THE Radio Amateur's Handbook

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By A. FREDERICK COLLINS

REVISED BY

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NINTH EDITION

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Preface to the Ninth Edition

In the nine years that have elapsed since the appearance of the eighth edition of *The Radio Amateur's Handbook* there have been more changes in radio and television than perhaps any other similar period in the history of these two industries. The war brought a tremendous increase of research and development, particularly in very-high-frequency and ultrahigh-frequency equipment, and new regulations of the Federal Communications Commission have enlarged the scope of amateur and commercial broadcasting. The effect of these changes is not as yet fully evident, and we can expect continued great strides within the coming years.

This new edition has been fully revised and completely reset to keep abreast of the times, without losing sight of the original aim of the book, which was and is to present the facts as simply as possible and to offer a completely practical approach to radio and related fields for the beginner who wants to build his own equipment. More than 50 per cent of the material is entirely new, and there are 40 new halftones and 50 new line drawings, including diagrams of new circuits employing the latest type vacuum tubes. The subject of television has been expanded in the light of the industry's extraordinary growth during the past two years, and two television kits are described and illustrated; frequency modulation is also brought up to date, with the inclusion of a new FM tuner kit. New chapters on the vacuum-tube voltmeter and oscilloscope and new transmitting equipment, including a new mobile transmitter, have been added.

The material in the Appendix has also been given a thorough overhauling, the major changes being a completely new, 450-entry glossary that includes many of the most recent terms; a new 24-page tube classification chart; a complete listing of the latest (November, 1948) Federal Communications Commission Rules Governing Amateur Service; the 1947 Fire Underwriters Code for Radio Equipment; 1949 List of International Call Letters; 1948 list of FCC Examining Points, and a new reference bibliography.

Grateful acknowledgment is made to the following companies for providing new information and illustrations for the present edition: Altec Lansing Corporation; Burgess Battery Company; Chicago Transformer Division (Essex Wire Corporation); Cornell-Dubilier Electric Corporation; Allen B. DuMont Laboratories, Inc.; Electronic Instrument Co., Inc.; Electro-Technical Industries; Electro-Voice, Inc.; Finch Telecommunications, Inc.; The Heath Company; The Instructograph Company; Jensen Manufacturing Company; P. R. Mallory and Company, Inc.; Meissner Manufacturing Division of the Maguire Industries, Inc.; James Millen Manufacturing Co., Inc.; The National Board of Fire Underwriters; D. W. Onan and Sons, Inc.; Radio Corporation of America; Radio Inventions, Inc.; Radio Wire Television, Inc.; Standard Transformer Corporation; Sylvania Electric Products, Inc.; Transvision, Inc.; The Ward Products Corporation; Ward Leonard Electric Company; Westinghouse Electric Corporation; Weston Electrical Instrument Corporation; and the Wincharger Corporation.

D. J. DUFFIN

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CHAPTER

1

Introduction to Radio

Since 1896, when Guglielmo Marconi took out the first patent ever granted for wireless telegraphy based on the use of electric waves, the art of radio has been of absorbing interest to a constantly increasing army of amateurs. There are many reasons for this attraction but it is probable that experimenters were drawn to the new industry in the majority of instances simply because they could acquire their experience in a perfectly normal manner by starting in a limited, inexpensive way, then expanding the scope of their activities as skill and knowledge came to them. Neither in the beginning of wireless nor in radio as we know it today is a great expenditure of money necessary for a start. As a matter of fact, any handy worker may easily assemble the majority of the parts needed for a workable apparatus even though radio manufacturers are now supplying all the necessities at prices that often make home construction more of a hobby than a necessity.

This book will attempt to guide the beginner from the fundamentals of the art through the somewhat more intricate multitube radio sets and amateur transmitters into the latest developments that embody television and facsimile apparatus. The radio world expands rapidly, spreading yearly into new fields, yet an understanding of the basic rules is all that is necessary to appreciate each new application as it comes along. This is one of the reasons for the wide appeal of Marconi's discovery.

The earliest radio experimenters were forced to make their receiving, transmitting, and testing apparatus step by step, but today there are stores in every large city where well-made components of high efficiency may be purchased at reasonable cost, thereby saving much time and trouble and reducing the job to one of relatively simple assembly of standardized parts. Amateurs living in rural sections may obtain similar service from mail-order houses that have recognized the large number of persons, old as well as young, absorbed in the hobby and in consequence have created special departments to supply their wants. In addition, scores of individual manufacturers offer catalogs, booklets, data sheets, etc., containing information designed to smooth the path of the amateur. One of the first moves of every amateur should be the formation of a small library comprising modern books and other forms of publications to which he can refer when facing the need for authoritative facts. The cost is slight but the value is untold.

RADIOTELEPHONY AND RADIOTELEGRAPHY

Before proceeding further the reader should understand the scope of radio as applied to all forms of wireless communication. Actually, except for the means used to modulate or shape the electrical waves which carry the message or signal, there is but little difference between radiotelephony and radiotelegraphy. While a radiotelegraph transmitter cannot always be used for telegraphy, any radiotelephone sending set, on the other hand, can be used to transmit the dots and dashes of code. But for music and other intelligible sounds of any description, a microphone is essential before the variations in sound waves can be converted into the purely electrical equivalents which are transmitted through the air. For code, a telegraph key suffices to chop the signals into the necessary long and short pulses that are everywhere recognized as the International Morse Code.

PARTS OF RADIO SYSTEMS

In analyzing radio transmitters and receivers we find an interesting resemblance. Each unit embodies (1) a source of energy, (2) an amplifying means, and (3) an elevated wire called the antenna or aerial. In a transmitting system the antenna radiates the energy; in a receiver the raised wire collects the electrical pulses. The telegraph key or microphone gives a recognized shape or character to the signal so that it may be recreated at the receiving end by headphones or by the more powerful loud speaker. In between the extremes of each unit are vacuum tubes, each of which performs a distinctive function that will be described in detail in later chapters.

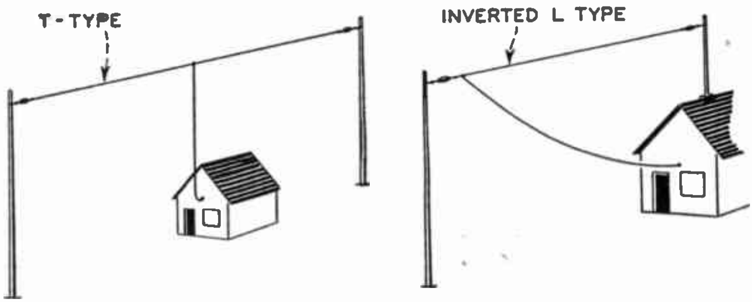
At one time the work of the vacuum tube was done by a jump spark or electric arc (in transmitters) or by a piece of natural crystal (in receivers), but today these devices are seldom used. In the transmitting field, the arc and spark are outlawed because of their generally inefficient styles of operation, whereas the vacuum tube, because of its amazing flexibility and accomplishments, has become truly the Aladdin's Lamp of Radio.

The ultimate objective of every amateur is to own and operate a transmitting station in order to communicate with other amateurs who may be hundreds and even thousands of miles away, but before undertaking this phase of radio work, the experimenter should acquire a solid groundwork in receiving apparatus, its theory, assembly, and operation. Once this has been accomplished it will be easier to understand the principles of radio transmission, and eventually to acquire a government license, without which no broadcasting station may be operated at any time or in any place.

SIMPLE ANTENNA

Whatever the type of receiving set used, some form of antenna is essential. For the simple receiver which we will discuss first, an equally simple antenna will be sufficient. This may take the form of a single wire strung in the open between two supports with one end as high as possible. Trees, buildings, or poles will provide good supporting points. The receiver is then connected to the antenna by another single wire leading to one end or the center of the span. Although not the most efficient type of collector for all purposes, the single wire L or T type will give good enough results until we are more advanced in our work. Modern forms of antennas including those advised for ultrahigh frequencies, television, and facsimile reception will be described later.

In addition to the antenna, every receiving set requires a ground connection of some type. Usually a cold water pipe is handiest, but occasionally an earth connection of this nature is not available. In such installations the amateur must make his ground connection by burying a piece of wire netting or copper plate in the dampest earth obtainable near by his radio set. The depth of such a ground varies with the consistency of the soil, but four feet is ordinarily sufficient. If preferred, a copper rod one half inch in diameter may be driven into the earth to take the place of a water-supply ground. However,



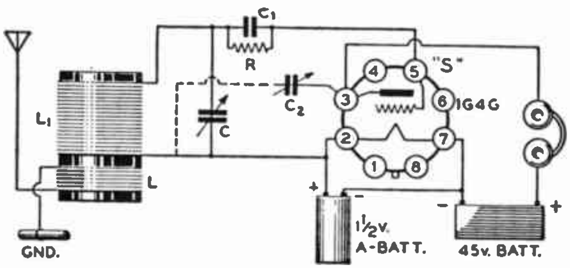
1. Two simple types of antennas most frequently used in reception.

the absence of an efficient ground does not mean so much today with modern radio sets. A reasonably good earth connection is obtained through the neutral wire of the power line. As a matter of fact, in the small a-c/d-c receivers this is the only ground used.

SIMPLEST RECEIVING SET

In the early days of wireless and even after commercial broadcasting had begun in 1920, the crystal was the accepted means of receiving radio signals, but the perfection of the vacuum tube soon relegated the small pieces of silicon, galena, and carborundum to the status of museum exhibits. Today a crystal receiving set would have a range limited to a few miles and would be so lacking in its ability to distinguish between one station and another that it would provide no entertainment whatsoever. The same criticism applies to the cumbersome tuning coils, called loose couplers, which were once considered a necessary adjunct to every crystal set. Replacing these components are the vacuum tube, the small compact tuning inductance, and the efficient variable condenser, a combination that is still surprising experimenters who apply them in any of the circuits that have been devised for radio purposes.

The simplest receiving set consists of (1) a tuning coil, (2) a variable condenser, (3) a battery-operated vacuum tube, (4) batteries for filament and plate of tube, (5) small fixed condenser and resistance for grid leak, and (6) headphones. Under average conditions this simple collection of parts will detect signals originating many hundreds of miles away, while if the additional connection represented by the dotted line, Fig. 2, is combined with the basic set, the sensitiveness of the little set is doubled or even tripled.



2. One-tube receiving set with regeneration supplied by the dotted circuit; several types of tubes may be used but for the beginner a 1G4G is recommended because of its simplicity and low current drain.

L and L1 are fixed coils
C and C2 are variable condensers
C1 is a fixed condenser
R is a fixed resistance
S is an octal socket

More will be said about these circuits when the construction of actual sets is discussed.

Although the majority of receiving sets for broadcast reception comprise five tubes or more, a large percentage of amateurs have found that smaller sets and a pair of headphones work out to better advantage as far as code signals are concerned. The reason for this preference merits some space here.

Actually, a vacuum tube used as a detector in an efficient circuit has no limit to the distance over which it can detect a signal. It functions with such an infinitesimally small pulse of energy that no meters have yet been devised sensitive enough to operate on the transmitted energy. On this basis, then, it would seem that any receiving set should be able to pick up a signal from the Antipodes at any time. This might be so if there were no electrical storms anywhere in the world, no motors; automobiles, hospitals, telephone lines, etc., for each of these classifications contributes to the cloud of "static" which permeates the atmosphere everywhere and limits the distance over which a radio station can be heard. The electrical noises generated wherever electric devices operate pass through the air to any radio antennas that may lie in their path, or frequently from one house to another directly through power and light lines. The character of both the foreign impulses and the radio signals is much the same; hence they are treated in the same way by any radio receiving apparatus they may happen to reach. It is then merely a question of which is the stronger. For normal reception, it is usually considered that the radio impulse must be at least four times as powerful as the noise in order to make reception agreeable to the listener. This relation between noise and signal is called the "signal-noise ratio" and it plays an important part in the design of all radio receiving apparatus. If too many stages of amplification are included in a receiver, the noise will increase in undue proportion to the signal and finally reach a point where the signal-noise ratio becomes too small to give good audible reception. This is why the great proportion of receivers both for the broadcast listener and the amateur are rarely supplied with more than one stage of audio-frequency amplification. It also explains why many amateurs are satisfied with fewer tubes and a pair of headphones as against the broadcast listener with his multitube set and loud speaker.

TYPES OF TRANSMITTERS

There are several methods to use in producing a radio signal and transmitting it, but the increased exactions of government agencies and the crowded condition of the usable channels have gradually outlawed all sources of radio energy excepting the vacuum tube. When radio was young, the majority of amateurs vibrated the ether with spark coils of various sizes. A few operated arc transmitters, and while the characteristics of both types sufficed in those days, the rapid progress of the art of radio, which included the development of the vacuum tube, eventually emphasized the inefficiency of spark coil and arc as transmitters of oscillating energy. The spark coil produced a rough note under normal reception conditions and occupied too many cycles in the radio spectrum. It could not be tuned sharply and therefore was a frequent cause of interference between stations. The arc was better than the spark coil in some respects and might have come into wider use if the vacuum tube had not appeared on the scene. The tube was economical to operate, quiet, and compact. Moreover, it could be embodied in a circuit that permitted extremely sharp tuning of the transmitted wave. More and more ships were adopting radio for communication purposes, thereby creating a problem of finding sufficient wave length for everyone with a minimum of interference. The vacuum tube was the solution.

As a result, spark coils and arcs are now outlawed for use by amateurs. Amateur stations must generate their energy by means of tubes, which are also further controlled as to wave length by small crystals that are ground to a definite frequency response. In this way the maximum number of amateurs succeed in conducting their conversations with the minimum of clashing, and the commercial services are enabled to continue their radio traffic without finding it necessary to criticize amateurs because of their wandering from their legally assigned frequencies.

REQUIREMENTS FOR A LICENSE

The United States is the most lenient of all governments in its attitude toward radio amateurs, yet Federal supervision includes a series of regulations that are strictly enforced for the benefit of all users of the air waves. The first and most important of the rules requires that every owner and operator of a transmitter demonstrate his knowledge and fitness before being allowed to operate. This entails obtaining *two* licenses, one for the operator and one for the station. A person operating a transmitter without a license violates the law and is subject to heavy penalties—a maximum of two years in jail and a fine of $10,000. The licenses are issued free of charge by the Federal Communications Commission (FCC) after the applicant has passed examinations conducted by FCC agents at any one of a number of offices established in principal cities in the U.S. and its territories. *Both licenses, without exception,* must be obtained before an amateur station of any kind is operated. Only citizens of the United States are eligible for either license.

The operator's license is based on a test of his knowledge of code plus an examination into his technical ability. The prospective amateur must be able to send and receive international code at the minimum rate of 13 words a minute, each word being based on five characters. The written examination consists of a few basic questions covering radio theory, the construction, operation, and adjustment of radio receivers and transmitters, and the most important points in the radio law and regulations. Any American citizen may own and operate an amateur radio station provided the transmitter is not located on property controlled by an alien, and the only physical infirmity which bars one from this interesting hobby is deafness.

The station license is the government's official acknowledgment of the individual's ability to operate without causing confusion in the ether spectrum and embodies the call letters by which he will be known to his radio confreres and the government. Both licenses must be available at all times when the station is being operated by its owner.

It is not necessary to own transmitting apparatus in order to obtain an operator's license but the station license will not be awarded until equipment has been assembled.

There are three classes of amateur operator licenses. Class A, known as the "unlimited 'phone" license, is the advanced grade. It grants all the privileges of the B and C licenses and in addition permits the holder to operate a radiophone transmitter in the restricted bands of 3,900–4,000 kilocycles and 14,150–14,250 kilocycles.

Class B and C licenses do not entitle the holder to operate a radiophone in the two frequency bands noted above. In other respects the privileges of the B and C licenses are identical with Class A privileges. The difference between a B and C license is that Class B is issued only when the license examination is taken in the presence of the radio inspector, while Class C is issued upon passing an examination by mail.

Only those persons who live more than one hundred and twenty-five miles (airline) from an examining point may take the mail examination and obtain a Class C license. As soon as the holder of a Class C license moves within one hundred and twenty-five miles of an examining point he must, within four months, take a Class B examination or forfeit his Class C license.

There are fifty-five examining points scattered about the United States, two in Alaska, one in Puerto Rico and one in Hawaii. Twenty-three of these are the regular Inspection Offices of the Federal Communications Commission and a list of them appears in the Appendix of this book. Examinations are given frequently at these points and quarterly in the following cities:

Birmingham, Alabama
Charleston, West Virginia
Cincinnati, Ohio
Columbus, Ohio
Corpus Christi, Texas
Davenport, Iowa
Des Moines, Iowa
Ft. Wayne, Indiana
Fresno, California
Grand Rapids, Michigan
Indianapolis, Indiana
Knoxville, Tennessee
Little Rock, Arkansas
Memphis, Tennessee
Milwaukee, Wisconsin
Nashville, Tennessee
Oklahoma City, Oklahoma
Omaha, Nebraska
Pittsburgh, Pennsylvania
St. Louis, Missouri
Salt Lake City, Utah
San Antonio, Texas
Schenectady, New York
Sioux Falls, South Dakota
Syracuse, New York
Tulsa, Oklahoma
Williamsport, Pennsylvania
Winston-Salem, North Carolina

Examinations for both Class A and B are also held twice a year in the following cities:

Albuquerque, New Mexico
Amarillo, Texas
Bakersfield, California
Bangor, Maine
Billings, Montana
Bismarck, North Dakota
Boise, Idaho
Butte, Montana
Cumberland, Maryland
El Paso, Texas
Hartford, Connecticut
Hilo, Territory of Hawaii
Jacksonville, Florida
Klamath Falls, Oregon
Las Vegas, Nevada
Lihue, Territory of Hawaii

Mobile, Alabama
Phoenix, Arizona
Portland, Maine
Reno, Nevada
Roanoke, Virginia
Spokane, Washington
Tucson, Arizona
Wichita, Kansas
Wilmington, North Carolina

If you live within one hundred and twenty-five miles airline of any of the cities in the above list or any of the Offices of the Federal Communications Commission given in the Appendix, you should write or visit the inspector of the district in which you live. Ask for an application blank for an amateur operator and station license and the date when examinations will be held in the city where you are to appear. Fill out the application form and return it to the inspector's office. Appear at the time specified for examination and you will be given a code test. If you pass this you will be given the written examination. Those who pass receive their combination license by mail several weeks later. Those who fail to pass are so notified and have the privilege of taking the examination again after an interval of thirty days, and repeating it, if necessary, any number of times.

If you live more than one hundred and twenty-five miles airline from any of the fifty-nine examining points and do not care to appear for examination, write to the inspector of the district in which you live and ask for application blank, etc., for a Class C amateur operator. When you receive the application, it will be accompanied by a sealed set of examination questions and an instruction sheet. Do not open the sealed envelope containing the examination. Read the instruction sheet first and do exactly as it tells you.

Your code test must be given by a licensed Class A or Class B amateur operator, or a professional radiotelegraph operator who will then certify whether or not you can send and receive code at the rate of thirteen words per minute. Your examination questions must be answered in writing before a witness who will open the sealed questions and certify that you wrote the answers without assistance. The application form and the examination are then returned to the Federal Communications Commission. If you have followed all the instructions and have passed the examination and test, you will receive your license in a few weeks. If you have failed, you will be notified and in another month you can try it again; or, if you feel up to it, you may apply immediately for a Class B personal examination before an FCC engineer.

CHAPTER

2

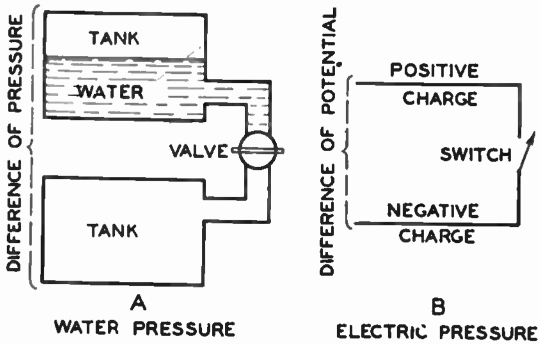
Electricity Simply Explained

It is easy to understand how electricity behaves and what it does if you get the right idea of it at the start. In the first place, if you will think of electricity as being a fluid like water, its fundamental actions will be greatly simplified. Both water and electricity may be at rest or in motion. When at rest, under certain conditions, either one will develop pressure, and this pressure when released will cause both to flow through their respective conductors and thus produce a current.

ELECTRICITY AT REST AND IN MOTION

Any wire or a conductor of any kind can be charged with electricity, but a Leyden jar, or other condenser, is generally used to hold an electric charge because it has a much larger *capacitance*, or amount of charge per volt of applied pressure, than a wire. As a simple analogy of a condenser, suppose you have a tank of water raised above a second tank and that these two tanks are then connected together by means of a pipe with a valve in it, as shown at *A* in Fig. 3.

Now if you fill the upper tank with water and the valve is turned off, no water can flow into the lower tank but there is a difference of pressure between them, and the moment you turn the valve a current of water will flow through the pipe. In very much the same way when you have a condenser charged with electricity the latter will be under *pressure*, that is, a *difference of potential* will be set up, for one of the sheets of metal will be charged positively and the other one, which is insulated from it, will be charged negatively, as shown at *B*. On closing the switch the opposite charges rush together and form a current which flows to and fro between the metal plates.*



3. Water analogy for electric pressure.

AN ELECTRIC CURRENT AND ITS CIRCUIT

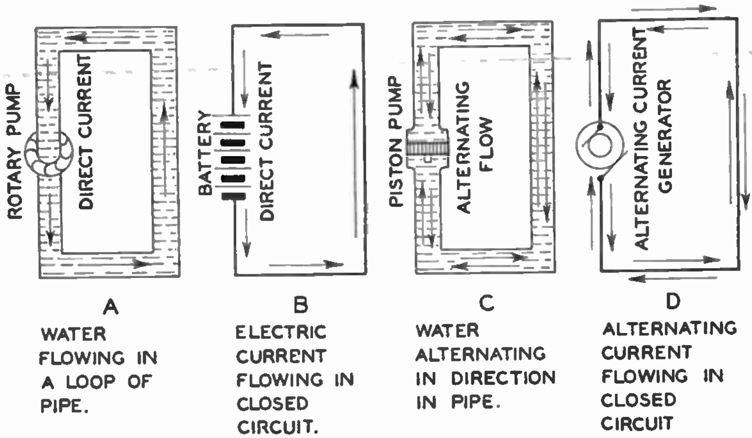
Just as water flowing through a pipe has *quantity* and *pressure* back of it and produces friction which tends to hold back the water, so, likewise, does electricity flowing in a circuit have: (1) *rate of flow*, or *current strength* (current, as it is called for short), or *amperage*, and (2) *pressure*, or *potential difference*, or *electromotive force*, or *voltage*, as it is variously called, and the wire, or circuit, in which the current is flowing has (3) *resistance* which tends to hold back the current.

A definite relation exists between the current, the electromotive force, and the resistance of the circuit; and if you will get this relationship clearly in your mind you will have a very good insight into how direct and alternating currents act. To keep a quantity of water flowing in a loop of pipe, which we will call the circuit, pressure must be applied to it. This may be done by a rotary pump as shown at *A* in Fig. 4. In the same way, to keep a quantity of electricity flowing in a loop of wire, or circuit, a battery or other means for generating electric pressure must be used, as shown at *B*.

If a piston pump is connected in a closed pipe line (Fig. 4*C*), as the piston moves to and fro the water in the pipe will move first one

* Actually, the difference of potential sets up an electromotive force.

way and then the other. So also when an alternating current generator is connected to a wire circuit, as at *D*, the current will flow first in one direction and then in the other; a current that reverses itself in this way is called an *alternating current.*

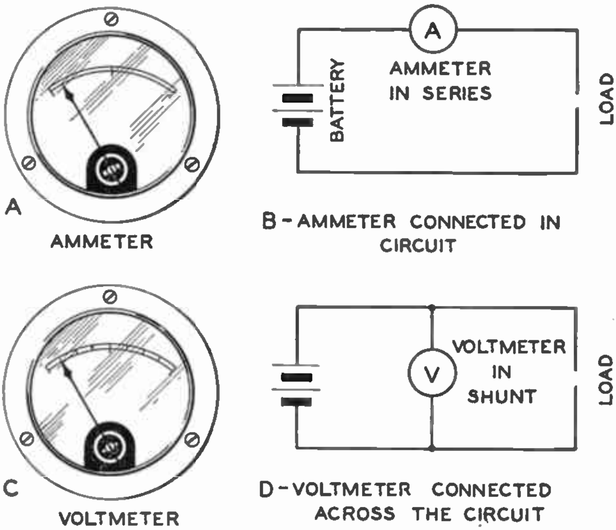


4. Water analogies for direct and alternating currents.

CURRENT AND THE AMPERE

The rate at which water flows in a closed, continuous pipe is the same in all parts of the pipe, regardless of the diameters of the various sections that comprise it. To understand this we need only recall that rate of flow of water means the number of gallons (or quantity) of water that pass a given point in a given time—for example, 100 gallons per minute. Obviously for a small pipe to deliver the same number of gallons per minute as a large pipe, the *velocity* of the water in the former must be greater; however, we must not confuse velocity with rate of flow, for velocity is measured in feet per minute whereas rate of flow is measured in gallons per minute. Regardless, then, of the resistance which each section of the pipe offers to the flow of water, the rate of flow will be the same in all sections.

Similarly, the rate at which electricity flows in a continuous or "series" circuit is the same in all parts of the circuit, regardless of the size or resistance of the wires that comprise it. Rate of flow of electricity, which is the definition of *current,* is the number of *coulombs* of electricity that pass a given point in one second, the coulomb being the practical unit of electrical quantity, just as the gallon is a practical unit of fluid quantity. A current of one coulomb per second is defined as a current of one *ampere;* in other words, the rate of flow, or strength, is said to be one ampere. The ampere is



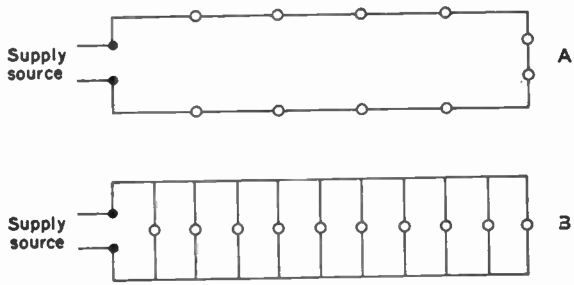
5. How the ammeter and voltmeter are used.
B. Ammeter connected in series.
D. Voltmeter connected parallel.

thus the practical unit of current strength, and refers to *flow* of electricity, not quantity. It is important to keep this distinction in mind in order to understand the practical applications of the above terms to electrical circuits.

Current is expressed by the symbol *I,* and is measured by means of an instrument called an *ammeter,* which is essentially a miniature motor that moves a pointer through a small arc against the tension of a spiral spring (Fig. 5). Note that to measure the current correctly, as well as to prevent damage to the instrument, an ammeter should always be connected in *series* with the circuit. It may be helpful to remember that the current flowing through the filament of a 100-watt bulb in a home-lighting circuit is about 0.85 ampere.

SERIES AND PARALLEL CIRCUITS

A circuit in which the current flows through the various elements in one continuous path is called a *series* circuit (Fig. 6*A*). As we have already noted, the current in a series circuit is everywhere the same. A circuit in which each element is connected separately across the source of electromotive force or supply is called a parallel circuit (Fig. 6*B*). Unlike series circuits, the current is not every-



6. Simple series (*A*) and parallel (*B*) circuits.

where the same in parallel circuits; it varies in each of the separate paths or branches, depending on the *resistance* (see below) of each branch. The total current flowing in the circuit is equal to the sum of the currents in the separate branches—for example, if there are ten 100-watt bulbs in a house circuit, the total current flowing in the circuit is 10 x 0.85 or 8.5 amperes. If, on the other hand, these ten 100-watt bulbs were to be connected in series, the total current in the circuit would be only 0.085 ampere, but the bulbs would not light.

Series-parallel circuits, as the name implies, are made up of a combination of series and parallel components, each of which must be analyzed separately in current calculations.

ELECTROMOTIVE FORCE AND THE VOLT

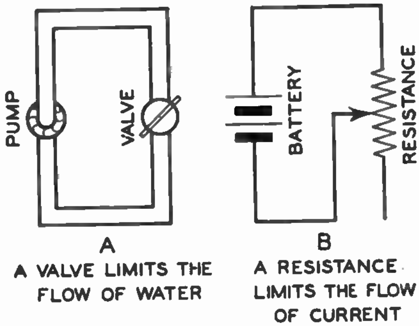
Before water can flow in a pipe there must be a pressure exerted on it either by a pump or in the form of gravity. Similarly, before current can flow in an electric circuit there must be a pressure exerted on it in the form of a *potential difference* or *electromotive force,* which may be provided either by a battery or an electric generator. This electrical pressure must be sufficient to overcome the opposition (or resistance) to current flow due to the circuit itself. The greater the pressure, the more current it will move along, just as the amount of water flowing in a pipe can be increased by increasing the pressure of the pump.

The unit of electromotive force is the *volt,* which is defined as the amount of electrical pressure that will force a current of one *ampere* through a resistance of one *ohm;* it is expressed by the symbol *E.* Voltage, or potential difference, or electromotive force, is measured by an instrument called a *voltmeter* (Fig. 5), which is always connected *across* the circuit as shown in the illustration.

RESISTANCE AND THE OHM

Just as a water pipe offers a certain amount of resistance to the flow of water through it because of friction between the inside of the pipe and the water, so a circuit opposes the flow of electricity in it to an extent depending on whether the materials in the circuit are poor conductors or good conductors. In the same way that a small pipe offers more resistance to the flow of water than a large one, so, too, a thin wire offers more resistance to the flow of electricity than a heavier wire of the same material. All metals have a certain amount of electrical resistance depending on the structure of their atoms; pure silver has the lowest resistance of the common metals, and steel wire the highest, while copper, which is only slightly higher than silver in resistance, has been found to be the best conductor from a practical standpoint.

If we connect a *resistance coil* wound with fine copper or other wire in a circuit, it acts in the same way as a partly closed valve in a pipe—both limit the flow of the fluid passing through them, as shown in Fig. 7. The resistance of a circuit is measured in terms of the *ohm,* which is defined as that amount of resistance through which an electromotive force of one *volt* will cause a current of one *ampere* to flow. Resistance is expressed by the symbol *R*. A No. 14 (Brown and Sharpe gage) annealed copper wire 1,000 feet long has a resistance at room temperature of 2.58 ohms, while an equal length of No. 17 wire (only about half as thick) has a resistance of 5.16 ohms, or twice that of No. 14.



7. Water-valve analogy of electrical resistance.

Resistance in a circuit or of electrical equipment is measured by various methods, including the use of such instruments as Wheatstone's bridge and the megohmmeter or "megger," the latter being used especially for insulation resistance. The resistance of most circuits can, however, be easily calculated by applying *Ohm's Law* as described below, using only a voltmeter and ammeter.

WHAT OHM'S LAW IS

If (1) you know what the current flowing in a circuit is in *amperes,* and what the electromotive force, or pressure, is in *volts,* you can then easily find the resistance in *ohms* of the circuit in which the current is flowing by this formula:

$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms, or } \frac{E}{I} = R$$

That is, if you divide the electromotive force in volts by the current in amperes the quotient will give you the resistance in *ohms.*

Or (2) if you know what the electromotive force of the current is in *volts* and the resistance of the circuit in *ohms*, then you can find the current flowing in the circuit in *amperes*, thus:

$$\frac{\text{Volts}}{\text{Ohms}} = \text{Amperes, or } \frac{E}{R} = I$$

That is, by dividing the electromotive force in volts by the resistance of the circuit in *ohms* you will get the amperes flowing in the circuit.

Finally (3) if you know the resistance of the circuit in *ohms* and the current in *amperes*, then you can find the electromotive force in *volts*, since:

$$\text{Ohms} \times \text{Amperes} = \text{Volts, or } R \times I = E$$

That is, if you multiply the resistance of the circuit in *ohms* by the current in *amperes* the result will give you the electromotive force in volts.

From this you will see that if you know the value of any two of the constants you can find the value of the unknown constant by a simple arithmetical process. This relation between these three constants is known as *Ohm's Law* and is the basis of all electrical calculations.

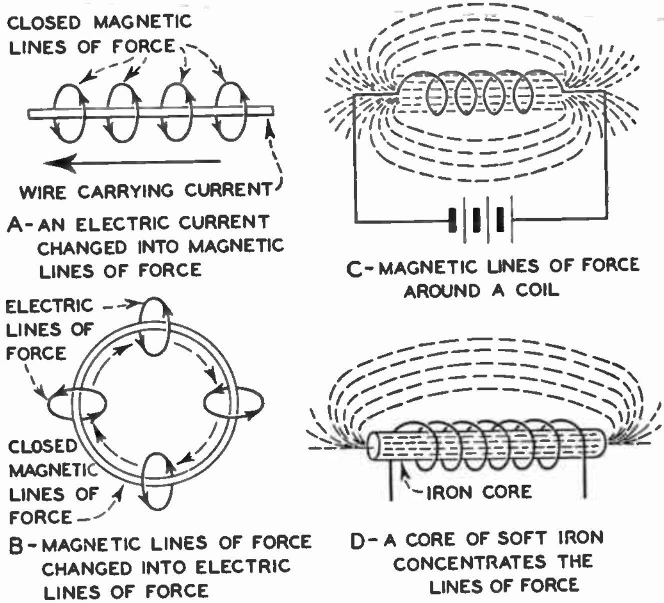
WHAT THE WATT AND KILOWATT ARE

Just as *horsepower*, or *hp*, is the unit of power indicating the rate at which steam does work, so the *watt* is the unit of power indicating the rate at which an electric current performs work. To find the *watts* developed by the flow of an electric current you need only to multiply the *amperes* by the *volts*. There are *746 watts* to *1 horsepower*, and *1,000 watts* are equal to *1 kilowatt* (*kw*).

ELECTROMAGNETIC INDUCTION

To show that a current of electricity sets up a magnetic field around it you have only to hold a compass over a wire whose ends are connected to a battery. The needle will swing at right angles to the length of the wire. By winding an insulated wire into a coil and connecting the ends of the latter with a battery you will find, if you test it with a compass, that the coil has developed magnetic properties.

This is due to the fact that the energy of an electric current flowing in the wire is partly changed into magnetic lines of force which are set up at right angles about it as shown at *A* in Fig. 8. The mag-



8. Illustrating one of the most important electrical properties of a wire and the effect on the magnetic lines of force when an iron core is inserted in the coil.

netic field produced by the current flowing in the coil is precisely the same as that set up by a permanent steel magnet. Conversely, when a magnetic line of force is set up a part of its energy goes to make up electric currents which flow about in a like manner, as shown at *B*.

SELF-INDUCTION OR INDUCTANCE

When a current is made to flow in a coil of wire the magnetic lines of force produced are concentrated, as at *C*, so that each turn of wire sets up action in the one next to it. This action is called *self-induction, self-inductance* or simply *inductance.* The self-induction, or inductance, forms a concentrated *magnetic field.* If a bar of soft iron is slipped into the coil it will be magnetized, as at *D,* and it will remain a magnet until the current is cut off.

MUTUAL INDUCTION

When two loops of wire—or better, two coils of wire—are placed close together the electromagnetic induction between them is reactive; that is, when a current is made to flow through one of the coils, closed magnetic lines of force are set up, and when these cut the other loop or turns of wire of the other coil they in turn produce electric currents in it.

It is the mutual induction that takes place between two coils of wire which makes it possible to transform *low-voltage currents* from a 110-volt source of alternating current into *high-voltage* currents by means of a spark coil or a transformer.

HIGH-FREQUENCY CURRENTS

High-frequency currents, or electric oscillations as they are called, are currents of electricity that surge to and fro in a circuit a million times (more or less) per second. Currents of such high frequencies will *oscillate*—that is, surge to and fro—in an *open circuit,* such as an antenna system, as well as in a *closed circuit.*

OSCILLATORY CIRCUITS; CONSTANTS

An *oscillatory circuit,* either open or closed, is a circuit containing inductance, capacitance, and resistance in which an impressed voltage will produce a current that oscillates or periodically reverses. The frequency of these oscillations depends upon the values of *inductance, capacitance,* and *resistance* used.

WHAT CAPACITANCE IS

If two conducting surfaces are separated by an insulating material such as air, paper, mica, glass, or oil, they will form a *con-*

denser or *capacitor* which stores electrical energy, blocks the flow of direct current, and allows alternating current to flow to an extent depending on the type of material used and the frequency of the current. *Capacitance* (or *capacity*) means the electrical size, measured in *farads*, of such a condenser, one farad being defined as the capacitance of a condenser that requires one coulomb of electricity to bring its plates to a potential difference of one volt. The farad has turned out to be too large a unit for most purposes, and the microfarad, or one-millionth of a farad (*mfd*), is commonly used instead. Capacitance is indicated by the symbol *C*. The capacity of a condenser depends on its size, form, and the materials of which it is made, and is directly proportional to the quantity of electricity that will charge it to a given potential.

Capacitance occurs between the metal of a conductor and the metallic sheath with which its insulation may be enclosed, but it is purposely introduced in the form of condensers or capacitors to control the flow of current in radio circuits.

WHAT INDUCTANCE IS

It has been shown above that it is the inductance of a coil that makes a current flowing through it produce a strong magnetic field. This is true for both direct and alternating currents, but an additional factor is introduced by the rise and fall of the alternating current in the conductor; the magnetic field surrounding it rises and falls also. This movement of the magnetic field relative to the conductor sets up an induced voltage that opposes the flow of the main current just as though additional resistance had been introduced in the conductor.

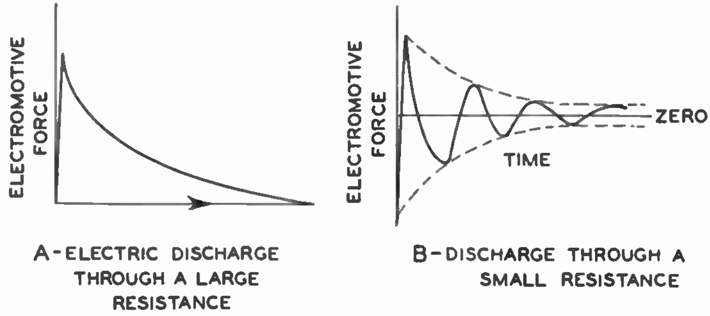
In high-frequency circuits inductance acts as a kind of electrical inertia, requiring time and electrical energy to set the current in motion or stop its flow. Because of inductance, when a current flows through a circuit it causes electrical energy to be absorbed and changes a large part of it into magnetic lines of force. Where high-frequency currents surge in a circuit, inductance becomes a powerful factor. It represents the ability of the circuit to store up energy in electromagnetic form. Inductance is measured in *henrys* and is represented by the symbol *L*.

WHAT RESISTANCE IS

The resistance of a circuit to high-frequency currents is different from that for low-voltage direct or alternating currents, as the former do not sink into the conductor to nearly so great an extent; in fact, they stick practically to the surface of it, and hence their flow is opposed to a very much greater extent. The unit of resistance is, as stated, the *ohm*, and its symbol is *R*.

EFFECT OF CAPACITY, INDUCTANCE AND RESISTANCE ON ELECTRIC OSCILLATIONS

If an oscillation circuit in which high-frequency currents surge has a large resistance, it will so oppose the flow of the currents that they will be damped out and reach zero gradually, as shown at *A* in Fig. 9. But if the resistance of the circuit is small—and in radio circuits it is usually so small as to be negligible—the currents will oscillate until their energy is damped out by radiation and other losses, as shown at *B*.



9. The effect of resistance on the discharge of an electric current.

As the capacity and the inductance of the circuit, which may be made any value you wish, determine the *time period,* that is, the length of time for a current to make one complete oscillation, it must be clear that by varying the values of the condenser and the inductance coil you can make the high-frequency current oscillate as fast or as slow as you wish within certain limits. If the electric oscillations that are set up are very fast, and are applied between an antenna and ground, the wave transmitted will be short; conversely, where the oscillations are slow the waves emitted will be long. Because of the higher speed of oscillations of short waves, the latter have greater energy than long waves.

CHAPTER

3

Component Parts of Radio Equipment

When the art of radio was new, a receiving set consisted of (1) an antenna, (2) a tuning circuit usually comprising a variable inductance or tuning coil, (3) a piece of natural crystal as a rectifier or detector, (4) a pair of headphones, and (5) one or two small fixed condensers. Seldom was it necessary to use a battery or other power source, although some crystal detectors worked better with a low-voltage primary cell. The passage of time with the natural development of improved substitutes for most of the aforementioned components has made the crystal receiver more or less a museum exhibit. The tuning coil, or loose coupler as it was termed, was both inefficient in the forms then available, and bulky besides. Of the equipment used in pioneer stations, only the headphones remain as an essential part of amateur apparatus and even then only as an adjunct to the loud speaker for the reception of extremely weak signals.

Similarly, the transmitter has passed through so many development stages that the amateur station of today bears no resemblance whatsoever to the bulky, inefficient, and noisy stations of yesteryear. For one thing, the spectacular crash of the spark gap is no longer heard. Governments outlawed that item because it contributed to chaos in an ether that was rapidly becoming overpopulated with radio services of a dozen different types. To take its place, scientists perfected the vacuum tube which, operating almost silently, managed to originate, modulate, and transfer much greater volumes of power in much smaller space. The rise of amateur radio is coincidental with the introduction and perfection of the vacuum tube.

COMPONENTS OF RECEIVERS

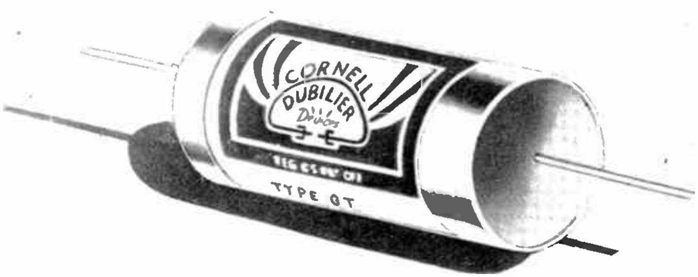
Instead of the variable tuning inductance for selecting the desired wave length, amateurs now depend mainly on fixed inductances and variable condensers. This combination not only gives finer control but the relation between inductance and capacity can be held at the point of maximum efficiency. In short-wave work, this ideal is approached by changing the value of the inductance in the circuit by shifting coils as the switchover is made from one band of frequencies to another. Exchangeable coils, called plug-in coils, came into use first because of the electrical losses encountered when several sets of coils were interconnected with a selector switch. However, in the past few years, low-loss switches have been developed which overcome this drawback. As a result, the majority of modern receivers use an array of four or five sets of coils so placed in an assembly that a rotary switch selects the group desired for a given frequency range. To make tuning easier, the principle of *bandspreading* has come into use in recent years, whereby the tuning range of any one coil is adjusted so that nearly all of the tuning dial scale is occupied by the band selected by the switch. This is accomplished by the use of a *bandspread condenser* connected in parallel with the tuning condenser across the tuning coil.

CONDENSERS, FIXED AND VARIABLE

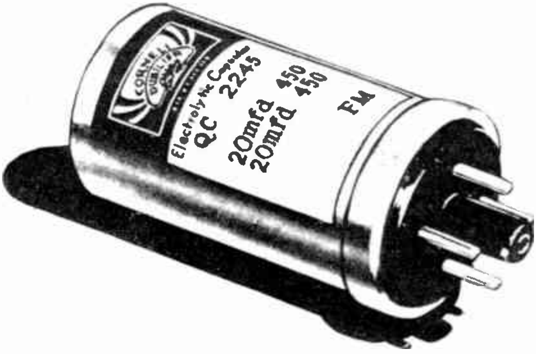
Condensers are of several types, fixed as well as variable in capacity. The variable condenser consists of a series of metal plates, one set fixed and the other variable, and so disposed that the latter interleave with the former when the common shaft is rotated. The plates may be semicircular in shape or they may take odd shapes, depending on the purpose for which they are to be used. New insulating materials have been discovered which produce variable condensers with extremely low electrical loss. This means sharper tuning and stronger signals. In addition, modern manufacturing methods have made it possible to reduce the spacing between the plates and thereby gain the desired capacitance in less space.

The modern radio receiver embodies a number of fixed condens-

10. Three types of molded-bakelite mica receiving capacitors.



11. Wax-impregnated tubular paper capacitor.



12. Twenty-mfd plug-in type dry electrolytic capacitor.

ers, or capacitors, to accomplish a variety of effects. The fixed condenser may be a combination of a conductor (usually aluminum or tin foil) with mica or paper as a dielectric or separator. Or it may be one of the forms of electrolytic condensers in which the dielectric is formed by the effect of electric charges on a moist or wet chemical. The latter are commonly employed where large capacitors must be compressed into a small space.

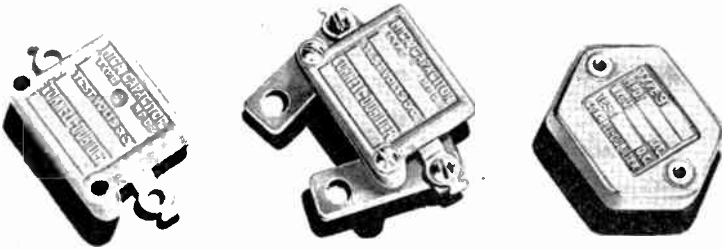
Mica type fixed condensers may be used where the extremes of voltage are high, the paper type where the voltages are more moderate, although paper dielectric condensers are available for almost any purpose today. These capacitors are usually inserted in radio circuits to by-pass currents of low voltage and of certain frequencies or to balance resonant circuits with other variable capacitors.

Electrolytic condensers will be found in the filter circuits of power supplies where large capacitors are essential in smoothing out the ripples in rectified alternating currents. One basic limitation of these condensers requires that they be used only where the dominant current is direct. An electrolytic condenser will be ruined speedily if subjected to an alternating current.

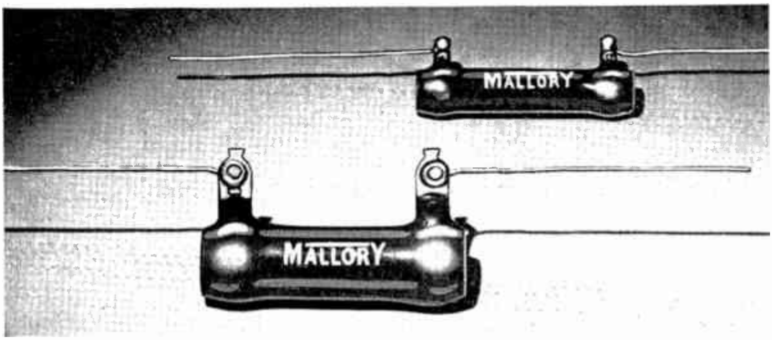
Because of their chemical make-up electrolytic condensers possess the property of self-healing if through an unusual condition the dielectric film is broken down. Mica and paper condensers must be discarded once they have been punctured by a voltage exceeding their rated value. On the other hand, an electrolytic condenser must never be located too near a source of intense heat, such as a rectifier tube, since the film will be destroyed and the voltage limit thereby reduced.

RESISTORS

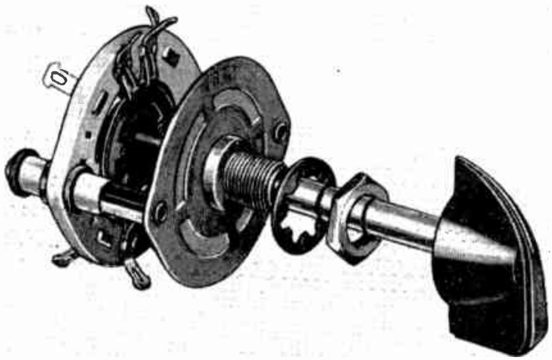
Accurate resistors are employed frequently in all receiving and transmitting sets. They are rated by the watts of electrical energy which must pass through them. They may be formed from compressed carbon mixtures or they may take the form of many turns of fine wire wound around an insulating rod. The exact type needed is invariably specified in the construction of any piece of radio apparatus. One type of resistance is the variable volume control which alters the voltage in any one of several circuits to establish the de-



13. Molded mica transmitting capacitors, employed for grid and plate blocking and for r-f by-pass functions. (*Cornell-Dubilier Electric Corp.*)



14. Vitreous enamel fixed resistors. (*P. R. Mallory and Co., Inc.*)



15. Ceramic "hamband" switch for transmitter-band switching of low-power transmitter circuits. (*P. R. Mallory and Co., Inc.*)

sired signal gain. These potentiometers, for that is what they are, are sometimes made by winding a large number of turns of very fine wire on a circular form with a sliding contact operated through a shaft to vary the tapping point of the voltage network. Other styles comprise impregnated fiber with a similar sliding contact moving around the periphery of the control. There are innumerable other styles of both condensers and resistors, all of which follow the basic outlines given here, but since the variations have been developed for special purposes it would not aid the amateur to outline them at this time. As refinements in receiver and transmitter are conceived the need for an unusual component will arise but by that time the amateur will have made himself acquainted with the field and will know the exact type for his work.

HEADPHONES

At one time there was a continual controversy over the best type of phones to use in amateur reception but so many other factors are more important today that it is sufficient to point out that headphones made by any reputable firm, with a total weight that is not unbearable and a resistance of either 2,000 or 3,000 ohms, will perform to the full satisfaction of the amateur. As a matter of fact, the amateur operator will soon discover that modern tubes and circuits will create an audible signal from far distant stations sufficient in strength to operate a loud speaker, thereby eliminating the need for headphones altogether. It is only in periods of heavy atmospheric noise when the audio gain of a loud speaker circuit amplifies the noise out of all proportion to the radio signal that recourse must be had to phones. With better antennas and more powerful transmitters, these periods will occur with lessening frequency.

GETTING THE MOST OUT OF YOUR HOBBY

In the preceding pages you have been introduced to radio and have become acquainted with receiving sets in their simplest form. In order to understand the assembly and operation of more elaborate receivers and of transmitters it is necessary to be familiar with some of the elementary principles of physics and electricity. The reader is urged to consult a few of the many books on these subjects that are available in any public library. Of course you can follow instructions implicitly and succeed in assembling receiving sets and you can learn to turn knobs in mechanical fashion without any knowledge of electricity. But if you wish to experiment intelligently and enjoy your hobby to the utmost learn all that you can about the elementary principles upon which it all is based.

CHAPTER

4

Mechanical and Electrical Tuning

There is a strikingly close resemblance between *sound waves* and the way they are set up in the *air* by a mechanically vibrating body, such as a steel spring or a tuning fork, and *electric waves* and the way they are set up in the *ether* * by a current oscillating in a circuit. As it is easy to grasp the way that sound waves are produced and behave, something will be told about them in this chapter together with an explanation of how electric waves are produced and behave. Thus you will be able to get a clear understanding of them and of tuning in general.

DAMPED AND SUSTAINED MECHANICAL VIBRATIONS

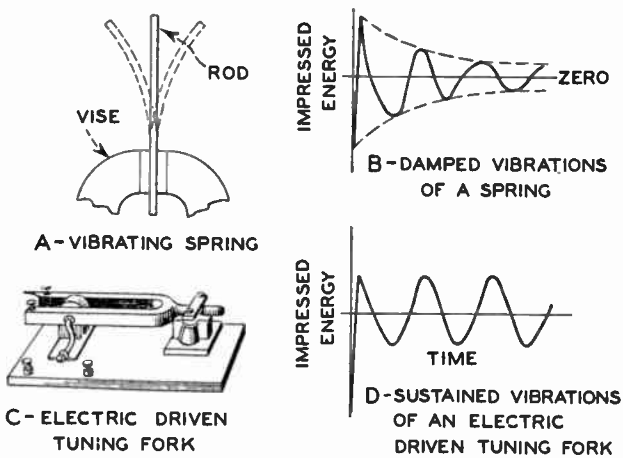
If you place one end of a flat steel spring in a vice and screw it up tight as shown at *A* in Fig. 16, and then pull the free end over and let it go, it will vibrate to and fro with decreasing amplitude until it comes to rest as shown at *B*. When you pull the spring over you store up energy in it, called *potential* energy; when you let it go the stored-up energy is changed into energy of motion or *kinetic* energy and the spring moves back and forth, or *vibrates*, until all of its stored-up energy is spent.

If it were not for the air surrounding it, and other frictional losses, the spring would vibrate for a very long time, as the stored-up energy and the energy of motion would practically offset each other, and the energy would not be used up. But as the spring beats the air, the latter is set in motion and the conversion of the vibrations of

* The ether is a hypothetical medium for the propagation of light, radio waves, and other forms of electromagnetic radiation. Many scientists, among them Einstein, have denied its existence, and prefer to speak of it simply as the *radiation field,* which is the interpretation given it in this book.

the spring into waves in the air soon uses up the energy imparted to it and the spring comes to rest.

In order to send out *continuous waves* in the air instead of *damped waves* as with a flat steel spring, you can use an electrically driven *tuning fork* (*C*) in which an electromagnet is fixed on the



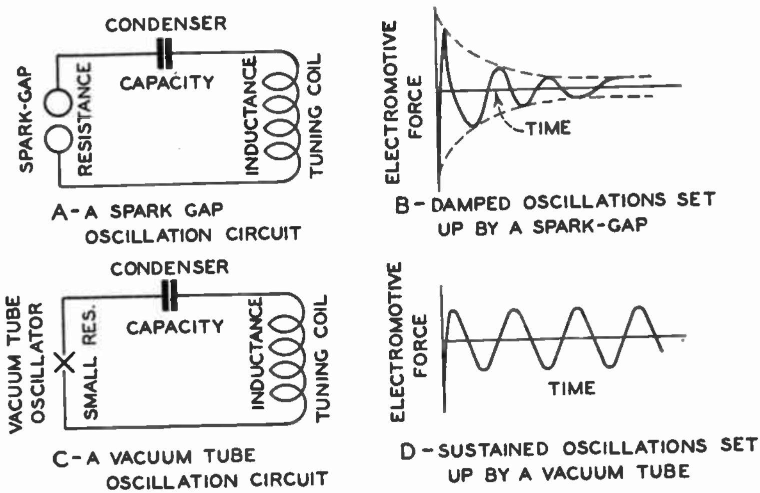
16. Illustrating damped and sustained mechanical vibrations.

inside of the prongs. When the electromagnet is energized by a battery current the vibrations of the prongs of the fork are kept going, or are *sustained*, as shown in the diagram at *D*.

DAMPED AND SUSTAINED ELECTRIC OSCILLATIONS

The vibrating steel spring described above is a very good analogue of the way that damped electric oscillations which surge in a circuit set up and send out periodic electric waves in the ether, while the electrically driven tuning fork is likewise a good analogue of how sustained oscillations set up and send out continuous electric waves in the ether, as the following shows.

The inductance and resistance of a circuit, such as is shown at *A* in Fig. 17, slows down the electric oscillations of the high-frequency currents, and finally damps them out entirely, where these oscillations are set up by the periodic discharge of a condenser, just as the vibrations of the spring are damped out by the friction of the air and other resistances that act upon it. As the electric oscillations surge to and fro in the circuit they are opposed by the action of the ether which surrounds it. Electric waves are set up and propagated and this transformation soon uses up the energy of the current that flows in the circuit.



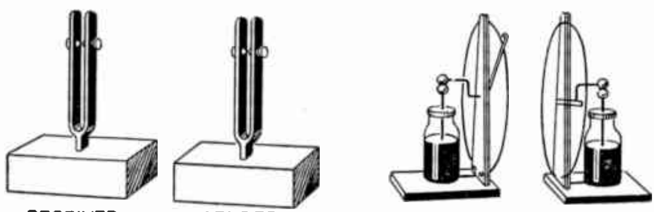
17. Damped and sustained electrical vibrations.

To send out *continuous waves* in the ether such as are needed for radiotelephony, instead of *damped waves*, a *vacuum tube oscillator* (*C*) must be used. Where a vacuum tube is used, the condenser is charged as rapidly as it is discharged, hence the oscillations are sustained as shown at *D*.

ABOUT MECHANICAL TUNING

A tuning fork is better than a spring or a straight steel bar for setting up mechanical vibrations. Actually, a tuning fork is simply a steel bar bent in the middle so that the two ends are parallel. A handle is attached to the middle point of the fork so that it can be held easily and allowed to vibrate freely, the ends of the prongs alternately approaching and receding from one another. When the prongs vibrate, the handle vibrates up and down, or longitudinally.

If you mount the fork on a sounding box, which is constructed so that it will vibrate in unison with the vibrations of the fork, there will be a direct reinforcement of the vibrations. The note emitted by it will thus be augmented in strength and quality. This reinforcement of vibration is called simple resonance. Now if you mount a pair of identical forks each on a sounding box tuned to the same vibrating frequency, you may observe another physical phenomenon known as sympathetic resonance. Set the boxes a foot or so apart, as shown at *A* in Fig. 18, then strike one of the forks with



18. Sound-wave and electrical-wave tuned transmitters and receivers.

a rubber mallet. It will vibrate at its natural frequency, setting up sound waves of a given wave length. When the latter pass over the short distance to the adjacent fork, the impact of the molecules of air of which the sound waves are formed will set its prongs vibrating and this in turn will cause the emission of sound waves of the same wave length. As previously pointed out, this effect is called *sympathetic resonance* in physics. In radio terms, we would say that the forks are *in tune* or *tuned* with each other.

Tuning forks are sometimes made with adjustable weights on their prongs which may be moved to different positions so as to change the frequency with which the fork vibrates, since the frequency varies inversely with the square of the length and directly with the thickness * of the prongs. Knowing this, we can adjust one

* This relationship is for forks having a rectangular cross section. Those having a round cross section have frequencies that vary directly with the radii of the prongs.

of the forks so that it vibrates at a frequency of, say, 16 oscillations per second; but if the other fork is not similarly adjusted it will not be in tune with the first fork and there will thus be no sympathetic resonance between them. The difference in frequency may be only slight, yet there will be no sympathetic vibrations set up.

ABOUT ELECTRICAL TUNING

Electrical resonance and electrical tuning are quite similar to acoustical resonance and mechanical tuning. Just as mechanical tuning may be simple or sympathetic, so electric resonance may be simple or sympathetic. *Simple acoustic resonance* is the direct reinforcement of a simple vibration, as when a vibrating tuning fork is mounted on a sounding box. In simple electric resonance an oscillating current of a given frequency flowing in a circuit having the proper inductance and capacitance may increase the voltage until it is several times greater than its normal value. Tuning the receiver circuits to the transmitter circuits are examples of electrical resonance. This can be demonstrated with two Leyden jars (capacitance) connected in circuit with two loops of wire (inductance) whose inductance can be varied as shown at *B* in Fig. 18. When you make a spark pass between the knobs of one of them by means of a spark coil, a spark will pass over the gap of the other one provided the inductance of the two loops of wire is the same. But if you vary the inductance of the one loop so that it is larger or smaller than that of the other loop no spark will occur in the second circuit.

When a tuning fork is made to vibrate it sends out waves in the air, or sound waves, in all directions. In the same way, when high-frequency currents surge in an oscillation circuit they send out electric waves in the ether that travel in all directions. For this reason, electric waves from a transmitting station cannot be sent to only a single receiver, although they may travel farther in one direction than another according to the way the antenna is constructed.

In recent years engineers have devised antennas that concentrate the major portion of the station energy in a narrow beam but the rays of this beam diverge or spread out once they are in the air so that when they have passed over the earth for hundreds of miles, the beam has assumed a width of many miles. *Beam antennas*, or *directive arrays*, as they are called, are being adopted by amateurs and arranged so that they may be rotated to give the maximum effect in the direction of the intended receiving station.

Since electric waves, unless specially directed, tend to travel out in all directions, any receiving set properly tuned to the wave length of the transmitter will receive the signals providing there is enough power in the wave, and providing also that the receiving set is sensitive enough to detect and amplify the weak signal as it arrives.

To do this, the receiver must be tuned to the transmitter just as one tuning fork is tuned to the other, although in radio tuning this must be done by varying the capacitance of a condenser or the tuning inductance, or both. Because it is so much simpler and quicker to alter the frequency at the receiver, the transmitter is maintained at a given frequency which has been found by test to give the best results.*

* The foregoing remarks apply to AM or *amplitude modulation* broadcasting and receiving; as we shall see in a later chapter, in FM or *frequency modulation* broadcasting the frequency at the transmitter is regularly increased and decreased according to the amplitude and polarity of the modulating signal.

CHAPTER

5

Antennas

It is doubtful if any individual component of an amateur station has been altered so radically in form as the antenna. When amateurs were not so closely supervised in their method of operation almost any elevated wire would do for both transmission and reception, but as international governments moved the sphere of the amateur from 200 meters (1,500 kilocycles) to 100 meters and then to 80, 40, and 20 meters, it became evident that special types of transmitting antennas were essential if long distances were to be covered by radio signals. New types of receiving antennas were also in order but they were not so vital, since signals could be received on almost any type of collector. But amateurs soon discovered that the best station in the world would not reach far if its antenna were erected in a haphazard manner. This applies to the sending of code as well as voice.

SELECTION OF ANTENNA TYPE

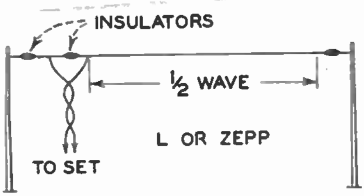
The type of antenna must be selected on the basis of its location and the desires of its owner. If short-wave *reception* is the goal then one form of antenna, the doublet, is indicated. If amateur *transmission* is to be attempted the owner has a choice of several simple types of antennas or one of the more elaborate forms which are highly recommended for their efficiency. On the other hand, if the receiving antenna must also be used occasionally for broadcast-band reception, the amateur is no longer advised to erect a separate collector for these frequencies. The short wave doublet will provide plenty of signal strength, thanks to the high amplification or gain in the modern broadcast set.

Residents in thickly populated districts such as the apartment house sections of the larger cities are the ones who will find it most difficult to raise an antenna for transmission as well as reception, but particularly the former. Broadcast antennas are so thickly clustered on most structures today that it requires the skill of a magician to spot an area where another may be added. Then, too, if the projected antenna is for amateur transmission, much thought must be given to the possibilities of interference with the BCL, as amateurs refer to the broadcast listener. When BCL's discover an amateur interfering with their favorite comedian or news commentator they are prone to register a complaint with the nearest representative of the Federal Government's radio inspection force. Although the amateur may be working well within his rights, the government is likely to take the benign attitude that broadcast listeners, being in the majority, should be satisfied first. This means that the amateur is told to remain inactive until the interference can be eliminated in some way such as by erecting a higher antenna or reducing its length, or by the installation at a suitable wavetrap between the BC receiver and its antenna. Knowing this, it behooves the man breaking into amateur radio to select his antenna location with the utmost care in order to forestall any of these irritating episodes. Even then, some further tests and alterations may be needed before perfect operation is assured.

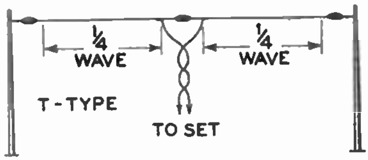
SIMPLE ANTENNA TYPES

The simplest antennas of all are the L or T types, so named from their shape. The L type, shown in Fig. 19, is better known as the Zeppelin or Zepp. It will be noted that while the double line connecting the transmitter with the antenna is "alive" on both sides, one terminal only is connected to the horizontal wire, the other terminating or "dead-ending" between two insulators. The simplest form of the T or doublet antenna is indicated in Fig. 20, but there are numerous variations which the amateur may try out for better radiation after the transmitter is in working order.

Because of the greater space demanded and the difficulties encountered in long antennas the length of the elevated wires is usually kept at a minimum consistent with efficiency. Usually the beginner starts with a half-wave antenna, that is, with the total length equal to one-half the wave length he intends to use. This does not mean that it will be necessary to erect a separate antenna for each frequency used, for the amateur bands have been chosen in exact multiples so that a one-half wave antenna for 40 meters is a full wave length for 20 meters. Actually, satisfactory radiation



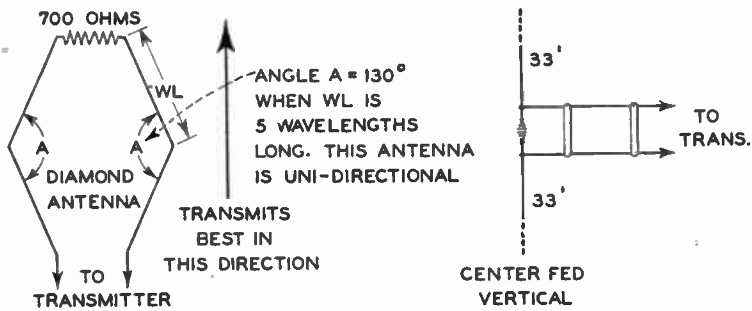
19. L-type antenna.



20. T-type antenna or doublet.

will be obtained even if the matching is not perfectly accurate, but eventually the amateur will discover the two bands on which he prefers to operate and adjust his radiators for best results on those frequencies.

For a simple half-wave antenna the computations are not at all difficult. Since a meter is equal to 39.37 inches the proper over-all



21. Two types of transmission antennas.

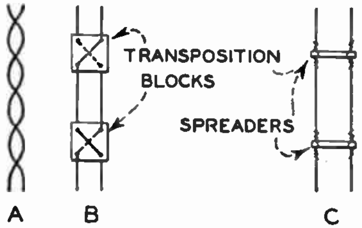
length for 40-meter transmission would be 20 (½ of 40 meters) times 39.37 inches or 65.6 feet long. On the same basis the length of wire for the 80 meter band, assuming a half-wave antenna, would be 131 feet.

Where space is extremely limited, such as in populated cities, it is often necessary to use a quarter-wave radiator which would halve the figures given above for the corresponding operating frequencies.

Experienced amateurs have expended so much thought on efficient antennas that the variations are almost beyond number. In addition to the two basic types mentioned previously there are other forms known as "V," Bent, Vertical, Rhombic, Stacked Dipole, Broadside, End-fire Directivity, Polarized, Corner-Reflector, and Rotary, to name only a few. Since each type has special applications and requires more extensive knowledge of the fundamentals of radiation it is not possible to treat each style here. The amateur, when he is ready for this phase of his hobby, should obtain one of the several excellent treatises on this subject and then carry out his experiments with the aid of instruments which he will have acquired. At the start he is advised to select the simplest of the many forms and concentrate on that until his operating technic has reached the point where he can proceed with full knowledge of his aims. Too many amateurs have become discouraged by attempting to swim beyond their technical depth when the hobby is new and relatively obscure to them.

TRANSMISSION LINES TO THE ANTENNA

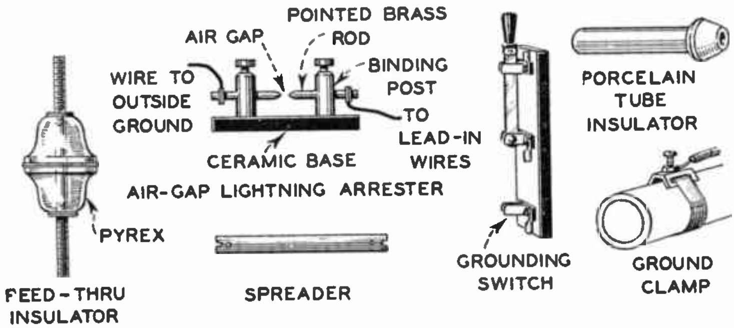
Once the amateur has made his selection of antenna type he will be concerned with the problem of feeding the transmitter energy to the radiator with the least loss of energy along the way. This brings up the subject of transmission lines.



22. Transmission lines.

Transmission lines are the wires—or sometimes a single wire—leading from the output of the transmitter to the antenna. These may be the twisted pair shown in Fig. 22*A*, the transposed feeder of Fig. *22B*, or the parallel feeder of Fig. *22C*. Here again, assuming that the beginner will be content to start with low power, the simplest form is the best. This is the twisted pair. The principal warning here is to secure the best quality of conductor available. The insulation in particular must consist of good, live rubber and the conductors should be at least No. 16 in size.

Another widely used form of transmission line comprises two conductors separated from 4 to 6 inches by insulating spreaders (see Fig. *22C*). One type is known as the Q antenna and consists



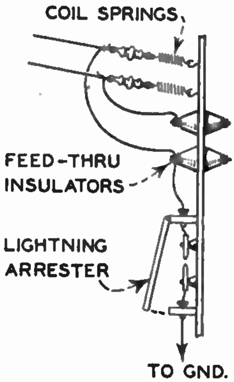
23. Some of the necessary equipment for an antenna.

of two parallel conductors of rather heavy dimensions connected to the center points of a half-wave antenna as in Fig. *22C*. This arrangement is somewhat more complicated, since a definite relation exists between the lengths of the antenna proper and transmission lines and the spacing between the latter. The preferred dimensions of these items have been worked out theoretically and are given in detail in the various publications on antennas.

PROTECTION OF ANTENNA

Transmitting antennas not only carry a high voltage requiring adequate protection of life and property but are also erected in the open where they are subject to direct and induced strokes of lightning. This means that the amateur must arrange for suitable termination of the transmission lines at the house end supplemented by approved lightning-protective devices. In the open country the latter precaution is not only desirable but mandatory because of insurance regulations.

Since the transmission lines, whatever the type used, must be prevented from undue swaying because of its effect on the stability of the radiated signals, it is vital that the lower terminals be anchored to sturdy supports near the point where the wires enter the transmitting room. Many amateurs use stiff coil springs between each transmission line and the eyelet or other anchor adopted.



24. Lightning-arrester installation.

This makes for a secure, permanent terminus for the lines. A wire is then attached to each down lead adjacent to the insulator separating the transmission line from the coil spring and carried downward to the standoff insulator through which the antenna passes on its way to the inside room. One way of doing this is shown in Fig. 24. It should be kept in mind that the transmission lines, if spaced, should be maintained with this identical spacing at all times even when passing through the walls of the house. Where conditions permit, the standoff insulator may be attached to the glass window pane by means of holes drilled through the glass. However, house panes of large area will not have the ruggedness to withstand the strain and must be replaced with plate glass of substantial thickness when this method of entry is preferred.

For the sake of safety and efficiency it is recommended that the transmission lines inside the transmitting room be carried direct and with the minimum of supports to the output terminals of the transmitter. Certainly they should be kept high and out of reach of inquisitive visitors.

In installing lightning protection it is a wise amateur who foregoes any attempt to be economical. Lightning arresters for amateur use are available at any store dealing in radio accessories and they should be procured in preference to home-made gaps. For efficient operation these devices should be enclosed in an asbestos-lined box or in one of the ample-dimensioned outlet boxes made of metal and sold in electrical supply stores. Under any circumstances an outside ground entirely independent of the transmitter and receiver grounds must be established. This may be a four-foot copper rod driven into the earth directly beneath the lightning arresters and connected with the latter by heavy copper conductors which pass downward without sharp bends.

Another precautionary measure is the installation of grounding switches inside the transmitting room at the point where the transmission lines enter. Usually these are manually operated and are thrown to the ground position at all times when the station is not in operation.

Because of the many special problems involved, the Bureau of Standards has prepared a valuable booklet on "Safety Rules for Radio Installations" which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., at a cost of 15 cents. Every amateur should procure a copy before beginning his operations.*

THE RECEIVING ANTENNA

So far the transmitting antenna has received prominence in the text because of the necessity for getting the maximum amount of generated energy into the radiating antenna. A few per cent of gain in the transmitting antenna well repays the amateur for his efforts and may mean the difference of hundreds and even thousands of miles in the distance covered. The receiving antenna on the other hand is not so important on the short waves. Inspection of many amateur stations reveals that an indoor wire is sufficient to pick up

* These rules comprise Part 5 of the *National Electrical Safety Code*.

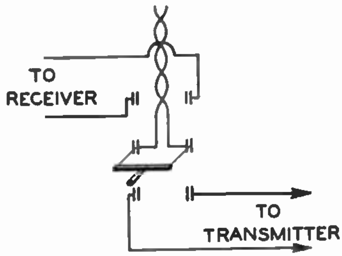
most of the other amateur stations that can be reached by the transmitter. This practice, however, is not to be recommended generally. As a matter of fact it is not always necessary to erect a separate collector for received signals. The transmitting antenna, properly installed, provides the owner with an excellent receiving antenna, a simple switching device being all that is required to shift the outside radiator from transmitter output to receiver input.

In the beginner's installation the switchover is handled by a manually operated switch arranged in such a manner that there is no chance for receiver and transmitter to become interconnected. In more advanced installations, the switchover takes place by means of relays so connected as to shift from receiver to transmitter automatically. Here again the problems involved both from the standpoint of safety as well as utility suggest that the beginner adopt the hand-operated changeover switch until he has mastered the intricacies of the art.

Where it is believed desirable to erect a separate antenna for receiving it will be found preferable to place it as far as possible from the transmitting antenna and at right angles to it. Obviously with the transmitter radiating considerable energy, any receiving antenna near by will pick up a signal far greater in intensity than that received from a typical broadcasting station and the impulses accordingly will crash into the receiver unless thwarted. Since the receiver is functioning at all times while the transmitter is active, amateurs usually arrange for some form of silencing circuit on earphones or loudspeaker when calling. This may be a shortcircuiting relay on the receiver input or an open-circuiting switch on the phone leads. These accessories are normally installed to operate in conjunction with the key or by means of a hand- or foot-controlled device.

The simplest switching device between transmitter and receiver is shown in Fig. 25, but as his skill increases and his knowledge of radio technic expands the amateur will develop his own system for accomplishing the same ends.

There is no difference between the antenna used for amateur reception and that found best for all-wave broadcast reception. For the reasons outlined above, the most condensed collector will provide the best reception under all conditions. Thus the familiar double doublet consisting of a wire about sixty-five feet in length, split in the middle, and connected to the receiver by a twisted pair of lead-in wires will be found to perform satisfactorily. Modern short-wave receiving circuits and tubes have been so highly developed in their effects on sensitivity and selectivity that a usable signal from great distances can be detected when almost any type of antenna is employed. The only limiting factor is the noise that is customarily found on the high-frequency bands. This noise may be due to atmospheric disturbances—otherwise known as static—or it may come from electrical devices such as automobile ignition systems, defective power lines, diathermic apparatus, and domestic

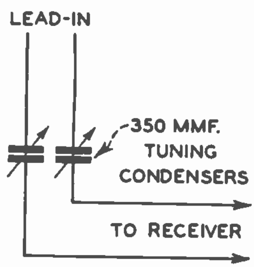


25. Antenna switching device.

appliances including oil burners, vacuum cleaners, electric shavers, etc. With these noise-making sources on the increase it behooves the amateur to select the antenna that picks up the maximum signal and the minimum noise. The double doublet is one of the types that meets these demands.

THEORY OF THE DOUBLE DOUBLET

Tests have shown that the majority of spurious noise impulses are picked up by the antenna lead-in. There are several reasons for this, including the fact that much of the man-made static that infests the air is vertically polarized and therefore exerts its greatest effects on vertical collectors. Another reason is that the lead-in by its very nature is closest to the earth where the majority of the sources are located, whereas the antenna is likely to be elevated above the zones of greatest noise intensity. Realizing this situation, it is easy to understand that if the lead-in can be made noise-free the desired signal in the antenna will reach the receiver at an intensity that will override the unwanted impulses. This condition can be established by using two lead-in wires, one from each half of the antenna, twisted around each other throughout their entire length from antenna to terminals of receiver. The radio signals in each half of the doublet are 180° out of phase with the other, which means that when the signal in one half is maximum, the other half is minimum, and thus they pass down the lead-in to the receiver without any mutual effect. The noise, on the other hand, is impressed on the two conductors of the lead-in simultaneously and induces equal voltages in both wires. Then by twisting the wires



26. Tuning a receiving antenna.

continually a transposing effect is produced with one signal voltage canceling the other.

In the majority of double doublets of the manufactured type, the length of lead-in supplied with the kit has been matched to the antenna for optimum results and the user is warned not to remove the excess length but to coil it up and hang it behind the receiver. In practice, however, it will be found that a considerable number of feet can be removed without having a discernible effect on the received signal.

When the utmost in receiving efficiency is desired, a tuning arrangement on the receiver end of the lead-in has been found extremely useful. One form frequently employed is shown in Fig. 26, where a small variable condenser is inserted in each side of the lead-in. By trial, the amateur will soon find the best relative setting for each condenser for the individual bands to which he tunes

THE GROUND SYSTEM

Every radio system, whether it is used for sending or receiving, requires some form of connection with the earth. For the receiver the demands are not exacting. A cold-water pipe to which a ground ~~clamp is first attached will do for all purposes, but if the stretch of~~ wire needed to reach such a pipe is extreme, a steam pipe will often do as well. Keep ground wires away from all fuel lines, such as oil and gas, for obvious reasons. If the home is in a remote location or in rural areas where water and steam piping are not available, establish your own ground by driving a rod into the dampest earth immediately available. The effect will often be equal to that of the more elaborate earthing methods. Direct grounds are not always essential to operation, as witness the case of a-c–d-c receivers which are not equipped with a ground wire, but the tenets of safety call for adequate grounding in some manner, particularly in amateur work.

For the transmitter, where a direct ground connection is advised, recourse should be had to a cold-water pipe or to an outside earth contact. When the transmitter chassis serves as an immediate neutral point for all current returns, the operator should see that the metal of the chassis is connected with a ground in order that any accidental disarrangement of the high-voltage components does not set up a voltage difference between chassis and earth, a condition that might lead to a fatal shock through careless operation of the equipment.

SOME ANTENNA PRECAUTIONS

In latitudes where sleet is likely to collect on exposed wires, don't stint on the size of wire used. Number 12 enamel-covered copper wire with a steel core will withstand almost any tension that will be applied to it under any seasonal condition. Moreover, it will not stretch or sag.

Never use a power-line pole for an antenna support.

Don't run the transmitting antenna parallel to a nearby power line, or over or under other wires.

Protect the external transmission line terminals, including lightning-protective devices, against easy access by children or even adults. Safety will be promoted by keeping such apparatus as high as possible above ground. In addition, place a sign, "High Voltage: Dangerous," on or near the transmission lines both inside and outside the transmitting room.

Don't adjust the antenna until you have taken every precaution against the accidental or unexpected application of transmitter power. It is only when every care has been taken against accident that amateur radio becomes an enjoyable hobby rather than a hazardous experiment.

NOTE.—A further word about antennas will be found in the chapters on Frequency Modulation and Television.

CHAPTER

6

Vacuum-Tube Principles

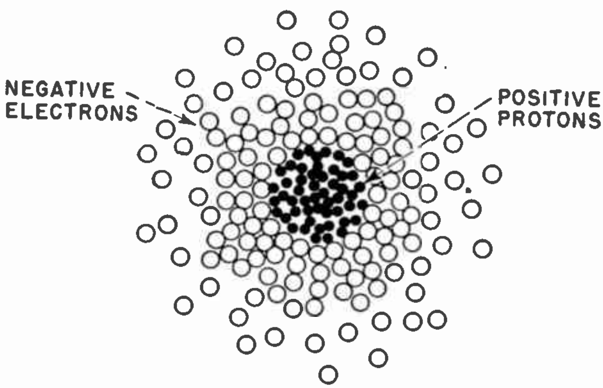
The vacuum or electron tube is a marvelous device. It is one of the most important contributions that science has made to civilization in the present century. It has given rise to an entirely new field of engineering—electronics—and it performs an extraordinary range of functions, from detecting and amplifying radio signals and converting electrical impulses into light images to the solution of mathematical problems too complex for the human brain. In radio, the vacuum tube serves as a detector and amplifier of infinitesimal electric currents, as a rectifier of alternating currents, as an amplifier of voice and music, and as an oscillator or generator of electromagnetic waves. More and more applications are constantly being found for this 20th-century Aladdin's Lamp, and its future uses seem almost unlimited.

WHAT AN ELECTRON IS

Before trying to understand how a vacuum tube acts in a circuit, it is necessary to learn something about what makes it operate. In order to comprehend this, we must start at the very root of the matter—the *electron.*

Matter, we know, exists in three forms—solids, liquids, and gases—and is composed of small particles known as *molecules;* which are the smallest subdivisions of a substance that retain the chemical and physical properties of the original material. Molecules in turn consist of groups of *atoms*, which are the smallest particles of the various chemical elements that compose each substance.

Science also tells us that atoms are composed of positive and negative *charges of electricity*, the number and arrangement of these charges determining the nature or identity of the atom. Every atom has a central core of positive particles of electricity, called *protons*, which are united in some mysterious way to other particles called *neutrons*, which have no electric charge. Around this *nucleus* rotate a number of negative charges of electricity, called *electrons*, and it is these charges that account not only for all of the amazing electrical phenomena in radio, television, facsimile, diathermy, industrial control, and electrical engineering generally, but also for the very nature of matter itself.



27. The grouping of electrons around the positive protons in an atom.

Electrons are inconceivably small. Carefully controlled experiments indicate that the diameter of an electron is about 10^{-13} centimeter, which is a mathematical way of saying that about 100 trillion electrons placed end to end would measure one centimeter. A further idea of their size may be gained from the estimate that in a very tiny globule of copper, having a diameter of 1/100,000 of an inch, there are about 20 billion electrons.

The arrangement of electrons and protons in an atom (Fig. 27) may be compared to a miniature solar system, in which one or more electrons are rapidly rotating about the positive nucleus, as the earth and other planets rotate about the sun. It is the number of protons and electrons in an atom that determine whether it be iron, gold, chlorine or hydrogen. The last-named element is the simplest in its make-up of the whole chemical table, as it has one proton for a positive nucleus and a single electron rotating about it, while uranium, one of the heaviest known elements, has 92 protons in its nucleus.

The speed with which the electrons travel about the positive nucleus depends on the temperature. The hotter the substance of which the atom is a part, the faster go the electrons. And, of course, the reverse is true: the colder the atom the slower the electrons travel, until at *absolute zero*, which is —273° C, theoretically all motion ceases entirely.

IONIZATION

As long as all of the electrons remain within the influence of the positive nucleus of an atom, its positive and negative charges are equalized and it is therefore electrically neutral. When, however, one or more of its electrons are removed from it—and there are several ways in which this can be done—the atom shows a positive charge, and in that state is called a *positive ion.*

In other words, a *positive ion* is an atom that has lost some of its electrons, while a *negative ion* is one that has acquired some additional electrons. Ionization, therefore, may be defined as *the addition or subtraction of one or more electrons from a neutral atom.*

THE RELATION OF THE ELECTRON TO CURRENT FLOW

It seems advisable to explain the differences between the three types of current flow and how the electron acts in each one. These three currents are: conduction, displacement, and space or emission current.

The fact has already been mentioned that in every atom there are one or more electrons whirling at a high speed about the positive nucleus, these electrons being kept in their orbits by nuclear attraction. Some of these electrons are attracted more strongly by the positive nucleus than others, which are called *loose* or *free* electrons, since they are rather easily removed from the atom by means of an external electrical force.

Now we know that some metals are better conductors of electricity than others, which means that these conductors have atoms that contain more free electrons than the others. When an electrical force, such as a battery or generator, is applied to a wire, for example, these free electrons in the wire begin to move from one atom to another toward the source of the force. This movement of electrons is called *conduction current* or *electronic drift*.

It should be remembered that the atoms remain fixed in their positions in the wire; *it is only the electrons that move.* Also the direction of current is from *negative* to *positive,* as the electrons are the negative portion of the atom.

DISPLACEMENT CURRENT

It is also a well-known fact that some materials, commonly called *insulators*, do not conduct current to any appreciable extent. It was explained previously that condensers were composed of two plates of a conducting material with an insulator or dielectric between them.

We have learned just above that in a conductor there are many free electrons in the atoms composing the material; the opposite is true in an insulator. The atoms have few if any free electrons, so that when an electrical force is applied to the material the electrons will not jump from atom to atom, and therefore no current will flow.

Although the electrons will not move from atom to atom, yet there is a definite force applied to them so that they are moved slightly from their original places. Now in a condenser we have a conducting wire attached to each plate. When an electrical force is applied to the wires, there is a conduction current set up that sets in motion the electrons in the wire. These electrons travel along until they come in contact with the electrons of the insulator. As more electrons are coming from behind, the negative charge on the positive side of the insulator, or dielectric, is increased, so that the electrons in the dielectric are strained or pushed out of their regular places in their respective atoms. They remain in this strained position (that is, the condenser maintains its charge) even after the electrical force that charged it is removed.

What happens when we discharge the condenser by bringing the ends of the wires connected to the two plates into contact? The electrons that have been strained from their original positions within the atoms of the dielectric at once tend to return to their previous state of neutrality, and the electrons that have been forced in are now pushed out and carried around through the connecting wire to the other plate of the condenser, which has been partially drained of its electrons. In other words, the whole system returns to a neutral state. This shifting of the electrons within the dielectric is called *displacement current*.

SPACE OR EMISSION CURRENT

Under ordinary conditions, electrons in a copper or tungsten wire will flow along easily when the proper electromotive force is applied. It would seem a difficult feat to remove these free electrons from the wire, yet if we change conditions slightly we can make them jump out into space from the surface of the metal. If the amount of current is increased so that the temperature of the wire is raised to the point of incandescence, the electrons of the wire will whirl about more rapidly in their orbits. This increase of speed, together with the increase of temperature, enlarges the diameter of their orbits, until at a certain point the electrons will be traveling so fast that they will fly off or escape from their atom and be "captured" by another atom. This, of course, is an unstable state of affairs as long as the electrons are moving at accelerated speeds, so that electrons tend to jump from atom to atom until they reach the surface of the wire or filament. When this occurs, the fast-moving electrons jump from the metal into the surrounding space. This process of removing electrons from atoms is called *ionization by heat*, as distinguished from *ionization by impact*, which occurs when conduction currents are set up.

If we enclose the filament in a glass tube from which the air has been removed and insert a metal plate to which a wire is connected. we can control the stream of electrons by giving the plate a positive charge so that electrons will be attracted to it. This stream of electrons between the filament and plate of a vacuum tube is called *space current* or *emission current*. The source of electrons (the filament) is called the *cathode*, and the plate (or destination of the negative charges of electricity) is called the *anode*. This two-electrode or *diode* vacuum tube is the simplest form of radio tube, and, as we shall see below, it was used in the early days of radio to detect and rectify radio-frequency currents.

RADIO TUBE CHARACTERISTICS

Engineers use the term "characteristics" to identify the distinguishing electrical features and values of a radio tube. These values are usually tabulated (as in the Appendix of this book) or shown in curve form.

The amateur operator should know something about the characteristics of the tubes he will use in his transmitter and receiver. Since there are over 400 different types of receiving tubes alone, out of a total of more than 1,200 different vacuum tubes of all types, and since the complete characteristics of tubes are highly technical in nature, it is not possible to go thoroughly into the subject here. In the present chapter we present the fundamentals of vacuum-tube operation, an outline of the principal differences in the more important types of tubes, and a few illustrations of representative types. A chart will be found in the Appendix giving the characteristics of all existing types of RCA receiving tubes. More comprehensive data on receiving and transmitting tubes are contained in the several excellent tube manuals published at low cost by the principal tube manufacturers and distributed either direct from the manufacturer or through radio supply stores.

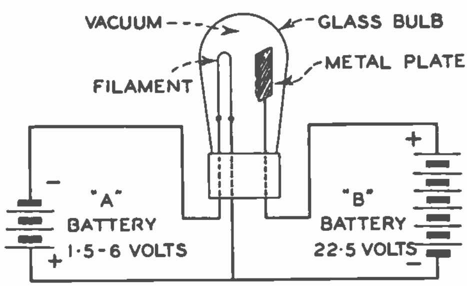
THE DIODE

We have learned above that when the filament of a two-electrode or diode vacuum tube is heated until it glows, it emits electrons. As these electrons are charges of *negative* electricity, they are attracted to the plate, which is charged *positively* by connecting it to the positive pole of a battery. In other words, the plate is positive with respect to the filament. (Fig. 28.)

The plate, moreover, does not emit electrons itself, being cold or below the temperature at which electrons are thrown off; it can only attract electrons due to its positive charge. Therefore, in the two-electrode or diode tube, *current passes in one direction only*—

from the filament to the plate. In other words, we have a *direct* or *unidirectional current* flowing from filament to plate.

An alternating current is one that changes its polarity periodically, from positive to negative then positive again. The number of changes or cycles that the current undergoes per second is called *frequency*. Radio-frequency currents are those which the human ear cannot hear and, as the name implies, audio-frequency currents are those that can be heard through suitable apparatus.



28. How a two-electrode (diode) vacuum tube is connected.

By means of an instrument called an oscilloscope (page 179) it is possible to see an alternating or direct current. The former has the appearance of a *sine wave,* illustrated in Fig. 49. The halves of the wave above the horizontal line are considered to be positive and the lower halves negative.

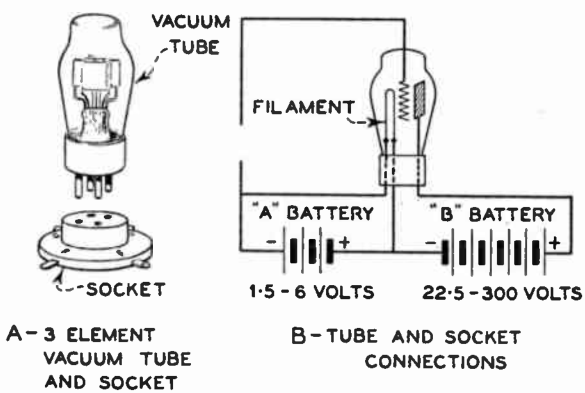
If we connect a source of alternating current to the elements (the filament and plate) of a vacuum tube, as well as the filament and plate batteries, so that we will have an electronic stream flowing, we find that there is a change in the appearance of the a-c wave. Only the top halves of the wave come through the tube. This is because during half the cycle (a cycle is one complete oscillation) the plate has a positive charge, which attracts the electrons emitted from the filament, and during the other half of the cycle the plate is negatively charged so that it will repel the electrons and no current flows. Such an output from a tube is called *pulsating direct current,* as it is not a steady flow, such as is obtained from a dry-cell battery.

Dr. John Fleming, of University College, London, discovered that a two-electrode vacuum tube could be used as a detector of radio-frequency currents, transforming them to currents that are audible to the human ear when a telephone receiver was connected in the output (between the plate of the tube and the plate battery).

The word "detector," although commonly used, is apt to mislead the reader. The action above described is really *rectifying*. At the present time the two-electrode vacuum tube is no longer used in radio receivers as a detector, for it is more efficient when used as a *rectifier* in the power units (see below, page 63).

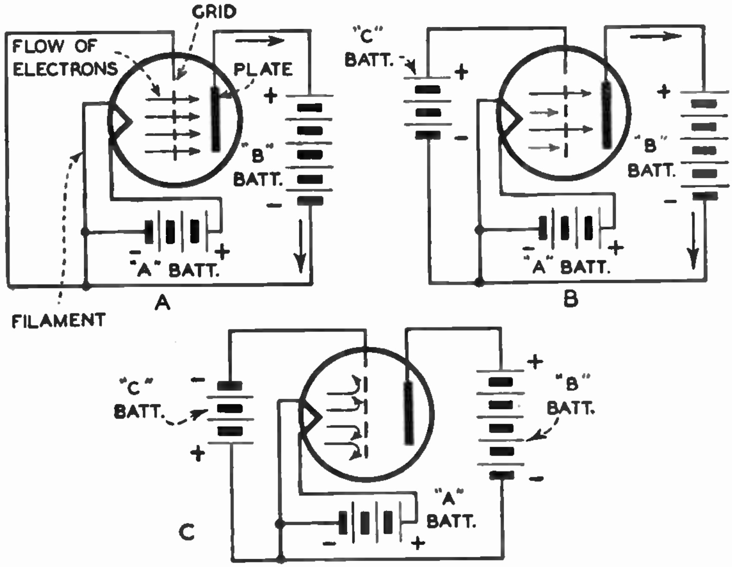
THE TRIODE

The diode has many limitations as a detector, and not long after Dr. Fleming had developed his "valve," experimenters turned their efforts to ways of improving it. An American, Dr. Lee De Forest, hit upon the idea of adding a third electrode or element, which he



29. Three-electrode (triode) vacuum tube and its connections.

called the *grid* because of its shape. He realized that the Fleming valve was too inflexible in itself for the demands of radio reception and believed that if a third element could be inserted between filament and plate the current in the latter could be minutely controlled. A solid sheet of metal inserted between the two basic elements would catch all the electrons flying off the filament and none would reach the plate, which was connected in the headphones circuit. He made a gridiron-shaped element, much like a coarse piece of window screening, placed it between filament and plate, and connected it to the negative terminal of the battery that supplied the filament current (Fig. 29). Thus was born the three-element tube, or *triode,* which completely transformed the transmission and reception of radio signals from a local affair to one of international



30. How the grid affects the electron flow from filament to plate. *A,* no charge on grid; *B,* positive charge on grid; *C,* negative charge on grid.

scope. With the grid in place and charged with a certain voltage, the stream of electrons from filament to plate could be accelerated or decreased at the whim of the operator. The grid also made it possible for the vacuum tube to be used either as a detector or as an amplifier of radio signals.

Let us see how a triode operates as a detector in a receiving circuit. Connected to the grid and the filament of the tube is the output of the antenna circuit, consisting of a coil shunted by a variable condenser, so that the circuit can be tuned to resonance with the incoming signal. The signal current is at radio frequency and is alternating, that is, changing from positive to negative, thousands of times per second.

As the grid is connected to this oscillating current, its polarity changes with the polarity of the r-f current. Let us now follow one complete cycle through the tube and see how it affects the electron stream coming from the filament. (See Fig. 30.)

During half the cycle the grid has a positive charge. This charge, in addition to the positive charge maintained on the plate, will attract more electrons that are being thrown off the filament in the direction of the plate. In other words, *when the grid has a positive charge, the plate current is increased.* Some electrons, of course, strike the wire grid and are absorbed in the grid circuit, but the majority of them reach the plate through the relatively large spaces between the grid wires.

When the negative half of the wave charges the grid, then the reverse is true. As the electrons are negative, the grid, having the same polarity, will repel some of them back toward the filament and therefore fewer will reach the plate of the tube, thus reducing the plate current.

Summing up, the grid of a vacuum tube permits more or fewer electrons to reach the plate depending on whether the grid is charged positively or negatively. Also the degree of these charges must be taken into consideration, for the variations of the incoming signal currents to the tube are very slight, and it is on these minute changes that the efficiency of the tube as a detector depends.

HOW THE TRIODE ACTS AS AN AMPLIFIER

If you connect up the filament and the plate of a triode with the batteries and do not connect the grid, you will find that the electrons thrown off by the filament will not get farther than the grid, regardless of how high a voltage you apply to the plate. This is due to the fact that a large number of electrons thrown off by the filament strike the grid and give it a negative charge, and consequently cannot get any farther. Since the electrons do not reach the plate, the current from the *B* battery cannot flow between it and the filament.

Now with a properly designed amplifier tube a very small negative voltage on the grid will keep a very large positive voltage on the plate from sending a current through the tube, and conversely, a very small positive voltage on the grid will let a very large plate current flow through the tube. This being true, it follows that any small variation of the voltage from positive to negative on the grid, and vice versa, will vary a large current flowing from the plate to the filament.

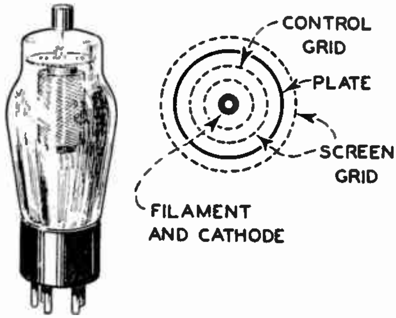
The action of the triode may be compared to that of a telegraph relay. In the Morse telegraph system, the relay permits the small current that is received from the distant sending station to energize a pair of magnets, and these draw an armature toward them and close a second circuit, whereby a large current from a local battery is available for working the sounder. The amplifier tube is a variable relay in that the feeble currents set by the incoming waves constantly and proportionately vary a large current that flows through the headphones. This, then, is the principle on which the triode amplifier works.

THE TETRODE, OR SCREEN-GRID TUBE

This type of vacuum tube was first investigated in Germany by Schottky and later by Dr. A. W. Hull of the General Electric Company Research Laboratory. Because of the more accurate control of electronic action it makes possible, the screen-grid tetrode has almost completely superseded the three-element or triode type of tube. One of the earliest types in which the screen grid appeared was the 24A and from this pioneer has grown an extensive collection, a fact that can be proved by a glance at the tube types in the appendix.

Using the 24A as an example (Fig. 31*A*), it will be seen that the control grid is brought out through an isolated terminal at the top of the bulb. This reduces the harmful capacity between the leads as they are brought down through the element supports and out through the base. Capacity thus formed lessens the value of the tube as an amplifier, particularly on the higher frequencies. But the relative location of the remaining elements gives to this tube and its later derivatives their main advantages.

