ited, and a simpler array of good performance is desired. The simple "H" with reflectors may also be fed with 300-ohm line without the necessity for special matching devices.

Desiring still further gain, ambitious 144-Mc. enthusiasts have doubled and even tripled the 16-element array with worth-while improvements in gain. The same general arrangement, but using four rows of 4 driven elements, with 16 reflectors, has been particularly effective in improving the gain and sharpening the pattern.

Long-Wire Antennas

Where space permits their use, the possibilities of long-wire antenna systems, particularly the rhomboid, should not be overlooked. Design problems are similar to those for lower frequencies, and data contained in Chapter Ten may be applied to systems for the v.h.f. bands. A vertical rhomboid for 144 Mc. or higher is of practical size, and such antennas have been used with outstanding results. At still higher frequencies the stacking of such arrays a half-wave apart presents interesting possibilities.

Mobile and Portable Antennas

A common type of antenna employed for mobile operation on 50 and 144 Mc. is the quarter-wave radiator which is fed with a coaxial line. The antenna, which may be a flexible telescoping "fish pole," is mounted in any of several places on the car. The inner conductor of the coaxial line is connected to the antenna, and the outer conductor is grounded to the frame of the car. Quite a good match may be obtained by this method with the 50-ohm coaxial line now available; however, it is well to provide some means of tuning the system, so that all variables can be taken care of. The simplest tuning arrangement consists of a variable condenser connected between the low side of the transmitter coupling coil and ground, as shown in Fig. 14-11. This condenser should have a maximum capacitance of 75 to 100 $\mu\mu$fd. for 50 Mc., and should be adjusted for maximum loading with the least coupling to the transmitter. Some method of varying the coupling to the transmitter should be provided.

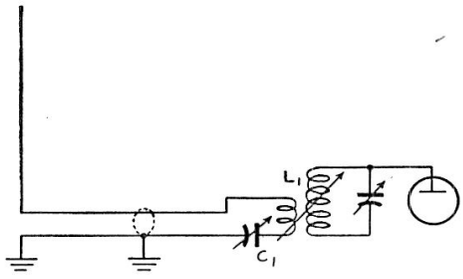


Fig. 14-11 — Method of feeding quarter-wave mobile antennas with coaxial line. C_1 should have a maximum capacitance of 75 to 100 $\mu\mu$fd. for 28- and 50-Mc. work. L_1 is an adjustable link.

The short antenna required for 144 Mc. (approximately 19 inches) permits mounting the antenna on the top of the car. Such an arrangement provides good coverage in all directions, the car body acting as a ground plane. When the antenna is mounted elsewhere on the car, it is apt to show quite marked directional characteristics. Because of this it is desirable to make provisions for the use of the same antenna for both transmitting and receiving.

A Collapsible Array for 50 Mc.

The best antenna possible for operation under mobile conditions is not particularly effective, as compared with antenna systems normally used in fixed-station work. To make the most of the fine opportunities for DX work afforded by countless high-altitude locations which are accessible by car, it is helpful to have some sort of collapsible antenna array which can be assembled "on the spot." Even a simple array like the one shown in Figs. 14-12 and 14-13 will effect a great improvement in the operating range of the low-powered gear normally used for mobile operation. This one is designed for 50-Mc. use, but similar arrangements can be made for other frequencies.

The array shown is a 2-element system, comprised of a radiator which is fed with coaxial line by means of a "T"-match, and a reflector which is spaced 0.15 wavelength in back of the



Fig. 14-12 — A 2-element collapsible array for 50-Mc. portable use.

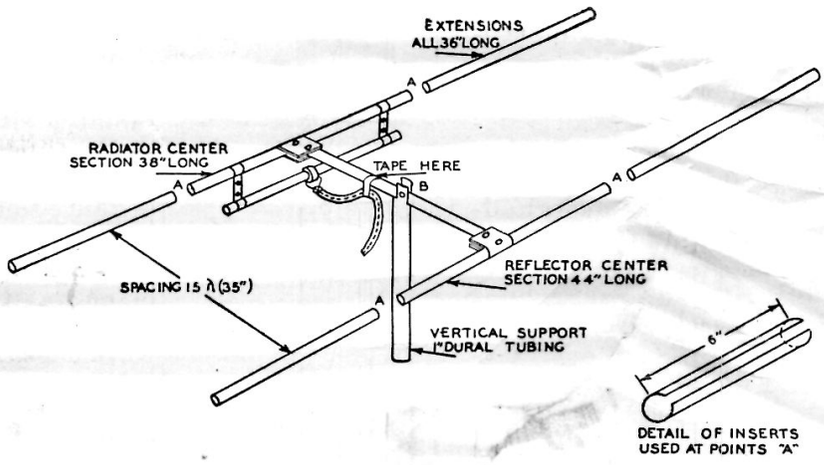


Fig. 14-13 — Detail drawing of the collapsible 50-Mc. array shown in Fig. 14-12. All parts except the vertical support, which is 1 inch in diameter, are made of ¾-inch duralumin tubing. For carrying purposes, it is taken apart at points *A* and *B*, inserts of slotted dural tubing being used at points *A* to hold the sections together. All extensions are the same length, the difference in element length being provided by the length of the center sections.

driven element. It is made entirely of ¾-inch dural tubing, except for the vertical support, which is 1-inch tubing of the same material. A suggested method of mounting is shown in Fig. 14-12. A short length of 1 × 2-inch or larger wood is bolted to the car bumper. A piece of ¾-inch dural tubing is bolted to this upright, and the 1-inch vertical section of the array slips over the top of the ¾-inch section. The array is turned by means of ropes attached to the reflector element. Height of the array may be increased over that shown by using a longer wooden support, in which case it is desirable to use a 2 × 2 for greater strength. An anchoring pin made from a spike inserted in the bottom end of the wooden support is helpful to prevent tilting of the array. With such a device embedded in the ground, the whole assembly will remain rigid, which is helpful in the high winds usually encountered in mountain-top locations. Portability is provided by making the elements in three sections, with the end sections all the same length. The center section of the radiator is 6 inches shorter than that of the reflector.

The fed section of the "T" matching device is composed of two pieces of ¾-inch dural tubing about 14 inches long. The two sections are held together mechanically, but insulated electrically, by a piece of polystyrene rod which is turned down just enough to make a tight fit in the tubing. The inner and outer conductors of the coaxial line are fastened to the two inside ends of the matching section. Clips made of spring bronze are used for connection between the radiator and the "T." The position of these should be adjusted for maximum loading and minimum standing-wave ratio on the line.

This antenna system may be used as a dipole on 29 Mc. by plugging the reflector sections into the driven element, thus bringing its over-all length to approximately that of a half-wave for the high end of the 10-meter band.

Miscellaneous Antenna Systems

Coaxial Antennas

With the "J" antenna radiation from the matching section and the transmission line tends to combine with the radiation from the antenna in such a way as to raise the angle of radiation. At v.h.f. the lowest possible radiation angle is essential, and the coaxial antenna shown in Fig. 14-14 was developed to eliminate feeder radiation. The center conductor of a 70-ohm concentric transmission line is extended one-quarter wave beyond the end of the line, to act as the upper half of a half-wave antenna. The lower half is provided by the quarter-wave sleeve, the upper end of which is connected to the outer conductor of the concentric line. The sleeve acts as a shield about the transmission line and very little current is induced on the outside of the line by the antenna field. The line is nonresonant, since its characteristic impedance is the same as the center impedance of the half-wave antenna. The sleeve may be made of copper or brass tubing of suitable diameter to clear the transmission line. The coaxial antenna is somewhat difficult to construct, but is superior to simpler systems in its performance at low radiation angles.

Cylindrical Antennas

Radiators such as are used for television and broad-band FM are of interest in amateur v.h.f. operation because they work at high efficiency without adjustment throughout the width of an amateur band.

At the very-high frequencies an ordinary dipole or equivalent antenna made of small wire is purely resistive only over a very small frequency range. Its *Q*, and therefore its selectivity, is sufficient to limit its optimum performance to a narrow frequency range, and readjustment of the length or tuning is required for each narrow slice of the spectrum. With tuned transmission lines, the effective length of the antenna can be shifted by retuning the whole system. However, in the case of antennas fed by matched-impedance lines, any appreciable frequency change requires an

actual mechanical adjustment of the system. Otherwise, the resulting mismatch with the line will be sufficient to cause significant reduction in power input to the antenna.

A properly-designed-and-constructed wide-band antenna, on the other hand, will exhibit very nearly constant input impedance over several megacycles.

The simplest method of obtaining a broad-band characteristic is the use of what is termed a "cylindrical" antenna. This is no more than a conventional doublet in which large-diameter tubing is used for the elements. The use of a relatively-large diameter-to-length ratio lowers the Q of the antenna, thus broadening the resonance characteristic.

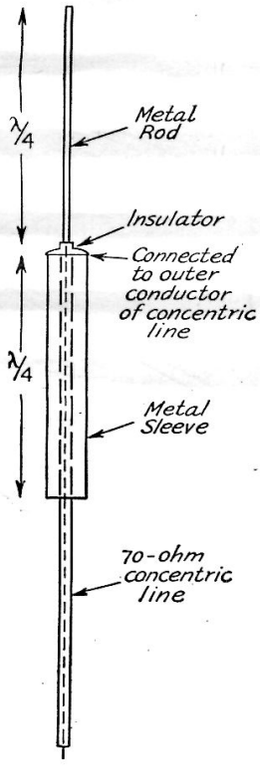


Fig. 14-14 — Coaxial antenna. The insulated inner conductor of the 70-ohm concentric line is connected to the quarter-wave metal rod which forms the upper half of the antenna.

As the diameter-to-length ratio is increased, end effects also increase, with the result that the antenna must be made shorter than a thin-wire antenna resonating at the same frequency. The reduction factor may be as much as 20 per cent with the tubing sizes commonly used for amateur antennas at v.h.f.

Cone Antennas

From the cylindrical antenna various specialized forms of broadly-resonant radiators have been evolved, including the ellipsoid, spheroid, cone, diamond and double diamond. Of these, the conical antenna is perhaps the most interesting. With large angles of revolution the characteristic impedance can be reduced to a very low value suitable for extremely wide-band operation. The cone may be made up either of sheet metal or of multiple wire spines, as in Fig. 14-15.

Plane Sheet Reflectors

The small physical size of v.h.f. antennas makes practical many methods not feasible on lower frequencies. For example, a plane flat-sheet reflector may be used with a half-wave dipole, obtaining gains of 5 to 7 db. Much higher gains are attainable with a number of stacked dipoles, spaced one-quarter or three-quarter wavelength apart, and a larger reflecting sheet; such an arrangement is called a "billboard" array.

Plane reflectors need not be constructed of solid sheets. Wire mesh, or a grid of closely-spaced parallel-wire spines, is more easily erected and offers lower wind resistance.

Parabolic Reflectors

A plane sheet may be formed into the shape of a parabolic curve and used with a driven radiator situated at its focus, to provide a highly-directive antenna system. If the parabolic reflector is sufficiently large so that the distance to the focal point is a number of wavelengths, optical conditions are approached and the wave across the mouth of the reflector is a plane wave. However, if the reflector is of the same order of dimensions as the operating wavelength, or less, the driven radiator is appreciably coupled to the reflecting sheet and minor lobes occur in the pattern. With an aperture of the order of 10 or 20 wavelengths, a beam-width of 5 degrees may be achieved.

A reflecting paraboloid must be carefully designed and constructed to obtain ideal performance. The antenna must be located at the focal point. The most desirable focal length of the parabola is that which places the radiator along the plane of the mouth; this length is equal to one-half the mouth radius. At other focal distances interference fields may deform the pattern or cancel a sizable portion of the radiation.

Corner Reflectors

The "corner" reflector consists of two flat conducting sheets which intersect at a designated angle. The corner-reflector antenna is particularly useful at v.h.f. where structures one or two wavelengths in maximum dimensions are more practical to build than larger systems.

The plane surfaces are set at an angle of 90 degrees, with the antenna set on a line bisecting this angle. For maximum performance, the distance of the antenna from the vertex should be 0.5 wavelength, but compromise designs can be built with closer spacings. The plane surfaces need not be solid sheets; spines spaced about 0.1 wavelength apart will serve as well. The spines do not have to be connected together electrically.

If the driven radiator is situated on a line bisecting the corner angle, as shown in Fig. 14-16, maximum radiation is in the direction of this line. There is no focus point for the driven radiator, as with a parabolic reflector, and the radiator can be placed at a variety of positions along the bisecting line.

Corner angles larger than 90 degrees can be

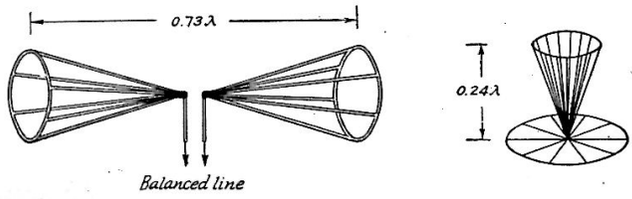


Fig. 14-15 — Conical broad-band antennas have relatively constant impedance over a wide frequency range. The three-quarter wavelength dipole at left and the quarter-wave vertical with ground plane at right have the same input impedance — approximately 65 ohms. Sheet-metal or spine-type construction may be used.

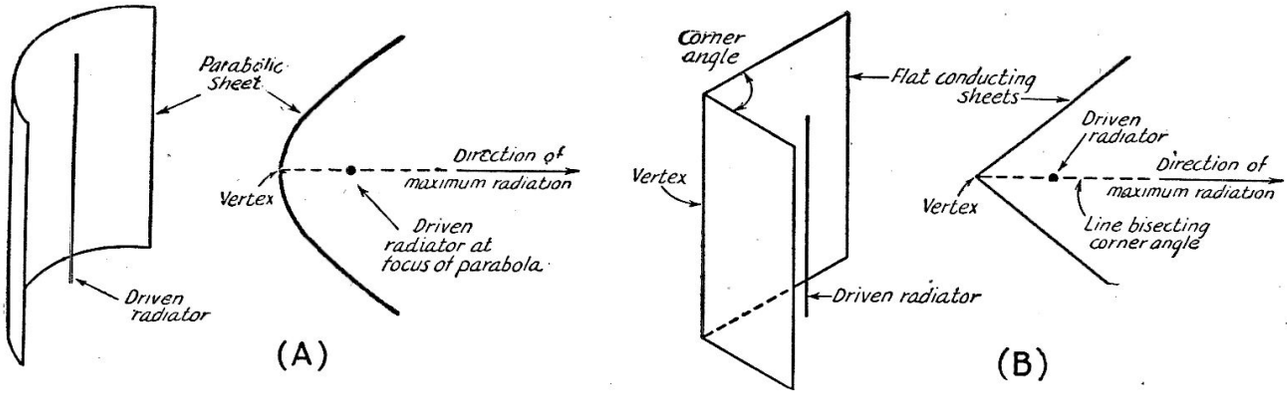


Fig. 14-16 — **Plane sheet reflectors for v.h.f. and u.h.f. A shows a parabolic sheet and B a square-corner reflector.**

used, with some decrease in gain. A 180-degree "corner" is equivalent to a single flat-sheet reflector. With angles smaller than 90 degrees, the gain theoretically increases as the corner angle is decreased. However, to realize this gain the size of the reflecting sheets must also be increased.

At a spacing of 0.5 wavelength from the driven dipole to the vertex, the radiation resistance of the driven dipole is approximately twice the radiation resistance of the same dipole in free space. Smaller spacings of driven dipole and vertex are practical, but at a slight sacrifice in efficiency. The alternative design for the 144- and 50-Mc. square-corner reflector has a dipole-to-vertex spacing of 0.4 wavelength. At this spacing the driven-dipole radiation resistance is still somewhat higher than its free-space value, but is considerably less than when the spacing is 0.5 wavelength.

CHAPTER 15

U.H.F. and Microwaves

Once the amateur passes the 144-Mc. band on the way up through the radio-frequency spectrum, he encounters a distinct change of technique. So far he has been operating in a region where various modifications make usable the familiar coils and condensers, the crystal-controlled transmitters, selective superhet receivers, and other more-or-less standard items of the amateur field.

The boundary line beyond which such conventional gear is no longer usable has moved ever higher and higher in frequency as new developments and improvements in existing equipment have come along. In the early '30s the boundary line was our 28-Mc. band; then, as that band filled, the line moved up to 56 Mc., which remained border territory until 1938, when stabilization of transmitters used was made a legal requirement of operation in the old 5-meter band. For some years, then, the 112-Mc. band, and since the war the 144-Mc. band, constituted the dividing line, but even the latter band has now swung into the stabilized-transmitter-and-superhet-receiver field.

In the light of current developments, it may be said that the 235-Mc. band is now true borderline territory. The multistage transmitter can be used successfully, as can the superheterodyne receiver of semiconventional design, but special tank circuits must be employed and extreme care in mechanical layout must be used, in order to achieve satisfactory results. For these reasons, equipment for the 235-Mc. band is included in this "microwave" chapter, though current nomenclature designates it as a v.h.f. band.

The 235- and 420-Mc. bands are fruitful territory for the experimentally-minded amateur. Most of the gear used will have to be made by the worker himself, but the techniques employed are such that construction of the necessary equipment will not be outside his capabilities. There is enough interest in a number of areas to support regular activity in both bands, and more can be generated with a little organizational effort.

Antenna work on these frequencies is particularly intriguing. The antenna systems are so small in size that arrays having a gain of 10 db. or more can be erected in almost any location. Experimentation with models built for 420 Mc. is a fine way of checking the performance of arrays for lower frequencies. The experimenter who starts to work with u.h.f. antenna systems is bound to find himself spending many interesting hours checking his pet antenna ideas. Since u.h.f. or microwave experimentation is best accomplished in groups of interested workers, it is a fine project for coöperative effort by radio clubs.

The communication possibilities of the u.h.f. region should not be overlooked. Recent experience in the 144-Mc. band has demonstrated the possibilities of that band for long-distance work, and it is reasonable to assume that propagation vagaries, as regards tropospheric effects, will continue on up through the microwave range. With suitable antenna systems, it is probable that operating ranges on the frequencies above 200 Mc. may equal or approach those now being covered in the 70–160-Mc. region.

At least some amateur work has been done in all the microwave bands now assigned. The work of the pioneers in adapting these frequencies to communication purposes has been in line with the best amateur tradition, and it is hoped that the almost unknown territory from 500 Mc. up will see much amateur exploration in the near future.

U.H.F. Tank Circuits

In resonant circuits as employed at the lower frequencies it is possible to consider each of the reactance components as a separate entity. A coil is used to provide the required inductance and a condenser is connected across it to provide the needed capacitance. The fact that the coil itself has a certain amount of self-capacitance, as well as some resistance, while the condenser also possesses a small self-inductance, can usually be disregarded.

At the very-high and ultrahigh frequencies, however, it is no longer possible to separate these components. The connecting leads which, at lower frequencies, would serve merely to join the condenser to the coil now may have more inductance than the coil itself. The required inductance coil may be no more than a single turn of wire, yet even this single turn may have dimensions comparable to a wavelength at the operating frequency. Thus the energy in the field surrounding the "coil" may in part be radiated. At a sufficiently high frequency the loss by radiation may represent a major portion of the total energy in the circuit. Since energy which cannot be utilized as intended is wasted, regardless of whether it is

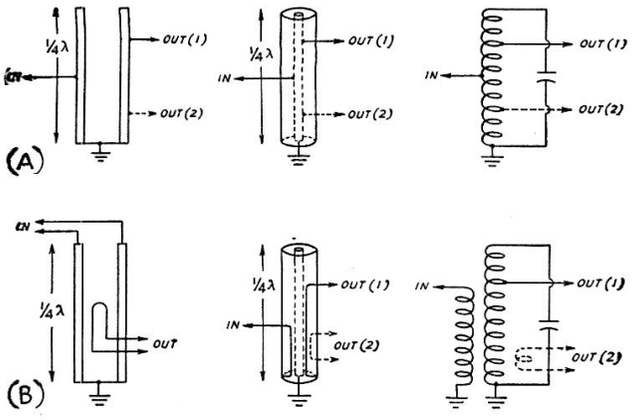


Fig. 15-1 — Equivalent coupling circuits for parallel-line, coaxial-line and conventional resonant circuits.

consumed as heat by the resistance of the wire or simply radiated into space, the effect is as though the resistance of the tuned circuit were greatly increased and its Q greatly reduced.

For this reason, it is common practice to utilize resonant sections of transmission line as tuned circuits at frequencies above 100 Mc. A quarter-wavelength line, or any odd multiple thereof, shorted at one end and open at the other, exhibits large standing waves. When a voltage of the frequency at which such a line is resonant is applied to the open end, the response is very similar to that of a parallel resonant circuit; it will have very high input impedance at resonance and a large current flowing at the short-circuited end. The input impedance may be as high as 0.4 megohm for a well-constructed line.

The action of a resonant quarter-wavelength line can be compared with that of a coil-and-condenser combination whose constants have been adjusted to resonance at a corresponding frequency. Around the point of resonance, in fact, the line will display very nearly the same characteristics as those of the tuned circuit. The equivalent relationships are shown in Fig. 15-1. At frequencies off resonance the line displays qualities comparable to the inductive and capacitive reactances of the coil-and-condenser circuit, although the exact relationships involved are somewhat different. For all practical purposes, however, sections of resonant wire or transmission line can be used in much the same manner as coils or condensers.

In circuits operating above 300 Mc., the spacing between conductors becomes an appreciable fraction of a wavelength. To keep the radiation loss as small as possible the parallel conductors should not be spaced farther apart than 10 per cent of the wavelength, center to center. On the other hand, the spacing of large-diameter conductors should not be reduced to much less twice the diameter because of what is known as the *proximity effect*, whereby another form of loss is introduced through eddy currents set up by the adjacent fields. Because the cancellation is no longer complete, radiation from an open line becomes so great that the Q is greatly reduced. Consequently, at these frequencies coaxial lines must be used.

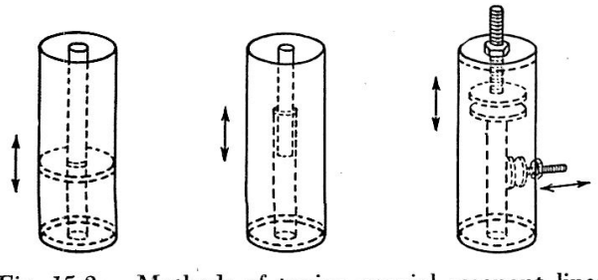


Fig. 15-2 — Methods of tuning coaxial resonant lines.

Construction

Practical information concerning the construction of transmission lines for such specific uses as feeding antennas and as resonant circuits in radio transmitters will be found in this and other chapters of this *Handbook*. Certain basic considerations applicable in general to resonant lines used as circuit elements may be considered here, however.

While either parallel-line or coaxial sections may be used, the latter are preferred for higher-frequency operation. Representative methods for adjusting the length of such lines to resonance are shown in Fig. 15-2. At the left, a sliding shorting disk is used to reduce the effective length of the line by altering the position of the short-circuit. In the center, the same effect is accomplished by using a telescoping tube in the end of the inner conductor to vary its length and thereby the effective length of the line. At the right, two possible methods of mounting parallel-plate condensers, used to tune a "foreshortened" line to resonance, are illustrated. The arrangement with the loading capacitor at the open end of the line has the greatest tuning effect per unit of capacitance; the alternative method, which is equivalent to "tapping" the condenser down on the line, has less effect on the Q of the circuit. Lines with capacitive "loading" of the sort illustrated will be shorter, physically, than an unloaded line resonant at the same frequency.

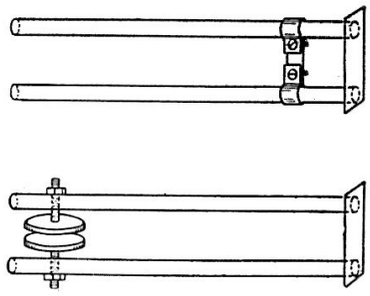


Fig. 15-3 — Methods of tuning parallel-type resonant lines.

The short-circuiting disk at the end of the line must be designed to make perfect electrical contact. The voltage is a minimum at this end of the line; therefore, it will not break down some of the thinnest insulating films. Usually a soldered connection or a tight clamp is used to secure good contact. When the length of line

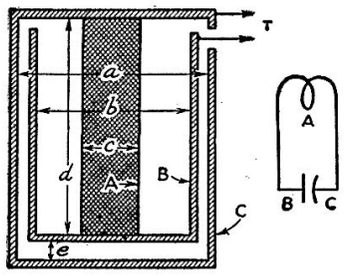


Fig. 15-4 — Concentric-cylinder or "pot"-type tank for v.h.f. The equivalent circuit diagram is also shown. Connections are made to the terminals marked *T*. For maximum *Q* the ratio of *b* to *c* should be between 3 and 5.

must be readily adjustable, the shorting plug is provided with spring collars which make contact on the inner and outer conductors at some distance away from the shorting plug at a point where the voltage is sufficient to break down the film between the collar and conductor.

Two methods of tuning parallel-conductor lines are shown in Fig. 15-3. The sliding short-circuiting strap can be tightened by means of screws and nuts to make good electrical contact. The parallel-plate condenser in the second drawing may be placed anywhere along the line, the tuning effect becoming less as the condenser is located nearer the shorted end of the line. Although a low-capacitance variable condenser of ordinary construction can be used, the circular-plate type shown is symmetrical and thus does not unbalance the line. It also has the further advantage that no insulating material is required.

Equivalent impedance points, for coupling or impedance-transformation purposes, are shown in Fig. 15-1 for parallel-line, coaxial-line, and conventional coil-and-condenser circuits.

Lumped-Constant Circuits

At the very-high frequencies the low values of L and C required make ordinary coils and condensers impracticable, while linear circuits offer mechanical difficulties in making tuning adjustments over a wide frequency range, and radiation from unshielded lines may reduce their effectiveness materially.

To overcome these difficulties, special high-Q lumped-constant circuits have been developed in which connections from the "condenser" to the "coil" are an inherent part of the structure. Integral design minimizes both resistance and inductance and increases the C/L ratio.

The simplest of these circuits is based on the use of disks combining half-turn inductance loops with semicircular condenser plates. By connecting several of these half-turn coils in parallel, the effective inductance is reduced to a value appreciably below that for a single turn. Tuning is accomplished by interleaving grounded rotor plates between the turns. Both by shielding action and short-circuited-turn effect, these further reduce the inductance.

Another type of high-C circuit is a single-turn toroid, commonly termed the "hat" resonator. Two copper shells with wide, flat "brims" are mounted facing each other on an axially-aligned copper rod. The capacitance in the circuit is that between the wide shells, while the central rod comprises the inductance.

"Pot"-Type Tank Circuits

The lumped-constant concentric-element tank in Fig. 15-4, commonly referred to as the "pot" circuit, is equivalent to a very short coaxial line (no linear dimension should exceed 1/20 wavelength), loaded by a large integral capacitor.

The inductance is supplied by the copper rod, A. Capacitance is provided by the concentric cylinders, B and C, plus the capacitance between the plates at the bottoms of the cylinders.

Approximate values of capacitance and inductance for tank circuits of the "pot" type can be determined by the following:

$$L = 0.0117 \log \frac{b}{c} \ \mu\text{h}.$$

$$C = \left(\frac{0.6225\ d}{\log \frac{a}{b}}\right) + \left(\frac{0.1775\ b^2}{e}\right) \ \mu\mu\text{fd}.$$

where the symbols are as indicated in Fig. 15-4, and dimensions are in inches. The left-hand term for capacitance applies to the concentric cylinders, B and C, while the second term gives capacitance between the bottom plates.

"Butterfly" Circuits

The tank circuits described in the preceding section are primarily fixed-frequency devices. The "butterfly" circuits shown in Fig. 15-5 are capable of being tuned over an exceptionally wide range, while still having high Q and reasonable physical dimensions. The circuit at A is derived from a conventional balanced-type variable condenser. The inductance is in the wide circular band connecting the stator plates. At its minimum setting the rotor plate fills the opening of the loop, reducing the inductance to a minimum. Connections are made to points *1* and *2*. This basic structure eliminates all connecting leads and avoids all sliding or wiping electrical contacts to a rotating member. A disadvantage is that the electrical midpoint shifts

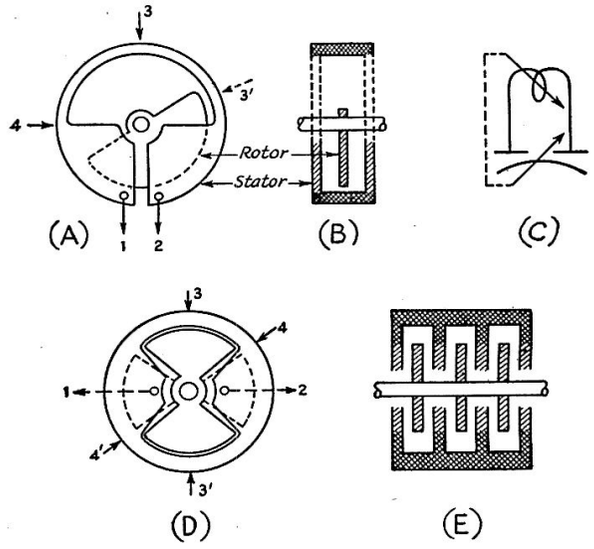


Fig. 15-5 — "Butterfly" tank circuits for v.h.f., showing front and cross-section views and the equivalent circuit.

from point *3* to point *3'* as the rotor is turned. Constant magnetic coupling may be obtained by a coupling loop located at point *4*, however.

In the modification shown at D, two sectoral stators are spaced 180 degrees, thereby achieving the electrical symmetry required to permit tapping for balanced operation. Connections to the circuit should be made at points *1* and *2* and it may be tapped at points *3* and *3'*, which are the electrical midpoints. Where magnetic coupling is employed, points *4* and *4'* are suitable locations for coupling links.

The capacitance of any butterfly circuit may be computed by the standard formula for parallel-plate condensers given in Chapter Twenty-Four. The maximum inductance can be obtained approximately by finding the inductance of a full ring of the same diameter and multiplying the result by a factor of 0.17. The ratio of minimum to maximum inductance varies between 1.5 and 4 with conventional construction.

Any number of butterfly sections may be connected in parallel. In practice, units of four to eight plates prove most satisfactory. The ring and stator sections may either be made in a single piece or with separate sectoral stator plates and spacing rings assembled with machine screws.

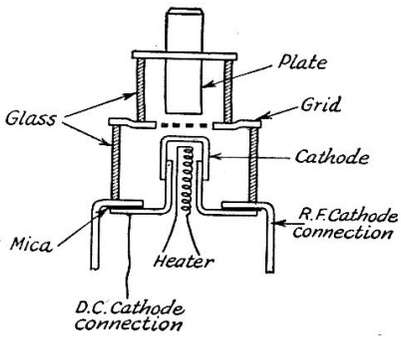


Fig. 15-6 — Sectional view of the "lighthouse" tube's construction. Close electrode spacing reduces transit time while the disk electrode connections reduce lead inductance.

V.H.F. and U.H.F. Tubes

At very-high frequencies, interelectrode capacitance and the inductance of internal leads determine the highest possible frequency to which a vacuum tube can be tuned. The tube usually will not oscillate up to this limit, however, because of dielectric losses, grid emission, and "transit-time" effects. In low-frequency operation, the actual time of flight of electrons between the cathode and the anode is negligible in relation to the duration of the cycle. At 1000 kc., for example, transit time of 0.001 microsecond, which is typical of conventional tubes, is only 1/1000 cycle. But at 100 Mc., this same transit time represents 1/10 of a cycle, and a full cycle at 1000 Mc. These limiting factors establish about 3000 Mc. as the upper frequency limit for negative-grid tubes.

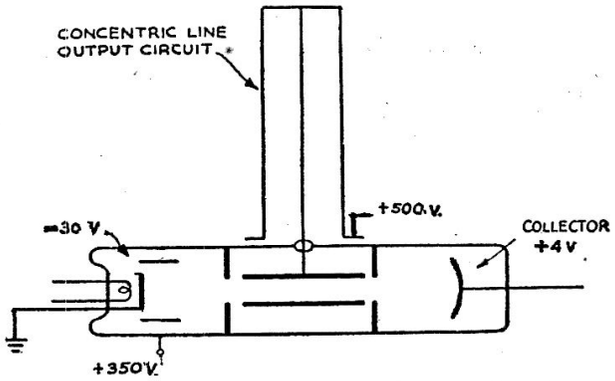


Fig. 15-7 — Simple form of cylindrical-grid velocity-modulated tube with retarding-field collector and coaxial-line output circuit, used as a superheterodyne high-frequency oscillator or as a superregenerative detector. Similar tubes can also be used as r.f. amplifiers and frequency converters in the 5–50-cm. region.

With tubes of ordinary construction, the upper limit of oscillation is about 150 Mc. For higher frequencies, v.h.f. tubes of special construction are used. The "acorn" and "doorknob" types and the special v.h.f. "miniature" tubes, in which the grid-cathode spacing is made as little as 0.005 inch, are capable of operation up to about 700–800 Mc. The normal frequency limit is around 600 Mc., although output may be obtained up to 800 Mc.

Very low interelectrode capacitance and lead inductance have been achieved in the newer tubes of modified construction. In multiple-lead types the electrodes are provided with up to three separate leads which, when connected in parallel, have considerably-reduced effective inductance. In double-lead types the plate and grid elements are supported by heavy single wires which run entirely through the envelope, providing terminals at either end of the bulb. When a resonant circuit is connected to each pair of leads, the shunting capacitance divides between the two circuits. With linear circuits the leads become a part of the line and have distributed rather than lumped constants. Radiation loss is minimized and the effect of the transit time is reduced. In "lighthouse" tubes or *megatrons* the plate, grid and cathode are assembled in parallel planes, as shown in Fig. 15-6, instead of coaxially. The uniform coplanar electrode design and disk-seal terminals permit low interelectrode capacitance.

Velocity Modulation

In negative-grid operation the potential on the grid tends to reduce the electron velocity during the more negative half of the oscillation cycle, while on the other half-cycle the positive potential on the grid serves to accelerate them. Thus the electrons tend to separate into groups, those leaving the cathode during the negative half-cycle being collectively slowed down, while those leaving on the positive half are accelerated. After passing into the grid-plate space only a part of the electron stream follows the original form of the oscillation cycle, the remainder traveling to the plate at differing velocities. Since these contribute nothing to the

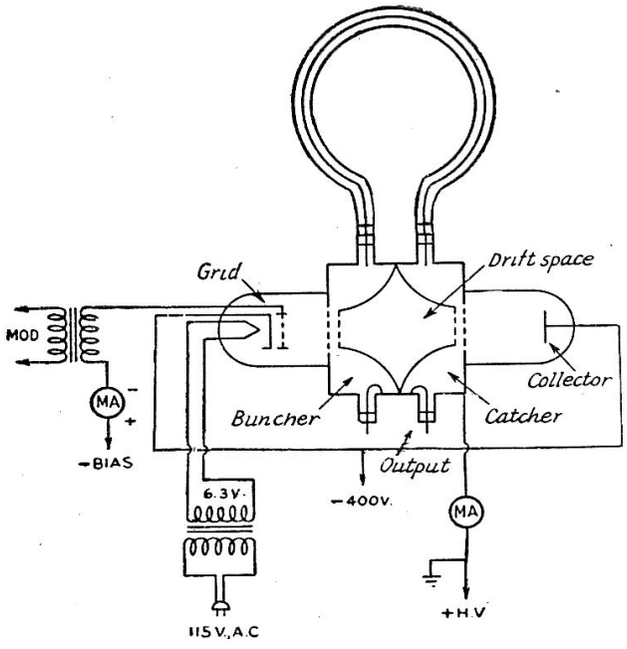


Fig. 15-8 — Circuit diagram of the klystron oscillator, showing the feed-back loop coupling the frequency-controlling rhumbatrons and the output loop in the catcher.

power output at the operating frequency, the efficiency is reduced in direct proportion to the variation in velocity, the output reaching a value of zero when the transit time approaches a half-cycle.

This effect, such a disadvantage in conventional tubes, is an advantage in velocity-modulated tubes in that the input signal voltage on the grid is used to change the velocity of the electrons in a constant-current electron beam, rather than to vary the intensity of a constant-velocity current flow as is the method in ordinary tubes.

A simple form of velocity-modulation oscillator tube is shown in Fig. 15-7. Electrons emitted from the cathode are accelerated through a negatively-biased cylindrical grid by a constant positive voltage applied to a sleeve electrode, shown in heavy lines. This electrode, which is the velocity-modulation control grid, consists of two hollow tubes, with a small space at each end between the inner tube, through which the electron beam passes, and the disks at the ends of the larger tube portion. With r.f. voltage applied across these gaps, which are small compared to the distance traveled by the electrons in one half-cycle, electrons entering the tube will be accelerated on positive half-cycles and decelerated on the negative half-cycles. The length of the tube is made equal to the distance covered by the electrons in one-half cycle, so that the electrons will be further accelerated or decelerated as they leave the tube.

As the beam approaches the collector electrode, which is at nearly zero potential, the electrons are retarded, brought to rest, and ultimately turned back by the attraction of the positive sleeve electrode. The collector electrode is, therefore, also termed a *reflector*. The point at which electrons are returned depends on their velocity. Thus the velocity modulation is again translated into current modulation.

Velocity-modulated tubes operate satisfactorily up to 6000 Mc. (5 cm.) and higher, with outputs of 100 watts or more.

The Klystron

In the *klystron* velocity-modulated tube, the electrons emitted by the cathode are accelerated or retarded during their passage through an electric field established by two grids in a cavity resonator, or *rhumbatron*, called the "buncher." The high-frequency electric field between the grids is parallel to the electron stream. This field accelerates the electrons at one moment and retards them at another, in accordance with the variations of the r.f. voltage applied. The resulting velocity-modulated beam travels through a field-free "drift space," where the slowly-moving electrons are gradually overtaken by the faster ones. The electrons emerging from the pair of grids therefore are separated into groups or bunched along the direction of motion. The velocity-modulated electron stream is passed to a "catcher" rhumbatron. Again the beam passes through two parallel grids; the r.f. current created by the bunching of the electron beam induces an r.f. voltage between the grids. The catcher cavity is made resonant at the frequency of the

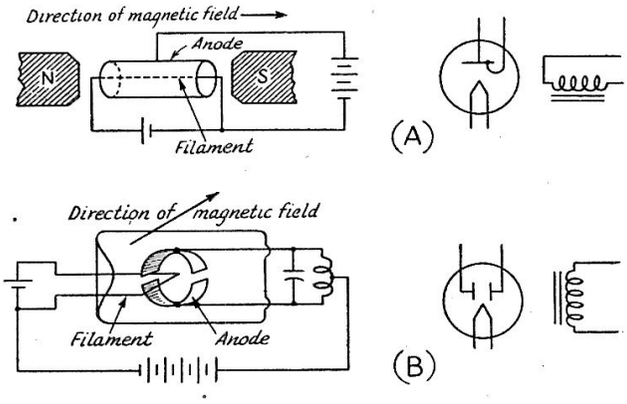


Fig. 15-9 — Conventional magnetrons, with equivalent schematic symbols at the right. A, simple cylindrical magnetron. B, split-anode negative-resistance magnetron.

velocity-modulated electron beam, so that an oscillating field is set up within it by the passage of the electron bunches through the grid aperture.

If a feed-back loop is provided between the two rhumbatrons, as shown in Fig. 15-8, oscillations will occur. The resonant frequency depends on the electrode voltages and on the shape of the cavities, and may be adjusted by varying the supply voltage and altering the dimensions of the rhumbatrons. The bunched beam current is rich in harmonics, but the output waveform is remarkably pure because the high Q of the catcher rhumbatron suppresses the unwanted harmonics.

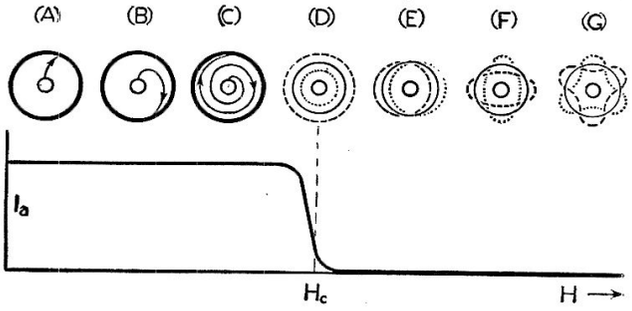


Fig. 15-10 — Electron trajectories for increasing values of magnetic field strength, H. Below is shown the corresponding curve of plate current, I_a. Oscillations commence when H reaches a critical value, H_c; progressively higher-order modes of oscillation occur beyond this point.

Magnetrons

A magnetron is fundamentally a diode with cylindrical electrodes placed in a uniform magnetic field with the lines of electromagnetic force parallel to the elements. The simple cylindrical magnetron consists of a filamentary cathode surrounded by a concentric cylindrical anode. In the more efficient split-anode magnetron the cylinder is divided longitudinally.

Magnetron oscillators are operated in two different ways. Electrically the circuits are similar, the difference being in the relation between electron transit time and the frequency of oscillation.

In the negative-resistance or dynatron type of magnetron oscillator, the element dimensions and anode voltage are such that the transit time is short compared with the period of the oscillation frequency. Electrons emitted from the cathode are driven toward both halves of the anode. If the potentials of the two halves are unequal, the effect of the magnetic field is such that the majority of the electrons travel to that half of the anode that is at the lower potential. In other words, a *decrease* in the potential of either half of the anode results in an *increase* in the electron current flowing to that half. The magnetron consequently exhibits negative-resistance characteristics. Negative-resistance magnetron oscillators are useful between 100 and 1000 Mc. Under the best operating conditions efficiencies of 20 to 25 per cent may be obtained. Since the power loss in the tube appears as heat in the anode, where it is readily dissipated, relatively large power-handling capacity can be obtained.

In the transit-time magnetron the frequency is determined primarily by its dimensions and by the electric and magnetic field intensities rather than by the tuning of the tank circuits. The efficiency is much better than that of a positive-grid oscillator and good power output can be obtained even on the superhighs.

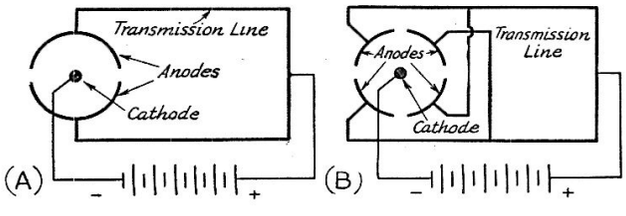


Fig. 15-11 — S.h.f. magnetron circuits. A, split-anode type. B, 4-anode type, opposite electrodes paralleled.

In a nonoscillating magnetron with a weak magnetic field, electrons traveling from the cathode to the anode move almost radially, their trajectories being bent only slightly by the magnetic field. With increased magnetic field the electrons tend to spiral around the filament, their radial component of velocity being much smaller than the angular component. Under critical conditions of magnetic field strength, a cloud of electrons rotates about the filament. It extends up to the anode but does not actually reach it.

The nature of these electron trajectories is shown in Fig. 15-10. Cases A, B and C correspond to the nonoscillating condition. For a small magnetic field (A) the trajectory is bent slightly near the anode. This bending increases for a higher magnetic field (B) and the electron moves through quite a large angle near the anode before reaching it, signifying a large increase of space charge near the anode. For a strong magnetic field (C) electrons start radially from the cathode but are soon bent and curl about the filament in the form of a long spiral before reaching the anode. This means a very long transit time and a very large space charge in the whole region where the spiraling takes place. Under critical conditions (D), no current flows to the anode and no electron is able to move from cathode to anode, but a large space charge still exists between the cathode and anode. The spiraling becomes a set of concentric circles, and the entire space-charge distribution rotates about the filament.

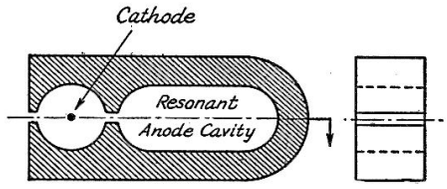


Fig. 15-12 — Split-anode magnetron with integral resonant anode cavity for use at u.h.f.

Fig. 15-10E, F and G depicts higher-order (harmonic-type) modes of operation in which the space charge oscillates not only symmetrically but in transverse directions contrasting to the vibrations of the fundamental.

In a transit-time magnetron oscillator the intensity of the magnetic field is adjusted so that, under static conditions, electrons leaving the cathode move in curved paths which just fail to reach the anode. All electrons are therefore deflected back to the cathode, and the anode current is zero. When an alternating voltage is applied between the two halves of the anode, causing the potentials of these halves to vary about their average positive values, the conditions in the tube become analogous to those in a positive-grid oscillator. If the period of the alternating voltage is made equal to the

time required for an electron to make one complete rotation in the magnetic field, the a.c. component of the anode voltage reverses direction twice with each electron rotation. Some electrons will lose energy to the electric field, with the result that they are unable to reach the cathode and continue to rotate about it. Meanwhile other electrons gain energy from the field and are returned to the cathode. Since those electrons that lose energy remain in the interelectrode space longer than those that gain energy, the net effect is a transfer of energy from the electrons to the electric field. This energy can be applied to sustain oscillations in a resonant transmission line connected between the two halves of the anode.

Split-anode magnetrons for u.h.f. are constructed with a cavity resonator built into the tube structure, as illustrated in Fig. 15-12. The assembly is a solid block of copper which assists in heat dissipation. At extremely high frequencies operation is improved by subdividing the anode structure into from 4 to 16 or more segments, the resonant cavities for each anode coupled by slots of critical dimensions to the common cathode region, as in Fig. 15-13.

The efficiency of multisegment magnetrons

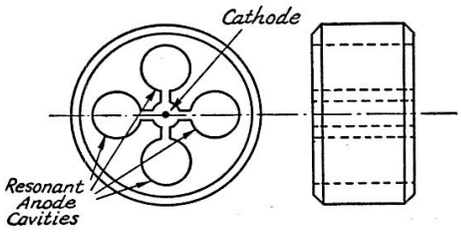


Fig. 15-13 — Multisegment magnetron with four resonant cavities. This construction is used for extremely high frequencies.

reaches 65 or 70 per cent. Slotted-anode magnetrons with four segments function up to 30,000 Mc. (1 cm.), delivering up to 100 watts at efficiencies greater than 50 per cent. Using larger multiples of anodes and higher-order modes, performance can be attained at 0.2 cm.

Equipment for 235 Mc.

While the serious experimenter, who is interested in fully exploring the possibilities of the 235-Mc. band, will undoubtedly wish to employ the most advanced techniques possible, there are many who will want to work the band with simple gear. The modulated oscillator and the superregenerative receiver are in disrepute among 144-Mc. enthusiasts principally because they were improperly used by many on that band, resulting in extremely bad-sounding signals and much needless interference. The simple-oscillator type of rig is capable of radiating a signal that is not unduly broad, and which sounds well when received on a not-too-sharp receiver. With proper attention to a few important details, the simplest form of equipment can be used on 235-Mc. with good results.

In the transmitter, it is a relatively simple matter to avoid the faults that have been so common in past experience. If an a.c. power supply is used on the transmitter, we should use heater-type tubes, to avoid hum modulation of the signal. Special attention should be paid to the design of the oscillator, making certain that sufficient feed-back (as indicated by the *grid* current) is provided so that the oscillator will function over a wide range of plate voltages. This assures that the carrier will stand up well under reasonable percentages of modulation, and that the degree of frequency modulation will be minimized. The loading of the oscillator should not be excessive, otherwise the signal will be broad and of poor quality. The tubes must be operated at considerably-lower ratings than would be used on lower frequencies, otherwise there will be severe drift, and shortened tube life.

If the receiver is the superregenerative type, we should avoid coupling the detector to the antenna, if there is appreciable other activity within a few miles, as nothing is more troublesome than receiver radiation. The superheterodyne principle can be used without excessive complication, and it should be employed wherever possible. A simple solution to this problem

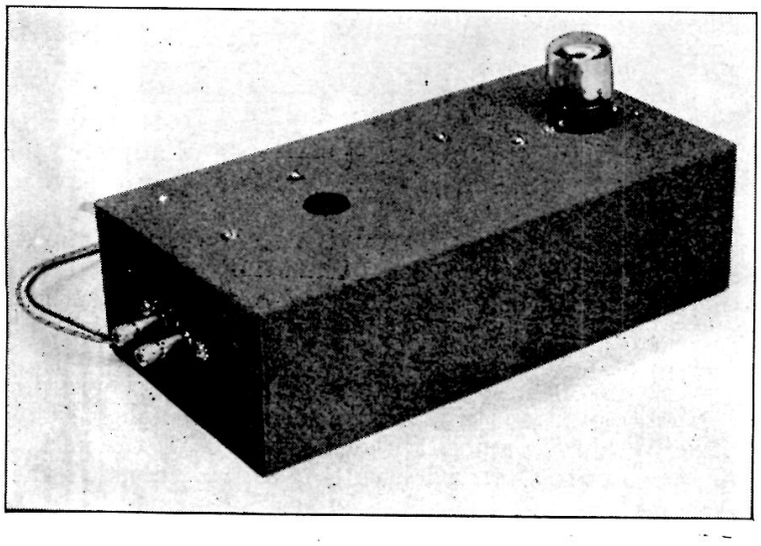


Fig. 15-14 — A one-tube transmitter for 235 Mc. The oscillator is a 7F8 dual triode. Lines and antenna coupling are below the chassis.

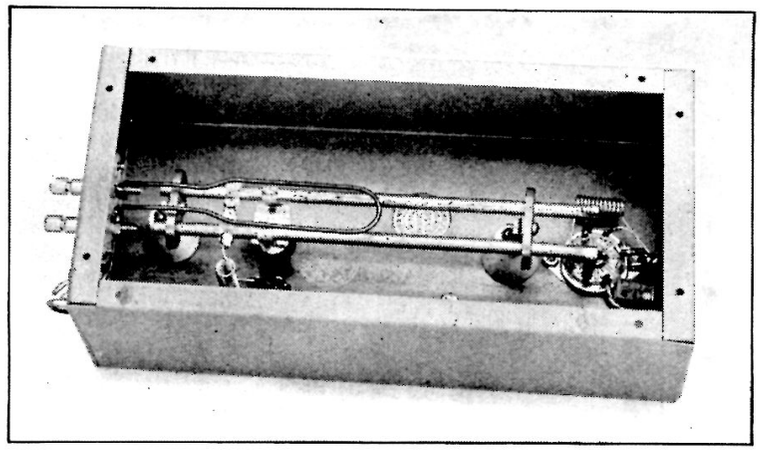


Fig. 15-15 — Under-chassis view of the 235-Mc. transmitter. Note the method of making the shorting bar and mounting the trimmer condenser — both by the use of spring grid clips, permitting adjustment of the position of either along the line.

is the use of a converter working into a super-regenerative detector on some lower frequency, or into a broad-band i.f. system, such as an FM broadcast receiver.

A 10-Watt Transmitter for 235 Mc.

A line oscillator which is suitable for low-power experimental work is shown in Figs. 15-14, 15-15 and 15-16. It is built entirely of readily-obtainable standard parts, and may be

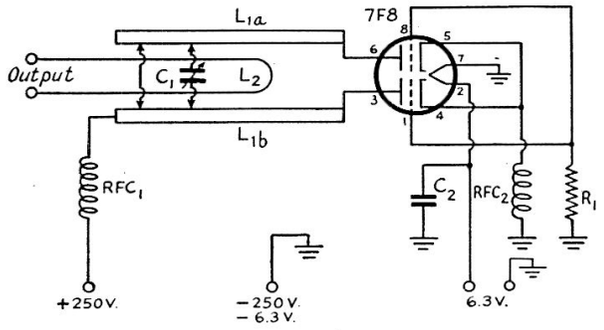


Fig. 15-16 — Schematic of the 235-Mc. transmitter. R.f. chokes are 12 turns No. 18 d.c.c. wire, ¼-inch diam. C_2 is 0.0047 μfd. See text for other values.

constructed at very low cost. The tube is a 7F8 dual triode, working as a push-pull oscillator, with parallel lines in the plate circuit. The frequency is varied by means of a mica trimmer which is connected across the line near the cold end, so that a vernier effect is attained. A rough adjustment of frequency is made by means of an adjustable shorting bar. When the proper setting of the shorting bar is found, the 235–240-Mc. band will be covered by about two complete turns of the trimmer.

The transmitter is mounted on a 3 × 5 × 10-inch chassis. Only the oscillator tube is above the chassis, with the lines and antenna coupling below. The antenna coupling loop is connected to a National FWG terminal assembly which projects through the end of the chassis. The plate lines are 7½ inches long and made of ¼-inch copper tubing spaced ¾ inch, center to center. They are held in position by two halves of a National FWH or FWJ terminal block. These blocks are of low-loss insulating material, and the hole spacing is right for this application. The connection between the plates and the lines should be made with ¼-inch-wide copper strip. They are mounted on two cone stand-offs 6 inches apart. Self-supporting r.f. chokes, one in the cathode lead and the other in the B-plus lead, a 1000-ohm resistor from grids to ground, and a small by-pass condenser from the hot heater terminal to ground, complete the circuit. The antenna coupling is a "U"-shaped loop 4½ inches long.

The transmitter may be placed in operation by applying 6.3 volts a.c. and about 250 volts d.c. Plate current, under load, should be under 40 ma. A lamp load should be used across the antenna terminals until the frequency is adjusted to within the band limits. The shorting bar is made from two National No. 8 grid clips, which make a tight fit on the ¼-inch tubing, and the trimmer condenser is also connected to the line by means of a pair of these clips, making it possible to adjust the position of the condenser along the line to give the desired degree of frequency coverage. The shorting bar and the trimmer should be set in such positions

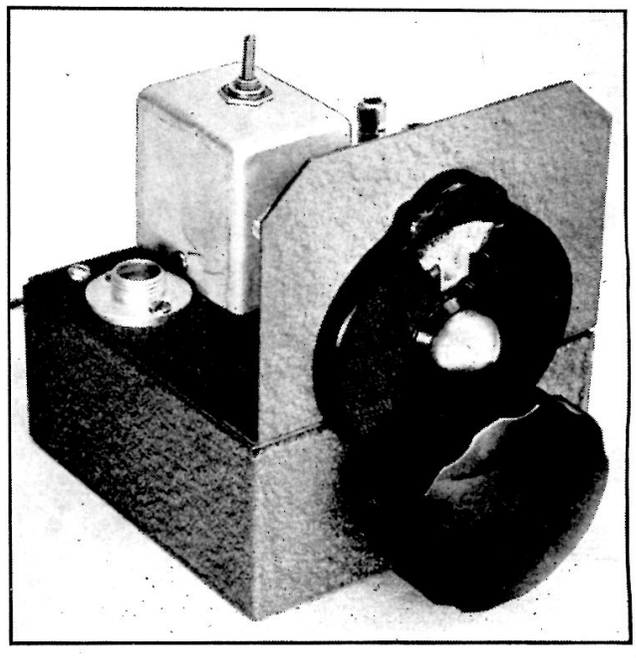


Fig. 15-17 — A simple converter for 235-Mc. reception. The large knob was substituted for the customary small one to facilitate slow tuning.

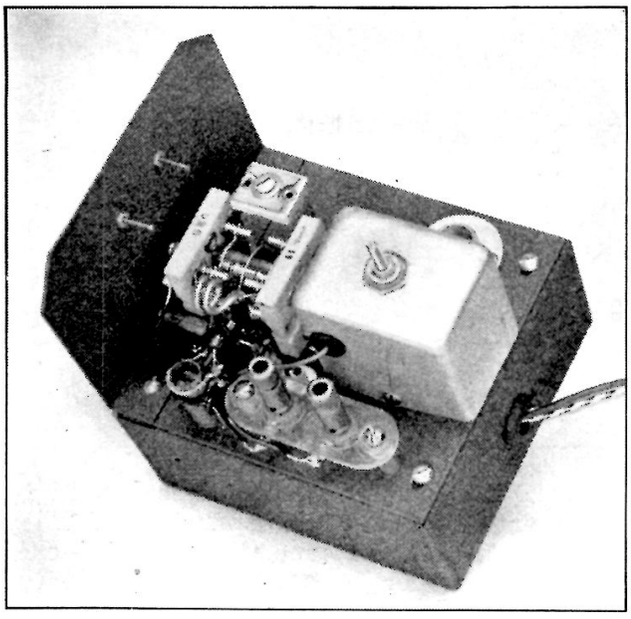


Fig. 15-18 — Top view of the 235-Mc. converter. At the lower left is the slug-tuned mixer input circuit. The output transformer, also slug-tuned, is in the shield. Just visible over the top of the shield is the coaxial i.f. output fitting. Oscillator tuning is by means of the split-stator condenser attached to the vernier dial.

that, with the trimmer set near maximum capacitance, the frequency of the oscillator is 235 Mc.

The antenna coupling may then be adjusted,

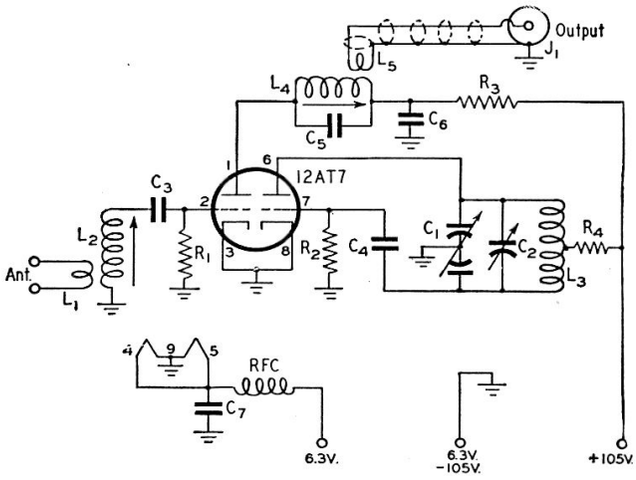


Fig. 15-19 — Circuit diagram of the 235-Mc. converter.

C_1 — 15-$\mu\mu$fd.-per-section split stator (Bud LC-1660 reduced to 1 stator and 1 rotor plate per section).
C_2 — 3–30-$\mu\mu$fd. mica trimmer (National M-30).
C_3, C_4 — 22-$\mu\mu$fd. mica.
C_5 — 27-$\mu\mu$fd. mica.
C_6, C_7 — 470-$\mu\mu$fd. mica.
R_1 — 1 megohm, ½ watt.
R_2 — 10,000 ohms, ½ watt.
R_3, R_4 — 1000 ohms, ½ watt.
L_1 — 1 turn insulated wire, ⅜-inch diam., wound at cold end of L_2.
L_2 — 1 turn No. 18 e. wire, ⅜-inch diam.
L_3 — 2 turns No. 12 tinned wire, ¼-inch diam., turns spaced wire diam.
L_4 — 9 turns No. 18 e. wire, ½-inch diam., ⅝ inch long.
L_5 — 2 turns insulated wire, close-wound over bottom end of L_4. L_1 and L_2 are wound on a Cambridge Thermionic Corp. Type LS-3 slug-tuned coil form, ⅜-inch diameter. L_4 and L_5 are wound on a National Type XR-50 slug-tuned form.
J_1 — Coaxial-cable connector (Jones S-201).
RFC — 12 turns No. 18 wire, ¼-inch diameter, 1 inch long.

with the antenna connected. The position of the loop should be adjusted for maximum power transfer (a field-strength meter close to the antenna is a good indication), using the minimum coupling that will give satisfactory output. The frequency should be checked again after the antenna is on and the coupling adjusted, as this operation may have shifted the frequency slightly.

The transmitter can be run at 10 watts input without endangering the tube. The useful output is in the vicinity of 2 watts. The rig may be modulated with a single 6V6 tube.

A Simple 235-Mc. Converter

A simple one-tube converter for 235 Mc. is shown in Figs. 15-17–15-20. It uses the new 9-pin miniature 12AT7 dual triode, but a 7F8 or 6J6 might work equally well. Its circuit is similar to that of the 7F8 converter for 144 Mc., described in Chapter Twelve. One section of the tube is used as the oscillator, and is tuned by means of a small split-stator condenser and the vernier dial. The mixer input circuit is untuned, except for the slug adjustment. Mixer output is on 27.9 Mc., but it could be changed to any lower or higher frequency within reason, to suit the i.f. to be used. The converter was designed for use with superregenerative receivers such as the National One-Ten, or with other broad-band receivers capable of tuning to the i.f. frequency. It has also been used successfully in reception of crystal-controlled transmitters, in conjunction with conventional low-frequency communications receivers, though the selectivity of such an arrangement is excessively sharp for most signals. Its sensitivity, with any of the above arrangements, is appreciably better than is obtainable

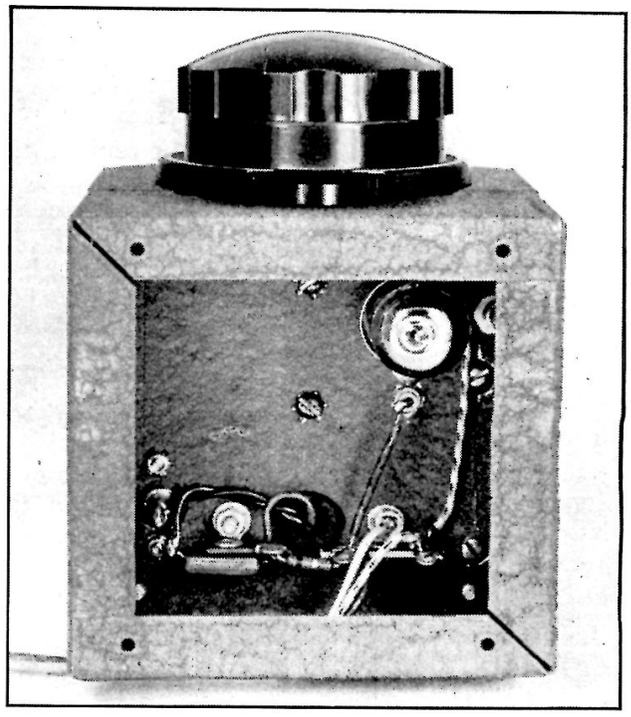


Fig. 15-20 — Bottom view of the 235-Mc. converter, showing the 12AT7 tube mounted below the chassis.

with superregenerative detectors operating on 235 Mc., and the radiation and other disadvantages of the superregen are eliminated.

The converter is built on the smallest-size standard utility box, with the bottom plate removed and used for a front panel. The tube is mounted with its socket above the chassis, permitting short leads to all r.f. components. Leads must, of course, be practically nonexistent at these frequencies. The general parts arrangement is visible in the photographs, and putting the converter into operation is similar to the process detailed for the 7F8 converter described in Chapter Twelve.

420-Mc. Gear

Though it is entirely possible to use crystal control, even on 420 Mc., it is highly improbable that many amateurs will care to go to the trouble necessary to accomplish it. For some time to come, at least, most work on this band will be done with simple oscillators supplying the r.f. power. Superheterodyne-receiver design is not too difficult, and a considerable number of experimenters will find the superhet the most satisfactory receiving system, especially when broad-band i.f. systems are employed. The i.f. strips used in radar work are readily adapted to 420-Mc. amateur work, as their extreme broadness is not important at the present state of activity on this frequency. Broadness in both the transmitter and receiver need not be troublesome in this band, which is considerably wider than any of our lower v.h.f. assignments.

A 420-Mc. Transmitter

Not too many tubes are available which can be made to function at 420 Mc. Of these, the 6J6 is a logical choice. The transmitter shown in Figs. 15-21 through 15-24 uses a pair of 6J6s in push-pull-parallel. It can be operated at 15 watts input and is capable of delivering about 2 watts output at 420 Mc., the output dropping off slightly toward the 450-Mc. end of the band.

The circuit and shorting-bar details were suggested by a war-surplus transmitter-receiver known as the AN/APS-13. Details of the tank

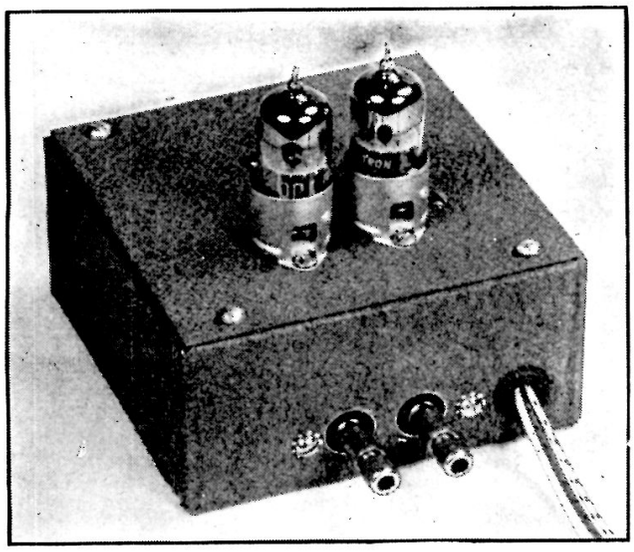


Fig. 15-21 — A transmitter for 420 Mc. using two 6J6 tubes in push-pull-parallel. Antenna coupling terminals project through the front of the chassis.

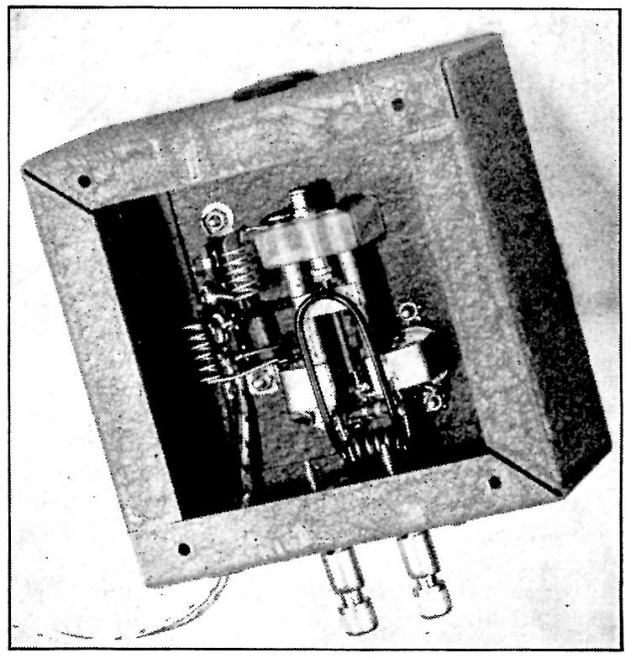


Fig. 15-22 — Bottom view of the 420-Mc. transmitter, showing the plate-line assembly. Note wide strips used to make connection to the tube plates.

circuit may be seen in the under-chassis photograph, and the drawing, Fig. 15-23. It is made of two pieces of 3/16-inch copper tubing, this size being used because it can be tapped

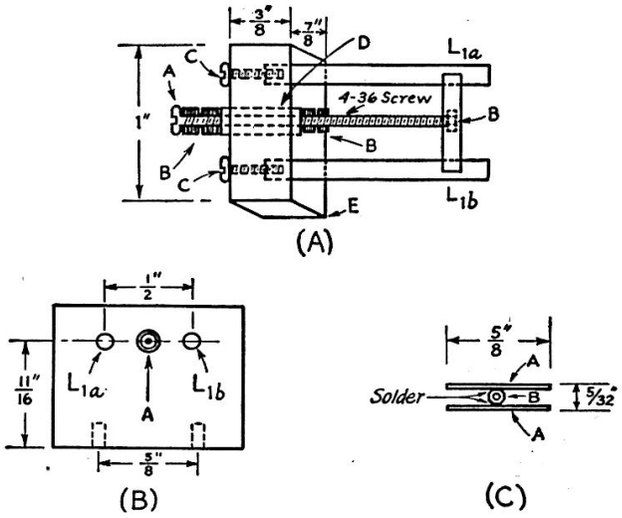


Fig. 15-23 — Detail drawing of the plate-line assembly used in the 420-Mc. transmitter. A shows the lines and method of mounting in the polystyrene block, which is shown in detail at B. The shorting bar, for frequency adjustment, is shown at C. In view A parts *B* are 4–36 nuts which are tightened on shaft *A*, a 1½-inch 4–36 screw. Part *D* is a bushing which is embedded in the polystyrene block. It serves as a bearing. Lines L_{1a} and L_{1b} are 1½ inches long.

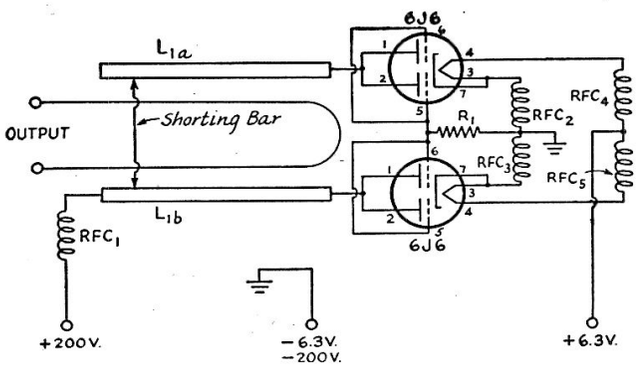


Fig. 15-24 — Circuit diagram of the 420-Mc. push-pull-parallel transmitter.
R_1 — 2700 ohms, ½ watt.
L_{1a}, L_{1b} — Plate line; see Fig. 15-23.
RFC_1, RFC_2, RFC_3, RFC_4, RFC_5 — 6 turns No. 20, 3/16-inch inside diameter, 5/8 inch long.

merely by running a 6–32 tap into the end of the tube, providing a simple means of mounting. The shorting bar is made of two pieces of spring bronze which are soldered to opposite faces of a 4–36 nut. A long screw, mounted in the polystyrene block which also acts as a support for the two portions of the line, serves as a means of frequency adjustment, its head being reached through a rubber-grommetted access hole in the end of the chassis. With the dimensions shown, movement of the shorting bar the whole length of the line just about covers the 420–450-Mc. range. Output drops off slightly at the high end, as might be expected, with most of the tank circuit shorted out. Note that the two plates of each 6J6 are connected to the tank circuit by means of 3/8-inch-wide copper strip, for negligible lead inductance.

The unit is mounted on the top plate of a small-sized utility box, with antenna terminals (National FWG) coming out through one side. Small self-supporting r.f. chokes are inserted in each heater lead, and the cathode is connected to the heater (be sure it's the grounded side) at the socket. Another r.f. choke is in the B-plus lead to the cold end of the tank circuit. A grid resistor is the only additional circuit component required.

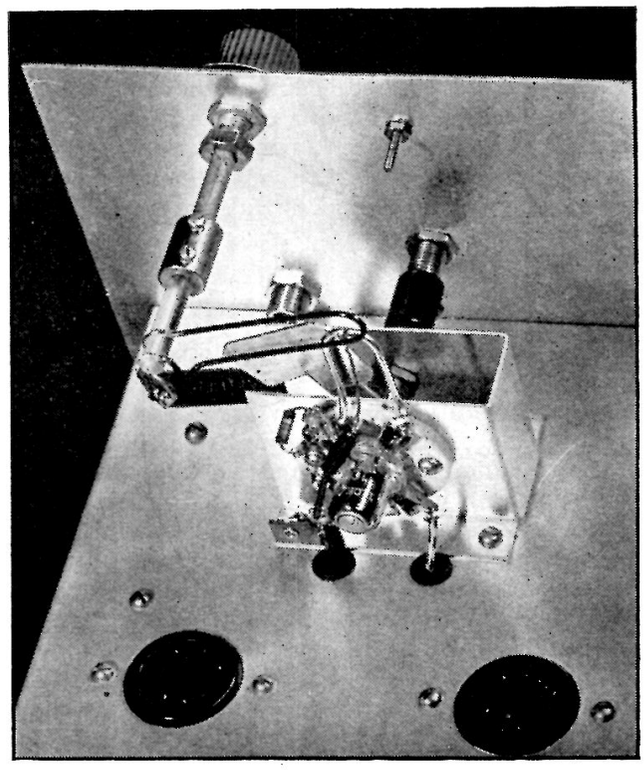


Fig. 15-26 — Close-up view of the detector assembly used in the 420-Mc. receiver. The frequency coverage is attained by moving a copper vane across the "U"-shaped detector tank circuit, maximum frequency being reached when the loop is covered by the vane. Antenna coupling is varied by means of the hairpin loop at the left. The two audio tubes were removed from their sockets to permit a clear view of the tuning system.

The transmitter should be checked at low voltage, preferably 200 or under, until it is determined that it is operating correctly. At 250 volts it can run as high as 60 ma. without damaging the 6J6s, provided a load is kept across the antenna terminals. Since few experimenters will have an absorption-type wavemeter for 420 Mc., it is best to check the frequency with Lecher wires. Antenna coupling should be adjusted until maximum output is obtained, the least amount of coupling possible being used. Frequency checks should be made with the antenna attached, once the frequency of the oscillator is found to be close to the band.

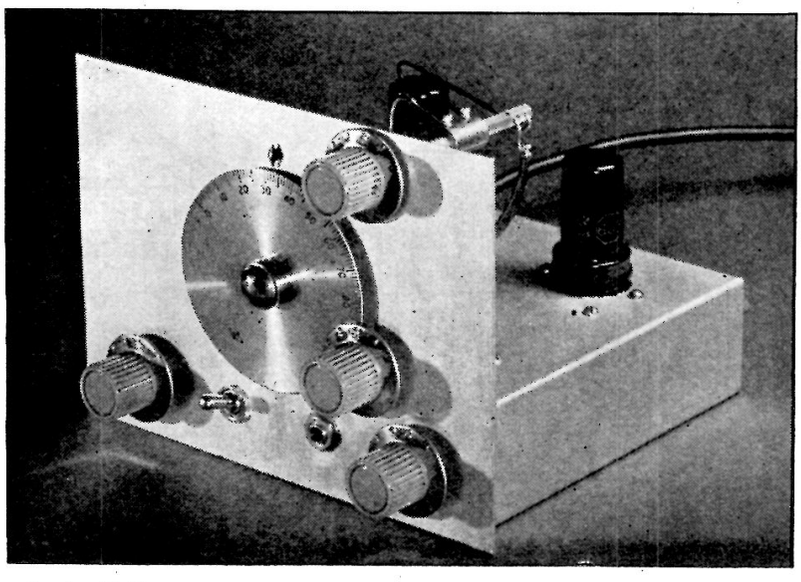


Fig. 15-25 — A superregenerative receiver for 420 Mc. The two lower controls are for variation of detector voltage (left) and audio gain. The vernier dial controls the position of the tuning vane, while the knob at the top adjusts the antenna coupling.

Though the output of this little transmitter is less than two watts, it is sufficient for much interesting work. Since it is a simple matter to attain antenna gains of 15 db. or more at this frequency, a small amount of power can be made to produce surprising results.

Superregenerative Receiver for 420 Mc.

Though the advanced experimenter will wish to use something more elaborate, the simple superregen is a good start on 420 Mc. The tuning system used in the receiver, see Fig. 15-26, could, however, be adapted to the tuning of the oscillator in a converter, if a suitable broad-band i.f. system is available.

It is obvious that coils and condensers, in the normal sense, are incapable of operation at 420 Mc. The tuning arrangement used in this receiver is the vane type, wherein a self-resonant loop of wire has its inductance reduced by passing a copper vane across the plane of the loop. The three-tube receiver shown in Figs. 15-25–15-28 uses a 955 superregenerative detector, with a loop of stiff wire connected between the plate and the grid-blocking condenser, in a manner similar to the conventional circuit used on lower frequencies. In details other than the tuning arrangement, the receiver is similar to self-quenched detectors used for years on lower v.h.f. bands.

The 955 socket is mounted on one side of a "U"-shaped bracket, with the grid and plate terminals at the top, so that the inductor extends above the top of the mounting bracket. The vane is attached to a ¼-inch polystyrene rod which extends through a shaft bearing on the opposite side of the bracket from the tube socket. The vane is moved across the coil by means of a vernier dial, providing slightly more than 30 Mc. tuning range. The vane is not grounded, so that if it accidentally touches the coil it will not short the B-plus to ground.

Adjustable antenna coupling, absolutely necessary at this frequency, is provided by a hairpin loop which is attached to a front-panel

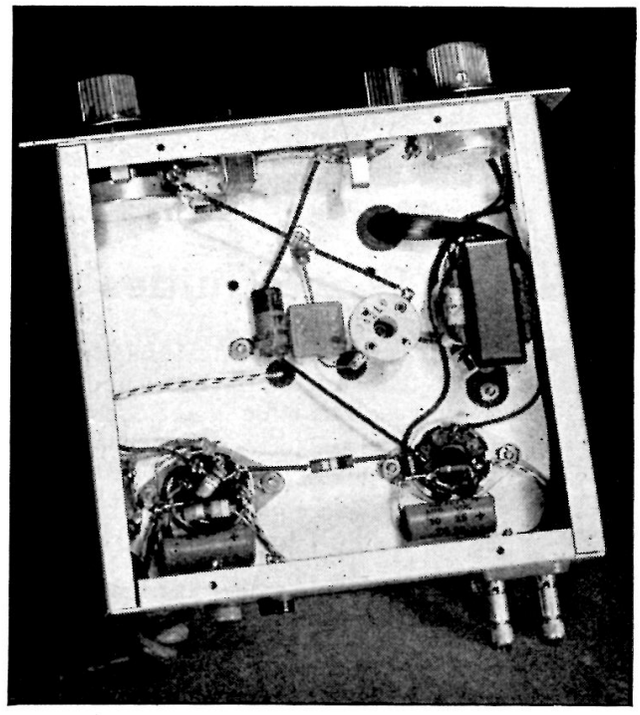


Fig. 15-27 — Bottom view of the 420-Mc. receiver. Loudspeaker terminals are at the lower left. At the right are the antenna terminals, from which a length of 300-ohm line runs up through the chassis to the antenna coupling loop.

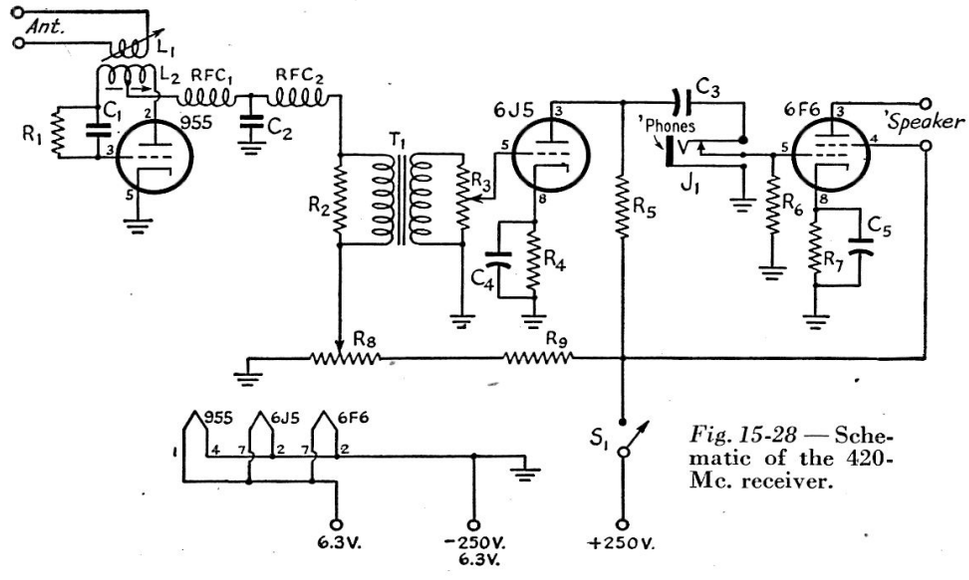


Fig. 15-28 — Schematic of the 420-Mc. receiver.

C_1 — 47-$\mu\mu$fd. trimmer (National XLA-C).
C_2 — 0.0033-μfd. mica.
C_3 — 0.01-μfd. 400-volt paper.
C_4, C_5 — 10-μfd. 25-volt electrolytic.
R_1 — 1.2 megohms, ½ watt.
R_2 — 47,000 ohms, ½ watt.
R_3 — 0.5-megohm potentiometer.
R_4 — 2200 ohms, ½ watt.
R_5, R_6 — 0.1 megohm, ½ watt.
R_7 — 470 ohms, 1 watt.
R_8 — 50,000-ohm potentiometer.
R_9 — 22,000 ohms, ½ watt.
L_1 — Hairpin loop; No. 12 wire with an inside diameter of ⅜ inch and a length of 2½ inches.
L_2 — Hairpin loop; No. 12 wire with an inside diameter of ½ inch and a length of 2 inches. Vane-tuned — see text and photograph.
J_1 — Closed-circuit jack.
RFC_1 — 4-μh. r.f. choke (Millen 34300).
RFC_2 — 10-mh. r.f. choke (Millen 34210).
S_1 — S.p.s.t. toggle switch.
T_1 — Interstage transformer.

control in a manner that will be clear from the front- and rear-view photographs. A length of 300-ohm line runs from the hairpin through a hole in the chassis to the antenna terminals on the back of the chassis.

Critical points in attaining smooth operation of the detector are the values of R_1, C_2 and R_2, and the condition of the 955 tube. Tubes which work satisfactorily on lower frequencies may fail to operate entirely on 420 Mc. The addition of r.f. chokes in the heater and cathode leads may be necessary in some cases. They should be similar to those used in the 420-Mc. transmitter.

Wave Guides and Cavity Resonators

A wave guide is a conducting tube through which energy is transmitted in the form of electromagnetic waves. The tube is not considered as carrying a current in the same sense that the wires of a two-conductor line do, but rather as a *boundary* which confines the waves to the enclosed space. Skin effect prevents any electromagnetic effects from being evident outside the guide. The energy is injected at one end, either through capacitive or inductive coupling or by radiation, and is received at the other end. The wave guide then merely confines the energy of the fields, which are propagated through it to the receiving end by means of reflections against its inner walls.

The difficulty of visualizing energy transfer without the usual closed circuit can be relieved somewhat by considering the guide as being evolved from an ordinary two-conductor line.

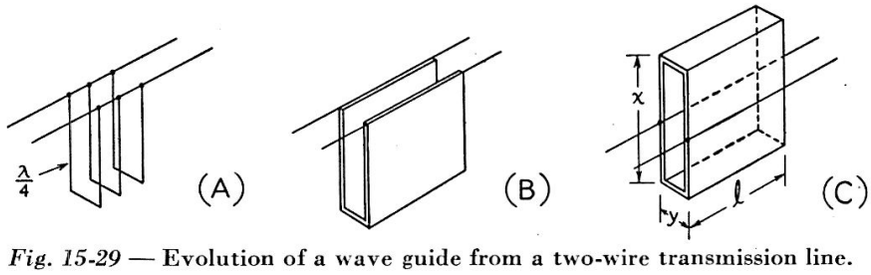


Fig. 15-29 — Evolution of a wave guide from a two-wire transmission line.

In Fig. 15-29A, several closed quarter-wave stubs are shown connected in parallel across a two-wire transmission line. Since the open end of each stub is equivalent to an open circuit, the line impedance is not affected by their presence. Enough stubs may be added to form a "U"-shaped rectangular tube with solid walls, as at B, and another identical "U"-shaped tube may be added edge-to-edge to form the rectangular pipe shown in Fig. 15-29C. As before, the line impedance still will not be affected. But now, instead of a two-wire transmission line, the energy is being conducted within a hollow rectangular tube.

This analogy to wave-guide operation is not exact, and therefore should not be taken too literally. In the evolution from the two-wire line to the closed tube the electric and magnetic field configurations undergo considerable change, with the result that the guide does not actually operate like a two-conductor line shunted by an infinite number of quarter-wave stubs. If it did, only waves of the proper length to correspond to the stubs would be propagated through the tube, but the fact is that such waves do *not* pass through the guide. Only waves of shorter length — that is, higher frequency — can go through. The distance x represents half the *cut-off wavelength*, or the shortest wavelength that is unable to go through the guide. Or, to put it another way, waves of length equal to or greater than $2x$ cannot be propagated in the guide.

