supply switch of the radio to be analyzed.

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Filament Circuit Analysis.—While analyzing, the UX heater switch, located between the testing set tube sockets, is thrown to UX position for analytical tests from radio tube sockets which do not utilize tubes with independent cathode emitters. For all tubes with independent cathode emitting elements, including *top heater* tubes, the switch is thrown to the *heater* position.

Fig. 7,404.—Supreme set analyzer. It makes available a great number of tests and provides 79 readings.

A special plug adapter is used for plugging into UY sockets. With the plug in the first socket and the tube laid aside, close the proper *Fil.* switch which will measure the filament voltage.

If testing in a *d.c.* tube socket, the needle of the *d.c.* volt meter may back off the scale, and the pole changer should be depressed to obtain correct readings; this will indicate the direct current voltage available at the filament terminals, and if the rheostat be turned on full and the other tubes removed, it will also indicate the *no load* A battery voltage.

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If testing in an *a.c.* socket, the reading will indicate the voltage available on open circuit. The reading obtained in either case should be recorded. With the plug still in the radio socket, place the tube in the *load socket* of the *analyzer* and again read the filament voltage, It is important that this reading be close to that for which the tube is rated; if it is above the rated voltage, the life of the tube will be correspondingly short, whereas if it is very much below the rated voltage, proper results will not be obtained. If an adjustment be possible with the radio being analyzed, proper adjustment should be made.

The best results will be obtained with the filament voltages at, or just below, their rated voltage.

Failure to obtain any filament reading will indicate an open or shorted filament circuit, with the following causes:

A battery exhausted

Open rheostat

Poor connection

Defective filament switch

Open primary or low voltage secondary of *a.c.* power transformer

Blown fuse

Poor socket contacts

Plate Circuit Analysis.—Plate voltage readings may be taken with or without the tube in the *load socket*. Before taking either voltage, open the *Fil.* switch.

Close one of the *plate switches* using the one which will best accommodate the voltage to be read and at the same time give a good discernible reading. The reading obtained with the tube in the *load socket* will be less than the reading obtained without the circuit loaded. This difference is occasioned by the internal resistance current drop of the B supply device, and it is, to a certain extent, except in detector sockets, an index to the condition of the apparatus supplying the plate voltage. If this voltage drop materially exceed 1 volt per milli-ampere drawn by the tube, the B batteries should be replaced, or the rectifying tube in the plate supply device should be replaced.

If means be available for adjusting the voltage in socket power devices, the plate voltage should be adjusted to that specified for the particular tube and the particular socket which is being tested. The readings obtained should be recorded.

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The plate current under load conditions is a very good index to the operating condition of the plate circuit, the current being the result of the voltages applied to the grid and plate circuits.

Decreasing the grid voltages has more effect, other factors being equal, on increasing the plate current than may be had by increasing the plate voltage.

Failure to obtain proper readings may be caused by any of the following troubles:

Weak or exhausted B batteries
Open primary winding of transformer
Open series plate resistor
Shorted by pass condenser
Loose connection
Loose or broken socket contact
Defective rectifier tube

Grid Circuit Analysis.—In radios employing batteries for supplying C bias, practically the same reading should be obtained without the tube in the *load socket* as with the tube in the *load socket*.

This is because the grid circuit has practically no current flow.

In radios employing biasing resistors, the correct voltage reading on the bias can be had only when the tube is in the *load socket* and the bias voltage should be read with the *grid* switch closed for the highest scale of the *d.c.* volt meter which will afford a discernible reading.

With the plug in the radio socket and the tube in the *load socket*, closing the *grid* switch will throw the volt meter across the grid and one of the filament contacts of the radio tube socket. The pole changer switch should be closed for each reading, and the lowest reading should be taken as the correct bias reading, as one of the readings may include the voltage of the filament.

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In *d.c.* radios, a reversed A battery may be indicated by the backing off scale of the *d.c.* volt meter needle when the *grid* switch is closed.

If no reading be obtained when the *grid* switch is closed after having tried the pole changer in both of its positions, the following sources of trouble should be investigated, except in radios employing synchrophase circuits; *a*, Open transformer, low voltage secondary; *b*, Open grid suppressor; *c*, Open grid bias resistor; *d*, Poor grid contact in tube socket.

When analyzing from the detector socket of a radio, it will usually be found that a very low voltage reading is obtained.

This is due to the fact that a grid leak is usually employed in series with the grid for grid leak detection, and is of such high resistance that it lowers the reading of grid voltage. The grid leak resistance may be temporarily shunted if it be desired to get a true grid voltage reading.

Cathode Circuit Analysis.—A cathode switch is provided for obtaining voltage readings of the cathode bias employed in 4 and 5 element tubes.

Cathode circuits are rarely the source of radio troubles, but the readings obtained should be recorded and compared with the specifications for the tube and tube socket analyzed. No reading, where cathode biasing resistors are known to be employed would indicate an open resistor, and a low reading would indicate a partially shorted resistor. If no means be available for reading the cathode bias, a defective bias would probably be indicated by excessive hum.

Screen Grid Analysis.—This is accomplished by plugging into the socket to be analyzed, connecting the clip, which ordinarily connects to the top of the tube, to the large control grid lug close to the top of the analyzing plug.

The screen grid tube is placed in the *load socket* in the usual manner, and one of the clip pin plug leads is used for connecting the control grid contact of the tube to a corresponding pin jack on the instrument panel.

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Overhead Heater Filament Analysis.—The procedure is similar to that for *screen grid* analysis, except that the *trolley* contacts are connected to the *trolley* contact lugs on the analyzer plug, and two clip pin plug leads are used for connecting the filament contacts of the tube to corresponding *overhead filament* pin jacks on the instrument panel.

Distortion Tests.—With analyzer plugged into last audio amplifying stage, with all testing set switches open, the action of the milli-ammeter is a fair index to the degree of distortion in the audio circuits. The ideal condition is to have the needle steady regardless of the signal fluctuations.

If the needle deflect upward with the signal impulses, it is an indication that the C voltage is too high for the B voltage being used, or that the B voltage is too low for the C voltage being used.

If the needle deflect downward for each signal impulse, it is an indication that the C voltage is too low for the B voltage being used, or that the B voltage is too high for the C voltage being used. This test, of course, should only be undertaken when it is known that all of the tubes in the radio are in normal operating condition. The adjustment, if any is possible with the radio being analyzed, will be obvious from the above description. The technical analysis of the causes of the distortion involves a study of the graphs plotting the characteristics of tubes, which is a very long drawn out discussion.

Analysis Charts.—These charts are arranged in duplicating pads and are very useful for recording the readings obtained during tube socket analyzing.

A copy of each chart may be kept for future reference on any radio. Radical readings will be indicated by comparison with other charts on the same type of radio. These charts have space provided for the *power plant* tube tests which should precede the analysis of any radio.

Input Circuit.—After completing the analysis of the tube circuits of a radio, the service man should turn his attention to the circuits of the radio system which are not amenable

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to tests by means of the tube socket analyzing methods just described.

The efficiency of these circuits can best be determined by tuning the radio to a modulated radio frequency signal known to exist within pick up distance of the radio.

The *modulated radiator* of the testing set affords an excellent means for setting up the modulated radio frequency signal for these tests. The necessary procedure for setting up the *modulated radiator* was covered at the beginning of this chapter.

The pick up circuit should first be checked as to efficiency.

This circuit consists of the aerial and the ground or counterpoise system, or of a loop or large pick up coil, or of two or more capacity areas, or of a combination of any two of these systems, coupled to the grid circuit of the first tube of the radio. The continuity of a loop aerial may be determined by socket analysis where the loop circuit is directly coupled to the first radio tube, but it is sometimes found that loop aerials are capacitively coupled to the tube circuit, in which case the continuity of the pick up loop cannot be determined by tube socket analysis.

Where the pick up circuit consists of an aerial and ground or counterpoise, no voltage is applied between the two, and even where the antenna is connected directly to the grid of the first tube, an open or shorted pick up circuit cannot be detected by tube socket analysis.

The antenna of the radio being tested should conform as nearly as practicable to the specifications of the manufacturer of the radio.

A comparative test of the pick up capabilities of the antenna may be had by tuning the radio to the *modulated radiator*, and then disconnecting the antenna. The signal strength should fall off when the antenna is disconnected, or a loud *clicking* sound should be emitted from the loud speaker when the aerial is disconnected and tapped on the antenna binding post of the radio. The absence of a strong *clicking* when this is done with the volume control of the radio at its normal setting, usually indicates an inefficient aerial circuit.

The ground circuit should be checked in a similar manner, although there should be a very perceptible drop, amounting to about 50%, in audibility when the ground is disconnected. If there be but slight change in signal strength with the ground lead removed, new grounds should be

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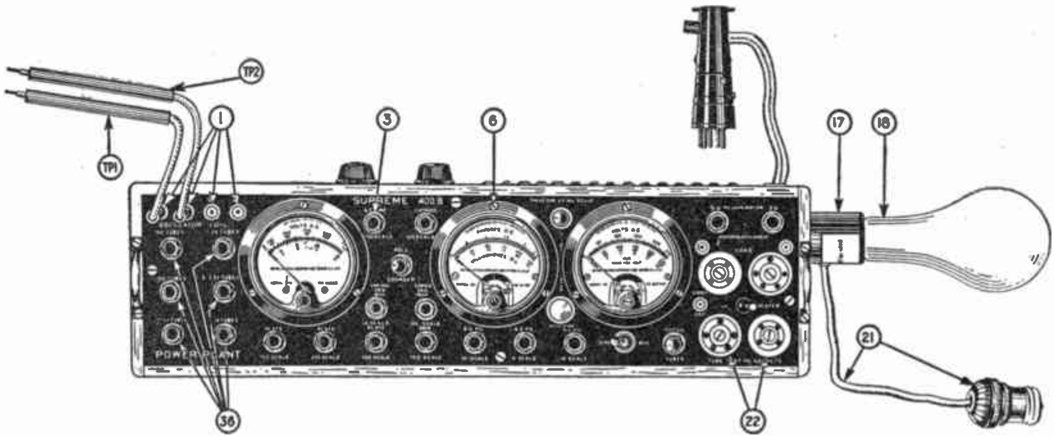

FIG. 7,405—Supreme continuity tests. ***Medium and high resistances.***

Medium resistances:

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert test probes TP1, and TP2, in the two left side B, and P, oscillator coil pin jacks 1;

F. Place a thermionic rectifier tube, such as the '81 or '80 type, in the UX tube testing socket 22;

G. Close a power plant jack 36, the voltage marking of which corresponds to the filament voltage rating of the tube used;

H. Closing the circuit with the free ends of the test leads will cause the plate current of the tube to be shown on the milli-ammeter, indicating continuity of the testing set plate circuit with the external circuit under test. This test should not be undertaken on

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tried on the radio. A high resistance ground is a very common cause of low audibility. In localities where one side of the *a.c.* supply system is grounded, the ground lead of a radio may be determined by connecting a lamp or *a.c.* volt meter between the ground lead and the ungrounded side of the line. This is also an excellent means for determining whether or not the antenna is shorted to the ground lead. This method also affords a very convenient means for differentiation between the antenna and ground leads when it is not convenient to differentiate them by visual inspection.