The actual construction of the individual elements varies with different manufacturers but in general the filament is coiled within the oxide-coated cathode and the grids consist of many turns of fine wire wound in spiral form. The screen grid is actually a double grid (Fig. 31*A*) in order to provide a complete coverage for both sides of the plate. By varying the pitch of the screen-grid wires, the characteristics of the tube can be changed to meet the particular purpose for which the tube is to be designed.

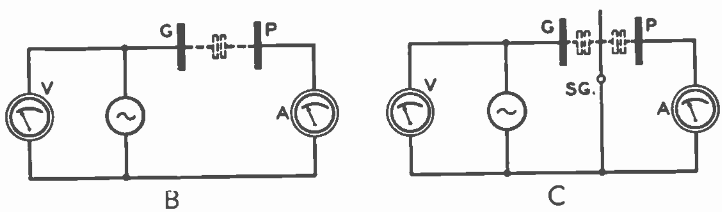


31*A*. The screen-grid tube is shown at the left; at the right, the four elements are arranged in their respective positions.

In fact, this point of design has been adopted to manufacture a so-called variable-mu or supercontrol tube which is widely used in modern receivers. In such tubes, the screen grid is spaced unevenly from top to bottom of its form, the purpose being to make the tube react differently to different strengths of r-f signals imposed on the control grid. Thus such a tube could be and is designed to give lower amplification on strong signals and much higher gain on weak signals. One advantage of this arrangement is to prevent overloading of the detector tube by unusually strong signals.

The question naturally arises: why is a tube like this necessary? The usual three-element tube when employed in a r-f amplifier circuit needs a form of neutralizing or balancing to stop the generation of oscillations which are caused by the capacity between the grid and plate. There have been heretofore two general methods of preventing oscillations due to this small capacity—the *losser* method and the *neutralization* method. In the former, sufficient losses were introduced into the circuit to keep the amplification down to a safe value, while in the latter, the feedback due to the internal capacity of the tube is balanced by a feedback of equal magnitude, but opposite in phase, introduced outside the tube. This bothersome internal capacity is eliminated by the introduction of the fourth element, the screen grid.

How this capacity is practically eliminated may be understood better by reference to the following example. Between two parallel plates, *P* and *G*, in Fig. 31*B*, there exists a capacity which can be measured by the alternating current which flows through the ammeter *A* for some voltage measured by the voltmeter *V*. (These



31*B* and *C*. Showing the condenser action caused by the insertion of a second element between the filament and plate in a screen-grid tube.

two plates represent the plate and grid elements of an ordinary three-electrode tube and the dotted condenser symbol the capacity existing between them.) If another plate, *SG* (representing the screen-grid element), is placed between the other two (see Fig. 31*C*) and connected as shown, the effect is now of two condensers in series, but the capacity between *SG* and *P* is shorted out of the circuit and the current indicated by the ammeter drops to zero. Therefore we may say that the effective capacity between *P* and *G* has been reduced to zero by the addition of the plate *SG* connected as shown. It may be said that *P* is *shielded* or *screened* by *SG*.

When the 24A is employed as a r-f amplifier the control grid is connected in the usual manner to the output of the coil and condenser, and should have a negative bias of about 3 volts, which can be supplied by a *C* battery. As will be seen, the *positive* voltage necessary on the screen grid is between 60 and 90 volts. Ninety to 250 volts are necessary on the plate.

Because of the higher amplification obtained through the use of the screen-grid tube it is essential that the effect of one of its circuits on another be minimized. This is done by shielding. The r-f coupling transformers are encased in metal shields and the control grid wire is surrounded by a metal sheath. More often than not, the tube itself is inserted within a metal enclosure; sometimes a metal coating is deposited directly on the glass. Such shields are always well grounded to the chassis to keep their potentials at zero.

Screen-grid tubes are now available for all uses from those having to do with transmitters to the light-weight portable sets operated from batteries.

RECTIFIERS

The early vacuum-tube radio receivers were designed to operate only from batteries, either dry or storage. The disadvantages of these methods of power supply were at once evident, and engineers turned their attention to designing new tubes that could draw their filament energy from alternating-current service generally available in most homes and buildings.

The principal obstacle in the operation of tubes from a-c supply lines was the tendency of the 60-cycle current to "creep" into the wires carrying the signal. The result was a low-pitched, annoying hum that was sometimes louder than the signal itself. The laboratory experts finally discovered that a balanced filament wound inside a thin-walled cylinder that had been coated with radioactive material was a solution to the problem of a-c hum. In this design, the electrons do not come from the filament itself but from the coated sleeve surrounding it. This type of tube is known as the *indirect heater* or *heater cathode* type, the sleeve rather than the filament being the cathode in the tube. Besides minimizing the introduction of hum, the heater-cathode construction results in a close-spaced rectifier tube with a resulting low voltage drop and improved regulation.

One of the earliest of the heater-cathode types of tubes was the 27, which, with its twins the 56 and 76, is still favored by some amateurs as a detector. In late years the majority of all new tubes for a-c operation have been of the heater-cathode type, and tube design has been carried forward so expertly that the problem of a-c hum is no longer a serious consideration. Such hum as creeps into a receiver is more likely to come from a defect in either the power pack or the filter than from the various tubes used in the circuit.

However, a number of types of directly heated cathode or filament-cathode tubes are still being made and are used in sets designed for battery operation because of their small current drain. Examples of battery-operated filament types are the 1A7-GT, 1R5, 1U4, 3V4, and 31; there are, also, at least two filament-cathode types for a-c operation, the 2A3 (power triode) and the 5Y3-GT (full-wave rectifier).

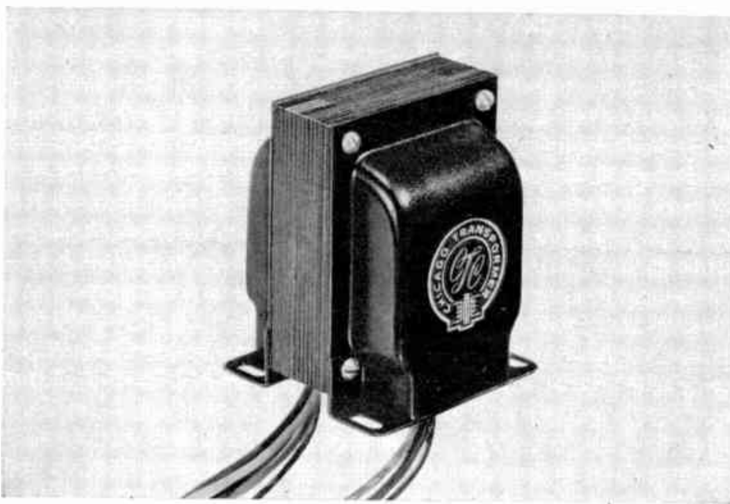
In addition to the heater-cathode type of rectifier tube, there are a number of tubes that depend for their operation on gas ionization. The *mercury-vapor rectifier* tube contains a small amount of mercury that partially vaporizes when the tube is operated and becomes ionized by the impact of the electrons moving from filament to plate, thus reducing the internal resistance and permitting full cathode emission current to flow with only a small voltage drop in the tube. This type of tube is produced in sizes that handle any voltage or current that is likely to be used in amateur transmitters, and is also represented by the full-wave rectifiers 82 and 83, used in receivers in which the rectified current requirements are subject to considerable variation.

Another type of rectifier tube that depends on gas ionization is the *ionic-heated-cathode* or *cold-cathode* type, represented by the OZ4 and OZ4-G, which are metal and glass octal types respectively, used in vibrator-type B-supply units (see page 118). They contain two anodes and a coated cathode sealed under a reduced pressure of inert gas. The cathode is heated by ionic bombardment instead of by heater or filament current from an external source.

Finally, there are the dry-disk and crystal-diode types of rectifier. Neither of these is a vacuum tube, but nevertheless they should be mentioned here. A *dry-disk rectifier* consists of disks of metal and other material in contact under pressure, so arranged that the resistance through the disks in one direction is considerably lower for electron flow than in the opposite direction, so that rectification is obtained. Selenium rectifiers, copper-oxide rectifiers, and copper sulphate rectifiers are examples of this type. The *crystal diode* rectifier makes use of a silicon or germanium crystal and is used in a number of high-frequency applications and in special types of electronic instruments.

RECTIFIER OPERATION

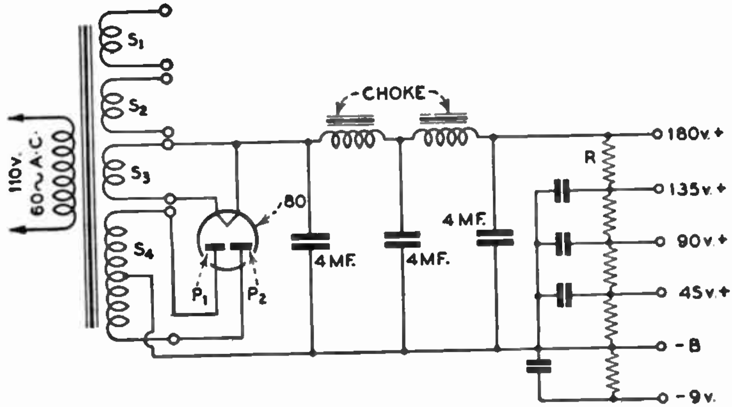
As mentioned previously, the filaments of a tube may be supplied with alternating current without affecting the quality of the signal, but the plate and screen grid must be fed direct current only. This is absolutely necessary. The rectifying tube accepts the a-c of the



32. Vertical-shield-type power transformer, 117 volts a.c. primary to 300 volts a.c. secondary, rated at 120 milliamperes d.c. (*Chicago Transformer.*)

power line, changes it to a pulsating direct current, and this in turn is smoothed out by a device called a filter so that the final output is practically pure d.c. However, the standard supply line is only about 117 volts, whereas modern tubes function at their best with from 180 to 300 volts on their plates. This higher potential is easily obtained by stepping up the 117 volts to the desired amount by means of a transformer. Since the current is actually low despite the higher voltage, the power transformer need not be anywhere near as large as the transformers observed on poles outside homes. A power transformer for a ten-tube receiver may easily be held in the hand (Fig. 32).

Rectifier tubes are discussed at length in the chapter on power supplies, but let us consider briefly at this point the type known as the 80, a full-wave rectifier tube widely used in all branches of radio.



33. Diagram of a circuit in which the 80 rectifier transforms a.c. into pulsating d.c., which the filter smooths out.

The 80 is a *diode*, which is the simplest form of vacuum tube, containing only two electrodes, a cathode (filament) and an anode (plate), the electrons flowing from the cathode to the plate and returning through the external circuit to the cathode. In the 80, however, the cathode consists of *two* filaments in series heated by alternating current supplied by the secondary winding of a power transformer (*S3* in Fig. 33), and the anode consists of *two* plates, each connected to one end of the winding (*S4*) of the power transformer. The center tap of this winding represents the negative side of the d-c supply. (*Note:* The other two windings, *S1* and *S2*, are those supplying power for operation of the a-c tubes in the amplifier and receiver.)

As has been explained, when the filament of the 80 is heated, electrons are emitted. Now we must imagine conditions during one complete cycle of the alternating current. When the positive half of the wave is induced in *S4* we will assume that the plate *P1* is charged positively. The stream of electrons will therefore be attracted toward that plate and current will flow through it, around through the upper half of *S4* and out through the center tap to the filter circuit. At this same instant the plate *P2* is charged negatively and will repel electrons.

Now when the other half of this same wave strikes *S4*, conditions will be reversed. *P1* will be negative and *P2* will have a positive charge. Therefore the stream of electrons will be attracted to the latter plate and the current will flow through the lower portion of *S4* and out into the filter circuit through the center tap, as it did in the former case. Thus it may be seen that current always flows in the same direction through the center tap of the secondary *S4*.

THE OPERATION OF THE FILTER

The function of the filter system shown in Fig. 33 is to smooth out the pulsating direct current delivered from the rectifying tube, so that it will be as nearly like that delivered from a battery as is possible.

The two choke coils have a high self-inductance, usually 20 to 30 henries, and their function is to keep the *current* flowing through the system unchanged. If the current fluctuates the magnetic lines of force produced about the windings of the chokes tend to induce a current that will buck the other and keep it constant. Also this counter e.m.f., set up within the choke, will charge the large condensers shunted across them with a higher voltage. Therefore, whenever the rectifier's output lowers in value, the voltage of the output will be less than that at which the condensers are ordinarily charged and the condensers will discharge so that the line will come back to its normal condition.

This happens every cycle, as the output of the rectifier is not a smooth line but a series of humps. The action of the filter system smooths out these irregularities and delivers to the resistor, *R*, a current sufficiently unvarying so that the difference between it and the output from a battery is negligible.

The tapped resistor, *R*, called a *bleeder*, is inserted in the circuit in order that a number of different voltages may be obtained for the various requirements of plate and grids in the receiver and amplifier. It is a simple matter to calculate the amount of resistance necessary to obtain the drop in voltage needed and to take a tap off at those particular points.

More recent examples of full-wave rectifiers are the 5Y3-GT, the 5U4-G, and the 5Z3, the first two of which have a five-prong base in which one prong is not connected, and the third having a four-prong base identical with that of the 80. The slight differences that exist in the characteristics of these tubes are indicated in the tube chart in the Appendix.

POWER TUBES

Power tubes are an essential part of every radio receiver in which the output is used to actuate a loud-speaker. These tubes comprise the last audio-frequency amplifying stage and their function is to convert the strong a-f voltage variations obtained by several consecutive stages of r-f and a-f amplifiers into identical variations of current with minimum distortion. Loud-speakers being, in effect, a form of electric motor, they require definite watts of energy in their operation. The power tube with its high voltage and high plate current produces this power.

The simplest types of power tubes are *triodes*, or three-element tubes, having in addition to the cathode and plate a grid which is usually a winding of wire extending the length of the cathode. When the voltage on the grid is varied from a large negative polarity to a small negative polarity by means of the incoming signal, the plate current increases correspondingly, so that a small voltage applied to the grid can produce a large amount of plate current and in this way the signal is amplified. Power tubes have a low amplification factor, in the majority of cases from 3 to 8, but their grids can handle large voltage swings which in turn give wide but identical variations in plate current.

In appearance, power tubes are similar to other tubes in their corresponding class except that they may be enclosed in a slightly larger envelope. Simplest of these in construction are the 45 and 50;

other typical power tubes are the 6K6-GT, 25A6, 7B5, and 1C5-GT, all of which are pentodes; and the 6BG6-G, 6L6, 6V6, and 7A5, which are pentode beam-power amplifiers (see below, p. 73).

THE PENTODE

Just as the addition of the screen grid was a step forward when it was added to the triode, so the adding of the suppressor * makes the tetrode (four elements) into a five-element tube (the *pentode*) that will do things that have not been done with the same ease before.

It will be remembered that when electrons collide with atoms the tendency is for them to dislodge an electron from the atom, if the first electron is traveling at sufficient speed. When the plate voltage is high in a tube the electrons move from the filament or the cathode to the plate at a high velocity and when they strike the plate, dislodge other electrons. In the ordinary triode these free electrons so dislodged do no particular harm, because there is no other positively charged body in the vicinity that they can affect. However, in the case of the screen-grid tube, where the screen is at a positive potential with respect to the filament (cathode), this element offers a strong attraction for these free electrons and in some cases the plate current is reduced in strength because of them.

In order to remove these so-called secondary electrons from the path of the main electronic stream from the cathode to the plate, the suppressor is placed between the screen grid and plate and is usually connected to the cathode. This element is greatly negative with respect to the plate, hence the secondary electrons moving out from the plate encounter this negative charge and are diverted back again to the plate, where they cause no trouble.

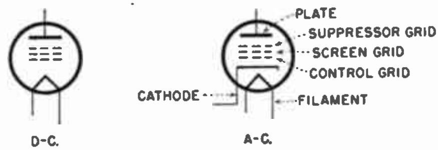
Pentodes are used in several places at the present time and there is little doubt that as further experimentation is carried on, still more uses will be found for them. Tubes such as the 1A5-GT, 33, 47, 6AK6 and 6F6 are used as power output tubes, where the suppressor element makes possible a large power output with a low grid voltage.

* The "suppressor" is similar to the screen grid in construction and is located between the screen grid and the plate.

Radio-frequency pentodes such as the 34, 58, 6AG5 and 6K7 use the suppressor grid as a means of obtaining a high voltage gain with moderate limits of plate voltages. Schematic diagrams of the pentode tube for both d-c and a-c operation are shown in Fig. 34.

TUBES CLASSED BY FILAMENT VOLTAGES

As radio applications have widened in scope the demand for tubes which operate from varied voltages has increased. As a result, the amateur has at his command an assortment of vacuum tubes with filament demands from 1.4 volts to 2, 6.3, and on up to the maximum of 117 volts. The filament current drain varies likewise from 0.04 amperes to as high as 3.0 amperes for some types of rectifier tubes.



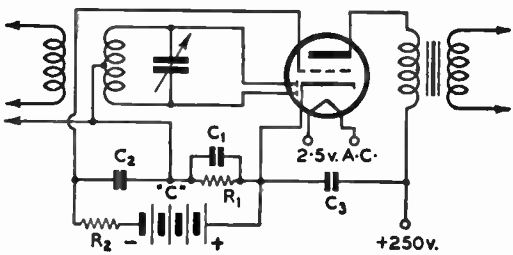
34. The suppressor grid is connected to the cathode in the pentode tube, for the purpose of removing the secondary electrons.

The lowest voltage filaments find their principal use in battery operated receivers. This includes the 1.4- and 2-volt classes. Other tubes, in general, are designed for use on storage batteries or direct from the a-c or d-c lighting lines. The 6.3-volt series, for instance, which is now the largest group of tubes in number of types, was originally introduced for automobile radio sets where the storage battery is depended upon for the filament supply; but its characteristics proved to be so favorable that many of this class are now found in a-c receivers.

When the combination a-c/d-c receiver came into wide use there arose a demand for tubes with higher voltage filaments which, when connected in series, would more nearly approximate in total voltage the potential of the supply line. Accordingly, the tube manufacturers brought out the 25Z5 with its 25-volt filament—and later, the 35-volt series. At least two manufacturers now offer a 117-volt tube which can be applied directly across the supply line without intervening transformer or series resistance (the 117L, 117N, 117P, and 117Z series).

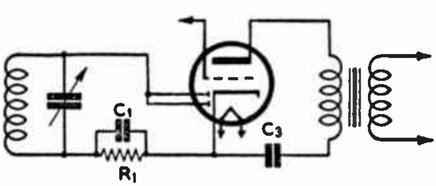
THE DUPLEX-DIODE (OR TWIN DIODE) TRIODE

This is one of the revolutionary types of tubes that have come out of the research laboratory in recent years. Actually, it is three tubes in one. The 7E6 and 6RS7, for instance, consist of two diodes and a medium-mu triode, while the 2A6 comprises the same two diodes combined with a high-mu triode. Still another type, the 2B7 and 7E7, has the double diode plus a remote-cutoff pentode, all within the single envelope.



35. The two diodes can be connected as shown to obtain full-wave rectification.

As commercially designed, the duplex-diode triode has independent elements except for a common cathode, with one emitting surface for the diodes and another for the triode.



36. Plates of the duplex-diode tube connected for half-wave rectification.

It has been stated heretofore that the simplest form of a vacuum tube detector was a diode, which depends for its rectifying properties on the fact that current will flow only from the cathode (filament) to the plate, when the plate is positive with respect to the cathode. As the diode is a simple rectifier, it has no amplifying properties and if an increased current is desired then other tubes must be introduced into the circuit. This will be explained in a subsequent section.

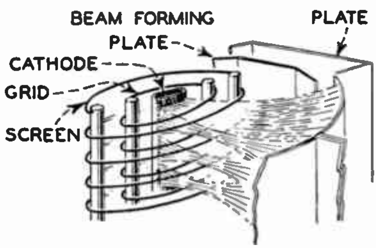
The two diodes in the 6SR7 or 7E6 tube can be used for full-wave rectification (Fig. 35), or their plates may be connected in parallel for half-wave rectification (Fig. 36). The former has some advantages, one being that no carrier frequency gets through to the grid of the following tube, but the latter gives about twice the output, necessitating some carrier-frequency filtering.

37. Type 7F8 multi-purpose high-frequency medium-mu twin-triode amplifier-oscillator with lock-in base. (*Sylvania Electric Products, Inc.*)

For amplifying the rectified signal, the triode is employed in the usual circuit arrangement (Fig. 35). The necessary grid-bias voltage may be obtained from a fixed voltage tap on the d-c power supply, or the variable voltage drop caused by the rectified current flowing through a resistor in the detector circuit can be utilized. The values of the various condensers and resistors in Fig. 35 are given herewith: *C1* has a capacity of 150 mmf; *C2*, 0.01 mfd; *C3*, .1 mfd–1.0 mfd; *R1* and *R2*, approximately 0.5 megohm. The *C* battery, supplying the negative grid bias, should be —20 volts, and the plate voltage should be 250, with 2.5 volts a.c. on the heater element.

BEAM POWER TUBES

Another recent type of tubes is the beam power tube, so called because the stream of electrons from the emitting surface of the cathode are formed into thin beams which then pass between the spiraled turns of the screen grid. Because of the low current drawn by the screen, the beam power tube gives an output of high power and a generally high over-all efficiency. It is not unusual for a single beam power tube to be used in a circuit which permits it to deliver



38. Schematic action of beam power tube showing shaping effect of beam-forming plate.

as high as ten watts of output power or for two such tubes in push-pull arrangement to produce an output of 47 watts. Fig. 38 illustrates the manner in which the beam-forming plates of these tubes turn the electron stream into thin sheets which have no difficulty in passing through the screen without interception. Beam power tubes are also widely used in short-wave amateur transmitters. Representative beam power tubes are the 6L6, 6V6, 7A5, 7C5, 14A5, 25L6-GT, 35A5, and 50A5.

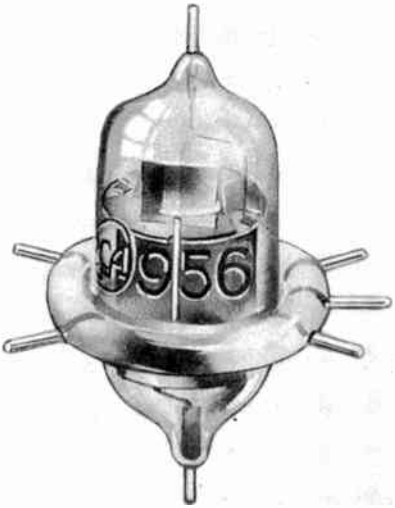
MULTI-UNIT TUBES

Space does not permit the individual description of all variations in tube design but mention should be made here of the multi-element tubes which have found growing favor among designers of modern radio receivers. Most of these are intended for very special applications. For instance, the 6L7 has seven individual elements and a heater or filament. These are the plate, cathode, two separate control grids shielded from each other, a suppressor grid, and two shield grids connected together within the tube. Called *pentagrid mixers* because of their five grids, these tubes find their maximum usefulness when serving as mixers in superheterodynes. Another type of multi-unit tube is the *twin-diode pentode,* such as the 1F7-G and 12C8, while still another is the *pentagrid converter,* such as the 1R5, 6BE6, and 6SA7, which perform the double function of oscillator and mixer in superheterodyne receivers.

So far in this chapter and those preceding it, the tubes under consideration have been the standard types with glass envelopes. In the past dozen years the metal tube has gained prominence, although the earliest predictions for its success have not always materialized. As will be seen from the Tube Chart in the Appendix, the metal tube (indicated by two vertical lines before the number) is still in the minority. Yet the metal tube has some characteristics that make it preferable to the glass tube. In some ultrahigh frequency circuits, for example, the lower inter-element capacitance of the metal tube gives it greater amplifying ability. Moreover, the metal covering acts as a perfect shield and makes additional shields unnecessary. The specific choice of glass or metal tubes, as far as the amateur is concerned, will depend on the use he will make of it and this calls for a study of the tube chart in the back of this book.

When the metal tube was first introduced in 1934, it brought with it a new type socket called the *octal,* a name derived from the eight terminals arranged symmetrically on the socket edge. With the octal base and socket, the positioning of the tube was simplified by the addition of a small rib or key on the base and a corresponding slot in the socket. This arrangement insured economy in manufacture since the same base could be used for all types of tubes with some of the prongs left unused in tubes where the number of elements was less than eight.

Of the other special forms of vacuum tubes, the one that is used by the amateur for ultrahigh frequency work is the *acorn* tube shown in Fig. 39. This tube has no base, the terminals of the elements extending from the glass envelope in such a manner that contact is made direct with a special socket or soldered permanently to the circuit leads in which it is to be used. The principal advantage of the acorn tubes (types 954 and 955) exists primarily in the extremely low capacity between the element terminals due to the absence of a base. They are therefore used frequently in the detection and amplification of ultrahigh frequencies—frequencies above 300 megacycles.



39. Acorn tube.

MINIATURE TUBES

During the past few years there has been an increase in the use of miniature tubes employed in small portable radios of the "camera" type, aircraft radio and communication systems, hearing aids, photoelectric equipment, servomechanisms, and other electronic devices where space conservation, light weight, and low heat dissipation are of first importance. At present there are over 60 different types of miniature tubes available, including half- and full-wave rectifiers, diode detectors, triode detectors and amplifiers, diode-triode amplifiers, pentode voltage and power amplifiers, beam power amplifiers, and pentagrid converters. Like the acorn type just described, the miniatures have no base, the terminals of the electrodes extending through the bottom of the glass envelope to make direct contact with a special miniature socket. Otherwise they perform the same functions as their full-sized counterparts and have similar characteristics. The beginning amateur is not likely, however, to make much use of the miniatures except in an experimental way. Miniature tubes are indicated in the Tube Chart in the Appendix by three vertical lines before and after the type number.

CHAPTER

7

A Simple Vacuum-Tube Receiving Set

While it is possible to receive code and voice or music from amateur and broadcasting stations by means of a coil, condensor, piece of crystal, and a pair of headphones, the sensitivity and reliability of such a device are so poor that crystal receivers are no longer used. The vacuum tube has replaced the crystal and in doing so has extended the range of reception from a few miles to thousands of miles. That is why the beginner starts his experiments with a one-tube receiver, then, when he has explored the magic of radio for a short time, he can add more tubes for greater distance and louder volume.

The vacuum-tube detector requires batteries or other source of current before it can perform its functions. When the proper current is supplied to the tube it becomes the most sensitive signal detector ever discovered, and improvements in design are constantly increasing this sensitivity. But the tube's possibilities do not cease with its ability to detect waves. It is also an admirable amplifier of weak signals both before and after the detector tube. When enough tubes have been added the resulting volume is great enough to operate one or more loud speakers, thus eliminating any need for headphones.

Although one-tube receiving sets can be purchased the assembly is so simple that most amateurs construct their own.

The use and application of vacuum tubes have become so widespread that, as was pointed out earlier, the number of different types of receiving tubes alone run well over 400, each with its individual characteristics which are considered best for a special task. Before setting out on the design of radio equipment, therefore, the amateur should study the available types and select the one that will work best and most economically for his purpose. He should keep in mind that tubes fall into two general classes—those for 117-volt a-c lighting circuits, and those for use with batteries—remembering that current drain or hum are likely to result if a battery-type tube is used on a.c. or an a-c tube on battery current. Battery-type tubes have filaments that draw small voltages up to 6 or 7 volts; a-c tubes, on the other hand, may be designed for voltages of from 2.5 to 117 and for currents up to 4 or more amperes.

BATTERIES FOR VACUUM-TUBE OPERATION

The *A* or filament battery may be a simple dry cell of the type used to operate door bells and buzzers, or it may be the familiar storage battery found in every automobile. At one time the storage cell was predominant in amateur work because of the current demands of the tubes then available, but with the refinements in

A B C

40. (*A*) 1½-volt plug-in-type portable *A* battery. (*B*) 22½-volt standard *B* battery. (*C*) 45-volt heavy-duty *B* battery with 22½-volt tap.

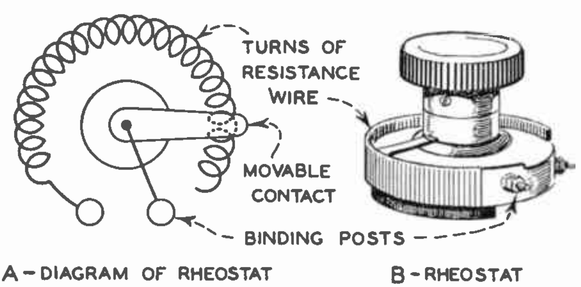
vacuum tubes, the 1.4-volt types now in use make the storage battery no longer essential. Since the normal maximum voltage of the No. 6 dry cell is 1.5, the tube can be operated direct from the cell terminals without any intervening control such as rheostats. If more than one tube is incorporated in a receiver, economy calls for the addition of other cells connected in parallel. These cells can be used until the chemical action within them has caused their internal resistance to become so high that the maximum voltage at their terminals is too little to force sufficient current through the filaments. Then they must be discarded and replaced with new ones.

The *B* or plate battery is available in units of 22½ and 45 volts. This higher voltage, as compared to the 1½ volts of the No. 6 filament cell, is obtained by stringing together enough cells to produce the desired total. Thus the 22½-volt *B* battery contains 15 individual cells connected in series; the 45-volt battery has 30 cells. But since the amateur is interested in the current output as well as the voltage it behooves him to acquire the largest battery (in mechanical dimensions) consistent with his pocketbook.

The *C* or grid battery is really a smaller version of the *B* battery and usually produces a maximum of 9 volts with taps at 4½ and 1½ volts.

THE FILAMENT RHEOSTAT

In some receiving circuits and also in some transmitter diagrams the amateur will find that the assembly calls for a resistance in the filament wiring. This resistance may be variable, in which case it



41. Rheostat for filament control.

is called a rheostat or it may be fixed, and be known as a ballast. One form of rheostat is shown in Fig. 41. It consists of numerous turns of rather fine wire of a special composition, wound on an insulating circular form with a sliding contact which permits the variation of the total resistance used. The maximum resistance of a rheostat is selected after a survey of the tube circuit in which it is to be used. If there is a great difference between the voltage of the battery and the filament voltage of the tube the rheostat will have a relatively higher value than when the voltages of battery and filament are approximately the same. A simple application of Ohm's Law will determine the proper value.

For instance, if a storage battery of 6 volts is to be used to heat the filament of a 1.4 volt tube, the rheostat must be of such a value of resistance that it will radiate enough energy in heat to dissipate the equivalent of 4.6 volts. Assuming that the tube draws .06 amperes, then 4.6 divided by .06 gives approximately 77 ohms as the correct value. Probably the nearest commercial unit would be one of 75 or 100 ohms, either of which would be satisfactory.

THE OPERATION OF A SIMPLE VACUUM-TUBE RECEIVING SET

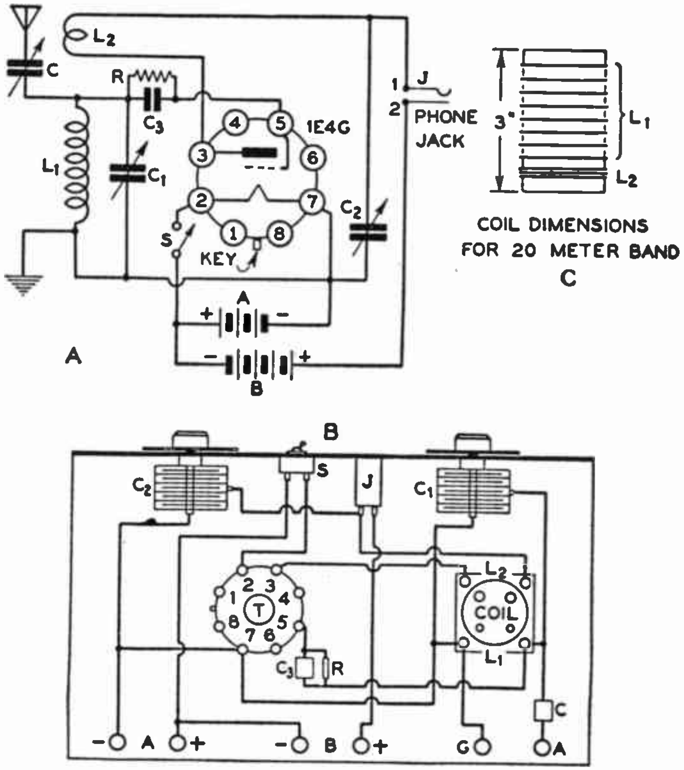
A simple vacuum-tube detector receiving set works thus: When the filament is heated it gives off electrons as previously described. Now when the electric waves impinge on the aerial wire they set up oscillations in it, and these surge through the tuning coil.

The energy of these oscillations sets up oscillations of the same frequency in the secondary circuit, and these high-frequency currents, whose voltage is first positive and then negative, surge in the closed circuit, which includes the secondary coil and the variable condenser. At the same time, the alternating positive and negative voltage of the oscillating currents is impressed on the grid; at each change from + to − and back again it allows the electrons to strike the plate and then shuts them off; as the electrons form the conducting path between the filament and the plate the larger direct current from the *B* battery is permitted to flow through the detector tube plate and the headphones.

PARTS REQUIRED

When the amateur considers his first receiver he should concentrate on the simplest circuit with the minimum of parts; then, after he has learned how to operate it, the addition of amplifying tubes will present few problems. For the one-tube short-wave receiver shown in Fig. 42 the following parts will be needed:

1 140 mmf (.00014 mfd) variable condenser, C1
1 250 mmf (.00025 mfd) variable condenser, C2
1 Compression type condenser (optional), C
1 100 mmf (.0001) fixed mica condenser, C3
1 Fixed resistance, 5 megohms, R
1 Type 1E4G (or 1G4-GT) vacuum tube, T
1 Octal socket for T
1 45-volt *B* battery
1 No. 6 dry cell for *A* battery
1 Phone jack (optional)
1 Pair headphones, 2,000 or 3,000 ohms
1 Coil form, 1½" in diameter, preferably of fiber or bakelite
1 4-prong socket for coil
1 On-off switch
8 Binding posts



42. Schematic diagram (*A*) and baseboard layout (*B*) for simple one-tube battery-operated regenerative receiver; (*C*) coil dimensions for 20-meter band.

ASSEMBLING THE PARTS

Secure a piece of dry hardwood about 7″ long, 6″ deep, and ½″ thick for the base on which the parts are to rest. For a front panel to support the knobs and present a good-looking appearance, get a piece of composition wood such as masonite or a piece of fiber or plastic material. The size should be 7″ long and 6″ high. This panel should not be attached to the base until later.

The first move is to lay out the sockets for coil and tube in about the respective positions shown in Fig. 42*B*, making sure that the terminals are spotted as indicated. Then drill the holes for the six binding posts toward the rear edge of the baseboard. Beginning with the antenna post, wire the parts exactly as shown, using either bus bar or No. 18 annunciator wire. Bus bar is sturdier and makes a better-looking job but it will not work any better than ordinary copper wire, bare or covered. The grid leak and condenser should be placed close to the tube socket. Keep wires in different circuits as far apart as possible but arrange the wiring so that it goes direct from one point to another. With this done and checked for errors, proceed to the panel.

Measure the diameter of the condenser shafts and bore holes in the panel just large enough to take the shafts without excess play. Do the same for the switch and phone jack if one is used. Put the condensers in place and set them up tightly by means of the hexagonal nuts supplied by the manufacturer. Finally, attach the panel to the baseboard by four or more screws or, if you prefer, by means of L-shaped brackets similar to shelf supports. Complete the connections from the baseboard to the condensers and jack and the job is done.

Small knobs will come with the variable condensers but for fine tuning and for logging stations, the amateur will want to secure graduated dials 3″ or 4″ in diameter.

CONSTRUCTION OF COILS

Although the wiring of the set is now complete, reception is not possible until the proper coil or coils have been obtained. Coils for the several short-wave bands are available in any radio store and in general are more efficient than those made at home, but for those amateurs who prefer to construct all possible parts, the coil winding data is given below:

WAVE BAND	L1		L2
20 meters	8	turns	4
40 "	17	"	6
80 "	36	"	15
160 "	65	"	22
Broadcast	130	"	24

In preparing the coils, the amateur will find it easier to purchase the plug-in type coil forms so that the prongs will be available for socket support. This arrangement permits instantaneous shifts from one band to the other when desired.

As shown at *C* in Fig. 42, the primary inductance *L1* is at the top of the coil with the tickler or feed back winding of fewer turns below. Both windings should be in the same direction but the size of wire varies. For the primary use No. 22 or No. 24 enameled copper wire; for the tickler use No. 34 double silk covered.

The primary windings with the exception of the 20-meter coil are not spaced but are wound close together. The 20-meter coil must be spaced between turns so that the entire 8 turns occupy approximately 1½". See Fig. 42*C*. All tickler windings are close together.

In bringing the ends of each winding through the coil form to the prongs at the base be sure that the corresponding prongs are used for primary and tickler so that the coils will be interchangeable. Solder all connections well and remove excess soldering flux with alcohol or carbon tetrachloride.

OPERATING THE RECEIVER

It is always a good idea to make one final check of the wiring before subjecting the tube and other associated circuits to the current from the batteries. One foolproof method which many amateurs have discovered is to lay out the diagram beside the chassis and trace each lead from point to point, checking it off the diagram with a colored pencil as each move is completed. If a wire is missing it will show up immediately on the diagram as an uncolored line. When this step in the procedure has been carried out the set is ready for its first test.

Connect the antenna lead-in to the "Ant" post on the set and do the same with the ground wire. If the antenna is a duplex with a double lead-in connect them to antenna and ground respectively. For a Zepp antenna, the lead from the antenna proper should go to "Ant," while the lead that is dead-ended at its upper end should be attached to the "Gnd" post. In the event that the two wires are not color coded, making it difficult to trace the individual leads, connect the wires as they come and reverse them later if reception is not as it should be.

Insert the 1E4G tube into its socket by placing the tube base over the socket opening and twirling the tube until the key slips through the keyway, then push gently downward until the tube is sitting firmly. Do not twist the tube once it is in place. Modern tubes are gripped securely by pressure of the socket contacts on the tube prongs, in contrast to early tubes which had a pin fitting into a slot in the side of the socket.

Connect the two batteries to their proper binding posts, making sure that the leads from the *B* battery do not touch the *A* binding posts. Even a slight touch to the wrong terminals will ruin the vacuum tube. Then throw the "on-off" switch to the "on" position. See that the tube lights up a dim red. If it does not, turn off the switch and check all wiring once more. If all seems in good order, place the phones on the head, turn the dial of condenser *C2* until the plates are about half meshed. Then rotate condenser *C1* very slowly until a sound is heard. If the sound is voice or music, readjust *C2* one way or the other until the response in the phones is at maximum. Readjust *C1* and perhaps alter *C2* again. The sound should now be loud and clear. If garbled, it is a sign that *C2* is too far advanced. The latter condenser, being the regenerative control, is also the volume control in this simple set.

If the sound heard is code, the amateur will notice that the tone of the code will change as *C2* is rotated. This feature will come in handy because it permits the operator to select the tone that is easiest to read through any other sounds that may be coming through the phones. This variation in pitch is the result of heterodyning or beating, a phenomenon which will be described in the chapter devoted to superheterodynes.

The amateur should be warned here against an overuse of the regenerative or feedback condenser, since a one-tube set of this type radiates a signal that may affect all radio sets within a quarter mile, and can be very annoying to radio listeners in the vicinity. Be considerate of others.

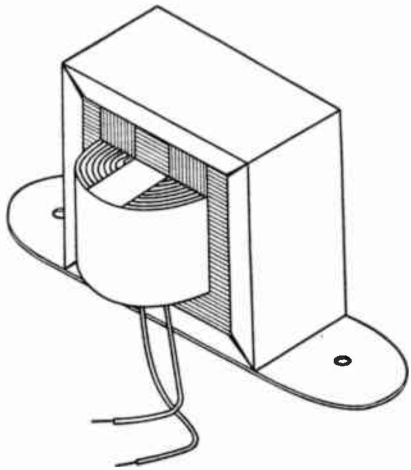
LOGGING THE DIALS

After the builder has become familiar with the operation of the one-tube receiver he should jot down the dial markings for stations which he has recognized. In a regenerative receiver there will be some variations in the dial settings from day to day since regeneration affects the main-tuned circuit, but the approximate locations of stations once logged will always be found again within a degree or two of the first settings. This procedure, obviously, must be carried out for each coil.

It will be found, also, that the tuning of broadcast stations on the coil with the largest number of turns will not be sharp. In fact, if the set is used within a few miles of a powerful broadcaster, it will be difficult to prevent interference or "cross talk" between stations. In a one-tube set of this type, there is no relief from this condition but the difficulty will be cleared up when the amateur has added another tube and a stage of radio frequency amplification. On all waves below 100 meters, the tuning should be as sharp as necessary for good reception.

AUDIO-FREQUENCY AND RADIO-FREQUENCY AMPLIFIERS

An audio-frequency amplifier increases the energy of currents of audio frequency, that is, those from about 60 to 4,000 cycles per second. In a radio receiver, it amplifies the fluctuating direct currents flowing through the plate circuit of the detector tube to which it is coupled by two resistances and a condenser or by an audio transformer. In amateur receivers the transformer method is preferred. Such a transformer (Fig. 43) consists of two windings around a soft iron core with from three to five times as many turns on the secondary as on the primary. The primary is placed in the plate circuit of the detector tube, replacing the phones. The greater the step-up ratio of the turns the greater the gain in signal strength; but if the ratio is made too large, the quality will suffer through distortion of the signal.

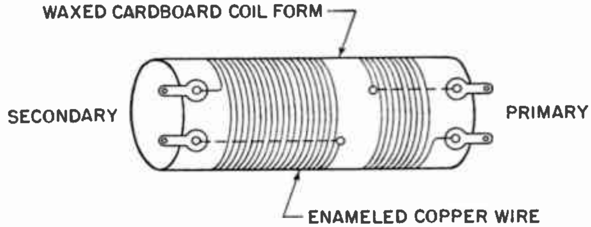


43. Audio-frequency transformer.

The second type of amplification takes place *before* the incoming signal reaches the detector and is called radio-frequency amplification. Here again a transformer is needed to transfer the energy in the r-f tube to the detector, but this transformer is similar to *L1* in Fig. 42 except that it has two windings (Fig. 44). Moreover, these may be wound on an air core, although some types of r-f coils contain small cores of pulverized iron special metallic compound in order to produce more gain per stage.

AUDIO-FREQUENCY AMPLIFIER

It is a simple matter to add a stage of audio-frequency amplification to the receiver just described. This will increase the signals measurably and will even make loud speaker operation possible on powerful stations. Because audio amplification is likely to add



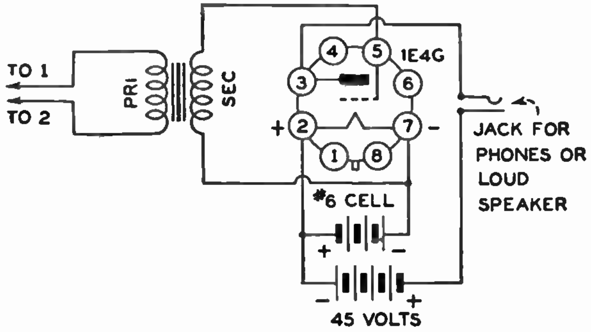
44. One type of radio-frequency transformer.

noise to reception it is unwise to use more than two stages in a receiver.

For a single stage of a-f amplification the amateur will need the following items:

1 1E4G tube
1 Octal socket
1 a-f transformer, ratio 3–1 or 5–1
1 45-volt *B* battery
1 No. 6 dry cell

The transformer and socket should be placed on the same baseboard shown in Fig. 42, locating them at the extreme left when viewed from the rear. Fig. 45 gives the wiring details. Since the transformer replaces the phones, the two wires connected to the jack should go instead to the two primary terminals of the transformer. The jack terminals are then transferred to the plate circuit of the new 1E4G as shown in Fig. 45.



45. Diagram of 1-stage audio amplifier to be used with 1-tube detector set.

CHAPTER

8

Operation of Vacuum-Tube Receivers

Despite the fact that modern radio receivers vary greatly in the complexity of their over-all design and applications, they can in general be classified into four main types according to the principle on which they operate. The basic circuits can be listed as follows:

1. Tuned radio frequency
2. Superheterodyne
3. Regenerative
4. Superregenerative

There are seemingly endless modifications and refinements of these basic circuits, particularly in very-high-frequency and ultrahigh-frequency receivers, and above the 235-megacycle band even these are no longer usable, for a wholly different technique for both transmitters and receivers is required when we enter this "microwave" region of tank and butterfly circuits, wave guides and cavity resonators. In a book of this type we shall naturally confine ourselves to conventional or standard equipment, leaving microwaves to those advanced amateurs who are now exploring this region.

EVOLUTION OF THE DETECTOR OR DEMODULATOR

The first detector used in radio receivers was, we have seen, the crystal detector, which served both to detect (or *demodulate*, i.e., remove the modulation from) the signals from an incoming radio wave and to rectify these alternating currents to direct current. We have seen also how the crystal was superseded by the diode detector (page 55), which not only detected and rectified these incoming signals but amplified them as well. The diode detector, however, did not make for a very sensitive receiver because of its inherent limitations. But with the development of the triode or grid detector, it became possible to add one or more stages of audio amplification so as to increase the output of the receiver.

The triode grid also made it possible to replace the diode plate entirely, thereby eliminating the diode as a detector. The triode thus served as a diode detector and audio amplifier at the same time, provided a high resistance was connected from the grid lead to form a discharge path for the grid coupling capacitor. The resulting circuit is known as a *grid-leak detector.*

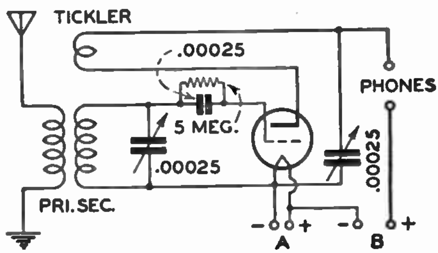
This simple arrangement is illustrated in Fig. 42*A*, and the reader should be familiar with it by now if he followed the instructions given in the preceding chapter for the construction of a one-tube receiver. In other words, the "simple vacuum-tube receiving set" described therein was essentially a grid-leak detector.

TUNED RADIO-FREQUENCY RECEIVERS

The tuned radio-frequency (t.r.f.) receiver can be thought of as an elaboration of the grid-leak detector wherein the incoming signals are first amplified through one or more stages before being fed to the detector for demodulation. The amplifier stages are tuned to resonance at the carrier frequency of the signal by a gang variable tuning condenser, consisting of several condensers varied as a single unit through a common shaft. From the detector, which may be a diode or triode, the demodulated rectified currents are fed to one or two stages of audio amplification and thence to the output transformer of the loud speaker. The t.r.f. receiver served very well in the early days of radio, but began to be superseded as the demand grew for increased selectivity, and also because the circuit had a tendency to oscillate. Partly to correct this latter trouble, the *neutrodyne* circuit was developed in the late 1920s and became an extremely popular type of receiver for a while, until it was supplanted by the much more efficient superheterodyne receiver. The t.r.f. receiver is now seldom used except in inexpensive portable models.

OPERATION OF THE REGENERATIVE RECEIVER

Soon after experimenters began to work with the vacuum-tube detector, two of them noticed that when an additional circuit was added between tube and its resonant circuit, the signals in the headphones were increased many fold. Both Major Armstrong and Dr. De Forest observed this phenomenon and the former immediately incorporated his findings in patent papers. The improvement was called *regeneration*, and for many years was incorporated in every receiving set. With the introduction of the superheterodyne its importance decreased, although it still plays a part in many amateur receivers and transmitters.



46. Typical regenerative or feedback circuit.

The process of regeneration is not difficult to understand. If part of the pulsating direct current in the output (phone) circuit of the detector is led back to the tuning coil supplying the detector with the incoming radio impulses, the latter are increased in amplitude with much the same effect as though the transmitting station were much nearer the receiver. By this action a signal so weak that it could scarcely be heard with a plain detector will be magnified until it becomes perfectly readable. Because of the reversing action created by the regenerative circuit, the latter is often called a feedback circuit (Fig. 46).

It may seem at first hand that the feedback could be increased indefinitely, but this is far from the truth. Since the energy fed back to the tuned circuit is impressed upon the tube grid along with the basic incoming signal, the detecting action of the tube is soon destroyed by the tendency of the tube to act as an oscillator at a frequency determined by the number of turns of wire in plate and grid circuits. The maximum signal gain is reached when the regeneration is carried to a point just previous to the point of oscillation. However, this tremendous gain in signal strength obtained through regeneration led Major Armstrong to the development of still another type of receiver called the superregenerative set, which has found favor as a v.h.f. receiver in aviation and amateur fields, although it is not so popular as the superheterodyne.

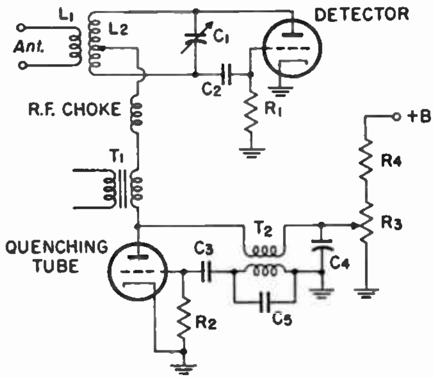
OPERATION OF THE SHORT-WAVE, SUPERREGENERATIVE RECEIVER

When an ordinary regenerative receiving set, as described above, reaches a certain point of amplification, the detector tube begins to set up oscillations, and this puts an end to further useful regeneration. Up to this critical point, and especially just before it is reached, the effects of regeneration are enormously increased, but they cannot go beyond it.

The reason for this is that the oscillation circuit has so small an effective resistance that after the initial energy of the feedback sets up the amplifying oscillations in the tube these oscillations continue to surge and with such persistency that the oscillations, which follow from the feedback, have very little effect upon them. The energy of the oscillations set up by the incoming waves is naturally less, and therefore the signal, speech or music is weaker when this condition is reached than when the effective resistance of the circuit is small enough to allow the current rectified by the detector tube to get back to the same value after each variation of the oscillations set up by the incoming waves.

Now the purpose of the superregenerative system is to circumvent this limitation of the original regenerative circuit so that amplification can go on beyond it, and this is the way it is done: In this new system the factors of the circuits are so arranged that the amplifying oscillations set up by the tube do not depend so much on the feedback oscillation as on those which the oscillator tube itself sets up. This is caused by alternating the values of positive and negative resistance from moment to moment; that is, an alternating positive and a negative resistance are set up by the oscillations of the oscillator tube.

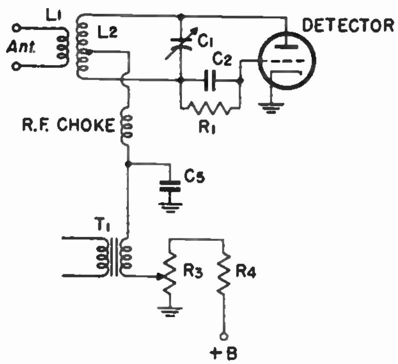
The result is that while the initial, or first, oscillations set up by the incoming waves are amplified, so long as the negative resistance is larger than the positive resistance the oscillations are instantly cut off by reversing these resistances, when the next incoming wave sets up fresh oscillations. In other words, the tube is kept from setting up oscillations when the critical point is reached, by changing the negative resistance to the positive and then changing them about the other way.



47. Two-tube superregenerator detector using a separate quenching tube.

The oscillating tube which provides the quenching frequency, as it is called, must operate at such a rate that the resulting sound is near or above the audible limit of the ear, otherwise the noise thus produced will ruin the signal it is desired to receive. This is not a simple task in the case of broadcast receivers but the difficulties decrease as the frequency of the incoming signal increases. This, obviously, makes the superregenerator ideal for short and ultra-short waves.

Fig. 47 shows a standard form of a two-tube superregenerative receiver with one of the tubes acting solely as an oscillator. This form is best for the amateur since the control of the quenching frequency can be easily adjusted for best results. However, for portable sets or where space is a consideration, the functions of detector and oscillator may be combined in a single tube as in Fig. 48. There are many variations of this one-tube self-quenching superregenerator but the principles are alike. Usually the constructor must discover the best operating components by trial. The placement of the wiring, the length of leads, and the value of the grid leaks are all important. When the set is not functioning properly a loud hiss appears in the headphones and it is only when this hiss is reduced to a barely audible sound that the receiver will give the tremendous amplification that is obtainable from it.

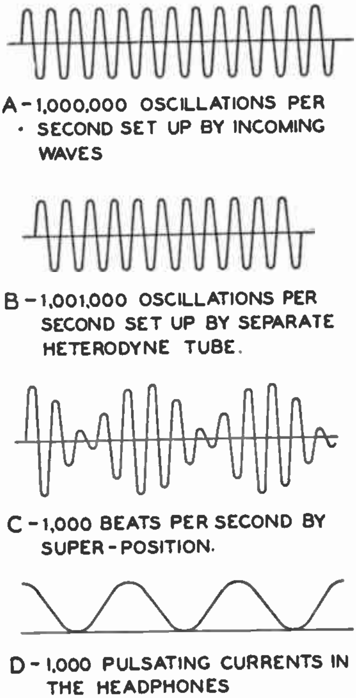


48. One-tube superregenerative detector in which the functions of detector and oscillator are combined in a single triode.

OPERATION OF AUTODYNE AND HETERODYNE RECEIVING SETS

At *A* in Fig. 18 is shown a picture of two tuning forks mounted on sounding boxes to illustrate the principle of electrical tuning. When a pair of these forks is made to vibrate exactly the same number of times per second there will be a condensation of the air and the sound waves that are sent out will be augmented. But if you adjust one of the forks so that it will vibrate 256 times a second, and the other fork so that it will vibrate 260 times a second, then there will be a phase difference between the two sets of waves, and the latter will augment each other 4 times every second and you will hear these rising and falling sounds as *beats*.

Now electric oscillations set up in two circuits that are coupled together act in exactly the same way as sound waves produced by two tuning forks that are close to each other. Since this is true, if you tune one of the closed circuits so that the oscillations in it will have a frequency of 1,000,000, and tune the other circuit so that the oscillations in it have a frequency of 1,001,000 a second, then the oscillations will augment each other 1,000 times every second.



49. Illustrating the operation of a heterodyne receiver.

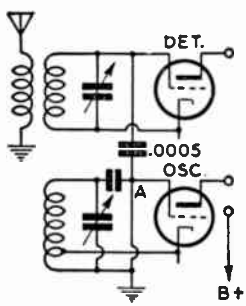
As these rising and falling currents act on the pulsating currents from the *B* battery which flow through the detector tube and the headphones you will hear them as *beats*. A graphic representation of the oscillating currents set up by the incoming waves, those produced by the heterodyne oscillator, and the beats they form is shown in Fig. 49. To produce these beats a receiver can use: (1) a single vacuum tube for setting up oscillations of both frequencies, in which case it is called an *autodyne,* or *self-heterodyne* receptor, or (2) a separate vacuum tube for setting up the oscillations for the second circuit, in which case it is called a *heterodyne* receptor.

THE AUTODYNE, OR SELF-HETERODYNE, RECEIVING SET

Where only one vacuum tube is used for producing both frequencies, you need only a regenerative, or feedback receiver; then you can tune the aerial wire system to the incoming waves and tune the closed circuit of the secondary coil so that it will be out of step with the former by 1,000 oscillations per second, more or less—the exact number does not matter in the least. From this you will see that any regenerative set can be used for autodyne, or self-heterodyne, reception.

SEPARATE HETERODYNE RECEIVER

For ease of operation it is best to use a separate vacuum tube as a generator of oscillations for heterodyning purposes. The latter



50. Diagram of external oscillator and detector, showing one of many methods of leading the locally generated oscillations into the grid circuit of the detector tube.

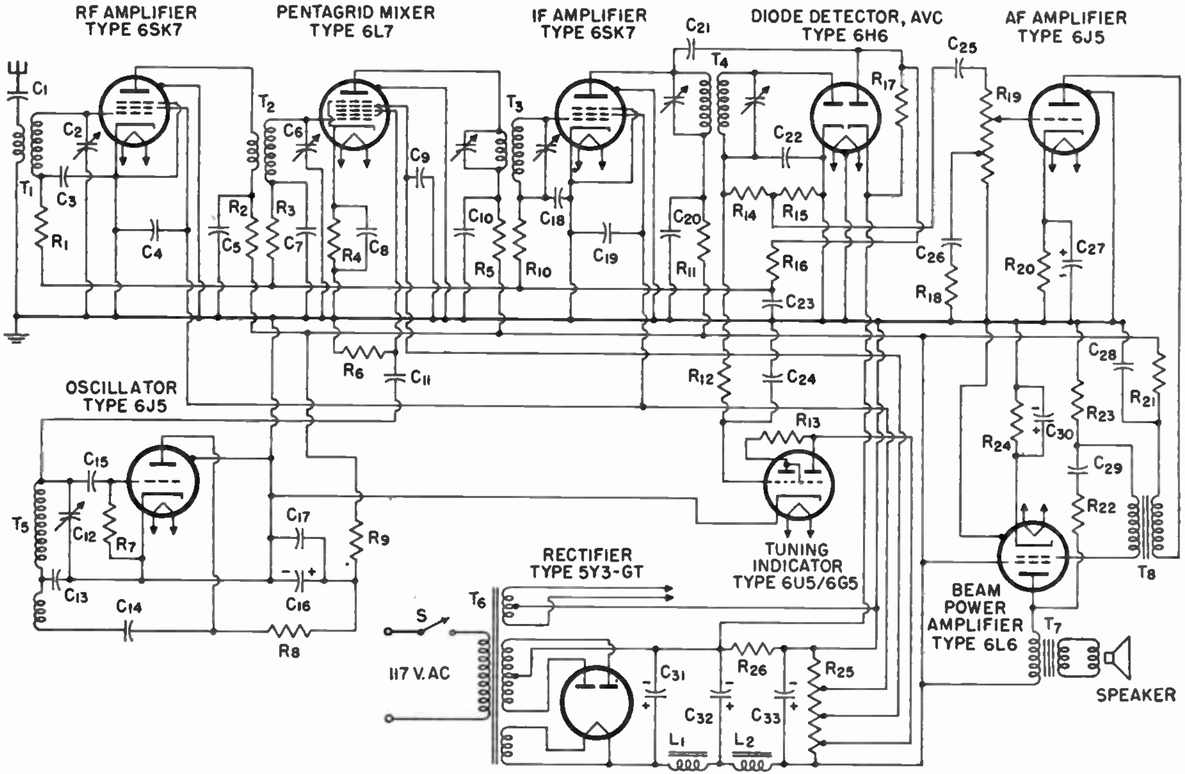
then acts on the oscillations of the incoming waves so that the mixed frequencies are impressed upon the grid of the detector tube. One form of oscillator and mixer circuit is shown in Fig. 50. Here the oscillating voltage appearing at point *A* is transferred to the grid of the detector tube where it encounters the voltage of the incoming signal and mixes with it before detection. The oscillations may also be injected into the detector tube by means of the cathode if one is available or by one of the grids in a multi-grid tube.

OPERATION OF SUPERHETERODYNE RECEIVER

It was the inefficiency of the tuned radio-frequency circuit both as regards its sensitivity and selectivity that caused Major Edwin H. Armstrong to experiment with the heterodyne system of short-wave reception. Fessenden had done some work on the same thought earlier but had not carried the basic ideas through to a point where they could be generally applied to commercial receivers. Armstrong developed a method whereby the incoming signal of high frequency was changed by heterodyning to another signal of lower frequency. This was essential at that time because little research had been carried out on the amplification of waves below 200 meters.

You have learned from preceding chapters that a definite wavelength corresponds to a definite frequency and that the longer the wave the lower the frequency and vice versa. You have also learned that in order to receive continuous wave signals on a vacuum-tube receiver it is necessary to employ the *autodyne* or *heterodyne* method, wherein a second frequency or wavelength is impressed on the receiving circuit so as to produce a *beat note* of the original signal that would be audible.

The separate heterodyne method is used in conjunction with the superheterodyne receiver, only instead of adjusting it so as to produce an audible beat note, a *radio-frequency* beat note is produced having a frequency that corresponds with the wavelength upon which the *intermediate frequency* transformers are designed to work. In this way the incoming signal is actually converted to a longer wavelength, passed through the first detector or mixer tube and then through a series of i-f amplifier stages, and finally into the second detector where the signal is rectified or demodulated, emerging as a pure signal of audible frequency. (See Fig. 51.) All of this takes place without noticeably affecting the characteristics of the



51. A-c operated superheterodyne receiver. (*Radio Corporation of America.*)

transmitted signal, even though the final impulse may be a million times as strong as the same impulse when it was first intercepted by the antenna. It is this ability of the superheterodyne to accomplish tremendous amplification without distortion that has caused it to become the heart of the majority of all present-day broadcast receivers and of many v.h.f. receivers.

AMPLIFICATION METHODS

A vacuum tube is more sensitive than a crystal detector because while the latter merely rectifies the oscillating current, the former acts as an amplifier at the same time. The vacuum tube can be used as a separate amplifier and will amplify either radio-frequency currents—that is, high-frequency oscillating currents—or it will amplify audio-frequency currents, that is, low-frequency currents.

In order to amplify radio-frequency currents or audio-frequency currents some sort of coupling device must connect the amplifier tube to the circuit. Two or more amplifier tubes may be coupled together so as to accomplish what is known as cascade amplification. In cascade amplification a coupling device is used to connect the plate circuit of the first amplifier tube and the grid circuit of the next amplifier tube.

RADIO-FREQUENCY AMPLIFICATION

The coupling device used in a radio-frequency amplifier is usually a radio-frequency transformer (page 87) consisting of two coils having an air core. Several radio-frequency amplifiers may be connected in cascade or stages. The radio-frequency currents pass through each stage of radio-frequency amplifier without being changed into low-frequency until they encounter the detector.

A radio-frequency amplifier ahead of the detector brings an increase in sensitivity to the receiver. It also separates the detector from the antenna and reduces radiation from the detector when the latter is in an oscillating condition. There are two types of radio-frequency amplification, *tuned* and *untuned*. The tuning is accomplished by variable condensers. Tuned radio-frequency amplification requires complete shielding of the tubes and transformers. It was tuned radio frequency that led to the development of gang condensers, i.e., two or more condensers varied by turning one shaft.

AUDIO-FREQUENCY AMPLIFICATION

This type of amplification can be divided into three groups, as follows:

Transformer coupling
Resistance coupling
Impedance coupling

There is also a fourth type of coupling, capacity coupling, but it is seldom used.

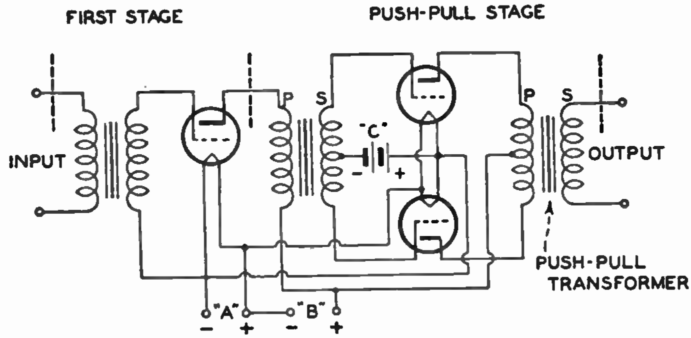
Each type of coupling has its own advantages and disadvantages. Transformer coupling gives the greatest gain because there is a step up in voltage in the transformer itself. A gain in both the tube and the transformer thus makes fewer stages necessary. One of the disadvantages of transformer coupling is the difficulty of securing a uniform gain over a wide range of frequencies. This is mainly because there is a change in the impedance of a transformer with a change in frequency. An ideal transformer would be one having a constant impedance at all frequencies, but that is not possible.

The only amplification that takes place with resistance coupling is in the tube itself. However, since the value of the coupling resistance does not change with frequency, a properly designed resistance-coupled amplifier has little distortion. Resistance coupling also has the advantage of being comparatively inexpensive.

Impedance coupling, accomplished by using a suitable coil having an iron core, overcomes some of the objections of resistance coupling.

PUSH-PULL AMPLIFICATION

When it is desirable to obtain more power than one tube is capable of giving without objectionable distortion, a push-pull circuit is employed. In this arrangement the energy from a single stage amplifier is fed into two tubes "in push-pull," the grids and plates of the two tubes being connected to opposite ends of the circuit, respectively. The energy is evenly distributed between the two tubes. When an alternating current is fed into the system, the grid of one of the push-pull tubes is positive when the other is negative and vice versa. The plate current of one tube is therefore rising while the other is falling.



52. Diagram of a push-pull audio-frequency amplifier.

CLASSES OF AMPLIFIERS

In addition to the different methods of coupling, amplifiers are distinguished by the class of service into which they fall. There are three distinct classes of service recognized by radio engineers, Classes A, B, and C. These are covered by definitions standardized by the Institute of Radio Engineers.

The beginner will see amplifiers described in radio catalogs as A, B, or C and may wonder what this classification means. The definitions will, however, be clear only to those who thoroughly understand tube characteristics and operation.

A Class A amplifier is one in which the grid bias voltage and the exciting voltage are such that the plate current flows through the tube at all times. A Class A amplifier is low in efficiency and output. A Class A power amplifier is used in the output stage of radio receivers to supply relatively large amounts of power to the loud speaker.

A Class B amplifier is one in which the grid bias voltage is such that the plate voltage is practically zero when no exciting grid voltage is applied. Class B amplifiers for audio applications are of interest where large power output is required.

A Class C amplifier is one in which the grid bias voltage is high enough so that the plate current is zero when no exciting grid voltage is present and so that the plate current also flows in each tube for appreciably less than one-half of each cycle when an exciting grid voltage is present.

CHAPTER

9

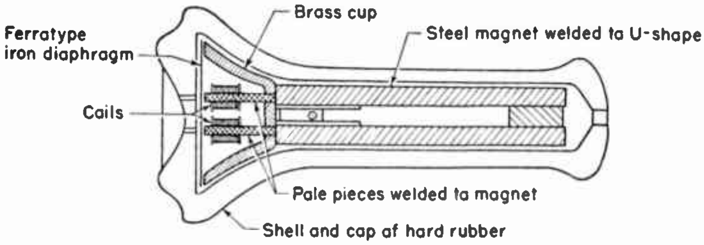
Headphones, Loud-Speakers, and Microphones

RADIO HEADPHONES

The headphone for a radio receiver is made on the same principle as the Bell telephone receiver, although there are certain structural differences between the two. The former is made flat and compact so that a pair of them can be fastened together with a band and worn on the head as a *headset*, while the latter is either long and cylindrical so that it can be held to the ear, as in the desk-stand or wall type, or else is mounted as a removable disk in a common handle with the telephone transmitter, as in the modern telephone hand set. A more fundamental difference between them is that the radio headphone is made as sensitive as possible so that it will respond to very feeble currents, while the ordinary telephone receiver responds only to larger currents. Crystal receivers and stethoscope-type "monosets" represent recent departures from conventional design.

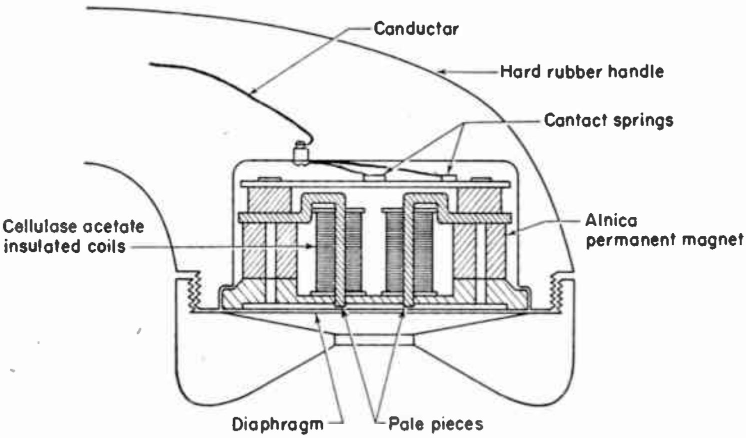
HOW A BELL TELEPHONE RECEIVER IS MADE

The bipolar telephone receiver consists essentially of a permanent magnet to which soft iron pole pieces are welded and form the cores of two electromagnetic coils, together with a thin circular diaphragm of japanned ferrotype iron. Changes in the current in the coils vary the strength of the magnet and cause vibrations in the metallic diaphragm, thus reproducing the original sound. Fig.



53. Desk-stand or wall type of bipolar telephone receiver.

53 shows the desk-stand or wall type of telephone receiver, while Fig. 54 illustrates the handset type.

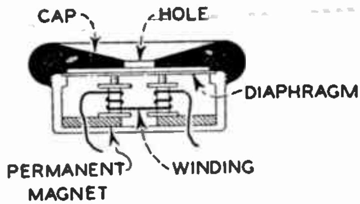


54. Handset type of telephone receiver. Entire assembly is made as a one-piece disk that is instantly replaceable without tools.

HOW A RADIO HEADPHONE IS MADE

For radio work a receiver of the watch-case type is generally used, two such receivers being connected with a headband to form a headset. Two types of headphones are in general use—the *magnetic* and *crystal* types.

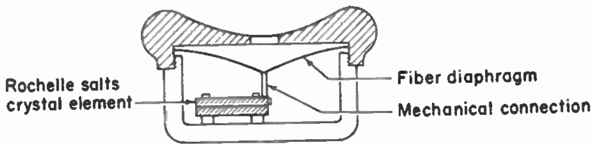
The magnetic type consists of a permanent magnet shaped so that it will fit into the shell of the receiver as shown in Fig. 55. The ends of this magnet, called *poles,* are bent up or else are made from separate pieces of softer iron. Headphones having only one coil around a central pole piece are known as *single-pole* phones, as distinguished from the bipolar type illustrated in Fig. 55. The electromagnets are wound with fine insulated wire and the diaphragm is held securely in place by means of a screwed-on cap.



55. Cross section of a bipolar type of receiver.

When no signal is being received, the diaphragm is under a constant pull or attraction exerted on it by the permanent magnet. When a current flows through the coils, the pull of the diaphragm is increased or decreased, as in the telephone receiver, and the resulting vibration reproduces the original sound.

Crystal headphones operate on an entirely different principle from magnetic phones. A crystal headphone consists of a two piezoelectric crystals (usually Rochelle salt crystals) cemented together

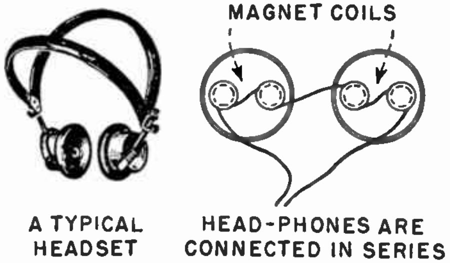


56. Schematic diagram of a crystal headphone.

to form a single element, which is mounted to the frame of the earpiece with its free end mechanically connected to a fiber diaphragm (Fig. 56). Its operation is based on the same principle as that of the crystal pickup or crystal detector—that is, the fact that piezoelectric crystals change their shape when an electric charge is impressed on them (and, conversely, generate minute currents when their shape is altered by pressure or vibration). When an alternating voltage is applied to the crystal headphone, the crystal element bends back and forth or vibrates and causes the diaphragm to vibrate also, thus reproducing the original sound. Crystal phones are very sensitive over the entire audio-frequency range and have the advantage of possessing high impedance, which makes them particularly suitable for use in high-impedance circuits.

ABOUT RESISTANCE, TURNS OF WIRE, AND SENSITIVITY OF HEADPHONES

If you are a beginner in radio you will hear those who are experienced speak of a telephone receiver as having a resistance of 75 ohms, 1,000 ohms, 2,000 or 3,000 ohms, as the case may be; from this you will gather that the higher the resistance of the wire on the magnets the more sensitive the receiver is. In a sense this is true, but it is not the *resistance* of the magnet coils that makes it sensitive—in fact, it cuts down the current—but it is the *number of turns* of wire on them that determines its sensitiveness. It is easy to see that this is so, for the larger the number of turns the more often will the same current flow round the cores of the magnet, and so magnetize them to a greater extent.



57. A radio headset and its connections.

But to wind a large number of turns of wire close enough to the cores to be effective, the wire must be very small and so, of course, the higher the resistance will be. Now the wire used for winding good receivers is usually No. 40, and this has a diameter of .0031 inch; consequently, when you know the ohmic resistance you get an idea of the number of turns of wire and from this you gather in a general way what the sensitivity of the receiver is.

A receiver that is sensitive enough for radio work should be wound to not less than 1,000 ohms (this means each earphone), while those of a better grade are wound to as high as 3,000 ohms for each one. A typical headset is shown in Fig. 57. Each phone of a headset should be wound to the same resistance, and these are connected in series as shown. Where two or more headsets are used with one radio receiving set they should all be of the same resistance and connected in series, that is, the coils of one headset are connected with the coils of the next headset, and so on to form a continuous circuit.

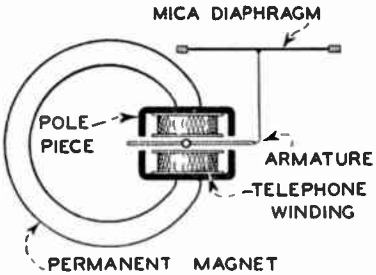
THE IMPEDANCE OF HEADPHONES

Telephone receivers possess in addition to resistance, a characteristic called *impedance*. The impedance of the receivers causes them to offer more resistance to the passage of an alternating current than to direct current. When a current is flowing through a circuit, not only does the material of which the wire is made oppose its passage (*ohmic resistance*), but a *counter electromotive force* is set up due to the inductive effects of the current on itself. This counter e.m.f. is called *impedance*. Where a wire is wound in a coil the impedance of the circuit is increased, and where an alternating current is used the impedance grows greater as the frequency gets higher. The impedance of the magnet coils of a receiver is so great for high-frequency oscillations that the latter cannot pass through them; in other words, they are choked off. Radio engineers take the impedance of a telephone headset into consideration in making a selection. In practice, a receiver is generally chosen whose total impedance is about equal to the a-c resistance from plate to filament of the tube to which the receiver is to be connected.

HOW THE HEADPHONES WORK

As you will see from Figs. 53 to 55, there is no connection, electrical or mechanical, between the diaphragm and the other parts of the headphone. Now when either feeble oscillations which have been rectified by a detector, or small currents from a *B* battery flow through the magnet coils, the permanent steel magnet is energized or de-energized to a certain extent depending upon the polarity of the current flowing through the coils. Added magnetic energy increases the pull on the diaphragm. If, on the other hand, the current is cut off, the pull of the magnet is lessened and as its attraction for the diaphragm is decreased the latter springs back to its original position. When varying currents flow through the coils the diaphragm vibrates accordingly and sends out sound waves.

A type of receiver known as the Baldwin phone (Fig. 58) has the



58. Essential elements of the Baldwin balanced-armature telephone receiver.

advantage that the diaphragm is not initially stressed. Thus it may be more responsive and sensitive to the pull exerted upon it by the magnetic changes caused by the signal current.

The armature of the receiver is a small piece of iron pivoted between the poles of a permanent magnet. It is in a neutral position and the pull upon it is equal from both sides. It is therefore not under stress. The armature is connected to a mica diaphragm and is surrounded by a coil winding. When a current flows through this winding there is no longer an equal magnetic pull on both sides of the armature. The armature becomes unbalanced, moves, and in so doing moves the mica diaphragm.

ABOUT LOUD-SPEAKERS

The simplest acoustic instrument ever invented is the *megaphone,* derived from Greek words meaning *great sound.* It is a very primitive device. Our Indians made it out of birch bark before Columbus discovered America. In its simplest form it consists of a cone-shaped horn and as the person talks into the small end the concentrated sound waves pass out of the large end in whatever direction it is held.

In the early days of radio broadcasting the megaphone idea was employed in the loud-speakers; that is, an ordinary watch-case receiver or pair of receivers was placed at the throat of a horn, which threw the sound in one direction, thus making it possible for a group of people to listen to one receiver.

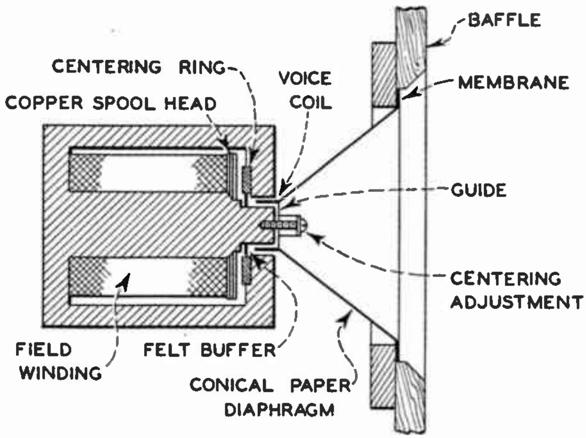
However, in order to make the volume sufficiently loud so that a large number of people could hear with ease, it was necessary to add to the receiving set audio-frequency amplification, as the output of the detector tube was too low. When such amplification was used the resulting music was far from pleasing. There was too great a current for the receivers and distortion resulted. Then engineers started on a quest for a loud-speaker that would faithfully reproduce amplified music and speech.

To understand fully the different types of loud-speakers that are today obtainable it might be well to consider for a moment the theory of reproducers in general. As has been explained previously, sounds are reproduced from a phone by the to-and-fro movement of the metal diaphragm. Now the greater the distance that this diaphragm moves the greater will be the sound. In order to increase the volume we can therefore increase the movement of the diaphragm, keeping its size the same, or we can increase its size so that it will set in motion a larger amount of air, and cut down on its movement.

Both these systems were tried, giving us (1) the *paper diaphragm* or *cone* type of speaker, which uses the larger diaphragm, and (2) the *dynamic* type, which uses a relatively small diaphragm having a relatively great movement. The cone speaker, while an interesting development, possessed certain faults that are missing in speakers of the dynamic type, and consequently has been largely superseded by the latter.

The dynamic speaker produces much better results than the cone type and has the added advantage that the entire speaker's physical proportions are much smaller, making it easier to place in a cabinet or console. In general the diaphragm is also of heavy paper and varies from 5 to 16 inches in diameter. The larger diameter of the cone, as may be seen in Fig. 59, is attached to a panel or baffle board by means of a ring of thin, flexible fabric or leather. This permits the cone to vibrate back and forth with hardly any mechanical resistance. On the smaller diameter of the cone there is a coil of very fine wire, supported in a magnetic field set up by a field winding. This coil carries the signal current delivered by the audio amplifier and is acted upon by the magnetic field moving the cone back and forth.

The speaker shown in Figs. 59 and 60 is known as the *field-coil*

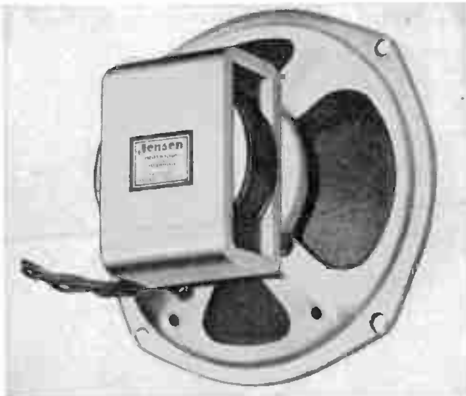


59. Cross section of an electrodynamic loud-speaker.

type, since its magnetic field is obtained by exciting the field winding from an outside source of current, which is supplied by a 6-volt storage battery or by utilizing the direct current that flows in the power-supply filter circuit. The other main type of dynamic speaker is the *permanent magnet* or PM type, described below.

THE PERMANENT-MAGNET DYNAMIC SPEAKER

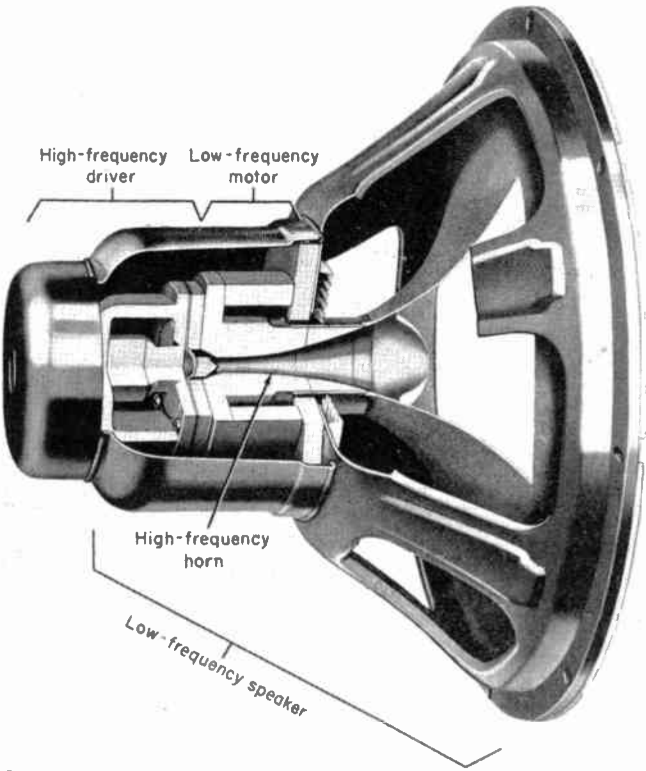
The loud-speaker in use today is the permanent-magnet type of dynamic speaker. Recent developments in magnetic alloys have greatly increased the strength of permanent magnets. Consequently there is a tendency to avoid the use of a field coil and to



60. Field-coil loud speaker. (*Jensen Manufacturing Company.*)

61. "Alnico 5" PM speaker. (*Jensen Manufacturing Company.*)

use powerful permanent magnets in its place. The saving in cost is considerable due to the absence of a field coil and the means required to excite it. Permanent-magnetic speakers—PM, as they



62. Cutaway view of coaxial loud-speaker which combines a low-frequency dynamic unit with a high-frequency unit in one housing, providing two-speaker performance where high-fidelity reproduction is desired. (*Jensen Manufacturing Company.*)

are called—find favor with amateurs for the reasons given above.

An electric generator delivers the greatest amount of power when its impedance is the same as the impedance of the circuit and load to which it is supplying energy. This same principle applies in the case of a loud-speaker connected to a radio receiving set or amplifier. The impedance of the voice coil in the speaker must be matched to the impedance of the plate circuit of the tube which is to supply energy to the speaker. This matching is most easily accomplished by means of a suitable transformer.

In the permanent-magnet dynamic speaker the current flowing through the coils will aid the magnetism when flowing in one direction and impede it if reversed. Generally the leads to the speaker are so marked that the proper lead can be connected to the positive side of the output. If not, then try the leads in reverse order to find the optimum results.

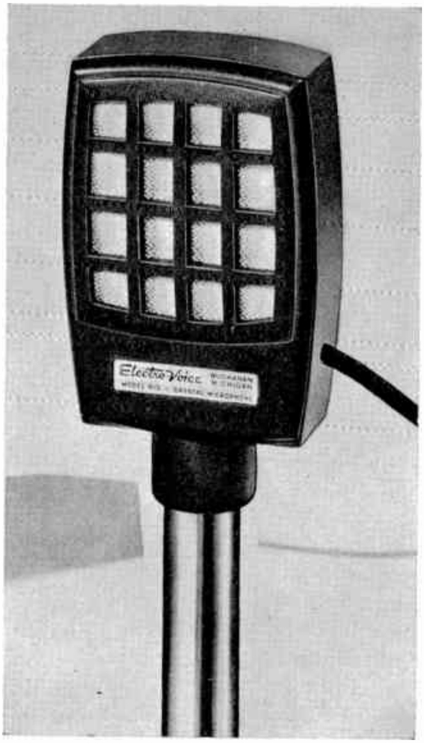
Nearly any speaker of a reputable make on the market today will give good results, the whole matter more or less depending on the amateur's pocketbook and the amount of volume desired.

MICROPHONES

A microphone is essentially a transmitter that converts acoustical energy into electrical energy, or in other words changes sound waves into audio-frequency signals. We are all familiar with the telephone transmitter, which consists of a flexible diaphragm attached to a chamber or cup containing carbon granules, through which line current flows. The speaker's voice causes the diaphragm to vibrate, thus varying the pressure on the carbon granules and changing the resistance of the cup, which in turn produces a fluctuation in the current that registers in the receiver on the other end in the manner described above. *Carbon microphones* for radio use may be of the telephone-transmitter type, in which case they are known as *single-button* microphones, or they may have *two* carbon-granule cups (*double-button*), one on each side of the diaphragm, giving a kind of push-pull effect that minimizes distortion. Although quite popular in the 1930s, the double-button carbon microphone is now seldom used.

The *condenser microphone* consists of a tightly stretched diaphragm which forms one plate of a two-plate condenser or capacitor, the vibration of the diaphragm causing a change in capacitance and thus producing a small a-c charging current. The condenser microphone requires a preamplifier and is expensive to manufacture, so that it has little use except in specialized applications.

The *crystal microphone* works on the piezoelectric principle referred to in the section on crystal headphones above, namely, that



63. Multi-purpose crystal microphone for communications, public address, paging, and recording. Can be mounted on stand or held in hand. (*Electro-Voice, Inc.*)

a change in the shape of a Rochelle salts crystal (or other piezoelectric material) generates a small a-c current that varies with the pressure on the crystal. Crystal microphones are of two types, the *diaphragm* type and the *grille* type, the former being essentially of the same construction as the crystal headphone in that it uses a diaphragm mechanically coupled to a crystal element. It is the type most popular with amateurs for a number of reasons—it is inexpensive, it requires no battery or transformer, and it can be connected directly to the grid of an amplifying tube. The grille type, which has higher fidelity, consists of a group of crystals cemented together in series or series-parallel. Fig. 63 shows a multi-purpose crystal microphone designed especially for communications and public-address work.

A *velocity* or *ribbon microphone* has a thin corrugated metallic strip or ribbon loosely suspended between the poles of a horseshoe magnet, the ribbon acting as a generator of minute a-c currents when it vibrates between the poles. This current can then be fed directly to the grid of an amplifier tube for the high-impedance type, or coupled to the first amplifier stage through a step-up transformer for a low-impedance type. The high-impedance velocity microphone is the more frequently used of the two, and both are used mainly for public address, high-fidelity recording, and remote broadcast, where unwanted sounds such as audience noise and feedback must be minimized.

Dynamic microphones are also known as *moving-coil* microphones, because, like the dynamic loudspeaker, they depend on the movement of a coil in a magnetic field for their operation. A thin coil of aluminum ribbon is attached to a flexible diaphragm to form a unit that moves between the poles of a powerful permanent magnet. Movement of this coil due to sound vibrations causes an alternating voltage to be generated, which may be connected directly into the grid of an amplifier tube. Fig. 64 illustrates a hand-held dynamic microphone designed especially for speech transmission in radio communications. An inexpensive dynamic microphone can also be made from a small 4- or 5-inch PM speaker, which will have a high enough fidelity for most speech and communications work.

To sum up, the amateur will probably find that the diaphragm-type crystal microphone costing in the neighborhood of $10 will meet all his requirements for good voice reproduction in communications work. Before deciding on which type to buy, however, it will be well to investigate the characteristics of the various types and makes on the market. Such matters as frequency response or fidelity, output, impedance, and other variables differ widely with different types.

64. Hand-held dynamic microphone for speech transmission, with press-to-talk switch. (*Electro-Voice, Inc.*)

THE DECIBEL

The decibel (abbreviated db) is a unit used to compare sound levels, and is defined as the amount of increase in sound intensity that is just perceptible to the human ear. It is used to express gains in amplifying equipment and comparisons between input and output values. In radio and communications work it is customary to assume that a level of zero decibel is equivalent to a power output of 0.006 watt or 6 milliwatts. Negative decibel ratings are therefore equivalent to power outputs of less than 6 mw. Knowing the decibel rating of a circuit or piece of equipment enables us to compute the total gain in an amplifying system merely by adding the individual gains and losses in the circuit.

Microphones are rated in decibel output to indicate the amount of amplification required in the circuit. A microphone with an output of —90 db, for example, has a power output of only 6 micro-microwatts, or 6×10^{-12} watt; this negative-decibel rating indicates a loss that must be made up in the amplifying system in addition to other losses so that the level feeding the loudspeaker will be at least 1 watt or approximately 22 db. In other words, at least 112 db must be added in the amplifying system due to the —90 db rating of the microphone in order to obtain satisfactory room volume. In the example given, a preamplifier stage would probably be required. For the sake of comparison, the output of a type 45 power tube is 2,000 milliwatts, which is approximately +22 db.

The average output rating of most microphones is between —48 and —55 db, although some velocity microphones run as low as —70 db and one type of carbon microphone has the relatively high output of —32 db. High-fidelity and bidirectional characteristics are usually associated with lower output in microphones and phonograph pickups.

CHAPTER

10

Power Supply

SOURCES OF POWER

The power supply, and by that is meant the current for the filaments and the plate circuits, is an important adjunct of every vacuum-tube receiving set and transmitter.

In some instances batteries must be used. When power from a commercial lighting circuit is available it will prove most satisfactory. Portable installations must necessarily depend upon batteries.

DRY CELLS

Two types of batteries are available, dry cells and storage cells. Dry cells will not deliver current at as great a rate as storage cells and consequently are satisfactory only for sets containing a small number of battery-type tubes. (See page 70.)

Two No. 6 dry cells connected in series will deliver approximately three volts. Together with the proper ballast resistance to regulate the current, they operate 1.4 and 2-volt filaments satisfactorily. There are, however, at least 20 different types of portable *A* batteries (ranging from 1½ to 7½ volts) and about 30 different types of combination "*A* & *B*" batteries now available on the market, so that the battery-set owner should have no trouble finding the right size and type for his purposes.

Special 3-volt dry *A* batteries for farm radio use are also available. The 3-volt flat type will deliver ½ ampere three hours per day for six months. A larger size, called the heavy-duty type, will deliver the same amount of current for approximately one year.

About 20 different types of *B* batteries, supplying from 22½ to 90 volts, can be obtained for use as power sources for the plate circuits of battery-type tubes.

STORAGE CELLS

A 2-volt storage cell may be used to light the filaments of 2-volt tubes provided the usual 3-volt ballast resistance is replaced with a 2-volt adapter ballast. A large-capacity 6-volt storage battery will operate tubes with 6.3-volt filaments satisfactorily.

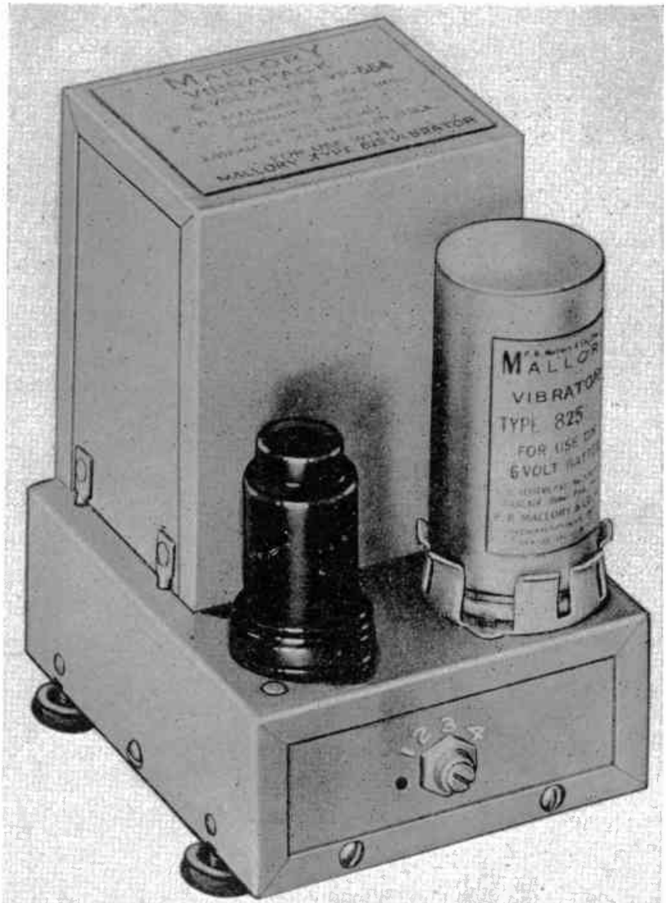
VIBRATOR-TRANSFORMERS

A vibrator-transformer (Fig. 65) is an electromagnetic device that provides high-voltage direct current from a 6-volt storage battery, so that the same battery used for filament lighting can also be used to supply plate voltages as high as 400 volts. The vibrator contains a vibrating armature that reverses the direction of current flow when it is connected to a storage battery, thus producing low alternating voltage. This is then stepped up by a power transformer mounted as a unit with the vibrator, and then rectified back to a d-c voltage either by a vacuum-tube rectifier or by an additional synchronized pair of vibrating contacts. Vibrator-transformers are used extensively in the power packs of automobile, aircraft, and marine radio receivers and transmitters.

Before the rectified current can be used in the plate circuit, it must be filtered by suitable inductances and condensers. Filter systems are discussed in detail later in the present chapter.

RECHARGING STORAGE BATTERIES

Storage batteries must be recharged when the specific gravity of the solution as indicated by a hydrometer falls to 1.100. To restore it to a full-charged condition (sp. g. 1.285), the chemical action that occurred during discharge must be reversed. This is accomplished by connecting it to a source of direct current of the same voltage as the battery so that the current flows through the battery in the opposite direction. Storage batteries can be charged from direct-current lines by connecting them in series with a suitable resistance to provide the necessary voltage drop, or they can be charged from a-c lines by using a vacuum-tube or dry-disk rectifier or battery-charging unit.



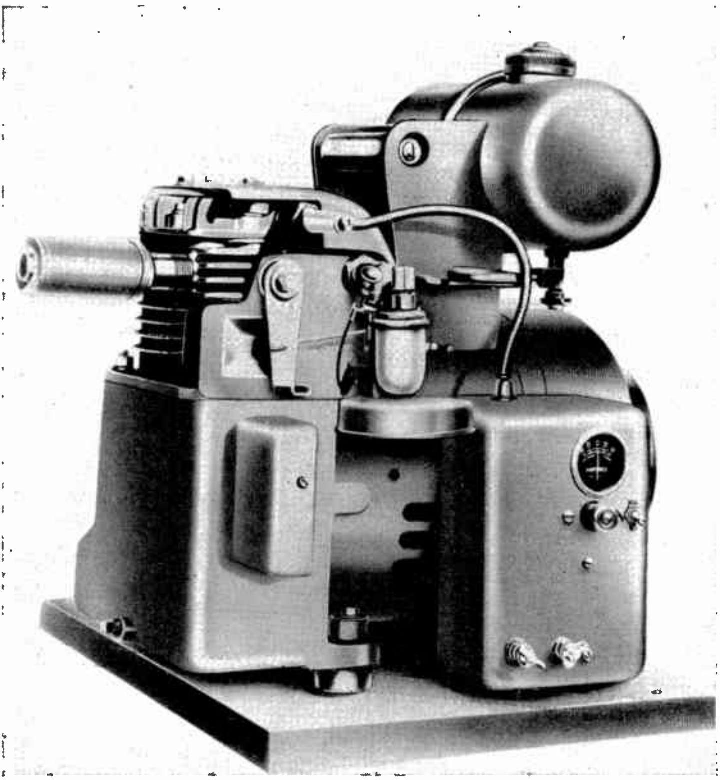
65. Mallory "Vibrapack" or vibrator-transformer with vacuum-tube rectifier, operating from 6-volt storage battery with output voltage of 225-300 volts and output current of 100 milliamperes. (*P. R. Mallory and Co., Inc.*)

However, on farms and other locations where no lighting circuit is available for charging, and where it is impractical to transport the storage battery to a service station for recharging, the radio amateur may prefer to install either a wind-driven or gasoline-operated d-c generator for the purpose. Fig. 66 shows a 6-volt heavy-duty "Wincharger" with 6-foot propeller, mounted on a 5-foot low tower. At right angles to the propeller blade is a 22-inch air-brake governor which prevents excessive speeds. Automatic

66. The Wincharger, a 6-volt wind-driven d-c generator used with storage batteries for farm radio and house lighting. (*Wincharger Corporation.*)

control relays raise or lower the charge as battery conditions require. This type of generator will start recharging in an 8-mile wind, and although its first cost is greater than a gasoline-engine generator delivering the same kilowatt-hour output, the savings in operating costs make this type of power well worth considering.