A second point of difference is that the apparent length of a wave along the direction of propagation through a guide always is greater than that of a wave of the same frequency in free space, whereas the wavelength along a two-conductor transmission line is the same as the free-space wavelength (when the insulation between the wires is air).

Operating Principles of Wave Guides

Analysis of wave-guide operation is based on the assumption that the guide material is a perfect conductor of electricity. Typical distributions of electric and magnetic fields in a rectangular guide are shown in Fig. 15-30. It will be observed that the intensity of the electric field is greatest at the center along the x dimension, diminishing to zero at the end walls. The latter is a necessary condition, since the existence of any electric field parallel to the walls at the surface would cause an infinite current to flow in a perfect conductor. This represents an impossible situation.

Zero electric field at the end walls will result if the wave is considered to consist of two separate waves moving in zigzag fashion down the guide, reflected back and forth from the end walls as shown in Fig. 15-31. Just at the walls, the positive crest of one wave meets the negative crest of the other, giving complete cancellation of the electric fields. The angle of reflection at which this cancellation occurs depends upon the width x of the guide and the length of the waves; Fig. 15-31A illustrates the case of a wave considerably shorter than the cut-off wavelength, while B shows a longer wave. When the wavelength equals the cut-off value, the two waves simply bounce back and forth between the walls and no energy is transmitted through the guide.

The two waves travel with the speed of light, but since they do not travel in a straight line the energy does not travel through the guide as rapidly as it does in space. A further conse-

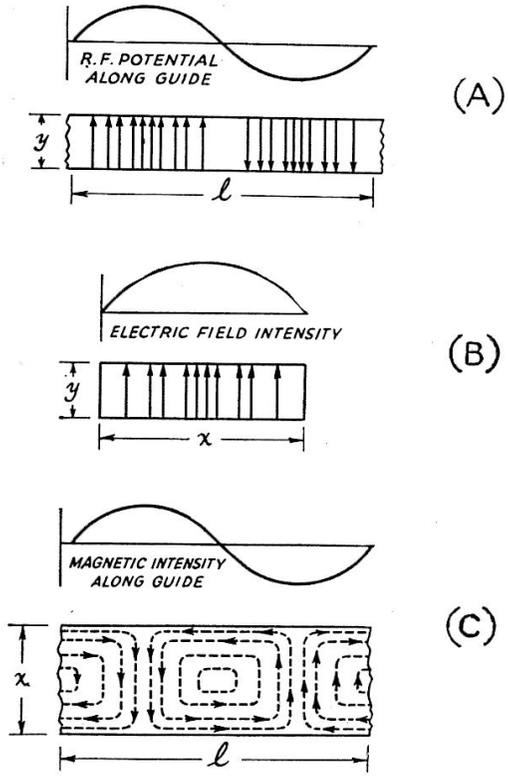


Fig. 15-30 — Field distribution in a rectangular wave guide. The $TE_{1,0}$ mode of propagation is depicted.

quence of the repeated reflections is that the points of maximum intensity or wave crests are separated more along the line of propagation in the guide than they are in the two separate waves. In other words, the wavelength in the guide is greater than the free-space wavelength. This is also shown in Fig. 15-31.

Modes of Propagation

Fig. 15-30 represents a relatively simple distribution of the electric and magnetic fields. There is in general an infinite number of ways in which the fields can arrange themselves in a guide so long as there is no upper limit to the frequency to be transmitted. Each field configuration is called a *mode*. All modes may be separated into two general groups. One group, designated *TM* (*transverse magnetic*), has the magnetic field entirely transverse to the direction of propagation, but has a component of electric field in that direction. The other type, designated *TE* (*transverse electric*) has the electric field entirely transverse, but has a component of magnetic field in the direction of propagation. TM waves are sometimes called *E* waves, and TE waves are sometimes called *H* waves, but the TM and TE designations are preferred.

The particular mode of transmission is identified by the group letters followed by two subscript numerals; for example, $TE_{1,0}$, $TM_{1,1}$, etc. The number of possible modes increases with frequency for a given size of guide. There is only one possible mode (called the *dominant* mode) for the lowest frequency that can be transmitted. The dominant mode is the one generally used in practical work.

Wave-Guide Dimensions

In the rectangular guide the critical dimension is x in Fig. 15-29; this dimension must be more than one-half wavelength at the lowest frequency to be transmitted. In practice, the y dimension usually is made about equal to $\frac{1}{2}x$ to avoid the possibility of operation at other than the dominant mode.

Other cross-sectional shapes than the rectangle can be used, the most important being the circular pipe. Much the same considerations apply as in the rectangular case.

Wavelength formulas for rectangular and circular guides are given in the following table, where x is the width of a rectangular guide and r is the radius of a circular guide. All figures are in terms of the dominant mode.

	Rectangular	*Circular*
Cut-off wavelength	$2x$	$3.41r$
Longest wavelength transmitted with little attenuation	$1.6x$	$3.2r$
Shortest wavelength before next mode becomes possible	$1.1x$	$2.8r$

Cavity Resonators

At low and medium radio frequencies resonant circuits usually are composed of "lumped" constants of L and C; that is, the inductance is concentrated in a coil and the capacitance concentrated in a condenser. However, as the frequency is increased, coils and condensers must be reduced to impracticably small physical dimensions. Up to a certain point this difficulty may be overcome by using linear circuits but even these fail at extremely high frequencies. Another kind of circuit particularly applicable at wavelengths of the order of centimeters is the *cavity resonator*, which may be looked upon as a section of a wave guide with the dimensions chosen so that waves of a given length can be maintained inside.

The derivation of one type of cavity resonator from an ordinary LC circuit is shown in Fig. 15-32. As in the case of the wave-guide derivation, this picture must be accepted with some reservations, and for the same reasons.

Considering that even a straight piece of wire has appreciable inductance at very-high fre-

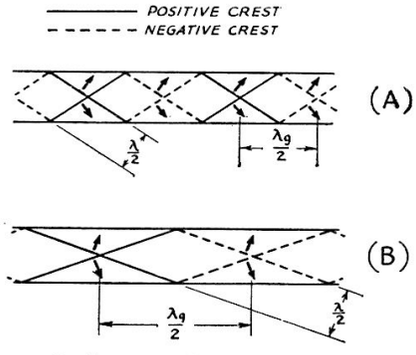


Fig. 15-31 — Reflection of two component waves in a rectangular guide. λ = wavelength in space, λg = wavelength in guide. Direction of wave motion is perpendicular to the wave front (crests) as shown by the arrows.

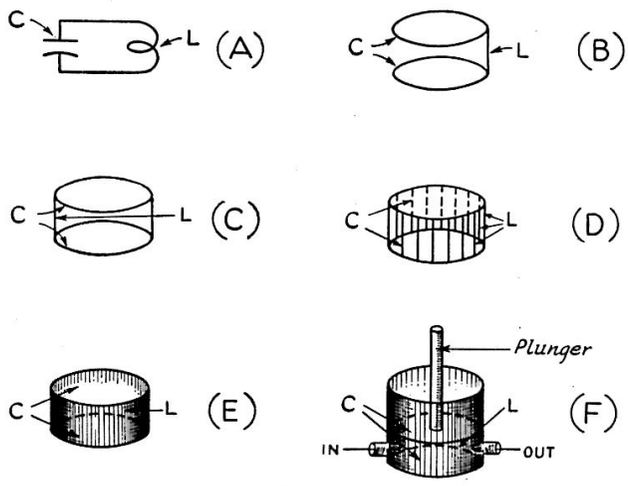


Fig. 15-32 — Steps in the derivation of a cavity resonator from a conventional coil-and-condenser tuned circuit.

quencies, it may be seen in Fig. 15-32A and B that a direct short across a two-plate condenser with air dielectric is the equivalent of a tuned circuit with a typical coiled inductance. With two wires between the plates, as shown in Fig. 15-32C, the circuit may be thought of as a resonant-line section. For d.c. or even low frequency r.f., this line would appear as a short across the two condenser plates. At the ultra-high frequencies, however, such a section of line a quarter wavelength long would appear as an open circuit when viewed from one of the plates with respect to the other end of the section.

Increasing the number of parallel wires between the plates of the condenser would have no effect on the equivalent circuit, as shown at D. Eventually, the closed figure at E will be developed. Since each wire which is added in D is like connecting inductances in parallel, the total inductance across the condenser becomes increasingly smaller as the solid form is approached, and the resonant frequency of the figure therefore becomes higher.

If energy now is introduced into the cavity in a manner such as that shown at F, the circuit will respond like any equivalent coil-condenser tank circuit at its resonant frequency. A cavity resonator may therefore be used as a u.h.f. tuning element, along with a vacuum tube of suitable design, to form the main components of an oscillator circuit which will be capable of functioning at frequencies considerably beyond the maximum limits possible when conventional tubes, coils and condensers are employed.

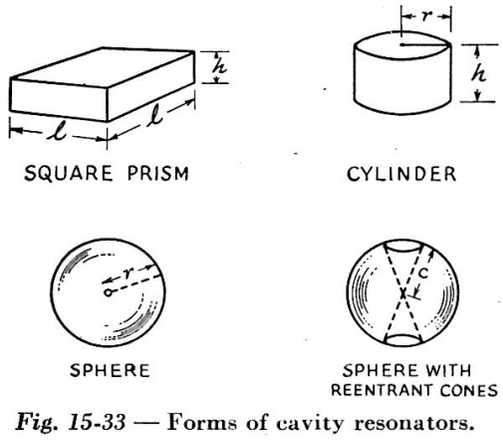


Fig. 15-33 — Forms of cavity resonators.

Other shapes than the cylinder may be used as resonators, among them the rectangular box, the sphere, and the sphere with re-entrant cones, as shown in Fig. 15-33. The resonant frequency depends upon the dimensions of the cavity and the mode of oscillation of the waves (comparable to the transmission modes in a wave guide). For the lowest modes the resonant wavelengths are as follows:

Cylinder	$2.61r$
Square box	$1.41l$
Sphere	$2.28r$
Sphere with re-entrant cones	$4r$

The resonant wavelengths of the cylinder and square box are independent of the height when the height is less than a half-wavelength. In other modes of oscillation the height must be a multiple of a half-wavelength as measured inside the cavity. Fig. 15-32F shows how a cylindrical cavity can be tuned when operating in such a mode. Other tuning methods include placing adjustable tuning paddles or "slugs" inside the cavity so that the standing-wave pattern of the electric and magnetic fields can be varied.

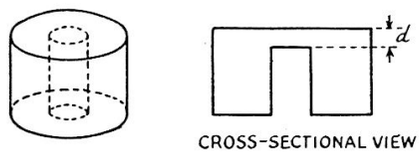


Fig. 15-34 — Re-entrant cylindrical cavity resonator.

A form of cavity resonator in wide practical use is the re-entrant cylindrical type shown in Fig. 15-34. It is useful in connection with vacuum-tube oscillators of the types described for u.h.f. use earlier in this chapter. In construction it resembles a concentric line closed at both ends with capacitance loading at the top, but the actual mode of oscillation may differ considerably from that occurring in coaxial lines. The resonant frequency of such a cavity depends upon the diameters of the two cylinders and the distance d between the ends of the inner and outer cylinders.

Compared to ordinary resonant circuits, cavity resonators have extremely-high Q. A value of Q of the order of 1000 or more is readily obtainable, and Q values of several thousand can readily be secured with good design and construction.

Coupling to Wave Guides and Cavity Resonators

Energy may be introduced into or abstracted from a wave guide or resonator by means of either the electric or magnetic field. The energy transfer frequently is through a coaxial line, two methods for coupling to which

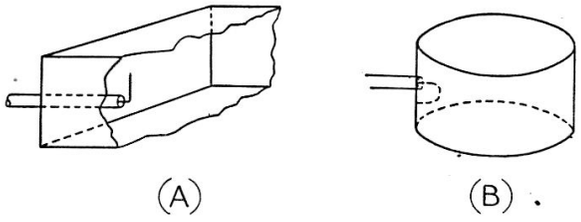


Fig. 15-35 — Coupling to wave guides and resonators.

are shown in Fig. 15-35. The probe shown at A is simply a short extension of the inner conductor of the coaxial line, so oriented that it is parallel to the electric lines of force. The loop shown at B is arranged so that it encloses some of the magnetic lines of force. The point at which maximum coupling will be secured depends upon the particular mode of propagation in the guide or cavity; the coupling will be maximum when the coupling device is in the most intense field.

Coupling can be varied by turning either the probe or loop through a 90-degree angle. When the probe is perpendicular to the electric lines the coupling will be minimum; similarly, when the plane of the loop is parallel to the magnetic lines the coupling will have its least possible value.

Amateur Microwave Technique

All the microwave bands allotted to amateurs have been used experimentally for communication purposes. Complete description of the equipment used is beyond the scope of this text, but reference is made to various articles which have appeared in *QST*, describing the gear devised by the amateur pioneers in this field.

For the experimentally inclined, our microwave assignments represent a challenge to amateur ingenuity. Who can say but greater use of these frequencies will repeat past history, turning up propagation peculiarities and potential uses which will make these bands as coveted a region as our "communication frequencies" are considered today?

The first amateur microwave communication was carried on by Merchant and Harrison, W6BMS/2 and W2LGF, who assembled the gear shown in Fig. 15-36 in time to communicate with each other on November 15, 1945 — the date that the microwave bands were officially opened to amateur experimentation. They used two klystron tubes, one as a frequency-modulated transmitter oscillator, the other as a local oscillator for receiving. The latter worked in conjunction with a crystal mixer, into a 30-Mc. i.f. in the form of an FM receiver.

The 2300-Mc. amateur assignment was first used for communication by Koch and Floyd, W9WHM/2 and W6OJK/2, who used lighthouse tubes in simple transceivers, both of which are shown in Fig. 15-37. Their antenna systems used parabolic reflectors, one being made of wire screening attached to a wooden frame, and the other, also shown in the photograph, was simply an electric-heater assembly, with the microwave dipole substituted for the heater element.

Amateur communication on 10,000 Mc. was first accomplished by Atwater and McGregor, W2JN and W2RJM, who modified 723-A/B klystrons to permit their operation in the amateur band. They are shown, with one of their equipment set-ups, in Fig. 15-38. A somewhat similar arrangement was used by W4HPJ/3 and W6IFE/3 to extend the distance record, and has since been employed by W6IFE in opening the 3300-Mc. band to amateur use, except that the tube used in the latter instance was a 707-B with an external cavity.

The highest frequency ever used in amateur work is 21,000 Mc., first employed by Sharbaugh and Watters, W1NVL/2 and W9SAD/2, whose laboratory set-up is shown in Fig. 15-39. The r.f. generator, for transmitting and receiving, was a developmental tube designated as the Z-668, a velocity-modulated tube of the reflex type. Communication was carried on, two-way, over a distance of 800 feet.

A list of *QST* references, arranged according to the amateur band concerned, follows. It should be emphasized that the equipment

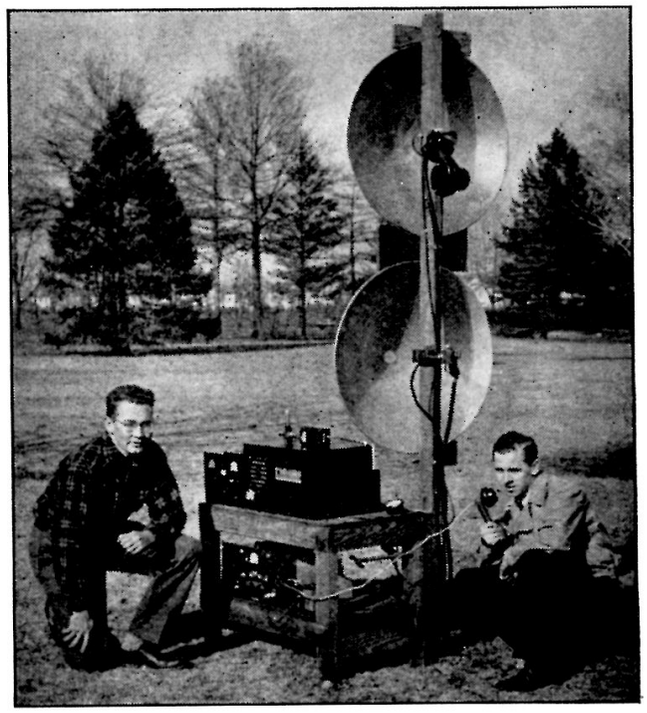


Fig. 15-36 — The first amateur microwave communication was accomplished by W6BMS (left) and W2LGF, who used two sets of similar equipment to open the 5300-Mc. amateur band on November 15, 1945, the date that the first microwave bands were released for amateur use.

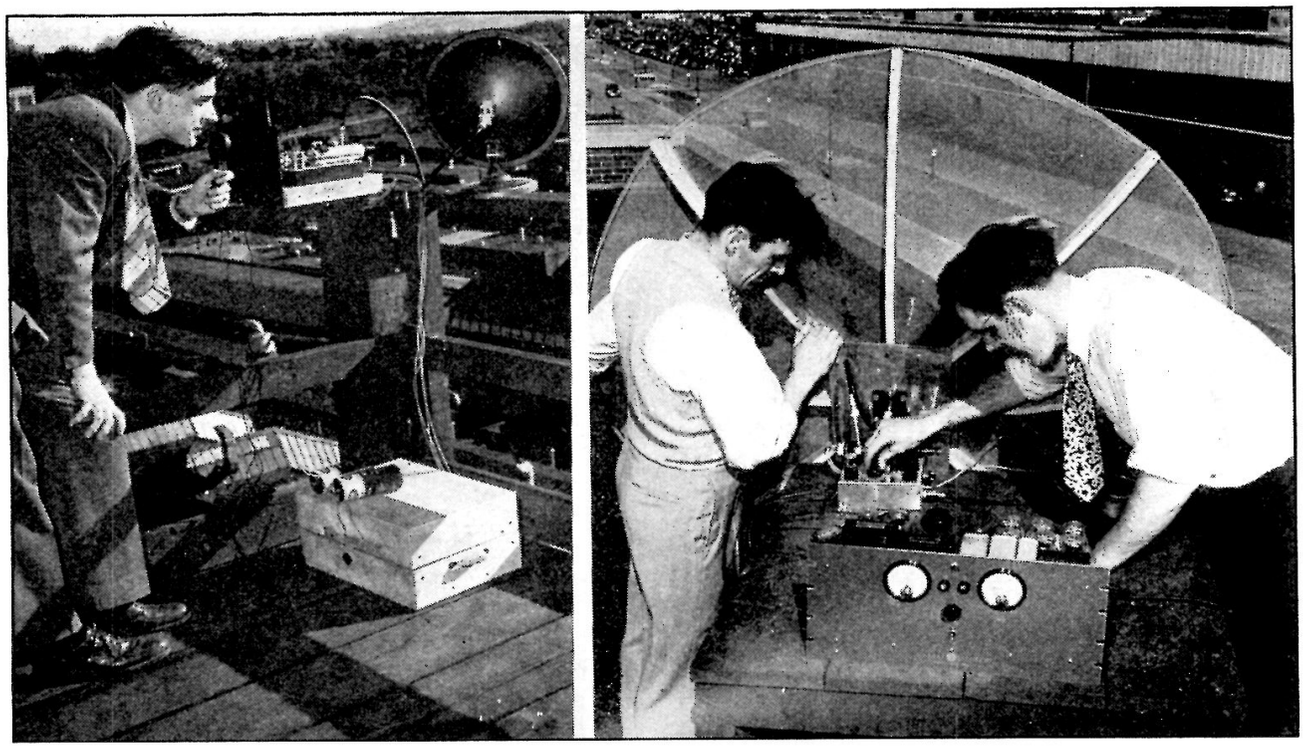


Fig. 15-37 — The 2300-Mc. band was first employed for amateur communication by W6OJK (left) and W9WHM (extreme right). Antenna systems employed a standard electric-heater unit and a handmade screen-lined parabola.

described in these reports is experimental in nature. In most instances it represents only one of several ways in which microwave communication equipment might be built. The distances covered in the pioneering work just mentioned are not, for the most part, indicative of the maximum working range, since exploration of the particular band in question was the end in view when the experiments were conducted, rather than the covering of any long distances.

Bibliography

1215 Mc. — "World Above 50 Mc." (W1BBM), May 1947 *QST*, page 136. Also July 1947 *QST*, page 136.

2300 Mc. — Koch and Floyd, "CQ — 2400 Mc.," July 1946 *QST*, page 32. Also "World Above 50 Mc." (W6IFE), Aug. 1947 *QST*, page 128.

3300 Mc. — "World Above 50 Mc." (W6IFE), Aug. 1947 *QST*, page 128.



Fig. 15-38 — W2RJM (left) and W2JN, with one of the equipments used in pioneering work on 10,000 Mc.

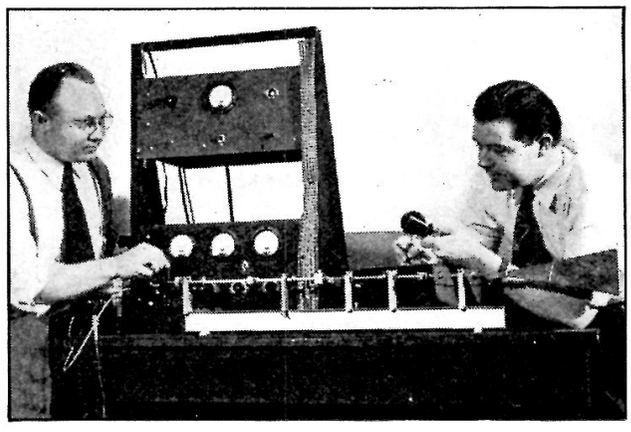


Fig. 15-39 — W1NVL (left) and W9SAD with the equipment used to work a distance of 800 feet on the highest frequency ever used for amateur communication — 21,000 Mc. Antenna systems employed a parabolic reflector at one end and a horn radiator at the other.

5250 Mc. — Merchant and Harrison, "Duplex 'Phone on 5300 Mc.," Jan. 1946 *QST*, page 19.

10,000 Mc. — McGregor and Atwater, "Dishing Out the Milliwatts on 10 KMc.," Feb. 1947 *QST*, page 58. Also "World Above 50 Mc." (W4HPJ/3, W6IFE/3), Sept. 1946 *QST*, page 152.

21,000 Mc. — Sharbaugh and Watters, "Our Best DX — 800 Feet!" Aug. 1946 *QST*, page 19.

CHAPTER 16

Measuring Equipment

To comply with FCC regulations it is necessary that the amateur station be equipped to make a few relatively simple measurements. For example, the regulations require that means be available for checking the transmitter frequency to make sure that it is inside the band. This means must be independent of the frequency control of the transmitter itself; it is not enough to depend on, say, the calibration of a crystal in the crystal-controlled oscillator that drives the transmitter. In addition, it is necessary to make sure that the plate power input to the final stage of the transmitter does not exceed one kilowatt. The regulations also impose certain requirements with respect to plate-supply filtering, stability and purity of the transmitted signal, and depth of modulation in the case of 'phone transmission.

In many cases all these measurements can be made to a satisfactory degree of accuracy with no more auxiliary equipment than the regular station receiver. However, a better job usually can be done by building and calibrating some relatively simple test gear. Too, the progressive amateur is interested in instruments as an aid to better performance.

Frequency Measurement

Frequency-measuring equipment can be divided into two broad classes: oscillators of various types generating signals of known frequency that can be compared with the signal whose frequency is unknown, and adjustable resonant circuits.

Instruments in the first classification are the more accurate. Two types are commonly used by amateurs, the **secondary frequency standard** and the **heterodyne frequency meter.** The secondary frequency standard, nearly always crystal-controlled, usually generates a frequency of 100 kc. and employs a circuit that is rich in harmonic output. As a result, it supplies a series of frequencies, all multiples of 100 kc., which provides accurate calibration points throughout the communications spectrum. The more elaborate instruments of this type are provided with frequency dividers (multivibrators) to supply intermediate calibration points; a divisor commonly used is 10, thus furnishing signals at intervals of 10 kc. when the fundamental frequency is 100 kc.

The heterodyne frequency meter is a variable-frequency oscillator which is calibrated in frequency against a secondary standard or by other means. The oscillator usually is designed to cover the lowest frequency band in which measurements are to be made; measurements then can be made in higher-frequency bands by using the harmonic output of the oscillator. For example, when the oscillator is set to 3560 kc. its second harmonic is 7120 kc., its fourth harmonic is 14,240 kc., and so on. The proper frequency reading is determined by knowing the fundamental frequency of the oscillator and the number of the harmonic that falls in the desired frequency range.

Both the secondary standard and the heterodyne meter are ordinarily used in conjunction with a receiver, the signals from the instruments being picked up just as though they were from distant stations. In the case of the secondary standard, the frequency of the unknown signal can be determined by locating it between two known 100-kc. or 10-kc. multiples. With the heterodyne meter, the frequency is measured by adjusting the frequency meter until its signal is at zero beat with the signal of unknown frequency, after which the frequency can be read from the frequency-meter calibration.

Since the secondary standard operates on a fixed frequency and can be crystal-controlled, its accuracy can be quite high. However, it simply establishes a series of known frequencies at regular intervals, and thus auxiliary methods must be used for determining frequencies between the known points. The series of fixed frequencies, when they mark the edges of amateur bands (as they do if they are multiples of 100 kc.), is quite sufficient for amateur work because the information that is required is whether or not the transmitter frequency is *inside* the band limits, rather than the exact frequency itself. On the other hand, the heterodyne frequency meter, while capable of giving readings at any point in its calibrated range, is inherently less accurate than the crystal-controlled standard because of the lower stability of the variable-frequency oscillator.

In the absence of more elaborate frequency-measuring equipment, a calibrated receiver may be used to indicate the approximate frequency of the transmitter. If the receiver is well made and has good inherent stability, a

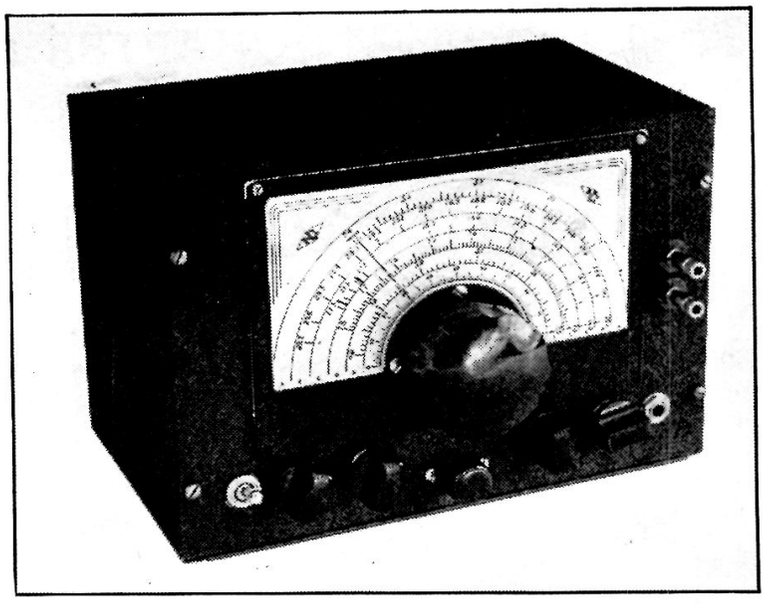


Fig. 16-1 — Heterodyne frequency meter with built-in harmonic amplifier, crystal calibrator, and detector, usable on all amateur bands up to 144 Mc. Controls along the bottom of the panel are, from left to right, crystal-oscillator on-off switch, 100/1000-kc. crystal-selector switch, calibration range switch, drift compensator, harmonic-amplifier range switch, output control, headphone jack. The two output terminals are along the right-hand edge.

bandspread dial calibration can be relied upon to within perhaps 0.2 per cent. For most accurate measurement maximum response in the receiver should be determined by means of a carrier-operated tuning indicator (such as an S-meter), the receive beat oscillator being turned off.

When checking the transmitter frequency the receiving antenna should be disconnected, so that the signal will not overload or "block" the receiver. If the receiver still blocks without an antenna the frequency may be checked by turning off the power amplifier and tuning in the oscillator alone.

HETERODYNE FREQUENCY METER AND CRYSTAL CALIBRATOR

The basis of the heterodyne frequency meter is a completely-shielded oscillator with a precise frequency calibration. The oscillator must be so designed and constructed that it can be accurately calibrated and will retain its calibration over long periods of time.

The oscillator used in the frequency meter must be very stable. Mechanical considerations are most important in its construction. No matter how good the instrument may be electrically, its accuracy cannot be depended upon if the mechanical construction is flimsy. Inherent frequency stability can be improved by avoiding the use of phenolic compounds and thermoplastics (bakelite, polystyrene, etc.) in the oscillator circuit, employing only high-grade ceramics instead. Plug-in coils ordinarily are not acceptable; instead, a solidly-built and firmly-mounted tuned circuit should be permanently installed. The oscillator panel and chassis should be as rigid as possible.

A stable oscillator circuit suitable for use in a heterodyne frequency meter is the electron-coupled circuit. It is possible to take output from the plate with but negligible effect on the frequency of the oscillator, and strong harmonics are generated in the plate circuit.

The heterodyne frequency meter shown in Figs. 16-1 to 16-4, inclusive, combines a number of features that make it suitable for accurate frequency measurement in the amateur bands from 3.5 to 144 Mc. As shown in the circuit diagram, Fig. 16-3, it consists of a 6SK7 electron-coupled oscillator followed by a 6AC7 amplifier that is used to intensify the higher-frequency harmonics. A second 6SK7 oscillator, using a crystal of the type that operates at either 100 or 1000 kc., provides check-points and a means for calibration of the frequency meter. A 6SL7 is incorporated to amplify the crystal harmonics and to provide a detector circuit in which the outputs of the crystal and e.c. oscillators can be mixed for calibration purposes. The detector also enables direct checking of the transmitter frequency.

The fundamental tuning range of the heterodyne oscillator is from 3500 to 4000 kc. By means of S_1 this range can be changed to 3500–3720 kc., approximately, so that the eighth harmonic just covers the 28–29.7-Mc. band. This avoids excessively critical tuning at the higher frequencies. The main tuning condenser, C_2, is connected across all of L_1 for the larger range and is connected to a tap on L_1 for the smaller to increase the bandspread. Simultaneously, an adjustable padding condenser, C_1, is switched in so that the oscillator frequency will be exactly 3500 kc. with C_2 set at maximum capacitance regardless of the switch position. C_4 is a fixed padding condenser to make the circuit fairly high C, and C_5 is the band-setting condenser. C_3 is a small padder adjustable from the panel; its function is to permit resetting the oscillator frequency to the calibration points provided by the crystal oscillator and thus take care of drift effects.

The 6AC7 plate circuit is broadly tuned by means of switched coils resonating, with the circuit capacitances, at 144, 50 and 28 Mc., and thus increases the harmonic strength on those bands. A radio-frequency choke is connected to the fourth switch position; this gives ample signal strength at 14 Mc. and lower frequencies. R_5 makes it possible to reduce the strength of the signal from the meter to the value desired for measurement purposes.

In the crystal-oscillator circuit, S_2 changes the frequency from 100 to 1000 kc. or vice versa. In the 100-kc. position C_{14} is connected across the crystal to provide means for adjusting the frequency to exactly 100 kc.

WWV SCHEDULES

Standard radio and audio frequencies are broadcast from WWV, the station of the Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C., on the following schedule:

Freq. in Mc.	*Time, EST*	*Modulation, c.p.s.*
2.5	7 P.M. to 9 A.M.	1 and 440
5	7 P.M. to 7 A.M.	1 and 440
5	7 A.M. to 7 P.M.	1, 440 and 4000
10	Continuously	1, 440 and 4000
15	Continuously	1, 440 and 4000
20	Continuously	1, 440 and 4000
25	Continuously	1, 440 and 4000
30	Continuously	1 and 440
35	Continuously	1

The 1-c.p.s. modulation is a 0.005-second pulse, the beginning of which marks each second to an accuracy of one part in 1,000,000. The pulse is omitted on the 59th second of every minute.

The accuracy of the radio and audio frequencies is within one part in 50,000,000. The audio frequencies are interrupted exactly on the hour and each five minutes thereafter; they are resumed in precisely one minute. During each silent interval the time is given in telegraphic code. A station announcement is given in voice on the hour and half hour.

As shown in Figs. 16-2 and 16-4, the frequency meter is built on a chassis folded from a piece of sheet aluminum, the dimensions being 9 inches wide by 5½ inches deep by 2 inches high. Half-inch lips are bent along the bottom edges of the walls to make the chassis more rigid. The cabinet into which the meter fits is 10 × 7 × 6 inches. The main tuning condenser, C_2, is mounted on an aluminum bracket above the chassis and the coil, L_1, is similarly mounted below it. The band-setting condenser, C_5, is mounted on the chassis behind the coil, with its shaft protruding through the chassis for screwdriver adjustment. Trimmer C_3 is mounted on the panel and is adjusted by a knob underneath the main tuning dial. The coil is shielded from the amplifier section by the small aluminum baffle shown in Fig. 16-4. The bandspread padder, C_1, is mounted to the left of the oscillator range switch and, like C_5, is screwdriver-adjusted from the top of the chassis. Wiring in the oscillator tuned circuit, including the switch, should be short, direct, and as rigid as possible.

The 100-kc. oscillator trimmer, C_{14}, does not require frequent adjustment and is therefore mounted on the rear edge of the chassis, close to the crystal unit. C_{16}, the plate tuning condenser for 1000 kc., is adjusted from the top of the chassis and is mounted to the right of the crystal-oscillator socket in Fig. 16-4.

In putting the instrument into operation, the crystal oscillator should be checked first. Connect a length of wire to the crystal output terminal (from C_{18}) and listen on a receiver over the range from 3.5 to 5 Mc. With S_2 in the 1000-kc. position, signals should appear at 4000 and 5000 kc., and with S_2 in the 100-kc. position signals should be heard every 100 kc. Tune in WWV on 5000 kc., wait for the modulation to go off, and then adjust C_{14} for zero beat. This sets the oscillator to precisely 100 kc. In the 1000-kc. position there may be a difference of a few kilocycles between the frequency of WWV and the 5-Mc. harmonic, but this is not a serious condition since the 1000-kc. crystal oscillator is used only as an aid in identification of the 100-kc. harmonics.

To set the range of the e.c. oscillator, put S_2 in the 1000-kc. position, plug a pair of 'phones into J_1, set S_2 on the maximum range position (C_2 across all of L_1), and set C_2 near minimum capacitance. Adjust C_5 until the 4000-kc. harmonic is heard. Then switch S_2 to 100 kc. and tune C_2 toward maximum, counting off five additional 100-kc. signals. C_5 may then be readjusted to bring the 3500-kc. marker close to the end of the tuning-dial scale. The 100-kc. points may then be marked off on the scale or the readings recorded. The second tuning range is adjusted by setting C_2 at 3500 kc. on the *first* range, then setting S_1 so that C_2 is connected to the tap, and adjusting C_1 (without touching C_2) so that the 3500-kc. marker is brought to the same point on the dial. The second range may be calibrated by the 100-kc. points in the same way as the first.

Calibration points may be obtained between the 100-kc. markers on both ranges by

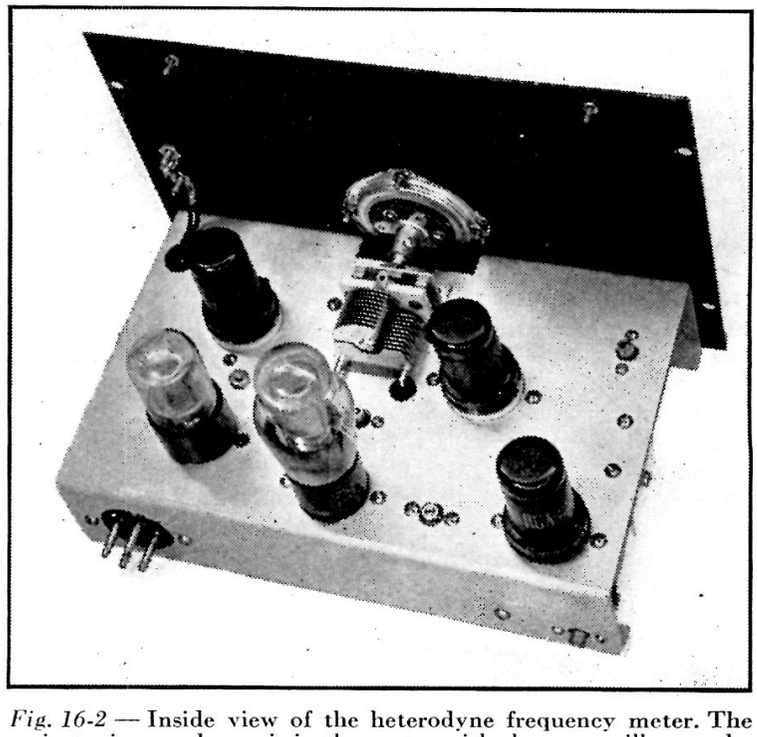


Fig. 16-2 — Inside view of the heterodyne frequency meter. The main tuning condenser is in the center with the e.c. oscillator tube to its right. The crystal-oscillator tube is at the upper left, and the twin-triode amplifier-detector is in line with it at the rear edge (foreground) of the chassis. The 6AC7 is in the lower-right corner.

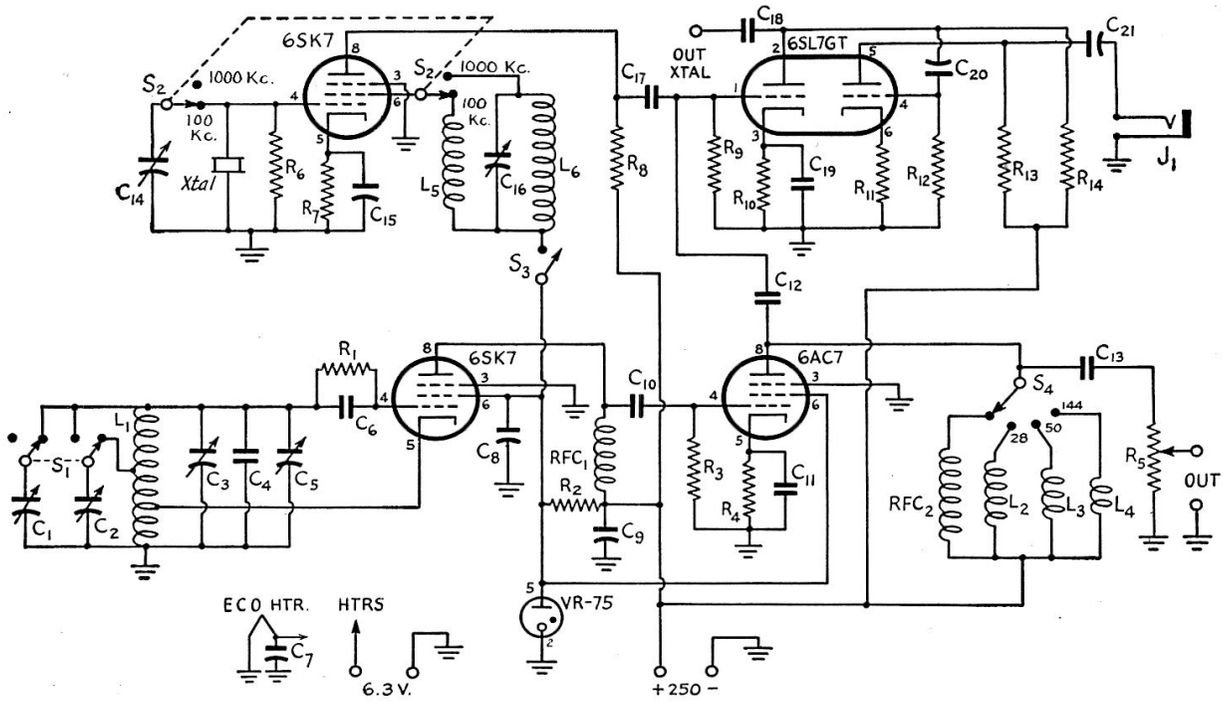


Fig. 16-3 — Circuit diagram of the heterodyne frequency meter.

C_1, C_5 — 75-$\mu\mu$fd. variable.
C_2, C_{16} — 100-$\mu\mu$fd. variable.
C_3, C_{14} — 25-$\mu\mu$fd. variable.
C_4 — 220-$\mu\mu$fd. mica.
C_6, C_{10}, C_{13} — 100-$\mu\mu$fd. mica.
C_7, C_8, C_9, C_{15}, C_{20}, C_{21} — 0.01-μfd. paper.
C_{11}, C_{19} — 470-$\mu\mu$fd. mica.
C_{12} — 10-$\mu\mu$fd. mica.
C_{17} — 0.001-μfd. mica.
C_{18} — 47-$\mu\mu$fd. mica.
R_1, R_3, R_9, R_{12} — 0.47 megohm, ½ watt.
R_2 — 10,000 ohms, 1 watt.
R_4 — 330 ohms, 1 watt.
R_5 — 25,000-ohm potentiometer.
R_6 — 4.7 megohms, ½ watt.
R_7 — 470 ohms, 1 watt.
R_8 — 0.22 megohm, 1 watt.
R_{10} — 10,000 ohms, 1 watt.
R_{11} — 1500 ohms, 1 watt.
R_{13}, R_{14} — 0.1 megohm, ½ watt.
L_1 — 18 turns No. 18 on 1-inch form, length 1½ inches. Cathode tap 5 turns from ground end; bandspread tap 11 turns from ground.
L_2 — 24 turns No. 18 enam. close-wound on ¼-inch form.
L_3 — 11 turns No. 18 enam. close-wound on ¼-inch form.
L_4 — 2 turns No. 16 spaced ½ inch, diameter ¼ inch.
L_5 — 8-mh. coil (r.f. choke).
L_6 — 1 pie of 4-pie 2.5-mh. r.f. choke.
J_1 — Open-circuit jack.
RFC_1, RFC_2 — 2.5-mh. r.f. choke.
S_1 — 2-position 2-pole ceramic wafer switch.
S_2 — 2-position 2-pole switch (bakelite insulation satisfactory).
S_3 — S.p.s.t. toggle.
S_4 — 4-position 1-pole ceramic wafer switch.
XTAL — 100/1000-kc. crystal unit (Bliley SMC-100).

using a receiver as an auxiliary. For example, if the receiver is adjusted to pick up the fifth harmonic of the e.c. oscillator (17.5 to 20 Mc.) and the harmonic is beat against 100-kc. points from the crystal oscillator in that range, 100-kc. intervals on the fifth harmonic will give 20-kc. intervals on the fundamental. With a straight-line capacitance condenser at C_2, the relationship between dial divisions and frequency is almost linear, and marking off the dial at the proper intervals between actual calibration points will result in a calibration of sufficient accuracy.

The various amateur bands are covered by the following harmonics: 3.5–4 Mc., fundamental; 7–7.3 Mc., 2nd harmonic; 14–14.4 Mc., 4th; 27.185–27.245 Mc., 7th; 28–29.7 Mc., 8th; 50–54 Mc., 14th; 144–148 Mc., 40th. At lower frequencies a short length of wire connected to the output terminal will give ample signal strength under average conditions, but in the v.h.f. range closer coupling — such as running the wire in close proximity to the receiving antenna lead, or actually connecting it to the antenna post through a small fixed condenser — may be necessary to get a good signal.

With an instrument of this type the edges of amateur bands may be quite accurately determined, if care is used in setting the 100-kc. oscillator to WWV and equal care is used in setting the e.c. oscillator scale to the 100-kc. crystal points. C_3 may be used for the latter purpose each time the meter is used, and particularly during the first 30 minutes or so of operation when the temperature of the equipment is rising. The accuracy at intermediate points will depend upon the accuracy of the original calibration; it should be possible to read within 0.05 per cent under normal conditions by using the "drift corrector," C_3.

ABSORPTION FREQUENCY METERS

The simplest possible frequency-measuring device is a resonant circuit, tunable over the desired frequency range and having its tuning dial calibrated in terms of frequency. Such a

frequency meter operates by extracting a small amount of energy from the oscillating circuit to be measured, the frequency then being determined by tuning the frequency-meter circuit to resonance and reading the frequency from the calibrated scale. This method is not capable of as high accuracy as the heterodyne methods for two reasons: First, the resonance indication is relatively "broad" as compared to the zero beat of a heterodyne; second, the necessarily close coupling between the frequency meter and the circuit being measured causes some detuning in both circuits, with the result that the calibration of the frequency-meter circuit depends to some degree on the coupling to the circuit being measured.

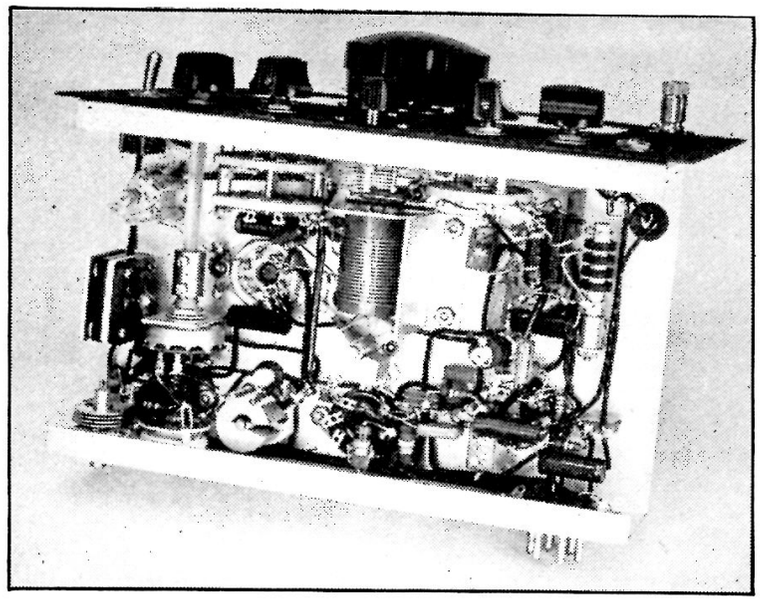


Fig. 16-4 — Underneath the chassis of the heterodyne frequency meter. The parts layout is discussed in the text.

It is necessary to have some means for indicating resonance with an absorption frequency meter. When such a meter is used for checking a transmitter, the plate current of the tube connected to the circuit being checked can provide the resonance indication. When the frequency meter is tuned through resonance the plate current will rise, and if the frequency meter is loosely coupled to the tank circuit the plate current will simply give a slight upward flicker as the meter is tuned through resonance. The greatest accuracy is secured when the loosest possible coupling is used.

A receiver oscillator may be checked by tuning in a steady signal and heterodyning it to give a beat-note as in ordinary c.w. reception. When the frequency meter is coupled to the oscillator coil and tuned through resonance the beat-note will change. Again, the coupling should be made loose enough so that a just-perceptible change in beat-note is observed when the meter is tuned through resonance.

Although the absorption-type frequency meter should not be depended upon for accurate measurement, it is a highly-useful instrument to have in the station even when better frequency-measuring equipment is available. Since it generates no harmonics itself, it will respond only to the frequency to which it is tuned. It is therefore indispensable for distinguishing between fundamental and various harmonics, and for detecting harmonics and parasitic oscillations. When provided with a sensitive resonance indicator it is also useful for detecting r.f. in undesired places such as power wiring, for making rough measurements of field strength in adjustment of antennas, and can likewise be used as a modulation monitor.

An approximate calibration — usually sufficient — may be obtained by comparison with a calibrated receiver. The usual receiver dial calibration is sufficiently accurate. A simple oscillator circuit covering the same range as the frequency meter will be useful in calibration. Set the receiver to a given frequency, tune the oscillator to zero beat at the same frequency, and adjust the frequency meter to resonance with the oscillator as described above. This gives one calibration point. When a sufficient number of such points has been obtained a graph may be drawn to show frequency *vs.* dial settings on the frequency meter.

● A SENSITIVE ABSORPTION FREQUENCY METER

Figs. 16-5 to 16-7, inclusive, show an absorption frequency meter or "wavemeter" with a crystal-detector/milliammeter resonance indicator that provides a relatively high degree of sensitivity. As shown in Fig. 16-6, a

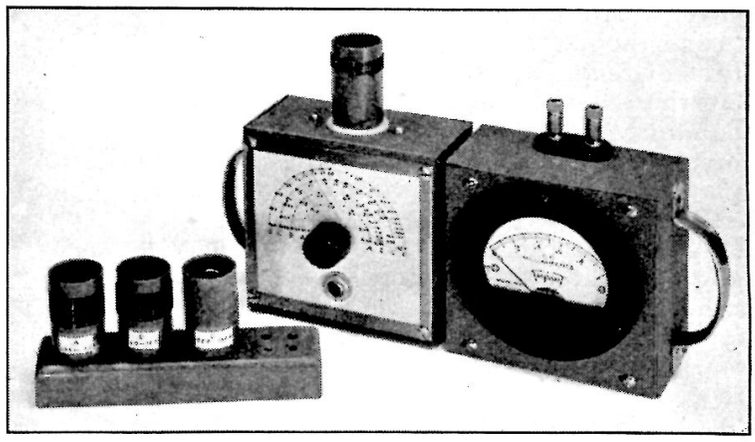


Fig. 16-5 — A sensitive absorption-type frequency meter with a crystal-detector rectifier and a d.c.-milliammeter indicating circuit. The meter is housed in a separate compartment so that it may be used with other measuring devices. The cabinet and front cover are drilled and tapped to accommodate the mounting screws for a large-size chart frame; frequency calibrations are marked on cardboard held in place by the chart frame. A short strip of wood, drilled to match the coil-form prongs, is used as a rack for the coils. Meter-box connections are shown in Fig. 16-15.

resonant circuit is connected in series with a crystal detector and a 0–1 milliammeter. The tank coil, L_1, serves as the pick-up coil, and the crystal is tapped down on the inductance in order to improve the sensitivity and selectivity of the meter. Plug-in coils are provided so that the unit covers a frequency range from about 1 megacycle to 165 megacycles. Any type of fixed crystal detector may be used, but the v.h.f. types are recommended. The meter box shown at the right in Fig. 16-5 is the same unit

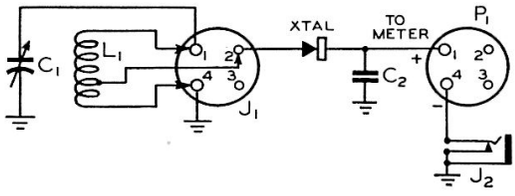


Fig. 16-6 — Circuit diagram of the absorption-type frequency meter.

C_1 — 140-$\mu\mu$fd. variable (Millen 22140).
C_2 — 0.0015-μfd. midget mica.
L_1 — 1.22–4.0 Mc.: 70 turns No. 32 enameled wire, 1-inch diam., ⅝ inch long. Tap 12½ turns from grounded end.
— 4.0–13.5 Mc.: 20 turns No. 20 enameled wire, 1-inch diam., 9/16 inch long. Tap 4½ turns from grounded end.
— 13.2–44.0 Mc.: 5 turns No. 20 enameled wire, 1-inch diam., 5/16 inch long. Tap 1½ turns from grounded end.
— 39.8–165 Mc.: Hairpin loop of No. 14 wire, ½-inch spacing, 2 inches long (total length including ends which fit down into the coil-form prongs). Tap 1⅝ inches from grounded end.
All four coils wound on Millen 45004 coil forms.
J_1 — 4-prong tube socket.
J_2 — Closed-circuit jack.
P_1 — 4-prong male plug.
XTAL — Type 1N34.

that is used with the volt-ohm-milliammeter described later in this chapter.

The frequency meter is housed in a 2 × 4 × 4-inch metal box, the milliammeter being mounted in a separate box of the same size. The coil socket is on the top near the front edge, with the tuning condenser just below it inside the case. This arrangement keeps the tuned-circuit leads short. A handle is mounted on the side of the box for convenience in handling. A headphone jack is provided for monitoring 'phone transmissions. The unit may be calibrated as described in the preceding section.

A two- or three-foot antenna rod may be added to the unit to permit using the instrument for field-strength measurements. The antenna should be connected to the top end of the tank coil, L_1. The rod antenna is not required for ordinary frequency measurement, and its use may be undesirable when the frequencies of individual simultaneously-operating circuits are to be checked — as in the case of a multistage transmitter with frequency multipliers — because the antenna increases the sensitivity to such an extent that it may be difficult to identify the output of a particular circuit. It may be convenient to interconnect the two units by means of a length of lamp cord or coaxial cable of any reasonable length (up to several hundred feet) when the meter is being used as a field-strength measuring device.

In addition to the uses mentioned in the preceding section, a meter of this type may be used for final adjustment of neutralization in r.f. amplifiers when loosely coupled to the plate tank coil.

LECHER WIRES

At very-high and ultrahigh frequencies it is possible to determine frequency by actually measuring the length of the waves generated. The measurement is made by observing standing waves on a two-wire parallel transmission line or **Lecher wires.** Such a line shows pronounced resonance effects, and it is possible to determine quite accurately the current loops (points of maximum current). The physical distance between two consecutive current loops is equal to one-half wavelength. Thus the wavelength can be read directly in meters (39.37 inches = 1 meter; 0.3937 inch = 1 cm.), or in centimeters for the very-short wavelengths.

The Lecher-wire line should be at least a wavelength long — that is, 7 feet or more on 144 Mc. — and should be entirely air-insulated except where it is supported at the ends. It may be made of copper tubing or of wires stretched tightly. The spacing between wires should be about one to one-and-one-half inches. The positions of the current loops are found by means of a "shorting bar," which is simply a metal strip or knife edge which can be slid along the line to vary its effective length. The system can be used more conveniently and with greater accuracy if it is built up in per-

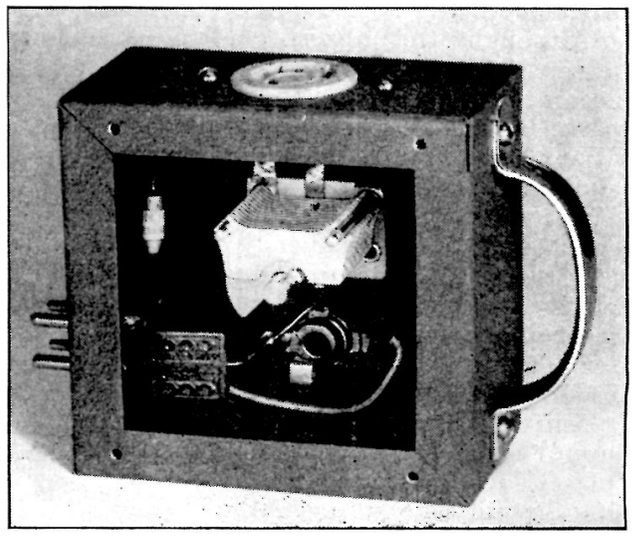


Fig. 16-7 — A rear view of the absorption-type frequency meter. The crystal is wired between the connector plug at the left and the coil socket at the top. The meter by-pass condenser is mounted between the plug and the grounded side of the 'phone jack. The variable-condenser terminals are connected directly to the coil socket.

manent fashion and provided with a shorting bar maintained at right angles to the wires (Fig. 16-8). The support may consist of two pieces of "1-by-2" pine fastened together with wood screws to form a "T"-girder, this arrangement being used to minimize bending of the wood when the wires are tightened.

A slider holds the shorting bar and acts as a guide to keep the wire spacing constant. A piece of wood held in the hand can be used; it is an easy matter to regulate the pressure so that free movement is secured. A spring device may be arranged for the same purpose.

For convenience in measuring lengths directly in the metric system used for wavelength, the supporting beam may be marked off in decimeter (10-centimeter) units. A 10-centimeter transparent scale (obtainable at 5 & 10 cent stores) may be cemented to the slider, extending out from the front, so that readings can be taken to the nearest millimeter. The difference between any two readings gives the half-wavelength directly.

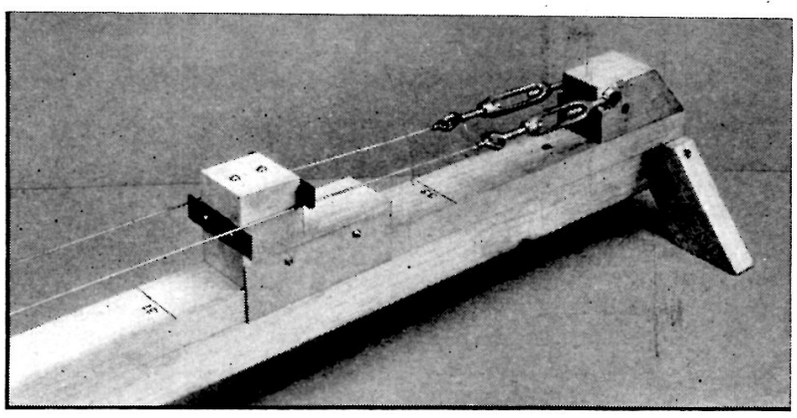


Fig. 16-8 — One end of a typical Lecher-wire system. The feet at each end keep the assembly from tipping over when in use. The wires terminate in airplane-type strain insulators at one end, and at the other in small turnbuckles for maintaining tension. The wire is No. 16 bare solid-copper antenna wire (hard-drawn). The turnbuckles are held in place by a 3/16 × 2-inch bolt through the anchor block. This end of the line is thus short-circuited; it does not matter whether it is open or shorted, since the other end is the one connected to the pick-up loop.

Making Measurements

Resonance indications can be obtained in several different ways. Let us suppose the frequency of a transmitter is to be measured. A convenient and fairly sensitive indicator can be made by soldering the ends of a one-turn loop of wire, of about the same diameter as the transmitter tank coil, to a low-current flashlight bulb, then coupling the loop to the tank coil to give a moderately bright glow. A similar coupling loop should be connected to the ends of the Lecher wires and brought near the tank coil, as shown in Fig. 16-9. Then the shorting bar should be slid along the wires outward from the transmitter until the lamp gives a sharp dip in brightness. This point should be marked and the shorting bar moved out until a second dip is obtained. Marking the second spot, the distance between the two points can be measured and will be equal to half the wavelength. If the measurement is made in inches, the frequency will be

$$F_{\text{Mc.}} = \frac{5905}{\textit{length}\ \text{(inches)}}$$

If the length is measured in meters,

$$F_{\text{Mc.}} = \frac{150}{\textit{length}\ \text{(meters)}}$$

In checking a superregenerative receiver, the Lecher wires may be similarly coupled to the receiver coil. In this case the resonance indication may be obtained by setting the receiver just to the point where the hiss is obtained, then as the bar is slid along the wires a spot will be found where the receiver goes out of oscillation. The distance between two such spots is equal to a half-wavelength.

In either case, the most accurate readings result only when the loosest possible coupling is used between the line and the tank coil. After taking a preliminary reading to find the regions along the line in which resonance occurs, loosen the coupling until the indications are just discernible and repeat the measurement. Unless this is done the tuning of the line will affect the frequency of the oscillator and inaccurate indications will be obtained. As the coupling is loosened the resonance points will become sharper, which is a further aid to accurate determination of the wavelength.

The shorting bar must be kept at right angles to the two wires. A sharp edge on the bar is desirable, since it not only helps make good contact but also definitely locates the *point* of contact.

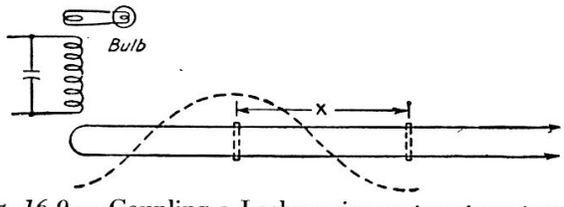


Fig. 16-9 — Coupling a Lecher-wire system to a transmitter tank coil. Typical standing-wave distribution is shown by the dashed line. The distance, *X*, between the positions of the shorting bar at the current loops equals one-half wavelength.

The accuracy with which frequency can be measured by such a system depends principally upon the technique of measurement. The necessity for using very loose coupling to the transmitter or receiver has already been mentioned. In addition, careful measurement of the exact distance between two current loops also is essential. Even if all other sources of error are eliminated, measurements within 0.1 per cent require an accuracy within 1 part in 1000, or 1 millimeter in one meter, in measuring the distance along the wires. This means that an accurate standard of length is necessary — a good steel tape, for instance — and that care must be used in determining the length exactly.

Signal Monitoring

Every amateur station should make provision for checking the quality of the transmitter output. This requires that some means be available in the station for reproducing the conditions existing at a distant receiving station; that is, for reducing the strength of the signal from the transmitter to such a point that its characteristics can be examined without danger of false indications from overloading the receiving equipment.

The simplest method of checking the quality of c.w. transmissions is to use the regular station receiver. If the receiver is a superheterodyne the process may simply be that of reducing the r.f. gain to minimum and tuning to the transmitter frequency. If distant signals are stable and have "pure-d.c." tone in normal reception, then the local transmitter should too, when the receiver gain is reduced to the point where the receiver does not overload. If the signal is too strong with the r.f. gain "off," shorting the receiver antenna input terminals may reduce it to suitable proportions, or the mixer circuit in the receiver may be temporarily detuned to arrive at the same result.

An alternative method is to set the receiver on the next lower-frequency band than the one in use, then tune the receiver so that the second harmonic of its oscillator beats with the transmitter signal to produce the intermediate frequency. Higher-order harmonics also may be used for this purpose. With this harmonic method there is ordinarily no danger that the receiver will overload, because the r.f. and mixer tuned circuits are so far from resonance with the transmitter frequency. The setting of the tuning dial bears no direct relation to the transmitter frequency under these conditions, since the oscillator harmonic must maintain a constant difference with the transmitter to produce the i.f. beat.

A 'phone signal may be monitored in the same way, provided a headset is used for reception. Use of a loudspeaker is not usually practicable because the sound output feeds back to the microphone and causes howling. A crystal detector and headset may also be used for the same purpose, as described in preceding sections. In monitoring a 'phone signal the best plan is to have another person speak into the microphone rather than to listen to one's own voice. It is difficult to judge quality when speaking and listening at the same time.

C.W. SIGNAL MONITOR

One trouble with checking a c.w. signal on the station receiver is that receivers frequently have hum and instability, particularly on the higher frequencies, that cause the signal to sound worse than it really is. The best way to get a true picture of the signal is to monitor it with a battery-operated oscillator. With battery plate and filament supplies, the monitor cannot introduce hum. If the oscillator is mechanically and electrically stable and is well shielded, a true replica of the signal can be obtained.

The construction of a shielded, battery-operated monitor is described in Chapter Eight. Instructions for its use also will be found in that chapter.

MODULATION MONITOR

Fig. 16-10 is the circuit of a 'phone monitor that can be used both for aural checking and for measuring modulation percentage. When a small r.f. voltage is applied to the input circuit it is rectified by the crystal. With switch S_1 in the "r.f." position the average value of the rectified current is measured by the 0–1 milliammeter, MA. With the switch in the "a.f." position, the audio modulation on the signal is transferred through T_1 to a second rectifier. The average value of the rectified audio is again read by the milliammeter. The circuit constants are chosen so that if the input is adjusted to make the meter read full scale on r.f., the a.f. meter readings will be directly proportional to percentage of modulation (for voice modulation), 100-percent modulation being represented by a cur-

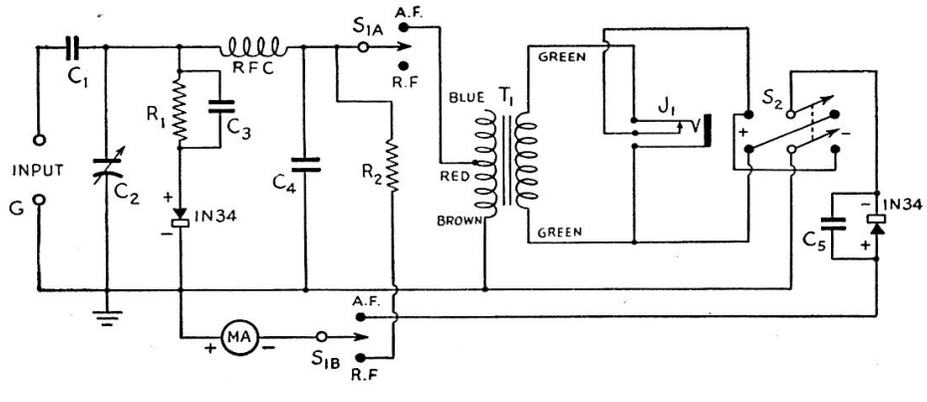


Fig. 16-10 — Circuit of direct-reading modulation meter.
C_1, C_4 — 1000-$\mu\mu$fd. ceramic.
C_2 — 100-$\mu\mu$fd. variable midget.
C_3 — 12-$\mu\mu$fd. mica.
C_5 — 470-$\mu\mu$fd. mica.
R_1 — 1100 ohms, 5%, 1 watt.
R_2 — 16,000 ohms, 5%, 1 watt.
J_1 — Closed-circuit jack.
MA — 0–1 ma., 100 ohms.
RFC — 20 μh.
$S_{1A\text{-}B}$, S_2 — D.p.d.t. toggle.
T_1 — Push-pull interstage transformer, 1:1 ratio (Stancor A-4711).

rent of 1 milliampere. Switch S_2 provides for reversing the "polarity" of the modulation, giving a qualitative indication of the up and down peaks. A headphone jack, J_1, is provided for listening to the quality of the modulation. (The percentage modulation cannot be read with 'phones plugged into J_1, so the 'phones must be removed when readings are to be taken.)

In constructing such an instrument, care should be used to prevent r.f. pick-up in the audio rectifier circuit. This can be checked by testing the instrument on an unmodulated carrier (which must be substantially hum-free); with a full-scale reading when S_1 is in the "r.f." position, the meter should read zero when S_1 is switched to "a.f." The values of R_1 and R_2 are critical and should be within 5 per cent of the recommended values.

A sample of the modulated carrier may be coupled into the instrument through a one-turn link and a length of Twin-Lead, the link being placed within a few inches of the final tank circuit of the transmitter. The coupling between the link and final tank coil must be adjusted to give a full-scale r.f. reading, after C_2 has been set for maximum reading. Alternatively, a coil that will resonate with C_2 at the operating frequency may be connected to the input terminals and the instrument located so that a suitable full-scale reading will be obtained.

Besides indicating modulation percentage, the instrument will show carrier shift (as shown by a change in the reading, when modulating, with S_1 in the "r.f." position) and thus detect nonlinearity in the modulated amplifier.

Measurement of Current, Voltage and Power

The amateur regulations require that when the power input to the final stage is above 900 watts, means must be provided for measuring the power input. This may be done by measuring the d.c. voltage applied to the final-stage plates and the d.c. current flowing to them. The instruments required are a milliammeter and voltmeter.

Although in lower-power transmitters power-input measurements are not required, it is nevertheless true that a milliammeter is an almost indispensable instrument in the amateur station. It is invaluable in the adjustment of transmitting amplifier stages; tuning a transmitter without measuring grid and plate currents is like working in the dark. A d.c. voltmeter, although not essential, is useful in conjunction with the milliammeter in determining whether tube ratings are being exceeded or not and thus is helpful in prolonging tube life.

Besides d.c. measurements, it is also well to measure the filament voltages applied to transmitting tubes. Tube performance is dependent upon proper cathode emission, which in turn depends upon the voltage applied to the filament or heater. Also, the life of some transmitting tubes, particularly the thoriated-tungsten filament types, is critically dependent upon maintaining the filament voltage within rather close limits. Since most transmitting-tube filaments are operated on a.c., an a.c. voltmeter is a worth-while addition to amateur transmitting equipment.

Adjustment of a transmitter for maximum power output to the antenna or transmission line is facilitated by the use of instruments which measure radio-frequency current. Such instruments, although not actually essential, round out the measuring equipment used in transmitter adjustment.

D.C. Instruments

D.c. ammeters and voltmeters are basically identical instruments, the difference being in the method of connection. An ammeter is connected in series with the circuit and measures the current flow. A voltmeter is a milliammeter that measures the current through a high resistance connected across the source to be measured; its calibration is in terms of the voltage drop in the resistance or **multiplier.**

If a single instrument must be used for measuring widely-different values of current or voltage, it is advisable to purchase one which will read, at about 75 per cent of full scale, the *smallest* value of current or voltage

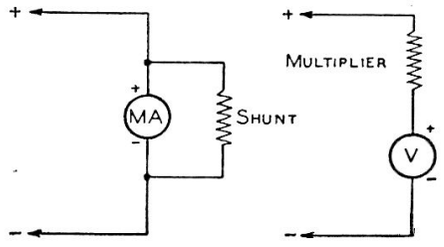


Fig. 16-11 — How voltmeter multipliers and milliammeter shunts are connected to extend the range of a d.c. meter.

to be measured. Small currents cannot be read with any degree of precision on a high-scale instrument; on the other hand, the range of a low-scale instrument can be extended as desired to take care of larger values. The ranges of both voltmeters and ammeters can be extended by the use of external resistors, connected in series with the instrument in the case of a voltmeter or in shunt in the case of an ammeter. Fig. 16-11 shows at the left the manner in which a shunt is connected to extend the range of an ammeter and at the right the connection of a voltmeter multiplier.

To calculate the value of a shunt or multiplier it is necessary to know the resistance of the meter. If it is desired to extend the range of a voltmeter, the value of resistance which must

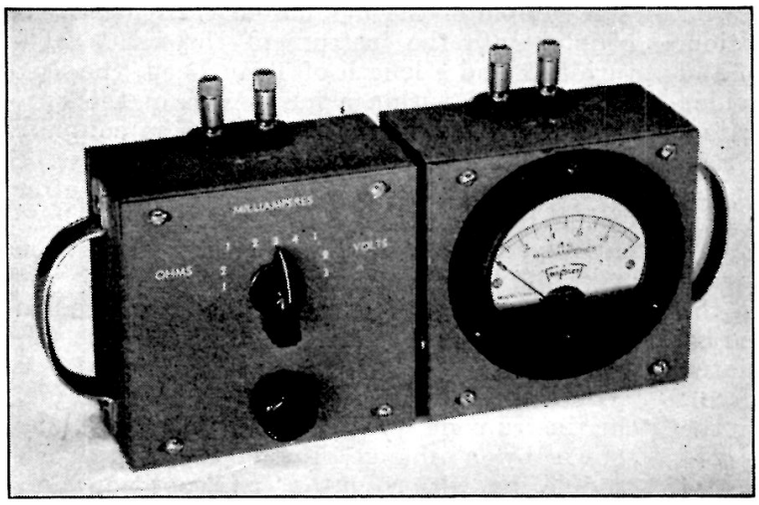


Fig. 16-12 — An inexpensive multirange volt-ohm-milliammeter. The 2 × 4 × 4-inch cabinet at the left houses the multipliers, shunts, switch and zero-adjustment resistor. The meter is mounted in the metal cabinet shown at the right. The units are provided with plugs and jacks so that the meter can be used independently or as the indicator component for other instruments. Connections to the volt-ohm-milliammeter, or to the meter alone, are made to the terminals mounted at the top of both boxes. Handles are mounted on the cabinets to facilitate handling.

be added in series is given by the formula:

$$R = R_m (n - 1)$$

where R is the multiplier resistance, R_m the resistance of the voltmeter, and n the scale multiplication factor. For example, if the range of a 10-volt meter is to be extended to 1000 volts, n is equal to 1000/10 or 100.

If a milliammeter is to be used as a voltmeter, the value of series resistance can be found by Ohm's Law:

$$R = \frac{1000E}{I}$$

where E is the desired full-scale voltage and I the full-scale reading of the instrument in milliamperes.

To increase the current range of a milliammeter, the resistance of the shunt is

$$R = \frac{R_m}{n - 1}$$

where the symbols have the same meanings as above.

Homemade milliammeter shunts can be constructed from any of the various special kinds of resistance wire, or from ordinary copper magnet wire if no resistance wire is available. The Copper Wire Table in Chapter Twenty-Four gives the resistance per 1000 feet for various sizes of copper wire. After computing the resistance required, determine the smallest wire size that will carry the full-scale current (at 250 circular mils per ampere). Measure off enough wire (pulled tight but not stretched) to provide the required resistance. Accuracy can be checked by causing enough current to flow through the meter to make it read full scale without the shunt; connecting the shunt should then give the correct reading on the new full-scale range.

Precision wire-wound resistors used as voltmeter multipliers cannot readily be made by the amateur because of the much higher resistance required (as high as several megohms). As an economical substitute, standard fixed resistors may be used. Such resistors are supplied in tolerances of 5, 10 or 20 per cent ± the marked values. By obtaining matched pairs from the dealer's stock, one of which is, for example, 4 per cent low while the other is 4 per cent high, and using the pairs in parallel or series to obtain the required value of resistance, good accuracy can be obtained at small cost. High-voltage multipliers are preferably made up of several resistors in series; this not only raises the breakdown voltage but tends to average out errors in the individual resistors attributable to manufacturing tolerances.

When d.c. voltage and current are known, the power in a d.c. circuit can be stated by simple application of Ohm's Law: $P = EI$. Thus the voltmeter and ammeter are also the instruments used in measuring d.c. power.

Multirange Voltmeters and Ohmmeters

A combination voltmeter-milliammeter having various ranges is extremely useful for experimental purposes and for trouble shooting in receivers and transmitters. As a voltmeter

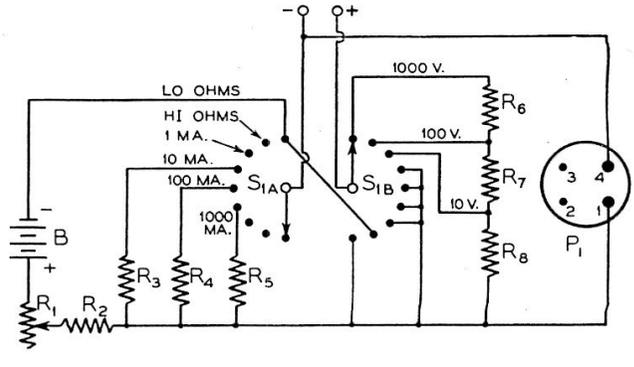


Fig. 16-13 — Diagram of the volt-ohm-milliammeter.

R_1 — 2000-ohm wire-wound variable.
R_2 — 3000 ohms, ½ watt.
R_3 — 10-ma. shunt, 6.11 ohms (see text).
R_4 — 100-ma. shunt, 0.555 ohm (see text).
R_5 — 1000-ma. shunt, 0.055 ohm (see text).
R_6 — 1000-volt multiplier, 0.9 megohm, ½ watt.
R_7 — 100-volt multiplier, 90,000 ohms, ½ watt.
R_8 — 10-volt multiplier, 10,000 ohms, ½ watt.
B — 4.5-volt dry battery (Burgess 5360).
P_1 — 4-prong male plug (for milliammeter).
S_{1A-B} — 9-point 2-pole selector switch (Mallory 3229J).

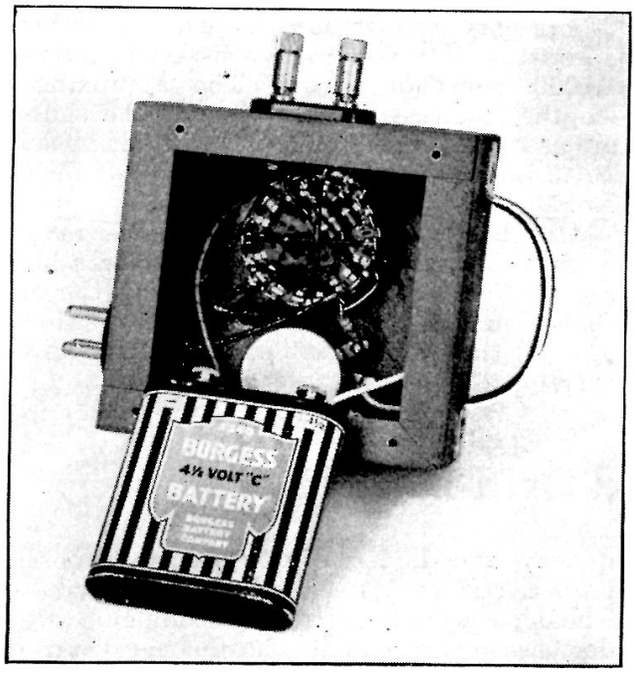


Fig. 16-14 — A rear view of the volt-ohm-milliammeter. The range-selector switch is mounted above the zero-adjustment potentiometer, and the shunts and multipliers are connected across the switch terminals. A four-prong male plug, for connection to the meter box, is shown at the left of the cabinet. The ohmmeter battery fits inside the case; the battery terminals should be insulated with tape or paper before the battery is installed in the box.

such an instrument should have high resistance so that very little current will be drawn in making voltage measurements. A voltmeter taking considerable current will give inaccurate readings when connected across a high-resistance source — as is often the case in various parts of a receiver circuit. For such purposes the instrument should have a resistance of at least 1000 ohms per volt; a 0–1 milliammeter or 0–500 microammeter (0–0.5 ma.) is the basis of most multirange meters of this type. Microammeters having a range of 0–50 μa., giving a sensitivity of 20,000 ohms per volt, also are used.

The various current ranges on a multirange instrument can be obtained by using a number of shunts individually switched in parallel with the meter. Care should be used to minimize contact resistance in the switch.

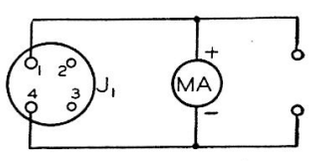


Fig. 16-15 — Wiring diagram of the 0–1 milliammeter shown in Figs. 16-5 and 16-12. J_1 is a 4-prong tube socket.

It is often necessary to check the value of a resistor or to find the value of an unknown resistance, particularly in receiver servicing. An **ohmmeter** is used for this purpose. The ohmmeter is simply a low-current d.c. voltmeter provided with a source of voltage (usually dry cells), the meter and battery being connected in series with the unknown resistance. If a full-scale deflection is obtained with the connections to the external resistance shorted, insertion of the resistance under measurement will cause the meter reading to decrease. The meter scale can be calibrated in ohms. When the resistance of the voltmeter is known, the following formula can be applied:

$$R = \frac{eR_m}{E} - R_m$$

where R is the resistance under measurement,
E is the voltage read on the meter,
e is the series voltage applied, and
R_m is the resistance of the voltmeter.

Since the resistance of a voltmeter is usually rather high, this method is not well adapted to measuring low values of resistance. For very low resistances, the unknown may be connected in shunt with the instrument (not including the multiplier) instead of in series.

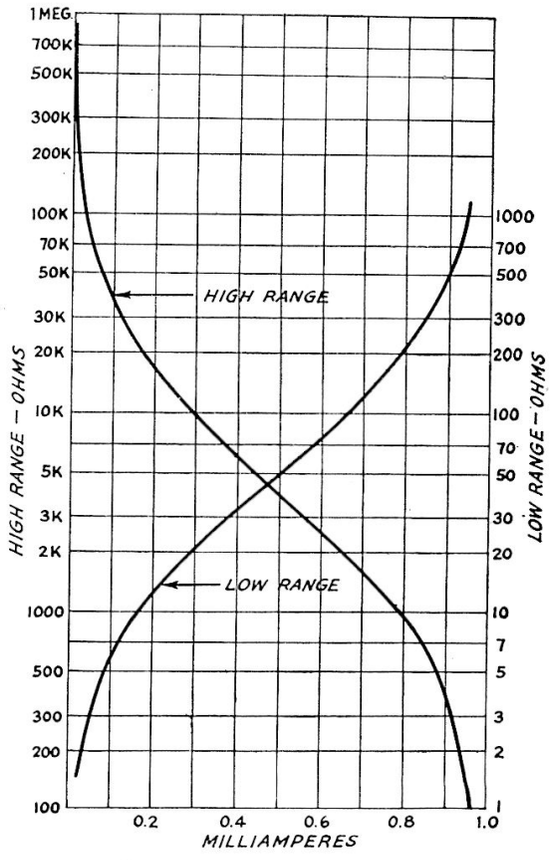


Fig. 16-16 — Calibration curve for the high- and low-resistance ranges of the volt-ohm-milliammeter.

AN INEXPENSIVE V.O.M.

A combination multirange volt-ohm-milliammeter, reduced to simple and inexpensive terms, is shown in Figs 16-12 to 16-15. Using a 0–1 milliammeter, the voltmeter has three ranges at 1000 ohms per volt: 0–10, 100 and 1000 volts. Current ranges of 0–1, 10, 100 and 1000 ma. are provided. There are two resis-

tance-measurement ranges, a series range that is useful up to about 0.5 megohm, and a shunt range of 0–1000 ohms.

For economy, ordinary carbon resistors are used as voltmeter multipliers. These can be obtained with an accuracy within 5 per cent. However, standard resistors of 10-per-cent tolerance can be used without introducing undue error. The 1000-volt multiplier, R_6, is two 1.8-megohm resistors in parallel, and the 100-volt multiplier, R_7, is two 0.18-megohm resistors in parallel.

The 10-, 100- and 1000-ma. shunts are made of ordinary copper magnet wire wound on ½-watt resistors of high resistance value — 10,000 ohms or higher. The approximate lengths and sizes of the wire for the shunts are as follows: R_3, 9 inches No. 38 enameled; R_4, 5 inches No. 30 enameled; R_5, 3 inches No. 18.

A calibration curve for the ohmmeter ranges is given in Fig. 16-16. With instruments having different internal resistance than the one shown in the photograph (Triplett Model 0321–1) the "low-ohms" curve will not apply exactly.

Test Oscillators and Grid-Dip Meters

A useful and inexpensive general-purpose instrument is an oscillator covering a wide frequency range. When it generates frequencies in the audio range it can be used as a signal source for checking the performance of audio amplifiers. As a radio-frequency oscillator it may be made to generate signals that can be used for receiver alignment, for calibrating absorption wavemeters as described earlier in this chapter, and for furnishing small r.f. voltages for whatever purpose may be required. When equipped with a low-range milliammeter connected to read the oscillator grid current, it becomes a grid-dip meter and may be used for checking the resonant frequencies of tuned circuits, and as a means for measuring inductance and capacitance as described in a later section.

The grid-dip meter is so called because when its oscillator is coupled to a tuned circuit, the oscillator grid current will show a decrease or "dip" when the oscillator is tuned through resonance with the unknown circuit. The reason for this is that the external circuit will absorb energy from the oscillator when both it and the oscillator are tuned to the same frequency, and the loss of energy from the oscillator circuit causes the feed-back to decrease. The decrease in feed-back is accompanied by a decrease in grid current. The dip in grid current is quite sharp when the circuit to which the oscillator is coupled has reasonably high Q.

GENERAL-PURPOSE OSCILLATOR AND GRID-DIP METER

A general-purpose test oscillator is shown in Figs. 16-17 and 16-19. This simple unit can be used as an audio oscillator, an r.f. signal generator, a grid-dip meter, a field-strength indicator, or as an absorption wavemeter, and has a frequency range of 200 cycles to 56 Mc.