FIG. 7,405.—*Text continued.*

a grounded radio or other grounded apparatus. This precaution is necessary for meter protection where the protective lamp 18, may be in the grounded side of the *a.c.* supply system;

I. This hook up may be used for measuring medium resistances, as outlined on pages 4,615 and 4,617.

NOTE.—*Continuity tests. High resistances* (fig. 7,405). For determining continuity through high ohmic resistances in either reactive (inductive and capacitive) or non-reactive circuits, and for the testing of condensers, but without the use of any battery, the following procedure is recommended:

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzing plug 10, from contact with any electrical conductors which may be grounded or connected to the common *a.c.* suppply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should be used in the series socket adapter 17, the milli-ammeter 6, might be harmed;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Place an '80 tube in the *UX* tube testing socket 22;

E. Insert the grooved rejuvenator plunger to the half way *aging* position in the 3v. rejuvenator jack 15. This will apply a filament voltage of about 3.3 volts to the '80 tube;

F. Insert a jack plunger in the *a.c. line jack* 3. The supply voltage should then be indicated on the *a. c.* volt meter 2;

G. Insert a second jack plunger in the *control grid bias* jack 32;

H. Connect a jumper between the *screen grid* 23, pin jack on the panel and one of the 500,000 ohm pin jacks I, on the back of the instrument tray;

I. Connect a jumper between the B and P oscillator coil pin jacks 1, on the panel;

J. Connect a test probe to the unoccupied 500,000 ohm pin jack K, on the back of the instrument tray;

K. Connect a test probe to the common *a.c.* pin jack L, on the back of instrument tray;

L. While touching the free ends of the test probes together, adjust the 500,000 ohm control knob Y, located on the back of the instrument tray, for a full scale needle deflection on the *d.c.* volt meter 8. The variable resistance has the effect of increasing the internal resistance of the 10 scale of the *d.c.* volt meter to a value of about 50,000 ohms for accommodating the applied rectified effective voltage of about 50 volts;

M. This test should not be undertaken on a grounded circuit. The common *a.c.* pin jack L, on the back of the instrument tray is connected to one side of the primary winding of the power transformer during this test, and grounding the test probe connected to this pin jack would probably short circuit the *a.c.* supply system in localities where one side of the *a.c.* supply system is grounded.

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Lightning arresters should always be checked for shorted electrodes.

Stapling the antenna and ground leads together on base boards is a very common source of trouble with antenna ground shorts.

Output Circuit.—This consists of the loud speaker, or other

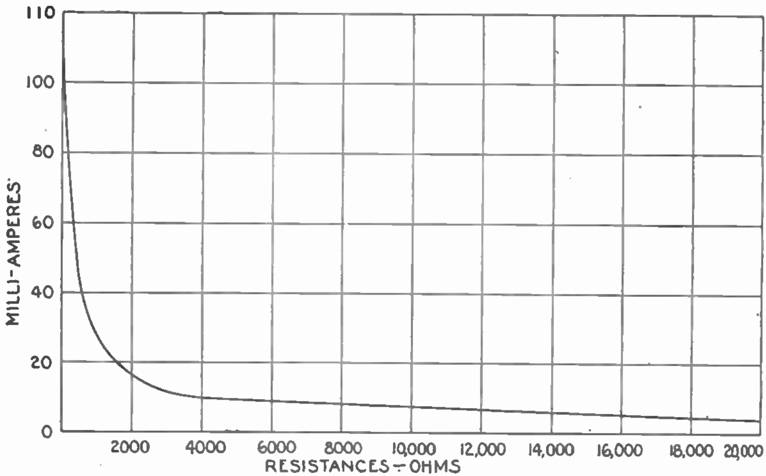

FIG. 7,406.—Resistance current curve plotted with the *continuity tester*, set up as outlined on page 4,615, utilizing an X-80 tube having a plate reading of 100 milli amperes with test probes touched together; that is, with full plate current load. *Example!* the 100 scale of 1,000 ohms per volt *d.c.* volt meter of the Diagnometer is used with a 45 volt B battery for measuring an unknown resistance. The internal resistance of the volt meter with this scale is 100,000 ohms. A reading of 30 volts is obtained across the battery, and a reading of 20 volts is obtained with the volt meter, battery, and unknown resistance connected in series.

NOTE.—In fig. 7,406 the formula to be used is:

$$R = r\left(\frac{V_1}{V_2} - 1\right)$$

where R = Unknown resistance r = Internal resistance of volt meter; V_1 = Unloaded voltage of battery or batteries in series, and V_2 = Reading of volt meter when in series with battery or batteries and unknown resistance.

Substituting: $30 \div 20 = 1.5$; $1.5 - 1 = 0.5$; $.5 \times 100{,}000 = 50.000$ ohms.

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device for audible reproduction, and the circuit which couples it to the last audio frequency stage of the radio.

In most of the earlier types of radios the loud speaker is directly coupled in series with the plate circuit of the last audio tube, and the continuity of the output circuit in such radios may be determined by tube socket analysis.

In most of the more recent models of radios, wherein the last audio plate voltage exceeds 135 volts, the loud speaker is usually indirectly coupled to the last audio stage, and a test of the output circuit cannot be made from a radio tube socket. In either of these types, the efficiency of the output circuit can best be determined by tuning in signals on the radio. If no other apparent defects exist in the radio system, and the loud speaker do not perform satisfactorily, the loud speaker circuits can be tested for opens and shorts with the *continuity tester*.

Loud speaker windings should not be required to carry a current load in excess of that specified by the speaker manufacturer.

In the absence of specifications to the contrary, the last audio or power tube chosen and the grid and plate voltages applied thereto should be such that the speaker load should not exceed 10 milli-amperes. If the plate current of the last audio-amplifying tube exceed this value, some type of filter circuit is generally required to protect the loud speaker windings from overload currents. A '71-A tube should not be substituted for a '12-A in an audio stage without changing the grid bias voltage to correspond to the tube to be used. This change in grid bias voltage must not affect the grid bias voltage of other tubes.

Some radios were designed for using a '01-A tube as the first audio amplifier, and a '12-A as the second audio, using 135 volts plate voltage and 9 volts grid bias on both tubes. If the '12-A be replaced with a '71-A, the 9 volts grid bias would be incorrect for the '71-A, while a change to 27 volts grid bias for the '71-A would place an incorrect bias on the '01-A used as the first audio tube. Where no filter system is used, the polarity of the loud speaker should be checked with a *d.c.* meter, as a reversed polarity will eventually weaken the magnetism of the speaker magnets.

Putting the Continuity Tester in Operation.—The *continuity tester* is especially adaptable for testing the input and output

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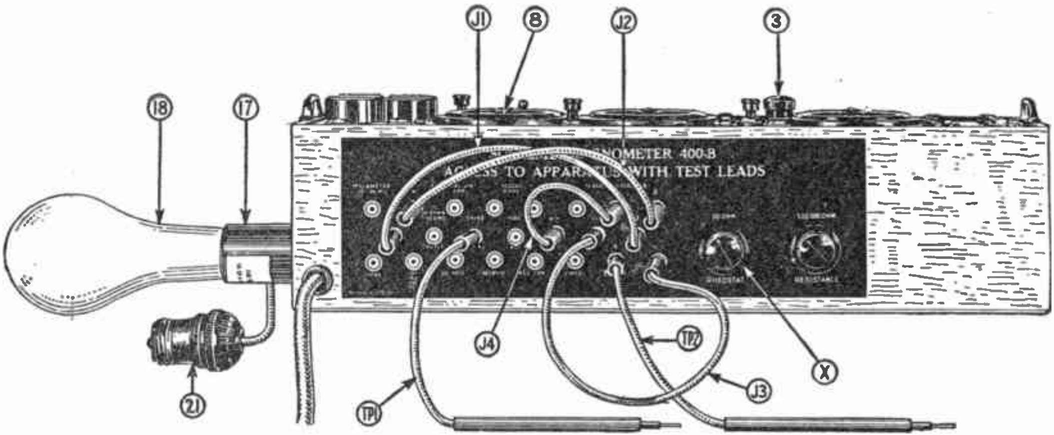

FIG. 7,407—Continuity tests. *Low resistances.*

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Connect jumpers J1, J2, J3, and J4, to the pin jacks as indicated;

E. Insert the jack plunger in the *a.c.* line jack 3;

F. Connect test probes TP1, and TP2, to the pin jacks as indicated;

G. With test probes touched together, adjust 30-ohm rheostat control knob X, for full scale reading on the *d.c.* volt meter 8. The approximate uncalibrated range of the meter in this resistance test is from 0.1 to 25 ohms, depending on the *a.c.* supply voltage. It is very useful in locating defective soldered joints, shorted variable condenser plates without disconnecting *r.f.* coils, and for checking the center tap of filament resistors or for indicating other low resistance values.

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circuits of a radio when these circuits are not supplied with any voltage from the radio power supply system. Care must be exercised, however, not to allow one of the test probes of the testing set to come in contact with a grounded conductor.

With the *modulated radiator* in operation, the following steps are required for putting the *continuity tester* in operation.

1. Disconnect apparatus to be tested from both the *a.c.* line and all grounded objects. This is a very necessary precaution for meter protection.