Fig. 67 shows a 300-watt, 6-volt gasoline-driven d-c generator powered by a 1-cylinder air-cooled engine that gives up to 7 hours' running per gallon of fuel at full rated load. The entire unit weighs less than 80 pounds and can be hand-carried for reasonable distances or stowed in an automobile trunk. A control box, mounted



67. Small gasoline-driven 6-volt d-c generator for storage-battery charging and house lighting. (*D. W. Onan and Sons, Inc.*)

on the generator, contains a charge-rate ammeter, push-switch for electrically starting the plant, and automatic controls that prevent the battery from overcharging. The charge rate is controlled by a simple adjustment of the engine throttle. The model illustrated is available for 6-, 12-, and 32-volt operation, with maximum ampere ratings of 40, 28.5, and 11 amperes respectively.

POWER PACKS

The 110-volt alternating-current electric light and power mains are the most satisfactory source of current for radio use. Alternating current obtained from the house current through a step-down transformer may be used for the filaments. However, before power from an alternating-current supply can be used in the plate circuit of a vacuum tube, it must be rectified, or changed into direct current, and filtered. The filament supply is simple; power for the plate circuit is more complicated. The equipment required for adapting the 110-volt alternating current for use in a radio set is known as a power pack or power-supply unit. It consists of a filament transformer, a plate transformer, a rectifier, and a filter. Rectifiers and filters are discussed in detail below.

RECTIFIER TUBES

There are two general types of rectifier tubes: (1) the high-vacuum or hot-cathode and (2) the gaseous. The latter has a small quantity of mercury vapor added after the air has been removed from the tube. The high-vacuum or kenotron type of tube is similar to a Fleming valve in principle. Conduction across the space between the filament and plate (cathode and anode) is purely by means of a stream of electrons passing from the filament to the plate. When a rectified tube of the mercury-vapor type is in operation, the mercury vapor becomes ionized and increases the conductivity between the anode and cathode.

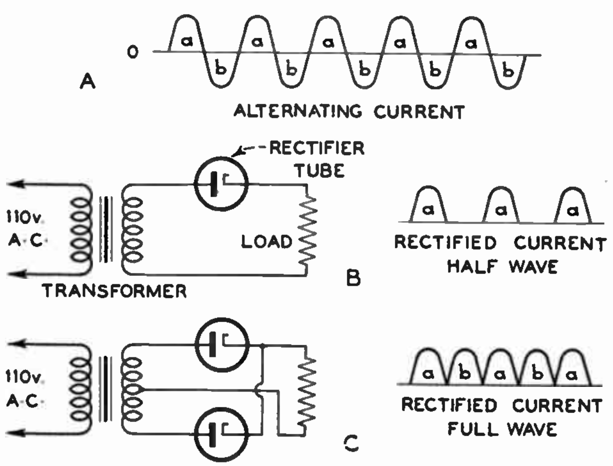
The high-vacuum type has a comparatively large voltage drop between the filament and plate, whereas the mercury-vapor type, on account of greater conductivity, has a relatively small voltage loss. This difference in characteristic makes it necessary to use a slightly different circuit arrangement for each type of rectifier tube. (See page 66.)

The efficiency of the mercury-vapor rectifier tube is greater than that of the high-vacuum type, but these are seldom used to supply current for receiving purposes. Rectifiers for receivers are nearly always of the high-vacuum type because mercury-vapor rectifiers are likely to cause noise in the receiver. Rectifiers for transmitters are usually of the mercury-vapor type, since efficiency and voltage regulation are important.

There are, in addition, the dry-disk and crystal-diode rectifiers mentioned on page 64. The selenium rectifier is becoming increasingly used in 3-way portable and "personal" battery radios, and in power supplies where 118-volt a.c. is to be converted into 6- to 30-volt d.c. and at currents from about 200 milliamperes to about 15 amperes. Unlike tubes, they require no warming-up period and thus provide instant starting of the radio as soon as it is turned on. Their advantage in small portable radios is their size, about that of a 1-inch cube, which makes them fit where even a miniature tube won't.

HALF-WAVE AND FULL-WAVE RECTIFIERS

There are two types of rectifier circuits: half-wave and full-wave. Tubes made for voltages above 500 usually have but one plate and are known as half-wave rectifiers. For voltages up to 500 they are made with two plates and are called full-wave rectifiers. Examples of the half-wave rectifier tube are the 81 and 35W4 (miniature, in a-c/d-c receivers). The 80 and 5Z4 are full-wave tubes.



68. Fundamental rectifier circuits employing rectifier tubes to change a.c. to d.c.

The difference between half-wave and full-wave rectifier systems is explained by Fig. 68. At *A* is shown a representation of a typical alternating current in which the current and voltage go through two complete reversals in each cycle. The portions of the curve above the line marked *a* are alternations in one direction and those marked *b* are alternations in the opposite direction.

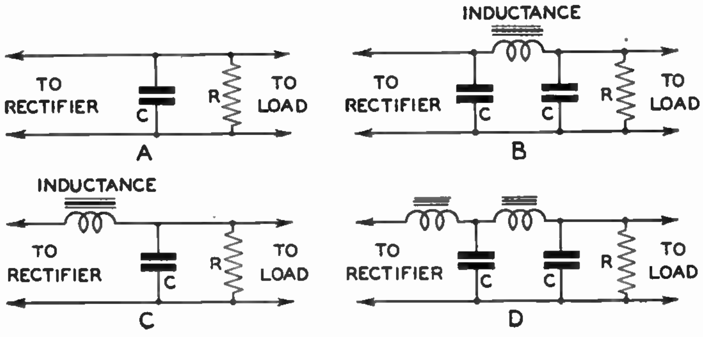
In a half-wave rectifier system (*B*) the valve action of the tube merely eliminates all alternations (*b*) in one direction, the resulting rectified current being ***intermittent*** direct current in the form of a series of impulses. Only one-half of each cycle is useful in furnishing power to the load.

In a full-wave rectifier system (*C*) the full cycle is used to furnish power to the load. The action of the tubes results in a continuous series of impulses. The amount of power which can be realized for the load is doubled and the rectified current is more like a true direct current.

FILTERS

Although the rectified current from a full-wave rectifier is direct current in the sense that it always flows in the same direction, it is not uniform but varies continually as shown by the series of humps (*a*, *b*, *a*, *b*) at *C*.

Such a current is full of ripples and if used in a radio receiving set would produce a humming noise. Used in a transmitter, espe-



69. Filter circuits.

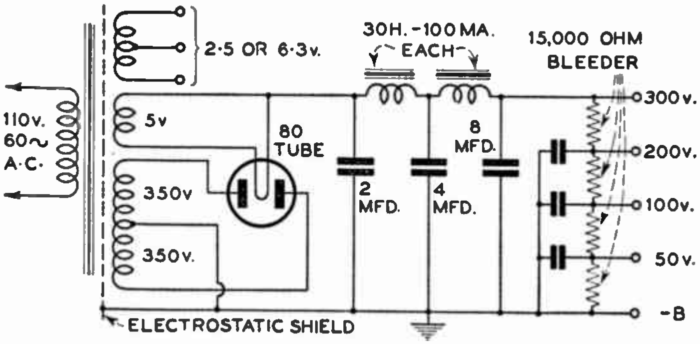
cially one having poor frequency stability, it would be the cause of broad signals. The current must therefore be "filtered" to turn it into "pure direct current."

Fig. 69 shows four representative filter circuits. A single condenser across the line as at *A* will do considerable smoothing but is not a satisfactory filter for radio work.

The addition of an inductance and another condenser as shown at *B* is an improvement and adequately smooths out the current but has the disadvantage that the voltage varies considerably with the load. *C* and *D* are what are known as choke input filters and in most cases are the ideal type for all-around use in the amateur station.

CONDENSERS AND INDUCTANCES FOR FILTERS

Two types of condensers are available for filter circuits: (1) electrolytic condensers using a dielectric which is an extremely thin oxide film formed on aluminum foil and (2) paper condensers using paper as a dielectric. A good paper condenser will last indefinitely



70. Wiring diagram of power supply for an amateur receiver.

if not abused, but once punctured is useless. Electrolytic condensers must be "reformed" if allowed to stand idle for a time and must be connected correctly in respect to polarity, but if broken down due to excessive voltage, the film can be restored. The negative leads are usually black.

Small inductances or "chokes" are obtainable from radio dealers.

Designing a power pack for a particular receiver or transmitter is not a job for the novice. It is distinctly work for an experienced engineer. There is a wide variety of power-pack parts, rectifying and filtering equipment available to amateurs but it is better to buy a complete kit rather than select your own parts.

In fact the whole subject of power packs has been discussed here with the purpose of explaining the operation of rectifiers and filters rather than to give constructional directions. The examination for an amateur radio operator's license usually contains one question about filters.

A word of caution is necessary. Never attempt to alter connections or touch the parts of a power pack without first switching off the current supply and discharging the condensers. A really dangerous shock can result from touching the high-voltage terminals. The plate supply equipment of even a low-powered transmitter can electrocute. Careless amateurs have been severely injured by coming in contact with the high-voltage circuits of power supplies.

CHAPTER

11

Assembling Your Own Radio Receivers

A great many amateurs prefer to buy rather than build their own receivers. Factory-made and -assembled apparatus is usually more efficient than a homemade product and, in the case of the more complicated sets, can usually be purchased more economically than the parts can be acquired and assembled. Nevertheless there is a great deal of pleasure and certainly a great deal of useful experience to be gained from the home construction of receiving sets.

RECEIVER CONSTRUCTION PRACTICE

In the early days of amateur radio, the component parts of receiving sets were usually mounted on the back of a bakelite panel forming the front of a suitable wooden dust-protecting cabinet. Very little if any shielding was used. A large number of tuning controls, consisting of variable condensers, variable inductances, variable couplers, resistors, potentiometers, wave-change switches, etc., frequently made tuning a radio set beyond the grasp of the beginner.

To permit general merchandising of radio receivers to the average citizen, simplifications in tuning controls were imperative. So receivers were developed in which the component parts are mounted on a metal chassis behind a metal or composition panel and provided with a nominal single-dial control.

The amateur experimenter has the choice of two schemes of construction: (1) the "bread-board" method, in which the apparatus is fastened to a flat wooden base and the connecting wires are above the base, and (2) the metal-chassis method, in which the component parts are mounted on a metal chassis and the wiring kept underneath as in most commercial receivers.

The bread-board method lends itself to experimental work. The design and layout can be easily changed. The metal-chassis system of construction is more permanent.

Component parts for every conceivable purpose in radio receivers and transmitters are available to the amateur at reasonable prices and the construction of an amateur-built receiver or transmitter really resolves into assembling and wiring.

No one but an experienced radio engineer is capable of designing a receiver of maximum efficiency of the superheterodyne type. These contain five or more tubes and that fact complicates matters. A receiver consisting of a single detector or a detector and an audio amplifier is of course a simple affair and it is not as important for the component parts to be properly matched as in the case of multiple-tube sets. But even when building a single-tube set it is best to assemble it from a carefully engineered kit of parts rather than from a somewhat heterogeneous collection of coils, condensers, old wire, and other salvaged items.

Given a properly selected set of component parts, the successful operation of the set will depend largely upon how well it has been wired. Wiring resolves itself into arrangement of wires and soldering the joints and connections.

SOLDERING

All joints in radio circuits must be well soldered to insure good electrical connections. The secret of good soldering is *sweating*. This consists in applying the hot tip of the iron to the joint for sufficient time so that the joint becomes hot enough to melt the solder without the necessity of touching the solder to the iron. When the solder has cooled, test the joint by pulling or wiggling it to be sure that it is tight. If the joint breaks or the wire wiggles in the soldered connection, it is not perfect. Probably the joint was not clean or insufficient flux or heat was used. In any event, it should be resoldered.

It is not safe to use any available soldering paste as a flux in radio work. Almost all pastes are slightly corrosive and slightly conductive. Use only rosin-cored solder and plenty of heat. Even then it is best to wipe away any residue in or around the completed joint.

WIRING

All wires connecting the component parts of a radio set should be kept as short as convenient and as a general rule should be placed close to the metal chassis. Wiring, especially plate and grid leads that stand out from the chassis too far, furnish objectional coupling or regeneration. Grid wires in particular should be clipped as short as possible—fractions of inches make a difference—and under no circumstances be placed near or parallel to plate and filament wires.

Most paper by-pass condensers have one terminal marked "ground" to indicate the outside foil of the unit and, to insure best operation, this terminal should always be connected to the ground or to the part of the circuit with the lowest voltage. Such condensers will work in either position but occasionally hum will be picked up if the above instructions are not followed.

Normally, the can of a "wet" or semiliquid electrolytic condenser is always negative, but the functioning of this type of capacitance is so dependent on several points that the amateur should always read its label. For instance, the gas generated in semiliquid electrolytic condensers must have an outlet which is provided on one end. If the can is supported upside down the gas will be prevented from escaping, sometimes with ruinous results.

The labels of all dry electrolytic condensers likewise give the operating data, including the polarity of the flexible leads coming from the interior electrodes. Follow these instructions implicitly.

The insides of both windings in an intermediate-frequency transformer are usually intended by the manufacturer to be the high-potential ends of the coils so that the outside ends will be the low-potential terminals and automatically act as spacers to keep high-potential wiring away from the high-potential ends of the coils.

CONSTRUCTION HINT

When fastening sockets on a chassis, be sure that the position of the keyway or the large locating prong is the same as that shown in the circuit diagram. Use lockwashers under all nuts so that they may be adequately fastened and made vibration proof.

ALIGNING

Modern radio receivers employing several tubes comprise a number of circuits in order to achieve the necessary sensitivity and selectivity. Unless these circuits are adjusted so that they operate at their proper frequencies simultaneously, the receiver will not give its maximum performance. In fact, if the alignment is poor enough, no signal will succeed in passing through and the receiver will be "dead."

Before a superheterodyne can be successfully aligned, the amateur must have a test oscillator, or a signal generator which in itself has been calibrated or checked against an accurate generator. Then he must know how to use the signal generator so that he will not detune the very circuits he is trying to line up. Actually, such work should be done by a competent serviceman or by an accomplished amateur who understands the procedure and the instruments he must use. There is no economy in building a fine receiver and then attempting to use it at a point below its best performance. Have it expertly aligned after completion and make frequent checks on it thereafter. Poor reception is often due to misalignment and nothing else.

USEFUL INFORMATION FOR KIT BUILDERS *

Recommended tools.—The minimum list of tools recommended for the beginner is as follows:

A good electric soldering iron (100-watt, with small tip).

One pair of 6″ long- or needle-nose pliers.

One pair of diagonal or side-cutting pliers, 5″ or 6″.

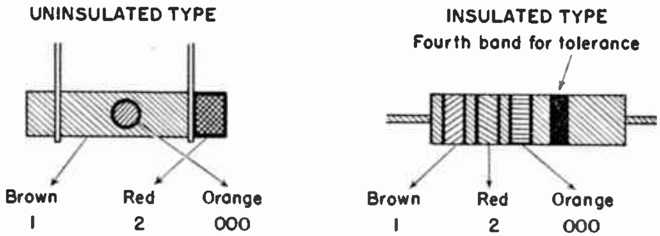
An assortment of screw drivers, both conventional and Phillips types.

A number of small files, round and flat types.

Resistor color code.—Resistors are identified by a color code used in several bands around the resistors. There are two general types of resistors—insulated and uninsulated. The latter type has the connecting wires bound around the ends of the resistor, while

* Courtesy of the Heath Company, Benton Harbor, Michigan.

on the insulated type the wires are connected internally and come out of either end. The resistance code uses a combination of three colors to indicate the size of the resistance in ohms. On uninsulated resistors, these colors are located on the body, on one end, and in a dot placed in the center over the body color. On insulated resistors, the colors are in the form of three rings placed at one end of the resistor. (See Fig. 71.) The color code is the same for each type,



71. Color code for resistors. See tables in text for examples. (*The Heath Company.*)

the only difference being the method of marking. The first ring from the end on the insulated type corresponds to the body color of the uninsulated type; the second ring, to the end color; the third ring, to the dot. The following table gives the meaning of these color combinations for both types:

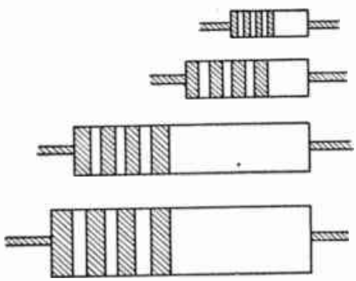
Uninsulated	Body Color	End Color	Dot Color
Insulated	First Ring	Second Ring	Third Ring
Color	*First Figure*	*Second Figure*	*Number of Zeros*
Black	0	0	None
Brown	1	1	0
Red	2	2	00
Orange	3	3	000
Yellow	4	4	0,000
Green	5	5	00,000
Blue	6	6	000,000
Violet	7	7	0,000,000
Gray	8	8	00,000,000
White	9	9	000,000,000

Examples of how this code works for some popular sizes of resistors are given below:

Body or First Ring	End or Second Ring	Dot or Third Ring	Resistance in Ohms
Green (5)	Black (0)	Black (No zeros)	50
Red (2)	Green (5)	Brown (0)	250
Brown (1)	Green (5)	Red (00)	1,500
Orange (3)	Black (0)	Orange (000)	30,000
Red (2)	Red (2)	Yellow (0,000)	220,000
Brown (1)	Black (0)	Green (00,000)	1 Megohm

Note that a fourth ring may be used to indicate *tolerance,* or resistance range in per cent of rating; a silver ring indicates 10 per cent tolerance, a gold ring 5 per cent tolerance, while no ring at all indicates standard 20 per cent tolerance.

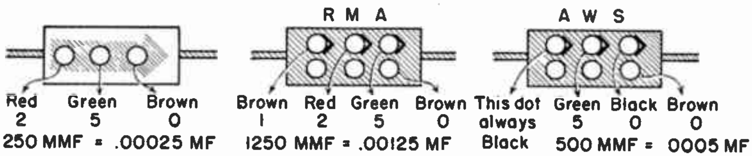
Wattage of resistors.—Resistors are also rated as to wattage according to their relative size. Fig. 72 shows approximate sizes and corresponding wattages for insulated types. Actual sizes, of course, vary with different manufacturers, but the relative proportions are about the same as shown.



72. Wattage of resistors is indicated by their relative size. (*The Heath Company.*)

Capacitor color code.—Capacitors or fixed condensers also are color coded, using a number of dots instead of rings but retaining the same numerical value for each color as given for resistors. However, there are three different methods of placing the dots (Fig. 73). If there is only one row of dots, they are read in the direction of the cross-hatched arrow that appears on the condenser as shown. The first color gives the first figure of the rating in mmf, the second color the second figure, and the third color the third figure. If there are two rows of dots, the code used may be either of two types, the

RMA (Radio Manufacturers' Association) or AWS (American War Standard), although the latter type should be appearing less frequently now. In both codes the first three dots, read in the direction of the arrows, indicate the first three figures of the mmf rating, while the third dot on the bottom row gives the decimal multiplier.



73. Color code for capacitors. See tables in text for examples. (*The Heath Company.*)

In the RMA code, the first two dots in the bottom row indicate, respectively, the voltage rating and tolerance, while in the AWS code they represent characteristic and tolerance respectively. These two codes may be distinguished by the fact that the first dot in the top row of the AWS code is always black. Examples of how this works out for some commonly used sizes of capacitors are given below:

First Dot	Second Dot	Third Dot	MMF	MF
Brown (1)	Black (0)	Black (no zero)	10	.00001
Green (5)	Black (0)	Black (no zero)	50	.00005
Brown (1)	Black (0)	Brown (0)	100	.0001
Red (2)	Green (5)	Brown (0)	250	.00025
Green (5)	Black (0)	Brown (0)	500	.0005
Brown (1)	Black (0)	Red (00)	1000	.001
Orange (3)	Black (0)	Red (00)	3000	.003
Brown (1)	Black (0)	Orange (000)	10,000	.01

The tolerance rating corresponds to the color code—i.e., red means 2 per cent, green 5 per cent, etc. The voltage rating corresponds to the code number multiplied by 100—i.e., orange means 300-volt rating, blue, 600-volt rating.

ALL-WAVE BEGINNER'S RADIO

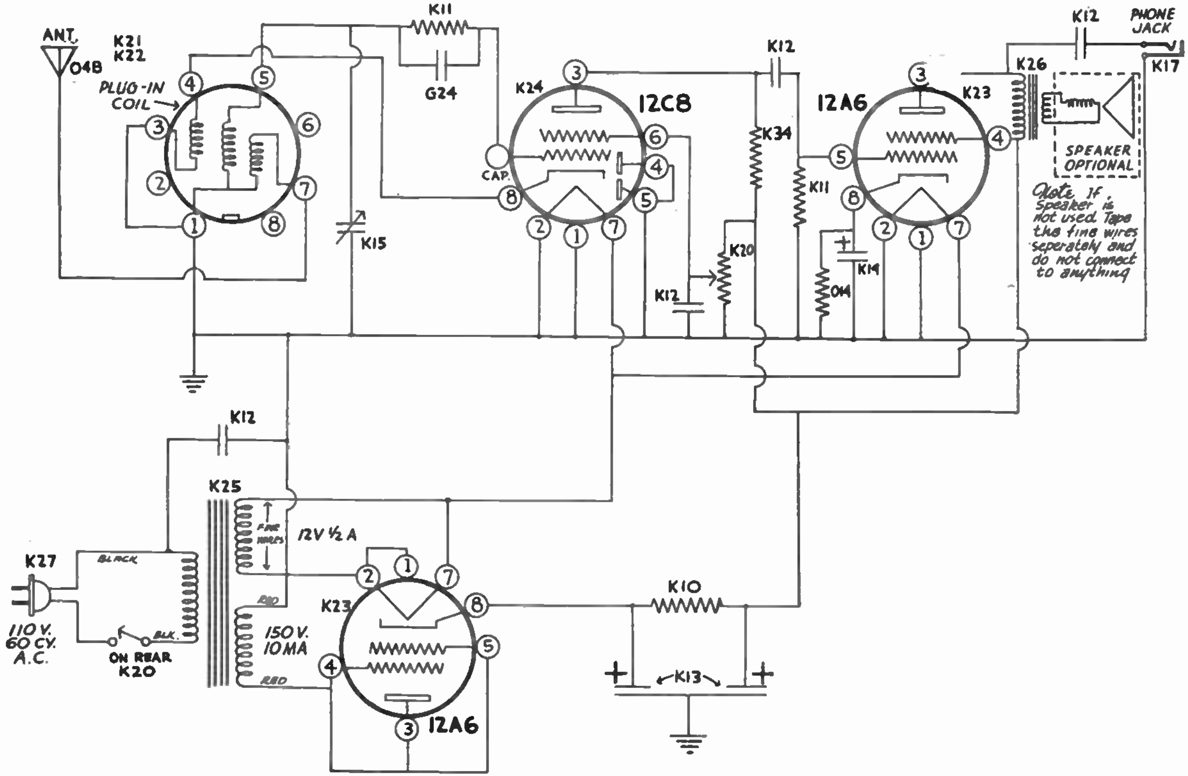
The regenerative type of receiver is a favorite with amateurs. It is used chiefly because of its low cost, and because it is easy to construct and operate.

The Heath All-Wave Beginner's Radio, Model K-1, described in this section, is a three-tube regenerative detector and beam power amplifier with transformer power supply, designed to operate on 110-118-volt 60-cycle a-c house current. It employs one 12C8 metal duplex-diode pentode and two 12A6 metal beam power amplifier tubes, both types being high-voltage heater tubes with heater currents of 12.6 amperes and plate voltages of 250 volts. These newest-type tubes give much greater power than comparable previous types, and the receiver is the first beginner's kit to use the more expensive transformer type of power supply, making it a much safer receiver to work with, since the danger of shock between radio and water pipes, radiators, etc., is eliminated. The description and illustrations (Figs. 74, 75, and 76) in the following pages are from the instruction manual furnished with this kit by the manufacturer, the Heath Company, Benton Harbor, Michigan, from whom the complete kit may be purchased, less speaker, headphones, and cabinet, for less than $10, or, with these items included, for about $15.

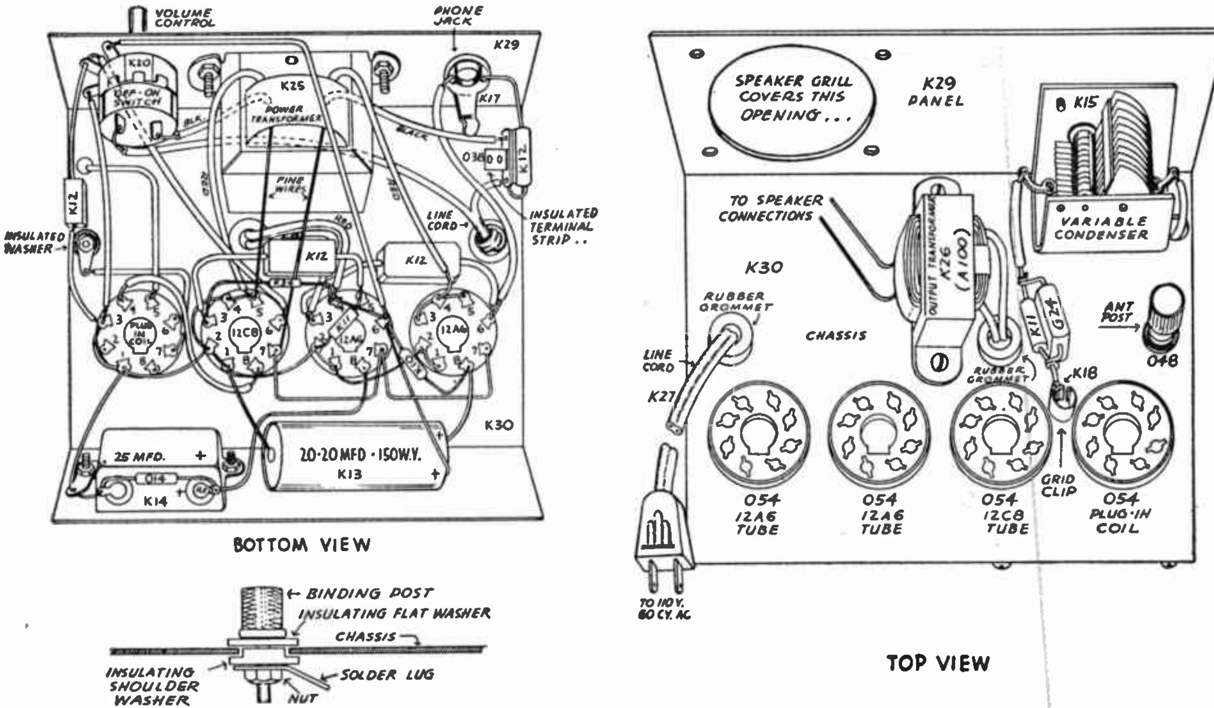
Parts for All-Wave Beginner's Radio

- 1 Punched steel panel
- 1 Punched steel chassis
- 1 470-ohm resistor (yellow-violet-brown)
- 1 2,700-ohm resistor (red-violet-red)
- 1 220,000-ohm resistor (red-red-yellow)
- 2 2-megohm resistors (red-black-green)
- 1 50-mmf fixed condenser
- 4 .01-mfd fixed condensers, 200-volt
- 1 Dual 20-mfd 150-volt electrolytic condenser
- 1 25-mfd 25-volt condenser
- 1 360-mmf variable condenser
- 2 Soldering lugs
- 11 6-32 x 3/8" machine screws
- 12 6-32 nuts
- 2 Potentiometer nuts
- 1 Lock washer
- 3 6-32 x 3/16" machine screws
- 2 3/8" rubber grommets
- 1 9/64" fiber shoulder washer
- 1 9/64" fiber plain washer
- 1 Insulated terminal strip
- 1 Phone jack
- 1 Grid clip
- 2 Pointer knobs
- 1 Antenna binding post
- 4 Octal tube sockets
- 4 Octal socket rings
- 1 Speaker screen
- 1 50,000-ohm volume-control, with switch
- 1 Plug-in coil, broadcast band
- 1 Plug-in coil, short-wave band
- 2 12A6 tubes
- 1 12C8 tube
- 1 Power transformer
- 1 Output transformer
- 1 Line cord
- 1 Roll of hookup wire, 2 ft.
- 1 Length spaghetti tubing, 1 ft.

Regardless of whether you are a mere beginner or an advanced expert, the very first step in assembling any kit is to check each

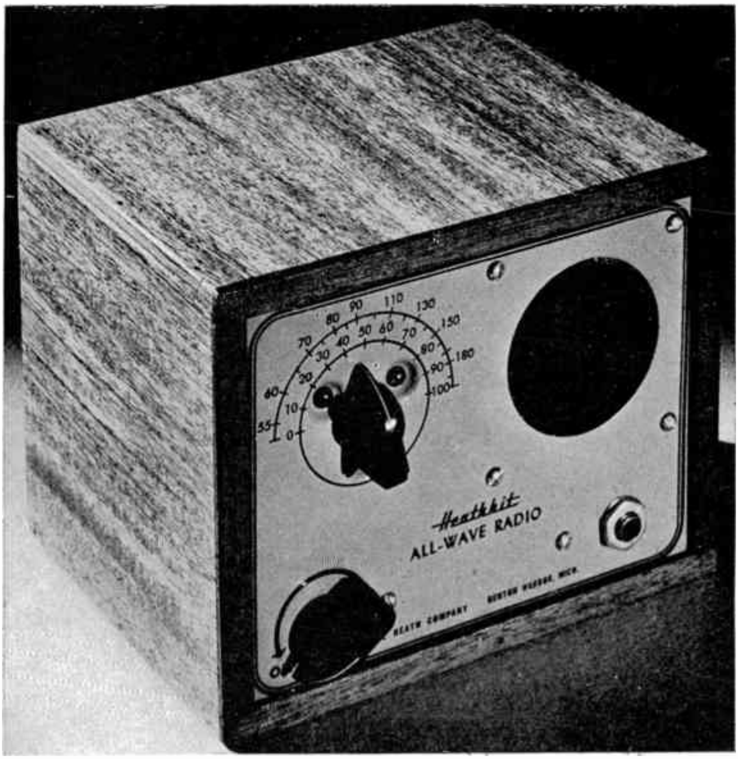


74. Schematic circuit diagram for Heath 3-tube regenerative All-Wave Beginner's Radio, Model K1. (*The Heath Company.*)



75. Pictorial diagram showing arrangement of parts and wiring for Heathkit All-Wave Beginner's Radio. (*The Heath Company.*)

part with the parts list furnished by the manufacturer. Don't throw away the packing until you are certain that no parts have been lost or mislaid. Identify the various resistors and condensers by their color-code markings as indicated earlier in this chapter. Study the



76. Heathkit 3-tube regenerative All-Wave Beginner's Radio. (*The Heath Company.*)

information sheet provided and examine the schematic and pictorial diagrams of the set so as to familiarize yourself with the placement and function of each part. Later, as each connection shown on the pictorial diagram is made, trace over it on the diagram with a colored pencil so as to be certain that all connections are made correctly.

Begin the construction of the All-Wave Beginner's Radio by installing the octal tube sockets. Note that there is a slot in the center hole of the socket which points to the rear of the chassis. The sockets are held in place by the wavy socket rings, which snap over the bottom of each socket and fit in the groove around the socket. Start with one end of the ring in the groove and press the rest of the ring over the socket and into the groove with a screw driver. The socket connection number will be found in small figures on the bottom of each socket.

The output transformer is mounted next, followed by the phone jack and volume control. The panel is held to the chassis by the lock nut on each of these fittings. Next mount the power transformer, with the two red and two fine wires showing. The small insulated terminal strip (038 in the pictorial diagram, Fig. 75) mounts in back of the phone jack, while the binding post (048) mounts behind the volume control. (Note that when the chassis is worked on upside down the position of each part as shown in the pictorial diagram is reversed from left to right as compared with the top view. It is particularly important to remember this fact when wiring the set.) In mounting the binding post, use one brown insulated washer on each side of the chassis, with the small shoulder on one washer extending through the chassis to prevent the binding-post metal from touching the chassis. Place a soldering lug under the binding-post nut as shown. The aerial connects to threaded upper end of this binding post.

The hookup wire supplied with the kit is the "push-back" type, meaning that it does not have to be skinned. It should be cut to the proper length for a connection and the insulating covering pushed back about a quarter of an inch so that the bright tinned wire can be fastened firmly to its connection before soldering. Where several lugs on one socket are connected together, the insulation may be completely removed from a small piece of the wire and the bare wire used to connect the lugs. The connecting leads to the condensers and resistors are bare wire. If there is danger of these bare leads touching any other lead or the metal chassis, use the insulated sleeving (spaghetti) to cover these wires.

In mounting the 25-mfd condenser, note that a solder lug is placed under the nut nearest the end of the chassis. The resistor (014) is connected across the terminals of this condenser and the terminal with the black mark connects to the soldering lug, which is the common chassis ground. This ground or chassis connection also connects to contact 8 of the plug-in coil, continuing from that point to contacts on the other sockets.

To mount the variable tuning condenser (K15), use the short screws supplied with the set and make sure that they do not touch the plates of the condenser when the shaft is turned. This condenser is very delicate and must be handled carefully. Always keep the plates fully meshed when handling. If these plates are bent so that there is contact between the rotating and stationary plates, the set will not work.

The plug-in coils are identified as follows: the built-up winding approximately 3/16" wide indicates the broadcast coil, while the coil with the flat, wider winding is the short-wave coil covering from 1,500 to 6,000 Kc.

In wiring the set, follow the pictorial diagram exactly, making the leads as short as possible and checking to see that all soldered connections are properly made. A rubber gromet is used in the holes of the chassis where the line cord and the output transformer wires go through.

If a speaker is used with the set, handle it carefully while mounting to avoid damage to the paper cone. If a speaker is not used, the two fine wires of the output transformer (which connect to the speaker) should be taped separately so that they do not make connection with each other or to the chassis.

After the wiring has been completed and checked with the pictorial diagram, install the tubes, connecting grid clip K18 to the top connection on the 12C8 tube. Install a plug-in coil and connect the aerial lead-in to the binding post. (For local or nearby stations a wire 20 feet long may be used indoors, but for long-distance reception an aerial 50 to 100 feet long should be used, erected with insulators outdoors at least 20 feet from the ground.) Connect the line cord to 110-118-volt 60-cycle house current. *This set will not operate on direct current.*

The on-off switch is on the same shaft as the volume-control switch and turns the set on when the shaft is turned in a clockwise direction until it "clicks." To shut the set off, turn the volume-control knob counterclockwise until the click is heard.

Now turn the set on and allow one minute for the tubes to heat up. Turn the tuning knob and advance the volume control until a whistle is heard in the headphones (plugged in to the phone jack) or in the loudspeaker (if one is used). Reduce the volume control until the whistle changes and voice or music is heard. Do not allow the set to whistle any longer than is necessary to tune in a station. When the set is whistling, it is radiating—that is, acting as a miniature transmitter—and therefore interfering with good reception on any receiver in the neighborhood that is tuned to the same station.

When using the short-wave coil (which covers police, aircraft, foreign, and amateur broadcasts) the tuning is very sharp, and care must be used in tuning to avoid missing weak stations.

If you run into trouble and the set doesn't operate as it should, it may be best to consult your local radio serviceman and have him help you in checking the wiring and connections. A word of caution —don't touch any of the connections on the bottom of the set while it is plugged in to the house current.

A photograph of the finished receiver enclosed in an inexpensive mahogany plywood cabinet is shown in Fig. 76.

A 5-TUBE A-C/D-C SUPERHETERODYNE RECEIVER

This receiver (Fig. 80) is of modern design and has a built-in loop antenna. The frequency range is from 530 to 1620 kc. It is simple to construct, compact, and has unusual volume and clarity. An inexpensive carrying case will make the receiver a handy companion when traveling, touring, or on vacation, or the ivory cabinet supplied at slightly additional cost will make this a handsome table radio for living room or den.

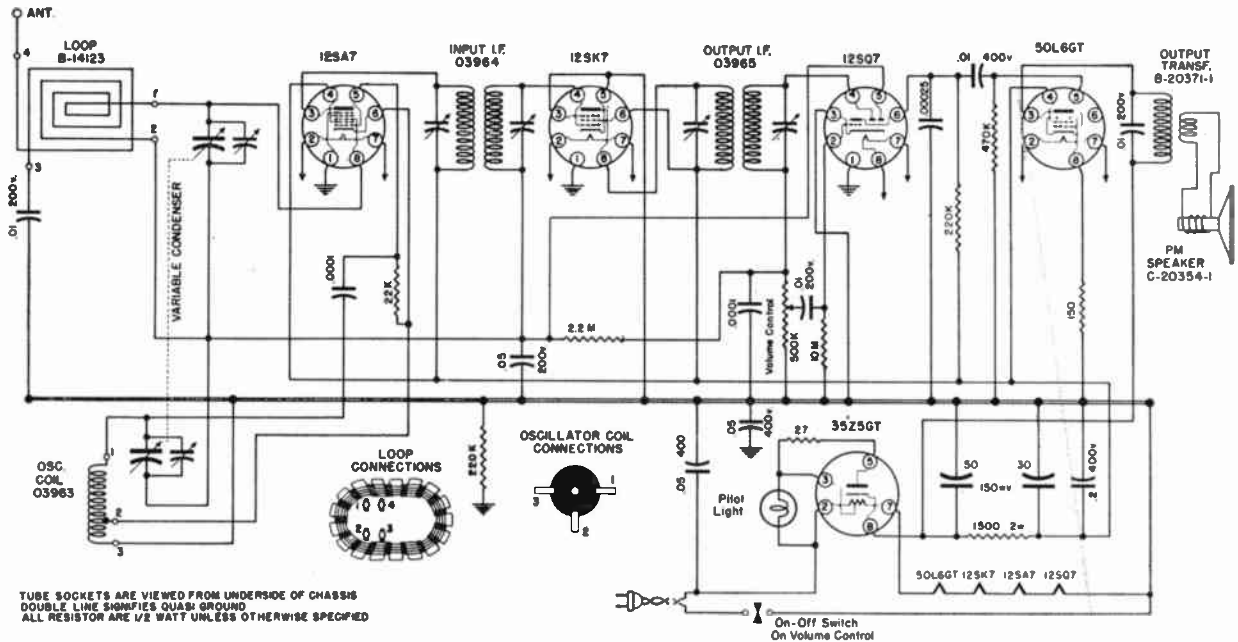
The receiver uses the following tubes:

12SA7 pentagrid converter
12SK7 remote-cutoff pentode for i.f. amplifier
12SQ7 twin-diode high-mu triode for detector, first a.f. amplifier, and automatic volume control
50L6GT beam power amplifier
35Z5GT half-wave vacuum rectifier

Parts List for 5-Tube A-C/D-C Superheterodyne Set

1 Punched steel chassis
1 Variable capacitor
1 Pulley and shaft
1 Input i.f. transformer, No. 03964
1 Output i.f. transformer, No. 03965
1 Loop antenna
1 Oscillator coil
1 5-inch PM loudspeaker
1 Volume control
1 50-30-mfd electrolytic capacitor
1 .2-mfd 400-volt paper condenser
1 .01-mfd, 400-volt paper condenser
2 .05-mfd, 400-volt paper condenser
1 .05-mfd, 200-volt paper condenser
3 .01-mfd, 200-volt paper condenser
1 .00025-mfd, 500-volt mica condenser (red-green-brown)
2 .0001-mfd, 500-volt mica condenser (brown-black-brown)
1 1500-ohm, 2-watt resistor (brown-green-red)
1 150-ohm, ½-watt resistor (brown-green-brown)
1 470,000-ohm, ½-watt resistor (yellow-violet-yellow)
2 220,000-ohm, ½-watt resistors (red-red-yellow)
1 2.2-megohm, ½-watt resistor (red-red-green)
1 10-megohm, ½-watt resistor (brown-black-blue)
1 22,000-ohm, ½-watt resistor (red-red-orange)
1 27-ohm, 1% tolerance, ½-watt resistor (red-violet-black)
5 Octal tube sockets
1 Dial cord
1 Dial tension spring
1 Volume-control bracket
1 Loop bracket
2 Bakelite washers, ½" O.D. × ¼" I.D. × 1/32"
1 Drive shaft
2 Hairpin spring clips
1 Insulator
1 Shield
1 Dial scale
2 Spacer dowels
1 Dial light socket
1 Dial pointer
1 Power cord
1 50L6GT vacuum tube
1 12SQ7 vacuum tube
1 12SK7 vacuum tube
1 12SA7 vacuum tube
1 35Z5GT vacuum tube
1 No. 47 pilot light
1 Palnut, 3/8-32
17 Nuts, No. 6/32 × ¼", hexagon
19 Lock washers
3 Steel washers, 9/16" O.D. × .172" I.D. × 1/32"
4 Steel washers, ½ O.D. × .154 I.D.
3 Brass spacers
3 Rubber grommets
1 Lug
1 Tie lug with 2 insulated terminals
11 Screws, 6/32 × ¼"
3 Screws, 6/32 × 9/16"
2 Screws, 6/32 × ½"
2 Self-tapping screws, No. 8 × 3/8"
3 Self-tapping screws, No. 7 × 1"
1 Self-tapping screw, No. 6 × 7/16"
3 Self-tapping screws, No. 6 × ¼"
1 Self-tapping screw, No. 4 × 3/8"
2 Knobs
2 Felt washers
1 Speaker baffle
1 Crystal
11 ft Black lead wire
1 ft Stranded yellow lead wire
10 ft Solder
4 in. Black sleeving

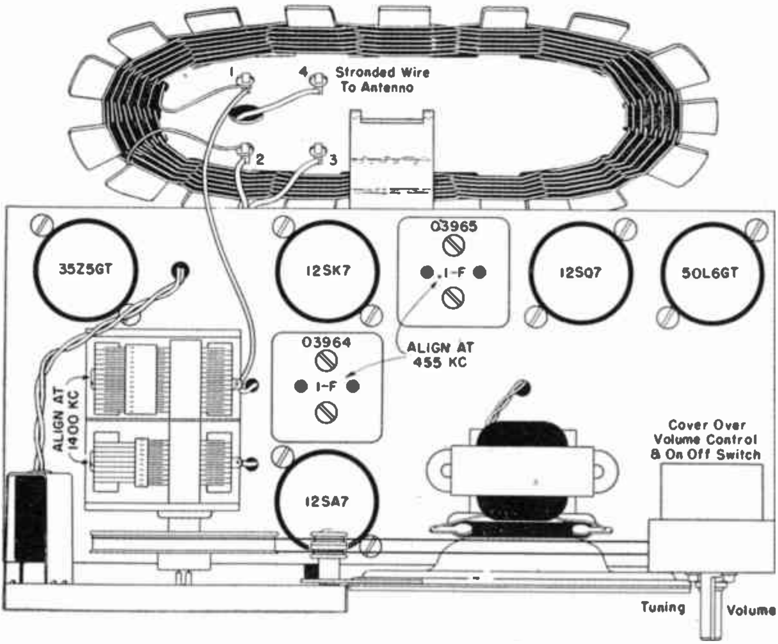
The assembly instructions, wiring, and alignment outlined below, together with the illustrations (Figs. 77, 78, 79, and 80), are reproduced from the Instruction Manual accompanying the complete parts kit, which may be obtained from the manufacturer, The



77. Schematic circuit diagram of Meissner 5-tube a-c/d-c superheterodyne receiver. (*Maguire Industries, Inc.*)

Meissner Manufacturing Division, Maguire Industries, Inc., Mt. Carmel, Ill.

As the kit is unpacked, check the parts contained against the parts list. Any discrepancies should be reported at once to the dealer from whom the kit was purchased.



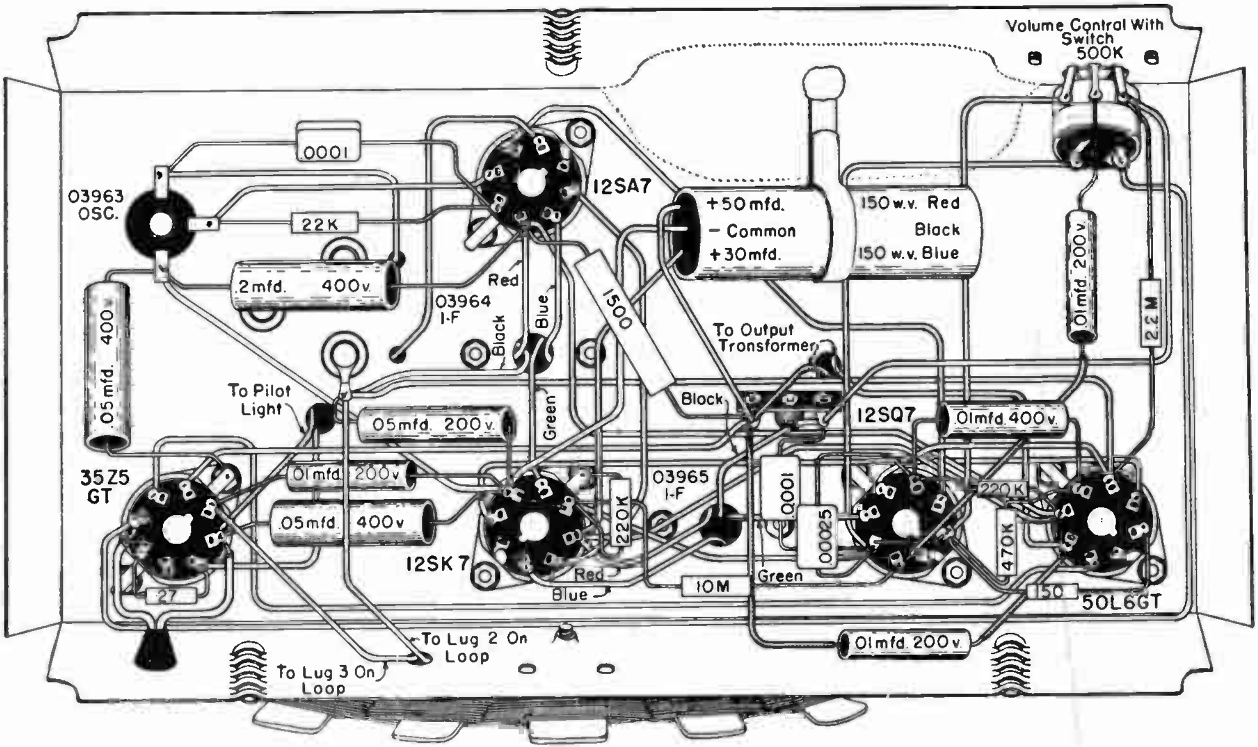
78. Top view of Meissner 5-tube a-c/d-c superheterodyne receiver showing layout of parts. (*Maguire Industries, Inc.*)

The following procedure is recommended to save time and trouble in construction:

(1). Mount tube sockets, making certain that keyways point as shown on the pictorial diagram of the botom of chassis (Fig. 79).

(2). Mount bracket on front of chassis, using the self-tapping screws provided. Mount the variable capacitor, using the rubber grommet, spacer, washer, and screw provided.

(3). Mount the input i.f. and output i.f. transformers, rotating them to give a minimum of crossed leads.



79. Pictorial wiring diagram of the 5-tube a-c/d-c superheterodyne receiver. (*Maguire Industries, Inc.*)

(4). Mount speaker and place dial drum on the variable-capacitor shaft so that it is in line with the pulleys on the speaker frame.

(5). Mount volume control in lower hole of bracket on front of chassis.

(6). String dial cord as indicated on Instruction Sheet.

(7). Mount dial plate and pointer.

(8). Mount oscillator coil under chassis.

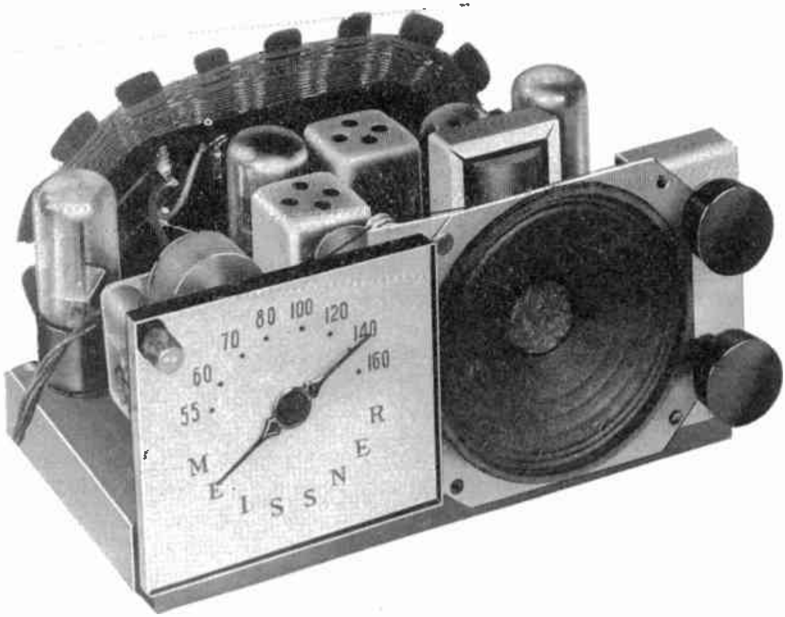
(9). Wire the receiver as directed in the pictorial diagram (Fig. 79) and using the schematic circuit diagram (Fig. 77) as a guide. As each section of wiring is completed, trace over the corresponding line on the pictorial diagram as a continuing check of your progress. Remember that (as the pictorial diagram shows) the relative position of the parts is reversed from left to right when the chassis is viewed from the underside, as compared with their positions as seen from the top (Fig. 78).

It will be found most convenient to wire the filament circuit (pins No. 2 and No. 7 on most tubes—see any chart of tube base diagrams) complete before any other wiring or parts are installed; then follow up with additional wiring, resistors, and condensers.

After the wiring is complete and before the tubes and dial light are inserted in the receiver—before the line cord is plugged in to the power-line outlet—a recheck should be made of the wiring against the pictorial drawing in order to eliminate any possible error.

All receivers after they have been assembled and wired must be properly *aligned*—that is, their tuned circuits must be adjusted mechanically so that they will respond properly to a given frequency and the dial pointer will point to the proper spot on the tuning dial for each station received. The following procedure is recommended for aligning the Meissner 5-tube a-c/d-c superheterodyne receiver:

(1). Use a *test oscillator* or *signal generator,* which is a test instrument employing a 6SN7 medium-mu twin triode as a r.f. oscillator to generate r.f. signals from approximately 150 kc to 30 megacycles, these frequencies being indicated on a calibrated dial. (An inexpensive model can be bought or assembled for less than $20, or if you know a radio serviceman or other ham who has one, you can borrow or rent it.) Set the signal generator at 455 kc. Connect the high side of the signal generator through a .1-mfd capacitor to pin No. 8 of the 12SA7 tube. Set volume control at maximum. Adjust the trimmers at the top of both i.f. transformers for maximum output. Reduce the output of the signal generator until the signal is just audible, and repeat this adjustment.



80. Assembly view of the Meissner 5-tube a-c/d-c superheterodyne receiver. (*Maguire Industries, Inc.*)

(2). Remove the signal generator lead from pin No. 8 of the 12SA7 tube and connect it to yellow wire (antenna lead) from the loop antenna. Set the receiver dial to 1400 kc. Adjust the signal generator to 1400 kc and rotate the oscillator trimmer (on front section of variable capacitor) until the signal is heard. There are two trimmers on the oscillator section of this receiver. If the trimmer on the right side is set too tight, it may not be possible to pick up the signal even with the trimmer on the left wide open. If this happens, the trimmer on the right should be backed off to permit the left trimmer to tune properly. Reduce the input to the receiver and adjust the trimmer on the rear section of the variable capacitor for maximum output.

If no signal generator is available, a broadcast receiver can be aligned fairly accurately by listening to a nearby station of known frequency between 1300 and 1600 kc. Tune in the station and adjust the trimmers as indicated above until maximum response is secured. Keep the volume low, because more accurate alignment can be made with weak signals.

For reception of distant stations, an external antenna may be connected to the antenna lead at the rear of the chassis.

A 6-TUBE A-C/D-C 2-BAND SUPERHETERODYNE RECEIVER

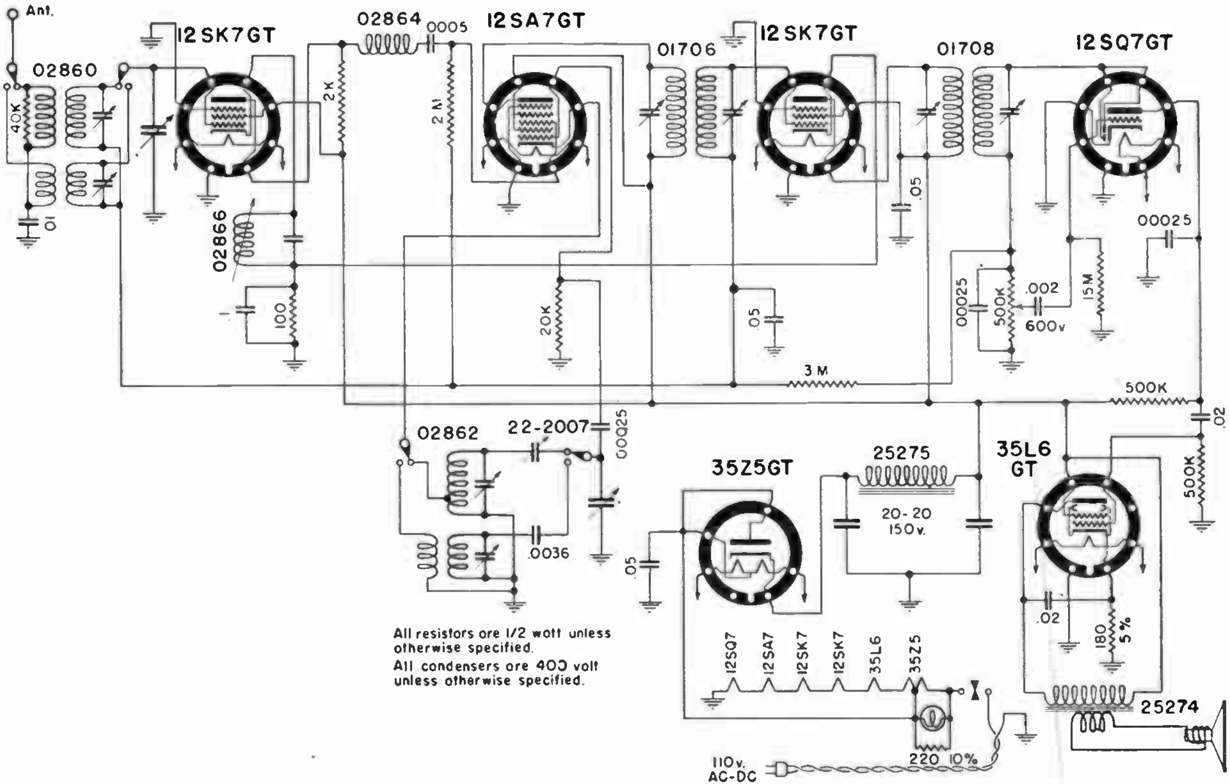
The Meissner 6-tube a-c/d-c Kit No. 10-1199 was designed to answer the requirements of a two-band, low-cost superheterodyne receiver. It has a high-impedance primary antenna coil which permits the use of almost any length of antenna available. It also has one stage of untuned r.f. and an i.f. wave trap. The receiver covers a frequency range of 530 to 1650 kc and from 5.7 to 18 megacycles. It will operate satisfactorily on voltages of from 105 to 125 volts, either d.c. or 50-60 cycles a.c. Extra filtering is required if it is desired to operate the set on a.c. below 50 cycles.

Tubes employed are as follows:

12SK7-GT remote-cutoff pentode amplifier
12SA7-GT pentagrid converter as oscillator-mixer
12SK7-GT remote-cutoff pentode as i.f. amplifier
12SQ7-GT twin-diode high-mu triode as detector, automatic volume control, and audio amplifier
35L6-GT beam power amplifier
35Z5-GT half-wave vacuum rectifier

The assembly instructions, wiring, and alignment outlined below, together with the illustrations (Figs. 81, 82, 83, and 84) are reproduced from the Instruction Manual accompanying the parts kit, which may be obtained from the manufacturer, The Meissner Manufacturing Division, Maguire Industries, Inc., Mt. Carmel, Ill.

As before, the kit should be carefully unpacked and all parts checked against the parts list before any assembly work is under-



81. Schematic circuit diagram of the Meissner 6-tube, 2-band a-c/d-c superheterodyne receiver. (*Mc-guire Industries, Inc.*)

taken. Don't throw away the wrappings before all parts have been accounted for.

Parts List for Meissner 6-Tube A-C/D-C 2-Band Receiver

1 Punched steel chassis
1 Input i-f transformer No. 01706
1 Output i-f transformer No. 01708
1 Broadcast and short-wave antenna coil
1 Broadcast and short-wave oscillator coil
1 Series peaking coil
1 I-f wave trap
1 PM speaker with output transformer
1 Variable condenser
1 Filter choke
6 Octal sockets
3 Tie lugs
1 Padder
1 500-ohm volume control, with switch
1 Band switch
1 Dial mechanism plate
1 Trimmer base assembly
1 Dial drum
4 Wood dowels
1 Dial cord and spring assembly
1 Dial shaft
1 "C" washer for dial shaft
1 Bakelite washer for dial shaft
1 Dial scale
1 Pilot socket and 6-8 volt pilot light
1 Dial pointer
3 Knobs
1 Line cord
1 Binding-post assembly
2 Black rubber grommets for 3/8" hole
1 Black rubber grommet for 5/16" hole
3 Gum rubber grommets 5/32" I.D. for 1/4" hole
1 Condenser mounting bracket
4 Chassis mounting brackets
2 Solder lugs
1 180-ohm resistor, 5%, 1/2 watt, carbon
2 500,000-ohm resistors, 20%, 1/2 watt, carbon
1 15-megohm resistor, 20%, 1/2 watt, carbon
1 3-megohm resistor, 20%, 1/2 watt, carbon
1 20,000-ohm resistor, 10%, 1/2 watt, carbon
1 2-megohm resistor, 20%, 1/2 watt, carbon
1 220-ohm resistor, 10%, 1/2 watt, carbon
1 100-ohm resistor, 10%, 1/2 watt, carbon
1 2,000-ohm resistor, 20%, 1/2 watt, carbon
1 40,000-ohm resistor, 20%, 1/2 watt, carbon
2. .02-mfd, 400-volt paper condensers
1 .002-mfd, 600-volt paper condenser
3 .05-mfd, 400-volt paper condensers
1 .01-mfd, 400-volt paper condenser
1 .1-mfd, 400-volt paper condenser
1 20-20-mfd, 150-volt electrolytic condenser
3 .00025-mfd, 205 mica condenser
1 .0036-mfd, 2% silver mica condenser
1 .0005-mfd mica condenser
2 12SK7-GT tubes
1 12SA7-GT tube
1 12SQ7-GT tube
1 35L6-GT tube
1 36Z5-GT tube
Miscellaneous assortment of screws, nuts, washers, hookup wire, and solder.

The parts should be mounted in the following sequence:

(1). Mount all sockets, making sure that the keyway in the central hole of each is turned in the direction corresponding to that shown in the pictorial diagram (Fig. 83), which shows the bottom view of the chassis.

(2). Mount the dial bracket on the front of the gang condenser.

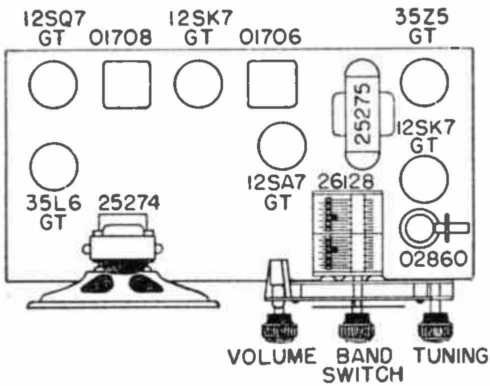
(3). Assemble the tuning drive in the following manner:

a. Mount the dial drum on the condenser shaft.

b. Double the dial string and thread the doubled portion through the hole in the rim of the pulley from the inside out.

c. Hook the free end of the spring into one of the holes in the flat part of the pulley.

d. Close the gang condenser and rotate the pulley until the hole in the rim occupies the same position as the figure 7 on a clock face, then tighten the set screw.



82. Top view of Meissner 6-tube, 2-band a-c/d-c superheterodyne receiver, showing layout of parts. (*Maguire Industries, Inc.*)

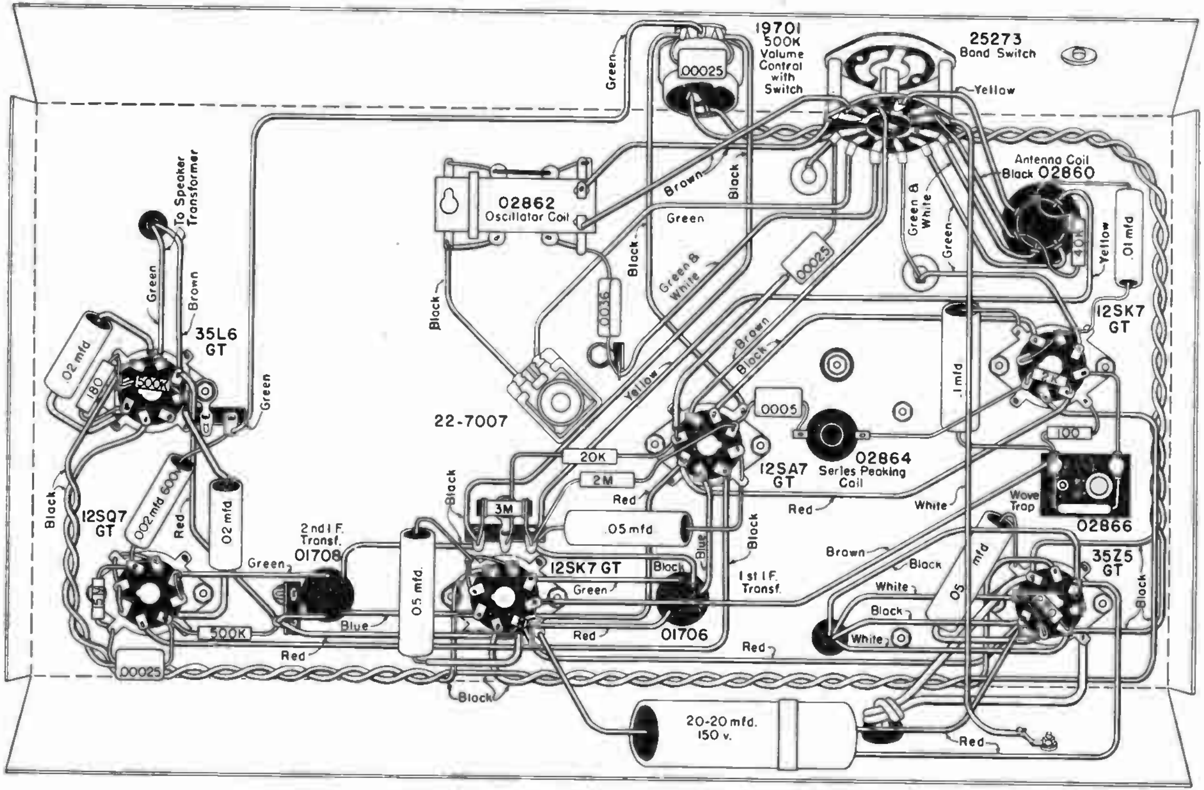
e. Mount the tuning shaft, looping the string around it 2½ turns, in such a direction that the string leaves the tuning shaft without crossing.

f. Stretch the string over the rim of the pulley.

(4). Mount the condenser-mounting bracket on the rear of the gang condensers, using the 6-32 x 3⁄16" screw supplied.

(5). Mount the variable condenser, putting three soft-rubber grommets in the three mounting holes in the chassis (one on top and two in front), then assemble the mounting accessories as shown in the detail drawing that accompanies the kit. Tighten the mounting screw and nut until they are snug.

(6). Mount the volume control and the band switch, seeing that



83. Pictorial wiring diagram for the 6-tube, 2-band superheterodyne receiver. (*Maguire Industries, Inc.*)

the locating lug on these controls engages in the holes in the chassis provided for the purpose of preventing rotation of the controls.

(7). Mount the i-f transformers, rotating them so as to have the leads go directly to their proper terminals with a minimum of crossed leads.

(8). Mount the speaker, using two or more black bakelite washers between speaker and chassis (six are supplied), so that the center of the speaker will be on the center line of the variable-condenser shaft. Thread the leads from the output transformer through the hole at the left of the speaker.

(9). Mount the antenna coil on top of the chassis with the lugs protruding below the chassis.

(10). The i-f wave trap is mounted by removing the lock nut which locks the adjustable iron core and base. After the coil is held in place on the chassis, the lock nut is then screwed on the adjustable iron core screw and the mounting screw tightened in its proper place. After the wave trap is adjusted, the lock nut should be tightened against the chassis.

(11). The remaining coils and parts should be mounted in accordance with the pictorial diagram (Fig. 83).

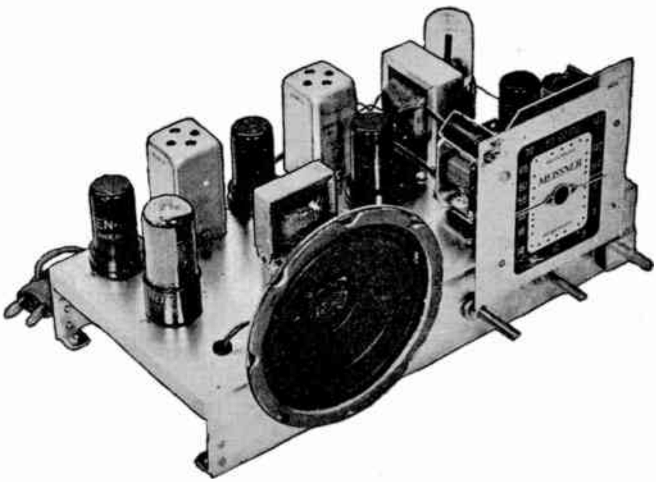
(12). The dial scale mounts on the dial bracket, using wood dowels as spacers between the two.

(13). The dial-light assembly clips into the upper left-hand corner of the dial. The leads should be threaded through the hole at the rear of the chassis. The leads from the filter choke also thread through this hole. A top view of the layout of parts appears in Fig. 82.

When the assembly has been completed as outlined above, the set is ready for wiring. It will be found most convenient to wire the filament-circuit (pins No. 2 and 7 on most tubes) complete before any other wiring or parts are installed. Then follow up with additional wiring, resistors, and condensers. It will be of considerable help if each wire in the pictorial diagram is marked over with a colored pencil as the corresponding wire is installed in the set.

Lead, resistor, and condenser placements should follow those shown in the pictorial diagram as closely as possible. Ground the variable condenser frame to the chassis, using the flexible wire provided.

It is recommended that the wiring be rechecked before the tubes are inserted in the receiver, and certainly before the line cord is connected to the power line. After this check has been made, the voltage on the tube terminals should be checked against the voltage chart that accompanies them, assuming a voltmeter is available. Lugs No. 4 and 6 on the 35Z5-GT tube socket are used as convenient tie points, as no connection is made through these to the tube itself.



84. Assembly view of Meissner 6-tube, 2-band a-c/d-c superheterodyne receiver. (*Maguire Industries, Inc.*)

Assemble the pointer on the gang-condenser shaft by pressing the projections on the back of the pointer into the hole in the end of the shaft. Close the gang condenser and set the pointer horizontal.

If a test oscillator or signal generator is available for alignment, its use will facilitate adjustment of the receiver and insure maximum sensitivity. The signal generator should be connected to the signal grid or pin No. 8 of the 12SA7-GT mixer tube. This connection should be made through a .0005 to .25 mfd condenser, the condenser being between the high side of the signal generator and the connection to the mixer grid. The signal generator should be set to 456 kc, which is the i-f frequency, and the volume control of the receiver should be set at maximum or in the extreme clockwise position. The output of the signal generator should then be turned up until a signal is heard, whereupon the trimmers on the i-f transformers should be adjusted (with an insulated-shaft screw driver) for maximum output, reducing the output of the generator as the receiver becomes progressively more sensitive, and always using as weak a signal as possible.

After the i-f transformers have been properly adjusted, remove the connection from the generator to the mixer grid, reconnecting the generator to the antenna binding post. Having set the frequency of the signal generator at 456 kc, adjust the wave trap by turning the adjusting screw which protrudes through the chassis. This adjustment should be made for the minimum of signal output. The generator output should be increased as the adjustment proceeds to insure maximum i-f rejection.

When the i-f transformers are adjusted for a maximum sensitivity, the antenna and oscillator trimmers should be adjusted in the following manner:

(1). Check the dial pointer to see that it is horizontal when the gang condenser is closed.

(2). Set the band switch in the broadcast position—counterclockwise.

(3). Rotate the gang condenser until the pointer indicates 1400 kc.

(4). Adjust the signal generator to 1400 kc and connect the output of the signal generator to the antenna lead, using a .0002-mfd condenser between the antenna and the high side of the oscillator. Increase the generator output to a medium level and adjust the oscillator trimmer, which is located through a hole on the top of the chassis just to the right of the speaker. The next step is to adjust the antenna coil by adjusting the trimmer that is closest to the chassis. Both of these trimmer adjustments should be made for maximum output, decreasing the generator signal strength as the set progressively becomes aligned. Leaving connections as they are, turn the dial pointer to approximately 600 kc and reset the signal generator for 600 kc, increasing the generator output until a signal can be heard. Adjust the padder screw, which is located near the center of the chassis, to maximum output. The best adjustment is obtained by simultaneously adjusting the padder screw and rocking the tuning control around 600 kc. Variation in wiring in circuit capacities may give the maximum output for 600 kc very slightly in error of 600 kc on the receiver dial.

(5). In the aligning of the short-wave band, the band switch must be turned clockwise. Replacing the .0002-mfd condenser with a 400-ohm resistor between the antenna post of the receiver and the output of the generator, set the generator to 16 megacycles and also the receiver dial pointer to 16 megacycles. Then adjust the oscillator trimmer, which is located through a hole on top of the chassis just to the right of the broadcast trimmer, for maximum output. When adjusting the oscillator trimmer on the short-wave band, the trimmer should be tightened and then loosened to the second peak. The second peak will be the correct peak for this adjustment. Next, adjust the short-wave antenna coil, which is a trimmer located near the top of the coil. As before, the adjustments of these trimmers should be made with as low a signal level from the generator as possible, as the alignment proceeds. The padding of the short-wave band is fixed.

CAUTION—The power line is connected directly to the chassis in this receiver. The receiver must be suitably protected by a nonmetallic cabinet and nonmetallic knobs so that no one can make contact with any metal part of this radio when it is in operation. A cabinet back must be used to prevent accidental contact with the chassis. This back should have small holes or slots to permit ventilation yet prevent accidental contact. Mounting screws to hold the set to the cabinet should also be covered to prevent contact.

CHAPTER

12

A 15-Watt General-Purpose High-Fidelity Amplifier

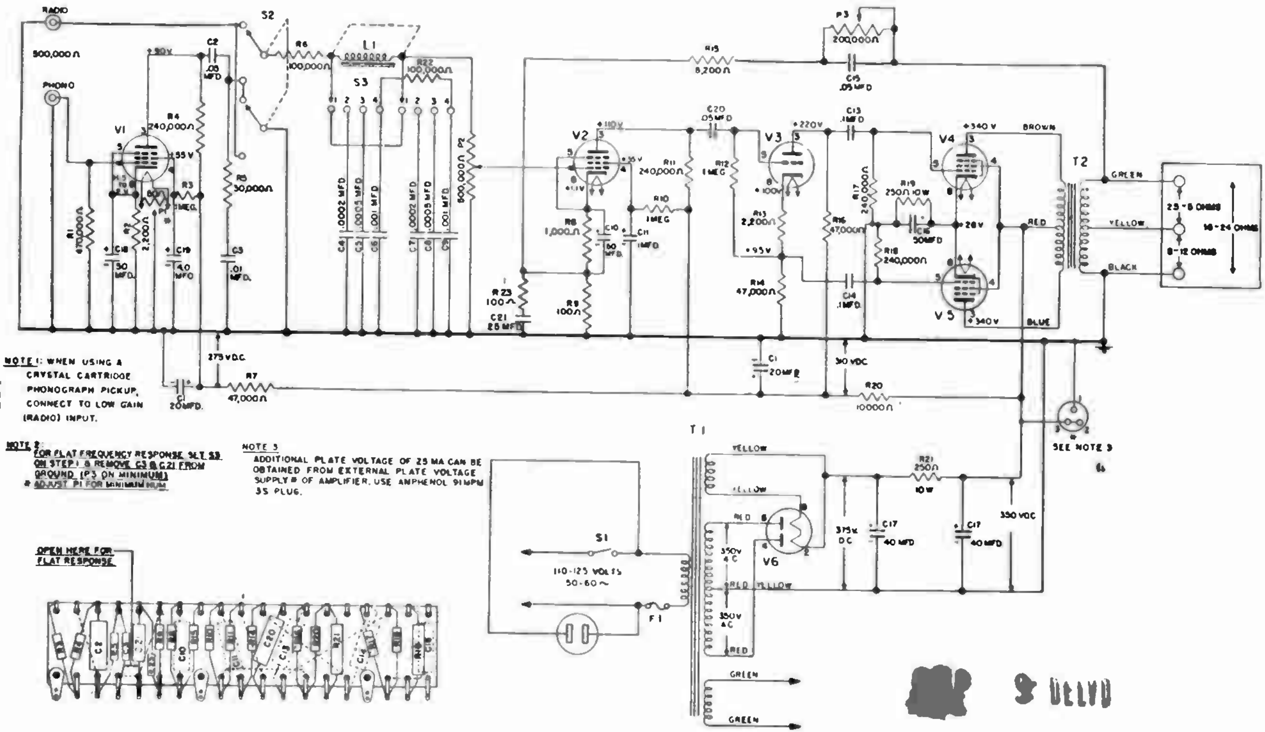
The Altec-Lansing A-323B amplifier described and illustrated in this chapter is a portable general-purpose amplifier designed for high-quality reproduction of sound, music, and speech from records, radio, and microphone. This model, introduced in 1947, has a high-gain input of 117 db (phono input) and a low-gain input of 77 db (radio input), with a flat frequency response from 20 to 20,000 cycles. It operates on 110-125 volts a.c., 50-65 cycles, and consumes only slightly more current than a 100-watt bulb.

The amplifier uses six tubes, as follows:

2 6J7 (metal) sharp-cutoff pentode, used as biased detectors
1 6J5 (metal) medium-mu triode, used as phase inverter
2 6L6G (glass) beam power amplifiers, for push-pull power stage
1 5U4G (glass) full-wave vacuum rectifier

The kit consists of one output and one power transformer, a low-pass scratch equalizer coil, a resistor-capacitor board, and a punched steel chassis, together with schematic circuit diagram (Fig. 85) and wiring diagrams (Figs. 86 and 87). All other parts, such as sockets, condensers, resistors, and controls, are standard and can be procured through any parts jobber or radio parts store. A parts list conforming to the schematic circuit diagram is given below.

One of the many interesting features of this amplifier is that it has a built-in equalization in the first stage that permits direct operation from any of the new variable-reluctance phonograph pickups—G.E., Pickering, or Clarkston—without the need for an external preamplifier. The amplifier also has an adjustable low-



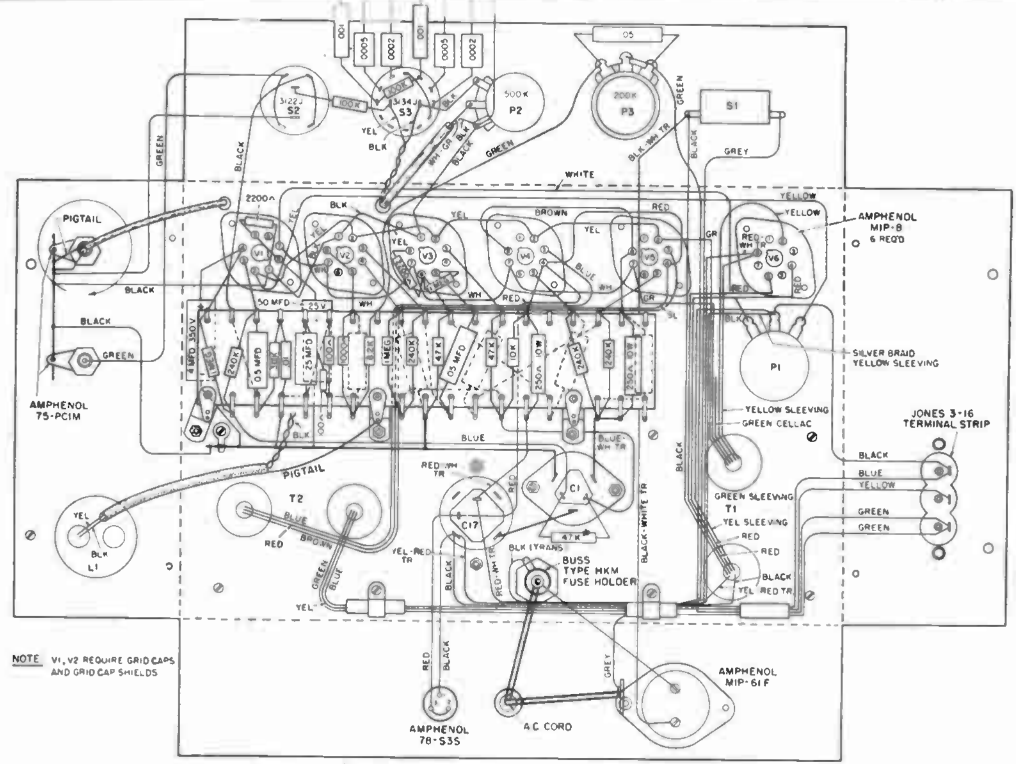
85. Schematic circuit diagram of Altec Lansing 15-watt general-purpose high-fidelity amplifier. (*Altec Lansing Corporation.*)

pass filter, primarily for record-scratch elimination, which is designed to give a very sharp cutoff so that the maximum usable recorded signal can be reproduced and the higher noise frequencies eliminated.

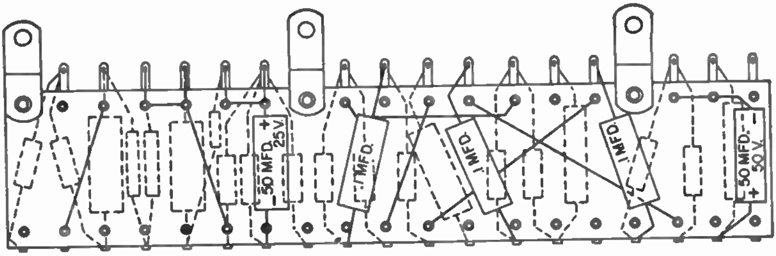
Parts List for Altec-Lansing A-323B Amplifier

1 .25-mfd, 200-volt capacitor
1 20-20-mfd, 450-volt capacitor
3 .05-mfd, 600-volt capacitors
1 .01-mfd, 300-volt capacitor
2 .0002-mfd, 500-volt capacitors
2 .0005-mfd, 500-volt capacitors
2 .001-mfd, 500-volt capacitors
2 50-mfd, 25-volt capacitors
1 40-40-mfd, 450-volt capacitor
1 4.0-mfd, 350-volt capacitor
1 470,000-ohm, ½-watt resistor
2 2,200-ohm, ½-watt resistors
3 1-megohm, ½-watt resistors
4 240,000-ohm, ½-watt resistors
1 30,000-ohm, ½-watt resistor
2 100,000-ohm, ½-watt resistors
3 47,000-ohm, ½-watt resistors
1 1,000-ohm, ½-watt resistor
2 100-ohm, ½-watt resistors
1 8,200-ohm, ½-watt resistor
2 250-ohm, 10-watt resistors
1 10,000-ohm, ½-watt resistor
1 Fuse, 1½ amperes
1 Potentiometer, 50 ohms
1 Potentiometer, 200,000 ohms
1 Potentiometer, 500,000 ohms
1 S.P.S.T. rotary switch
1 Selector switch
1 Power transformer, type TL608
1 Output transformer, type TL217B
1 Scratch-equalizer coil, type TA325
2 Type 6J7 tubes (V1 and V2 in Fig. 85)
1 Type 6J5 tube (V3)
2 Type 6L6G tubes (V4 and V5)
1 Type 4U4G tube (V6)
1 Selector switch
1 Punched steel chassis
1 Resistor-capacitor board
6 Octal sockets
Wiring, sleeving, terminal strip, fuse holder, etc., as per wiring diagram. (See Figs. 86 and 87.)

In assembling the amplifier kit, the first step is to mount the transformers, sockets, resistor-capacitor (RC) board, controls, and terminal strip on the chassis, utilizing the punched holes provided. Capacitors and resistors are then mounted on the RC board as indicated on the wiring diagrams (Figs. 86 and 87). Next, the transformers should be wired in, followed progressively by the remainder of the circuit. Bear in mind that the capacitors and resistors must be placed *exactly* as shown on the wiring diagram, for these positions were arrived at after long experimenting by the designers in order to yield the minimum amount of hum. Any changes from the pattern may lead to excessive hum. However, as a means of controlling whatever hum may exist, the potentiometer (P1) connected across the heater of the first 6J7 tube (V1 in Fig. 85) can be adjusted by means of a screw driver. It permits adjust-



86. Schematic wiring diagram for the Altec Lansing general-purpose amplifier. (*Altec Lansing Corporation.*)



87. Rear view of resistor-capacitor board shown in Fig. 86. (*Altec Lansing Corporation.*)

88. Assembly view of Altec Lansing 15-watt general-purpose amplifier. (*Altec Lansing Corporation.*)

ing for minimum noise with any set of vacuum tubes, thus reducing the need for selecting tubes for quiet operation.

The built-in frequency equalization referred to above can be disconnected from the first amplifying stage by unsoldering the series resistor-capacitor circuit as shown in Fig. 85 when the phonograph input connection is to be used for microphone amplification in public-address work. This gives a flat frequency response that can be varied by means of the bass and treble controls. A high-impedance microphone will work directly into the input of the amplifier. A suitable loud-speaker must, of course, be purchased separately and connected to the terminal strip. Also, a carrying cover with handle may be obtained for portable operation.

A photograph of the assembled amplifier is given in Fig. 88.

CHAPTER

13

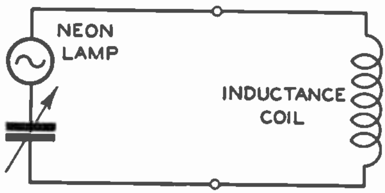
Wavelength and Frequency Measurements; Test Instruments

There was a period in amateur radio when the instrument called a wavemeter (absorption type) was used for tuning and checking transmitters, for measuring the wavelength of received signals, the capacity of condensers, and the inductance of coils. Regulations of the Federal Communications Commission make it necessary to have some means of monitoring the frequency of a transmitter, and for this purpose an absorption type instrument is not sufficiently accurate to comply with today's standards. It is necessary to resort to the device known as a heterodyne frequency meter, which will be described later. We are continuing to discuss the wavemeter because it embodies fundamental principles of interest and instructive value to the amateur and young student, and also because it is useful in detecting harmonics and parasitic oscillations, and for modulation monitoring (page 167).

ABSORPTION TYPE FREQUENCY METER

The simplest type of wavemeter consists of a coil connected across the terminals of a variable condenser, tunable over the wavelength range desired. The instrument is a wavemeter if it is calibrated so that its indications denote wavelength, and a frequency meter if the calibrations indicate frequency. When the wavemeter or frequency meter is put into use, the variable condenser is turned until the neon lamp glows at maximum intensity or, if a milliammeter or voltmeter is used, until the meter shows a maximum reading. The lamp or meter is an indicating device for determining the point of resonance. The phenomenon of resonance is the principle underlying absorption type wavemeters and frequency meters.

If a relatively small electromotive force is applied to a circuit, it is possible to induce in this circuit a fairly large current, provided that the latter circuit is in tune, or in *resonance*, with the circuit in which the e.m.f. is flowing. A wavemeter or frequency meter working on the absorption principle indicates when the point of resonance is reached at some particular frequency or indicates the frequency at which a circuit is in resonance. This is the same thing, it will be remembered, that occurs when you receive a station on your receiver—you "tune in" the signals until you get them with maximum volume and clarity. This means that your receiver circuit is in resonance with the transmitter.



89*A*. Basic circuit of an absorption frequency meter.

A wavemeter or frequency meter of the absorption type, when loosely coupled to the tank coil of a transmitter, will extract a small amount of energy from the tank. This energy will light a small flashlight lamp, a neon lamp, or move the needle of a suitable voltmeter or ammeter. The maximum current will flow when the wavemeter or frequency meter is tuned exactly to the transmitter frequency. Hence the brightness of the lamp or the movement of the indicating needle on the voltmeter or ammeter indicates resonance.

As already stated, the essential parts of this type of wavemeter are but three: a variable condenser, a coil, and an indicating device. The condenser should be of high-quality workmanship, enclosed in a metal case if possible, thus eliminating hand capacitance effects. It should have a maximum capacity of 0.0005 mfd. The coil may be homemade. The indicating device may be a small neon lamp, this being the cheapest form of visual indicator and sufficiently sensitive for ordinary use.

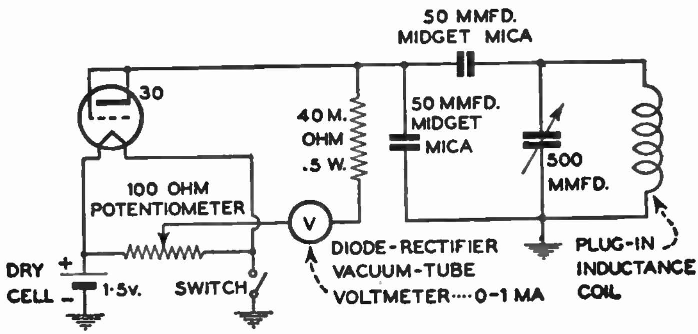
BUILDING AN ABSORPTION WAVEMETER

As with any circuit where resonance is concerned, different coils must be used for the different wave bands to be covered. Since the amateur is likely to have a collection of 1½" coil forms among his spare parts these will be satisfactory for the wavemeter (Fig. 89*B*).

Assuming the use of the .00014 mfd variable condenser the coils for the principal amateur bands will have the following number of turns:

20	meters	7½	turns
40	"	16	"
80	"	33	"
160	"	67	"

The wire may be of almost any size within reason and either bare, enameled, or insulated with cotton or silk. Spread the turns apart in each case so that the winding occupies about 1¼" in length. If the turns tend to slip, a minute dab of collodion at several spots will prevent any considerable movement.



89*B*. Schematic circuit for an absorption-frequency meter with vacuum-tube voltmeter resonance indicator.

If the wavemeter condenser is enclosed in a metal case the neon lamp or the flashlight bulb may also be placed inside. A small hole about ⅛" in diameter may then be drilled in the top of the case so that the lamp may be viewed through it. This method is recommended as the glow lamp is in darkness and the maximum intensity can be more readily recognized.

CALIBRATING THE METER

The most important thing about a wavemeter is that it must be calibrated accurately or it will not serve its purpose. That is, you must know exactly at what frequency the wavemeter circuit is in resonance for every reading of the condenser with a particular coil. This may be done in several ways. After the wavemeter is built according to the specifications given below, you can take it to someone who has a wavemeter, and by using his transmitter operating at certain frequencies, your instrument can be calibrated. Several broadcast stations also transmit standard frequencies at regular periods each month. These you can pick up on your receiver and then calibrate your meter. For accurate guide points, however, no homemade means can ever equal the official frequency signals transmitted on regular schedule by WWV, the station operated by the Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D.C. These signals are sent out at various times on continuous wave as well as i.c.w., and are accurate to within one part in fifty million. The schedule of WWV is as follows:

Eastern Standard Time	*Frequency in Mc*	*Modulation, c.p.s.*
7 p.m. to 9 a.m.	2.5	1 and 440
7 p.m. to 7 a.m.	5	1 and 440
7 a.m. to 7 p.m.	5	1, 440, and 4,000
Continuously	10	1, 440, and 4,000
Continuously	15	1, 440, and 4,000
Continuously	20	1, 440, and 4,000
Continuously	25	1, 440, and 4,000
Continuously	30	1 and 440
Continuously	35	1

Another method makes use of a regenerative type receiver to which the coil in the meter can be coupled. Adjust the receiver so that the detector is oscillating very feebly. Then bring the meter near the receiver so that the meter coil is close to the detector coil. Vary the condenser through its range until a setting is found which causes the detector tube to stop oscillating. Then loosen the coupling by increasing the distance between the meter coil and the detector coil until the detector stops oscillating at only one point on the meter condenser dial. The meter is then tuned to the same frequency at which the receiver is set. If you know the various settings of the receiver you thus have a means of calibrating the meter. If the receiver is set on a number of different stations of known frequency or wavelength, a number of points for making a calibration curve for each meter coil can be obtained.

With these points, a curve may be drawn on regular graph or cross-section paper by means of a "French curve," such as is used for drawing curves of varying diameter. Or if the amateur wishes to be more accurate, he may draw the calibration curve on logarithmic paper, in which case it will be a straight line.

If you make two sets of curves, one showing wavelengths and the other frequency settings, you will have a combination wavelength and frequency meter.

The method of building and calibrating a meter as just described does not result in an accurate or an entirely dependable instrument. The calibration is rough and is not retained over long periods of time. However, as already stated, it should be of instructive value to the young amateur or radio student and for that same reason instructions are given below for roughly calibrating a transmitter, a receiver and measuring capacity or inductance.

CALIBRATING A TRANSMITTER

Attach the coil to the wavemeter that will cover the waveband in which you wish to transmit. From your calibration curve find the exact setting for the wavemeter condenser and set it at this reading. Now bring the wavemeter near enough to the closed circuit of the transmitter so that the neon lamp just glows when the two circuits are in resonance. The condenser of the transmitter is varied until maximum glow occurs in the neon lamp.

CALIBRATING A RECEIVER

As the majority of the receivers for short waves employ an oscillating detector, you can calibrate your receiver so that you will know upon what wave you are listening. This is done in the same way that you calibrated the wavemeter's standard coil. Set the wavemeter to a certain reading and bring it near the coil of the receiver. When a click is heard then the two circuits will be in resonance. Sometimes it is wise to have the wavemeter at such a distance that two clicks will be heard very close together. Dial readings are taken of each click and the point of resonance will be halfway between them.

MEASURING CAPACITY OR INDUCTANCE

It has been stated previously that a wavemeter may be used for the measurement of a capacity or inductance. If you have an oscillating circuit in which there is a known capacity, then it is possible to determine the inductance of the circuit. The same is true if the inductance of a coil is known, the capacity being then easily determined. This is based on the formula

$$\text{Wavelength } (\lambda) = 59{,}600 \times \sqrt{LC}.$$

If the wavelength of a certain circuit is known together with either one of the two variables, L or C, then the other can be found by the following formulas:

$$C = \frac{\lambda^2}{3.56 \times 10^9 \times L}; \qquad L = \frac{\lambda^2}{3.56 \times 10^9 \times C}.$$

In these formulas, L is the inductance in millihenries, C, the capacity in microfarads, and λ is the wavelengths in meters.

It might also be mentioned that a number of companies manufacture wavemeters having the same characteristics that have been described in this chapter. They are obtainable already accurately calibrated.

MONITORING A TRANSMITTER

In order to monitor the frequency of a transmitting station in accordance with the regulations of the Federal Communications Commission—and you must do so if you wish to retain your license—you can use an accurately calibrated receiver. With this you can check the quality of the emitted signal and ascertain whether or not the station is operating within its legal frequency band. A receiver may be calibrated so as to give a quite accurate idea of band limits by listening to other amateur stations and noting where amateur activity ceases at the end of each band. By listening to your own transmitter with your receiver you can ascertain your position in the band.

If operation near the edges of a band is intended, the Federal Communications Commission requires more accurate methods and it is necessary to monitor with a receiver which has been checked against standard frequency transmissions such as those of the American Radio Relay League. A schedule of these transmissions appears regularly in the League's magazine *QST*. Do not attempt to calibrate a receiver or use it for monitoring unless it has first been warmed up by an hour or so of operation.

Monitoring the modulation of a radiotelephone transmitter to detect distortion or overmodulation is best done by means of the cathode-ray oscilloscope (Chapter 15).

In order to measure the exact frequency of a transmitter, you must resort to what is known as a heterodyne frequency meter.

THE HETERODYNE FREQUENCY METER

This device is a small oscillator, completely shielded and electron coupled. Anyone who is going to build a frequency meter of this type must have ability and experience beyond that of the average amateur in order to succeed. The device must be very carefully constructed so that its frequency characteristics are extremely stable.

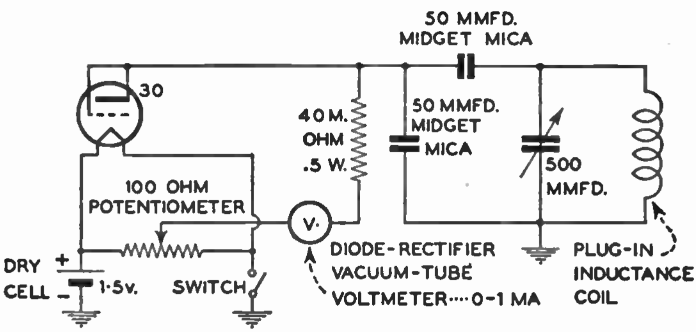
This oscillator, after being calibrated, is heterodyned with the frequency of the transmitter. A detector is used to pick the beat or indicate zero beat between the transmitter and the oscillator. Zero beat indicates that the frequency of the transmitter and the frequency of the heterodyne meter are the same.

CHAPTER

14

A Vacuum-Tube Volt-Ohmmeter

The vacuum-tube voltmeter (or volt-ohmmeter) is a very useful and versatile measuring instrument for amateur radio and television work. It is used extensively in signal tracing, measurement of radio-frequency and audio-frequency voltages, automatic volume control voltages, automatic frequency control voltages, alignment of receivers, measurement of oscillator performance, measurement of gain per stage in amplifiers and receivers, checking of resonance—and, if the instrument contains an ohmmeter unit (as does the one described in the present chapter), it can be used to measure resistances of from one ohm to one billion ohms.



90. Elementary triode vacuum-tube voltmeter.

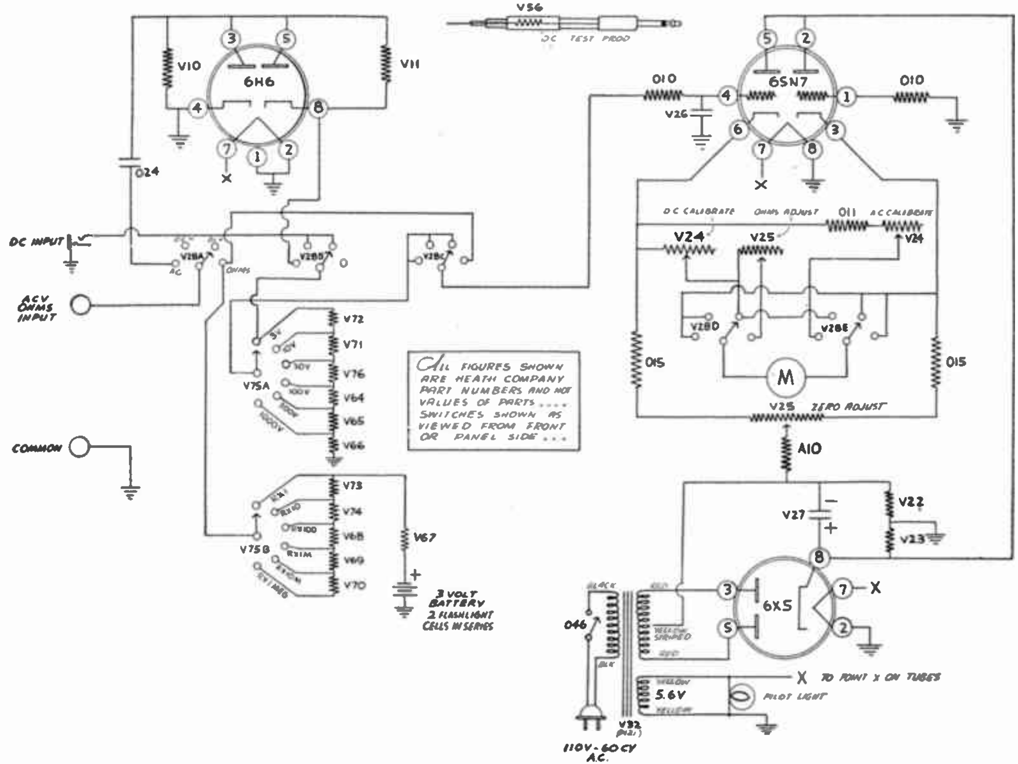
The reason that a vacuum-tube voltmeter is to be preferred over the conventional moving-coil voltmeter in a.f. and r.f. circuits is that, unlike the latter, its connection in the circuit being measured does not change, to any appreciable extent, the potentials of the circuit, so that a high degree of accuracy is obtained. Essentially a vacuum-tube voltmeter is a vacuum-tube detector in which the grid and cathode are connected across the circuit to be measured, with the plate connected to a d'Arsonval type indicating instrument (Fig. 90). The potential thus impressed on the grid causes a corresponding change in the plate voltage, which is indicated by the deflection of the meter. Since the vacuum tube also acts as a rectifier, alternating-current voltages are thus registered as direct-current deflections so that the instrument serves as an a-c/d-c voltmeter. The simplest type of vacuum-tube voltmeter uses a three-element tube (triode), but modern instruments use three tubes—a twin diode, a medium-mu twin triode, and a full-wave vacuum rectifier for greater sensitivity and accuracy. (See Fig. 91.)