As shown by the circuit diagram, Fig. 16-18, a Type 6SN7GT tube is used in a cathode-coupled oscillator circuit. The only critical values are those of the cathode resistor, R_2, and the coupling condenser, C_4. Use of a cathode resistor of less than 1000 ohms will result in a poor waveform at audio frequencies, and the oscillator output will be greatly reduced if the cathode resistor is larger than 3000 ohms. The audio attenuator, R_4, loads the circuit to some

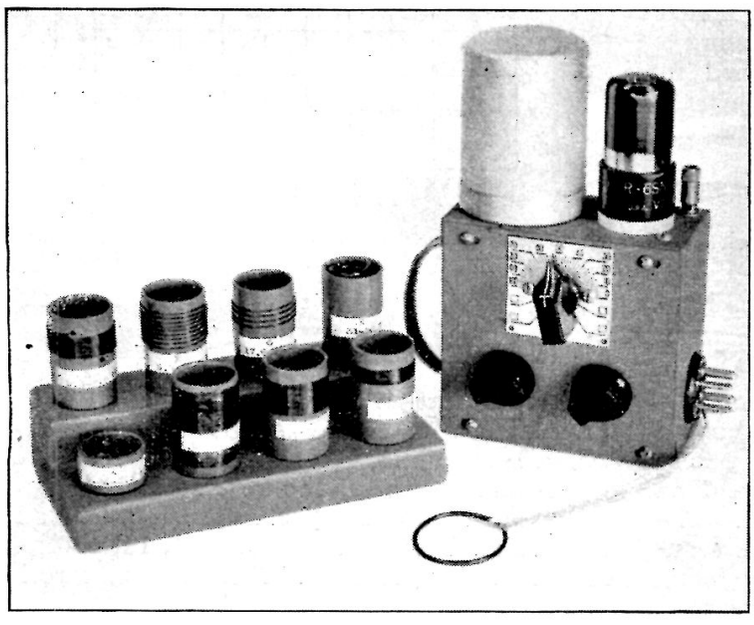


Fig. 16-17 — The general-purpose test oscillator. The variable condenser, sensitivity control and audio-output potentiometer are mounted on the front panel of a 2 × 4 × 4-inch metal box. A handle at the left of the box, and a meter jack at the right, are provided so that the oscillator may be used with the meter unit shown in Fig. 16-12. Sockets for the oscillator tube and the plug-in coils are mounted on the top of the box. The coil shield is necessary only when the oscillator is being used as a signal generator. The r.f. coils are shown mounted in a wooden rack which has been drilled to fit the prongs of the coil forms.

extent, and will prevent oscillation if the coupling condenser, C_4, is made much smaller than 0.1 μfd. The oscillator requires a filament supply of 6.3 volts at 0.6 amp., and the plate supply should deliver 150 to 250 volts at 14 ma. (the plate-current drain will be less than 10 ma. at the audio and the low radio frequencies).

The frequency of the oscillator is controlled by the values of inductance and capacitance connected across points *C* and *D* in Fig. 16-18. The coil chart lists values of capacitance and inductance that can be used for either audio- or radio-frequency output. At audio frequencies, the *LC* combination is connected across terminals *C* and *D*, and at radio frequencies the coils plug into the socket provided for this purpose. The variable condenser, C_1, is used as the frequency adjustment over the r.f. range of the oscillator, and can be used as a vernier adjustment at audio frequencies.

A potentiometer, R_3, serves as the sensitivity control when the oscillator is used as a grid-dip meter, an absorption wavemeter, or as a field-strength indicator. This control also acts as an output attenuator when the oscillator is used as a signal generator. It should be noticed that the audio-output attenuator, R_4, in series with the output coupling condenser, C_5, is connected to the resonant circuit by means of a jumper connected between terminals *A* and *C*. This jumper must be removed when the oscillator is used at radio frequencies; otherwise the circuit will not oscillate.

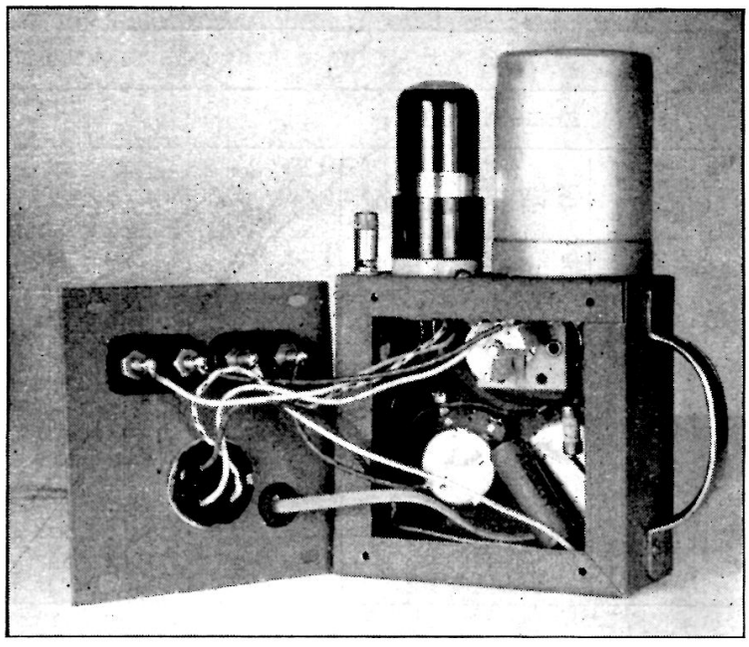


Fig. 16-19 — A rear view of the general-purpose test oscillator. The low impedance link for the pick-up loop feeds through a rubber grommet mounted in the rear cover. Input and output jacks are also located on the backplate. The arrangement of components inside the box is not critical. The 1N34 crystal and the meter bypass condenser, C_6, are mounted inside the box.

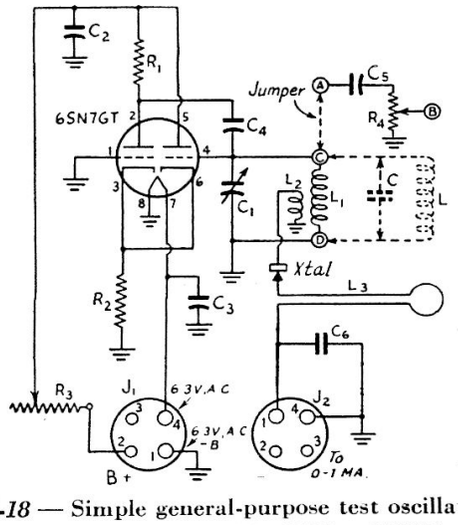


Fig. 16-18 — Simple general-purpose test oscillator.
C_1 — 100-μμfd. midget variable (Millen 20100).
C_2, C_3 — 0.01-μfd. 400-volt paper.
C_4, C_5 — 0.1-μfd. 400-volt paper.
C_6 — 100-μμfd. midget mica.
R_1 — 68,000 ohms, 1 watt.
R_2 — 1500 ohms, 1 watt.
R_3 — 0.2-megohm carbon potentiometer.
R_4 — 50,000-ohm carbon potentiometer.
L_1, L_2, L_3 — See text and coil table.
J_1, J_2 — 4-prong plug (Amphenol 86-CP4).
XTAL — Type 1N34.

The rectifier system consists of coil L_2, the 1N34 crystal, a pick-up loop, and a meter bypass condenser. R.f. current generated by the oscillator circuit is coupled to the crystal rectifier by means of L_2. The current is rectified by the crystal and flows through the pick-up loop to an external meter (any 0–1 milliammeter will do). The pick-up loop, if placed in series with the crystal as shown, will not overload the oscillator circuit.

For output in the audio-frequency range, the desired *LC* combination is connected across the circuit and output connections are made to terminals *B* and *D* (the jumper is connected between *A* and *C*). If a test signal of radio frequency is desired, the jumper connection is removed and a coil is plugged in the coil socket. Terminal *C* will then serve as a short antenna from which the signal is radiated. The strength of the signal being radiated can be increased by adding a short length of wire to the output terminal. It is advisable to shield the r.f. coil for this type of operation so that hand-capacitance effects will be minimized.

To use the oscillator as a grid-dip meter, connect a 0–1 milliammeter to the meter jack, J_2. With the proper r.f. coil in place, and with power turned on, adjust the sensitivity control for maximum meter deflection (full deflection will be approximately 0.5 ma. on the highest frequency range). The pick-up loop can then be coupled to the circuit under measurement and, if the oscillator frequency is varied by means of the tuning condenser, C_1, there will be a pronounced dip in grid current as the resonant frequency of the external circuit is passed.

COIL CHART FOR THE TEST OSCILLATOR

Audio Frequencies			Radio Frequencies				
Frequency (Cycles)	*Inductance (hy.) (L)*	*Capacitance (μfd.) (C)*	*Freq. (Mc.)*	*Coil*	*No. Turns*	*Wire Size*	*Length of Winding (Inches)*
200	1.2	0.02	0.955–1.75	L_1	120	No. 30 enam.	1 5/16
400	"	0.06		L_2	12	" 18 "	
600	"	0.15	1.72–3.1	L_1	50	" 30 "	9/16
1000	"	0.5		L_2	6	" 18 "	
1300	0.125 (Meissner) No. 19–6848.	0.1	3.0–5.4	L_1	23	" 30 "	1/4
				L_2	2	" 18 "	
1800	"	0.05	5.3–9.8	L_1	15	" 22 "	7/16
2000	"	0.04		L_2	6	" 18 "	
2300	"	0.03	9.7–17.8	L_1	9	" 22 "	5/8
2800	"	0.02		L_2	2	" 18 "	
3300	"	0.015	17.6–31.5	L_1	4	" 22 "	3/8
4000	"	0.01		L_2	2	" 18 "	
5200	"	0.0068	31.0–56.0	L_1	3	" 12 "	1/2
6250	"	0.005		L_2	1	" 18 "	
10,000	"	0.002					

L_1 and L_2 for 0.33 to 0.6 Mc. are the primary and secondary windings of a 456-kc. i.f. transformer, closely coupled, and mounted inside the coil form. L_1 for 31.0 to 56.0 Mc. has a diameter of 5/8 inch and is mounted inside the form. For all other frequencies L_1 is wound on the outside of the coil form. All L_2 windings are close-wound, have a diameter of 7/8 inch, and are mounted inside the forms. Millen Type 45004 forms are used throughout. L_3, the pick-up coil, is one turn of No. 12 enameled wire, 1½ inches in diameter, connected to a length of 75-ohm Twin-Lead.

The 0–1 milliammeter is also required when the unit is used as an absorption wavemeter or as a field-strength indicator. However, the power supply is not required for these types of operation. It is only necessary that the proper r.f. coil be selected and that the coil (or the pick-up loop) be placed in the field of the frequency-generating device that is being measured. The sensitivity, during field-strength measurements, can be increased by attaching a short antenna to terminal *C*.

Because of the large frequency range covered by this instrument, it is not practical to employ a dial calibrated directly in terms of frequency. Therefore, an ordinary 0–100 degree dial is used and the actual frequency calibrations are marked on a separate chart. The r.f. ranges can be calibrated by using a calibrated receiver for listening to the oscillator output signal. An alternative method is to use the unit as a grid-dip meter coupled to a calibrated absorption wavemeter. The audio-frequency range can be calibrated by feeding the oscillator output to the vertical amplifier of an oscilloscope while the horizontal amplifier of the 'scope is being excited by the output of a calibrated audio oscillator. A circular pattern will be registered on the screen of the 'scope when the outputs of the two audio oscillators are adjusted to the same frequency. An alternative method of a.f. calibration is to connect a headset to the oscillator output terminals and compare the tone to the notes of a piano, determining which piano note is nearest. The approximate frequency then can be found from the table in Chapter Twenty-Four.

Measuring Inductance and Capacitance

The ability to measure the inductance of coils, the capacitance of condensers, or the resonant frequency of a tuned circuit frequently saves time that might otherwise be spent in cut-and-try. A convenient instrument for this purpose is the grid-dip oscillator, described earlier in this chapter.

For measuring inductance, the coil to be measured is connected to a condenser of known capacitance as shown at A in Fig. 16-20. A mica condenser may be used as a standard; a 100-μμfd. 5-per-cent tolerance unit will serve for most purposes. With the unknown coil connected to the standard condenser, the pick-up loop is coupled to the coil and the oscillator frequency adjusted for the grid-current dip, using the loosest coupling that gives a detectable indication. The inductance is then given by the formula

$$L_{\mu h.} = \frac{25{,}300}{C_{\mu\mu fd.} f_{Mc.}^2}$$

A calibrated variable condenser is required for measuring capacitance. The circuit used is shown at B in Fig. 16-20. The frequency of the circuit, using any convenient coil, is first measured with the unknown capacitance disconnected and the calibrated condenser set near maximum. The unknown is then connected and the calibrated condenser readjusted to resonance. The unknown capacitance is then equal to the difference between the capacitances at the two settings of the calibrated condenser. Obviously only capacitances smaller

than the maximum capacitance of the calibrated condenser can be measured by this method. Since high accuracy in capacitance measurement is not ordinarily required, a satisfactory standard is any condenser of the straight-line capacitance type, for which a sufficiently good calibration curve can be constructed by noting the dial divisions at which the plates just start to mesh and are completely meshed, and assuming that the capacitance change is linear within those limits. The minimum and maximum capacitance (corresponding closely enough to these condenser settings) can be obtained from the manufacturer's data on the particular condenser used.

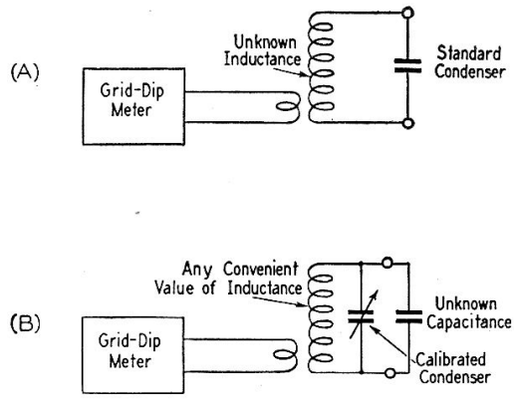


Fig. 16-20 — Set-ups for measuring inductance and capacitance with the grid-dip meter.

The Oscilloscope

The cathode-ray oscilloscope is an instrument of great versatility, and in conjunction with the instruments herein described, should be a valuable addition to the practical amateur station. The oscilloscope is useful on d.c., and audio and radio frequencies, and is particularly suited to a.f. and r.f. measurements because, compared to other types of measuring equipment, it introduces relatively little error at such frequencies.

CATHODE-RAY TUBES

The heart of the oscilloscope is the **cathode-ray tube,** a vacuum tube in which the electrons emitted from a hot cathode are first accelerated to give them considerable velocity, then formed into a beam, and finally allowed to strike a special translucent screen which *fluoresces*, or gives off light at the point where the beam strikes. A narrow beam of moving electrons is analogous to a wire carrying current, and can be moved laterally, or **deflected,** by electric or magnetic fields.

Since the cathode-ray beam consists only of moving electrons, its weight and inertia are negligibly small. For this reason, it can be made to follow instantly the variations in periodically-changing fields at both audio and radio frequencies.

The electrode arrangement that forms the electrons into a beam is called the **electron gun.** In the simple tube structure shown in Fig. 16-21, the gun consists of the cathode, grid, and anodes Nos. 1 and 2. The intensity of the electron beam is regulated by the grid in the same way as in an ordinary tube. Anode No. 1 is operated at a positive potential with respect to the cathode, thus accelerating the electrons that pass through the grid, and is provided with small apertures through which the electron stream passes. On emerging from the apertures the electrons are traveling in practically parallel straight-line paths. The electrostatic fields set up by the potentials on anode No. 1 and anode No. 2 form an **electron lens** system which makes the electron paths converge to a point at the fluorescent screen. The potential on anode No. 2 is usually fixed, while that on anode No. 1 is varied to bring the beam into focus. Anode No. 1 is, therefore, called the **focusing electrode.**

Sharpest focus is obtained when the electrons of the beam have high velocity, so that relatively high d.c. potentials are common with cathode-ray tubes. However, the current required is small, so that the power consumption is negligible. A second grid may be placed between the control grid and anode No. 1, for additional acceleration of the electrons.

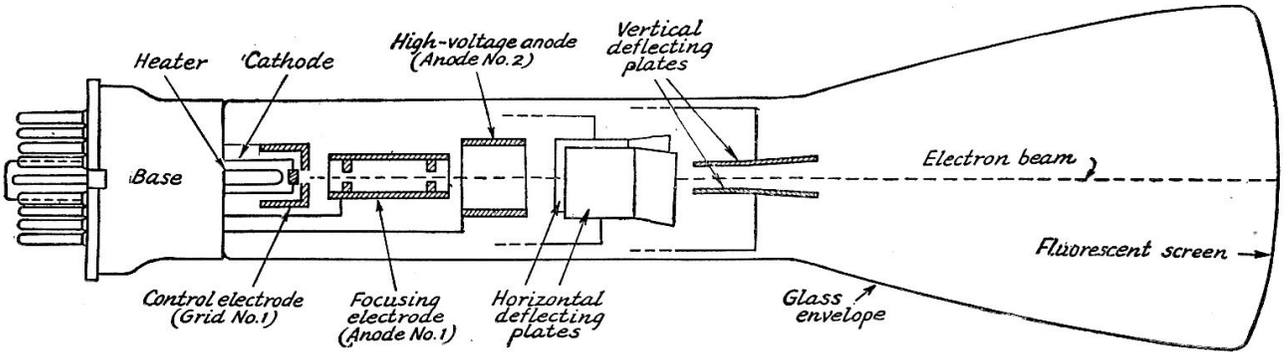


Fig. 16-21 — Typical construction for a modern cathode-ray tube of the electrostatic-deflection type. The envelope is made of glass, with the fluorescent screen at one end. Leads for the high-voltage anode, the deflection plates, and other electrodes are insulated low-capacitance conductors carried inside the envelope to the base.

Methods of Deflection

When focused, the beam from the gun produces only a small spot on the screen, as described above. However, if after leaving the gun the beam is deflected by either magnetic or electrostatic fields, the spot will move across the screen in accordance with the force exerted on the beam. If the motion is rapid, the path of the spot **(trace)** appears as a continuous line.

Electrostatic deflection, the type generally used in the smaller tubes, is produced by **deflecting plates.** Two sets of plates are placed at right angles to each other, as indicated in Fig. 16-21. The fields are created by applying suitable voltages between the two plates of each pair. Usually one plate of each pair is connected to anode No. 2, to establish the polarities of the vertical and horizontal fields with respect to the beam and to each other.

Formation of Patterns

When periodically-varying voltages are applied to the two sets of deflecting plates, the path traced by the fluorescent spot forms a **pattern** that is stationary so long as the amplitude and phase relationships of the voltages remain unchanged. Fig. 16-22 shows how such

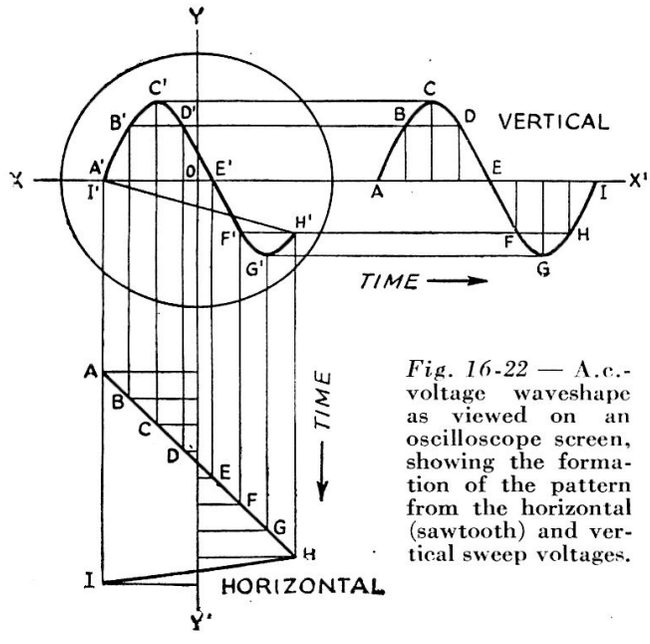


Fig. 16-22 — A.c.-voltage waveshape as viewed on an oscilloscope screen, showing the formation of the pattern from the horizontal (sawtooth) and vertical sweep voltages.

patterns are formed. The horizontal sweep voltage is assumed to have the "sawtooth" waveshape indicated. With no voltage applied to the vertical plates the trace simply sweeps from left to right across the screen along the horizontal axis X–X' until the instant H is reached, when it reverses direction and returns to the starting point. The sine-wave voltage applied to the vertical plates similarly would trace a line along the axis Y– Y' in the absence of any deflecting voltage on the horizontal plates. However, when both voltages are present the position of the spot at any instant depends upon the voltages on both sets of plates at that instant. Thus at time B the horizontal voltage has moved the spot a short distance to the right and the vertical voltage has similarly moved it upward, so that it reaches the actual position B' on the screen. The resulting trace is easily followed from the other indicated positions, which are taken at equal time intervals.

Types of Sweeps

A sawtooth sweep-voltage waveshape, such as is shown in Fig. 16-22, is called a **linear sweep,** because the deflection in the horizontal direction is directly proportional to time. If the sweep were perfect the **fly-back** time, or time taken for the spot to return from the end (H) to the beginning (I or A) of the horizontal trace, would be zero, so that the line HI would be perpendicular to the axis Y–Y'. Although the fly-back time cannot be made zero in practicable sweep-voltage generators it can be made quite small in comparison to the time of the desired trace AH, at least at most frequencies within the audio range. The fly-back time is somewhat exaggerated in Fig. 16-22, to show its effect on the pattern. The line $H'I'$ is called the **return trace**; with a linear sweep it is less brilliant than the pattern, because the spot is moving much more rapidly during the fly-back time than during the time of the main trace. If the fly-back time is short enough, the return trace will be invisible.

The linear sweep has the advantage that it shows the shape of the wave in the same way that it is usually represented graphically. If the time of one cycle of the a.c. voltage applied to the vertical plates is a fraction of the time taken to sweep horizontally across the screen, several cycles of the vertical or "signal" voltage will appear in the pattern. The shape of only the last cycle (or the last few cycles, depending upon the number in the pattern and the characteristics of the sweep) to appear will be affected by the fly-back in such a case.

The shape of the pattern obtained, with a given signal waveshape on the vertical plates, obviously will depend upon the shape of the horizontal sweep voltage. If the horizontal sweep is sinusoidal, the main and return sweeps each occupy the same time and the spot moves faster horizontally in the center of the pattern than it does at the ends. When two sinusoidal voltages of the same frequency are applied to both sets of plates, the pattern may be a straight line, an ellipse, or a circle, depending upon the amplitudes and phase relationships of the two voltages.

For many amateur purposes a satisfactory horizontal sweep is simply a 60-cycle voltage of adjustable amplitude. In modulation monitoring (described in Chapter Nine) audio-frequency voltage can be taken from the modulator to supply the horizontal sweep. For examination of audio-frequency waveforms, the linear sweep is essential. Its frequency should be adjustable over the entire range of audio frequencies to be inspected on the oscilloscope.

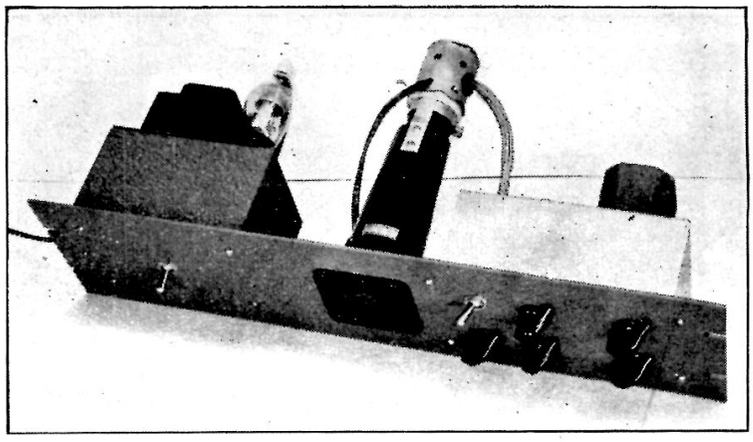


Fig. 16-23 — Front view of a rack-mounting oscilloscope for modulation monitoring. All components are mounted on the rear of a 19 × 5½-inch rack panel. The power-supply components are built into a utility box bolted on the left side of the panel, and the 'scope circuits are mounted on the right-hand side, enclosed by a shield box. The a.c. switch is on the left. All other controls are on the right, as follows: top row, l. to r., sweep switch, intensity control, focus control; bottom row, sweep-amplitude control, horizontal centering, vertical centering.

A SIMPLE OSCILLOSCOPE FOR MODULATION MONITORING

Figs. 16-23 through 16-25 show the circuit and constructional details of a simple 2-inch oscilloscope that is suitable for use as a modulation monitor. It is designed to be mounted in the transmitter rack, becoming a permanent part of the 'phone station. Inexpensive parts are used throughout, and the circuits themselves are simple to build and operate.

The 2AP1 cathode-ray tube is mounted with its screen protruding through a 2-inch hole in the 19 × 5¼-inch aluminum rack panel. The cathode-ray tube is enclosed in a Millen shield, and its screen is covered by a Millen Type 80072 bezel. The power-supply components are housed in a standard 3 × 4 × 5-inch utility box that is bolted to the left rear of the rack panel. An inexpensive replacement-type transformer is used with a 2X2 half-wave rectifier to deliver about 800 volts at the required 4 or 5 ma. drain.

The voltage-divider circuit components and the sweep-circuit controls are mounted on the right-hand side of the panel, and are enclosed by a 6 × 4¼ × 2½-inch three-sided box folded from sheet aluminum. A small audio transformer, mounted on the rear of this box, serves to provide 60-cycle sweep voltage. The by-pass condensers, C_2, C_3 and C_4, used to eliminate a.c. components from the d.c. control circuits, are connected directly to the rotor arms of their respective potentiometers, R_1, R_8 and R_9.

The socket for the cathode-ray tube is not fastened to any of the structural members of the unit, but is used as a plug, with the socket terminals enclosed in a tubular aluminum shield made by cutting down a National Type T-78 tube shield. The base plate of this assembly is used as the support for a two-terminal tie-

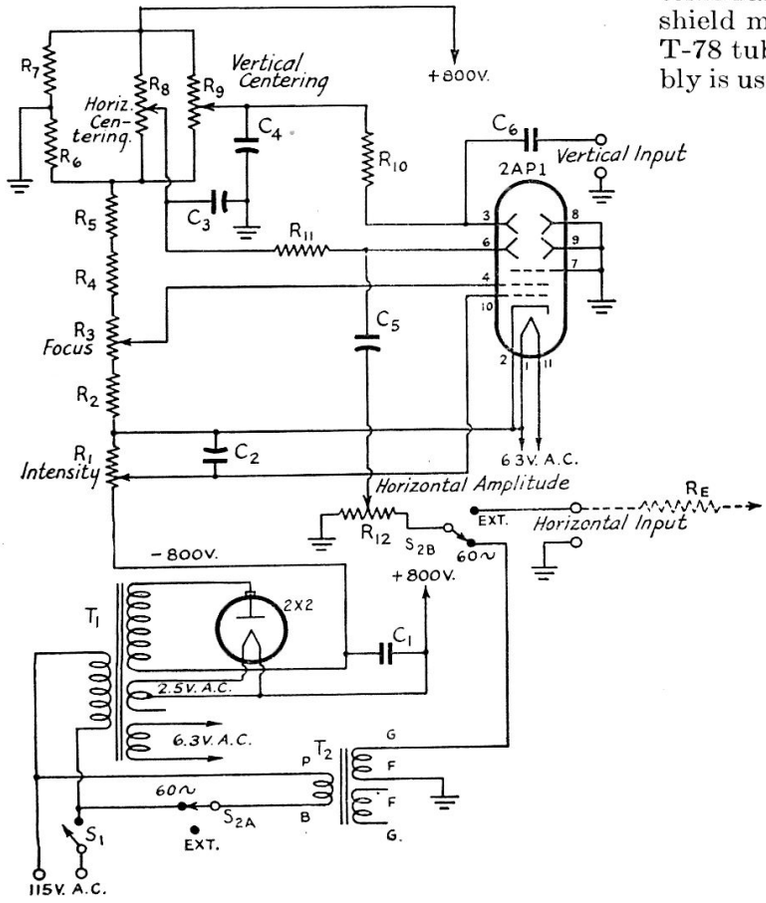


Fig. 16-24 — Circuit diagram of the simple oscilloscope for modulation monitoring.
C_1 — 1 μfd., 1000 volts, oil-filled.
C_2, C_3, C_4 — 0.01-μfd. 600-volt paper.
C_5 — 0.1 μfd., 1000 volts, paper.
C_6 — 0.001 μfd., 600 volts, mica.
R_1 — 20,000-ohm potentiometer, linear taper.
R_2 — 4700 ohms, ½ watt.
R_3 — 50,000-ohm potentiometer, linear taper.
R_4, R_5 — 33,000 ohms, 1 watt.
R_6, R_7 — 47,000 ohms, 1 watt.
R_8, R_9 — 50,000-ohm potentiometer, linear taper.
R_{10}, R_{11} — 1 megohm, ½ watt.
R_{12} — 0.25-megohm potentiometer, linear taper.
S_1 — S.p.s.t. toggle switch.
S_2 — D.p.d.t. toggle switch.
T_1 — Replacement-type receiver transformer, 350 v. each side of c.t., 70 ma. (Stancor P-6011.)
T_2 — Interstage audio transformer. (UTC S-2, with half of secondary unused, to produce approx. 1:1 turns ratio.)

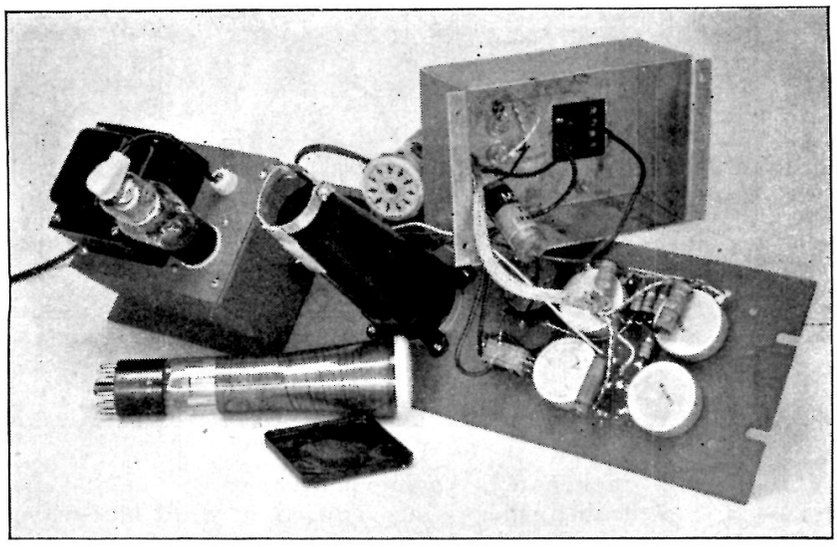


Fig. 16-25 — Rear view of the rack-mounting oscilloscope. The shield covering the voltage-divider components has been removed to show wiring. Mounted on the shield are the audio transformer and the horizontal input terminals. The 'scope tube and its socket have been removed.

point that holds isolating resistors R_{10} and R_{11}. These resistors are mounted inside the socket shield, as close to the tube base as possible. A ½-inch hole is drilled through the side of the shield to pass the cabled and shielded d.c. leads that run from the tube socket into the divider network in the aluminum shield box. A ceramic feed-through bushing requiring a ⅜-inch clearance hole passes through the opposite side of the socket shield to serve as the vertical input terminal. C_6 is connected between this bushing and the vertical deflection-plate pin on the tube socket. C_5, the coupling condenser for the horizontal plates, is mounted inside the larger shield box, near the horizontal-amplitude control, R_{12}.

The horizontal input terminals of the 'scope are mounted on the rear of the shield box, alongside of the audio transformer. The transformer secondary is connected to produce a turns ratio of approximately 1-to-1, which is sufficient to produce more than enough sweep voltage. A double-pole toggle switch is used to open the primary circuit of the audio transformer and to connect the external terminal to the amplitude control when the 'scope is used for transmitter monitoring. In this case sweep voltage is obtained from the audio system of the transmitter. R_{12} is connected on the tube side of the sweep switch, so that it remains in the circuit at all times to give control of voltage applied to the horizontal plates.

Details for using this oscilloscope to monitor a 'phone transmitter and to check both linearity and percentage modulation are contained in Chapter Nine. It should be remembered that an external resistor, R_E in Fig. 16-24, must be used in series with the lead to the horizontal input terminals to reduce the audio voltage to the desired level. Instructions for selection of this resistor are given in Chapter Nine.

LINEAR SWEEPS AND AMPLIFIERS

Probably the chief use of the oscilloscope in amateur work is in measuring the percentage modulation in 'phone transmitters and in serving as a continuous monitor of modulation percentage. An oscilloscope for this purpose may be quite simple and inexpensive, consisting only of a small cathode-ray tube and an appropriate power supply as described above. However, by providing amplifiers for the deflection plates and furnishing a linear sweep circuit, the possibilities of the instrument are greatly extended. It then becomes possible, for example, to examine audio-frequency waveforms and to check and locate the causes of distortion in a.f. amplifiers.

Gas-Tube Sweep Generator

A typical circuit for a linear sweep generator and amplifier is shown in Fig. 16-26. The tube is a gas triode or grid-control rectifier. The striking or breakdown voltage, which is the plate voltage at which the tube ionizes or "fires" and starts conducting, is determined by the grid bias. When plate voltage, E_b in Fig. 16-27, is applied, the condenser between plate and cathode acquires a charge through R_6R_7. The charging voltage rises relatively slowly, as shown by the solid line, until the breakdown or flashing point, V_f, is reached. Then the condenser discharges rapidly through the comparatively low plate-cathode resistance of the tube. When the voltage drops to a value too low to maintain plate-current flow, E_a, the ionization is extinguished and the condenser once more charges through R_6R_7. If they are large enough, the voltage across the condenser rises linearly with time up to the breakdown point. This linear voltage change is used for the sweep. The fly-back time is the time required for discharge through the tube; to keep this time small, the resistance during discharge must be low.

The "sawtooth" rate is controlled by varying the capacitance between plate and cathode and the resistance of R_6R_7. To obtain a stationary pattern, the sweep is synchronized by introducing some of the voltage being observed on the vertical plates into the grid circuit of the 884 tube. This voltage "triggers" the tube into

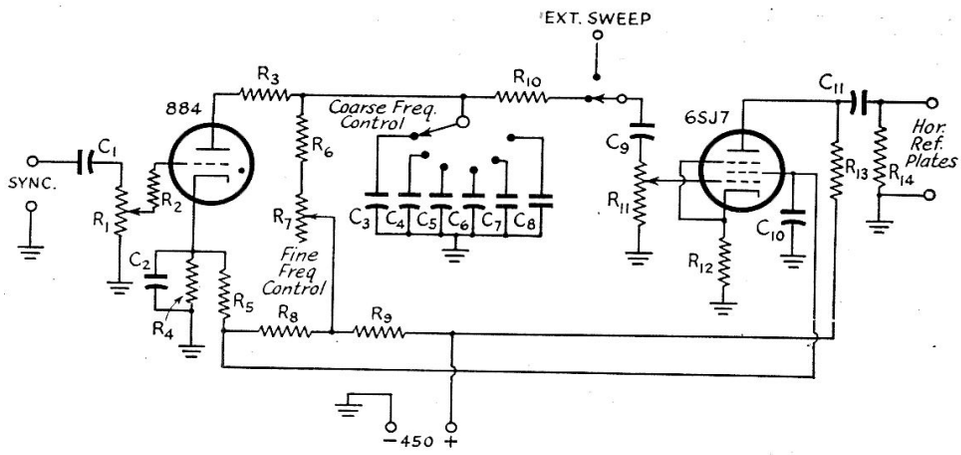


Fig. 16-26 — Linear sweep generator and horizontal amplifier.

C_1 — 0.1-μfd. paper.
C_2 — 25-μfd. 25-volt electrolytic.
C_3 — 0.25-μfd. paper, 600 volts.
C_4 — 0.1-μfd. paper, 600 volts.
C_5 — 0.04-μfd. paper, 600 volts.
C_6 — 0.015-μfd. paper, 600 volts.
C_7 — 0.005-μfd. paper or mica, 600 volts.
C_8 — 0.0022-μfd. mica.
C_9, C_{11} — 0.5-μfd. paper, 600 volts.
C_{10} — 8-μfd. electrolytic, 450 volts.
R_1 — 0.25-megohm potentiometer.
R_2 — 22,000 ohms, ½ watt.
R_3 — 470 ohms, ½ watt.
R_4 — 2200 ohms, ½ watt.
R_5 — 22,000 ohms, 1 watt.
R_6 — 0.33 megohm, ½ watt.
R_7 — 1-megohm potentiometer.
R_8, R_9 — 62,000 ohms, 1 watt.
R_{10} — 1 megohm, ½ watt.
R_{11} — 0.5-megohm potentiometer.
R_{12} — 820 ohms, ½ watt.
R_{13} — 0.1 megohm, 1 watt.
R_{14} — Bleed resistor for horizontal deflection plates.

operation in synchronism with the signal frequency. Synchronization will occur so long as the signal frequency is nearly the same as, or a multiple of, the self-generated sweep frequency.

The pentode amplifier in Fig. 16-26 can be used either to amplify the sweep-voltage output of the 884 oscillator, or to amplify any external voltage that it may be desired to use as a horizontal sweep. The gain control, R_{11},

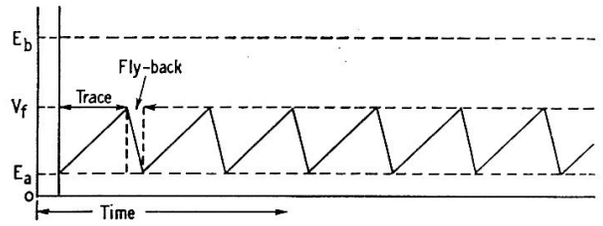


Fig. 16-27 — Condenser charging curves showing how a sawtooth wave is produced by a gaseous-tube linear sweep oscillator.

provides a means for adjusting the width of the pattern on the cathode-ray tube screen. The output of the amplifier should be connected to the horizontal deflection plates of the tube. If this circuit is to be used with the oscilloscope previously described, the output terminals may be connected directly to Terminals 6 and 9 on the 2AP1 socket. In such case C_5 in Fig. 16-24 should be disconnected, but all other connections should be left unchanged.

Vertical Amplifiers

When using an oscilloscope for checking audio-frequency waveforms a "vertical" amplifier is a practical necessity. For most purposes the amplifier will be satisfactory if its frequency-response characteristic is flat over the a.f. range and if it has a gain of 100 or so. A typical circuit is shown in Fig. 16-28. It will be recognized as being practically similar to the "horizontal" amplifier of Fig. 16-26. A high-resistance gain control is desirable, to avoid loading the audio circuits to which the amplifier is connected.

When such an amplifier is used with the oscilloscope of Fig. 16-24, the output terminals should be connected between Terminals 3 and 8 on the 2AP1 socket. It is advisable to connect Terminal 3 to the arm of a 2-position ceramic switch, one contact going to the vertical amplifier and the other to C_6 in Fig. 16-24. This permits using either r.f. or a.f. input to the vertical deflection plates, disconnecting the a.f. amplifier circuit when r.f. is to be applied.

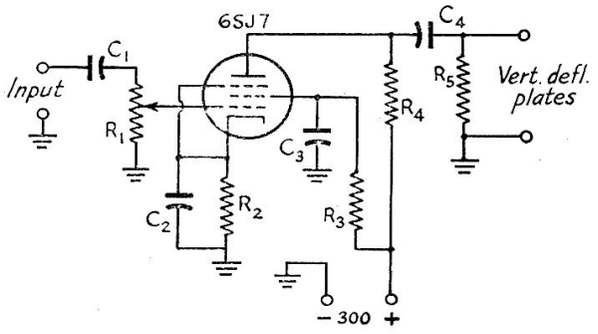


Fig. 16-28 — Circuit diagram of vertical amplifier.

C_1, C_3, C_4 — 0.1-μfd. paper, 400 volts.
C_2 — 25-μfd. 25-volt electrolytic.
R_1 — 1-megohm potentiometer.
R_2 — 1500 ohms, ½ watt.
R_3 — 2.2 megohms, 1 watt.
R_4 — 0.47 megohm, 1 watt.
R_5 — Bleed resistor for vertical deflection plates.

Constructional Considerations

In building an oscilloscope, care should be taken to see that the tube is shielded from stray electric and magnetic fields that might deflect the beam, and means should be provided to protect the operator from accidental shock, since the voltages employed with the larger tubes are quite high. In general, the preferable form of construction is to enclose the instrument completely in a metal cabinet. It is good practice to provide an interlock switch that automatically disconnects the high-voltage supply when the cabinet is opened for servicing or other reasons.

In laying out the unit, the cathode-ray tube must be placed so that the alternating magnetic field from the power transformer has no effect on the electron beam. The transformer should be mounted directly behind the base of the tube, with the axes of the transformer windings and of the tube on a common line.

It is important that provision be included either for switching off the electron beam or reducing the spot intensity when no signal voltage is being applied. A thin, bright line or a spot of high intensity will "burn" the tube screen.

If trouble is experienced in obtaining a clean pattern from a high-power transmitter because of r.f. voltage introduced by the 115-volt line, by-pass condensers (0.01 or 0.1 μfd.) should be connected in series across the primary of the power transformer, the common connection between the two being grounded to the case.

Antenna Measurements

Antenna measurements are made for the purpose (a) of securing maximum transfer of power to the antenna from the transmitter, and (b) of adjusting directional antennas to conform with design conditions. Measurements of the antenna system include the measurement of transmission-line performance.

● FIELD-INTENSITY METERS

In adjusting antenna systems for maximum radiation and in determining radiation patterns, use is made of field-intensity meters. Fundamentally the field-intensity meter consists of a pick-up antenna and an indicating device such as a rectifier and microammeter, or a vacuum-tube voltmeter provided with a tuned input circuit. It is used to indicate the relative intensity of the radiation field under actual *radiating* conditions. It is particularly useful on the very-high frequencies and in adjusting directional antennas. Field-intensity checks should be made at points at least several wavelengths distant from the antenna and at heights corresponding with the desired angle of radiation.

The absorption frequency meter shown in Fig. 16-5 may be used as a field-strength meter if provided with a pick-up antenna. It is convenient to have the indicating device separate from the actual pick-up. This arrangement allows the pick-up unit to be set up out in the field to pick up radiation from the antenna under test, while the meter unit is near where adjustments are to be made. Antenna adjustment thus becomes a one-man job.

The unit shown in Figs. 16-29 to 16-31, inclusive, is particularly suitable for measurements in the v.h.f. range. It is constructed in two sections, one containing a tuned circuit, crystal rectifier, and antenna connection, and the other housing a microammeter for registering the rectified current from the crystal. The two units are fitted with matching plug and socket, permitting them to be used together, or they may be interconnected by means of a cable which can be any length up to several hundred feet. Three coils are used, so that measurements may be made on 28, 50 and 144 Mc. A resistor is inserted in series with the crystal and meter, to lessen the loading effect on the tuned circuit and to make the response of the crystal more linear with variations in radiated power. As the resistor reduces the sensitivity somewhat, a switch is provided to short it out in case measurements are to be made with extremely low power or at large distances from the transmitting antenna. A 100-microampere meter is used to give high sensitivity, and a shunt is

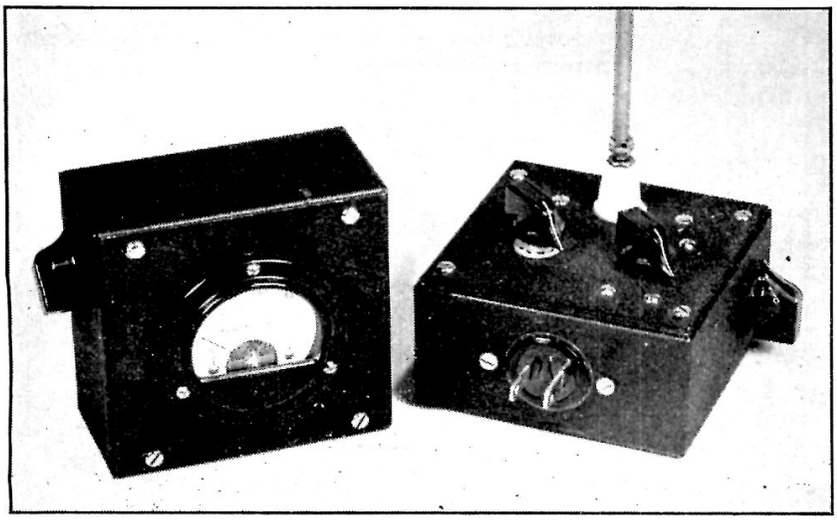


Fig. 16-29 — Remote-indicating field-strength meter, consisting of an r.f. pick-up and rectifier unit, and a meter unit. The knob on the left side of the meter unit is the switch for the shunt. On the pick-up unit the two controls are the bandswitch (left) and tuning. The knob at the right is for the resistor-shorting switch.

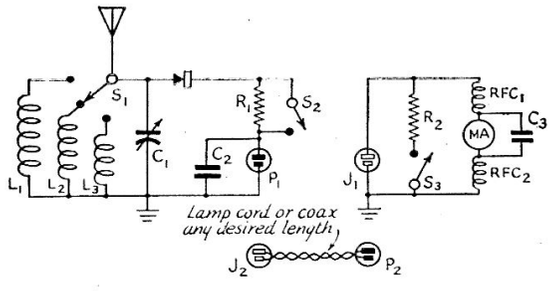


Fig. 16-30 — Wiring diagram of the remote-indicating field-strength meter.

C_1 — 25-$\mu\mu$fd. midget variable.
C_2, C_3 — 0.001-μfd. mica.
R_1 — 1000 ohms, ½ watt.
R_2 — 220 ohms, ½ watt.
L_1 — 28-Mc. coil — 7 turns No. 22 enamel, ¼ inch long, on ¾-inch dia. form (National PRF-1).
L_2 — 50-Mc. coil — 6 turns No. 22 enamel, ¼ inch long, on 9/16-inch dia. form (National PRE-1).
L_3 — 144-Mc. coil — 3 turns No. 18 enamel, ¼ inch long, ⅜-inch dia., self-supporting.
J_1, J_2 — Universal receptacle, two-pole retainer-ring type (Amphenol 61-F).
MA — 0–100 microammeter (0–500 microammeter or 0–1 milliammeter may be used, with reduced sensitivity).
P_1, P_2 — Polarized plug, two-pole retainer-ring type (Amphenol 61-MP).
S_1 — 3-position wafer-type switch.
S_2, S_3 — S.p.s.t. snap switch.
RFC_1, RFC_2 — 2.5 mh. choke (National R-100).

available to multiply the range of the meter by three. This shunt is also provided with a switch so that low or high readings can be taken without making a trip to the pick-up unit. The crystal is the 1N21 type. Germanium crystals (1N34) also may be used with good results.

The two units are housed in 2 × 4 × 4-inch steel boxes with front and back removable. In the pick-up unit all parts except the resistor-shorting switch and connecting plug are mounted on the top panel, permitting easy wiring of the assembly. The interconnecting plug and socket are the polarized type, with one prong on the plug slightly larger than the other. The plug will fit a standard a.c. outlet, so the interconnecting cable (ordinary rubber-covered lamp cord) doubles as a long a.c. extension cord when not in use for its intended purpose.

The antenna connection is a steatite feed-through bushing fitted with a "banana-plug" socket. A convenient pick-up antenna is made by drilling and tapping a ¼-inch rod for 6/32 thread to take the threaded end of a banana plug. The length of the antenna will vary the sensitivity of the unit. If measurements are to be made with high power levels, a rod a few inches in length will suffice, but for ordinary work a length of 24 inches or so will be about right.

CHECKING STANDING WAVES

Standing waves on a transmission line can be measured if it is possible to measure the current at every point along the line, or the voltage between the two conductors at every point along the line. Rough checks can be made by going along the line with an absorption wavemeter having a crystal rectifier, taking care to keep the pick-up coil (or pick-up antenna) at the same distance from the line at every measurement. With such a device the milliammeter usually will indicate current loops if a small pick-up coil is used, and voltage loops if a short pick-up antenna is used.

On two-conductor lines the current can be checked by means of the device shown in Fig. 16-32. The hooks, which should be sharp enough to cut through the insulation (if any) on the wires, are placed on one of the wires. The spacing between the hooks should be adjusted to give a suitable reading on the meter. The standing-wave ratio can be determined by taking readings to determine the maximum and minimum currents along the line. At any one position along the line the currents in the two wires should be identical. If they are not, the line is carrying current either induced by the field of the antenna or coupled into the line through stray capacitance at the transmitter end.

BRIDGE-TYPE STANDING-WAVE INDICATORS

The standing-wave ratio on a transmission line can be found without actually going along

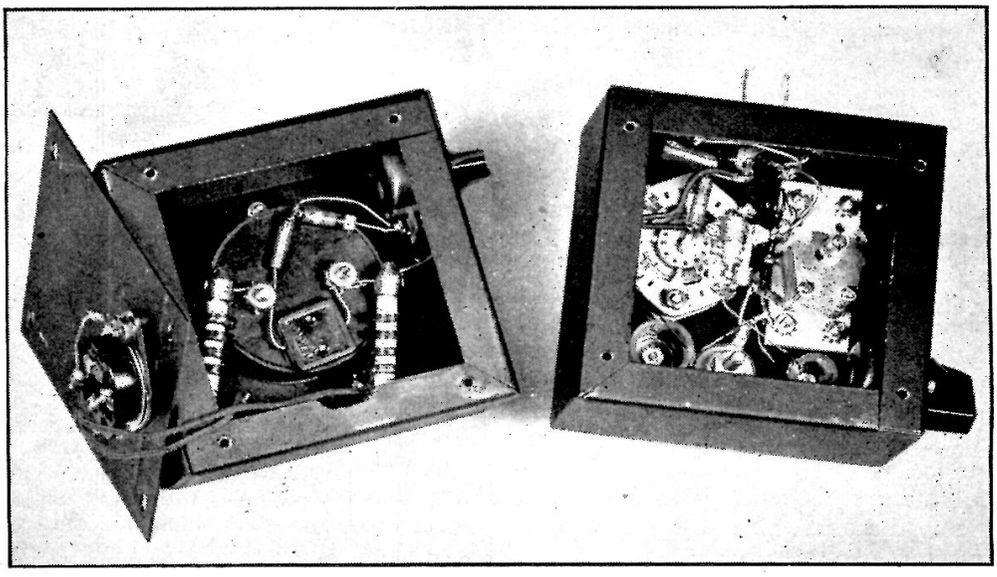


Fig. 16-31 — Inside view of the two units of the remote-indicating field-strength meter.

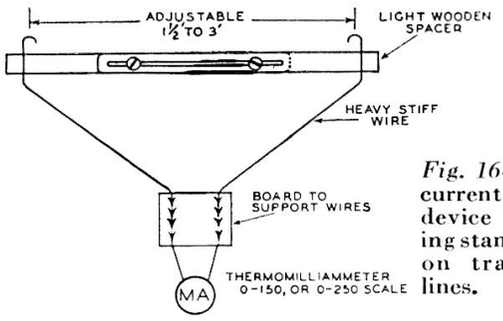


Fig. 16-32 — Line-current measuring device for checking standing waves on transmission lines.

the line and measuring the current or voltage. The basis of such measurement is the separation of the power traveling outward along the transmission line to the load from the power reflected back from the load toward the source. At any point along the line the following relationship is true:

$$S.W.R. = \frac{V_o + V_r}{V_o - V_r}$$

where $S.W.R.$ = Standing-wave ratio

V_o = Outgoing component of voltage
V_r = Reflected component of voltage

V_o and V_r are both taken at the point where the s.w.r. measurement is made.

An ordinary voltage measurement on the line simply shows the resultant of the two voltage components, but by using special bridge-type circuits it is possible to obtain voltage readings that are proportional to each component. Two circuits of this type are shown in Fig. 16-33. The one at A is a resistance-capacitance bridge and that at B a Maxwell-type bridge. Both bridges are theoretically independent of the applied frequency, and are practically so up to the frequency where stray inductance, capacitance, and coupling between circuit elements and wiring become of importance. In both circuits the radio-frequency voltmeter, V, must be a high-impedance device. The conditions for "balance" — that is, for the voltmeter to read zero regardless of the voltage applied to the input terminals — are given in the equations to the right of each diagram. C_1 in Fig. 16-33A, and C in the circuit at B, are made adjustable so that the ratio of the bridge can be varied for various load resistances, R_L.

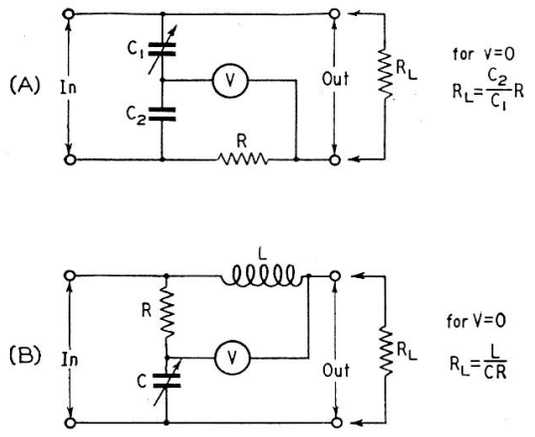


Fig. 16-33 — **Fundamental circuits of two bridge-type standing-wave indicators. The upper circuit is used in the "Micro-Match" unit; the lower is a Maxwell bridge.**

If the load, R_L, is a transmission line, it will look like a pure resistance equal to its characteristic impedance when the line is correctly terminated. Consequently, the voltmeter will read zero when the line is perfectly matched, if the bridge has previously been balanced for that same value of resistance. If the line is not matched, the reflected power will cause the voltmeter to register a reading that is proportional to the *reflected* voltage. If the load is connected to the "input" terminals and the source of power to the "output" side, the voltmeter reading will be proportional to the *outgoing* component of voltage. Substituting the two voltmeter readings in the formula above will then give the standing-wave ratio.

Practical circuits corresponding to the two in Fig. 16-33 are given in Figs. 16-34 and 16-35. The r.f. voltmeter is a crystal rectifier and 0–1 d.c. milliammeter (or microammeter) with chokes and resistors for keeping the r.f. out of the meter circuit. In order to keep the voltmeter impedance high and to improve the linearity, it is advisable to use as much resist-

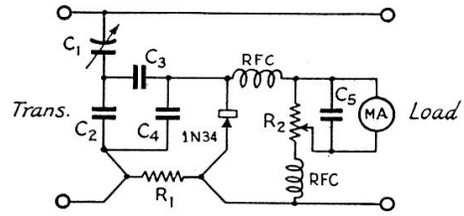


Fig. 16-34—Circuit diagram of the "Micro-Match" standing-wave indicator.

C_1 — 3–15-$\mu\mu$fd. midget variable.
C_2, C_4 — 220-$\mu\mu$fd. mica.
C_3 — 82-$\mu\mu$fd. mica.
C_5 — 0.0047-μfd. mica.
R_1 — 1.1-ohm resistor (9 10-ohm 1-watt carbon resistors in parallel).
R_2 — 5000-ohm potentiometer.
MA — 0–1 d.c. milliammeter.
RFC — 2.5-mh. r.f. choke.

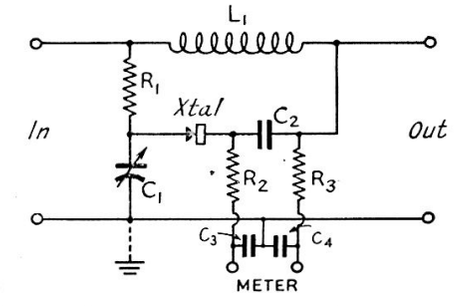


Fig. 16-35 — Circuit diagram of the Maxwell-bridge standing-wave indicator. The meter should have a full-scale range of 1 milliampere or less.

C_1 — 10–100-$\mu\mu$fd. Ceramicon variable.
C_2 — 470-$\mu\mu$fd. mica.
C_3, C_4 — (Optional) 100-$\mu\mu$fd. mica.
R_1 — 500 ohms, nonreactive.
R_2, R_3 — 10,000 ohms, ½-watt carbon.
L_1 — Approx. 29 turns No. 18, diameter 0.6 inch, 2.5 inches long.
XTAL — 1N34 or equivalent.

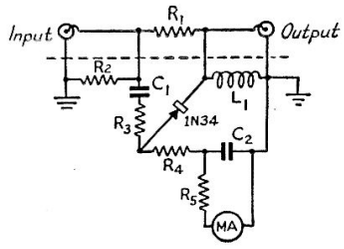


Fig. 16-36 — Circuit diagram of resistance bridge for measuring s.w.r., as adapted for coaxial lines. This circuit operates at very low power level and provision must be made for reducing the transmitter power to a low value when using it.

C_1, C_2 — 470-$\mu\mu$fd. mica.
R_1 — 1-watt composition resistor, value equal to impedance of line being measured.
R_2 — 10 ohms, 1 watt.
R_3, R_4 — 56-ohm 1-watt composition. Exact value not important but the two resistors must have the same value.
R_5 — 470 ohms, ½ watt.
L_1 — Good r.f. choke at operating frequency. Not required if antenna system is closed type that offers d.c. return. At 28 Mc., 40 turns of No. 36 d.c.c. wound on a 1-watt 0.1-megohm resistor is satisfactory, or a regular 2.5-mh. choke may be used.
MA — 0–1 milliammeter.

ance in series with the meter as possible while still obtaining full-scale indications at the r.f. power level used.

Several precautions must be observed in constructing and using such instruments. The leads must be kept short, to avoid introducing reactance that would prevent obtaining proper balance. The rectifier-circuit wiring should be kept out of the fields of the other components insofar as possible, since stray pick-up in this wiring will give a "residual" voltmeter reading that will not balance out. It is absolutely essential that the resistors have negligible capacitance and inductance; wire-wound resistors cannot be used with any success.

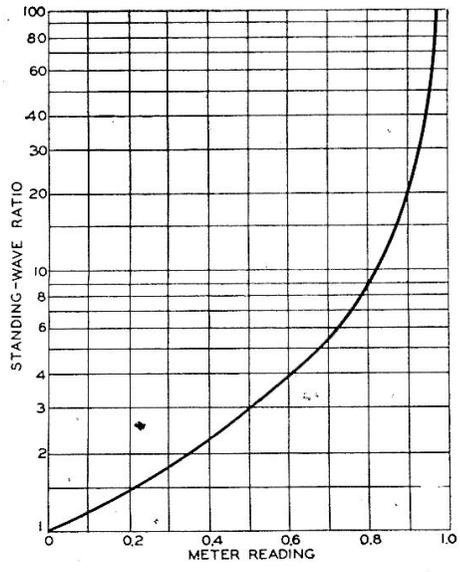


Fig. 16-37 — Standing-wave ratio in terms of meter reading (relative to full scale) after setting outgoing voltage to full scale. This graph is a plot of the formula

$$S.W.R. = \frac{Vo + Vr}{Vo - Vr}$$

To calibrate such a bridge, connect a noninductive resistor equal to the characteristic impedance of the line to be used to the output terminals, apply an r.f. voltage to the input terminals, and adjust the variable condenser for minimum reading. Then reverse the bridge so that the power source is connected to the output terminals and the resistor load to the input. Adust the r.f. voltage (by changing the coupling to the transmitter) to make the meter read full scale. Then reverse the bridge connections and check the reading. If it is more than one or two per cent of the full-scale reading it will be necessary to try different arrangements of the wiring until the null reading can be brought as close to zero as possible. The variable condenser can be calibrated in terms of various line impedances by substituting load resistances of the appropriate values, noting the setting for balance at each resistance

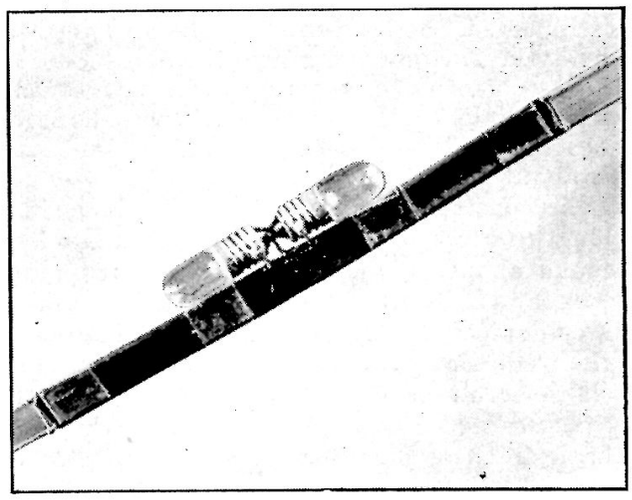


Fig. 16-38 — The "twin-lamp" standing-wave indicator.

value. Both circuits can be used over the range of 50 to 300 ohms, approximately.

In using standing-wave indicators, the readings will be reliable only when there are no "antenna" currents on the transmission line. (See Chapter Ten.) If there is no stray pick-up on the line, it will not matter which line conductor is connected to which output terminal; the meter reading will be the same both ways. The same is true of the connections to the power source. If the way the line or source is connected does make a difference in the readings the results can be considerably in error. Coaxial lines usually are less troublesome in this respect than parallel-conductor lines.

Resistance Bridge

The bridge circuit in Fig. 16-36 uses equal resistance arms and can be used with only one value of line impedance. However, it is not necessary to reverse the line and power source to obtain a standing-wave reading. When properly constructed (noninductive resistors must be used) the meter reading will be zero when a noninductive resistance equal to the

line impedance is connected to the output terminals.

To use the bridge, the output terminals are first short-circuited and the input voltage adjusted to give a full-scale reading on the milliammeter. When the short-circuit is removed and the line connected to the output terminals, the meter reading (relative to the full-scale reading) indicates the s.w.r. as shown in Fig. 16-37.

The "Twin-Lamp"

A simple and inexpensive standing-wave indicator for 300-ohm line is shown in Fig. 16-38. It consists only of two flashlight lamps and a short piece of 300-ohm line. When laid flat against the line to be checked, the combination of inductive and capacitive coupling is such that outgoing power on the line causes the lamp nearest to the transmitter to light, while reflected power lights the lamp nearest the load. When the line is matched and no power is reflected, the lamp toward the antenna will be dark. The power input to the line should be adjusted to make the lamp nearest the transmitter light to full brilliance. When the lamp nearest the load just begins to glow, the s.w.r. is about 1.5 to 1.

To construct the "twin-lamp," take a short length (a foot or two) of 300-ohm line and remove about ¼ inch of insulation from one wire at the center of the piece. Then take a second piece, 4 to 10 inches long (depending on the frequency and the transmitter power) and short-circuit both ends. Cut one wire in the exact center of the piece and peel the ends back on either side just far enough to provide

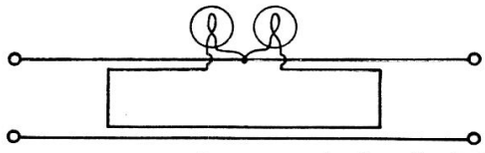


Fig. 16-39 — Wiring diagram of the "twin-lamp" standing-wave indicator.

leads to the flashlight lamps. Use the lowest-current flashlight bulbs or dial lamps available. Solder the tips of the bulbs together and connect them to the bare point in the long section of line, then solder the ends of the cut portion of the short piece to the shells of the bulbs. Figs. 16-38 and 16-39 should make the construction clear. The whole unit forms a "test section" that can be inserted in series with the line to be measured.

While the "twin-lamp" cannot readily be used for quantitative measurement of s.w.r., it is very useful in checking the effect of load adjustments on the standing-wave ratio, when 300-ohm line is used.

References

The construction of a bridge-type standing-wave indicator is critical both as to layout and materials. Additional information will be found in the following *QST* articles:

Jones and Sontheimer, "The 'Micromatch,'" April, 1947; "Additional Notes on the 'Micromatch,'" July, 1947.

Pattison, Morris and Smith, "A Standing-Wave Meter for Coaxial Lines," July, 1947.

Wright, "The 'Twin-Lamp,'" October, 1947.

Tiffany, "A Universal Transmission Bridge," December, 1947.

CHAPTER 17

Assembling a Station

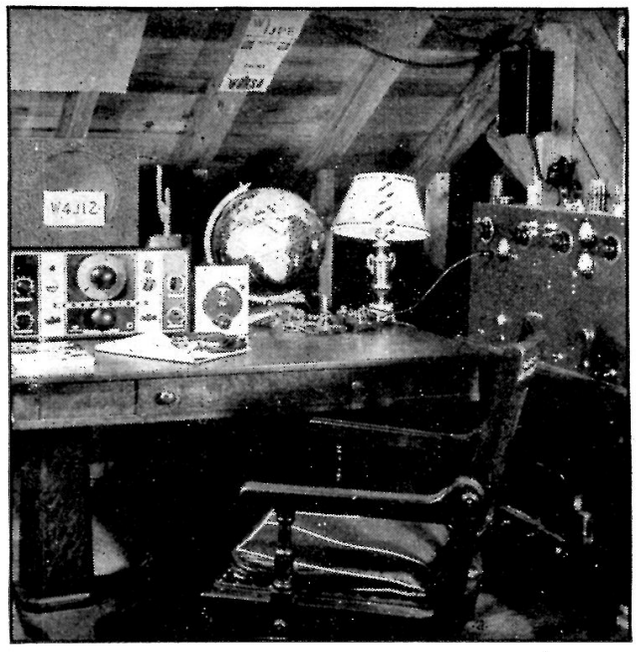
An amateur station is generally far better known by its signal and good operation than by its physical appearance. Good operating and a clean signal will build a reputation faster than thousands of dollars invested in special equipment and an elaborate "shack," and it is this very fact that makes amateur radio the democratic hobby that it is. However, most amateurs take pride in the arrangement of their stations, in the same way that they are careful of the appearance and arrangement of anything else which is part of the household. An antenna installation is the only external indication of the amateur station, and the degree of neatness required is generally determined by the district where the amateur lives and the attitude of the neighbors.

The actual location inside the house of the "shack" — the room where the transmitter and receiver are located — depends, of course, on the free space available for amateur activities. Fortunate indeed is the amateur with a separate room that he can devote to his amateur station, or the few who can have a special small building separate from the main house. However, most amateurs must share a room with other domestic activities, and amateur stations will be found tucked away in a corner of the living room, a bedroom, a large closet, or even under the kitchen stove! A spot in the cellar or the attic can almost be classed as a separate room, although it may lack the "finish" of a normal room.

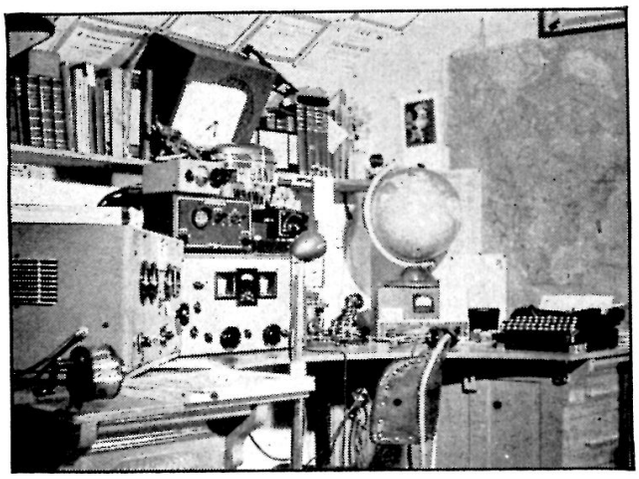
Regardless of the location of the station, however, it should be designed for maximum operating convenience and safety. It is foolish to have the station arranged so that the throwing of several switches is required to go from "receive" to "transmit," just as it is silly to have the equipment arranged so that the operator is in an uncomfortable and cramped position during his operating hours. The reasons for building the station as safe as possible are obvious, if you are interested in spending a number of years with your hobby!

CONVENIENCE

The first consideration in any amateur station is the operating position, which includes the operator's table and chair and the pieces of equipment that are in constant use (the receiver, send-receive switch, and key or microphone). The table should be as large as possible, to allow sufficient room for the receiver or receivers, frequency-measuring equipment, monitoring equipment, control switches, and keys and microphones, with enough space left over for the logbook, a pad and pencil, and perhaps a *large* ash tray. Suitable space should be included for radiogram blanks and a call book, if these accessories are in frequent use. If the table is small, or the number of pieces of equipment is large, it is often necessary to build a shelf or rack for the auxiliary equipment, or to mount it in some less convenient location in or under the table. If one has the facilities, a semicircular "console" can be built of wood, or a simpler solution is to use two small wooden cabinets to support a table top of wood or Masonite. Home-built tables or consoles can be finished in any of the available oil stains, varnishes, paints or lacquers. Many operators



This station is tucked away in a corner of the attic, and everything is accessible to the operator without his leaving the chair. The second-hand furniture was not an attempt to be fancy, but simply the only way the operator could find any lumber during a shortage. (W4JIZ/W4KFC, Annandale, Va.)

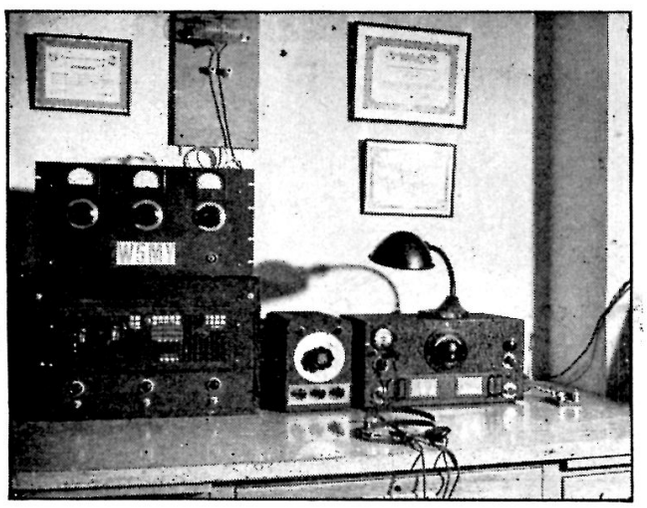


A convenient operating position can be obtained by building a "horseshoe-type" operating desk as shown here. Considerably more equipment can be placed on the desk around the operator than if an ordinary desk is used. (W9AND, Dixon, Ill.)

use a large piece of plate glass over part of their table, since it furnishes a good writing surface and can cover miscellaneous charts and tables, prefix lists, operating aids, calendar, and similar accessories.

If the major interests never require frequent band changing, or frequency changing within a band, the transmitter can be located some distance from the operator, in a location where the meters can be observed from time to time (and the color of the tube plates noted!). If frequent band or frequency changes are a part of the usual operating procedure, the transmitter should be mounted close to the operator, either along one side or above the receiver, so that the controls are easily accessible without the need for leaving the operating position.

A compromise arrangement would place the VFO or crystal-switched oscillator at the operating position and the transmitter in some convenient location not adjacent to the operator. Since it is usually possible to operate over a portion of a band without retuning the transmitter stages, an operating position of this type is an advantage over one in which the operator must leave his position to make a change in frequency.



When one specializes in clean-cut c.w. operation on all bands, he is likely to come up with a neat arrangement like this. The transmitter runs 400 watts, despite its small size. The small unit between transmitter and receiver is the VFO. (W5MY, San Antonio, Texas)

Controls

The operator has an excellent chance to exercise his ingenuity in the location of the operating controls. The most important controls in the station are the receiver tuning dial and the send-receive switch. The receiver tuning dial should be located four to eight inches above the operating table, and if this requires mounting the receiver off the table, a small shelf or bracket will do the trick. With the single exception of the amateur whose work is almost entirely in traffic or rag-chew nets, which require little or no attention to the receiver, it will be found that the operator's hand is on the receiver tuning dial most of the time. If the tuning knob is too high or too low, the hand gets cramped after an extended period of operating, hence the importance of a properly-located receiver. The majority of c.w. operators tune with the left hand, preferring to leave the right hand free for copying messages and handling the key, and so the receiver should be mounted where the knob can be reached by the left hand. 'Phone operators aren't tied down this way, and tune the communications receiver with the hand that is more convenient.

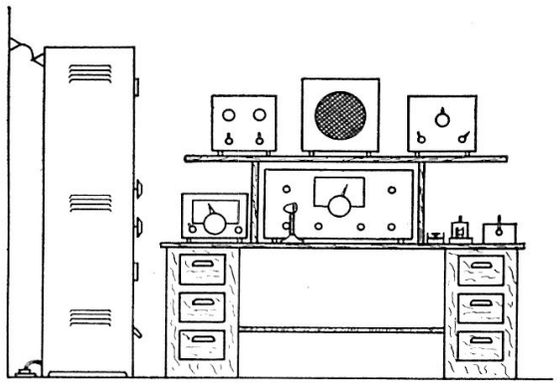


Fig. 17-1 — In a station assembled for maximum ease in frequency or band changing, the transmitter should be located next to the operating position, as shown above. On the operating table, the receiver is in front of the operator and VFO or crystal-switching oscillator on the left. (The VFO or crystal oscillator could be part of the transmitter proper, but most operators seem to prefer a separate VFO.)

The frequency standard and other auxiliary equipment can be mounted on a shelf above the receiver. The operating table can be an old desk, or a top supported by two small wooden cabinets. The "send-receive" switch is to the right of the telegraph keys — other switches are on the transmitter or the individual units.

The above arrangement can be made to look cleaner by arranging all of the equipment on the table behind a single panel or a set of panels. In this case, provision must be made for getting behind the panel for servicing the units.

The hand-key should be fastened securely to the table, in a line just outside the right

shoulder and far enough back from the front edge of the table so that the elbow can rest on the table. A good location for the semiautomatic or "bug" key is right next to the hand-key, although some operators prefer to mount the automatic key in front of them on the left, so that the right forearm rests on the table parallel to the front edge.

The best location of the microphone is directly in front of the operator, so that he doesn't have to shout across the table into it, or run up the speech-amplifier gain so high that all manner of external sounds are picked up.

In any amateur station worthy of the name, it should be necessary to throw no more than one switch to go from the "receive" to the "transmit" condition. In 'phone stations, this switch should be located where it can be easily reached by the hand that isn't on the receiver. In the case of c.w. operation, this switch is most conveniently located to the right or left of the key, although some operators prefer to have it mounted on the left-hand side of the operating position and work it with the left hand while the right hand is on the key. Either location is satisfactory, of course, and the choice depends upon personal preference. Some operators use a foot-controlled switch, which is a convenience but doesn't allow too much freedom of position during long operating periods.

If the microphone is hand-held during 'phone operation, a "push-to-talk" switch on the microphone is convenient, but hand-held microphones tie up the use of one hand and

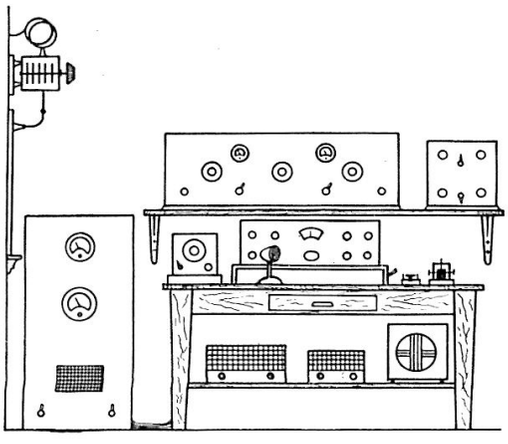
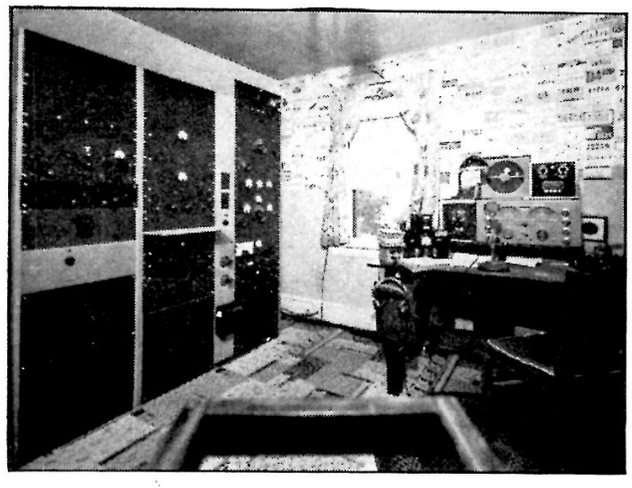


Fig. 17-2 — When little space is available for the amateur station, the equipment has to be spotted where it will fit. In the above arrangement, the transmitter, modulator and power supplies (separate units) are sandwiched in alongside the operating table and on a shelf above the table. The antenna tuning unit is mounted over the feed-through insulators that bring the antenna line into the "shack," and loudspeaker and small power supplies are mounted under the table. The operating position is clean, however, with the VFO, receiver and keys at table level. The tuning knob of this receiver would be uncomfortably low if the receiver weren't raised by the wooden arch, and the "send-receive" switch is mounted on the right-hand side of this arch, next to the hand-key. Interconnecting leads should be cabled along the back of the table and table legs, to keep them inconspicuous.



A high-powered station in a room with enough space to locate the transmitters along one wall and the operating table along another. Note the convenient location of the control switches, and the receiver raised above the table. (W1CH, Worcester, Mass.)

are not too desirable, although they are widely used in mobile and portable work. A breast, chin or throat microphone is safer for mobile work, if the operator is also the driver of the vehicle.

The location of other switches, such as those used to control power supplies, filaments, 'phone/c.w. change-over and the like, is of no particular importance, and they can be located on the unit with which they are associated. This is not strictly true in the case of the 'phone/c.w. DX man, who sometimes has need to change in a hurry from c.w. to 'phone. In this case, the change-over switch should be at the operating table, although the actual change-over should be done by a relay that the switch controls.

If a rotary beam is used the control of the beam should be convenient to the operator. The beam-direction indicator, however, can be located anywhere within sight of the operator, and does not have to be located on the operating table unless it is small, or included with the beam control.

When several fixed beams are used, the selection of any one should be possible from the operating position, to minimize the time required to select the proper one. This generally means using a series of antenna relays or a stepping switch.

Frequency Spotting

In a station where a VFO is used, or where a number of crystals is available, the operator should be able to turn on only the oscillator of his transmitter, so that he can spot accurately his location in the band with respect to other stations. This allows him to see if he has anything like a clear channel (if such a thing exists in the amateur bands!), or to see what his frequency is with respect to another station. Such a provision can be part of the "send-receive" switch. Switches are available with a center "off" position, a "hold" position on one side,

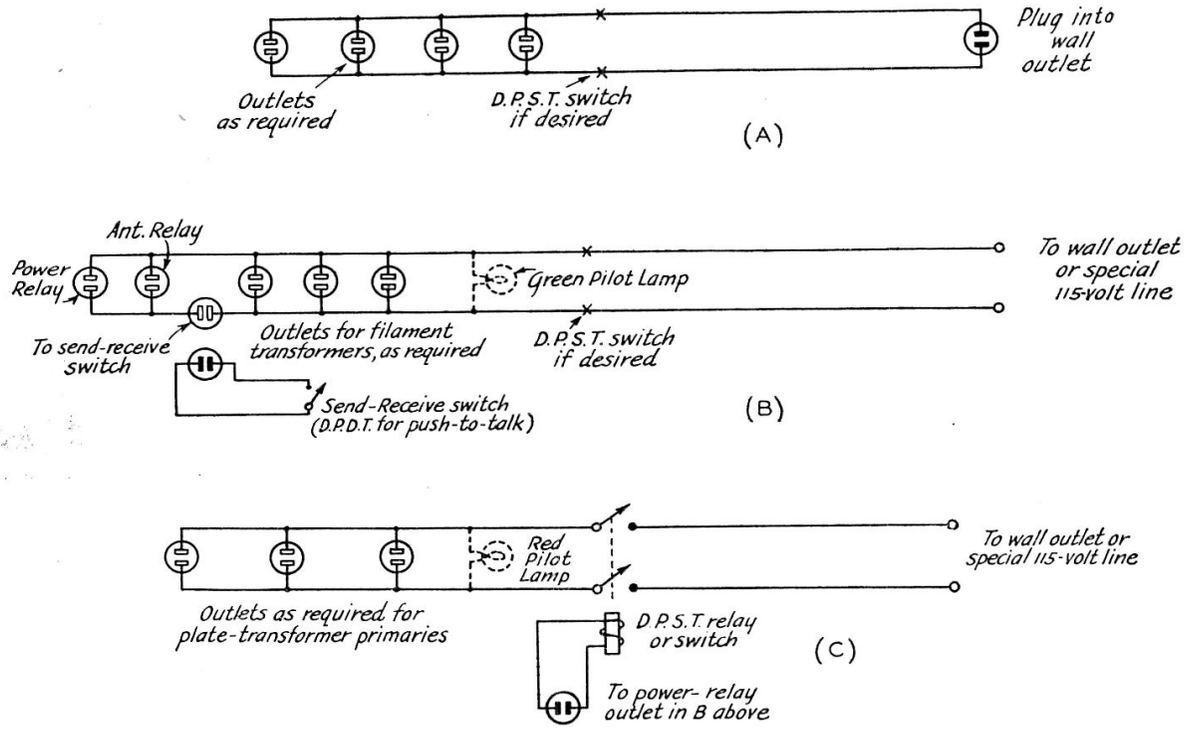


Fig. 17-3 — Power circuits for a high-power station. A shows the outlets for the receiver, monitoring equipment, speech amplifier and the like. The outlets should be mounted inconspicuously on the operating table. B shows the transmitter filament circuits and control-relay circuits, if the latter are used. C shows the plate-transformer primary circuits, controlled by the power relay. A heavy-duty switch can be used instead of the relay, in which case the antenna relay would be connected in circuit C.

If 115-volt pilot lamps are used, they can be connected as shown. Lower-voltage lamps must be connected across suitable windings on transformers.

With "push-to-talk" operation, the "send-receive" switch can be a d.p.d.t. affair, with the second pole controlling the "on-off" circuit of the receiver.

for turning on the oscillator only, and a "lock" position on the other side for turning on the transmitter and antenna relays. If oscillator keying is used, the key serves the same purpose, provided a "send-receive" switch is available to turn off the high-voltage supplies and prevent a signal going out on the air during adjustment of the oscillator frequency.

For 'phone operation, the telegraph key or an auxiliary switch can control the transmitter oscillator, and the "send-receive" switch can then be wired into the control system so as to control the oscillator as well as the other circuits.



An example of the compact station, complete on the operating table. The receiver is mounted on the left side of the table, for left-hand tuning. The beam-direction indicator and switches are housed in a small box sitting on the VFO. (W2NFU, Forest Hills, N. Y.)

Comfort

Of prime importance is the comfort of the operator. If you find yourself getting tired after a short period of operating, examine your station to find what causes the fatigue. It may be that the chair is too soft or hasn't a straight back or is the wrong height for you. The key or receiver may be located so that you assume an uncomfortable position while using them. If you get sleepy fast, the ventilation may be at fault. (Or you may need sleep!)

POWER CONNECTIONS AND CONTROL

Following a few simple rules in wiring your power supplies and control circuits will make it an easy job to change units in the station. If the station is planned in this way from the start, or if the rules are recalled when you are rebuilding, you will find it a simple matter to revise your station from time to time *without* a major rewiring job.

The regular wall outlets in a home are generally rated at 15 amperes at 115 volts, and so will furnish sufficient power for receivers, monitoring equipment, speech amplifiers, and anything that doesn't draw too high an intermittent load (such as a keyed transmitter or Class B modulator). A low-powered transmitter, under one or two hundred watts, can be supplied by an ordinary wall outlet. To make a neat installation, it is better to run a single pair of wires from the outlet over to the

operating table or some central point, rather than to use a number of adapters at the wall outlet.

In a high-powered station, the receiver and auxiliary equipment can get their power from the wall outlet, but it is advisable to run in a special, heavy three-wire line from the meter box for the transmitter. This three-wire line will, of course, be 115 volts either side of neutral (ground), or 230 volts across the outside In many cases it is possible to run the filaments and constant loads from one side of this three-wire line and the intermittent loads (plate transformers) from the other side. In this case the filament voltages will *rise* slightly with the application of load, because of the reduced *net* current in the neutral. However, this procedure often unbalances the system too much, resulting in considerable "blinking" of the lights, and the load must be distributed equally across the 230-volt circuit. This can be done by using plate transformers with 230-volt primaries, by dividing the load as equally as possible across both 115-volt circuits, or by using autotransformers that step down the 230 volts to 115 volts and connecting the plate-transformer primaries across the autotransformer secondaries. Obviously balancing the load is the cheapest "out" and the first one to try.

If the lights blink with keying or modulation of a low-powered transmitter that gets its power from a regular wall outlet, taking some of the power from another outlet may help to improve the regulation and is always worth a try.