2. Remove the oscillator coil from its prescribed pin jack position.

3. Plug two test cords in the two left side (B and P) oscillator coil pin jacks.

4. Place a thermionic rectifier tube, such as the '81 or '80 or other heavy current tube, in one of the *tube testing sockets*.

5. Close the *power plant* jack switch, the voltage marking of which corresponds to the filament voltage specified for the tube used.

6. Closing the circuit with the free ends of the test leads will cause the plate current of the tube to be shown on the milli-ammeter, indicating continuity of the testing set plate circuit with the external circuit under test.

Any three or four element tube capable of showing comparatively good discernible plate current readings, such as the '71-A, '12-A, '26 and '01-A types, may be used with its corresponding *power plant* switch closed instead of rectifying tubes for this test, by connecting a jumper between the two oscillator coil pin jacks which are not occupied with the test probe leads.

The *continuity tester* is adaptable for testing the input and output circuits of a radio when these circuits are not supplied with any voltage from the radio power supply system so that they may be tested with the *analyzer* from tube sockets. It is also useful for testing for loose contacts in circuits.

Synchronizing Procedure.—Having determined that the tubes, tube circuits, and the input and output circuits of a radio are in their proper conditions, the next step in servicing should be to check the synchronous relation of the tuning condensers. The two methods of obtaining a meter indication of resonance are shown in fig. 7,408.

World Radio History

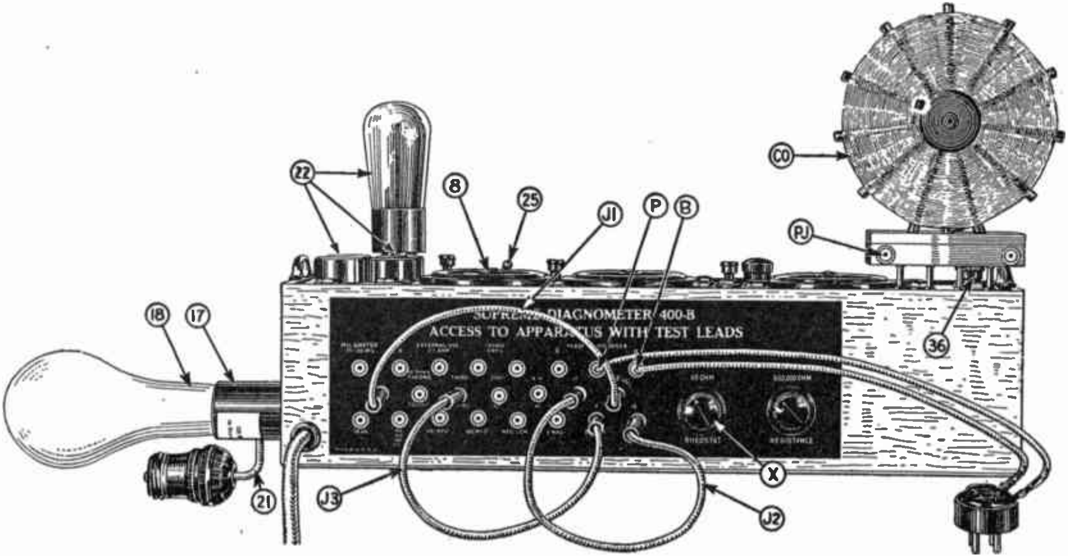

FIG. 7,408—Supreme synchronizing without meters. ***Thermo-couple output meter synchronizing.***

Letters in parentheses refer to fig. 7,397, page 4,588.

A. Put the modulated oscillator in operation as in fig. 7,398;

B. Set the 30-ohm rheostat control (X), in its approximate center position;

C. Connect jumpers (J1), (J2), and (J3), to the pin jacks as indicated;

D. Connect the synchronizing (plate break) adapter terminals to the P and B, pin jacks, on the back of the instrument tray. (When synchronizing radios designed for magnetic speakers, the loud speaker terminals of the radio may be connected to the P and B, pin jacks, instead of using the synchronizing (plate break) adapter.)

World Radio History

FIG. 7,408.—*Text continued.*

E. Remove a tube from the last audio stage of the radio and insert the tube in the adapter. Place the adapter in the vacant audio tube socket;

F. Rotate the tuning knob of the radio while adjusting the 30-ohm rheostat for the desired needle deflection which will occur on the *d.c.* volt meter 8, as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator. When using the synchronizing (plate break) adapter in push pull stages, the needle deflection of the meter may be increased on some radios when the push pull socket not occupied by the adapter is left vacant during the synchronizing operations;

G. Adjust the coupling between the diagnometer and the radio for the desired signal strength;

H. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

NOTE.—*Thermo-couple output meter measurements* (fig. 7,408). By omitting sections A, F, G, H, in fig. 7,403, this hook up may be used for comparing the gain of any two audio amplifiers in the following manner;

A. Remove the aerial and ground leads from the radio under test;

B. Remove the detector tube of the radio;

C. With suitable test leads, apply an audio frequency signal to the plate and cathode contacts of the vacant detector socket. For these comparisons, the ordinary 110 volt 60 cycle power supply may be used for supplying the audio signal voltage;

D. The same tests may be accomplished with the *a.c.* volt meter by similar modifications of the following procedures.

NOTE.—*Low impedance output a.c. volt meter synchronizing* (fig. 7,408).

A. Put the modulated oscillator in operation in the manner outlined in fig. 7,398;

B. Connect the *plus or minus a.c.* L, and the 1 *mfd.* U, external pin jacks of the diagnometer to the voice coil terminals of the radio;

C. Close the 4 volt *a.c.* filament jack 28;

D. Throw the *UX-heater* toggle switch 20, to the *heater* position;

E. Rotate the tuning control of the radio. A decided *a.c.* volt meter 2, deflection will occur as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator;

F. Adjust the coupling between the diagnometer and the radio for the desired signal strength;

G. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

NOTE.—*High impedance output a.c. volt meter synchronizing* (fig. 7,408).

A. Put the modulated oscillator in operation in the manner outlined in fig. 7,398;

B. Connect a jumper between the *third winding* H, and *plus or minus a.c.* L, external pin jacks;

C. Connect a jumper between the 30 *ohm* E, and 1 *mfd.* U, external pin jacks;

D. Throw the *UX-heater* toggle switch 20, to the *heater* position;

E. Close the 4 volt *a.c.* filament jack 28;

F. Connect the synchronizing (plate break) adapter terminals to the P, and B, pin jacks on the back side of the instrument tray. When synchronizing radios designed for magnetic speakers, the loud speaker terminals of the radio may be connected to the P, and B, external pin jacks, instead of using the synchronizing adapter.

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Volt Meter, A.C. Low Scales.—The pin jack connections of the testing set afford external access to a low scale of the *a.c. volt meter*, the scale range being determined by the closed *a.c.* filament jack. The current required for full scale deflection on each of the low ranges is approximately 100 milli-amperes.

Neutralizing Procedure.—The neutralization of tuned radio frequency radios provided with adjustable neutrodon condensers may be accomplished as follows:

1. Place the *modulated radiator* in operation in the manner previously described.

2. Connect antenna and ground to radio to be neutralized.

3. Put radio in operation at its maximum volume.

4. Tune the radio to a strong modulated harmonic at a frequency between 1,350 and 1,500 kilocycles, or between whatever other frequency limits prescribed by the manufacturer of the radio to be neutralized.

5. Move testing set far enough away from the radio so that inductive reactions will not occur between the radio and the testing set; but if the signals cannot be picked up, move the instrument closer to the radio, use a better oscillating tube, or use an insulated coupling lead brought in close proximity to the oscillator coil and the antenna lead in of the radio.

6. Adjust each neutrodon for maximum signal strength so as to increase pick up.

NOTE.—FIG. 7,408.—*Continued*.

G. Remove a tube from the last audio stage of the radio and insert the tube in the adapter. Place the adapter in the vacant audio tuhe socket;

H. Rotate the tuning knob of the radio. A decided *a.c.* volt meter 2, deflection will occur as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator. When using the synchronizing adapter in push pull stages, the needle deflection of the meter may be increased on some radios when the push pull socket not occupied by the adapter is left vacant during the synchronizing operations;

I. Adjust the coupling between the diagnometer and the radio for the desired signal strength;

J. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

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7. Remove the tube of the radio frequency stage nearest the detector.

8. If the radio be wired with its tube socket filament connections in parallel, place the tube in the *neutralizing adapter* and replace in the radio socket; or substitute a *dummy* tube (*i.e.*, a good tube with one of the filament prongs cut off) of the same type in the socket.

9. If the radio be wired with its tube socket filament connections in series, temporarily strap the filament prongs of the tube together and replace it in its socket.

10. If the signal remain audible, the internal capacity of the cold tube is probably by-passing the signals which should be tuned to maximum strength.

11. Slowly adjust the neutrodon which corresponds to the cold tube stage, using a fibre wrench or fibre screw driver to minimize body capacity effects, until the signal disappears entirely or is reduced to minimum audibility.

12. The stage in which the cold tube is located will then be neutralized, and the cold tube should be removed and replaced by the original tube.

13. Proceed in a similar manner with each of the stages in order until all of the radio frequency stages are neutralized.

The degree of accuracy attained when using a *dummy* tube for neutralizing parallel filament radios is determined by the degree of uniformity of the internal capacities of tubes.

It cannot be expected that all tubes, even of the same type, will have the same internal capacity as the *dummy* tube chosen for neutralizing purposes. It is frequently found that an adjustment for neutralizing one tube is an improper adjustment for another tube.

Calibrating.—Every broadcasting station operates upon a particular frequency, assigned to it by the Federal Radio Commission. Each channel is designated by the middle frequency.

With the aid of a graph, plotted to a few representative dial settings corresponding to known frequencies, it is possible to tune to any desired broadcasting station within the pick up distance of the radio, when the frequency at which that station broadcasts is known.

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To make a dial calibration graph, tune to at least five or six stations at settings throughout the complete range of the tuning dial.

While receiving each station, listen for the announcer's statement of the frequency that his station is using. Then record this frequency and the corresponding dial setting. With this data plot a curve and from the curve the dial settings for a desired station may be obtained.

Having a particular radio calibrated in the manner described above, it is a simple matter to chart the harmonics of the testing set.