THE HEATHKIT VACUUM-TUBE VOLTMETER

The construction of the Heathkit VTVM is not difficult, but consideration must be given to the fact that it is a delicate precision instrument that deserves the best of workmanship. The parts list, assembly instructions, and illustrations (Figs. 91, 92*A*, 92*B*, and 93) are reproduced from the Instruction Manual published by the Heath Company, Benton Harbor, Michigan, from whom the kit may be obtained.

Parts List for Vacuum-Tube Voltmeter

Designation in Illus.	*Quantity and Description*
A10	1 47,000-51,000-ohm resistor
G44	1 6SN7 tube
O10	2 3.3-megohm resistors
O11	1 10,000-ohm resistor
O15	2 2,000-ohm resistors
O24	1 .01-mfd, 150-volt electrolytic condenser
O28	5 ⅜" nickel washers
O30	2 No. 10-24 × 38" handle screws
O31	5 No. 6-32 × ⅜" machine screws
O32	8 No. 6-32 nuts
O33	7 Control nuts
O34	4 Rubber feet
O35	3 ⅜" rubber grommets
O37	4 Soldering lugs
O38	1 Single terminal strip
O39	1 Pilot bulb
O40	1 Pilot-light nut



91. Schematic circuit diagram of Heathkit vacuum-tube voltmeter. (*The Heath Company.*)

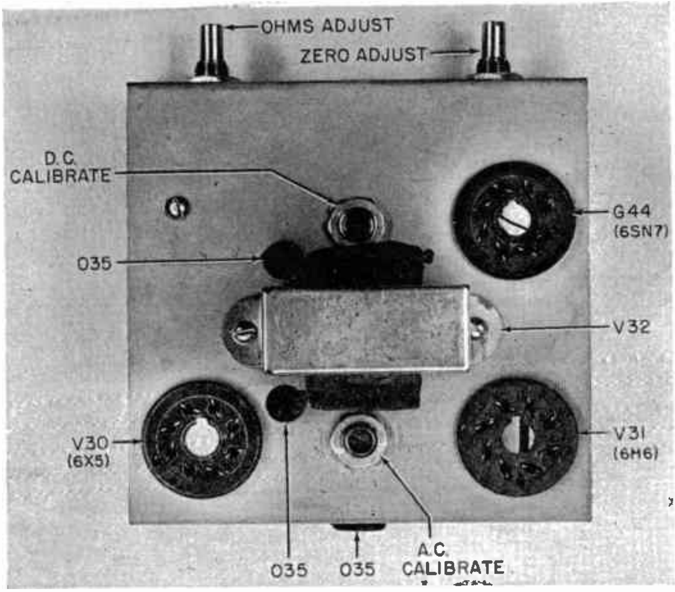
O41	1	Pilot-light bushing
O42	1	Pilot-light jewel
O43	3	Octal socket rings
O51	2	Pointer knobs
O52	1	Pilot-light socket
O54	3	Octal sockets
O78	1	Line cord
O79	1	Handle
O94	1	SPST slide switch
O101	7	Lock washers
O102	8	No. 6-32 × 3/8" self-tapping metal screws
S22	2	No.6-32 × 1/4" nuts for switch
V10	1	18-megohm resistor
V11	1	200,000-ohm resistor
V22	1	20,000-ohm, 10% resistor
V23	1	15,000-ohm, 10% resistor
V24	2	10,000-ohm controls, a-c and d-c calibrate
V25	2	5,000-ohm control, "Ohms Adjust" and "Zero Adjust"
V26	1	.003-mfd mica condenser
V27	1	12-mfd, 150-volt electrolytic condenser
V28	1	5-pole, 4-position rotary switch
V30	1	6 X 5 tube
V31	1	6H6 tube
V32	1	Power transformer
V34	2	Flashlight cells (one calibrated)
V36	1	Black banana jack (common post)
V37	1	Red banana jack (a.c.-ohm post)
V38	2	5/16" fiber shoulder washers
V39	1	Black banana plug
V40	1	Red banana plug
V42	1	Red test prod
V43	1	Black test prod
V44	1	Alligator clip
V45	1	Length black test-lead wire
V46	1	Length red test-lead wire
V47	1	Length shielded test-lead wire
V48	2	Acorn knobs
V49A	1	200-microampere meter
V50	1	Roll of hookup wire, 10 feet
V51A	1	Punched steel panel
V52	1	Punched steel chassis
V53A	1	Gray crackle-finish cabinet
V56	1	1-megohm resistor
V64	1	200,000-ohm precision resistor
V65	1	70,000-ohm precision resistor
V66	1	30,000-ohm precision resistor
V67	1	9.5-ohm, 1-watt, 5% resistor
V68	1	9,000-ohm precision resistor
V69	1	90,000-ohm precision resistor
V70	1	9.9-megohm, 1/2-watt precision resistor

V71	1	2-megohm, 1% precision resistor
V72	1	7-megohm, 1% precision resistor
V73	1	90-ohm, 1% precision resistor
V74	1	900-ohm, 1% precision resistor
V75	1	2-pole, 6-position rotary switch
V76	1	700,000-ohm precision resistor
V82	1	Battery mounting bracket strap
V83	1	Battery mounting bracket
V84	1	No. 6-32 × 1¾" machine screw
V86	1	Wing nut
V87	1	Microphone jack (d-c post)
V88	1	PL68 phone plug

The first step is to check the parts against the parts list; identify each part and do not discard any wrappings until each part is accounted for. Use the schematic and pictorial diagrams to identify resistors and condensers. Thoroughly familiarize yourself with the layout before beginning any assembly or wiring. Don't attempt to change the design, as this will throw off the calibration and operation of the instrument. However, from time to time small changes in parts may be made by the Heath Company—for example, 47,000-ohm resistors (which is the new RMA rating for 50,000 ohms) may be substituted for 50,000-ohm resistors, etc. The circuit is designed to accommodate these and other variations that may be made.

Begin by fastening the socket connections (which are numbered on the bottom of the sockets) into the chassis by means of the wavy metal rings, forcing these over the bottom of the socket and into the grooves in the socket. The end of the ring can be held in the groove and the rest of the ring forced over and into the groove with a screw driver. Note that the keyways in all sockets face the panel. Next, mount the controls. The "Calibrate" controls have only screw-driver slots, while the "adjust" controls have a shaft long enough to accommodate a knob. On some controls and jacks, a locating pin must be removed before mounting to prevent damage to the unit. Next, install the power transformer with the leads above the two holes in the chassis, allowing them to connect to the sockets and switch. Use a solder lug under each transformer-mounting bolt below the chassis. Install the insulated terminal strip below the chassis with the machine screw provided.

Proceed with the wiring as indicated on the lettered photograph of the underside of the chassis (Fig. 92*B*), remembering that all parts are reversed when the chassis is upside down; mark the values shown on the parts list beside the part number on the schematic diagram. Connect the transformer leads, the ground or chassis connections to the sockets, and the filament connections. Twist the leads carrying a.c. coming from the power transformer. The location of the wires is not critical, but the locations shown in Fig.

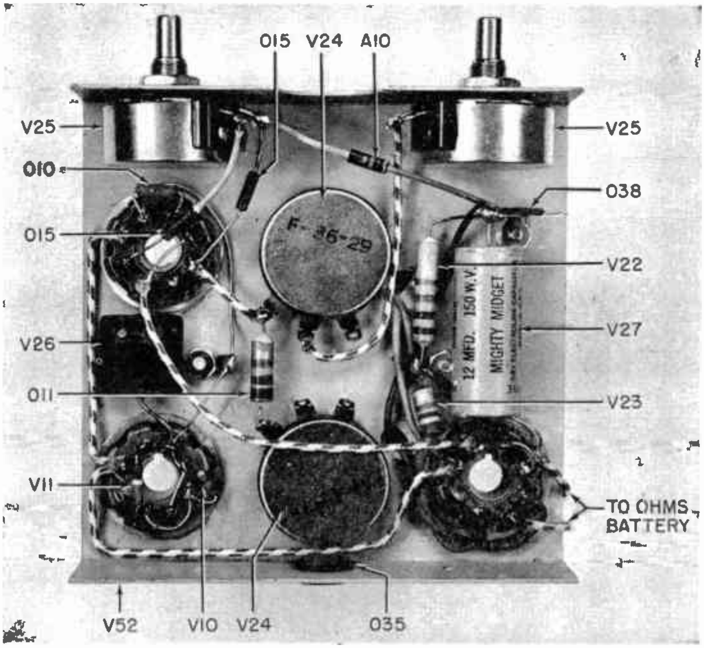


92*A*. Top view of chassis of Heathkit vacuum-tube voltmeter, showing layout of parts. (*The Heath Company.*)

92*B* have proven very satisfactory. Note that the center tap of the high-voltage winding of the transformer is connected to the insulated terminal strip. Install the filter condenser (V27), observing polarity, and place the resistors as shown.

The selector and range switches should now be wired. This should be very carefully done, otherwise faulty operation may result. Use care to prevent rosin from running onto the contacts, as this will cause erratic operation of the instrument.

Mount the panel to the chassis by fastening it with the nuts of the "Adjust" controls. Mount the pilot light and toggle switch. Next mount the range and selector switches and the input jacks. The a-c and common jacks are insulated from the panel with the insulated shoulder washers supplied. The common jack must have a good soldered ground connection to the chassis itself; it is insulated from the panel only to insure that a good soldered connection



92*B*. Bottom view of chassis of Heathkit vacuum-tube voltmeter, showing layout of parts and wiring. (*The Heath Company.*)

will be made. Mount the balance of the resistors, wire the switches, and install the line cord. Then mount and connect the meter. When the wiring is complete, recheck all connections by following each connection in the instrument and marking it on the circuit diagram with a colored pencil.

The battery-mounting bracket and strap (V83) are wired up by connecting two adjacent solder lugs together and soldering conveniently long leads to the other two solder lugs. This places the two batteries in series, giving 3 volts. The bracket is then mounted in the cabinet with the long screw and is held in place with a regular nut against the bracket. The flashlight cells are installed one upright and one inverted, and are held in place by a metal strip over the long center bolt and thumb nut over it. One of these cells is used as the calibrating battery for the d-c ranges; do not use this cell until the calibration is completed.

~~If the wiring checks correctly, plug the line cord into 110-volt~~ 60-cycle a-c house current. Set the selector switch to DC$+^{-}$ and turn the instrument on. Allow one minute for it to warm up. Leave the instrument on while the test leads and prod are assembled. To assure maximum accuracy over a long period, the tubes must be "aged." This is best done by leaving the instrument on continuously for 48 hours before calibration. A preliminary calibration can be made, however, after one-half hour. Insert the test leads and check the small flashlight cell supplied for calibration purposes. If the meter reads backwards, reverse the leads from the switch to meter.

In changing the range switch on a.c. from 30-volt and 10-volt ranges to the 3-volt range, a change in the zero setting of the meter pointer will be observed, a small amount of which is normal and will decrease as the tubes are aged. Some 6SN7 and 6H6 tubes, however, are sufficiently unbalanced to cause a greater-than-normal change, and should be replaced, although they are entirely satisfactory for radio use in this unbalanced condition. The zero setting should be corrected on each of the ranges used.

The instrument is calibrated on d.c. with the flashlight cell, which has the exact voltage marked on it. With the instrument turned off, set the meter pointer exactly on zero with adjustment on front of the meter. Turn the power on and set the selector to DC+ (Fig. 93) and the range to 3 volts. Connect the d-c test prod and common lead together and adjust zero control until the meter reads exactly zero. Connect leads to battery and adjust d-c calibrate controls until the meter reads the voltage indicated on the battery. Read on 30-volt scale by dropping the zero so that 1½ volts is exactly one-half scale—that is, the meter reads 15 on the 30-volt range. Remove the leads and short them together to check the zero position. Again connect to the battery and repeat the calibration procedure several times until certain of both zero and correct battery setting.

To calibrate the a.c., set the selector switch (V28) to "AC" and

93. Assembly view of Heathkit vacuum-tube voltmeter. (*The Heath Company.*)

the range switch (V75) to 300 volts. (See Fig. 93.) Connect the common and a.c. test leads to the 110-volt a.c. line and adjust the a-c calibrating control (V24) until the scale reads 110 volts. Most power companies maintain the voltage within 5 per cent of this figure. If greater accuracy is required, the instrument should be calibrated against a known a-c standard voltage. This completes the calibration and the instrument is now ready for use. However, this calibration should be repeated after 48-hour continuous aging of the tubes, or after several weeks of use, at which time the instrument should not vary from calibration except when the tubes are changed.

To use the ohmmeter, set the zero adjust while the selector is on DC+. Turn the selector to "Ohms" and the pointer will swing to the right side of the scale. Adjust the ohms knob until the pointer is exactly on the heavy line at the right end of the scale at 10 on the 10-volt scale. Unknown resistances can now be read by connecting them between the common lead and the ohms-test lead. For very low resistance, connect the leads directly together and reset the zero-adjust to correct for resistance of leads before measurement. Never leave the instrument on "Ohms," because this will greatly shorten the life of the ohmmeter battery.

An r-f test probe and a television test probe in kit form are available for use in measuring r-f and television voltages. These probes are plugged into the instrument in place of the regular d-c test probe assembly and read on the appropriate scales.

The assembled instrument in its crackle-finish case is shown in Fig. 93.

CHAPTER

15

The Cathode-Ray Oscilloscope

The cathode-ray oscilloscope * is one of the most versatile of all instruments used in radio work. It will be a valuable tool for the radio amateur once he has passed the beginner's stage, for it makes it possible for him to see exactly what is going on in audio- and radio-frequency circuits under either steady or transient conditions, and can be used in radio testing, measurement, troubleshooting, modulation monitoring, alignment of receivers and adjustment of radiophone transmitters. It is superior to other types of instruments in that it introduces practically no error in such measurements. With the advent of frequency modulation and television, the oscilloscope has become almost indispensable to the serviceman, while for monitoring an amplitude-modulated 'phone transmitter the oscilloscope provides more complete and accurate information than any other type or combination of types of instrument. More important, perhaps, is the fact that the oscilloscope used in amateur radio work is not an expensive instrument; although laboratory types may cost as much as $500, the instrument described in this chapter can be built for less than $40.

HOW THE OSCILLOSCOPE WORKS

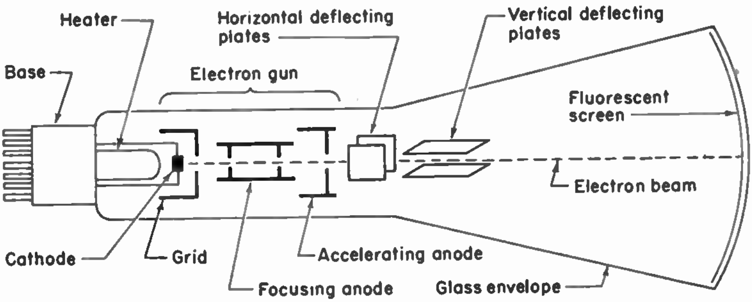
Only a brief account of the operation of the oscilloscope can be given here. For the complete theory and operation of this instrument the reader is urged to consult any of the excellent books †

* Also called "oscillograph," although this term is more properly used to indicate an instrument that makes a photographic *record* of a varying electrical quantity.

† Soller, Starr, and Valley, "Cathode Ray Tube Displays" (McGraw-Hill, 1948); Bly, "A Guide to Cathode Ray Patterns" (Wiley, 1943); and Reyner, "Cathode-Ray Oscillographs" (Pitman, 1943), as well as articles in *Radio News*, *Radiocraft*, and *QST*.

and articles on the subject, together with the Instruction Book provided by the manufacturer.

The oscilloscope consists essentially of a cathode-ray tube (Fig. 94), a sweep-circuit oscillator tube or "sweep generator," two amplifying circuits, and a rectifier. The cathode-ray tube is similar in design and operation to that used in television receivers, and consists of a series of electrodes known as the *electron gun*, a set of horizontal and vertical *deflecting plates*, and an internal fluorescent *screen* on the end of the tube. The electron gun consists of an indirectly heated cathode, a grid, a focusing anode, and an accelerating anode. The heated cathode emits electrons as in an ordi-



94. Basic elements of a cathode-ray tube.

nary receiving tube, which are then drawn into a thin beam and accelerated by the two anodes. This beam strikes the fluorescent screen and produces a small stationary spot. By impressing voltages on the horizontal and vertical deflecting plates, the spot may be made to move in either direction and thus trace a curve on the screen. The "sweep generator" is connected to the horizontal deflecting plates, producing a saw-tooth pattern, while the voltage to be analyzed is connected to the vertical deflecting plates, causing the beam to move up and down. Depending on the frequency of the voltage being analyzed, the resulting wave form will show one or more sine-wave curves, which, by comparison with known patterns (the so-called "Lissajous figures") can be interpreted to give the frequency of the unknown voltage. Rough- and fine-frequency controls are provided for the sweep-generator voltage, and a synchronization ("sync") control is used to lock the horizontal sweep to the frequency being observed (internal sync) or to connect to an external source of synchronizing voltage (external sync). The face of the tube is calibrated by means of rectangular coordinates printed on the glass surface, so that the oscilloscope indicates proportional values of voltage as well.

THE EICO MODEL 400 OSCILLOSCOPE

This instrument, which is available in kit form from the manufacturer, the Electronic Instrument Company, Inc., Brooklyn, N.Y., is primarily designed as a general-purpose instrument for the analysis of electrical circuits by the study of wave forms of voltage and current. It may, however, be used to study any variable within the limits of its frequency response (50 cycles to 50 kilocycles). It uses two 6SJ7 sharp-cutoff pentode amplifiers (one each in the horizontal and vertical deflecting circuits), two 5Y3-GT full-wave vacuum rectifiers, an 884 gas triode (thyratron) in the sweep-generator circuit, and a 5-inch 5BP1-type cathode-ray tube.

Complete instructions for assembly are, of course, provided with the oscilloscope kit; a summary of these, together with representative illustrations, is included here to give a general idea of how it is constructed, based on the Instruction Sheets prepared by the manufacturer.

Parts List for Eico Oscilloscope

Description	*Designation on Fig. 95*
1 Punched steel chassis	
2 Chassis brackets	
1 Tube support	
1 Cathode-ray tube support	
1 Panel	
1 Cabinet	
1 Handle	
1 Power transformer	T1
1 High-voltage filter condenser, 1 mfd or over	C15
1 10-10-10 mfd, 450-volt condenser	C14
2 .25-mfd bathtub condensers	C2, C11
3 .5-mfd bathtub condensers	C3, C6, C12
1 .1-mfd tubular condenser	C7
2 .02-mfd tubular condensers	C5, C8
1 .01-mfd, 1,000-volt condenser	C1
1 .003-mfd condenser	C9
2 .005-mfd condensers	C4, C13

Description	*Designation on Fig. 95*
1 270-mmfd mica condenser	C10
1 5-megohm potentiometer	R14
1 250,000-ohm potentiometer	R23
2 100,000-ohm potentiometers	R5, R25
2 1-megohm potentiometers with SPDT switch	R2, R15
2 1-megohm potentiometers	R10, R11
2 5.1-megohm, ½-watt resistors	R9, R12
3 510,000-ohm, ½-watt resistors	R1, R13, R22
1 150,000-ohm, 2-watt resistor	R18
1 100,000-ohm, 2-watt resistor	R19
3 100,000-ohm, ½-watt resistors	R6, R17, R24
2 1-megohm, ½-watt resistors	R3, R21
2 10,000-ohm, ½-watt resistors	R7, R26
2 2,000-ohm, ½-watt resistors	R4, R16
1 1,100-ohm or 1,200-ohm, ½-watt resistor	R20
1 510-ohm, ½-watt resistor	R8
1 Filter choke	L1
2 6SJ7 tubes	
1 884 tube (or 6Q5G)	
2 5Y3-GT tubes	
1 5BP1 cathode-ray tube (or 5BP1A)	
1 1-pole, 5-position rotary switch	
1 SPST toggle switch	S1
2 SPDT toggle switches	S2, S3
1 Line cord	
1 Pilot-light assembly	
1 Pilot-light bulb	
1 Condenser mounting wafer	
4 Fiber shoulder washers	
2 ⅜" panel washers	
9 ⅜" potentiometer nuts	
6 7/16" toggle-switch nuts	
9 ⅜" lock washers	
14 No. 6 self-tapping screws	
2 10/24 handle screws	
40 6/32 × ¼" screws	
48 6/32 nuts	
2 ⅜" rubber grommets	
1 ¾" rubber grommet	
9 Ground lugs	
3 1-lug terminal strips	
1 Pin jack	
1 Pin jack lock washer	
1 Cathode-ray tube socket	
1 Cathode-ray tube socket retaining ring	
5 Octal sockets	
6 Binding posts	
9 Knobs	
1 Fuse mount	

2 Fuses
1 Felt strip
1 Roll of wire
1 Length of spaghetti tubing
48 No. 6 lock washers
1 2-lug terminal strip
1 Bare wire strip
1 Mounting hardware for high-voltage filter condenser
2 $\frac{6}{32} \times \frac{1}{2}''$ screws
4 Flat fiber washers

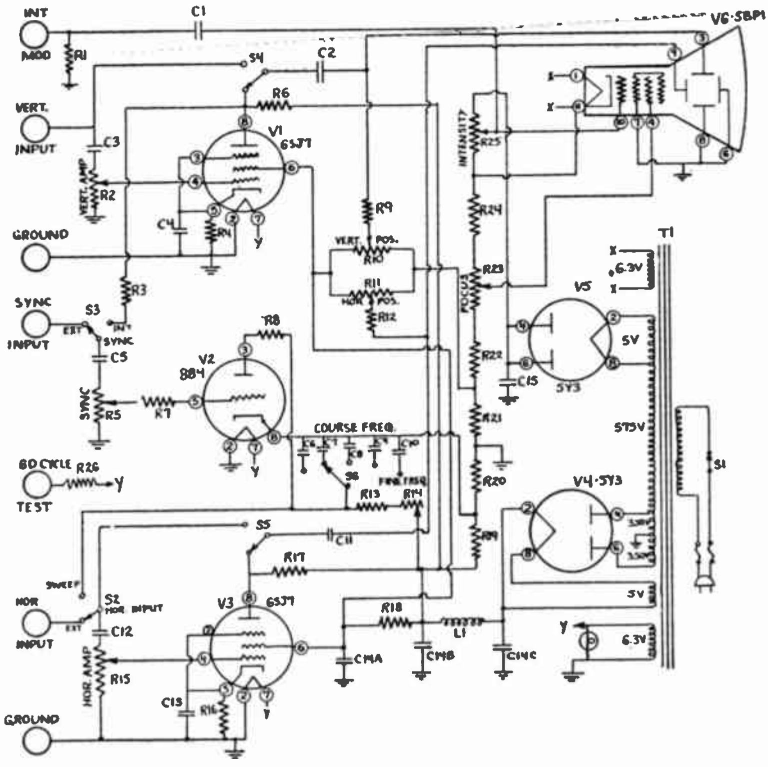
The assembly of the Eico oscilloscope is not difficult, and if proper care is used in following the manufacturer's instructions no trouble should be encountered. First, all parts should be unpacked and checked against the parts list. (Substitutions may be made by the manufacturer for various resistances, etc. All parts thus supplied will work just as well as the part for which it is substituted.)

The tools needed for the work are a cleaned and tinned soldering iron, and an assortment of screw drivers, pliers, and side-cutters. Use a good grade of rosin-core solder—don't use acid-core solder or flux. Before starting the actual construction, study the schematic (Fig. 95) and pictorial wiring diagrams provided and get all the steps clear in mind; don't try to rush the assembly.

Assemble the panel first. Mount all parts with lock washers behind the panel and put flat washers under the nuts to keep the latter from marring the panel. Don't insulate the controls from the panel—in event of control failure, an uninsulated control will blow the fuses, whereas an insulated control might convey the full negative voltage to the operator, with serious consequences.

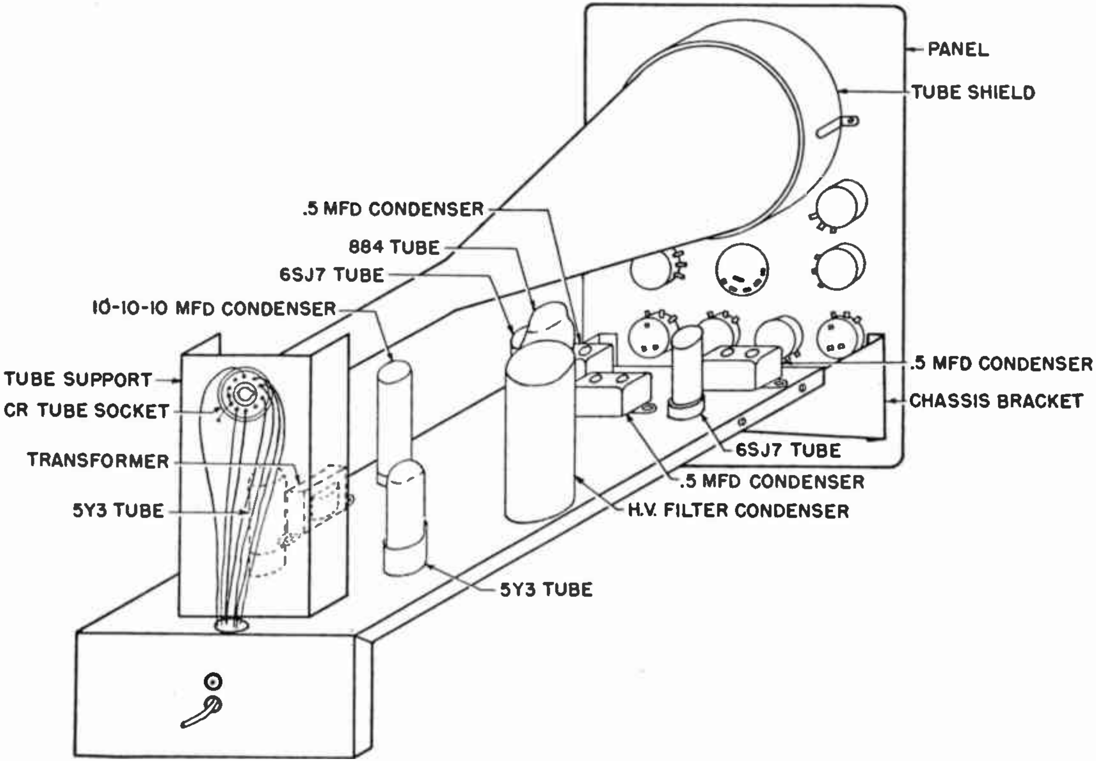
Assemble the chassis next. Mount the ground lugs and terminal strips under the chassis, as shown in the manufacturer's assembly diagrams. Mount the transformer as indicated, twisting the leads Keep the leads to the deflection plates away from leads carrying alternating current. Observe polarity on all condensers. Mount the cathode-ray tube socket on the tube support with pin No. 4 toward the base, which will give approximately the proper position for the tube. Wire as shown on the numbered diagram supplied with the kit Assemble the chassis to the panel and wire as shown. Check all wiring and soldering carefully. Place the knobs on the various control shafts. (See Figs. 96 and 97.)

Before plugging the oscilloscope into the line, check the resistance from B+ to ground; it should be over 75,000 ohms. Now insert the tubes. Always remember that the instrument develops voltages of over 1,000 volts, so that extreme care should be exercised when working with it. Connect to 110 volts 60-cycle alter-



95. Schematic circuit diagram of Eico oscilloscope. See parts list for identification of elements. (*Electronic Instrument Co., Inc.*)

nating-current supply, turn the unit on, and allow a minute for the tubes to heat up. Turn the positioning controls to approximate center. Turn the intensity control nearly full on and observe that a trace appears on the fluorescent screen; focus this trace to a spot or thin line. Set the course-frequency control between the 15 and 80 positions in its extreme counterclockwise position; thus the fine-



96. Assembly diagram of Eico oscilloscope. (*Electronic Instrument Co., Inc.*)

97. Assembly view of Eico oscilloscope, with cabinet removed. (*Electronic Instrument Co., Inc.*)

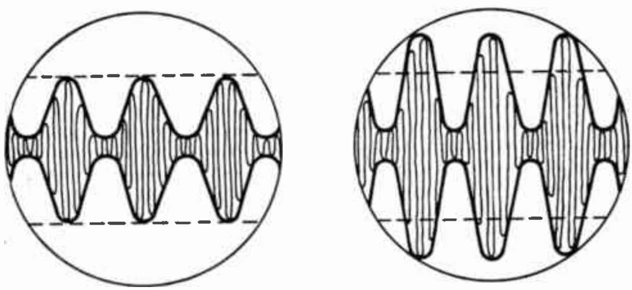
98. The assembled Eico oscilloscope, with cabinet in place, ready for use.
(*Electronic Instrument Co., Inc.*)

frequency control will vary the frequency between 15 and 80 cycles per second.

Before placing the oscilloscope in its cabinet (Fig. 98), check the voltages on the tubes. Below is a list of the voltages taken from the tube pins to ground as furnished by the manufacturer. The readings were taken with a vacuum-tube voltmeter, but variations up to 15 per cent can be expected:

Pin	*6SJ7*	*884*	*5BP1*
1	0	0	over 1,000 volts negative
2	0	0	0
3	4–6 volts	30–40 volts	varies with signal
4	0	30–40 volts	negative 600–1,000 volts
5	4–6 volts	0–3 volts	negative 1,000 volts or 0
6	100–150 volts	0–3 volts	0
7	6.3 volts a.c.	6.3 volts a.c.	0
8	220–280 volts	5–6 volts	0
9			varies with signal
10			over 1,000 volts negative
11			over 1,000 volts negative

The operation of the controls is fully explained in the Instruction Book accompanying the kit. The uses of the oscilloscope are numerous and so varied that it is impossible to indicate them in a brief account of the instrument. One of the most frequent uses, that of checking the modulation of a carrier to show if overmodulation is occurring, is illustrated in Fig. 99. By comparing the heights of



100% Modulation Pattern   Overmodulation Pattern

99. Modulation patterns on oscilloscope screen.

the peaks shown on the screen the operator can estimate the percentage of modulation; also, overmodulation or distortion "splashes" can easily be seen on the screen.

CHAPTER

16

Learning to Telegraph

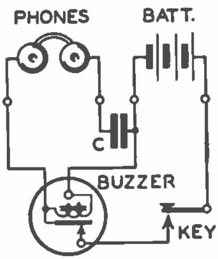
It is not difficult to acquire sufficient skill to pass the code test necessary to obtain an amateur license. The government examination requires the ability to send and receive Continental Morse Code at the rate of thirteen words per minute. Five letters count as one word. Each numeral or punctuation mark is counted as two letters. Learning to send and receive code is mostly a matter of practice. There is nothing difficult about the art. Speed and skill come with experience.

The first step is to memorize the code. (See Appendix, page 329.) You must know the characters for all the letters of the alphabet, the numerals and punctuation marks. As in everything else, there is a right and wrong way of doing this. Memorize the *letters* of the alphabet first. Study them in groups of five or six. When you have learned one group go on to the next. Notice that some letters are the reverse of others. "A" is the reverse of "N"; "B" is the reverse of "V," etc. This will help fix them in your memory. Learn to think of the letters in terms of sound rather than as visual dots and dashes. A dot sounds like *dit* and a dash like *dah* when heard on a radio receiver. So think of "A" as the sound "dit-DAH" instead of a printed "dot-dash." Repeat the sounds of the letters to yourself either audibly or mentally. Keep everlastingly at it. Don't lose patience. Practice fifteen or twenty minutes at a session several times a day.

The secret of learning a language is to acquire the ability to think in that language without translating it. Telegraphic code is a language. Learn to understand it without mental translation. A key and a buzzer will help to fix the sounds in your mind. Connect a telegraph key to a radio buzzer and one or two dry cells. Pressing the key will operate the buzzer and produce the sounds of dots or dashes.

It is important to form correct habits when beginning. If you acquire the proper technique of grasping and manipulating a key at the start, you will not have to "unlearn" a bad habit later.

The telegraph key should be mounted on a table thirty to thirty-two inches high and back from the front edge about eighteen to twenty-four inches, thus providing room for the elbow to rest on the table. The key knob should be grasped lightly with the thumb and first two fingers. An up-and-down motion is given to the key, using as little movement of the forearm as possible but flexing the



100. Buzzer code practice set. If phones are used with the set the capacitance of the capacitor *C* will determine the strength of the signal in the phones.

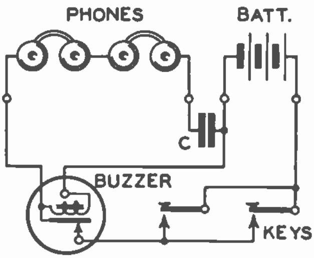
wrist. The fingers should not leave the key knob and tap. Movements should be firm, not jerky.

A beginner should not attempt to send fast. Speed will come automatically with practice. A smooth, clean-cut, steady rate of sending is the mark of a good operator. A dot is made with a quick, firm, down-and-up motion of the key. In making a dash, the key should be held down three times as long as in making a dot. The space between the parts of the same letter is equal to one dot. The space between letters is equal to three dots and the space between two words is equal to five dots.

If someone can be found to send to you, skill will come faster. Even another beginner will be helpful. You can rig up a good practice set by arranging two keys so that they control the same buzzer. Two pairs of phones can also be connected. This arrangement will make it convenient to send messages back and forth with a fellow code student.

Another method of acquiring code practice is to listen to messages with a short-wave receiver. Tune in on amateur or commercial stations. See if you cannot recognize some letters or characters and write down as many as possible. Probably the first letters and numerals you will be able to identify will be the call letters of various stations. After a while you will be able to pick out short words. The proper way to "copy" messages with a pencil and paper is to "lag." Try to listen to a whole word before writing it down. Do the actual writing of a word while you are listening to the next one.

Since it is not always possible to get the help of another person to send to you, it may be desirable to use a telegraph instructing



101. Two keys arranged to control the same buzzer for code practice.

machine. (Fig. 102.) You can buy one outright, or rent one for approximately $3.50 per month. The machine will send telegraphic characters perfectly at any desired speed by means of a perforated tape. Some models of these code-instructing devices are provided with an attachment to record signals that you send. Not only can you hear your own signals but you can send them as well. By comparing your own recordings with those which come with the machine, you can see and correct your mistakes in timing. It is more difficult to learn to send code properly than it is to receive it.

A word in regard to keys. A radio key is usually heavier and more ruggedly built than an ordinary telegraph key. Radio telegraph signals therefore have a slight characteristic "heaviness" compared to line telegraph signals. It is well to practice radio code with a radio key so that your ear becomes used to the slightly different sending.

There are keys on the market designed to operate sideways in-

102. The Instructograph machine for teaching the sending and receiving of telegraph code. (*The Instructograph Company.*)

stead of up and down. These are for speed sending. They save wrist motion, since they make dots automatically. Such a device is popularly called a "bug." "Bugs" are for skilled operators. Leave these special devices alone until you have become expert with an ordinary key.

CHAPTER

17

A 25-Watt Radiotelephone Transmitter for 27–32 MC

A REMINDER

This is undoubtedly a good place to remind the reader again that the Federal Communications Act of 1934, as amended, requires that anyone operating a radio transmitter of any type must possess a license for the transmitter or station. Furthermore, if he operates it himself, an operator's license is necessary. The owner of a station may obtain the services of a licensed operator for his station, but if the operator is an amateur, he must not be paid.

It makes no difference whether the transmitter is of very low power with signals that can be heard only for a few feet, or whether the transmitter is put on the air for a second or for a long period of time—*a license must be obtained.* Operating without a license subjects the offender to a fine of $10,000 or imprisonment for two years, or both.*

CAUTION

A radio transmitter is not a plaything. If misused it can cause a great deal of interference with other stations. If carelessly handled, transmitter power can electrocute. Every year radio experimenters are killed because they did not take proper precautions for their own safety.

* For licensing information the reader should write to the Secretary, Federal Communications Commission, Washington 25, D.C., indicating the type of equipment and the proposed use. The fact that a transmitter is operable on certain frequencies does not constitute authorization for use on those frequencies. It is the personal responsibility of every operator to keep himself informed on current FCC regulations governing frequency allocations, and the types of communication services permitted therein, granted for use under his class of license.

The constructor or operator should be absolutely certain that the current is shut off before making any major adjustments. Not only can transmitter power electrocute under some conditions, but the radio-frequency currents from the tank coils of buffers and power amplifiers can cause severe burns. These burns are deep and difficult to cure. If burned by radio, apply oil or grease as first aid treatment and see a doctor immediately.

A radio transmitter converts low-frequency alternating or direct current into high-frequency power and radiates it through a suitable radiating system. By controlling the transmitter with a key, it will send telegraph signals. If the radiation is properly modulated at voice frequencies the transmitter becomes a radiotelephone transmitter.

Building and operating an amateur transmitter is not a job for a youngster. It is a hobby for older boys and men possessed of proper engineering knowledge and mechanical ability.

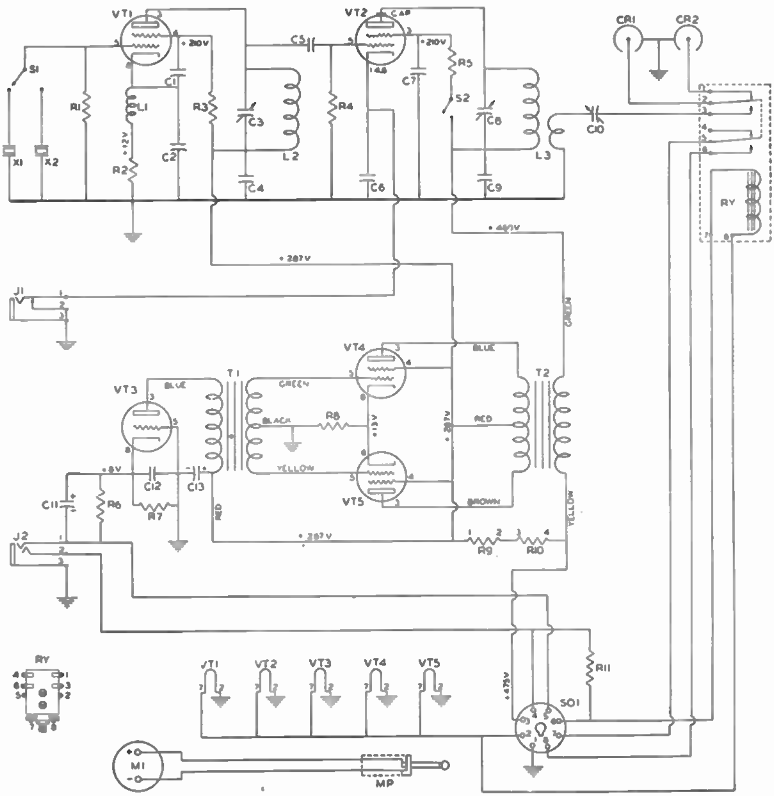
A transmitter must be designed and operated so as to comply with certain requirements imposed by present-day regulations and operating conditions; the frequency which it generates must not vary appreciably, its radiation must be free from the effects of an a-c power supply.

Government regulation limits the power of amateur transmitters to one kilowatt input. It requires an elaborate, expensive apparatus to convert 1,000 watts of a-c or d-c power into radio frequency current, keep the frequency constant and modulate it properly. A 1-kw "rig" is for the advanced amateur whose knowledge qualifies him as a professional and who can also pay for costly "bottles" (tubes) and other equipment.

THE STANCOR ST-203-A TRANSMITTER

You cannot assemble a miscellaneous collection of condensers, tubes, and resistors and have a transmitter. Parts must have suitable electrical and physical characteristics. Satisfactory operation and, in the long run, economy, are achieved by assembling a transmitter from a well-engineered kit of parts.

The Stancor ST-203-A comes in kit form and when assembled results in a versatile transmitter providing telephonic emission in the 27- to 32-megacycle frequency range. (Coils are easily altered to shift frequency range considerably higher.) The kit is obtainable from the manufacturer, the Standard Transformer Corporation, of Chicago, Ill., who has provided most of the information in this

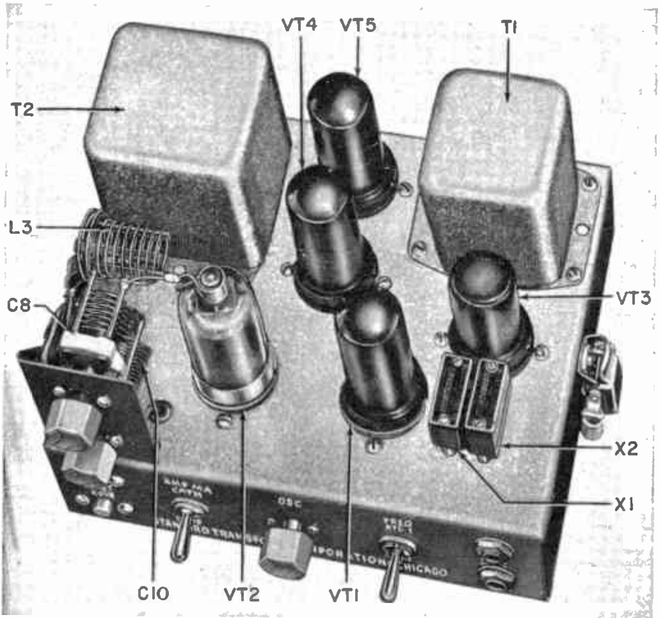


103. Schematic circuit diagram of the Stancor ST-203-A transmitter. (*Standard Transformer Corporation.*)

chapter. Designed primarily for mobile operation, the ST-203-A can also be used for fixed-station service. Electrically, the transmitter can be powered from a dynamotor or vibrator supply for mobile work, or from an a-c supply for transmission from a fixed location. You can operate this small, compact transmitter in your car, then quickly transfer it for use at your regular shack, summer home, or other fixed location. The transmitter is quickly released from a base mounting plate in the car to which it firmly attaches by means of two spring-loaded catch fasteners.

104. Assembly view of the Stancor ST-203-A radio transmitter with cover in place. (*Standard Transformer Corporation.*)

The rated amplifier plate power input is 25-27.5 watts, and the frequency is controlled by a quartz plate. Periods of transmission and standby are controlled by a press-to-talk switch mounted on the microphone. Operating control of the transmitter is available at a remote position or at the unit itself. In consideration of safety to the operator, external exposure of high voltage is prevented; control circuits are arranged so that, should the connector plug from the power-supply system be removed from the chassis while the transmitter is in operation, the high voltage will automatically turn off. Any suitable type of antenna system may be used, although for mobile operation it is expected that a one-quarter wavelength, vertical whip antenna will be most commonly used.



105. Top chassis view of the Stancor ST-203-A transmitter. (*Standard Transformer Corporation.*)

GENERAL DESCRIPTION OF THE CIRCUIT

A 6V6 beam tetrode (VT1 in Fig. 103) is used in a crystal oscillator circuit having controlled regeneration to provide harmonic output at twice the crystal frequency. A 2E26 beam tetrode (VT2) is employed in the r-f amplifier output stage in which it functions as a modulated Class C frequency doubler. Power output from this tube is transferred to the antenna system by means of a pick-up winding inductively coupled to the "cold" end of plate coil L3 (Fig. 103) and by the variable tuning capacitor C10, which adjusts loading of the antenna system upon the r-f amplifier. A 6J5 triode (VT3) is used in a grounded-grid speech amplifier circuit, and two 6V6 beam tetrodes (VT4 and VT5) are employed in a conventional push-pull, Class A_1, a-f power amplifier for high-level modulation of the Class C r-f amplifier. The relay RY, besides performing the antenna-changeover function, turns on the supply of high voltage when actuated by the press-to-talk button.

THE LAYOUT

Oscillator, amplifier, and antenna tuning knobs, crystal and meter switches, are located on the front of the unit, as are the microphone and meter jacks and the coaxial connectors to the antenna system and receiving equipment. Figures 104 and 105 show the front panel and cover and completed chassis respectively, with components and controls clearly indicated.

PARTS LIST FOR STANCOR ST-203-A TRANSMITTER

Diagram Reference (Fig. 103)	*Description of Component*	*Function in Circuit*
C1	2,000-mmfd, 500 WV * mica capacitor	Oscillator screen by-pass
C2	100-mmfd, 500 WV mica capacitor	Oscillator regeneration throttler
C3	35-mmfd, .025" airgap variable capacitor	Oscillator plate circuit tuning
C4	2,000-mmfd, 500 WV mica capacitor	Oscillator plate circuit by-pass
C5	100-mmfd, 500 WV mica capacitor	Oscillator output coupling
C6	2,000-mmfd, 500 WV mica capacitor	Amplifier cathode by-pass
C7	2,000-mmfd, 500 WV mica capacitor	Amplifier screen by-pass
C8	35-mmfd, .025" airgap variable capacitor	Amplifier plate circuit tuning
C9	1,000-mmfd, 800 WV mica capacitor	Amplifier plate circuit by-pass
C10	75-mmfd, .015" airgap variable capacitor	Antenna loading of amplifier
C11	10-mfd, 25 WV electrolytic capacitor	Speech amplifier cathode by-pass
C12	100-mmfd, 500 WV mica capacitor	Speech input r-f by-pass
C13	4-mfd, 450 WV electrolytic capacitor	Speech amplifier plate circuit by-pass
CR1	2-conductor connector	Receptacle for line from antenna
CR2	2-conductor connector	Receptacle for line from receiver
J1	Single closed-circuit, 2-conductor jack	Meter plug receptacle

* Working voltage.

Diagram Reference (Fig. 103)	*Description of Component*	*Function in Circuit*
J2	Open-circuit, 3-conductor jack	Microphone plug receptacle
L1	2.5 mh, 50-ma RFC coil	Oscillator regeneration inductance
L2	Air-wound inductor	Oscillator plate tank coil
L3	Air-wound inductor with link pick-up	Amplifier plate tank coil
M1	0–100 DC milliammeter	Tuning indicator
MP	Standard 2-conductor phone plug	Connects meter to J1
R1	47,000-ohm, ½-watt carbon resistor	Oscillator grid-leak bias
R2	560-ohm, ½-watt carbon resistor	Oscillator cathode bias
R3	27,000-ohm, ½-watt carbon resistor	Oscillator screen voltage reduction
R4	100,000-ohm, 1-watt carbon resistor	Amplifier grid-leak bias
R5	30,000-ohm, 2-watt carbon resistor	Amplifier screen voltage reduction
R6	560-ohm, ½-watt carbon resistor	Speech amplifier cathode bias
R7	27,000-ohm, ½-watt carbon resistor	Speech input circuit shunt
R8	150-ohm, 2-watt wirewound resistor	Modulator cathode bias
R9	750-ohm, 14-watt wirewound resistor	Plate and screen voltage reduction
R10	750-ohm, 14-watt wirewound resistor	Plate and screen voltage reduction
R11	7.5-ohm, 2-watt wirewound resistor	Voltage reduction to RY coil
RY	DPDT relay with 6-volt a-c/2-volt d-c coil	Ant. switching and power control
S1	SPDT toggle switch	Crystal selector
S2	SPST toggle switch	Amplifier screen voltage gate
SO1	Octal socket	Power and control circuit receptacle
T1	Plate to PP grids audio transformer	Interstage coupling
T2	PP 6V6's to Class C load mod. transformer	Amplitude modulation of VT2
VT1	Type 6V6 radio tube †	Crystal-controlled oscillator
VT2	Type 2E26 radio tube †	Class C RF Amplifier
VT3	Type 6J5 radio tube †	Speech amplifier
VT4	Type 6V6 radio tube †	Audio modulator
VT5	Type 6V6 radio tube †	Audio modulator
X1	1st crystal position	Frequency control
X2	2nd crystal position	Frequency control
	Miscellaneous hardware, fittings, screws, wire, etc.	

† Not furnished with kit.

Accessories

Accessories needed, but not furnished, with the ST-203-A Kit for operation as a mobile transmitter are:

Tubes — 1-2E26, 1 metal 6J5, and three metal 6V6.

Crystals — Quartz crystal plates mounted in plug-in type housings. The

	ST-203-A accommodates two of the popular type crystal holders having .095" diameter pins centered .487" apart. Crystal frequencies should be one-fourth the desired output channel frequencies.
Microphone	200-ohm, single-button, carbon microphone with press-to-talk switch, three-wire cord, and three-conductor plug with .205" diameter tip rod. (Representative type: U.S. Signal Corps T-17-B.)
Meter	0-100 d-c milliammeter wired to standard two-conductor phone plug.
Dynamotor	Six volts d-c input to 400–500 volts d-c output at 200 ma (intermittent service) dynamotor with filters, control relay, and heavy battery cables. (Representative type: U.S. Signal Corps PE-103-A with Cannon No. P 8-CG-12S connector plug.)
Antenna system	One-quarter wave length long whip antenna with insulating mounting base. Also required is sufficient RG-58/U coaxial cable to run from antenna and receiver to the ST-203-A.
Remote control	Consists of a three-conductor microphone jack, SPST toggle switch, green jewel pilot-light assembly (optional), red jewel pilot-light assembly (optional), and wiring leads needed to form extension cable.

ASSEMBLY AND WIRING

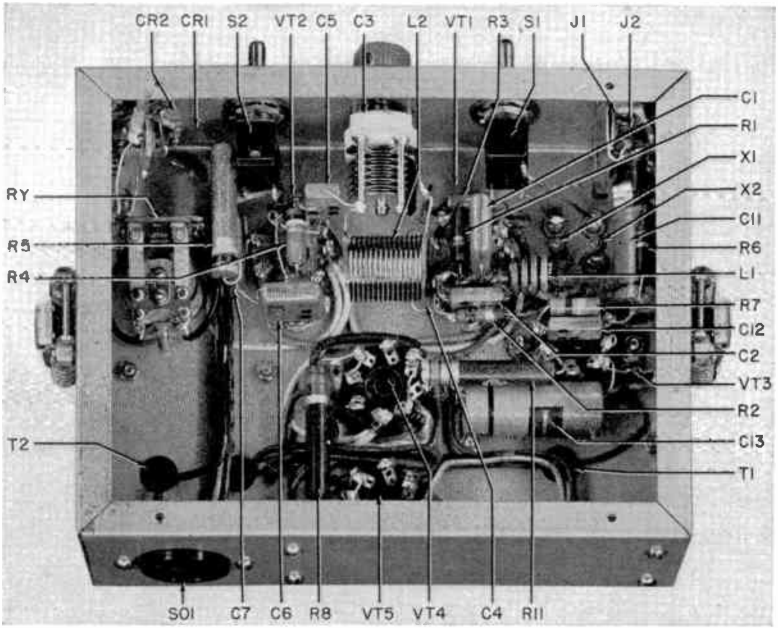
Before starting actual assembly, all parts should be checked against the packing list, schematic diagram, and photographs for identity and location. Mounting and wiring operations should be performed in the order listed in the Instruction Book. Each prepared lead should be identified by its length and color for wiring into the particular circuit for which it is intended.

The ST-203-A is shipped with transformers T1 and T2 already mounted on the chassis.

Mount both crystal sockets first (X1 and X2), then mount the octal sockets for VT1 and VT2 with their keyways facing the rear of the chassis. Mount the octal socket for VT3 with keyway to the right, then the octal sockets for VT4 and VT5 with their keyways facing to the left of the chassis. Mount octal socket for SO1 with keyway to the right, followed by resistors R9 and R10 against the inside of the chassis rear apron. Mount the polystyrene bushing in the ¼" hole near the left front corner of the chassis, and affix the rubber grommet to the ¼" hole to the right of this bushing.

Fasten mounting bracket to the front left corner of the chassis, followed by catch fasteners, coaxial chassis connectors, SPST toggle switch S2, SPDT toggle switch S1, and make all connections as directed in the sequence chart provided.

Mount jacks J2 and J1 in that order, followed by the resistors and capacitors as indicated; then mount L1 (the RFC coil) and changeover relay (RY), the oscillator plate coil, and the variable



106. Bottom chassis view of the Stancor ST-203-A transmitter. (*Standard Transformer Corporation.*)

capacitors C3, C8, and C10. Note that all wiring is done as the assembly and mounting proceeds; the foregoing is only a summary of the 94 different operations outlined in the manufacturer's step-by-step construction procedure. In soldering, the same precautions should be taken to insure a good connection as outlined earlier in this book. Figure 106 shows the bottom view of the completely wired chassis.

ADJUSTMENT AND OPERATION

Before attempting to adjust and operate this transmitter, the operator should be fully aware of and alert to the presence of dangerous electrical potentials. Before removing top or bottom covers from the chassis, for any purpose whatever, all power controls should be turned off and the power plug detached from the chassis receptacle. In addition, if a PE-103-A dynamotor is used for power, its circuit breakers, behind hinged side door, should be switched off.

The oscillator knob, OSC, is used for rotation of capacitor C3. Resonance of the tank circuit which it tunes is attained when a setting is found that produces a peak amplifier grid current of 2.0 to 2.5 milliamperes on the meter. The amplifier knob, AMP, is used for rotation of capacitor C8, while the antenna knob, ANT, is used for capacitor C10. The correct setting for AMP is that which permits a minimum amplifier cathode current on the meter, and for ANT that which permits the amplifier tube to become loaded up to 65 milliamperes of cathode current with minimum dip adjustment of the AMP knob. The crystal switch, FREQ, when moved to XTL1, selects a crystal in the left-hand socket; at XTL2, a crystal in the right-hand socket.

To tune the oscillator, first select XTL1 or XTL2 and throw meter switch to GRID position. Depress microphone button to turn on high voltage and rotate OSC knob until meter reads 2.0 to 2.5 milliamperes; then release microphone button.

To tune the amplifier, throw meter switch to CATH position and set ANT knob for minimum capacitance of C10 (pointer to left). Depress microphone button and quickly rotate AMP knob to setting providing approximately 20 milliamperes on meter; release microphone button.

To tune the antenna, depress microphone button and rotate ANT knob to increase capacitance until CATH reading on meter rises to 65 milliamperes. Carefully readjust AMP knob to re-establish the point of minimum current, the new level of which is determined by the degree of antenna loading. If the resultant current value drops below 65 milliamperes, increase capacitance with the ANT knob and follow with the retuning of AMP knob for the dip in CATH current. This procedure should be repeated until the antenna system loads up the amplifier tube to 65 milliamperes with the AMP knob set to the point of current dip. Should the ANT knob be set at too high a capacitance and cause CATH current in excess of the amount specified, its capacitance should be decreased to establish the desired current level. Release microphone button.

An appreciable change in crystal frequency should be followed by the readjustment of the oscillator, amplifier, and antenna tuning controls.

When working the ST-203-A from an a-c power pack at a fixed location, the tuning procedure is identical to that already described, except that the remote-control feature is not needed.

A WORD ABOUT OPERATING

One of the best ways to learn how to operate and how not to operate a radio transmitter is to be a good listener. The fellow who sits down and listens in, covering the whole amateur spectrum thoroughly, will soon notice the mistakes of the other fellows. He will learn that it is applied common sense:

1. Not to operate too near the edge of any amateur band.
2. To check frequency often.
3. Not to make a plaything of a radio transmitter.
4. Not to CQ fifty times and sign twice.
5. To send clean-cut steady stuff rather than try to show speed.

Some people only obey the traffic laws because they are afraid of a traffic cop. If you are that kind of person it would be beneficial to everyone else if you would stay off the air. However, it is only a matter of time before one of the checking stations maintained by the Federal Communications Commission will catch you if you are off frequency or a smart aleck. You will be cited and under certain circumstances you may cease to be a radio operator by order of your Uncle Sam.

WATCH YOUR FREQUENCY

Don't work too close to the edge of an amateur band. If you do not own a frequency meter check your spot with your own receiver. There is a commercial station at the end of each band. Tune for it. It will give you a good idea of the band limits.

If you want to calibrate your receiver or a homemade frequency receiver you can use the commercial broadcasting stations as a standard for some of your calibrations. A broadcasting station must maintain very close frequency adjustment. It must keep within a few cycles of its assigned frequency, hence its signals are always dependable markers for the amateur.

CHAPTER

18

Very High Frequencies (VHF) and Ultrahigh Frequencies (UHF)

The Federal Communications Commission has made the following designations for the entire radio spectrum:

Designation	*Frequency*	*Wave Length, Meters*
vlf (very low frequency)	10 to 30 kilocycles	30,000 to 10,000
lf (low frequency)	30 to 300 kilocycles	10,000 to 1,000
mf (medium frequency)	300 to 3,000 kilocycles	1,000 to 100
hf (high frequency)	3 to 30 megacycles *	100 to 10
vhf (very high frequency)	30 to 300 megacycles	10 to 1
uhf (ultrahigh frequency)	300 to 3,000 megacycles	1 to 0.1
shf (superhigh frequency)	3,000 to 30,000 megacycles	0.1 to 0.01

The standard broadcast or long-wave band includes only those m-f frequencies between 550 and 1,600 kilocycles, or roughly 540 to 185 meters. In the early 1920s the wavelengths below 200 meters, previously held to be "worthless," became known as the short-wave or amateur bands as distinguished from the long-wave or commercial broadcasting bands, and in the years that followed the amateur range was broadened to include, successively, the 100-, 80-, 40-, 20-, 10-, and 5-meter bands. Even a number of commercial broadcasting stations, such as WQXR and WWRL in New York City, had encroached on the original short-wave territory by transmitting below the 200-meter band (approximately 190 and 185 meters respectively).

By the early 1930s the use of frequencies higher than 60,000 kilocycles (60 mc, 5-meter band) were investigated by a number of amateurs, and by 1938 this area of vhf communication had already become fairly crowded with amateurs in all of our large cities. In 1939, 1940, and 1941 amateur activity encompassed the 112-mc

* A megacycle is 1,000 kilocycles, or 1,000,000 cycles per second.

band (about 2.5 meters) and by the time the United States entered the recent war amateurs were beginning to work the 224- and 400-mc bands (1.4 to about 0.7 meters). During the war all amateur activity was suspended, of course, but military applications of these frequencies brought a tremendous increase of knowledge about vhf and uhf, the latter in connection with the development of radar. Ultrahigh frequencies are still in the realm of advanced experiment, although some amateur communications work has already been done since the war in the *microwave* bands assigned—so called because ultrahigh frequencies correspond to wavelengths shorter than 1 meter.

Superhigh frequencies are mentioned here only for the sake of completeness. They are as yet not widely used in amateur radio communication and have highly specialized applications that are quite beyond the scope of this book.

VHF PROPAGATION

To understand how vhf waves are propagated we must first consider the nature of radio-wave propagation in general. Radio waves travel with the speed of light (about 186,000 miles per second) and may be reflected from various layers of the atmosphere and from the earth itself. Radio waves emitted by the ordinary antenna travel not only along the surface of the earth but also through the upper atmosphere. That part of the wave or energy from the antenna which travels along the surface of the earth is called the *ground wave*; that part which goes out at an angle above the horizontal is called the *sky wave* or *ionospheric wave*, from the fact that it is directed at the ionosphere, which is a region of rarefied and ionized atmosphere surrounding the earth at a distance of from 50 to 200 miles. A third wave, called the *tropospheric wave*, is that part of the original wave which is refracted and reflected in the troposphere, or area of clouds and storms lying from 3 to 7 miles above the earth.

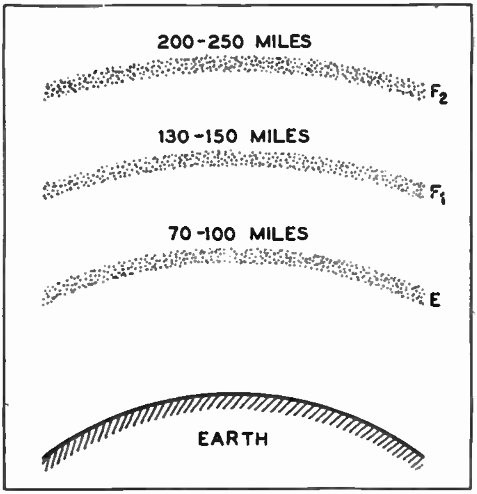
The importance of the ionosphere (also called the Kennelly-Heaviside layer, after Dr. A. E. Kennelly in America and Oliver Heaviside in England) in the propagation and transmission of radio signals is now well recognized. If it were not for the existence of this layer much of the energy emitted by a short-wave transmitter would escape into space and be lost.

The ground wave becomes rapidly weaker as it progresses away from the antenna until it no longer has any useful strength. Sky waves travel on outward into space and do not become as quickly attenuated as the ground waves. This is especially true of vhf and uhf waves.

It may seem at first that the sky waves would be lost and therefore of no value in communication, but actually this strange behavior is the fundamental reason for the great distance-covering characteristic of short waves. As these waves are impelled from the transmitting antenna at angles depending on the frequency and the type of radiator, they travel until they meet one of the ionized layers far in the sky. At one time it was believed that there was but one such layer, but intensive and prolonged tests carried out by the U.S. Bureau of Standards have shown the presence of at least three layers and perhaps more. The transmitted wave striking one of these regions of ionized particles is bent or reflected back toward the earth in much the same manner as a ray of light striking a mirror. Thus instead of passing off into some remote region in the ionosphere the signal eventually comes back to earth at a point hundreds and sometimes thousands of miles from the starting place. The distance between the transmitter and the return point is called the *skip distance* and comprises the area over which the station cannot be heard. A powerful signal often returns to the earth's surface several times before its strength is so reduced that it can no longer be detected.

The approximate positions of the principal ionized layers are illustrated in Fig. 107. Tests have shown that most of the waves transmitted at night pass through the E layer and on to one of the F layers before they are reflected back to earth. During the daytime, each of the three layers is effective depending on the frequency of the waves; hence scientists have compiled tables which show communications engineers exactly what they may expect in the performance of transmitters at different times of the day. Thus at any hour, the wavelength of a station would be one figure for a transmission of one thousand miles and another figure for a signal that was to be sent thousands of miles away, to China or Australia, for instance. That is one reason for the wide variation in frequencies assigned to the amateurs. For strictly local traffic, the amateur will resort to 160 or 80 meters, but when his objective is a brother amateur in a foreign country he will turn his transmitter to the 20-meter wave or lower.

The F_2 or highest layer of the ionosphere is responsible for most of the normal radio contacts in high-frequency communication just below the vhf threshold, 28,000 kc (28 mc) being the average maxi-



107. Locations of the principal ionized layers which affect the transmission of radio waves of different frequencies.

mum usable frequency (m.u.f.) for F_2 reflection. This m.u.f. varies according to a well-defined cycle or system of cycles, being related to the 11-year solar cycle as well as to daily and seasonal variations of the sun with respect to the earth. F_2 reflection has been known to account for long-distance communication on vhf frequencies of as high as 50 mc (6 meters) over distances as great as 10,000 miles.

The E layer is often responsible for reflections of signals on 28 and 50 mc in the vhf region, this so-called *short skip* or *sporadic E skip* being quite unpredictable as to season or time of day probably because of irregularities of ionization in the E layer. E-layer contact has been observed on vhf frequencies of as high as 100 mc

(3 meters), and it provides good contact over relatively short distances of from 400 to 1,200 miles. Magnetic storms, aurora displays, sun-spot activity, and even ionized trails of meteors crossing the signal path are all believed to exert an effect upon the range of hf and vhf signals.

Changes of temperature in the troposphere also cause variations in vhf transmission and reception, due to the *refraction* of the signals as they pass through alternate layers of cold and warm air masses; vhf signals may be greatly increased by the rapid cooling of the earth during the evening and night following a hot summer day, or by the heating of the upper layers of the troposphere during the early morning hours after sunrise.

On vhf and uhf work, the antenna becomes increasingly important. Due to its much smaller dimensions it is possible to secure directional properties from an antenna that are not possible with longer waves. In recent years the development of high-gain directional antennas on vhf has almost completely eliminated the earlier need for highly elevated locations such as hill tops and mountain tops. For 50-mc communication high elevation has become a negligible factor, while for 144-mc work a high elevation is not too important except during the winter months when the tropospheric bending and other reflection phenomena are at a low point.

The most successful results in vhf work have been on the 50- and 144-mc bands, although only slightly less reliable results have been reported on the 235-mc band, near the edge of the vhf spectrum (about 1.3 meters).

Natural static is a smaller problem in vhf and uhf reception than it is in the case of longer waves; in fact, it may be said to be practically nonexistent. But man-made static is a greater problem. The ignition systems of automobiles, diathermy and x-ray equipment, and other electrical devices cause intense interference and must be controlled by the use of certain types of noise limiters before satisfactory reception can be attained.

VHF AND UHF ANTENNAS

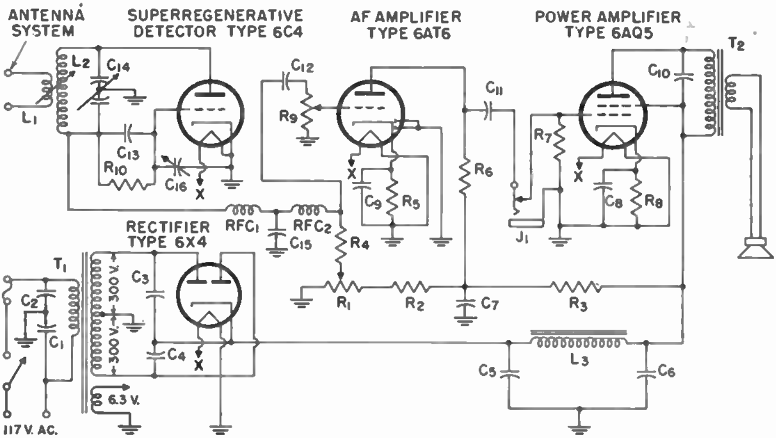
Radio waves that are vertically polarized—that is, emitted from an antenna perpendicular to the surface of the earth and received on a vertical antenna—are more subject to man-made static than horizontally polarized waves (those emitted and received by a horizontal antenna). For ordinary transmission and reception of vhf and uhf signals, any type of antenna system that works well on the lower frequencies may be used if the operator is not particular about distance and selectivity. The fundamental form of antenna for vhf and uhf work of this sort is a single wire approximately one-half wavelength long, or a quarter-wave antenna may also be used. Energy is not emitted uniformly in all directions from a half-wave or quarter-wave antenna. It is zero along the direction of the wire itself and most intense at right angles to the wire. Therefore if the antenna is vertical, the waves will be uniform in all horizontal directions, but if the antenna is horizontal, the greatest horizontal radiation will be in a direction at right angles to the wire. Signals will be best received when a vertical receiving antenna is used for receiving vertically polarized waves and a horizontal antenna for horizontally polarized waves.

However, for high-quality vhf and uhf work it is essential to use some form of directional array instead of the simple vertical or horizontal antenna. These arrays consist of a number of elements (usually three or more) arranged in either flat-top, lazy-H, Sterba curtain, corner-reflector, or other design, the purpose of the elements being to intercept the greatest amount of wave-front area and thus pick up the greatest amount of signal power from the distant transmitter. These are called high-gain antennas because they greatly increase the signal-to-noise ratio of the receiver. The advantages and characteristics of each type should be determined before planning any installation. There are also such antennas as the rotatable and tippable arrays consisting of a rotating structure holding the elements, which can then be rotated or tipped horizontally and vertically to secure maximum directional effect.

VHF RECEIVERS

At the present time, the three most important vhf bands are those at 50 mc, 144 mc, and 235 mc, with the 144-mc band seeming to be the most popular. Commercial receivers that cover the 50-mc band are now available on the market, and superregenerative receivers for the 144-mc band can be constructed without too much difficulty in the home workshop, but for frequencies above 200 mc, and especially for those above 300 mc, the construction of a receiver becomes a job for the radio engineer, because in that region the conventional tubes, condensers, and other components are no longer practicable.

The simplest type of vhf receiver is the *superregenerative receiver* (page 91), which is still used by amateurs for 144-mc reception, although it is not as popular as it was a few years ago. It is simple to construct, having only 3 or 4 tubes and a simple circuit,



108. Four-tube superregenerative receiver for 144 mc. (*Radio Corporation of America.*)

and has good sensitivity. However, the receiver when operated generates a signal which may cause serious interference to other receivers in the vicinity, which makes it necessary to operate it at the smallest amount of plate voltage on the detector tube that will permit satisfactory superregeneration.

A four-tube superregenerative receiver for 144 mc is illustrated schematically in Fig. 108. The tubes employed are as follows:

6C4 hf triode used as superregenerative detector
6AT6 twin diode high-mu triode used as a-f amplifier
6AQ5 beam power amplifier, used as power amplifier
6X4 full-wave vacuum rectifier

These are all miniature tubes.

Parts List for 144-mc Superregenerative Receiver

Description	Designation, Fig. 108
2 0.1-mfd, 400-volt paper condensers	C_1, C_2
2 100-mmfd, 500-volt paper condensers	C_3, C_4
3 20-mfd, 450-volt electrolytic condensers	C_5, C_6, C_7
1 25-mfd, 50-volt electrolytic condenser	C_8
1 25-mfd, 25-volt electrolytic condenser	C_9
1 0.002-mfd, 600-volt paper condenser	C_{10}
1 0.01-mfd, 400-volt paper condenser	C_{11}
1 0.005-mfd, 400-volt paper condenser	C_{12}
1 50-mmfd, 300-volt mica condenser	C_{13}
1 variable condenser, 10-mmfd per section	C_{14}
1 0.006-mmfd, 300-volt mica condenser	C_{15}
1 3-30-mmfd ceramic or mica variable condenser	C_{16}
1 Jack for earphones	J_1
1 Antenna pickup loop	L_1
4 turns of No. 12 copper wire on a ½" I.D. form (144 mc); adjust spacing to set band	L_2
1 Speaker field or filter choke, 12 henries, 70 ma	L_3
1 Potentiometer, 47,000 ohms, 1 watt, wire-wound	R_1
2 47,000-ohm, 1-watt resistors	R_2, R_3
1 27,000-ohm, ½-watt resistor	R_4
1 2,700-ohm, 1-watt resistor	R_5
2 100,000-ohm, ½-watt resistors	R_6, R_7
1 270-ohm, 1-watt resistor	R_8
1 Volume-control potentiometer, 500,000 ohms	R_9
1 4.7-megohm, ½-watt resistor	R_{10}
1 One-quarter wavelength of No. 23 enameled wire, close wound on a ¼" I.D. form (144 mc)	RFC_1
1 R-f choke, 8 millihenries	RFC_2
1 Power transformer, 300-0-300 volts RMS, 70 ma	T_1
1 Output transformer for matching impedance of voice coil to 5,000-ohm tube load	T_2
4 7-prong miniature tube sockets	
1 6C4 tube (miniature)	
1 6AT6 tube (miniature)	
1 6AQ5 tube (miniature)	
1 6X4 tube (miniature)	
1 Punched steel chassis	
1 Panel	
Hook-up wire, tubing, mounting screws, etc.	

In wiring the receiver care must be taken to place the components so that the shortest possible connections will result, for short leads are essential to successful vhf reception. The two coils L_1 and L_2, the tuning capacitor C_{14}, and the r-f choke RFC_2 should be mounted behind the panel directly in back of the main tuning dial and as close to the terminals of the 6C4 as possible. For best results coil L_2 should be soldered directly to the terminals of the tuning capacitor C_{14}. The antenna terminals should be mounted on a small polystyrene strip to the rear of the panel.

As noted above, the operation of any superregenerative receiver can cause considerable interference in other receivers in the neighborhood. To reduce this, an r-f stage may be inserted before the superregenerative detector; here, since the detector is coupled directly to the antenna, the smallest amount of plate voltage consistent with satisfactory superregeneration should be used—180 to 250 volts, the maximum plate voltage rating of the 6C4 tube being 300 volts.

When the receiver is operated a continuous hissing sound will be heard in the headphones, which will be considerably reduced or cut out altogether when a strong signal is tuned in. Regenerative control R_1 should be set for that position which gives strong signals with minimum hiss and best voice quality.

VHF CONVERTERS

The trend among amateurs is away from the construction of complete receivers for vhf work. The general practice is to use a conventional superheterodyne communications receiver designed for the frequencies below 30 mc and tune the converter to the intermediate frequency of the receiver. This makes construction a great deal simpler, for the communications receiver can be bought ready-made for a small part of the cost of building a complete vhf superheterodyne receiver, and at the same time it allows the amateur to benefit from the increased advantages of superheterodyne reception in the higher frequencies. The superheterodyne system of reception is almost exclusively used on 50-mc work, and to a large extent on 144 mc, for it is far more selective and has a much better signal-to-noise ratio than the superregenerative receiver, besides being free from radiation interference. These converters are simple one- or two-tube affairs, and the reader will find a number of them described in various recent issues of such magazines as *QST* and *CQ*. Many types of superheterodyne receivers designed for radar and aircraft use during the recent war are now available as war-surplus material and are easily convertible to 144-mc amateur use.

Converters can also be used in conjunction with an FM receiver not only for vhf but for uhf or microwave reception as well.

VHF TRANSMITTERS

The mobile transmitter described in pages 193 to 204 covers the lower part of the vhf region (28 to 32 mc) and will thus serve to illustrate one type of vhf transmitter. However, as we go higher in the vhf region, it becomes desirable if not essential to use specially designed equipment rather than to try to adapt a transmitter designed for the lower frequencies by simply using a different set of plug-in coils. At 50 mc and higher the so-called "all-band" transmitter is not a satisfactory arrangement.

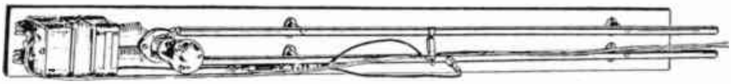
Above 51 mc and into the uhf region, the FCC permits the use of frequency-modulation as well as amplitude-modulation transmitters; any crystal-controlled transmitter can be converted to FM by replacing crystal with a frequency-modulated oscillator using a pentagrid mixer of the 6L7 type.

At the present time the FCC regulations permit the operation of vhf transmitters on three frequency bands—50 to 54 mc, 144 to 148 mc, and 235 to 240 mc, and the operation of uhf transmitters on seven bands—420 to 450 mc, 1,215 to 1,295 mc, 2,300 to 2,450 mc, 3,300 to 3,500 mc, 5,650 to 5,850 mc, 10,000 to 10,500 mc, and 21,000 to 22,000 mc. Above 333 mc we enter the world of microwaves and radar, and the construction of microwave equipment is still something for the advanced radio engineer rather than the radio amateur.

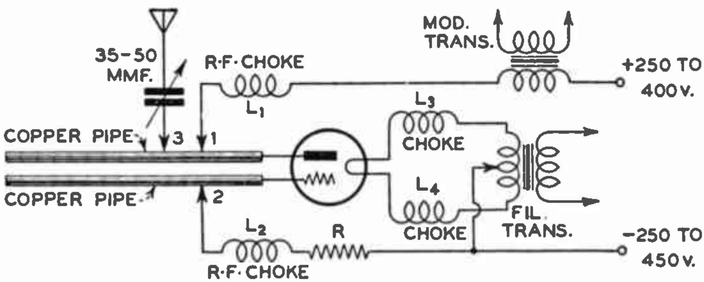
A SIMPLE VHF TRANSMITTER FOR 144 AND 235 MC

All of the electrical principles discussed in other chapters apply equally well to vhf and uhf, but in this specialized field the apparatus changes in size and appearance. Tubes, condensers, and inductances become very much smaller. The variable condensers have only a few plates; inductance coils but a few turns. In some cases the inductances are straight rods. With frequencies above 30 mc the materials used for insulation become highly important. Losses that are negligible at broadcast frequencies assume important proportions at vhf and uhf frequencies.

Since the capacities and inductances used are of relatively small dimensions, the capacity and inductance of connecting wires may be a large proportion of the total capacity and inductance in the circuit. In the construction of vhf and uhf transmitters and receivers, the utmost care is necessary in arrangement and layout.



109. A 2-meter vhf transmitter.



110. Schematic circuit diagram for a 144-mc linear transmitter.

A simple, low-cost vhf transmitter of the modulated oscillator type is described below. While this type of transmitter is not now as widely used for 144-mc work as formerly because of the recent trend to stabilized transmitters and selective superheterodyne receivers, it is presented here as being perhaps the simplest vhf transmitter that the beginning amateur can construct in his home workshop. By proper operation and adjustment it is possible to radiate a very satisfactory signal with this transmitter that can be clearly received on superregenerative receivers and on all but the most selective superheterodyne receivers.

The essential part of the transmitter illustrated in Figs. 109 and 110 consists of a pair of copper rods or pipes connected to the plate and grid of a triode oscillator tube, forming a linear oscillator or line-stabilized oscillator. Modulation is effected by means of a 10-watt modulation transformer connected to the output of a suitable feedback amplifier using a 6L6 tube. Almost any of the usual triode tubes will serve in a linear oscillator circuit, such as types 10, 45, and 801; in one version of this transmitter an HY-75A tube with plate voltage of 450 volts and plate current of 90 ma is used.

List of Parts for Ultrahigh-Frequency Transmitter

Circuit Designation	*Quantity*	
	2	½ dia. copper tubes 36 inches long
	5	Small porcelain standoff insulators
L1 and L2	2	Radio-frequency chokes, National R100
R	1	10,000-ohm wirewound grid leak
	1	Tube socket
	1	Filament transformer
	1	Modulation transformer
	1	35 to 50 micromicrofarad feeder condenser chokes.
L3 and L4	2	These are homemade and consist of 25 to 30 turns #14 wire wound around a pencil

The filament transformer should be mounted on one end of a wooden base approximately four inches wide and forty inches long. Next to it mount the tube socket, leaving space between it and the transformer terminals for the filament lead chokes. The socket should be mounted on a standoff insulator so that it is raised to the same height as the copper pipes.

The copper pipes are mounted on standoff insulators and connected to the grid and plate terminals of the socket. The space between the pipes should be approximately equal to the diameter of the pipes. The adjustable contacts (*1* and *2*) leading from the radio-frequency chokes to the copper pipes are "universal" clips. The proper position for the clips is at the voltage node point. This is found by experiment. Connect a ½-watt neon lamp across the free ends of the copper pipes and move the clips until the lamp is brightest. This will be somewhere in the close neighborhood of twenty-seven to thirty inches from the free end when a No. 10 or an 801 tube is used. In the case of a No. 45 tube, the distance will be shorter.

The antenna lead (*3*) is tapped off the copper tube connected to the plate. Tap off about three or four inches either side of the clip (*1*).

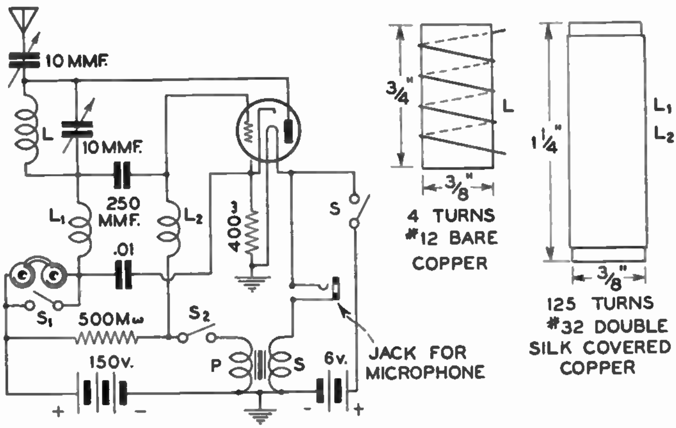
For 144 megacycles the antenna wire should be a horizontal wire approximately 41.5 inches long. Tap it 14 per cent off center and bring a single wire down to the transmitter. Final tuning adjustments can be made with a 6–8 volt flashlight lamp. Solder a copper wire to each of the lamp terminals and hang the lamp on the antenna wire. The ends of the wires soldered to the lamp should be three or four inches apart and in electrical contact with the antenna.

The secondary of the modulation transformer included in the plate circuit should have an impedance which matches the load impedance of the plate circuit. The load impedance is calculated by dividing the voltage by the current flowing in the circuit.

By proper adjustment of the plate lines on the oscillator the transmitter can be used on either the 144-mc or 235-mc band. The transmitter will be tuned to the 144-mc band with nearly all of the copper-rod line in the circuit; with the rod length at approximately 5 inches, the transmitter will be tuned to the 235-mc band. The exact frequency can be determined by using a pair of *Lecher wires,* which consist of a tightly stretched two-wire transmission line at least 7 feet long for use on 144 mc. The wavelength corresponding to the frequency of the transmitter is read directly in centimeters after the points of maximum current in the Lecher wires, set up by resonance with the transmitter, have been determined by means of a glow lamp.

TRANSCEIVERS

A combination transmitter-receiver, commonly called a transceiver, has come into wide use among amateurs, especially for portable equipment and for emergency applications, and received tremendous development during the war in the form of "walkie-talkie" or "handie-talkie" equipment. By means of suitable switching, the same one-tube circuit functions either as a modulated transmitting detector or as a superregenerative detector, but obviously it is neither a highly efficient transmitter nor a selective receiver. Its range is limited to a few miles at best, but it has worked out well where it is necessary to establish an operating point quickly or where the terrain would not permit the passage of a vehicle carrying a more powerful unit. With a little ingenuity the entire "station" can be compressed into a space scarcely larger than a lunch box, making the transceiver ideal for hand-carried portable equipment. The transceiver can, however, be a source of serious interference if operated on other than very low power, and its use should be avoided for regular operation on the 144-mc band.



111. One-tube transceiver.

Fig. 111 shows such a transceiver. More intricate combinations have been devised, but the one illustrated will serve to introduce the amateur to the characteristics and mode of operation peculiar to a transceiver.

If the circuit is traced first as a receiver it will be noticed that it then functions as a superregenerator. As a transmitter it is a grid modulated oscillator. The type 76 tube which is shown here functions well on the band for which the circuit is intended. The switches *S1* and *S2* are operated simultaneously to change over from "send" to "receive" and should therefore be ganged as a double-pole-double-throw switch. *S3* is merely an on-off switch of any handy type. Since the transceiver is not intended for continual use, the batteries should be the smallest size obtainable.

For the microphone, a sturdy carbon mike will suffice, with the modulation transformer selected to match microphone (primary) and grid circuit (secondary). After winding coil *L* it may be removed from its form and soldered directly and permanently by its end turns.

An antenna can be arranged as a rod on top of the transceiver cabinet. For best results the rod should be fifty inches long, but shorter lengths will give adequate operation.

UHF AND MICROWAVE COMMUNICATION

As stated earlier, once we go beyond the 144-mc band we encounter an entirely different technique and require entirely different types of coils, condensers, tubes, and other radio components. Actually, however, the line of demarcation between vhf and uhf techniques is at present the 235-mc band, which, according to definition, is still in the vhf region. For 420 mc and above, we get into the use of cavity resonators, "lighthouse" tubes and klystrons, magnetrons, and other devices that were first brought into prominence through the intensive research in radar during the recent war.

At the present time all of the microwave bands assigned for amateur use have been successfully worked for communication purposes. The superheterodyne receiver is being used on the 420-mc (0.7 meter) band, and even the simple superregenerative receiver has given good results consistent with the seasonal nature of the propagation. The first amateur microwave communication was carried on in the fall of 1945 and since then at least two amateur stations have communicated at 21,000 mc, the highest frequency yet used in amateur work. Description of uhf and shf equipment will be found in issues of the magazine *QST*, where much of the pioneering work in these fields is reported.

OTHER UHF APPLICATIONS

There are several applications for ultrahigh frequencies outside of the communication field. Use has been found for them by the physiologist and the botanist. In some diseases it is advisable to create a fever in the patient in order that the increase in body temperature will combat the malignant bacteria. Heretofore this was accomplished by deliberately giving the patient another disease which would raise the temperature of the body, but now it has been found that if the patient is exposed to ultrahigh frequency radiations the body temperature will be increased without resorting to a second disease. The tissue of the body can be destroyed by the use of the so-called *radio knife*, which permits practically bloodless surgical operations. Small animal and insect life can be destroyed, so that vermin extermination is a possibility. On the other hand, plants that have been exposed to ultrahigh-frequency wave radiations have grown faster and larger than those raised under ordinary conditions. In brief, the list of possibilities is too long to include in a limited space.

CHAPTER

19

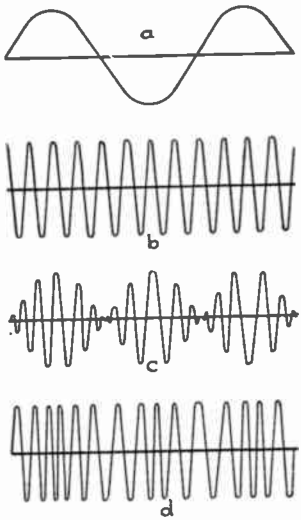
Frequency Modulation and FM Receivers

Although frequency modulation does not represent an entirely new form of radio transmission it was not ready for general usage until 1939 when Major Edwin H. Armstrong, already accredited with the regenerative and superheterodyne circuits, succeeded in convincing a sizable proportion of the industry of its advantages over the established system of amplitude modulation. And since it is likely that the amateur will discover in FM a solution to many of his problems, the experimenter should understand its fundamentals both as regards transmission and reception.

Fig. 112 shows the comparative action of AM and FM when applied to a simple sine wave transmitted by both systems. Under our present method, the sine wave signal (a) is caused to modulate a continuous carrier (b) with the result shown at (c). But when the transmitting system is based on FM, the wave sent out from the sending station has the characteristic shown at (d). It will be noticed from these curves that while the modulated AM wave changes its height or amplitude to correspond with the sine wave. the FM system varies the number of alternations according to the extent of the sine wave while maintaining a uniform amplitude at all times.

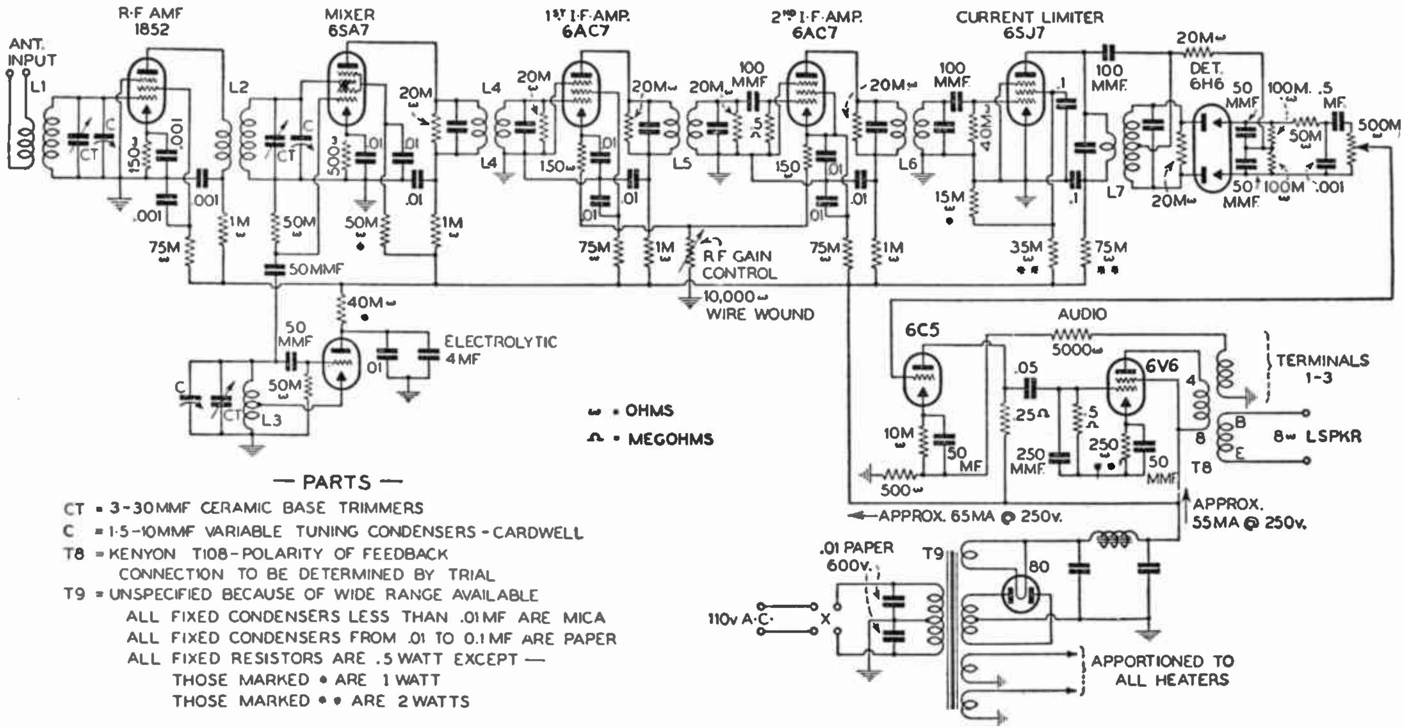
There are obvious transmitting advantages in FM, such as a lower first cost of equipment, but the principal gain is found in reception. Outstanding is the freedom from atmospheric and man-made static enjoyed by the owner of an FM receiver. Briefly, this highly valuable feature is made possible because the majority of static is *amplitude modulated;* hence it has little or no effect when encountering the circuits of an FM receiver. Frequency modulated receivers may be operated throughout a local thunderstorm with scarcely a trace of noise, whereas an amplitude modulated signal would be overridden by the bursts of static.

Another feature which FM insures is the detection and amplification of high quality programs, an important point for the broadcast listener if not for the amateur. The wide frequency swing of FM signals—sometimes as much as 75 kilocycles either side of the median frequency—permits reproduction of all tones and overtones up to and even beyond the normal hearing limit of the human ear. Contrasted with the 5,000 cycles permitted standard broadcasts, the improvement is obvious.



112. Comparative action of amplitude modulation (AM) and frequency modulation (FM).

The secret of an FM receiver lies in two circuits, the *limiter* and the *discriminator* (sometimes known as a *slope filter*), the latter being in effect the second detector of a superheterodyne, following immediately after the limiter circuit. The forepart of the receiver is the familiar superheterodyne designed in oscillator and intermediate frequency stages to work on the vhf wavelength of approximately 7 meters. Because of the small gain per stage even with the latest types of tubes such as the 6AC7 (1852) complicated by the



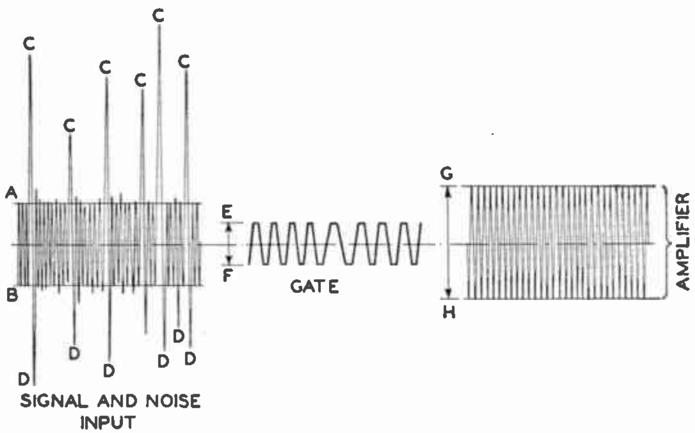
113. Complete frequency-modulation receiver.

necessity for loading each i-f stage to pass a broad frequency band, a number of stages must be included in order to provide the necessary signal strength at the second detector.

One of the simplest FM receiver circuits is shown in Fig. 113. The amateur will discover that the majority of the components outside the i-f transformers are standard and will be found in his box of spare parts. The procedure to follow in altering existing i-f transformers to pass the wide frequency band is described in the following text. If desired the FM portion of the circuit may be assembled as a unit with the output lead of the detector arranged to feed into any existing audio amplifier. In this case, it might be desirable to include a separate power supply for the FM tuner rather than depend on the amplifier power supply for the various voltages for filaments plates and screens, but such a move is not essential to the satisfactory functioning of the FM receiver.

THE LIMITER STAGE

Before beginning the actual assembly of an FM set, the builder should understand the function and arrangement of the limiter stage which in brief is an amplifier that is practically insensitive to amplitude variations while being very sensitive to variations in carrier frequency.



114. How the limiter circuit of an FM receiver operates to exclude noise.

Such an amplifier may be formed by any pentode tube with a sharp cut-off characteristic if the plate and screen voltages are held low. Under such conditions, the tube saturates rapidly with increasing grid voltage and therefore causes little or no variation in the plate current. The stage thus becomes a current limiter and no matter how powerful the incoming signal-plus-noise voltage may be, the plate current will reach a predetermined level and remain there. From the foregoing, it can be seen that if the limiter or gate is made to operate too quickly the plate current will be too small to supply the needed signal to the detector or discriminator while if the gate is opened too wide, a higher percentage of noise will accompany the desired signal. A satisfactory compromise has been reached in the receiver about to be described.

AN FM RECEIVER

This receiver consists of 10 tubes of which two are a standard high quality audio-amplifier. For greater signal strength the antenna feeds into a stage of radio frequency and then passes to the mixer tube (6SA7), where it encounters the locally generated oscillations from the 6J5. The intermediate frequency selected is about 4,300 kc, which seems to give best results. After the two i-f stages comes the current limiter and then the detector which in this case is the 6H6, a double diode. After the signal passes the 6H6 it has lost its FM characteristics and in its place is an audio signal with a shape that corresponds precisely with the originally transmitted train of FM impulses. Hence, the signal removed from the cathodes of the 6H6 may be led to any suitable audio amplifier and treated exactly like the output of any detector. If an existing radio receiver possesses good tonal qualities, this output may be fed into the first audio stage, thereby making it unnecessary to build another audio amplifier unit.

COIL CONSTRUCTION

Since FM for some time will be used within a narrow band of frequencies, it is not necessary to arrange for covering several bands as in all-wave sets or amateur receivers. Amateurs are likely to operate near 144 megacycles, while the broadcast listener will find his program fare between 88 and 108 megacycles. The coil data given here are for the latter band.

For the coil forms, secure three pieces of ⅝-inch low-loss tubing such as polystyrene or steatite. The secondaries of *L1* and *L2* consist of 4½ turns of No. 18 bare wire spaced to occupy ½ inch. *L3* also has 4½ turns with a tap 1½ turns from the ground end. The primaries of *L1* and *L2* consist of 2 turns of No. 26 double cotton-covered wire wound with the turns close together at the ground end of each secondary. To prevent interaction each coil should be enclosed in a can shield at least three times the diameter of the inductance forms.

The i-f transformers *L4*, *L5*, and *L6* are identical and while they may be purchased in kit form they may be made easily from existing transformers by the simple expedient of altering the coupling between primary and secondary. First it is necessary to obtain three i-f transformers with a designed frequency of about 4,300 k.c. Then insert a warm, not hot, soldering iron into the coil forms until the wax holding the two coils is softened sufficiently to permit it to be chipped off. With the coils thus freed, they may be pushed closer together with a distance of only half an inch or less from the center of one coil to the center of the other. A little wax melted and dropped back on the coils will hold them in this position.

For the discriminator coil, the builder must secure a 4,300-k.c. i-f transformer with a center-tapped secondary and proceed in the same manner to tighten the coupling.

In wiring the receiver, the amateur should keep in mind the absolute necessity for shortening each and every lead to the utmost. Here as in any circuit dealing with very high frequencies, a fraction of an inch of lead may make the difference between a perfectly working set and one that is so temperamental due to regeneration that all the fun of using it is lost.

It is not necessary to give the step-by-step procedure in wiring the parts for this set, since it is assumed that its assembly will not be attempted by an amateur until he has acquired considerable experience in receiver construction. A general understanding of radio principles, an insistence on neat work with careful attention to wire lengths, placing of resistors and capacitors, soldering and wiping of joints, and a fair amount of patience are the ingredients that make for a workmanlike product.

ALIGNING THE FM RECEIVER

Because of the need for a good signal generator and a high resistance voltmeter, the alignment should be turned over to a qualified serviceman. He will set his generator to 4,300 k.c. and feed the impulse to the first 6SA7 so that the three intermediate transformers are properly peaked. He will then adjust the primary of *L7* while he swings his signal generator 75 k.c. to either side of the mid frequency.