When a special heavy line is run into the shack for a high-powered transmitter, it will generally be done by a licensed electrician who can advise you on the various types of outlets that are available. Some amateurs terminate their special lines in switch boxes, while others end the line in an electric-stove receptacle. In case you do the work yourself, it is wise to find out if there are any special regulations in your area covering the type of wire, insulation and outlet which must be used. The power companies are always willing to advise you if it looks as though you will be using more power!

Interconnections

The wiring of any station will entail two or three common circuits. The circuit for the receiver, monitoring equipment and the like, assuming it to be taken from a wall outlet, should be run from the wall to an inconspicuous point on the operating table, where it terminates in a multiple outlet large enough to handle the required number of plugs. A single switch between the wall outlet and the receptacle will then turn on all of this equipment at one time, or the plug can simply be pulled out at the wall when leaving the shack.

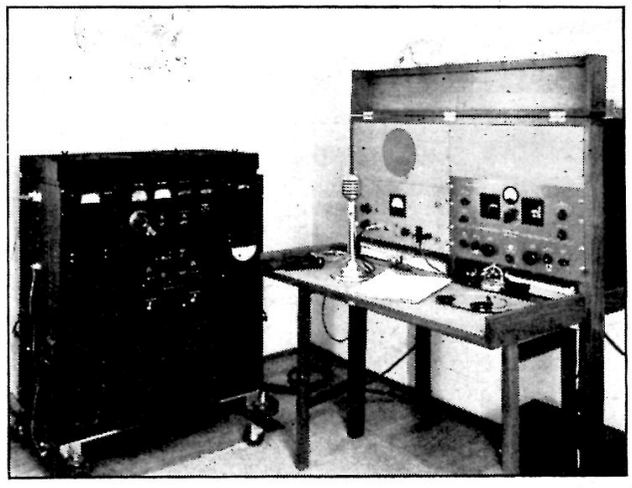
The second common circuit in the station is that supplying voltage to rectifier- and transmitter-tube filaments, bias supplies, and anything else that is not switched on and off during transmit and receive periods. The coil power for control relays should also be obtained from this circuit. The power for this circuit can come from a wall outlet or from the transmitter line, if a special one is used.

The third circuit is the one that furnishes power for the power-supply transformers for the r.f. stages and for the modulator. When it is opened, the transmitter is disabled except for the filaments, and the transmitter should be safe to work on. However, one always feels safer when working on the transmitter if he has turned off everything pertaining to the transmitter.

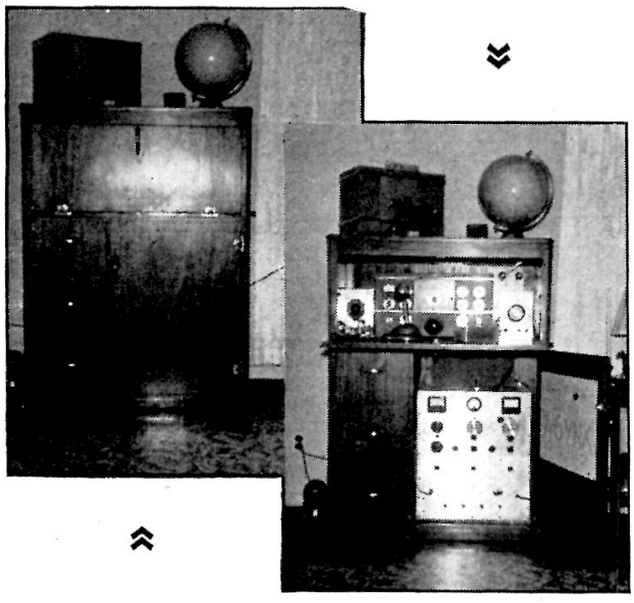
With these three circuits established, it becomes a simple matter to arrange the station for different conditions and with new units. Anything on the operating table (which runs all the time) ties into the first circuit. Any new power supply or r.f. unit gets its filament power from the second circuit. Since the third circuit is controlled by the send-receive switch (or relay), any power-supply primary that is to be switched on and off for send and receive connects to circuit No. 3.

Break-In and Push-To-Talk

In c.w. operation, "break-in" is any system that allows the transmitting operator to hear the other fellow's signal during the "key-up" periods between characters and letters. This allows the sending station to be "broken" by the receiving station at any time, to shorten calls, ask for "fills" in messages, and speed up operation in general. With present techniques, it requires the use of a separate receiving antenna and, with high power, some means for protecting the receiver from the transmitter when the key is "down." Several methods, applicable to high-powered stations, are described in Chapter Eight. If the transmitter is low-powered (50 watts or so), no special



In this example of a compact high-powered station, the operating table folds up when not in use and covers the receiver and speech amplifier. Special furniture, like this homemade operating table, goes a long way toward solving the space problem for many amateurs. (W4HAV, Fort Thomas, Ky.)



This station goes all the way in concealment by housing the entire station in a special cabinet. When the cabinet is opened, the operating table is formed and all pieces of gear are accessible. (W6YNX, Mountain View, Calif.)

equipment is required except the separate receiving antenna and a receiver that "recovers" fast. Where break-in operation is used, there should be a switch on the operating table to turn off the plate supplies when adjusting the oscillator to a new frequency, although during all break-in work this switch will be closed.

"Push-to-talk" is an expression derived from the "push" switch on some microphones, and it means a 'phone station with a single control for all change-over functions. Strictly speaking, it should apply only to a station where this single send-receive switch must be held in place during transmission periods, but any fast-acting switch will give practically the same effect. A control switch with a center "off" position, and one "hold" and one "lock" position, will give more flexibility than a straight "push" switch. The one switch must control the antenna change-over relay, the transmitter power supplies, and the receiver "on-off" circuit. This latter is necessary to disable the receiver during transmit periods, to avoid acoustic feed-back.

Switches and Relays

It is dangerous to use an overloaded switch in the power circuits. After it has been used for some time, it may fail, leaving the power on the circuit even after the switch is thrown to the "off" position. For this reason, large switches, or relays with adequate ratings, should be used to control the plate power. Relays are rated by coil voltages (for their control circuits) and by their contact ratings (what they will carry safely).

When relays are used, the send-receive switch closes the circuit to their coils, thus closing the relay contacts. The relay contacts are in the power circuit being controlled, and thus the switch handles only the relay-coil current.

SAFETY

Of prime importance in the layout of the station is the personal safety of the operator and of visitors, invited or otherwise, during normal operating practice. If there are small children in the house, every step must be taken to prevent their accidental contact with power leads of any voltage. A locked room is a fine idea, if it is possible, otherwise, housing the transmitter and power supplies in metal cabinets is an excellent, although expensive, solution. Lacking a metal cabinet, a wooden cabinet or a wooden framework covered with wire screen is the next best solution. Many stations have the power supplies housed in metal cabinets in the operating room or in a closet or basement, and this cabinet or entry is kept locked — with the key out of reach of everyone but the operator. The power leads are run through conduit to the transmitter, using ignition cable for the high-voltage leads. If the power supplies and transmitter are in the same cabinet, a lock-type main switch for the incoming line power is a good precaution.

A simple substitute for a lock-type main switch is an ordinary line plug with a short connecting wire between the two pins. By wiring a female receptacle in series with the main power line in the transmitter, the shorting plug will act as the main safety lock. When the plug is removed and hidden, it will be impossible to energize the transmitter, and a stranger or child isn't likely to spot or suspect the open receptacle.

An essential adjunct to any station is a **shorting stick** for discharging any high voltage to ground before any work or coil changing is done in the transmitter. Even if interlocks and power-supply bleeders are used, the failure of one or more of these components may leave the transmitter in a dangerous condition. The shorting stick is made by mounting a small metal hook, of wire or rod, on one end of a dry stick or bakelite rod. A piece of ignition cable or other well-insulated wire is then run from the hook on the stick to the chassis or common ground of the transmitter, and the stick is hung alongside the transmitter. Whenever the power is turned off in the transmitter to work on the rig, or to change coils, the shorting stick is first used to touch the several high-voltage leads (tank condenser, filter condenser, tube plate connection, etc.) to insure that there is no high voltage at any of these points. Most commercial installations require the use of this simple device, and it has saved many a life. Use it!

Fusing

A minor hazard in the amateur station is the possibility of fire through the failure of a component. If the failure is complete and the component is large, the house fuses will generally blow. However, it is unwise and inconvenient to depend upon the house fuses to

protect the lines running to the radio equipment, and every power supply should have its own set of fuses, with the fuse ratings selected at about 150 or 200 per cent of the maximum rating of the supply. If, for example, a power transformer is rated at 600 watts, it would draw about 5 amperes from the a.c. line ($600 \div 115 = 5.2$), and a 10-ampere fuse should be used in the primary circuit of the transformer. Circuit breakers can be used instead of fuses if desired.

Wiring

Control-circuit wires running between the operating position and a transmitter in another part of the room should be hidden if possible. This can be done by running the wires under the floor or behind the base molding, bringing the wires out to terminal boxes or regular wall fixtures. Such construction, however, is generally only possible in elaborate installations, and the average amateur must content himself with trying to make the wires as inconspicuous as possible. If several pairs of leads must be run from the operating table to the transmitter, as is generally the case, a single piece of rubber- or vinyl-covered multiconductor cable will always look neater than several pieces of rubber-covered lamp cord.

The antenna wires always present a problem, unless coaxial-line feed is used. Open-wire line from the point of entry of the antenna line should always be arranged neatly, and it is generally best to support it at several points. Many operators prefer to mount their antenna-tuning assemblies right at the point of entry of the feedline, together with an antenna change-over relay (if one is used), and then the link from the tuning assembly to the transmitter can be made of inconspicuous coaxial line or Twin-Lead. If the transmitter is mounted near the point of entry of the antenna line, it simplifies the problem of "what to do with the feeders."



There was enough room at this station to build the transmitter into the wall, and to protect it with glass doors. In an installation like this, it is convenient to have access to the rear of the transmitter units, for making connection to them and for testing. If the rear cannot be reached, all power leads should be cabled up along the side walls, at the rear. (W6NY, Whittier, Calif.)

General

You can check your station arrangement by asking yourself the following questions. If all of your answers are an honest "Yes," your station will be one of which you can be proud.

1) Is your station safe, under normal operating conditions, both for the operator and the visitor?

2) Is the operating position comfortable, even after several hours of operating?

3) Do you throw not more than one switch to go from "receive" to "transmit"?

4) Does it take only a short time to explain to another amateur how to work your station?

5) Do you show your station to visiting amateurs or laymen without apologizing for its appearance?

The Amateur's Workshop

TOOLS AND MATERIALS

While an easier, and perhaps a better, job can be done with a greater variety of tools available, by taking a little thought and care it is possible to turn out a fine piece of equipment with only a few of the common hand tools. A list of tools which will be indispensable in the construction of radio equipment will be found on this page. With these tools it should be possible to perform any of the required operations in preparing panels and metal chassis for assembly and wiring. It is an excellent idea for the amateur who does constructional work to add to his supply of tools from time to time as finances permit.

Several of the pieces of light woodworking machinery, often sold in hardware stores and mail-order retail stores, are ideal for amateur radio work, especially the drill press, grinding head, band and circular saws, and joiner. Although not essential, they are desirable should you be in a position to acquire them.

INDISPENSABLE TOOLS

Long-nose pliers, 6-inch.
Diagonal cutting pliers, 6-inch.
Screwdriver, 6- to 7-inch, ¼-inch blade.
Screwdriver, 4- to 5-inch, ⅛-inch blade.
Scratch awl or scriber for marking lines.
Combination square, 12-inch, for laying out work.
Hand drill, ¼-inch chuck or larger, 2-speed type preferable.
Electric soldering iron, 100 watts.
Hacksaw, 12-inch blades.
Center punch for marking hole centers.
Hammer, ball-peen, 1-lb. head.
Heavy knife.
Yardstick or other straightedge.
Carpenter's brace with adjustable hole cutter or socket-hole punches (see text).
Large, coarse, flat file.
Large round or rat-tail file, ½-inch diameter.
Three or four small and medium files—flat, round, half-round, triangular.
Drills, particularly ¼-inch and Nos. 18, 28, 33, 42 and 50.
Combination oil stone for sharpening tools.
Solder and soldering paste (noncorroding).
Medium-weight machine oil.

ADDITIONAL TOOLS

Bench vise, 4-inch jaws.
Tin shears, 10-inch, for cutting thin sheet metal.
Taper reamer, ½-inch, for enlarging small holes.
Taper reamer, 1-inch, for enlarging holes.
Countersink for brace.
Carpenter's plane, 8- to 12-inch, for woodworking.
Carpenter's saw, crosscut.
Motor-driven emery wheel for grinding.
Long-shank screwdriver with screw-holding clip for tight places.
Set of "Spintite" socket wrenches for hex nuts.
Set of small, flat, open-end wrenches for hex nuts.
Wood chisel, ½-inch.
Cold chisel, ½-inch.
Wing dividers, 8-inch, for scribing circles.
Set of machine-screw taps and dies.
Folding rule, 6-foot.
Dusting brush.

Twist Drills

Twist drills are made of either high-speed steel or carbon steel. The latter type is more common and will usually be supplied unless specific request is made for high-speed drills. The carbon drill will suffice for most ordinary equipment construction work and costs less than the high-speed type.

While twist drills are available in a number of sizes those listed in bold-faced type in Table 18-I will be most commonly used in construction of amateur equipment. It is usually desirable to purchase several of each of the commonly-used sizes rather than a quantity of odd sizes, most of which will be used infrequently, if at all.

Care of Tools

The proper care of tools is not alone a matter of pride to a good workman. He also realizes the energy which may be saved and the annoyance which may be avoided by the possession of a full kit of well-kept sharp-edged tools.

Drills should be sharpened at frequent intervals so that grinding is kept at a minimum each time. This makes it easier to maintain the rather critical surface angles required for best cutting with least wear. Occasional oilstoning of the cutting edges of a drill or reamer will extend the time between grindings.

The soldering iron can be kept in good condition by keeping the tip well tinned with solder and not allowing it to run at full voltage for long periods when it is not being used. After each period of use, the tip should be removed and cleaned of any scale which may have accumulated. An oxidized tip may be

cleaned by dipping it in sal ammoniac while hot and then wiping it clean with a rag. If the tip becomes pitted, it should be filed until smooth and bright, and then tinned by dipping it in solder.

Useful Materials

Small stocks of various miscellaneous materials will be required in constructing radio apparatus, most of which are available from hardware or radio-supply stores. A representative list follows:

- ½ × 1/16-inch brass strip for brackets, etc. (half-hard for bending).
- ¼-inch-square brass rod or ½ × ½ × 1/16-inch angle brass for corner joints.
- ¼-inch diameter round brass rod for shaft extensions.
- Machine screws: Round-head and flat-head, with nuts to fit. Most useful sizes: 4–36, 6–32 and 8–32, in lengths from ¼ inch to 1½ inches. (Nickel-plated iron will be found satisfactory except in strong r.f. fields, where brass should be used.)
- Bakelite and hard-rubber scraps.
- Soldering lugs, panel bearings, rubber grommets, terminal-lug wiring strips, varnished-cambric insulating tubing.

Machine screws, nuts, washers, soldering lugs, etc., are most reasonably purchased in quantities of a gross.

CHASSIS WORKING

With a few essential tools and proper procedure, it will be found that building radio gear on a metal chassis is no more of a chore than building with wood, and a more satisfactory job results.

The placing of components on the chassis is shown quite clearly in the photographs in this *Handbook*. Aside from certain essential dimensions, which usually are given in the text, exact duplication is not necessary.

Much trouble and energy can be saved by spending sufficient time in planning the job. When all details are worked out beforehand the actual construction is greatly simplified.

Cover the top of the chassis with a piece of wrapping paper or, preferably, cross-section paper, folding the edges down over the sides of the chassis and fastening with adhesive tape. Then assemble the parts to be mounted on top of the chassis and move them about until a satisfactory arrangement has been found, keeping in mind any parts which are to be mounted underneath, so that interferences in mounting may be avoided. Place condensers and other parts with shafts extending through the panel first, and arrange them so that the controls will form the desired pattern on the panel. Be sure to line up the shafts squarely with the chassis front. Locate any partition shields and panel

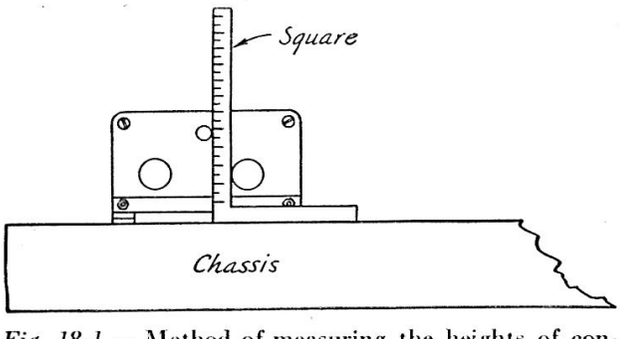


Fig. 18-1 — Method of measuring the heights of condenser shafts, etc. If the square is adjustable, the end of the scale should be set flush with the face of the head.

TABLE 18-I

Numbered Drill Sizes

Number	*Diameter (mils)*	*Will Clear Screw*	*Drilled for Tapping Iron, Steel or Brass**
1	228.0	—	—
2	221.0	12–24	—
3	213.0	—	14–24
4	209.0	12–20	—
5	205.0	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10–32	—
11	191.0	10–24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12–24
17	173.0	—	—
18	**169.5**	**8–32**	—
19	166.0	—	12–20
20	161.0	—	—
21	159.0	—	10–32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10–24
26	147.0	—	—
27	144.0	—	—
28	**140.0**	**6–32**	—
29	**136.0**	—	**8–32**
30	128.5	—	—
31	120.0	—	—
32	116.0	—	—
33	**113.0**	**4–36, 4–40**	—
34	111.0	—	—
35	**110.0**	—	**6–32**
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	099.5	3–48	—
40	098.0	—	—
41	096.0	—	—
42	**093.5**	—	**4–36, 4–40**
43	089.0	2–56	—
44	086.0	—	—
45	082.0	—	3–48
46	081.0	—	—
47	078.5	—	—
48	076.0	—	—
49	073.0	—	2–46
50	**070.0**	—	—
51	067.0	—	—
52	063.5	—	—
53	059.5	—	—
54	055.0	—	—

*Use one size larger for tapping bakelite and hard rubber.

brackets next, and then the tube sockets and any other parts, marking the mounting-hole centers of each accurately on the paper. Watch out for condensers whose shafts are off center and do not line up with the mounting holes. Do not forget to mark the centers of socket holes and holes for leads under i.f. transformers, etc., as well as holes for wiring leads.

By means of the square, lines indicating accurately the centers of shafts should be extended to the front of the chassis and marked on the panel at the chassis line, the panel being fastened on temporarily. The hole centers may then be punched in the chassis with the center punch. After drilling, the parts which require mounting underneath may be located and the mounting holes drilled, making sure by trial that no interferences exist with parts mounted on top. Mounting holes along the front edge

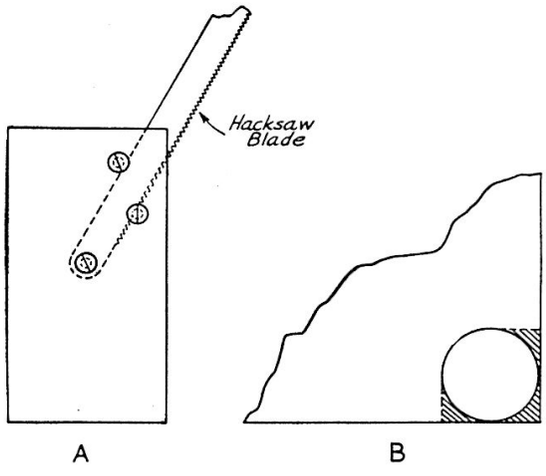


Fig. 18-2 — To cut rectangular holes in a chassis corner, holes may be filed out as shown in the shaded portion of B, making it possible to start the hacksaw blade along the cutting line. A shows how a single-ended handle may be constructed for a hacksaw blade.

of the chassis should be transferred to the panel, by once again fastening the panel to the chassis and marking it from the rear.

Next, mount on the chassis the condensers and any other parts with shafts extending to the panel, and measure accurately the height of the center of each shaft above the chassis, as illustrated in Fig. 18-1. The horizontal displacement of shafts having already been marked on the chassis line on the panel, the vertical displacement can be measured from this line. The shaft centers may now be marked on the back of the panel, and the holes drilled. Holes for any other panel equipment coming above the chassis line may then be marked and drilled, and the remainder of the apparatus mounted.

Drilling and Cutting Holes

When drilling holes in metal with a hand drill it is important that the centers first be located with a center punch, so that the drill point will not "walk" away from the center when starting the hole. When the drill starts to break through, special care must be used. Often it is an advantage to shift a two-speed drill to low gear at this point. Holes more than ¼ inch in diameter may be started with a smaller drill and reamed out with the larger drill.

The chuck on the usual type of hand drill is limited to ¼-inch drills. Although it is rather tedious, the ¼-inch hole may be filed out to larger diameters with round files. Another method possible with limited tools is to drill a series of small holes with the hand drill along the inside of the diameter of the large hole, placing the holes as close together as possible. The center may then be knocked out with a cold chisel and the edges smoothed up with a file. Taper reamers which fit into the carpenter's brace will make the job easier. A large rat-tail file clamped in the brace makes a very good reamer for holes up to the diameter of the file, if the file is revolved counterclockwise.

For socket holes and other large round holes, an adjustable cutter designed for the purpose may be used in the brace. Occasional application of machine oil in the cutting groove will help. The cutter first should be tried out on a block of wood, to make sure that it is set for the correct diameter. Probably the most convenient device for cutting socket holes is the socket-hole punch. The best type is that which works by turning a take-up screw with a wrench.

Rectangular Holes

Square or rectangular holes may be cut out by making a row of small holes as previously described, but is more easily done by drilling a ½-inch hole inside each corner, as illustrated in Fig. 18-2, and using these holes for starting and turning the hacksaw. The socket-hole punch also may be of considerable assistance in cutting out large rectangular openings.

The burrs or rough edges which usually result after drilling or cutting holes may be removed with a file, or sometimes more conveniently with a sharp knife or chisel. It is a good idea to keep an old wood chisel sharpened and available for this purpose. A burr reamer will also be useful.

CONSTRUCTION NOTES

If a control shaft must be extended or insulated, a flexible shaft coupling with adequate insulation should be used. Satisfactory support for the shaft extension can be provided by means of a *metal* panel bearing made for the purpose. Never use panel bearings of the non-metal type unless the condenser shaft is grounded. *The metal bearing should be connected to the chassis with a wire or grounding strip.* This prevents any possible danger of shock.

The use of fiber washers between ceramic insulation and metal brackets, screws or nuts will prevent the ceramic parts from breaking.

Cutting and Bending Sheet Metal

If a sheet of metal is too large to be cut conveniently with a hacksaw, it may be marked with scratches as deep as possible along the line of the cut on both sides of the sheet and then clamped in a vise and worked back and forth until the sheet breaks at the line. Do not carry the bending too far until the break begins to weaken; otherwise the edge of the sheet may become bent. A pair of iron bars or pieces of heavy angle stock, as long or longer than the width of the sheet, to hold it in the vise will make the job easier. "C"-clamps may be used to keep the bars from spreading at the ends. The rough edges may be smoothed up with a file or by placing a large piece of emery cloth or sandpaper on a flat surface and running the edge of the metal back and forth over the sheet.

Bends may be made similarly. The sheet should be scratched on both sides, but not so deeply as to cause it to break.

Cutting Threads

Brass rod may be threaded, or the damaged threads of a screw repaired, by the use of *dies*. Holes of suitable size (see Table 18-I) may be threaded for screws by means of *taps*. Taps and dies are obtainable in all standard machine-screw sizes. A set usually consists of taps and dies for 4–36, 6–32, 8–32, 10–32 and 14–20 sizes, with a holder suitable for use with either tap or die. Machine oil applied to the tap usually makes cutting easier and sticking less troublesome.

Wiring

A popular type of wire for receivers and low-power transmitters is that known as "push-back" wire. It comes in sizes No. 16, 18, 20, etc., which are sufficiently large for all power circuits except filament. The insulating covering, which is sufficient for circuits where voltages do not exceed 400 or 500, can be pushed back a few inches at the end, making cutting of the insulation unnecessary when making a connection. Filament wiring should be done with sufficiently large conductors to carry the required current without appreciable voltage drop (see Copper Wire Table, Chapter Twenty-Four). Rubber-covered house-wire sizes No. 14 to No. 10 are suitable for heavy-current transmitting tubes, while No. 18 to No. 14 flexible wire is satisfactory for receivers and low-drain transmitting tubes where the total length of the leads is not excessive.

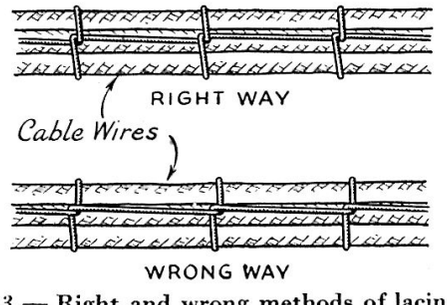


Fig. 18-3 — **Right and wrong methods of lacing cable. With the right way the leading line is pinched under each turn and will not loosen if a break occurs in the lacing.**

Stiff bare wire, sometimes called **bus wire** or **bus bar,** is most favored for the high r.f.-potential wiring of transmitters and, where practicable, in receivers. It comes in sizes No. 14 and No. 12 and is usually tin-dipped. Soft-drawn antenna wire also may be used. Kinks or bends can be removed by stretching 10 or 15 feet of the wire and then cutting it into small usable lengths.

The insulation covering power wiring which is to carry high transmitter voltages should be appropriate for the voltage involved. Wire with rubber and varnished cambric covering, similar to ignition cable, is available from radio parts dealers.

It is usually advisable to do the power-supply wiring first. The leads should be bunched together as much as possible and kept down close to the surface of the chassis. The lacing of power wiring in cable form not only improves its appearance but also strengthens the wiring. Fig. 18-3 shows the correct way of lacing cabled wires.

Chassis holes for wires should be lined with **rubber grommets** which fit the hole, to prevent chafing of the insulation. In cases where power-supply leads have several branches, it is often convenient to use fiber **terminal strips** as anchorages. These strips also form handy mountings for wire-terminal resistors, etc.

High-voltage wiring should have exposed points kept at a minimum and those which cannot be avoided rendered as inaccessible as possible to accidental contact.

Soldering

The secret of good soldering is in allowing time for the *joint*, as well as the solder, to attain sufficient temperature. Enough heat should be applied so that the solder will melt when it comes in contact with the wires being joined, without touching the solder to the iron.

Soldering paste, if of the noncorroding type, is extremely helpful when used correctly. In general, it should not be used for radio work except when necessary. The joint should first be warmed slightly and the soldering paste applied with a piece of wire. Only the bit of paste which melts from the warmth of the joint should be used. If the soldering iron is clean it will be possible with one hand to pick up a drop of solder on the tip of the iron which can be applied to the joint, while the other hand is used to hold the connecting wires together. The use of excessive soldering paste causes the paste to spread over the surface of adjacent insulation, causing leakage or breakdown of the insulation. Except where absolutely necessary, solder should never be depended upon for the mechanical strength of the joint; the wire should be wrapped around the terminals or clamped with soldering terminals.

COMPONENT VALUES

Values of composition resistors and small condensers (mica and ceramic) are specified throughout this *Handbook*, in terms of "preferred values." In the preferred-number system, all values represent (approximately) a constant-percentage increase over the next lower value. The base of the system is the number 10. Only two significant figures are used. Table 18-II shows the preferred values based on tolerance steps of 20, 10 and 5 per cent. All other values are expressed by multiplying or dividing the base figures given in the table by the appropriate power of 10. (For example, resistor values of 33,000 ohms, 6800 ohms, and 150 ohms are obtained by multiplying the base figures by 1000, 100, and 10, respectively.)

"Tolerance" means that a variation of plus or minus the percentage given is considered satisfactory. For example, the actual resistance of a "4700-ohm" 20-per-cent resistor can lie anywhere between 3700 and 5600 ohms, approximately. The permissible variation in the same resistance value with 5-per-cent tolerance would be in the range from 4500 to 4900 ohms, approximately.

Only those values shown in the first column of Table 18-II are available in 20-per-cent tolerance. Additional values, as shown in the second column, are available in 10-per-cent tolerance; still more values can be obtained in 5-per-cent tolerance.

In the component specifications in this *Handbook*, it is to be understood that when no tolerance is specified the *largest* tolerance available in that value will be satisfactory.

TABLE 18-II

Standard Component Values

20% Tolerance	*10% Tolerance*	*5% Tolerance*
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
	39	39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91
100	100	100

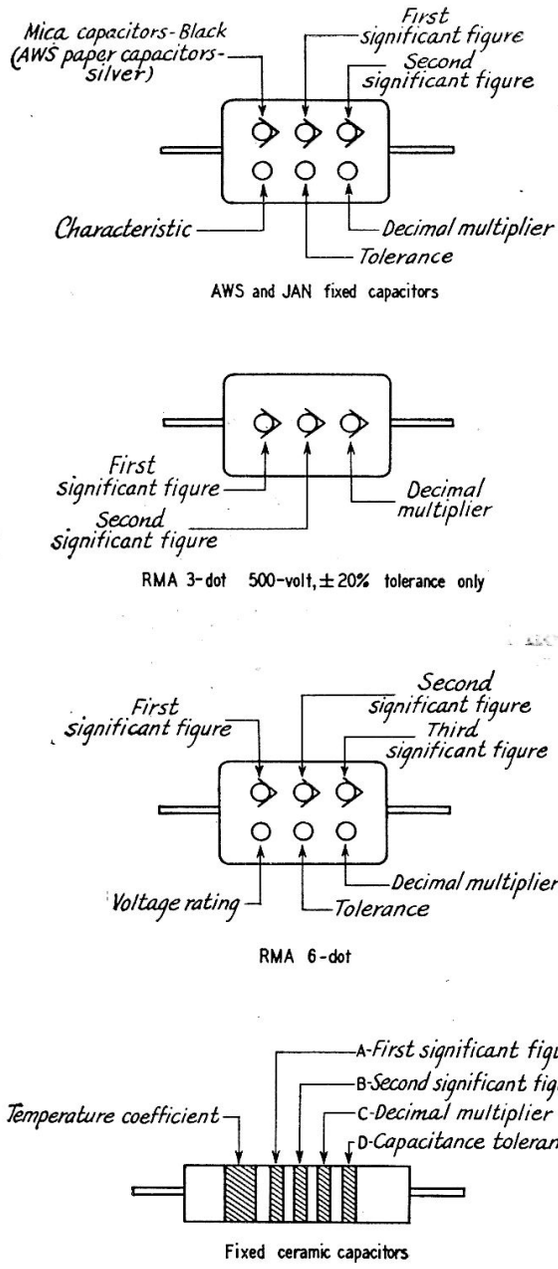


Fig. 18-4 — Color coding of fixed mica, molded paper, and tubular ceramic condensers. The color code for mica and molded paper condensers is given in Table 18-III. Table 18-IV gives the color code for tubular ceramic condensers.

Values that do not fit into the preferred-number system (such as 500, 25,000, etc.) easily can be substituted. It is obvious, for example, that a 5000-ohm resistor falls well within the tolerance range of the 4700-ohm 20-per-cent resistor used in the example above. It would not, however, be usable if the tolerance were specified as 5 per cent.

COLOR CODES

Standardized color codes are used to mark values on small components such as composition resistors and mica condensers, and to identify leads from transformers, etc. The resistor-condenser number color code is given in Table 18-III.

Fixed Condensers

The methods of marking "postage-stamp" mica condensers, molded paper condensers, and tubular ceramic condensers are shown in Fig. 18-4. Condensers made to American War Standards or Joint Army-Navy specifications are marked with the 6-dot code shown at the top. Practically all surplus condensers are in this category. The 3-dot RMA code is used for condensers having a rating of 500 volts and ±20% tolerance only; other ratings and tolerances are covered by the 6-dot RMA code.

Examples: A condenser with a 6-dot code has the following markings: Top row, left to right, black, yellow, violet; bottom row, right to left, brown, silver, red. Since the first color in the top row is black (significant figure zero) this is the AWS code and the condenser has mica dielectric. The significant figures are 4 and 7, the decimal multiplier 10 (brown, at right of second row), so the capacitance is 470 μμfd. The tolerance is ±10%. The final color, the characteristic, deals with temperature coefficients and methods of testing, and may be ignored.

A condenser with a 3-dot code has the following colors, left to right: brown, black, red. The significant figures are 1, 0 (10) and the multiplier is 100. The capacitance is therefore 1000 μμfd.

A condenser with a 6-dot code has the following markings: Top row, left to right, brown, black, black; bottom row, right to left, black, gold, blue. Since the first color in the top row is neither black nor silver, this is the RMA code. The significant figures are 1, 0, 0 (100) and the decimal multiplier is 1 (black). The capacitance is therefore 100 μμfd. The gold dot shows that the tolerance is ±5% and the blue dot indicates 600-volt rating.

Ceramic Condensers

Conventional markings for ceramic condensers are shown in the lower drawing of Fig. 18-4. The colors have the meanings indicated in Table 18-IV. In practice, dots may be used instead of the *narrow* bands indicated in Fig. 18-4.

Example: A ceramic condenser has the following markings: Broad band, violet; narrow bands or dots, green, brown, black, green. The significant figures are 5, 1 (51) and the decimal multiplier is 1, so the capacitance is 51 μμfd.

TABLE 18-IV

Color Code for Ceramic Condensers

Color	*Significant Figure*	*Decimal Multiplier*	*Capacitance Tolerance*		*Temp. Coeff. p.p.m./deg. C.*
			More than 10 μμfd. (in %)	*Less than 10 μμfd. (in μμfd.)*	
Black	0	1	± 20	2.0	0
Brown	1	10	± 1		−30
Red	2	100	± 2		−80
Orange	3	1000			−150
Yellow	4				−220
Green	5		± 5	0.5	−330
Blue	6				−470
Violet	7				−750
Gray	8	0.01		0.25	30
White	9	0.1	± 10	1.0	500

TABLE 18-III

Resistor-Condenser Color Code

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance (%)*	*Voltage Rating**
Black	0	1	–	—
Brown	1	10	1*	100
Red	2	100	2*	200
Orange	3	1000	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

* Applies to condensers only.

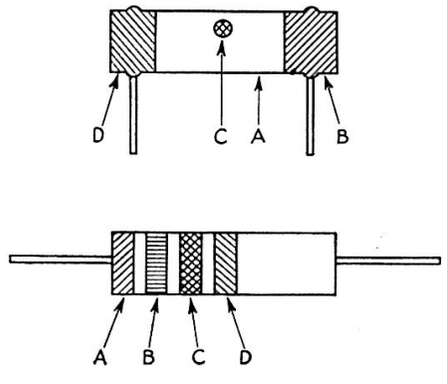
The temperature coefficient is — 750 parts per million per degree C., as given by the broad band, and the capacitance tolerance is ±5%.

Fixed Composition Resistors

Composition resistors (including small wire-wound units molded in cases identical with the composition type) are color-coded as shown in Fig. 18-5. Colored bands are used on resistors having axial leads; on radial-lead resistors the colors are placed as shown in the drawing. When bands are used for color coding the body color has no significance.

Examples: A resistor of the type shown in the lower drawing of Fig. 18-5 has the following color bands: A, red; B, red; C, orange; D, no color. The significant figures are 2, 2 (22) and the decimal multiplier is 1000. The value of resistance is therefore 22,000 ohms and the tolerance is ±20%.

A resistor of the type shown in the upper drawing has the following colors: body (A), blue; end (B), gray; dot, red; end (D), gold. The significant figures are 6, 8 (68) and the decimal multiplier is 100, so the resistance is 6800 ohms. The tolerance is ±5%.



Fixed composition resistors

Fig. 18-5 — Color coding of fixed composition resistors. The color code is given in Table 18-III. The colored areas have the following significance:

A — First significant figure of resistance in ohms.
B — Second significant figure.
C — Decimal multiplier.
D — Resistance tolerance in per cent. If no color is shown, the tolerance is ± 20%.

I.F. Transformers

Blue — plate lead.
Red — "B" + lead.
Green — grid (or diode) lead.
Black — grid (or diode) return.

NOTE: If the secondary of the i.f.t. is center-tapped, the second diode plate lead is green-and-black striped, and black is used for the center-tap lead.

A.F. Transformers

Blue — plate (finish) lead of primary.
Red — "B" + lead (this applies whether the primary is plain or center-tapped).
Brown — plate (start) lead on center-tapped primaries. (Blue may be used for this lead if polarity is not important.)
Green — grid (finish) lead to secondary.
Black — grid return (this applies whether the secondary is plain or center-tapped).
Yellow — grid (start) lead on center-tapped secondaries. (Green may be used for this lead if polarity is not important.)

NOTE: These markings apply also to line-to-grid and tube-to-line transformers.

Loudspeaker Voice Coils

Green — finish.
Black — start.

Loudspeaker Field Coils

Black and Red — start.
Yellow and Red — finish.
Slate and Red — tap (if any).

Power Transformers

1) Primary Leads . . . . . *Black*
   If tapped:
   Common . . . . . *Black*
   Tap . . . . . *Black and Yellow Striped*
   Finish . . . . . *Black and Red Striped*
2) High-Voltage Plate Winding . . . . . *Red*
   Center-Tap . . . *Red and Yellow Striped*
3) Rectifier Filament Winding . . . . . *Yellow*
   Center-Tap . . *Yellow and Blue Striped*
4) Filament Winding No. 1 . . . . . *Green*
   Center-Tap . . *Green and Yellow Striped*
5) Filament Winding No. 2 . . . . . *Brown*
   Center-Tap . *Brown and Yellow Striped*
6) Filament Winding No. 3 . . . . . *Slate*
   Center-Tap . . . *Slate and Yellow Striped*

CHAPTER 19

Eliminating Broadcast Interference

It is the duty of every amateur to make sure that the operation of his station does not result in annoyance to others in the form of interference with broadcast reception, police and aviation radio, or any other radio service. The nature of this duty is twofold: First, the amateur does not want to jeopardize his own right to be on the air, and second, he does not want to place amateur radio as a whole in an unfavorable light with the public, or with other radio services.

FCC Regulations

The FCC has formulated certain regulations pertaining to interference, as follows:

§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 o'clock 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.

Needless to say, no amateur likes to have his operating hours curtailed by enforced "silent periods," and where interference exists, special efforts are necessary to eliminate the trouble.

Interference with broadcast reception produces more than just a technical problem. There is a definite "public relations" aspect that requires tactful handling on the part of the amateur. Whether the amateur equipment is at fault or not, the broadcast listener is usually unfamiliar with the technical side of radio, and with amateur radio itself, and therefore cannot understand readily that his own receiver may be contributing its share to the trouble. It is only natural that the broadcast listener has a certain amount of pride in his receiver, and often he is not easily convinced without tactful, polite instruction by the amateur. Thus, the amateur who is confronted with BCI usually faces, in addition to the technical problem, a public relations problem that must be solved if he is to live in harmony with his neighbors. Both the public relations problem and the technical problem can be solved if the right approach is used.

Public Relations Aspect

There must be a spirit of coöperation between the amateur and the listener if a satisfactory solution to any BCI problem is to be obtained. The FCC recognizes this fact, and in cases where complaints are received, two letters are written, one to the amateur, the other to the complainant. The amateur is directed to investigate the complaint, and to file a written report of the steps he has taken to eliminate the difficulty. The complainant is informed that the amateur has been requested to investigate, and is asked to cooperate with the amateur in the solution of the problem. The listener is informed that interference is not always the fault of the amateur, but may exist because of deficiencies in his own receiver, and is told what steps he is expected to take in coöperating with the amateur. The FCC offers technical assistance in solving stubborn cases, requesting from the listener a description of the circuits of his receiver. In every instance, both the amateur and the listener are informed that coöperation between them is required. The amateur should never merely assume that the broadcast receiver is at fault, but should first determine that his own station is operating in full compliance with FCC regulations. Once he is certain of this, he should attempt to secure the coöperation of the listener in making whatever adjustments and changes are necessary to eliminate the interference.

SOME "DOs" AND "DON'Ts"

Experience has shown that observance of a few simple diplomatic precepts will go a long way toward smoothing the ruffled dispositions that are encountered in BCI difficulties.

Prompt Action

Do something to show the listener that you are concerned for his welfare as soon as a complaint is received. The average person will tolerate a limited amount of interference, but no one can be expected to put up with frequent and extended interruption of his listening pleasures. The sooner you take steps to eliminate the interference, the more agreeable the listener will be; the longer he has to wait for you, the less willing he will be to coöperate.

Don't Hide Your Identity

If a listener thinks that you are "trying to get away with something" he will not only be unwilling to coöperate, but may be actively hostile. As a general rule, whenever you change location, or mode of transmission, or increase power, or put up a new antenna, check with your neighbors to make sure that they are not



experiencing interference. Announce your presence and conduct occasional tests on the air, requesting anyone whose reception is being spoiled to let you know about it so that you may take steps to eliminate the trouble.

Check Your Transmitter

Before visiting a complainant check your transmitter thoroughly to make sure that it is free from such things as parasitic oscillations, key clicks, spurious sidebands arising from overmodulation, and other effects that might result in radiation on frequencies not assigned to amateurs. Only when you know your transmitter is "clean" can you approach a complainant with confidence.

Solve the BCI problem in your own home first! It is always convincing if you can say — and demonstrate, if necessary — that you do not interfere with broadcast receivers in your own house.

Present Your Story Tactfully

Put yourself in the listener's place. He has a right, he believes, to interference-free reception of the broadcast programs he likes. When you interfere, his natural reaction is to assume that you are the one at fault. When you call on him, explain that you do not operate on the frequencies to which he wants to listen, and the real trouble is that you and he happen to be located so close to each other. Explain to him that there are thousands of stations operating simultaneously, all the time, and that the problem of rejecting all but the one he happens to want to hear is one of receiver design. Point out that the average broadcast receiver is made to sell as cheaply as possible, and that features that would prevent interference from near-by stations are left out.

It should be explained to the listener that if it is simply the presence of your strong signal on his receiving antenna that causes the difficulty, the situation can be cleared up by a wavetrap. In other cases the wiring of the receiver itself is picking up your signal, and such cases can be cured only by suppressing this unwanted pick-up in the receiver itself; in other words, some modifications will have to be made in the receiver if he is to expect interference-free reception. Arrange to try a test with a wavetrap, if there is a chance that the type of interference experienced will respond to such treatment.

Avoid Working on the Receiver

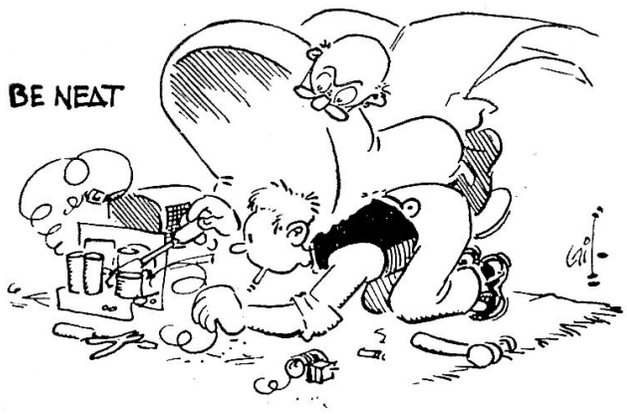
If your tests show that the fault has to be remedied in the receiver itself, *do not offer to work on the receiver.* It is not your fault that the receiver design is defective. Recommend that the work be done by a reliable serviceman, and offer to advise the latter as to the cause and cure if necessary.

It is inadvisable to tackle broadcast receivers, particularly the midget varieties, unless you have had experience working on them. In any event, if you do work on the receiver yourself the chances are that if anything goes wrong later on you'll be blamed for it. Explain that, while you may be technically competent to make the necessary modifications, radio servicing is best left to those who specialize in it, and that you are sure he, the owner, will prefer to have the work done by someone whom he can hold responsible.

If the owner of the receiver obviously prefers to have you make the modifications, do so only with the understanding that it is purely as a favor and because you are anxious to cooperate. Make him understand, with as much tact as possible, that the responsibility for the interference does not lie with you (your transmitter having previously been checked and found O.K.); if the receiver responds to frequencies to which it is not tuned that is a defect in its design. You also have no obligation to pay for having the receiver modified. If you do the work yourself you should not make any charge, of course. In that event, insist that you must take the receiver to your own shop in order to work on it properly; you will be able to tell immediately whether the changes you make effect an improvement and therefore can work more rapidly and conveniently — and without turning the owner's living room into a repair shop. If it is necessary to do some work in the listener's home, *be neat* in the work you do. Remember, the listener's living room cannot be treated in the same manner you would treat your own ham shack!

● RADIO CLUB BCI COMMITTEES

Organized amateur radio clubs can do a lot to pave the way toward coöperation between individual amateurs and the broadcast listen-



ers. Most clubs maintain an interference committee, charged with handling both the public relations and the technical aspects of BCI. Through such committees, mutual technical assistance is made available to all members of the club, so that those less qualified can have the benefit of the experience of others. The committee should also maintain contact with the local radio servicemen, supplying them with information and technical assistance whenever possible. Where needed, the committee can maintain valuable contacts with the local newspapers and other authorities to provide the right kind of publicity for the efforts of individuals or groups who are trying to clear up BCI problems.

The Communications Department of the ARRL, as one of its services to affiliated clubs, has prepared material suggesting various ways in which local clubs can form interference committees, and methods by which such groups can function efficiently for the good of all concerned. This material is available to affiliated clubs on request, addressed to ARRL headquarters.

Technical Aspects of BCI

There are no hard-and-fast rules that can be applied as certain cures for all cases of BCI. The great number of different types of broadcast receivers that have been produced make it necessary for the amateur to apply one remedy for one set, and another for a different set. There are, however, a few generalizations that will be of assistance in most cases. A knowledge of some of the types of interference, and the general methods required to eliminate them, will enable the amateur to avoid much tedious cut-and-try procedure, and will lead to a rapid appraisal of the situation when interference arises.

Improper Transmitter Operation

An amateur transmitter can create BCI if it is not operating properly. In c.w. transmitters, key clicks and spurious emissions are the usual sources of trouble. In 'phone transmitters overmodulation, parasitic oscillations that occur only under modulation, and low-frequency parasitic oscillations are often the source of trouble. In some instances, an unbalanced antenna system can cause BCI. In any event, the amateur must be certain that none of these faults exists within his own station before he can assume that the "blame" for the interference can be placed on the broadcast set. The methods of determining when improper operating conditions exist are discussed in detail in Chapters Six and Nine.

Types of Interference

BCI can usually be classified as one of two types. It is either tunable, appearing only at certain spots on the receiver dial, or it is untunable, appearing throughout the entire tuning range. The tunable type is usually encountered only when the transmitter frequency is low enough to permit the amateur signal to beat against one of the harmonics of the oscillator in the broadcast set. In most cases, this type is encountered only by stations operating in the 3.5- to 4-Mc. band. The untunable type may be encountered by almost any transmitter, regardless of frequency, but is generally restricted to receivers within the immediate area of the transmitter and its antenna. Within these classifications, several variations may be encountered, the general nature of which is described below.

Blanketing

The interference takes the form of an untunable signal that partially or completely masks all other signals on the broadcast receiver. In the case of a c.w. transmitter, each time the key is pressed, all broadcast signals disappear or are reduced greatly in amplitude. If the transmitter is amplitude-modulated, each time the carrier is turned on, the same "washout" occurs, and the voice modulation is usually severely distorted.

Blanketing is usually encountered only when the transmitting antenna and the receiver are close together. Several things may be done to reduce this form of interference: (1) The receiving antenna may be relocated so that it picks up less energy from the transmitter. If possible, orientate the two wires at right angles to each other. (2) The receiving antenna may be shortened. If it is of such length that it approaches resonance at the transmitter frequency, it will act as a tuned circuit, applying a signal of relatively great amplitude to the receiver. (3) If the receiver is located in a metropolitan area served by several powerful stations, satisfactory reception may be obtained with an indoor antenna a few feet long. (4) Wavetraps tuned to the operating frequency of the transmitter may be installed between the receiver and its antenna.

Superheterodyne Interference

This type of BCI is tunable, appearing only at certain points on the receiver dial. If one of these points happens to fall within audio range of a desired broadcast station, a "birdie" will result. The interference may be noticed at several points on the dial, but these points will usually bear a definite relationship to one another, as they are all the result of the amateur signal beating with a harmonic of the oscillator in the broadcast set to produce a difference-frequency signal that is within the passband of the i.f. stages of the receiver. In rare instances, an amateur signal will beat with the signal from another near-by transmitter, either amateur or commercial, to produce what is called a "phantom" signal. Naturally, the phantom will appear only when both stations are transmitting at the same time. Interference of the superheterodyne type can sometimes be eliminated by wavetraps tuned to the frequency of the interfering signal. In stubborn cases, however, it may be necessary to improve the shielding of the oscillator stage in the receiver, or to change the operating frequency of the transmitter to shift the difference-frequency product away from the points where it interferes with local broadcast stations.

Cross-Talk

In this type of interference, the amateur signal is heard superimposed on each broadcast signal, with no interference noticeable between stations. This type is experienced mainly in older receivers having poorly-shielded input stages. It is seldom experienced in receivers using a variable-μ tube in the input stage. If it is not possible to install such a tube in the set, shielding the input stage and the wiring associated with it will usually reduce the interference. A wavetrap, tuned to the frequency of the amateur signal, will also be useful in eliminating this type of BCI.

Stray Receiver Rectification

This type is perhaps the most frequently encountered in present-day receivers. It is untunable, with the amateur signal being heard at all settings of the receiver dial. It is caused by rectification of the amateur signal at some point within the receiver, and is found usually in sets located close to a transmitter. The rectification can take place in the second detector, or in the audio system. Its elimination can be accomplished only after determining just where the signal is entering the set, and then finding out which tube, or tubes, are doing the rectification. This can be determined by removing one tube at a time until one is found that eliminates the interference. Details concerning this method are discussed under the heading "Tracking Down Interference" in a later portion of this chapter. Once the offending tube has been located, the r.f. energy may be eliminated by any one of the methods shown under the same heading.

Power-Line Pick-Up

In some cases BCI is caused by r.f. energy entering the broadcast set through the a.c. power lines. In most instances, the r.f. gets into the lines because the transmitting antenna runs close to the a.c. lines, but in some cases, the r.f. may be forced back into the line through the power supply of the transmitter. This is usually caused by unbalance in the transmitting antenna system, and is especially prevalent with Marconi and end-fed Hertz systems. It may also be caused by poorly choked and by-passed supply leads in the r.f. sections of the transmitter. The method of entry into the lines may be determined by operating the transmitter into a dummy load. If the interference disappears when this is done, but is present when the transmitter is operated with its antenna, it is certain that the antenna system is the cause of the trouble, either in being unbalanced, or because it runs close to a.c. lines. Elimination of BCI of this type can be accomplished by redesign or relocation of the antenna system, or by the use of line filters at the receiver power source. Line filters are discussed under a separate heading below.

V.H.F. Interference

Most BCI caused by stations operating at frequencies higher than 28 Mc. is of the type discussed under "Stray Receiver Rectification" above, and is attributable to the fact that the higher-frequency signals are more apt to be picked up by the receiver circuits themselves than are signals from lower-frequency transmitters. Similar methods may be used to eliminate such interference, but in some cases, an a.c. line filter designed for the operating frequency and installed at the power input plug of the receiver is the only cure.

Interference with Television Reception

Severe distortion of the televised image, or even complete blanking of the 'scope screen, can result when a transmitter is operated in the immediate vicinity of a television receiver. Not a great deal of information is available at the present time, but the experience of several amateurs indicates that by far the greatest number of TVI cases is the result of harmonic radiation from the amateur transmitter. A chart showing the harmonic relation of several of the amateur bands to the currently-used television channels is shown in Fig. 19-1. The reduction of harmonic radiation is discussed in Chapter Ten. It is also possible that TVI can be caused by appearance of an amateur signal in the video stages of the television receiver. These stages are comparable to the audio stages of a broadcast set, but with extremely-broad frequency characteristics, because the video stage must be capable of amplifying frequencies all the way through the audio range and up to 3.5 or 4 Mc. Thus, a

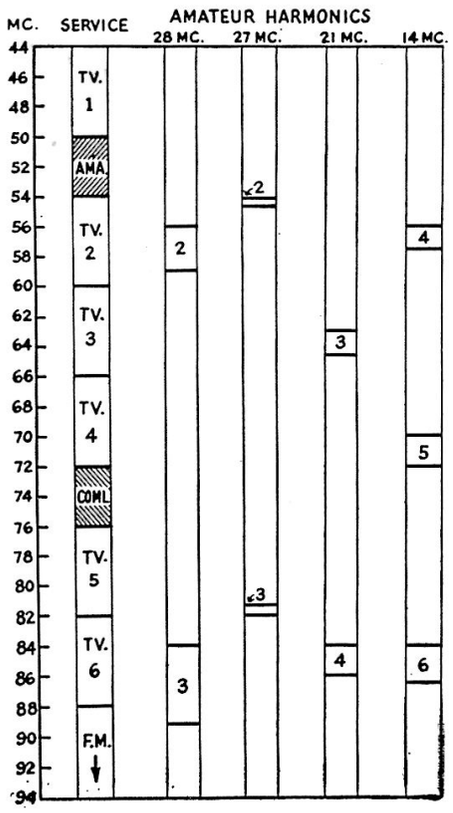


Fig. 19-1 — The relationship of amateur-band harmonics, 14 to 28 Mc., and frequency assignments in the 44–88 megacycle region.

signal from a transmitter operating in the 3.5-Mc. band could easily be amplified if it were to get into the video channel. In such cases, it is probable that the interfering signal is entering through the power lines, or by direct pick-up to the wiring of the video stages. Fortunately, good shielding is required in the video stages of television receivers, so interference of this sort is not apt to be severe, and should be reduced by a.c. line chokes in most cases. No *general* solution to the TVI problem is known at this writing, but reduction of harmonic radiation seems to be productive of best results. Additional information concerning TVI will be published in *QST* as progress is made.

TRACKING DOWN AND ELIMINATING INTERFERENCE

A certain amount of cut-and-try is necessary in the tracking down and elimination of BCI, but there are several short-cut procedures that can be used to keep the time required to a minimum. The assistance of another licensed amateur who can operate your transmitter while you conduct tests at the location of the broadcast receiver will save much time and eliminate the misinterpretation that almost always follows when the results of tests are reported to the amateur by someone who is unfamiliar with the "symptoms" and the effects being looked for. The procedure outlined below will save valuable time in getting at the source of the trouble and in satisfactorily eliminating it.

1) Determine whether the interference is tunable or untunable. This will usually indicate the methods required for elimination of the trouble, as it will show which of the general *types* of interference discussed above is present. In severe cases it is possible that two or more types will be present at the same time, and steps will be necessary to eliminate each type.

2) Disconnect the antenna from the set, turn the volume control up full, and see if the interference disappears. If it does, it is merely necessary to prevent the r.f. appearing on the antenna from entering the set. Wavetraps and low-pass filters should be tried, and if they produce marked reduction in the amplitude of the interfering signal, but some is still present, try relocating the receiving antenna. It should be placed as far as possible from the transmitting antenna, and should run at right angles to it to minimize coupling. If the interference persists even after the antenna is disconnected, the search is narrowed to an investigation of whether the signal is coming in on the power lines, or is being picked up directly on the receiver wiring.

3) Check for power-line interference by using a sensitive wavemeter such as that described in Chapter Sixteen of this *Handbook* to probe along the a.c. cord that connects the set to the power source. Checks should be made at the transmitter frequency, and also at harmonic frequencies. If r.f. is detected in the line, by-pass both sides of the a.c. line to ground with 0.005-μfd. mica condensers at the point where the line cord enters the set. If this does not completely eliminate the interference, try a line filter designed for the operating frequency.

4) If it is evident that the interference is being picked up on the receiver wiring, explain the situation to the owner and tell him that the exact cause cannot be determined without removing the chassis from the cabinet, and that, in any event, the receiver will have to be modified somewhat if the interference is to be eliminated. As suggested before, recommend that the actual work be done by a radio serviceman. Offer to check into the cause yourself, if he wishes and will allow you to take the set to your shop (with the understanding that you will not make any changes in the receiver

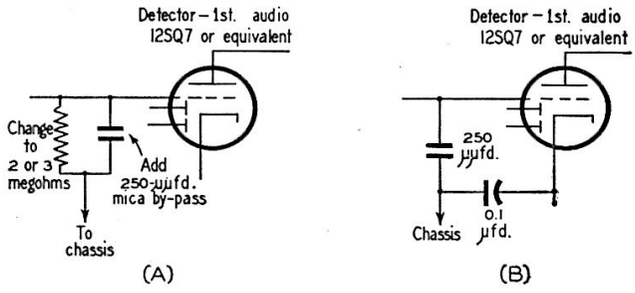


Fig. 19-2 — Two methods of eliminating r.f. from the grid of a combined detector/first-audio stage. At A, the value of the grid leak is reduced to 2 or 3 megohms, and a mica by-pass condenser is added. At B, both grid and cathode are by-passed.

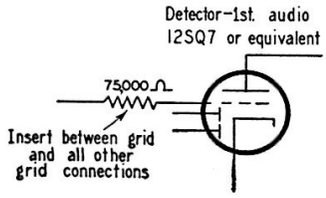


Fig. 19-3 — Using a 75,000-ohm resistor to form a low-pass filter with the tube capacitance. The resistor must be mounted at the tube pin, between the grid and all other grid connections.

without his express permission) so the serviceman can be told what needs to be done.

5) In the event that the owner allows you to take the receiver, set it up near your transmitter and check to see if the amplitude of the interfering signal is changed by various settings of the receiver volume control. If the volume of the interference changes with changes in the volume control, the r.f. is entering the set *ahead* of the volume control. If it is unaffected by the volume control, it is getting into the audio stages at a point following the volume control.

6) Pin the source down, if it is ahead of the volume control, by removing one tube at a time until one is found that kills the interference when it is removed. In sets using series-connected filaments, this will be possible only if a tube of equal heater rating, and with all but the heater pins clipped off, is *substituted* for the tube.

7) Determine which element (or elements) of the tube is picking up the interference by touching each tube pin with a test lead about three feet long. The lead, acting as an antenna, will cause the interference to increase when it is placed on a tube pin that is contributing to the interference. Once the sensitive points have been determined, the trouble can be eliminated by shielding the leads connected to the tube element that is affected, and by shielding the tube itself. Grid leads are the principal offenders, especially the long leads that run from a tube cap to a tuning condenser, and it may be necessary to shield thoroughly several parts of the set before the interference is eliminated completely.

8) If the pick-up is found to be in the audio system — as is the case in many sets, especially when the transmitter is operating at 28 Mc. or higher — it can be eliminated by one or another of the methods shown in Fig. 19-2A and B. Fig. 19-2A is a method that has proved successful with many a.c.-d.c. midget receivers. Both sides of the a.c. line are by-passed to ground with 0.001-μfd. mica condensers, and the value of the grid leak in the combined detector/first-audio tube (usually a 12SQ7 or its equivalent) is reduced to 2 or 3 megohms. The grid is then by-passed for r.f. with a 250-μμfd. mica condenser. Fig. 19-2B is a similar method. A third method that has worked in a.c.-d.c. receivers requires only that the heater of the detector/first-audio stage be by-passed to ground with a 0.001-μfd. condenser. The method shown in Fig. 19-3 uses a 75,000-ohm ½-watt resistor to form, with the tube capacitance, a low-pass filter. The resistor is connected between the grid pin of the audio stage and *all other* wires connected to the grid.

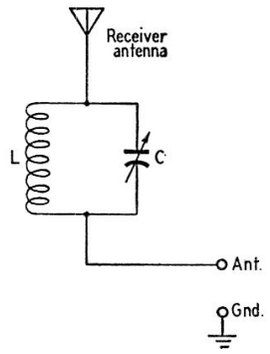


Fig. 19-5 — A simple wavetrap circuit. *L* and *C* must resonate at the frequency of the interfering signal. Suitable constants are tabulated below.

Band	*C*	*L*			
80	140 μμfd.	16 μh.,	32 turns	#22, 1″ diam.,	1″ long
40	100 μμfd.	6	19	#22, 1″	1″
20	50 μμfd.	3.5	14	#18, 1″	1″
10	25 μμfd.	1.5	9½	#18, 1″	1″

Interference with T.R.F. Receivers

Although few t.r.f. receivers are still in use, an occasional set will be found. Interference in these sets is almost always caused by inadequate shielding of the detector stage. Enclosing the tube in a shield, and shielding the wiring to the stage, should eliminate the trouble.

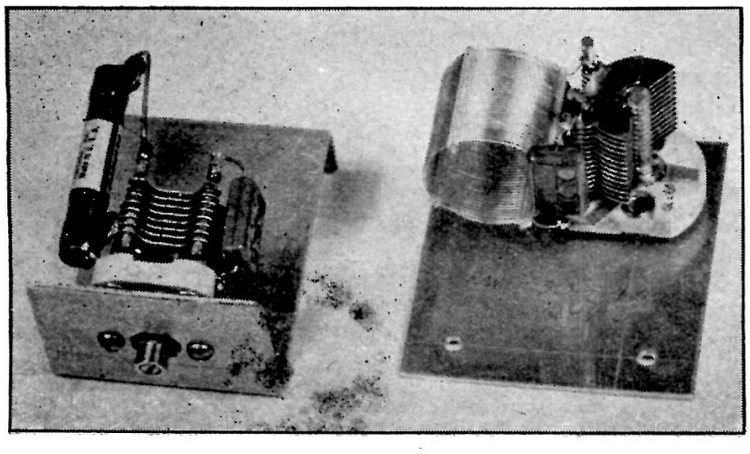


Fig. 19-4 — Two examples of simple wavetraps. In the unit on the left, a 2-meter r.f. choke (Ohmite Z-0) is used with a 50-μμfd. variable condenser shunted by a 22-μμfd. mica condenser to form a trap for the 14-Mc. band. The larger unit on the right uses a 32-turn "Miniductor" (B & W) with a 100-μμfd. variable condenser shunted by a 67-μμfd. mica condenser to cover the 3.5- to 4-Mc. range. Both units are bracket-mounted with provision for mounting within the cabinet of a broadcast receiver. The circuit is shown in Fig. 19-5.

WAVETRAPS

In its simplest form, a wavetrap consists of a parallel-tuned circuit that is connected in series with the broadcast antenna and the antenna post of the receiver. It should be designed to resonate at the frequency of the interfering signal. The circuit of a simple trap is shown in Fig. 19-5. If multiband operation is necessary, several traps may be connected in series, each tuned to the center of one of the bands in which operation is contemplated. A more elaborate form is illustrated in Fig. 19-6, in which a combination of a parallel-tuned circuit and a series-tuned circuit is used. To adjust the wavetrap, have another licensed amateur operate the transmitter while you tune the trap for maximum attenuation of the interference. The trap should be connected to the broadcast receiver and the normal receiving antenna should be connected in series with the trap, as shown in Figs. 19-5 or 19-6.

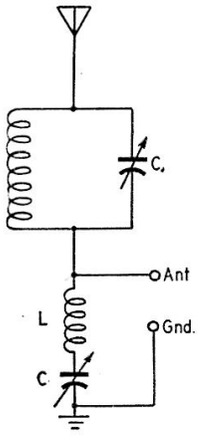


Fig. 19-6 — Combination of parallel-tuned and series-tuned wavetraps to obtain greater attenuation of the interfering signal. Values for *LC* are the same as those listed below Fig. 19-5.

A.C. LINE FILTERS

An a.c. line filter usually consists of two r.f. chokes each having an inductance of 10 mh. or so, connected as shown in Fig. 19-7 and by-passed for r.f. The entire trap should be enclosed in a shield can, and the components used should be large enough to carry the full current drawn by the power supply. For traps to be installed in the power lead to a small receiver, No. 16 wire will be adequate but for traps designed to be used ahead of a transmitter power supply, larger wire must be used, in keeping with the current requirements of the supply.

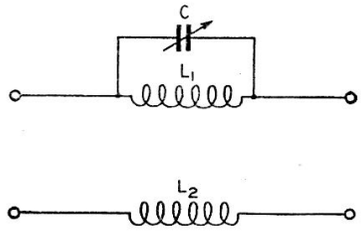


Fig. 19-7 — An a.c. line filter. A single condenser tunes both L_1 and L_2, which are unity-coupled, one wound on top of the other. Constants for amateur bands are tabulated below.

Band	*C*	*L1 - L2*
80	140 + 150 (fixed)	25 t. No. 18 insulated, 1¼" dia. × 2⅜" lg.
40	140 μμfd.	18 t. No. 18 insulated, 1¼" dia. × 2⅜" lg.
20	100 μμfd.	12 t. No. 18, 1¼" dia. × 2⅜" lg.
10	25 μμfd.	9 t. No. 18, 1½" dia. × 2⅜" lg.

Insulated, stranded wire should be used for all coils.

CHAPTER 20

Operating a Station

The enjoyment of our hobby usually comes from the operation of our station once we have finished its construction. Upon the *station* and its *operation* depend the communication records that are made. We have taken every bit of care that was possible in constructing our transmitter, receiver, frequency-measuring and monitoring equipment, and in erecting a suitable antenna system. Unless we use good judgment and care in operating our stations, we shall fall far short of realizing the utmost in results achieved. More than this, unless we do the right thing, we may interfere with other stations or delay their work, thus acquiring a bad reputation. Occasionally you will pick up an amateur whose method of operating is so clean-cut, so devoid of useless effort, so snappy and systematic, that your respect is gained and it is a pleasure to listen and work with him. One benefits proportionately from what one puts into amateur radio, so make the most of your hobby in the time and opportunities given you.

For best results, the transmitter should be adjusted for stable, satisfactory operation on several amateur frequencies. Known settings for definite frequencies will enable the operator to change frequency quickly at any time. Whenever such a change is made, be sure to check the transmitter frequency accurately. There is absolutely *no excuse* for a station operating off frequency. Any frequency calibrations should be checked often to guard against variations.

The operator and his methods have much to do with limiting the range of the station. The operator must have a good "fist," or good voice procedure. He must have patience and judgment. Some of these qualities in operating will make more station records than many kilowatts of power. Engineering or applied common sense is as essential to the radio operator as to the experimenter. Do not make several changes in the transmitter or receiver hoping for better results. Make one change at a time until the basic trouble or the best adjustment is found.

An operator with a slow, steady, clean-cut method of sending has a big advantage over the poor operator. Good sending is partly a matter of practice but patience and judgment are just as important qualities of an operator as a good "fist." The technique of speaking in connected thoughts and phrases is equally important for the operator who uses voice.

● TOLERANCE AND COURTESY

None of us particularly enjoys working through interfering signals. As amateurs we have always had the "interference problem." It's nothing new. We accept it as a part of operation. We have eased the situation to a considerable extent by using VFOs and crystal filters in our receivers. That's part of the solution.

In amateur radio, each amateur may operate on any frequency he chooses in any amateur band, provided he abides by the existing regulations. No amateur or group of amateurs has any *exclusive* claim to any frequency in any band. We must work together, each respecting the rights of the other. QRM is often unavoidable. We occasionally find ourselves on the frequency used by another station. "Who was there first?" or "Whose communication is most important?" doesn't enter the picture. In bona fide emergency communications the station not engaged in emergency work must of course move from the frequency, or QRT. That is in the tradition of amateur radio. FCC in its declarations of emergency requires stations not engaged in bona fide handling of emergency communications to remain silent or go to other than useful emergency frequencies.

Our normal operating interests in amateur radio vary considerably. Some prefer to ragchew, others handle traffic, others work DX, others concentrate on working certain areas or states, still others get on for an occasional contact to check a new rig or new antenna. "Why do they have to run a traffic net on my frequency?"; "What's the idea of chewing the rag on a traffic-net frequency?"; "Why do these eggs have to use *my* frequency for their contest QSOs?"; etc. We have heard such expressions, and more! Each amateur should be tolerant of the other fellow's interests. He should exercise operating courtesy and common sense.

Before putting the transmitter on the air, listen on your own frequency. If you hear a trunk line or traffic net in operation on the frequency you intend to use, or if you hear any stations ragchewing or conducting any form of communication on that frequency, stand by until you are sure no QRM will be caused by your operations, or shift to another frequency. Remember, those other chaps can cause you as much QRM as you cause them, sometimes more! The majority of amateurs own more than one crystal, many have VFO. It is not always necessary to stick to a single operating frequency.

Spend some time listening on all the frequencies you use for transmitting. You soon will learn what uses other amateurs are making of those spots. If you find, for example, that a net meets on one of the frequencies you use, or someone uses it for a regular schedule, you will soon learn the time that the net or schedule operates, and will be able to coöperate to avoid a conflict. It has become quite general operating procedure these days to work stations on or near your own frequency. This practice will automatically assist in reducing interference.

If we will each do our part to operate with tolerance and consideration, avoiding an attitude of running roughshod over other operators, we will do much to make ham operating more productive and enjoyable for ourselves as well as the other fellow!

C.W. PROCEDURE

Official ARRL stations, *both* those using voice and c.w., observe the rules regarded as "standard practice" carefully. Any actively-operating c.w. stations will do well to copy these rules, and follow them when operating.

Calling Stations

1) *Calls:* The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed by its own call signal sent not more than three times thus: W6EY W6EY W6EY DE W1AW W1AW W1AW. In amateur practice this procedure may be expanded somewhat. The call signal of the calling station must be inserted at frequent intervals for identification. Repeating the call of the called station five times and signing not more than twice (repeating not more than five times) has proved excellent practice.

CQ: The general-inquiry call (CQ) should be sent not more than five times without interspersing one's station identification. The length of repeated calls is carefully limited in intelligent amateur operating. CQ is not to be used when testing or when the sender is not expecting or looking for an answer.

The special abbreviations indicating from what part of the band tuning will start after a CQ are helpful in making your procedure known to the receiving operator.

HM — Will start to listen at *high*-frequency end of band and tune toward *middle* of band.
MH — Will start to listen in the *middle* of the band and tune toward the *high*-frequency end.
LM — Will start to listen at *low*-frequency end of band and tune toward *middle* of band.
ML — Will start to listen in the *middle* of the band and tune toward the *low*-frequency end.

Example: If the procedure will be to tune from the middle of the band to the high end, a CQ call goes: CQ DE W6RBQ MH K.

The directional CQ: To reduce the number of useless answers and lessen QRM, every CQ call should be made informative when possible. Stations desiring communication should follow each CQ by an indication of direction, district, state, or the like.

Examples: A United States station looking for any Hawaiian amateur calls: CQ K6 CQ K6 CQ K6 DE W4IA W4IA W4IA K. A Western station with traffic for the East Coast when looking for an intermediate relay station calls: CQ EAST CQ EAST CQ EAST DE W5IGW W5IGW W5IGW K. A station with messages for points in Massachusetts calls: CQ MASS CQ MASS CQ MASS DE W7CZY W7CZY W7CZY K. In each example indicated it is understood that the combination used is repeated three times.

Hams who do not raise stations readily may find that their sending is poor, their calls ill-timed or judgment in error. When conditions are right to bring in signals from the desired locality, the way to raise stations is to use the appropriate frequency and to call these stations. Reasonably short calls, with appropriate and brief breaks to listen, will raise stations with minimum time and trouble.

2) *Answering a Call:* Call three times (or less); send DE; sign three times (or less); after contact is established decrease the use of the call signals of both stations to *once or twice.* When a station receives a call without being certain that the call is intended for it, QRZ? may be used. It means "By whom am I being called?" QRZ should not be used to replace CQ.

3) *Ending Signals and Sign-Off:* The proper use of $\overline{\text{AR}}$, K, $\overline{\text{KN}}$, $\overline{\text{SK}}$ and CL ending signals is as follows:

$\overline{\text{AR}}$ — End of transmission. Recommended after call to a specific station before contact has been established.

Example: W6ABC W6ABC W6ABC DE W9LMN W9LMN W9LMN $\overline{\text{AR}}$. Also at the end of transmission of a radiogram, immediately following the signature, preceding identification.

K — Go ahead (any station). Recommended after CQ and at the end of each transmission during QSO when there is no objection to others breaking in.

Example: CQ CQ CQ DE W1ABC W1ABC W1ABC K or W9XYZ DE W1ABC K.

$\overline{\text{KN}}$ — Go ahead (specific station), all others keep out. Recommended at the end of each transmission during a QSO, or after a call, when calls from other stations are not desired and will not be answered.

Example: W4FGH DE XU6GRL $\overline{\text{KN}}$.

$\overline{\text{SK}}$ — End of QSO. Recommended before signing *last* transmission at end of a QSO.

Example: . . . $\overline{\text{SK}}$ W8LMN DE W5BCD.

CL — I am closing station. Recommended when a station is going off the air, to indicate that it will not listen for any further calls.

Example: . . . $\overline{\text{SK}}$ W7HIJ DE W2JKL CL.

4) *Test Signals* used to adjust a transmitter or at the request of another station to permit the latter to adjust receiving equipment usually consist of a series of Vs with the call signal of the transmitting station at frequent intervals.

5) *Receipting* for conversation or traffic: Never send acknowledgment until the transmission has been entirely received. "R" means

"All right, OK, I understand *completely.*" Use R *only* when *all* is received correctly.

6) *Repeats:* When most of transmission is lost, a call should be followed by correct abbreviations to ask for repeats. When but a few words are lost the last word received correctly is given after ?AA, meaning that "all after" this should be repeated. ?AB for "all before" a stated word should be used if most of the first part of the copy is missing. ?BN. . . . . and . . . . . (two stated words) asks for a fill "between" certain sections. If only a word or two is lost this is the quickest method of getting it repeated.

Do not send words twice (QSZ) unless it is requested. Send single. Do not fall into the bad habit of sending double *without a request* from fellows you work. Message-handling practices and procedure are discussed in another chapter.

General Practices

When a station has receiving trouble, the operator asks the transmitting station to "QSV." The letter "R" is often used in place of a decimal point (e.g., "3R5 Mc.") or the colon in time designation (e.g., "2R30 P.M."). A long dash for "zero" is in common use. Figures are spelled out in texts, for highest accuracy. NFT for "no filing time" is common.

The law concerning superfluous signals should be noted carefully by every amateur. Do not hold the key down for long periods when testing. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna. Send your call frequently when operating. Pick a time for adjusting the station apparatus when few stations will be bothered.

Long calls after communication has been established are unnecessary and inexcusable. The up-to-date amateur station uses "break-in." The best sending speed is a medium speed with the letters quickly formed and sent evenly with proper spacing. The standard-type telegraph key is best for all-round use. Before any freak keys are used, a few months should be spent listening-in and practising. Regular daily practice periods, two or three half-hour periods a day, are best to acquire real familiarity and proficiency with code.

No excuse can be made for a "garbled" text. Operators should copy what is sent and refuse to acknowledge messages until every word has been received correctly. *Good operators never guess.* "Swing" in a fist is *not* the mark of a good operator, is undesirable. Unusual words are sent twice, the word repeated following transmission of "?" If not *sure,* good operators systematically ask for fills or repeats.

Don't say, "QRM" or "QRN" when you mean "QRS."

Don't acknowledge any message until you have received it completely.

Don't CQ unless there is definite reason for so doing. When sending CQ, use judgment. Sign your call frequently, interspersed with calls, and at the end of all transmissions.

Speed-Key Adjustment

Manual skill can be acquired only by practice, but no amount of practice will produce accurate sending if the key itself is improperly adjusted. The adjustment of a straight key is discussed in Chapter One and the requirement for proper adjustment is likewise important in using a "bug" or speed-key. Contact points should be carefully cleaned using a burnishing tool or crocus cloth from time to time. If pitted, an initial dressing-off with an oilstone may be necessary.

Make sure that the movable and fixed dot contact points are parallel and have good contact over their entire surface. The pivot bearings should be adjusted so that no play can be felt when finger pressure is applied vertically to the shaft at its outer end.

For the preliminary adjustments, the weights should be at least halfway down the shaft. For a given speed, the exact position will vary considerably with the stiffness of the flat spring.

Back off the horizontal adjusting screw until the end of the shaft is resting against the damper weight. Apply pressure to the thumb paddle moving the shaft slowly toward the dot side, without allowing it to vibrate. If the adjustment is correct, the entire shaft will remain straight as it leaves the stop screw and the damper weight. The stop screw should be backed out as far as possible to allow good damping action by the damper weight without bending the flat spring when the thumb paddle is pressed slowly to the dot side.

Again press the shaft to the dot side without allowing it to vibrate. Vary the left-side stop screw until there is about $\frac{1}{8}$ inch between the side of the shaft and the damper weight. This determines the total swing of the shaft. The exact amount is a matter of personal preference, but the $\frac{1}{8}$-inch separation will be satisfactory to most operators. The swing should not be much greater or less than this figure.

The dash adjustment is made by varying the contact screw until the operating paddle moves the same distance to the *left* of center to make a dash as it moves to the *right* to make dots. If the paddle travel is excessive on the dash side, choppy sending is almost sure to result with spaces too wide between successive dashes. If the travel is too small, the dashes may be insufficiently spaced.

The coil springs should have about the same tension. The spring should return the shaft quickly and positively from the dot side to the rest position against the damper. The dash spring is then adjusted to a corresponding tension. Operators of fixed stations will generally prefer a comparatively light adjustment to minimize arm fatigue. Flight and marine operators like a rather stiff adjustment to compensate for ship motion.

The length of a dot should be equal to the space between dots. If the paddle is held to the dot side, a series of at least 15 to 20 dots will be

made with most "bugs" before there is any noticeable reduction in spacing between dots. If the dot adjustment is screwed in too far, a short series of heavy dots with very little separation will result. If the adjustment is screwed out too far, very light dots with excessive spacing will result. This adjustment is critical.

Many "bugs" are set to make excessively-fast dots. It will be found that most keys having a normal stiffness in the flat spring can be operated at a speed of about 30 w.p.m. with both weights toward the outer end of the shaft. Most operators cannot properly control a "bug" if the dot speed exceeds 11 per second. The rate at which your "bug" is adjusted can be determined by making a string of dots on recorder tape for 3 to 5 seconds, timing with a stop watch, and counting the dots.

The milliammeter method of adjustment involves connecting a battery (or any suitable source of d.c.), rheostat and milliammeter in series with the bug contacts. A typical set-up might use a 22½-volt battery, a 1000-ohm rheostat and a 0–100 milliammeter. With the key contacts closed, adjust the rheostat at the start with all the resistance in the circuit (to avoid burning out the meter!) until the meter reads 100 ma. A string of dots is then produced with the "bug" and the average-current reading on the meter is noted. If the dots are too light, the reading will be less than 50 ma.; if too heavy, more than 50 ma.

There is no point in making dots faster than the operator is able to make dashes to correspond. The purpose of any telegraphic communication is to convey intelligence. Mistakes in sending have no meaning and confuse the receiving operator. The time taken to repeat an incorrectly-transmitted word will result in a net loss in speed of about two words per minute on the average. Set your "bug" for a speed at which you can handle it easily and without an appreciable number of errors.

Beginners with a "bug," and some old hands too, will do well to imitate the 15 w.p.m. transmissions of W1AW or some press station using punched tape at moderate speed. Confine your practice to an audio oscillator until you are able to send correctly for at least two or three minutes at a rate of 20 w.p.m. During the initial practice stages, the dots should be slowed down to not more than 6 per second. Every effort should be made at the start to achieve good control rather than speed.

USING A BREAK-IN SYSTEM

If you aim to have the best, and every ham does, you will have break-in, whether of the push-to-talk or open-the-key variety. If you haven't the ideal installation yet, by all means take every advantage of the other fellow's facilities when break-in is offered! Break-in avoids unnecessarily long calls, prevents QRM, gives you more communication per hour of operating. Brief calls with frequent short pauses for reply can approach (but not equal) break-in efficiency.

A separate receiving antenna makes it possible to listen to most stations while the transmitting tubes are lighted. It is only necessary with break-in to pause just a moment occasionally when the key is up (or to cut the carrier momentarily and pause in a 'phone conversation) to listen for the other station. The click when the carrier is cut off is as effective as the word "break."

C.w. *telegraph* break-in is usually simple to arrange. With break-in, ideas and messages to be transmitted can be pulled right through the holes in the QRM. Snappy, effective, efficient, enjoyable amateur work really requires but a simple switching arrangement in your station to cut off the power and switch 'phones from monitor to receiver. If trouble occurs the sending station can "stand by" (QRX), or it can take traffic until the reception conditions at the distant point are again good.

In calling, the transmitting operator sends the letters "BK" at frequent intervals during his call so that stations hearing the call may know that break-in is in use and take advantage of the fact. *He pauses at intervals* during his call, to listen for a moment for a reply from the station being called. If the station being called does not answer, the call can be continued. If the station called answers someone else, he will be heard and the calling can be broken off. With *full* break-in, the transmitter may be remotely-controlled so no receiver switching is necessary. A tap of the key, and the man on the receiving end can interrupt (if a word is missed) since the receiver is monitoring, awaiting just such directions constantly. But it is not necessary that *you* have such complete perfect facilities to take advantage of break-in when the stations you work are break-in-equipped. It is not intelligent handling of a station or coöperation with an operator advertising that he has "break-in" with his calls, to sit idly by minute after minute of a properly-sent call. After the first invitation to break is given and at each subsequent pause, turn on your transmitter and tap your key — and you will find that conversation or business can start immediately.

VOICE OPERATING

Voice work has become increasingly popular over the years. With the availability of new NFM equipment it will make additional progress. The use of proper procedure to get best results is just as important as in using code. In telegraphy words must be spelled out letter by letter. It is therefore but natural that abbreviations and short-cuts should have come into widespread use; they make it possible to convey intelligence faster. In voice work, however, abbreviations are not necessary, and should have no part in our operating procedure when using voice.

The letter "K" has been agreed to in tele-

graphic practice so that the operator will not have to pound out the separate letters that spell the words "go ahead." The voice operator can more readily and understandably say the words "go ahead" or "over," or "come in please."

One laughs on c.w. by spelling out the letters HI. Strangely enough, there are some voice operators who have never thought much about procedure who say HI or "Aitch eye" instead of actually laughing. Use a laugh when one is called for. Be natural as you would with your family and friends.

The matter of reporting *readability* and *strength* is as important to 'phone operators as to those using code. With telegraph nomenclature, it is necessary to spell out words to describe signals or use the abbreviated signal reporting system (RST . . . see Chapter Twenty-Four). Using voice, we have the ability to "say it with words." "Readability four, Strength eight" is the best way to give a quantitative report. Reporting can be done so much more meaningfully with ordinary words: "You are weak but you are in the clear and I can understand you, so go ahead," or "Your signal is strong but you are buried under local interference." Why not say it with words?

Voice Equivalents to Code Procedure

Voice	*Code*	*Meaning*
Go ahead; over	K	Self-explanatory.
Wait; stand by	$\overline{AS}$, QRX	Self-explanatory.
Okay	R	Receipt for a correctly-transcribed message or for "solid" transmission with no missing portions.
Repeat each word twice	QSZ	Self-explanatory.
All after	AA	Repeat everything after ..... (word).
I will repeat; I say again	$\overline{IMI}$	Repeating a difficult word, phrase or expression.

'Phone-Operating Practice

Efficient voice communication, like good c.w. communication, demands good operating. Adherence to certain points "on getting results" will go a long way toward improving our 'phone-band operating conditions.

Use push-to-talk technique. Where possible arrange on-off switches or controls for fast back-and-forth exchanges that emulate the practicality of the wire telephone. This will help reduce the length of transmissions and keep brother amateurs from calling you a "monologuist" — a guy who likes to hear himself talk!

Listen with care. Carelessness in listening is intolerable. If one has time to operate at all, he should look over his operating practices and "do it right." Noise and other diversions must not be permitted to interfere with the primary objectives in the operating room.