Once the frequencies of the *modulated radiator* harmonics are known, the testing set may be used instead of broadcasting stations for plotting other dial calibration graphs for other radios, or for checking the accuracy of the calibration of radios the dials of which are already calibrated in kilocycles, wave-lengths, or both.

Final Check Up.—As a final check up on each completed service job, it is recommended that the *modulated radiator* be set up and each of its harmonics tuned in.

The radio man should soon acquaint himself with the relative strength of these signals, and the audible pick up response of the average radio to these signals. Dial calibration, as described above, affords an excellent final check up on the operating characteristics of a radio.

Sources of Radio Trouble.—The following trouble list will afford a quick reference guide for the service man during the process of servicing. The source of the trouble may frequently be found by reference to the list.

When

All tubes fail to light

A battery discharged;

Open rheostat;

Poor battery connection;

Broken lead in battery cable;

World Radio History

Poor switch;

Burned out tubes;

Open primary of power transformer (*a.c.* set);

Open in *a.c.* lead cord;

Fuse blown.

Part of tubes fail to light

Open rheostat;

Dead tube;

Open in power secondary;

Poor socket contact.

No reception (set dead)

B supply dead or defective;

May be B batteries down, open in power secondary, defective rectifier tube, shorted power supply condenser, open choke in power unit, defective resistor in power unit, open in plate cable lead;

A battery connections reversed;

Open primary of radio frequency transformer;

Open primary of audio frequency transformer;

Shorted grid condenser;

Open or shorted speaker cord;

Shorted by pass condenser;

Defective tube;

Open or shorted speaker choke;

Open circuit in wiring;

Short circuit in wiring;

Tube prongs not making contact in socket;

Grid resistors open;

Short between aerial and ground leads;

Shorted lightning arrester.

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Weak reception

- Defective tube
- A or B voltages low
- Corroded battery connections
- Partially shorted audio transformer
- Partially shorted radio frequency transformer
- Open radio frequency transformer secondary
- Leaky audio transformer
- Set out of synchronization
- Poor grid resistors
- Partially shorted power transformer primary
- Partially shorted power transformer secondary
- Poor rectifier
- Poor lightning arrester
- Incorrect eliminator resistor values
- Poor aerial insulation
- Poor ground
- Poor socket contacts
- Defective grid condenser
- High resistance wiring connection
- Speaker weak
- Speaker out of adjustment

Noisy

- A.c. plug loose
- Swinging antenna, grounding
- Poor lightning arrester
- Defective ground connection
- Defective by pass condenser
- Defective tube
- Variable condenser shorted
- Variable condenser dirty
- Defective grid leak
- Defective resistors
- Loose connection in wiring
- Loose contacts in socket
- Defective filter condensers, punctured
- Defective audio transformer, grounded
- Defective eliminator resistors
- Grid resistor open
- Poor battery connections
- Defective B batteries
- Speaker cord shorted, partially
- Speaker cord tips loose
- Speaker unit defective
- Dirty switch contacts
- Volume control worn

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Distortion

Defective A or B power supply or overloaded

Speaker out of adjustment

Poor tube

Incorrect type of tubes

Incorrect battery voltages

C battery disconnected

Incorrect C voltage

Set out of synchronization

Open biasing resistor

Shorted biasing resistor

Poor rectifier tube or elements

High regeneration

Reaction between radio and audio frequency elements

Inter-action between transformers

Acoustic coupling between speaker and set

Poor by pass condensers

Reactive coupling in power leads

Hums or continuous whistle

Defective tube

Speaker too close to set

Defective power supply

Open grid circuit

Low detector voltage

Grounded audio transformer

Open antenna choke

Partially open power transformer secondary

Open filament balancing resistances

Shorted filter choke

Open primary circuit

A.c. plug in wrong position

Cooked winding of power transformer

Ground binding posts not making good ground contact

Grounded choke

Grounded speaker jack

Grounded resistors

Open grid circuits

Open or shorted or grounded by pass condensers

Open resistor

Open leads in cable

Shorts in wiring

Reaction between wiring

Intermittent reception

Poor tube

Loose connections

Poor lightning arrester

Defective grid leak

Open in grid circuit resistors

Corroded connections

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Poor aerial insulation

Poor grounds

Swinging ground or aerial

Weak A battery

Defective rectifier tube or elements

Open biasing resistor

Overheating

Shorted power transformer primary

Shorted power secondary circuit

Continued oscillation

Defective tube

Poor ground connection

Grid resistor shorted

Excess radio frequency plate voltage

Open grid circuit

Antenna lead too close to set

Reaction or poor shielding

Poor radio frequency by pass condensers

Power Pack Tests—Type Variations.—In making tests on power packs, it should be remembered that there are slight variations in circuital arrangements of power packs, and that the manufacturer's diagrams, if avaliable, should be studied for any device under test.

Most power packs employ tapped voltage divider resistances which carry waste or "bleeder" current for improved voltage regulation, while with some there is no continuity from the positive to the negative side of the filter through the divider network.

In the latter types, the whole output of the filter system generally passes through a series of plate circuit resistances, and through the tubes and biasing resistors employed in the radio, detector, and audio systems.

Power Pack Troubles.—Any defect in a power pack will generally be reflected in the plate voltage and current readings obtained by analysis of the tube sockets of the radio supplied by the power pack, and such an analysis should precede any *power plant* tests.

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It follows that normal load voltages applied to the various tube sockets of the radio should generally indicate normal power pack conditions. There are possible exceptions, however, as in the case where a few shorted windings in the power transformer may cause excessive heating of the transformer without negligible variations in the output voltages of well regulated power packs.

Transformer Defects.—The operation of the modern type of radio is usually controlled by an *on off* switch which opens or closes the power transformer primary. Obviously, an open primary circuit of a power transformer would result in no voltages in the secondary circuits of the power transformer.

Shorted turns in any of the transformer windings would cause excessive heating of the transformer, with lowered voltages across the secondary circuit in which windings are shorted. In the case of the center tapped full wave rectifier plate secondary, shorted windings on either side of the center tap will result in an unbalanced condition, the voltage applied to one plate being lower than that applied to the other plate. An open in the center tap lead would result in no voltages applied to the filter system.

Filter Defects.—Some radios employing dynamic speakers utilize the field windings of the speaker as a part or all of the choke in the filter circuits of the power pack. An open choke will result in no output voltages.

A similar result will be obtained when the other side of the filter is open. Shorted windings within the choke may cause excessive output voltages with hum. Filter condenser leakages reduce the output voltages, a shorted condenser across the filter system resulting in no output voltages, and an analysis from the rectifier tube socket would reveal excessive rectifier plate current.

An open filter condenser would probably introduce hum in the loud speaker output.

Some power packs include by pass condensers between the grounded or negative side of the filter and each plate voltage tap. A leaky or shorted by pass condenser would reduce the voltage available between the corresponding tap and the common negative side of the filter and voltage divider system.

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Voltage Divider Defects.—Some power packs are designed so that the *bleeder* or waste current through the voltage divider exceeds the load current of the radio to be supplied with the power pack. The most common voltage divider defects are open circuits.

An open divider results in no plate voltages on tubes supplied with a lower or intermediate plate voltage, with excessive plate voltage on the power or other tubes supplied with the higher plate voltages. A shorted plate circuit by pass condenser would result in a shorted section of the voltage divider system.

Grid Biases.—In some radios, the grid biasing resistors are included in the power pack. An open grid bias resistor has the effect of opening the plate circuit of the tubes biased with the resistor. A short circuited or leaking by pass condenser loses its by passing qualities, and if connected across a biasing resistor, the effective resistance of the bias is lowered, resulting in excessive plate current in the tubes depending on the resistor for grid bias.

Diagnometer Tests.—The plate current of rectifier tubes may be measured in the same manner as employed for other tubes. However, when analyzing from thermionic full wave rectifier tube sockets, the current of only one plate can be determined.

With a normal tube and properly functioning power pack, the total rectifier plate current would be double the value obtained. The 750 volt scale of the *a.c.* volt meter is helpful in making tests of the *a.c.* voltages applied to rectifier plates, and for determining unbalanced plate secondaries. Such tests should be made from plate to plate in full wave rectifier sockets, and from each plate to the rectifier filament, the chassis, or radio cathode circuits. The *a.c.* plate voltages should be the same for each plate of full wave rectifier tube sockets, and each voltage should be about half that indicated from plate to plate.

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The high voltages encountered in power packs necessitates caution in such tests so as to prevent bodily harm. In any test the isolation of defects is facilitated if the manufacturer's service data be available.

TEST QUESTIONS

1. *What kind of an outfit should a service man be provided with to properly test radio sets?*
2. *What is the first step in servicing?*
3. *What equipment is used with testing sets?*
4. *Describe the method of putting the testing set with its various attachments into operation.*
5. *Describe methods used in testing tubes.*
6. *How are tube socket circuits tested?*
7. *Explain the method of screen grid tube socket analysis.*
8. *What is the object of making no load and load voltage tests?*
9. *Describe filament circuit analysis.*
10. *What does failure to obtain any filament reading indicate?*
11. *How are plate voltage readings taken?*
12. *Explain fully the method of plate circuit analysis.*
13. *Explain grid circuit analysis.*
14. *How is the correct voltage reading on the bias obtained in radios employing biasing resistors?*
15. *What kind of voltage reading is obtained when analyzing from the detector socket and why?*

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16. *Describe the cathode circuit analysis.*
17. *How is a defective cathode bias indicated?*
18. *Explain the method of screen grid analysis.*
19. *How is overhead heater filament analysis made?*
20. *Describe distortion test.*
21. *How should lightning arresters be checked?*
22. *How should the output circuit be tested?*
23. *Describe synchronizing procedure.*
24. *Describe neutralizing procedure.*
25. *How is a dial calibration chart made?*
26. *Name the multiplicity of sources of radio trouble.*

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CHAPTER 184

Radio Compass

The radio compass, invented by F. S. Kolster, is a device with which bearings can be taken in dense fog, snow storms and over distances greatly beyond the horizon with an accuracy equal to that obtained with visible sights, thus eliminating one of the greatest hazards to navigation.

Although light vessels and light houses are maintained along the coast and harbor entrances the world over, they fail to serve their purpose adequately during fog or thick weather.