Although the oscillator may be ganged with the r-f stage, the experimenter will find that a separate control at this point will tend toward sharper tuning besides simplifying the adjustments which will be necessary before the two circuits can be made to track perfectly over the entire FM band.

COILS FOR AMATEUR BAND

If the amateur band of 144 m.c. rather than the broadcast FM band is the objective, the r-f and oscillator coils may be wound for the proper frequency range by altering the diameter of the low loss forms from ⅝ inches to ⅜ inches and keeping the number of turns the same for primary and secondary. However, for this purpose there will be some considerable gain in amplification as well as a better image ratio if the intermediate frequency is selected as 4.3 megacycles or more. It is probable that any current amateur publication will reveal the names of manufacturers equipped to supply such i-f transformers.

As indicated in the preceding chapter, a standard FM wide-band broadcast receiver may be used in conjunction with the proper converter to provide wide-band FM reception on any frequency, including the amateur microwave (uhf) bands.

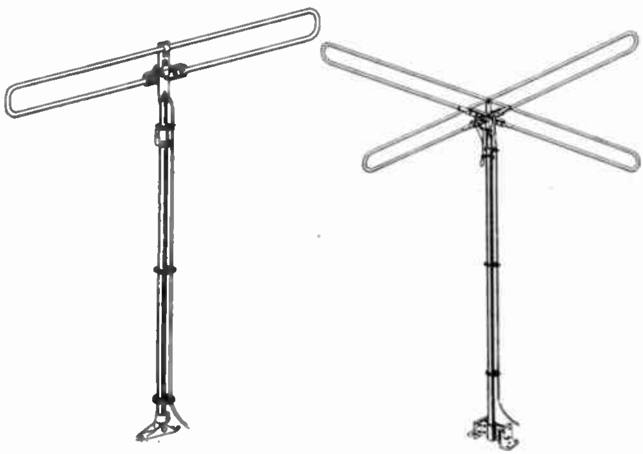
NARROW-BAND FREQUENCY MODULATION

What we have been describing in this chapter is known as wideband frequency modulation, where the frequency swings may be as high as plus or minus 75 kc (100 per cent modulation), meaning that the band width of the transmitter is 150 kc. When FM is used in the crowded radiophone bands below 30 mc, such swings are entirely out of the question because there simply isn't room for them. Therefore the transmitted signal is given a relatively small modulation index or deviation ratio so that the channel width it occupies is not greater than that occupied by an AM signal. A maximum deviation of 15 kc cannot be exceeded and this can be further reduced if a telegraphic signal alone is used instead of voice. However, narrow-band FM (NBFM), while it eliminates a certain amount of interference to broadcast reception, is said to be no more effective for communication than an equivalent AM transmitter operating at one-fourth its power input.

Four NBFM bands are assigned at the present time for amateur use—3.8 to 3.9 megacycles, 14.2 to 14.25 mc, 28.5 to 29 mc, and 51 to 52.5 mc.

FM ANTENNAS

While most FM broadcast receivers are now equipped with built-in antennas, there are a number of special FM antennas on the market that are designed to improve reception, provide broader



115. Two types of FM antennas. Left, folded dipole; right, folded "turnstile." (*Ward Products Corporation.*)

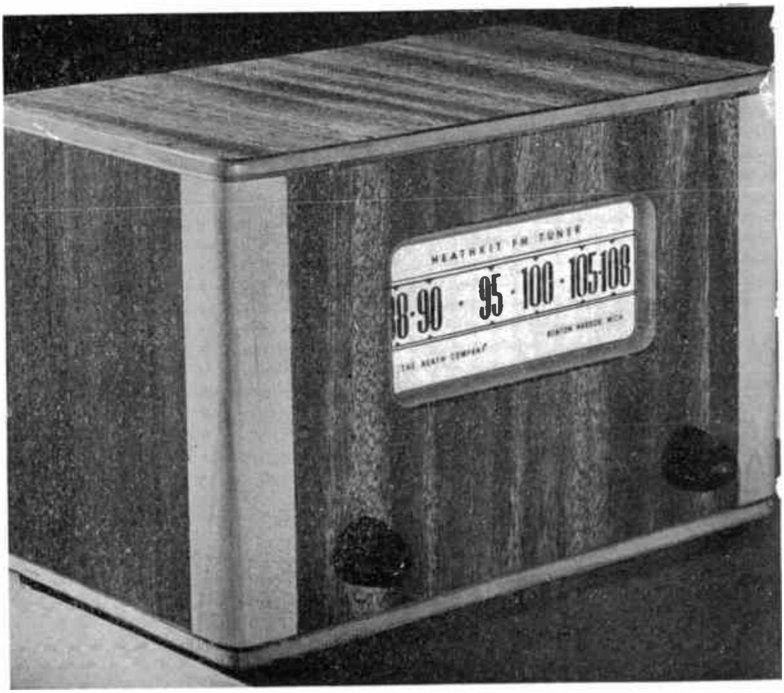
tuning, and give high signal gain over the entire 88-108 mc band. Figure 115 shows two of these antennas, which are sold in kit form, pre-assembled into component parts for quick installation. With the folded dipole the signal gain is greatest broadside to the dipole in both front and rear, and the mounting is adjustable for greater ease of orienting. The folded "turnstile" type is designed for an equal amount of signal gain from all directions and therefore requires no orienting. Five-foot mast extensions are also available from the same manufacturer to increase the height of the vertical mast, which may occasionally be necessary to improve reception.

CHAPTER

20

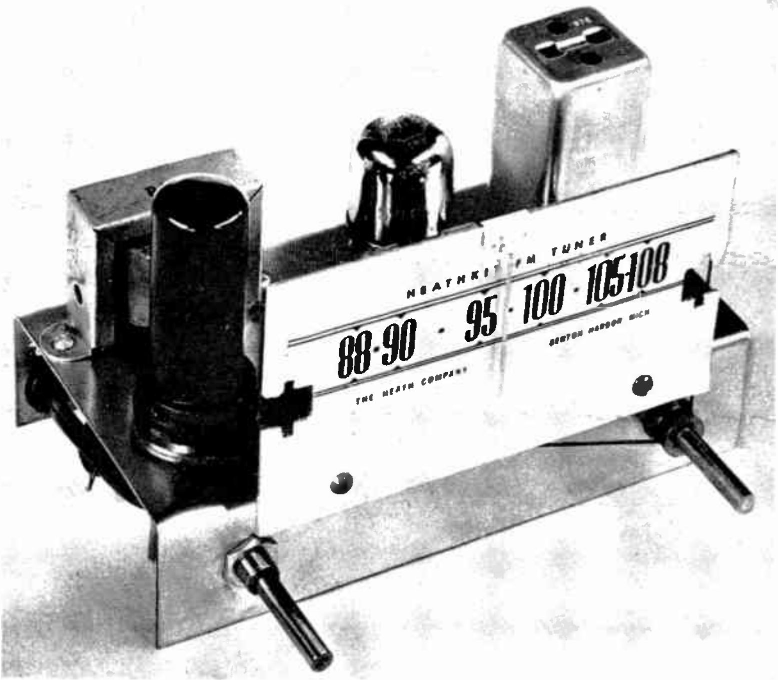
A Simple FM Tuner for 88–108 MC

The Heathkit Model FM-1 tuner is a simple, 2-tube adapter that can be connected to the phonograph connection or FM connection of any AM radio to provide static-free reception of all FM stations on the new FM band of 88 to 108 mc. It may also be connected to a separate audio amplifier to make a complete FM receiver unit. All



116. The Heathkit FM tuner for 88–108 mc. (*The Heath Company.*)

of the parts required for assembly are supplied in kit form by the manufacturer, The Heath Company, Benton Harbor, Mich. The material which follows is based on the Instruction Manual that accompanies the kit.



117. Heathkit FM tuner with cabinet removed. (*The Heath Company.*)

LAYOUT AND PARTS

Fig. 118 shows the schematic circuit diagram of the tuner, which operates on the superregenerative principle and uses a 110-volt 60-cycle power-transformer supply. The tubes are one 14F8 lock-in duotriode serving as oscillator-amplifier, and one 12A6 metal beam power amplifier. Because the tuner is operated by a power transformer, it can safely be attached to a-c/d-c receivers for amplification without any loss of performance. To make the assembly easier and insure proper operation of the unit, the manufacturer ships the kit with the tuning coils already assembled to the tuning condenser and with the i-f transformer mounted and aligned. The tuning condenser is also factory-aligned and set for peak performance; moreover, the trimmers are soldered to prevent misalignment during assembly.

Parts List for Heathkit FM Tuner

Description	Designated on Figs. 118, 119, 120, 121
1 100-ohm resistor	SW11
1 470-ohm resistor	O14
1 2,000-ohm resistor	O15
1 22,000-ohm resistor	SW13
1 27,000-ohm resistor	FM36
1 100,000-ohm resistor	O12
1 3-mmfd ceramic condenser	FM10
1 47-mmfd mica condenser	G24
1 470-mmfd mica condenser	MT10
1 1,000-mmfd mica condenser	FM11
1 1,000-mmfd ceramic condenser	SW17
1 .005-mfd condenser	O22
1 .01-mfd, 300-volt condenser	T13
1 12-mfd, 150-volt electrolytic condenser	V27
1 20-20-mfd, 150-volt electrolytic condenser	K13
1 Tuning consenser with coils	FM12
1 Rotary switch, SPST	FM13
1 14F8 tube	FM14
1 12A6 tube	K23
1 Loctal tube socket	FM15
1 Octal tube socket	O54
1 Octal socket ring	O43
2 Brown acorn knobs	FM16
2 Screw-type dual terminal strips	FM17
1 Single-terminal strip	O38
2 Dual-terminal strips	S32
1 3/8" lock washer	
14 6–32 × 3/8" screws	
3 6–32 × 3/16" screws	
16 6–32 × 1/4" nuts	
1 8–32 set screw for pulley	
1 Control nut	O33
1 Driveshaft nut	FM19
2 3/8" grommets	O35
3 Soldering lugs	O37
1 28" length of dial cable	FM20
1 Dial cable spring	
1 Slide pointer	FM22
1 Driveshaft	FM23

Description	*Designated on Figs. 118, 119, 120, 121*
1 Pulley	FM24
1 2-ft. length hookup wire	
1 4" length spaghetti tubing	
1 Line cord	O78
1 I-f transformer	FM27
1 R-f choke	FM28
1 Power transformer (P127)	K25
1 Punched steel chassis	FM29
1 Condenser mounting bracket	SW24
1 Dial plate assembly	FM30
2 Dial mounting brackets	FM31

ASSEMBLY

By this time the reader should be familiar with the first step in assembling any kit of radio parts—*check the parts against the parts list first!* In this kit the manufacturer has obligingly numbered each part in the list and in the illustrations so that it is almost impossible to go wrong. As noted previously, the manufacturer may, from time to time, make minor substitutions in the parts list, mostly in the resistors, but all such substituted parts will work equally well or better than the originals.

The socket connections of the large (octal) socket are numbered on the bottom of the socket, which is fastened into the chassis with the wavy metal ring, the later being forced over the bottom of the socket and into the grooves in the socket. The end of the ring can be held in the groove and the rest of the ring forced over and into the groove with a screw driver.

Begin the assembly by mounting the sockets. Note that the keyway in the octal (12A6) socket points toward the center of the chassis. The keyway in both sockets is between contacts 1 and 8. The loctal (14F8) socket has the keyway toward the power-transformer mounting holes.

Mount the i-f transformer next. The hole in the bakelite base of this transformer should be nearest the 14F8 tube socket, and the nuts on the mounting bolts should be removed so that the transformer can be mounted directly to the chassis. A 2-lug terminal strip mounts under the nut nearest the end of the chassis, while a single-terminal strip goes under the other nut. Be sure that none of the terminals of the transformer are touching the chassis or the terminal-strip mounting lugs.

Next, mount the dial brackets, the dial driveshaft, and the rotary switch; the latter uses a lock washer between the body of the switch and the chassis. The dial driveshaft takes a special nut (3/8" X 28) which will be determined by trying each of the two 3/8" nuts supplied with the kit.

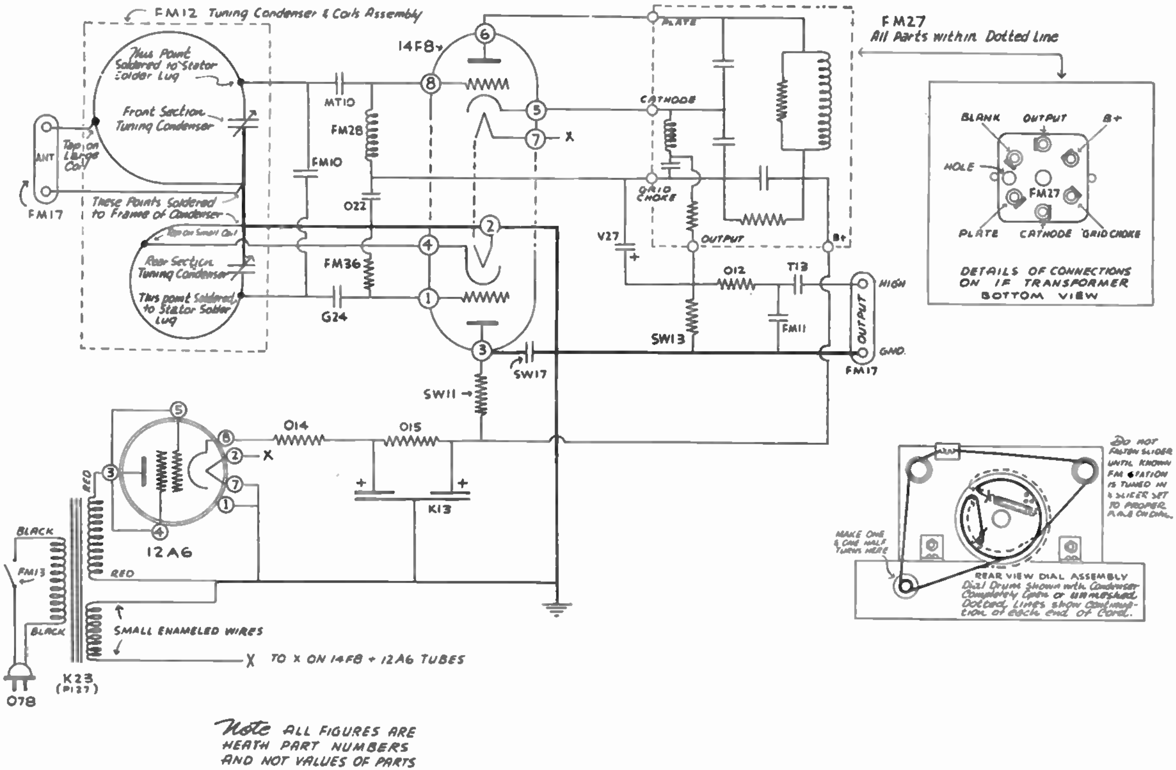
Then mount the condenser bracket (SW24) to the chassis, using a solder lug under the nut nearest the 14F8 socket and a dual terminal strip under the nut nearest the 12A6 tube. The dial drum is then attached to the tuning condenser with the flat side out and in the location shown on the inset to Fig. 118. The condenser is mounted to the condenser-mounting bracket with the special short 6/32 screws provided.

Next mount the two screw-type terminal strips (antenna and output connections) at the rear side of the chassis, as indicated by FM17 in Fig. 121. Use a solder lug under the nut of the mounting bolt nearest the end of the chassis. Mount the dial plate and adjust the mounting brackets to prevent the dial drum from rubbing against the dial plate.

Next cut two lengths of the spaghetti tubing and slide these over the small enameled wires of the power transformer (K25 in Fig. 120). Mount the transformer as shown, using a solder lug under the nut of the mounting bolt nearest the end of the chassis. Use a rubber grommet in the hole of the chassis through which the red and small enameled leads from the transformer are carried. The other grommet goes in the hole in the rear of the chassis through which the line cord passes. (A grommet is not necessary for the black rubber-covered transformer leads.)

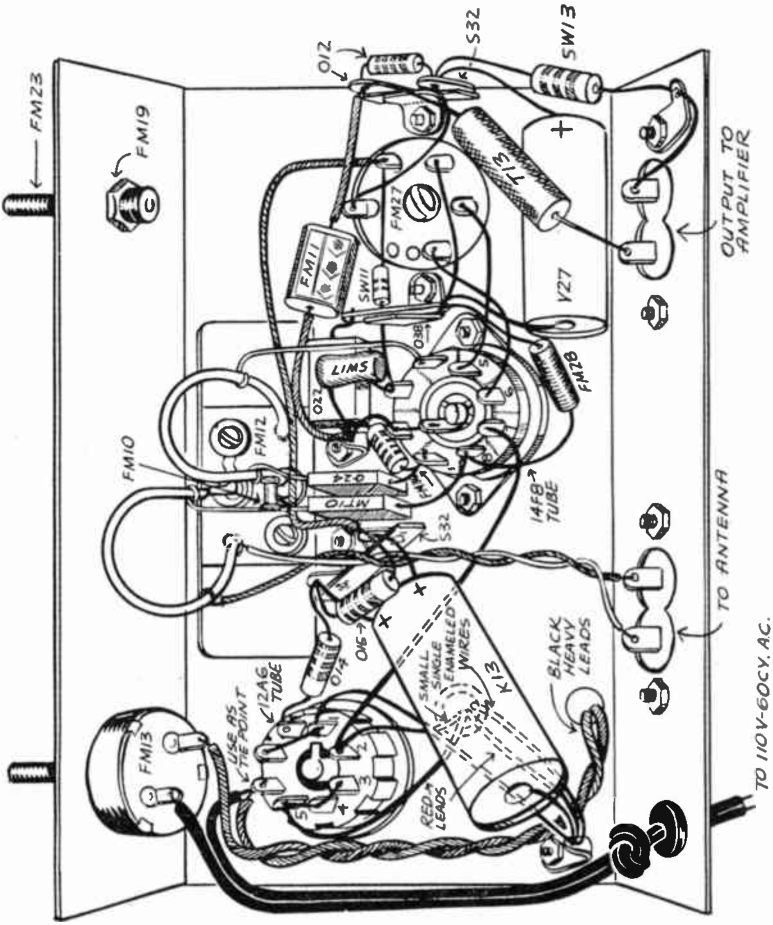
Note that all components shown within the dotted line in Fig. 118 and designated as FM27 are pre-assembled in the "can" or casing of the i-f transformer, which, as noted above, is already mounted on the chassis and aligned in the factory.

Now you are ready to begin the wiring. Start with the transformer leads and follow the schematic (Fig. 118) or pictorial diagram (Fig. 119). After all of the contacts that can be wired at this point have been connected, the resistors 014 and 015 are mounted, after which the filter condenser K13 is added.



118. Schematic circuit diagram of Heathkit FM tuner. (*The Heath Company.*)

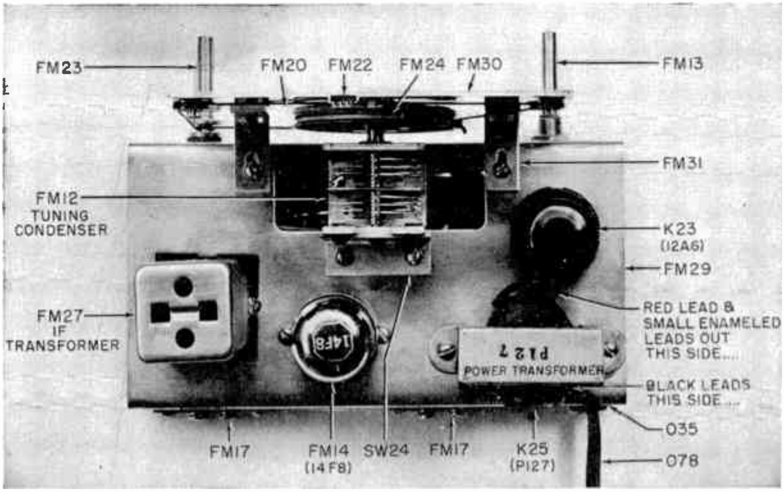
Next, condensers G24 and MT10 are installed and connected to the coils at the point of contact with the condenser solder lug. Use extreme care in handling these coils and in making this connection, for any bending or change of shape of these coils will affect



119. Pictorial wiring diagram of Heathkit FM tuner.

the performance of the tuner. The small 3-mmfd ceramic condenser (FM10) is connected across the two leads of the condensers G24 and MT10 near the smaller tuning coil (Figs. 119 and 121.)

The i-f transformer can now be connected. Join the B+ lead from the i-f transformer to the filter terminal strip as shown, being careful to keep it away from the 14F8 socket and other leads. The rest of the resistors and small condensers are now mounted and wired as indicated on the illustrations. Note that one of the antenna leads is already properly placed on the larger of the tuning coils. The other connection is made on the coil at the point where it is soldered to the frame of the tuning condenser. Be careful not to disturb the position of this coil in attaching the antenna lead.



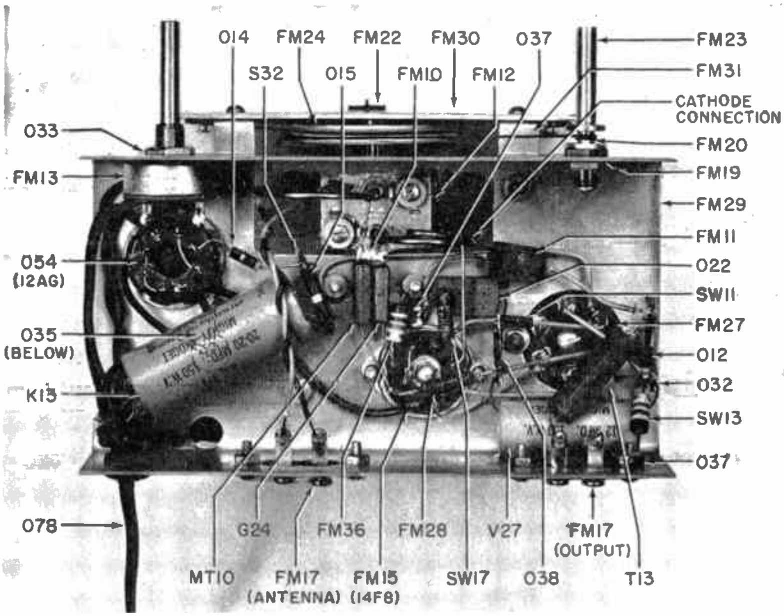
120. Top chassis view of Heathkit FM tuner with parts identified. (*The Heath Company.*)

The cathode connection also is already properly located on the smaller coil, and is carried directly to contact 4 of the 14F8 lock-in tube.

The final step in the wiring consists of connecting the line cord as shown in Fig. 119, placing a double knot in it inside the chassis to take any strain off the soldered connections.

The dial cable is then attached as shown on the inset to Fig. 118 and in accordance with the special instructions accompanying the kit.

Before connecting the line cord to a power supply, recheck the entire wiring step-by-step with the schematic and pictorial diagrams (Figs. 118 and 119). Follow each lead on these diagrams with a colored pencil as you trace it out on the tuner. Most frequent cause of trouble is reversed connections—have a friend check the wiring with you so that you won't consistently overlook the same error.



121. Bottom chassis view of Heathkit FM tuner with parts identified. (*The Heath Company.*)

OPERATION

"In connecting the tuner to an amplifier, be certain that the grounded side of the tuner is connected to the grounded side of the amplifier. The usual connecting cable is a single shielded wire and the grounded side is the shield. The tuner may be connected to the phonograph or FM connection of any radio. The connecting plug depends on the type of radio and should be obtained from the radio dealer. For local stations, a single wire approximately 3 feet long can be connected to one of the antenna terminals but for distant reception an FM dipole antenna is recommended with connections to both antenna connections. On single wire, try each post and use the one with the best results.

"In tuning FM, a high level of noise will be found between stations. Upon tuning an FM station, a point will be found where the reception is distorted and mushy—the proper tuning position is to one side of this position, where the reception is natural and pleasant. If, in tuning stations, the loud noise heard between stations is still heard with the station, it is an indication that a better or higher antenna is needed. FM antennas are quite directional and should be turned to the point of highest reception. Under normal operation, stations up to 10 miles away may be received with a short piece of wire, and reception up to 100 miles is possible with an FM dipole antenna. FM waves are high-frequency and reception over 100 miles is not customary."

In case difficulty is encountered and is not cleared up by a thorough recheck of the wiring, the voltages between the chassis and tube socket contacts should be measured and checked with the following table, which gives standard measurements taken at the factory with a 1,000-ohms-per-volt voltmeter; normal variation of ± 15 per cent is to be expected due to variations in the line voltages between 110 and 118 volts:

12A6 Tube		*14F8 Tube*	
Pin No.	*Volts*	*Pin No.*	*Volts*
1	0	1	0
2	9–12 (a.c.)	2	0
3	110–150 (a.c.)	3	110–140
4	110–150 (a.c.)	4	0
5	110–150 (a.c.)	5	40–50
6	(tie point)	6	110–140
7	0	7	9–12 (a.c.)
8	120–150	8	3–20

Figures 116 and 117 show the assembled tuner ready for operation.

CHAPTER

21

The Photoelectric Cell and Its Uses

The light-sensitive cell is not new. It is nearly sixty years old, originating about 1887 in the photoelectric experiments of Heinrich Hertz. From about 1900 on the cell was used for two generations by scientists who deplored its bad characteristics. When a large market for photocells was furnished by the motion picture industry, intensive development work was encouraged and produced great improvements. The vacuum tube amplifier in connection with a phototube made it really practical to use a beam of light as a medium of control. The phototube makes it possible to employ light for purposes other than illumination.

There are three types of light-sensitive cells. All are called indiscriminately "photocells," "photoelectric cells," and "phototubes." In popular language, they are "electric eyes." But they are far from that. Although a light-sensitive cell responds to light, it seldom sees as the eyes see. Its action differs radically.

LIGHT INTO ELECTRICITY

The function of a photoelectric cell is to transform light energy into electrical energy. This is done by three different methods, resulting, as already stated, in three different types of cells, namely:

1. *Photoconductive cells*, in which the resistance of a material to the flow of current is changed when illuminated by a beam of light. Selenium is the best example of this type of light sensitive material. Selenium is one of the chemical elements which belong to the sulphur family.

2. *Photovoltaic cells*, in which the passage of electrons from one surface to another is increased by illumination.

3. *Photoemissive cells*, in which a beam of light causes a surface to emit electrons.

THE SELENIUM CELL

Selenium is, in its crystalline state, very sensitive to light. Originally, selenium cells were made by winding a piece of slate, porcelain or some other suitable insulating material with two parallel, bare platinum wires. In such an arrangement the wires do not touch each other but have a space between. They form the electrodes of the cell and lead to the terminals. Over the wires is painted a thin layer of molten selenium. After undergoing a heat-treating process, during which the selenium is crystallized and then annealed, the cell is ready for operation. When the cell is illuminated, the resistance between the two parallel conductors decreases and more current flows from a battery through a relay.

Such an amateurish form of selenium cell had disadvantages. It suffered by aging, was affected by temperature, was slow in response, and the same cell did not always deliver the same current under the same change in illumination.

Modern technique involves placing the selenium element in a vacuum tube and using methods of manufacture which eliminate the undesirable effects of moisture and oxygen during the formation and annealing of the crystalline layer. Cells made in this way have very little time lag, that is, respond practically instantly, show small temperature changes, and remain practically constant in characteristics over a long period. Such cells are rugged and, where an "on-and-off" function is required and a slight lag in response is not objectionable, have an important place in controlling many machines and industrial processes.

THE PHOTOVOLTAIC CELLS

These are of two types, *dry* and *liquid*. The liquid type utilizes the Becquerel effect, a phenomenon in which an electromotive force or potential is created when one of a pair of electrodes immersed in an electrolyte is illuminated more than the other. The electrodes are usually a cathode of cuprous oxide and an anode of lead immersed in a dilute solution of lead nitrate. A good cell of this type will deliver as much as 3 milliamperes through 100 ohms in direct sunlight.

The dry type of photovoltaic cell has the advantage of portability. It consists of two dissimilar elements or compounds in contact. The Westinghouse Photox is a copper oxide photovoltaic cell

122. Weston Photronic Cell. (*Western Electrical Instrument Corporation.*)

which consists essentially of a copper disk, oxidized on one surface, a transparent film of metal being deposited on the oxide. The transparent conducting film is connected to one terminal while the bare copper is connected to the other. When illuminated so that light passes through the transparent film and strikes the copper oxide, the copper becomes positive with respect to the film.

The Weston Photronic Cell (Fig. 122) is a dry self-generating cell which delivers current when illuminated and operates on the same electronic principle as the Photox.

Such cells, connected to a suitable meter, have great value as simple portable measuring instruments for the determination of light intensity. Fig. 123 shows a Weston foot-candle meter actuated by a photronic cell. The instrument measures the illumina-

123. Weston foot-candle meter. (*Weston Electrical Instrument Corporation.*)

tion in foot-candles when it is placed on a surface with the light perpendicular to the photronic cell. Another example of this type of instrument is the familiar photographer's exposure meter.

PHOTOEMISSIVE CELLS

The two types of light sensitive tubes which have been described will operate sensitive relays directly. The photoemissive cell will not operate a conventional electromagnetic relay directly. It will, however, produce a large voltage change which may be led to the grid of an amplifier tube having a relay in the plate circuit. By means of a power amplifier tube, a heavy relay may be operated.

THE STRUCTURE OF A PHOTOEMISSIVE TUBE

A phototube of the emissive type consists essentially of two elements, a cathode and an anode, in an exhausted glass bulb, either spherical or cylindrical in shape, and in which there may or may not be an inert gas at a low pressure.

The cathode, which may be a metal plate or a thin film of silver deposited on the glass wall of the tube, is coated with a thin layer of one of the alkaline metals. Both the cathode and the anode are connected by wires to the prongs in the base of the cell, so that connections can be made to them from the external circuits. The number of electrons emitted by the cathode depends on the wave length and the amount of radiant energy falling on it.

Experimenters in photoelectricity found that the metals of the alkali group (lithium, sodium, potassium, rubidium, an caesium) have the property of emitting electrons when light that is visible to the human eye, as well as the so-called invisible light, falls upon them. From the structure of the atoms of these metals it was found that there were one or more electrons in each atom that were not as much under the influence of the positive nucleus as the others. Therefore, when light impinged on one of these alkali metals, the energy possessed by the light was transferred to the electrons in such a way that they became detached from their parent atom and went out into space. These electrons having a negative charge would be attracted to a positively charged body in the same way that the electrons emitted by the filament of a vacuum tube travel to the plate, which is positively charged with respect to the filament.

According to the latest theories advanced by scientists, light possesses a certain amount of energy, the unit of which is called a quantum, and the more intense the light the greater the number of quanta.

Summing up, light can be considered to be a series of drops of energy that is raining upon the light-sensitive surface of a photoelectric cell. Every time one of these drops of energy, a quantum, encounters an electron, the latter is released from the atom of metal with a certain amount of energy, which it uses to move toward the anode.

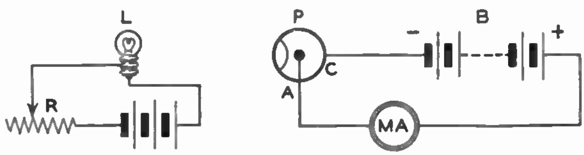
A great deal has been accomplished within the past few years in developing phototubes whose greatest response lies in particular parts of the spectrum. For general control purposes the gaseous cell, being more sensitive, is most frequently used. The gaseous tubes usually contain argon. For measuring light intensities, vacuum type phototubes are used because their response is more directly proportional to the light intensity.

HIGH-VACUUM AND GAS-FILLED PHOTOELECTRIC CELLS

When a given light ray of a certain color impinges on the cathode of a cell, a certain number of electrons are released from the cathode and go to the positively charged anode. It is important that their path between the cathode and the anode be as free from obstructions as possible, so that the resistance will be low and likewise the consequent losses. For this reason, all the molecules of air that possibly can be removed from the interior of the glass bulb are pumped out after the photosensitive surface is prepared. Such tubes having a comparatively small amount of gas in the bulb are called high-vacuum photoelectric cells.

On the other hand, it was found that when some gas of a nature that did not react with the chemicals of the cathode was left in the cell, the current from the anode was greater for a given amount of light than it was when a high-vacuum cell was used. The reason advanced for this action was that when the electrons in their journey from the cathode to anode encountered an atom of the gas, the resulting collision liberated another electron, which in turn went toward the anode. Perhaps this second electron collided with another gas atom and a third electron joined the other two. Of course, the more electrons coming to the anode and so going out to the external circuit meant an increase in current output. Therefore the gas introduced into the cell really supplies additional electrons, which are called secondary electrons, as they are the result of collisions by the primary electrons emitted from the cathode due to the action of the impinging light energy.

124. Two of the principal types of RCA phototubes. Left, gas-filled type 928; right, high-vacuum type 917. The anode is brought out on the cap in the 917. (*Radio Corporation of America.*)



125. Light energy from the lamp *L* can be varied by the rheostat *R* as well as the distance between *L* and *P*. Note that the positive terminal of the battery is connected to the anode *A* and the negative terminal to the cathode *C*.

ACTION OF A PHOTOELECTRIC CELL

In Fig. 125 an electric lamp, *L*, is powered by the battery and the current going to the filament can be regulated by the rheostat, *R*. *P* is a photoelectric cell with its window opposite *L* and to its cathode, *C*, is connected the negative side of the battery, *B*, the plus side of which is connected to a microammeter (measuring millionths of an ampere). The anode *A* of the cell, *P*, has impressed on it a positive potential from *B* through the microammeter, *MA*.

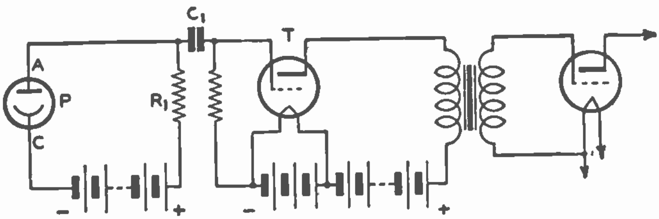
Let us assume that all the resistance of *R* is cut out so the lamp *L* will give out as much light energy as possible. This will pass to the photoelectric cell, *P*, and be received on *C*, the cathode, as a certain intensity of light. This intensity will vary with the distance *P* is from *L*, the proportion being the square of the distance; that is to say, if an intensity of perhaps 10 lumens is reaching *C* when *P* is 1 foot from *L*, if the distance be increased to 2 feet then the intensity will drop to 2.5 lumens. Let us assume further that with 10 lumens the microammeter will read 20 microamperes.

Now resistance is introduced in the filament circuit of *L* by cutting in some turns on the rheostat and the light energy passing to *P* is reduced. This will result at once in a reduction of the current indicated on *MA*. The more resistance that is cut into the circuit of *L*, the less light will fall upon *C* and as a result, the less current will flow through *MA*. The same reduction in current could be obtained by keeping the light source constant and increasing the distance between *L* and *P*, as was mentioned above.

However, this will show that the less light that impinges on *C* will result in a smaller flow of electrons to *A* and so a smaller current in the output, as indicated on *MA*. This action can be thought of in terms of an increased resistance between *C* and *A*; the less light coming to *C*, the greater is the resistance in the *C*-to-*A* circuit. and therefore, the less current flow. The amount of voltage in the battery *B* is of importance and the value recommended by the manufacturer should never be exceeded. If it is, it is liable to reduce considerably the useful life of the cell.

UTILIZING THE PHOTOELECTRIC CELL

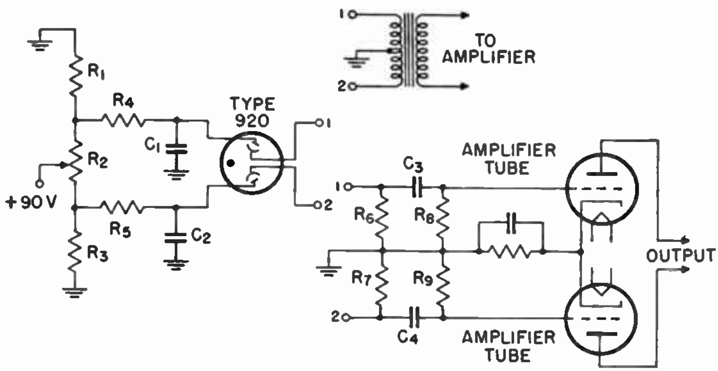
The output current of a photoelectric cell is measured in microamperes, which is an extremely small unit. (For example, the current consumption of the filament of a 201-A vacuum tube is 0.25 ampere, which is equivalent to 250,000 microamperes.) Such a minute current and a consequent small voltage must be amplified before it can be put to any useful work, so the output of a cell can be connected to a circuit such as is shown in part in Fig. 126. This will be recognized as a combination of resistance and transformer coupling. The necessary anode voltage is impressed on that element A of the cell P through the resistor, $R1$, the negative terminal of that battery being connected to the cathode, C. The *variations* of the current coming from A act on the condenser, $C1$, like alternating current and charge and discharge $C1$, producing a varying voltage on the grid of the amplifying tube, T. The output of this tube is connected to an a-f transformer through which the voltage is further amplified by one or more stages if necessary.



126. Circuit for amplifying the output of a photoelectric cell so that the current will have sufficient strength to actuate a relay.

Of course, the use to which the current from the photoelectric cell is to be put will determine the type and amount of amplification necessary. If the cell is being used in conjunction with the reproduction of sound-on-film motion pictures (Fig. 127), then a great deal of amplification must be introduced before the currents are of a sufficient size to actuate the loud speakers. Also the amplification must be carefully controlled to see that no distortion enters. However, when cells are used for controlling the starting or stopping of certain operations or for counting operations, then the amount of amplification is not so large nor is distortion an important factor.

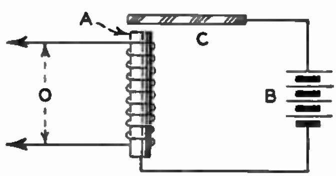
In the latter operations use is made of a device that is called a relay. This consists of a coil of wire through which the current from the anode of the cell flows, after amplification. Let this output circuit of the cell be O, as in Fig. 128. Within the coil of wire is a movable piece of iron called the armature, A. When current flows through the coil, the magnetic lines of force set up by the current will cause the iron to move upward (or downward, as the case may be) and so close a circuit, one contact of which is C, and the other is perhaps through the armature. Thus a relatively small current can control one of great magnitude, because as soon as the current stops flowing or falls below a certain level in the coil, the armature will drop, opening the second circuit.



R_1, R_2, R_3, R_4, R_5 = 0.5 MEGOHM — R_8, R_9 = 1 TO 5 MEGOHMS

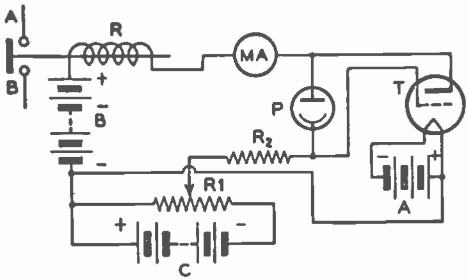
R_6, R_7 = 0.1 TO 5 MEGOHMS — C_1, C_2, C_3, C_4 = 0.1 μf

127. Typical circuit for twin RCA phototube type 920 with either transformer or resistance coupling for sound reproduction. (*Radio Corporation of America.*)



128. When current flows through the coil, the armature *A* sets up magnetic lines of force which pull down the contact *C*, closing the circuit. *O* is the output of a photoelectric cell.

In Fig. 129 is a diagram of an amplifier circuit that is designed for d-c operation, although if desired the filament of the vacuum tube may be heated by a-c. *P* is the photoelectric cell with the anode connected to one side of the milliammeter, *MA*, and the cathode connected to the resistor, *R2*, known as the grid resistor. This same side of *R2* is connected to the grid of the amplifying vacuum tube, *T*, the plate of which is connected to the anode of *P* and *MA*. *R1* is a potentiometer that is shunted across a 45-volt battery, *C*, the plus side of which is connected to the minus side of a 90-volt battery, *B*. The plus side of *B* is connected to one side of the relay's coil, *R*, the other end of which is connected to the milliammeter. The small circles, *A* and *B*, at the relay indicate the terminals for the external circuit which the current in *R* will control through the movements of the armature. It is assumed that when a current flows through *R* the armature will be pulled to the right and close the circuit from *A* to *B*.



129. When light impinges on the cathode of *P*, the resulting current flow causes the grid of *T* to become positive with respect to the filament and thus an increased current will flow from the plate.

First assume that no light is falling on the photoelectric cell, *P*. The circuit through the cell then can be said to have maximum resistance, making the grid of *T* negative with respect to the filament, which bias has been established by the setting of *R1* and the value of the battery *C*. Thus, no current—or perhaps a minimum current —will flow through *R*. If light energy be allowed to impinge on the cathode of *P*, then a certain current will flow in accordance with the intensity of the light. This current will flow because of the positive potential impressed on the anode from *B*, through *R* and *MA*, with its return circuit through *B*, a portion of *R1* and the whole of *R2*. In this latter resistor there will occur a voltage drop, and this is an important point. This voltage, or *IR* drop, will cause the grid of *T* to become more positive with respect to the filament, and when this occurs it results in an increased flow of plate current. The increased flow of plate current will mean an increased flow through the relay's coil, *R*, and this will be sufficient to energize the relay so that the armature will move to the right and close the circuit through *A* and *B*. As long as this larger current flows the relay armature can be made to stay toward the right, but when the current is decreased, due to the lessening of the light intensity falling on the cell's cathode, then by means of a spring the armature is released, opening the circuit through *A* and *B*.

Such a circuit can also be made to function in the reverse manner, i.e., when the light is increased on the cathode, the plate current of *T* can be made to decrease, thus opening the relay and the *A–B* circuit.

PRACTICAL USES

If all the known uses to which the photoelectric cell is put were now to be listed, by the time this book was in the reader's hands that list would be incomplete. In the research laboratories of every large electrical company experiments are being conducted wherein new uses for cells are being discovered.

In general, the functions of a photoelectric cell can be divided into two groups: starting and stopping operations; and continuous operations.

Under the first classification would be placed counting operations. Here the objects to be counted intercept a beam of light falling on the cathode, and each time the beam is shut off the plate current of a vacuum tube may be made to decrease and so open a circuit through the medium of a relay, which would actuate a counting or tally device. Such objects might be wooden boxes on an endless belt, or barrels. (Figs. 130 and 131.) On the other hand, if the objects being counted would reflect light to the cathode of the cell, the light source could be on the same side of the objects as the cell and when one of the objects passed through the beam of light, it would be reflected to the cell, causing a relay to function. as described above, and so actuating a counter. If the objects themselves emit light energy, as is the case of red-hot ingots in a foundry, then the light source could be eliminated.

Photoelectric cells have proven to be accurate when used in counting devices; more accurate, in fact, than a man, because they proper proportions are determined generally by the color of the mixture. While some human eyes are quite sensitive to small changes in color, the photoelectric cell can detect the most minute variations, and without fatigue. Such uses of a cell can be made in the grading of objects by their color, as selecting oranges, bananas, etc., or putting cigars into different groups; in short, almost any job that the human eye can do, the photoelectric cell and its attendant apparatus can do also.

CHAPTER

22

Television

Few industries have made such tremendous strides in the past few years as television, which at the present time is the fastest growing industry in the United States. In November, 1949, there were over 2,000,000 television sets in operation, with an estimated audience of more than 8,000,000. In the 12-month period from April, 1948, to April, 1949, the number of television stations in the country jumped from 16 to 64, so that today there are television stations in 42 cities and 28 states, with applications pending for the construction of over 300 additional stations. It is estimated that by the end of 1949 there will be over 3,000,000 television receivers in use, and over 6,000,000 by the end of 1950. By 1955, the estimates continue, there will be nearly 1,000 television stations in the country. "I predict that within three years the broadcast of sound, or ear radio, over giant networks will be wiped out," said Merlin H. Aylesworth, former president of the National Broadcasting Company in a *Look* magazine article for April 26, 1949. "Powerful network television will take its place, completely overshadowing the few weather reports and recorded programs left to the remaining single, independent ear radio stations." There are radio men who strongly disagree with such a sweeping prediction, but the very fact that it was made by a responsible authority is an indication of the impact that television is making in radio circles.

Television today is already a major medium of entertainment. The average program day now begins at 10 a.m. and continues on until after 11 o'clock in the evening—in New York City at least, where there are six television stations offering about 225 hours of programs each week. These programs, in the order of time allotted to each, include the following types: Motion-picture films; comedy-variety shows; children's programs; musical programs; sports events; interview-discussion programs; women's programs; news programs and commentators; "live-talent" studio plays; quiz programs; religious programs; and educational programs.

Television receivers vary in size today from the midget 2 × 3-inch screen to the giant 3-foot × 4-foot panorama projection re-

132. DuMont 15-inch table-model television receiver. (*Allen B. DuMont Laboratories, Inc.*)

ceiver which uses a regular movie screen, with the most popular screen sizes being roughly 9 × 6¾ inches (10-inch tube) and 13 × 9¾ inches (16-inch tube). Receivers with 10-inch tubes range from $175 to $325 in price at the present time, with every indication pointing toward a steady reduction in price together with improved performance. Many new models now have a 16-inch tube and sell for about $450.

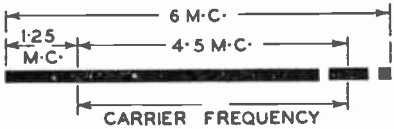
TELEVISION TECHNIC

Modern electronic television is only 10 years old, having been inaugurated on April 30, 1939, at the opening of the New York World's Fair. Mechanical television, using flat circular scanning disks having a spiral of small holes, dates back to 1884, when the German scientist Paul von Nipkow succeeded in transmitting a somewhat coarse-grained picture over a wire circuit by means of a single photosensitive cell placed behind the rotating disk. The American inventor G. R. Carey is said to have developed a rudimentary selenium-cell television system as early as 1875 but the apparatus was too cumbersome for practical use. None of the early experimenters succeeded in producing even passable television pictures, mainly because the photocells used were too weak. With the development of the vacuum-tube amplifier by De Forest in 1907, mechanical television gained a new lease on life and by 1930 Baird of England had transmitted pictures across the Atlantic while Alexanderson of the General Electric Company had shown television pictures on a 6-foot by 7-foot movie screen. Even with the best mechanical equipment, however, these television pictures were of low quality and poor definition, and no great improvement in television took place until the invention of electronic beam scanning in the early 1930s, which revolutionized television and made possible the present system of high-quality definition and picture brilliance.

Commercial television in the United States, seemingly off to a good start in the summer of 1939, when the first major-league baseball game was televised, was held up for 15 months (or until July, 1941) while the Federal Communications Commission investigated the proposed standards of transmission and television broadcasting. The new standards called for a picture definition of 525 lines (see below) instead of the 441 lines used up to that time. The war brought the struggling industry almost to a complete halt, although research and experiment continued and coaxial networks were laid between Philadelphia, New York, Washington, and Schenectady. In 1945 the FCC reallocated the channels used by television stations to the present range of 44 to 216 megacycles, thus increasing the old range of 50 to 108 megacycles. The present television channels or frequency bands are as follows:

Channel No.	*Megacycles*	*Channel No.*	*Megacycles*
1	44–50	8	180–186
2	54–60	9	186–192
3	60–66	10	192–198
4	66–72	11	198–204
5	76–82	12	204–210
6	82–88	13	210–216
7	174–180		

The possible use of color television, which has now reached the state where it is entirely practical, has been held up by a decision of the FCC to restrict television broadcasting to black-and-white images in the interests of better standardization. However, because of the already crowded condition of the video channels and the prospect of some 1,000 television transmitters in operation in the next few years, there is the possibility that the FCC will in the near future again reallocate the channels from their present vhf position to the uhf range above 300 megacycles. According to Mr. Wayne Coy, chairman of the Federal Communications Commission, such a shift is not likely for "a considerable length of time," but when it takes place existing sets can be converted to the uhf band with relatively little trouble. The biggest problem of video crowding is the fact that a television transmitter requires a channel 6,000 kilocycles wide, as compared with the 10-kilocycle channel of a standard AM broadcasting station.



133. Arrangement of picture and sound signals in each television channel.

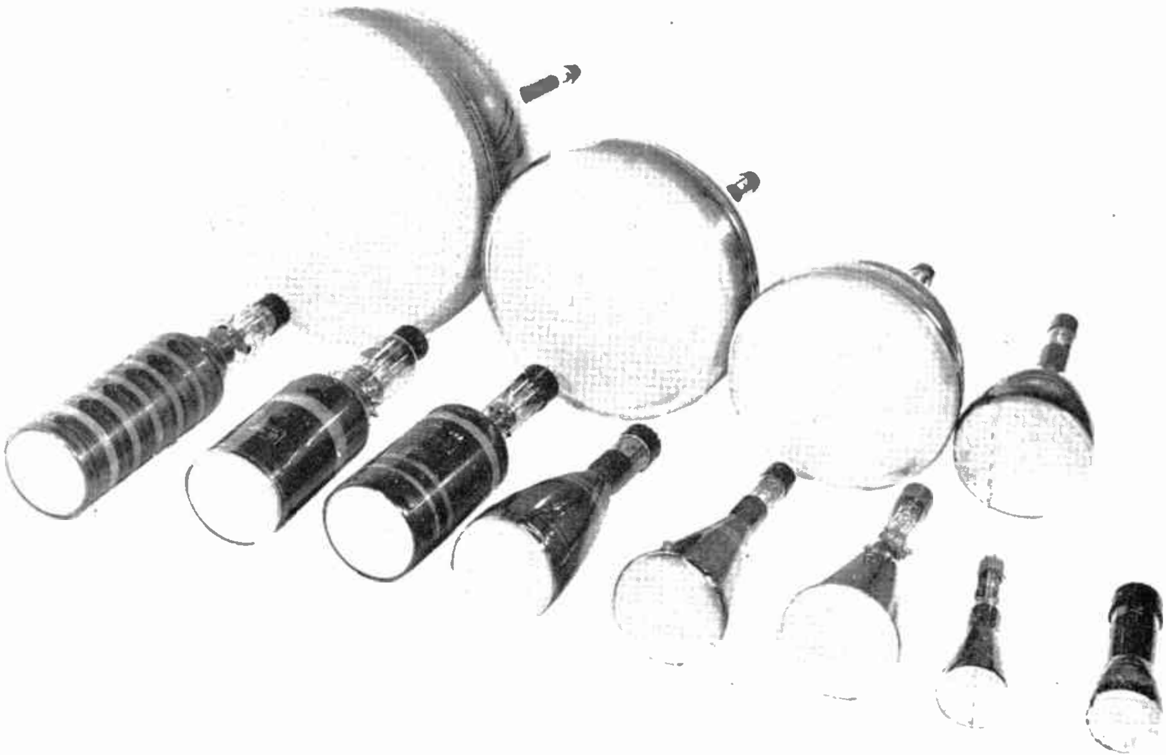
The 6,000 kilocycles embraced by each television channel is necessary in order to accommodate a picture signal 4,500 kilocycles wide (4.5 mc) and still leave room for the audio or sound wave. By a general working agreement between the FCC and the Radio Manufacturers Association (RMA), standards have been established which all transmitters follow. Thus the individual channels are utilized by every station in the manner shown in Fig. 133. A study of this arrangement will reveal one unusual feature. For instance, the wave band assigned to the video signal is unequal on the sides of its carrier. This is caused by the fact that only a portion of one side band is used, while the entire width of the other falls within the channel. This is called vestigial side-band transmission. By adopting it, a great deal of spectrum space is saved. It also has other advantages in transmission and reception.

In addition to the coaxial cable network, which now extends west to St. Louis, south to Richmond, Va., and north to Boston and Schenectady, there are radio-relay stations located about 25 miles apart between big cities—New York and Boston, New York and Schenectady, New York and Philadelphia, Chicago and Milwaukee, and Detroit and Toledo—which pick up the original television signal, amplify it, and send it on to the next relay in a focused straight-line beam, so that the normal 50-mile range of the television transmitter is extended and the signals are, in effect, made to follow the curvature of the earth.

THE CATHODE-RAY TUBE

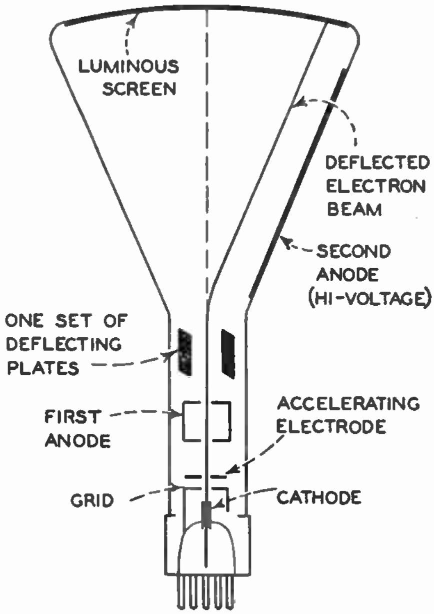
The heart of every television receiver is the cathode-ray tube (Figs. 94 and 135). This tube, described in Chapter 15, was familiar to many amateurs before the advent of full-scale television through its use in oscilloscopes, and is known as a *kinescope* in television practice. The electron beam previously described on page 180 scans a fluorescent screen on the end of the tube in much the same manner as in the oscilloscope, except that the beam intensity is controlled by the amplified picture signal from the television receiver. In the less expensive sets, where the *C.R.* tube is likely to be one of the smaller types, deflection is accomplished by means of plates placed inside the tube. Such a tube is called an *electrostatic type* in contrast to the *electromagnetic type,* which depends for deflection on coils wrapped around the tube neck.

Fig. 135 shows the essential parts of the kinescope type of cathode-ray tube. The electrons thrown off by the heated cathode are drawn toward a positively charged electrode which contains a pinhole through which a very small beam of the fast moving elec-



134. DuMont cathode-ray tubes: 20-inch, 15-inch and 12-inch television tubes and industrial types (oscilloscope tubes, etc.). (*Allen B. DuMont Laboratories, Inc.*)

trons can pass on their way to the screen. A short distance farther on, the electron beam encounters another electrode which further shapes the beam to a small diameter and gives it added impetus toward its destination. Emerging from this electrode, the beam passes between two sets of plates—one set placed horizontally and the other vertically. These are the deflecting plates. After passing



135. Simplified details of a kinescope cathode-ray tube.

these plates the beam encounters the heavily charged second anode which gives it a terrific velocity so that when the electrons strike the fluorescent screen, their impact creates a luminous spot, thus providing visual evidence of their presence.

Let us return now to the deflecting plates. We know that any body charged, for example, with a positive charge, will be attracted by the negative pole of a magnet and deflected or repelled by the positive pole. The deflecting plates of a cathode-ray tube work in the same way. The electron beam, being negative, will be turned one way or another if it encounters a positive or negative field. This is shown with one set of plates in Fig. 135.

Two sets of plates are required in order to scan a television image. One set moves the beam sidewise from left to right while the other exerts its varying force to shift the beam up and down. By a combination of the two forces, the electron beam can be made to create any desired pattern on the screen.

So much for the movement of the beam. It now becomes necessary in television to vary the brightness of the spots on the screen in order to have a halftone picture. This is done by placing a control grid very close to the hot cathode of the tube. The grid position is shown in Fig. 135. This grid is controlled by the signal transmitted from the sending station, and when properly adjusted will alter the number of electrons, leaving the cathode from maximum (bright screen spot) to minimum (black).

The voltages required to operate the various electrodes of a cathode-ray tube are dependent on the screen size and extend from a maximum of 25,000 volts in the case of the 20″ diameter tube to 1,500 volts or less for the 3″ tube. This high voltage is applied to the second anode and second grid only and determines the brilliance of the picture. The voltages on the other electrodes are increased gradually, beginning with the accelerating electrode which is closest to the cathode.

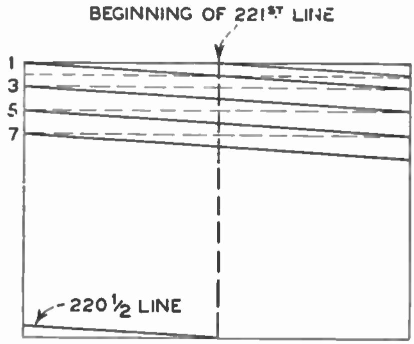
Each set of deflecting plates is connected to a push-pull amplifier which in turn is fed by voltage impulses originating in an oscillator tube adjusted to function at a definite frequency. Thus the horizontal oscillator works at a frequency of 15,750 cycles per second, while the oscillator intended to energize the vertical plates of the cathode-ray tube works at only 60 cycles per second. The reason for these particular frequencies will be discussed below.

Very recently a revolutionary new projection-type television picture tube, known as the *Protelgram*, was introduced on the market by the North American Philips Company. It consists of a 2½-inch-wide tube about 12 inches long combined with a hardened gelatin lens and two mirrors, the unit giving an undistorted 12- by 16-inch projection picture said to be the equivalent in brilliance and definition of much larger and more expensive cathode-ray tubes.

THE SCANNING PROCESS

Television transmission consists in breaking up an image into minute units, and reforming these units in the same order at the receiver. The process is called *scanning*. There are several methods in use but only the American system will be mentioned here.

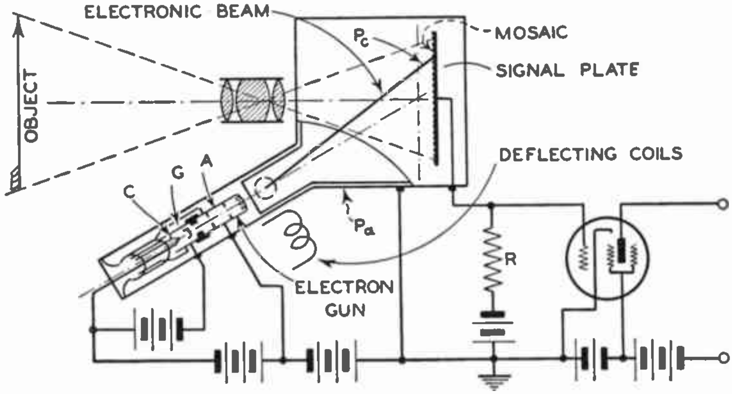
Just as in a newspaper illustration the finer the dots the clearer the picture, so in television the better image will be produced when the maximum number of individual pin points of light are present on the luminous screen of the cathode-ray tube. But there is an electrical limit to the fineness of detail which can be transmitted



136. Interlaced scanning system used in the United States.

since roughly each dot represents a cycle in the allotted band. Realizing this, the firms interested in television carried out many tests and it was finally agreed that a satisfactory picture could be transmitted using 525 lines. On this basis a square image would be the equivalent of a picture with close to 275,000 individual gradations of light. However, this is not believed to be the ultimate fineness of television images, a prophecy which is bolstered by the activities of several research groups who are working on a 625-line picture in the belief that television images of outdoor sports will not be acceptable until they have become as fine in detail as the best of newspaper illustrations.

In scanning an object at the transmitter, use is made of a camera device called an iconoscope or orthicon, which, like the cathode-ray tube, makes use of an electron gun. First the image is focused on a sensitized plate within the tube after which a fine beam of electrons is played back and forth across the plate. The reflected light from the object striking the sensitized plate generates small charges which, when struck by the electron beam, are released into an amplifying circuit and eventually, when sufficiently strengthened, are used to modulate the transmitter. Fig. 137 shows a typical iconoscope arrangement.



137. Simplified circuit of an iconoscope tube and signal amplifier.

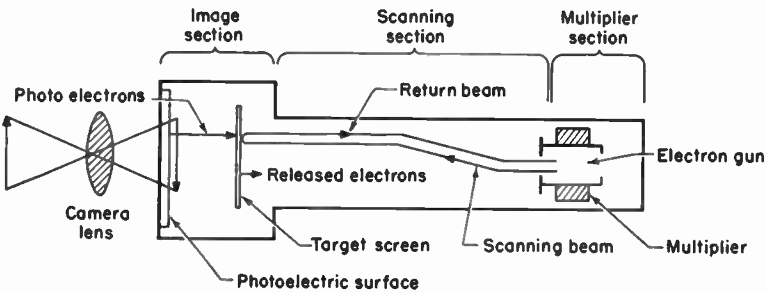
The American system of television does not build up its image by transmitting the 525 lines in consecutive order because of the bad flicker effect that would then be produced. Instead, the camera scans one line, skips the second and scans the third and so on until 262½ lines have been scanned (Fig. 136), after which the beam returns to Line No. 2 and proceeds to complete the image at the 525th line. In reality, this system transmits sixty half pictures or *fields* per second or thirty complete *frames* per second.

At the receiving end, the procedure is reversed with the beam of electrons painting narrow strips of the picture in alternate sequence from top to bottom of the screen and then returning to the second line to fill in the open spaces.

In a preceding paragraph it was stated that one of the deflation oscillators of the receiver was adjusted to generate a frequency of 15,750 cycles per second. This figure is arrived at by multiplying the number of lines per frame by the number of frames per second.

Thus 525 times 30 gives 15,750. The other oscillator functions at a frequency of 60 cycles per second because of the half frames which are transmitted during that time.

A new type of television camera tube, known as the *image orthicon* (Fig. 138), was developed in the RCA laboratories in 1943 to solve the problem of lighting requirements where the amount of light available for transmitted scenes is not sufficient to make adequate impression on the relatively insensitive iconoscopes. The tube, which is said to be capable of picking up a picture by the light of a match, is quite different in principle from the iconoscope in that the electrons emitted from the sensitized mosaic strike a

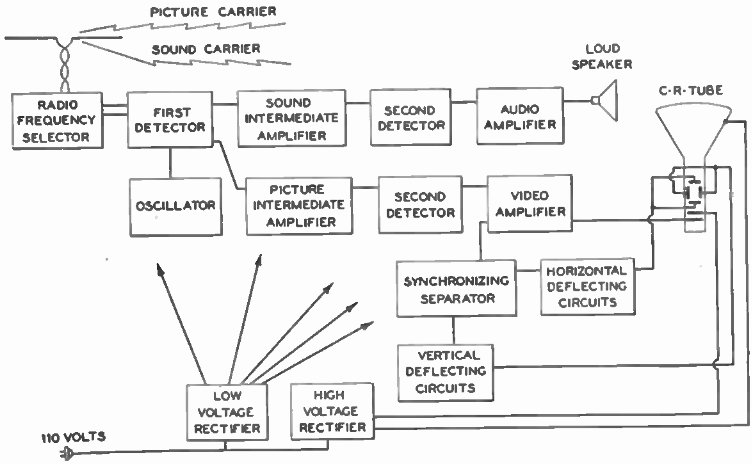


138. Simplified detail of image orthicon television camera tube.

"target" or positively charged grid, where they knock off a number of electrons from the target face and produce the equivalent of a photographic negative in terms of positive (remaining) electrons. The target is scanned by an electron beam from an electron gun in the base of the tube, but, unlike the scanning beam of the iconoscope, the image orthicon's beam is returned to the base of the tube to be amplified and broadcast. The amplification is performed by a device called an electron multiplier also located in the base of the tube.

TELEVISION RECEIVER CIRCUITS

The sound portion of a television broadcast is transmitted by frequency modulation, not only because it is relatively noise-free and allows a wider dynamic range to be utilized, but also because it is a simpler engineering problem to design a receiver in which the sound and video signals operate in the same frequency spectrum, for FM, as we have seen, operates in the 88-108 megacycle band, while TV ranges from 44 to 216 megacycles. Because of the standard arrangement of video and sound channels (see block diagram, Fig. 139), receiver operation can be simplified by so arranging tuning controls that both picture and sound are brought in with one motion.



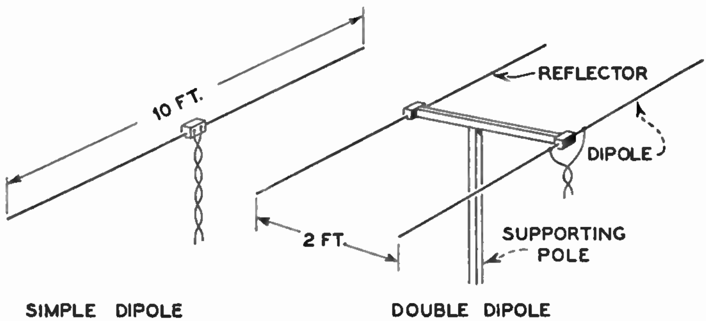
139. Block diagram of a television receiver of the superheterodyne type.

The superheterodyne circuit is now standard for television receivers. By admitting the full 6-megacycle band width to the receiver and heterodyning video and sound signals simultaneously with a single local oscillator, it is possible to produce two new frequencies (intermediate frequencies) which can then be separated and carried to a loud speaker (for the sound) and a cathode-ray tube (for the image). If a tuned radio frequency circuit were used instead of a superheterodyne, two separate receivers would have to be assembled for sound and image and both tuned independently. Moreover, the large number of r-f stages that are necessary for the video would complicate the assembly.

The average circuit for a television receiver with a 10-inch picture tube embodies seventeen or eighteen tubes, twelve or thirteen of which are for the picture and five for the sound. Included in this array are two power supplies. One provides the high voltage of about 9,000 for the second anode of the picture tube and the other delivers all remaining plate and screen potentials for the vacuum tubes in video and audio circuits.

TELEVISION ANTENNAS

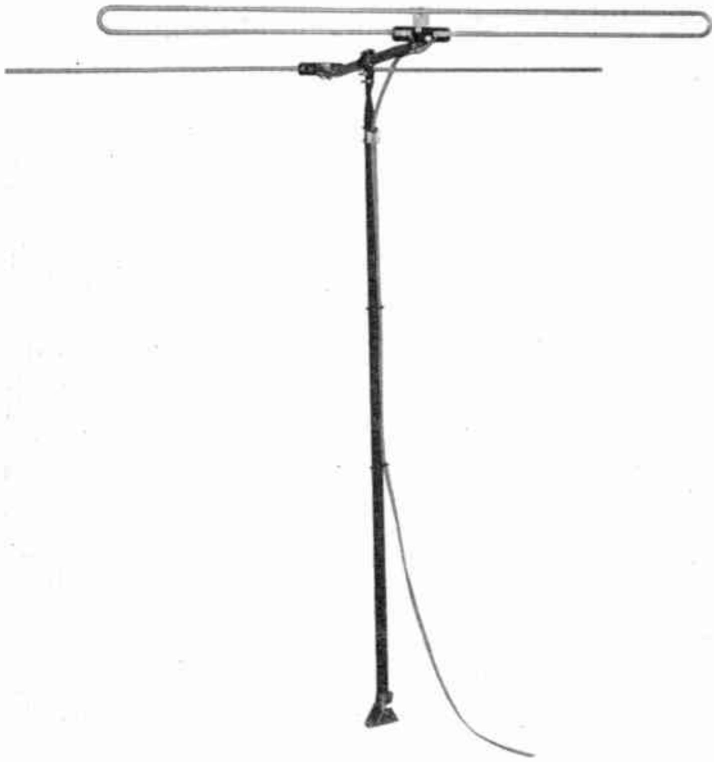
Because of the necessity for a powerful signal free from noise with which to actuate a television set, a tuned half-wave dipole has come into general use. In its simplest form this consists of a metal rod about ten feet long, split in the center and connected from its



140. Two popular forms of television antennas.

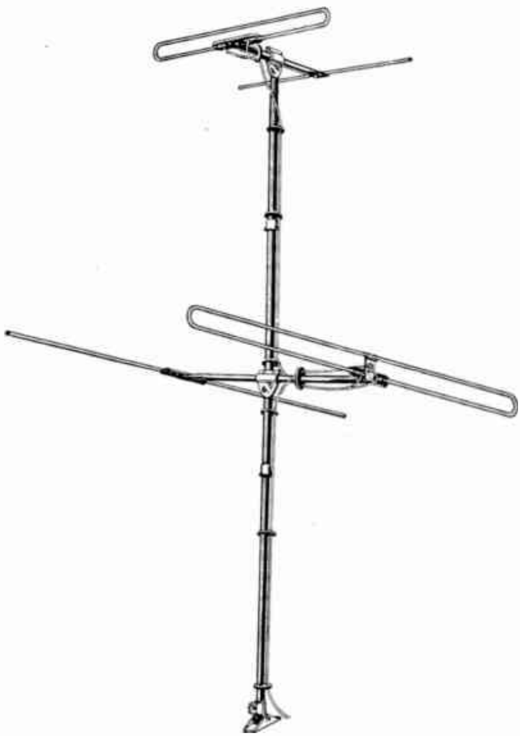
inner ends by means of a high efficiency lead-in to the input of the televisor. Where noise is rampant, such as in heavily populated areas or where the signal is weak as would be the case at all listening posts more than forty miles from the transmitter, a more elaborate double dipole is recommended (Figs. 140 to 142). The dipole must be erected with the rods at right angles to the line of sight from the antenna location to the transmitter and it should be elevated as high as possible above all buildings, trees, and other structures.

With the great increase in home television receivers in the past year, the problem of outdoor antennas is becoming a serious one, particularly for apartment dwellers. A tenant may not install a roof antenna without the landlord's permission, and the landlords are not too ready to grant permission, for obviously there is not enough room on the average apartment roof to accommodate all the tenants who want to erect antennas. Moreover, TV antennas should not be installed too close together, otherwise cross-interference will re-



141. Folded dipole and reflector television array. (*Ward Products Corporation.*)

sult. Two solutions seem possible to the problem of apartment-house antennas—the master antenna, proportionately large and expensive, to serve all of the tenants under one rooftop, consisting of a separate antenna oriented for each television station in the area, with all programs fed through a common lead-in cable to each apartment; or (what is more practicable) an improved indoor antenna of the telescoping variety which may be moved about the room until the best location is obtained. Several makes of indoor antennas are now on the market and give satisfactory results. However, just as the modern radio no longer needs an outdoor antenna for all ordinary reception purposes, it may be expected that improvements in television receiver design will largely eliminate the need for outdoor antennas in the not too distant future.



142. High-band television array consisting of two folded dipoles and reflector units at right angles, the upper unit designed for high-signal reception in the 174-216–megacycle band. (*Ward Products Corporation.*)

CHAPTER

23

Building Your Own Television Receiver

The home construction of high-quality television receivers is no more difficult, in terms of skill required, than the home construction of radio receivers and amplifiers. However, the TV receiver circuit is naturally much more complex, so that there are a greater number of parts, a good deal more wiring to be done, and the necessity of following with utmost attention to detail the methods outlined by the manufacturer. As in all vhf receiver construction, the placement of parts is a highly critical feature of the proper operation of the set; the various condensers, resistors, coils, transformers, etc., should be placed exactly as shown in the diagrams accompanying the parts kit. Then, too, there is the matter of extremely high operating voltages—up to 10,000 volts or more—which makes the construction of a TV receiver no job for the rank beginner who has not previously worked on the more elementary radio circuits and is not aware of the proper precautions to take in working with high voltages.

Yet the various TV kit manufacturers have done a remarkably fine job in breaking down the numerous construction steps and providing a foolproof procedure so that the average home radio builder who has put together at least one of the sets described earlier in this book can be almost certain of producing a satisfactory, trouble-free television set that will not only operate as well or better than some of the commercial models now on the market but will cost him considerably less in the end, in terms of actual cost and maintenance. Over and above these considerations is the undeniable pride of achievement that comes with assembling one of these fine, precision electronic devices. For those who are aware of the great opportunities in television servicing and design during the coming decade, the home construction of a TV receiver is perhaps one of the best ways of breaking into this phase of a highly important industry.

A GENERAL WORD ABOUT TV KITS

There are a number of television kits on the market, two of the best known of these being described in the present chapter. In each case the manufacturer has prepared an accompanying Instruction Manual that is nothing short of a feat of engineering in itself. The entire detailed assembly is broken down into a series of step-by-step procedures, each numbered in sequence and each a relatively simple operation in itself. All parts are numbered or otherwise identified and are shipped in a number of different packages or envelopes which in turn are carefully identified. Even if you don't know the difference between a resistor and a capacitor, the instructions are so clear that you can't make a mistake. As each step is outlined, the part needed is indicated both by part number and package number; you simply reach for the package number indicated in the instructions and remove the part number called for. It is essential to return all unwanted parts to their respective envelope before each step is completed, otherwise the care taken by the manufacturer to identify them for you will have been wasted and you will end with a jumble of parts on your worktable and little chance of completing the job.

It should hardly be necessary to repeat that the carefully planned Instruction Manual should be followed religiously down to the last detail. No matter how experienced you may be at putting radio sets together, you must follow the directions implicitly, without deviation, short-cuts, or rearrangement of procedure. The layout and step-by-step procedure given in the Instruction Manual is the result of months of planning and research by the skilled technical staffs of the kit manufacturers and there is only one way of putting the receiver together for satisfactory, trouble-free performance—by following the instructions. Even such an apparently slight deviation as cutting a piece of wire an inch longer than the recommended amount can add enough inductance to the circuits as to detune them considerably.

Before you start to build any TV kit, arrange all the parts packages in numerical order and place them in a convenient box or drawer; check the contents of each package *separately* against the parts list, returning all parts to their proper package or envelope. If any parts should be missing or mislaid, you might just as well put off any work on the kit until these parts have been found or replaced.

THE NO. 10A TELEKIT RECEIVER

The No. 10A Telekit (Fig. 143), designed by the Television Training Institute for Electro-Technical Industries, Philadelphia, Pa., is an entirely new model television receiver in kit form covering all thirteen television channels. It employs 17 tubes plus a picture tube, as follows:

Tube Type	*Function in Telekit Receiver*
6J6	R.f. amplifier in tuner
12AT7	Oscillator-mixer in tuner
6AG5	1st video i.f.
6AG5	2nd video i.f.
6AG5	3rd video i.f.
6SN7	Video detector and 1st video amplifier
6SN7	2nd video amplifier and d.c. restorer
6SN7	Separator and sync amplifier
6AG5	Sound i.f.
6T8	Discriminator and 1st audio
6V6	Audio output
6SN7	Vertical oscillator and amplifier
6SN7	Horizontal oscillator and discharge
6BG6	Horizontal output
6X5	Damper
5U4	Rectifier (low voltage)
1B3/8016	Rectifier (high voltage)
10BP4	10-inch kinescope (picture tube)

A synopsis of the assembly is given below, reproduced with permission from the Telekit Instruction Manual. This outline is offered only as a general idea of the work involved, not as a guide to actual construction, for the manual itself runs to 39 large pages and includes 8 double-page pictorial diagrams. Due to limitations of format, it is unfortunately not possible to reproduce either these or the schematic circuit diagram of the complete receiver, for these drawings at the maximum legible reduction require an 11 × 16 page size, or more than four times the area of this page. Fig. 144

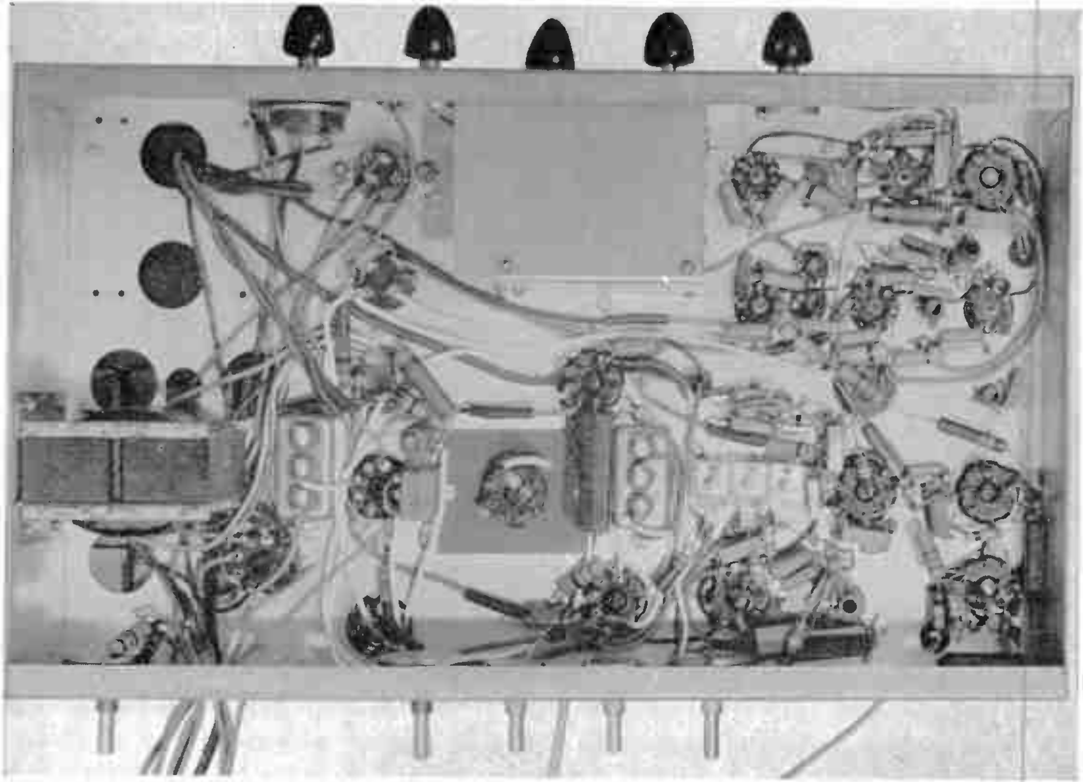
143. Assembly view of 13-channel Telekit receiver No. 10A. (*Electro-Technical Industries.*)

is a photograph of the completely wired underside of the chassis, while Fig. 145 shows a top view of the chassis with the picture tube wired, ready for installation in the cabinet.

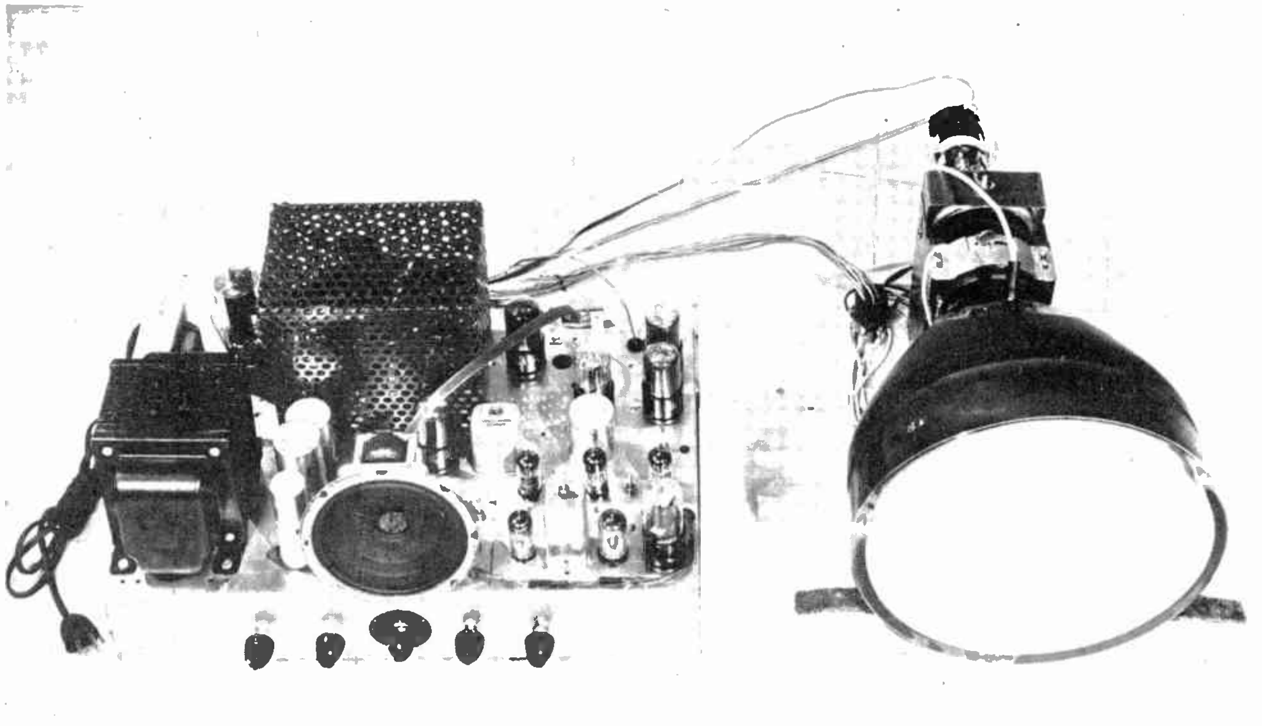
PARTS LIST FOR No. 10A TELEKIT RECEIVER

Package No. 1

4 Miniature 7-prong sockets with rings
2 Octal sockets with rings
1 Zip-in nine-pin socket
1 Zip-in octal socket (mounted)
5 ft Bare (ground) wire
4 ft Heater wire
25 ft solder
2 self-tapping screws



144 Bottom view of fully wired Telekit chassis. (*Electro-Technical Industries.*)



145. Top view of completed Telekit chassis and picture tube, ready for cabinet installation. (*Electro-Technical Industries.*)

Package No. 2

1 Power choke
2 Self-tapping screws

Package No. 3

1 Power transformer
3 Self-tapping screws

Package No. 4

1 Can condenser (2 x 20 at 450 volts)
(1 x 20 at 25 volts)
(with insulator)
2 Can condenser (4 x 10 at 450 volts)
1 Can condenser (2 x 30 at 450 volts)
(1 x 20 at 450 volts)
(1 x 40 at 25 volts)
2 Bathtub condensers (3 x .1 at 600 volts)
2 Bolts
2 Nuts
4 Self-tapping screws

Package No. 5

1 2,000-ohm wire-wound potentiometer
1 5,000-ohm wire-wound potentiometer
1 10,000-ohm potentiometer with ground lug
1 50,000-ohm potentiometer
1 100,000-ohm potentiometer with switch and ground lug
1 500,000-ohm potentiometer with ground lug
2 2-megohm potentiometers
1 Vertical oscillator transformer
2 Self-tapping screws
2 Rubber sleeves
60 ft Hookup wire
Mounting nuts on control shafts

Package No. 6

1 50-ohm, 1-watt resistor
1 100-ohm, 1-watt resistor
2 200-ohm, 1-watt resistor
1 1,000-ohm, 1-watt resistor
1 50,000-ohm, 1-watt resistor
1 Vertical output transformer with hardware
1 8-prong plug
1 Picture-tube socket
1 A-c line cord and plug
4 Rubber sleeves

Package No. 7

1 200-ohm, ½-watt resistor
1 500-ohm, ½-watt resistor
1 1,000-ohm, 2-watt resistor
1 50,000-ohm, ½-watt resistor
1 30,000-ohm, 1-watt resistor
2 500,000-ohm, ½ watt resistors
1 250,000-ohm, ½-watt resistor
1 10-megohm, ½-watt resistor
1 1,000-mmf (.001) condenser
2 5,000-mmf (.005) condensers
3 .01-mfd condensers
1 Sound discriminator can
1 30-inch length of red wire
1 30-inch length of blue wire
1 Rubber grommet
1 Rubber sleeve
1 Self-tapping screw
1 No. 13 Telekit tuner (assembled and aligned)

Package No. 8

3 200-ohm, ½-watt resistors
1 2,000-ohm, ½-watt resistor
2 2,000-ohm, 1-watt resistors
1 5,000-ohm, ½-watt resistor
2 5,000-ohm, 1-watt resistors
5 10,000-ohm, ½-watt resistors
1 30,000-ohm, ½-watt resistor
3 30,000-ohm, 1-watt resistors
1 100,000-ohm, ½-watt resistor
1 500,000-ohm, ½-watt resistor
2 1-megohm, ½-watt resistors
1 5-mmfd condenser
1 50-mmfd condenser
1 2-megohm, ½-watt resistor
3 200-mmfd condensers
7 5,000-mmfd (.005) condensers
1 .01-mfd condenser
2 .1-mfd condenser
4 I-f coils
1 Cathode trap transformer
1 Peaking coil (36 uh), small size
2 Peaking coils (120 uh), medium size
1 Peaking coil (180 uh), large size
1 Rubber grommet
2 Rubber sleeves

Package No. 9

1 50-ohm, ½-watt resistor
1 50-ohm, 1-watt resistor

1 1,000-ohm, 1-watt resistor
1 1,000-ohm, 2-watt resistor
1 2,000-ohm, 1-watt resistor
1 5,000-ohm, 1-watt resistor
2 5,000-ohm, ½-watt resistor
3 10,000-ohm, ½-watt resistors
1 10,000-ohm, 1-watt resistor
1 20,000-ohm, ½-watt resistor
1 30,000-ohm, ½-watt resistor
1 50,000-ohm, ½-watt resistor
3 100,000-ohm, ½-watt resistors
5 150,000-ohm, ½-watt resistors
2 250,000-ohm, ½-watt resistors
2 500,000-ohm, ½-watt resistors
4 1-megohm, ½-watt resistors
3 2-megohm, ½-watt resistors
1 5-mmfd condenser
1 100-mmfd condenser
1 200-mmfd condenser
2 1,000-mmfd (.001) condensers
4 5,000-mmfd (.005) condensers
3 .01-mfd condensers
1 .02-mfd condenser (or 2 parallel .01 condensers)
2 .25-mfd condensers
3 40-370-mmfd trimmer condensers with mounting bracket and hardware
1 Horizontal synchro-lock coil
1 Horizontal linearity coil
1 Horizontal width coil
1 Horizontal output and high-voltage transformer
1 High-voltage case
1 30-inch length of high-voltage wire
1 Antenna post
1 High-voltage pin
1 Rubber grommet
5 Rubber sleeves
5 Self-tapping screws
3 Knobs

Package No. 10
1 Speaker and output transformer
2 Rubber sleeves
1 Self-tapping screw

Package No. 11
1 Yoke
1 Yoke hood
1 Focus coil
1 Ion trap magnet
2 560-chm resistors
1 50-mmfd condenser
1 8-prong wafer socket
1 wing bolt

Package No. 12
1 Metal yoke mount
1 Mounting board
1 Focus-coil saddle
1 Wing nut
3 Woodscrews, ¼"
2 Self-tapping screws, No. 6/32 × 8"
2 Self-tapping screws, No. 4 × ¼"
1 Large washer
2 Small washers
2 Stand-off bushings
2 Wood screws (large)

ASSEMBLY OF THE TELEKIT

The assembly of the Telekit receiver is divided into nine units or operation groups, each of which is in turn broken down into numbered steps, correlated with the eight assembly drawings on which the location of all parts is clearly indicated by numbers. The major operations are summarized as follows:

(1). The first job to be undertaken is the mounting of all sockets in the punched steel chassis, the first sockets to be mounted being the bantam sockets, followed by the octal sockets, then the high-voltage octal socket. After all sockets are mounted, they should be double-checked for proper key alignment, tinned as indicated, and ground connections made. Following this, heater circuits 1 and 2 are installed and wired.

(2). The second operation consists of mounting and wiring the power-supply units, controls, and deflection-circuit transformers.

(3). Step 3 consists of mounting and wiring the a-c line cord and picture-tube filament winding and socket.

(4). The fourth step covers wiring of the sound portion of the receiver. (The FM tuner comes pre-assembled and aligned.)

(5). Step 5 consists of wiring the sockets for the 1st, 2nd, and 3rd i.f. video, video detector and 1st video amplifier, and 2nd video amplifier and d-c restorer.

(6). This step covers the wiring of the deflection oscillators and associated circuits.

(7). Next, the speaker and output transformer are mounted and wired.

(8). Step 8 includes the wiring of the picture-tube coils.

(9). The final step covers mounting of the metal yoke mount and focus-coil saddle.

OPERATION

When the wiring of the entire set has been completed, all circuits should be checked against the schematic wiring diagram provided, and if everything checks properly, the "hot check" and alignment procedures may be made. The receiver has 15 controls (though only 5 panel knobs) as follows: sound volume, contrast, station selector, fine tuning, brightness and a-c switch, focus, horizontal hold control, horizontal drive, horizontal speed, synchro-lock, horizontal width, horizontal linearity, vertical hold, vertical size, and vertical linearity.

The three hot checks (heaters, B+ power supply, and high-voltage) are fully outlined step-by-step in the Instruction Manual, as is the fairly simple alignment procedure. The manual gives 36 test-pattern pictures showing correct and incorrect settings and various distortions due to external or internal trouble.

After all adjustments have been made on the i-f coils as directed, they are to be locked in place with liquid cement or "dope," for vibration will cause the slugs in the coils to change position otherwise.

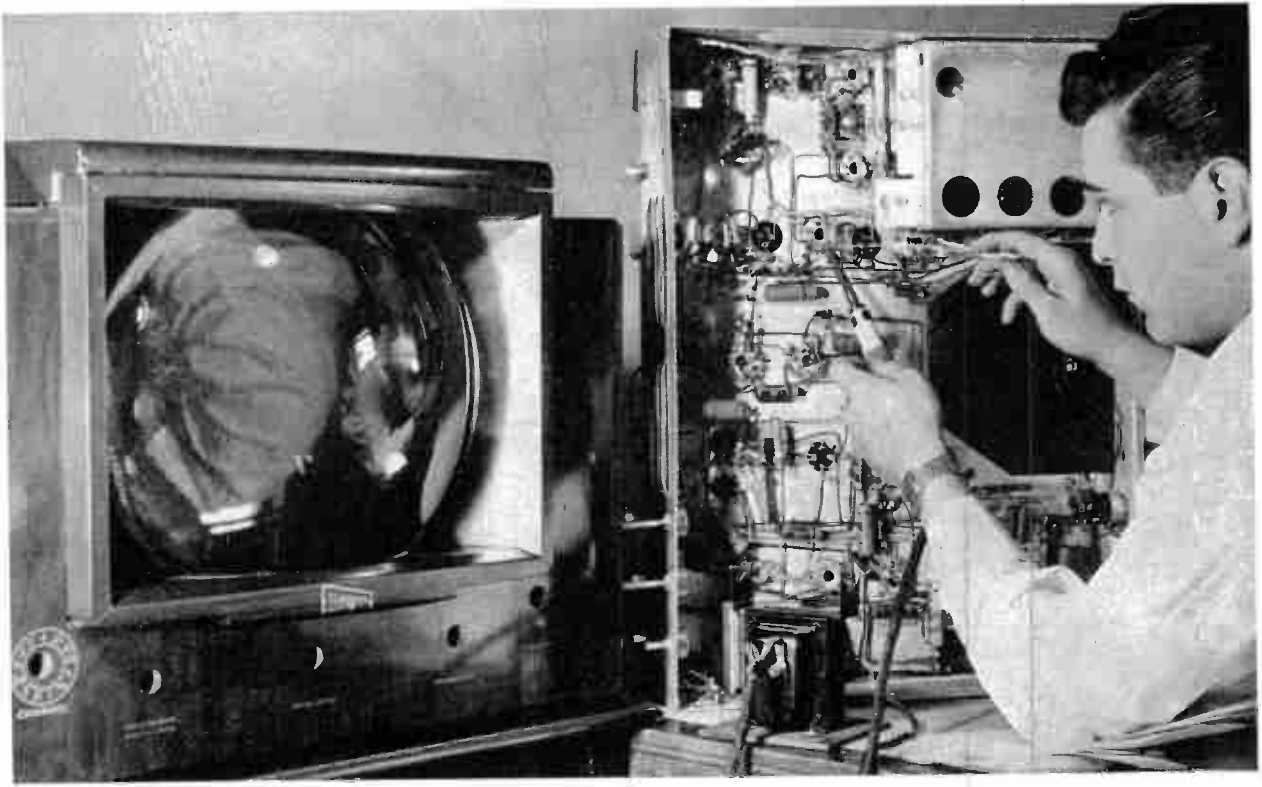
The Telekit receiver will perform best with a television antenna kit and a 300-ohm lead-in line. For city use, the manufacturer recommends a single dipole or a folded dipole antenna, while for suburban use a multi-element antenna should be used. In some remote locations an antenna tower may have to be used to secure satisfactory reception. This is true for all types of television receivers and has nothing to do with the fact that the receiver may be home-assembled or custom-built.

The manufacturer has anticipated any type of trouble that you may run into in the operation of the receiver, by providing a detailed trouble-shooting chart just in case you made a few mistakes in wiring or haven't aligned the set properly, etc. The listing of all the possible sources of trouble shouldn't alarm the operator, however, for if the instructions were followed correctly the set should be as nearly free of trouble as mechanical ingenuity can make it these days. And you can always have the benefit of the expert advice of the manufacturer's service department.

THE TRANSVISION TELEVISION KIT

Another high-quality television kit now on the market is the Transvision Kit, shown in the process of assembly in Fig. 146. Here also the manufacturer has provided the set builder with a fully engineered Instruction Manual that makes it possible for a person with minimum mechanical ability to put together a fine instrument, providing he follows the directions implicitly. The Transvision receiver consists of a 3-tube tuner and 18 tubes plus a picture tube as follows:

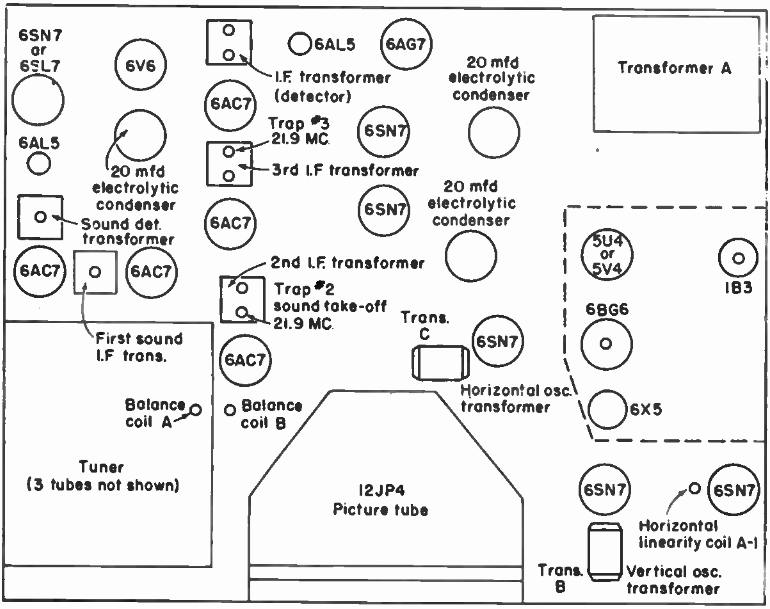
5 6AC7 sharp-cutoff pentodes in 1st video and picture amplifier
5 6SN7 remote-cutoff pentodes in vertical oscillator and discharge, vertical output, horizontal oscillator and discharge, 2nd video amplifier, and separator
2 6AL5 twin diode, high-perveance video detectors
1 6AG7 power pentode video amplifier
1 6V6/GT beam power amplifier in sound output circuit
1 6SL7 high-mu twin triode as resistance-coupled amplifier
1 6X5GT full-wave vacuum rectifier in horizontal damping
1 8016 (1B3) half-wave vacuum rectifier in horizontal output
1 6BG6G beam power amplifier in horizontal deflection circuit
1 12JP4 12" picture tube



146. Transvision television receiver in process of assembly. (*Transvision, Inc.*)

As before, space doesn't permit the reproduction of the schematic or pictorial wiring diagrams; however, some idea of the layout of the chassis can be had from Fig. 147, which shows the position of the tubes and transformers

The parts are numbered and shipped in numbered packages, and are clearly identified in the Instruction Manual as they are required. A special feature of this manual is that it is published in



147. Simplified pictorial view of top of chassis of Transvision receiver, showing relative placement of tubes, etc. (*Transvision, Inc.*)

the form of large 17" × 22" charts which may be mounted on the wall or on a large board near the assembly table and each step checked off as it is performed. The pictorial diagrams may be mounted separately for quicker reference. There are seven major construction stages, each of which is broken down into numerous steps—in many cases a step consists only of wiring a lead from one terminal to another. This makes it so much easier to assemble and wire the set, for actually the manufacturer does the thinking for you and all you have to do is follow the directions and check off each step as it is completed. Also, this chart form makes it easier to go back and check your work against the instructions—a very desirable thing to do, for one small error when the wiring and assembly is nearly complete can easily ruin many expensive circuit parts later on when you try to operate the set.

Accompanying the instructions are a resistance-reading chart and a voltage chart, which enables the operator to make a final check of the entire set before attempting to align or operate it. There is also a detailed account of alignment procedure and trouble shooting. In other words, the manufacturer has left nothing to chance and has given the kit builder the most complete set of instructions conceivable. The fact that hundreds of these kits have been successfully built and operated is proof that it doesn't take a television engineer to construct one of these fine instruments—provided, we repeat, that the instructions are followed to the letter.