Interpose your call regularly and at frequent intervals. Three short calls are better than one long one. In calling CQ, one's call should certainly appear at least once for every five or six CQs. Calls with frequent breaks to listen will save time and be most productive of results. In identifying, always transmit your *own* call *last. Don't* say "This is W1ABC standing by for W2DEF"; say "W2DEF, this is W1ABC, over." FCC regulations *require* that the call of the transmitting station be sent *last.*

Monitor your own frequency. This helps in timing calls and transmissions. Send when there is a chance of being copied successfully — not when you are merely "more QRM." Timing transmissions is an art to cultivate.

Speak near the microphone. Don't let your gaze wander all over the station causing sharply-varying input to your speech amplifier. Keep a proper distance from the microphone, and keep an eye on any modulation indicator used. Change distance or gain only as necessary to insure uniform transmitter performance without overmodulation, splatter or distortion.

Make connected thoughts and phrases. Don't mix disconnected subjects. Ask questions consistently. Pause and get answers.

Have a pad of paper handy. It is convenient and desirable to jot down questions as they come in the course of discussion in order not to miss any. It will help you to make intelligent to-the-point replies.

Steer clear of inanities and soap-opera stuff. Our amateur radio and also our personal reputation as a serious communications worker depend on us.

Avoid repetition. Don't repeat back what the

Voice-Operating Hints

1) Listen before calling.
2) Make short calls with breaks to listen. Avoid long CQs; do not answer any.
3) Use push-to-talk. Give essential data concisely in first transmission.
4) Make reports honest. Use definitions of strength and readability for reference. Make your reports informative and useful. Honest reports and *full* word description of signals save amateur operators from FCC trouble.
5) Limit QSO length. Two minutes or less will convey much information. When three or more stations converse in round tables, brevity is essential.
6) Display sportsmanship and courtesy. Bands are congested . . . make transmissions meaningful . . . give others a break.
7) Check transmitter adjustment . . . avoid AM overmodulation and splatter. Do not radiate when moving VFO frequency or checking NFM swing. Use receiver b.f.o. to check stability of signal. Complete testing before busy hours!

other fellow has just said. Too often we hear a conversation like this: "Okay on your new antenna there, okay on the trouble you're having with your receiver, okay on the company who just came in with some ice cream, okay . . . [etc.]." Just *say* you received everything OK. Don't try to prove it.

Use phonetics only as required. When clarifying genuinely doubtful expressions and in getting your call identified positively we suggest use of the ARRL Phonetic List. Limit such use to really-necessary clarification.

The speed of radiotelephone transmission (with perfect accuracy) depends almost entirely upon the skill of the two operators involved. One must learn to speak at a rate allowing perfect understanding as well as permitting the receiving operator to copy down the message text, if that is necessary. Because of the similarity of many English speech sounds, the use of alphabetical word lists has been found necessary. All voice-operated stations should use a *standard* list as needed to identify call signals or unfamiliar expressions.

ARRL Word List for Radiotelephony

ADAM	JOHN	SUSAN
BAKER	KING	THOMAS
CHARLIE	LEWIS	UNION
DAVID	MARY	VICTOR
EDWARD	NANCY	WILLIAM
FRANK	OTTO	X-RAY
GEORGE	PETER	YOUNG
HENRY	QUEEN	ZEBRA
IDA	ROBERT	

Example: W1EH . . . W 1 EDWARD HENRY.

Round Tables. One of the most popular kinds of contact on the 'phone bands is the round table, in which several amateurs establish contact with each other and pass the conversation from one to another. The effect is somewhat the same as personal conversation in a group, with one important difference: the person talking cannot be interrupted. The round table has many advantages if run properly. It clears frequencies of interference, especially if all stations involved are on the same frequency, while the enjoyment value remains the same, if not greater. By use of push-to-talk, the conversation can be kept lively and interesting, giving each station ample opportunity to participate without waiting overlong for his turn.

Round tables can become very unpopular if they are not conducted properly. The monologuist, off on a long spiel about nothing in particular, cannot be interrupted; *make your transmissions short and to the point.* "Butting in" is discourteous and unsportsmanlike: *don't enter a round table, or any contact between two other amateurs, unless you are invited.* It is bad enough trying to understand voice through prevailing interference without the added difficulty of poor quality: *check your transmitter adjustments frequently.* In general, follow the precepts as hereinbefore outlined for the most enjoyment in round tables as well as any other form of radiotelephone communication.

WORKING DX

DX is merely radio shorthand for "distance." Most amateurs at one time or another make "working DX" a major aim. As in every other phase of amateur work, there are right and wrong ways to go about getting best results in working foreign stations, and it is the intention of this section to outline a few of them.

The ham who has trouble raising DX stations readily may find that poor transmitter efficiency is not the reason. He may find that his sending is poor, or his calls ill-timed, or his

DX ETHICS

Unfortunately, there have been some amateurs specializing in DX work who have not observed proper operating procedures and practices in the methods they are trying to get DX contacts. The points below, if observed by all amateurs interested in DX, will go a long way toward making DX more enjoyable for everybody.

1) Call DX only after he calls CQ, QRZ? or signs $\overline{SK}$.
2) Do *not* call a DX station:
   a) On the frequency of the station he is working until you are *sure* the QSO is over. This is indicated by the ending signal $\overline{SK}$.
   b) Because you hear someone else calling him.
   c) When he signs $\overline{KN}$, $\overline{AR}$ or CL.
   d) Exactly on his frequency.
   e) After he calls a directional CQ, unless of course you are in the right direction or area.
3) Keep within frequency-band limits. Some DX stations operate outside. Perhaps they can get away with it, but you cannot.
4) Familiarize yourself with the meanings of ML, LM, HM, MH. DX stations often use these signals.
5) Give honest reports. Flattery will get you nowhere. Many foreign stations *depend* on W reports for adjustment of station and equipment.
6) Keep your signal clean. Thumps, clicks, chirps and ripple give you a bad reputation and get you a pink ticket from FCC.
7) *Listen* and call the station you want. Calling CQ DX is not the best assurance that the *rare* DX will reply.

DATE TIME	STATION CALLED	CALLED BY	HIS FREQ. OR DIAL	HIS SIGNALS RST	MY SIGNALS RST	FREQ. MC.	EMISSION TYPE	POWER INPUT WATTS	TIME OF ENDING QSO	OTHER DATA
10-20-47										
6:15 PM	WØTQD	x	3.65	589x	569x	3.5	A-1	250	6:43	Lots of ufc! Rec'd 6, sent 10.
7:20	CQ	x				7				
7:21	x	W4TWI	7.24	369	579x				7:32	Too much QRM! Gave it up.
9:32	W3UA	x				3.95	A-3	100		Guess I was snowed under.
10-21-47										
7:05AM	VK4DV	x	14.03			14	A-1	250		Answered a W6
7:07	AC4YN	x	14.02							ND
7:09	VK2ADW	x	14.07	339	559x				7:20	Sydney, Australia First VK!!
7:31	CQ	x								No luck
7:42	W6RBQ	x	14.05	589	579				8:02	Had to QRT for breakfast & Nice chat.
8:02	—	off								

KEEP AN ACCURATE AND COMPLETE STATION LOG AT ALL TIMES! THE F.C.C. REQUIRES IT.

A page from the official ARRL log is shown above, answering every Government requirement in respect to station records. Bound logs made up in accord with the above form can be obtained from Headquarters for a nominal sum or you can prepare your own, in which case we offer this form as a suggestion. The ARRL log has a special wire binding and lies perfectly flat on the table.

judgment in error. When conditions are right to bring in the DX, and the receiver sensitive enough to bring in several stations from the desired locality, the way to work DX is to use the appropriate frequency and timing and *call these stations*, as against the common practice of calling "CQ DX."

The call CQ DX means slightly different things to amateurs in different bands:

a) On v.h.f., CQ DX is a general call ordinarily used only when the band is open, under favorable "skip" conditions. For v.h.f. work such a call is used for looking for new states and countries, also for distances beyond the customary "line-of-sight" range on most v.h.f. bands.

b) CQ DX on our 7-, 14- and 28-Mc. bands may be taken to mean "General call to any foreign station." The term "foreign station" usually refers to any station in a foreign continent. (*Experienced* amateurs in the U. S. A. and Canada do *not* use this call, but *answer* such calls made by foreign stations.)

c) CQ DX used on 3.5 Mc. under winter-night conditions may be used in this same manner. At other times, under average 3.5-Mc. propagation conditions, the call may be used in domestic work when looking for new states or countries in one's own continent, usually applying to stations located over 1000 miles distant from your own.

The way to work DX is not to use a CQ call at *all* (in our continent). Instead, use your best tuning skill — and listen — and listen — and *listen. You have to hear them before you can work them.* Hear the desired stations first; time your calls well. Use your utmost skill. A sensitive receiver is often more important than the power input in working foreign stations. Before you can expect to be successful in working any particular foreign country or area, you should be able to hear ten or a dozen stations from that area.

In any band, particularly at line-of-sight frequencies, when directional antennas are used, the directional CQ such as CQ W5, CQ north, etc., is the preferable type of call. Mature amateurs agree that CQ DX is a wishful rather than a practical type of call for most stations in the North Americas looking for contacts in foreign countries. Ordinarily, it is a cause of unnecessary QRM.

Conditions in the transmission medium make all field strengths from a given region more nearly equal at a distance, irrespective of power used. In general, the higher the frequency band, the less important power considerations become.

KEEPING AN AMATEUR STATION LOG

The FCC requires every amateur to keep a complete station operating record. It may also contain records of experimental tests and adjustment data. A stenographer's notebook can be ruled with vertical lines in any form to suit the user. The Federal Communications Commission requirements are that a log be maintained that shows (1) the date and time of *each* transmission, (2) *all calls* and transmissions made (whether two-way contacts resulted or not), (3) the input power to the last stage of the transmitter, (4) the frequency band used, (5) the time of *ending* each QSO and the operator's identifying signature for responsibility for each session of operating. Messages may be written in the log or separate records kept — but record must be made for one year as required by the FCC. For the convenience of amateur station operators ARRL stocks both logbooks and message blanks, and if one uses the official log he is sure to comply fully with the Government requirements if the precautions and suggestions included in the log are followed.

Message Handling

Amateur traffic handling is highly developed and effective, *if one knows how to use it.* Don't expect that you can get on the air with the message you have written and give it to the first station that comes along and expect miracles to happen. You fellows who get your fun principally from DX, rag-chewing and building equipment should appreciate that you must place the occasional message *you* start and wish to have reach its destination, not in the hands of others like yourselves, but in the hands of one of the many operators who *specializes* in keeping schedules and handling messages, one who gets his fun mainly out of this branch of our hobby, who knows the best current routes and is in a position to use them.

Station owners may originate traffic *of any kind* going to any part of the United States, Hawaii, Puerto Rico and Alaska. Messages with radio amateurs in Canada, Chile and Peru may be handled under certain restrictions. Important traffic in emergencies or messages from expeditions for delivery in Canada must be put on a landwire by the U. S. amateur station handling. International regulations prohibit the handling of third-party messages to the majority of foreign countries. Messages relating to experiments and personal remarks of such unimportance that recourse to the public telegraph service would be out of the question may be handled freely with the amateurs of any country, but third-party messages only under special arrangements between U. S. A. and other governments, and only to the extent agreed upon by the contracting governments.

Messages should be put in as complete form as possible before transmitting them. *Incomplete messages should not be accepted.* As messages are often relayed through several stations before arriving at their destination, *no abbreviations should be used in the text* as mistakes are bound to happen when the text is shortened in this manner. To people not acquainted with radio abbreviations, messages written in shortened form are meaningless. Delivering stations must be careful to see that messages are written out fully.

In handling messages, we are doing something really worth while. We want to start only good worth-while messages from our stations. Our efforts should be directed to making the quality of our message service high. The number of messages we handle is of secondary importance. The *kind of messages* we originate or start from our station, the *speed* with which the messages pass through our station, and the *reliability or accuracy* with which the messages are handled are the things of paramount importance.

Just as the ultimate aim of amateur radio on all frequency bands is *communication,* so is the relaying of word by radiogram a "natural" when one has something to say to a party beyond immediate reach. Not all hams perhaps appreciate the utility that results from using amateur message service in our ham correspondence. However, no ham, not even a new member of the brotherhood, but feels the satisfaction of having really accomplished something tangible in exchanging a message (recorded communication) with another amateur. Of course, not all beginners develop the advanced operating technique of the finished message handler, but it is within the reach of all who will try. In this chapter we shall discuss basic points to follow in message-handling activities.

The amateur who handles traffic is automatically training himself to do the kind of a job official agencies desire in emergencies, and he becomes a valuable exponent of the whole amateur service.

Message Form

Each message originated and handled should contain the following component parts in the order given:

(a) Number
(b) Station of Origin
(c) Check
(d) Place of Origin
(e) Time Filed
(f) Date
(g) Address
(h) Text
(i) Signature

A standard form enables one to know just what is coming next, and makes accuracy possible with speed. Start some messages to familiarize yourself with the proper way to write and send traffic in good form. Just as you would be ashamed to admit it if you could not qualify as an experienced amateur by at least "15-w.p.m." code capability, be equally proud of your basic knowledge of how properly to form and send record communications.

a) Every message transmitted should bear a "number." On the first day of each calendar year, each transmitting station establishes a new series of numbers, beginning at Nr. 1. Keep a sheet with a consecutive list of numbers

handy. File all messages without numbers. When you send the messages, assign numbers to them from the "number sheet," scratching off the numbers on that list as you do so, making a notation on the number sheet of the station to which the message was sent and the date. Such a system is convenient for reference to the number of messages originated each month.

b) The "station of origin" refers to the call of the station at which the message was filed. This should always be included so that a "service" message may be sent back to the originating station if something interferes with the prompt handling or delivery of a message. In the example in (d) below, W1AW is the station of origin, that call being the one assigned the station at the national headquarters of the League.

c) Every word and numeral *in the text* of a message counts in the check. Full information on checking messages is given later in this chapter.

d) The "place of origin" refers to the name of the city from which the message was started. If a message is filed at League headquarters by someone in West Hartford, Conn., the preamble reads *Nr 457 W1AW ck 21 West Hartford Conn 8R57 p June 11, etc.*

If a message is sent to your station by mail the preamble shows the place of origin as the town from which the message came. If a message was filed at ARRL headquarters and if it came by mail from Wiscasset, Maine, the preamble would run like this to avoid confusion: *Hr msg nr 457 W1AW ck 21 Wiscasset Maine 8R57 p June 11, etc.*

e) The time filed is the time at which the message is received at the station for transmission. "NFT" in a preamble means no filing time.

f) Every message shall bear a "date" and this date is transmitted by each station handling the message. The date is the "day filed" at the originating station unless otherwise specified by the sender.

g) The "address" refers to the name, street and number, city, state, and telephone number of the party to whom the message is being sent. A *very complete address* should always be given to *insure* delivery. When accepting messages this point should be stressed. In transmitting the message the address is followed by a double dash or break sign (— . . . —) and it always precedes the text.

h) The "text" consists of the words in the body of the message. No abbreviations should ever be substituted for the words in the text of the message. The text follows the address and is set off from the signature by another break (— . . . —).

i) The "signature" is usually the name of the person sending the message. When no signature is given it is customary to include the words "no sig" at the end of the message to avoid confusion and misunderstanding. When there *is* a signature, it follows the break; *the abbreviation "sig" is not transmitted.*

The presence of unnecessary capital letters, periods, commas or other marks of punctuation may alter the meaning of a text. For this reason commercial communication companies use a shiftless typewriter (capitals only). The texts of messages are typed in block letters (all capitals) *devoid of punctuation*, underlining and paragraphing, *except where expressed in words*. In all communication work accuracy is of first importance. Spell out figures and punctuation.

Numbering Messages

Use of a "number sheet" or consecutive list of numbers enables any operator to tell quickly just what number is "next." Numbers may be crossed off as the messages are filed for origination. Another method of use consists of filing messages in complete form *except for the number*. Then the list of numbers is consulted and numbers assigned as each message is sent. As the operator you work acknowledges (QSLs) each message, cross off the number used and note the call of the station and the date opposite this number.

The original number supplied each message by the operator at the originating station is transmitted by each station handling the message. No new numbers are given the message by intermediate stations.

Checking Traffic — The Landline Check

The ARRL check is the landline or "text-only" count, consisting of the count of only the words in the body or text of the message. It is quicker and easier to count in this fashion than to use the cable count of words in address, text and signature check which is followed in marine-operating work, this simplification being the reason for its adoption. When in the case of a few exceptions to the basic rule in landline checking, certain words in address, signature or preamble are counted, they are known as extra words, and all such are so designated in the check right after the total number of words.

Counting Words in Messages

The check includes: (1) all words, figures and letters in the body, and (2) the following extra words:

a) Signatures except the first, when there are more than one (a title with signature does not count extra, but an *address* following a signature does).

b) Words "report delivery" or "rush" in the check.

c) Alternative names and/or street addresses, and such extras as "personal" or "attention – – – – – – – – –."

Examples: "Mother, Father, James and Henry" is a family signature, no names counted extra. "John Brown, Second Lieutenant" and "Richard Johnson, Secretary Albany Auto Club" are each one signature with no words counted as extra. An official title or connection is part of one signature, not extra. "Technical Department, Grammer *and Mix*" as a signature would count two extra words, those italicized after the first name counting as extras. The check of a message with ten words text and two such extras in the signature would be "CK 13 2 extra."

Dictionary words in most languages count as one word irrespective of length of the word. Figures, decimal points, fraction bars, etc., count as one word *each*. It is recommended that, where feasible, words be substituted for figures to reduce the possibility of error in transmission. Detailed examples of word counting are about as difficult in one system of count as in another.

Count as words dictionary words taken from English, German, French, Spanish, Latin, Italian, Dutch and Portuguese languages; initial letters, surnames of persons, names of countries, cities and territorial subdivisions. Abbreviations as a rule should be used only in service messages. Complete spelling of words

is one way to avoid error. Contractions such as "don't" should be changed to "do not." Examples:

Emergency (English dictionary)	1 word
Nous arriverrons dimanche (French dictionary)	3 words
DeWitt (surname)	1 word
E.L.B.D. (initials)	4 words
United States (country)	1 word
Prince William Sound	3 words
M.S. *City of Belgrade* (motor ship)	2 words

EXCEPTIONS

A.M., P.M.	1 word
F.O.B. (or fob)	1 word
O.K.	1 word
Per cent (or percent)	1 word

Figures, punctuation marks, bars of division, decimal points—count each separately as one word. The best practice is to spell out all such when it is desired to send them in messages. In groups consisting of letters and figures *each* letter and figure will count as one word. In ordinal numbers, affixes *d, nd, rd, st* and *th* count as one word. Abbreviations of weights and measures in common use count as one word each. Examples:

10 000 000 (figures)	8 words
Ten millions (dictionary words)	2 words
5348 (figures)	4 words
67.98 (figures)	5 words
64A2	4 words
45¼ (figures and bar of division)	5 words
3rd (ordinal number and affix)	2 words

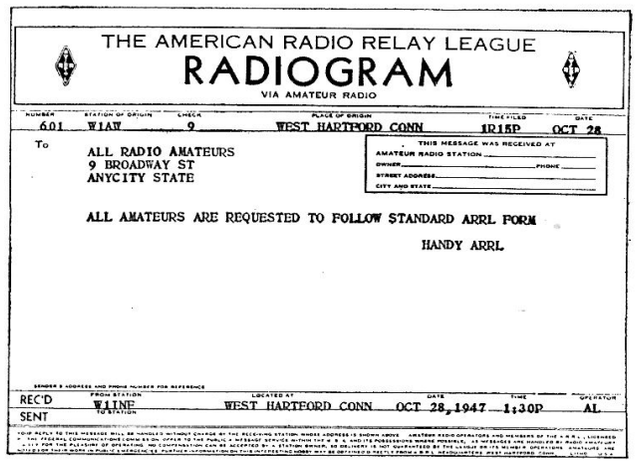
Groups of letters which are not dictionary words of one of the languages enumerated, or combinations of such words, will count at the rate of five letters or fraction thereof to a word. In the case of combinations each dictionary word so combined will count as a word. In addition, USS, USCG, etc., written and sent as compact letter groups, count as one word. Examples:

Tyffa (artificial 5-letter group)	1 word
Adccol (artificial 6-letter group)	2 words
Dothe (improperly combined)	2 words
allright, alright (improperly combined)	2 words
ARRL	1 word

At the request of sender the words "report back delivery," asking for a service showing success or failure in delivering at the terminal station, may be inserted after the check, or "rush" or "get answer" similarly, such words counting as extras in the group or check designation as just covered by example. "Phone" or "don't phone" or other sender's instructions in the address are not counted as extra words. In transmitting street addresses where the words east, west, north or south are part of the address, spell out the words in full. Suffixes "th," "nd," "st," etc., should not be transmitted. Example: Transmit "19 W 9th St" as "19 West 9 St." "F St NE" should be sent "F St Northeast." When figures and a decimal point are to be transmitted, add the words CNT DOT in the check.

Isolated characters each count as one word. Words joined by a hyphen or apostrophe count as separate words. Such words are sent as two words, without the hyphen. A hyphen or apostrophe each counts as one word. However, they are seldom transmitted. Two quotation marks or parenthesis signs count as one word. Punctuation is *never* sent in radio messages except at the express command of the sender. *Even then it is spelled out.*

Here is an example of a plain-language message in correct ARRL form, carrying the landline check:



THE AMERICAN RADIO RELAY LEAGUE

RADIOGRAM

VIA AMATEUR RADIO

NUMBER 601 | STATION OF ORIGIN W1AW | CHECK 9 | PLACE OF ORIGIN WEST HARTFORD CONN | TIME FILED 1215P | DATE OCT 28

To

ALL RADIO AMATEURS
9 BROADWAY ST
ANYCITY STATE

THIS MESSAGE WAS RECEIVED AT
AMATEUR RADIO STATION
OWNER PHONE
STREET ADDRESS
CITY AND STATE

ALL AMATEURS ARE REQUESTED TO FOLLOW STANDARD ARRL FORM

HANDY ARRL

REC'D FROM STATION W1INE | LOCATED AT WEST HARTFORD CONN | DATE OCT 28, 1947 | TIME 1:30P | OPERATOR AL

SENT TO STATION

Very important messages should be checked carefully to insure accuracy. Request originators *to spell out all punctuation marks that must appear in delivered copies. Likewise, never abbreviate in texts,* nor use ham abbreviations except in conversations.

Message handling is one of the major activities that lies in our power as amateurs to do to show our amateur radio in a respected light, rather than from a novelty standpoint. Regardless of experimental, QSL-collecting, friendly rag-chews, and DX objectives, we doubt if the amateur exists who does not want to know how to phrase a message, how to put the preamble in order, how to communicate wisely and well when called upon to do so. Scarcely a month passes but what some of us in some section of our ARRL are called upon to add to the service record of the amateur.

It is important that deliveries be made in businesslike fashion to give the best impression, so that in each instance a new friend and booster for amateur radio may be won. Messages should be typed or neatly copied, preferably on a standard blank, retaining original for the FCC station file. The designation and address of the delivering station should be plainly given so a reply can be made by the same route, if desired.

For those who would disparage some message texts as unimportant, perhaps a reminder is in order that in the last analysis it is not the importance to the ham that handles it that counts, but the importance to the party that sends and the party that receives a message.

The individual handling of traffic in small quantities as well as large is to a very great extent the material that we amateurs use for developing our operating ability, for organizing our relay lines, and for making ourselves such a very valuable asset to the public and our coun-

try in every communications emergency that comes along.

For those "breaking-in" may we say that any ORS, Trunk-liner or experienced ARRL traffic handler will be only too glad to answer your questions and give additional pointers regarding procedure and your station set-up, to help you make your station a really effective communications set-up. Since experience is the only real teacher, newcomers are reminded that becoming highly proficient in any branch of the game is partly just a matter of practice. Start a few messages, to get accustomed to the form. Check some messages to become familiar with the official ARRL (landline) check. You will find increased enjoyment in this side of amateur radio by adding to your ability to perform; by your familiarity with these things the chance of being able to serve your community or country in emergency will be greater. Credit will be reflected on amateur radio as a whole thereby.

Foreign Traffic Restrictions

Any and all kinds of traffic may be handled between amateur stations in different parts of the United States, Hawaii, Alaska and Puerto Rico. There is no qualification or restriction except that amateur status must be observed and no compensation, direct or indirect, be accepted for station operations or services.

Internationally the general regulations attached to the international communications treaty state the limitations to which work between amateur stations in different foreign countries is subject. In practically every nation outside our own country and its possessions, the government owns or controls the public communications systems. Since these systems are maintained as a state monopoly, foreign amateurs have been prohibited by their governments from exchanging traffic which might be regarded as in "competition" with state-owned telegraphs. The international treaty regulations reflect this condition and the domestic traffic restrictions (internal policy) of the majority of foreign countries. Any country ratifying the Madrid (1932) or Cairo(1938) conventions can make its domestic regulations as liberal as it likes; in addition it may conclude special agreements with other governments for amateur communications that are *more liberal* than the quoted terms of the treaty itself. If no specific formal negotiations have been concluded, however, amateurs must observe the following (treaty) regulations in conducting international amateur work:

The exchange of communications between amateur stations and between private experimental stations of different countries shall be forbidden if the Administration of one of the interested countries has given notice of its opposition to this exchange.

When this exchange is permitted the communications must be conducted in plain language and be limited to remarks of a personal nature, for which, by reason of their lack of importance, recourse to the public telegraph service would not be warranted. It shall be absolutely forbidden to licensees of amateur stations to transmit international communications emanating from third parties. The above provisions may be modified by special arrangements between the interested countries.

Referring to the first paragraph above, in the years since the Washington convention (1927) *no* prohibition on amateur communication (international QSOs) has been filed by *any* country with the Berne Bureau. In some countries, principally European, amateurs are restricted by regulation to privileges much *less* than made available by international agreement. In the U. S. A. it is the policy, and of course necessary to take care of our greater numbers of amateurs, to give amateurs the fullest frequency allocations and rights possible under international treaty provisions, and to permit free exchange of domestic noncommercial traffic in addition. This policy has justified itself, giving the public amateur radio traffic service and developing highly-skilled operators and technicians who have the ability to keep the U. S. A. in the lead in radio matters.

The second paragraph quoted prohibits *international* handling of third-party traffic, except where two governments have a special arrangement for such exchange. In any event, traffic relating to experimental work, and personal remarks which would not be sent by commercial communications channels, may be sent, when in communication with foreign amateurs.

Previous special arrangements, extending the basic international telecommunications treaty arrangements, have also been effected through ARRL and U. S. A. representations. The special U. S. A.-Canadian agreement will be explained later. Similar arrangements with Chile and Peru permit the handling to those countries of certain types of traffic.

The Canadian Agreement

The special reciprocal agreement concluded between our country and the Dominion of Canada, at the behest of the ARRL, permits Canadian and U. S. amateurs to exchange messages of importance under certain restrictions. This agreement is an expansion of the international regulations to permit the handling of important traffic.

The authorized traffic is described as follows:

"1. Messages that would not normally be sent by any existing means of electrical communication and on which no tolls must be charged.

"2. Messages from other radio stations in isolated points not connected by any regular means of electrical communications; such messages to be handed to the local office of the telegraph company by the amateur receiving station for transmission to final destination, e.g., messages from expeditions in remote points such as the Arctic, etc.

"3. Messages handled by amateur stations in cases of emergency, e.g., floods, etc., where the regular electrical communication systems

become interrupted; such messages to be handed to the nearest point on the established commercial telegraph system remaining in operation."

The arrangement applies to the United States and its territories and possessions including Alaska, the Hawaiian Islands, Puerto Rico, the Virgin Islands and the Panama Canal Zone. The agreements with Chile and Peru are similar to the above.

Originating Traffic

Messages to other amateurs are a natural means of exchanging comment and maintaining friendships. The simplest additional way to get messages is to offer to send a few for friends, reminding them that the message service is free and no one can be held responsible for delay or nondelivery. Wide-awake amateurs have distributed message blanks to tourist camps. Lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A neatly-typed card should be displayed near by explaining the workings of our ARRL traffic organization, and *listing the points to which the best possible service can be given.*

Messages that are not complete in every respect *should not be accepted* for relaying. *Complete address* on every message is important.

To represent amateur radio properly, placards, when used, should avoid any possible confusion with telegraph and cable services. Any posters should refer to *amateur radiograms,* and explain that messages are sent through *amateur radio stations,* as a *hobby, free,* without cost (since amateurs can't and will not accept compensation). The exact conditions of the service should be stated or explained as completely as possible, including the fact that there is *no guarantee of delivery.* The individual in charge of the station has full powers to refuse any traffic unsuitable for radio transmission, or addressed to points where deliveries cannot be made. Relaying is subject to radio conditions and favorable opportunity for contacting. Better service can be expected on 15-word texts *of apparent importance* than on extremely long messages. Amateur radio traffic *should not* be accepted for "all over the world."

Careful planning and organized schedules are necessary if a *real* job of handling traffic is to be done. Advance schedules are essential to assist in the distribution of messages. It may be possible to schedule stations in cities to which you know quantities of messages will be filed. Distribute messages, in the proper directions, widely enough so that a few outside stations do not become seriously overburdened. Operators must route traffic properly — not merely aim to "clear the hook."

It is better to handle a small or moderate volume of traffic *well* than to attempt to break records in a manner that results in delayed messages, nondeliveries, and the like which certainly cannot help in creating any public good will for amateur radio.

Amateur Stations at Exhibits and Fairs

Whatever type of exhibit is planned, write ARRL in advance, in order to receive sample material to make your amateur booth more complete. A *portable* station can be installed and operated by an already-licensed amateur, subject to FCC notification of location, etc., as provided by regulations. No license coverage is needed if no station is operated, of course.

If the time is short and there is no opportunity for special organization of schedules to insure reliable routing and delivery, quite likely exhibit work, to be most productive of good-will results, had best *not* include message-handling plans — at least not from the booth-station itself where subject to noise, electrical interference, and other handicaps. To handle such traffic as offered with *real efficiency,* it should be distributed for origination with existing schedules of the *several most reliable local amateur stations. By dividing the traffic filed with other stations it may be sent more speedily on its way.* Be sure that the operators undertaking to help are qualified and have good schedules for distributing messages.

"Show stations" must avoid origination of "poor traffic" by rigid supervision and elimination of meaningless messages with guessed-at, inaccurate and incomplete addresses *at the source.*

General

In successful relaying, *all* factors including "apparent importance" must be taken into account. Incomplete preambles are a common fault. Every station should demand an "office of origin" from stations who have messages, and traffic may be rightly canceled (QTA) on failure to include it. Thus messages will never get on the air without a starting place.

Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meager. A simple logbook, a good filing system, an accurate frequency meter and an equally accurate clock, are sure signs of a well-operated station. The apparatus on the operating table will tell a story without words.

The well-balanced amateur will not only know how to handle a message, but will have extended the principles of neatness and efficiency to his other station activities. The complete amateur station includes attention to traffic matters as part of its regular routine; it is one essential in building a reputation for "reliability" in amateur work. Communication (general) involves an exchange of thoughts. "Traffic" is merely the exchange of thoughts for ourselves or others, using *messages.*

Relay Procedure

Messages shall be relayed to the station nearest the location of the addressee and over the greatest distance permitting reliable communication.

No abbreviations shall be substituted for the words in the text of a message with the exception of "service messages," to be explained. Delivering stations must be careful that no confusing abbreviations are written into delivered messages.

Sending words twice is a practice to avoid. Use it only when expressly called for by the receiving operator, when receiving conditions are poor.

Messages shall be transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three attempts, the receiving operator shall cancel the message (QTA).

Agreement to handle (relay or deliver) a message properly and promptly is always tacitly implied in accepting traffic. When temporarily *not* in a position to so handle, it is a service to amateur radio and your fellow ham to courteously *refuse* a message.

An operator with California traffic does not hear any Western stations so he decides to call a directional "CQ" as per ARRL practice. He calls, *CQ CALIF CQ CALIF DE W1INF W1INF W1INF*, repeating the combination three times.

He listens and hears W9BRD in Chicago calling him, *W1INF W1INF W1INF DE W9BRD W9BRD W9BRD AR.*

Then he answers W9BRD, indicating that he wishes him to take the message. W1INF says, *W9BRD W9BRD DE W1INF R QSP MILL VALLEY CALIF NEAR SF? K.*

After W9BRD has given him the signal to go ahead, the message is transmitted, thus:

HR MSG NR 78 W1INF CK18 WEST HARTFORD CONN NFT (for "no filing time") NOV 18

ALAN D WHITTAKER JR W6SG
79 ELINOR AVE
MILL VALLEY CALIF

SUGGEST YOU USE ARRL TRUNK LINE K THROUGH W5NW TO HANDLE PROPOSED VOLUME TRAFFIC REGARDS

BUBB W1JTD

W9BRD acknowledges the message like this: *W1INF DE W9BRD NR 78 R K.* Not a single *R* should be sent unless the whole message has been correctly received.

Full handling data are placed on the message for permanent record at W1INF. The operator at W9BRD has now taken full responsibility for doing his best in forwarding the message.

Abbreviated Procedure

Abbreviated procedure deserves a word in the interest of brevity on the air. Abbreviated practices help to cut down unnecessary transmission. However, make it a rule not to abbreviate unnecessarily when working an operator of unknown experience.

NIL is shorter than *QRU CU NEXT SKED.* Instead of using the completely spelled-out preamble *HR MSG NR 287 W1GME CK 18 MIDDLEBURY CONN OCTOBER 28 TO*, etc., transmission can be saved by using *287 W1GME 18 MIDDLEBURY CT OCT 28 TO*, etc. One more thing that conserves operating time is the cultivation of the operating practice of writing down "287 W1UE 615P 11/13/37" with the free hand during the sending of the next message.

"Handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and entry of date, time and station call *on the traffic*, as handled, for purposes of record.

Getting Fills

If the first part of a message is received but substantially all of the latter portions lost, the request for the missing parts is simply *RPT TXT AND SIG*, meaning "Repeat text and signature." *PBL* and *ADR* may be used similarly for the preamble and address of a message. *RPT AL* or *RPT MSG* should not be sent unless nearly all of the message is lost.

Each abbreviation used after a question mark (. . — — . .) asks for a repetition of that particular part of a message.

When a few word groups in conversation or message handling have been missed, a selection of one or more of the following abbreviations will enable you to ask for a repeat on the parts in doubt. 'Phone stations, of course, request fills by using the full wording specified, without attempt at abbreviation.

Abbreviation	*Meaning*
?AA	Repeat all after
?AB	Repeat all before
?AL	Repeat all that has been sent
?BN...AND	Repeat all between..and
?WA	Repeat the word after...
?WB	Repeat the word before

The good operator will ask for only what fills are needed, separating different requests for repetition by using the break sign or double dash (— ... —) between these parts. There is seldom any excuse for repeating a whole message just to get a few lost words.

Another interrogation method is sometimes used, the question signal (. . — — . .) being sent between the last word received correctly and the first word (or first few words) received after the interruption. *RPT FROM . . . . TO . . . .* is a long way of asking for message fills.

The figure four (. . . . —) is a time-saving abbreviation which deserves popularity with traffic men. It is another of those hybrid abbreviations whose original meaning, "Please start me, where?" has come to us from Morse practice. Of course *?AL* or *RPT AL* will serve the same purpose, where a request for a repetition of parts of a message has been missed.

Delivering Messages

Provisions of the Communications Act make it a misdemeanor to give out information of any sort to any person except the addressee of a message. It is in no manner unethical to deliver an unofficial copy of a radiogram, if you carefully mark it *duplicate* or *unofficial copy* and do it to improve the speed of handling a message or to insure certain and prompt delivery. Do not forget that there are heavy fines prescribed by Federal laws for divulging the contents of messages to anyone *except* the person addressed in a message.

When it is possible to deliver messages in person, that is usually the most effective way. When the telephone does not prove instrumental in locating the party addressed in the message, it is usually quickest to mail the message.

ARRL delivery rules:

Messages received by stations shall be delivered immediately.

Every domestic message shall be relayed within forty-eight (48) hours after receipt, or if it cannot be relayed within this time shall be mailed to the addressee.

Messages for points outside North America must not be held longer than half the length of time required for them to reach their destination by mail.

When a message cannot be delivered, or if it is unduly delayed, a "service" message should be written and started back to the "office of origin."

Each operator who reads these pages is asked to assume *personal responsibility* for accuracy, speed of each message handled, and *delivery*, that we may approach a 100% delivery figure.

The Service Message

A service message is a message sent by one station to another station, relating to the service which we are or are not able to give in message handling. The service message may refer to nondeliveries, to delayed transmission, to errors, or to any phase of message-handling activity. It is not proper to abbreviate words in the texts of regular messages, but it is quite desirable and correct to use abbreviations in these station-to-station messages relating to traffic-handling work. Example:

HR SVC NR 291 W4IA CK XX ARLINGTON VA NFT AUG 19
L C MAYBEE W7GE
110 SOUTH SEVENTH AVE
PASCO WASHN —···—
UR NR 87 AUG 17 TO CUSHING SIG BOB HELD HR UNDLD PSE GBA —···—

BATTEY W4IA

Counting Messages

To compare the number originated and delivered each month, in order to learn some facts about the "efficiency" of our work in handling messages, a method of counting is used. Each time a message is *handled by radio* it counts one in the total.

A message received in person, by telephone, by telegraph, or by mail, *filed at the station and transmitted by radio* in proper form, counts as *one originated.*

A message *received by radio and delivered* in person, or by telephone, telegraph, or mail, counts as *one delivered.*

A message *received by radio and sent forward by radio* counts as two messages *relayed* (one when received and again one when sent forward).

All messages counted under one of the three classes mentioned must be handled within a 48-hour (maximum) delay period to count as "messages handled." Messages for continents except North America may be held half the length of time it would take them to reach their destination by mail. A "service" message counts the same as any other type of message.

Extra Delivery Credit

In addition to the basic count of *one* for each time a message is handled by radio, an *extra credit* of one point for each delivery made by mail, telephone, in person, by messenger or other external means *other than use of radio* (which would count as a "relay" of course) will also be allowed. A message received by an operator for himself or his station or a party on the immediate premises counts *only* "one delivered." A message for a third party delivered by *additional means or effort* will receive a point under "extra delivery credits."

The message total shall be the *sum* of the messages originated, delivered and relayed, and the "extra" delivery credits. Each station's message file and log shall be used to determine the report submitted by that particular station. Messages with identical texts (so-called rubber-stamp messages) shall count once only for *each* time the complete text, preamble and signature are sent by radio.

In whatever volunteer work it is engaged, a station has an amateur status, and the total is a strictly "amateur" total if handled under ham-band conditions on amateur frequencies.

Examples of Counting

Let us assume that at the end of the month one operator of a large amateur station receives several messages from another station. (a) Some of these messages are for relaying by radio. (b) Some of them are for local delivery. (c) There are still other messages, the disposal of which cannot be accurately predicted. They are for the immediate neighborhood but either can be mailed or forwarded to another amateur by radio. A short-haul telephone toll call will deliver them but the chances of landing them nearer the destination by radio are pretty good. This operator's "trick" ends at midnight. He must make the report with some messages "on the hook," to be carried over for the next month's report.

a) The messages on the hook that are to be relayed have been received and are to be sent. They count as "1 relayed" in the report that is made out now, and they will also count as "1 relayed" in the next month's report (the month during which they were forwarded by radio).

b) By mailing or 'phoning the messages at once, they count as "1 delivered" for the current report. By holding them until next day they will count in the *next* report as "1 delivered." Also, they will each have a count of one *extra* delivery credit since they had to be telephoned, mailed, etc.

c) The messages in this class may be carried forward into the next month. If they *have* to be mailed then they will count in the *next* report as "1 delivered." If they are relayed, we count them as "1 relayed," "1 received" in the preceding month (already reported), and "1 relayed" for the next month, the month in which it was sent forward by radio. If the operator wishes to count this message *at once* as delivered it must be mailed promptly and counted at once.

Some examples of counting:

The operator of Station A gets a message by radio from Station B addressed to himself. This counts as "1 delivered" by himself and by Station A. There is no extra delivery credit possible for no additional delivery effort was needed.

The operator of Station A takes a verbal message from a friend for relaying. He gives it to Station B over the telephone. Operator A does not handle the message by radio. Station B and Operator B count the message as "1 originated." A cannot count the message in *any* manner.

The operator and owner of Station A visits Station B and *while operating* there takes a message for relaying. The operator and owner of B cannot operate for a day or two so the message is carried back to Station A by Operator A who relays it along within a few hours. The traffic report of both Station A and Station B shows "1 relayed" for this work.

Please note that "handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and the entry of date, time, and station call on the traffic, as handled, for purposes of record. Only messages promptly handled and with information so recorded shall be counted in ARRL totals.

"Rubber-Stamp" Messages

The handling of traffic can be both fun and constructive, interesting work. Because multiple-address (rubber-stamp) messages mean much drudgery and little accomplished, they cannot be handled effectively in a hobby such as amateur radio.

Obviously, a station in handling a rubber-stamp message has to exert only a small amount of effort in receiving the text and signature once. Then by handling the address to different points *en groupe* a large number of messages (?) can be received and transmitted with little time and effort. The League's system for crediting points for messages handled (and except for any *extra* delivery credit) is based on giving one credit each time a *complete* message is handled by amateur radio, i.e., one credit for each originated message, one credit for each delivered message and two credits for each relayed message (one credit for the work in receiving it and one for the work in transmitting it). *Only* every message handled by radio *with a complete preamble, address, text, and signature* shall be counted, except in the case of *deliveries*, each mailed, telephoned or otherwise delivered message shall count "one delivered" *regardless* of handling in "book" form (with text sent once only).

Reporting

Whether the principal accomplishments of the station are in traffic handling or other lines, *what you are doing* is always of interest. One part of *QST* is devoted to Station Activities, this written up by your elected section communications manager. His address is given on page 6 of each *QST*. Reports from *all active hams*, sent the SCM at the end of each month and covering the 30 days just previous, are welcomed.

Operating on Schedules

Traffic-handling work can be most advantageously carried on by arranging and keeping a few schedules. The message "hook" can be cleared in a few minutes of work on schedule and the station will be free for DX or experimental work. Aim at station appointments if you can do so, and become a member of your ARRL section net. If at the moment you cannot go this far, start out by making some individual schedules, with at least one tie-in to some organized net.

Traffic Handling Develops Skill

The dispatch of messages makes operators keen and alert. The better the individual operator, the better the whole organization. Proper form in handling traffic, getting fills, and in general operating procedure develops operators who excel in "getting results." Station performance depends 90% on operating ability and 10% on the equipment involved, granting of course that station and operator are always interdependent. Experience in message handling develops a high degree of operating "intelligence."

Message handling leads to organization naturally, through the need for schedules and coöperation between operators. It offers systematic training in "real" operating. It leads to planned, useful, unselfish, constructive work for others at the same time it represents the highest form of operating "skill" and enjoyment to its devotees. Emphasis should be placed on the importance of traffic handling in training operators in the use of procedure — and in general operating reliability. The value of the amateur (as a group), in cases of local or national emergency, depends to a great extent on the *operating ability* of individual operators. This ability is largely developed by message handling.

Practice in handling traffic familiarizes one with detailed time-saving procedure, and develops general skill and accuracy to a higher extent than obtains in "just rag-chewing" or haphazard work.

CHAPTER 22

Emergency Operation

Public service in emergencies is part of the tradition of amateur radio. It constitutes important justification for the frequency assignments granted by our Government. The public has come to appreciate our emergency work through the consistent performance of amateurs in bridging disaster-created gaps in hundreds of instances, over many years of amateur radio operation. In view of these emergency-communication values emergency work takes on ever-increasing importance. Handling emergency communications puts across in a striking way that which we most need to have the public appreciate about our ability and willingness to serve. Every licensed amateur owes it to his community to be ready to play a proper part (not necessarily to transmit) in communications emergencies.

This chapter will be dedicated entirely to outlining amateur-service emergency work, plans and policies.

OUR ABILITY TO SERVE

Of all the civilian services licensed by the FCC, amateur stations are most numerous. While the technique of radio use is expanding to embrace new horizons, it is doubtful if the geographical numbers and distribution of amateurs closely in proportion to the urban and suburban population will be challenged in any large way. But new services automatically capable of emergency employment do naturally point to increased competition in this field of potential service.

It remains for the amateur to exercise continuing and increased initiative in the field of emergency organization. Liaison with agencies and officials active in emergencies who are potential users of the amateur service, liaison with other communicators with whom emergency burden will be shared, and the implementation of emergency plans through drills and tests are necessary after local mobilization of equipment and operator facilities by the amateur. Only proper all-out support of emergency plans will permit the amateur to continue to hold the top records for accomplishment in this field.

ADVANCE PLANNING NECESSARY

Individual preparedness and organization of amateurs, community by community, are the most essential elements of a successfully-functioning amateur emergency service. Annual ARRL Field Days supply a tremendous incentive to clubs and individuals to perfect and test emergency-powered equipment. Training in message handling and the principles of working together under unusual circumstances combine in this outing an annual "shakedown" of communications gear afield, to challenge individual and group efforts. But unless each individual in addition to working casually in annual events attaches himself to community organization and the support of local plans, our group effort may sometimes fall short of its organized capabilities of performing a public service.

The chief lesson, from past emergencies, calls for support and membership of every active operator in the ARRL Emergency Corps. By joining, one is supporting organized amateur radio for any and every emergency! The AEC member can enjoy and benefit from *advance* discussions, literature, and participation in exercises covering such matters as procedure, priorities, station dispositions, and other factors. By such alignment with AEC, one justifies his license as "in the public interest." Such support contributes to our emergency-readiness. Emergency-readiness contributions to public welfare as well as our self-training and experimenting characteristics permit FCC to grant amateur licenses as of public value. Once in the AEC you are on the "inside" in any amateur-service plans worked out by your emergency coördinator. Your local ARRL coördinator can provide appropriate blanks for joining the Emergency Corps . . . or write Headquarters.

The ARRL Emergency Corps

The AEC was first announced in September, 1935. Participation in the Corps is not limited exclusively to members of ARRL or any other group or organization. All amateurs in the U. S. and Canada can belong. The Corps is a challenge to each individual licensee. It provides a flexible framework of organization with responsibility for local leadership decentralized to a community emergency coördinator. EC appointments are made by section communications managers whose election and broad field-organization administrative duties and

appointments "of, by and for" the amateur are covered in another chapter.

The Emergency Corps in a given city or town consists of the coördinator and all local radio amateurs who have indicated their support and readiness for participation in emergency plans. The mission of the group in providing emergency radio service is accomplished through organization, self-training, and actual operating tests and activities.

The 144-Mc. band is often used for local AEC nets at points where this v.h.f. band has most stations willing to volunteer for coverage of local points in organized fashion. Other frequency bands may be chosen for local organization, where emergency coördinators find insufficient 2-meter activity, or if interference attributable to a volume of 144-Mc. casual activity requires supplementary means.

H.f. band stations will be recruited for long-haul emergency requirements. Stations should be encouraged to participate in ARRL section nets. Preference in AEC work should be given stations having definite regular traffic schedules to outside points.

FULL AND SUPPORTING MEMBERSHIP

Local emergency coördinators will issue ARRL AEC membership cards to individual amateurs whose application forms indicate their availability and willingness to participate in organized emergency assistance to the community in the event of any emergency. Activity and interest are the criteria for continued membership. *Any* amateur licensee is eligible. Assistant ECs and AEC members are not required to hold ARRL membership, though of course most of them do. The cards must be endorsed annually by the emergency coördinator to keep appointments in effect.

Full membership cards will be issued to those amateurs with stations who can be active in regular as well as occasional test periods. Every full member should strive to have *emergency power* and equipment available! Supporting AEC membership cards will be issued to all individuals who otherwise qualify but who must give limited time to this activity and who are seldom able to participate in group radio activity. ECs will issue new cards or transfer AEC members from "supporting" to "full" status or vice versa on application and as appropriate.

Both portable and fixed amateur station equipment working from commercial power and emergency power are needed in the Emergency Corps to fulfill its missions on h.f. and v.h.f. Equipment types or power source will not be used as a criterion for classification of AEC membership; instead, your activity and the contributions to organized community emergency work and tests within the framework of the AEC will decide your classification.

"Joining" the Emergency Corps is on an annual basis. The Corps membership cards provide for annual endorsement, at which time ECs should require new station information so that at all times the papers held permit them to know current facts such as the usual operating frequency, telephone number, and available hours for test and operation.

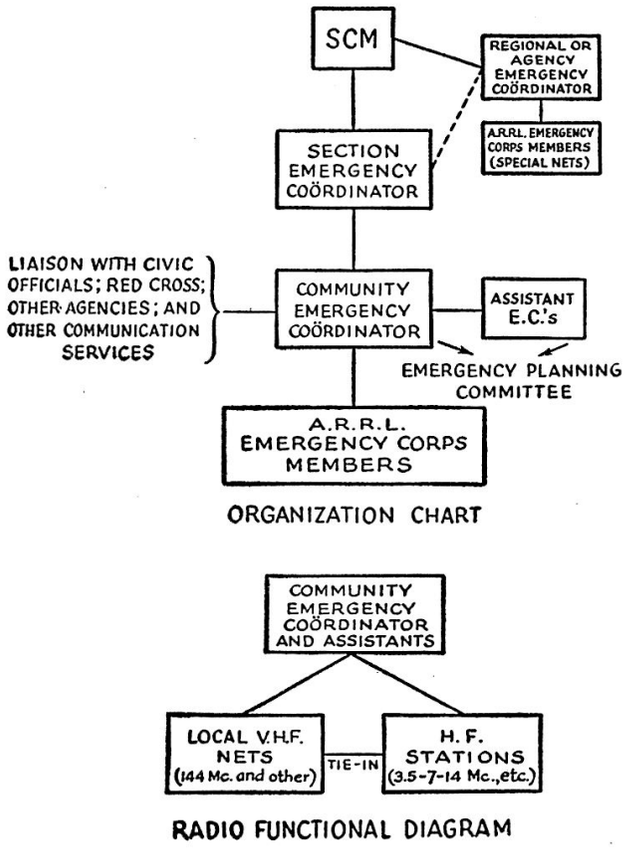


Fig. 22-1 — Chart of AEC organization.

ORGANIZATION

A four-part diagram will best show over-all Emergency Corps organization. The section manager (SCM on Fig. 22-1), is elected under the Constitution and By-Laws of the League to appoint individual member-stations for specific activities in accordance with their qualifications, interest and ability. *Before* emergencies the SCM arranges the most complete local leadership possible through his selection and appointment of qualified men to give exclusive attention to the amateur-service emergency-organizing field.

Section managers (address, p. 6, *QST*) welcome recommendations from *emergency-interested* amateur groups, radio clubs, and individuals, naming qualified individuals for local emergency leadership. ARRL members who inspire the confidence of community officials, who will act impartially to work out amateur-service plans with amateurs in each local band and mode group, while maintaining friendly contact with agencies served and representatives of other communications facilities, will be appointed by SCMs wherever vacancies exist.

The Section Emergency Coördinator

A Section Emergency Coördinator (SEC on Fig. 22-1) is appointed by the SCM to promote Emergency Corps organization throughout his entire section. The SEC encourages EC recommendations from local groups, and determines the territory handled by ECs as required. His functions include: (1) Recommendations for EC appointments and endorsements for community coördinators. (2) Promulgation of Emergency Corps membership drives, meetings, activities, tests, procedures, etc., at section levels. The SEC will work through local ECs, or sign AEC member cards for those not in areas covered by a local EC, while trying to secure an EC appointee for such cities. (3) Policy and planning recommendations to the SCM on emergency matters. (4) Consolidation of monthly reports from coördinators for the SCM and ARRL headquarters.

The section emergency coördinator must be an SCM appointee who will devote his full energy and effort to this *one* important emergency-organizing program for amateur radio. His responsibilities require him to act as "Assistant SCM" for emergency-organization matters.

The Emergency Coördinator

The Emergency Coördinator often has a good station and emergency equipment himself, to set the example, but his *primary* duty is *organization.*

In carrying out his seven-point program, the EC registers (on AEC Form 7A) all available local emergency equipment and operators. His community plan of preparedness will be determined with the assistance of his emergency planning committee (of assistant coördinators) or by otherwise depending on the geography of the area, state of training and past experience in emergency work, and the best assessments that can be made of community needs and available amateur facilities. Points common to every EC program are as follows:

(1) Organization meetings of all available amateurs . . . explaining objectives, enlisting support of every amateur.
(2) Designation of assistant ECs for an emergency planning committee.
(3) General planning for assumed community emergencies.
(4) Committee meetings and appointments to handle particular responsibilities.
(5) Liaison with (a) official agencies served, (b) other communications services.
(6) Designations of (a) exceptional simulated-emergency tests, (b) of regular operational AEC periods.
(7) Monthly assessment of progress. Reports for ARRL-SCM-*QST.*

The organizational chart also shows contact by the SCM and the SEC with "regional (or agency) emergency coördinators." Section nets, groups organized by SECs for the Weather Bureau, Engineers, and others often serve as points for reliable "outside" communication in case of an unexpected local emergency. The "regional" ARRL coördinator is SCM-appointed only after policy review with ARRL Hq. to provide and maintain stand-by facilities for specific agencies of a *regional* or community nature. His post will not be explained in detail in these paragraphs except to say that local tie-ins with all such networks should be arranged by emergency coördinators where they may be helpful.

● TYPICAL COMMUNITY PLAN

Another diagram (Fig. 22-2) illustrates the key position of the ARRL emergency coördinator as chairman of the amateur-service planning committee. This indicates a "typical" set-up for a town or city, containing practically every element of proper program planning.

Each group plan for utilization of amateur radio should contemplate tying the work of the different groups using different frequencies in emergency instances to an amateur radio control center. In simple wire overloads (minor emergencies) and where only a few amateurs in a locality are concerned, telephone connections between stations or from the coördinator himself to operators in each group, may suffice. As the communities covered are of larger size and the number of amateurs concerned is greater, it is essential that more complete plans for use of telephone, courier, or common v.h.f. channel with stringent circuit discipline be made to facilitate accurate message exchanges and full emergency control. Geographical considerations may require the establishment of relay points within one large community.

A potential list of the agencies served is indicated at the left of Fig. 22-2, showing the organized groups of AEC member-stations (fixed, mobile, and emergency-powered) available in each of the different bands. Liaison is necessary with other communicating services as well as with those officials for whom we handle traffic. At some points airways communications facilities, state police, sheriff's office, state forestry service or military communications facilities may be an important factor, or the local water bureau or public utilities supplying light and power might be served in important ways.

A first important item for the coördinator and his planning committee then is to translate our generalized diagram to a community plan that can be reduced to paper for a specific community. The final "blueprint" should show the names of representatives of agencies and their telephone numbers, the calls of amateurs representative of each frequency band/mode, and if practicable, any assignments of special responsibility under existence of an emergency.

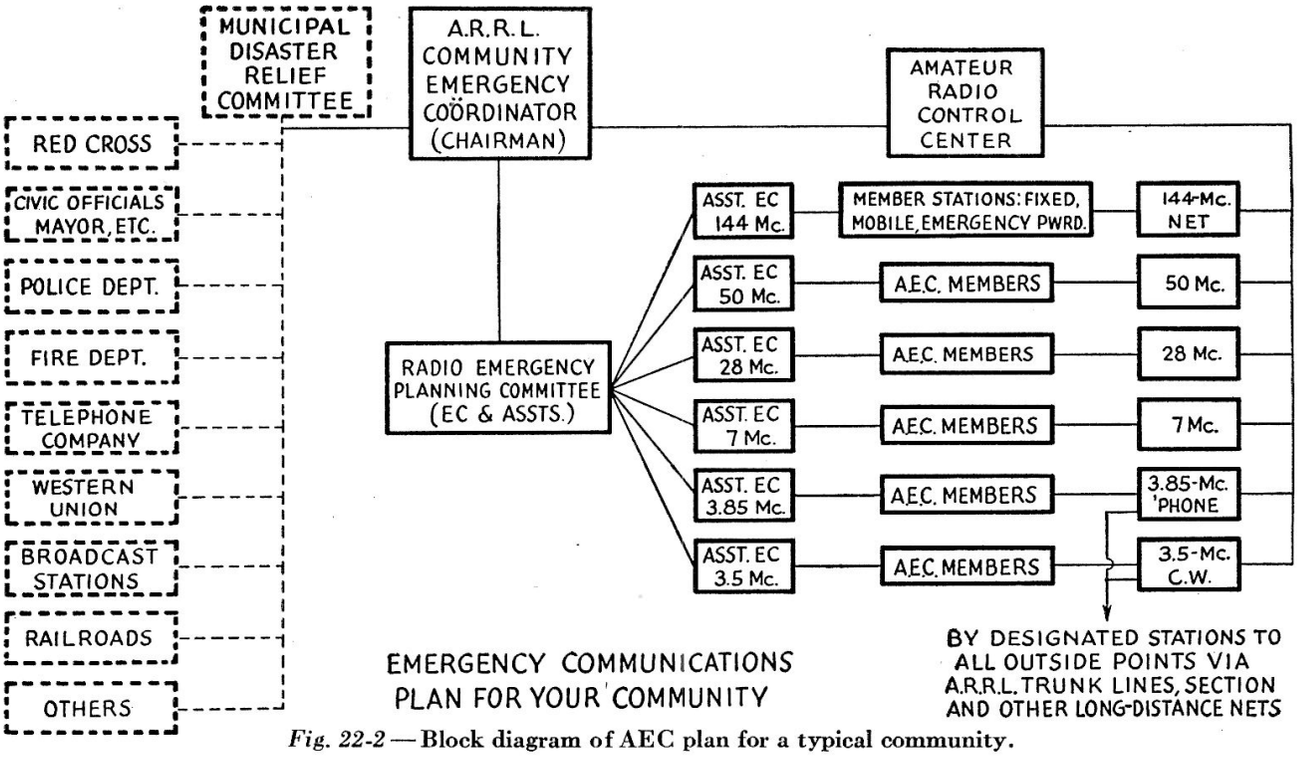


Fig. 22-2 — **Block diagram of AEC plan for a typical community.**

Three Phases of Emergency Planning

1) There are two types of provisions to be made for emergency radio coverage: (a) that for local short-haul work, (b) that for necessary out-of-the-area or distant coverage. Emergency coördinators have to make plans to cover both cases for implementation, separately or together, depending on the seriousness of the situation.

2) In using radio in the simplest form of emergency work, there is but one objective: to establish contact with an outside point to report difficulties, summon aid, or communicate intelligence of a limited character, when other means fail or are unavailable. *Coverage to some outside point is the thing!*

3) When a populated center has its communications crippled by causes that also disrupt transportation, food and water supply, and other organized public services, the *real emergency* is basically the same, but the effects are greatly magnified by the increased requirements. In addition to communicating considerable distances to get help from outside the paralyzed area, there is a problem of maintaining necessary communications between workers *within the area.*

Short-Haul Work — Local Nets

Local emergency networks should be established on a regular basis if possible, or on a stand-by basis with monthly tests and simulated drills wherever facilities permit in all the larger cities. Some mobiles and portables usually are assigned to cover points deemed strategically important by city officials for expected emergency use. Ordinarily local nets will use v.h.f. bands. Whether two meters or six meters or ten meters is used will depend on the community and the number of voluntary amateur workers equipped on a common frequency. In very large cities it may be justifiable to have local emergency nets using more than one amateur frequency band, with proper provision for traffic exchanged through common points. It is suggested that all regularly-operating v.h.f. nets identified with particular communities dedicate themselves to emergency operation in the event of any public need. The responsible net control stations will be glad to assist the appropriate ARRL ECs to permit occasional exceptional tests as well as participation in all major Amateur Emergency Corps exercises.

H.F. Stations for Outside Contact

Local stations working on lower amateur frequencies should be included in every community plan, for contact to outside points via ARRL trunk lines, section nets, and other h.f. or regional nets. Amateur-service planners should attempt to determine from agencies they expect to serve from what cities or points *outside* the immediate local area supplies, assistance or exchanges of communication would be required in event of possible emergencies. The needs of some agencies may warrant advance designation of a station. Or the setting up of traffic schedules or stand-by c.w. telegraph arrangements between neighboring cities for accurate handling of record communications can be tried on a weekly or other recurrent basis. It is *not* desirable to have too many stations operating on h.f. in haphazard fashion when there is an emergency. In any major catastrophe designated stations should be manned by several shifts of amateurs on a 24-hour basis, to avoid overworking one-man set-ups. Create least band congestion and give the best service!

Policies for Your Emergency Operating

DEFINITION — AGENCIES SERVED

A communications emergency occurs whenever normal facilities are interrupted or overloaded. It may or may not involve general public participation. Public-relief-or-welfare emergencies during floods, tornadoes, hurricanes, blizzards, fires, explosions, or other unexpected conditions are usually accompanied by a communications emergency.

Amateur radio is dedicated to serving any agency that it may help in public interest. The League has long had a coöperative understanding with the National Headquarters of the American Red Cross, the primary agency serving in disasters. Long-term plans for cooperation with relief agencies by ARRL results from careful and deliberate study and consultation over a period of time. Work with the U. S. Weather Bureau, Division of Climatological and Hydrologic Services, and with the Army Engineer Corps, which likewise has certain emergency responsibilities to the public, has developed as important in postwar amateur radio. At the request of the Weather Bureau, the League has asked SCMs to designate liaison men with regional administrative offices of this agency in order that stand-by facilities (amateur nets) may be arranged in as many as practicable of 86 different river courses where emergency radio facilities might be needed. Aside from work with the mentioned agencies, present conditions do not permit the diversion of operator availabilities and station facilities to too great an extent.

ASSIST AS ONE STRONG, INTERCONNECTED FACILITY

In emergencies, the public interest is paramount. Our effectives, who are organized and practiced in handling relief communications, are not so numerous as to permit their services to be devoted closely to assisting all the different private or commercial interests that might like to have an exclusive radio service under emergency conditions. Interconnected nets as diagrammed, one organized group per community, can do the best job. So we say: Join the ARRL Emergency Corps. Build on the principle of *one strong facility.*

Our function *as radio amateurs* is to provide emergency communication. We are not responsible for predicting when dams will fall, estimating lives lost or property damage. There are proper public officials to make technical reports on flood stages, and ask for food or medical supplies. As amateurs we do not wish to take it upon ourselves or be held responsible for making pronouncements in such matters. The standing amateur policy is, therefore, to handle information *only* from official sources and to be sure all information handled is definitely signed or labeled as to its source, with rumors either not transmitted at all or plainly marked as such.

PROVIDING MESSAGE SERVICE

Data on roads should come from the state police or highway department, information on weather and flood conditions from the U. S. Weather Forecaster, data on relief needs and property damage from the Red Cross or mayor's office. Get your inquiries put in the form of messages. Information handled is *not* to be given out to reporters or individuals *by amateurs.* We amateurs are obliged to observe the Communications Act, which imposes heavy penalties for violating the provisions on secrecy of correspondence. Only with express authority from a person or agency addressed may information be released. The message belongs to the addressee and the sender!

Priorities

Priorities (or precedence) will be determined by the degree of public interest involved in all traffic filed. Highest priority must be given vital first-traffic from officials and responsible agencies from an emergency-stricken area to points outside the affected terrain. Of a wholly secondary nature, *personal-inquiry messages* are commonly referred to as "agony" traffic. They do *not* rate the same "time" importance as official and agency messages which must be handled *first.* In the Texas City disaster in 1947, at least two groups of amateurs rendered special service in the early history of that emergency by "dead-ending and delivering by courier" a large volume of inquiry messages which would have served only to congest already-overloaded emergency radio facilities to no good purpose. In view of the dispersion of "displaced persons" from flood areas and those otherwise devastated, it sometimes takes the appropriate welfare agency ten days to three weeks to locate some of the persons to whom inquiry traffic is directed from "outside," a fact that highlights the secondary nature of such messages.

Address Traffic Correctly

"Accuracy first" is a slogan constantly before communicators. No operator has a right in emergency or otherwise to *change* the address or text of a message, once it has been filed and is en route. This compounds any chance for error. Service messages and notations should be filed supplementing traffic where absolutely necessary. Originating stations must be especially careful to get correct and complete addresses. There are perhaps a dozen inquiry messages to our ham credit for *each* message from an official. But no message counts for anything but a black mark . . . if it cannot

be delivered. Even though the order of merit may not rate as heavily, the sum total of public appreciation reaches an amazing total for completing the handling of "inquiry" messages. Of course no one files *any* message unless it's with the idea that it will mean something to him or the addressee. Using good message forms, standard operating procedure, phonetic word lists where voice is used, and asking for appropriate fills when necessary, reduces the chance of error. Giving oneself plenty of practice in handling record traffic *before* an emergency comes along is the best precaution to insure accuracy. There are special satisfactions and skill from this type of amateur operation, too.

Authentication and Routing

The *signed* message is the best identification for the person who receives a message. We recommend that amateurs link emergency stations direct to civil and military authorities, so that all messages derive from reliable sources. Broadcasters and others are often criticized for transmitting hearsay and rumors, even for sending traffic requiring delivery "broadcast" and the like. The more nearly our amateur service can make results conform to the pattern of commercial *communications* and *not* to the field of broadcasting, the higher are our achievements acclaimed by agencies served in emergencies!

QRR

QRR is the "official ARRL land SOS." It is a distress call for emergency use only, to be used only by a station definitely asking assistance!

Operators *outside* emergency zones, deprived of power in major floods and other disasters, have in the past failed to appreciate adequately the problem of battery-and low-powered stations trying to clear traffic and establish contact to "outside" points. It is *all wrong* for operators having picked up an inquiry message addressed to a point in a devastated area to work themselves up to the point of sending "CQ flood area" or sometimes even "QRR." *Listening* and coöperating by keeping quiet are practically always best for "outside stations" until they are called for. It is *also a service* for amateurs to forward inquiry traffic, during the secondary phases of an emergency after all-important first messages have been sent and answers delivered, but the practice of *solicitation* of public traffic of the inquiry type through broadcasting stations or otherwise is rather to be discouraged. All questions of priority and procedure should be decided by evaluation of each particular matter in the light of the degree of public interest involved.

Keeping Channels Clear

In past emergencies the greatest credit is due those amateurs who have acted as monitors on frequencies *near* those carrying emergency traffic to keep them clear. Every amateur licensee should quickly *stand by and listen* on request or suspicion that either a near-by or distant communications emergency, large or small, is in progress. Only when convinced that he has every detail that can be learned from listening and can contribute definite constructive effort to the people in the area where the difficulty exists, should a distant station try to communicate with the emergency station. Nine times out of ten such a station in all probability will indicate by its calls the station, city, or direction with which communications are required.

FIXED TEXT MESSAGES — "ARL" CHECK

In the secondary or personal-inquiry phase of communications emergencies the use of numbered-text messages is recommended. At all times, of course, the recommended phonetic alphabet should be used on those channels employing voice. This will minimize possible chance of error and prevent misunderstandings, as difficult or unusual words occur. The numbered-text message series can be used also to avoid garbled texts. Extra care, repeat-backs and phonetics may be advantageous on addresses and signatures and the text shortened to insure absolute accuracy. The following list of texts was prepared with possible emergency needs and utility in mind. It is a special tool for special occasions. It should be used *only* when stations at each end of a QSO are equipped with lists so that every message delivered or relayed to a station not having a list can be expanded. The device saves a great deal of repeat-transmission time and is, therefore, useful when a large volume of inquiries to be handled can just as well conform to the "numbered-text" plan.

In using the following list the amateur starting the message sends the *number* corresponding to that particular text instead of the text itself. The letters ARL (short for American Radio Relay League numbered-text-to-follow) must be placed before the figures of the check to show that the text is from this particular numbered text list. ARL identifies a communication as a message that has to be expanded for delivery or relaying to a station without such a list. In radio handling, the number designating the text always should be spelled out, for accuracy.

ONE	All safe. Do not be concerned about disaster reports.
TWO	Coming home as soon as possible.
THREE	Am perfectly all right. Don't worry.
FOUR	Everyone safe here. Only slight property damage.
FIVE	All well here. Love to folks.
SIX	Everyone safe, writing soon.
*SEVEN	Reply by amateur radio.
EIGHT	All safe, writing soon, love.
NINE	Come home at once.

TEN	Will be home as soon as conditions permit.
ELEVEN	Cannot get home. Am perfectly all right. Will be home as soon as conditions permit.
*TWELVE	Are you safe? Anxious to hear from you.
*THIRTEEN	Is ..... safe? Anxious to hear.
*FOURTEEN	Anxious to know if everything is OK. Please advise.
*FIFTEEN	Advise at once if you need help.
*SIXTEEN	Please advise your condition.
*SEVENTEEN	Kindly get in touch with us.
*EIGHTEEN	Please contact me as soon as possible (at .....).

*Not to be solicited in emergency.

Operators must be alert and careful to insure accurate, useful radio service by whatever method. Sent by itself ARL? means "Do you have the list of ARRL numbered radiograms and are you ready for such a message?" ARL (reply) gives an affirmative answer to both questions.

Example: NR 1 W1AW CK ARL 1 NEWINGTON, CONNECTICUT MARCH 2
(address) BT THREE BT JOHN AR.

The principle of effective military communication (and emergency communication requirements are very similar) is to *use all channels* intelligently without fear or favoritism and as efficiently as possible. Accuracy, speed, and secrecy (avoiding public rumors) are all desirable and important considerations in handling the priority traffic in emergencies. Accurate point-to-point work with messages receipted for properly in two-way handling is preferable to any work patterned after "broadcasting," and c.w. is the preferred method for such work. All amateur stations should endeavor to give officials and agencies written-out messages; our facilities are seldom used for conference exchanges when an emergency arrives. Both voice and c.w. operators should practise handling difficult messages, including same in preëmergency tests. Traffic should be written on proper forms and delivered just as a telegraph office delivers messages. All traffic should be numbered to show *origin* and put in standard form to avoid duplications. Voice operators should be brief, talk as fast as good reception permits, repeat or use phonetics as required for accuracy, and should *not* comment casually about the text of messages.

The important thing is to *get the message through* and to get it through exactly as it was given to us. The *place of origin, date* of the message, number of words and *signature* are all highly important to establish the responsibility for statements made in the message, to permit evaluation of the message as to the conditions at the time it was sent, and to fix the place where it originated so a reply can be made if desired. The "word count" is helpful to make sure no words are added to or dropped from the text.

Traffic Experience Counts; Make Delivery from First Outside Point

Proper organization and establishment of nets, and tie-in with existing ARRL section traffic-handling nets which specialize in doing an accurate, speedy job, can expedite service for agencies in any emergency. It is perfectly natural that the networks which dedicate their operating fun to handling some traffic *regularly* can do a better job as to speed and accuracy than those that are thrown together haphazardly when an emergency presents itself. It is important to the amateur service that every ham participate in radio exercises and message handling in connection with Field Days and tests. This should make it possible to raise the level of skill from that of casual voice operation to that which permits successful, reasonably-accurate written-down work typifying a communications service best fitted to cope with any emergency that comes along.

Once a message is transmitted outside an emergency zone it may be forwarded to its destination by commercial or Government wire service. As long as wires are set up they should carry the load. Wire lines from secondary points greatly reduce radio interference. Where needed, however, amateur radio must do its share and do it effectively with as little noise and heroics as possible. Results are what count.

Further Steps To Reduce Interference

It is only good common sense to invite the attention of coördinators and amateurs generally to the necessity for complete utilization in emergency of *all* the frequency bands having appropriate propagation characteristics. Every c.w. frequency is a clear channel compared to the voice bands. Every one of the c.w. channels should be utilized, if possible, by amateurs who are able to put their code to work, before complaint of "congestion" is made. This can be done only by having a sufficient number of trained, skilled operators, familiar with c.w. telegraph message handling, ready and on the job to supplement any voice channels that may be established. No one questions the value of voice work for conferences and fast local liaison, where recorded actionable information is not of prime importance and secrecy is not a consideration. However, many agencies (Red Cross, Western Union, and Weather Bureau) that we expect to serve have stressed from time to time that secrecy from the public is important to prevent leakage of information and the start of rumors, as well as to insure accuracy — always a paramount consideration.

The business of "calling in" to help, as engaged in by some casual operators, should be more and more curtailed in the future. Emergency calls to different points should come from the emergency-area stations. The amateur service should demonstrate "circuit discipline" in emergencies, coöperation in standing by and quickly appointing watchers over the frequencies used by emergency stations, to permit good work to go forward

without calling for official declaration of emergency.

Appointing Net Monitors To Reduce Interference

Both c.w. and voice networks operating in future emergencies should make increased provision for appointing one of their number, *not* actually engaged in handling pertinent traffic, to "stand by." The function of this station should be to operate on an adjacent frequency (not exactly on the net frequency itself) for the purpose of seeing that interference-free operation goes forward. If and whenever stations are observed to come on the frequency for work *not* pertinent to the emergency, the "monitor" opens up in businesslike fashion and in the fewest possible words arranges courteously and tactfully for the troublesome station to move elsewhere or desist from interference.

● LOCAL EMERGENCIES

With full advance participation in the AEC and through meetings at suitable intervals, *almost* all amateurs should know what is expected of them in emergency, and where they fit into community plans.

In case of any local trouble, report to the EC and ask for information, advising what you know and what you and your station can do to assist.

In local emergency, as many amateurs as possible should be ready to go into action based on their thorough familiarity with the local plans of the emergency coördinator and his committee. If it is a matter of isolation of an individual or small party, or a wire disruption without any public emergency, the station participation will *not* require invoking FCC orders or declaration of a general emergency in most cases. However, all amateurs should follow the rules for orderly standing by and helping with minimum use of the transmitter, nevertheless. If a major area is concerned or FCC has not yet acted, follow the *principles* outlined in this chapter and in the FCC regulations, whether or not yet invoked.

Individual amateurs can assist most materially during an emergency if they will keep the ARRL coördinator fully informed, thus assisting him to fulfill his normal functions creditably. By securing early reports from several amateurs, an EC can assign appropriate h.f. stations to agencies and permit outgoing traffic to flow to points where communications are established to "outside." As amateurs report in, the EC will be able to place numerous volunteer operators in key places where they can help by manning telephones, writing up messages, and setting up delivery systems, to insure proper results and over-all coördination such as are necessary to permit the amateur service to do a creditable job!

● THE REMOTE EMERGENCY

Absolute silence, for those not in an emergency area, is often the best form of coöperation. Unless and until one logs an emergency station giving a directive call for his very city, it is fitting that one stand by. The glory seeker who itches to be at his rig, whether microphone or key, is not one whit a better citizen than the individual novelty seeker who tries to intercept police calls or tries to beat the fire engine to the fire, congesting the streets and increasing public losses and hazards!

Let the operator working under emergency conditions establish reliable contacts with stations as near to him as possible or at points logical for handling his traffic. Urge *your* locals (and places remote from any emergency) to stand by. Do not make an excuse for getting into a situation someone else can handle better, by reason of his signal (propagation conditions) or location. As a rule it is *not* necessary for stations many hundreds of miles distant to organize themselves into nets for an emergency occasion, since the very nature of emergency makes it a fifty-and-one-hundred-mile proposition. A learning-by-listening attitude permits the actual situation to be handled constructively, keeping interference levels much lower.

● RED CROSS WIRE NET

Often a relatively small gap need be bridged by radio before communities with commercial power, wire service, and all modern means of providing aid can be reached. The American Red Cross now has a private wire system which operates coast-to-coast and functions not just for emergencies but for the daily handling of its organizational traffic. In future emergencies three of the points on this wire system, it is understood, will be a "delivery" point for any Red Cross messages. As we write, plans that may result in establishing three special dependable amateur service stations, under control of ARRL-affiliated groups or officials at points like Washington, Chicago, and San Francisco, are under study. The Red Cross will put wire printer loops into all such stations. Follow *QST* for operational plans of such key amateur stations, as established. They will be manned both day and night by radio amateurs to collect *your inquiry* and additional agency traffic during any major disaster!

The Disaster Service of the American Red Cross recommends that under the above policy, for example, a local 3.5-Mc. station in Delaware with a message from his chapter for Atlanta, Ga., might transmit this directly to the designated special amateur station at Washington, D. C., or a 28-Mc. Delaware amateur with the same message might as readily send it directly to Chicago or San Francisco (if Washington is in his skip zone) where it

will be put on the wire printer system of the Red Cross Telecommunications Service to obviate additional relaying. This set-up should effectively reduce radio-interference levels, expedite deliveries, and, it is hoped, eliminate duplication in deliveries. Reducing the number of relays may also cut the possibility of garbles and errors.

Coöperation with The American National Red Cross

An official "understanding" between the Red Cross and amateurs, in effect for many years, has been reviewed and reaffirmed. This appears in the *Disaster Preparedness and Relief Manual* (ARC 209) published by the Red Cross. This manual, for the guidance of Red Cross chapters, assigns the function of providing and maintaining communication services to a subcommittee on transportation and communication. In preparing to meet the needs for communications incident to a disaster relief operation, the subcommittee is charged with surveying all communication resources within a chapter jurisdiction to obtain coöperation and plan necessary coördination and mobilization of appropriate facilities in any emergency situation.

Officials of the ARRL Emergency Corps may be invited to serve on the subcommittee, with other members representing telephone and telegraph companies, radio stations of other services, NCR, AARS, or Air Corps communications agencies, where concerned. Additional "transportation" members serve on subcommittees. Here are pertinent extracts of the ARC 209 information:

Every avenue of communication should be kept open to permit the prompt receipt and dispatch of Red Cross messages. If communications are cut, the subcommittee should establish courier service (by Boy Scouts, motorcycle, etc.), to the nearest communication outlet. Local telephone companies will tag the circuits for authorized Red Cross messages in emergency periods under a coöperative understanding with A. T. & T. The needs of other subcommittees for communications should be determined.

Amateur radio stations and operators, including members of the ARRL, will be contacted to develop a plan for extending priority for emergency communications, and for receiving and transmitting all Red Cross messages, by telephone, telegraph, or radio. Test drills should be held from time to time in coöperation with the Emergency Corps of ARRL. The American Radio Relay League has designated EMERGENCY COÖRDINATORS in many communities to unify the service of amateur radio operators for emergency communications. The Emergency Coördinators or other designated representatives should be asked to assume radio communication responsibilities as part of the subcommittees' plans. Such committee member should designate, and arrange for the services of amateur radio stations and the designation of these facilities, with other radio services, for the American Red Cross.

THE SENDING OF UNAUTHORIZED MESSAGES, ESPECIALLY APPEALS FOR MEDICAL AND NURSING PERSONNEL, SUPPLIES, AND FUNDS SHOULD BE DISCOURAGED. THE SUBCOMMITTEE SHOULD INFORM ALL COMMUNICATION AGENCIES OF *THE PERSONS AUTHORIZED TO SEND RED CROSS MESSAGES.*

A WRITTEN PLAN FOR "WHEN DISASTER STRIKES" SHOULD BE FORMULATED. PLANS SHOULD BE MADE FOR THE MAINTENANCE OF A *MESSAGE CENTER,* IN TIME OF DISASTERS, UNDER THE CONTROL OF THE SUBCOMMITTEE, IN COÖPERATION WITH COMMUNICATION AGENCIES.

Thus the Red Cross provides a special place for ARRL emergency coördinators in its recommended set-up. This place dovetails perfectly with EC functions. It says (1) that amateurs will be taken into consideration, (2) that stations and operators will be lined up, (3) that simulated-emergency tests may be arranged — and (4) that the ARRL emergency coördinator should designate the amateur facilities or station(s) for particular service to the Red Cross — with full coördination with the other types of radio service represented in the subcommittee, of course.

Amateurs may serve many agencies but it is to be noted that ARRL recognizes the Red Cross as the primary disaster relief agency, and therefore entitled to our best possible arrangements. The Communications Department policy is to create and extend effective emergency radio coverage to every possible community and Red Cross chapter jurisdiction, where advance preparedness may pay dividends in the form of service. *All* amateurs are invited to become members of the Emergency Corps. Drills and other activities help make AEC tests enjoyable, and our ability to serve more effective! Meetings of SECs and ECs, to plan recruitment, and AEC drills, are highly desirable.

Emergency coördinators will find "Amer Red Cross, chap ofs" in the telephone book. Arrange to contact the appropriate chapter official to discuss these matters informally in person at a mutually convenient time. What are the local prospects for meetings of the Red Cross subcommittee — and who are some of the other communications members? If no written plans involving communication are yet available, perhaps you can be of assistance by making a preliminary examination of the problems as you see them for an informal report to the Red Cross chapter on what could and should be done. If a group has been active, find out how amateur radio is represented in it.

In such contact give the Red Cross folks the idea that you are a communicator, that (without boasting) amateur stations have supplied vital help in many past emergencies of record. The official ARRL-RC "understanding" is detailed in the publication ARC 209 to which reference may be made by Red Cross personnel. You would like the opportunity to assist within the established RC framework, in the advance planning and review of communications plans relative to supply of emergency radio communications. You represent the amateur service and ARRL, of course.

FCC Amateur-Service Regulations Applicable to Emergencies

All amateurs, insofar as possible, should be familiar with every word of all FCC regulations applicable to amateurs. The numbered sections of the regulations particularly pertinent to emergencies (see §12.156) should be religiously observed.

Band Segments for Calling Only

When FCC "declares" an emergency, the 25-kc. segments on the designated band-edges are reserved by FCC for *emergency calling.* Band segments such as the following are then *for emergency calling* only: 3500–3525 kc., 3975–4000 kc.

First Five-Minute Listening Periods Required Hourly

Every amateur operator using the designated frequency bands for handling relief and emergency traffic must stop and observe the five-minute hourly quiet period (0000–0005) . . . the only exception to that rule, *following a declaration of public emergency by the FCC,* is that a message of utmost priority being handled by an amateur in an emergency zone may be continued, ignoring this quiet-period requirement.

Emergency Communications Bands

Since 25-kc. band-edge segments are specified in the regulations as pertinent to any declaration of a general public-service emergency, the remaining band segments are those that must be used for the purpose of handling all emergency traffic. Such bands are: 3525–3850 kc., 3850–3975 kc.

All Casual Operation Prohibited

The text of the FCC emergency-applicable regulations is quoted specifically below. Note the directness and implication of the language! *Casual* conversation, *incidental* calling, testing, *or working, unrelated to the emergency* "shall be prohibited." Remarks *not* pertinent to constructive handling of the communications emergency situation are thus prohibited. The FCC in designating assisting amateur stations (§152.54d) says that these "will report stations failing to comply with any part of the emergency rules."

While there are limitations on the authority of the observer-policing stations, and since they act when possible in an advisory capacity, there is the expressed intention of the Commission to examine fully the reports of the designated operators, taking any necessary disciplinary action after investigation of examples of non-compliance with the Commission's regulations.

F.C.C. REQUIREMENTS SUMMARIZED

The text of the current FCC regulations follows, these having complete force and effect from the time the FCC has "declared" a communications emergency until the Commission declares the emergency ended.

Excerpts of §12.156. *Operations 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 the center of the affected area), whereupon it shall be incumbent upon each amateur station in such area or areas to observe . . . restrictions for the duration of such emergency: (a) States that transmissions, other than those relating to relief work or other emergency service such as amateur networks can provide shall not be made within designated sub-bands. Incidental calling, testing and working, including casual conversations and remarks not pertinent or necessary to constructive handling of the emergency situation, shall be prohibited.

(b) Frequencies (designated channels) shall be reserved for emergency calling channels, for initial calls from isolated stations of first calls concerning very important emergency relief matters. . . . All stations having occasion to use such channels shall change as quickly as possible to other frequencies for communication.

(c) A five minute listening period for the first five minutes of each hour (during which no traffic of less than the highest priority can be handled) is designated by this section. No replies to calls or resumption of routine traffic shall be made in the five minute (first five minutes of each hour) listening period.