Light waves do not penetrate fog to any practical distance and sound waves, due to echo effects, are unreliable and cannot be depended upon to indicate either direction or distance. On the other hand electro-magnetic or so-called radio waves, do penetrate fog and can be used through the medium of the radio compass to indicate both direction and distance.

The modern method of obtaining radio compass bearings on shipboard requires the installation of radio beacons on light vessels and light houses in the vicinity of harbor entrances and other places dangerous to navigation, the exact locations of which are clearly shown on all sailing charts.

The radio beacon sends out characteristic radio signals by which the operator of the radio compass may take bearings. Such beacons are under the supervision of the U. S. Bureau of Lighthouses, the sole purpose of which is to maintain aids to navigation.

The navigator of a vessel equipped with a radio compass can take bearings as often as is desired without requesting the cooperation of anyone and without the knowledge of any second party either on board ship or on shore.

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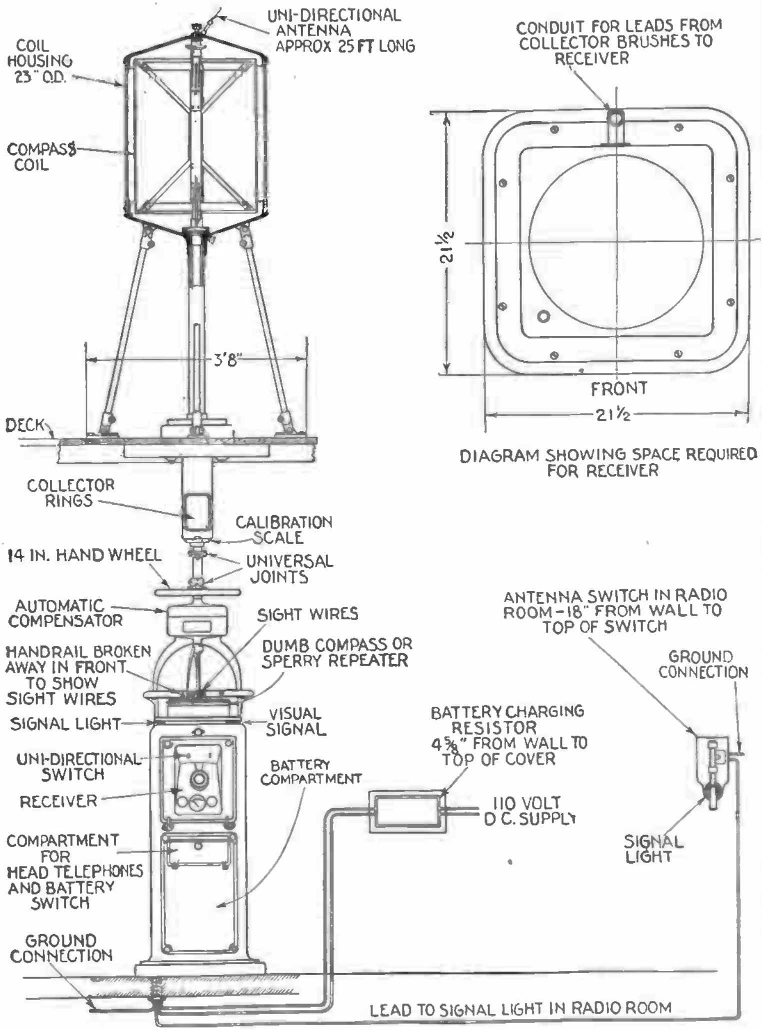

Fig. 7,409 and 7,410.—Kolster radio compass installation.

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Since each vessel is equipped with its own radio compass any number of vessels can take simultaneous bearings.

The compass is direct reading thus eliminating the possibility of error in applying correction.

It is possible for vessels equipped with radio compasses and radio transmitters to safely pass in fog by taking bearings on each other.

A vessel equipped with a radio compass may obtain a leading bearing to another vessel calling for assistance and thereby proceed immediately and directly to the scene of the disaster in either fog or clear weather.

A typical radio compass installation is shown in figs. 7,409 and 7,410.

Radio Compass Construction.—A suitable loop frame is wound with several turns of special radio frequency cable to form a coil. The frame is mounted edgewise upon a vertical hollow shaft which is in turn supported by a ball thrust bearing for ease in turning.

The coil is enclosed within a circular housing in a manner such that it is free to rotate even under the most severe conditions of the wind and sea. This is of value in northern latitudes, where, during the winter months, the ship's superstructure is generally covered with ice. The housing also protects the coil from mechanical damage.

The coil and housing with its stem are mounted on the upper deck, the base of the loop housing projecting approximately six inches above the surrounding hand rail. The assembly is rigidly supported by four braces which may be supplied in various lengths to suit the installation.

The shaft on which the coil is supported extends through a suitable housing to the room in which the compass is located. The leads from the coil pass through the tubular shaft to a set of collector rings. From the collector rings the leads pass through a conduit to the compass receiver which is located in the upper part of the compass binnacle.

At the lower end of the shaft there is attached a pair of sight wires which travel over a compass card or azimuth circle by means of which the angle between the station upon which the bearing is taken and magnetic North, true North, or the ship's direction (depending on the type of installation) can be read directly.

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The sight wires are not rigidly fastened to the shaft but are connected thereto through a simple mechanical device which automatically corrects for variations in the direction of the incoming radio waves caused by the influence of the ship's hull and rigging. This device is called the Automatic Compensator.

Operation.—When the coil is rotated by means of a hand wheel, the characteristic signal from the beacon station will be heard in the telephones with a gradual varying degree of loudness until the plane of the coil is at right angles to the direction of the incoming waves, at which point the signal fades out entirely.

This position of silence is very critical and sharp and therefore indicates with great accuracy the line of direction of the waves. By means of cross bearings on two or more stations or by several bearings on a single station with the distances logged between bearings, the position of the ship can be determined by simple triangulation with an accuracy equal to sight bearings on visible fixed objects.

In obtaining a compass bearing it is essential to eliminate the so called antenna effect of the compass coil. This is accomplished by a simple adjustment on the receiver panel.

Although two bearings 180 degrees apart can be obtained, they do not indicate more than the waves' line of travel and before accurate bearings may be taken it will be required to know the true direction from which the waves are approaching.

To obtain the true direction it is necessary *to unbalance the compass coil by exaggerating the antenna effect.*

This is done by connecting a small antenna, usually not greater than twenty-five feet long, to the receiver through a suitable spring switch, also located on the receiver panel. Normally this uni-directional switch remains open when taking a bearing but when the true direction is desired the operator closes the switch by a slight pressure of the finger and turns the compass coil to the position of maximum signal strength, at which point the

World Radio History

plane of the loop lies in the direction of the signaling station and points toward it as indicated by an index pointer provided for the purpose.

In the construction of the compass one end of the sight wire frame is painted white, further identified by a recessed star, painted grey and referred to as the *star end.* This end should always be turned toward the beacon on which bearings are to be taken.

Visual Indicator.—The method of obtaining a bearing by means of visual indicator consists *in observing the change in brilliancy in the glow of a gaseous conductor lamp.*

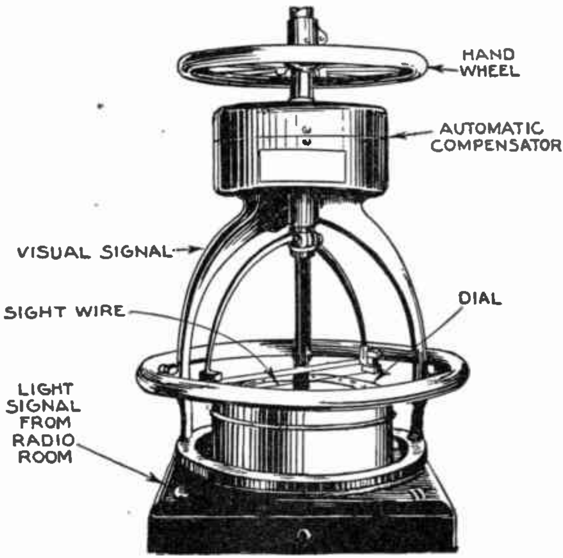

FIG. 7,421.—Kolster dumb compass and compensator.

It will be found that the lamp will cease to glow between two readings of the sight wires, the mean of which will be the true bearing. The width of the compass sector over which the sector is dark will depend on the strength of the transmitting station and the distance from the station to the ship taking the bearing. A reading accurate to within two degrees can usually be obtained over a distance of 25 miles.

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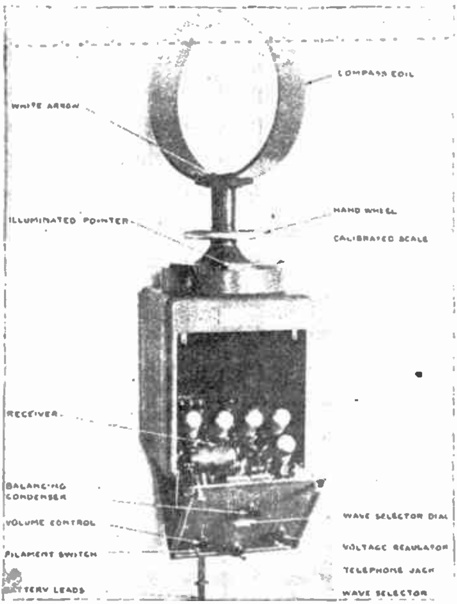

FIG. 7,412.—Kolster radio compass with receiver open. ***In construction*** a suitable coil is formed by winding several turns of a single piece of special high frequency cable in grooves on the periphery of a cylindrical shaped bakelite frame, the ends terminating at a receiver, by means of suitable collector rings, located directly under the coil pedestal. The shaft on which the coil is mounted, is connected to a hand wheel for rotating the compass coil while taking bearings. Directly under the hand wheel is a short pedestal to which a flat circular 360° scale is secured. This scale rotates with the compass coil under a fixed pointer in the form of a glass window with an engraved sight line. The glass window is provided with a low candle power lamp for illuminating the scale under the sight line for use at night. Bearings are read directly from this scale. The zero degree mark must be kept turned toward the beacon on which bearings are taken. For convenience, so as to facilitate locating its position without reference to the engraved figures on the scale, the zero side of the coil is identified by a large white arrow painted on the upper casting of the coil support. ***In operation,*** as the coil is rotated, the characteristic signal from the beacon station will be heard in the telephones with a gradual varying degree of loudness, until the plane of the coil is at right angles to the direction of the incoming wave, at which point the signal fades out entirely. This position of silence is very critical and sharp and, therefore, indicates with great accuracy the line of direction of the wireless waves. The bearing is then read directly from the calibrated scale on the degree mark which registers with the sight line engraved on the glass window. The manner of taking bearings with this type of radio compass is precisely the same as obtaining sights with the pelorus on visible fixed objects. In both cases the bearings obtained are with respect to the ship's head. By reference to the vessel's magnetic or gyro-compass, as the case may be, the position may be plotted by simple triangulation.