As a final word of caution, always be sure that no loose pieces of wire or solder are permitted to remain in the television chassis after the wiring has been completed, for they can cause short circuits that may ruin the work of hours or days and necessitate the replacement of many parts. Second, remember that you are dealing with very high voltages when you work on a television receiver "alive." Third, handle the picture tube with the utmost care—don't pick it up by the neck, but place both hands on the screen end, where the weight of the glass is concentrated. Don't let it strike against any solid object, and above all, don't drop it. If you do, you may have to sweep it up. Finally, if you run into trouble you can't fix by following the recommendations in the manufacturer's trouble-shooting chart, don't hesitate to have it looked over by a factory-trained technician. The charge is small and it may save you from considerable expense later in replacing damaged parts.

CHAPTER

24

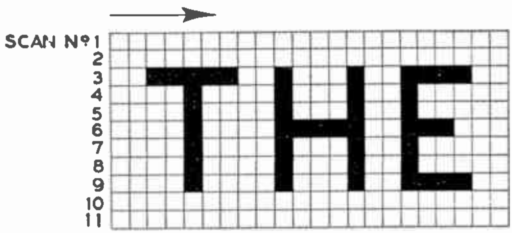
Radio Facsimile

Facsimile is a still relatively new term to many radio amateurs and experimenters but it is now destined to appear more frequently in the periodicals devoted to radio transmission and reception. The word itself means an exact copy of an original object; when applied to radio it means the transmission from one point and the reproduction at a distant point of the still image of a scene, individual or a sheet of printed words. Facsimile has been used for many years by commercial firms for the transmission of weather maps to ships at sea and photographs from one country to another. Over wire lines it has found increasing use in the sending of telegrams as written in the handwriting of the sender. Because of the fact that a successful transmission places a permanent copy of the original object in the possession of the receiver, radio facsimile has been called the "newspaper of tomorrow" and many tests have been carried out in recent years to examine its possibilities in this field.

TRANSMITTING THE IMAGE

In sending a picture by radio facsimile the procedure is closely akin to that of television. The photographic print is wrapped around a revolving cylinder while a pin point of light is focused on the print's surface and moved across it. A sensitive photoelectric cell catches the reflected light, converts it into electric energy, and passes the impulses to an amplifier which in turn modulates a carrier wave of considerable power. In other words, the picture is broken down into a great number of elemental areas and the average light value of each area transmitted in the form of an electrical impulse to the receiving equipment. By taking each area in a predetermined order and arranging to have the receiver reproduce each area in the same order the result is a duplicate of the original, providing that the sender and receiver are in step or in synchronism, and also providing that spurious impulses such as static do not register on the receiving apparatus.

Fig. 148 shows how a portion of a word would be scanned at the transmitting end with each of the small squares representing one of the elemental areas. Here because of the black and white characteristics of the object the light reflected onto the photoelectric cell would be either maximum or zero, a condition met with in transmitting newspaper pages. But it is not difficult to see that this condition is changed when a photograph or other halftone object is transmitted. In such a case, the reflected light would vary by mi-



148. How an area to be scanned is broken up into many elemental units.

nute degrees as it encountered all gradations of tone from solid black to perfect whiteness. This, obviously, creates the most difficult problem of radio facsimile transmission and reception.

As in newspaper and magazine printing where the fineness of an illustration depends to a great extent on the halftone screen, so does the facsimile result depend on the number of elemental areas per square inch into which the picture is divided by the scanning spot. Tests have shown that 150 dots per linear inch or 22,500 per square inch give excellent reproductions, but when this detail is reduced to less than 100 a linear inch (10,000 a square inch) the legibility of the facsimile suffers acutely.

FACSIMILE PROGRAMS

Because of the future possibilities of radio facsimile in sending printed intelligence from one point to another, the Federal Communications Commission has set aside several bands in different parts of the ether spectrum for experiments. In addition, permission has been granted to existing broadcasting stations to utilize their facilities from midnight to morning for the transmission of experimental programs. As a result, facsimile signals are available over most of the country for those amateurs who wish to assemble the necessary apparatus for receiving the material.

Because of the growing interest in this field, the number of stations is constantly increasing. The amateur who intends to investigate facsimile should obtain the working schedules of all stations near him by writing to the station directors. Reception reports are eagerly sought and full cooperation is a simple matter to obtain.

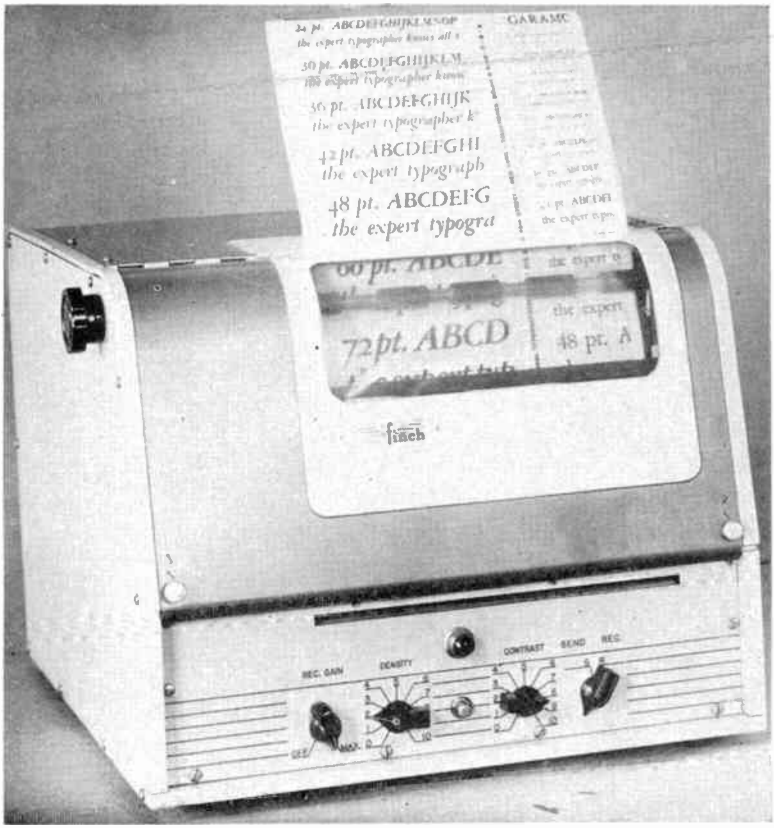
At the present time, however, the greater part of facsimile operations are carried on over leased telephone wires, similar to the arrangement used for teletype service, for most of the commercial applications lend themselves to this type of point-to-point facsimile communication. At the moment there does not seem to be much indication of a nationwide radio facsimile network for depositing the daily newspaper in the living-room receiver, for newspapers are still much easier to get from the corner newsstand.

TYPES OF TRANSMISSIONS AND RECEIVERS

Since the art of facsimile communication is relatively young in spite of the fact that a fellow named Bain outlined a completely workable facsimile system as early as 1842, there are as yet no hard-and-fast standards of transmission and reception, but activities have narrowed down to three systems—the Finch, Hogan, and RCA systems. The first is a development of William G. H. Finch of New York, the second by John V. L. Hogan, and the third is the result of research by a group of RCA technicians headed by Charles J. Young.

THE FINCH SYSTEM

The Finch Telefax machine (Fig. 149) is a complete sending and receiving facsimile unit which can transmit writing, pictures, or printed matter between any two points that are connected by a wire circuit of reasonably good quality, such as a telephone line, or by a radio channel. Transmission originates at a photoelectric cell which scans the message as previously described, converting the blacks and grays of the numerous scanning lines into a varying sig-



149. The Finch Telefax duplex facsimile unit, a complete sending and receiving machine using radio or wire communication channels. (*Finch Telecommunications, Inc.*)

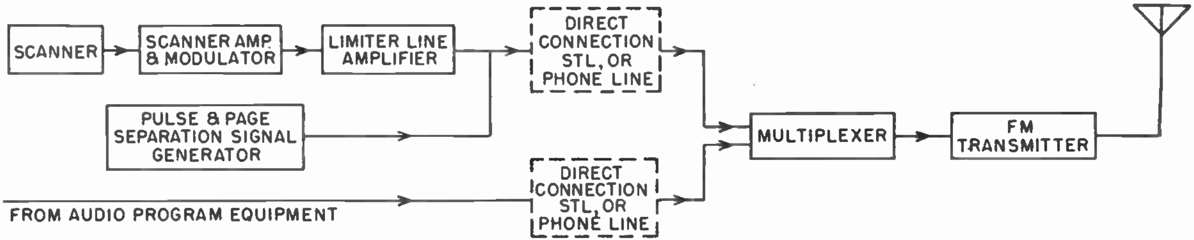
nal voltage which is amplified and sent over the circuit to the unit at the other end. In the receiver, the signal is recorded on electrosensitive paper to reproduce the shadows and contrasts of the original message or picture in their proper relationship. The result is said to be comparable in quality to a 100-line halftone engraving similar to those used in this book.

The transmission speed depends entirely on the quality of the communication channel used; that is, on the frequency that can be transmitted without excessive attenuation, since the carrier frequency rises with increased speed. A speed of 13.5 square inches or 1.7 linear inches per minute is available for standard telephone-line channels, while a speed of 28 square inches or 3.4 linear inches per minute can be obtained for FM communication channels having a modulation band width of 700–6,200 cycles. Medium-speed units operate on an FM band width of 200–2,700 cycles.

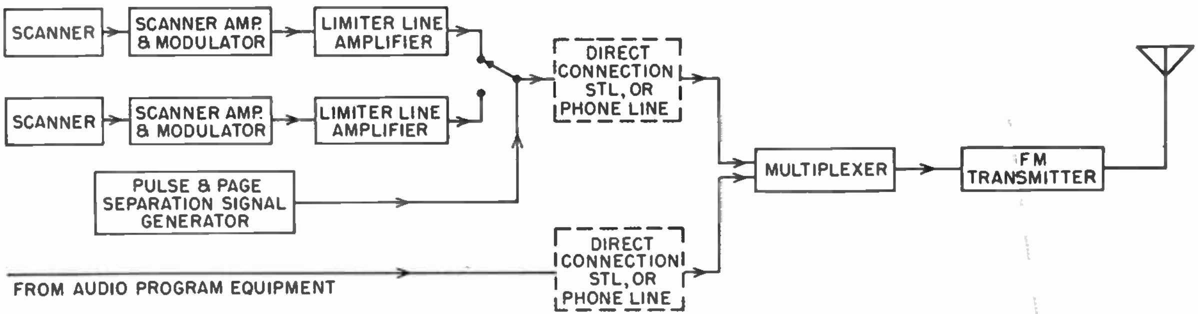
THE HOGAN "FAXIMILE" SYSTEM

Under this system two facsimile scanners may be used to permit continuous transmission while copy is being set up. It employs a lamp, optical system, phototube, and amplifier tube mounted in the movable scanner head or carriage. The scanner amplifier, which supplies power to the scanner, in turn uses the signals from the scanner to modulate a subcarrier that is generated in the scanner amplifier itself; this subcarrier is then amplified and fed into the limiter-line amplifier (see Fig. 150). The output of the limiter-line amplifier may be fed directly into an FM transmitter for simplex facsimile bradcasting, or it may be fed into the facsimile input channel of a transmitting multiplexer unit first and then to the FM transmitter.

In the "Faximile" receiver (the trade-mark of the Hogan system) the signals needed to operate the reproducing equipment are taken directly from the output of the discriminator of an FM receiver (see Fig. 151). The discriminator output signal is then applied to a recorded amplifier to be amplified and rectified; the amplifier also supplies a constant current at low voltage corresponding to the signal, to a pair of marking electrodes. These consist of a printing blade and a helix drum. As the recording current, which is about 250 milliamperes d.c., flows through the moistened electrolytic recording paper, the resulting electrolytic action deposits atoms of iron on the paper in proportion to the amount of current flowing through it. Since the recording current varies precisely with

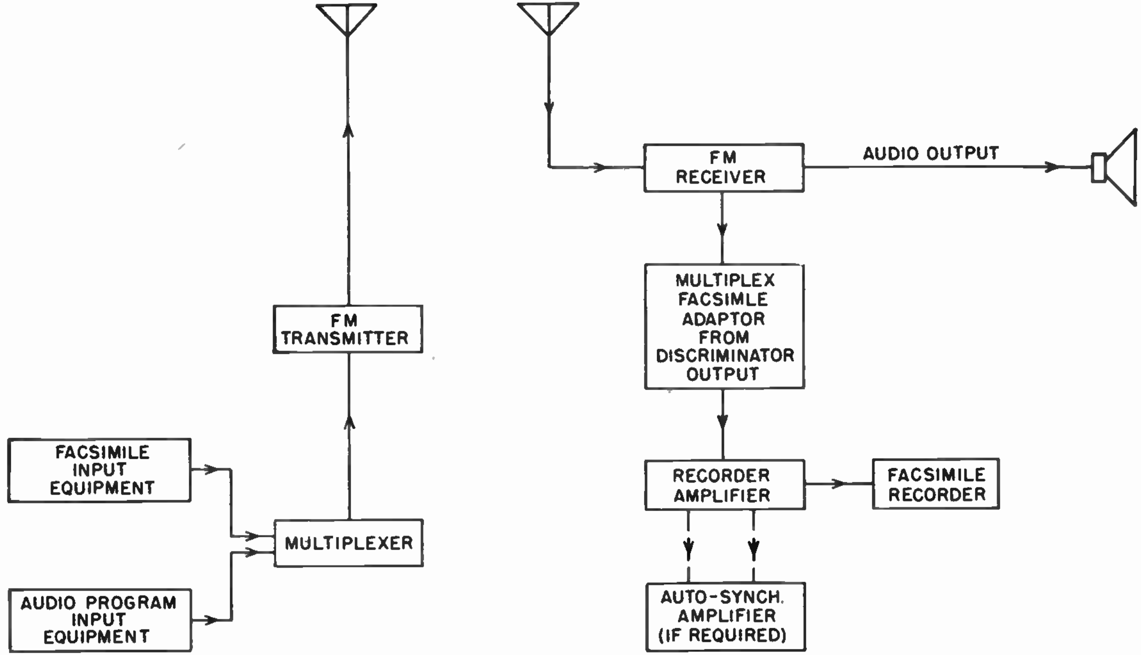


(A) SINGLE SCANNER OPERATION



(B) DUAL SCANNER OPERATION WITH OUTPUT SWITCHING

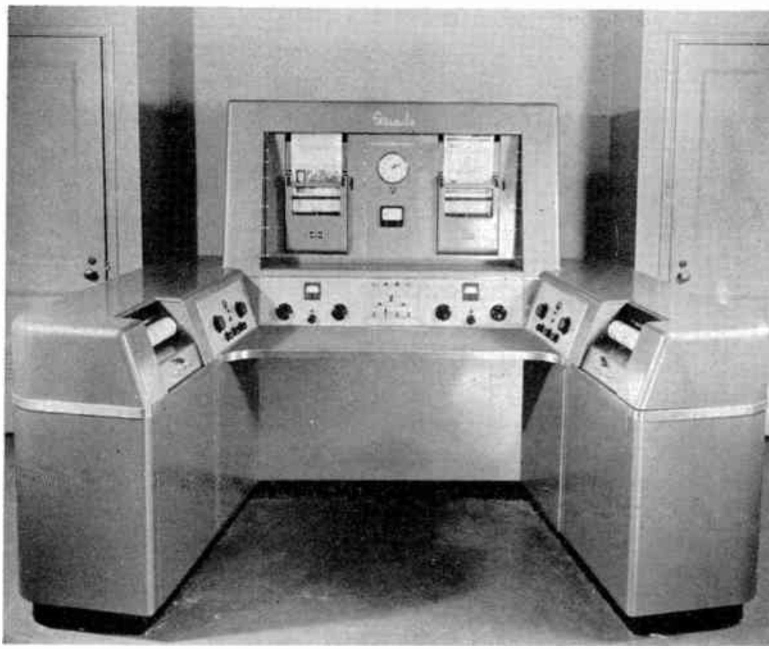
150. Block diagram showing input equipment used in a multiplex facsimile broadcast operation. (*Radio Inventions, Inc.*)



151. Block diagram showing equipment used in multiplex FM facsimile broadcast operation. (*Radio Inventions, Inc.*)

152. Table model of Hogan Faximile receiver manufactured by J. H. Bunnell Co. (*Radio Inventions, Inc.*)

variations of light and shade at the transmitting end, the paper develops a pattern that is an exact replica of the original printed matter or illustration being scanned at the transmitter. The printing blade is gradually consumed by the electrolytic action and must be replaced about the same time that the electrosensitive roll of recording paper is replaced.



153. General Electric dual facsimile transmitting console using Hogan Faximile equipment. (*Radio Inventions, Inc.*)

The recorder helix drum and scanner drum both rotate in synchronism at a speed of 360 revolutions per minute. Synchronism, which is as essential in facsimile as in television, is obtained by using identical or interconnected power sources and is then dependent upon the stability of the power line used; in areas where powerline synchronization is not possible, automatic sychronizing amplifiers are used. Paper feed in the recorder is the same as that of the scanner—3.43 lineal inches per minute. Approximately 28 square inches of facsimile copy can be received per minute on these units; a quarter-hour broadcast program will give about four pages of facsimile copy approximately 8" × 11½" including page separations.

Figures 152 and 153 illustrate two Faximile installations in current use.

ASSEMBLING THE READO KIT

In the belief that facsimile held considerable interest for the amateur experimenter, Powel Crosley, Jr., one of America's leading radio manufacturers, secured a license from the Finch Telecommunications Laboratories for the design and sale of a facsimile kit, sufficiently simplified for home use and yet retaining the ability to make good reproductions of transmitted programs. Thousands of the kits are now in regular use, giving their owners a working acquaintance with this new branch of radio. The kits include all essential parts and can be built into a complete unit in a few hours with the aid of simple tools found in every workshop.

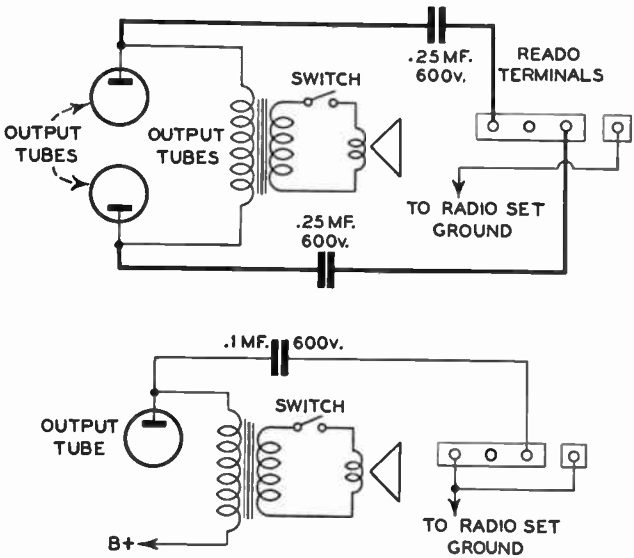
In assembling the Reado, the bracket which supports the roll of paper is first anchored in position on the steel base plate followed by the cam and gear box and then the driving motor. When a sub chassis holding the input transformer and rectifier tube is bolted in place, the facsimile mechanism is complete except for a few wires that must be soldered and some minor adjustments. Step-by-step instructions expressed in simple terms accompany each kit of parts for the benefit of those whose mechanical experience is limited.

When the last adjustment has been made to cams and ratchets, the roll of special paper is placed on the lower drum of the paper bracket and threaded carefully through the gate and over the toothed guide rolls at the top. The unit is then ready for attaching to the radio receiver.

RECEIVING THE FACSIMILE SIGNAL

Although the Reado will function after a fashion with almost any type of receiver, best results are obtained with a set having a good automatic volume control (AVC) and an output of at least five watts. If the unit is to be used within a score of miles of a powerful station the AVC becomes of less importance, but a good black-and-white image is obtained only when a powerful signal is fed into the Reado.

There are several methods of removing the facsimile signals from a receiver, depending on the type of output incorporated in the latter. One method which is to be followed in the case of push-pull output is shown in Fig. 154*A*. If a single output tube feeds the loud speaker, Fig. 154*B* shows the connections.



154. Method of drawing facsimile signals from output circuits of standard broadcast receivers.

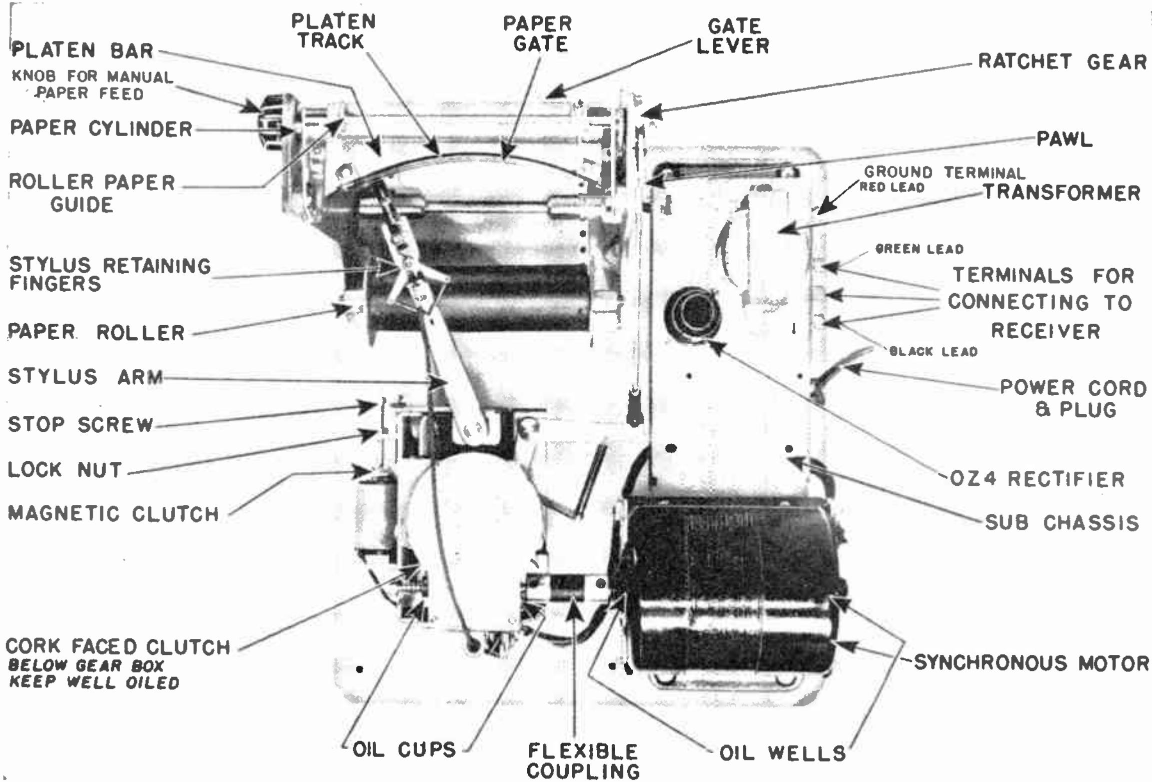
Since the transmissions on standard broadcast stations take place after midnight, it will be desirable to insert a switch in the voice coil of the loud speaker so that the operation will be quiet. A further refinement is to secure an inexpensive time clock to turn both set and Reado on and off at the proper time. If this is done, all arrangements can be made for the normal operation of the facsimile system before the owner retires for the night, leaving the actual work to be done automatically by the clock and the radio receiver. In the morning the entire production of news, pictures, and allied material will be found on the strip of paper which has passed through the machine during the preceding hours.

The Reado (Fig. 155) functions with very little noise, but the slight hum of the motor and the movement of the cams and ratchets may prove annoying to light sleepers. In this case the entire unit may be enclosed in a ventilated box line on the inside with celotex or other sound-absorbing material.

SYNCHRONIZING THE SIGNAL

So far nothing has been said about the means used to keep the Reado in step or in synchronism with the transmitter. In early days, experimenters depended on the use of synchronous motors deriving their speed regulation from the same power line feeding the transmitter, but this limited the use of receivers to the immediate vicinity of the sending stations. To remove this limitation, Finch arranged his transmitting scanner so that a special pulse was sent out at the beginning of each scanned line. The Reado works on this idea. As the receiver scanner carrying the printing stylus reaches the extreme left side of the paper strip, it is locked in that position until the arrival of the synchronizing pulse. This pulse is rectified by the type OZ4 gaseous rectifier tube and the direct-current impulse passes through a magnet which releases the clutch and allows the scanner arm to resume its movement. This assures that the receiver is in perfect step with the transmitter at the beginning of each line. If this condition were not maintained, the images would be distorted and the type matter hard to read.

The motor also drives a ratchet rod which moves the paper ahead one one-hundredth of an inch during the return trace of the stylus. This produces a facsimile roughly equivalent to a picture detail of 100 lines per linear inch or 10,000 dots per square inch. At the normal speed of travel, the Reado will turn out copy at the rate of one inch a minute or five feet of paper strip each hour. Since the paper width is equivalent to two newspaper columns, five hours of operation will deliver about thirty newspaper columns, a good night's accomplishment for an apparatus that can be assembled by anyone in a few hours of pleasant work.



155. The completed Reado facsimile recorder viewed from above.

Appendix

RCA Receiving Tubes Characteristics Chart

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
00-A	Detector Triode	D12	D.C. F	5.0	0.25	Grid-Leak Detector	45	Grid Return to (−) Filament			1.5	30000	666	20	——	——	00-A
01-A	Detector★ Amplifier	D12	D.C. F	5.0	0.25	Class A Amplifier	90 135	− 4.5 − 9.0	——	——	2.5 3.0	11000 10000	725 800	8.0 8.0	——	——	01-A
0Z4	Full-Wave Gas Rectifier	B3	Cold	——	——	Rectifier	Starting-Supply Voltage per Plate, 300 min. peak volts. Peak Plate Current, 200 max. ma. D-C Output Current, 75 max., 30 min. ma. D-C Output Voltage, 300 max. volts.										0Z4
0Z4-G	Full-Wave Gas Rectifier	B1	Cold	——	——	Rectifier											0Z4-G
1A3	HF Diode	B0	H	1.4	0.15	Detector Rectifier	Max. Peak Inverse Volts, 330 Max. Peak Plate Ma., 5 Max. D-C Output Ma., 0.5 Max. Peak Heater-Cathode Volts, 140										1A3
1A4-P	Supercontrol R F Amplifier Pentode	D0	D.C. F	2.0	0.06	Amplifier	For other characteristics, refer to Type 1D5-GP.										1A4-P
1A5-GT	Power Amplifier Pentode	C3	D.C. F	1.4	0.05	Class A Amplifier	85 90	− 4.5 − 4.5	85 90	0.7 0.8	3.5 4.0	300000 300000	800 850	——	25000 25000	0.100 0.115	1A5-GT
1A6	Pentagrid Converter ●	D0	D.C. F	2.0	0.06	Converter	135 180	− 3.0 min.	67.5 67.5	2.5 2.4	1.2 1.3	400000 500000	Anode-Grid (# 2): 180 ▲ max. volts, 2.3 ma. Oscillator-Grid (# 1) Resistor ●. Conversion Transcond., 300 micromhos.				1A6
1A7-GT	Pentagrid Converter ●	C3	D.C. F	1.4	0.05	Converter	90	0	45♣	0.7	0.6	600000	Anode-Grid (# 2): 90 max. volts, 1.2 ma. Oscillator-Grid (# 1) Resistor, 0.2 meg. Conversion Transcond., 250 micromhos.				1A7-GT
1B3-GT/8016	Half-Wave Rectifier	D1a	F	1.25	0.2	Half-Wave Rectifier	Max. Peak Inverse Plate Volts, 40000 Max. Peak Plate Ma., 17 Max. Average Plate Ma., 2 Max. Frequency of Supply Voltage, 300 Kc										1B3-GT/8016
1B4-P	RF Amplifier Pentode	D0	D.C. F	2.0	0.06	Amplifier	For other characteristics, refer to Type 1E5-GP.										1B4-P
1B5/25S	Duplex-Diode Triode	D5	D.C. F	2.0	0.06	Triode Unit as Amplifier	For other characteristics, refer to Type 1H6-G.										1B5/25S
1B7-GT	Pentagrid Converter	C3	D.C. F	1.4	0.10	Converter	90	0	45♣	1.3	1.5	350000	Anode-Grid (# 2): 90 max. volts, 1.6 ma. Oscillator-Grid (# 1) Resistor, 0.2 meg. Conversion Transcond., 350 micromhos.				1B7-GT
1C5-GT	Power Amplifier Pentode	C3	D.C. F	1.4	0.10	Class A Amplifier	83 90	− 7.0 − 7.5	83 90	1.6 1.6	7.0 7.5	110000 115000	1500 1550	——	9000 8000	0.20 0.24	1C5-GT
1C6	Pentagrid Converter ●	D0	D.C. F	2.0	0.12	Converter	For other characteristics, refer to Type 1C7-G.										1C6
1C7-G	Pentagrid Converter ●	D8	D.C. F	2.0	0.12	Converter	135 180	− 3.0 − 3.0	67.5 67.5	2.5 2.0	1.3 1.5	600000 700000	Anode-Grid (# 2): 180 ▲ max. volts, 4.0 ma. Oscillator-Grid (# 1) Resistor ●. Conversion Transcond., 325 micromhos.				1C7-G
1D5-GP	Supercontrol RF Amplifier Pentode	D8	D.C. F	2.0	0.06	Class A Amplifier	90 180	− 3.0 min.	67.5 67.5	0.9 0.8	2.2 2.3	600000 1.0§	720 750	——	——	——	1D5-GP

1D5-GT	Supercontrol RF Amplifier Tetrode	D8	D.C. F	2.0	0.06	Class A Amplifier	180	−3.0	67.5	0.7	2.2	600000	650	—	—	—	1D5-GT
1D7-G	Pentagrid Converter ●	D8	D.C. F	2.0	0.06	Converter	For other characteristics, refer to Type 1A6.										1D7-G
1D8-GT	Diode-Triode-Power Amplifier Pentode	C3	D.C. F	1.4	0.10	Pentode Unit as Class A Amplifier	45 90	−4.5 −9.0	45 90	0.3 1.0	1.6 5.0	300000 200000	650 925	—	20000 12000	0.035 0.200	1D8-GT
						Triode Unit as Class A Amplifier	45 90	0 0	—	—	0.3 1.1	77000 43500	325 575	25 25	—	—	
1E5-GP	RF Amplifier Pentode	D8	D.C. F	2.0	0.06	Class A Amplifier	90 180	−3.0 −3.0	67.5 67.5	0.7 0.6	1.6 1.7	1.0§ 1.3§	600 650	—	—	—	1E5-GP
1E7-G	Twin-Pentode Power Amplifier	D3	D.C. F	2.0	0.24	Class A Amplifier	135	−7.5	135	—	Power Output is for one tube at stated plate-to-plate load.				24000	0.575	1E7-G
1F4	Power Amplifier Pentode	D12	D.C. F	2.0	0.12	Amplifier	For other characteristics, refer to Type 1F5-G.										1F4
1F5-G	Power Amplifier Pentode	D10	D.C. F	2.0	0.12	Class A Amplifier	90 135	−3.0 −4.5	90 135	1.1 2.4	4.0 8.0	240000 200000	1400 1700	—	20000 16000	0.11 0.31	1F5-G
1F6	Duplex-Diode Pentode	D9	D.C. F	2.0	0.06	Pentode Unit as Amplifier	For other characteristics, refer to Type 1F7-G.										1F6
1F7-G	Duplex-Diode Pentode	D8	D.C. F	2.0	0.06	Pentode Unit as RF Amplifier	180	−1.5	67.5	0.7	2.2	1.0§	650	—	—	—	1F7-G
						Pentode Unit as AF Amplifier	135✖	−2.0	Screen Supply, 135 volts applied through 0.8-megohm resistor. Grid Resistor,** 1.0 megohm. Voltage Gain, 46.								
1G4-GT	Detector Amplifier Triode	C3	D.C. F	1.4	0.05	Class A Amplifier	90	−6.0	—	—	2.3	10700	825	8.8	—	—	1G4-GT
1G5-G	Power Amplifier Pentode	D10	D.C. F	2.0	0.12	Class A Amplifier	90 135	−6.0 −13.5	90 135	2.5 2.5	8.5 8.7	133000 160000	1500 1550	—	8500 9000	0.25 0.55	1G5-G
1G6-GT	Twin-Triode Amplifier	C3	D.C. F	1.4	0.10	Class B Amplifier	90	0	—	—	Power Output is for one tube at stated plate-to-plate load.				12000	0.350	1G6-GT
1H4-G	Detector★ Amplifier	D3	D.C. F	2.0	0.06	Class A Amplifier	90 135 180	−4.5 −9.0 −13.5	—	—	2.5 3.0 3.1	11000 10300 10300	850 900 900	9.3 9.3 9.3	—	—	1H4-G
						Class B Amplifier	157.5	−15.0	—	—	1.0♠	—	—	—	8000	2.1†	
1H5-GT	Diode High-Mu Triode	C3	D.C. F	1.4	0.05	Triode Unit as Class A Amplifier	90	0	—	—	0.15	240000	275	65	—	—	1H5-GT
1H6-G	Duplex-Diode Triode	D3	D.C. F	2.0	0.06	Triode Unit as Class A Amplifier	135	−3.0	—	—	0.8	35000	575	20	—	—	1H6-G
1J5-G	Power Amplifier Pentode	D10	D.C. F	2.0	0.12	Class A Amplifier	135	−16.5	135	2.0	7.0	105000	950	—	13500	0.45	1J5-G
1J6-GT	Twin-Triode Amplifier	C5b	D.C. F	2.0	0.24	Class B Amplifier	135 135	0 −3.0	—	—	Power Output is for one tube at stated plate-to-plate load.				10000 10000	2.2 2.0	1J6-GT
1L4	RF Amplifier Pentode	B6	D.C. F	1.4	0.05	Class A Amplifier	90 90	0 0	67.5 90	1.2 2.0	2.9 4.5	600000 260000	925 1025	—	—	—	1L4
1LA4	Power Amplifier Pentode	B5	D.C. F	1.4	0.05	Amplifier	For other characteristics, refer to Type 1A5-GT.										1LA4
1LA6	Pentagrid Converter	B5	D.C. F	1.4	0.05	Converter	90	0	45♣	0.6	0.55	750000	Anode-Grid (#2), 90 max. volts, 1.2 ma. Oscillator Grid (#1) Resistor, 0.2 meg. Conversion Transcond., 250 micromhos.				1LA6

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use Values to right give operating conditions and characteristics for indicated typical use	Plate Supply Volts	Grid Bias Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	A-C Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
1LB4	Power Amplifier Pentode	B5	D.C. F	1.4	0.05	Class A Amplifier	For other characteristics, refer to Pentode Unit of Type 1D8-GT.										**1LB4**
1LC5	RF Amplifier Pentode	B5	D.C. F	1.4	0.05	Class A Amplifier	45 90	0 0	45 45	0.35 0.30	1.10 1.15	700000 1.5§	750 775	— —	— —	— —	**1LC5**
1LC6	Pentagrid Converter	B5	D.C. F	1.4	0.05	Converter	45 90	0 0	35 35	0.75 0.70	0.70 0.75	300000 300000	Anode-Grid (# 2): 45 max. volts, 1.4 ma. Oscillator-Grid (# 1) Resistor, 1.0 meg. Conversion Transcond., 275 micromhos.				**1LC6**
1LD5	Diode-Pentode	B5	D.C. F	1.4	0.05	Pentode Unit as Class A Amplifier	Plate Supply, 90 volts applied through 1 meg. resistor. Screen Supply, 90 volts applied through 5.6 meg. resistor. Grid Bias, 0 volts. Grid Resistor, 10 megohms. Voltage Gain, 101 approx.										**1LD5**
1LE3	Detector Amplifier Triode	B5	F	1.4	0.05	Class A Amplifier	90 90	0 − 3	— —	— —	4.5 1.4	11200 19000	1300 760	14.5 14.5	— —	— —	**1LE3**
1LH4	Diode High-Mu Triode	B5	D.C. F	1.4	0.05	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 1H5-GT.										**1LH4**
1LN5	RF Amplifier Pentode	B5	D.C. F	1.4	0.05	Class A Amplifier	90	0	90	0.35	1.6	1.1§	800	—	—	—	**1LN5**
1N5-GT	RF Amplifier Pentode	C3	D.C. F	1.4	0.05	Class A Amplifier	90	0	90	0.3	1.2	1.5§	750	—	—	—	**1N5-GT**
1N6-G	Diode—Power Amplifier Pentode	D1	D.C. F	1.4	0.05	Pentode Unit as Class A Amplifier	90	− 4.5	90	0.7	3.4	300000	800	—	25000	0.1	1N6-G
1P5-GT	Supercontrol RF Amplifier Pentode	C3	D.C. F	1.4	0.05	Class A Amplifier	90	0	90	0.7	2.3	800000	750	—	—	—	**1P5-GT**
1Q5-GT	Beam Power Amplifier	C3	D.C. F	1.4	0.1	Class A Amplifier	110	− 6.6	110	1.4	10.0	100000	2200	—	8000	0.40	**1Q5-GT**
1R5	Pentagrid Converter▲	B0	D.C. F	1.4	0.05	Converter	45 90	0 0	45 67.5	1.9 3.2	0.7 1.6	600000 600000	Grid # 1 Resistor, 100000 ohms. Conversion Transcond., 300 micromhos.				**1R5**
1S4	Power Amplifier Pentode	B0	D.C. F	1.4	0.1	Class A Amplifier	45 90	− 4.5 − 7.0	45 67.5	0.8 1.4	3.8 7.4	100000 100000	1250 1575	—	8000 8000	0.065 0.27	**1S4**
1S5	Diode-Pentode	B0	D.C. F	1.4	0.05	Pentode Unit as AF Amplifier	Plate Supply, 90 volts applied through 1 meg. resistor. Screen Supply, 90 volts applied through 3 meg. resistor. Grid Bias, 0 volts. Grid Resistor, 10 megohms. Voltage Gain, 50 approx.										**1S5**
1T4	Super-Control RF Amplifier Pentode	B0	D.C. F	1.4	0.05	Class A Amplifier	45 90	0 0	45 67.5	0.7 1.4	1.7 3.5	350000 500000	700 900	—	—	—	**1T4**
1T5-GT	Beam Power Amplifier	C3	D.C. F	1.4	0.05	Class A Amplifier	90	− 6.0	90	0.8	6.5	—	1150	—	14000	0.17	**1T5-GT**
1U4	RF Amplifier Pentode	B0	D.C. F	1.4	0.05	Class A Amplifier	90	0	90	0.45	1.6	1.5§	900	—	—	—	**1U4**
1U5	Diode-Pentode	B0	D.C. F	1.4	0.05	Pentode Unit as Class A Amplifier	Plate Supply, 90 volts applied through 1 meg. resistor. Screen Supply, 90 volts applied through 3.3 meg. resistor. Grid Bias, 0 volts. Grid Resistor, 10 megohms. Voltage Gain, 66 approx.										**1U5**
1-v	Half-Wave Rectifier	D5	H	6.3	0.3	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 325 Max. D-C Output Ma., 45				Min. Total Effective Plate-Supply Impedance: Up to 117 volts, 0 ohms; at 150 volts, 30 ohms; at 325 volts, 75 ohms.						**1-v**

2A3	Power Amplifier Triode	E3	F	2.5	2.5	Class A Amplifier	250	−45.0	—	—	60.0	800	5250	4.2	2500	3.5	**2A3**
						Push-Pull Class AB₁ Amplifier	300	Cath. Bias, 780 ohms♠			80.0♠	—	—	—	5000	10.0†	
							300	−62 volts, fixed bias			80.0♠				3000	15.0†	
2A5	Power Amplifier Pentode	D12	H	2.5	1.75	Amplifier	For other characteristics, refer to Type 6F6-G.										**2A5**
2A6	Duplex-Diode High-Mu Triode	D9	H	2.5	0.8	Triode Unit as Amplifier	For other characteristics, refer to Type 6SQ7.										**2A6**
2A7	Pentagrid Converter ⊙	D9	H	2.5	0.8	Converter	For other characteristics, refer to Type 6A8.										**2A7**
2B7	Duplex-Diode Pentode	D9	H	2.5	0.8	Pentode Unit as Amplifier	For other characteristics, refer to Type 6B8-G.										**2B7**
2E5	Electron-Ray Tube	D5	H	2.5	0.8	Visual Indicator	For other characteristics, refer to Type 6E5.										**2E5**
3A8-GT	Diode-Triode RF Amplifier Pentode	C5a	D.C. F	1.4 2.8	0.1 0.05	Triode Unit as Class A Amplifier	90	0	—	—	0.2	200000	325	65	—	—	**3A8-GT**
						Pentode Unit as Class A Amplifier	90	0	90	0.5	1.5	800000	750	—	—	—	
3LF4	Beam Power Amplifier	B5	D.C. F	1.4 2.8	0.1 0.05	Class A Amplifier	For other characteristics, refer to Type 3Q5-GT.										**3LF4**
3Q4	Power Amplifier Pentode	B0	D.C. F	1.4 2.8	0.1 0.05	Class A Amplifier	For other characteristics, refer to Type 3V4.										**3Q4**
3Q5-GT	Beam Power Amplifier	C3	D.C. F	1.4 2.8	0.1 0.05	Class A Amplifier	110 110	−6.6 −6.6	110 110	1.4 1.1	10.0 8.5	100000 110000	2200 2000	—	8000 8000	0.40 0.33	**3Q5-GT**
3S4	Power Amplifier Pentode	B0	D.C. F	1.4 2.8	0.1 0.05	Class A Amplifier	90 90	−7 −7	67.5 67.5	1.4 1.1	7.4 6.1	100000 100000	1575 1425	— —	8000 8000	0.27 0.235	**3S4**
3V4	Power Amplifier Pentode	B0	D.C. F	1.4 2.8	0.1 0.05	Class A Amplifier	90 90	−4.5 −4.5	90 90	2.1 1.7	9.5 7.7	100000 120000	2150 2000	— —	10000 10000	0.27 0.24	**3V4**
5T4	Full-Wave Rectifier	D7	F	5.0	2.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 675				Min. Total Effect. Supply Imped. per Plate, 150 ohms		**5T4**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 550 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 675				Min. Value of Input Choke, 3 henries		
5TP4	Projection Kinescope	H1	H	6.3	0.6	Picture Reproduction With Reflective Optical System	Focus: Electrostatic Deflection: Magnetic Deflection Angle: 50° Phosphor: No. 4 Picture Size: 18″ x 24″			Anode-No. 2 Volts, 27000 (max.) Anode-No. 1 Volts for Focus, 4300 to 5400 (6000 max.) Grid-No. 2 Volts, 200 (350 max.) Grid-No. 1 Volts for Visual Cutoff, −42 to −98					Anode-No. 2 Current Range, 100 to 200 microamperes Anode-No. 1 Current, 75 microamperes (max.) Grid-No. 2 Current Range, −15 to +15 microamperes		**5TP4**
5U4-G	Full-Wave Rectifier	E2	F	5.0	3.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 675				Min. Total Effect. Supply Imped. per Plate, 75 ohms		**5U4-G**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 550 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 675				Min. Value of Input Choke, 3 henries		
5V4-G	Full-Wave Rectifier	D10	H	5.0	2.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 375 Max. Peak Inverse Volts, 1400				Max. D-C Output Ma., 175 Max. Peak Plate Ma., 525				Min. Total Effect. Supply Imped. per Plate, 100 ohms		**5V4-G**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 500 Max. Peak Inverse Volts, 1400				Max. D-C Output Ma., 175 Max. Peak Plate Ma., 525				Min. Value of Input Choke, 4 henries		
5W4 5W4-GT	Full-Wave Rectifiers	C2 C7	F	5.0	1.5	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 350 Max. Peak Inverse Volts, 1400				Max. D-C Output Ma., 100 Max. Peak Plate Ma., 300				Min. Total Effect. Supply Imped. per Plate, 50 ohms		**5W4** 5W4-GT
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 500 Max. Peak Inverse Volts, 1400				Max. D-C Output Ma., 100 Max. Peak Plate Ma., 300				Min. Value of Input Choke, 6 henries		

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
5X4-G	Full-Wave Rectifier	E2	F	5.0	3.0		For other ratings, refer to Type 5U4-G.										5X4-G
5Y3-GT	Full-Wave Rectifier	C7	F	5.0	2.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 350 Max. Peak Inverse Volts, 1400 Max. D-C Output Ma., 125 Max. Peak Plate Ma., 375 Min. Total Effect. Supply Imped. per Plate, 50 ohms										5Y3-GT
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 500 Max. Peak Inverse Volts, 1400 Max. D-C Output Ma., 125 Max. Peak Plate Ma., 375 Min. Value of Input Choke, 5 henries										
5Y4-G	Full-Wave Rectifier	D10	F	5.0	2.0		For other ratings, refer to Type 5Y3-GT.										5Y4-G
5Z3	Full-Wave Rectifier	E3	F	5.0	3.0		For other ratings, refer to Type 5U4-G.										5Z3
5Z4	Full-Wave Rectifier	C2	H	5.0	2.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 350 Max. Peak Inverse Volts, 1400 Max. D-C Output Ma., 125 Max. Peak Plate Ma., 375 Min. Total Effect. Supply Imped. per Plate, 50 ohms										5Z4
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 500 Max. Peak Inverse Volts, 1400 Max. D-C Output Ma., 125 Max. Peak Plate Ma., 375 Min. Value of Input Choke, 5 henries										
6A3	Power Amplifier Triode	E3	F	6.3	1.0	Amplifier	For other characteristics, refer to Type 6B4-G.										6A3
6A4/LA	Power Amplifier Pentode	D12	F	6.3	0.3	Class A Amplifier	100 180	−6.5 −12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	—	11000 8000	0.31 1.40	6A4/LA
6A6	Twin-Triode Amplifier	D12	H	6.3	0.8	Amplifier	For other characteristics, refer to Type 6N7-GT.										6A6
6A7	Pentagrid Converter ●	D9	H	6.3	0.3	Converter	For other characteristics, refer to Type 6A8.										6A7
6A7S	Pentagrid Converter ●	D9	H	6.3	0.3	Converter	For other characteristics, refer to Type 6A8.										6A7S
6A8 6A8-G 6A8-GT	Pentagrid Converters ●	C1 D8 C3	H	6.3	0.3	Converter	100 250	−1.5 −3.0	50 100	1.3 2.7	1.[illegible] 3.5	600000 360000	Anode-Grid (#2): 250 ▲ max. volts, 4.0 ma. Oscillator-Grid (#1) Resistor ●. Conversion Transcond., 550 micromhos.				6A8 6A8-G 6A8-GT
6AB5/ 6N5	Electron-Ray Tube	D4	H	6.3	0.15	Visual Indicator	Plate & Target Supply = 135 volts. Triode Plate Resistor = 0.25 meg. Target Current = 2.0 ma. Grid Bias, − 10.0 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.5 ma.										6AB5/ 6N5
							Plate & Target Supply = 135 volts. Triode Plate Resistor = 1.0 meg. Target Current = 1.9 ma. Grid Bias, −15.5 volts; Shadow Angle, 0°. Bias, 0 volts; Angle 90°; Plate Current, 0.13 ma.										
6AB7/ 1853	Television Amplifier Pentode	B3	H	6.3	0.45	Class A Amplifier	300	− 3.0	200	3.2	12.5	700000	5000	—	—	—	6AB7/ 1853
6AC5-GT	High-Mu Power Amplifier Triode	C3	H	6.3	0.4	Class B Amplifier	250	0	—	—	5.0♠	—	—	—	10000	8.0†	6AC5-GT
						Dynamic-Coupled Amplifier With 76 Driver	250	Bias for both 6AC5-GT and 76 is developed in coupling circuit. Average Plate Current of Driver = 5.5 milliamperes. Average Plate Current of 6AC5-GT = 32 milliamperes.							7000	3.7	
6AC7/ 1852	Television Amplifier Pentode	B3	H	6.3	0.45	Class A Amplifier	300	Cath. Bias	150	2.5	10.0	1.0§	9000	Cathode-Bias Resistor, 160 ohms			6AC7/ 1852

6AD6-G	Electron-Ray Tube Twin Indicator Type	B5a	H	6.3	0.15	Visual Indicator	Target Voltage, 100 volts. Control-Electrode Voltage, −23 volts; Shadow Angle, 135°; Target Current, 0.8 ma. Control-Electrode Voltage, 45 volts; Angle, 0°; Target Current, 1.5 ma. Target Voltage, 150 volts. Control-Electrode Voltage, −50 volts; Shadow Angle, 135°; Target Current, 1.2 ma. Control-Electrode Voltage, 75 volts; Angle, 0°; Target Current, 3 ma.										6AD6-G
6AD7-G	Triode-Power Amplifier Pentode	D10	H	6.3	0.85	Triode Unit as Class A Amplifier	250	−25.0	—	—	3.7	19000	325	6	—	—	6AD7-G
						Pentode Unit as Class A Amplifier	250	−16.5	250	6.5	34.0	80000	2500	—	7000	3.2	
						Pentode Unit With 6F6-G as Push-Pull Class AB_1 Amplifier	375	Cath. Bias	250	6.7♠	41.0♠	Cathode-Bias Resistor, 470 ohms♠			16000	9.0†	
6AE5-GT	Amplifier Triode	C3	H	6.3	0.3	Class A Amplifier	95	−15.0	—	—	7.0	3500	1200	4.2	—	—	6AE5-GT
6AE6-G	Twin-Plate Control Tube	D3	H	6.3	0.15	Remote-Cutoff Triode	250 250	− 1.5 −35.0	— —	— —	6.5 0.01	25000 —	1000 —	25 —	— —	— —	6AE6-G
						Remote-Cutoff Triode	250 250	− 1.5 − 9.5	— —	— —	4.5 0.01	35000 —	950 —	33 —	— —	— —	
6AE7-GT	Twin-Input Triode Amplifier	C3	H	6.3	0.5	Class A Amp.▲▲	250	−13.5	—	—	10.0	4650	3000	14	—	—	6AE7-GT
						Driver For Push-Pull 6AC5-GT In Dynamic-Coupled Amplifier	250	Bias for both 6AC5-GT and 6AE7-GT developed in coupling circuit. Zero-Signal Plate Current of 6AE7-GT = 10 milliamperes. Zero-Signal Plate Current of 6AC5-GT = 64 milliamperes. Power Output is for two 6AC5-GT at stated plate-to-plate load.							10000	9.5	
6AF6-G	Electron-Ray Tube Twin Indicator Type	B2	H	6.3	0.15	Visual Indicator	Target Voltage, 125 volts. Control-Electrode Voltage, 0 volts; Shadow Angle, 95°; Target Current, 0.65 ma. Control-Electrode Voltage, 80 volts; Angle, 0°. Target Voltage, 250 volts. Control-Electrode Voltage, 0 volts; Shadow Angle, 95°; Target Current, 2.2 ma. Control-Electrode Voltage, 160 volts; Angle, 0°.										6AF6-G
6AG5	RF Amplifier Pentode	B0	H	6.3	0.3	As Pentode Class A Amplifier	100 250	Cath. Bias	100 150	1.6 2.0	5.5 7.0	300000 800000	4750 5000	Cath. Bias Res., 100 ohms Cath. Bias Res., 200 ohms			6AG5
						As Triode□ Class A Amplifier	180 250	Cath. Bias	— —	— —	7.0 5.5	7900 11000	5700 3800	Cath. Bias Res., 350 ohms Cath. Bias Res., 825 ohms			
6AG7	Video Power Amplifier Pentode	C2	H	6.3	0.65	Class A Amplifier	300	Cath. Bias − 2.0	125	7.0	28.0	Cathode-Bias Resistor, 57 ohms. Load Resistance, 3500 ohms. Peak-to-Peak Volts Output, 140 approx.					6AG7
6AK6	Power Amplifier Pentode	B0	H	6.3	0.15	Class A Amplifier	180	− 9.0	180	2.5	15	200000	2300	—	10000	1.1	6AK6
6AL5	Twin Diode	A1	H	6.3	0.3	Detector Rectifier	Max. Peak Inverse Volts, 420 Max. Peak Plate Ma. per Plate, 54					Max. D-C Output Ma. per Plate, 9 Max. Peak Heater-Cathode Volts, 330					6AL5
6AQ5	Beam Power Amplifier	B1a	H	6.3	0.45	Single Tube Class A Amplifier	180 250	− 8.5 −12.5	180 250	3.0 4.5	29.0 45.0	58000 52000	3700 4100	— —	5500 5000	2.0 4.5	6AQ5
						Push-Pull Class AB_1 Amplifier	250	−15.0	250	5.0♠	70.0♠	—	—	—	10000	10.0†	
6AQ6	Duplex-Diode High-Mu Triode	B0	H	6.3	0.15	Triode Unit as Class A Amplifier	100 250	− 1.0 − 3.0	— —	— —	0.8 1.0	61000 58000	1150 1200	70 70	— —	— —	6AQ6
6AT6	Duplex-Diode High-Mu Triode	B0	H	6.3	0.3	Triode Unit as Class A Amplifier	100 250	− 1.0 − 3.0	— —	— —	0.8 1.0	54000 58000	1300 1200	70 70	— —	— —	6AT6
6AU6	RF Amplifier Pentode	B0	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 1.0	100 150	2.0 4.3	5.2 10.8	500000 1.0§	3900 5200	— —	— —	— —	6AU6

RCA Type	Name	Tube Dimensions	Cathode Type and Rating: C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply (Volts)	Grid Bias ■ (Volts)	Screen Supply (Volts)	Screen Current (Ma.)	Plate Current (Ma.)	AC Plate Resistance (Ohms)	Transconductance (Grid-plate) (µmhos)	Amplification Factor	Load for Stated Power Output (Ohms)	Power Output (Watts)	RCA Type
6AV6	Twin-Diode High-Mu Triode	B0	H	6.3	0.3	Triode Unit as Class A Amplifier	100 250	− 1.0 − 2.0	—— ——	—— ——	0.5 1.2	80000 62500	1250 1600	100 100	—— ——	—— ——	6AV6
6B4-G	Power Amplifier Triode	E2	F	6.3	1.0	Class A Amplifier	250	−45.0	——	——	60.0	800	5250	4.2	2500	3.20	6B4-G
						Push-Pull Class AB₁ Amplifier	325 325	Cath. Bias, 850 ohms♠ −68 volts, fixed bias			80.0♠ 80.0♠	——	——	——	5000 3000	10.0† 15.0†	
6B5	Direct-Coupled Power Amplifier	D12	H	6.3	0.8	Class A Amplifier	For other characteristics, refer to Type 6N6-G.										6B5
6B6-G	Duplex-Diode High-Mu Triode	D8	H	6.3	0.3	Triode Unit as Amplifier	For other characteristics, refer to Type 6SQ7.										6B6-G
6B7	Duplex-Diode Pentode	D9	H	6.3	0.3	Pentode Unit as Amplifier	For other characteristics, refer to Type 6B8-G.										6B7
6B7S	Duplex-Diode Pentode	D9	H	6.3	0.3	Pentode Unit as Amplifier	For other characteristics, refer to Type 6B8-G.										6B7S
6B8	Duplex-Diode Pentode	C1	H	6.3	0.3	Pentode Unit as Amplifier	For other characteristics, refer to Type 12C8.										6B8
6B8-G	Duplex-Diode Pentode	D8	H	6.3	0.3	Pentode Unit as RF Amplifier	100 250	− 3.0 − 3.0	100 125	1.7 2.3	5.8 9.0	300000 600000	950 1125	——	——	——	6B8-G
						Pentode Unit as AF Amplifier	90 ¤ 300 ¤	Cath. Bias, 3500 ohms. Screen Resistor = 1.1 meg. Cath. Bias, 1600 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.		Gain per stage = 55 Gain per stage = 79		
6BA6	RF Amplifier Pentode	B0	H	6.3	0.3	Class A Amplifier	100 250	Cath. Bias	100 100	4.4 4.2	10.8 11.0	250000 1.0	4300 4400	Cath. Bias Res., 68 ohms Cath. Bias Res., 68 ohms			6BA6
6BE6	Pentagrid Converter▲	B0	H	6.3	0.3	Converter	100 250	− 1.5 − 1.5	100 100	8.0 7.8	2.8 3.0	500000 1.0§	Grid # 1 Resistor, 20000 ohms Conversion Transcond., 475 micromhos				6BE6
6BF6	Duplex-Diode Triode	B0	H	6.3	0.3	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 6SR7.										6BF6
6BG6-G	Beam Power Amplifier	F1	H	6.3	0.9	Deflection Amplifier in Television Equipment	Max. Ratings: D-C Plate Volts, 500 D-C Plate Current, 100 ma. Plate Dissipation, 20 watts Typical Operation: D-C Plate and Grid # 2 Supply Volts, 400 D-C Plate Current, 70 ma.										6BG6-G
6BH6	Sharp-Cutoff Pentode	B0	H	6.3	0.15	Class A Amplifier	100 250	− 1.0 − 1.0	100 150	1.4 2.9	3.6 7.4	700000 1.4§	3400 4600	—— ——	—— ——	—— ——	6BH6
6BJ6	RF Amplifier Pentode	B0	H	6.3	0.15	Class A Amplifier	100 250	− 1.0 − 1.0	100 100	3.5 3.3	9.0 9.2	250000 1.3§	3650 3800	—— ——	—— ——	—— ——	6BJ6
6C4	HF Power Triode	B0	H	6.3	0.15	Class A Amplifier	100 250	0 − 8.5	——	——	11.8 10.5	6250 7700	3100 2200	19.5 17	——	——	6C4
						Class C Amplifier	300	−27.0	——	——	25.0	Grid Current, 7 ma. Driving Power, 0.35 watt			——	5.5	
6C5 6C5-GT	Medium-Mu Triodes	B3 C3	H	6.3	0.3	Class A Amplifier	250	− 8.0	——	——	8.0	10000	2000	20	——	——	6C5 6C5-GT
							90♥ 300♥	Cath. Bias, 6400 ohms. Cath. Bias, 5300 ohms.				Grid Resistor,** 0.25 megohm.			Gain per stage = 11 Gain per stage = 13		
						Bias Detector	250	−17.0 approx. Plate current to be adjusted to 0.2 milliampere with no signal.									

6C6	Triple-Grid Detector Amplifier	D13	H	6.3	0.3	Amplifier Detector	For other characteristics, refer to Type 6J7.										**6C6**
6C7	Duplex-Diode Triode	D9	H	6.3	0.3	Triode Unit as Class A Amplifier	250	− 9.0	——	——	4.5	16000	1250	20	——	——	6C7
6C8-G	Twin-Triode Amplifier	D8	H	6.3	0.3	Each Unit as Amplifier	250	− 4.5	——	——	3.2	22500	1600	36	——	——	**6C8-G**
6D6	Triple-Grid Supercontrol Amplifier	D13	H	6.3	0.3	Amplifier Mixer	For other characteristics, refer to Type 6U7-G.										**6D6**
6D7	Triple-Grid Detector Amplifier	D13	H	6.3	0.3	Amplifier Detector	For other characteristics, refer to Type 6J7.										6D7
6D8-G	Pentagrid Converter ■	D8	H	6.3	0.15	Converter	135 250	− 3.0 − 3.0	67.5 100	1.7 2.6	1.5 3.5	600000 400000	Anode-Grid (#2): 250 ■ max. volts, 4.3 ma. Oscillator-Grid (#1) Resistor ■, Conversion Transcond., 550 micromhos.				**6D8-G**
6E5	Electron-Ray Tube	D4	H	6.3	0.3	Visual Indicator	Plate & Target Supply = 125 volts. Triode Plate Resistor = 1.0 meg. Target Current = 0.8 ma. Grid Bias, −4.0 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.1 ma. Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 2.0 ma. Grid Bias, −7.5 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.2 ma.										**6E5**
6E6	Twin-Triode Power Amplifier	D12	H	6.3	0.6	Push-Pull Class A Amplifier	180 250	−20.0 −27.5	——	——	Power Output is for one tube at stated plate-to-plate load.				15000 14000	0.75 1.60	6E6
6E7	Triple-Grid Supercontrol Amplifier	D13	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6U7-G.										6E7
6F5	High-Mu Triode	C1	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6SF5.										**6F5**
6F5-GT	High-Mu Triode	C3	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6SF5.										**6F5-GT**
6F6	Power Pentodes	C2	H	6.3	0.7	Pentode Class A Amplifier	250 285	−16.5 −20.0	250 285	6.5 7.0	34.0 38.0	80000 78000	2500 2550	——	7000 7000	3.2 4.8	**6F6**
						Triode□ Class A Amplifier	250	−20.0	——	——	31.0	2600	2600	6.8	4000	0.85	
6F6-G		D10				Pentode Push-Pull Class A Amplifier	315 315	Cath. Bias −24.0	285 285	12.0♠ 12.0♠	62.0♠ 62.0♠	Cath. Bias Resistor, 320 ohms♠ ——	 ——	 ——	10000 10000	10.5† 11.0†	**6F6-G**
6F6-GT		C5b				Pentode Push-Pull Class AB_2 Amplifier	375 375	Cath. Bias −26.0	250 250	8.0♠ 5.0♠	54.0♠ 34.0♠	Cath. Bias Resistor, 340 ohms♠ ——	 ——	 ——	10000 10000	19.0† 18.5†	**6F6-GT**
						Triode Push-Pull□ Class AB_1 Amplifier	350 350	Cath. Bias −38.0	——	——	50.0♠ 48.0♠	Cath. Bias Resistor, 730 ohms♠ ——	 ——	 ——	10000 6000	9.0† 13.0†	
6F7	Triode-Pentode	D9	H	6.3	0.3	Triode Unit as Class A Amplifier	100	− 3.0 min.	——	——	3.5	16000	500	8	——	——	**6F7**
						Pentode Unit as Class A Amplifier	100 250	− 3.0 min.	100 100	1.6 1.5	6.3 6.3	290000 850000	1050 1100	——	——	——	
						Pentode Unit as Mixer	250	−10.0	100	0.6	2.8	Oscillator Peak Volts = 7.0. Conversion Transcond. = 300 micromhos.					
6F8-G	Twin-Triode Amplifier	D8	H	6.3	0.6	Each Unit as Amplifier	For other characteristics, refer to Type 6J5.										**6F8-G**

Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	Type
6G6-G	Power Amplifier Pentode	D3	H	6.3	0.15	Pentode Class A Amplifier	135 180	− 6.0 − 9.0	135 180	2.0 2.5	11.5 15.0	170000 175000	2100 2300	—	12000 10000	0.6 1.1	6G6-G
						Triode□ Class A Amplifier	180	−12.0	—	—	11.0	4750	2000	9.5	12000	0.25	
6H6 6H6-GT	Twin Diodes	A1a C3	H	6.3	0.3	Voltage Doubler	Max. A-C Supply Volts per Plate (RMS), 150 Max. D-C Output Ma., 8. min. Total Effect. Plate-Supply Imped. per Plate: half-wave, 30 ohms; full-wave, 15 ohms.										6H6 6H6-GT
						Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 150 Max. D-C Output Ma., 8 per Plate. Min. Total Effective Plate-Supply Impedance: up to 117 volts, 15 ohms; at 150 volts, 40 ohms.										
6J5 6J5-GT	Medium-Mu Triodes	B3 C3	H	6.3	0.3	Class A Amplifier	90 250	0 − 8.0	—	—	10.0 9.0	6700 7700	3000 2600	20 20	—	—	6J5 6J5-GT
6J6	Medium-Mu Twin Triode	B0	H	6.3	0.45	Each Unit as Class A Amplifier	100	Cathode Resistor, for both units, 50 ohms			8.5	7100	5300	38	—	—	6J6
						Push-Pull Class C Amplifier	150	−10.0	Cath. Res., 220 ohms, both units		30.0	Grid Current, 16 ma. Driving Power, 0.35 watt.			—	3.5	
6J7 6J7-G 6J7-GT	Sharp-Cutoff Pentodes	C1 D8 C3	H	6.3	0.3	Pentode Class A RF Amplifier	100 250	− 3.0 − 3.0	100 100	0.5 0.5	2.0 2.0	1.0§ 1.0 +§	1185 1225	—	—	—	6J7 6J7-G 6J7-GT
						Pentode Class A AF Amplifier	90 ⌘ 300 ⌘	Cath. Bias, 2600 ohms. Screen Resistor = 1.2 meg. Cath. Bias, 1200 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.		Gain per stage = 85 Gain per stage = 140		
						Pentode Bias Detector	250	− 4.3	100	Cathode Current 0.43 ma.		—	Plate Resistor, 500000 ohms. Grid Resistor,** 250000 ohms.				
						Triode⧧ Class A Amplifier	180 250	− 5.3 − 8.0	—	—	5.3 6.5	11000 10500	1800 1900	20 20	—	—	
6J8-G	Triode-Heptode Converter	D8	H	6.3	0.3	Triode Unit as Oscillator	100 250 ⌘	Triode-Grid Resistor, 50000 ohms			4.0 5.8	Triode-Grid & Heptode-Grid Current, 0.3 ma. Triode-Grid & Heptode-Grid Current, 0.4 ma.					6J8-G
						Heptode Unit as Mixer	100 250	− 3.0 − 3.0	100 100	3.0 2.9	1.4 1.3	900000 4.0§	Conversion Transcond., 260 micromhos. Conversion Transcond., 290 micromhos.				
6K5-GT	High-Mu Triode	D8	H	6.3	0.3	Class A Amplifier	100 250	− 1.5 − 3.0	—	—	0.35 1.1	78000 50000	900 1400	70 70	—	—	6K5-GT
6K6-GT	Power Amplifier Pentode	C3	H	6.3	0.4	Single-Tube Class A Amplifier	100 250 315	− 7.0 −18.0 −21.0	100 250 250	1.6 5.5 4.0	9.0 32.0 25.5	104000 68000 75000	1500 2300 2100	—	12000 7600 9000	0.35 3.40 4.50	6K6-GT
						Push-Pull Class A Amplifier	285 285	−25.5 Cath. Bias	285 285	9.0♠ 9.0♠	55.0♠ 55.0♠	— Cath. Bias Resistor, 400 ohms.♠	—	—	12000 12000	10.5† 9.8†	
6K7 6K7-G 6K7-GT	Remote-Cutoff Pentodes	C1 D8 C3	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 3.0	100 125	2.7 2.6	9.5 10.5	150000 600000	1650 1650	—	—	—	6K7 6K7-G 6K7-GT
						Mixer in Superheterodyne	250	−10.0	100	—	—	Oscillator Peak Volts = 7.0					
6K8 6K8-G 6K8-GT	Triode-Hexode Converters	C1 D8 C7a	H	6.3	0.3	Triode Unit as Oscillator	100	Triode-Grid Resistor, 50000 ohms			3.8	Triode-Grid & Hexode-Grid Current, 0.15 ma.					6K8 6K8-G 6K8-GT
						Hexode Unit as Mixer	100 250	− 3.0 − 3.0	100 100	6.2 6.0	2.3 2.5	400000 600000	Conversion Transcond., 325 micromhos. Conversion Transcond., 350 micromhos.				

6L5-G	Detector Amplifier Triode	D3	H	6.3	0.15	Class A Amplifier	135 250	−5.0 −9.0	— —	— —	3.5 8.0	11300 9000	1500 1900	17 17	—	—	**6L5-G**
6L6 **6L6-G**	Beam Power Amplifiers	D7 E2	H	6.3	0.9	Single-Tube Class A Amplifier	250 250	−14.0 Cath. Bias	250 250	5.0 5.4	72.0 75.0	— Cath. Bias Resistor, 170 ohms.	—	—	2500 2500	6.5 6.5	**6L6** **6L6-G**
						Push-Pull Class A Amplifier	270 270	−17.5 Cath. Bias	270 270	11.0♠ 11.0♠	134.0♠ 134.0♠	— Cath. Bias Resistor, 125 ohms.♠	—	—	5000 5000	17.5† 18.5†	
						Push-Pull Class AB_1 Amplifier	360 360	−22.5 Cath. Bias	270 270	5.0♠ 5.0♠	88.0♠ 88.0♠	— Cath. Bias Resistor, 250 ohms.♠	—	—	6600 9000	26.5† 24.5†	
						Push-Pull Class AB_2 Amplifier	360 360	−18.0 −22.5	225 270	3.5♠ 5.0♠	78.0♠ 88.0♠	—	—	—	6000 3800	31.0† 47.0†	
						Single Triode□ Class A Amplifier	250 250	−20.0 Cath. Bias	—	—	40.0 40.0	1700 Cath. Bias Resistor, 490 ohms.	4700	8.0	5000 6000	1.4 1.3	
6L7 **6L7-G**	Pentagrid Mixers▲	C1 D8	H	6.3	0.3	Mixer in Superheterodyne	250	−3.0	100	7.1	2.4	Oscillator-Grid (#3) Bias, −10 volts. Grid #3 Peak Swing, 12 volts minimum. Conversion Transcond., 375 micromhos.					**6L7** **6L7-G**
						Class A Amplifier	250	−3.0◆	100	6.5	5.3	600000	1100	—	—	—	
6N6-G	Direct-Coupled Powrr Amplifier	D10	H	6.3	0.8	Class A Amplifier	Output Triode: Plate Volts, 300; Plate Ma., 45; Load, 7000 ohms. Input Triode: Plate Volts, 300; Grid Volts, 0; A-F Signal Volts (Peak), 21; Plate Ma., 8.									4.0	6N6-G
6N7 **6N7-GT**	High-Mu Twin Power Triodes	C2 C3	H	6.3	0.8	Class A Amplifier (as Driver)[9]	250 294	−5.0 −6.0	—	—	6.0 7.0	11300 11000	3100 3200	35 35	20000 or more	exceeds 0.4	**6N7** **6N7-GT**
						Class B Amplifier	300	0	—	—	Power Output is for one tube at stated plate-to-plate load.				8000	10.0	
6P5-GT	Detector Amplifier Triode	C3	H	6.3	0.3	Amplifier Detector	For other characteristics, refer to Type 76.										**6P5-GT**
6P7-G	Triode-Pentode	D8	H	6.3	0.3	Amplifier and Converter	For other characteristics, refer to Type 6F7.										6P7-G
6Q7 **6Q7-G** **6Q7-GT**	Twin-Diode High-Mu Triodes	C1 D8 C3	H	6.3	0.3	Triode Unit as Class A Amplifier	100 250	−1.0 −3.0	—	—	0.8 1.1	58000 58000	1200 1200	70 70	—	—	**6Q7** **6Q7-G** **6Q7-GT**
							90⌘ 300⌘	Cath. Bias, 7600 ohms. Cath. Bias, 3000 ohms.	Grid Resistor,** 0.5 megohm.						Gain per stage = 32 Gain per stage = 45		
6R7 6R7-G **6R7-GT**	Twin-Diode Medium-Mu Triodes	C1 D8 C3	H	6.3	0.3	Triode Unit as Class A Amplifier	250	−9.0	—	—	9.5	8500	1900	16	—	—	**6R7** 6R7-G **6R7-GT**
							90♥ 300♥	Cath. Bias, 4400 ohms. Cath. Bias, 3800 ohms.	Grid Resistor,** 0.25 megohm.						Gain per stage = 10 Gain per stage = 10		
6S7 **6S7-G**	Remote-Cutoff Pentodes	C1 D8	H	6.3	0.15	Class A Amplifier	135 250	−3.0 −3.0	67.5 100	0.9 2.0	3.7 8.5	1.0§ 1.0§	1250 1750	—	—	—	**6S7** **6S7-G**
6S8-GT	Triple-Diode Triode	C7b	H	6.3	0.3	Triode Unit as Class A Amplifier	100 250	−1.0 −2.0	—	—	0.4 0.9	110000 91000	900 1100	100 100	—	—	**6S8-GT**
6SA7	Pentagrid Converter▲	B3	H	6.3	0.3	Mixer	100 250	Self-Excited	100 100	8.5 8.5	3.3 3.5	500000 1.0§	Grid #1 Resistor, 20000 ohms. Conversion Transcond., 450 micromhos.				**6SA7**
6SA7-GT	Pentagrid Converter▲	C3	H	6.3	0.3	Mixer	For other characteristics, refer to Type 6SA7.										**6SA7-GT**
6SB7-Y	Pentagrid Converter▲	B3	H	6.3	0.3	Mixer	100 250	−1.0 −1.0	100 100	10.2 10.0	3.6 3.8	500000 1.0§	Grid #1 Resistor, 20000 ohms Conversion Transcond., 950 micromhos				**6SB7-Y**

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
6SC7	Twin-Triode Amplifier	B3	H	6.3	0.3	Each Unit as Amplifier	250	− 2.0	——	——	2.0	53000	1325	70	——	——	6SC7
6SF5 6SF5-GT	High-Mu Triodes	B3 C3	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 2.0	——	——	0.4 0.9	85000 66000	1150 1500	100 100	——	——	6SF5 6SF5-GT
							90 ✠ 300 ✠	Cath. Bias, 8800 ohms. Cath. Bias, 3200 ohms.			Grid Resistor,** 0.5 megohm.				Gain per stage = 43 Gain per stage = 63		
6SF7	Diode-Remote-Cutoff Pentode	B3	H	6.3	0.3	Pentode Unit as Class A Amplifier	100 250	− 1.0 − 1.0	100 100	4.3 4.1	13.5 13.9	200000 700000	1975 2050	——	——	——	6SF7
6SG7	Semi-Remote-Cutoff Pentode	B3	H	6.3	0.3	Class A Amplifier	100 250 250	− 1.0 − 1.0 − 2.5	100 125 150	3.2 4.4 3.4	8.2 11.8 9.2	250000 900000 1.0+§	4100 4700 4000	——	——	——	6SG7
6SH7	Sharp-Cutoff Pentode	B3	H	6.3	0.3	Class A Amplifier	100 250	− .0 − 1.0	100 150	2.1 4.1	5.3 10.8	350000 900000	4000 4900	——	——	——	6SH7
6SJ7 6SJ7-GT	Sharp-Cutoff Pentodes	B3 C3	H	6.3	0.3	Class A Amplifier	100 250	− 3.0 − 3.0	100 100	0.9 0.8	2.9 3.0	700000 1.0+§	1575 1650	——	——	——	6SJ7 6SJ7-GT
							90 ✠ 300 ✠	Cath. Bias, 1700 ohms. Cath. Bias, 860 ohms.			Grid Resistor,** 0.5 megohm.				Gain per stage = 93 Gain per stage = 167		
6SK7 6SK7-GT	Remote-Cutoff Pentodes	B3 C3	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 3.0	100 100	4.0 2.6	13.0 9.2	120000 800000	2350 2000	——	——	——	6SK7 6SK7-GT
6SL7-GT	Twin-Triode Amplifier	C3	H	6.3	0.3	Each Unit as Amplifier	250	− 2.0	——	——	2.3	44000	1600	70	——	——	6SL7-GT
6SN7-GT	Twin-Triode Amplifier	C3	H	6.3	0.6	Each Unit as Amplifier	For other characteristics, refer to Type 6J5.										6SN7-GT
6SQ7 6SQ7-GT	Twin-Diode High-Mu Triodes	B3 C3	H	6.3	0.3	Triode Unit as Class A Amplifier	100 250	− 1.0 − 2.0	——	——	0.4 0.9	110000 91000	900 1100	100 100	——	——	6SQ7 6SQ7-GT
							90 ✠ 300 ✠	Cath. Bias, 11000 ohms. Cath. Bias, 3900 ohms.			Grid Resistor, ** 0.5 megohm.				Gain per stage = 40 Gain per stage = 53		
6SR7	Duplex-Diode Triode	B3	H	6.3	0.3	Triode Unit as Class A Amplifier	250	− 9.0	——	——	9.5	8500	1900	16	10000	0.3	6SR7
6SS7	Triple-Grid Supercontrol Amplifier	B3	H	6.3	0.15	Class A Amplifier	100 250	− 1.0 − 3.0	100 100	3.1 2.0	12.2 9.0	120000 1.0§	1930 1850	——	——	——	6SS7
6ST7	Duplex-Diode Triode	B3	H	6.3	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6SR7.										6ST7
6SZ7	Duplex-Diode High-Mu Triode	B3	H	6.3	0.15	Triode Unit as Class A Amplifier	100 250	− 1.0 − 3.0	——	——	0.8 1.0	61000 58000	1150 1200	70 70	——	——	6SZ7
6T7-G	Duplex-Diode High-Mu Triode	D8	H	6.3	0.15	Triode Unit as Class A Amplifier	135 250	− 1.5 − 3.0	——	——	0.9 1.2	65000 62000	1000 1050	65 65	——	——	6T7-G
							90 ✠ 300 ✠	Cath. Bias, 8300 ohms. Cath. Bias, 4580 ohms.			Grid Resistor,** 0.5 megohm.				Gain per stage = 30 Gain per stage = 40		

6U5/6G5	Electron-Ray Tube	D4	H	6.3	0.3	Visual Indicator	Plate & Target Supply = 125 volts. Triode Plate Resistor = 0.5 meg. Target Current = 1.0 ma. Grid Bias, −8 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.19 ma. Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 4.0 ma. Grid Bias, −22 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.24 ma.										6U5/6G5
6U7-G	Triple-Grid Supercontrol Amplifier	D12a	H	6.3	0.3	Class A Amplifier	100 250	− 3.0 − 3.0	100 100	2.2 2.0	8.0 8.2	250000 800000	1500 1600	—	—	—	6U7-G
						Mixer in Superheterodyne	100 250	−10.0 −10.0	100 100	—	—	Oscillator Peak Volts = 7.0					
6V6 6V6-GT	Beam Power Amplifiers	C2 C3	H	6.3	0.45	Single-Tube Class A Amplifier	180 250 315	− 8.5 −12.5 −13.0	180 250 225	3.0 4.5 2.2	29.0 45.0 34.0	58000 52000 77000	3700 4100 3750	— — —	5500 5000 8500	2.0 4.5 5.5	6V6 6V6-GT
						Push-Pull Class AB_1 Amplifier	250 285	−15.0 −19.0	250 285	5.0♠ 4.0♠	70.0♠ 70.0♠	— —	— —	— —	10000 8000	10.0† 14.0†	
6V7-G	Duplex-Diode Triode	D8	H	6.3	0.3	Triode Unit as Amplifier	For other characteristics, refer to Type 85.										6V7-G
6W7-G	Triple-Grid Detector Amplifier	D8	H	6.3	0.15	Class A Amplifier	250	− 3.0	100	0.5	2.0	1.5§	1225	—	—	—	6W7-G
6X4	Full-Wave Rectifier	B1a	H	6.3	0.6	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 210			Min. Total Effect. Supply Imped. per Plate, 150 ohms			6X4
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 210			Min. Value of Input Choke, 8 henries			
6X5 6X5-GT	Full-Wave Rectifiers	C2 C3	H	6.3	0.6	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 210			Min. Total Effect. Supply Imped. per Plate, 150 ohms			6X5 6X5-GT
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 210			Min. Value of Input Choke, 8 henries			
6Y5	Full-Wave Rectifier	D5	H	6.3	0.8	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 350 Max. D-C Output Ma., 50										6Y5
6Y6-G	Beam Power Amplifier	D10	H	6.3	1.25	Single-Tube Class A Amplifier	135 200	−13.5 −14.0	135 135	3.5 2.2	58.0 61.0	9300 18300	7000 7100	— —	2000 2600	3.6 6.0	6Y6-G
6Y7-G	Twin-Triode Amplifier	D3	H	6.3	0.6	Class B Amplifier	For other characteristics, refer to Type 79.										6Y7-G
6Z5	Full-Wave Rectifier	D5	H	6.3 12.6	0.8 0.4	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 230 Max. D-C Output Ma., 60										6Z5
6Z7-G	Twin-Triode Amplifier	D3	H	6.3	0.3	Class B Amplifier	135 180	0 0	—	—	Power Output is for one tube at stated plate-to-plate load.				9000 12000	2.5 4.2	6Z7-G
6ZY5-G	Full-Wave Rectifier	D3	H	6.3	0.3	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 40 Max. Peak Plate Ma., 120			Min. Total Effect. Supply Imped. per Plate, 225 ohms			6ZY5-G
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 40 Max. Peak Plate Ma., 120			Min. Value of Input Choke, 13.5 henries			
7A4	Detector Amplifier Triode	B5	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6J5.										7A4
7A5	Beam Power Amplifier	C6	H	6.3	0.75	Class A Amplifier	110 125	− 7.5 − 9.0	110 125	3.0 3.3	40.0 44.0	14000 17000	5800 6000	—	2500 2700	1.5 2.2	7A5
7A6	Twin Diode	B5	H	6.3	0.15	Detector Rectifier	Maximum A-C Voltage per Plate..............................150 Volts, RMS Maximum D-C Output Current per plate................ 8 Milliamperes										7A6
7A7	Triple-Grid Supercontrol Amplifier	B5	H	6.3	0.3	Class A Amplifier	For other characteristics, refer to Type 6SK7.										7A7

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use Values to right give operating conditions and characteristics for indicated typical use	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
7A8	Octode Converter	B5	H	6.3	0.15	Converter	100 250	− 3.0 − 3.0	75 100	2.7 3.2	1.8 3.0	650000 700000	Anode-Grid (#2): 250 ■ max. volts, 4.2 ma. Oscillator-Grid (#1) Resistor ■. Conversion Transcond., 550 micromhos.				7A8
7B4	High-Mu Triode	B5	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6SF5.										7B4
7B5	Power Amplifier Pentode	C8	H	6.3	0.4	Class A Amplifier	For other characteristics, refer to Type 6K6-GT.										7B5
7B6	Duplex-Diode High-Mu Triode	B5	H	6.3	0.3	Triode Unit as Amplifier	For other characteristics, refer to Type 6SQ7.										7B6
7B7	Triple-Grid Supercontrol Amplifier	B5	H	6.3	0.15	Class A Amplifier	250	− 3.0	100	1.7	8.5	750000	1750	——	——	——	7B7
7B8	Pentagrid Converter●	B5	H	6.3	0.3	Converter	For other characteristics, refer to Type 6A8.										7B8
7C5	Beam Power Amplifier	C8	H	6.3	0.45	Class A Amplifier	For other characteristics, refer to Type 6V6-GT.										7C5
7C6	Duplex-Diode High-Mu Triode	B5	H	6.3	0.15	Triode Unit as Class A Amplifier	250	− 1.0	——	——	1.3	100000	1000	100	——	——	7C6
7C7	Triple-Grid Detector Amplifier	B5	H	6.3	0.15	Class A Amplifier	100 250	− 3.0 − 3.0	100 100	0.4 0.5	1.8 2.0	1.2§ 2.0§	1225 1300	——	——	——	7C7
7DP4	Directly Viewed Kinescope	11	H	6.3	0.6	Picture Reproduction	Focus: Electrostatic Deflection: Magnetic Deflection Angle: 50° Phosphor: No. 4 Picture Size: 4" x 5¼" Uses Ion-Trap Magnet			Anode-No. 2 Volts, 8000 (max.) Anode-No. 1 Volts for Focus, 1216 to 1644 (2400 max.). Grid-No. 2 Volts, 250 (410 max.) Grid-No. 1 Volts for Visual Cutoff, −27 to −63				Anode-No. 1 Current Range, −15 to +10 microamperes Ion-Trap Magnet Current, 70 approx. ma. (dc) Deflection Coil Current, 410 approx. ma. (dc)				7DP4
7E6	Duplex-Diode Triode	B5	H	6.3	0.3	Triode Unit as Amplifier	For other characteristics, refer to Type 6R7.										7E6
7E7	Duplex-Diode Pentode	B5	H	6.3	0.3	Pentode Unit as Class A Amplifier	100 250	− 1.0 − 3.0	100 100	2.7 1.6	10.0 7.5	150000 700000	1600 1300	——	——	——	7E7
7F7	Twin-Triode Amplifier	B5	H	6.3	0.3	Each Unit as Amplifier	For other characteristics, refer to Type 6SL7-GT.										7F7
7F8	Twin-Triode Amplifier	B0b	H	6.3	0.3	Each Unit as Class A Amplifier	250	Cathode-Bias Res., 500 ohms			6.0	——	3300	48	——	——	7F8
7G7/1232	Television Amplifier Pentode	B5	H	6.3	0.45	Class A Amplifier	250	− 2.0	100	2.0	6.0	800000	4500	——	——	——	7G7/1232
7GP4	Directly Viewed Kinescope	11a	H	6.3	0.6	Picture Reproduction	Anode-No. 2 and Grid-No. 2 Volts, 4000 (max.) Anode-No. 1 Volts for Focus, 1080 to 1600 Grid-No. 1 Volts for Visual Cutoff, 48 to 112							For other characteristics, refer to Type 7JP4.			7GP4

7H7	Triple-Grid Supercontrol Amplifier	B5	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 2.5	100 150	3.3 3.5	8.2 9.5	250000 800000	3800 3800	—	—	—	**7H7**
7J7	Triode-Heptode Converter	B5	H	6.3	0.3	Triode Unit as Oscillator	100 250	Triode-Grid Resistor, 50000 ohms			3.2 5.0	Triode-Grid & Heptode-Grid Current, 0.3 ma. Triode-Grid & Heptode-Grid Current, 0.4 ma.					**7J7**
						Heptode Unit as Mixer	100 250	− 3.0 − 3.0	100 100	2.6 2.8	1.5 1.4	500000 1.5§	Conversion Transcond., 280 micromhos. Conversion Transcond., 290 micromhos.				
7JP4	Directly Viewed Kinescope	11a	H	6.3	0.6	Picture Reproduction	Focus: Electrostatic Deflection: Electrostatic Phosphor: No. 4 Picture Size: 4" x 5½" Deflection Factors: DJ_1 and DJ_2 (nearer screen), 31 to 41 vdc/in./kv; DJ_3 and DJ_4 (nearer base), 25 to 34 vdc/in./kv					Anode-No. 2 and Grid-No. 2 Volts, 6000 (max.) Anode-No. 1 Volts for Focus, 1620 to 2400 (2500 max.) Anode-No. 1 Current Range, −15 to + 10 microamperes Grid-No. 1 Volts for Visual Cutoff, −72 to −168						**7JP4**
7L7	RF Amplifier Pentode	B5	H	6.3	0.3	Class A Amplifier	100 250	− 1.0 − 1.5	100 100	2.4 1.5	5.5 4.5	100000 1.0§	3000 3100	—	—	—	**7L7**
7N7	Twin-Triode Amplifier	C8	H	6.3	0.6	Each Unit as Class A Amplifier	For other characteristics, refer to Type 6SN7-GT.										**7N7**
7Q7	Pentagrid Converter▲	B5	H	6.3	0.3	Converter	100 250	− 2.0 − 2.0	100 100	8.5 8.5	3.3 3.5	500000 1.0§	Grid #1 Resistor, 20000 ohms. Conversion Transcond., 550 micromhos.				**7Q7**
7R7	Duplex-Diode Pentode	B5	H	6.3	0.3	Pentode Unit as Class A Amplifier	100 250	− 1.0 − 1.0	100 100	2.2 1.6	5.5 6.2	350000 1.0§	3000 3400	—	—	—	**7R7**
7S7	Triode-Heptode Converter	B5	H	6.3	0.3	Triode Unit as Oscillator	100 250	Triode-Grid Resistor, 50000 ohms			3.0 5.0	Triode-Grid & Heptode-Grid Current, 0.3 ma. Triode-Grid & Heptode-Grid Current, 0.4 ma.					**7S7**
						Heptode Unit as Mixer	100 250	− 2.0 − 2.0	100 100	3.0 3.0	1.9 1.8	500000 1.25§	Conversion Transcond., 500 micromhos. Conversion Transcond., 525 micromhos.				
7V7	RF Amplifier Pentode	B5	H	6.3	0.45	Class A Amplifier	300	—	150	3.9	10.0	300000	5800	Cath. Bias Res., 160 ohms			**7V7**
7W7	RF Amplifier Pentode	B5	H	6.3	0.45	Class A Amplifier	For other characteristics, refer to Type 7V7.										**7W7**
7Y4	Full-Wave Rectifier	B5	H	6.3	0.5	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 180			Min. Total Effect. Supply Imped. per Plate, 150 ohms			**7Y4**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 180			Min. Value of Input Choke, 10 henries			
7Z4	Full-Wave Rectifier	C8	H	6.3	0.9	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 100 Max. Peak Plate Ma., 300			Min. Total Effec. Supply Imped. per Plate, 75 ohms			**7Z4**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 100 Max. Peak Plate Ma., 300			Min. Value of Input Choke, 6 henries			
9AP4	Directly Viewed Kinescope	K1	H	2.5	2.1	Picture Reproduction	Focus: Electrostatic Deflection: Magnetic Phosphor: No. 4 Picture Size: 5⅜" x 7¼"				Anode-No. 2 Volts, 7000 (max.) Anode-No. 1 Volts for Focus, 1192 to 1788 (2000 max.) Grid-No. 2 Volts, 250 (300 max.)			Grid-No. 1 Volts for Visual Cutoff, −20 to −60 Grid-No. 1 Signal Voltage, (Peak-to-Peak) value, 30 volts approx.			**9AP4**
10	Power Amplifier Triode	E3	F	7.5	1.25	Class A Amplifier	350 425	−32.0 −40.0	—	—	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	**10**
10BP4	Directly Viewed Kinescope	J1	H	6.3	0.6	Picture Reproduction	Focus: Magnetic Deflection: Magnetic Deflection Angle: 50° Phosphor: No. 4 Picture Size: 6" x 8" Uses Ion-Trap Magnet				Anode Volts, 10000 (max.) Grid-No. 2 Volts, 250 (450 max.) Grid-No. 1 Volts for Visual Cutoff, −27 to −63 Grid-No. 1 Circuit Resistance, 1.5 megohms (max.)			Focusing Coil Circuit, 115 approx. ma. (dc) Ion-Trap Magnet Current, 109 approx. ma. (dc) Deflection Coil Current, 470 approx. ma. (dc)			**10BP4**

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use Values to right give operating conditions and characteristics for indicated typical use	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
11 12	Detector★ Amplifier Triodes	D2 D11	O.C. F	1.1	0.25	Class A Amplifier	90 135	− 4.5 −10.5	—	—	2.5 3.0	15500 15000	425 440	6.6 6.6	—	—	11 12
12A5	Power Amplifier Pentode	D6	H	6.3 12.6	0.6 0.3	Class A Amplifier	100 180	−15.0 −25.0	100 180	3.0 8.0	17.0 45.0	50000 35000	1700 2400	—	4500 3300	0.8 3.4	12A5
12A7	Rectifier-Pentode	D9	H	12.6	0.3	Pentode Unit as Class A Amplifier	135	−13.5	135	2.5	9.0	102000	975	—	13500	0.55	12A7
						Half-Wave Rectifier	Maximum A-C Plate Voltage......125 Volts, RMS Maximum D-C Output Current...... 30 Milliamperes										
12A8-GT	Pentagrid Converter ●	C3	H	12.6	0.15	Converter	For other characteristics, refer to Type 6A8.										12A8-GT
12AH7-GT	Twin Triode	C9	H	12.6	0.15	Each Unit as Class A Amplifier	100 180	− 3.6 − 6.5	—	—	3.7 7.6	10300 8400	1550 1900	16 16	—	—	12AH7-GT
12AL5	Twin-Diode	A1	H	12.6	0.15	Detector Rectifier	For other characteristics, refer to Type 6AL5.										12AL5
12AP4	Directly Viewed Kinescope	L1	H	2.5	2.1	Picture Reproduction	Focus: Electrostatic Deflection: Magnetic Phosphor: No. 4 Picture Size: 7⅜" x 9¾"	Anode-No. 2 Volts, 7000 (max.) Anode-No. 1 Volts for Focus, 1192 to 1788 (2000 max.) Grid-No. 2 Volts 250 (300 max.)	Grid-No. 1 Volts for Visual Cutoff, −20 to −60 Grid-No. 1 Signal Voltage, (Peak-to-Peak) value, 30 volts approx.								12AP4
12AT6	Duplex-Diode High-Mu Triode	B0	H	12.6	0.15	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 6AT6.										12AT6
12AU6	RF Amplifier Pentode	B0	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6AU6										12AU6
12AU7	Twin-Triode Amplifier	B0a	H	6.3 12.6	0.3 0.15	Each Unit As Class A Amplifier	100 250	0 − 8.5	— —	— —	11.8 10.5	6250 7700	3100 2200	19.5 17	— —	— —	12AU7
12AV6	Twin-Diode High-Mu Triode	B0	H	12.6	0.15	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 6AV6.										12AV6
12AW6	RF Amplifier Pentode	B0	H	12.6	0.15	As Pentode Class A Amplifier As Triode □ Class A Amplifier	For other characteristics, refer to Type 6AG5										12AW6
12AX7	High-Mu Twin Triode	B0a	H	6.3 12.6	0.3 0.15	Each Unit as Class A Amplifier	100 250	− 1.0 − 2.0	— —	— —	0.5 1.2	80000 62500	1250 1600	100 100	— —	— —	12AX7
12B8-GT	Triode-Pentode	C7a	H	12.6	0.3	Triode Unit as Class A Amplifier	90	0	—	—	2.8	37000	2400	90	—	—	12B8-GT
						Pentode Unit as Class A Amplifier	90	− 3.0	90	2.0	7.0	200000	1800	—	—	—	
12BA6	RF Amplifier Pentode	B0	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6BA6										12BA6
12BE6	Pentagrid Converter▲	B0	H	12.6	0.15	Converter	For other characteristics, refer to Type 6BE6.										12BE6

12C8	Duplex-Diode Pentode	C1	H	12.6	0.15	Pentode Unit as RF Amplifier	250	− 3.0	125	2.3	10.0	600000	1325	——	——	——	12C8
						Pentode Unit as AF Amplifier	90 * 300 *	Cath. Bias, 3500 ohms. Screen Resistor = 1.1 meg. Cath. Bias, 1600 ohms. Screen Resistor = 1.2 meg.						Grid Resistor,** 0.5 megohm.	Gain per stage = 55 Gain per stage = 79		
12F5-GT	High-Mu Triode	C3	H	12.6	0.15	Amplifier	For other characteristics, refer to Type 6SF5.										12F5-GT
12H6	Twin-Diode	A1	H	12.6	0.15	Detector Rectifier	For other ratings, refer to Type 6H6.										12H6
12J5-GT	Detector Amplifier Triode	C3	H	12.6	0.15	Amplifier	For other characteristics, refer to Type 6J5.										12J5-GT
12J7-GT	Triple-Grid Detector Amplifier	C3	H	12.6	0.15	Amplifier	For other characteristics, refer to Type 6J7.										12J7-GT
12K7-GT	Triple-Grid Supercontrol Amplifier	C3	H	12.6	0.15	Amplifier	For other characteristics, refer to Type 6K7.										12K7-GT
12K8	Triode-Hexode Converter	C1	H	12.6	0.15	Oscillator Mixer	For other characteristics, refer to Type 6K8.										12K8
12Q7-GT	Duplex-Diode High-Mu Triode	C3	H	12.6	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6Q7.										12Q7-GT
12SA7	Pentagrid Converter▲	B3	H	12.6	0.15	Mixer	For other characteristics, refer to Type 6SA7.										12SA7
12SA7-GT	Pentagrid Converter▲	C3	H	12.6	0.15	Mixer	For other characteristics, refer to Type 6SA7.										12SA7-GT
12SC7	Twin-Triode Amplifier	B3	H	12.6	0.15	Each Unit as Class A Amplifier	For other characteristics, refer to Type 6SC7.										12SC7
12SF5	High-Mu Triode	B3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SF5.										12SF5
12SF5-GT	High-Mu Triode	C3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SF5.										12SF5-GT
12SF7	Diode-Remote-Cutoff Pentode	B3	H	12.6	0.15	Pentode Unit as Amplifier	For other characteristics, refer to Type 6SF7.										12SF7
12SG7	Semi-Remote-Cutoff Pentode	B3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SG7.										12SG7
12SH7	Sharp-Cutoff Pentode	B3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SH7.										12SH7
12SJ7 12SJ7-GT	Sharp-Cutoff Pentodes	B3 C3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SJ7.										12SJ7 12SJ7-GT
12SK7 12SK7-GT	Remote-Cutoff Pentodes	B3 C3	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SK7.										12SK7 12SK7-GT
12SL7-GT	Twin-Triode Amplifier	C3	H	12.6	0.15	Each Unit as Amplifier	For other characteristics, refer to Type 6SL7-GT.										12SL7-GT
12SN7-GT	Twin-Triode Amplifier	C3	H	12.6	0.3	Each Unit as Amplifier	For other characteristics, refer to Type 6J5.										12SN7-GT
12SQ7	Duplex-Diode High-Mu Triode	B3	H	12.6	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6SQ7.										12SQ7