(d) FCC may designate certain amateur stations to assist in promulgating the emergency announcement, to police the bands of frequencies designated and to warn non-complying stations observed to be operating therein. These stations shall report fully to the Commission on any non-compliance, after notice with the pertinent provision. Policing-observer stations 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 when the Commission terminates the emergency declaration.

TERMINATION OF EMERGENCY DECLARATIONS

The termination of an FCC emergency order should not normally be anticipated at the exact time of restoration of wire facilities. Just as the FCC indicates that it will consult with those primarily interested in making a declaration of public emergency, FCC will similarly examine the conditions "in the public interest" before it terminates any emergency order. At such time as the amateur service and representatives of wire and radio services can indicate to the FCC that communications facilities have been supplemented or restored *so that all communications filed can be handled on a current basis,* the FCC may be expected to issue an order terminating any emergency declaration.

CHAPTER 23

League Operating Organization

Your ARRL arranges amateur operating activities, promotes preparation and organization for communications emergencies, establishes procedure for efficient operation, encourages good operating, and maintains a strong field organization. The Communications Department of the League is concerned with the practical operation of stations in all branches of amateur activity. Appointments or awards are available for rag-chewer, 'phone operator, traffic enthusiast, experimenter and DX man. It is the League's policy to benefit each group concerned along lines of natural interest. Activities have specific objectives, and widest participation is invited. This insures maximum fun and benefit to all.

Operation must have point and constructive purpose to win public respect. Each individual amateur is the ambassador of the entire fraternity in his public relations and attitude toward his hobby. ARRL field organization adds point and purpose to amateur operating.

Organization of the League is by Divisions and by Sections. Members in each division and Canada elect sixteen Directors. With the President and Vice-President chosen by this group they constitute the governing and policy-making body of the League. Seventy-one ARRL sections, the territory of the several sections within each division determined jointly by the director and the communications manager, form convenient units for field organization and operating administration. Operating affairs in each section are supervised by a Section Communications Manager elected by members in that section for a two-year term of office. Organization appointments are made by the section managers. The election of officials is covered in detail in the League's Constitution and By-Laws. Section communications managers' addresses for all sections are given in full in each issue of *QST*. SCMs welcome monthly activity reports from all amateur stations in their jurisdiction. Full information on appointments may be obtained from SCMs and is also contained in a League booklet, *Operating an Amateur Radio Station*, which will be sent from Headquarters on request (10¢ to nonmembers).

Whether your activity embraces 'phone or telegraphy, or both, there is a place for you in League organization.

Organization Appointments

The section manager desires representative appointees in each city and town and radio club. He studies geographical distribution and coverage in making leadership and station appointments, and gives consideration to the initiative, experience, tact, ability and other recognized qualifications of candidates, to build the best section organization possible.

● LEADERSHIP POSTS

To advance each type of station work and group interest in amateur radio, and to develop practical communications plans with the greatest success, appointments of leaders and organizers in particular single-interest fields are made by SCMs. Each leadership post is important. Each provides activities and assistance for appointee groups and individual members along the lines of natural interest. While some posts further the general ability of amateurs to communicate efficiently at all times, by pointing activity toward networks and round tables, others are aimed specifically at establishment of provisions for organizing the amateur service as a stand-by communications group to serve the public in disaster or emergency of any sort.

Section Communications Manager

The Section Manager is the section executive or administrator in operating matters. He is the only elected official for the section alone, and the office is open to election each two years, or oftener if a vacancy occurs. Requirements for nomination and the system of mail balloting are covered in the operating booklet. Section managers report on all forms of amateur activity (for *QST*) monthly. Every active amateur licensee is invited to report his station activity to his SCM. Reports are mailed to Hq. by SCMs on or before the 1st of each month, for the reporting month, in mainland U. S. A. and Canada.

The Section Emergency Coördinator

Each SEC is appointed to promote and develop the ARRL Emergency Corps within his section. He endeavors to find qualified local leaders to organize amateur facilities in each and every town or city; he studies the need for regional nets and tie-ins with these cities as well as recommending individual EC territory and plans for grouped communities. The SEC promulgates membership drives, meetings, tests, procedure discussions; takes measures to overcome inertia and avoid jurisdictional conflicts in emergency work. Analysis of reports and monthly progress, and programs to get the fullest support of *all* amateurs, are his responsibility at section level.

Emergency Coördinator

Community organization for emergencies, the building of one strong amateur facility to serve all agencies, liaison with other communications services as well as officials and groups likely to have disaster traffic, the setting up of drill periods and working out simulated-emergency tests in an interesting manner, are all in the directive given this official. The Emergency Coördinator must be a man with initiative and organizing ability who will inspire the coöperation of all classes of amateurs in his locality, attracting the support of active operators who may normally work in any of the bands. To develop broad plans it is recommended that every EC designate Assistant Coördinators, constituting his amateur-service emergency planning committee, and representing each frequency band and geographical or club group for a given area. Emergency coördinators must know and use the principles of teamwork in assuring the successful implementation of tests and planning in advance of the occurence of actual emergencies.

Route Manager

The Route Manager is the authority on schedules and routes, and his station must be active in traffic and organization work. The route manager's duties include coöperation with all radio amateurs in his territory in organizing and maintaining traffic routes, nets, and schedules. RMs also test candidates for ORS appointment as directed by the SCM. Advice to amateurs wanting schedules or traffic routings via trunk lines, section nets, etc., will be given by RMs on request.

Phone Activities Manager

The 'Phone Activities Manager may sponsor 'phone-operating activities in his territory, in the name of the League. The PAM appointment, while paralleling that of RM in some respects, has to do with the upbuilding of ARRL-section 'phone organization. The 'phone activities manager also tests candidates for OPS when referred by the SCM. 'Phone nets may develop ability to handle traffic or follow objectives divorced from traffic, as worked out with net members by the PAM.

STATION APPOINTMENTS

ARRL's field organization has a place for every active amateur who has a station. The Communications Department organization exists to increase individual enjoyment in amateur radio work, and we extend a cordial invitation to every amateur to participate fully in the activities and to apply to the SCM for ORS, OPS, OES, OBS or OO appointment as soon as sufficiently experienced in amateur radio work.

The section manager makes appointments for specific work in accordance with the qualifications and rules for such appointments. He makes cancellations, likewise, for inactivity, inaptitude or failure to perform adequately the actions contemplated in appointment. All appointment certificates must be returned to SCMs annually for endorsement to keep them in effect — no trouble to this if there is continuing activity. The object is to keep field-organization standards high, and insure a live-functioning organization in each amateur group at all times.

Official Relay Station Appointment

Every radio-telegraphing amateur interested in traffic work and operating activities, who can meet the qualifications, is eligible for appointment of his station as Official Relay Station. Brass pounders handle traffic because they enjoy such work. The potential value to his community and country of the operator who handles traffic is enhanced by his ability, as well as by the readiness of his station and schedules to function for the community in emergency.


The American Radio Relay League, Inc.
COMMUNICATIONS DEPARTMENT
West Hartford, Conn., U. S. A.
Official Relay Station

The appointment identifies the holder with high standards of amateur operating, and indicates personal keenness and responsibility. The holder voluntarily agrees to report each month, and with absolute reliability to for-

ward and deliver messages regularly through his station. Secure application forms from your local SCM. See full details on requirements in the booklet *Operating an Amateur Radio Station.*

Official 'Phone Station Appointment

This appointment is for every qualified ham who uses his microphone more than his key in his amateur station, who takes pride in the manner of signal he puts on the air and who aims to have his station really accomplish worth-while communication work. Official 'Phone Station appointees endeavor to live up to the Amateur's Code. OPS appointment aids 'phone-operating enjoyment by helping to promote good voice-operating practices and readiness for meeting the demands of emergency work.

Cultivation of operating ability that is essential to assure accuracy, conciseness and speed for point-to-point work, in which this desirable technique is altogether different than in broadcasting, is encouraged. OPS technique and operating are designed to encourage fraternalism, facilitate tests between stations of the group, and cultivate by example a precept for excellence looked up to by other voice-operating stations. Official 'Phone Station appointees, like ORS, agree voluntarily in accepting appointment that they will keep active stations and report on activities to the SCM monthly. Application forms are available from your SCM.

Official Experimental Station

The experimenting amateur also finds in the field organization an appointment designed to assist him in his aims. Official Experimental Station work is dedicated to progress in developing successful communications systems and equipment applications, and in collecting propagation data applicable to the v.h.f., u.h.f. and s.h.f. amateur bands. ARRL makes a special effort to coördinate OES reports on problems of interest to large numbers of amateurs by over-all analysis of data reported. This experimenter appointment is available only to amateurs operating stations on bands above 50 Mc.

The Official Experimental Station appointment is designed to cover our postwar requirements in promoting operating progress, from 50 Mc. through the microwaves, as methods applicable to the use of these for various amateur purposes may be evolved. The broad group aim will be production of data to aid in discussion and knowledge of transmission phenomena peculiar to each of our higher-frequency bands. The correlation of reports and results on the broadest possible scale will assist us in knowing how to use antenna structures, from notation of the pattern of these radiations in different terrain and circumstances, as regards transmitted-wave polarization, absorption, refraction and reflection.

Official Broadcasting Station

OBS are appointed by section managers, and regularly transmit information specifically addressed to ARRL member-amateurs by code and voice, in all frequency bands. Official and special transmissions, daily except holidays, are made from the Headquarters station, W1AW. OBS appointees receive their information direct from this source and by mail, upward of 500 stations covering all ARRL sections with amateur information of national and local interest, with new information at least once a week. Member-stations must agree to render a good service on regular schedule to receive appointment, and power and signal quality are carefully considered. Many of the stations are so well operated that beginners use their transmissions for code practice. Hours between 6 P.M. and midnight have been chosen for most OBS schedules, for that is the time when most amateurs are listening. Code transmissions are preceded by the call "QST" for four or five minutes to inform amateurs this official information is to be sent.

Official Observers

To help all amateurs keep on assigned frequencies, and to assist brother amateurs in keeping clear of FCC citations and advisory notices and the penalties for infraction of regulations, ARRL Official Observers are appointed. SCMs require such appointees to have an accurate frequency meter, or other equipment for accurate work of the type in which a specific observer engages. Postal warning forms are provided for different classes of trouble. Reports direct to the amateurs concerned by radio or mail cover improper broadness, a.c. notes, overmodulation, poor speech quality, off-frequency operation, harmonic radiation or other emissions, and technical violations of good practice. If you need a frequency check (or other test) ask the SCM for the address of the OO. Observers not only help amateurs individually, they also protect the privileges of all amateurs and avert official Government restriction invited by the careless. Valuable occupancy and station-distribution surveys have been made several times in the history of the Observing System. The top OO appointment requires qualification at intervals in actual Frequency Measuring Tests. The OO certificate is a badge of high technical proficiency in the measurement field.

Emblem Colors

Members of the League only may obtain the official League emblem and member stationery. Members wear the emblem with black-enamel background. A red background for an emblem will indicate that the wearer is SCM. SECs, ECs, RMs, PAMs may wear the emblem with green background. Observers and all station appointees are entitled to wear emblems with blue background.

SECTION NETS AND TRUNK LINES

Amateurs can add much experience and pleasure to their own amateur lives, and substance and accomplishment to the credit of all of amateur radio, when organized into effective interconnection of cities and towns.

The successful operation of a net depends a lot on the Net Control Station. This station should be chosen carefully and be one that will not hesitate to enforce each and every net rule and set the example in his own operation on the air.

A progressive net grows, obtaining new members both directly and through other net members. Bulletins may be issued at intervals to keep in direct contact with the members regarding general net business, to keep tab on net procedure and make suggestions for improvement, to keep track of active members and weed out inactive ones. At least, a net manager will obtain and circulate as much information as possible to members.

Official Relay Stations at key points are organized in trunk-line formation, covering fourteen east-west and north-south routes, connecting with numerous section and local networks and feeder systems for the purpose of efficient dispatch of traffic. Speedy and reliable work is carried on, the operation entirely on separate spot frequencies in the 3.5-Mc. amateur band. A station must hold ORS appointment to be considered for a trunk-line post.

RADIO CLUBS AND AFFILIATIONS

It is the policy of the League to grant affiliation to any amateur society having 51 per cent of its licensed amateurs also members of the ARRL. Where a society has common aims and wishes to add strength to that of other club groups to strengthen amateur radio by affiliation with the national amateur organization, a request addressed to the Communications Manager will bring the necessary forms and information to initiate the application for affiliation. Affiliated-club news appears in *QST*, and such clubs receive field-organization bulletins and special information at intervals for posting on club bulletin boards or for relay to their memberships. A travel plan providing communications, technical and secretarial contact from the Headquarters is worked out seasonally to give maximum benefits to as many as possible of the more than four hundred affiliated radio clubs. Papers on club work, suggestions for organizing, for constitutions, for radio courses of study, etc., are available in mimeographed form, free on request.

Club Training Aids

One section of the ARRL Communications Department devotes its full time to the Training Aids Program. This program is a service to affiliated clubs. Material is supplied for club programs aimed at education, training and entertainment of club members, to make your club meetings more interesting and consequently better attended.

Training Aids include such items as motion-picture films, film strips, slides, recordings, and lecture outlines. Also, code-proficiency training equipment such as recorders, tape transmitters and tapes will be loaned when such items are available. Training Aids cannot presently be supplied to either nonamateurs or nonaffiliated clubs.

All Training Aids materials are loaned free (except for shipping charges) to ARRL-affiliated clubs. Data on affiliation are available on request and numerous groups use this new ARRL service to good advantage. If your club is affiliated but has not yet taken advantage of this service, you are missing a good chance to add the available features to your meeting programs and general club activities. Watch club bulletins and *QST* or write the ARRL Communications Department for full details.

W1AW

The Maxim Memorial Station, W1AW, is on the air every day, except holidays. Operated by the League headquarters, W1AW is located about four miles south of the Headquarters offices on a seven-acre site. Telegraph and 'phone transmitters are provided for all bands from 3.5 to 144 Mc. The normal frequencies in each band for c.w. and voice transmissions are as follows: 3555, 3950, 7210, 14,150, 14,280, 28,060, 29,150, 52,000 and 146,000 kc. Operating-visiting hours and station programs are listed every other month in *QST*.



W1AW is dedicated to fraternity and service. The available time is divided between different bands and modes.

All amateurs are invited to visit W1AW, as well as to work the station from their own shacks. The station was made possible by the Board of Directors, and established to be a living memorial to Hiram Percy Maxim and carry on the work and traditions of the amateur fraternity.

OPERATING ACTIVITIES

Within the ARRL field organization (in which appointments are open for specified lines of work in ham radio for those with the qualifications) there are several special activities. The first Saturday night each month is set aside for all ARRL officials, officers, and di-

rectors to get together over the air from their own stations. This activity is known to the gang as LO-NITE. Quarterly tests for official relay stations and official 'phone stations are scheduled to develop operating ability and a spirit of fraternalism. All League members may participate in the Annual ARRL Member Party, usually held in January.

In addition to these special activities for appointees and members, ARRL sponsors various other activities open to all amateurs. The DX-minded amateur may participate in the Annual ARRL International DX Competition scheduled during February and March. This popular contest may bring you the satisfaction of working new countries. Then there is the ever-popular Sweepstakes in November. Of domestic scope, the SS affords the opportunity to work new states for that WAS award. The interests of v.h.f. enthusiasts are also provided for in activities especially planned by ARRL.

As in all our operating, the idea of having a good time is combined in the Annual Field Day, with the more serious thought of preparing ourselves to shoulder the communication load as emergencies turn up and the occasion requires. A premium is placed on the use of equipment without connection to commercial sources of power supply. Clubs and individual groups always have a good time, learn much about the requirements for knockabout conditions afield, and achieve success in testing equipment.

Contest activities are diversified to appeal to all operating interests, and will be found announced in detail in issues of *QST* preceding the different events.

AWARDS

The League sponsors a variety of operating activities as mentioned above. These have useful objectives and add much enjoyment for members of the fraternity. Point is also added to achievement through recognition in the following:

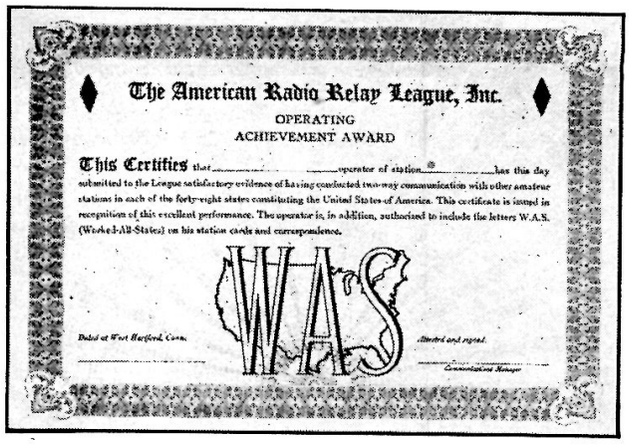
WAS (Worked All States)
DX Century Club
Code Proficiency Award
Rag Chewers Club
A-1 Operator Club
Brass Pounders League
Old Timers Club

WAS Award

ARRL certificates are available for those radio amateurs who "work all forty-eight of the United States."

WAS means "Worked All States." This award is available regardless of affiliation or nonaffiliation with any organization. Here are the few simple rules to follow in applying for a WAS Certificate:

1) Two-way communications must be established on the amateur bands with all forty-eight United States; any and all amateur bands may be used. A card from the District of Columbia may be submitted in lieu of one from Maryland.



2) Contacts with all forty-eight states must be made from the same location. Within a given community one location may be defined as from places no two of which are more than 25 miles apart.

3) Contacts may be made over any period of years, and may have been made any number of years ago, provided only that all contacts are from the same location.

4) Forty-eight QSL cards, or other written communications from stations worked confirming the necessary two-way contacts, must be submitted to ARRL headquarters.

5) Sufficient postage must be sent with the confirmations to finance their return. No correspondence will be returned unless sufficient postage is furnished.

6) The WAS award is available to all amateurs.

7) Address all applications and confirmations to the Communications Department, ARRL, 38 La Salle Road, West Hartford, Conn.

List your missing states and go after QSOs with them. You will find it a very considerable operating achievement. How complete is your coverage? Your certificate awaits you.

DX Century Club Award

Here are the rules under which the DX Century Club Award will be issued to amateurs who have worked and confirmed contact with 100 countries in the postwar period. If you worked fewer than 100 countries before the war and have since worked and confirmed a sufficient number to make the 100 mark, the DXCC is still available to you under the rules detailed on page 74 of June 1946 *QST*.

1) The Century Club Award Certificate for confirmed contacts with 100 or more countries is available to all amateurs everywhere in the world.

2) Confirmations must be submitted direct to ARRL headquarters for all countries claimed. Claims for a total of 100 countries must be included with first application. Confirmation from foreign contest logs may be requested in the case of the ARRL International DX Competition only, subject to the following conditions:

a) Sufficient confirmations of other types must be submitted so that these, plus the DX Contest confirmations, will total 100. In every case, Contest confirmations must not be requested for any countries from which the applicant has regular confirmations. That is, contest confirmations will be granted only in the case of countries from which applicants have no regular confirmations.

b) Look up the contest results as published in *QST* to see if your man is listed in the foreign scores. If he isn't, he did not send in a log and no confirmation is possible.

c) Give year of contest, date and time of QSO.

d) In future DX Contests, do not request confirmations until after the final results have been published, usually in one of the early fall issues. Requests before this time must be ignored.

3) The ARRL Countries List, printed periodically in *QST*, will be used in determining what constitutes a "country." The Miscellaneous Data chapter of this *Handbook* contains the Postwar Countries List.

4) Confirmations must be accompanied by a list of claimed countries and stations to aid in checking and for future reference.

5) Confirmations from additional countries may be submitted for credit each time ten additional confirmations are available. Endorsements for affixing to certificates and showing the new confirmed total (110, 120, 130, etc.) will be awarded as additional credits are granted. ARRL DX Competition logs from foreign stations may be utilized for these endorsements, subject to conditions stated under (2).

6) All contacts must be made with amateur stations working in the authorized amateur bands or with other stations licensed to work amateurs.

7) In cases of countries where amateurs are licensed in the normal manner, credit may be claimed only for stations using regular government-assigned call letters. No credit may be claimed for contacts with stations in any countries in which amateurs have been temporarily closed down by special government edict where amateur licenses were formerly issued in the normal manner.

8) All stations contacted must be "land stations" . . . contacts with ships, anchored or otherwise, and aircraft, cannot be counted.

9) All stations must be contacted from the same call area, where such areas exist, or from the same country in cases where there are no call areas. One exception is allowed to this rule: where a station is moved from one call area to another, or from one country to another, all contacts must be made from within a radius of 150 miles of the initial location.

10) Contacts may be made over any period of years from November 15, 1945, provided only that all contacts be made under the provisions of Rule 9, and by the same station licensee; contacts may have been made under different call letters in the same area (or country), if the licensee for all was the same.

11) All confirmations must be submitted exactly as received from the stations worked. Any altered or forged confirmations submitted for CC credit will result in disqualification of the applicant. The eligibility of any DXCC applicant who was ever barred from DXCC to reapply, and the conditions for such application, shall be determined by the Awards Committee. Any holder of the Century Club Award submitting forged or altered confirmations must forfeit his right to be considered for further endorsements.

12) OPERATING ETHICS: Fair play and good sportsmanship in operating are required of all amateurs working toward the DX Century Club Award. In the event of specific objections relative to continued poor operating ethics an individual may be disqualified from the DXCC by action of the ARRL Awards Committee.

13) Sufficient postage for the return of confirmations must be forwarded with the application. In order to insure the safe return of large batches of confirmations, it is suggested that enough postage be sent to make possible their return by first-class mail, registered.

14) Decisions of the ARRL Awards Committee regarding interpretation of the rules as here printed or later amended shall be final.

15) Address all applications and confirmations to the Communications Department, ARRL, 38 La Salle Road, West Hartford 7, Conn.

WAC Award

The International Amateur Radio Union issues WAC (Worked All Continents) certificates to all members of member-societies who submit proof of two-way communication with at least one station on each continent. Foreign amateurs submit their proof direct to member-societies in the IARU. A c.w. and a telephony certificate are available. Also, special 28-Mc. endorsement will be placed on certificates upon receipt of request accompanied by proof of this way of having worked all continents.

Code Proficiency Award

A good many hams can follow the general idea of a contact "by ear" but when pressed to write it down as in real communications work they "muff" the copy. The Code Proficiency Award invites every man to prove himself as a proficient operator, and sets up a progressive system of awards for step-by-step gains in copying proficiency. It enables every radio amateur to check his code proficiency, to better that proficiency, and to receive a certification of his receiving speed.

This program is a whale of a lot of fun. The League will give a certificate to any licensed radio amateur who demonstrates that he can copy perfectly by ear for at least one minute, plain-language Continental code at 15, 20, 25, 30 or 35 words per minute, all of special monthly transmissions from your ARRL station, W1AW, or from WØCO and others mentioned in *QST*.

There are two objectives: (1) To copy by ear, write down by pencil and paper, or better yet, write on a "mill" what is sent, to qualify for a certificate and rating on the best one can now do. (2) To put in a few minutes a day operating our station at the best speeds we can, also listening and copying PX and practice transmissions to train our powers of coordination, in order to win from the League the conspicuous endorsement that will be awarded to go on that first Proficiency Certificate whenever we can boost our speed honestly another 5 w.p.m.!


The American Radio Relay League, Inc.

West Hartford, Connecticut, U. S. A.

Certificate of Proficiency in Reception of the Continental Code

By this certificate and any appended endorsements to show additional qualifications, the Communications Department of the American Radio Relay League expresses its recognition of merit and progress in code proficiency on the part of

JOHN SMITH, W9XYZ

who has this date demonstrated skill in the hand use of the true amateur, reception by ear of the International Morse or Continental Code. Our examination of copy submitted as his work in copying by ear indicates absolute accuracy in his performance at a speed of 35 words per minute for a period of at least one minute of plain-language automatic tape-sent text averaging five characters to the word, which we hereby certify. Date of the A.R.R.L. transmission from W1AW, June 28, 1946.

20 WPM JUL 19 1946 · 25 WPM OCT 17 1946 · 30 WPM APR 16 1947 · 35 WPM SEP 18 1947

One of these handsome certificates is yours if you can make one minute's solid copy of the monthly ARRL Code Proficiency qualifying run. The schedules of W1AW and other stations transmitting such runs are announced in each issue of *QST*. Submit your copy to ARRL headquarters for checking. Progress in code proficiency is shown after initial qualification, if below 35 w.p.m., by a separate dated endorsement sticker to be attached to the award as shown. All licensed amateurs are invited to try for the Code Proficiency Certificate and endorsements.

W1AW transmits practice material at speeds from 9 to 35 w.p.m. The tape transmissions are of plain-language material, accompanied by identification of the station, and the speed is briefly indicated.

Rag Chewers Club

The Rag Chewers Club is designed to encourage friendly contacts and discourage the "hello-good-by" type of QSO. Its purpose is to bond together operators interested in honest-to-goodness rag-chewing over the air. Membership certificates are available.

How To Get In: (1) Chew the rag with a member of the club for at least a solid half hour. This does not mean a half hour spent in trying to get a message over through bad QRM or QRN, but a solid half hour of conversation or message handling. (2) Report the conversation by card to The Rag Chewers Club, ARRL, Communications Department, West Hartford, Conn., and ask the member station you talk with to do the same. When both reports are received you will be sent a membership certificate entitling you to all the privileges of a Rag Chewer.

How To Stay In: (1) Be a conversationalist on the air instead of one of those tongue-tied infants who don't know any words except "cuagn" or "cul," or "QRU" or "nil." Talk to the fellows you work with and get to know them. (2) Operate your station in accordance with the radio laws and ARRL practice. (3) Observe rules of courtesy on the air. (4) Sign "RCC" after each call so that others may know you can talk as well as call.

A-1 Operator Club

The A-1 Operator Club should include in its ranks every good operator. To become a member, one must be nominated by at least two operators who already belong. General keying or voice technique, procedure, copying ability, judgment and courtesy all count in rating candidates under the club rules detailed at length in *Operating an Amateur Radio Station*. Aim to make yourself a fine operator, and one of these days you will be pleasantly surprised by an invitation to belong to the A-1 Operator Club, which carries a worth-while certificate in its own right.

Brass Pounders League

Every individual reporting more than a specified minimum in official monthly traffic totals is given an honor place in the *QST* listing known as the Brass Pounders League.

The value to amateurs in operator training, and the utility of amateur message handling to the members of the fraternity itself as well as to the general public, make message-handling work of prime importance to the fraternity. Fun, enjoyment, and the feeling of having done something really worth while for one's fellows (in traffic handling) is accentuated by pride in message files, records, and letters from those served.

Old Timers Club

The Old Timers Club is open to anyone who holds an amateur call at the present time, and who held an amateur license (operator or station) 20-or-more years ago. Lapses in activity during the intervening years are permitted.

If you can qualify as an "Old Timer," send us a brief chronology of your ham career, being sure to indicate the date of your first amateur license, and your present call. If the evidence submitted proves you eligible for the "Old Timers Club," you will be added to the roster and will receive a membership certificate.

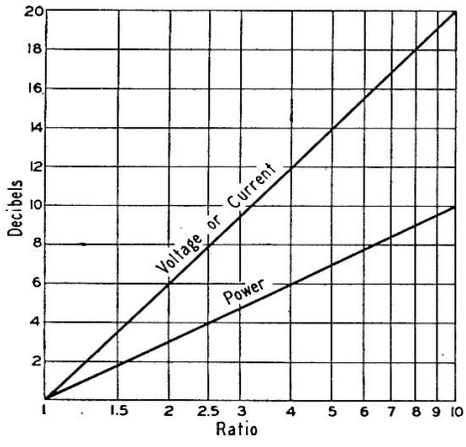
● INVITATION

Amateur radio is capable of giving enjoyment, self-training, social, and organization benefits in proportion to what the individual amateur puts into his hobby. All amateurs are invited to become ARRL members, to work toward awards, and to accept the challenge and invitation offered in field-organization appointments. Drop a line for the booklet *Operating an Amateur Radio Station*, which has detailed information on the field-organization appointments and awards. Accept today the invitation to take full part in all ARRL activities and organization work.

Miscellaneous Data

THE DECIBEL

In most radio communication the received signal is converted into sound. This being the case, it is useful to appraise signal strengths in terms of relative loudness as registered by the ear. A peculiarity of the ear is that an increase or decrease in loudness is responsive to the *ratio* of the amounts of power involved, and is practically independent of absolute *value* of the power. For example, if a person estimates that the signal is "twice as loud" when the transmitter power is increased from 10 watts to 40 watts, he will also estimate that a 400-watt signal is twice as loud as a 100-watt signal. In other words, the ear has a *logarithmic* response.



This fact is the basis for the use of the relative-power unit called the **decibel.** A change of one decibel (abbreviated **db.**) in the power level is just detectable as a change in loudness under ideal conditions. The power ratio and decibels are related by the following formula:

$$Db. = 10 \log \frac{P_2}{P_1}$$

Common logarithms (base 10) are used.

Note that the decibel is based on *power* ratios. Voltage or current ratios can be used, but *only when the impedance is the same for both values of voltage, or current.* The gain of an amplifier cannot be expressed correctly in db. if it is based on the ratio of the output voltage to the input voltage unless both voltages are measured across the same value of impedance. When the impedance at both points of measurement is the same, the following formula may be used for voltage or current ratios:

$$Db. = 20 \log \frac{V_2}{V_1} \qquad \text{or } 20 \log \frac{I_2}{I_1}$$

The two formulas are shown graphically in the accompanying chart for ratios from 1 to 10. Gains (increases) expressed in decibels may be added arithmetically; losses (decreases) may be subtracted. A power decrease is indicated by prefixing the decibel figure with a minus sign. Thus +6 db. means that the power has been multiplied by 4, while −6 db. means that the power has been divided by 4. The chart may be used for other ratios by adding (or subtracting, if a loss) 10 db. each time the ratio scale is multiplied by 10, for power ratios; or by adding (or subtracting) 20 db. each time the scale is multiplied by 10 for voltage or current ratios.

Example: The power input to a transmitter is increased from 75 to 600 watts. Assuming that the efficiency is the same in both cases, the ratio of the new output power to the old is 600/75 = 8. From the chart, the signal will be increased 9 db. Note that increasing the power to 750 watts, a ratio of 10, would increase the signal to 10 db., a barely perceptible increase over 600 watts.

Example: A speech amplifier has an output of 10 watts when excited by 0.02 volt from a crystal microphone. The nominal impedance of the microphone is 50,000 ohms. In a 50,000-ohm load, the voltage developed by the 10 watts would be

$$E = \sqrt{PR} = \sqrt{10 \times 50{,}000} = \sqrt{500{,}000} = 707 \text{ volts}$$

The voltage ratio of the amplifier therefore is 707/0.02 = 35,350. This is the same as $3.5 \times 10{,}000$. A voltage ratio of 10,000 (10^4) is equal to $4 \times 20 = 80$ db. From the chart, a voltage ratio of 3.5 = 11 db. Adding the two gives 11 + 80 = 91 db. as the gain of the amplifier.

Example: A transmission line is terminated in its characteristic impedance and operates without standing waves. The power put into the line is 150 watts, but the power measured at the output end is 100 watts. The ratio is 150/100 = 1.5. From the chart, this ratio is equal to 1.9 db. The loss in the line is therefore 1.9 db.

DECIMAL EQUIVALENTS OF FRACTIONS

1/32	.03125	17/32	.53125
1/16	.0625	9/16	.5625
3/32	.09375	19/32	.59375
1/8	.125	5/8	.625
5/32	.15625	21/32	.65625
3/16	.1875	11/16	.6875
7/32	.21875	23/32	.71875
1/4	.25	3/4	.75
9/32	.28125	25/32	.78125
5/16	.3125	13/16	.8125
11/32	.34375	27/32	.84375
3/8	.375	7/8	.875
13/32	.40625	29/32	.90625
7/16	.4375	15/16	.9375
15/32	.46875	31/32	.96875
1/2	.5	1	1.0

SYMBOLS FOR ELECTRICAL QUANTITIES

Admittance	Y, y
Angular velocity ($2\pi f$)	ω
Capacitance	C
Conductance	G, g
Conductivity	γ
Current	I, i
Difference of potential	E, e
Dielectric constant	K
Dielectric flux	Ψ
Energy	W
Frequency	f
Impedance	Z, z
Inductance	L
Magnetic intensity	H
Magnetic flux	Φ
Magnetic flux density	B
Magnetomotive force	F
Mutual inductance	M
Number of conductors or turns	N
Period	T
Permeability	μ
Phase displacement	θ
Power	P, p
Quantity of electricity	Q, q
Reactance	X, x
Reactance, Capacitive	X_C
Reactance, Inductive	X_L
Reluctivity	v
Resistance	R, r
Resistivity	ρ
Susceptance	b
Speed of rotation	n
Voltage	E, e
Work	W

Pilot-Lamp Data

Lamp No.	*Bead Color*	*Base (Miniature)*	*Bulb Type*	*RATING*	
				Volts	*Amp.*
40	Brown	Screw	T-3¼	6–8	0.15
40A[1]	Brown	Bayonet	T-3¼	6–8	0.15
41	White	Screw	T-3¼	2.5	0.5
42	Green	Screw	T-3¼	3.2	**
43	White	Bayonet	T-3¼	2.5	0.5
44	Blue	Bayonet	T-3¼	6–8	0.25
45	*	Bayonet	T-3¼	3.2	**
46[2]	Blue	Screw	T-3¼	6–8	0.25
47[1]	Brown	Bayonet	T-3¼	6–9	0.15
48	Pink	Screw	T-3¼	2.0	0.06
49[3]	Pink	Bayonet	T-3¼	2.0	0.06
[4]	White	Screw	T-3¼	2.1	0.12
49A[3]	White	Bayonet	T-3¼	2.1	0.12
50	White	Screw	G-3½	6–8	0.2
51[2]	White	Bayonet	G-3½	6–8	0.2
—	White	Screw	G-4½	6–8	0.4
55	White	Bayonet	G-4½	6–8	0.4
292[5]	White	Screw	T-3¼	2.9	0.17
292A[5]	White	Bayonet	T-3¼	2.9	0.17
1455	Brown	Screw	G-5	18.0	0.25
1455A	Brown	Bayonet	G-5	18.0	0.25

* White in G.E. and Sylvania; green in National Union Raytheon and Tung-Sol.

** 0.35 in G.E. and Sylvania; 0.5 in National Union Raytheon and Tung-Sol.

[1] **40A** and **47** are interchangeable.

[2] Have frosted bulb.

[3] **49** and **49A** are interchangeable.

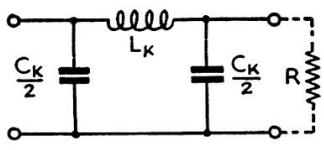
[4] Replace with No. **48.**

[5] Use in 2.5-volt sets where regular bulb burns out too frequently.

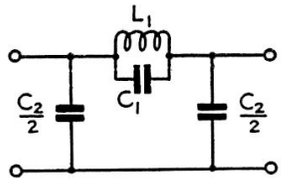
ABBREVIATIONS FOR ELECTRICAL AND RADIO TERMS

Alternating current	a.c.	Medium frequency	m.f.
Ampere (amperes)	a.	Megacycles (per second)	Mc.
Amplitude modulation	AM	Megohm	MΩ
Antenna	ant.	Meter	m.
Audio frequency	a.f.	Microfarad	μfd.
Centimeter	cm.	Microhenry	μh.
Continuous waves	c.w.	Micromicrofarad	μμfd.
Cycles per second	c.p.s.	Microvolt	μv.
Decibel	db.	Microvolt per meter	μv/m.
Direct current	d.c.	Microwatt	μw.
Electromotive force	e.m.f.	Milliampere	ma.
Frequency	f.	Millivolt	mv.
Frequency modulation	FM	Milliwatt	mw.
Ground	gnd.	Modulated continuous waves	m.c.w.
Henry	h.	Ohm	Ω
High frequency	h.f.	Power	P
Intermediate frequency	i.f.	Power factor	p.f.
Interrupted continuous waves	i.c.w.	Radio frequency	r.f.
Kilocycles (per second)	kc.	Ultrahigh frequency	u.h.f.
Kilovolt	kv.	Very-high frequency	v.h.f.
Kilowatt	kw.	Volt (volts)	v.
Magnetomotive force	m.m.f.	Watt (watts)	w.

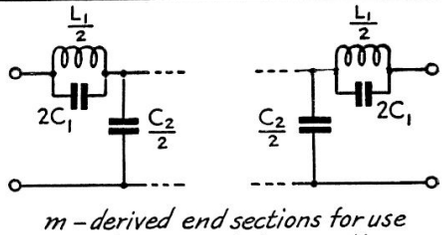
LOW-PASS FILTERS



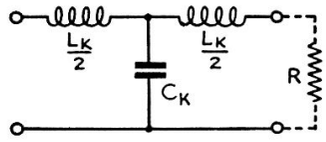
Constant-k π section



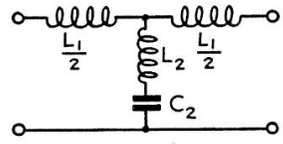
m-derived π section



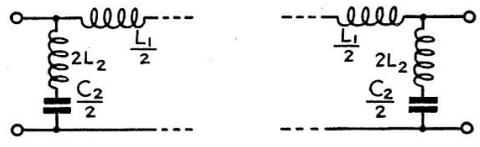
m-derived end sections for use with intermediate π section



Constant-k T section



m-derived T section



m-derived end sections for use with intermediate T section

$$L_K = \frac{R}{\pi f_c} \quad C_K = \frac{1}{\pi f_c R}$$

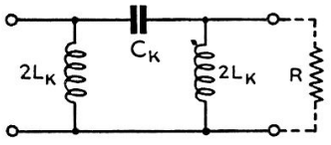
$$L_1 = mL_K \quad C_1 = \frac{1-m^2}{4m} C_K$$

$$L_2 = \frac{1-m^2}{4m} L_K \quad C_2 = m C_K$$

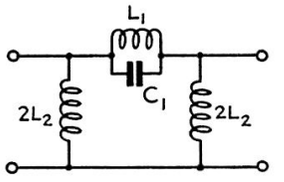
$$L_1 = mL_K \quad C_1 = \frac{1-m^2}{4m} C_K$$

$$L_2 = \frac{1-m^2}{4m} L_K \quad C_2 = m C_K$$

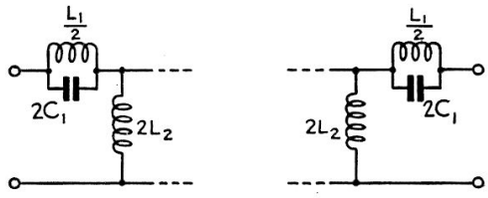
HIGH-PASS FILTERS



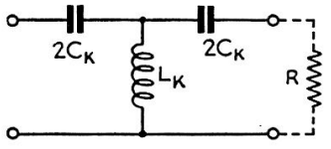
Constant-k π section



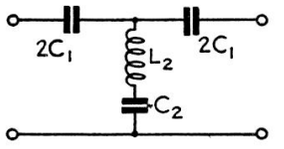
m-derived π section



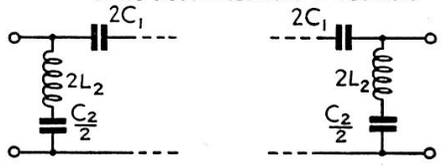
m-derived end sections for use with intermediate π section



Constant-k T section



m-derived T section



m-derived end section for use with intermediate T section

$$L_K = \frac{R}{4\pi f_c} \quad C_K = \frac{1}{4\pi f_c R}$$

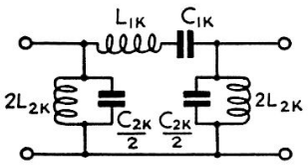
$$L_1 = \frac{4m}{1-m^2} L_K \quad C_1 = \frac{C_K}{m}$$

$$L_2 = \frac{L_K}{m} \quad C_2 = \frac{4m}{1-m^2} C_K$$

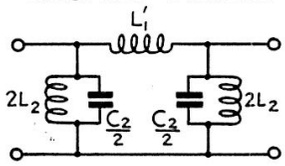
$$L_1 = \frac{4m}{1-m^2} L_K \quad C_1 = \frac{C_K}{m}$$

$$L_2 = \frac{L_K}{m} \quad C_2 = \frac{4m}{1-m^2} C_K$$

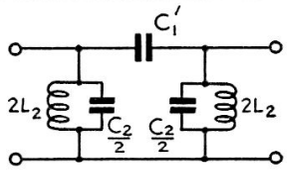
BANDPASS FILTERS



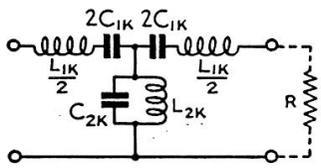
Constant-k π section



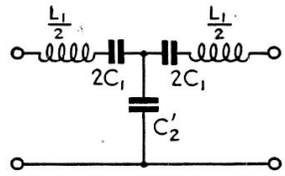
Three-element π section



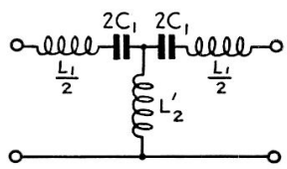
Three-element π section



Constant-k T section



Three-element T section



Three-element T section

$$L_{1K} = \frac{R}{\pi(f_2-f_1)} \quad C_{1K} = \frac{f_2-f_1}{4\pi f_1 f_2 R}$$

$$L_{2K} = \frac{(f_2-f_1)R}{4\pi f_1 f_2} \quad C_{2K} = \frac{1}{\pi(f_2-f_1)R}$$

$$L_1 = L_{1K} \quad L_1' = \frac{R}{\pi(f_1+f_2)}$$

$$C_1 = \frac{f_2-f_1}{4\pi f_1^2 R} \quad L_2 = \frac{(f_2-f_1)R}{4\pi f_1^2}$$

$$C_2 = C_{2K} \quad C_2' = \frac{1}{\pi(f_1+f_2)R}$$

$$L_1 = \frac{f_1 R}{\pi f_2(f_2-f_1)} \quad C_1 = C_{1K}$$

$$C_1' = \frac{f_1+f_2}{4\pi f_1 f_2 R} \quad L_2 = L_{2K}$$

$$L_2' = \frac{(f_1+f_2)R}{4\pi f_1 f_2} \quad C_2 = \frac{f_1}{\pi f_2(f_2-f_1)R}$$

FILTERS

The filter sections shown on the opposite page can be used alone or, if greater attenuation and sharper cut-off are required, several sections can be connected in series. In the low- and high-pass filters, f_c represents the cut-off frequency, the highest (for the low-pass) or the lowest (for the high-pass) frequency transmitted without attenuation. In the bandpass-filter designs, f_1 is the low-frequency cut-off and f_2 the high-frequency cut-off.

If several low- (or high-) pass sections are to be used, it is advisable to use m-derived end sections on either side of a constant-k section, although an m-derived center section can be used. The factor m relates the ratio of the cut-off frequency and f_∞, a frequency of high attenuation. A value of 0.6 is usually used for m, although a deviation of 10 or 15 per cent from this value is not too serious in amateur work. For a value of $m = 0.6$, f_∞ will be $1.25f_c$ for the low-pass filter and $0.8f_c$ for the high-pass filter. Other values can be found from

$$m = \sqrt{1 - \left(\frac{f_c}{f_\infty}\right)^2}$$ for the low-pass filter and

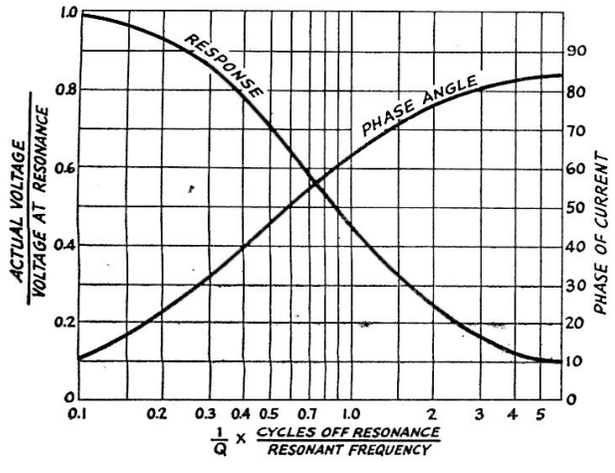
$$m = \sqrt{1 - \left(\frac{f_\infty}{f_c}\right)^2}$$ for the high-pass filter.

The filters shown should be terminated in a resistance = R, and there should be little or no reactive component in the termination.

Simple audio filters can be made with powdered-iron-core chokes and paper condensers, but above this range mica condensers should be used. The values of the components can vary by ±5% with little or no reduction in performance. The more sections there are to the filter the greater is the need for accuracy in the components. High resistance in the coils or appreciable leakage in the condensers will also reduce the effectiveness of the filter.

TUNED-CIRCUIT RESPONSE

The graph below gives the response and phase angle of a high-Q parallel-tuned circuit.



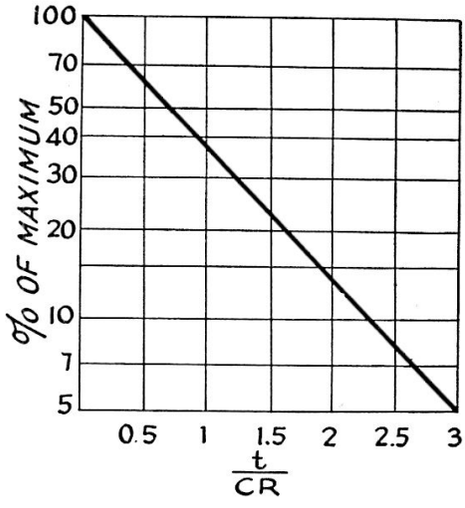
Circuit Q is equal to

$$2\pi fRC \quad \text{or} \quad \frac{R}{2\pi fL}$$

where L and C are the inductance and capacitance at the resonant frequency, f, and R is the parallel resistance across the circuit. The curves above become more accurate as the circuit Q is higher, but the error is not especially great for values as low as $Q = 10$.

VOLTAGE DECAY IN *RC* CIRCUITS

The accompanying chart enables calculation of the instantaneous voltage across the terminals of a condenser discharging through a resistance. The voltage is given in terms of percentage of the voltage to which the condenser is initially charged. To obtain the



voltage-decay time in seconds, multiply the factor (t/CR) by the time constant of the resistor-condenser circuit.

Example: A 0.01-μfd. condenser is charged to 150 volts and then allowed to discharge through a 0.1-megohm resistor. How long will it take the voltage to fall to 10 volts? In percentage, 10/150 = 6.7%. From the chart, the factor corresponding to 6.7% is 2.7. The time constant of the circuit is equal to $CR = 0.01 \times 0.1 = 0.001$. The time is therefore $2.7 \times 0.001 = 0.0027$ second, or 2.7 milliseconds.

Example: An RC circuit is desired in which the voltage will fall to 50% of the initial value in 0.1 second. From the chart, $t/CR = 0.7$ at the 50%-voltage point. Therefore $CR = t/0.7 = 0.1/0.7 = 1.43$. Any combination of resistance and capacitance whose product (R in megohms and C in microfarads) is equal to 1.43 can be used; for example, C could be 1 μfd. and R 1.43 megohms.

TABLE OF DIELECTRIC CHARACTERISTICS

Dielectric material [1]	*Dielectric constant (K)*	*Power factor*					*Dielectric strength (puncture voltage)* [2]	*Volume resistivity* [3] *(ρ)*
		60 cycles	*1 kc.*	*1 Mc.*	*10 Mc.*	*100 Mc.*		
Air (normal pressure)	1.0						19.8–22.8	
AlSiMag A196	5.7–6.3	2.9		0.21	0.15		240	10^{14}
Aniline formaldehyde	3–5	1–6					400	
Asphalts	2.7–3.1		2.3				25–30	
Bakelite — *See* Phenol								
Beeswax	2.9–3.2							
Casein plastics [4]	6.1–6.4			5.2–6			165	
Castor oil	4.3–4.7			7			380	
Celluloid	4–16			5–10				
Cellulose acetate [5]	6–8	3–6	4–6	4–6	5.5		300–1000	4.5×10^{10}
Cellulose nitrate [6]	4–7			2.8–5			300–780	$2–30 \times 10^{10}$
Ceresin wax	2.5–2.6			0.12–0.21				
Cresol formaldehyde	6	10					400	
Dilectene	3.57					0.33		
Ethyl cellulose	2–2.7	0.7	1.2	1.5			1500	10^{15}
Fiber	5–7.5			4.5–5			150–180	5×10^{9}
Formica MF-66	4.6–4.9		1.5	1.1			450	
Glass:								
Cobalt	7.3			0.7				
Common window	7.6–8			1.4			200–250	
Crown	6.2–7		1	1 [3]			500	
Electrical	4–5			0.5			2000	8×10^{14}
Flint	7–10		0.45	0.4				
Nonex	4.2			0.25		0.28		
Photographic	7.5			0.8–1				
Plate	6.8–7.6			0.6–0.8				
Pyrex	4.2–4.9		0.5	0.7		0.54	335	10^{14}
Gutta percha	2.5–4.9						200–500	$5 \times 10^{14}–10^{15}$
Lucite [7]	2.5–3	7	5	1.5–3	1.9		480–500	
Melamine formaldehyde	8	16					300	
Mica	2.5–8	0.2	0.3	0.2–6	0.02			2×10^{17}
Mica (clear India)	6.4–7.5	2	2	2	2		600–1500	
Mycalex	7.4			0.18			250	10^{13}
Mycalex (British)	6			0.3			350	
Mykroy	6.5–7			0.1–0.2			630	
Nylon	3.6			2.2				
Paper	2.0–2.6						1250	
Paraffin wax (solid)	1.9–2.6			0.1–0.3			300	$10^{15}–10^{19}$
Pemque	7.21			0.2				
Phenol: [8]								
Pure	5			1			400–475	1.5×10^{12}
Asbestos base	7.5			15			90–150	
Black molded	5–5.5			3.5			400–500	
Fabric base	5–6.5			3.5–11			150–500	
Mica-filled	5–6			0.8–1			475–600	
Paper base	3.8–5.5			2.5–4			650–750	$10^{10}–10^{13}$
Yellow	5.3–5.4			0.36–0.7			500	
Polyethylene	2.3–2.4	0.02	0.02	0.02–0.05			1000	10^{17}
Polyindene	3	0.04						
Polyisobutylene	2.4–2.5	0.04–5	0.05				500	10^{16}
Polystyrene [9]	2.4–2.9(2.6)	0.02	0.018	0.02	0.02	0.02	500–2500	10^{20}
Porcelain (dry process)	6.2–7.5			0.7–15			40–100	5×10^{8}
Porcelain (wet process)	6.5–7			0.6			150	
Pressboard (untreated)	2.9–4.5						125–300	
Pressboard (oiled)	5						750	
Quartz (fused)	3.5–(3.8)	0.01	0.01	0.015–0.03	0.01	0.05	200	$10^{14}–10^{18}$
Rubber (hard) [10]	2–3.5(3)			0.5–1			450	$10^{12}–10^{15}$
Shellac	2.5–4			0.09			900	10^{16}
Steatite: [11]								
"Commercial" grade	4.9–6.5	0.02	0.2	0.2	0.4	0.5		
"Low-loss" grade	4.4	0.02	0.2	0.2	0.18	0.13	150–315	$10^{14}–10^{15}$
Titanium dioxide [12]	90–170		0.1	0.1				
Urea formaldehyde [13]	5–7	3–5	2–3	2–4	4		300–550	$10^{12}–10^{13}$
Varnished cloth [14]	2–2.5			2–3			440–550	
Vinyl resins	4			1.4–1.7			400–500	10^{14}
Vitrolex	6.4			0.3				
Wood (dry oak)	2.5–6.8(3)		3.8	4.2				
Wood (paraffined maple)	4.1						115	

[1] Most data taken at 25° C.

[2] Puncture voltage, in volts per mil. Most data apply to relatively thin sections and cannot be multiplied directly to give breakdown for thicker sections without added safety factor.

[3] In ohm-cm.

[4] Includes such products as Aladdinite, Ameroid, Galalith, Erinoid, Lactoid, etc.

[5] Includes Fibestas, Lumerith, Nixonite, Plastacele, Tenite, etc.

[6] Includes Amerith, Nitron, Nixonoid, Pyralin, etc.

[7] Methylmethacrylate resin.

[8] Phenolaldehyde products include Acrolite, Bakelite, Catalin, Celeron, Dielecto, Durez, Durite, Formica, Gemstone, Heresite, Indur, Makalot, Marblette, Micarta, Opalon, Prystal, Resinox, Synthane, Textolite, etc. Yellow bakelite is so-called "low-loss" bakelite.

[9] Includes Amphenol 912A, Distrene, Intelin IN 45, Loalin, Lustron, Quartz Q, Rezoglas, Rhodolene M, Ronilla L, Styraflex, Styron, Trolitul, Victron, etc.

[10] Also known as Ebonite.

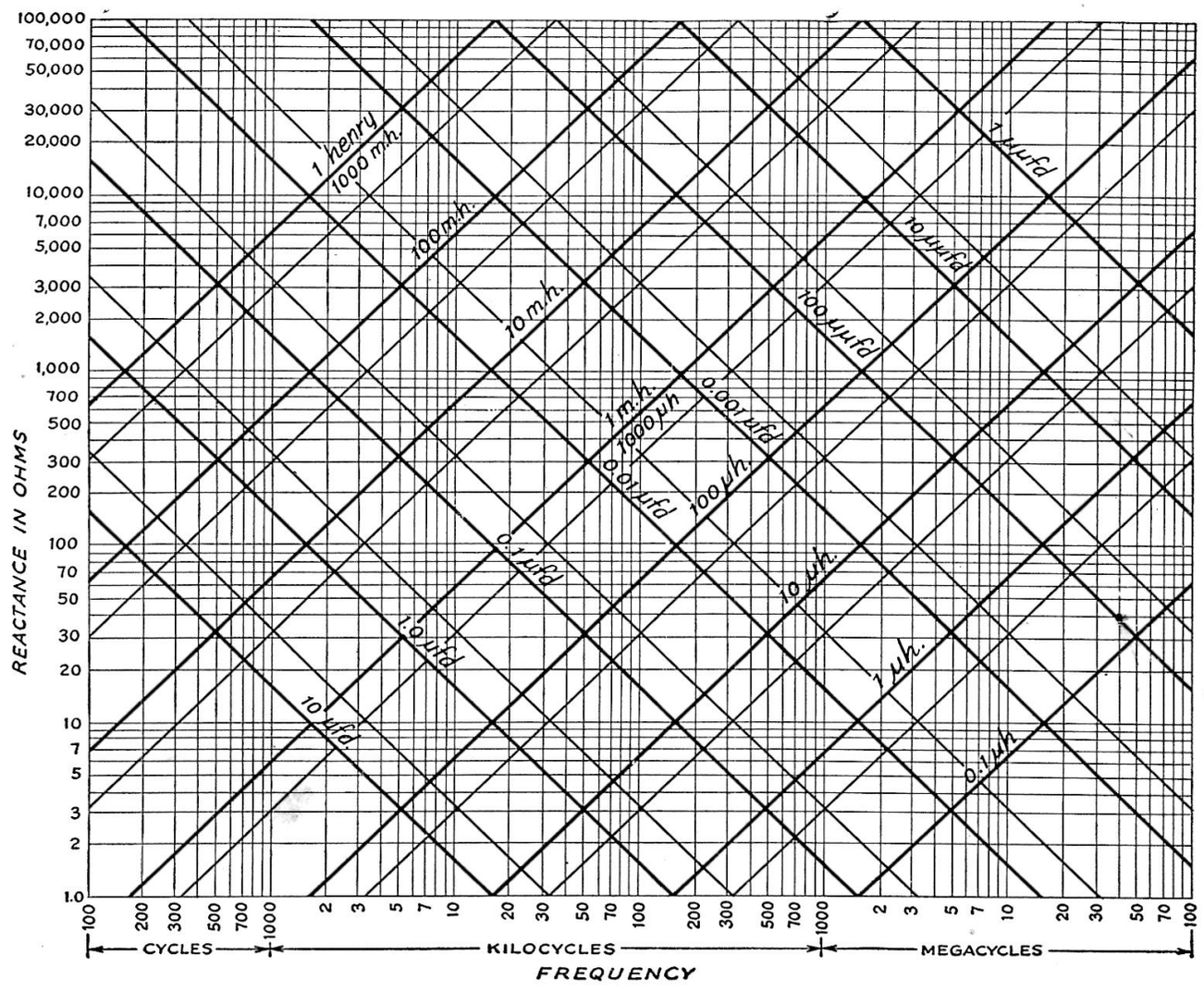
[11] Soapstone — Alberene, Alsimag, Isolantite, Lava, etc.

[12] Rutile. Used in low temperature-coefficient fixed condensers.

[13] Includes Aldur, Beetle, Plaskon, Pollopas, Prystal, etc.

[14] Includes Empire cloth.

INDUCTIVE AND CAPACITIVE REACTANCE *VS.* FREQUENCY CHART



By use of the chart above, the approximate reactance of any capacitance from 1.0 $\mu\mu$fd. to 10 μfd. at any frequency from 100 cycles to 100 megacycles, or the reactance of any inductance from 0.1 μh. to 1.0 henry, can be read directly. Intermediate values can be estimated by interpolation. In making interpolations, remember that the rate of change between lines is logarithmic. Use the frequency or reactance scales as a guide in estimating intermediate values on the capacitance or inductance scales.

This chart also can be used to find the approximate resonance frequencies of *LC* combinations, or the frequency to which a given coil-and-condenser combination will tune. First locate the respective slanting lines for the capacitance and inductance. The point where they intersect, i.e., where the reactances are equal, is the resonant frequency (projected downward and read on the frequency scale).

ELECTRICAL CONDUCTIVITY OF METALS

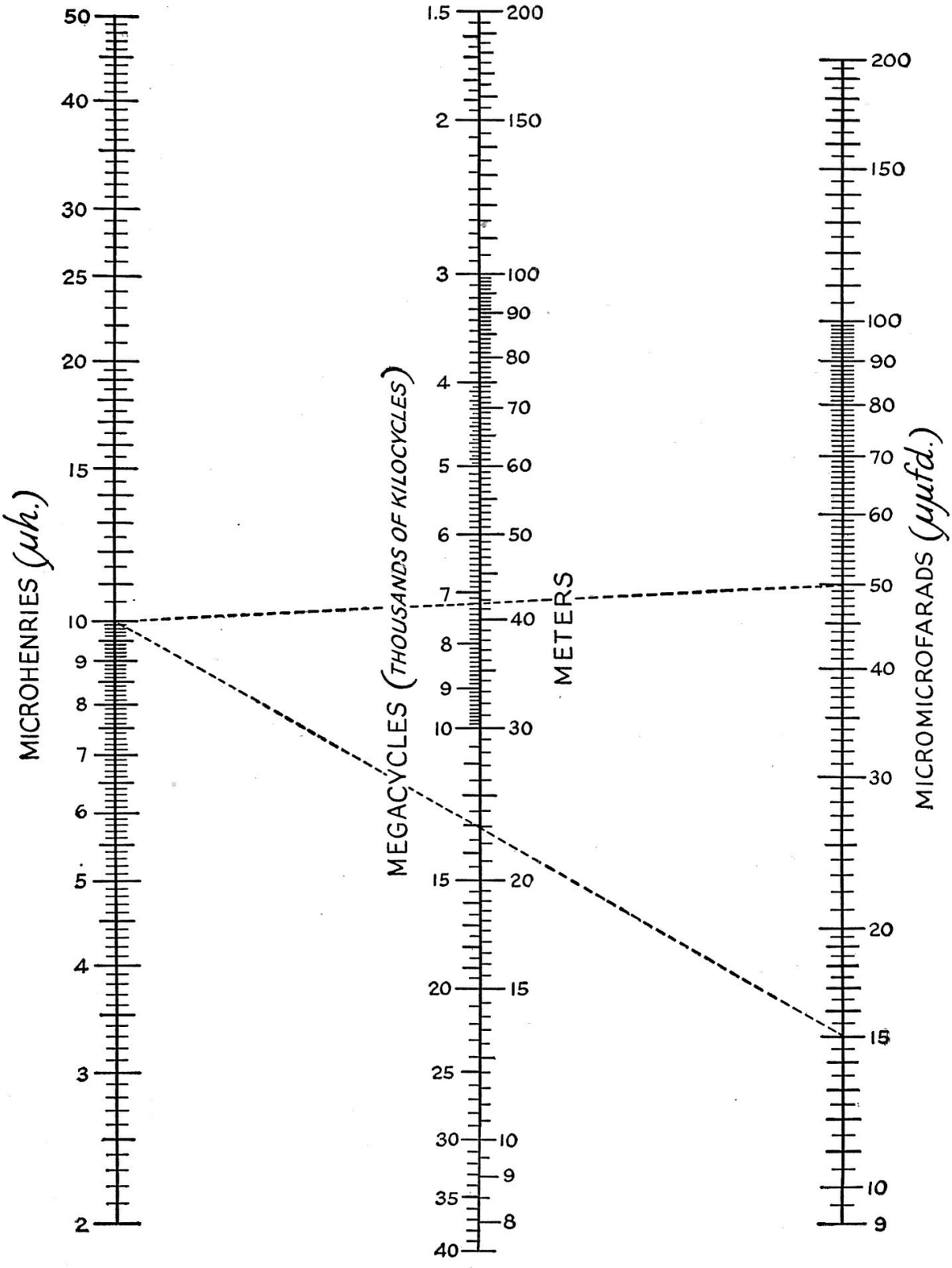
	Relative Conductivity [1]	*Temp. Coeffi.* [2] *of Resistance*
Aluminum (2S; pure)	59	0.0049
Aluminum (alloys):		
Soft-annealed	45–50	
Heat-treated	30–45	
Brass	28	0.002–0.007
Cadmium	19	
Chromium	55	
Climax	1.83	
Cobalt	16.3	
Constantin	3.24	0.00002
Copper (hard drawn)	89.5	0.004
Copper (annealed)	100	
Everdur	6	
German Silver (18%)	5.3	0.00019
Gold	65	
Iron (pure)	17.7	0.006
Iron (cast)	2–12	
Iron (wrought)	11.4	
Lead	7	0.0041
Manganin	3.7	0.00002
Mercury	1.66	0.00089
Molybdenum	33.2	0.0033
Monel	4	0.0019
Nichrome	1.45	0.00017
Nickel	12–16	0.005
Phosphor Bronze	36	0.004
Platinum	15	
Silver	106	0.004
Steel	3–15	
Tin	13	0.0042
Tungsten	28.9	0.0045
Zinc	28.2	0.0035

[1] At 20° C., based on copper as 100. [2] Per °C. at 20° C.

Approximate relations:

An increase of 1 in A. W. G. or B. & S. wire size increases resistance 25%.
An increase of 2 increases resistance 60%.
An increase of 3 increases resistance 100%.
An increase of 10 increases resistance 10 times.

INDUCTANCE, CAPACITANCE AND FREQUENCY CHART — 1.5–40 MC.



This chart may be used to find the values of inductance and capacitance required to resonate at any given frequency in the medium- or high-frequency ranges; or, conversely, to find the frequency to which any given coil-condenser combination will tune. In the example shown by the dashed lines, a condenser has a minimum capacitance of 15 μμfd. and a maximum capacitance of 50 μμfd. If it is to be used with a coil of 10-μh. inductance, what frequency range will be covered? The straightedge is connected between 10 on the left-hand scale and 15 on the right, giving 13 Mc. as the high-frequency limit. Keeping the straightedge at 10 on the left-hand scale, the other end is swung to 50 on the right-hand scale, giving a low-frequency limit of 7.1 Mc. The tuning range would, therefore, be from 7.1 Mc. to 13 Mc., or 7100 kc. to 13,000 kc. The center scale also serves to convert frequency to wavelength.

The range of the chart can be extended by multiplying each of the scales by 0.1 or 10. In the example above, if the capacitances are 150 and 500 μμfd. and the inductance 100 μh., the range becomes approximately 231 to 422 meters or 0.7 to 1.3 Mc. Alternatively, 1.5 to 5 μμfd. and 1 μh. will give a range of approximately 71 to 130 Mc.

COPPER-WIRE TABLE

Gauge No. B. & S.	Diam. in Mils[1]	Circular Mil Area	Turns per Linear Inch[2]				Turns per Square Inch[2]			Feet per Lb.		Ohms per 1000 ft. 25° C.	Current Carrying Capacity at 1500 C.M. per Amp.[3]	Diam. in mm.	Nearest British S.W.G. No.
			Enamel	S.C.C.	D.S.C. or S.C.C.	D.C.C.	S.C.C.	Enamel S.C.C.	D.C.C.	Bare	D.C.C.				
1	289.3	83690	—	—	—	—	—	—	—	3.947	—	.1264	55.7	7.348	1
2	257.6	66370	—	—	—	—	—	—	—	4.977	—	.1593	44.1	6.544	3
3	229.4	52640	—	—	—	—	—	—	—	6.276	—	.2009	35.0	5.827	4
4	204.3	41740	—	—	—	—	—	—	—	7.914	—	.2533	27.7	5.189	5
5	181.9	33100	—	—	—	—	—	—	—	9.980	—	.3195	22.0	4.621	7
6	162.0	26250	—	—	—	—	—	—	—	12.58	—	.4028	17.5	4.115	8
7	144.3	20820	—	—	—	—	—	—	—	15.87	—	.5080	13.8	3.665	9
8	128.5	16510	7.6	—	7.4	7.1	—	—	—	20.01	19.6	.6405	11.0	3.264	10
9	114.4	13090	8.6	—	8.2	7.8	—	—	—	25.23	24.6	.8077	8.7	2.906	11
10	101.9	10380	9.6	—	9.3	8.9	87.5	84.8	80.0	31.82	30.9	1.018	6.9	2.588	12
11	90.74	8234	10.7	—	10.3	9.8	110	105	97.5	40.12	38.8	1.284	5.5	2.305	13
12	80.81	6530	12.0	—	11.5	10.9	136	131	121	50.59	48.9	1.619	4.4	2.053	14
13	71.96	5178	13.5	—	12.8	12.0	170	162	150	63.80	61.5	2.042	3.5	1.828	15
14	64.08	4107	15.0	—	14.2	13.8	211	198	183	80.44	77.3	2.575	2.7	1.628	16
15	57.07	3257	16.8	—	15.8	14.7	262	250	223	101.4	97.3	3.247	2.2	1.450	17
16	50.82	2583	18.9	18.9	17.9	16.4	321	306	271	127.9	119	4.094	1.7	1.291	18
17	45.26	2048	21.2	21.2	19.9	18.1	397	372	329	161.3	150	5.163	1.3	1.150	18
18	40.30	1624	23.6	23.6	22.0	19.8	493	454	399	203.4	188	6.510	1.1	1.024	19
19	35.89	1288	26.4	26.4	24.4	21.8	592	553	479	256.5	237	8.210	.86	.9116	20
20	31.96	1022	29.4	29.4	27.0	23.8	775	725	625	323.4	298	10.35	.68	.8118	21
21	28.46	810.1	33.1	32.7	29.8	26.0	940	895	754	407.8	370	13.05	.54	.7230	22
22	25.35	642.4	37.0	36.5	34.1	30.0	1150	1070	910	514.2	461	16.46	.43	.6438	23
23	22.57	509.5	41.3	40.6	37.6	31.6	1400	1300	1080	648.4	584	20.76	.34	.5733	24
24	20.10	404.0	46.3	35.3	41.5	35.6	1700	1570	1260	817.7	745	26.17	.27	.5106	25
25	17.90	320.4	51.7	50.4	45.6	38.6	2060	1910	1510	1031	903	33.00	.21	.4547	26
26	15.94	254.1	58.0	55.6	50.2	41.8	2500	2300	1750	1300	1118	41.62	.17	.4049	27
27	14.20	201.5	64.9	61.5	55.0	45.0	3030	2780	2020	1639	1422	52.48	.13	.3606	29
28	12.64	159.8	72.7	68.6	60.2	48.5	3670	3350	2310	2067	1759	66.17	.11	.3211	30
29	11.26	126.7	81.6	74.8	65.4	51.8	4300	3900	2700	2607	2207	83.44	.084	.2859	31
30	10.03	100.5	90.5	83.3	71.5	55.5	5040	4660	3020	3287	2534	105.2	.067	.2546	33
31	8.928	79.70	101	92.0	77.5	59.2	5920	5280	—	4145	2768	132.7	.053	.2268	34
32	7.950	63.21	113	101	83.6	62.6	7060	6250	—	5227	3137	167.3	.042	.2019	36
33	7.080	50.13	127	110	90.3	66.3	8120	7360	—	6591	4697	211.0	.033	.1798	37
34	6.305	39.75	143	120	97.0	70.0	9600	8310	—	8310	6168	266.0	.026	.1601	38
35	5.615	31.52	158	132	104	73.5	10900	8700	—	10480	6737	335.0	.021	.1426	38–39
36	5.000	25.00	175	143	111	77.0	12200	10700	—	13210	7877	423.0	.017	.1270	39–40
37	4.453	19.83	198	154	118	80.3	—	—	—	16660	9309	533.4	.013	.1131	41
38	3.965	15.72	224	166	126	83.6	—	—	—	21010	10666	672.6	.010	.1007	42
39	3.531	12.47	248	181	133	86.6	—	—	—	26500	11907	848.1	.008	.0897	43
40	3.145	9.88	282	194	140	89.7	—	—	—	33410	14222	1069	.006	.0799	44

[1] A mil is 1/1000 (one-thousandth) of an inch.

[2] The figures given are approximate only, since the thickness of the insulation varies with different manufacturers.

[3] The current-carrying capacity at 1000 C.M. per ampere is equal to the circular-mil area (Column 3) divided by 1000.

STANDARD METAL GAUGES

Gauge No.	American or B. & S. [1]	U. S. Standard [2]	Birmingham or Stubs [3]
1	.2893	.28125	.300
2	.2576	.265625	.284
3	.2294	.25	.259
4	.2043	.234375	.238
5	.1819	.21875	.220
6	.1620	.203125	.203
7	.1443	.1875	.180
8	.1285	.171875	.165
9	.1144	.15625	.148
10	.1019	.140625	.134
11	.09074	.125	.120
12	.08081	.109375	.109
13	.07196	.09375	.095
14	.06408	.078125	.083
15	.05707	.0703125	.072
16	.05082	.0625	.065
17	.04526	.05625	.058
18	.04030	.05	.049
19	.03589	.04375	.042
20	.03196	.0375	.035
21	.02846	.034375	.032
22	.02535	.03125	.028
23	.02257	.028125	.025
24	.02010	.025	.022
25	.01790	.021875	.020
26	.01594	.01875	.018
27	.01420	.0171875	.016
28	.01264	.015625	.014
29	.01126	.0140625	.013
30	.01003	.0125	.012
31	.008928	.0109375	.010
32	.007950	.01015625	.009
33	.007080	.009375	.008
34	.006350	.00859375	.007
35	.005615	.0078125	.005
36	.005000	.00703125	.004
37	.004453	.006640626	....
38	.003965	.00625	....
39	.003531	.....	....
40	.003145	.....	....

[1] Used for aluminum, copper, brass and nonferrous alloy sheets, wire and rods.
[2] Used for iron, steel, nickel and ferrous alloy sheets, wire and rods.
[3] Used for seamless tubes; also by some manufacturers for copper and brass.

MUSICAL SCALE

Approximate frequencies of notes of the musical scale, based on A-440.

(Bottom Octave)

	Note	Frequency		Note	Frequency
	A-1	28	Middle C —	C3	262
	A♯-1	29		C♯3	277
	B-1	31		D3	294
Third octave below Middle C	Co	33	First octave above Middle C	D♯3	311
	C♯o	35		E3	330
	Do	37		F3	349
	D♯o	39		F♯3	370
	Eo	41		G3	392
	Fo	44		G♯3	415
	F♯o	46		A3	440
	Go	49		A♯3	466
	G♯o	52		B3	494
	Ao	55		C4	523
	A♯o	58		C♯4	554
	Bo	62		D4	587
	C1	65	Second octave above Middle C	D♯4	622
	C♯1	69		E4	659
	D1	73		F4	698
	D♯1	78		F♯4	740
Second octave below Middle C	E1	82		G4	784
	F1	87		G♯4	831
	F♯1	93		A4	880
	G1	98		A♯4	932
	G♯1	104		B4	988
	A1	110		C5	1047
	A♯1	117		C♯5	1109
	B1	123		D5	1175
	C2	131		D♯5	1245
	C♯2	139		E5	1319
	D2	147	Third octave above Middle C	F5	1397
	D♯2	156		F♯5	1480
	E2	165		G5	1568
	F2	175		G♯5	1661
First octave below Middle C	F♯2	185		A5	1760
	G2	196		A♯5	1865
	G♯2	208		B5	1976
	A2	220		C6	2093
	A♯2	233		C♯6	2217
	B2	247	Fourth octave above Middle C	D6	2349
				D♯6	2489
				E6	2637
				F6	2794
				F♯6	2960
				G6	3136
				G♯6	3322
				A6	3520
				A♯6	3729
				B6	3951
				C7	4186

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.

GREEK ALPHABET

Greek Letter	*Greek Name*	*English Equivalent*
A α	Alpha	a
B β	Beta	b
Γ γ	Gamma	g
Δ δ	Delta	d
E ϵ	Epsilon	e
Z ζ	Zeta	z
H η	Eta	é
Θ θ	Theta	th
I ι	Iota	i
K κ	Kappa	k
Λ λ	Lambda	l
M μ	Mu	m
N ν	Nu	n
Ξ ξ	Xi	x
O o	Omicron	ŏ
Π π	Pi	p
P ρ	Rho	r
Σ σ	Sigma	s
T τ	Tau	t
Υ υ	Upsilon	u
Φ ϕ	Phi	ph
X χ	Chi	ch
Ψ ψ	Psi	ps
Ω ω	Omega	ō

THE R-S-T SYSTEM

READABILITY

1 — Unreadable.
2 — Barely readable, occasional words distinguishable.
3 — Readable with considerable difficulty.
4 — Readable with practically no difficulty.
5 — Perfectly readable.

SIGNAL STRENGTH

1 — Faint signals, barely perceptible.
2 — Very weak signals.
3 — Weak signals.
4 — Fair signals.
5 — Fairly good signals.
6 — Good signals.
7 — Moderately strong signals.
8 — Strong signals.
9 — Extremely strong signals.

TONE

1 — Extremely rough hissing note.
2 — Very rough a.c. note, no trace of musicality.
3 — Rough low-pitched a.c. note, slightly musical.
4 — Rather rough a.c. note, moderately musical.
5 — Musically-modulated note.
6 — Modulated note, slight trace of whistle.
7 — Near d.c. note, smooth ripple.
8 — Good d.c. note, just a trace of ripple.
9 — Purest d.c. note.

If the signal has the characteristic steadiness of crystal control, add the letter X to the RST report. If there is a chirp, the letter C may be added to so indicate. Similarly for a click, add K. The above reporting system is used on both c.w. and voice, leaving out the "tone" report on voice.

Q SIGNALS

Given below are a number of Q signals whose meanings most often need to be expressed with brevity and clearness in amateur work. (Q abbreviations take the form of questions only when each is sent followed by a question mark.)

QAV Are you calling me? I am calling. . . .
QRG Will you tell me my exact frequency in kilocycles? Your frequency is.....kc.
QRH Does my frequency vary? Your frequency varies.
QRI Is my note good? Your note varies.
QRJ Are you receiving me badly? Are my signals weak? I cannot receive you. Your signals are too weak.
QRK What is the readability of my signals (1 to 5)? The readability of your signals is... (1 to 5).
QRL Are you busy? I am busy or busy with (.....)
QRM Are you being interfered with? I am interfered with.
QRN Are you troubled by atmospherics? I am being troubled by atmospherics.
QRQ Shall I send faster? Send faster (.....words per min.).
QRS Shall I send more slowly? Send more slowly (.... w.p.m.)
QRT Shall I stop sending? Stop sending.
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRW Shall I tell.....that you are calling him? Please tell.....that I am calling him.
QRX Shall I wait? When will you call me again? Wait (or wait until I have finished with.....). I will call you at.....o'clock (or immediately).
QRZ By whom am I being called? You are being called by .....
QSA What is the strength of my signals (1 to 5)? The strength of your signals is.....(1 to 5).
QSB Does the strength of my signals vary? The strength of your signals varies.
QSD Is my keying correct? Are my signals distinct? Your keying is incorrect; your signals are bad.
QSG Shall I send.....telegrams (or one) at a time? Send.....telegrams at a time.
QSL Can you give me acknowledgment of receipt? I give you acknowledgment of receipt.
QSM Shall I repeat the last telegram I sent you? Repeat the last telegram you sent me.
QSO Can you communicate with.....direct (or through.....)? I can communicate with .....direct (or through.....).
QSP Will you relay to.....? I will relay to.....
QSV Shall I send a series of VVV.....? Send a series of VVV.
QSW Will you send on.....kc., etc.? I will send on .....kc., etc.
QSX Will you listen for.....(call sign) on.....kc.? I am listening for....on....kc.
QSY Shall I change to.....kilocycles without changing the type of wave? Change to.....kc. without changing type of wave.
QSZ Shall I send each word or group twice? Send each word or group twice.
QTA Shall I cancel nr.....as if it had not been sent? Cancel nr.....as if it had not been sent.
QTB Do you agree with my number of words? I do not agree with your number of words; I will repeat the first letter of each word and the first figure of each number.
QTC How many telegrams have you to send? I have.... telegrams for you or for.....
QTH What is your position (location)? My location is.....(by any indication.)
QTR What is the exact time? The time is.....

Special abbreviations adopted by ARRL:

QST General call preceding a message addressed to all amateurs and ARRL members. This is in effect "CQ ARRL."
QRR Official ARRL "land SOS." A distress call for emergency use only by a station in an emergency situation.