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The visual indicator possesses several advantages not possible with the audible system of taking bearings.

As an example; it is possible to orientate the radio compass coil such that a signal transmitted from either a land beacon or a mobile radio beacon installed on another ship will cause the lamp to light up as soon as the vessel comes into a dangerous position. By this means the navigator on the bridge does not have to keep continuous watch on the radio compass but may walk around the bridge, occasionally glancing at the lamp which is always visible when glowing. As soon as the navigator is aware of approaching danger, he can then take a compass bearing, determine the exact position of his ship and act accordingly.

Receiver.—The radio compass receiver is located directly beneath the compass as shown in fig. 7,412 and utilizes *a circuit specially designed to give maximum sensitivity and selectivity.*

The receiver contains seven tubes, large type, so operated that they are equivalent to four stages of radio frequency amplification, a detector and two stages of special design audio frequency amplification. The receiver is designed to operate over a wave length range of from approximately 550 to 1,050 meters.

Tuning is accomplished by a one dial wave selector. The dial having an engraved scale in degrees and lettered to designate the position of three major wave length zones, namely, Radio Beacon (1,000 meters), Navy Compass Stations (800 meters) and Ship Stations (600 meters).

A low candle power lamp is located in the receiver cabinet directly behind the above scale which serves the purpose of indirect lighting, giving a subdued illumination of the dial for night use. The azimuth circle and dumb compass, when supplied is similarly illuminated. The Kolster radio compass can be operated as satisfactorily in a darkened chart or wheel house as during the day.

Should the receiver in the radio room become irreparably damaged, communication could be carried on by using the compass receiver. Its normal receiving range is 250 miles for day and 1,500 miles at night.

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The A and B batteries for the tube filaments and plates respectively are located beneath the receiver at the bottom of the binnacle. The A battery consists of an Edison storage battery which is designed for reliability and long service. A double pole double throw snap switch is located within the telephone compartment directly beneath the receiver by means of which the battery may be connected either to the receiver or to the ship's mains for charging. A charging resistor to limit the amount of current is mounted in some suitable location in series with the ship's supply.

The battery when kept fully charged, has a useful life of approximately eighteen hours continuous service. This reserve is valuable in case the vessel become totally disabled, as the compass could still be operated for a period governed only by the condition of its battery.

The antenna switch and signal light shown in fig. 7,409 are for the purpose of assuring that the ship's main antenna switch is open when bearings are taken.

This antenna switch is normally located in the ship's radio room under control of the radio operator. Red lights on the base of the switch and on the radio compass binnacle indicate that the antenna switch is open. If the light on the binnacle is not lit when it is desired to operate the compass, the navigator communicates with the radio personnel and requests that the antenna switch be opened before taking bearings.

TEST QUESTIONS

1. *Who invented the radio compass?*
2. *How does a radio compass work?*
3. *Is a radio compass direct reading?*
4. *Describe the construction of a radio compass.*
5. *Explain in full detail the operation of a radio compass.*
6. *What is the visual indicator?*
7. *Explain the method of obtaining a bearing by means of the visual indicator.*
8. *Describe the construction of the radio compass receiver.*
9. *How is tuning accomplished?*

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CHAPTER 205

Television

By definition, television is *vision obtained of a distant object through a telegraphoscope or instrument involving the use of selenium cells for telegraphically transmitting a picture.*

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.

Given means for accomplishing these three essential tasks, the problem becomes that of developing these means to the requisite degree of sensitiveness, speed, efficiency, and accuracy, in order to recreate a changing scene at a distant point, without appreciable lapse of time, in a form satisfactory to the eye.

A convenient starting point for the discussion of television is the human eye itself.

In this an image is formed upon the retina, a sensitive screen, consisting of a multitude of individual light sensitive elements. Each of these elements is the termination of a nerve fibre which goes directly to the brain, the entire group of many million fibres constituting the optic nerve.

A theoretically possible television system could be made by copying the eye.

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Thus a large number of photo-sensitive elements could be connected each with an individual transmission channel leading to a distant point, and signals could be sent simultaneously from each of the sensitive elements to be simultaneously used for the re-creation of the image at the distant point. The number of wires or other communication channels demanded in a television system of this sort would be impractically large.

For practical purposes, reduction of the number of transmission channels is made possible by the fact that, while in vision all parts of the image on the

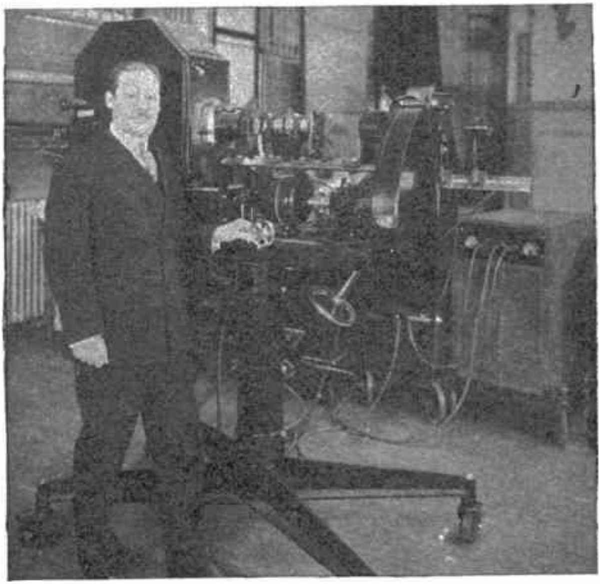

FIG. 7,961.—Dr. E. F. W. Alexanderson, engineer in charge of the radio consulting department of the General Electric Company, with his television apparatus which projects the picture on the theatre screen.

retina are simultaneously and continuously acting to send nerve impulses, the inertia of the visual system is such that a sensation of continuity is obtained from discontinuous signals, provided these succeed each other rapidly enough.

This sensation of continuity is due to what is called the *persistence of vision*. It is immaterial to the eye whether the whole view be presented

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simultaneously or whether its various elements be viewed in succession, provided the entire image be traversed in a sufficiently brief interval. This accordingly permits as a basic principle of television, what is known as *scanning*.

In television *scanning* is defined as *running over the elements of the image in sequence, instead of endeavoring to transmit all of the elementary signals simultaneously.*

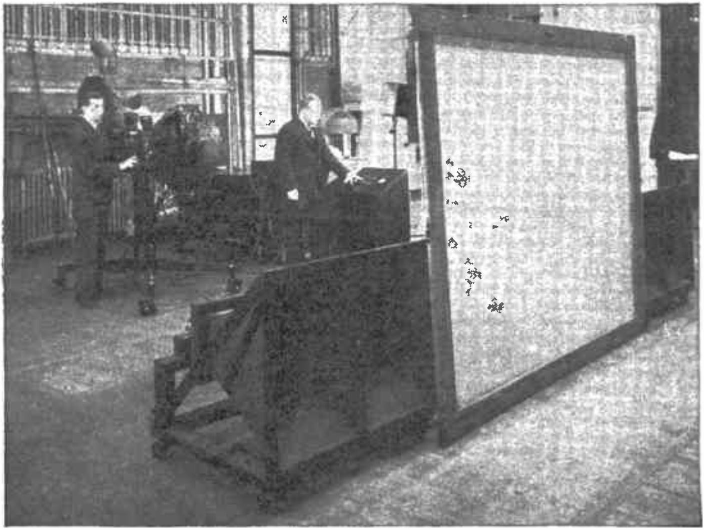

FIG. 7,962.—The 6 by 7 foot screen upon which television pictures are projected, in a Schenectady theatre. When in use curtains are dropped about the sides and top of this special screen.

The development of a television system therefore necessitates, at an early stage, the design of some scanning system by which *the image to be transmitted may be broken up into sequences of signals.*

In the simplest case, where one transmission channel is to be used, the whole image will be resolved into a single series of signals.

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Scanning is accomplished by means of a scanning device which makes possible the decomposing of an image into a large number of small images for the purpose of transmission.

There are two methods of scanning known as:

1. Beam;
2. Direct.

In the original television system, the subject was scanned by a beam of light and the reflected light was employed to actuate the photo-electric cells. The reflected light after being picked up by a bank of large photo-electric cells was converted into variations of electric current. Sufficiently amplified, this current controlled the brightness of a Neon lamp at the receiving station.

The Neon lamp when scanned by a moving aperture in synchronism with the initial beam of light appeared to the observer to re-create the original object. This method had the decided advantage that artificial light could be used at an intensity which would be decidedly uncomfortable for the subject were his whole face illuminated at once.

With the development of photo-electric cells of greater sensitivity, it became possible to illumine the subject broadly by daylight, and allow the photo-electric cell to behold only one small area of the picture at a time. This method is called *direct scanning*.

The direct scanning system requires the broad illumination typical of outdoor scenes. It lends itself to action at a distance from the lens.

Home built apparatus may be constructed which will bring in pictures, if it be properly tuned to and synchronized with a transmitting station which happens to be broadcasting pictures. The system which shows promise for the home construction is that known as the scanning disc.

In construction a number of holes are drilled near the outer surface of a scanning disc in a spiral. The number of holes in the disc determines the number of vertical or transverse divisions in the picture. To secure the best clarity or definition with a given number of small images, or dots, the width of each dot should equal its height. This makes it advisable to have a square image.

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Since the number of holes in the disc determines the number of dots in one direction, and since the picture is to be square, it follows that the total number of dots is equal to the square of the number of disc holes. If, for example, the disc have 48 holes, then the image will be decomposed into 48×48, or 2,304 dots at the transmitting end.

The receiving process recomposes these 2,304 dots of different intensity into an image. These must be reassembled or composed in the same order and at the same speed that obtained at the transmitting end.