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use Values to right give operating conditions and characteristics for indicated typical use	Plate Supply Volts	Grid Bias Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
12SQ7-GT	Duplex-Diode High-Mu Triode	C3	H	12.6	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6SQ7.										12SQ7-GT
12SR7	Duplex-Diode Triode	B3	H	12.6	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6SR7.										12SR7
12SR7-GT	Duplex-Diode Triode	C3	H	12.6	0.15	Triode Unit as Amplifier	For other characteristics, refer to Type 6SR7.										12SR7-GT
12Z3	Half-Wave Rectifier	D5	H	12.6	0.3	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 235 Max. D-C Output Ma., 55				Min. Total Effective Plate-Supply Impedance: Up to 117 volts, 0 ohms; at 150 volts, 30 ohms; at 235 volts, 75 ohms.						12Z3
14A4	Detector Amplifier Triode	B5	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6J5.										14A4
14A5	Beam Power Amplifier	B5	H	12.6	0.15	Class A Amplifier	250	−12.5	250	3.5	30	70000	3000	——	7500	2.8	14A5
14A7/ 12B7	Triple-Grid Supercontrol Amplifier	B5	H	12.6	0.15	Class A Amplifier	100 250	− 1.0 − 3.0	100 100	4.0 2.6	13.0 9.2	120000 800000	2350 2000	——	——	——	14A7/ 12B7
14B6	Duplex-Diode High-Mu Triode	B5	H	12.6	0.15	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 6SQ7.										14B6
14B8	Pentagrid Converter ●	B5	H	12.6	0.15	Converter	For other characteristics, refer to Type 6A8.										14B8
14C7	Triple-Grid Detector Amplifier	B5	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 6SJ7.										14C7
14E6	Duplex-Diode Triode	B5	H	12.6	0.15	Triode Unit as Class A Amplifier	For other characteristics, refer to Type 6SR7.										14E6
14F7	Twin-Triode Amplifier	B5	H	12.6	0.15	Each Unit as Class A Amplifier	For other characteristics, refer to Type 6SL7-GT.										14F7
14H7	Triple-Grid Supercontrol Amplifier	B5	H	12.6	0.15	Class A Amplifier	For other characteristics, refer to Type 7H7.										14H7
14J7	Triode-Heptode Converter	B5	H	12.6	0.15	Converter	For other characteristics, refer to Type 7J7.										14J7
14N7	Twin-Triode Amplifier	C8	H	12.6	0.3	Each Unit as Class A Amplifier	For other characteristics, refer to Type 6SN7-GT.										14N7
14Q7	Pentagrid Converter ▲	B5	H	12.6	0.15	Converter	For other characteristics, refer to Type 6SA7.										14Q7
14R7	Duplex-Diode Pentode	B5	H	12.6	0.15	Pentode Unit as Class A Amplifier	For other characteristics, refer to Type 7R7.										14R7
15	RF Amplifier Pentode	D9	D.C. H	2.0	0.22	Class A Amplifier	67.5 135	− 1.5 − 1.5	67.5 67.5	0.3 0.3	1.85 1.85	630000 800000	710 750	——	——	——	15

19	Twin-Triode Amplifier	D5	D.C. F	2.0	0.26	Amplifier	For other characteristics, refer to Type 1J6-G.										**19**
20	Power Amplifier Triode	D1	D.C. F	3.3	0.132	Class A Amplifier	90 135	−16.5 −22.5	—	—	3.0 6.5	8000 6300	415 525	3.3 3.3	9600 6500	0.045 0.110	20
22	RF Amplifier Tetrode	E1	D.C. F	3.3	0.132	Screen-Grid RF Amplifier	135 135	− 1.5 − 1.5	45 67.5	0.6* 1.3*	1.7 3.7	725000 325000	375 500	—	—	—	22
24-A	RF Amplifier Tetrode	E1	H	2.5	1.75	Screen-Grid RF Amplifier	180 250	− 3.0 − 3.0	90 90	1.7* 1.7*	4.0 4.0	400000 600000	1000 1050	—	—	—	**24-A**
						Bias Detector	250●	− 5.0 (approx.)	20 to 45	—	Plate current to be adjusted to 0.1 milliampere with no signal.						
25A6	Power Amplifier Pentode	C2	H	25.0	0.3	Class A Amplifier	95 160	−15.0 −18.0	95 120	4.0 6.5	20.0 33.0	45000 42000	2000 2375	—	4500 5000	0.9 2.2	**25A6**
25A6-GT	Power Amplifier Pentode	C3	H	25.0	0.3	Class A Amplifier	For other characteristics, refer to Type 25A6.										25A6-GT
25A7-GT	Rectifier Pentode	C3	H	25.0	0.3	Pentode Unit as Class A Amplifier	100	−15.0	100	4.0	20.5	50000	1800	—	4500	0.77	25A7-GT
						Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 350				Max. D-C Output Ma., 75 Max. Peak Plate Ma., 450			Min. Total Effect. Supply Impedance, 15 ohms.			
25AC5-GT	High-Mu Power Amplifier Triode	C3	H	25.0	0.3	Class B Amplifier	180	0	—	—	4.0♠	—	—	—	4800	6.0	25AC5-GT
						Dynamic-Coupled Amp. With Type 6AE5-GT Driver	110	Bias for both 25AC5-GT and 6AE5-GT developed in circuit. Average Plate Current of Driver = 7 milliamperes. Average Plate Current of 25AC5-GT = 45 milliamperes.							2000	2.0	
25B5	Direct-Coupled Power Amplifier	D9a	H	25.0	0.3	Amplifier	For other characteristics, refer to Type 25N6-G.										25B5
25B6-G	Power Amplifier Pentode	D10	H	25.0	0.3	Class A Amplifier	105 200	−16.0 −23.0	105 135	2.0 1.8	48.0 62.0	15500 18000	4800 5000	—	1700 2500	2.4 7.1	25B6-G
25B8-GT	Triode-Pentode	C3	H	25.0	0.15	Triode Unit as Class A Amplifier	100	− 1.0	—	—	0.6	75000	1500	112	—	—	25B8-GT
						Pentode Unit as Class A Amplifier	100	− 3.0	100	2.0	7.6	185000	2000	—	—	—	
25C6-G	Beam Power Amplifier	D10	H	25.0	0.3	Class A Amplifier	For other characteristics, refer to Type 6Y6-G.										25C6-G
25L6	Beam Power Amplifier	C2	H	25.0	0.3	Amplifier	For other characteristics, refer to Type 50L6-GT.										**25L6**
25L6-GT	Beam Power Amplifier	C3	H	25.0	0.3	Amplifier	For other characteristics, refer to Type 50L6-GT.										**25L6-GT**
25N6-G	Direct-Coupled Power Amplifier	D9	H	25.0	0.3	Class A Amplifier	Output Triode: Plate Volts, 180; Plate Ma., 46; Load, 4000 ohms. Input Triode: Plate Volts, 100; Grid Volts, 0; A-F Signal Volts (Peak), 29.7; Plate Ma., 5.8.									3.8	25N6-G
25Y5	Rectifier-Doubler	D5	H	25.0	0.3	Half-Wave Rectifier	Max. A-C Volts per Plate (RMS), 235 Max. D-C Output Ma. per Plate, 75				Min. Total Effective Plate-Supply Impedance per Plate, 0 ohms.						25Y5
25Z5	Rectifier-Doubler	D5	H	25.0	0.3	Rectifier-Doubler	For other ratings, refer to Type 25Z6.										**25Z5**
25Z6 **25Z6-GT**	Vacuum Rectifier-Doublers	C2 C3	H	25.0	0.3	Voltage Doubler	Max. A-C Volts per Plate (RMS), 117 Max. D-C Output Ma., 75				Min. Total Effective Plate-Supply Impedance: Half-Wave, 30 ohms; Full-Wave, 15 ohms.						**25Z6** **25Z6-GT**
						Half-Wave Rectifier	Max. A-C Volts per Plate (RMS), 235 Max. D-C Output Ma. per Plate, 75				Min. Total Effect. Supply Imped. per Plate: Up to 117 volts, 15 ohms; at 150 volts, 40 ohms; at 235 volts, 100 ohms.						
26	Amplifier Triode	D12	F	1.5	1.05	Class A Amplifier	90 180	− 7.0 −14.5	—	—	2.9 6.2	8900 7300	935 1150	8.3 8.3	—	—	**26**

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use Values to right give operating conditions and characteristics for indicated typical use	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
27	Detector★ Amplifier Triode	D5	H	2.5	1.75	Class A Amplifier	135 250	− 9.0 −21.0	—	—	4.5 5.2	9000 9250	1000 975	9.0 9.0	—	—	27
						Bias Detector	250	−30.0 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
30	Detector★ Amplifier Triode	D6	D.C. F	2.0	0.06	Amplifier	For other characteristics, refer to Type 1H4-G.										30
31	Power Amplifier Triode	D5	D.C. F	2.0	0.13	Class A Amplifier	135 180	−22.5 −30.0	—	—	8.0 12.3	4100 3600	925 1050	3.8 3.8	7000 5700	0.185 0.375	31
32	RF Amplifier Tetrode	E1	D.C. F	2.0	0.06	Screen-Grid RF Amplifier	135 180	− 3.0 − 3.0	67.5 67.5	0.4 0.4	1.7 1.7	950000 1.0+§	640 650	—	—	—	32
						Bias Detector	180♥	− 6.0 approx.	67.5	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
32L7-GT	Rectifier-Beam Power Amplifier	C3	H	32.5	0.3	Amplifier Unit as Class A Amplifier	90 90	− 5.0 − 7.0	90 90	3.0 2.0	38.0 27.0	15000 17000	6000 4800	—	2600 2600	0.8 1.0	32L7-GT
						Half-Wave Rectifier	Maximum A-C Plate Voltage.........125 Volts, RMS Maximum D-C Output Current.........60 Milliamperes.										
33	Power Amplifier Pentode	D12	D.C. F	2.0	0.26	Class A Amplifier	180	−18.0	180	5.0	22.0	55000	1700	—	6000	1.5	33
34	Supercontrol RF Amplifier Pentode	E1	D.C. F	2.0	0.06	Screen-Grid RF Amplifier	135 180	− 3.0 min.	67.5 67.5	1.0 1.0	2.8 2.8	600000 1.0§	600 620	—	—	—	34
35	Supercontrol RF Amplifier Tetrode	E1	H	2.5	1.75	Screen-Grid RF Amplifier	180 250	− 3.0 min.	90 90	2.5• 2.5•	6.3 6.5	300000 400000	1020 1050	—	—	—	35
35A5	Beam Power Amplifier	C8	H	35.0	0.15	Single-Tube Class A Amplifier	For other characteristics, refer to Type 35L6-GT.										35A5
35B5	Beam Power Amplifier	B1a	H	35.0	0.15	Class A Amplifier	110	− 7.5	110	3.0	40	—	5800	—	2500	1.5	35B5
35L6-GT	Beam Power Amplifier	C3	H	35.0	0.15	Single-Tube Class A Amplifier	110 200	− 7.5 − 8.0	110 110	3.0 2.0	40.0 41.0	14000 40000	5800 5900	—	2500 4500	1.5 3.3	35L6-GT
35W4	Half-Wave Rectifier♦ Heater Tap for Pilot	B1a	H	35.0	0.15	With Capacitive-Input Filter	Max A-C Plate Volts (RMS), 117 Min. Total Effect. Plate-Supply Impedance, 15 ohms Max. D-C Output Ma.: With Pilot and No Shunt Res., 60; With Pilot and Shunt Res., 90; Without Pilot, 100										35W4
35Y4	Half-Wave Rectifier♦	C8	H	35.0	0.15	With Capacitive-Input Filter	For other characteristics, refer to Type 35W4										35Y4
35Z3	Half-Wave Rectifier	C8	H	35.0	0.15	With Capacitive-Input Filter	For other ratings, refer to Type 35Z4-GT.										35Z3
35Z4-GT	Half-Wave Rectifier	C3	H	35.0	0.15	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 235 Max. D-C Output Ma., 100 Min. Total Effective Plate-Supply Impedance: Up to 117 volts, 15 ohms; at 235 volts, 100 ohms.										35Z4-GT
35Z5-GT	Half-Wave Rectifier Heater Tap for Pilot♦	C3	H	35.0	0.15	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 235 Min. Total Effect. Plate-Supply Imped.: Up to 117 volts, 15 ohms; at 235 volts, 100 ohms. Max. D-C Output Ma.: With Pilot and No Shunt Res., 60; With Pilot and Shunt Res., 90; Without Pilot, 100.										35Z5-GT

36	RF Amplifier Tetrode	D9	H	6.3	0.3	Screen-Grid RF Amplifier	100 250	− 1.5 − 3.0	55 90	— 1.7*	1.8 3.2	550000 550000	850 1080	—	—	—	**36**
						Bias Detector	100● 250●	− 5.0 − 8.0	55 90	—	Grid-bias values are approximate. Plate current to be adjusted to 0.1 milliampere with no signal.						
37	Detector★ Amplifier Triode	D6	H	6.3	0.3	Class A Amplifier	90 250	− 6.0 −18.0	—	—	2.5 7.5	11500 8400	800 1100	9.2 9.2	—	—	**37**
						Bias Detector	90 250	−10.0 −28.0	—	—	Grid-bias values are approximate. Plate current to be adjusted to 0.2 milliampere with no signal.						
38	Power Amplifier Pentode	D9	H	6.3	0.3	Class A Amplifier	100 250	− 9.0 −25.0	100 250	1.2 3.8	7.0 22.0	140000 100000	875 1200	—	15000 10000	0.27 2.50	**38**
39/44	Supercontrol RF Amplifier Pentode	D9	H	6.3	0.3	Class A Amplifier	90 250	(− 3.0 min.)	90 90	1.6 1.4	5.6 5.8	400000 1.0§	1000 1050	—	—	—	**39/44**
40	Voltage Amplifier Triode	D12	D.C. F	5.0	0.25	Class A Amplifier	135⌘ 180⌘	− 1.5 − 3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
41	Power Amplifier Pentode	D5	H	6.3	0.4	Amplifier	For other characteristics, refer to Type 6K6-GT.										**41**
42	Power Amplifier Pentode	D12	H	6.3	0.7	Amplifier	For other characteristics, refer to Type 6F6-G.										**42**
43	Power Amplifier Pentode	D12	H	25.0	0.3	Amplifier	For other characteristics, refer to Type 25A6-GT.										**43**
45	Power Amplifier Triode	D12	F	2.5	1.5	Class A Amplifier	180 275	−31.5 −56.0	—	—	31.0 36.0	1650 1700	2125 2050	3.5 3.5	2700 4600	0.82 2.00	**45**
						Push-Pull Class AB, Amplifier	275 275	Cath. Bias, 775 ohms♠ −68.0 volts, fixed bias			36.0♠ 28.0♠	—	—	—	5060 3200	12.0† 18.0†	
45Z3	Half-Wave Rectifier	B0	H	45.0	0.075	Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 350				Max. D-C Output Ma., 65 Max. Peak Plate Ma., 390			Min. Total Effect. Plate-Supply Imped., 15 ohms.			**45Z3**
45Z5-GT	Half-Wave Rectifier Heater Tap for Pilot ♀	C3	H	45.0	0.15	With Capacitive-Input Filter	For other ratings, refer to Type 35Z5-GT.										**45Z5-GT**
46	Dual-Grid Power Amplifier	E3	F	2.5	1.75	Class A Amplifier □	250	−33.0	—	—	22.0	2380	2350	5.6	6400	1.25	**46**
						Class B Amplifier♦	300 400	0 0	—	—	8.0♠ 12.0♠	—	—	—	5200 5800	16.0† 20.0†	
47	Power Amplifier Pentode	E3	F	2.5	1.75	Class A Amplifier	250	−16.5	250	6.0	31.0	60000	2500	—	7000	2.7	**47**
48	Power Amplifier Tetrode	E3	D.C. H	30.0	0.4	Tetrode Class A Amplifier	96 125	−19.0 −20.0	96 100	9.0 9.5	52.0 56.0	— —	3800 3900	— —	1500 1500	2.0 2.5	48
						Tetrode Push-Pull Class A Amplifier	125	−20.0	100	—	100.0♠	—	—	—	3000	5.0†	
49	Dual-Grid Power Amplifier	D12	D.C. F	2.0	0.12	Class A Amplifier □	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	**49**
						Class B Amplifier♦	180	0	—	—	4.0♠	—	—	—	12000	3.5†	
50	Power Amplifier Triode	F1a	F	7.5	1.25	Class A Amplifier	300 400 450	−54.0 −70.0 −84.0	—	—	35.0 55.0 55.0	2000 1800 1800	1900 2100 2100	3.8 3.8 3.8	4600 3670 4350	1.6 3.4 4.6	**50**
50A5	Beam Power Amplifier	C6	H	50.0	0.15	Class A Amplifier	For other characteristics, refer to Type 50L6-GT.										**50A5**
50B5	Beam Power Amplifier	B1a	H	50.0	0.15	Class A Amplifier	110	− 7.5	110	4	49	10000	7500	—	2500	1.9	**50B5**

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
50L6-GT	Beam Power Amplifier	C3	H	50.0	0.15	Single-Tube Class A Amplifier	110 200	− 7.5 − 8.0	110 110	4.0 2.0	49.0 50.0	13000 30000	9000 9500	——	2000 3000	2.1 4.3	50L6-GT
50Y6-GT	Rectifier-Doubler	C3	H	50.0	0.15	Rectifier-Doubler	For other ratings, refer to Type 25Z6.										50Y6-GT
50Z7-G	Rectifier-Doubler Heater Tap for Pilot ‡	D3	H	50.0	0.15	Voltage Doubler	Max. A-C Volts per Plate (RMS), 117 Max. D-C Output Ma., 65					Min. Total Effective Plate-Supply Impedance: 15 ohms.					50Z7-G
						Half-Wave Rectifier	Max. A-C Volts per Plate (RMS), 235 Max. D-C Output Ma. per Plate, 65					Min. Total Effective Plate-Supply Impedance per Plate: Up to 117 volts, 15 ohms; at 235 volts, 100 ohms.					
53	Twin-Triode Amplifier	D12	H	2.5	2.0	Amplifier	For other characteristics, refer to Type 6N7-GT.										53
55	Duplex-Diode Triode	D9	H	2.5	1.0	Triode Unit as Amplifier	For other characteristics, refer to Type 85.										55
56	Detector Amplifier Triode★	D5	H	2.5	1.0	Amplifier Detector	For other characteristics, refer to Type 76.										56
57	Triple-Grid Detector Amplifier	D13	H	2.5	1.0	Amplifier Detector	For other characteristics, refer to Type 6J7.										57
58	Triple-Grid Supercontrol Amplifier	D13	H	2.5	1.0	Amplifier Mixer	For other characteristics, refer to Type 6U7-G.										58
59	Triple-Grid Power Amplifier	E3	H	2.5	2.0	Triode¶ Class A Amplifier	250	−28.0	——	——	26.0	2300	2600	6.0	5000	1.25	59
						Pentode●● Class A Amplifier	250	−18.0	250	9.0	35.0	55000	2500	——	6000	3.0	
						Triode● Class B Amplifier	300 400	0 0	——	——	20.0♠ 26.0♠	——	——	——	4600 6000	15.0† 20.0†	
70L7-GT	Rectifier-Beam Power Amplifier	C5b	H	70.0	0.15	Amplifier Unit as Class A Amplifier	110	− 7.5	110	3.0	40.0	15000	7500	——	2000	1.8	70L7-GT
						Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 350				Max. D-C Output Ma., 70 Max. Peak Plate Ma., 420			Min. Total Effect. Plate-Supply Imped., 15 ohms			
71-A	Power Amplifier Triode	D12	F	5.0	0.25	Class A Amplifier	90 180	−16.5 −40.5	——	——	10.0 20.0	2170 1750	1400 1700	3.0 3.0	3000 4800	0.125 0.790	71-A
75	Duplex-Diode High-Mu Triode	D9	H	6.3	0.3	Amplifier	For other characteristics, refer to Type 6SQ7.										75
76	Detector Amplifier Triode★	D5	H	6.3	0.3	Class A Amplifier	250	−13.5	——	——	5.0	9500	1450	13.8	——	——	76
						Bias Detector	250	−20.0 approx.	——	——	Plate current to be adjusted to 0.2 milliampere with no signal.						
77	Triple-Grid Detector Amplifier	D9	H	6.3	0.3	Class A Amplifier	100 250	− 1.5 − 3.0	60 100	0.4 0.5	1.7 2.3	600000 1.0+§	1100 1250	——	——	——	77
						Bias Detector	250	− 1.95	50	Cathode current 0.65 ma.		——	Plate Resistor, 250000 ohms. Grid Resistor,●● 250000 ohms.				

78	Triple-Grid Supercontrol Amplifier	D9	H	6.3	0.3	Amplifier Mixer	For other characteristics, refer to Type 6K7.										**78**
79	Twin-Triode Amplifier	D9	H	6.3	0.6	Class B Amplifier	180 250	0 0	—	—	Power Output is for one tube at stated plate-to-plate load.				7000 14000	5.5 8.0	**79**
80	Full-Wave Rectifier	D12	F	5.0	2.0	For other ratings, refer to Type 5Y3-GT.											**80**
81	Half-Wave Rectifier	F1	F	7.5	1.25	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 700 Max. Peak Inverse Volts, 2000					Max. D-C Output Ma., 85 Max. Peak Plate Ma., 500					**81**
82	Full-Wave▶ Rectifier	D12	F	2.5	3.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 115 Max. Peak Plate Ma., 600				Min. Total Effect. Supply Imped. per Plate, 50 ohms.		**82**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 550 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 115 Max. Peak Plate Ma., 600				Min. Value of Input Choke, 6 henries		
83	Full-Wave▶ Rectifier	E3	F	5.0	3.0	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 1000				Min. Total Effect. Supply Imped. per Plate, 50 ohms.		**83**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 550 Max. Peak Inverse Volts, 1550				Max. D-C Output Ma., 225 Max. Peak Plate Ma., 1000				Min. Value of Input Choke, 3 henries		
83-v	Full-Wave Rectifier	D12	H	5.0	2.0	For other ratings, refer to Type 5V4-G.											**83-v**
84/6Z4	Full-Wave Rectifier	D5	H	6.3	0.5	With Capacitive-Input Filter	Max. A-C Volts per Plate (RMS), 325 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 60 Max. Peak Plate Ma., 180				Min. Total Effect. Supply Imped. per Plate, 150 ohms.		**84/6Z4**
						With Inductive-Input Filter	Max. A-C Volts per Plate (RMS), 450 Max. Peak Inverse Volts, 1250				Max. D-C Output Ma., 60 Max. Peak Plate Ma., 180				Min. Value of Input Choke, 10 henries		
85	Duplex-Diode Triode	D9	H	6.3	0.3	Triode Unit as Class A Amplifier	135 250	−10.5 −20.0	—	—	3.7 8.0	11000 7500	750 1100	8.3 8.3	25000 20000	0.075 0.350	**85**
89	Triple-Grid Power Amplifier	D9	H	6.3	0.4	As Triode¶ Class A Amplifier	160 250	−20.0 −31.0	—	—	17.0 32.0	3300 2600	1425 1800	4.7 4.7	7000 5500	0.30 0.90	**89**
						As Pentode▪▪ Class A Amplifier	100 250	−10.0 −25.0	100 250	1.6 5.0	9.5 32.0	104000 70000	1200 1800	—	10700 6750	0.33 3.40	
						As Triode♥ Class B Amplifier	180	0	—	—	6.0♠	—	—	—	13600 9400	2.50† 3.50†	
V-99 X-99	Detector★ Amplifier Triodes	C4 D1	D.C. F	3.3	0.063	Class A Amplifier	90	− 4.5	—	—	2.5	15500	425	6.6	—	—	V-99 X-99
112-A	Detector★ Amplifier Triode	D12	D.C. F	5.0	0.25	Class A Amplifier	90 180	− 4.5 −13.5	—	—	5.0 7.7	5400 4700	1575 1800	8.5 8.5	—	—	112-A
117L7/ M7-GT	Rectifier-Beam Power Amplifier	C5b	H	117	0.09	Amplifier Unit as Class A Amplifier	105	− 5.2	105	4.0	43.0	17000	5300	—	4000	0.85	**117L7/ M7-GT**
						Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 350				Max. D-C Output Ma., 75 Max. Peak Plate Ma., 450				Min. Total Effect. Plate-Supply Imped., 15 ohms.		
117N7-GT	Rectifier-Beam Power Amplifier	C5b	H	117	0.09	Amplifier Unit as Class A Amplifier	100	− 6.0	100	5.0	51.0	16000	7000	—	3000	1.2	**117N7-GT**
						Half-Wave Rectifier	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 350				Max. D-C Output Ma., 75 Max. Peak Plate Ma., 450				Min. Total Effect. Plate-Supply Impedance, 15 ohms.		
117P7-GT	Rectifier-Beam Power Amplifier	C5b	H	117	0.09	Amplifier Unit as Class A Amplifier	For other characteristics, refer to Type 117L7/M7-GT.										**117P7-GT**
						Half-Wave Rectifier	For other ratings, refer to Type 117L7/M7-GT.										

RCA Type	Name	Tube Dimensions	Cathode Type and Rating C. T.	Volts	Amp.	Use (Values to right give operating conditions and characteristics for indicated typical use)	Plate Supply Volts	Grid Bias ■ Volts	Screen Supply Volts	Screen Current Ma.	Plate Current Ma.	AC Plate Resistance Ohms	Transconductance (Grid-plate) µmhos	Amplification Factor	Load for Stated Power Output Ohms	Power Output Watts	RCA Type
‖ 117Z3	Half-Wave Rectifier	81a	H	117	0.04	With Capacitive-Input Filter	Max. A-C Plate Volts (RMS), 117 Max. Peak Inverse Volts, 330				Max. D-C Output Ma., 90 Max. Peak Plate Ma., 540			Min. Total Effect. Plate-Supply Imped., 15 ohms			117Z3 ‖
117Z6-GT	Rectifier-Doubler	C3	H	117	0.075	Voltage Doubler	Max. A-C Volts per Plate (RMS), 117 Max. D-C Output Ma., 60				Min. Total Effective Plate-Supply Impedance per Plate: Half-Wave, 30 ohms; Full-Wave, 15 ohms.						117Z6-GT
						Half-Wave Rectifier	Max. A-C Volts per Plate (RMS), 235 Max. D-C Output Ma. per Plate, 60				Min. Total Effect. Supply Imped. per Plate: Up to 117 volts, 15 ohms; at 150 volts, 40 ohms; at 235 volts, 100 ohms.						
183/483	Power Amplifier Triode	D12	F	5.0	1.25	Class A Amplifier	250	−60.0	——	——	30.0	1750	1700	3.0	5000	1.8	183/483
485	Detector Amplifier Triode	D5	H	3.0	1.25	Class A Amplifier	180	− 9.0	——	——	5.8	8900	1400	12.5	——	——	485

Three vertical rules before or after type No. = Miniature type.

Two vertical rules before or after type No. = Metal type.

One vertical rule before or after type No. = GT or other larger glass type.

Light Face = Discontinued type.

Note 1: Subscript 1 on class of amplifier service (as AB_1) indicates that grid current does not flow during any part of input cycle.

Note 2: Subscript 2 on class of amplifier service (as AB_2) indicates that grid current flows during some part of input cycle.

■ Supply voltage applied through 20000-ohm voltage-dropping resistor.

▲ Grids # 2 and # 4 are screen. Grid # 1 is signal-input control grid.

★ For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.

♠ For two tubes.

■ Either ac or dc may be used on filament or heater, except as specifically noted. For use of dc on ac filament types, decrease stated grid volts by ½ (approx.) of filament voltage.

▬ 50000 ohms.

§ Megohms.

♣ Obtained preferably by using 70000-ohm voltage-dropping resistor in series with 90-volt supply.

•• For grid of following tube.

✖ Applied through plate resistor of 250000 ohms.

▲▲ Both grids connected together; likewise both cathodes.

○ Grids # 3 and # 5 are screen. Grid No. 4 is signal-input grid.

▲ Grids # 2 and # 4 are screen. Grid # 3 is signal-input control grid.

† Power output is for two tubes at stated plate-to-plate load.

► Mercury-Vapor Type.

¶ Grid # 1 is control grid. Grids # 2 and # 3 tied to plate.

▪▪ Grid # 1 is control grid. Grid # 2 is screen. Grid # 3 tied to cathode.

● Grids # 1 and # 2 connected together. Grid # 3 tied to plate.

♥ Applied through plate resistor of 100000 ohms.

⫯ Panel lamp section is between pins 2 and 3.

● Applied through plate resistor of 250000 ohms or 500-henry choke shunted by 0.25-megohm resistor.

• Maximum.

✢ Grids # 2 and # 3 tied to plate.

♀ Both grids connected together; likewise, both plates.

◀ For signal-input control-grid (# 1); control-grid # 3 bias, −3 volts.

KEY TO TUBE DIMENSIONS

Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter
A1	1 3/4" x 3/4"	C2	3 1/4" x 1 5/16"	D3	4 1/8" x 1 9/16"	D13	4 15/16" x 1 9/16"
A1a	1 3/4" x 1 5/16"	C3	3 5/16" x 1 5/16"	D4	4 3/16" x 1 3/16"	E1	5 1/32" x 1 13/16"
B0	2 1/8" x 3/4"	C4	3 1/2" x 1 1/16"	D5	4 3/16" x 1 9/16"	E2	5 5/16" x 2 1/16"
B0a	2 3/16" x 7/8"	C5a	3 1/2" x 1 5/16"	D6	4 5/16" x 1 3/16"	E3	5 3/8" x 2 1/16"
B0b	2 9/32" x 1 3/16"	C5b	3 7/16" x 1 5/16"	D7	4 5/16" x 1 5/8"	F1	5 11/16" x 2 1/16"
B1	2 5/8" x 1 1/16"	C6	3 5/32" x 1 3/16"	D8	4 15/32" x 1 9/16"	F1a	6 1/4" x 2 7/16"
B1a	2 5/8" x 3/4"	C7	3 3/8" x 1 5/16"	D9	4 17/32" x 1 9/16"	G1	8" x 2 1/16"
B2	2 5/16" x 1 5/16"	C7a	3 9/16" x 1 5/16"	D9a	4 19/32" x 1 9/16"	H1	12 1/8" x 5 1/8"
B3	2 5/8" x 1 5/16"	C7b	3 5/8" x 1 3/16"	D10	4 5/8" x 1 13/16"	I1	14 7/16" x 7 5/16"
B5	2 25/32" x 1 3/16"	D1	4" x 1 3/16"	D11	4 11/16" x 1 7/16"	I1a	14 7/8" x 7 1/8"
B5a	2 7/8" x 1 5/16"	D1a	4 1/16" x 1 5/16"	D12	4 11/16" x 1 13/16"	J1	18" x 10 5/8"
C0	3 1/16" x 1 5/16"	D2	4 1/8" x 1 3/16"	D12a	4 7/8" x 1 9/16"	K1	21 3/8" x 9 1/8"
C1	3 1/8" x 1 5/16"					L1	25 3/8" x 12 3/16"

Useful Information

Abbreviations of Units and Terms *

Unit	*Abbreviation*	*Unit*	*Abbreviation*
alternating current	a.c.	kilometers	km.
ampere	amp.	kilowatts	kw.
ampere-hours	amp.-hr.	kilowatt-hours	kw.-hr.
centimeter	cm.	kilovolt-amperes	kva.
centimeter-gram-second	c.g.s.	medium frequency	m.f.
continuous waves	c.w.	meters	m.
cubic centimeters	$cm.^3$	microfarads	*μf.*
cubic inches	cu. in.	micromicrofarads	*μμf.*
cycles per second	c.p.s.	millihenries	mh.
decibel	db.	millimeters	mm.
degrees Centigrade	°C.	modulated continuous waves	m.c.w.
degrees Fahrenheit	°F.	pounds	lb.
direct current	d.c.	radio frequency	r.f.
feet	ft.	seconds	sec.
foot-pounds	ft.-lb.	square centimeters ...	$cm.^2$
grams	g.	square inches	sq. in.
henries	h.	ultrahigh frequency ...	uhf
inches	in.	very high frequency ...	vhf
intermediate frequency ..	i.f.	volts	v.
kilograms	kg.	watts	w.

Prefixes Used with Metric System Units

Prefix	*Abbreviation*	*Meaning*
micro	*μ*	1 millionth
milli	m.	1 thousandth
centi	c.	1 hundredth
deci	d.	1 tenth
deka	dk.	10
hekto	h.	1 hundred
kilo	k.	1 thousand
mega	m.	1 million

* See also List of Abbreviations, page 338.

Symbols Used for Various Quantities

Quantity	*Symbol*	*Quantity*	*Symbol*
admittance	y	magnetic induction	B
capacitance	C	magnetic intensity	H
conductance	g	period of a complete oscillation	T
coupling coefficient	k	potential difference	E
current, instantaneous value	i	quantity of electricity	Q
current, effective value	I	ratio of the circumference of a circle to its diameter = 3.1416	π
decrement	δ	reactance	X
dielectric constant	K	reactance, capacitive	X_C
dielectric flux	ψ	reactance, inductive	X_L
electric field intensity	ϵ	resistance	R
electromotive force, instantaneous value	E	resistivity	ρ
electromotive force, effective value	F	time	t
energy	W	velocity	v
force	F	velocity of light	c
frequency	f	wavelength	λ
impedance	Z	wavelength in meters	λm
inductance, self	L	work	W
inductance, mutual	M	permeability	μ
magnetic field intensity	A	square root	$\sqrt{}$
magnetic flux	ψ		

Table of Enameled Wire

No. of Wire, B.&S. Gauge	*Turns per Linear Inch*	*Turns per Square Inch*	*Ohms per Cubic Inch of Winding*	*No. of Wire, B.&S. Gauge*	*Turns per Linear Inch*	*Turns per Square Inch*	*Ohms per Cubic Inch of Winding*
20	30	885	.748	32	116	13,430	183.00
22	37	1,400	1.88	34	145	21,000	456.00
24	46	2,160	4.61	36	178	31,820	1,098.00
26	58	3,460	11.80	38	232	54,080	2,968.00
28	73	5,400	29.20	40	294	86,500	7,547.00
30	91	8,260	70.90				

Letter Symbols for Vacuum-Tube Notation

Grid potential	E_g, e_g	Mutual conductance	g_m
Grid current	I_g, i_g	Amplification factor	μ
Grid conductance	g_g	Filament terminal voltage	E_f
Grid resistance	r_g	Filament current	I_f
Grid bias voltage	E_c	Grid-plate capacitance	C_{gp}
Plate potential	E_p, e_p	Grid-cathode capacitance	C_{gk}
Plate current	I_b, I_p, i_p	Plate-cathode capacitance	C_{pk}
Plate conductance	g_p	Grid capacitance (input)	C_g
Plate resistance	r_p	Plate capacitance (output)	C_p
Plate supply voltage	E_b		
Cathode current	I_c		
Emission current	I_s		

NOTE.—Small letters refer to instantaneous values.

Table of Frequency and Wavelengths

λ—Wavelengths in meters. F.—Number of kilocycles per second. O. or $\sqrt{L.C.}$ is called Oscillation Constant. C.—Capacity in Microfarads. L.—Induction in Centimeters. 1,000 Centimeters = 1 Microhenry.

$$F = \frac{V}{\lambda}$$

where V is the speed of electromagnetic waves, 300,000,000 meters per second.

λ	F.	O. or $\sqrt{L.C.}$	L.C.	λ	F.	O. or $\sqrt{L.C.}$	L.C.
0.1	3,000,000						
0.2	1,500,000						
0.3	1,000,000						
0.4	745,000						
0.5	600,000						
0.6	500,000						
0.7	429,000						
0.8	375,000						
0.9	333,000						
1	300,000	.0173	.0003	1,300	230	21.81	475.70
2	150,000	.0331	.0011	1,400	214	23.49	551.80
3	100,000	.0424	.0018	1,500	200	25.17	633.50
4	75,000	.0671	.0045	1,600	187	26.84	720.40
5	60,000	.0755	.0057	1,700	176	28.52	813.40
6	50,000	.101	.0101	1,800	166	30.20	912.00
7	42,900	.1174	.0138	1,900	157	31.88	1,016.40
8	37,500	.134	.0180	2,000	150	33.55	1,125.60
9	33,330	.151	.0228	2,100	142	35.23	1,241.20
10	30,000	.168	.0282	2,200	136	36.91	1,362.40

λ	F.	O. or $\sqrt{L.C.}$	L.C.	λ	F.	O. or $\sqrt{L.C.}$	L.C.
20	15,000	.336	.1129	2,300	130	38.59	1,489.30
30	10,000	.504	.2530	2,400	125	40.27	1,621.80
40	7,500	.671	.450	2,500	120	41.95	1,759.70
50	6,000	.839	.7039	2,600	115	43.62	1,902.60
100	3,000	1.68	2.82	2,700	111	45.30	2,052.00
150	2,000	2.52	6.35	2,800	107	46.89	2,207.00
200	1,500	3.36	11.29	2,900	103	48.66	2,366.30
250	1,200	4.19	17.55	3,000	100	50.33	2,533.20
300	1,000	5.05	25.30	4,000	75	67.11	4,504.00
350	857	5.87	34.46	5,000	60	83.89	7,038.00
400	750	6.71	45.03	6,000	50	100.7	10,130.00
450	666	7.55	57.00	7,000	41	117.3	13,630.00
500	600	8.39	70.39	8,000	37	134.1	18,000.00
550	545	9.23	85.19	9,000	33	151.0	22,820.00
600	500	10.07	101.41	10,000	30	167.9	28,150.00
700	428	11.74	137.83	11,000	27	184.8	34,150.00
800	375	13.42	180.10	12,000	25	201.5	40,600.00
900	333	15.10	228.01	13,000	23	218.3	47,600.00
1,000	300	16.78	281.57	14,000	21	235.0	55,200.00
1,100	272	18.45	340.40	15,000	20	252.0	63,500.00
1,200	250	20.13	405.20	16,000	18	269.0	72,300.00

Resistor-Capacitor Color Code

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance Per cent*	*Voltage Rating (Capacitors Only)*
Black	0	1	—	—
Brown	1	10	1	100
Red	2	100	2	200
Orange	3	1,000	3	300
Yellow	4	10,000	4	400
Green	5	100,000	5	500
Blue	6	1,000,000	6	600
Violet	7	10,000,000	7	700
Gray	8	100,000,000	8	800
White	9	1,000,000,000	9	900
Gold	—	0.1	5	1000
Silver	—	0.01	10	2000
No color	—	—	20	500

Table of Sparking Distances

In Air for Various Voltages Between Needle Points

Volts	Distance		Volts	Distance	
	Inches	Centimeter		Inches	Centimeter
5,000	.225	.57	60,000	4.65	11.8
10,000	.470	1.19	70,000	5.85	14.9
15,000	.725	1.84	80,000	7.10	18.0
20,000	1.000	2.54	90.000	8.35	21.2
25,000	1.300	3.30	100,000	9.60	24.4
30,000	1.625	4.10	110.000	10.75	27.3
35,000	2.000	5.10	120,000	11.85	30.1
40,000	2.450	6.20	130,000	12.95	32.9
45,000	2.95	7.50	140,000	13.95	35.4
50,000	3.55	9.00	150,000	15.00	38.1

Feet Per Pound of Insulated Magnet Wire

No. of B. & S. Gauge	Single Cotton, 4-Mils	Double Cotton, 8-Mils	Single Silk, 1¾-Mils	Double Silk, 4-Mils	Enamel
20	311	298	319	312	320
21	389	370	403	389	404
22	488	461	503	493	509
23	612	584	636	631	642
24	762	745	800	779	810
25	957	903	1,005	966	1,019
26	1,192	1,118	1,265	1,202	1,286
27	1,488	1,422	1,590	1,543	1,620
28	1,852	1,759	1,972	1,917	2,042
29	2,375	2,207	2,500	2,485	2,570
30	2,860	2,534	3,145	2,909	3,240
31	3,500	2,768	3,943	3,683	4,082
32	4,375	3,737	4,950	4,654	5,132
33	5,390	4,697	6,180	5,689	6,445
34	6,500	6,168	7,740	7,111	8,093
35	8,050	6,737	9,600	8,534	10,197
36	9,820	7,877	12,000	10,039	12,813
37	11,860	9.309	15,000	11,666	16,110
38	14,300	10,636	18,660	14,222	20,274
39	17,130	11,907	23,150	16,516	25,519
40	21,590	14,222	28,700	21,333	32,107

International Morse, Code and Conventional Signals

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

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	..——..
Apostrophe	.————.
Hyphen	—....—
Bar indicating fraction	—..—.
Parenthesis	—.——.—
Inverted commas	.—..—.
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.....)	..——..
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)	...—.—

Q SIGNALS

The following three-letter code words, all beginning with Q, have been devised to simplify the handling of messages between stations. They are recognized by ship and shore stations of all nations and serve as a readily understood form of telegraphic shorthand. When a Q signal is followed by a question mark (..– –..) a question is being asked; if the Q signal stands alone, it is translated as an affirmation or reply.

Signal	*As a Question*	*As a Reply*
QRA	What is your station?	My station is . . .
QRB	How far distant are you?	My distance is . . .
QRG	What is my frequency?	Your frequency is . . .
QRH	Is my frequency steady?	Your frequency is steady.
QRI	How is my tone?	Your tone changes.
QRJ	Are my signals weak?	Your signal is weak.
QRK	Are my signals legible?	Legibility is (1 to 5).
QRL	Are you free to handle traffic?	I am busy now.
QRM	Are you meeting interference?	I am being interfered with.
QRN	Are atmospherics bothering you?	Atmospherics are bothering me.
QRO	Shall I increase power?	Increase your power.
QRP	Shall I use less power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you any messages for me?	No traffic for you.
QRV	Are you ready?	I am ready.
QRW	Shall I notify . . . that you are calling him?	Notify . . . I am calling him.
QRX	Shall I stand by?	Stand by until I call you.
QRZ	Who is calling me?	You are being called by . . .
QSA	What is my signal strength (1 to 5)?	Your signal strength is (1 to 5).
QSB	Does my signal strength vary?	Your signal strength varies.
QSD	Is my keying correct? Are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Shall I send . . . telegrams at a time?	Send . . . telegrams at a time.

Signal	*As a Question*	*As a Reply*
QSK	Shall I continue?	Continue with traffic.
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat last message?	Repeat last message.
QSO	Can you communicate with . . . direct?	I can communicate with . . . direct.
QSP	Will you relay to . . . ?	I will relay to . . .
QSU	On what wave and type of transmission shall I reply?	Reply on . . . k.c. with . . . type emission.
QSV	Shall I send V's?	Send a series of V's.
QSW	Will you send on . . . k.c. with . . . type transmission?	I will send on . . . k.c. with . . . type emission.
QSX	Will you listen for . . . on . . . k.c.?	I will listen for . . . on . . . k.c.
QSY	Shall I change to . . . k.c.?	Change to . . . k.c.
QSZ	Shall I duplicate each word?	Duplicate each word.
QTA	Shall I cancel message # . . . ?	Cancel message # . . .
QTB	Do you check number of words?	I do not check.
QTC	How many messages have you?	I have . . . messages.
QTH	What is your position in longitude and latitude?	My position is . . . latitude and . . . longitude.
QTR	What time is it?	Exact time is . . .

Abbreviations for C.W. Work

Abbreviations help to cut down unnecessary transmission. However, make it a rule not to abbreviate unnecessarily when working an operator of unknown experience.

AA	All after
AB	All before
ABT	About
ADR	Address
AGN	Again
ANT	Antenna
BCI	Broadcast interference
BCL	Broadcast listener
BK	Break; break me; break in
BN	All between; been
B4	Before
C	Yes
CFM	Confirm; I confirm
CK	Check
CL	I am closing my station; call
CLD-CLG	Called; calling
CUD	Could
CUL	See you later
CUM	Come
CW	Continuous wave

DLD-DLVD	Delivered
DX	Distance
ECO	Electron-coupled oscillator
FB	Fine business; excellent
GA	Go ahead (or resume sending)
GB	Good-by
GBA	Give better address
GE	Good evening
GG	Going
GM	Good morning
GN	Good night
GND	Ground
GUD	Good
HI	The telegraphic laugh; high
HR	Here; hear
HV	Have
HW	How
LID	A poor operator
MILS	Milliamperes
MSG	Message; prefix to radiogram
N	No
ND	Nothing doing
NIL	Nothing; I have nothing for you
NR	Number
NW	Now; I resume transmission
OB	Old boy
OM	Old man
OP-OPR	Operator
OSC	Oscillator
OT	Old timer; old top
PBL	Preamble
PSE-PLS	Please
PWR	Power
PX	Press
R	Received solid; all right; OK; are
RAC	Rectified alternating current
RCD	Received
REF	Refer to; referring to; reference
RPT	Repeat; I repeat
SED	Said
SEZ	Says
SIG	Signature; signal
SINE	Operator's personal initials or nickname
SKED	Schedule
SRI	Sorry
SVC	Service; prefix to service message
TFC	Traffic
TMW	Tomorrow
TNX-TKS	Thanks
TT	That
TU	Thank you
TXT	Text
UR-URS	Your; you're; yours
VFO	Variable-frequency oscillator
VY	Very
WA	Word after
WB	Word before
WD-WDS	Word; words
WKD-WKG	Worked; working
WL	Well; will
WUD	Would
WX	Weather
XMTR	Transmitter
XTAL	Crystal
YF (XYL)	Wife
YL	Young lady
73	Best regards
88	Love and kisses

W Prefixes by States

Alabama	W4	Nebraska	WØ
Arizona	W7	Nevada	W7
Arkansas	W5	New Hampshire	W1
California	W6	New Jersey	W2
Colorado	WØ	New Mexico	W5
Connecticut	W1	New York	W2
Delaware	W3	North Carolina	W4
District of Columbia	W3	North Dakota	WØ
Florida	W4	Ohio	W8
Georgia	W4	Oklahoma	W5
Idaho	W7	Oregon	W7
Illinois	W9	Pennsylvania	W3
Indiana	W9	Rhode Island	W1
Iowa	WØ	South Carolina	W4
Kansas	WØ	South Dakota	WØ
Kentucky	W4	Tennessee	W4
Louisiana	W5	Texas	W5
Maine	W1	Utah	W7
Maryland	W3	Vermont	W1
Massachusetts	W1	Virginia	W4
Michigan	W8	Washington	W7
Minnesota	WØ	West Virginia	W8
Mississippi	W5	Wisconsin	W9
Missouri	WØ	Wyoming	W7
Montana	W7		

International Call Letters

Under international agreement, the first letter of the first two letters of radio call signals indicates the nationality of the station. According to Section 1, Article 14 of the International Radio Conference at Cairo in 1938, as annexed to the International Telecommunications Convention at Madrid in 1932:

"All stations open to the international service of public correspondence and all aircraft stations not open to the international service of public correspondence as well as amateur stations, private experimental stations and private radio stations, must have call signals from the international series assigned to each country. . . ."

As a general rule, land stations use three letters, ship stations four letters, and aircraft stations five letters. One or two letters and a single figure followed by a group of not more than three letters identify amateur stations and private stations.

Below is a list of call letters assigned to the countries of the world by the 1947 International Radio Conference at Atlantic City, as given in the 26th Edition of the *Radio Amateur's Handbook* (1949) published by the American Radio Relay League. The list, which became effective on January 1, 1949, contains the essentials of the Cairo agreement plus other assignments to be allocated in the future.

AAA-ALZ	United States of America
AMA-AOZ	(Not allocated)
APA-ASZ	Pakistan
ATA-AWZ	India
AXA-AXZ	Commonwealth of Australia
AYA-AZZ	Argentina Republic
BAA-BZZ	China
CAA-CEZ	Chile
CFA-CKZ	Canada
CLA-CMZ	Cuba
CNA-CNZ	Morocco
COA-COZ	Cuba
CPA-CPZ	Bolivia
CQA-CRZ	Portuguese Colonies
CSA-CUZ	Portugal
CVA-CXZ	Uruguay
CYA-CZZ	Canada
DAA-DMZ	Germany
DNA-DQZ	Belgian Congo
DRA-DTZ	Bielorussian Soviet Socialist Republic
DUA-DZZ	Republic of the Philippines
EAA-EHZ	Spain
EIA-EJZ	Ireland
EKA-EKZ	Union of Soviet Socialist Republics
ELA-ELZ	Republic of Liberia
EMA-EOZ	Union of Soviet Socialist Republics
EPA-EQZ	Iran
ERA-ERZ	Union of Soviet Socialist Republics
ESA-ESZ	Estonia
ETA-ETZ	Ethiopa
EUA-EZZ	Union of Soviet Socialist Republics
FAA-FZZ	France and Colonies and Protectorates
GAA-GZZ	Great Britain
HAA-HAZ	Hungary
HBA-HBZ	Switzerland
HCA-HDZ	Ecuador
HEA-HEZ	Switzerland
HFA-HFZ	Poland
HGA-HGZ	Hungary
HHA-HHZ	Republic of Haiti
HIA-HIZ	Dominican Republic
HJA-HKZ	Republic of Colombia
HLA-HMZ	Korea
HNA-HNZ	Iraq
HOA-HPZ	Republic of Panama
HQA-HRZ	Republic of Honduras
HSA-HSZ	Siam
HTA-HTZ	Nicaragua
HUA-HUZ	Republic of El Salvador
HVA-HVZ	Vatican City State
HWA-HYZ	France and Colonies and Protectorates
HZA-HZZ	Kingdom of Saudi Arabia
IAA-IZZ	Italy and Colonies
JAA-JSZ	Japan
JTA-JVZ	Outer Mongolia Peoples Republic
JWA-JXZ	Norway
JYA-JZZ	(Not allocated)
KAA-KZZ	United States of America
LAA-LNZ	Norway
LOA-LWZ	Argentina Republic

LXA-LXZ	Luxemburg
LYA-LYZ	Lithuania
LZA-LZZ	Bulgaria
MAA-MZZ	Great Britain
NAA-NZZ	United States of America
OAA-OCZ	Peru
ODA-ODZ	Republic of Lebanon
OEA-OEZ	Austria
OFA-OJZ	Finland
OKA-OMZ	Czechoslovakia
ONA-OTZ	Belgium and Colonies
OUA-OZZ	Denmark
PAA-PIZ	Netherlands
PJA-PJZ	Curaçao
PKA-POZ	Netherlands Indies
PPA-PYZ	Brazil
PZA-PZZ	Surnam
QAA-QZZ	(Service abbreviations)
RAA-RZZ	Union of Soviet Socialist Republics
SAA-SMZ	Sweden
SNA-SRZ	Poland
SSA-SUZ	Egypt
SVA-SZZ	Greece
TAA-TCZ	Turkey
TDA-TDZ	Guatemala
TEA-TEZ	Costa Rica
TFA-TFZ	Iceland
TGA-TGZ	Guatemala
THA-THZ	France and Colonies and Protectorates
TIA-TIZ	Costa Rica
TJA-TZZ	France and Colonies and Protectorates
UAA-UQZ	Union of Soviet Socialist Republics
URA-UTZ	Ukrainian Soviet Socialist Republic
UUA-UZZ	Union of Soviet Socialist Republics
VAA-VGZ	Canada
VHA-VNZ	Commonwealth of Australia
VOA-VOZ	Newfoundland
VPA-VSZ	British Colonies and Protectorates
VTA-VWZ	India
VXA-VYZ	Canada
VZA-VZZ	Commonwealth of Australia
WAA-WZZ	United States of America
XAA-XIZ	Mexico
XJA-XOZ	Canada
XPA-XPZ	Denmark
XQA-XRZ	Chile
XSA-XSZ	China
XTA-XWZ	France and Colonies and Protectorates
XXA-XXZ	Portuguese Colonies
XYA-XZZ	Burma
YAA-YAZ	Afghanistan
YBA-YHZ	Netherlands Indies
YIA-YIZ	Iraq
YJA-YJZ	New Hebrides
YKA-YKZ	Syria
YLA-YLZ	Latvia
YMA-YMZ	Turkey
YNA-YNZ	Nicaragua
YOA-YRZ	Rumania
YSA-YSZ	Republic of El Salvador
YTA-YUZ	Yugoslavia
YVA-YYZ	Venezuela
YZA-YZZ	Yugoslavia
ZAA-ZAZ	Albania
ZBA-ZJZ	British Colonies and Protectorates
ZKA-ZMZ	New Zealand
ZNA-ZOZ	British Colonies and Protectorates
ZPA-ZPZ	Paraguay
ZQA-ZQZ	British Colonies and Protectorates
ZRA-ZUZ	Union of South Africa
ZVA-ZZZ	Brazil
2AA-2ZZ	Great Britain
3AA-3AZ	Principality of Monaco
3BA-3FZ	Canada
3GA-3GZ	Chile
3HA-3UZ	China
3VA-3VZ	France and Colonies and Protectorates
3WA-3XZ	(Not allocated)
3YA-3YZ	Norway
3ZA-3ZZ	Poland
4AA-4CZ	Mexico
4DA-4IZ	Republic of the Philippines
4JA-4LZ	Union of Soviet Socialist Republics
4MA-4MZ	Venezuela

4NA-4OZ	Yugoslavia	4XA-4ZZ	(Not allocated)
4PA-4SZ	British Colonies and Protectorates	5AA-5ZZ	(Not allocated)
4TA-4TZ	Peru	6AA-6ZZ	(Not allocated)
4UA-4UZ	United Nations	7AA-7ZZ	(Not allocated)
4VA-4VZ	Republic of Haiti	8AA-8ZZ	(Not allocated)
4WA-4WZ	Yemen	9AA-9ZZ	(Not allocated)

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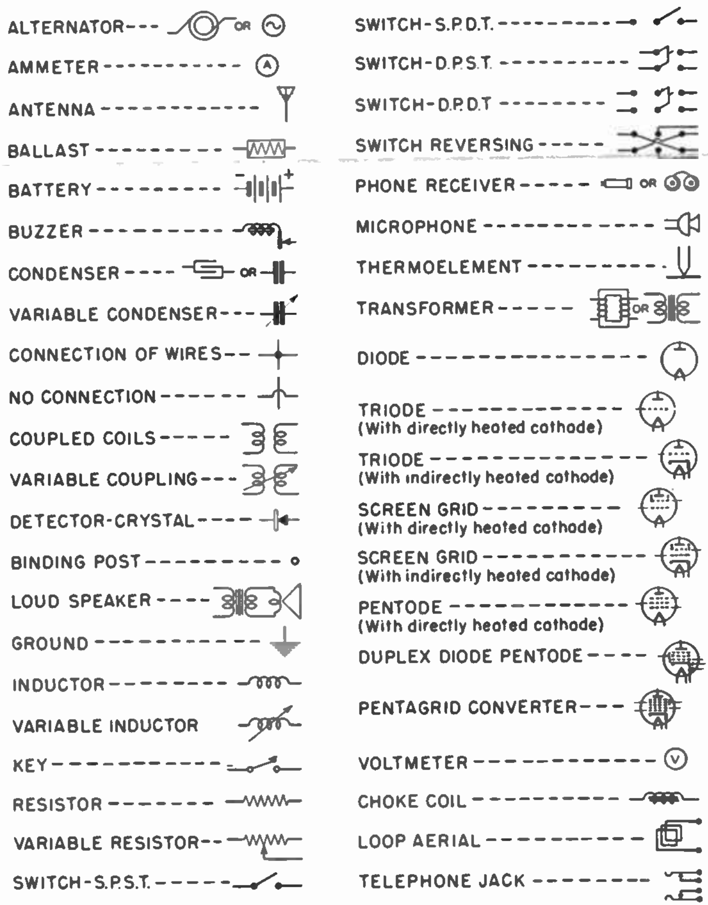
Abbreviations of Common Terms

ant. ....Antenna
a.c. ....Alternating current
a.f. ....Audio-frequency
B. and S. ....Brown & Sharpe wire gauge
C. ....Capacity or capacitance

c.g.s. .... Centimeter-gram-second
cond. .... Condenser
c.w. .... Continuous waves
d.c. .... Direct current
D.P.D.T. .... Double-pole, double-throw
D.P.S.T. .... Double-pole, single-throw
DX. .... Distance
E. .... Short for electromotive force (volts)
e.m.f. .... Electromotive force
F. .... Filament or frequency
G. .... Grid
gnd. .... Ground
I. .... Current strength (amperes)
i.c.w. .... Interrupted continuous waves
i.f. .... Intermediate frequency
kw. .... Kilowatt
L. .... Inductance
Litz. .... Litzendraht
mfd. .... Microfarad
mmfd. .... Micromicrofarad
Neg. .... Negative
P. .... Plate
P.A. .... Public address system
pri. .... Primary
pos. .... Positive
R. .... Resistance
r.f. .... Radio-frequency
r.m.s. .... Root-mean-square
sec. .... Secondary
s.l.f. .... Straight-line frequency
S.P.D.T. .... Single-pole, double-throw
S.P.S.T. .... Single-pole, single-throw
T. .... Telephone or period (time) of complete oscillation
V. .... Voltage
var. cond. .... Variable condenser
v.t. .... Vacuum tube
w.l. .... Wavelength
X. .... Reactance
Z. .... Impedance



Television Stations in Operation, 1949

State and city	*Call letters*	*Channel No.*
ALABAMA:		
Birmingham	WBRC-TV	4
CALIFORNIA:		
Hollywood	KTLA	5
Los Angeles	KECA-TV	7
Los Angeles	KFI-TV	9
Los Angeles	KNBH	4

State and city	Call letters	Channel No.
Riverside	KARO	1
San Diego	KFMB-TV	–
San Francisco	KGO-TV	7
San Francisco	KRON-TV	4
CONNECTICUT:		
New Haven	WNHC-TV	6
DELAWARE:		
Wilmington	WDEL-TV	7
DISTRICT OF COLUMBIA:		
Washington	WMAL-TV	7
Washington	WNBW	4
Washington	WOIC	9
Washington	WTTG	5
FLORIDA:		
St. Petersburg	WSEE	–
Miami	WTVJ	–
GEORGIA:		
Atlanta	WAGA-TV	5
Atlanta	WSB-TV	–
ILLINOIS:		
Chicago	WBKB	4
Chicago	WENR-TV	7
Chicago	WGN-TV	9
Chicago	WNBQ	5
INDIANA:		
Bloomington	WTTV	10
Indianapolis	WWHB	3
IOWA:		
Ames	WOI-TV	4
KENTUCKY:		
Louisville	WAVE-TV	5
LOUISIANA:		
New Orleans	WRTV	4
New Orleans	WDSU-TV	–
MARYLAND:		
Baltimore	WAAM-TV	13
Baltimore	WBAL-TV	11

State and city	*Call letters*	*Channel No.*
Baltimore	WMAR-TV	2
MASSACHUSETTS:		
Boston	WBZ-TV	4
Boston	WNAC-TV	7
MICHIGAN:		
Detroit	WXYZ-TV	7
Detroit	WTVO	2
Detroit	WWJ-TV	4
MINNESOTA:		
Minneapolis	WTCN-TV	4
St. Paul	KSTP-TV	5
MISSOURI:		
St. Louis	KSD-TV	5
NEBRASKA:		
Omaha	WOW-TV	6
NEW JERSEY:		
Newark	WATV	13
NEW MEXICO:		
Albuquerque	KOB-TV	4
NEW YORK:		
Buffalo	WBEN-TV	4
New York City	WABD	5
New York City	WCBS-TV	2
New York City	WJZ-TV	7
New York City	WNBT	4
New York City	WOR-TV	9
New York City	WPIX	11
Rochester	WHAM-TV	–
Schenectady	WRGB	4
Syracuse	WHEN	–
OHIO:		
Cincinnati	WLWT	4
Cleveland	WEWS	5
Cleveland	WNBK	4
Columbus	WLWC	3

State and city	*Call letters*	*Channel No*
Dayton	WLWD	5
Toledo	WTVT	13
Toledo	WSPD-TV	–
PENNSYLVANIA:		
Erie	WDTE	12
Johnstown	WJAC-TV	13
Lancaster	WGAL-TV	4
Philadelphia	WCAU-TV	10
Philadelphia	WFIL-TV	6
Philadelphia	WPTZ	3
Pittsburgh	WDTV	3
RHODE ISLAND:		
Providence	WJAR-TV	11
TENNESSEE:		
Memphis	WMCT	4
TEXAS:		
Fort Worth	WBAP-TV	5
Houston	KLEE	–
UTAH:		
Salt Lake City	KDYL-TV	2
VIRGINIA:		
Richmond	WTVR	6
WASHINGTON:		
Seattle	KRSC	–
WISCONSIN:		
Milwaukee	WTMJ	3

Rules Governing Amateur Radio Service

Effective April 1, 1946 (Revised to May 6, 1949)

The Communications Act of 1934 created a Federal Communication Commission composed of seven commissioners appointed by the President. The commissioners are empowered to issue such regulations not inconsistent with the law as it may deem necessary to properly regulate radio and wire communication. General regulations for amateurs have been drafted and those in effect at the present time are printed here.

It is not necessary to memorize the exact wording but every amateur should be thoroughly familiar with these regulations.

DEFINITIONS

§ 12.1 *Amateur service.*—The term "amateur service" means a radio service carried on by amateur stations.

§ 12.2 *Amateur operator.*—The term "amateur operator" means a person interested in radio technique solely with a personal aim and without pecuniary interest, holding a valid license issued by the Federal Communications Commission authorizing him to operate licensed amateur stations.

§ 12.3 *Amateur station.*—The term "amateur station" means a station used by an amateur operator, and it embraces all radio transmitting apparatus at a particular location used for amateur service and operated under a single instrument of authorization.

§ 12.4 *Amateur portable station.*—The term "amateur portable station" means an amateur station that is so constructed that it may conveniently be moved about from place to place for communication, but which is not operated while in motion.

§ 12.5 *Amateur mobile station.*—The term "amateur mobile station" means an amateur station that is so constructed that it may conveniently be transferred to or from a mobile unit or from one such unit to another, and is ordinarily used while such mobile unit is in motion.

§ 12.6 *Amateur radio communication.*—The term "amateur radio communication" means radio communication between amateur stations solely with a personal aim and without pecuniary interest.

§ 12.7 *Remote control.*—The term "remote control" as applied to the Amateur Radio Service, means control of transmitting equipment of an amateur station from an operating position other than one at which the transmitter is in view and immediately accessible; except that, direct mechanical control or direct electrical control by wired connections of an amateur transmitter from a point located on board any aircraft, vessel or vehicle on which such transmitter is located shall not be considered remote control within the meaning of this definition.

AMATEUR OPERATORS

LICENSES—PRIVILEGES

§ 12.21 *Eligibility for license.*—The following are eligible to apply for amateur operator license and privileges:

Class A.—Any citizen of the United States who at any time prior to receipt of his application by the Commission has held, for a period of a year or more, an amateur operator license issued by the Commission.

Class B.—Any citizen of the United States.

Class C.—Any citizen of the United States whose actual residence, address, and amateur station are more than 125 miles air line distant from the nearest location at which examinations are held at intervals of not more than 3 months for class B amateur operator license; or who is shown by physician's certificate to be unable to appear for examination because of protracted disability; or who is shown by certificate of the commanding officer to be in the armed forces of the United States at a military, naval or Coast Guard station and, for that reason, to be unable to appear for examination at the time and place designated by the Commission.

§ 12.22 *Application for amateur operator license.*—Each application for amateur operator license shall comply with the Commission's Rules and Regulations and shall be made in writing on Form 610 (application for amateur operator and/or station license). The application shall be filed with the district field office of the Commission if personal appearance is required for operator examination. If personal appearance is not required, the application shall be sent instead to the Commission, Washington 25, D.C. All applications for class C operating privileges shall be sent to the Commission, Washington 25, D.C.

§ 12.23 *Classification of operating privileges.*—Amateur operating privileges are classified as follows:

Class A.—All authorized amateur privileges.

Class B or C.—All authorized amateur privileges except the use of type A-3 emission on the frequency bands 3850 to 4000 kilocycles and 14200 to 14300 kilocycles.

§ 12.24 *Scope of operator authority.*—Amateur operator licenses are valid only for the operation of licensed amateur stations; and, on a temporary basis, for the operation of experimental stations (except class two stations) in the experimental service licensed for operation exclusively on a frequency or frequencies above 450 megacycles if such services are performed without compensation, direct or indirect, paid or promised.

§ 12.25 *Availability of operator license.*—The original operator license of each operator shall be kept in the personal possession of the operator while operating an amateur station. When operating an amateur station at a fixed location, however, the license may be posted in a conspicuous place in the room occupied by the operator. The license shall be available for inspection by any authorized Government official whenever the operator is operating an amateur station and at other times upon request made by an authorized representative of the Commission, except when such license has been filed with application for modification or renewal thereof, or has been mutilated, lost, or destroyed, and application has been made for a duplicate license in accordance with § 12.26. No recognition shall be accorded to any photocopy of an operator license.

§ 12.26 *Duplicate license.*—Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, shall submit with the application the mutilated license or a statement setting forth the facts regarding the manner in which the original license was lost or destroyed. If, subsequent to receipt by the licensee of the duplicate license, the original license is found, either the duplicate or the original license shall be returned immediately to the Commission.

§ 12.27 *Renewal of amateur operator license.*[1]—An amateur operator license may be renewed upon proper application showing that within the last 6 months of the license term the licensee has lawfully operated an amateur station or stations licensed by the Commission, and has thereby communicated by radio telegraphy with at least three other such amateur stations in the United States. The applicant shall qualify for a new license by examination if the requirements of this section are not fulfilled. Application for renewal of an amateur operator license shall be filed not more than 120 days prior to date of expiration of such license and not later than the date of expiration.

§ 12.28 *Who may operate an amateur station.*—An amateur station may be operated only by a person holding a valid amateur operator license, and then only to the extent provided for by the class of privileges granted under

[1] Order No. 115–C, adopted by the Commission effective January 3, 1947, provides that the amateur operator and station licenses (except those suspended, revoked, or voluntarily surrendered) of all amateurs whose operator licenses were issued on or between Decembr 7, 1938 and December 31, 1944 be extended and validated and if expired on or after December 7, 1946, be reinstated and extended and validated, to expire in 1948 at 3 a.m. e.s.t., on the same day and month as the date of issuance of the operator license. The Order is automatic and no action by the licensee is required. However, the licensees affected by Order No. 115–C should use the new expiration date established by this order as a basis for compliance with the provisions of Sections 12.27 and 12.67.

The requirement of this section for a showing of service or use of license for purposes of renewal of licenses without examination is suspended from July 1, 1948 through December 31, 1948. This suspension continues the suspension in effect through June 30, 1948 by virtue of Commission Order No. 77–H.

the license. When an amateur station is used for telephony, the station licensee may permit any person to transmit by voice, provided that during such transmission call signs are announced as prescribed by § 12.82 and a duly licensed amateur operator maintains actual control over the emissions. including turning the carrier on and off for each transmission and signing the station off after communication with each station has been completed.

§ 12.29 *License term.*—An amateur operator license is valid normally for a period of 5 years from the date of issuance of a new, renewed, or modified license.

§ 12.30 *Order of suspension.*—No order of suspension of any operator's license shall take effect until 15 days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said 15 days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have 15 days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the 15-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission shall deem appropriate. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

§ 12.31 *Proceedings.*—Proceedings for the suspension of an operator's license shall in all cases be initiated by the entry of an order of suspension. Respondent will be given notice thereof together with notice of his right to be heard and to contest the proceeding. The effective date of the suspension will not be specified in the original order but will be fixed by subsequent motion of the Commission in accordance with the conditions specified above. Notice of the effective date of suspension will be given respondent, who shall send his operator license to the office of the Commission in Washington, D.C., on or before the said effective date, or, if the effective date has passed at the time notice is received, the license shall be sent to the Commission forthwith.

EXAMINATIONS

§ 12.41 *When examination is required.*—Examination is required for the issuance of a new amateur operator license, and for a change in class of operating privileges. Credit may be given, however, for certain elements of examination as provided in § 12.46.

§ 12.42 *Elements of examination.*—The examination for amateur operator privileges comprises the following:

Element 1. *Code test.*—Ability to send and receive, in plain language, messages in the International Morse Code at a speed of not less than 13 words per minute, free of omission or other error for a continuous period of at least 1 minute, during a test period of 5 minutes, counting five characters to the word, each numeral or punctuation mark counting as two characters.

Element 2. Amateur radio operation and apparatus, including telephone and telegraph.

Element 3. Provisions of treaties, statutes, and regulations affecting amateurs.

Element 4. Advanced amateur telephony.

§ 12.43 *Elements required for various privileges.*—The examination for class A privileges will include all of the examination elements specified in § 12.42.

The examination for class B and class C privileges will include elements 1, 2, and 3 specified in § 12.42.

§ 12.44 *Manner of conducting examination.*—The examinations for class A and class B privileges will be conducted by an authorized Commission employee or representative at locations and at times specified by the Commission.

Each examination for class C privileges will be conducted and supervised by not more than two volunteer examiners, whom the Commission may designate or permit the applicant to select; in the event the examiner for the code test is selected by the applicant, such examiner shall be the holder of an amateur operator license with class A or B operating privileges, or shall have held, within the 5 years prior to the date of the examination, a commercial radiotelegraph operator license issued by the Commission or within that time shall have been employed in the service of the United States as the operator of a manually operated radiotelegraph station. The examiner for the written test shall be at least 21 years of age.

§ 12.45 *Additional examination for holders of class C operating privileges.*—The Commission may require a licensee holding class C operating privileges to appear for a class B examination at a location designated by the Commission. If the licensee fails to appear for the class B examination when directed to do so, or fails to pass such examination, the class C operator license previously issued shall be subject to cancellation and, upon cancellation, a new license will not be issued for the class C privileges.

Whenever the holder of class C amateur operating privileges changes his actual residence or station location to a location where he would not have been eligible to apply for class C privileges in the first instance, or whenever a new examining location is established in an area within which the holder of class C amateur operating privileges would not have been eligible because of such examining location, to apply for class C privileges, such holder of class C privileges shall appear within 4 months thereafter at an examining location and time designated by the Commission and be examined for class B privileges. If, under such circumstances, the licensee fails to appear for class B examination, or fails to pass such examination, the class C operator license previously issued shall be subject to cancellation and, upon cancellation, a new license will not be issued for the class C privileges.

§ 12.46 *Examination credit.*—An applicant for class A privileges who holds an amateur operator license authorizing class B privileges will be required to pass only the examination element No. 4, advanced amateur telephony.

An applicant for class A privileges will be given credit for examination element 4 if within 2 years prior to the receipt of his application by the Commission he held class A privileges.

An applicant for any class of amateur privileges will be given credit for examination element 1 if within 5 years prior to the receipt of his application by the Commission he held a radiotelegraph first- or second-class operator license.

No examination credit for other classes of licenses or privileges shall be allowed.

A holder of an amateur operator license authorizing class C privileges will not thereby be accorded an abridged examination for either class B or class A privileges.

§ 12.47 *Examination procedure.*—When taking an examination for amateur operator license, or for additional amateur operating privileges, the applicant shall write in longhand, by means of pen and ink. Diagrams shall be drawn either with pen and ink or with pencil; code tests shall be written or hand printed with either pen and ink or with pencil. Applicants unable to comply with these requirements, because of physical disability, may dictate their answers to examination questions, and if unable to draw required diagrams, may dictate a detailed description essentially equivalent. If the examination or any part thereof is dictated, the examiner shall certify the nature of the applicant's disability and the name and address of the person(s) taking and transcribing the applicant's dictation.

§ 12.48 *Grading.*—Code tests are graded as "passed" or "failed," separately for sending and receiving tests. Failure to pass the required code test for either sending or receiving will terminate the examination.

Seventy-four percent is the passing grade for written examinations. For the purpose of grading, elements 2 and 3 (required for class B and class C privileges) are considered to be a single examination and element 4 (required, in addition to the other elements, for class A privileges) is considered to be a separate examination.

§ 12.49 *Eligibility for reexamination.*—An applicant who fails examination for amateur operator privileges may not take another examination for such privileges within 30 days, except that this limitation shall not apply to an examination for class B operating privileges following an examination for class C privileges.

AMATEUR RADIO STATIONS

LICENSES

§ 12.61 *Eligibility for amateur station license.*—A license for an amateur station will be issued in response to proper application therefor to a licensed amateur operator who has made a satisfactory showing of control of the transmitting station for which license is desired and of control of the specific premises upon which all of the station apparatus is to be located, at a designated fixed location. An amateur station license may be issued to an individual, not a licensed amateur operator (other than an alien or a representative of an alien or of a foreign government), who is in charge of a proposed amateur station located in approved public quarters and established for training purposes in connection with the armed forces of the United States, but not operated by the United States Government.

§ 12.62 *Eligibility of corporations or organizations to hold license.*—An amateur station license will not be issued to a school, company, corporation, association, or other organization, nor for their use except that in the case of a bona fide amateur radio organization or society, a station license may be issued to a licensed amateur operator as trustee for such society.

§ 12.63 *Application for amateur station license.*—(*a*) Each application for an amateur station license shall comply with the Commission's Rules and Regulations and shall be made in writing, subscribed and verified on FCC Form No. 610 (application for amateur operator and/or station license). FCC Form No. 602 should be used where the applicant is in charge of a proposed amateur station located in approved public quarters and established for training purposes in connection with the armed forces of the United States, but not operated by the United States Government.

(*b*) One application and all papers incorporated therein and made a part thereof shall be submitted for each amateur station license and shall be filed with the district field office of the Commission if personal appearance is required for operator examination in connection with the application for station license. If personal appearance is not required, the station application shall be sent to the Commission, Washington 25, D.C.

§ 12.64 *Location of station.*—(*a*) Every amateur station shall have a fixed transmitter location. Only one fixed transmitter location will be authorized and will be designated on the license for each amateur station, except that when remote control is authorized, the location of the remote control position as well as the location of the remotely controlled transmitter shall be considered as fixed transmitter locations and will be so designated on the station license. Unless remote control of the transmitting apparatus is authorized, such apparatus shall be operated only by a duly licensed amateur radio operator present at the location of such apparatus.

(*b*) Authority for operation of an amateur station with the licensed operator on duty at a specific remote control point in lieu of the remote transmitter location may be granted upon filing an application for a modified station license on FCC Form No. 610 or FCC Form No. 602, as appropriate, and provided that the following conditions are met:

(1) The remote control point as well as the remotely controlled transmitter, shall be located on premises controlled by the licensee.

(2) The remotely controlled transmitter shall be so installed and protected that it is inaccessible to other than duly authorized persons.

(3) In addition to the requirements of § 12.68 a photocopy of the amateur station license shall be posted in a conspicuous place at the location of the remotely controlled transmitter.

(4) Means shall be provided at the control point to permit the continuous monitoring of the emissions of the remotely controlled transmitter, and it shall be continuously monitored when in operation.

(5) Means shall be provided at the remote control point immediately to suspend the radiation of the transmitter when there is any deviation from the terms of the station license or from the Rules Governing Amateur Radio Service.

(6) In the event that operation of an amateur transmitter from a remote control point by radio is desired, an application for a modified station license on FCC Form No. 610 or FCC Form No. 602, as appropriate, should be submitted with a letter requesting authority to operate in such a manner stating that the controlling transmitter at the remote location will operate within amateur frequency bands 420 megacycles or higher and that there will be full compliance with § 12.64 (b), subparagraphs (1) through (5). Supplemental statements and diagrams should accompany the application and show how radio remote control will be accomplished and what means will be employed to prevent unauthorized operation of the transmitter by signals other than those from the controlling unit. There should be included complete data on control channels, relays and functions of each, directional antenna design for the trasmitter and receiver in the control circuit, and

means employed for turning on and off the main transmitter from the remote control location.

(*c*) An amateur transmitter may be operated from a remote control point in lieu of the remote transmitter location without special authorization by the Commission when there is direct mechanical control or direct electrical control by wired connections of the transmitter from a point located in the same or closely adjoining building or structure provided there is full compliance with the conditions set forth in § 12.64 (*b*), subparagraphs (1) through (5).

§ 12.65 *License period.*—The license for an amateur station is valid normally for a period of 5 years from the date of issuance of a new, renewed, or modified license.

§ 12.66 *Authorized apparatus.*—An amateur station license authorizes the use under control of the licensee of all transmitting apparatus at the fixed location specified in the station license which is operated on any frequency, or frequencies allocated to the amateur service, and in addition authorizes the use, under control of the licensee, of portable and mobile transmitting apparatus operated at other locations.

§ 12.67 *Renewal of amateur station license.*[2]—An amateur station license may be renewed upon proper application filed not more than 120 days prior to date of expiration of such license and not later than the date of expiration.

§ 12.68 *Availability of station license.*—The original license of each amateur station or a photocopy thereof shall be posted in a conspicuous place in the room occupied by the licensed operator while the station is being operated at a fixed location or shall be kept in his personal possession. When the station is operated at other than a fixed location, the original station license or a photocopy thereof shall be kept in the personal possession of the station licensee (or a licensed representative) who shall be present at the station while it is being operated as a portable or mobile station. The original station license shall be available for inspection by any authorized Government official at all times while the station is being operated and at other times upon request made by an authorized representative of the Commission, except when such license has been filed with application for modifica-

[2] Order No. 115–C, adopted by the Commission effective January 3, 1947, provides that the amateur operator and station licenses (except those suspended, revoked, or voluntarily surrendered) of all amateurs whose operator licenses were issued on or between December 7, 1938, and December 31, 1944, be extended and validated and if expired on or after December 7, 1946, be reinstated and extended and validated, to expire in 1948 at 3 a.m., e.s.t., on the same day and month as the date of issuance of the operator license. The Order is automatic and no action by the licensee is required. However, the licensees affected by Order No. 115–C should use the new expiration date established by this order as a basis for compliance with the provisions of Sections 12.27 and 12.67.

tion or renewal thereof, or has been mutilated, lost, or destroyed, and application has been made for a duplicate license in accordance with § 12.26.

§ 12.69 *Revocation of station license.*—Whenever the Commission shall institute a revocation proceeding against the holder of any radio station license under section 312 (a) of the Communications Act of 1934, as amended, it shall initiate said proceeding by serving upon said licensee an order of revocation effective not less than 15 days after written notice thereof is given the licensee. The order of revocation shall contain a statement of the grounds and reasons for such proposed revocation and a notice of the licensee's right to be heard by filing with the Commission a written request for hearing within 15 days after receipt of said order. Upon filing of such written request for hearing by said licensee the order of revocation shall stand suspended and the Commission will set a time and place for hearing and shall give the licensee and other interested parties notice thereof. If no request for hearing on any order of revocation is made by the licensee against whom such an order is directed within the time hereinabove set forth, the order of revocation shall become final and effective, without further action of the Commission. When any order of revocation has become final, the person whose license has been revoked shall forthwith deliver the station license in question to the Engineer in Charge of the district in which the licensee resides.

§ 12.70 *Modification of station license.*—(*a*) Whenever the Commission shall determine that public interest, convenience, and necessity would be served, or any treaty ratified by the United States will be more fully complied with, by the modification of any radio station license either for a limited time, or for the duration of the term thereof, it shall issue an order for such licensee to show cause why such license should not be modified.

(*b*) Such order to show cause shall contain a statement of the grounds and reasons for such proposed modification, and shall specify wherein the said license is required to be modified. It shall require the licensee against whom it is directed to be and appear at a place and time therein named, in no event to be less than 30 days from the date of receipt of the order to show cause why the proposed modification should not be made and the order of modification issued.

(*c*) If the licensee against whom the order to show cause is directed does not appear at the time and place provided in said order, a final order of modification shall issue forthwith.

CALL SIGNS

§ 12.81 *Assignment of call sign.*—(*a*) The call signs of amateur stations will be assigned systematically by the Commission with the following exceptions:

(1) A specific unassigned call sign may be reassigned to the most recent holder thereof;

(2) A specific unassigned call sign may be assigned to a previous holder if not under license during the past 5 years;

(3) A specific unassigned call sign may be assigned to an amateur organization in memoriam to a deceased member and former holder thereof;

(4) A specific call sign may be temporarily assigned to a station connected with an event, or events, of general public interest;

(5) An unassigned "two-letter call" (a call sign having two letters following the numeral) may be assigned to a previous holder of a "two-letter call."

(*b*) An amateur call sign will consist of a sequence of one or two letters, a numeral designating the call sign area, and two or three letters. The call sign areas are as follows:

NO.

1. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
2. New York, New Jersey.
3. Pennsylvania, Delaware, Maryland, District of Columbia.
4. Virginia, North and South Carolina, Georgia, Florida, Alabama, Tennessee, Kentucky, Puerto Rico and Virgin Islands.
5. Mississippi, Louisiana, Arkansas, Oklahoma, Texas, New Mexico.
6. California, Hawaii and Pacific possessions except those included in area 7.
7. Oregon, Washington, Idaho, Montana, Wyoming, Arizona, Nevada, Utah, Alaska and adjacent islands.
8. Michigan, Ohio, West Virginia.
9. Wisconsin, Illinois, Indiana.
10. Colorado, Nebraska, North and South Dakota, Kansas, Minnesota, Iowa, Missouri.

§ 12.82 *Transmissions of call signs.*—(*a*) An operator of an amateur station shall transmit the call sign of the station called or being worked and the call sign assigned the station which he is operating at the beginning and end of each transmission and at least once every 10 minutes during every transmission of more than 10 minutes' duration. In the case of stations conducting an exchange of several transmissions in sequence, with each transmission less than 3 minutes' duration, the call signs of the communicating stations need be transmitted only once every 10 minutes of operation as well as at the beginning and at the termination of the correspondence.

(*b*) In addition to complying with the requirements of paragraph (*a*) above, an operator of an amateur station operated as a portable or mobile station using radiotelegraphy shall transmit immediately after the call sign of such station, the fraction-bar character $\overline{\text{(DN)}}$ followed by the number of the amateur call sign area in which the portable or mobile amateur station is then being operated, as for example:

Example 1.—Portable or mobile amateur station operating in the third amateur call sign area calls a fixed amateur station: W1ABC W1ABC W1ABC DE W2DEF $\overline{\text{DN}}$ 3 W2DEF $\overline{\text{DN}}$ 3 W2DEF $\overline{\text{DN}}$ 3 AR.

Example 2.—Fixed amateur station answers the portable or mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC K.

Example 3.—Portable or mobile amateur station calls a portable or mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL $\overline{\text{DN}}$ 4 W4JKL $\overline{\text{DN}}$ 4 W4JKL $\overline{\text{DN}}$ 4 AR.

When telephony is used, the call sign of the station shall be preceded by the words "this is" or the word "from" instead of the letters "de," followed by an announcement of the geographical location in which the portable or mobile station is being operated.

Example 4.—Portable or mobile amateur radiotelephone station operating in the third call area calls a fixed amateur station: W1ABC W1ABC W1ABC "this is" or the word "from" W2DEF W2DEF W2DEF operating portable (or mobile) 3 miles north of Bethesda, Md., over.

(*c*) When telephony is used, the transmission of call signs prescribed by subsections (*a*) and (*b*) of this section may be made by the person transmitting by voice in lieu of a duly licensed operator provided the licensed operator maintains the control required by § 12.28.

(*d*) When using telephony, phonetic aids to identify the call sign of the station may be employed.

(*e*) In addition to complying with the requirements of paragraph (*a*) above, an operator of an amateur station operated as a mobile station aboard a vessel on the high seas, or aboard an aircraft en route on an international voyage, shall, when the vessel or aircraft is outside the 10 call sign areas prescribed by the Commission in § 12.81 (*b*), comply with the following calling procedure:

(1) Mobile operations aboard a vessel.

i. When using telegraphy the amateur operator shall transmit immediately after the call sign of the station the fraction bar $\overline{\text{DN}}$ followed by the designator MM to indicate that the station is being operated as a mobile station aboard a vessel. In addition, the name of the vessel and its approximate geographical location shall be transmitted at the end of each transmission immediately prior to signing off. If the vessel does not have a name, the number of the vessel shall be transmitted in lieu of the name of the vessel.

ii. When using telephony the call sign of the station shall be preceded by the words "this is," or the word "from" followed by the words "maritime mobile," to indicate that the station is being operated as a mobile station aboard a vessel. In addition the name of the vessel and its approximate geographical location shall be transmitted at the end of each transmission immediately prior to signing off. If the vessel does not have a name, the number of the vessel shall be transmitted in lieu of the name of the vessel.

(2) Mobile operations aboard aircraft.

i. When using telegraphy the amateur operator shall transmit immediately after the call sign of the station the fraction bar $\overline{DN}$ followed by the designator AM to indicate that the station is being operated as a mobile station aboard an aircraft. In addition, the number of the aircraft and its approximate geographical location shall be transmitted at the end of each transmission immediately prior to signing off.

ii. When using telephony the call sign of the station shall be preceded by the words "this is," or the word "from" followed by the words "aeronautical mobile," to indicate that the station is being operated as a mobile station aboard an aircraft. In addition, the number of the aircraft and its approximate geographical location shall be transmitted at the end of each transmission immediately prior to signing off.

PORTABLE AND MOBILE STATIONS

§ 12.91 *Requirements for portable and mobile operation.*—(*a*) Within the continental limits of the United States, its territories, or possessions, an amateur station may be operated as either a portable or a mobile station on any frequency authorized and available for the amateur radio service. Whenever portable operation is, or is likely to be, for an over-all period in excess of 48 hours away from the fixed transmitter location designated in the station license, the licensee shall give prior written notice to the Engineer in Charge of the radio inspection district in which such portable operation is intended. This notice is required even though the station is, or is likely to be. operated during any part of this over-all period at the fixed transmitter location. Whenever mobile operation is, or is likely to be, for a period in excess of 48 hours without return to the fixed transmitter location designated in the station license, the licensee shall give prior written notice to the Engineer in Charge of the radio inspection district in which such mobile operation is intended. The notice required for either portable or mobile operation shall state the station call sign, the name of the licensee, the date or dates of proposed operation and the contemplated portable station locations, or mobile station itinerary, as specifically as possible. An amateur station operated under the provisions of this section shall not be operated during any period exceeding one month away from the fixed station location designated in the station license without giving additional notice to the Engineer in Charge of the radio inspection district in which the station is intended to be further operated, nor for more than four consecutive periods of 1 month each as portable at the same location. Mobile operation without return to the fixed transmitter location may be continued beyond the four consecutive periods of 1 month each provided that the above mentioned notice of mobile operation is given each month.

(*b*) Outside the continental limits of the United States, its territories or possessions, an amateur station may be operated as portable or mobile only in the amateur band 28.0 to 29.7 Mc. Within areas under the jurisdiction of a foreign government, operation is also limited to this band and then only with the permission of that government. Whenever such portable or mobile operation is, or is likely to be, for a period in excess of 48 hours away from the continental limits of the United States, its territories, or possessions, the licensee shall give prior written notice to the Engineer in Charge of the radio inspection district in which the fixed transmitter site designated in the station license is located. Only one such notice shall be required during any continued absence from the continental limits of the United States, its territories, or possessions.

§ 19.92 *Deleted.*

§ 12.93 *Special provisions for nonportable stations.*—The specific provisions of these rules relative to portable stations are not applicable to a nonportable station except that—

(*a*) An amateur station that has been moved from one permanent location to another permanent location may be operated at the latter location, in accordance with the provisions governing portable stations (including notice to the Engineer in Charge of the district in which the station is located) for a period not exceeding four consecutive months, but in no event beyond the expiration date of the license, provided a formal application for modification of license to change the permanent location has been filed with the Commission.

(*b*) The licensee of an amateur station who changes residence temporarily and moves his amateur station to a temporary location associated with his temporary residence, or the licensee-trustee for an amateur radio society which changes the normal location of its amateur station to a different and temporary location may use the station at the temporary location if the station is to remain there for a period of not more than 4 months and the following requirements are met:

(1) Advance notice in writing shall be given by the amateur station licensee or licensee-trustee to the Commission in Washington, D.C., and to the Engineer in Charge of the district in which the station is to be temporarily operated.

(2) Similar notice shall be given for each change in station location and for transfer of the station to the former permanent location, or to a new permanent location before the transmitting apparatus is operated.

(*c*) When the station is operated under the provisions of this section the calling procedure specified in § 12.82 shall be used, including transmissions of the fractional bar character when telegraphy is used followed by the number of the amateur call sign area in which the station is being operated. When telephony is used, an announcement shall be made of the geographical location in which the station is being operated.

§ 12.94 *Special provisions for mobile stations aboard ships or aircraft.*—In addition to complying with all other applicable rules, an amateur mobile station operated on board a ship or aircraft must comply with all of the following special conditions: (*a*) The installation and operation of the amateur mobile station shall be approved by the master of the ship or captain of the aircraft; (*b*) The amateur mobile station shall be separate from and independent of all other radio equipment if any, installed on board the same ship or aircraft; (*c*) The electrical installation of the amateur mobile station shall be in accord with the rules applicable to ships or aircraft as promulgated by the appropriate government agency; (*d*) The operation of the amateur mobile station shall not interfere with the efficient operation of any other radio equipment installed on board the same ship or aircraft; and (*e*) The amateur mobile station and its associated equipment, either in itself or in its method of operation, shall not constitute a hazard to the safety of life or property.

USE OF AMATEUR STATIONS

§ 12.101 *Points of communications.*—An amateur station may be used to communicate only with other amateur stations, except that in emergencies or for test purposes it may also be used temporarily for communication with other classes of stations licensed by the Commission, and with United States Government stations. Amateur stations may also be used to communicate with any radio station other than amateur which is authorized by the Commission to communicate with amateur stations. Amateur stations may be used also for transmitting signals, or communications, or energy, to receiving apparatus for the measurement of emissions, temporary observation of transmission phenomena, radio control of remote objects, and for similar experimental purposes and for the purposes set forth in § 12.106 of these rules.

§ 12.102 *No remuneration for use of station.*—An amateur station shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

§ 12.103 *Broadcasting prohibited.*—Subject to the provisions of § 12.106 of these rules, an amateur station shall not be used to engage in any form of broadcasting, that is, the dissemination of radio communications intended to be received by the public directly or by the intermediary of relay stations, nor for the retransmission by automatic means of programs or signals emanating from any class of station other than amateur. The foregoing provision shall not be construed to prohibit amateur operators from giving their consent to the rebroadcast by broadcast stations of the transmissions of their amateur stations, provided, that the transmissions of the amateur stations shall not contain any direct or indirect reference to the rebroadcast.

§ 12.104 *Radiotelephone tests.*—The transmission of music by an amateur station is forbidden. However, single audiofrequency tones may be transmitted for test purposes of short duration for the development and perfection of amateur radiotelephone equipment.

§ 12.105 *Codes and ciphers prohibited.*—The transmission by radio of messages in codes or ciphers in domestic and international communications to or between amateur stations is prohibited. All communications regardless of type of emission employed shall be in plain language except that generally recognized abbreviations established by regulation or custom and usage are permissible as are any other abbreviations or signals where the intent is not to obscure the meaning but only to facilitate communications.

§ 12.106 *One-way communications.*—In addition to the experimental one-way transmissions permitted by § 12.101, the following kinds of one-way communications, addressed to amateur stations, are authorized and will not be construed as broadcasting: (a) Emergency communications, including bona-fide emergency drill practice transmissions; (b) Information bulletins consisting solely of subject matter having direct interest to the amateur radio service as such; (c) Round-table discussions or net-type operations where more than two amateur stations are in communication, each station taking a turn at transmitting to other station(s) of the group; and (d) Code practice transmissions intended for persons learning or improving proficiency in the International Morse Code.

ALLOCATION OF FREQUENCIES [3]

§ 12.111 *Frequencies and types of emission for use of amateur stations.*—(a) Subject to the limitations and restrictions set forth herein and in § 12.114 of these rules, the following frequency bands and types of emissions are allocated and available for amateur station operation as follows:

(1) 1750 to 2050 kc. Not available for use.

(2) 3500 to 4000 kc. Use of this band is restricted to amateur radio stations as follows:

(i) 3500 to 4000 kc, using type A1 emission, to those stations located within the continental limits of the United States, the Territories of Alaska and Hawaii, Puerto Rico, the Virgin Islands and all United States possessions lying west of the Territory of Hawaii to 170° west longitude.

(ii) 3850 to 4000 kc, using type A3 emission, to those stations located within the continental limits of the United States, the Territories of Alaska and Hawaii, Puerto Rico, the Virgin Islands and all United States possessions lying west of the Territory of Hawaii to 170° west longitude, subject to the further restriction that type A3 emission may be used only by an amateur station which is licensed to an amateur operator holding Class A privileges and then only when operated and controlled by an amateur operator holding Class A privileges.

(3) 7000 to 7300 kc, using type A1 emission.

(4) 14000 to 14400 kc, using type A1 emission, and, on frequencies 14200 to 14300 kc, type A3 emission, subject to the restriction that type A3 emission may be used only by an amateur station which is licensed to an amateur operator holding Class A privileges and then only when operated and controlled by an amateur operator holding Class A privileges.

(5) 26.960 to 27.230 Mc, using unmodulated carrier, radiotelegraphy, radiotelephony, radio printer, or facsimile, with any type of emission except damped waves and pulse, subject to such interference as may result from the emissions of industrial, scientific and medical devices within 160 kc of the frequency 27.120 Mc.

(6) 28.0 to 29.7 Mc, using type A1 emission, and on frequencies 28.5 to 29.7 Mc, using type A3 emission, and on frequencies 29.0 to 29.7 Mc, using special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques).

(7) 50.0 to 54.0 Mc, using types A1, A2, A3, and A4 emission and, on frequencies 52.5 to 54.0 Mc, special emission for frequency modulation

[3] The assignment and use of all frequencies below 25 megacycles contained in these regulations are subject to change in accordance with the Commission's final report of allocations below 25 megacycles, in Docket Proceeding No. 6651.

(radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques).

(8) 144 to 148 Mc, using types AØ, A1, A2, A3, and A4 emission and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques).

(9) 220 to 225 Mc, using types AØ, A1, A2, A3, and A4 emission and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques), provided that until January 1, 1952, if this band is required for distance measuring equipment at certain United States gateways and Canadian border locations, amateurs within interference range of those gateways and locations shall, after publication by the Commission of an order designating the areas involved, cease to use this band, but shall be entitled in lieu thereof to use the band 235 to 240 Mc.

(10) 235 to 240 Mc, using types AØ, A1, A2, A3, and A4 emission and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carried shift or other frequency modulation techniques) until January 1, 1952, provided that commencing with June 9, 1948, this band may be used only as a substitute for the band 220 to 225 Mc in those cases in which the band 220 to 225 Mc may not be used, as provided in (9), above, of this section.

(11) 420 to 450 Mc, using types AØ, A1, A2, A3, A4, and A5 emissions and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques). Peak antenna power shall not exceed 50 watts in order to minimize interference to aircraft altimeters temporarily allocated to this band.

(12) 1215 to 1300 Mc, using types AØ, A1, A2, A3, A4, and A5 emission and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques).

(13) 2300 to 2450 Mc, 3300 to 3500 Mc, 5650 to 5925 Mc, 10,000 to 10,500 Mc, 21,000 to 22,000 Mc, and any frequency or frequencies above 30,000 Mc, using on these frequencies types AØ, A1, A2, A3, A4, A5 emission and special emission for frequency modulation (radiotelephone transmissions and radiotelegraph transmissions employing carrier shift or other frequency modulation techniques), and pulse emission. Operations in the frequency bands 2300 to 2450 Mc and 5650 to 5925 Mc are subject to such interference between 2400 and 2450 Mc and between 5775 and 5925 Mc, respectively, as may result from emissions of industrial, scientific and medical devices on the frequencies 2450 and 5850 Mc, respectively.

§ 12.112. *Deleted.*

§ 12.113 *Individual frequency not specified.*—Transmissions by an amateur station may be on any frequency within any authorized amateur band. Sideband frequencies resulting from keying or modulating a carrier wave shall be confined within the authorized amateur band.

§ 12.114 *Types of emission.*—(*a*) Type AØ emission, where not specifically designated in the bands listed in § 12.111 of these rules, may be used for short periods of time when required for authorized remote control purposes or for experimental purposes. However, these limitations do not apply where type AØ emission is specifically designated.

(*b*) Narrow band frequency or phase modulation may be used, in addition to the types of emission specifically designated in § 12.111 of these rules, by certain amateur stations for radiotelephone communication until further order of the Commission, but in no event beyond July 31, 1949 as follows:

(1) Amateur stations licensed to and operated by Class A amateur operators in the frequency bands 3850 to 3900 kc and 14200 to 14250 kc; and

(2) Amateur stations licensed to and operated by all classes of amateur operators in the frequency bands 28.5 to 29.0 Mc and 51.0 to 52.5 Mc and all frequency bands where "special emission for frequency modulation" (wide band FM) are presently authorized.