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
Arizona	W7
Arkansas	W5
California	W6
Colorado	WØ
Connecticut	W1
Delaware	W3
District of Columbia	W3
Florida	W4
Georgia	W4
Idaho	W7
Illinois	W9
Indiana	W9
Iowa	WØ
Kansas	WØ
Kentucky	W4
Louisiana	W5
Maine	W1
Maryland	W3
Massachusetts	W1
Michigan	W8
Minnesota	WØ
Mississippi	W5
Missouri	WØ
Montana	W7
Nebraska	WØ
Nevada	W7
New Hampshire	W1
New Jersey	W2
New Mexico	W5
New York	W2
North Carolina	W4
North Dakota	WØ
Ohio	W8
Oklahoma	W5
Oregon	W7
Pennsylvania	W3
Rhode Island	W1
South Carolina	W4
South Dakota	WØ
Tennessee	W4
Texas	W5
Utah	W7
Vermont	W1
Virginia	W4
Washington	W7
West Virginia	W8
Wisconsin	W9
Wyoming	W7

INTERNATIONAL PREFIXES

Below is the list of prefixes assigned to the countries of the world by the 1947 International Radio Conference at Atlantic City. While not yet officially in force, it is reproduced here because it embodies the essentials of the present (Cairo) table as well as contains new assignments which will undoubtedly see use 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	Curacao
PKA-POZ	Netherlands Indies
PPA-PYZ	Brazil
PZA-PZZ	Surinam
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
4PA-4SZ	British Colonies and Protectorates
4TA-4TZ	Peru
4UA-4UZ	United Nations
4VA-4VZ	Republic of Haiti
4WA-4WZ	Yemen
4XA-4ZZ	(Not allocated)
5AA-5ZZ	(Not allocated)
6AA-6ZZ	(Not allocated)
7AA-7ZZ	(Not allocated)
8AA-8ZZ	(Not allocated)
9AA-9ZZ	(Not allocated)

A.R.R.L. COUNTRIES LIST

Official List for ARRL DX Contest and the Postwar DXCC

Aden and Socotra Island VS9
Afghanistan ..... YA
Alaska KL7
Albania ..... ZA
Aldabra Islands .....
Algeria ..... FA
Andaman Ids. and Nicobar Ids ...
Andorra ..... PX
Anglo-Egyptian Sudan ..... ST
Angola CR6
Argentina ..... LU
Ascension Island ZD8
Australia (including Tasmania) ... VK
Austria ..... OE
Azores Islands CT2
Bahama Islands VP7
Bahrein Island VU7
Baker Island, Howland Island and Am. Phoenix Islands KB6
Balearic Islands EA6
Barbados VP6
Basutoland ZS4
Bechuanaland .....
Belgian Congo ..... OQ
Belgium ..... ON
Bermuda Islands VP9
Bhutan .....
Bolivia ..... CP
Bonin Islands and Volcano Islands (e.g., Iwo Jima) .....
Borneo, British North VS4
Borneo, Netherlands PK5
Brazil ..... PY
Brunei VS5
Bulgaria ..... LZ
Burma ..... XZ
Cameroons, French FE8
Canada ..... VE
Canal Zone KZ5
Canary Islands EA8
Cape Verde Islands CR4
Caroline Islands .....
Cayman Islands VP5
Celebes and Molucca Islands PK6
Ceylon VS7
Chagos Islands VQ8
Channel Islands ..... GC
Chile ..... CE
China ..... XU, C
Christmas Island ZC3
Clipperton Island .....
Cocos Island ..... TI
Cocos Islands ZC2
Colombia ..... HK
Comoro Islands .....
Cook Islands ZK1
Corsica .....
Costa Rica ..... TI
Crete ..... SV
Cuba ..... CM-CO
Cyprus ZC4
Czechoslovakia ..... OK
Denmark ..... OZ
Dodecanese Islands (e.g., Rhodes) SV5
Dominican Republic ..... HI
Easter Island .....
Ecuador ..... HC
Egypt ..... SU
Eire (Irish Free State) ..... EI
England ..... G
Eritrea I6
Ethiopia ..... ET
Faeroes, The ..... OY
Falkland Islands VP8
Fanning Island (Christmas Island) VR3
Fiji Islands VR2
Finland ..... OH
Formosa (Taiwan) .....
France ..... F
French Equatorial Africa FQ8
French India ..... FN
French Indo-China FI8
French Oceania (e.g., Tahiti) FO8
French West Africa FF8
Fridtjof Nansen Land (Franz Josef Land) .....
Galapagos Islands .....
Gambia ZD3
Germany ..... D
Gibraltar ZB2
Gilbert & Ellice Islands and Ocean Island VR1
Goa(Portuguese India) CR8
Gold Coast (and British Togoland) ZD4
Greece ..... SV
Greenland ..... OX
Guadeloupe FG8
Guantanamo Bay NY4
Guatemala ..... TG
Guiana, British VP3
Guiana, Netherlands (Surinam) ... PZ
Guiana, French, and Inini FY8
Guinea, Portuguese CR5
Guinea, Spanish .....
Haiti ..... HH
Hawaiian Islands KH6
Honduras ..... HR
Honduras, British VP1
Hong Kong VS6
Hungary ..... HA
Iceland ..... TF
Ifni .....
India ..... VU
Iran ..... EP-EQ
Iraq ..... YI
Ireland, Northern ..... GI
Isle of Man ..... GD
Italy I
Jamaica VP5
Jan Mayen Island .....
Japan ..... J
Jarvis Island, Palmyra group (Christmas Island) KP6
Java ..... PK
Johnston Island KJ6
Kenya VQ4
Kerguelen Islands .....
Korea .....
Kuwait .....
Laccadive Islands VU4
Leeward Islands VP2
Liberia ..... EL
Libya ..... (LI)
Liechtenstein HE1
Little America KC4
Luxembourg LX
Macau CR9
Madagascar FB8
Madeira Islands CT3
Malaya VS1, VS2
Maldive Islands .....
Malta ZB1
Manchuria .....
Marianas Islands (Guam) KG6
Marshall Islands .....
Martinique FM8
Mauritius VQ8
Mexico ..... XE
Midway Island KM6
Miquelon and St. Pierre Islands FP8
Monaco .....
Mongolia .....
Morocco, French ..... CN
Morocco, Spanish EA9
Mozambique CR7
Nepal .....
Netherlands ..... PA
Netherlands West Indies ..... PJ
New Caledonia FK8
Newfoundland and Labrador ..... VO
New Guinea, Netherlands PK6
New Guinea, Territory of VK9
New Hebrides ..... FU8, YJ
New Zealand ..... ZL
Nicaragua ..... YN
Nigeria ZD2
Niue ZK2
Norway ..... LA
Nyasaland ZD6
Oman .....
Palau (Pelew) Islands .....
Palestine ZC6
Panama ..... HP
Papua Territory VK4
Paraguay ..... ZP
Peru ..... OA
Philippine Islands ..... KA
Phoenix Islands (British) .....
Pitcairn Island VR6
Poland ..... SP
Portugal ..... CT
Principe and Sao Thome Islands ..
Puerto Rico KP4
Reunion Island FR8
Rhodesia, Northern VQ2
Rhodesia, Southern ..... ZE
Rio de Oro .....
Roumania ..... YR
Ryukyu Islands (e.g., Okinawa) ...
St. Helena ZD7
Salvador ..... YS
Samoa, American KS6
Samoa, Western ..... ZM
Sarawak VS5
Sardinia .....
Saudi Arabia (Hedjaz and Nejd) .. HZ
Scotland ..... GM
Seychelles VQ9
Siam ..... HS
Sierra Leone ZD1
Sikkim ..... (AC3)
Solomon Islands VR4
Somaliland, British VQ6
Somaliland, French FL8
Somaliland, Italian .....
South Georgia VP8
South Orkney Islands VP8
South Sandwich Islands VP8
South Shetland Islands VP8
Southwest Africa ZS3
Soviet Union:
- European Russian Socialist Federated Soviet Republic UA1-3-4-6
- Asiatic Russian S.F.S.R. UA9-0
- Ukraine UB5
- White Russian Soviet Socialist Republic UC5
- Azerbaijan UD6
- Georgia UF6
- Armenia UG6
- Turkoman UH8
- Uzbek UI8
- Tadzhik UJ8
- Kazakh UL7
- Kirghiz UM8
- Karelo-Finnish Republic UN1
- Moldavia UO5
- Lithuania ..... UP
- Latvia ..... UQ
- Estonia ..... UR

Spain ..... EA
Sumatra PK4
Svalbard (Spitzbergen) .....
Swan Island KS4
Swaziland .....
Sweden ..... SM
Switzerland ..... HB
Syria ..... (AR)
Tanganyika Territory VQ3
Tangier Zone ..... EK
Tannu Tuva .....
Tibet AC4
Timor, Portuguese CR10
Togoland, French FD8
Tokelau (Union) Islands .....
Tonga (Friendly) Islands VR5
Trans-Jordan ZC1
Trieste .....
Trinidad and Tobago VP4
Tristan da Cunha and Gough Island ZD9
Tunisia FT4
Turkey ..... TA
Turks and Caicos Islands VP5
Uganda VQ5
Union of South Africa ..... ZS
United States of America ..... W, K
Uruguay CX
Venezuela ..... YV
Virgin Islands KV4
Wake Island KW6
Wales ..... GW
Windward Islands VP2
Wrangel Islands .....
Yemen .....
Yugoslavia ..... YT-YU
Zanzibar VQ1

INTERNATIONAL AMATEUR PREFIXES

To make possible identification of calls heard on the air, the international telecommunications conferences assign to each nation certain alphabetical blocks, from which *all* classes of stations are assigned prefixes. The following prefixes are used by amateurs:

AC3 ... Sikkim
AC4 ... Tibet
AR ... Syria
C ... China (unofficial)
CE ... Chile
CM, CO ... Cuba
CN ... Morocco, French
CP ... Bolivia
CR4 ... Cape Verde Islands
CR5 ... Guinea, Portuguese
CR6 ... Angola
CR7 ... Mozambique
CR8 ... Goa (Portuguese India)
CR9 ... Macau
CR10 ... Timor, Portuguese
CT1 ... Portugal
CT2 ... Azores Islands
CT3 ... Madeira Islands
CX ... Uruguay
D ... Germany
EA ... Spain
EA6 ... Balearic Islands
EA8 ... Canary Islands
EA9 ... Morocco, Spanish
EI ... Eire (Irish Free State)
EK ... Tangier Zone
EL ... Liberia
EP, EQ ... Iran (Persia)
ET ... Ethiopia
F ... France
FA ... Algeria
FB8 ... Madagascar
FD8 ... Togoland, French
FE8 ... Cameroons, French
FF8 ... French West Africa
FG8 ... Guadeloupe
FI8 ... French Indo-China
FK8 ... New Caledonia
FL8 ... Somaliland, French
FM8 ... Martinique
FN ... French India
FO8 ... French Oceania (e.g., Tahiti)
FP8 ... St. Pierre & Miquelon Islands
FQ8 ... French Equatorial Africa
FR8 ... Reunion Island
FT4 ... Tunisia
FU8 ... New Hebrides
FY8 ... Guiana, French & Inini
G ... England
GC ... Channel Islands
GD ... Isle of Man
GI ... Ireland, Northern
GM ... Scotland
GW ... Wales
HA ... Hungary
HB ... Switzerland
HC ... Ecuador
HE1 ... Liechtenstein
HH ... Haiti
HI ... Dominican Republic
HK ... Colombia
HP ... Panama
HR ... Honduras
HS ... Siam
HZ ... Saudi Arabia (Hedjaz & Nejd)
I ... Italy
I6 ... Eritrea
J ... Japan
J9 ... Ryukyu Islands (e.g., Okinawa)
K ... United States of America
KA ... Philippine Islands
KB6 ... Baker, Howland & American Phoenix Islands
KC4 ... Little America
KG6 ... Guam, Saipan, Tinian
KH6 ... Hawaiian Islands
KJ6 ... Johnston Islands
KL7 ... Alaska
KM6 ... Midway Islands
KP4 ... Puerto Rico
KP6 ... Palmyra Group, Jarvis Island
KS6 ... American Samoa
KS4 ... Swan Island
KV4 ... Virgin Islands
KW6 ... Wake Island
KZ5 ... Canal Zone
LA ... Norway
LI ... Libya
LU ... Argentina
LX ... Luxembourg
LZ ... Bulgaria
MB9 ... Austria
MD1 ... Cyrenaica
MD2 ... Tripolitania
MD3 ... Eritrea
MD4 ... Somalia
MD5 ... Suez Canal Zone
MD6 ... Iraq
MX ... Manchukuo (Manchuria)
NY4 ... Guantanamo Bay
OA ... Peru
OE ... Austria
OH ... Finland
OK ... Czechoslovakia
ON ... Belgium
OQ ... Belgian Congo
OX ... Greenland
OY ... Faeroes, The
OZ ... Denmark
PA ... Netherlands
PJ ... Netherlands West Indies
PK1, 2, 3 ... Java
PK4 ... Sumatra
PK5 ... Borneo, Netherlands
PK6 ... Celebes & Molucca Islands
PK6 ... New Guinea, Netherlands
PX ... Andorra
PY ... Brazil
PZ ... Guiana, Netherlands (e.g., Surinam)
SM ... Sweden
SP ... Poland
ST ... Anglo-Egyptian Sudan
SU ... Egypt
SV ... Greece
SV ... Crete
SV5 ... Dodecanese (e.g., Rhodes)
TA ... Turkey
TF ... Iceland
TG ... Guatemala
TI ... Costa Rica
TI ... Cocos Island
UA1, 3, 4, 6 ... European Russian Socialist Federated Soviet Republic
UA9, Ø ... Asiatic Russian S.F.S.R.
UB5 ... Ukraine
UC ... White Russian Soviet Socialist Republic
UD6 ... Azerbaijan
UF6 ... Georgia
UG6 ... Armenia
UH8 ... Turkoman
UI8 ... Uzbek
UJ8 ... Tadzhik
UL7 ... Kazakh
UM8 ... Kirghiz
UN1 ... Karelo-Finnish Republic
UO5 ... Moldavia
UP ... Lithuania
UQ ... Latvia
UR ... Estonia
VE ... Canada
VK ... Australia (including Tasmania)
VK4 ... Papua Territory
VK9 ... New Guinea, Territory of
VO ... Newfoundland & Labrador
VP1 ... British Honduras
VP2 ... Leeward & Windward Islands
VP3 ... British Guiana
VP4 ... Trinidad & Tobago
VP5 ... Jamaica & Cayman Islands
VP5 ... Turks & Caicos Islands
VP6 ... Barbados
VP7 ... Bahama Islands
VP8 ... Falkland Islands
VP8 ... South Georgia
VP8 ... South Orkney Islands
VP8 ... South Sandwich Islands
VP8 ... South Shetland Islands
VP9 ... Bermuda Islands
VQ1 ... Zanzibar
VQ2 ... Northern Rhodesia
VQ3 ... Tanganyika Territory
VQ4 ... Kenya
VQ5 ... Uganda
VQ6 ... Somaliland, British
VQ8 ... Mauritius & Chagos Islands
VQ9 ... Seychelles
VR1 ... Gilbert & Ellice Islands & Ocean Island
VR2 ... Fiji Islands
VR3 Fanning Island (Christmas Island)
VR4 ... Solomon Islands
VR5 ... Tonga (Friendly) Islands
VR6 ... Pitcairn Island
VS1 ... Strait Settlements
VS2 ... Federated Malay States
VS3 ... Non-Federated Malay States
VS4 ... Borneo, British North
VS5 ... Sarawak, Brunei
VS6 ... Hong Kong
VS7 ... Ceylon
VS8 (VU7) ... Bahrein Islands
VS9 ... Maldive Islands
VU ... India
VU4 ... Laccadive Islands
VU7 ... Bahrein Islands
W ... United States of America
XA*
XE ... Mexico
XU ... China
XZ ... Burma
YA ... Afghanistan
YI ... Iraq
YN ... Nicaragua
YR ... Roumania
YS ... Salvador
YT, YU ... Yugoslavia
YV ... Venezuela
ZA ... Albania
ZB1 ... Malta
ZB2 ... Gibraltar
ZC1 ... Trans-Jordan
ZC2 ... Cocos Islands
ZC3 ... Christmas Island
ZC4 ... Cyprus
ZC6 ... Palestine
ZD1 ... Sierra Leone
ZD2 ... Nigeria
ZD3 ... Gambia
ZD4 ... Togoland, Gold Coast
ZD6 ... Nyasaland
ZD7 ... St. Helena
ZD8 ... Ascension Island
ZD9 ... Tristan da Cunha & Gough Island
ZE1 ... Southern Rhodesia
ZK1 ... Cook Islands
ZK2 ... Niue
ZL ... New Zealand
ZM ... British Samoa
ZP ... Paraguay
ZS1, 2, 4, 5, 6 ... Union of South Africa
ZS3 ... Southwest Africa
ZS4 ... Basutoland
ZS6 ... Bechuanaland

*** In addition to call signs starting with the prefixes listed in this tabulation, four-letter calls beginning with the letters XA have been assigned for use in the Mediterranean area by amateurs in the British and American military services.**

CHAPTER 25

Vacuum-Tube Data

For the convenience of the designer, the receiving-type tubes listed in this chapter are grouped by filament voltages and construction types (glass, metal, miniature, etc.). For example, all 6.3-volt metal tubes are listed in Table I, all lock-in base tubes are in Table III, all miniatures are in Table XI, and so on.

Transmitting tubes are divided into triodes and tetrodes-pentodes, then listed according to rated plate dissipation. This permits direct comparison of ratings of tubes in the same power classification.

For quick reference, all tubes are listed in numerical-alphabetical order in the index beginning on the following page.

Tube Ratings

Vacuum tubes are designed to be operated within definite maximum (and minimum) ratings. These ratings are the maximum safe operating voltages and currents for the electrodes, based on inherent limiting factors such as permissible cathode temperature, emission, and power dissipation in electrodes.

In the transmitting-tube tables, maximum ratings for electrode voltage, current and dissipation are given separately from the typical operating conditions for the recommended classes of operation. In the receiving-tube tables, because of space limitations, ratings and operating data are combined. Where only one set of operating conditions appears, the positive electrode voltages shown (plate, screen, etc.) are, in general, also the maximum rated voltages for those electrodes.

For certain air-cooled transmitting tubes, there are two sets of maximum values, one designated as CCS (Continuous Commercial Service) ratings, the other ICAS (Intermittent Commercial and Amateur Service) ratings. Continuous Commercial Service is defined as that type of service in which long tube life and reliability of performance under continuous operating conditions are the prime consideration. Intermittent Commercial and Amateur Service is defined to include the many applications where the transmitter design factors of minimum size, light weight, and maximum power output are more important than long tube life. ICAS ratings are considerably higher than CCS ratings. They permit the handling of greater power, and although such use involves some sacrifice in tube life, the period over which tubes will continue to give satisfactory performance in intermittent service can be extremely long.

Typical Operating Conditions

The typical operating conditions given for transmitting tubes represent, in general, maximum ICAS ratings where such ratings have been given by the manufacturer. They do not represent the *only* possible method of operation of a particular tube type. Other values of plate voltage, plate current, grid bias, etc., may be used so long as the maximum ratings for a particular voltage or current are not exceeded.

INDEX TO TUBE TABLES

I — 6.3-Volt Metal Receiving Tubes . . . 572
II — 6.3-Volt Glass Tubes with Octal Bases 573
III — 7-Volt Lock-In Base Tubes 575
IV — 6.3-Volt Glass Receiving Tubes . . . 576
V — 2.5-Volt Receiving Tubes 577
VI — 2.0-Volt Battery Receiving Tubes . 578
VII — 2.0-Volt Battery Tubes with Octal Bases 579
VIII — 1.5-Volt Battery Tubes 579
IX — High-Voltage Heater Tubes 581
X — Special Receiving Tubes 583
XI — Miniature Receiving Tubes 585
XII — Control and Regulator Tubes . . . 587
XIII — Cathode-Ray Tubes and Kinescopes 588
XIV — Rectifiers 590
XV — Triode Transmitting Tubes 592
XVI — Tetrode and Pentode Transmitting Tubes 603

BASE TYPE DESIGNATIONS

The type of base used on each tube listed in the tables is indicated in the base column by a letter.

The meaning of each letter is as follows:

A = Acorn
B = Glass button miniature
J = Jumbo
L = Lock-in
M = Medium
N = None or special type
O = Octal
S = Small
W = Wafer

INDEX TO VACUUM-TUBE TYPES

For convenience in locating data on specific tube types the index below lists all tubes in numerical-alphabetical order, showing the page number where individual tubes may be found in the classified-data section (pages 572-608) and the identifying base-diagram number in the base-diagram section (pages 565-571).

Type	Page	Base
0-A	583	4D
1-A	583	4D
A2	587	5BO
A3	587	4AJ
A4G	587	4V
B2	587	5BO
B3	587	4AJ
C3	587	4AJ
D3	587	4AJ
Y4	590	4BU
Z4	590	4R
Z4A	591	4R
	590	4G
A3	585	4AP
A4P	578	4M
A4T	578	4K
A5G	579	6X
A6	578	6L
A7G	579	7Z
AB5	580	5BF
B3GT	590	3C
B4P	578	4M
B5	578	6M
B7G	580	7Z
B8GT	580	8AW
B47	587	—
B48	590	—
C5G	580	6X
C6	578	6L
C7G	579	7Z
C21	587	4V
D5GP	579	5Y
D5GT	579	5R
D7G	579	7Z
D8GT	580	8AJ
E4G	580	5S
E5GP	579	5Y
E7G	579	8C
F4	578	5K
F5G	579	6X
F6	578	6W
F7GV	579	7AD
G4G	580	5S
G5G	579	6X
G6G	580	7AB
H4G	579	5S
H5G	580	5Z
H6G	579	7AA
J5G	579	6X
J6G	579	7AB
L4	585	6AR
LA4	580	5AD
LA6	580	7AK
LB4	580	5AD
LB6	580	8AX
LC5	580	7AO
LC6	580	7AK
LD5	580	6AX
LE3	580	4AA
LG5	580	Fig. 42
LH4	580	5AG
LN5	580	7AO
N5G	580	5Y
N6G	580	7AM
P5G	580	5Y
Q5G	580	6AF
R4	580	4AH
R5	585	7AT
S4	585	7AV
S5	585	6AU
SA6GT	580	6CA
SB6GT	580	6AF
T4	585	6AR
T5GT	580	6CB
U4	585	6AR
U5	585	6BW
V	590	4G
Z2	590	7CB
2A3	577	4D
2A4G	587	5S
2A5	577	6B
2A6	577	6G
2A7	577	7C
2AP1	588	11D
2B4	587	6Q
2B6	578	7J
2B7	578	7D
2B25	590	3T
2BP1	588	12C
2C4	587	5AS
2C21	576	7BH
2C21	592	7BH
2C22	573	4AM
2C22	592	4AM
2C25	592	4D
2C26A	592	4BB
2C34	592	T-7DC
2C35	585	Fig. 38
2C39	599	—
2C40	592	Fig. 19
2C43	592	Fig. 19
2D21	587	7BM
2E5	578	6R
2E22	605	5J
2E24	603	7CL
2E25	604	5BJ
2E26	603	7CK
2E30	585	7CQ
2E30	603	7CQ
2E32	583	—
2E36	583	—
2E42	583	—
2G5	578	6R
2G22	583	—
2K25	608	Fig. 60
2K28	608	Fig. 61
2K33	608	Fig. 62
2K34	608	Fig. 58
2K35	608	Fig. 58
2K39	608	Fig. 59
2K41	608	Fig. 59
2K42	608	Fig. 59
2K43	608	Fig. 59
2K44	608	Fig. 59
2K46	608	Fig. 58
2K47	608	Fig. 58
2S/4S	577	5D
2V3G	590	T-4BC
2W3	590	4X
2X2	590	4AB
2X2-A	590	4AB
2Y2	590	4AB
2Z2	590	4B
3A4	585	7BB
3A4	603	7BB
3A5	585	7BC
3A5	592	7BC
3A8GT	583	8AS
3AP1	588	7AN
3B5GT	583	7AP
3B7	580	7BE
3B24	590	T-4A
3B25	590	4P
3B26	590	Fig. 31
3BP1	588	14A
3C5GT	583	7AQ
3C6	583	7BW
3C22	599	Fig. 30
3C23	587	3G
3C24	593	2D
3C28	593	Fig. 56
3C34	593	3G
3C37	600	—
3D6	580	6BB
3D23	605	Fig. 54
3D24	605	T-9
3DP1	588	Fig. 49
3DX3	605	Fig. 40
3E22	605	8BY
3E29	605	7BP
3EP1	588	11A
3GP1	588	11A
3JP1	588	14B
3K21	608	Fig. 58
3K22	608	Fig. 58
3K23	608	Fig. 59
3K27	608	Fig. 59
3K30	608	Fig. 58
3KP1	588	11M
3LE4	584	6BA
3LF4	584	6BB
3Q4	585	7BA
3Q5GT	584	7AP
3S4	585	7BA
3V4	585	6BX
3-25A3	593	3G
3-25D3	593	2D
3-50A4	595	3G
3-50D4	595	2D
3-50G2	595	2D
3-75A2	597	2D
3-75A3	597	2D
3-100A2	598	2D
3-100A4	598	2D
3X-100A11	599	—
3-150A2	600	4BC
3-150A3	600	4BC
3X-150A3	600	—
3-250A2	601	2N
3-250A4	601	2N
3-300A2	602	4BC
3-300A3	602	4BC
4A6G	579	AL
4C32	601	2N
4C34	601	2M
4C36	599	Fig. 56
4D22	606	Fig. 50
4D23	607	Fig. 27
4D32	606	Fig. 51
4E27	606	7BM
4X150A	607	T-9J
4-65A	606	Fig. 55
4-125A	607	Fig. 27
4-250A	607	Fig. 27
5AP1	588	11A
5BP1	588	11A
5CP1	588	14B
5FP1	588	5AN
5HP1	588	11A
5JP1	588	11E
5LP1	588	11F
5MP1	588	7AN
5R4GY	590	5T
5RP1	588	14F
5T4	590	5T
5TP4	588	Fig. 46
5U4G	590	5T
5UP1	589	12E
5V4G	590	5L
5W4	590	5T
5X3	590	4C
5X4G	590	5Q
5Y3G	590	5T
5Y4G	590	5Q
5Z3	590	4C
5Z4	590	5L
6A3	576	4D
6A4	576	5B
6A5G	573	6T
6A6	576	7B
6A7	576	7C
6A8	572	8A
6AB5	576	6R
6AB6G	573	7AU
6AB7	572	8N
6AC5G	573	6Q
6AC6G	573	7AU
6AC7	572	8N
6AD5G	573	6Q
6AD6G	573	7AH
6AD7G	573	8AY
6AE5G	573	6Q
6AE6G	573	7AH
6AE7GT	574	7AX
6AF5G	574	6Q
6AF6G	576	7AG
6AF7G	574	8AG
6AG5	585	7BD
6AG6G	574	7S
6AG7	572	8Y
6AG7	603	8Y
6AH5G	574	6AP
6AH7GT	574	8BE
6AJ5	585	7PM
6AJ7	572	8M
6AK5	585	7BD
6AK6	586	7BK
6AK6	603	7BK
6AK7	572	8Y
6AL5	586	6BT
6AL6G	574	6AM
6AL7GT	574	8CH
6AN6	586	7BJ
6AQ5	586	7BZ
6AQ5	603	7BZ
6AQ6	586	7BT
6AQ7GT	574	8CK
6AR5	586	6CC
6AR6	574	6BQ
6AR7GT	574	8CG
6AS6	586	7CN
6AS7GT	574	8BD
6AT6	586	7BT
6AU6	586	7BK
6B4G	574	5S
6B5	576	6AS
6B6G	574	7V
6B7	576	7D
6B8	572	8E
6BA6	586	7CC
6BD6	586	7CC
6BE6	586	7CH
6BF6	586	7BT
6BG6	574	5BT
6BJ6	586	7CM
6C4	586	6BG
6C4	592	6BG
6C5	572	6Q
6C6	576	6F
6C7	576	7G
6C8G	574	8G
6D4	587	5AY
6D6	576	6F
6D7	576	7H
6D8G	574	8A
6E5	576	6R
6E6	576	7B
6E7	576	7H
6E8G	574	8O
6F4	584	7BR
6F4	592	7BR
6F5	572	5M
6F6	572	7S
6F6	603	7S
6F7	577	7E
6F8G	574	8G
6G5	577	6R
6G6G	574	7S
6H4GT	574	5AF
6H5	577	6R
6H6	572	7Q
6H8G	574	8E
6J4	586	7BQ
6J5	572	6Q
6J6	586	7BF
6J6	592	7BF
6J7	572	7R
6J8G	574	8H
6K5GT	574	5U
6K6G	574	7S
6K7	572	7R
6K8	572	8K
6L5G	574	6Q
6L6	572	7AC
6L6	604	7AC
6L6GX	604	7AC
6L7	572	7T
6M6G	574	7S
6M7G	574	7R
6M8GT	574	8AU
6N4	586	7CA
6N4	592	7CA
6N5	576	6R
6N6G	574	7AU
6N7	572	8B
6N7	592	8B
6P5GT	574	6Q
6P7G	574	7U
6P8G	574	8K
6Q5G	587	5A
6Q6G	574	6Y
6Q7	572	7V
6R6G	574	6AW
6R7	572	7V
6S6GT	574	5AK
6S7	572	7R
6S8GT	574	8CB
6SA7	572	8R
6SB7Y	577	8R
6SC7	572	8S
6SD7GT	574	8M
6SE7GT	574	8N
6SF5	572	6AB
6FS7	572	7AZ
6SG7	572	8BK
6SH7	573	8BK
6SH7L	574	Fig 44
6SJ7	573	8M
6SJ7Y	573	8N
6SK7	573	8N
6SL7GT	574	8BD
6SN7GT	574	8BD
6SQ7	573	8Q
6SR7	573	8Q
6SS7	573	8N
6ST7	573	8Q
6SU7GTY	574	8BD
6SV7	573	7AL
6SZ7	573	8Q
6T5	577	6R
6T6GM	575	6Z
6T7	573	7V
6U5	577	6R
6U6GT	575	7AC
6U7G	575	7R
6V6	573	7AC
6V6GT	603	7AC
6V7G	575	7V
6W5G	590	6S
6W6GT	575	7AC
6W7G	575	7R
6X4	590	7CF
6X5	590	6S
6X6G	575	7AL
6Y5	590	6J
6Y6G	575	7AC
6Y7G	575	8B
6Z3	590	4G
6Z4	591	5D
6Z5	590	6K
6Z7G	575	8B
6ZY5G	590	6S
7A4	575	5AC
7A5	575	6AA
7A6	575	7AJ
7A7	575	8V
7A8	575	8U
7AB7	584	Fig. 5
7AF7	575	8AC
7AG7	575	Fig. 45
7AP4	589	5AJ
7B4	575	5AC
7B5	575	6AE
7B6	575	8W
7B7	575	8V
7B8	575	8X
7BP1	589	5AN
7C4	584	4AH
7C5	575	6AA
7C6	575	8W
7C7	575	8V
7CP1	589	6AZ
7D7	575	8AR
7DP4	589	Fig. 46
7E5	584	8BM
7E6	575	8W
7E7	575	8AE
7F7	575	8AC
7F8	575	8BW
7G7	575	8V
7G8	576	8BV
7GP4	589	Fig. 47
7H7	576	8V
7J7	576	8AR
7K7	576	8BF
7L7	576	8V
7N7	576	8AC
7Q7	576	8AL
7R7	576	8AE
7S7	576	8BL
7T7	576	8V
7V7	576	8V
7W7	576	8BJ
7X7	576	8BZ
7Y4	590	5AB
7Z4	590	5AB
9AP4	589	6AL
9CP4	589	4AF
9JP1	589	8BR
10	584	4D
10BP4	589	Fig. 48
10Y	592	4D
11/12	584	4F
12A5	581	7F
12A6	581	7AC
12A7	581	7K
12A7	590	7K
12A8G	581	8A
12AH7GT	581	8BE
12AL5	586	6BT
12AP4	589	6AL
12AT6	586	7BT
12AU6	586	7CC
12AU7	586	9A
12AU7	592	9A
12AW7	586	7CM
12B6M	581	6Y
12B7	582	8V
12B7ML	581	8V
12B8GT	581	8T
12BA6	586	7CC
12BD6	586	7CC
12BE6	586	7CH
12BF6	586	Fig. 37
12CS	581	8E
12CP4	589	4AF
12DP4	589	5AN
12E5GT	581	6Q
12F5GT	581	5M
12G7G	581	7V
12H6	581	7Q
12J6GT	581	6Q
12J7GT	581	7R
12K7GT	581	7R
12K8	581	8K
12L8GT	581	8BU
12Q7GT	581	7V
12SA8GT	581	Fig. 34
12SA7	581	8R
12SC7	581	8S
12SF5	581	6AB
12SF7	581	7AZ
12SG7	581	8BK
12SH7	582	8BK
12SJ7	582	8M
12SK7	582	8M
12SL7GT	582	8BD
12SN7GT	582	8BD
12SQ7	582	8Q
12SR7	582	8Q
12SW7	582	8Q
12SX7	582	8BD
12SY7	582	8R
12Z3	590	4G
12Z5	590	7L
14A4	582	5AC
14A5	582	6AA
14A7	582	8V
14AF7	582	7AC
14B6	582	8W
14B8	582	8X
14C5	582	6AA
14C7	582	8V
14E6	582	8W
14E7	582	8AE
14F7	582	8AC
14H7	582	8V
14J7	582	8AR
14N7	582	8AC
14Q7	582	8AL
14R7	582	8AE
14S7	582	8BL
14V7	582	8V
14W7	582	8BJ
14Y4	590	5AB
14Z3	590	4G
15	579	5F
15E	593	T-4AF
17	587	3G
18	582	6B
19	579	6C
20	584	4D
20J8GM	582	8H
21A7	582	8AR
22	584	4K
24-A	578	5E
24-G	593	2D
25A6	582	7S
25A7G	582	8F

Type	Page	Base
25A7G	590	8F
25AC5G	582	6Q
25B5	582	6D
25B6G	582	7S
25B8GT	582	8T
25C6G	582	7AC
25B8GT	582	8AF
25L6	582	7AC
25N6G	582	7W
25S	578	6M
25T	593	3G
25X6GT	590	7Q
25Y4GT	590	5AA
25Y5	590	6E
25Z3	590	4G
25Z4	590	5AA
25Z5	590	6E
25Z6	590	7Q
26	584	4D
26A6	586	7BK
26A7GT	583	8BU
26C6	586	7BT
26D6	586	7CH
27	578	5A
28D7	583	8BS
28Z5	590	5AB
30	579	4E
31	579	4D
32	579	4K
32L7GT	583	8Z
32L7GT	590	8Z
33	579	5K
34	579	4M
35/51	578	5E
35A5	583	6AA
35B5	586	7BZ
35L6G	583	7AC
35T	595	3G
35TG	595	2D
35W4	590	5BQ
35Y4	590	5AL
35Z3	590	4Z
35Z4GT	590	5AA
35Z5G	590	6AD
35Z6G	590	7Q
36	577	5E
37	577	5A
38	577	5F
39/44	577	5F
40	584	4D
40Z5GT	591	6AD
41	577	6B
42	577	6B
43	583	6B
45	578	4D
45Z3	591	5AM
45Z5GT	591	6AD
46	578	5C
47	578	5B
48	583	6A
49	579	5C
50	584	4D
50A5	583	6AA
50B5	586	7BZ
50C6GT	583	7AC
50L6GT	583	7AC
50T	597	2D
50X6	591	7AJ
50Y6GT	591	7Q
50Z6G	591	7Q
50Z7G	591	8AN
51	578	5E
52	577	Fig. 33
53	578	7B
53A	584	T-4B
55	578	6G
56	578	5A
56AS	577	5A
57	578	6F
57AS	577	6F
58	578	6F
58AS	577	6F
59	578	7A
70A7GT	583	8AB
70A7GT	591	8AB
70L7GT	583	8AA
70L7GT	591	8AA
71-A	584	4D
72	591	4P
73	591	4Y
75	577	6G
75TH	597	2D
75TL	597	2D
76	577	5A
77	577	6F
78	577	6F
79	577	6H
80	591	4C
81	591	4B
82	591	4C
83	591	4C
83-V	591	4AD
84/6Z4	591	5D
85	577	6G
85AS	577	6G
89	577	4D
99	584	4D
100TH	598	2D
100TL	598	2D
111H	597	2D
112-A	584	4D
117L7GT	583	8AO
117L7GT	591	8AO
117M7GT	583	8AO
117M7GT	591	8AO
117N7GT	583	8AV
117N7GT	591	8AV
117P7GT	583	8AV
117P7GT	591	8AV
117Z3	591	4BR
117Z4	591	5AA
117Z6GT	591	7Q
150T	600	2N
152TH	600	4BC
152TL	600	4BC
182-B	584	4D
183	584	4D
203-A	598	4E
203-H	598	T-3AB
204-A	602	T-1A
205D	592	4D
211	598	4E
212-E	602	T-2A
217A	591	T-3A
217C	591	T-3A
227A	598	T-4B
241B	602	T-2A
242A	597	4E
242B	598	4E
242C	598	4E
249B	591	Fig. 53
250TH	601	2N
250TL	601	2N
254A	604	T-4C
254B	605	T-4C
261A	598	4E
270A	602	T-1A
276A	598	4E
282A	606	T-4C
284B	599	T-3AB
284D	597	4E
295A	599	4E
300T	602	2N
303A	598	4E
304A	602	T-1A
304B	595	T-1A
304TH	602	4BC
304TL	602	4BC
305A	606	T-4CE
306A	604	T-5CB
307A	604	5J
308B	602	T-2A
310	593	4D
311	598	4E
311CH	599	Fig. 57
312A	606	T-6C
312E	602	T-2AA
316A	594	—
327A	598	T-4AD
327B	597	T-4AB
342D	598	4E
356A	596	T-4BD
361A	598	4E
376A	598	4E
410R	608	Fig. 58
482B	684	4D
483	584	4D
485	584	5A
527	602	T-4B
559	584	Fig. 18
705A	591	T-3AA
707B	608	Fig. 61
715B	605	—
717A	575	8BK
723AB	608	Fig. 60
756	595	4D
800	594	2D
801	593	4D
801A	593	4D
802	603	T-7C
803	607	5J
804	606	5J
805	599	T-3AB
806	601	2N
807	604	T-5BB
808	596	2D
809	594	3G
810	600	2N
811	596	3G
812	596	3G
812H	597	3G
813	607	Fig. 28
814	606	T-5D
815	604	T-8FA
816	591	4P
822	601	T-3AB
822S	601	2N
826	596	T-9A
828	606	5J
829	605	7BP
829A	605	7BP
829B	605	7BP
830	595	4D
830B	596	3G
831	602	T-1AA
832	604	7BP
832A	604	7BP
833A	602	7AB
834	596	2D
835	598	4E
836	591	4P
837	603	T-7C
838	599	4E
840	579	5J
841	593	4D
841A	596	3G
841SW	596	3G
843	593	5A
844	604	T-5BB
849	602	T-1A
850	607	T-3B
852	599	2D
860	607	T-4CB
861	607	T-1
864	584	4D
865	604	T-4C
866	591	4P
866A	591	4P
866B	591	4P
866jr	591	4B
871	591	4P
872	591	T-3A
872A	591	T-3A
874	587	4S
876	587	—
878	591	4P
879	591	4P
884	587	6Q
885	587	5A
886	587	—
902	589	Fig. 1
903	589	6AL
904	589	Fig. 3
905	589	Fig. 6
906P1	588	7AN
907	589	Fig. 6
908	589	7AN
908A	589	7CE
909	589	Fig. 6
910	589	7AN
911	589	7AN
912	589	Fig. 8
913	589	Fig. 1
914	589	Fig. 12
930B	596	3G
938	599	4E
950	579	5R
951	578	4M
954	584	5BB
955	584	5BC
955	591	5BC
956	584	5BB
957	584	5BD
958	584	5BD
958A	584	5BD
958A	592	5BD
959	584	5BE
967	587	3G
975A	587	T-3A
991	587	—
1003	591	4R
1005	591	T-9F
1006	591	4C
1201	584	8BM
1203	584	4AH
1204	584	Fig. 5
1206	576	8BV
1221	577	6F
1223	575	7R
1229	579	4K
1231	576	8V
1232	575	8V
1265	587	—
1266	587	4AJ
1273	576	8V
1275	591	4C
1276	584	4D
1284	583	Fig. 4
1291	580	7BE
1293	580	Fig. 2
1294	580	4AH
1299	580	6BB
1602	593	4D
1603	577	6F
1608	593	4D
1609	584	5B
1610	603	T-5CA
1611	573	7S
1612	573	7T
1613	603	7S
1614	604	7AC
1616	591	4P
1619	604	7AC
1620	573	7R
1621	573	7S
1622	573	7AC
1623	594	3G
1624	605	T-5DC
1625	605	5AZ
1626	592	6Q
1627	600	2N
1628	594	T-4BB
1629	583	8RA
1631	583	7AC
1632	583	7AC
1633	583	8BD
1634	583	8S
1635	575	8B
1641	591	T-4AG
1642	876	7BH
1644	583	8BU
1654	591	Fig. 41
1800	589	6AL
1801	589	Fig. 13
1803P4	589	6AL
1804P4	589	6AL
1805P1	588	11A
1806P1	588	11A
1809P1	589	8BR
1851	573	7R
1852	572	8N
1853	572	8N
2001	589	Fig. 2
2002	589	Fig. 1
2005	589	Fig. 1
2050	587	8BA
2051	587	8BA
24XH	589	Fig. 1
2523N/128AS	587	5A
5514	596	4BO
5516	604	7CL
5556	592	4D
5562	606	Fig. 45
7000	575	7R
7193	592	4AM
7700	577	6F
8000	600	2N
8001	606	7BM
8003	599	T-3AB
8005	597	3G
8008	591	Fig. 11
8010-R	595	—
8012	594	T-4BB
8013-A	591	4P
8016	591	4AC
8020	591	4P
8025	594	4AQ
9001	586	7PM
9002	586	7TM
9002	592	7TM
9003	586	7PM
9004	584	4BJ
9005	584	Fig. 16
9006	586	6BH
AT-340	607	Fig. 27
BA	590	4J
BH	590	4J
BR	590	4H
CE220	590	4P
CK501	580	—
CK502	580	—
CK503	580	—
CK504	580	—
CK505	580	—
CK506	580	—
CK507	580	—
CK509	581	—
CK510	581	—
CK515BX	581	—
CK1005	591	T-9F
CK1006	591	4C
CK1007	591	T-9G
CK1009	591	—
DR-3B27	590	4B
DR123C	599	Fig. 26
EF50	584	Fig. 14
F123A	599	Fig. 26
F127A	601	Fig. 26
G84	590	2B
GL2C44	584	Fig. 17
GL2C44	592	Fig. 17
GL5C24	600	Fig. 26
GL146	599	T-4G
GL152	599	T-4BG
GL159	601	T-4BG
GL169	601	T-4BG
GL446A	584	Fig. 19
GL446B	584	Fig. 19
GL446A	584	Fig. 17
GL559	584	Fig. 18
GL592	601	Fig. 52
GL8012A	594	T-4BB
HD203A	600	T-3AB
HF60	596	2D
HF75	597	2D
HF100	597	2D
HF120	598	—
HF125	598	—
HF130	599	—
HF140	598	—
HF150	599	—
HF175	599	—
HF200	600	2N
HF250	600	2N
HF300	601	2N
HK24	594	3G
HK54	594	2D
HK154	594	2D
HK158	594	2D
HK252L	600	T-4BF
HK253	591	T-3A
HK254	598	2N
HK257	606	7BM
HK257B	606	7BM
HK304L	602	4BC
HK354	600	2N
HK354C	600	2N
HK354D	600	2N
HK354E	600	2N
HK354F	600	2N
HK454H	602	2N
HK454L	602	2N
HK654	602	2N
HV10	600	2N
HV12	601	T-3AB
HV27	601	T-3AB
HY6J5GTX	592	6Q
HY6L6GTX	604	7AC
HY6V6GTX	603	7AC
HY24	592	4A
HY25	594	3G
HY30Z	594	4BO
HY31Z	594	T-4D
HY40	594	3G
HY40Z	595	3G
HY51A	596	3G
HY51B	596	3G
HY51Z	596	4BO
HY57	595	3G
HY60	603	T-5BB
HY61	604	T85BB
HY63	603	T-8DB
HY65	603	T-8DB
HY67	606	T-5DB
HY69	605	T-5D
HY75	593	2T
HY75A	593	2T
HY113	581	5K
HY114B	592	2T
HY115	581	5K
HY123	581	5K
HY125	581	5K
HY145	581	5K
HY155	581	5K
HY615	592	T-8AG
HY801A	593	4P
HY866jr	591	5P
HY1231Z	594	T-4
HY1269	605	T-5DB
HYE1148	592	T-8AG
KY21	587	—
KY866	587	Fig. 8
M54	585	—
M64	585	—
M74	585	—
NU-2C35	585	Fig. 38
PE340	607	Fig. 27
QK159	608	Fig. 63
RK10	593	4D
RK11	594	3G
RK12	594	3G
RK15	578	4D
RK16	578	5A
RK17	578	5F
RK18	594	3G
RK19	591	T-3A
RK20	605	5J
RK20A	605	5J
RK21	591	4P
RK22	591	T-4AG
RK23	606	T-7C
RK24	579	4D
RK24	592	4D
RK25	603	T-7C
RK25B	603	T-7C
RK28	607	5J
RK28A	607	5J
RK30	594	2D
RK31	594	3G
RK32	595	2D
RK33	592	T-7DA
RK34	592	T-7DC
RK35	595	2D
RK36	597	2D
RK37	595	2D
RK38	598	2D
RK39	604	T-5BB
RK41	604	T-5BB
RK42	581	4D
RK43	581	6C
RK44	603	T-7C
RK46	605	5J
RK47	606	T-5D
RK48	607	T-5D
RK48A	607	T-5D
RK49	604	T-6B
RK51	596	T-3G
RK52	596	3G
RK66	603	T-5BB
RK57	599	T-3AB
RK58	598	T-3AB
RK59	593	T-4D
RK60	591	T-4AG
RK61	587	—
RK62	587	4D
RK63	600	2N
RK63A	600	2N
RK64	603	T-5BB
RK65	607	T-3BC
RK66	605	5J
RK75	604	5J
RK100	593	T-6B
RK705A	591	T-3AA
RK866	591	—
RM208	587	—
RM209	587	—
T20	593	3G
T21	604	T-6B
T40	595	3G
T55	596	3G
T60	596	2D
T100	597	2D
T125	599	2N
T200	601	2N
T300	601	—
T814	601	T-3AB
T822	601	T-3AB
TB35	605	Fig. 54
TUF20	593	2T
TW75	597	2D
TW150	600	2N
TZ20	593	3G
TZ40	595	3G
UE100	597	2D
UE468	600	Fig. 57
UH35	596	3G
UH50	595	2D
UH51	595	2D
V70	596	T-3AB
V70A	597	T-3AB
V70B	596	3G
V70C	597	3G
V70D	597	3G
VR75	587	4AJ
VR90	587	4AJ
VR105	587	4AJ
VR150	587	4AJ
VT127A	598	T-4B
WE304A	595	2D
XXB	585	Fig. 9
XXD	583	8AC
XXL	576	5AC
XXFM	585	Fig. 10
Z225	591	4P
Z668	608	—

VACUUM-TUBE BASE DIAGRAMS

The diagrams on the following pages show standard socket connections corresponding to the base designations given in the column headed "Socket Connections" in the classified tube-data tables. Bottom views are shown throughout. Terminal designations are as follows:

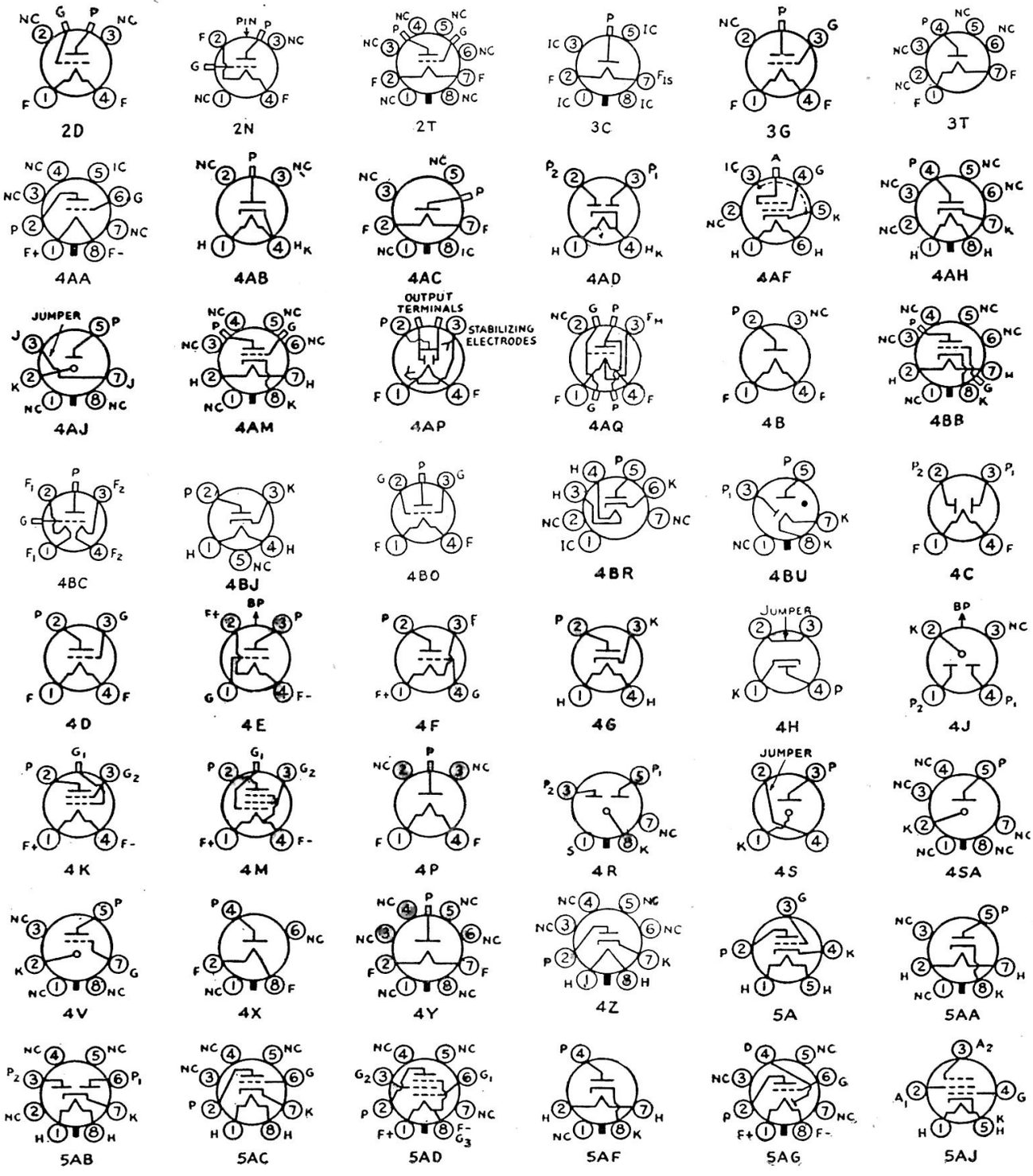
A = Anode	F = Filament	IS = Internal Shield	PBF = Beam-Forming Plates			S = Shell repeller
B = Beam	G = Grid	K = Cathode				
BP = Bayonet Pin	H = Heater	NC = No Connection	RC = Ray-Control Electrode			TA = Target
BS = Base sleeve	IC = Internal Connection	P = Plate (Anode)				● = Gas-Type Tube
D = Deflecting Plate		P1 = Starter-Anode	Ref = Reflector or			U = Unit

Alphabetical subscripts D, P, T and HX indicate, respectively, diode unit, pentode unit, triode unit or hexode unit in multi unit types. Subscript M, T or CT indicates filament or heater tap.

Generally when the No. 1 pin of a metal-type tube in Table I, with the exception of all triodes, is shown connected to the shell, the No. 1 pin in the glass (G or GT) equivalent is connected to an internal shield.

R.M.A. TUBE BASE DIAGRAMS

Bottom views are shown. Terminal designations on sockets are shown above.

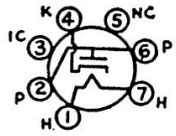


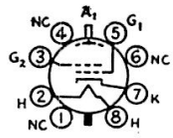
R.M.A. TUBE BASE DIAGRAMS

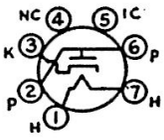
Bottom views are shown. Terminal designations on sockets are given on page 565.

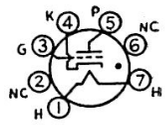

5AK


5AL

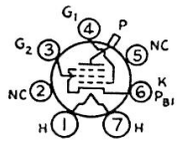

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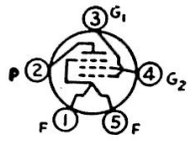

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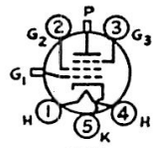

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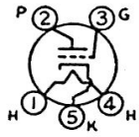

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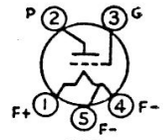

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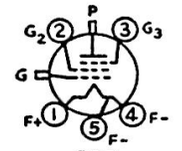

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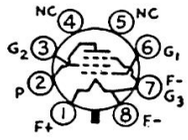

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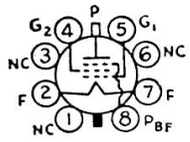

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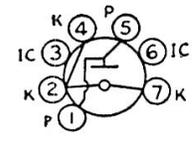

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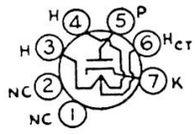

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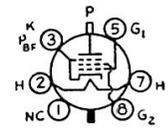

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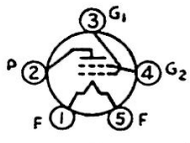

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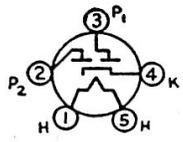

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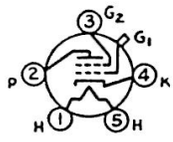

5BO


5BQ

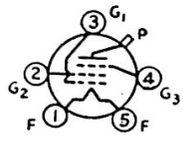

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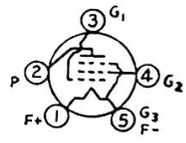

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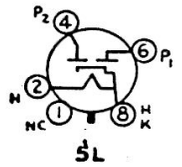

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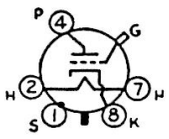

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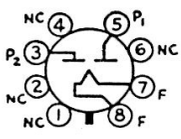

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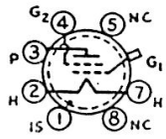

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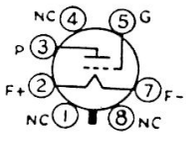

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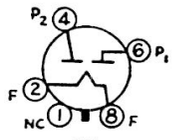

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5M


5Q

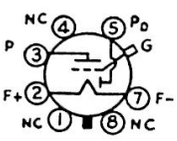

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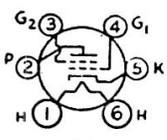

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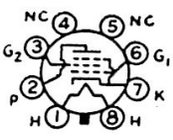

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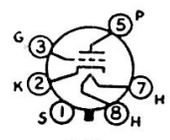

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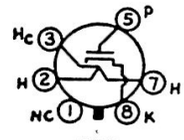

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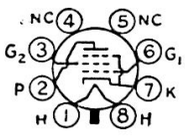

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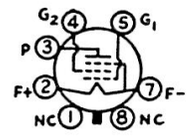

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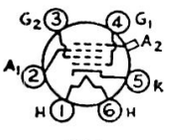

6AA


6AB

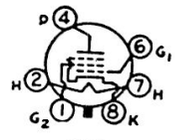

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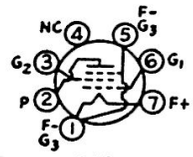

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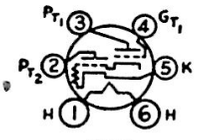

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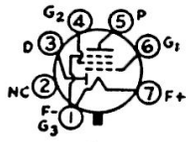

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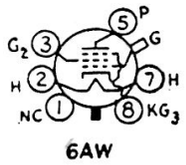

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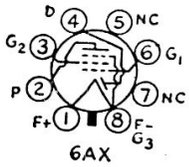

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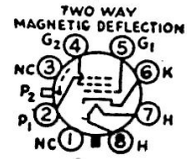

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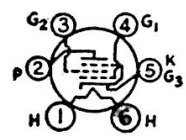

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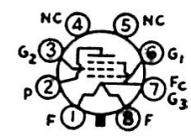

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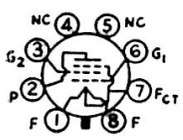

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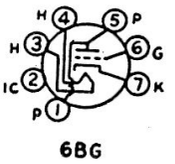

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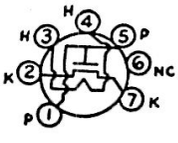

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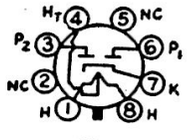

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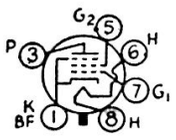

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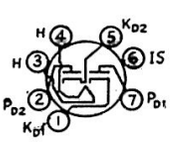

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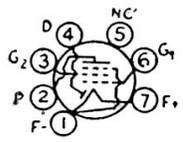

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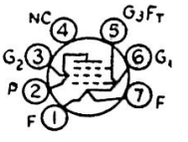

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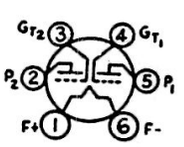

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6BQ


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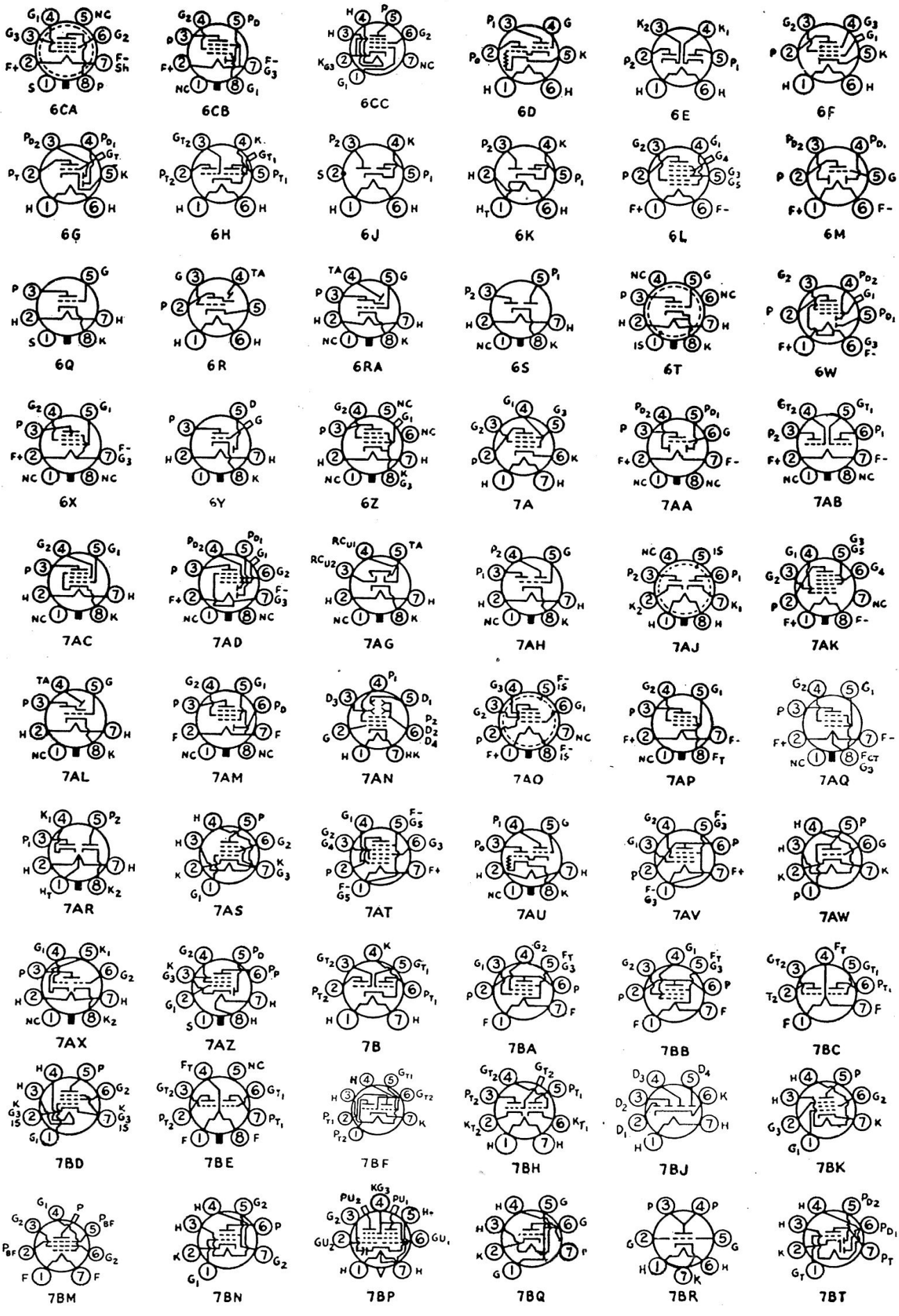

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6BX


6C

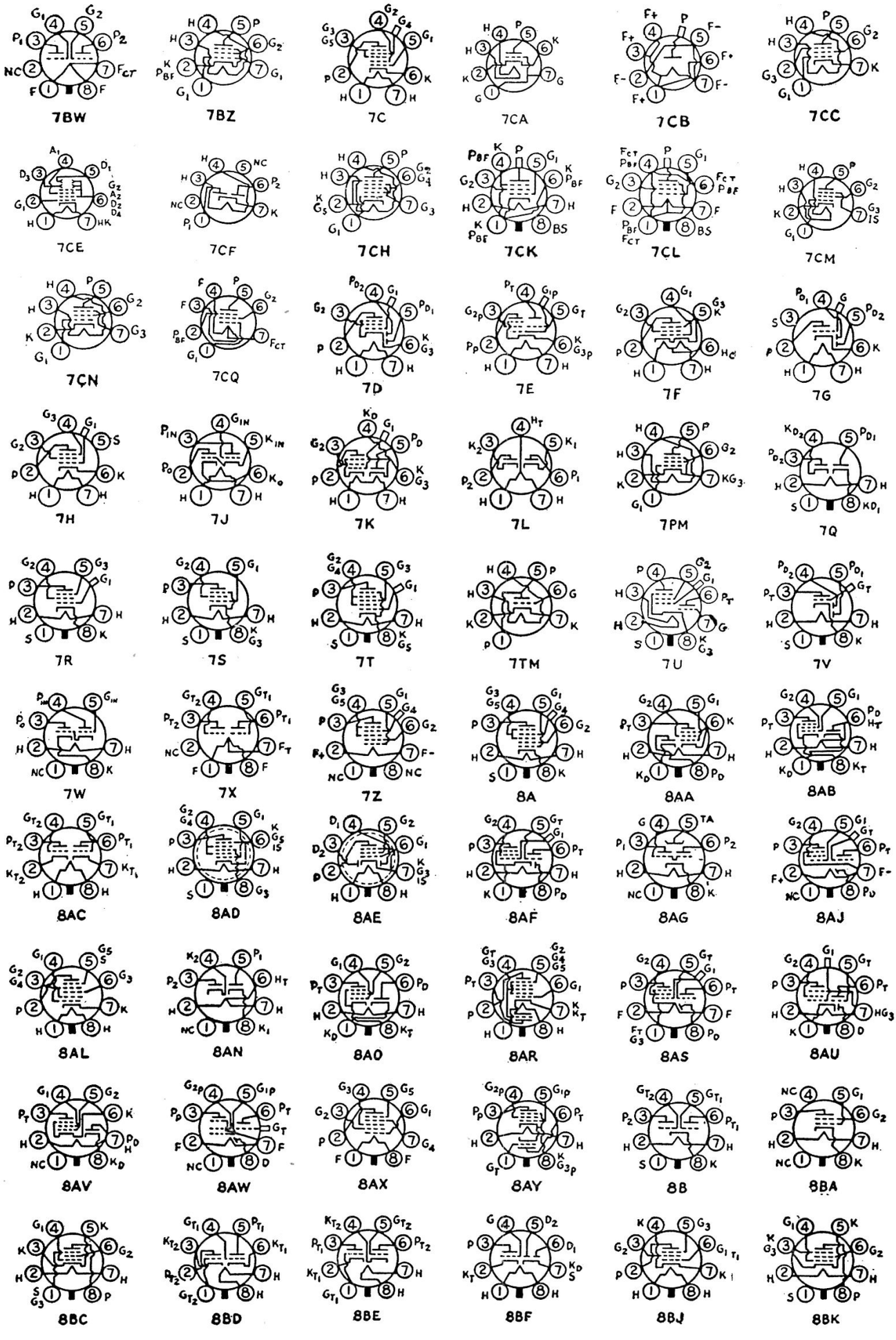
R.M.A. TUBE BASE DIAGRAMS

Bottom views are shown. Terminal designations on sockets are given on page 565.



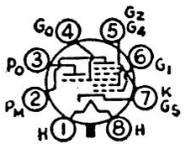
R.M.A. TUBE BASE DIAGRAMS

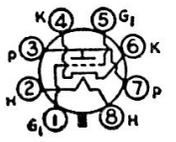
Bottom views are shown. Terminal designations on sockets are given on page 565.

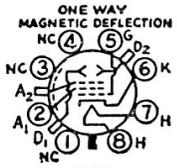


R.M.A. TUBE BASE DIAGRAMS

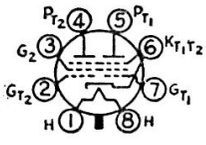
Bottom views are shown. Terminal designations on sockets are given on page 565.

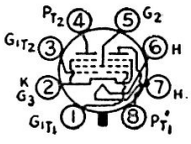

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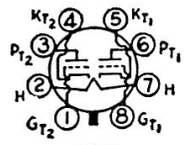


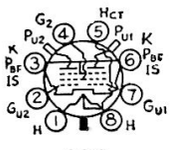
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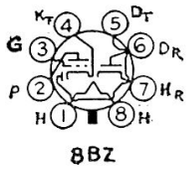

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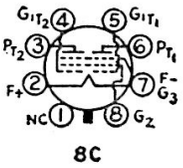

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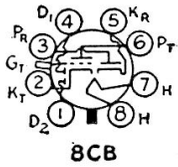

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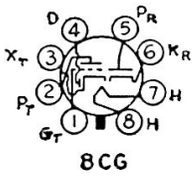

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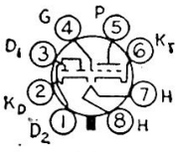

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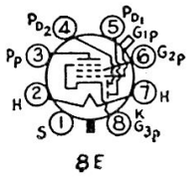

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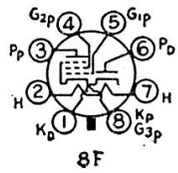

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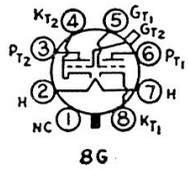

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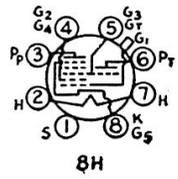

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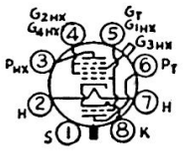

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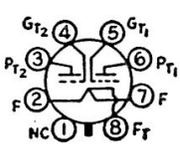

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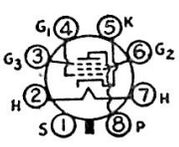

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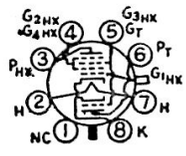

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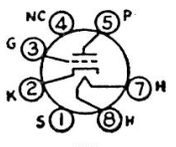

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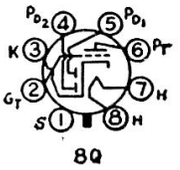

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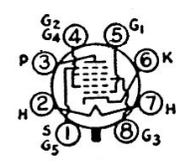

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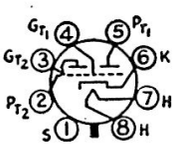

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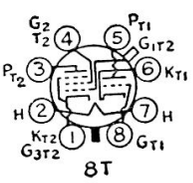

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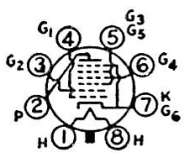

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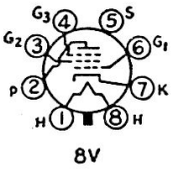

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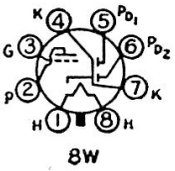

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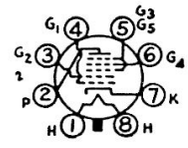

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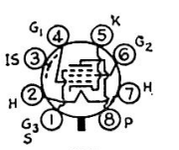

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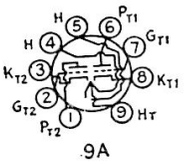

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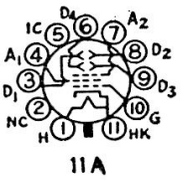

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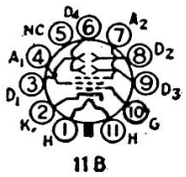

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8Y


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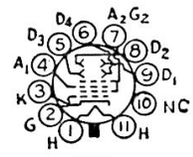

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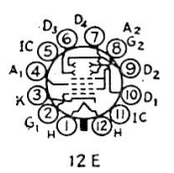

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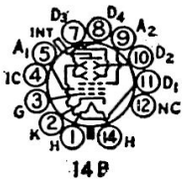

11E

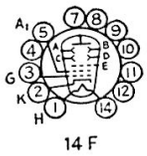

11F


11M

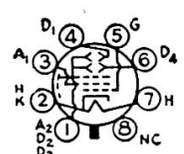

12E

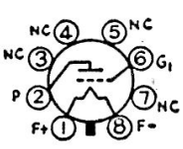

14A


14B


14F

SUPPLEMENTARY BASE DIAGRAMS


FIG. 1


FIG. 2

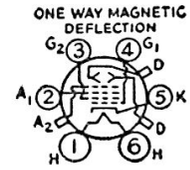
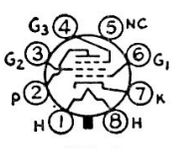
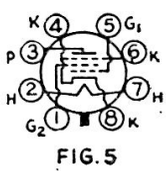
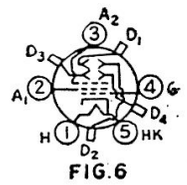
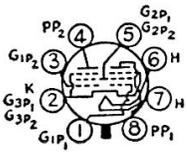


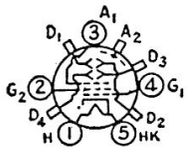
FIG. 3

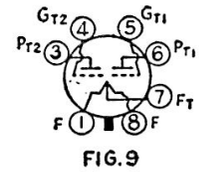

FIG. 4

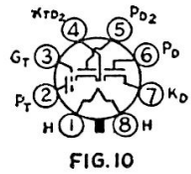

FIG. 5

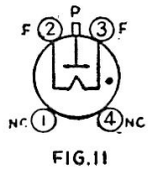

FIG. 6

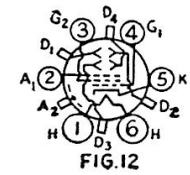

FIG. 7


FIG. 8


FIG. 9


FIG. 10


FIG. 11


FIG. 12

SUPPLEMENTARY BASE DIAGRAMS

Bottom views are shown. Terminal designations on sockets are given on page 565.

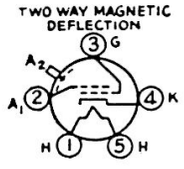


FIG. 13

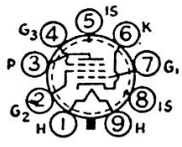


FIG. 14

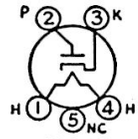


FIG. 15

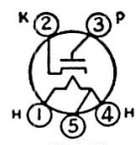


FIG. 16

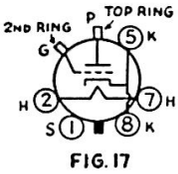


FIG. 17

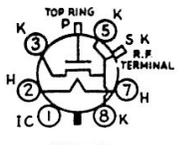


FIG. 18

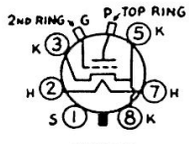


FIG. 19

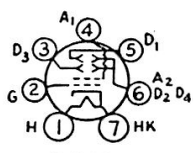


FIG. 20

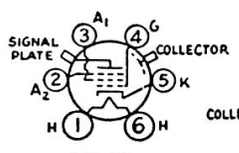


FIG. 21

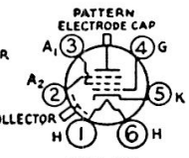


FIG. 22

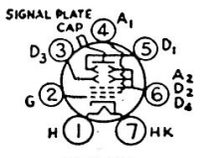


FIG. 23

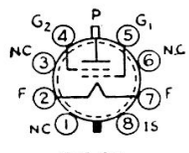


FIG. 24

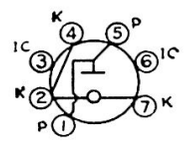


FIG 25

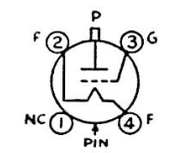


FIG. 26

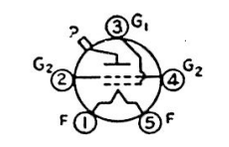


FIG. 27

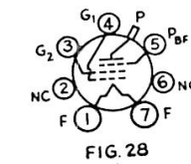


FIG. 28

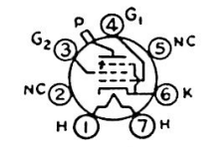


FIG. 29

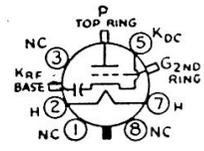


FIG. 30

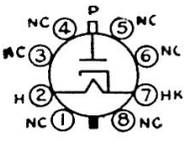


FIG 31

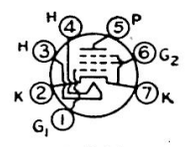


FIG 32

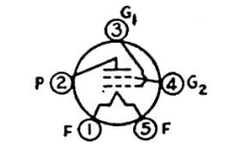


FIG. 33

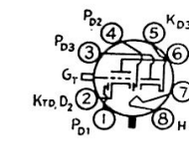


FIG 34

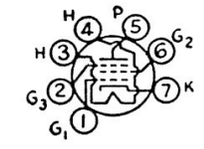


FIG. 36

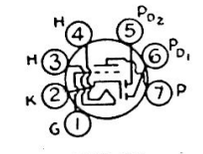


FIG. 37

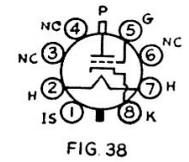


FIG. 38

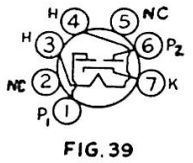


FIG. 39

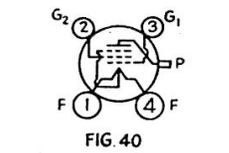


FIG. 40

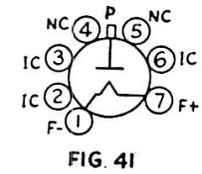


FIG. 41

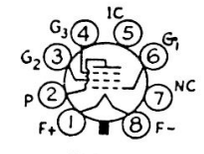


FIG. 42

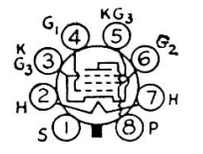


FIG. 44

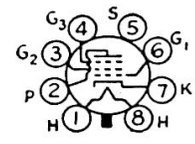


FIG. 45

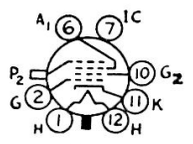


FIG. 46

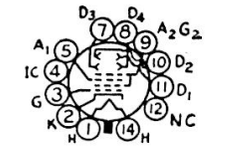


FIG. 47

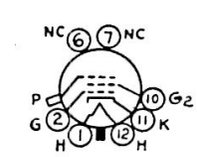


FIG. 48

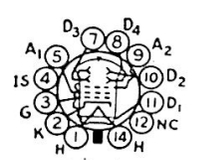


FIG. 49

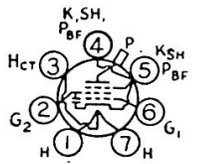


FIG. 50

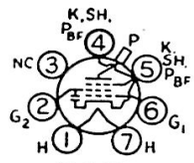


FIG. 51

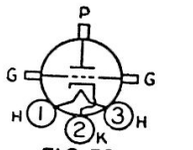


FIG. 52

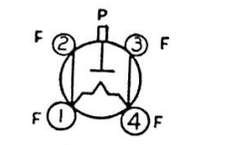


FIG. 53

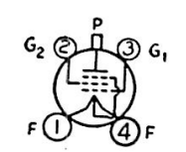


FIG. 54

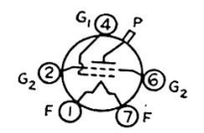


FIG. 55

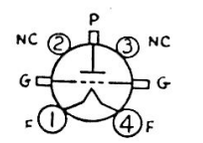


FIG 56

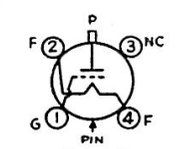


FIG. 57

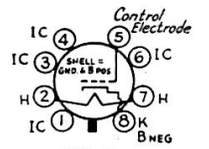


FIG. 58

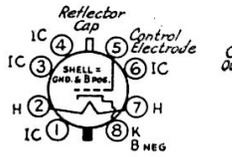


FIG. 59

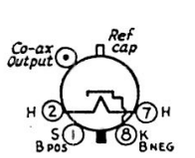


FIG. 60

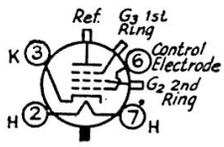


FIG. 61

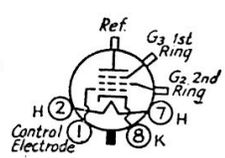


FIG. 62

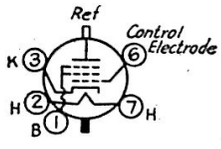
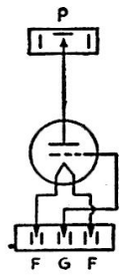


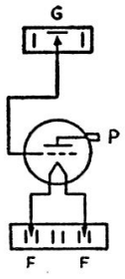
FIG. 63

SUPPLEMENTARY "T"-GROUP BASE DIAGRAMS

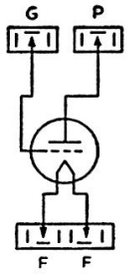
Bottom views are shown. Terminal designations on sockets are given on page 565.



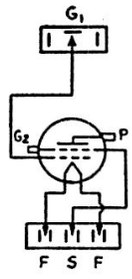
T-1A



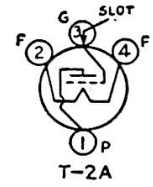
T-1AA



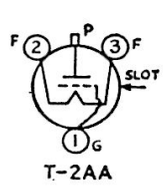
T-1AB



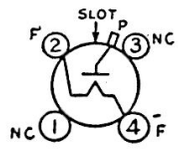
T-1B



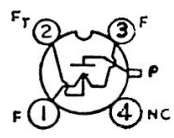
T-2A



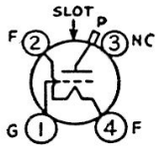
T-2AA



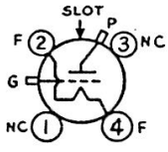
T-3A



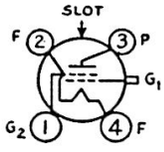
T-3AA



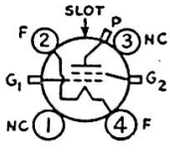
T-3AB



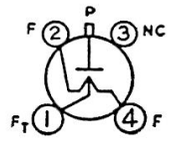
T-3AC



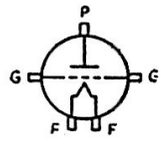
T-3B



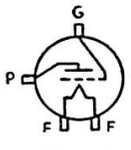
T-3BC



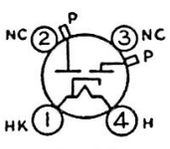
T-4A



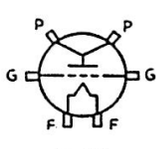
T-4AD



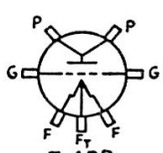
T-4AF



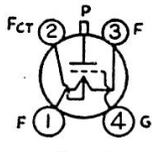
T-4AG



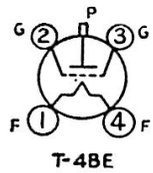
T-4B



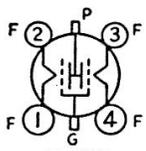
T-4BB



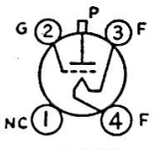
T-4BD



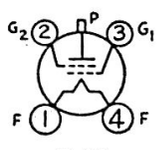
T-4BE



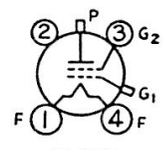
T-4BF



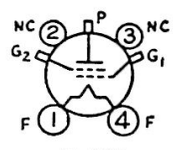
T-4BG



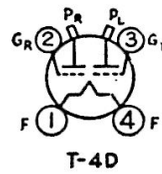
T-4C



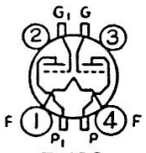
T-4CB



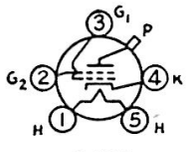
T-4CE



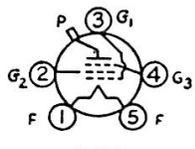
T-4D



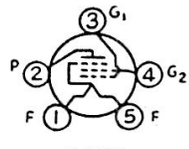
T-4DB



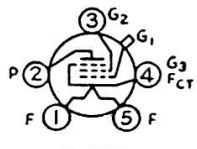
T-5BB



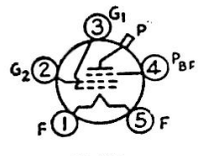
T-5C



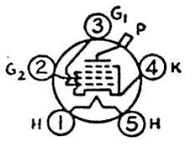
T-5CA



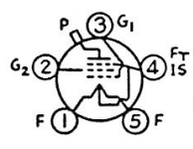
T-5CB



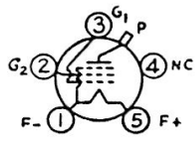
T-5D



T-5DA



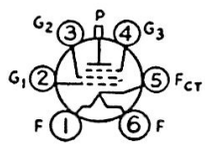
T-5DB



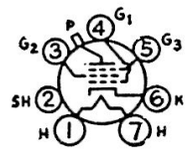
T-5DC



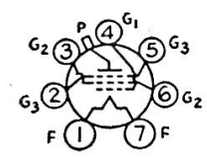
T-6B



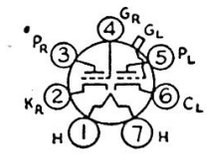
T-6C



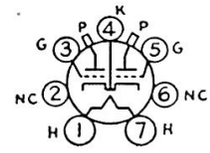
T-7C



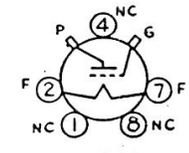
T-7CB



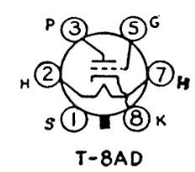
T-7DA



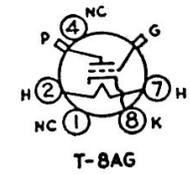
T-7DC



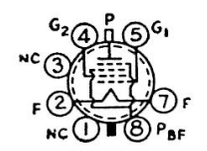
T-8AC



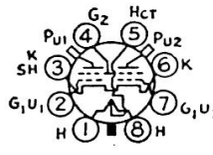
T-8AD



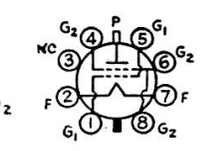
T-8AG



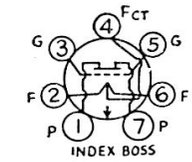
T-8DB



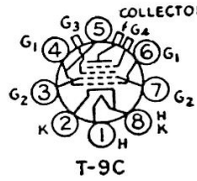
T-8FA



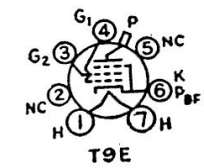
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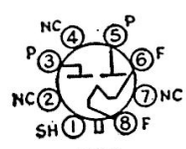
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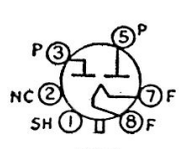
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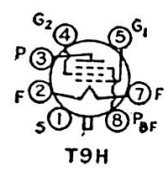
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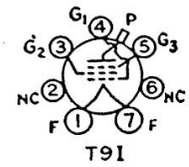
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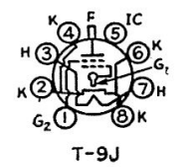
T9G



T9H



T9I



T-9J

TABLE I—METAL RECEIVING TUBES

Characteristics given in this table apply to all tubes having type numbers shown, including metal tubes, glass tubes with "G" suffix, and bantam tubes with "GT" suffix. For "G" and "GT" tubes not listed (not having metal counterparts), see Tables II, VII, VIII and IX.