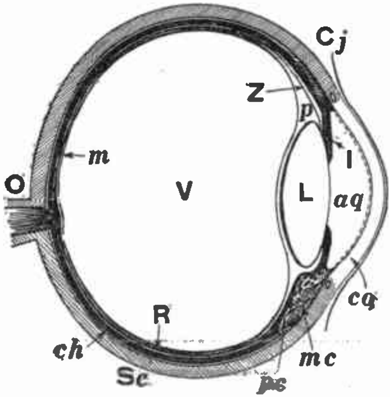

FIG. 7,963.—Section through eye ball. ***The parts are:*** Cj, conjunctiva; co, cornea; Sc, sclerotic coat; ch, choroid coat; pc, ciliary processes; mc, ciliary muscle; O, optic nerve; R, retina; I, iris; aq, anterior chamber containing aqueous humor; L, lens; V, vitreous humor; Z, zonule of Zinn, which supports the lens; p, space known as the canal of Petit; m, position of the macula, or yellow spot.

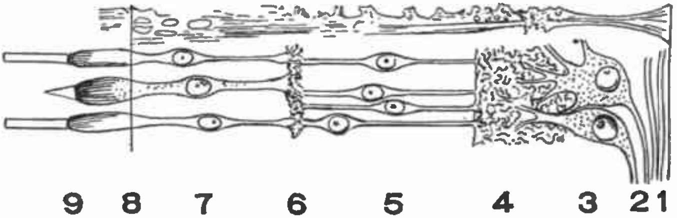

FIG. 7,964.—Diagrammatic section of the retina, showing its various layers, which are numbered as in the illustration. The first layer consists of nerve fibres, the ninth is the layer of rods and cones. The tenth layer, of pigment cells beyond the rods and cones, is not shown.

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Peristence of Vision means that *the electro-chemical process taking place in the nerves and the brain, as a result of a stimulus on the retina, persists for a brief time after the stimulus has been removed.*

Persistence lasts for about one tenth of a second; so if a series of stimuli be applied to the eye at that interval the result will be, not a broken, but a continuous reaction. It is this

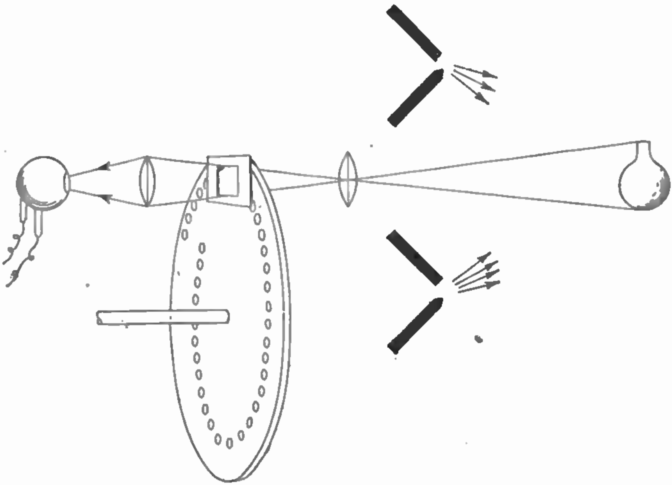

FIG. 7,965.—***Television principles 1.*** Several light sources illuminate the subject; a lens forms an image which is scanned by a spiral of apertures, through which the light falls on a single photo-electric cell.

defect in vision that makes possible motion pictures and television, since the illusion of motion is produced by sending a series of pictures, each of which is a still, at the rate of ten or more a second.

The operation and advantages of the scanning method actually used in the present process for transmitting television

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images may be better understood by first considering a simple and analogous method illustrated in fig. 7,965.

The subject is illuminated by lights placed in front of it as shown. A lens forms an image of the subject on the rotating disc. This disc is pierced with a series of small holes or apertures arranged in the form of a spiral; and, as the disc rotates, the apertures trace across the image one after the other in a series of parallel lines.

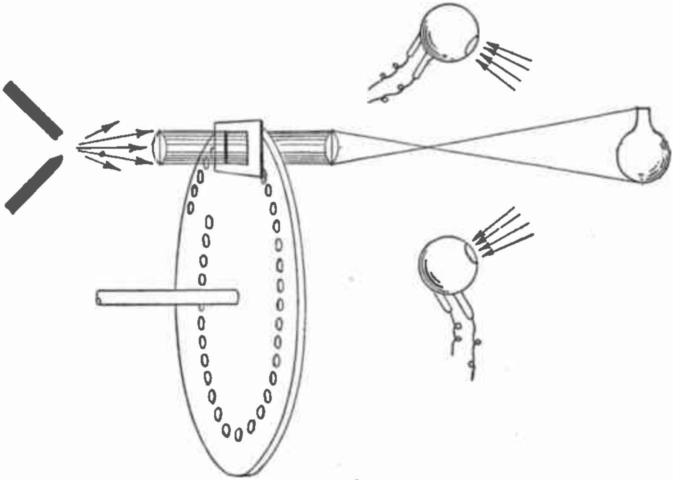

FIG. 7,966—*Television principles 2.* Light from a single source is projected as a small moving spot on the subject; the reflected light is received by several photo-electric cells.

The frame limits the size of the image and prevents more than one aperture being in the image at one time.

Light, passing through an aperture as it travels across the image, falls in the light sensitive cell and generates a picture current proportional to the brightness of the image from point to point along steps taken one after the other across the image.

In any system, such as that outlined above, which depends upon scanning an image of the view as formed by a lens, the efficiency of the system is ultimately limited, for any given

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size of image that can be scanned, by the ratio of aperture to focal length of the best lens that can be secured.

Experiments show that, with the best lens available to form a one inch square image, it would be necessary to illuminate a subject with a 16,000 candle power arc at a distance of about four feet in order to secure an image bright enough for a photo-electric cell to give an output current above the noise level in an amplifier system. In other words, television would apparently be extremely inconvenient to the subject if it were to be carried out from an image formed by a lens.

FIG. 7,967.—Television apparatus. Light from the arc lamp is condensed on the disc, which is driven by a high frequency synchronous motor. The disc carries a spiral of pin hole apertures.

In the system actually used for television transmission, this apparent limitation has been evaded by reversing the entire optical system of fig. 7,965, and arranging it as shown diagrammatically in fig. 7,966. Instead of scanning an image of the subject, the actual subject is scanned directly by a rapidly moving spot of light.

An illustrative laboratory set up, fig. 7,967, shows the arrangement of parts in such a transmitting station. A fifteen inch disc rotating approximately eighteen times per second carries a series of fifty small apertures

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arranged in the form of a spiral. A beam of light is condensed by a lens from a 40 ampere Sperry arc to intensely illuminate a limited area in the path of the moving apertures; and a slender, intense beam of light passes through each aperture as it moves across the illuminated area. A frame in front of the disc permits light to emerge from only one aperture at a time and the lens in front of the disc focuses an image of this moving aperture on the subject. As a result of this arrangement the subject is completely scanned in a series of successive, parallel lines by a rapidly moving spot of light, once for each revolution of the disc; and on account of the transient nature of the illumination the subject is scarcely aware that he is being exposed to it.

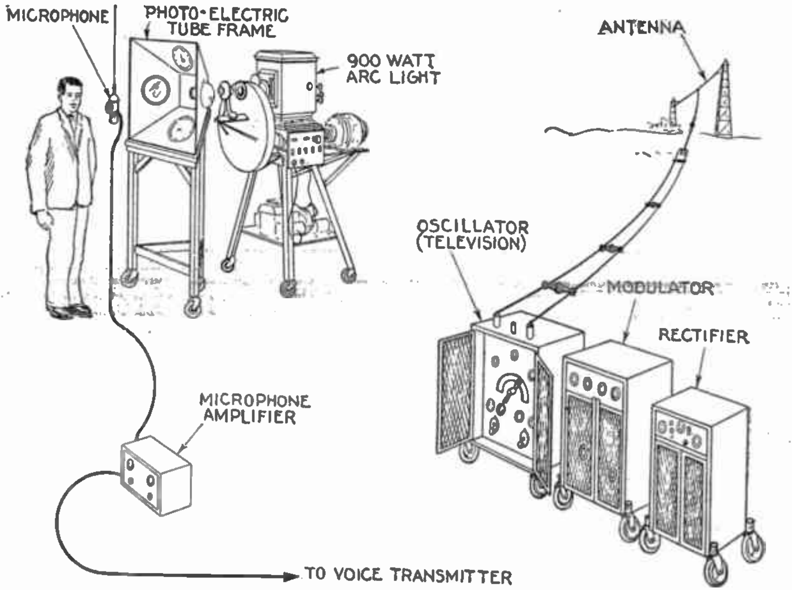

FIG. 7,968.—Television pick up apparatus. At the studio, feeding into transmitter.

As the spot of light traces across the subject, light is diffusely reflected or scattered from the subject in all directions, and some of the light that is reflected forward passes

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into three large photo-electric cells placed just in front of the person who is being viewed.

The current outputs from the three photo-electric cells operate in parallel into a common amplifier system. As the beam of light passes, for instance, across the person's eyebrow less light is reflected to the photo-electric cells, and as the beam passes across his forehead more light is reflected. Since the current output from the photo-electric cells is proportional to the received light, the current follows accurately the brightness of the various elemental areas of the subject's features as he is traced over by the scanning beam. The fluctuating current is uni-directional.

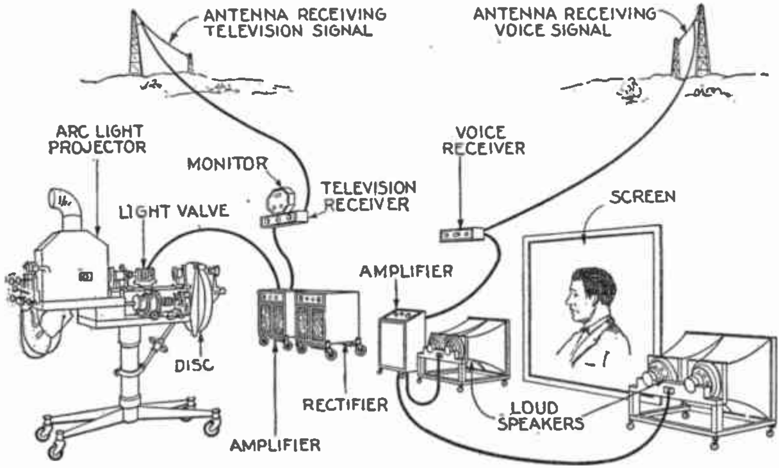

Fig. 7,969.—Television apparatus showing arrangement of image and voice reception systems.