(*c*) The authorization provided by (*b*), above, is subject to the conditions that the band-width of the modulated carrier shall not exceed the band-width occupied by an amplitude-modulated carrier of the same audio characteristics, and that the purity and stability of such emissions shall be maintained in accordance with the requirements of § 12.133 of the Commission's Rules Governing Amateur Radio Service.

§ 12.115 *Deleted.*

§ 12.116 *Deleted.*

§ 12.117 *Deleted.*

EQUIPMENT AND OPERATION

§ 12.131 *Maximum authorized power.*—Except on frequencies within the band 420 to 450 megacycles (where peak antenna power shall not exceed 50 watts), each amateur transmitter may be operated with a power input not exceeding 1 kilowatt to the plate circuit of the final amplifier stage of an amplifier-oscillator transmitter or to the plate circuit of an oscillator transmitter. An amateur transmitter operating with a power input exceeding 900 watts to the plate circuit shall provide means for accurately measuring the plate power input to the vacuum tube or tubes supplying power to the antenna.

§ 12.132 *Power supply to transmitter.*—The licensee of an amateur station using frequencies below 144 megacycles shall use adequately filtered direct-current plate power supply for the transmitting equipment to minimize modulation from this source.

§ 12.133 *Purity and stability of emissions.*—Spurious radiation from an amateur station being operated with a carrier frequency below 144 megacycles shall be reduced or eliminated in accordance with good engineering practice. This spurious radiation shall not be of sufficient intensity to cause interference in receiving equipment of good engineering design including adequate selectivity characteristics, which is tuned to a frequency or frequencies outside the frequency band of emission normally required for the type of emission being employed by the amateur station. In the case of A-3 emission, the amateur transmitter shall not be modulated to the extent that interfering spurious radiation occurs, and in no case shall the emitted carrier wave be amplitude-modulated in excess of 100 percent. Means shall be employed to insure that the transmitter is not modulated in excess of its modulation capability for proper technical operation. For the purposes of this section a spurious radiation is any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks, and other transient effects, and parasitic oscillations. When using amplitude modulation on frequencies below 144 megacycles, simultaneous frequency modulation is not permitted and when using frequency modulation on frequencies below 144 megacycles simultaneous amplitude modulation is not permitted. The frequency of the emitted carrier wave shall be as constant as the state of the art permits.

§ 12.134 *Modulation of carrier wave.*—Except for brief tests or adjustments and except for operation in the band 26.960 to 27.230 megacycles, an amateur radiotelephone station shall not emit a carrier wave on frequencies below 144 megacycles unless modulated for the purpose of communication.

§ 12.135 *Frequency measurement and regular check.*—The licensee of an amateur station shall provide for measurement of the emitted carrier frequency or frequencies and shall establish procedure for making such measurement regularly. The measurement of the emitted carrier frequency or frequencies shall be made by means independent of the means used to control the radio frequency or frequencies generated by the transmitting apparatus and shall be of sufficient accuracy to assure operation within the amateur frequency band used.

§ 12.136 *Logs.*—Each licensee of an amateur station shall keep an accurate log of station operation, including the following:

(*a*) The date and time of each transmission. (The date need only be entered once for each day's operation. The expression "time of each transmission" means the time of making a call and need not be repeated during the sequence of communication which immediately follows; however, an entry shall be made in the log when signing off so as to show the period during which communication was carried on.)

(*b*) The signature of each licensed operator who manipulates the key of a radiotelegraph transmitter or the signature of each licensed operator who operates a transmitter of any other type and the name of any person not holding an amateur operator license who transmits by voice over a radiotelephone transmitter. The signature of the operator need only be entered once in the log, in those cases when all transmissions are made by or under the supervision of the signatory operator, provided a statement to that effect also is entered. The signature of any other operator who operated the station shall be entered in the proper space for that operator's transmission.

(*c*) Call sign of the station called. (This entry need not be repeated for calls made to the same station during any sequence of communication, provided the time of signing off is given.)

(*d*) The input power to the oscillator, or to the final amplified stage where an oscillator-amplifier transmitter is employed. (This need be entered only once, provided the input power is not changed.)

(*e*) The frequency band used. (This information need be entered only once in the log for all transmissions until there is a change in frequency to another amateur band.)

(*f*) The type of emission used. (This need be entered only once until there is a change in the type of emission.)

(*g*) The location of the station (or the approximate geographical location of a mobile station) at the time of each transmission. (This need be entered only once provided the location of the station is not changed. However, suitable entry shall be made in the log upon changing the location. Where operating at other than a fixed location, the type and identity of the vehicle or other mobile unit in which the station is operated shall be shown.)

(*h*) The message traffic handled. (If record communications are handled in regular message form, a copy of each message sent and received shall be entered in the log or retained on file at the station for at least 1 year.)

§ 12.137 *Retention of logs.*—The log shall be preserved for a period of at least 1 year following the last date of entry. The copies of record communications and station log required by § 12.136 shall be available for inspection by authorized representatives of the Commission.

SPECIAL CONDITIONS

§ 12.151 *Additional conditions to be observed by licensee.*—In all respects not specifically covered by these regulations each amateur station shall be operated in accordance with good engineering and good amateur practice.

§ 12.152 *Restricted operation.*—(*a*) If the operation of an amateur station causes general interference to the reception of transmissions from stations operating in the domestic broadcast service when receivers of good engineering design including adequate selectivity characteristics are used to receive such transmissions and this fact is made known to the amateur station licensee, the amateur station shall not be operated during the hours from 8 p. m. to 10:30 p. m., local time, and on Sunday for the additional period from 10:30 a. m. until 1 p. m., local time, upon the frequency or frequencies used when the interference is created. (*b*) In general, such steps as may be necessary to minimize interference to stations operating in other services may be required after investigation by the Commission.

§ 12.153 *Second notice of same violation.*—In every case where an amateur station licensee is cited within a period of 12 consecutive months for the second violation of the provisions of §§ 12.111, 12.113, 12.114, 12.132, or 12.133, the station licensee, if directed to do so by the Commission, shall not operate the station and shall not permit it to be operated from 6 p. m. to 10:30 p. m., local time, until written notice has been received authorizing the resumption of full-time operation. This notice will not be issued until the licensee has reported on the results of tests which he has conducted with at least two other amateur stations at hours other than 6 p. m. to 10:30 p. m., local time. Such tests are to be made for the specific purposes of aiding the licensee in determining whether the emissions of the station are in accordance with the Commission's rules. The licensee shall report to the Commission the observations made by the cooperating amateur licensees in relation to the reported violations. This report shall include a statement as to the corrective measures taken to insure compliance with the rules.

§ 12.154 *Third notice of same violation.*—In every case where an amateur station licensee is cited within a period of 12 consecutive months for the third violation of §§ 12.111, 12.113, 12.114, 12.132, or 12.133, the station licensee if directed by the Commission, shall not operate the station and shall not permit it to be operated from 8 a. m. to 12 midnight, local time, except for the purposes of transmitting a prearranged test to be observed by a monitoring station of the Commission to be designated in each particular case. The station shall not be permitted to resume operation during these hours until the licensee is authorized by the Commission, following the test, to resume full-time operation. The results of the test and the licensee's record shall be considered in determining the advisability of suspending the operator license or revoking the station license, or both.

§ 12.155 *Answers to notices of violations.*—Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, as amended, any legislative act, Executive order, treaty to which the United States is a party, or the Rules and Regulations of the Federal Communications Commission, shall, within 3 days from such receipt, send a written answer direct to the office of the Commission originating the official notice: *Provided, however,* That if an answer cannot be sent nor an acknowledgment made within such 3-day period by reason of illness or other unavoidable circumstances, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to some violation that may be due to the physical or electrical characteristics of transmitting apparatus, the answer shall state fully what steps, if any, are taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery. If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name of the operator in charge shall be given.

§ 12.156 *Operation in emergencies.*—In the event of widespread emergency conditions affecting domestic communication facilities, the Commission may confer with representatives of the amateur service and others, and if deemed advisable, declare that a state of general communications emergency exists, designating the area or areas concerned (normally not exceeding 1,000 miles from center of the affected area), whereupon it shall be incumbent upon each amateur station in such area or areas to observe the following restrictions for the duration of such emergency:

(*a*) Transmissions, other than those relating to relief work or other emergency service, such as amateur station networks can provide, shall not be made within the 1750–2050-kilocycle or 3500–4000-kilocycle bands. Incidental calling, testing and working, including casual conversation or remarks not pertinent or necessary to constructive handling of the emergency situation shall be prohibited.

(*b*) Frequencies within the bands 2025–2050-kilocycle, 3500–3525-kilocycle and 3975–4000-kilocycle shall be reserved for emergency calling channels, for initial calls from isolated stations or first calls concerning very important emergency relief matters or arrangements. All stations having occasion to use such channels shall change, as quickly as possible, to other frequencies for carrying on their communications.

(*c*) A 5-minute listening period for the first 5 minutes of each hour shall be uniformly observed for initial calls of major importance, both in the designated emergency calling channels and throughout the 1750–2050-kilocycle and 3500–4000-kilocycle bands. Only stations isolated or engaged in handling official traffic of the highest priority may continue with transmissions in these listening periods. No replies to calls or resumption of routine traffic shall be made in the 5-minute listening periods.

(*d*) The Commission may designate certain amateur stations to assist in promulgation of its emergency announcement, to police the 1750–2050-kilocycle and 3500–4000-kilocycle bands and to warn noncomplying stations observed to be operating therein. The operators of these observing stations shall report fully to the Commission the identity of any stations failing to comply, after notice, with any of the pertinent provisions of this section. Such designated stations will act in an advisory capacity when able to provide information on emergency circuits. Their policing authority shall be limited to the transmission of information from responsible official sources, and full reports of noncompliance which may serve as a basis for investigation and action under section 502 of the Communications Act. Such policing authority shall apply only to the 1750–2050-kilocycle and 3500–4000-kilocycle bands. Individual policing transmissions shall refer to this section of the rules by number (§ 12.156) and shall specify briefly and concisely the date of the Commission's declaration and the area and nature of the emergency. Policing observer station shall not enter into discussions with other stations beyond the furnishing of essential facts relative to the emergency.

(*e*) The special conditions imposed under this section will cease to apply only after the Commission shall have declared such emergency to be terminated.

§ 12.157 *Obscenity, indecency, profanity.*—No licensed radio operator or other person shall transmit communications containing obscene, indecent, or profane words, language, or meaning.

§ 12.158 *False signals.*—No licensed radio operator shall transmit false or deceptive signals or communications by radio, or any call letter or signal which has not been assigned by proper authority to the radio station he is operating.

§ 12.159 *Unidentified communications.*—No licensed radio operator shall transmit unidentified radio communications or signals.

§ 12.160 *Interference.*—No licensed radio operator shall willfully or maliciously interfere with or cause interference to any radio communication or signal.

§ 12.161 *Damage to apparatus.*—No licensed radio operator shall willfully damage, or cause or permit to be damaged, any radio apparatus or installation in any licensed radio station.

§ 12.162 *Fraudulent licenses.*—No licensed radio operator or other person shall obtain or attempt to obtain, or assist another to obtain or attempt to obtain. an operator license by fraudulent means.

EXAMINATION POINTS

Examinations for amateur radio operator licenses are conducted at the Commission's office in Washington, D.C., Monday through Friday, except holidays (office hours are from 8:30 a. m. to 5 p. m.), and at each radio district office of the Commission on the days designated by the Engineer in Charge of the office. Specific dates should be obtained from the Engineer in Charge. For a list of such offices see the following pages.

Examinations are also given frequently, by appointment, at the Commission's offices at the following points:

Cleveland, Ohio.
Savannah, Ga.
San Diego, Calif.
Tampa, Fla.
Juneau, Alaska.
Anchorage, Alaska.

Examinations are also given at greater intervals at the places named below, which are visited for that purpose by Commission examiners from the district offices for such locations. For current schedules, exact time. place, and other details, inquiry should be addressed to the office conducting examinations at the chosen point.

QUARTERLY EXAMINATIONS

Birmingham, Ala.
Charleston, W. Va.
Cincinnati, Ohio.
Columbus, Ohio.
Corpus Christi, Tex.
Davenport, Iowa.
Des Moines, Iowa.
Fort Wayne, Ind.
Fresno, Calif.
Grand Rapids, Mich.
Indianapolis, Ind.
Knoxville, Tenn.
Little Rock, Ark.
Memphis, Tenn.
Milwaukee, Wis.
Nashville, Tenn.
Oklahoma City, Okla.
Omaha, Nebr.
Pittsburgh, Pa.
St. Louis, Mo.
Salt Lake City, Utah.
San Antonio, Tex.
Schenectady, N.Y.
Sioux Falls, S. Dak.
Syracuse, N.Y.
Tulsa, Okla.
Williamsport, Pa.
Winston-Salem, N.C.

SEMIANNUAL EXAMINATIONS

Albuquerque, N. Mex.
Amarillo, Tex.
Bakersfield, Calif.
Bangor, Maine.
Billings, Mont.
Bismarck, N. Dak.
Boise, Idaho.
Butte, Mont.
Cumberland, Md.
El Paso, Tex.
Hartford, Conn.
Hilo, T. H.
Jacksonville, Fla.
Klamath Falls, Ore.
Las Vegas, Nev.
Lihue, T. H.
Mobile, Ala.
Phoenix, Ariz.
Portland, Maine.
Reno, Nev.
Roanoke, Va.
Spokane, Wash.
Tucson, Ariz.
Wichita, Kans.
Wilmington, N.C.

ANNUAL EXAMINATIONS

KAUNAKAKAI, T. H. LANAI, T. H. WAILUKU, T. H.

Arrangements have also been made, including cooperation of other Federal agencies, for classes A and B examinations in outlying areas as follows:

Alaska: United States Signal Corps stations.
Guam: District Communications Officer, United States naval station.
Hawaii: At not exceeding one point on any island, by the Engineer in Charge (Honolulu).

Insurance Requirements

STANDARDS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS FOR ELECTRIC WIRING AND APPARATUS AS RECOMMENDED BY THE NATIONAL FIRE PROTECTION ASSOCIATION (1947 NATIONAL ELECTRICAL CODE)

ARTICLE 810—RADIO EQUIPMENT *

* The National Board of Fire Underwriters advises that some sections of Article 810 may be revised in 1949 to cover specific application to television, and that there may possibly be some provisions for other radio devices.—D. J. D.

8101. *Scope.* This article shall apply to radio receiving equipment and to amateur radio transmitting equipment, but shall not apply to equipment and antennas used for coupling carrier current to power line conductors.

It is recommended that the authority enforcing this code be freely consulted as to the specific methods to be followed in any case of doubt relative to installation of antenna and counterpoise conductors and that the National Electrical Safety Code, Part 5, be followed.

8102. *Application of Other Articles.* Wiring from the source of power to and between devices connected to the interior wiring system shall comply with Chapters 1 to 4, inclusive [of the National Electrical Code], except as modified by sections 6403, 6404 and 6405. Wiring for radio-frequency and audio-frequency equipment and loud speakers shall comply with Article 640.*

8111. *Material.* Antenna, counter-poise, and lead-in conductors shall be of hard-drawn copper, bronze, copper-clad steel, or other high-strength, corrosion-resistant material. Soft-drawn or medium-drawn copper may be used for lead-in conductors where the maximum span between points of support is less than 35 feet.

8112. *Supports.* Outdoor antenna and counter-poise and lead-in conductors shall be securely supported. They shall not be attached to poles or similar structures carrying electric light or power wires or trolley wires of more than 250 volts. Insulators supporting the antenna or counter-poise conductors shall have sufficient mechanical strength to safely support the conductors. Lead-in conductors shall be securely attached to the antenna.

8113. *Avoidance of Contacts with Conductors of Other Systems.* Outdoor antenna, counter-poise and lead-in conductors from an antenna to a building shall not cross over electric light or power circuits and shall be kept well away from all such circuits so as to avoid the possibility of accidental contact. Where proximity to electric light and power service conductors of less than 250 volts cannot be avoided, the installation shall be such as to provide a clearance of at least two feet. It is recommended that antenna and counter-poise conductors be so installed as not to cross under electric light or power conductors.

8114. *Splices.* Splices and joints in antenna and counter-poise span shall be made with approved splicing devices or by such other means as will not appreciably weaken the conductors.

Soldering may ordinarily be expected to weaken the conductor. Therefore, when soldering is employed it should be independent of the mechanical support.

8115. *Indoor Antenna.* There are no requirements for indoor antennas except that they shall have the same clearance from the conductors of

* Article 640 of the 1947 National Electrical Code covers Sound Recording and Similar Equipment.

electric light and power circuits and signaling circuits as is required for lead-in conductors.

ANTENNA SYSTEMS—RECEIVING STATION

8121. *Size of Antenna and Counter-poise.* Outdoor antenna and counter-poise conductors for receiving stations shall be of a size not less than given in the following table:

	Minimum Size of Conductors When Maximum Open Span Length Is		
Material	*Less Than 35 Feet*	*35 Feet to 150 Feet*	*Over 150 Feet*
Hard-drawn copper	19	14	12
Copper-clad steel, bronze or other high strength material	20	17	14

For very long span lengths larger conductors will be required, depending on the length of the span and the ice and wind loading.

8122. *Size of Lead-In.* Lead-in conductors from outside antenna, and counter-poise for receiving stations, shall, for various maximum open-span lengths, be of such size as to have a tensile strength at least as great as that of the conductors for antenna as specified in Section 8121. When the lead-in consists of two or more conductors which are twisted together or are enclosed in the same covering or are concentric, the conductor size shall, for various maximum open span lengths, be such that the tensile strength of the combination will be at least as great as that of the conductors for antenna as specified in Section 8121.

8123. *On Buildings.* Lead-in conductors attached to buildings shall be so installed that they cannot swing closer than two feet to the conductors of circuits of 250 volts or less, or ten feet to the conductors of circuits of more than 250 volts, except in the case of circuits not exceeding 150 volts, if all conductors involved are supported so as to insure permanent separation, the clearance may be reduced but shall not be less than four inches. The clearance between lead-in conductors and any conductor forming a part of a lightning rod system shall be not less than six feet.

8124. *Electric Supply Circuits Used in Lieu of Antenna.* If an electric supply circuit is used in lieu of an antenna, the device by which the radio receiving set is connected to the supply circuit shall be specially approved for the purpose.

ANTENNA SYSTEM—TRANSMITTING STATIONS

8131. *Size of Antenna.* Antenna and counter-poise conductors for transmitting station shall be of a size not less than given in the following table:

	Minimum Size of Conductors When Maximum Open Span Length Is	
Material	*Less Than 150 Feet*	*Over 150 Feet*
Hard-drawn copper	14	10
Copper-clad steel, bronze, or other high-strength material	14	12

For very long span length larger conductors will be required, depending on the span length and the ice and wind loading.

8132. *Size of Lead-In Conductors.* Lead-in conductors for transmitting stations shall, for various maximum span lengths, be of a size at least as great as that of conductors for antenna as specified in Section 8131.

8133. *Clearance on Building.* Antenna and counter-poise conductors for transmitting stations, attached to buildings, shall be firmly mounted at least 3 inches clear of the surface of the building on non-absorptive insulating supports, such as treated pins or brackets, equipped with insulators having not less than 3-inch creepage and air-gap distances. Lead-in conductors attached to buildings shall also conform to these requirements, except when they are enclosed in a continuous metallic shield which is permanently and effectively grounded. In this latter case the metallic shield may also be used as a conductor.

8134. *Entrance to Building.* Except where protected with a continuous metallic shield which is permanently and effectively grounded, lead-in conductors for transmitting station shall enter buildings by one of the following methods:

a. Through a rigid, non-combustible, non-absorptive insulating tube or bushing.

b. Through an opening provided for the purpose in which the entrance conductors are firmly secured so as to provide a clearance of at least 2 inches.

c. Through a drilled window pane.

8135. *Protection against Accidental Contact.* Lead-in conductors to radio transmitters shall be so located or installed as to make accidental contact with them difficult.

PROTECTORS

8141. *Lightning Arresters—Receiving Stations.* Each conductor of a lead-in from an outdoor antenna shall be provided with a lightning arrester approved for the purpose, except where the lead-in conductors from antenna to entrance to building are protected by a continuous metallic shield which is permanently and effectively grounded. Lightning arresters shall be located outside the building, or inside the building between the point of entrance of the lead-in and the radio set or transformers, and as near as practicable to the entrance of the conductors to the building. The lightning arrester shall not be located near combustible material nor in a hazardous location.

8142. *Lightning Arresters—Transmitting Stations.* Except where protected by a continuous metallic shield which is permanently and effectively grounded, or the antenna is permanently and effectively grounded, each conductor of a lead-in for outdoor antenna shall be provided with a lightning arrester or a grounding switch or other suitable means which will drain static charges from the antenna system.

GROUNDING CONDUCTORS—GENERAL

8151. *Material.* The grounding conductor shall, unless otherwise specified, be of copper, copper-clad steel, bronze, or other corrosion-resistant material.

8152. *Insulation.* The grounding conductors may be uninsulated.

8153. *Supports.* The grounding conductors shall be securely fastened in place and may be directly attached to the surface wired over without the use of insulating supports.

8154. *Mechanical Protection.* The grounding conductor shall be protected where exposed to mechanical injury.

8155. *Run in Straight Line.* The grounding conductor shall be run in as straight a line as practicable from the equipment to the grounding electrode.

8156. *Ground Electrode.* The grounding conductor shall be connected to a grounding electrode as specified in Sections 2581 and 2582 of Article 250.*

* Sections 2581 and 2582 of the 1947 National Electrical Code are as follows:

2581. *Water Pipe.* A continuous metallic underground water piping shall always be used as the grounding electrode where such piping system is available.

2582. *Other Available Electrodes.* Where a water system as described in section 2581 is not available, the grounding connection may be made to any of the following:

a. The metal frame of the building, if effectively grounded;

b. A continuous metallic underground gas piping system;

c. A local metallic underground piping system, metal well casing, and the like.

GROUNDING CONDUCTORS—RECEIVING STATIONS

8161. *Inside or Outside Building.* The grounding conductor may be run either inside or outside the building.

8162. *Size of Protective Ground.* The protective grounding conductor for receiving stations shall be not smaller than No. 14 copper or No. 17 copper-clad steel or bronze, provided that where wholly inside the building it shall not be smaller than No. 18.

8163. *Common Ground.* A single grounding conductor may be used for both protective and operating purposes.

If a single conductor is so used, the ground terminal of the equipment should be connected to the ground terminal of the protective device.

GROUNDING CONDUCTORS—TRANSMITTING STATIONS

8171. *Size of Protective Ground.* The protective ground conductor for transmitting stations shall be as large as the lead-in, but not smaller than No. 14 copper, bronze, or copper-clad steel.

8172. *Size of Operating Grounding Conductor.* The operating grounding conductor for transmitting stations shall be not less than No. 14 copper or its equivalent.

INTERIOR INSTALLATION—GENERAL

8181. *Clearance from Other Conductors.* Except as provided in Article 640, all conductors inside the building shall be separated at least 4 inches from the conductor of any other light or signal circuit unless separated therefrom by conduit or some firmly fixed non-conductor such as porcelain tubes or flexible tubing.

8182. *Radio Noise Suppressors.* Radio interference eliminators, interference capacitors, or radio noise suppressors connected to power supply leads shall be of a type approved for the purpose. They shall not be exposed to mechanical injury.

TRANSMITTING STATIONS

8191. *General.* Transmitters shall comply with the following:

a. *Enclosing.* The transmitter shall be enclosed in a metal frame or grille, or separated from the operating space by a barrier or other equivalent means, all metallic parts of which are effectually connected to ground.

b. *Grounding of Controls.* All external metallic handles and controls accessible to the operating personnel shall be effectually grounded.

No circuit in excess of 150 volts should have any parts exposed to direct contact. A complete dead-front type of switchboard is preferred.

c. *Interlocks on Doors.* All access doors shall be provided with interlocks which will disconnect all voltages in excess of 350 volts when any access door is opened.

d. *Audio-Amplifiers.* Audio-amplifiers which are located outside the transmitter housing shall be suitably housed and shall be so located as to be readily accessible and adequately ventilated.

Radio Districts

Radio district	Address of the engineer in charge	Territory within district	
		States, etc.	Counties
1	1600 Customhouse, Boston 9, Mass	Connecticut	All counties.
		Maine	Do.
		Massachusetts	Do.
		New Hampshire	Do.
		Rhode Island	Do.
		Vermont	Do.
2	748 Federal Bldg., 641 Washington St., New York 14, N.Y.	New Jersey	Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic, Somerset, Sussex, Union and Warren.
		New York	Albany, Bronx, Columbia, Delaware, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Sullivan, Ulster and Westchester.
3	Room 1005, New United States Customhouse, 2nd and Chestnut Sts., Philadelphia 6, Pa.	Delaware	New Castle.
		New Jersey	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean, and Salem.
		Pennsylvania	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton, Perry, Philadelphia, Schuylkill, and York.
4	508 Old Town Bank Bldg., Gay St. and Fallsway, Baltimore 2, Md.	Delaware	Kent and Sussex.
		District of Columbia	All.
		Maryland	All counties.
		Virginia	Arlington, Clarke, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William, Rappahannock, Shenandoah, and Warren.
		West Virginia	Barbour, Berkeley, Grant, Hampshire, Hardy, Harrison, Jefferson, Lewis, Marion, Mineral, Monongalia, Morgan, Pendleton, Preston, Randolph, Taylor, Tucker, Upshur.
5	Room 402, New Post Office Bldg., Norfolk 10, Va.	North Carolina	All except district 6.
		Virginia	All except district 4.
6	411 Federal Annex, Atlanta 3, Ga.	Alabama	All except district 8.
		Georgia	All counties.
		North Carolina	Ashe, Avey, Buncombe, Burke, Caldwell, Cherokee, Clay,

Radio district	Address of the engineer in charge	Territory within district: States, etc.	Territory within district: Counties
			Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga, and Yancey.
		South Carolina	All counties.
		Tennessee	Do.
	Suboffice, P.O. Box 77, 214 Post Office Bldg. York and Bull Sts., Savannah, Ga.		
7	P.O. Box 150, 312 Federal Bldg., Miami 1, Fla.	Florida	All except district 8.
	Suboffice, 410 P.O. Bldg., Florida Ave., Tampa 2, Fla.		
8	400 Audubon Bldg., New Orleans 16, La.	Alabama	Baldwin and Mobile.
		Arkansas	All counties.
		Florida	Escambia.
		Louisiana	All counties.
		Mississippi	Do.
		Texas	City of Texarkana only.
9	324 U.S. Appraisers Stores Bldg., 7300 Wingate St., Houston 11, Tex.	Texas	Angelina, Aransas, Atascosa, Austin, Bandera, Bastrop, Bee, Bexar, Blanco, Brazoria, Brazos, Brooks, Burleson, Caldwell, Calhoun, Cameron, Chambers, Colorado, Comal, DeWitt, Duval, Dimmit, Edwards, Fayette, Fort Bend, Frio, Galveston, Gillespie, Goliad, Gonzales, Grimes, Guadalupe, Hardin, Hays, Harris, Hidalgo, Jackson, Jasper, Jefferson, Jim Hogg, Jim Wells, Karnes, Kenedy, Kendall, Kerr, Kinney, Kleberg, LaSalle, Lavaca, Lee, Liberty, Live Oak, Matagorda, Madison, Maverick, McMullen, Medina, Montgomery, Nacogdoches, Newton, Nueces, Orange, Polk, Real, Refugio, San Augustine, San Jacinto, San Patricio, Sabine, Starr, Travis, Trinity, Uvalde, Val Verde, Victoria, Walker, Waller, Washington, Webb, Wharton, Willacy, Williamson, Wilson, Zapata, Zavala, and Tyler.
	Suboffice, P.O. Box 1527, 329 Post Office Bldg., 300 Willow St., Beaumont, Tex.		
10	P.O. Box 5238, 500 U.S. Terminal Annex Bldg., Houston and Jackson Sts., Dallas 2, Tex.	New Mexico	All counties.
		Oklahoma	Do.
		Texas	All except district 9 and the city of Texarkana.

Radio Districts (Continued)

Radio district	Address of the engineer in charge	Territory within district	
		States, etc.	Counties
11	539 U.S. Post Office and Courthouse Bldg., Temple and Spring Sts., Los Angeles 12, Calif.	Arizona	All counties.
		California	Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Ventura.
		Nevada	Clark.
	Suboffice, 230 U.S. Customhouse and Courthouse Bldg. Union and "F" Sts. San Diego 1, Calif.	....	
12	323-A Customhouse, San Francisco 26, Calif. .	California	All except District 11.
		Nevada	All except Clark.
13	406 Central Bldg., 530 SW. 10th Ave., Portland 5, Ore.	Idaho	All except district 14.
		Oregon	All counties.
		Washington	Wahkiakum, Cowlitz, Clark, Skamania, and Klickitat.
14	801 Federal Office Bldg., Seattle 4, Wash.	Idaho	Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, and Shoshone.
		Montana	All counties.
		Washington	All except district 13.
15	521 New Customhouse, 19th St. between California and Stout Sts., Denver 2, Colo.	Colorado	All counties.
		Utah	Do.
		Wyoming	Do.
		Nebraska	Banner, Box Butte, Cheyenne, Dawes, Deuel, Garden, Kimball, Morrill, Scotts Bluff, Sheridan, Sioux.
		South Dakota	Butte, Custer, Fall River, Lawrence, Meade, Pennington, Shannon, Washington.
16	208 Uptown Post Office and Federal Courts Bldg., 5th and Washington Sts., St. Paul 2, Minn.	Minnesota	All counties.
		Michigan	Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon, and Schoolcraft.
		South Dakota	All except district 15.
		North Dakota	All counties.
		Wisconsin	All except district 18.
17	838 U.S. Courthouse, 811 Grand Ave., Kansas City 6, Mo.	Iowa	All except district 18.
		Kansas	All counties.
		Missouri	Do.
		Nebraska	All except district 15.

Radio district	Address of the engineer in charge	Territory within district	
		States, etc.	Counties
18	246 U.S. Courthouse, 219 South Clark St., Chicago 4, Ill.	Illinois	All counties.
		Indiana	Do.
		Iowa	Allamekee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington, and Winneshiek.
		Wisconsin	Brown, Columbia, Calumet, Crawford, Dane, Dodge, Door, Fond du Lac, Grant, Green, Iowa, Jefferson, Kewaunee, Kenosha, Lafayette, Manitowoc, Marinette, Milwaukee, Ozaukee, Oconto, Outagamie, Racine, Richland, Rock, Sauk, Sheboygan, Walworth, Washington, Waukesha, and Winnebago.
		Kentucky	All except district 19.
19	1029 New Federal Bldg., Detroit 26, Mich.	Kentucky	Bath, Bell, Boone, Bourbon, Boyd, Bracken, Breathitt, Campbell, Carter, Clark, Clay, Elliott, Estill, Fayette, Fleming, Floyd, Franklin, Gallatin, Garrard, Grant, Greenup, Kenton, Harlan, Harrison, Jackson, Jessamine, Johnson, Knott Knox, Laurel, Lawrence, Lee, Leslie, Letcher, Lewis, Lincoln, Madison, Magoffin, Martin, Mason, McCreary, Menifee, Montgomery, Morgan, Nicholas, Owen, Owsley, Pendleton, Perry, Pike, Powell, Pulaski, Robertson, Rockcastle, Rowan, Scott, Wayne, Whitley, Wolfe, Woodford.
		Ohio	All counties.
		Michigan	All except district 16.
		West Virginia	All except district 4.
19-Con.	Suboffice, 541 Federal Bldg., Superior Avenue and Public Sq., Cleveland 14, Ohio.		
20	328 Post Office Bldg., Ellicott and Swan Streets, Buffalo 3, N.Y.	New York	All except district 2.
		Pennsylvania	All except district 3.
21	609 Stangenwald Bldg., 119 Merchant St., Honolulu 1, T.H.	Territory of Hawaii and outlying Pacific possessions, except Alaska and adjacent islands.	

Radio Districts (Continued)

Radio district	Address of the engineer in charge	Territory within district	
		States, etc.	Counties
22	P.O. Box 2987, 322-323 Federal Bldg., San Juan 13, P.R.	Puerto Rico	
		Virgin Islands	
23	P.O. Box 1421, 7-8 Shattuck Bldg., Third and Seward Sts., Juneau, Alaska.	Alaska	
	Suboffice, 53 U.S.P.O. and Court House, P.O. Box 644, Anchorage, Alaska.	....	

Glossary

A BATTERY. The battery used to heat the filament of a vacuum tube.

ABSORPTION WAVEMETER. An instrument that measures the wavelength of a transmitter by "absorbing" maximum energy when a tuning circuit is made to resonate with the signal being measured, the frequency being read on a calibrated dial. Also called *absorption frequency meter.*

ACCELERATING ANODE. The electrode used in cathode-ray tubes to increase the velocity of the electron beam.

ACORN TUBE. An acorn-shaped glass vacuum tube in which the electrodes are spaced close together, providing low capacitance between them; designed for use in ultrahigh frequency work.

AIR-CORE TRANSFORMER. A transformer in which the coils are wound over a hollow form without any iron in its magnetic circuits. Used primarily as a radio-frequency transformer, intermediate-frequency transformer, or oscillator coil.

ALTERNATING CURRENT. An electric current that periodically reverses its direction of flow, usually 60 times per second.

ALTERNATOR. An electric generator that generates an alternating voltage.

AMATEUR. In radio, a person who operates a short-wave transmitter, receiver, or other radio device as a hobby; usually taken to mean a licensed operator of such a transmitter. Often shortened to *ham* in popular parlance.

AMATEUR STATION. A short-wave radio station owned and operated by a radio amateur and licensed by the Federal Communications Commission in this country and by similar bodies abroad.

AMERICAN MORSE CODE. A dot-dash code used in telephone-line telegraphy in this country, and differing considerably from the International Morse code (*q.v.*) used in radio work. The radio amateur does not use the American Morse code.

AMMETER. An instrument for measuring the current flowing in a circuit. Ammeters used for measuring direct and alternating currents make use of the magnetic effects of a current; those used for high-frequency currents in radio work make use of the heating effects of these currents.

AMPERE. The practical unit of current strength, being the amount of current that flows in a circuit when one volt is impressed across a resistance of one ohm. One ampere also means a rate of current flow of one coulomb per second. *See* coulomb.

AMPERE-HOUR. The quantity of electricity transferred by a current of one ampere flowing for one hour; equal to 3,600 coulombs.

AMPERE-TURNS. The product of the current in amperes flowing through a coil times the number of turns of wire in the coil. The strength of a coil's magnetic field is directly proportional to the number of ampere-turns.

AMPLIFICATION. The increase in strength of a signal caused by increasing its voltage, current, or power. Amplification of alternating currents having frequencies in the audible range from 0 to 20,000 cycles per second is called *audio-frequency amplification;* amplification of alternating currents having frequencies above the audible range (20,000 cycles or more per second) is called *radio-frequency amplification.* Amplification is performed in a vacuum tube by controlling the flow of electrons between the electrodes.

AMPLIFICATION FACTOR. The number of times the strength of a signal is increased; specifically, the ratio of the change in plate voltage in a vacuum tube to the change in voltage of the control electrode or grid.

AMPLIFIER. A vacuum-tube device for increasing the strength of signals without changing their quality or wave pattern. Amplifiers are designated as Class A, AB, B, and C, depending on the value of the plate current flowing in the amplifier circuit.

AMPLITUDE. The total height of an alternating-current sine wave above and below the zero line, i.e., the total amount of variation of an alternating current from its zero value.

AMPLITUDE MODULATION. The method of modulating a carrier wave by causing the transmitted signal to change the amplitude of the carrier-frequency current from its normal height above and below the zero line without changing its frequency. See *frequency modulation.*

ANODE. The electrode toward which a stream of electrons flow, and which is positive with respect to the source of electrons, called the *cathode.* In an ordinary vacuum tube the anode is the plate and the cathode the filament.

ANTENNA. A wire, series of wires, metal rod or array of rods elevated above the earth and insulated from it for the purpose of propagating or receiving radio waves. In the early days of radio the single horizontal wire of an overhead antenna was called an *aerial,* but this term is falling into disuse.

ANTENNA ARRAY. An arrangement of two or more antenna elements to provide directional reception or transmission.

ANTENNA CURRENT. The radio-frequency current flowing in an antenna that is connected to a transmitter or receiver.

ANTENNA RESISTANCE. The total electrical resistance of a transmitter antenna at the carrier frequency; it is greater than the ohmic resistance of the antenna wires due to skin effect at high frequencies.

ANTENNA SWITCH. A switch used to change over the antenna lead from transmitter to receiver where one antenna is used for both purposes. Many types of antenna changeover switches are automatically operated by press-to-talk relays.

APERIODIC CIRCUIT. One that has no tendency to oscillate; an untuned circuit.

AQUADAG. Trade name for a graphite coating used on the inside of certain types of cathode-ray tubes for improved operating characteristics.

ARMSTRONG CIRCUIT. A term frequently given to the regenerative, super-regenerative, superheterodyne, and frequency-modulation circuits after their inventor, Major Edwin H. Armstrong, one of the world's outstanding radio engineers.

ARRL. Abbreviation for the American Radio Relay League, the largest radio amateur organization in the world, with headquarters at West Hartford, Conn. Founded by Hiram Percy Maxim in 1914, it numbers most of the 80,000 American radio amateurs in its membership, operates amateur headquarters station W1AW at Newington, Conn., and publishes the monthly magazine *QST* and the yearly *Radio Amateur's Handbook*.

ATMOSPHERICS. Same as static.

ATTENUATION. The decrease in intensity of sound or radio waves.

AUDIO. Pertaining to frequencies in the range of audible sound waves (20 to 20,000 cycles per second), as distinguished from radio frequencies above 20,000 cycles per second.

AUDIO FREQUENCY. A frequency in the range of from 20 to 20,000 cycles per second.

AUDIO-FREQUENCY AMPLIFIER. A vacuum-tube circuit or circuits used to amplify signals in the audio-frequency range. Also known as *audio amplifier*.

AUDIO-FREQUENCY OSCILLATOR. A vacuum-tube oscillator circuit that generates voltages in the audio-frequency range.

AUDION. An early trade name applied to the DeForest triode detector.

AUDIO TRANSFORMER. An iron-core transformer used to transform audio-frequency voltages.

AUTODYNE RECEIVER. A receiver that has a regenerative circuit in which the same tube is used as a detector and as a generator of local oscillations.

AUTOMATIC VOLUME CONTROL (AVC). An additional circuit in some receivers that limits the output volume to a given value for all locally received stations, in which a specially designed avc diode detector or twin-diode-triode detector-amplifier is used, together with an avc filter, to apply automatic compensation in volume for variations in input signal strength.

AUTOTRANSFORMER. A power transformer in which a single coil of wire forms both the primary and secondary, the coil being tapped at the appropriate number of turns.

AVC. Abbreviation for *automatic volume control.*

B BATTERY. The battery used to energize the plate of a vacuum tube.

BAKELITE. A phenolic insulating compound used in the construction of radio parts.

BALLAST TUBE. A resistor enclosed in an evacuated glass envelope that increases in resistance when the current flowing through it is increased, and decreases in resistance when the current is decreased; used to compensate for variations in line voltage in radio receivers and other electronic equipment.

BAND. A range of frequencies between two given limits; e.g., the 50–54 megacycle band; also, the range of frequencies corresponding to the vicinity of a certain wavelength, as the 144-meter band.

BANDSPREADING. A method of spreading out the tuning indications over a greater scale to make it easier to tune in a crowded band of frequencies.

BANTAM TUBE. A tube with a smaller glass envelope than a standard glass tube, but with a standard base; identified by the letters GT after the tube number. Not to be confused with miniature tubes or with bantam jr. tubes, which have special bases and are much smaller in size than the standard or bantam tubes.

BATHTUB CONDENSER. A paper capacitor enclosed in a metal container resembling a miniature bathtub in that it has broadly rounded corners.

BATTERY. A combination of two or more dry or wet cells connected together to produce an electric current when placed in a circuit. A single dry cell is loosely known as a battery, as in the term flashlight battery.

BCI. Abbreviation for broadcast interference caused by improper operation of an amateur transmitter, poor receiver design, or other factors. Amateurs are expected to take all necessary steps to prevent BCI and may have his hours of operation restricted by the Federal Communications Commission if such interference is not corrected.

BEAM POWER AMPLIFIER. A vacuum tube in which special deflecting electrodes concentrate the flow of electrons from cathode to plate into beams, giving increased power output and improved audio-frequency amplification.

BEAT. A rise and fall in frequency due to the interference between two waves of slightly different frequencies. The two additional frequencies obtained in this manner are known as *beat frequencies.*

BEAT RECEPTION. Receiving radio waves by means of superimposing locally generated oscillations upon the oscillations set up in the antenna by the incoming waves to produce a beat frequency that is more easily amplified in the receiver. Also known as *heterodyne reception.*

BIAS. The d-c voltage impressed on the grid of a vacuum tube to make it negative with respect to the cathode; also called *C bias* and *grid bias.*

BLUE GLOW DISCHARGE. The bluish-white glow seen in mercury-vapor type electronic tubes due to ionization of the mercury vapor. The same phenomenon may also be seen in a defective vacuum tube, caused by ionization of gas particles that should not be present in the tube; however, a soft or pale blue glow on the glass of a vacuum tube is normal and does not mean a defective tube.

BRILLIANCE. The degree of brightness and definition in a television image. controlled by a special circuit in the receiver.

BROADCAST. The transmission of speech or music for public reception. Distinguished from *transmitting* in the amateur sense, which is not intended for public reception and is limited to code and speech.

BROADCAST BAND. The range of frequencies between 550 and 1,600 kilocycles in which all standard broadcast stations in the United States have their carrier-frequency assignments.

BROAD TUNING. The condition existing when two or more stations are heard at the same point on the receiver dial, due to poor selectivity of the receiver.

BRUSH DISCHARGE. The faintly luminous discharge that takes place from the positive pointed terminal of an induction coil or other high-voltage apparatus.

BUTTERFLY CIRCUIT. A rotor-type circuit element used in place of conventional tuning condensers in ultrahigh-frequency oscillator circuits, resembling in shape the wings of a butterfly.

BYPASS CONDENSER. A condenser connected across a circuit element to provide a low-impedance path for radio-frequency or audio-frequency currents.

C BATTERY. A small battery used to supply a negative potential to the grid of a vacuum tube.

CALL LETTERS. Identification letters and numbers assigned by the Federal Communications Commission to amateur and broadcast stations in the United States. By international agreement, similar identification letters and numbers are assigned to international amateur and government radio stations.

CAPACITANCE. The property of a capacitor or condenser to store electrical energy or permit alternating current to flow at a given frequency. Measured in microfarads or micromicrofarads (mfd or mmfd).

CAPACITANCE COUPLING. The electrical linking of two or more circuits by means of a common capacitance.

CAPACITOR. A device used in electric and radio circuits to store electrical energy, block direct current, and allow alternating current to flow; it consists of two conducting surfaces separated by air, paper, mica, or other insulating medium. Also known as *condenser*, though this term is falling into disuse in radio work. Capacitors may be either fixed or variable.

CAPACITY. A term incorrectly used for *capacitance*.

CARBON MICROPHONE. A microphone actuated by the varying electrical resistance of a container or button containing carbon granules which is subject to varying pressure of sound waves striking the diaphragm attached to it. A two-button microphone has a carbon button on either side of the diaphragm to give push-pull control.

CARBON REGULATOR. A variable resistance made up of a number of carbon plates under varying pressure from a screw or other pressure device, an increase of pressure causing a decrease of resistance. Also known as a *carbon rheostat*.

CARDIOID MICROPHONE. A microphone having a heart-shaped response pattern (whence the name), providing uniform response in a 180-degree arc in front and minimum response in the opposite direction.

CARRIER CURRENT. The alternating current generated in a transmitter at the assigned frequency of the station. Also, the high-frequency current superimposed on a power, telegraph, or telephone line for communication purposes, by means of which many separate circuits can be operated on a single pair of wires.

CARRIER FREQUENCY. A radio-frequency wave on which two or more audio-frequencies are superimposed and carried to the receiver, where the two frequencies are then separated or demodulated. Also, the frequency of the unmodulated transmitter wave.

CASCADE AMPLIFIER. Two or more amplifying tubes arranged in a circuit with a coupling device between them so that one amplifier stage feeds into the next, and so on.

CATHODE. 1. An electrode from which electrons flow in a vacuum tube. 2. A negatively charged electrode.

CATHODE RAY. The stream of electrons emitted by the cathode in a vacuum tube.

CATHODE-RAY TUBE. A funnel-shaped glass vacuum tube with a fluorescent screen at the large end and an electron gun in the neck that focuses a stream of electrons on the screen, which in turn is made to sweep over the screen by means of horizontal and vertical deflection plates placed inside the tube where it begins to widen. Cathode-ray tubes are used to from the picture in television receivers and may be either electrostatic or electromagnetic, the latter using electromagnetic deflection coils placed outside the neck instead of deflection plates.

CATWHISKER. A long thin wire used to make contact with the crystal in a crystal detector.

CAVITY RESONATOR. An enclosed space in a metallic conductor which when made to resonate becomes a source of electromagnetic oscillations. Used in ultrahigh-frequency (microwave) work instead of the conventional resonant circuits.

CERAMIC CAPACITOR. A capacitor in which a ceramic material is used as the insulating medium.

CGS. Abbreviation for centimeter-gram-second, the metric unit of measurement for length, mass (or weight), and time.

CGS ELECTROSTATIC SYSTEM. A system of measuring electric and magnetic values in which the dielectric value of a vacuum is considered to be unity and in which electrical energy is measured in mechanical units.

CHANNEL. A band of radio frequencies. In television, one of 13 assigned frequency bands on which video and sound signals are transmitted at very high frequencies.

CHARGER. A device used for converting a-c line current to a pulsating direct current for recharging a storage battery.

CHASSIS. The metal frame on which the components of a radio receiver, amplifier, transmitter, etc. are mounted.

CHOKE COIL. A coil of wire usually wound on an air core, used to impede or prevent the passage of high-frequency currents from one circuit to another without affecting the flow of direct current. Also known as an *impedance coil.*

CHOPPER MODULATION. The modulation of radio-frequency oscillations by a device known as a *chopper* that breaks up the sustained oscillations of a transmitter into audio-frequency impulses.

CIRCUIT. An electrical path over which a current flows. Low-frequency currents require a closed circuit, whereas high-frequency currents will surge in a wire that is open at one end, such as an antenna.

CIRCULAR MIL. A unit of cross-sectional area used in designating conductor sizes, being equal to the area of a circle whose diameter is one mil (0.001 inch). Abbreviated cm.

CLASS A AMPLIFIER. A vacuum-tube amplifier in which the plate current flows at all times, giving straight-line or linear amplification, i.e., directly proportional to the current strength.

CLASS AB AMPLIFIER. A vacuum-tube amplifier in which the plate current flows for more than one-half of each input cycle but not for the entire cycle.

CLASS B AMPLIFIER. A vacuum-tube amplifier in which the plate current is zero when there is no input signal, and flows for approximately one-half of each input cycle.

CLASS C AMPLIFIER. A vacuum-tube amplifier in which the plate current is zero when there is no input signal, and flows for appreciably less than one-half of each input cycle. Used mostly in radio-frequency stages in transmitters.

CLIPPING. The distortion or cutting off of speech syllables by improper transmitter operation or faulty equipment.

CLOSE-COUPLED CIRCUIT. A circuit in which the primary and secondary windings of a radio- or intermediate-frequency transformer are close together.

COAXIAL CABLE. A special cable used in transmitting television signals through a network or telephone messages through a carrier system, which is essentially a metal tube in which a wire is placed so that the axis of each is on the same line. The inner wire is supported by insulating disks and the metal tube serves as the outer conductor. This construction is necessary due to the special nature of high-frequency current flow. As many as six or more of these cables may be enclosed in a common sheath for underground installation between large cities.

CODE. In radio, an alphabet consisting of combinations of long and short signals (dots and dashes) used to transmit messages. See *American Morse code; Continental* or *International code.*

COLD-CATHODE TUBE. A vacuum tube in which the cathode is not heated, as in the ordinary filament tube, the electrons being emitted by the application of a sufficiently high voltage to a pointed anode. See also *heater-type cathode tube.*

COLOR CODE. A code employing a number of bands of different colors for identifying the values of resistors and capacitors.

CONDENSER. A term now generally replaced by the word *capacitor,* which see.

CONTINENTAL MORSE CODE. An equivalent term for the International Morse Code, so-called because the use of the code originated on the European continent but later became international in scope. See *International Morse code.*

CONTINUOUS WAVE. A radio wave whose amplitude is constant except when keying, used as the standard for radio telegraph communication.

CONTINUOUS-WAVE TRANSMISSION. Transmission of telegraph signals by means of a constant-amplitude, continuous wave, as distinguished from modulated-wave transmission. Also known as A1 emission.

COPPER-OXIDE RECTIFIER. A device consisting of a number of copper disks that are coated on one side with cuprous oxide, in which the electron flow from copper to oxide is greater than in the reverse direction, so that an a-c current flowing through it is converted into a pulsating direct current.

COULOMB. A quantity of current equal to one ampere flowing for one second; also, the quantity of electricity transferred during the electrolytic deposition of 0.001118 gram of silver from a solution of silver nitrate. Conversely, an ampere is defined as a current flowing at the rate of one coulomb per second.

COUNTER ELECTROMOTIVE FORCE. The voltage set up in an inductive circuit when an alternating current flows through it, and which is counter or opposed to the applied voltage. Also called counter emf.

COUNTERPOISE. A system of wires raised a few feet from the ground and insulated from it, which is connected to a radio transmitter in place of the usual ground. Usually there is no connection between the counterpoise and the earth itself.

COUPLED CIRCUIT. A circuit in which the various components are mutually linked by resistors, capacitors, or coils.

CPS. Abbreviation for cycles per second.

CRO. Abbreviation for cathode-ray oscilloscope.

CROSSTALK. Interference between a radio network line and the telephone lines carried on the same or adjacent cables.

CRYSTAL. A piece of Rochelle salts, carborundum, or quartz having piezoelectric properties. Crystals are used in generating or controlling the carrier frequency of a transmitter, in filter and detector circuits of receivers and amplifiers, and in microphones and phonograph pickups.

CRYSTAL RECTIFIER. A crystal detector, usually of carborundum, silicon, germanium, or similar piezoelectric material.

CRYSTAL RECEIVER. A radio receiver, widely used in the early days of radio, having a crystal detector instead of vacuum tubes to demodulate the received signals.

CUTOFF. The minimum amount of grid bias required to prevent the flow of plate current in a vacuum tube.

CYCLE. One complete change from maximum positive value to maximum negative value and back to maximum positive in an alternating current. The number of cycles per second is called the *frequency*.

DAMPING. The reducing of energy in an oscillation or vibration; specifically, the introduction of resistances or impedances in an oscillating circuit to reduce or eliminate the oscillations.

DECIBEL. One tenth of a bel, the unit named after Alexander Graham Bell to denote differences in sound levels. A decibel is defined as the amount of change in sound level that is just barely perceptible to the human ear; however, since this naturally varies with individuals, a more exact equivalent is used to express the change in power level necessary to effect this change in sound level. If two different power levels are designated by p_1 and p_2, then, assuming p_2 to be the higher level, the number of decibels required to raise p_1 to p_2 is given by the formula $db = 10 \log p_2/p_1$. The decibel notation provides an accurate and convenient method of comparing power outputs and inputs and calculating the gain of amplifying systems.

DEMODULATION. A more exact term for detection of radio signals transmitted on a modulated carrier wave, signifying the separation of the signal from the modulated wave.

DETECTION. Separation of an incoming signal from its carrier wave.

DETECTOR. The receiver stage in which one or more vacuum tubes act to separate the audio-frequency signal from the radio-frequency carried signal.

DIELECTRIC. An insulating material placed between two electrically charged plates in a capacitor. It may be either air, oil, mica, paper, glass, or other insulator suitable for the purpose.

DIODE. A vacuum tube having only two electrodes, a cathode and an anode, or filament and plate respectively.

DIODE DETECTOR. A diode vacuum tube that serves as a rectifier of incoming high-frequency alternating currents in a detector circuit.

DIODE-PENTODE. A multi-purpose vacuum tube consisting of a diode and a pentode enclosed in the same glass envelope.

DIODE-TRIODE. A multi-purpose vacuum tube consisting of a diode and a triode enclosed in the same envelope.

DIPOLE ANTENNA. An antenna that is one-half the length of the wavelength of the signal it is intended to receive.

DIRECT CURRENT. A current that flows in one direction.

DIRECTIONAL ANTENNA. An antenna designed to receive or transmit radio waves in one direction only rather than in a radial pattern.

DIRECTIONAL FINDER. A form of loop antenna which when oriented to receive the greatest signal strength from a transmitter indicates the direction of the latter and hence serves to locate a ship or airplane on which the receiver is installed.

DISTRESS SIGNAL. The SOS signal in International Morse code, written as . . . — — — . . .

DISTRIBUTED CAPACITANCE. The capacitance of a circuit due to wires, insulation, and other elements, as distinguished from the capacitance inserted in the form of a capacitor. Specifically, the capacitance between the turns of a coil of wire.

DOUBLE DIODE. A vacuum tube consisting of two diodes in the same glass envelope. Also called a *duodiode* or *twin diode*.

DOUBLET. An antenna consisting of two halves of a length of wire with a twisted pair of transmission lines or lead-in wires connected to the two halves in the form of a T.

DOUBLE TRIODE. A multi-purpose vacuum tube consisting of two triodes enclosed in the same glass envelope. Also called a *duotriode* or *twin triode*.

DPDT. Abbreviation for double-pole, double-throw switch.

DPST. Abbreviation for double-pole, single-throw switch.

DUODIODE-PENTODE. A multi-purpose vacuum tube consisting of two diodes and a pentode in the same glass envelope.

DUODIODE-TRIODE. A multi-purpose vacuum tube having two diodes and a triode in the same glass envelope.

DUOTRIODE. A multi-purpose vacuum tube having two triodes in the same glass envelope. Also called a *double triode* or *twin triode*.

DUPLEX COMMUNICATION. A radio-telephone system in which it is possible to communicate simultaneously in either direction between two stations without the use of switches.

DX. Abbreviation or symbol for distance as applied to the communication with distant radio stations.

DYNAMIC SPEAKER. A loud-speaker in which the voice coil moves in and out of a magnetic field and moves a diaphragm to produce sound waves of speech or music. The magnetic field may be produced either by a permanent magnet (PM speaker) or by a field coil (electrodynamic speaker).

DYNAMOTOR. A compact motor-generator set used with portable transmitters or public-address systems.

EDISON STORAGE BATTERY. A storage battery in which the elements are made of nickel and iron and immersed in an alkaline electrolyte.

E LAYER. An ionized layer of the ionosphere.

ELECTRIC CURRENT. The rate of flow of electricity or of electrons in a circuit or circuit element.

ELECTRIC EYE. Popular name for an electron-ray tube used as a tuning indicator in some types of receivers; not as widely used in new sets as formerly. Also, a phototube.

ELECTRICITY. A force or effect fundamental to matter and intimately related to the structure of the atom. Electricity in motion consists of a transference of positive and negative charges which in their ultimate analysis have been traced to the electrons and protons comprising the atom itself. Electricity is far better understood in terms of its effects—electromagnetic, electrochemical, and thermal—than in terms of its ultimate nature. Electricity at rest is the subject matter of electrostatics, while electricity in motion comes under the heading of electromagnetism.

ELECTRODE. A terminal, plate, or other contact between a metallic conductor and a nonmetallic conductor (electrolyte, ionized gas, or vacuum) from which electrons flow or to which they are attracted; examples are the electrodes of zinc and carbon in a dry cell, the plates of an electrolytic capacitor, the lead plates of a storage battery, and the cathode, plate, and grids of a vacuum tube.

ELECTRODYNAMIC SPEAKER. See *dynamic speaker.*

ELECTROLYTE. The name given to a liquid or chemical paste that conducts electricity by means of a transfer of ions or charged particles.

ELECTROLYTIC CAPACITOR. A capacitor made up of two metallic conductors separated by an electrolyte. Also known as *electrolytic condenser.*

ELECTROMAGNET. A piece of soft iron around which is wound a number of turns of fine wire through which a current flows, creating a magnetic field.

ELECTROMAGNETIC WAVES. The waves that propagate an electromagnetic field in space or in a conducting medium. Depending on their frequency, electromagnetic waves may take the form of heat, light, radio waves, x rays, etc.

ELECTROMOTIVE FORCE. The pressure or potential that causes an electric current to flow. Also known as *voltage.* Abbreviated emf.

ELECTRON. The smallest charge of negative electricity and a primary element of the structure of the atom. Their behavior and movement are responsible for the flow of electricity in a conductor, the operation of a vacuum tube. and many other electrical and chemical phenomena.

ELECTRON EMISSION. The throwing off of electrons from the surface of a filament or conductor due to heat, high voltage, etc.

ELECTRON GUN. The electron-emitting cathode accelerating electrodes, and focusing electrodes in the neck of a cathode-ray tube.

ELECTRONICS. The science that deals with the causes, effects, and applications of electron movement and conduction in gases or through a vacuum, including radio, television, facsimile, photoelectricity, electronic computers, industrial control, automatic machinery, etc.

ENVELOPE. The glass or metal·bulb or housing enclosing the elements of a vacuum tube.

ETHER. A hypothetical medium once generally supposed by scientists to account for the propagation of electromagnetic waves. Its existence is now questioned or even denied by most physicists.

FACSIMILE. A method of transmitting pictures or printed matter by radio or telephone line to a receiver which recreates the original image on photographic or electrosensitive paper.

FADING. The variation in strength of signals received from a transmitter caused by changes in the atmosphere.

FARAD. The capacitance of a capacitor in which a potential difference of one volt produces a charge of one coulomb. The farad being too large for practical work, the microfarad (mfd, one-millionth of a farad) and the micromicrofarad (mmfd, one millionth of a microfarad) are used instead. The unit was named in honor of Michael Faraday (1791–1867), the English chemist and physicist who discovered many of the laws and effects of electricity.

FCC. Abbreviation for Federal Communications Commission.

FEDERAL COMMUNICATIONS COMMISSION. A governing body set up by the Communications Act of 1934 to regulate all electrical communications systems in the United States, including amateur and commercial radio. television, facsimile, telegraph and telephone systems. Its regulations and amendments are available from the Superintendent of Documents, Washington 25, D.C.

FEEDBACK. The feeding back of part of the output of an amplifier tube or stage to the input of the same tube or a preceding stage to strengthen the amplification; also known as *regenerative feedback* or *regeneration*. When the signal is fed back slightly out of phase with the input signal, the result is known as *degeneration* or *negative feedback,* which is sometimes desired in order to increase the stability of the circuit.

FILAMENT. The wire in a vacuum tube that is heated to incandescence to emit electrons; also, the separate heater filament in indirectly heated tubes.

FILAMENT CURRENT. The current applied to the filament of a vacuum tube to heat it and cause it to emit electrons; also the current applied to the separate heater in an indirectly heated tube.

FILAMENT RHEOSTAT. A variable resistance used to adjust the voltage supply to the needs of the filaments of vacuum tubes in the circuit.

FILTER. A device consisting of inductance coils or capacitors or both designed to prevent troublesome voltages from acting on the various circuits of a receiver or other radio equipment or to smooth out alternating currents after they have been rectified.

FILTER CAPACITOR. A capacitor used in a power-pack filter system, usually of the electrolytic type.

FILTER CHOKE. An iron-core induction coil used in a power-pack filter system.

FIRST DETECTOR. In a superheterodyne circuit, the stage in which the incoming signal is mixed with the locally generated radio-frequency signal to produce a modulated intermediate-frequency signal. Also known as the *mixer* stage.

FIXED CAPACITOR. A capacitor with a fixed value of capacitance that cannot be changed without replacing the capacitor; opposed to *variable capacitor* or *variable condenser*.

FIXED RESISTOR. A resistor with a fixed value of resistance that cannot be varied; opposed to *variable resistance*.

F LAYER. An ionized layer of the atmosphere responsible for the reflection of very-high-frequency signals. It is assumed to be divided into two layers, the F_1 and F_2 layers, the latter being the higher of the two.

FLEMING VALVE. Early name for a two-electrode vacuum tube or diode used as a detector.

FOOT-CANDLE. The amount of illumination on a surface one foot distant from a standard candle; used as a unit of light measurement as in the foot-candle meter.

FORCED OSCILLATIONS. Oscillations that are made to surge in a circuit whose natural period is different from that of the oscillations set up in it.

FREE OSCILLATIONS. Oscillations that are allowed to continue in a circuit after the impressed voltage has been removed.

FREQUENCY. The number of cycles per second of an alternating current, such as the radio-frequency currents generated by a radio transmitter. The FCC has made the following designations for the entire range of allocated frequencies:

very low frequency—10 to 30 kc
low frequency—30 to 300 kc
medium frequency—300 to 3,000 kc
high frequency—3 to 30 megacycles
very high frequency—30 to 300 megacycles
ultrahigh frequency—300 to 3,000 megacycles
superhigh frequency—3,000 to 30,000 megacycles

FREQUENCY METER. An instrument for measuring the frequency of a transmitter.

FREQUENCY MODULATION. A method of modulating a carrier wave by causing its frequency to vary periodically between two fixed limits while keeping the amplitude of the wave constant. Distinguished from amplitude modulation, where the amplitude varies while the frequency is kept constant. Frequency modulation stations are assigned to the very-high-frequency range (90 to 100 megacycles), where there is less crowding, because an FM station requires a band width of about 100 kilocycles as compared with the 10-kilocycle band width of the average amplitude-modulation station.

FULL-WAVE RECTIFIER. A vacuum-tube rectifier that converts each half of an alternating-current cycle into direct current by having two elements that operate in sequence during the full cycle.

GAIN. The amount of amplification in an amplifier stage or amplifying system, expressed as a ratio of output power to input power, and usually measured in decibels. Loosely used to mean increase of volume.

GAIN CONTROL. A volume control.

GANG TUNING CAPACITOR. Two or more variable tuning capacitors mounted on a common shaft to allow two or more stages to be tuned by a single movement of a control.

GRID. 1. The metal gauze element placed between the filament and plate of a vacuum tube to control the current flowing from the filament to plate. 2. One of the perforated lead-plate elements of a storage battery. 3. A network of high-voltage transmission lines.

GRID BIAS. The voltage applied to the control grid of a vacuum tube to make it negative with respect to the cathode.

GRID CHARACTERISTICS. The various relations that exist between the voltages and currents of the grid of a vacuum tube, generally shown in graph form.

GRID CIRCUIT. The circuit to which the grid of a vacuum tube is connected.

GRID LEAK. A high-resistance unit connected to the grid lead of both transmitting and receiving sets. In a transmitter it keeps the voltage of the grid at a constant value and thus controls the output of the antenna; in a receiver it controls the current flowing between the plate and filament.

GRID LEAK DETECTOR. A grid circuit in which a resistor is used to provide a discharge path for the grid coupling capacitor. The radio-frequency currents flowing through the resistor cause changes in the audio-frequency plate currents.

GRID MODULATION. The method of modulating an oscillator tube by connecting the secondary of a transformer in the grid lead, the primary being connected to a microphone circuit.

GRID POTENTIAL. The negative or positive voltage of the grid in a vacuum tube.

GROUND. A ground connection, i.e., a metal plate, pipe, or wire buried in the ground to which a receiver chassis may be connected to reduce the hazard of electrical shock or to reduce the effect of body capacitance, etc.

HALF-WAVE ANTENNA. An antenna having a length approximately equal to one-half the wavelength of the signal being received or transmitted.

HALF-WAVE RECTIFIER. A vacuum-tube rectifier that changes only one-half of each cycle of an alternating current into direct current, thereby producing a pulsating direct current, so called because of the resulting interval of zero current between successive halves of the original cycle.

HAM. Slang for amateur.

HARD TUBE. A vacuum tube in which the vacuum is high, as opposed to one in which there is an appreciable amount of residual air or gas, the latter type being known as a *soft tube*.

HEADSET. A pair of telephone receivers or headphones joined by a headband and worn over both ears, used for the reception of weak signals or for monitoring, etc.

HEATER-TYPE CATHODE. A type of vacuum tube in which the cathode is indirectly heated by a separate tungsten filament.

HENRY. The inductance in a circuit in which the electromotive force induced is 1 volt when the inducing current varies at the rate of one ampere per second. The henry is too large a unit for practical use, consequently the millihenry, or one-thousandth of a henry, is used instead. Named after the American physicist Joseph Henry (1797–1878).

HETERODYNE RECEIVER. A receiver that operates on the principle of beat frequencies (see *beat reception*) or by means of superimposing locally generated oscillations in the receiver upon the oscillations set up in the antenna by the incoming signal to produce a beat frequency that is more easily amplified.

HETERODYNING. A whistling sound produced in a receiver by the beat formed by interference between two stations having only slightly different carrier frequencies.

HF. Abbreviation for high frequency. See *frequency*.

HIGH-FREQUENCY RESISTANCE. The resistance offered to the flow of high-frequency alternating current in a circuit. When a high-frequency current oscillates in a wire, the current inside the wire lags behind the current flowing on the outside of the wire and the amplitude of the current is largest on the surface, growing smaller as the center of the wire is reached. This phenomenon, known as *skin effect*, is equivalent to a reduction in the effective size of the wire, hence the increase of resistance. Resistance is also produced by eddy currents, corona losses, etc. Also known as *radio-frequency resistance*.

HIGH-MU VACUUM TUBE. A vacuum-tube amplifier having a high amplification factor.

HORSEPOWER. A unit of power equal to 746 watts.

HOT-WIRE AMMETER. An instrument used in measuring high-frequency currents which depends for its operation on the heating effect of an alternating current. Also called a *thermal ammeter*.

ICONOSCOPE. A special type of cathode-ray tube used in a television camera to convert an image into electrical impulses by scanning it with an electron beam.

IMAGE DISSECTOR. A cathode-ray type television camera tube that differs widely from the iconoscope in operation but is used for the same purpose, i.e., that of converting an optical image into electrical impulses to form a video signal. Developed in 1928 by P. T. Farnsworth, the image dissector forms the optical image on a flat cathode instead of on a fluorescent screen. It is not so widely used today as the iconoscope for general television work, although it is better adapted for televising motion-picture film than the iconoscope.

IMPEDANCE. The total opposition to the flow of alternating current in a conductor, including both inductive and capacitive reactance together with the resistance of the conductor. It is measured in ohms and designated by the letter *Z*.

IMPEDANCE MATCHING. Matching of the impedances of two circuits so that when they are connected the maximum transfer of electrical energy can take place.

INDIRECTLY HEATED CATHODE. See *heater-type cathode.*

INDUCTANCE. The opposition to the flow of an alternating current caused by the back emf set up by the rise and fall of the current. It is measured in henries or millihenries and is designated by the letter *L*.

INDUCTION COIL. A coil in which a direct current flowing in the primary winding is interrupted by a vibrating contact so as to induce a high alternating-current voltage in the secondary winding.

INDUCTIVE COUPLING. The connecting together of oscillation circuits by means of mutual inductance provided by an induction coil or transformer.

INPUT. The electrical energy or power that is fed into an amplifier or other electrical device.

INPUT TRANSFORMER. A transformer used to convey energy from an alternating-current source to an amplifier or other electrical device.

INTERFERENCE. The crossing or superposing of two sets of radio waves of the same or slightly different frequencies so that both are received at the same point on the receiver dial and cannot be separated.

INTERMEDIATE FREQUENCY. In a superheterodyne receiver, the frequency that is set up by the combination of the received frequency with that of the locally generated signal, this being easier to amplify than the original signal itself. The intermediate-frequency stage is usually located between the first and second detectors in a superheterodyne receiver. Abbreviated i.f.

INTERNATIONAL MORSE CODE. The code used throughout the world, regardless of language barriers, for radio telegraphy. Known also as the Continental code, especially when used in wired telegraphy in European countries.

INVERTER. A mechanical or electronic device that changes direct current into alternating current for small power applications.

IONIZED LAYER. The Kennelly-Heaviside layer.

IRE. Abbreviation for Institute of Radio Engineers.

JACK. A spring contact receptacle into which a plug is inserted to complete a circuit to the device connected to the plug.

JAMMING. Intentional transmission of interfering signals to render the signals of another station unintelligible.

JOULE. The unit of energy equal to the work required to maintain the flow of a one-ampere current through a resistance of one ohm for a period of one second; equal to one watt-second.

JOULE'S LAW. The relation between the heat produced in a circuit and the resistance of the circuit, the amount of current flowing, and the number of seconds the current flows.

KENNELLY-HEAVISIDE LAYER. A region in the ionosphere about 65 to 70 miles above the surface of the earth where radio waves are reflected back to earth under varying conditions depending on the time of day or night, the weather and temperature, season of the year, sunspot cycle, etc.

KEYING. The type of emission occurring in telegraphic communication while the code elements are being transmitted.

KILOCYCLE. One thousand cycles; a measure of the frequency of an alternating current or radio signal.

KILOWATT. One thousand watts.

KLYSTRON TUBE. A vacuum tube that changes direct current into radio-frequency current by varying the speed of an electron beam. Used in ultrahigh-frequency radio work.

LATTICE-WOUND COIL. A tuning coil wound in a crisscross or lattice pattern to keep its distributed capacitance low; also called *honeycomb*, *spider-web*, *basket wound*, etc.

LEAD STORAGE CELL. The cell of an ordinary storage battery in which the elements or electrodes are made of lead and are immersed in an acid electrolyte.

LECHER WIRES. A pair of parallel wires of calibrated length used to measure wavelength in vhf and uhf work.

LEVEL. The electrical output of a microphone or other device for a given sound intensity; usually expressed in decibels. Also, the volume at input or output of various sound equipment.

LF. Abbreviation for low frequency. See *frequency*.

LIGHTNING SWITCH. The switch that connects the antenna lead-in or transmission-line wire to ground when the station is not in use as a precaution in case of lightning storms.

LINE-CORD RESISTOR. A resistance element enclosed in the asbestos covering of the regulation two-wire line cord and connected in series so as to lower the line voltage to the value required by a given piece of equipment, such as a phonograph oscillator or universal a-c/d-c receiver. The cord may get hot enough to cause burns if held in the hand any length of time.

LITZ WIRE. A conductor formed of a number of fine insulated copper wires either twisted or braided together to reduce skin effect. Also known by its full name, *litzendraht* (lace wire).

LOADING COIL. A coil connected in the antenna or closed oscillation circuit so that longer wavelengths can be received.

LOCAL OSCILLATOR. The oscillator circuit used in a superheterodyne receiver.

LOCTAL BASE OR SOCKET. A special design for small vacuum tubes whereby the tube is firmly locked in a special 8-pin socket.

LONG WAVES. Wavelengths longer than 1,000 meters, corresponding to frequencies below 300 kilocycles. [*Not* those of the standard broadcast band (190 to 550 meters).]

LOOP ANTENNA. An antenna made from many turns of wire wound on a small frame either flat or circular in form, having pronounced directional characteristics.

LOUD-SPEAKER. A device that changes electrical energy into sound energy and reproduces the original sound waves loud enough to be heard by a number of people in a room or outdoors. See also *dynamic speaker*.

LOW FREQUENCY. See *frequency*.

MAGIC EYE. See *electric eye*.

MAGNETIC FIELD. The area permeated by the lines of force of a magnet.

MAGNETIC SPEAKER. See *dynamic speaker*.

MAGNET WIRE. Insulated copper wire used for winding the coils of electromagnets and certain types of radio devices.

MC. Abbreviation for megacycle.

MEDIUM FREQUENCY. See *frequency*.

MEGACYCLE. One million cycles.

MEGOHM. One million ohms.

MERCURY-VAPOR TUBE. An electronic tube in which mercury vapor is used in place of the usual vacuum.

MICA CAPACITOR. A fixed capacitor in which the dielectric material is in the form of mica sheets, the capacitor being usually encased in bakelite.

MICRO-. A prefix meaning *one millionth of*.

MICROMICRO-. A prefix meaning *one millionth of a millionth of.*

MICROWAVES. Waves shorter than about one meter in length, corresponding to ultrahigh frequencies.

MILLI-. A prefix meaning one thousandth of.

MIXER TUBE. The vacuum tube used in the mixer stage of a superheterodyne receiver. See *first detector.*

MODULATION. The varying or changing of the amplitude, frequency, or phase of a carrier wave by means of an impressed signal. See *amplitude modulation; frequency modulation; demodulation.*

MORSE CODE. See *American Morse code; International Morse code.*

MOTORBOATING. A type of feedback occurring in a receiver or amplifier that produces a sound like that of a motorboat.

MU FACTOR. A basis for comparing the amplification factors of different circuits or vacuum tubes.

MULTI-PURPOSE TUBES. Vacuum tubes having two or more sets of electrodes or elements and designed to serve as combination diode-triodes, diode-pentodes, etc. in amplifying, detecting, and in oscillator circuits. Also known as *multi-electrode* or *multi-unit tubes.*

MUTUAL INDUCTION. The inducing of a voltage in a coil or circuit by a change in current in a second coil or cuit that is inductively coupled to the former.

NATIONAL ELECTRIC CODE. A set of regulations devised by the National Board of Fire Underwriters for the electrical installations in buildings on which insurance companies carry risks. The code covers amateur radio receiving and transmitting equipment. (See page 369.)

NC. Abbreviation for *no connection* or *not connected* on tube-base diagrams.

NEGATIVE BIAS. See *bias.*

NEGATIVE FEEDBACK. See *feedback.*

OHM. The unit of electrical resistance, being that amount of resistance that will allow one ampere to flow when a voltage of one volt is applied across the resistance.

OHM'S LAW. The current flowing in a circuit is directly proportional to the electromotive force or voltage and inversely proportional to the resistance of the circuit; expressed as $I = E/R$.

OPEN-CORE TRANSFORMER. A transformer in which the path of the magnetic flux is partly through iron and partly through air, as in induction coils.

ORTHICON. An improved type of iconoscope.

OSCILLATION. A periodic to-and-fro motion or alternation from a maximum to a minimum value, as in radio-frequency currents.

OSCILLATOR. In radio use, a circuit or tube that generates a radio-frequency current or signal. Electric oscillations may also be set up with a spark gap or electric arc.

OSCILLOSCOPE. A cathode-ray instrument for displaying visually the wave pattern of an alternating voltage or a modulated carrier signal, and used for a wide variety of test purposes.

OUTPUT. The electrical energy or power delivered by an electric machine or other device.

OUTPUT TRANSFORMER. The iron-core transformer used to match the audio-frequency output of an amplifier with a loudspeaker.

PAPER CAPACITOR. A fixed capacitor in which the plates consist of two strips of metal foil separated by waxed paper and rolled into a tubular or cylindrical form.

PENTAGRID CONVERTER. A multi-unit tube used as oscillator-mixer-detector in certain types of superheterodyne receivers; the name comes from the fact that the tube has five grids and converts the incoming carrier frequency to intermediate frequency.

PENTAGRID MIXER. A form of pentagrid converter in which the first grid is coupled with the cathode.

PENTODE. A five-element vacuum tube having in addition to the cathode. plate, and control grid, two additional electrodes for control purposes.

PERIOD. The length of time required for a complete cycle of oscillation.

PERMEABILITY TUNING. The tuning of a resonant circuit by means of a moving-coil electromagnet that changes the inductance of the circuit. Still used in electromagnetic push-button tuning.

PHASE. The angular relation between current and voltage in a circuit containing inductance and capacitance; also, the angle between two alternating-current sine waves that are out of step by a fixed amount.

PHOTOELECTRIC CELL. An electrochemical cell that converts light energy into electrical energy.

PHOTOTUBE. A vacuum tube in which the anode is a vertical wire and the cathode a curved vertical plate with a light-sensitive coating. Electron emission is produced by light falling on the cathode.

PICTURE TUBE. The cathode-ray tube used in a television receiver. Also called *kinescope.*

PIEZOELECTRIC EFFECT. The generation of a minute voltage in certain types of crystals when they are subject to deformation by pressure; and conversely, the minute deformation produced in such crystals by the passage of a small electric current.

PLATE. The anode of a vacuum tube.

PLATE CIRCUIT. The circuit in which the plate of a vacuum tube is connected.

PLATE CURRENT. The flow of electrons from cathode to plate in a vacuum tube.

PLATE MODULATION. Modulation of oscillations set up in a vacuum tube by varying the current in the plate circuit.

PLATE VOLTAGE. The voltage existing between the plate and cathode in a vacuum tube.

PLUG-IN COIL. A coil wound on a short octagonal form with a tube-base socket used for changing the tuning range of a transmitter or receiver.

POLES. The ends of a magnet or the electrodes of a battery.

POLYSTYRENE. A thermoplastic synthetic resin used for insulation of radio parts, particularly in ultrahigh-frequency work.

POSITIVE TERMINAL. The terminal or electrode toward which electrons flow from the negative terminal or electrode.

POTENTIAL DIFFERENCE. The electrical pressure between two charged conductors or between two terminals connected to a source of emf.

POTENTIOMETER. A form of variable resistor used for sudividing a voltage. Also called *voltage divider*.

POWER PACK. The unit in a radio receiver or other device that supplies power by converting the line or battery voltage to the required voltages required by the receiver or device.

POWER TRANSFORMER. The iron-core transformer in a radio receiver that changes the values of the a-c power line to the values required by the various parts of the receiver circuit.

POWER TUBE. The tube or tubes used in the last stage of audio-frequency amplification.

PREAMPLIFIER. An audio-frequency amplifier added to the main audio-amplifying circuit to increase the signal from extremely low-level input devices such as the variable-reluctance phonograph pickup and certain types of microphones, etc.

PRIMARY. The input coil or circuit of a transformer, regardless of whether its voltage is higher or lower than the secondary or output voltage.

PUSH-PULL CIRCUIT. An arrangement of two amplifier tubes in an amplifying circuit (or two elements in a single glass envelope) so connected to the input and output transformers that the grid voltage on one tube is at a maximum when the grid voltage on the other tube is at a minimum, with the result that the total plate current remains constant. Distortion is thereby reduced to a minimum while double the output of a single tube is obtained.

Q SIGNALS. See Appendix, page 330.

QUALITY FACTOR. The value of the reactance of a coil or capacitor at resonant frequency divided by the resistance of the circuit. Also called

Q factor or Q, and expressed as $Q = X/R$, where X is the reactance and R is the resistance.

QUARTER-WAVE ANTENNA. An antenna having a length equal to one-fourth the wavelength of the transmitted or received signal.

QUARTZ CRYSTAL. A naturally occurring piezoelectric crystal used to control the frequency of a vacuum-tube oscillator stage in a transmitter.

QUENCHING FREQUENCY. A locally generated frequency used in a super-regenerative receiver to prevent oscillation of the detector stage when strong signals are received.

RADAR. A device or system in which ultrahigh-frequency waves are sent out at closely spaced intervals to be reflected back to the sender from objects that they encounter, picked up on an ultrahigh-frequency receiver and made to form outline or spot patterns on a cathode-ray screen. The system was developed under great secrecy during the war but now has many peacetime applications. (Word coined from first letters of "*ra*dio *d*etecting *a*nd *r*anging.")

RADIATION. In radio, the emission or throwing off of electromagnetic waves by a transmitter and antenna system.

RADIO BEACON. A transmitter used in direction finding.

RADIO COMPASS. A receiver using a loop antenna calibrated to indicate the direction from which a signal comes.

RADIO FREQUENCY. An oscillating current or electromagnetic wave with a frequency above 20,000 cycles per second, or beyond the range of audible sound-wave frequencies, yet lower than heat or light waves.

RADIO-FREQUENCY AMPLIFIER. A vacuum-tube amplifier stage used to increase the strength of radio-frequency signals.

RADIO-FREQUENCY CURRENT. An alternating current having a frequency higher than 15,000 cycles per second.

RADIO-FREQUENCY TRANSFORMER. A transformer having either an air core or a pulverized iron core and used to transform radio-frequency currents.

RADIO-RANGE BEACON. A transmitter that sends out a highly directive cone of radio waves modulated by an A (. —) and N (— .) signal, the path where the two combine to form a steady dash (——) being the indicated course.

RADIO SPECTRUM. The entire range of frequencies comprising radio communication. See *frequency*.

RADIOTELEPHONY. Two-way voice communication by radio.

RADIO WAVE. An electromagnetic wave having frequencies above the audible range, but below the frequencies of heat and light waves, x-rays, etc.

REACTANCE. The retarding effect of a current flowing in a circuit when the latter contains capacitance and/or inductance. *Inductive reactance* is measured in ohms and is equal to $2\pi fL$, where f is the frequency of the current in cycles per second and L is the inductance in henries; capacitive reactance is also measured in ohms and is equal to $1/2\pi fC$, where C is the capacitance in farads. Note, however, that capacitive reactance in series circuits is always considered to be negative, so that the total reactance is equal to inductive reactance *minus* capacitive reactance. In resonance, inductive reactance equals capacitive reactance, i.e., $2\pi fL = 1/2\pi fC$.

REACTOR. A coil of wire (or capacitor) designed to provide inductive reactance (or capacitive reactance) in a circuit.

RECTIFIER. An apparatus or device (vacuum tube, mercury arc, copper oxide, selenium, etc.) that rectifies or converts alternating current to unidirectional or direct current by allowing the impressed current to flow in one direction only.

REFLECTOR. A horizontal wire added to an FM or TV antenna to increase the effectiveness of the dipole, which faces the source of waves (for reception).

REGENERATIVE DETECTOR. A vacuum-tube detector circuit in which the plate current is fed back to the grid circuit to increase the amplification factor and sensitivity of the circuit.

REGENERATIVE RECEIVER. A receiver employing a regenerative circuit.

REMOTE-CUTOFF TUBE. A tube that requires a considerably large grid bias for completely cutting off the plate current.

RESISTANCE. The opposition to the flow of current offered by a wire or other conductor. It is measured in ohms and designated by the letter R.

RESISTANCE BRIDGE. An apparatus for measuring the resistance of a circuit by the principle of the Wheatstone bridge, in which three known and one unknown resistances are connected and calculations made from Ohm's law.

RESISTANCE COUPLING. The connecting together of circuit elements by means of resistors. Also called *resistive coupling*.

RESISTIVITY. The resistance in ohms of a given length of wire of uniform cross section; the reciprocal of conductivity.

RESISTOR. A fixed or variable reistance unit or group of such units. Resistors are rated in ohms (or megohms) and in watts, the latter rating indicating the amount of power that the resistor dissipates in the form of heat. Fixed resistors are color-coded as explained on page 131.

RESONANCE. The condition that exists in a circuit when its inductance is equal to its capacitance ($2\pi fL = 1/2\pi fC$) so that the equivalent or combined reactance is zero. The resonant frequency f is then given by the formula $f = 1/2\pi\sqrt{LC}$. In parallel resonant circuits, which is the type met most frequently in radio work, the current applied to the circuit is minimum at resonance, the voltage across the circuit being at maximum; in a series resonant circuit, the current in the circuit is at a maximum at resonance, being limited only by the circuit resistance. Tuning in a station on a radio receiver is therefore a process of adjusting a variable capacitor or "tuning condenser" until the inductive reactance of a fixed inductance coil at a particular frequency is cancelled out by the capacitive reactance of the variable capacitor at a particular setting.

R.F. Abbreviation for radio frequency.

RHEOSTAT. A variable resistor.

RMA. Abbreviation for Radio Manufacturers' Association.

ROTOR PLATES. The movable plates of a variable capacitor or tuning condenser.

SATURATION CURRENT. The maximum current that can be obtained as voltage is increased in a vacuum tube.

SCANNING. The process of passing a beam of electrons back and forth over an image on the fluorescent screen of an iconoscope in a methodical pattern, the scanning process being duplicated in the kinescope or picture tube of a television receiver so that the original image is built up from the scanned elements.

SCREEN-GRID TUBE. A vacuum tube in which there is a wire mesh or screen surrounding the plate which serves as a second grid (in addition to the control grid). The screen grid acts to prevent variations in plate voltage from affecting the control grid and filament circuits and causing feedback. The fact that the plate current in a screen-grid tube is largely independent of the plate voltage makes this tube (called a *tetrode*) a much better amplifier than a triode.

SECONDARY. The output coil or winding of a transformer in which a voltage is induced by the primary. The voltage of the secondary winding may be higher or lower than that of the primary, depending on the relative number of turns in each.

SELENIUM RECTIFIER. A type of dry-disk rectifier used in small portable and battery-operated receivers to provide instant starting without the heating-up period required by the filament of vacuum-tube rectifiers, and also to conserve space. The operating principle is similar to that of the copper-oxide rectifier (*q.v.*). Larger types of selenium rectifiers are also used in various power applications.

SHF. Abbreviation for superhigh-frequency. See *frequency*.

SHIELD. A metal barrier or enclosure placed around one or more components of a circuit to prevent interaction between circuits.

SHIELDED PAIR. A two-wire transmission line enclosed in a metallic sheath, used on transmitter antenna systems.

SHORT WAVES. A somewhat inexact term still used to refer to radio waves shorter than those of the standard broadcast band (about 190 to 550 meters); not, however, to be taken as meaning all radio waves that are not *long waves,* which by definition are those of longer wavelength than the broadcast band, and hence of lower frequency. Short waves correspond to frequencies higher than 1,600 kilocycles, and may have frequencies as high as 30,000,000 kilocycles (30,000 megacycles). But even such superhigh-frequency waves of less than a centimeter wavelength are "long" waves when compared with heat waves (0.01 millimeter, or ten million megacycles), light waves (about 0.0004 millimeter, or 1 billion megacycles) and x rays (0.0000001 millimeter, or 1 trillion megacycles). The cosmic rays, of which relatively little is yet known, have almost infinitely short wavelengths (0.00000000001 millimeter) and frequencies as high as 3 quintillion megacycles per second.

SIDEBAND. A band of frequencies on both sides of a carrier frequency.

SIGNAL. The modulated carrier wave of a transmitter serving to transmit code, speech, music, or light image.

SKIN EFFECT. See *high-frequency resistance.*

SKY WAVE. The radio wave that is reflected back to earth by the ionosphere.

SOS. The distress signal in radiotelegraphy.

SPACE-CHARGE EFFECT. The electric field created by the excess of electrons in the space between the filament and plate which equals and neutralizes the charge due to the positive potential of the plate, so that there is no force acting on the electrons near the filament.

SPAGHETTI. Linen, cotton fabric, or plastic tubing in which an impregnating insulating oil has been baked, and which is used to cover sections of bare copper wire in wiring radio equipment.

SPARK. A sudden breaking down of the air between the electrodes of an induction coil or other high-potential apparatus, causing a momentary discharge of electricity through the air.

SPARK COIL. An induction coil used to produce a spark discharge.

SPDT. Abbreviation for single-pole, double-throw switch.

SPECTRUM. See *radio spectrum* and *frequency.*

SPST. Abbreviation for single-pole, single-throw switch.

STATIC. Either atmospheric or man-made electrical disturbances that result in noise in a radio receiver.

STORAGE BATTERY. A group of storage cells. See *lead storage cell.*

STRAIGHT-LINE FREQUENCY. The term applied to capacitors whose variable plates are cut in such a shape that if the frequency is plotted on graph paper against the dial settings the result will be a straight line. There are also dials for rotating the movable plates of the ordinary type of capacitor in such a way that the distance they move per scale unit varies throughout the length of the scale, giving the same effect as a straight-line-frequency capacitor.

STRAYS. A name applied to atmospheric static.

SUP. Abbreviation for suppressor grid.

SUPERHETERODYNE RECEIVER. A receiver operating on the superheterodyne principle, in which an intermediate frequency is created by combining the received signal with a locally generated frequency, the intermediate frequency being then amplified and detected.

SUPERHIGH FREQUENCY. See *frequency*.

SUPERREGENERATIVE RECEIVER. A tuned-radio-frequency receiver using the principle of duperregenerative detection, in which a vacuum-tube detector circuit is made to oscillate continuously at the frequency being received and the oscillations quenched by a separate circuit to prevent regeneration from exceeding a maximum value depending on the receiver design.

SUPPRESSOR GRID. A grid placed between the screen grid and the plate of a vacuum tube in order to prevent a flow of electrons between them.

SYNC. Short for the synchronization control on an oscilloscope.

TANK CIRCUIT. A parallel resonant circuit.

TELEVISION. A system of transmitting visual images, usually synchronized with sound, by converting them into electrical impulses that are then made to modulate a carrier wave and broadcast to television receivers, where the electrical impulses are converted back to visual images.

TELEVISION CHANNEL. A band of frequencies 6,000 kilocycles wide to which a single television broadcast station in a designated area is assigned.

THERMIONIC TUBE. A vacuum tube in which the filament serves as the cathode. Distinguished from *heater-type cathode tube* and *cold-cathode tube*.

TICKLER. A coil forming part of a tuned circuit which permits the feeding back of part of the oscillations from plate to grid circuit of a detector tube. The basis of every regenerative receiver.

TINNED WIRE. Copper wire coated with a layer of tin or solder.

TRANSCEIVER. A combination transmitter-receiver designed for special portable applications.

TRANSDUCER. Any device that transfers energy from one system to another.

TRANSFORMER. An electromagnetic device consisting of primary and secondary coils on an air core or iron core which changes the voltage or current values of an alternating current by means of electromagnetic induction, without, however, altering the frequency.

TRANSMISSION LINE. A set of conductors used to carry the signal from a transmitter to the antenna, which may be a considerable distance away.

TRANSMITTER. In radio, the equipment used to generate, amplify, and modulate a radio-frequency signal, which is then radiated into space from an antenna.

TRIODE. A three-element vacuum tube, consisting of a cathode, a grid, and an anode, enclosed in a glass or metal envelope.

TRIODE-PENTODE. A vacuum tube having a triode and a pentode in the same envelope.

TUNING. See *resonance*.

TUNING COIL. A variable inductance coil used in tuning circuit.

TWIN DIODE. Two diode vacuum tubes in the same envelope.

TWIN TRIODE. Two triode vacuum tubes in the same envelope.

UHF. Abbreviation for ultrahigh-frequency. See *frequency*.

UNIDIRECTIONAL CURRENT. An electric current that flows in the same direction but may not have constant strength, as has a direct current.

VACUUM TUBE. A glass or metal envelope with two or more electrodes enclosed in a vacuum or filled with an inert gas, used as a detector, amplifier, oscillator, and rectifier in radio and in numerous industrial electronic applications.

VARIABLE CAPACITOR OR CONDENSER. A capacitor composed of fixed and movable plates separated by a thin layer of air, whose capacitance can be changed by turning a common shaft to vary the amount of meshing between the plates.

VARIOCOUPLER. A tuning device for varying inductance, consisting of a fixed and rotatable coil whose windings are not interconnected.

VARIOMETER. A tuning device for varying inductance, consisting of a fixed and rotatable coil connected in series.

VERNIER CAPACITOR. A small capacitor connected in parallel with a larger capacitor to provide fine tuning adjustment.

VERY HIGH FREQUENCY. See *frequency*.

VHF. Abbreviation for very high frequency.

VIBRATOR. An electromagnetic device containing a vibrating armature that changes direct current from a storage battery to a small alternating current by rapidly reversing the current flow. The low-voltage a-c current is then stepped up by a transformer and rectified back to a high-voltage direct current.

VIDEO. The visual part of a television broadcast.

VOICE COIL. The moving coil of a dynamic loudspeaker, regardless of whether the speaker is used for music or speech.

VOLT. The unit of electromotive force, defined as that force which will cause a current of one ampere to flow through a resistance of one ohm.

VOLTAGE DIVIDER. See *potentiometer*.

VOLTMETER. An instrument for measuring voltage.

VOLT-OHMMETER. A combination instrument for measuring voltage, current, and resistance.

VOLUME CONTROL. A variable resistor or potentiometer used to increase or decrease the output of an amplifier or receiver.

VTVM. Abbreviation for vacuum-tube voltmeter.

WALKIE-TALKIE. A small portable transceiver widely used during the war and now licensed for civilian use.

WATT. The unit of electrical power, being 1/746th of a horse-power. For direct currents, watts = volts × amperes; for alternating currents, watts = volts × amperes × power factor, which is 1 for circuits containing only pure resistance.

WAVELENGTH. The distance between the crests of a wave, or the distance traveled by the wave in one complete cycle.

WAVEMETER. An instrument for measuring the length of a radio wave or electric oscillation, from which its frequency can be computed from the formula $F = V/\lambda$, where $V = 300{,}000{,}000$ meters per second and λ (the Greek letter lambda) is the wavelength in meters.

WAVE TRAP. A suppressor circuit connected to the antenna of a radio receiver to by-pass unwanted signals from a local station that may be interfering with distant reception.

WHEATSTONE BRIDGE. See *resistance bridge.*

WIRED RADIO. Communication by means of superimposing one or more high-frequency waves on a telephone line or power line instead of propagating them through space. Also called *carrier-frequency telephony* or *guided-wave telephony.*

RADIO DON'TS

ANTENNAS

DON'T—use any old piece of wire for your antenna. For long spans choose copper wire with a steel core or one of the heavier stranded cables.

—STINT on insulators, particularly when transmitting. Poor quality insulators will prevent any success in making distant contacts.

—FAIL to install a lightning arrester especially if your location is in the country or in an open space in the city. And once installed, inspect it before thunder storms are due each year. A good arrester will also help to reduce noise by draining inductive charges from the antenna.

—TRY to get a good ground connection via a gas pipe line. Such piping is usually insulated from the earth, and while it might function for a receiving set it would constitute a hazard if selected for a transmitter ground.

—LEAVE joints unsoldered, particularly where lead-ins join the antenna proper. Joints that are merely twisted together are responsible for much of the noise that creeps into radio receivers.

—BRING the lead-in through the house walls without using an insulator.

—LET antenna or lead-in come in contact at any time with trees, structures, wires, or other antennas.

—ERECT an antenna within twenty feet of a power line and *never* string the wire so that it passes over or under power or telephone wires.

—PUT UP a transmitting antenna in such a way that it cannot be lowered easily for repairs, inspection, or alteration.

TRANSMITTERS

DON'T—attempt to transmit until you have received your license.

—OPERATE until you have become acquainted with every important rule and regulation of the Federal laws governing Amateur Radio.

—USE more power than permitted even for a brief instant. That might be the one time when your signal is being checked by an inspector.

—OVERLOOK every safety precaution in the arrangement and operation of your station. Only a *live* amateur is a credit to his craft.

—ASSUME an overbearing attitude toward complaints of BCI. You have some rights; they have many rights and are in the majority. A friendly approach will do more for you and amateur radio than all the technical arguments you can advance.

—TRANSMIT until you have first listened in.

—MONOPOLIZE the air with long calls. Give a short call and wait for a response, then call again.

—TRY to show your cleverness and speed with key or bug. The man who moves traffic is the operator with a smooth, clean fist who leaves his show of speed to the speed contests.

—FORGET to keep your log up to date. The more complete the data the higher your standing as an amateur. The FCC requires that each amateur keep his log for one year. To do otherwise is to risk a citation.

—OVERLOOK the possibility of an emergency in your vicinity and be prepared for it with at least the "makings" of a low-powered transmitter.

—FAIL to monitor your signal frequently, particularly if you know you are working near one end of the allotted band.

RECEIVERS

DON'T—expect to get the same results from an old receiver even if it was the best of its kind when new. With more amateurs operating, the receiver must be more selective if traffic is to be moved freely.

—OVERLOOK the new tubes, many of which can be incorporated in an old receiver with only slight alterations.

—CONDEMN a commercial receiver over the air merely because you may have had bad luck with it. Talk about something else.

—OVERDO the transmitting just because you have a station available. Do a fair amount of listening and leave the air to those who have more important business to transact.

—LAY out a new circuit on panel and permanent baseboard at first. Set up the parts on a breadboard and check its operation, make any alterations that are advisable and THEN transfer the components to the final chassis and panel.

—HESITATE to rearrange parts if an inch of grid wiring can be eliminated thereby, particularly in the r-f and i-f circuits.

—CONTINUE to use a power transformer that becomes too hot to touch after continuous operation. Replace it with one of sufficient output.

—USE an underrated rectifier tube if you expect stable operation of the tubes in your receiver.

—WASTE time in replacing an electrolytic condenser in the filter unit if it shows signs of overloading. If the metal case gets hot or if a white deposit appears around the "breather" ring, a breakdown with possible damage to tube and transformer is in the offing.

—ENVY the man who owns a super-super receiver of 14 tubes if you can't afford one. Many a highly rated amateur is doing yeoman work with a pair of headphones on the rear end of a five-tube, homemade receiver.

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See the Glossary, pp. 381–409, for additional terms and definitions