The actual operation of such an optical system, its influence on the lighting effects and quality of the reproduced image, may best be understood by noting that optically the system is identically the same as if all of the rays of light were reversed in direction to give an optical system equivalent to fig. 7,965.

The television apparatus sees the subject exactly as if rays of light came out of the photo-electric cells to illuminate the

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subject; the lens formed an image of the subject on the disc, and the apparatus scanned this image and reproduced it at the receiving end.

The lights and shadows seen in the image are the same as if the subject were illuminated by three large lights in the positions of the photo-electric cells and looked at from the position of the lens.

It also follows from the considerations that, within its range of resolving power, this scanning method will not only reproduce a plane subject, such as a drawing, but it will also faithfully reproduce three dimensional figures with sharp edges and elevations and depressions, just as well as they could be reproduced in a photograph.

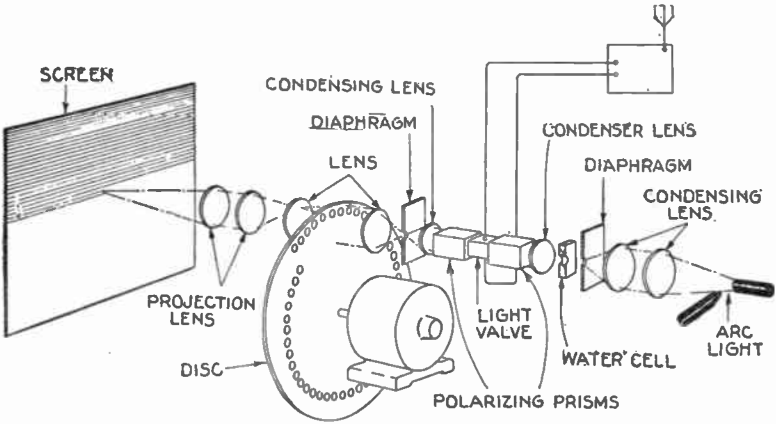

Fig. 7,970.—Elementary television diagram showing details of the Karolus system; the water cell removes heat rays; the Nicoll polarizing prism at the right polarizes the light; the *light valve* (Kerr cell) then rotates the ray, to a degree which determines the amount to be cut off by the polarizing prism at the left; and the light spot is then caused to move over the screen, reproducing the image.

In addition, because the light passes in an approximately parallel beam through a disc aperture, the slender beams of light sweeping across the region in front of the transmitter just barely overlap each other even at a considerable distance from the apparatus. Consequently, it is not necessary that the subject be at the exact positions at which the small apertures are sharply focused; and within wide limits no confusion results as the subject moves toward or away from the apparatus. The brightness as well as the size of the received image decreases as the subject moves away from the

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photo-electric cells; and for good transmission of the human features, which reflect very little blue light to which the photo-electric cells are sensitive, a person should not be more than a few feet away from the cells.

At the studio, the person to be televisioned stands before a bank of photo-electric cells as in fig. 7,968, while a large lamp casts a ray of light, which is directed by the scanning disc, over the features of the subject.

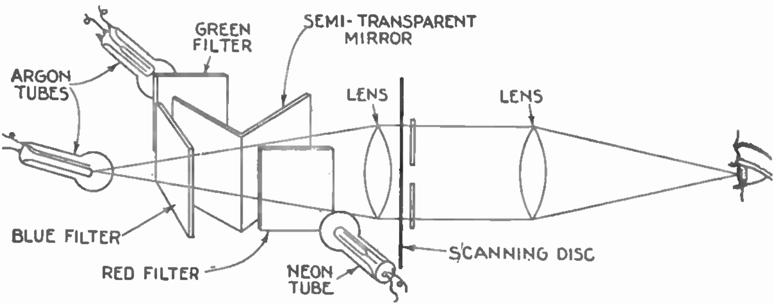

FIG. 7,971.—Arrangement of lamps, color filters and mirrors at receiving end in monochrome television work.

The reflectivity of the area covered by this spot, about ½ in. in diameter, at any time governs the strength of the impulse being instantaneously sent out from the transmitter. The reception arrangement, which requires two distinct channels, is shown in fig. 7,969. The television signal on 140 meters is picked up, amplified and conducted to the projector, at the left of the figure.

Television in Colors.—The method here described is the *beam scanning method*. In this method *the positions of light source, image forming lens, and sensitive surface, in photography, are reversed*. The lens projects a narrow moving beam of light and the light reflected from the object is picked up by photo-electric cells which occupy the positions which in photography would be taken by the light sources.

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In more detail, the essential feature of the beam scanning method of three-color television consists in the use of three sets of photo-electric cells, one set with its accompanying filters recording the red constituent, the second the green and the third the blue constituent of the image. The light source and the scanning disc are in no way altered from the form as used in monochrome television. The three sets of cells are each connected to a separate communication channel, and the television signals going over these three channels correspond to the three colors.

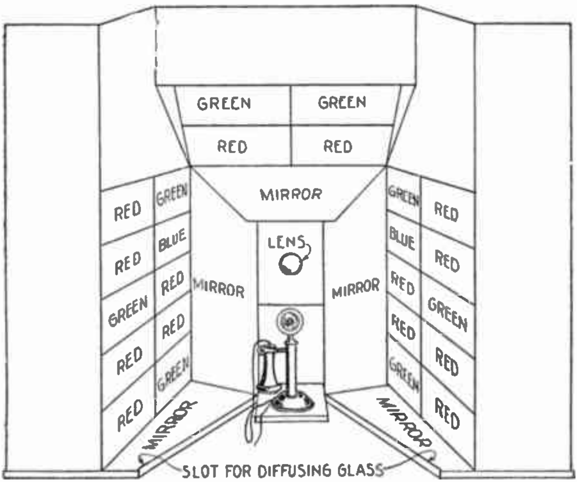

FIG. 7,972.—Arrangement of photo-electric cells for three color television.

At the receiving end a number of possibilities are open; one of these is the projection of three colored beams of light on to the same spot on a screen, which would correspond to a three-color lantern projector; a second possibility is the use of a triple grid vacuum tube similar to the large grid which has been used previously for exhibiting television images to an audience, except that three juxtaposed sets of tubes would be used with three distributers. A third possibility, which is the one used in this work, is to superpose the light from three different colored television glow lamps by means of semi-transparent mirrors. This is comparable to the additive superposition in three-color photography exemplified in the chromoscope.

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TEST QUESTIONS

1. *What is television?*
2. *How is television accomplished?*
3. *Explain the physics of the human eye.*
4. *What is understood by persistence of vision?*
5. *Define scanning.*
6. *Name two methods of scanning and describe each.*
7. *Can home built apparatus be constructed that will bring in pictures?*
8. *Describe in full, persistence of vision.*
9. *Draw diagrams illustrating basic principles of television.*
10. *Describe television apparatus.*
11. *Draw a diagram illustrating the Karolus system.*
12. *Describe method of television in colors.*

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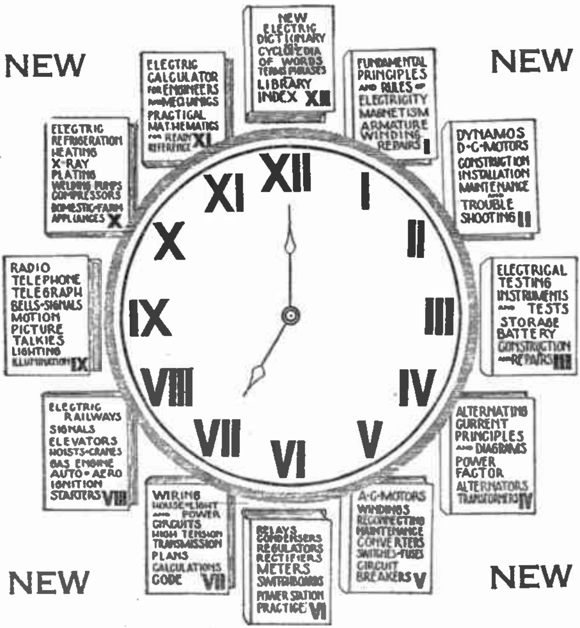

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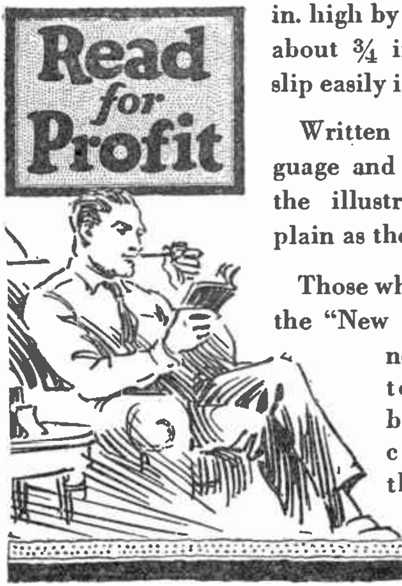

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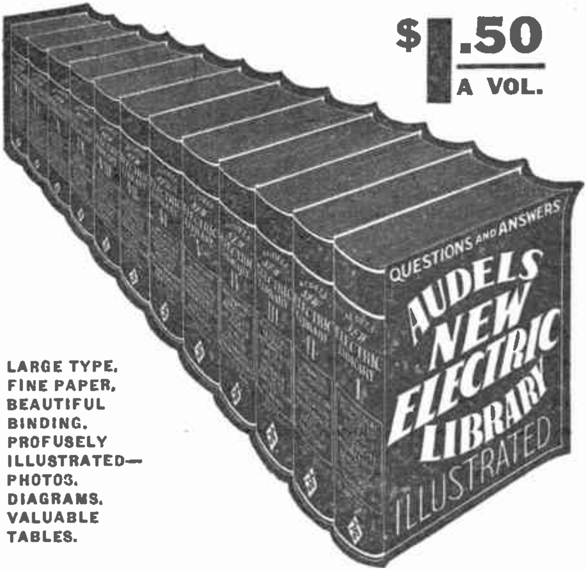

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