Type	Name	Socket Connections	Fil. or Heater		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
6A8	Pentagrid Converter	8A	6.3	0.3	—	—	—	Osc.-Mixer	250	— 3.0	100	3.2	3.3	Anode-grid (No. 2) 250 volts max. thru 20,000 ohms					6A8
6AB7 1853	Television Amp. Pentode	8N	6.3	0.45	8	5	0.015	Class-A Amp.	300	— 3.0	200	3.2	12.5	700000	5000	3500	—	—	6AB7 1853
6AC7 1852	Television Amp. Pentode	8N	6.3	0.45	11	5	0.015	Class-A Amp.	300	— 2.0	150	2.5	10	750000	9000	6750	—	—	6AC7 1852
6AG7	Video Beam Power Amp.	8Y	6.3	0.65	13	7.5	0.06	Class-A_1 Amp.	300	— 3.0	150	7/9	30/30.5	130000	11000	—	10000	3.0	6AG7
6AJ7	Sharp-Cut-Off Pentode	8N	6.3	0.45	—	—	—	Class-A Amp.	300	160*	300	2.5	10	1000000	9000	—	—	—	6AJ7
6AK7	Pentode Power Amp.	8Y	6.3	0.65	13	7.5	0.06	Class-A Amp.	300	— 3	150	7	30	130000	11000	—	10000	3.0	6AK7
6B8	Duplex-Diode Pentode	8E	6.3	0.3	6	9	0.005	Class-A Amp.	250	— 3.0	125	2.3	9.0	650000	1125	730	—	—	6B8
6C5	Triode Detector, Amplifier	6Q	6.3	0.3	3	11	2	Class-A Amp.	250	— 8.0	—	—	8.0	10000	2000	20	—	—	6C5
								Bias Detector	250	—17.0	—	—	Plate current adjusted to 0.2 ma. with no signal						
6F5	High-μ Triode	5M	6.3	0.3	5.5	4	2.3	Class-A Amp.	250	— 1.3	—	—	0.2	66000	1500	100	—	—	6F5
								Class-A_1 Pent.[5]	250 315	—16.5 —22.0	250 315	6.5 8.0	36 [7] 42	80000 75000	2500 2650	200 200	7000 7000	3.2 5.0	
6F6	Pentode Power Amplifier	7S	6.3	0.7	6.5	13	0.2	Triode Amp.[1]	250	—20.0	—	—	34 [7]	2600	2600	6.8	4000	0.85	6F6
								Class-AB_2 Amp.[6] Class-AB_2 Amp.[6]	375 350	340* —38.0	250 —	18 [7] —	77 [7] 22.5	Power output for 2 tubes at stated load, plate-to-plate			10000 [8] 6000 [8]	19.0 18.0	
6H6	Twin Diode	7Q	6.3	0.3	—	—	—	Rectifier	Max. a.c. voltage per plate = 100 r.m.s. Max. output current 4.0 ma. d.c.										6H6
6J5	Detector-Amplifier Triode	6Q	6.3	0.3	3.4	3.6	3.4	Class-A Amp.	250	— 8.0	—	—	9	7700	2600	20	—	—	6J5
6J7	Triple-Grid Detector, Amp.	7R	6.3	0.3	7	12	0.005	R.F. Amp.	250	— 3.0	100	0.5	2.0	1.5 meg.	1225	1500	—	—	6J7
								Bias Detector	250	— 4.3	100	Cathode current 0.43 ma.		—	—	0.5 meg.	—	
6K7	Triple-Grid Variable-μ Amp.	7R	6.3	0.3	7	12	0.005	R.F. Amp.	250	— 3.0	125	2.6	10.5	600000	1650	990	—	—	6K7
								Mixer	250	—10.0	100	—	—	—	Oscillator peak volts = 7.0				
6K8	Triode-Hexode Converter	8K	6.3	0.3	—	—	—	Converter	250	— 3.0	100	6	2.5	Triode Plate (No. 2) 100 volts, 3.8 ma.					6K8
6L6	Beam Power Amplifier	7AC	6.3	0.9	10	12	0.4	Single Tube Class A_1	250 300	170* 220*	250 200	5.4/7.2 3.0/4.6	75/78 51/54.5	—	—	—	2500 4500	6.5 6.5	6L6
								Single Tube Class A_1	250 350	—14.0 —18.0	250 250	5.0/7.3 2.5/7.0	72/79 54/66	22500 33000	6000 5200	—	2500 4200	6.5 10.8	
								P.P. Class A_1 [6]	270	125*	270	11/17	134/145	—	—	—	5000 [8]	18.5	
								P.P. Class A_1 [6]	250 270	—16.0 —17.5	250 270	10/16 11/17	120/140 134/155	24500 23500	5500 5700	—	5000 [8] 5000 [8]	14.5 17.5	
								P.P. Class AB_1 [5]	360	250*	270	5/17	88/100	Power output for 2 tubes. Load plate-to-plate			9000 [8]	24.5	
								P.P. Class AB_1 [6]	360	—22.5	270	5/15	88/132				6600 [8]	26.5	
								P.P. Class AB_2 [6]	360 360	—18.0 —22.5	225 270	3.5/11 5/16	78/142 88/205				6000 [8] 3800 [8]	31.0 47.0	
6L7	Pentagrid Mixer Amplifier	7T	6.3	0.3	—	—	—	R.F. Amp.	250	— 3.0	100	5.5	5.3	800000	1100	—	—	—	6L7
								Mixer	250	— 6.0	150	8.3	3.3	Over 1 meg.	Oscillator-grid (No. 3) voltage = —15				
6N7	Twin Triode	8B	6.3	0.8	—	—	—	Class-B Amp.	300	0	—	—	35–70	—	—	—	8000	10.0	6N7
6Q7	Duplex-Diode Triode	7V	6.3	0.3	5	3.8	1.4	Triode Amp.	250	— 3.0	—	—	1.1	58000	1200	70	—	—	6Q7
6R7	Duplex-Diode Triode	7V	6.3	0.3	4.8	3.8	2.4	Triode Amp.	250	— 9.0	—	—	9.5	8500	1900	16	10000	0.28	6R7
6S7	Triple-Grid Variable-μ	7R	6.3	0.15	6.5	10.5	0.005	Class-A Amp.	250	— 3.0	100	2.0	8.5	1000000	1750	1750	—	—	6S7
6SA7	Pentagrid Converter	8R[2]	6.3	0.3	—	—	—	Converter	250	0[3]	100	8.0	3.4	800000	Grid No. 1 resistor 20000 ohms				6SA7
6SC7	Twin-Triode Amplifier	8S	6.3	0.3	—	—	—	Class-A Amp.	250	— 2.0	—	—	2.0	53000	1325	70	—	—	6SC7
6SF5	High-μ Triode	6AB	6.3	0.3	4	3.6	2.4	Class-A Amp.	250	— 2.0	—	—	0.9	66000	1500	100	—	—	6SF5
6SF7	Diode Variable-μ Pentode	7AZ	6.3	0.3	5.5	6	0.004	Class-A Amp.	250	— 1.0	100	3.3	12.4	700000	2050	—	—	—	6SF7
6SG7	Triple-Grid Semivariable-μ	8BK	6.3	0.3	8.5	7	0.003	H.F. Amp.	250	— 2.5	150	3.4	9.2	Over 1 meg.	4000	—	—	—	6SG7

Type	Name	Socket Connections	Fil. or Heater		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
6SH7	Triple-Grid Amplifier	8BK	6.3	0.3	8.5	7	0.003	H.F. Amp.	250	— 1.0	150	4.1	10.8	900000	4900	—	—	—	6SH7
6SJ7 [4]	Triple-Grid Amplifier	8N	6.3	0.3	6	7	0.005	Class-A Amp.	250	— 3.0	100	0.8	3	1500000	1650	2500	—	—	6SJ7
6SK7	Triple-Grid Variable-μ	8N	6.3	0.3	6	7	0.003	Class-A Amp.	250	— 3.0	100	2.4	9.2	800000	2000	1600	—	—	6SK7
6SQ7	Duplex-Diode Triode	8Q	6.3	0.3	3.6	3.2	1.80	Class-A Amp.	250	— 2.0	—	—	0.8	91000	1100	100	—	—	6SQ7
6SR7	Duplex-Diode Triode	8Q	6.3	0.3	3.6	2.8	2.40	Class-A Amp.	250	— 9.0	—	—	9.5	8500	1900	16	—	—	6SR7
6SS7	Triple-Grid Variable-μ	8N	6.3	0.15	5.5	7.0	0.004	Class-A Amp.	250	— 3.0	100	2.0	9.0	1000000	1850	—	—	—	6SS7
6ST7	Duplex-Diode Triode	8Q	6.3	0.15	2.8	3	1.50	Class-A Amp.	250	— 9.0	—	—	9.5	8500	1900	16	—	—	6ST7
6SV7	Diode R.F. Pentode	7AZ	6.3	0.3	6.5	6	0.004	Class-A Amp.	250	— 1	150	2.8	7.5	800000	3400	—	—	—	6SV7
6SZ7	Duplex-Diode Triode	8Q	6.3	0.15	2.6	2.8	1.10	Class-A Amp.	250	— 3	—	—	1.0	58000	1200	70	—	—	6SZ7
6T7	Duplex-Diode Triode	7V	6.3	0.15	1.8	3.1	1.70	Class-A Amp.	250	— 3.0	—	—	1.2	62000	1050	65	—	—	6T7
6V6	Beam Power Amplifier	7AC	6.3	0.45	2.0	7.5	0.7	Class-A_1 Amp.[5]	250	—12.5	250	4.5/7.0	45/47	52000	4100	218	5000	4.5	6V6
								Class-AB_1 Amp.[6]	250	—15.0	250	5/13	70/79	60000	3750	—	10000 [8]	10.0	
									285	—19.0	285	4/13.5	70/92	65000	3600	—	8000 [8]	14.0	
1611	Pentode Power Amplifier	7S	6.3	0.7	—	—	—	Audio Amp.	Characteristics same as 6F6										1611
1612	Pentagrid Amplifier	7T	6.3	0.3	7.5	11	0.001	Class-A Amp.	250	— 3.0	100	6.5	5.3	600000	1100	880	—	—	1612
1620	Triple-Grid Det.-Amp.	7R	6.3	0.3	—	—	—	Class-A Amp.	Characteristics same as 6J7										1620
1621	Power Amplifier Pentode	7S	6.3	0.7	—	—	—	Class-AB_2 Amp.[6]	300	—30.0	300	6.5/13	38/69	—	—	—	4000 [8]	5.0	1621
								Class-A_1 Amp.[6] [1]	330	500*	—	—	55/59	—	—	—	5000 [8]	2.0	
1622	Beam Power Amplifier	7AC	6.3	0.9	—	—	—	Class-A_1 Amp.	300	—20.0	250	4/10.5	86/125	—	—	—	4000	10.0	1622
1851	Television Amp. Pentode	7R	6.3	0.45	11.5	5.2	0.02	Class-A Amp.	300	— 2.0	150	2.5	10	750000	9000	6750	—	—	1851

* Cathode resistor—ohms.

[1] Screen tied to plate.
[2] For 6SA7GT use base diagram 8AD.
[3] Grid bias—2 volts if separate oscillator excitation is used.
[4] Also Type "6SJ7Y."
[5] Values are for single tube.
[6] Values are for two tubes in push-pull.
[7] Max.-signal value.
[8] Plate-to-plate value.

TABLE II—6.3-VOLT GLASS TUBES WITH OCTAL BASES

(For "G" and "GT"-Type Tubes Not Listed Here, See Equivalent Type in Table I; Characteristics and Connections Will Be Identical)

Type	Name	Socket Connections	Fil. or Heater		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
2C22	Triode Amplifier	4AM	6.3	0.3	2.2	0.7	3.60	Class-A Amp.	300	—10.5	—	—	11	6600	3000	20	—	—	2C22
6A5G	Triode Power Amplifier	6T	6.3	1.0	—	—	—	Class-A Amp.[4]	250	—45.0	—	—	60	800		4.2	2500	3.75	6A5G
								P.P. Class AB [5]	325	—68.0	—	—	80	—	5250	—	3000 [6]	15.0	
								P.P. Class AB [5]	325	850*			80	—		—	5000 [6]	10.0	
6AB6G	Direct-Coupled Amplifier	7AU	6.3	0.5	—	—	—	Class-A Amp.	250	0	Input		5.0	40000	1800	72	8000	3.5	6AB6G
									250	0	Output		34						
6AC5G	High-μ Power-Amplifier Triode	6Q	6.3	0.4	—	—	—	P.P. Class B [5]	250	0	—	—	5.0	36700	3400	125	10000 [6]	8.0	6AC5G
								Dyn.-Coupled	250	—	—	—	32				7000	3.7	
6AC6G	Direct-Coupled Amplifier	7AU	6.3	1.1	—	—	—	Class-A Amp.	180	0	Input		7.0	—	3000	54	4000	3.8	6AC6G
									180	0	Output		45						
6AD5G	High-μ Triode	6Q	6.3	0.3	—	—	—	Class-A Amp.	250	— 2.0	—	—	0.9	—	1500	100	—	—	6AD5G
6AD6G	Electron-Ray Tube	7AG	6.3	0.15	—	—	—	Indicator	100	0 for 90°; —23 for 135°; 45 for 0°. Target current 1.5 ma.									6AD6G
6AD7G	Triode-Pentode	8AY	6.3	0.85	—	—	—	Triode Amp.	250	—25.0	—	—	4.0	19000	325	6.0	—	—	6AD7G
								Pentode Amp.	250	—16.5	250	6.5	34	80000	2500	—	7000	3.2	
6AE5G	Triode Amplifier	6Q	6.3	0.3	—	—	—	Class-A Amp.	95	—15.0	—	—	7.0	3500	1200	4.2	—	—	6AE5G
6AE6G	Twin-Plate Triode with Single Grid	7AH	6.3	0.15	Remote cut-off			Class-A Amp.	250	— 1.5	—	—	6.5	25000	1000	25	—	—	6AE6G
					Sharp cut-off			Class-A Amp.	250	— 1.5			4.5	35000	950	33			

TABLE II—6.3-VOLT GLASS TUBES WITH OCTAL BASES—*Continued*

Type	Name	Socket Connections	Fil. or Heater		Capacitance $\mu\mu$fd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
6AE7GT	Twin-Input Triode	7AX	6.3	0.5	—	—	—	Driver Amplifier	250	−13.5	—	—	5.0	9300	1500	14	—	—	6AE7GT
6AF5G	Triode Amplifier	6Q	6.3	0.3	—	—	—	Class-A Amplifier	180	−18.0	—	—	7.0	—	1500	7.4	—	—	6AF5G
6AF7G	Twin Electron Ray	8AG	6.3	0.3	—	—	—	Indicator Tube											6AF7G
6AG6G	Power-Amplifier Pentode	7S	6.3	1.25	—	—	—	Class-A Amplifier	250	− 6.0	250	6.0	32	—	10000	—	8500	3.75	6AG6G
6AH5G	Beam Power Amplifier	6AP	6.3	0.9	—	—	—	Class-A Amplifier	350	−18	250	—	—	33000	5200	—	4200	10.8	6AH5G
6AH7GT	Twin Triode	8BE	6.3	0.3	—	—	—	Converter & Amp.	250	− 9.0	—	—	12[1]	6600	2400	16	—	—	6AH7GT
6AL6G	Beam Power Amplifier	6AM	6.3	0.9	—	—	—	Class-A Amplifier	250	−14.0	250	5.0	72	22500	6000	—	2500	6.5	6AL6G
6AL7GT	Electron-Ray Tube	8CH	6.3	0.15	—	—	—	Indicator	Outer edge of any of the three illuminated areas displaced 1/16 in. min. outward with +5 volts to its electrode. Similar inward disp. with −5 volts. No pattern with −6 volts grid.										6AL7GT
6AQ7GT	Duplex Diode Triode	8CK	6.3	0.3	2.3	1.5	2.8	Class-A Amplifier	250	− 2.0	—	—	2.3	44000	1600	70	—	—	6AQ7GT
6AR6	Beam Power Amp.	6BQ	6.3	1.2	11	7	0.55	Class-A Amplifier	250	−22.5	250	5	77	21000	5400	95	—	—	6AR6
6AR7GT	Diode Triode Rectifier	8CG	6.3	0.3	1.4	1	2	Class-A Amplifier	250	− 2	—	—	1.3	66500	1050	70	—	—	6AR7GT
6AS7G	Low-Mu Twin Triode	8BD	6.3	2.5	—	—	—	D.C. Amplifier	135	250*	—	—	125	280	7500	2.1	—	—	6AS7G
6B4G	Triode Power Amplifier	5S	6.3	1.0	—	—	—	Power Amplifier	Characteristics same as Type 6A3—Table IV							—	—	—	6B4G
6B6G	Duplex-Diode High-μ Triode	7V	6.3	0.3	1.7	3.8	1.7	Detector-Amplifier	Characteristics same as Type 75—Table IV							—	—	—	6B6G
6BG6	Beam Power Amplifier	5BT	6.3	0.9	11	6.5	0.5	Deflection Amp.	400	−50	350	6.0	70	—	6000	—	—	—	6BG6
6C8G	Twin Triode	8G	6.3	0.3	—	—	—	Amp. 1 Section	250	− 4.5	—	—	3.1	26000	1450	38	—	—	6C8G
6D8G	Pentagrid Converter	8A	6.3	0.15	—	—	—	Converter	250	− 3.0	100	Cathode current 13.0 Ma.			Anode grid (No. 2) Volts = 250[3]				6D8G
6E8G	Triode-Hexode Converter	8O	6.3	0.3	—	—	—	Osc.-Mixer	250	− 2.0	Triode Plate 150 volts								6E8G
6F8G	Twin Triode	8G	6.3	0.6	—	—	—	Amplifier	250	− 8.0	—	—	9[1]	7700	2600	20	—	—	6F8G
6G6G	Pentode Power Amplifier	7S	6.3	0.15	—	—	—	Class-A Amplifier	180	− 9.0	180	2.5	15	175000	2300	400	10000	1.1	6G6G
								Class-A Amplifier[2]	180	−12.0	—	—	—	4750	2000	9.5	12000	0.25	
6H4GT	Diode Rectifier	5AF	6.3	0.15	—	—	—	Detector	100	—	—	—	4.0	—	—	—	—	—	6H4GT
6H8G	Duo-Diode High-μ Pentode	8E	6.3	0.3	—	—	—	Class-A Amplifier	250	− 2.0	100	—	8.5	650000	2400	—	—	—	6H8G
6J8G	Triode Heptode	8H	6.3	0.3	—	—	—	Converter	250	− 3.0	100	2.8	1.2	Anode-grid (No. 2) 250 volts max.[3] 5 ma.					6J8G
6K5GT	High-μ Triode	5U	6.3	0.3	2.4	3.6	2.0	Class-A Amplifier	250	− 3.0	—	—	1.1	50000	1400	70	—	—	6K5GT
6K6G	Pentode Power Amplifier	7S	6.3	0.4	—	—	—	Class-A Amplifier	Characteristics same as Type 41—Table IV										6K6G
6L5G	Triode Amplifier	6Q	6.3	0.15	—	—	—	Class-A Amplifier	250	− 9.0	—	—	8.0	—	1900	17	—	—	6L5G
6M6G	Power Amplifier Pentode	7S	6.3	1.2	—	—	—	Class-A Amplifier	250	− 6.0	250	4.0	36	—	9500	—	7000	4.4	6M6G
6M7G	Triple-Grid Amplifier	7R	6.3	0.3	—	—	—	R.F. Amplifier	250	− 2.5	125	2.8	10.5	900000	3400	—	—	—	6M7G
6M8GT	Diode Triode Pentode	8AU	6.3	0.6	—	—	—	Triode Amplifier	100	—	—	—	0.5	91000	1100	—	—	—	6M8GT
								Pentode Amplifier	100	− 3.0	100	—	8.5	200000	1900	—	—	—	
6N6G	Direct-Coupled Amplifier	7AU	6.3	0.8	—	—	—	Power Amplifier	Characteristics same as Type 6B5—Table IV							—	—	—	6N6G
6P5GT	Triode Amplifier	6Q	6.3	0.3	3.4	5.5	2.6	Class-A Amplifier	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	6P5GT
6P7G	Triode-Pentode	7U	6.3	0.3	—	—	—	Class-A Amplifier	Characteristics same as 6F7—Table IV										6P7G
6P8G	Triode-Hexode Converter	8K	6.3	0.8	—	—	—	Osc.-Mixer	250	− 2.0	75	1.4	1.5	Triode Plate 100 v. 2.2 ma.					6P8G
6Q6G	Diode-Triode	6Y	6.3	0.15	—	—	—	Class-A Amplifier	250	− 3.0	—	—	1.2	—	1050	65	—	—	6Q6G
6R6G	Pentode Amplifier	6AW	6.3	0.3	—	—	—	Class-A Amplifier	250	− 3.0	100	1.7	7.0	—	1450	1160	—	—	6R6G
6S6GT	Triple-Grid Variable-μ	5AK	6.3	0.45	—	—	—	R.F. Amplifier	250	− 2.0	100	3.0	13	350000	4000	—	—	—	6S6GT
6S8GT	Triple Diode Triode	8CB	6.3	0.3	1.2	5	2	Class-A Amplifier	250	− 2.0	—	—	0.9	91000	—	100	—	—	6S8GT
6SD7GT	Triple-Grid Semi-Variable-μ	8M	6.3	0.3	9	7.5	.0035	R.F. Amplifier	250	− 2.0	100	1.9	6.0	1000000	3600	—	—	—	6SD7GT
6SE7GT	Triple-Grid Amplifier	8N	6.3	0.3	8	7.5	.005	R.F. Amplifier	250	− 1.5	100	1.5	4.5	1100000	3400	3750	—	—	6SE7GT
6SH7L	Pentode R.F. Amp.	Fig. 44	6.3	0.3	—	—	—	Class-A Amplifier	100	− 1.0	100	2.1	5.3	350000	4000	—	—	—	6SH7L
									250	− 1.0	150	1.4	10.8	900000	4900	—	—	—	
6SL7GT	Twin Triode	8BD	6.3	0.3	—	—	—	Amplifier	250	− 2.0	—	—	2.3[1]	44000	1600	70	—	—	6SL7GT
6SN7GT	Twin Triode	8BD	6.3	0.6	—	—	—	Amplifier	250	− 8.0	—	—	9.0[1]	7700	2600	20	—	—	6SN7GT
6SU7GTY	Twin Triode	8BD	6.3	0.3	—	—	—	Class-A Amplifier	250	− 2.0	—	—	2.3	44000	1600	70	—	—	6SU7GTY

TABLE II—6.3-VOLT GLASS TUBES WITH OCTAL BASES—*Continued*

Type	Name	Socket Connections	Fil. or Heater		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
6T6GM	Triple-Grid Amplifier	6Z	6.3	0.45	—	—	—	R.F. Amplifier	250	— 1.0	100	2.0	10	1000000	5500	—	—	—	6T6GM
6U6GT	Beam Power Amplifier	7AC	6.3	0.75	—	—	—	Class-A Amplifier	200	—14.0	135	3.0	56	20000	6200	—	3000	5.5	6U6GT
6U7G	Triple Grid Variable-μ	7R	6.3	0.3	5	9	.007	R.F. Amplifier	Characteristics same as Type 6D6—Table III										6U7G
6V7G	Duplex Diode-Triode	7V	6.3	0.3	2	3.5	1.7	Detector-Amplifier	Characteristics same as Type 85—Table III										6V7G
6W6GT	Beam Power Amplifier	7AC	6.3	1.25	—	—	—	Class-A Amplifier	135	— 9.5	135	12.0	61.0	—	9000	215	2000	3.3	6W6GT
6W7G	Triple-Grid Det. Amplifier	7R	6.3	0.15	5	8.5	.007	Class-A Amplifier	250	— 3.0	100	2.0	0.5	1500000	1225	1850	—	—	6W7G
6X6G	Electron-Ray Tube	7AL	6.3	0.3	—	—	—	Indicator Tube	250	0 v. for 300°, 2 ma. —8 v. for 0°, 0 ma. Vane grid 125 v.									6X6G
6Y6G	Beam Power Amplifier	7AC	6.3	1.25	15	8	0.7	Class-A Amplifier	135	—13.5	135	3.0	60.0	9300	7000	—	2000	3.6	6Y6G
6Y7G	Twin Triode Amplifier	8B	6.3	0.3	—	—	—	Class-B Amplifier	Characteristics same as Type 79—Table IV										6Y7G
6Z7G	Twin Triode Amplifier	8B	6.3	0.3	—	—	—	Class-B Amplifier	180	0	—	—	8.4	—	—	—	12000	4.2	6Z7G
									135	0	—	—	6.0	—	—	—	9000	2.5	
717A	Pentode Amplifier	8BK	6.3	0.175	—	—	—	Class-A Amplifier	120	— 2.0	120	2.5	7.5	390000	4000	—	—	—	717A
1223	Pentode Amplifier	7R	6.3	0.3	—	—	—	Class-A Amplifier	Characteristics same as 6C6—Table IV										1223
1635	Twin Triode Amplifier	8B	6.3	0.6	—	—	—	Class-B Amplifier	400	0	—	—	10/63	—	—	—	14000	17	1635
7000	Low-Noise Amplifier	7R	6.3	0.3	—	—	—	Class-A Amplifier	Characteristics same as Type 6J7—Table I										7000

* Cathode resistor-ohms. [1] Per plate. [2] Screen tied to plate. [3] Through 20,000-ohm dropping resistor. [4] Values are for single tube. [5] Values are for two tubes in push-pull. [6] Plate-to-plate value.

TABLE III—7-VOLT LOCK-IN-BASE TUBES

For other lock-in-base types see Tables VIII, IX, X and XIII

Type	Name	Socket Connections	Heater		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
7A4	Triode Amplifier	5AC	7.0	0.32	3.4	3	4	Class-A Amplifier	250	— 8.0	—	—	9.0	7700	2600	20	—	—	7A4
7A5	Beam Power Amplifier	6AA	7.0	0.75	—	—	—	Class-A_1 Amplifier	125	— 9.0	125	3.2/8	37.5/40	17000	6100	—	2700	1.9	7A5
7A6	Twin Diode	7AJ	7.0	0.16	—	—	—	Rectifier	Max. A.C. volts per plate—150. Max. Output current—10 ma.										7A6
7A7	Remote Cut-off Pentode	8V	7.0	0.32	6	7	.005	R.F. Amplifier	250	— 3.0	100	2.0	8.6	800000	2000	1600	—	—	7A7
7A8	Multigrid Converter	8U	7.0	0.16	—	—	—	Osc.-Mixer	250	— 3.0	100	3.1	3.0	50000	Anode-grid 250 volts max.[1]				7A8
7AF7	Twin Triode	8AC	6.3	0.3	2.2	1.6	2.3	Class-A Amp.	250	—10	—	—	9.0	7600	2100	16	—	—	7AF7
7AG7	Sharp Cut-off Pentode	Fig. 45	7.0	0.16	—	—	—	Class-A_1 Amp.	250	250*	250	2.0	6.0	750000	4200	—	—	—	7AG7
7B4	High-μ Triode	5AC	7.0	0.32	3.6	3.4	1.6	Class-A Amplifier	250	— 2.0	—	—	0.9	66000	1500	100	—	—	7B4
7B5	Pentode Power Amplifier	6AE	7.0	0.43	—	—	—	Class-A_1 Amplifier	250	—18.0	250	5.5/10	32/33	68000	2300	—	7600	3.4	7B5
7B6	Duo-Diode Triode	8W	7.0	0.32	—	—	—	Class-A Amplifier	250	— 2.0	—	—	1.0	91000	1100	100	—	—	7B6
7B7	Remote Cut-off Pentode	8V	7.0	0.16	5	7	.005	R.F. Amplifier	250	— 3.0	100	2.0	8.5	700000	1700	1200	—	—	7B7
7B8	Pentagrid Converter	8X	7.0	0.32	—	—	—	Osc.-Mixer	250	— 3.0	100	2.7	3.5	360000	Anode-grid 250 volts max.[1]				7B8
7C5	Tetrode Power Amplifier	6AA	7.0	0.48	—	—	—	Class-A_1 Amplifier	250	—12.5	250	4.5/7	45/47	52000	4100	—	5000	4.5	7C5
7C6	Duo-Diode Triode	8W	7.0	0.16	2.4	3	1.4	Class-A Amplifier	250	— 1.0	—	—	1.3	100000	1000	100	—	—	7C6
7C7	Pentode Amplifier	8V	7.0	0.16	5.5	6.5	.007	R.F. Amplifier	250	— 3.0	100	0.5	2.0	2 meg.	1300	—	—	—	7C7
7D7	Triode-Hexode Converter	8AR	7.0	0.48	—	—	—	Osc.-Mixer	250	— 3.0	Triode Plate (No. 3) 150 v. 3.5 ma.								7D7
7E6	Duo-Diode Triode	8W	7.0	0.32	—	—	—	Class-A Amplifier	250	— 9.0	—	—	9.5	8500	1900	16	—	—	7E6
7E7	Duo-Diode Pentode	8AE	7.0	0.32	4.6	4.6	.005	Class-A Amplifier	250	— 3.0	100	1.6	7.5	700000	1300	—	—	—	7E7
7F7	Twin Triode	8AC	7.0	0.32	—	—	—	Class-A Amplifier[2]	250	— 2.0	—	—	2.3	44000	1600	70	—	—	7F7
7F8	Twin Triode	8BW	6.3	0.30	2.8	1.4	1.2	R.F. Amplifier	250	— 2.5	—	—	10.0	10400	5000	—	—	—	7F8
									180	— 1.0			12.0	8500	7000				
7G7/1232	Triple-Grid Amplifier	8V	7.0	0.48	9	7	.007	Class-A Amplifier	250	— 2.0	100	2.0	6.0	800000	4500	—	—	—	7G7/1232

TABLE III—7-VOLT LOCK-IN-BASE TUBES—*Continued*

Type	Name	Socket Connections	Heater Volts	Heater Amp.	Capacitance μμfd. In	Out	Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
7G8/1206	Dual Tetrode	8BV	6.3	0.30	3.4	2.6	0.15	R.F. Amplifier[2]	250	— 2.5	100	0.8	4.5	225000	2100	—	—	—	7G8/1206
7H7	Triple-Grid Semi-Variable-μ	8V	7.0	0.32	8	7	.007	R.F. Amplifier	250	— 2.5	150	2.5	9.0	1000000	3500	—	—	—	7H7
7J7	Triode-Hexode Converter	8AR	7.0	0.32	—	—	—	Osc.-Mixer	250	— 3.0	100	2.9	1.3	Triode Plate 250 v. Max.[1]					7J7
7K7	Duo-Diode High-μ Triode	8BF	7.0	0.32	—	—	—	Class-A Amplifier	250	— 2.0	—	—	2.3	44000	1600	70	—	—	7K7
7L7	Triple-Grid Amplifier	8V	7.0	0.32	8	6.5	.01	Class-A Amplifier	250	— 1.5	100	1.5	4.5	100000	3100	Cathode Resistor 250 ohms			7L7
7N7	Twin Triode	8AC	7.0	0.6	—	—	—	Class-A Amplifier[2]	250	— 8.0	—	—	9.0	7700	2600	20	—	—	7N7
7Q7	Pentagrid Converter	8AL	7.0	0.32	—	—	—	Osc.-Mixer	250	0	100	8.0	3.4	800000	Grid No. 1 resistor 20000 ohms				7Q7
7R7	Duo-Diode Pentode	8AE	7.0	0.32	5.6	5.3	.004	Class-A Amplifier	250	— 1.0	100	1.7	5.7	1000000	3200	—	—	—	7R7
7S7	Triode Hexode Converter	8BL	7.0	0.32	—	—	—	Osc.-Mixer	250	— 2.0	100	2.2	1.7	2000000	Triode Plate 250 v. Max.[1]				7S7
7T7	Triple-Grid Amplifier	8V	7.0	0.32	8	7	.005	Class-A Amplifier	250	— 1.0	150	4.1	10.8	900000	4900	—	—	—	7T7
7V7	Triple-Grid Amplifier	8V	7.0	0.48	—	—	—	Class-A Amplifier	300	160*	150	3.9	9.6	300000	5800	—	—	—	7V7
7W7	Triple-Grid Variable-μ	8BJ	7.0	0.48	—	—	—	Class-A Amplifier	300	— 2.2	150	3.9	10	300000	5800	—	—	—	7W7
7X7	Duo-Diode Triode	8BZ	6.3	0.3	—	—	—	Class-A Amplifier	250	— 1.0	—	—	1.9	67000	1500	100	—	—	7X7
1231	Pentode Amplifier	8V	6.3	0.45	8.5	6.5	.015	Class-A Amplifier	300	200*	150	2.5	10	700000	5500	3850	—	—	1231
1273	Nonmicrophonic Pentode	8V	7.0	0.32	6.0	6.5	.007	Class-A_1 Amplifier	250	— 3.0	100	0.7	2.2	1000000	1575	—	—	—	1273
									100	— 1.0	100	1.8	5.7	400000	2275	—	—	—	
XXL	Triode Oscillator	5AC	7.0	0.32	—	—	—	Oscillator	250	— 8.0	—	—	8.0	—	2300	20	—	—	XXL

* Cathode resistor—ohms.

[1] Applied through 20000-ohm dropping resistor.

[2] Each section.

TABLE IV—6.3-VOLT GLASS RECEIVING TUBES

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Out	Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
2C21/1642	Twin-Triode Amplifier	M.	7BH	6.3	0.6	—	—	—	Class-A Amp.	250	−16.5	—	—	8.3	7600	1375	10.4	—	—	2C21/1642
6A3	Triode Power Amplifier	M.	4D	6.3	1.0	—	—	—	Class-A_1 Amp.	250	−45	—	—	60	800	5250	4.2	2500	3.5	6A3
									Class A_1 Amp.[10]	300 300	−62 780*	Fixed Bias Self Bias		40 40	Power output for 2 tubes load plate-to-plate			3000[11] 5000[11]	15 10	
6A4	Pentode Power Amplifier	M.	5B	6.3	0.3	—	—	—	Class-A Amp.	180	−12.0	180	3.9	22	45500	2200	100	8000	1.4	6A4
6A6	Twin Triode Amplifier	M.	7B	6.3	0.8	—	—	—	Class-B Amp.	250 300	0 0	—	—	Power output is for one tube at stated load, plate-to-plate				8000 10000	8.0 10.0	6A6
6A7	Pentagrid Converter	S.	7C	6.3	0.3	—	—	—	Converter	250	— 3.0	100	2.2	3.5	360000	Anode grid (No. 2) 200 volts max.				6A7
6AB5/6N5	Electron-Ray Tube	S.	6R	6.3	0.15	—	—	—	Indicator Tube	180	Cut-off Grid Bias = −12 v.			0.5	Target Current 2 ma.				—	6AB5/6N5
6AF6G	Electron-Ray Tube Twin Indicator Type	S.	7AG	6.3	0.15	—	—	—	Indicator Tube	135 100	Ray Control Voltage = 81 for 0° Shadow Angle. Target current 1.5 ma. Ray Control Voltage = 60 for 0° Shadow Angle. Target current 0.9 ma.									6AF6G
6B5	Direct-Coupled Power Amplifier	M.	6AS	6.3	0.8	—	—	—	Class-A Amp.[9] Push-Pull Amp.[10]	300 400	0 −13.0	— —	6[1] 4.5[1]	45 40	241000 —	2400 —	58 —	7000 10000[11]	4.0 20	6B5
6B7	Duplex-Diode Pentode	S.	7D	6.3	0.3	3.5	9.5	.007	Pentode R.F. Amp.	250	— 3.0	125	2.3	9.0	650000	1125	730	—	—	6B7
6C6	Triple-Grid Amplifier	S.	6F	6.3	0.3	5	6.5	.007	R.F. Amplifier	250	— 3.0	100	0.5	2.0	1500000	1225	1500	—	—	6C6
6C7	Duplex Diode Triode	S.	7G	6.3	0.3	—	—	—	Class-A Amp.	250	— 9.0	—	—	4.5	—	20	1250	—	—	6C7
6D6	Triple-Grid Variable-μ	S.	6F	6.3	0.3	4.7	6.5	.007	R.F. Amplifier	250	— 3.0	100	2.0	8.2	800000	1600	1280	—	—	6D6
6D7	Triple-Grid Amplifier	S.	7H	6.3	0.3	5.2	6.8	.01	Class-A Amp.	250	— 3.0	100	0.5	2.0	—	1600	1280	—	—	6D7
6E5	Electron-Ray Tube	S.	6R	6.3	0.3	—	—	—	Indicator Tube	250	0	—	—	0.25	Target Current 4 ma.				—	6E5
6E6	Twin Triode Amplifier	M.	7B	6.3	0.6	—	—	—	Class-A Amp.	250	−27.5	Per plate—18.0			3500	1700	6.0	14000	1.6	6E6
6E7	Triple-Grid Variable-μ	S.	7H	6.3	0.3				R.F. Amplifier	Characteristics same as 6U7G—Table II										6E7

TABLE IV—6.3-VOLT GLASS RECEIVING TUBES—*Continued*

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6F7	Triode Pentode	S.	7E	6.3	0.3	—	—	—	Triode Unit Amp.	100	— 3.0	—	—	3.5	16000	500	8	—	—	6F7
									Pentode Unit Amplifier	250	— 3.0	100	1.5	6.5	850000	1100	900	—	—	
6U5/6G5	Electron-Ray Tube	S.	6R	6.3	0.3	—	—	—	Indicator Tube	250	Cut-off Grid Bias = —22 v.			0.24	Target Current 4 ma.				—	6U5/6G5
										100	Cut-off Grid Bias = —8 v.			0.19	Target Current 1 ma.					
6H5	Electron-Ray Tube	S.	6R	6.3	0.3	—	—	—	Indicator Tube		Same characteristics as Type 6G5—Circular Pattern									6H5
6SB7Y	Pentagrid Converter	O.	8R	6.3	0.3	9.6	9.2	—	Converter	100	— 1	100	10.2	3.6	500000	900	—	—	—	6SB7Y
									Converter	250	— 1	100	10	3.8	1000000	950	—	—	—	
						Osc. Section in 88–108 Mc. Serv.				250	22000 [6]	12000 [7]	12.6/12.5	6.8/6.5	—	—	—	—	—	
6T5	Electron-Ray Tube	S.	6R	6.3	0.3	—	—	—	Indicator Tube	250	Cut-off Grid Bias = —12 v.			0.24	Target Current 4 ma.				—	6T5
36	Tetrode R.F. Amplifier	S.	5E	6.3	0.3	3.8	9	.007	R.F. Amplifier	250	— 3.0	90	1.7	3.2	550000	1080	595	—	—	36
37	Triode Detector Amplifier	S.	5A	6.3	0.3	3.5	2.9	2	Class-A Amp.	250	—18.0	—	—	7.5	8400	1100	9.2	—	—	37
38	Pentode Power Amplifier	S.	5F	6.3	0.3	3.5	7.5	0.3	Class-A Amp.	250	—25.0	250	3.8	22.0	100000	1200	120	10000	2.5	38
39/44	Variable-μ R.F. Amplifier	S.	5F	6.3	0.3	3.8	10	.007	R.F. Amplifier	250	— 3.0	90	1.4	5.8	1000000	1050	1050	—	—	39/44
41	Pentode Power Amplifier	S.	6B	6.3	0.4	—	—	—	Class-A Amp.	250	—18.0	250	5.5	32.0	68000	2200	150	7600	3.4	41
42	Pentode Power Amplifier	M.	6B	6.3	0.7	—	—	—	Class-A Amp.	250	—16.5	250	6.5	34.0	100000	2200	220	7000	3.0	42
52	2-Grid Triode	M.	Fig. 33	6.3	0.3	—	—	—	Class-A Preamp. [4]	110	0	—	—	43.0	1750	3000	5.2	2000	1.5	52
									Class-B, 2 tubes [5]	180	0	—	—	3.0				10000	5.0	
56AS	Triode Amplifier	S.	5A	6.3	0.4	—	—	—	Class-A Amp.	Characteristics same as 56										56AS
57AS	Pentode	S.	6F	6.3	0.4	—	—	—	R.F. Amplifier	Characteristics same as 57										57AS
58AS	Triple-Grid Variable-μ	S.	6F	6.3	0.4	—	—	—	R.F. Amplifier	Characteristics same as 58										58AS
75	Duplex-Diode Triode	S.	6G	6.3	0.3	1.7	3.8	1.7	Triode Amplifier	250	— 1.35	—	—	0.4	91000	1100	100	—	—	75
76	Triode Detector Amplifier	S.	5A	6.3	0.3	3.5	2.5	2.8	Class-A Amp.	250	—13.5	—	—	5.0	9500	1450	13.8	—	—	76
77	Triple-Grid Detector	S.	6F	6.3	0.3	4.7	11	.007	R.F. Amplifier	250	— 3.0	100	0.5	2.3	1500000	1250	1500	—	—	77
78	Triple-Grid Variable-μ	S.	6F	6.3	0.3	4.5	11	.007	R.F. Amplifier	250	— 3.0	100	1.7	7.0	800000	1450	1160	—	—	78
79	Twin Triode Amplifier	S.	6H	6.3	0.6	—	—	—	Class-B Amp.	250	0	—	—	Power output is for one tube				14000	8.0	79
85	Duplex-Diode Triode	S.	6G	6.3	0.3	1.5	4.3	1.5	Class-A Amp.	250	—20.0	—	—	8.0	7500	1100	8.3	20000	0.35	85
85AS	Duplex-Diode Triode	S.	6G	6.3	0.3	—	—	—	Class-A Amp.	250	— 9.0	—	—	5.5	—	1250	20	—	—	85AS
89	Triple-Grid Power Amp.	S.	6F	6.3	0.4	—	—	—	Triode Amp. [2]	250	—31.0	—	—	32.0	2600	1800	4.7	5500	0.9	89
									Pentode Amp. [8]	250	—25.0	250	5.5	32.0	70000	1800	125	6750	3.4	
1221	Pentode R.F. Amplifier	S.	6F	6.3	0.3	—	—	—	Class-A Amp.	Special non-microphonic. Characteristics same as 6C6										1221
1603 [3]	Triple-Grid Amplifier	M.	6F	6.3	0.3	—	—	—	Class-A Amp.	Characteristics same as 6C6										1603
7700 [3]	Triple-Grid Amplifier	S.	6F	6.3	0.3	—	—	—	Class-A Amp.	Characteristics same as 6C6										7700

* Cathode bias resistor–ohms.

[1] Current to input plate (P_1).
[2] Grids Nos. 2 and 3 connected to plate.
[3] Low noise, nonmicrophonic tubes.
[4] G_2 tied to plate.
[5] G_1 tied to G_2.
[6] Osc. grid leak ohms.
[7] Screen dropping resistor ohms.
[8] Grid No. 2, screen; grid No. 3, suppressor.
[9] Values for single tube.
[10] Values for two tubes in push-pull.
[11] Plate-to-plate value.

TABLE V—2.5-VOLT RECEIVING TUBES

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
2S/4S	Duodiode	M.	5D	2.5	1.35	—	—	—	Detector	At 50 d.c. Volts per plate, cathode ma. = 80										2S/4S
2A3	Triode Power Amplifier	M.	4D	2.5	2.5	7.5	5.5	16.5	Class-A Amp.	Characteristics same as Type 6A3, Table IV										2A3
2A5	Pentode Power Amplifier	M.	6B	2.5	1.75	—	—	—	Class-A Amp.	Characteristics same as Type 42, Table IV										2A5
2A6	Duplex-Diode Triode	S.	6G	2.5	0.8	1.7	3.8	1.7	Class-A Amp.	Characteristics same as Type 75, Table IV										2A6
2A7	Pentagrid Converter	S.	7C	2.5	0.8	—	—	—	Osc.-Mixer	Characteristics same as Type 6A7, Table IV										2A7

TABLE V—2.5-VOLT RECEIVING TUBES—*Continued*

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
2B6	Direct-Coupled Amplifier	M.	7J	2.5	2.25	—	—	—	Amplifier	250	−24.0	—	—	40.0	5150	3500	18.0	5000	4.0	2B6
2B7	Duplex-Diode Pentode	S.	7D	2.5	0.8	3.5	9.5	.007	Pentode Amp.	Characteristics same as Type 6B7—Table IV										2B7
2E5	Electron-Ray Tube	S.	6R	2.5	0.8	—	—	—	Indicator Tube	Characteristics same as Type 6E5—Table IV										2E5
2G5	Electron-Ray Tube	S.	6R	2.5	0.8	—	—	—	Indicator Tube	Characteristics same as 6U5/6G5—Table IV										2G5
24-A	Tetrode R.F. Amplifier	M.	5E	2.5	1.75	5.3	10.5	.007	Screen-Grid R.F. Amplifier	250	− 3.0	90	1.7	4.0	600000	1050	630	—	—	24-A
									Bias Detector	250	− 5.0	20/45	Plate current adjusted to 0.1 ma. with no signal							
27	Triode Detector-Amplifier	M.	5A	2.5	1.75	3.1	2.3	3.3	Class-A Amp.	250	−21.0	—	—	5.2	9250	975	9.0	—	—	27
									Bias Detector	250	−30.0	—	Plate current adjusted to 0.2 ma. with no signal							
35/51	Variable-μ Amplifier	M.	5E	2.5	1.75	5.3	10.5	.007	Screen-Grid R.F. Amplifier	250	− 3.0	90	2.5	6.5	400000	1050	420	—	—	35/51
45	Triode Power Amplifier	M.	4D	2.5	1.5	4	3	7	Class-A Amp.	275	−56.0	—	—	36.0	1700	2050	3.5	4500	2.00	45
46	Dual-Grid Power Amp.	M.	5C	2.5	1.75	—	—	—	Class-A Amp.[2]	250	−33.0	—	—	22.0	2380	2350	5.6	6400	1.25	46
									Class-B Amp.[3]	400	0	—	—	Power output for 2 tubes				5800	20.0	
47	Pentode Power Amplifier	M.	5B	2.5	1.75	8.6	13	1.2	Class-A Amp.	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
53	Twin Triode Amplifier	M.	7B	2.5	2.0	—	—	—	Class-B Amp.	Characteristics same as Type 6A6, Table IV										53
55	Duplex-Diode Triode	S.	6G	2.5	1.0	1.5	4.3	1.5	Class-A Amp.	Characteristics same as Type 85, Table IV										55
56	Triode Amplifier, Detector	S.	5A	2.5	1.0	3.2	2.4	3.2	Class-A Amp.	Characteristics same as Type 76, Table IV										56
57	Triple-Grid Amplifier	S.	6F	2.5	1.0	—	—	—	R.F. Amplifier	250	− 3.0	100	0.5	2.0	1500000	1225	1500	—	—	57
58	Triple-Grid Variable-μ	S.	6F	2.5	1.0	4.7	6.3	.007	Screen-Grid R.F. Amplifier	250	− 3.0	100	2.0	8.2	800000	1600	1280	—	—	58
59	Triple-Grid Power Amplifier	M.	7A	2.5	2.0	—	—	—	Class-A Triode[4]	250	−28.0	—	—	26.0	2300	2600	6.0	5000	1.25	59
									Class-A Pentode[5]	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.0	
RK15	Triode Power Amplifier	M.	4D[1]	2.5	1.75	—	—	—	Characteristics same as Type 46 with Class-B connections											RK15
RK16	Triode Power Amplifier	M.	5A	2.5	2.0	—	—	—	Characteristics same as Type 59 with Class-A triode connections											RK16
RK17	Pentode Power Amplifier	M.	5F	2.5	2.0	—	—	—	Characteristics same as Type 2A5											RK17

[1] Grid connection to cap; no connection to No. 3 pin. [2] Grid No. 2 tied to plate. [3] Grids Nos. 1 and 2 tied together. [4] Grids Nos. 2 and 3 connected to plate. [5] Grid No. 2, screen; grid No. 3, suppressor.

TABLE VI—2.0-VOLT BATTERY RECEIVING TUBES

Type	Name	Base	Socket Connections	Filament Volts	Filament Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1A4P	Variable-μ Pentode	S.	4M	2.0	0.06	5	11	.007	R.F. Amplifier	180	− 3.0	67.5	0.8	2.3	1000000	750	750	—	—	1A4P
1A4T	Variable-μ Tetrode	S.	4K	2.0	0.06	5	11	.007	R.F. Amplifier	180	− 3.0	67.5	0.7	2.3	960000	750	720	—	—	1A4T
1A6	Pentagrid Converter	S.	6L	2.0	0.06	—	—	—	Converter	180	− 3.0	67.5	2.4	1.3	500000	Anode grid (No. 2) 180 max. volts				1A6
1B4P/951	Pentode R.F. Amplifier	S.	4M	2.0	0.06	5	11	.007	R.F. Amplifier	180 90	− 3.0 − 3.0	67.5 67.5	0.6 0.7	1.7 1.6	1500000 1000000	650 600	1000 550	—	—	1B4P/951
1B5/25S	Duplex-Diode Triode	S.	6M	2.0	0.06	1.6	1.9	3.6	Triode Class-A	135	− 3.0	—	—	0.8	35000	575	20	—	—	1B5/25S
1C6	Pentagrid Converter	S.	6L	2.0	0.12	10	10	—	Converter	180	− 3.0	67.5	2.0	1.5	750000	Anode grid (No. 2) 135 max. volts				1C6
1F4	Pentode Power Amplifier	M.	5K	2.0	0.12	—	—	—	Class-A Amp.	135	− 4.5	135	2.6	8 0	200000	1700	340	16000	0.34	1F4
1F6	Duplex-Diode Pentode	S.	6W	2.0	0.06	4	9	.007	R.F. Amplifier	180	− 1.5	67.5	0.6	2.0	1000000	650	650	—	—	1F6
									A.F. Amplifier	135	− 1.0	135	Plate, 0.25 megohm; screen, 1.0 megohm				Amp. = 48			

TABLE VI—2.0-VOLT BATTERY RECEIVING TUBES—*Continued*

Type	Name	Base	Socket Connections	Filament		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
				Volts	Amp.	In	Out	Plate-Grid												
15	R.F. Pentode	S.	5F	2.0	0.22	2.3	7.8	0.01	R.F. Amplifier	135	— 1.5	67.5	0.3	1.85	800000	750	600	—	—	15
19	Twin-Triode Amplifier	S.	6C	2.0	0.26	—	—	—	Class-B Amp.	135	0	—	—	—	Load plate-to-plate			10000	2.1	19
30	Triode Detector Amplifier	S.	4D	2.0	0.06	—	—	—	Class-A Amp.	180	−13.5	—	—	3.1	10300	900	9.3	—	—	30
31	Triode Power Amplifier	S.	4D	2.0	0.13	3.5	2.7	5.7	Class-A Amp.	180	−30.0	—	—	12.3	3600	1050	3.8	5700	0.375	31
32	Tetrode R.F. Amplifier	M.	4K	2.0	0.06	5.3	10.5	.015	R.F. Amplifier	180	— 3.0	67.5	0.4	1.7	1200000	650	780	—	—	32
33	Pentode Power Amplifier	M.	5K	2.0	0.26	8	12	1	Class-A Amp.	180	−18.0	180	5.0	22.0	55000	1700	90	6000	1.4	33
34	Variable-μ Pentode	M.	4M	2.0	0.06	6	11	.015	R.F. Amplifier	180	— 3.0	67.5	1.0	2.8	1000000	620	620	—	—	34
49	Dual-Grid Power Amp.	M.	5C	2.0	0.12	—	—	—	Class-A Amp.[1]	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	49
									Class-B Amp.[2]	180	0	—	—	Power output for 2 tubes				12000	3.5	
840	R.F. Pentode	S.	5J	2.0	0.13	—	—	—	Class-A Amp.	180	— 3.0	67.5	0.7	1.0	1000000	400	400	—	—	840
950	Pentode Power Amplifier	M.	5K	2.0	0.12	—	—	—	Class-A Amp.	135	−16.5	135	2.0	7.0	100000	1000	100	13500	0.45	950
RK24	Triode Amplifier	M.	4D	2.0	0.12	—	—	—	Class-A Amp.	180	−13.5	—	—	8.0	5000	1600	8.0	12000	0.25	RK24
1229	Tetrode R.F. Amplifier	M.	4K	2.0	0.06	—	—	—	Class-A Amp.	Special Type 32 for low grid current applications										1229

[1] Grid No. 2 tied to plate.

[2] Grids Nos. 1 and 2 tied together.

TABLE VII—2.0-VOLT BATTERY TUBES WITH OCTAL BASES

Type	Name	Socket Connections	Filament		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
			Volts	Amp.	In	Out	Plate-Grid												
1C7G	Pentagrid Converter	7Z	2.0	0.06	—	—	—	Converter	Characteristics same as Type 1C6—Table VI										1C7G
1D5GP	Variable-μ R.F. Pentode	5Y	2.0	0.06	5	11	.007	R.F. Amplifier	Characteristics same as Type 1A4P—Table VI										1D5GP
1D5GT	Variable-μ R.F. Tetrode	5R	2.0	0.06	—	—	—	R.F. Amplifier	180	— 3.0	67.5	0.7	2.2	600000	650				1D5GT
1D7G	Pentagrid Converter	7Z	2.0	0.06	—	—	—	Converter	Characteristics same as Type 1A6—Table VI										1D7G
1E5GP	R.F. Amplifier Pentode	5Y	2.0	0.06	5	11	.007	R.F. Amplifier	Characteristics same as Type 1B4—Table VI										1E5GP
1E7G	Double Pentode Power Amp.	8C	2.0	0.24	—	—	—	Class-A Amplifier	135	— 7.5	135	2.0[1]	6.5[1]	220000	1600	350	24000	0.65	1E7G
1F5G	Pentode Power Amplifier	6X	2.0	0.12	—	—	—	Class-A Amplifier	Characteristics same as Type 1F4—Table VI										1F5G
1F7GV[2]	Duplex-Diode Pentode	7AD	2.0	0.06	3.8	9.5	0.01	Detector-Amplifier	Characteristics same as Type 1F6—Table VI										1F7GV
1G5G	Pentode Power Amplifier	6X	2.0	0.12	—	—	—	Class-A Amplifier	135	−13.5	135	2.5	8.7	160000	1550	250	9000	0.55	1G5G
1H4G	Triode Amplifier	5S	2.0	0.06	—	—	—	Detector-Amplifier	Characteristics same as Type 30—Table VI										1H4G
1H6G	Duplex-Diode Triode	7AA	2.0	0.06	1.6	1.9	3.6	Detector-Amplifier	Characteristics same as Type 1B5—Table VI										1H6G
1J5G	Pentode Power Amplifier	6X	2.0	0.12	—	—	—	Class-A Amplifier	135	−16.5	135	2.0	7.0	—	950	100	13500	0.45	1J5G
1J6G	Twin Triode	7AB	2.0	0.24	—	—	—	Class-B Amplifier	Characteristics same as Type 19—Table VI										1J6G
4A6G	Twin Triode	8L	2.0	0.12	—	—	—	Class-A, 1 section	90	— 1.5	—	—	1.1	26600	750	20			4A6G
			4.0	0.06				Class-B, 2 sections	90	— 1.5	—	—	1.1[3]				8000	1.0	

[1] Total current for both sections; no signal.

[2] Also Type G or GH.

[3] Max. signal plate current = 10.8 Ma.

TABLE VIII—1.5-VOLT FILAMENT BATTERY TUBES

See also Table X for Special 1.4-volt Tubes

Type	Name	Base	Socket Connections	Filament		Capacitance μμfd.			Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output M-watts	Type
				Volts	Amp.	In	Out	Plate-Grid												
1A5G	Pentode Power Amplifier	O.	6X	1.4	0.05	—	—	—	Class-A_1 Amp.	90	−4.5	90	0.8	4.0	300000	850	240	25000	115	1A5G
1A7G	Pentagrid Converter	O.	7Z	1.4	0.05	—	—	—	Osc.-Mixer	90	0	45	0.6	0.55	600000	Anode-grid volts 90				1A7G

TABLE VIII—1.5-VOLT FILAMENT BATTERY TUBES—*Continued*

Type	Name	Base	Socket Connections	Filament Volts	Filament Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output M-watts	Type
1AB5	Pentode R.F. Amplifier	O.	5BF	1.2	0.05	2.8	4.2	0.25	R.F. Amplifier	90 150	0 −1.5	90 150	0.8 2.0	3.5 6.8	275000 125000	1100 1350	—	—	—	1AB5
1B7G	Pentagrid Converter	O.	7Z	1.4	0.1	—	—	—	Converter	90	0	45	1.3	1.5	350000	Grid No. 1 resistor 200,000 ohms				1B7G
1B8GT	Diode Triode Pentode	O.	8AW	1.4	0.1	—	—	—	Triode Amplifier Pentode Amp.	90 90	0 −6.0	— 90	— 1.4	0.15 6.3	240000 —	275 1150	— —	— 14000	— 210	1B8GT
1C5G	Pentode Power Amplifier	O.	6X	1.4	0.1	—	—	—	Class-A_1 Amp.	90	−7.5	99	1.6	7.5	115000	1550	165	8000	240	1C5G
1D8GT	Diode Triode Pentode	O.	8AJ	1.4	0.1	—	—	—	Triode Amp. Pentode Amp.	90 90	0 −9.0	— 90	— 1.0	1.1 5.0	43500 200000	575 925	25 —	— —	— —	1D8GT
1E4G	Triode Amplifier	O.	5S	1.4	0.05	2.4	6	2.40	Class-A Amp.	90 90	0 −3.0	—	—	4.5 1.5	11000 17000	1325 825	14.5 14	—	—	1E4G
1G4G	Triode Amplifier	O.	5S	1.4	0.05	2.2	3.4	2.80	Class-A Amp.	90	−6.0	—	—	2.3	10700	825	8.8	—	—	1G4G
1G6G	Twin Triode	O.	7AB	1.4	0.1	—	—	—	Class-A Amp. Class-B Amp.	90 90	0 0	— —	— —	1.0 1/7	45000 34 volts input per grid	675	30 12000	— 675	— —	1G6G
1H5G	Diode High-μ Triode	O.	5Z	1.4	0.05	1.1	6	1.00	Class-A Amp.	90	0	—	—	0.14	240000	275	65	—	—	1H5G
1LA4	Pentode Power Amplifier	L.	5AD	1.4	0.05	—	—	—	Class-A Amp.	90	Characteristics same as 1A5G									1LA4
1LA6	Pentagrid Converter	L.	7AK	1.4	0.05	—	—	—	Converter	90	0	45	0.6	0.55		Anode Grid Volts 90				1LA6
1LB4	Pentode Power Amplifier	L.	5AD	1.4	0.05	—	—	—	Class-A Amp.	90	−9	90	1.0	5.0	200000	925	—	12000	200	1LB4
1LB6	Heptode Converter	L.	8AX	1.4	0.05	—	—	—	Converter	90	0	67.5	2.2	0.4	Grid No. 4—67.5 v., No. 5—0 v.					1LB6
1LC5	Triple-Grid Variable-μ	L.	7AO	1.4	0.05	3.2	7	.007	R.F. Amplifier	90	0	45	0.2	1.15	1500000	775	—	—	—	1LC5
1LC6	Pentagrid Converter	L.	7AK	1.4	0.05	—	—	—	Converter	90	0	35[4]	0.7	0.75		Anode Grid Volts 45				1LC6
1LD5	Diode Pentode	L.	6AX	1.4	0.05	3.2	6	0.18	Class-A Amp.	90	0	45	0.1	0.6	950000	600	—	—	—	1LD5
1LE3	Triode Amplifier	L.	4AA	1.4	0.05	1.7	3	1.70	Class-A Amp.	90 90	0 −3	—	—	4.5 1.3	11200 19000	1300 760	14.5	—	—	1LE3
1LG5	Pentode R.F. Amp.	L.	Fig. 42	1.4	0.05	—	—	—	Class-A Amp.	90	0	45	0.4	1.7	1000000	800	—	—	—	1LG5
1LH4	Diode High-μ Triode	L.	5AG	1.4	0.05	1.1	6	1.00	Class-A Amp.	90	0	—	—	0.15	240000	275	65	—	—	1LH4
1LN5	Triple-Grid Amplifier	L.	7AO	1.4	0.05	3.4	8	.007	Class-A Amp.	90	0	90	0.3	1.2	1500000	750	—	—	—	1LN5
1N5G	Pentode R.F. Amplifier	O.	5Y	1.4	0.05	3	10	.007	Class-A Amp.	90	0	90	0.3	1.2	1500000	750	1160	—	—	1N5G
1N6G	Diode-Power-Pentode	O.	7AM	1.4	0.05	—	—	—	Class-A Amp.	90	−4.5	90	0.6	3.1	300000	800	—	25000	100	1N6G
1P5G	Triple-Grid Pentode	O.	5Y	1.4	0.05	3	10	.007	R.F. Amplifier	90	0	90	0.7	2.3	800000	800	640	—	—	1P5G
1Q5G	Tetrode Power Amplifier	O.	6AF	1.4	0.1	—	—	—	Class-A Amp.	85 90	−5.0 −4.5	85 90	1.2 1.6	7.2 9.5	70000 75000	1950 2100	—	9000 8000	250 270	1Q5G
1R4/1294	U.h.f. Diode	L.	4AH	1.4	0.15	—	—	—	Rectifier	Max. r.m.s. voltage per plate—30				Max. d.c. output current—340 μa.						1R4/1294
1SA6GT	R.F. Pentode	O.	6CA	1.4	0.05	5.2	8.6	0.01	R.F. Amplifier	90	0	67.5	0.68	2.45	800000	970	—	—	—	1SA6GT
1SB6GT	Diode Pentode	O.	6CB	1.4	0.05	3.2	3	0.25	Class-A Amp. R.C. Amplifier	90 90	0 0	67.5 90	0.38 Screen resistor 5 meg., grid 10 meg.	1.45	700000	665	—	— 1 meg.	— 110[6]	1SB6GT
1T5GT	Beam Power Amplifier	O.	6AF	1.4	0.05	4.8	8	0.50	Class-A Amp.	90	−6.0	90	1.4	6.5	—	1150	—	14000	170	1T5GT
3B7/1291	U.h.f. Twin Triode	L.	7BE	1.4	0.22	—	—	—	Class-A Amp.	90	0	—	—	5.2	11350	1850	21	—	—	3B7/1291
1293	U.h.f. Triode	L.	Fig. 2	1.4	0.11	—	—	—	Class-A Amp.	90	0	—	—	4.7	10750	1300	14	—	—	1293
3D6/1299	U.h.f. Tetrode	L.	6BB	2.8[8]	0.11	7.5	6.5	0.30	Class-A Amp.	135	−6	90	0.7	5.7	—	2200	—	13000	500	3D6/1299
CK501	Pentode Voltage Amplifier	—[1]	—[7]	1.25	0.033	—	—	—	Class-A Amp.	30 45	0 −1.25	30 45	0.06 0.055	0.3 0.28	1000000 1500000	325 300	—	—	—	CK501
CK502	Pentode Output Amplifier	—[1]	—[7]	1.25	0.033	—	—	—	Class-A Amp.	30	0	30	0.13	0.55	500000	400	—	60000	3	CK502
CK503	Pentode Output Amplifier	—[1]	—[7]	1.25	0.033	—	—	—	Class-A Amp.	30	0	30	0.33	1.5	150000	600	—	20000	6[2]	CK503
CK504	Pentode Output Amplifier	—[1]	—[7]	1.25	0.033	—	—	—	Class-A Amp.	30	−1.25	30	0.09	0.4	500000	350	—	60000	3[2]	CK504
CK505	Pentode Voltage Amplifier	—[1]	—[7]	0.625[5]	0.03	—	—	—	Class-A Amp.	30 45	0 −1.25	30 45	0.07 0.08	0.17 0.2	1100000 2000000	140 150	—	—	—	CK505
CK506	Pentode Output Amplifier	—[1]	—[7]	1.25	0.05	—	—	—	Class-A_1 Amp.	45	−4.5	45	0.4	1.25	120000	500	—	30000	25	CK506
CK507	Pentode Output Amplifier	—[1]	—[7]	1.25	0.05	—	—	—	Class-A_1 Amp.	45	−2.5	45	0.21	0.6	360000	500	—	50000	12	CK507

TABLE VIII—1.5-VOLT FILAMENT BATTERY TUBES—*Continued*

Type	Name	Base	Socket Connections	Filament Volts	Filament Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output M-watts	Type
CK509	Triode Voltage Amplifier	—[1]	——[7]	0.625[5]	0.03	—	—	—	Class-A Amp.	45	0	—	—	0.15	150000	160	16	1000000	—	CK509
CK510	Dual Space-Charge Tetrode	—[1]	——[7]	0.625[5]	0.05	—	—	—	Class-A Amp.	45	0	0.2	200 μα	60 μα	500000	65	32.5	—	—	CK510
CK515BX	Triode Voltage Amplifier	—[1]	——[7]	0.625[5]	0.03	—	—	—	Class-A Amp.	45	0	—	—	0.15	—	160	24	1000000	—	CK515BX
HY113 HY123	Triode Amplifier	—[1]	5K[3]	1.4	0.07	—	—	—	Class-A Amp.	45	−4.5	—	—	0.4	25000	250	6.3	40000	6.5	HY113 HY123
HY115 HY145	Pentode Voltage Amplifier	—[1]	5K	1.4	0.07	—	—	—	Class-A Amp.	45 90	−1.5 −1.5	22.5 45	0.008 0.1	0.03 0.48	5200000 1300000	58 270	300 370	—	—	HY115 HY145
HY125 HY155	Pentode Power Amplifier	—[1]	5K	1.4	0.07	—	—	—	Class-A Amp.	45 90	−3.0 −7.5	45 90	0.2 0.5	0.9 2.6	825000 420000	310 450	255 190	50000 28000	11.5 90	HY125 HY155
RK42	Triode Amplifier	S.	4D	1.5	0.6	—	—	—	Class-A Amp.	Characteristics same as Type 30—Table VI										RK42
RK43	Twin Triode Amplifier	S.	6C	1.5	0.12	—	—	—	Class-A Amp.	135	−3	—	—	4.5	14500	900	13	—	—	RK43

[1] Special miniature peanut base.
[2] With 5-megohm grid resistor and 0.02-μfd. grid coupling condenser.
[3] No screen connection.
[4] Through series resistor. Screen voltage must be at least 10 volts lower than oscillator anode.
[5] Two tubes connected in series for 1.4-volt operation.
[6] Voltage gain.
[7] Tinned wire leads labeled on tube.
[9] Center-top filament permits 1.4-volt operation.

TABLE IX—HIGH-VOLTAGE HEATER TUBES

Type	Name	Base	Socket Connections	Heater Volts	Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
12A5	Pentode Power Amplifier	M.	7F	12.6 6.3	0.3 0.6	—	—	—	Class-A_1 Amp.[6]	100 180	−15 −25	100 180	3/6.5 8/14	17/19 45/48	50000 35000	1700 2400	— —	4500 3300	0.8 3.4	12A5
12A6	Beam Power Amplifier	O.	7AC	12.6	0.15	—	—	—	Class-A Amp.	250	−12.5	250	3.5	30	70000	3000	—	7500	3.4	12A6
12A7	Rectifier-Amplifier	M.	7K	12.6	0.3	—	—	—	Class-A Amp.	135	−13.5	135	2.5	9.0	102000	975	100	13500	0.55	12A7
12A8GT	Pentagrid Converter	O.	8A	12.6	0.15	—	—	—	Converter	Characteristics same as 6A8—Table I										12A8GT
12AH7GT	Twin Triode	O.	8BE	12.6	0.15	Each Triode Sect.			Class-A Amp.	180	− 6.5	—	—	7.6	8400	1900	16	—	—	12AH7GT
12B6M	Diode Triode	O.	6Y	12.6	0.15	—	—	—	Class-A Amp.	250	− 2.0	—	—	0.9	91000	1100	100	—	—	12B6M
12B7ML	Pentode Amplifier	O.	8V	12.6	0.15	—	—	—	Class-A Amp.	250	− 3.0	100	2.6	9.2	800000	2000	—	—	—	12B7ML
12B8GT	Triode-Pentode	O.	8T	12.6	0.3	Triode Section Pentode Section			Class-A Amp. Class-A Amp.	100 100	− 1 − 3	— 100	— 2	0.6 8	73000 170000	1500 2100	110 360	— —	— —	12B8GT
12C8	Duplex-Diode Pentode	O.	8E	12.6	0.15	6	9	.005	Class-A Amp.	Characteristics same as 6B8—Table I										12C8
12E5GT	Triode Amplifier	O.	6Q	12.6	0.15	3.4	5.5	2.60	Class-A Amp.	250	−13.5	—	—	50	—	1450	13.8	—	—	12E5GT
12F5GT	Triode Amplifier	O.	5M	12.6	0.15	1.9	3.4	2.40	Class-A Amp.	Characteristics same as 6F5—Table I										12F5GT
12G7G	Duplex-Diode Triode	O.	7V	12.6	0.15	—	—	—	Class-A Amp.	250	− 3.0	—	—	—	58000	1200	70	—	—	12G7G
12H6	Twin Diode	O.	7Q	12.6	0.15	—	—	—	Rectifier	Characteristics same as 6H6—Table I										12H6
12J5GT	Triode Amplifier	O.	6Q	12.6	0.15	3.4	3.6	3.40	Class-A Amp.	Characteristics same as 6J5—Table I										12J5GT
12J7GT	Pentode Voltage Amplifier	O.	7R	12.6	0.15	—	—	—	Class-A Amp.	Characteristics same as 6J7—Table I										12J7GT
12K7GT	Remote Cut-off Pentode	O.	7R	12.6	0.15	4.6	12	.005	R.F. Amplifier	Characteristics same as 6K7—Table I										12K7GT
12K8	Triode Hexode Converter	O.	8K	12.6	0.15	—	—	—	Converter	Characteristics same as 6K8—Table I										12K8
12L8GT	Twin Pentode	O.	8BU	12.6	0.15	5	6	0.70	Class-A_1 Amp.	180	− 9.0	180	2.8	13.0	160000	2150	—	10000	1.0	12L8GT
12Q7GT	Duplex-Diode Triode	O.	7V	12.6	0.15	2.2	5	1.60	Class-C Amp.	Characteristics same as 6Q7—Table I										12Q7GT
12S8GT	Triple-Diode Triode	O.	Fig. 34	12.6	0.15	2.0	3.8	1.2	Class-A Amp.	250	− 2.0	—	—	0.9	91000	1100	100	—	—	12S8GT
12SA7	Pentagrid Converter	O.	8R	12.6	0.15	—	—	—	Converter	Characteristics same as 6SA7—Table I										12SA7
12SC7	Twin Triode	O.	8S	12.6	0.15	—	—	—	Class-A Amp.	Characteristics same as 6SC7—Table I										12SC7
12SF5	High-μ Triode	O.	6AB	12.6	0.15	4	3.6	2.40	Class-A Amp.	Characteristics same as 6SF5—Table I										12SF5
12SF7	Diode Variable-μ Pentode	O.	7AZ	12.6	0.15	5.5	6.0	.004	Class-A Amp.	Characteristics same as 6SF7—Table I										12SF7
12SG7	Triple-Grid Variable-μ	O.	8BK	12.6	0.15	8.5	7.0	.003	Class-A Amp.	Characteristics same as 6SG7—Table I										12SG7

TABLE IX—HIGH-VOLTAGE HEATER TUBES—*Continued*

Type	Name	Base	Socket Connections	Heater Volts	Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
12SH7	H-F Amplifier Pentode	O.	8BK	12.6	0.15	8.5	7.0	.003	H-F Amplifier	Characteristics same as 6SH7—Table I										12SH7
12SJ7	Pentode Voltage Amplifier	O.	8N	12.6	0.15	—	—	—	Class-A Amp.	Characteristics same as 6SJ7—Table I										12SJ7
12SK7	Remote Cut-off Pentode	O.	8N	12.6	0.15	6.0	7.0	.003	R.F. Amplifier	Characteristics same as 6SK7—Table I										12SK7
12SL7GT	Twin Triode	O.	8BD	12.6	0.15	—	—	—	Class-A Amp.	Characteristics same as 6SL7GT—Table II										12SL7GT
12SN7GT	Twin Triode	O.	8BD	12.6	0.3	—	—	—	Class-A Amp.	Characteristics same as 6SN7GT—Table II										12SN7GT
12SQ7	Duplex-Diode Triode	O.	8Q	12.6	0.15	3.2	3.0	1.60	Class-A Amp.	Characteristics same as 6SQ7—Table I										12SQ7
12SR7	Duplex-Diode Triode	O.	8Q	12.6	0.15	3.6	2.8	2.40	Class-A Amp.	Characteristics same as 6R7—Table I										12SR7
12SW7	Duplex-Diode Triode	O.	8Q	12.6	0.15	3.0	2.8	2.4	Class-A_1 Amp.	250	— 9	—	—	9.5	8500	1900	16	—	—	12SW7
12SX7	Twin Triode	O.	8BD	12.6	0.3	3.0	0.8	3.6	Class-A_1 Amp.[5]	250	— 8	—	—	9	7700	2600	20	—	—	12SX7
12SY7	Heptode Converter	O.	8R	12.6	0.15	Osc.-Grid leak 20000 ohms			Converter	250	— 2	100	8.5	3.5	1000000	450	—	—	—	12SY7
14A4	Triode Amplifier	L.	5AC	14	0.16	3.4	3.0	4.00	Class-A Amp.	Characteristics same as 7A4—Table III										14A4
14A5	Beam Power Amplifier	L.	6AA	14	0.16	—	—	—	Class-A_1 Amp.	250	−12.5	250	3.5/5.5	30/32	70000	3000	—	7500	2.8	14A5
14A7/12B7	Triple-Grid Variable-μ	L.	8V	14	0.16	6.0	7.0	.005	Class-A Amp.	250	— 3.0	100	2.6	9.2	800000	2000	—	—	—	14A7/12B7
14AF7	Twin Triode	L.	8AC	14	0.16	2.2	1.6	2.30	Class-A Amp.	250	−10	—	—	9	7600	2100	16	—	—	14AF7
14B6	Duplex-Diode Triode	L.	8W	14	0.16	—	—	—	Class-A Amp.	Characteristics same as 7B6—Table III										14B6
14B8	Pentagrid Converter	L.	8X	14	0.16	Ic2 = 4 Ma.			Converter	Characteristics same as 7B8—Table III										14B8
14C5	Beam Power Amplifier	L.	6AA	14	0.24	—	—	—	Class-A Amp.	Characteristics same as 6V6—Table I										14C5
14C7	Triple-Grid Amplifier	L.	8V	14	0.16	6.0	6.5	.007	Class-A Amp.	250	— 3.0	100	0.7	2.2	1000000	1575	—	—	—	14C7
14E6	Duplex-Diode Triode	L.	8W	14	0.16	—	—	—	Class-A Amp.	Characteristics same as 7E6—Table III										14E6
14E7	Duplex-Diode Pentode	L.	8AE	14	0.16	4.6	5.3	.005	Class-A Amp.	Characteristics same as 7E7—Table III										14E7
14F7	Twin Triode	L.	8AC	14	0.16	—	—	—	Class-A Amp.	Characteristics same as 7F7—Table III										14F7
14H7	Triple-Grid Semi-Variable-μ	L.	8V	14	0.16	8.0	7.0	.007	Class-A Amp.	250	— 2.5	150	3.5	9.5	800000	3800	—	—	—	14H7
14J7	Triode-Hexode Converter	L.	8AR	14	0.16	Ipt = 5 Ma.			Converter	Characteristics same as 7J7—Table III										14J7
14N7	Twin Triode	L.	8AC	14	0.32	—	—	—	Class-A Amp.	Characteristics same as 7N7—Table III										14N7
14Q7	Heptode Pentagrid Converter	L.	8AL	14	0.16	—	—	—	Converter	Characteristics same as 7Q7—Table III										14Q7
14R7	Duplex-Diode Pentode	L.	8AE	14	0.16	5.6	5.3	.004	Class-A Amp.	Characteristics same as 7R7—Table III										14R7
14S7	Triode Heptode	L.	8BL	14	0.16	Ipt = 5 Ma.			Converter	250	— 2.0	100	3	1.8	1250000	525	—	—	—	14S7
14V7	H.f. Pentode	L.	8V	14	0.24	—	—	—	Class-A Amp.	300	— 2.0	150	3.9	9.6	300000	5800	—	—	—	14V7
14W7	Pentode	L.	8BJ	14	0.24	Rk = 160 ohms			Class-A Amp.	300	— 2.2	150	3.9	10	300000	5800	—	—	—	14W7
18	Pentode	M.	6B	14	0.30	—	—	—	Class-A Amp.	Characteristics same as 6F6G										18
20J8GM	Triode Heptode Converter	O.	8H	20	0.15	—	—	—	Converter	250	— 3.0	100	3.4	1.5	Triode Plate (No. 6) 100 v. 1.5 ma.					20J8GM
21A7	Triode Hexode Converter	L.	8AR	21	0.16	—	—	—	Converter	250 150	— 3.0 — 3.0	100	2.8 Triode	1.3 3.5	— —	275 1900	— 32	— —	— —	21A7
25A6	Pentode Power Amplifier	O.	7S	25	0.3	8.5	12.5	0.20	Class-A Amp.	135	−20.0	135	8	37	35000	2450	85	4000	2.0	25A6
25A7G	Rectifier-Amplifier	O.	8F	25	0.3	—	—	—	Class-A Amp.	100	−15.0	100	4	20.5	50000	1800	90	4500	0.77	25A7G
25AC5G	Triode Power Amplifier	O.	6Q	25	0.3	—	—	—	Class-A Amp.	110	+15.0	—	—	45	—	3800	58	2000	2.0	25AC5G
										165	Used in dynamic-coupled circuit with 6AF5G driver							3500	3.3	
25B5	Direct-Coupled Triodes	S.	6D	25	0.3	—	—	—	Class-A Amp.	110	0	110	7	45	11400	2200	25	2000	2.0	25B5
25B6G	Pentode Power Amplifier	O.	7S	25	0.3	—	—	—	Class-A Amp.	95	−15.0	95	4	45	—	4000	—	2000	1.75	25B6G
25B8GT	Triode Pentode	O.	8T	25	0.15	—	—	—	Class-A Amp.	Characteristics same as 12B8GT										25B8GT
25C6G	Beam Power Amplifier	O.	7AC	25	0.3	—	—	—	Class-A_1 Amp.	135	−13.5	135	3.5/11.5	58/60	9300	7000	—	2000	3.6	25C6G
25D8GT	Diode Triode Pentode	O.	8AF	25	0.15	—	—	—	Triode Amp.	100	— 1.0	—	—	0.5	91000	1100	100	—	—	25D8GT
									Pentode Amp.	100	— 3.0	100	2.7	8.5	200000	1900	—	—	—	
25L6	Beam Power Amplifier	O.	7AC	25	0.3	16	13.5	0.30	Class-A_1 Amp.	110	— 8.0	110	3.5/10.5	45/48	10000	8000	80	2000	2.2	25L6
25N6G	Direct-Coupled Triodes	O.	7W	25	0.3	—	—	—	Class-A Amp.	110	0	110	7	45	11400	2200	25	2000	2.0	25N6G

TABLE IX—HIGH-VOLTAGE HEATER TUBES—*Continued*

Type	Name	Base	Socket Connections	Heater Volts	Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
26A7GT	Twin Beam-Power Audio Amplifier	O.	8BU	26.5	0.6	Each Unit Push-Pull			Class-A Amp.[3]	26.5	− 4.5	26.5	2/5.5	20/20.5	2500	5500	—	1500	0.2	26A7GT
									Class-AB Amp.[3]	26.5	− 7.0	26.5	2/8.5	19/30	—	—	—	2500[4]	0.5	
32L7GT	Diode-Beam Tetrode	O.	8Z	32.5	0.3	—	—	—	Class-A Amp.	110	− 7.5	110	3	40	15000	6000	—	2500	1.5	32L7GT
35A5	Beam Power Amplifier	L.	6AA	35	0.15	—	—	—	Class-A_1 Amp.	110	− 7.5	110	3/7	40/41	14000	5800	—	2500	1.5	35A5
35L6G	Beam Power Amplifier	O.	7AC	35	0.15	13	9.5	0.80	Class-A_1 Amp.	110	− 7.5	110	3/7	40/41	13800	5800	—	2500	1.5	35L6G
43	Pentode Power Amplifier	M.	6B	25	0.3	8.5	12.5	0.20	Class-A Amp.	95	−15.0	95	4.0	20.0	45000	2000	90	4500	0.90	43
48	Tetrode Power Amplifier	M.	6A	30	0.4	—	—	—	Class-A Amp.	96	−19.0	96	9.0	52.0	—	3800	—	1500	2.0	48
50A5	Beam Power Amplifier	L	6AA	50	0.15	—	—	—	Class-A_1 Amp.	110	− 7.5	110	4/11	49/50	10000	8200	—	2000	2.2	50A5
50C6GT	Beam Power Amplifier	O.	7AC	50	0.15	—	—	—	Class-A_1 Amp.	135	−13.5	135	3.5/11.5	58/60	9300	7000	—	2000	3.6	50C6GT
50L6GT	Beam Power Amplifier	O.	7AC	50	0.15	—	—	—	Class-A Amp.	110	− 7.5	110	4/11	49/50	—	8200	82	2000	2.2	50L6GT
70A7GT	Diode-Beam Tetrode	O.	8AB[1]	70	0.15	—	—	—	Class-A Amp.	110	− 7.5	110	3.0	40	—	5800	80	2500	1.5	70A7GT
70L7GT	Diode-Beam Tetrode	O.	8AA	70	0.15	—	—	—	Class-A_1 Amp.	110	− 7.5	110	3/6	40/43	15000	7500	—	2000	1.8	70L7GT
117L7GT/ 117M7GT	Rectifier-Amplifier	O.	8AO	117	0.09	—	—	—	Class-A Amp.	105	− 5.2	105	4/5.5	43	17000	5300	—	4000	0.85	117L7GT/ 117M7GT
117N7GT	Rectifier-Amplifier	O.	8AV	117	0.09	—	—	—	Class-A Amp.	100	− 6.0	100	5.0	51	16000	7000	—	3000	1.2	117N7GT
117P7GT	Rectifier-Amplifier	O.	8AV	117	0.09	—	—	—	Class-A Amp.	105	− 5.2	105	4/5.5	43	17000	5300	—	4000	0.85	117P7GT
1284	U.h.f. Pentode	O.	Fig. 4	12.6	0.15				Class-A Amp.	250	− 3.0	100	2.5	9.0	800000	2000	—	—	—	1284
1629	Electron-Ray Tube	O.	6RA	12.6	0.15	—	—	—	Indicator Tube	Characteristics same as 6E5—Table IV										1629
1631	Beam Power Amplifier	O.	7AC	12.6	0.45	—	—	—	Class-A Amp.	Characteristics same as 6L6—Table I										1631
1632	Beam Power Amplifier	O.	7AC	12.6	0.6	—	—	—	Class-A Amp.	Characteristics same as 25L6										1632
1633	Twin Triode	O.	8BD	25	0.15	—	—	—	Class-A Amp.	Characteristics same as 6SN7GT—Table II										1633
1634	Twin Triode	O.	8S	12.6	0.15	—	—	—	Class-A Amp.	Characteristics same as 6SC7—Table I										1634
1644	Twin Pentode	O.	Fig. 7	12.6	0.15	—	—	—	Class-A Amp.	180	− 9.0	180	2.8/4.6	13	160000	2150	—	10000	1.0	1644
XXD	Twin Triode	L.	8AC	12.6	0.15	—	—	—	Class-A Amp.	250	−10	—	—	9.0	—	2100	16	—	—	XXD
28D7	Double Beam Power Amplifier	L.	8BS	28.0	0.4	—	—	—	Class-A Amp.	28	390*	28[2]	0.7[2]	9.0[2]	—	—	—	4000[4]	0.08[2]	28D7
											180*	28[3]	1.2[3]	18.5[3]	—	—	—	6000[4]	0.175[3]	

* Cathode resistor—ohms.

[1] 6.3-volt pilot lamp must be connected between Pins 6 and 7.
[2] Per section—resistance-coupled.
[3] P.p. operation—values for both sections, resistance-coupled.
[4] Plate to plate.
[5] Values are for each unit.
[6] Values are for single tube.

TABLE X—SPECIAL RECEIVING TUBES

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
00-A	Triode Detector	M.	4D	5.0	0.25	3.2	2.0	8.50	Grid Leak Det.	45	—	—	—	1.5	30000	666	20	—	—	00-A
01-A	Triode Detector Amplifier	M.	4D	5.0	0.25	—	—	—	Class-A Amp.	135	− 9.0	—	—	3.0	10000	800	8.0	—	—	01-A
2E32	Sub miniature Pentode	1	—	1.25	0.05				Class-A Amp.	22.5	0	22.5	0.3	0.4	350000	500	—	—	—	2E32
2E36	Sub miniature Pentode	1	—	1.25	0.03				Class-A_1 Amp.	22.5	0	22.5	0.07	0.27	220000	385	—	150000	0.0012	2E36
										45	−1.25	45	0.11	0.45	250000	500	—	100000	0.006	
2E42	Sub miniature Diode Pent.	1	—	1.25	0.03				Detector Amp.	22.5	0	22.5	0.12	0.35	250000	375	—	1 meg.	—	2E42
2G22	Sub miniature Converter	1	—	1.25	0.05				Converter	22.5	0	22.5	0.3	0.2	500000	60	—	—	—	2G22
3A8GT	Diode Triode Pentode	O.	8AS	1.4	0.1	—	—	—	Class-A Triode	90	0	—	—	0.15	240000	275	65	—	—	3A8GT
				2.8	0.05				Class-A Pentode	90	0	90	0.3	1.2	600000	750	—	—	—	
3B5GT	Beam Power Amplifiers	O.	7AP	1.4	0.1	—	—	—	Class-A Amp.	67.5	− 7.0	67.5	0.6	8.0	100000	1650	—	5000	0.2	3B5GT
				2.8	0.05								0.5	6.7		1500			0.18	
3C5GT	Power Output Pentode	O.	7AQ	1.4	0.1	—	—	—	Class-A Amp.	90	− 9.0	90	1.4	6.0	—	1550	—	8000	0.24	3C5GT
				2.8	0.05											1450		10000	0.26	
3C6	Twin Triode	L.	7BW	1.4	0.1	—	—	—	Class-A Amp.	90	0	—	—	4.5	11200	1300	14.5	—	—	3C6
				2.8	0.05															

TABLE X—SPECIAL RECEIVING TUBES—*Continued*

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
3LE4	Power Amplifier Pentode	L.	6BA	2.8	0.05	—	—	—	Class-A Amp.	90	− 9.0	90	1.8	9.0	110000	1600	—	6000	0.30	3LE4
3LF4	Power Amplifier Tetrode	L.	6BB	1.4 2.8	0.1 0.05	—	—	—	Class-A Amp.	90	− 4.5	90	1.3 1.0	9.5 8.0	75000 80000	2200 2000	—	8000 7000	0.27 0.23	3LF4
3Q5GT	Beam Power Amplifier	O.	7AP	1.4 2.8	0.1 0.05	Parallel Filaments Series Filaments			Class-A Amp.	90	− 4.5	90	1.3 1.0	9.5 7.5	—	2100 1800	—	8000	0.27 0.25	3Q5GT
4A6G	Twin Triode Amplifier	O.	8L	4	0.06	Triodes Parallel			Class-A Amp.	90	− 1.5	—	—	2.2	13300	1500	20	—	—	4A6G
				2	0.12	Both Sections			Class-B Amp.	90	0	—	—	4.6	—	—	—	8000	1.0	
6F4	Acorn Triode	A.	7BR	6.3	0.225	2.0	0.6	1.90	Class-A Amp.	80	150*	—	—	13.0	2900	5800	17	—	—	6F4
10	Triode Power Amplifier	M.	4D	7.5	1.25	4.0	3.0	7.00	Class-A Amp.	425	−39.0	—	—	18.0	5000	1600	8.0	10200	1.6	10
11/12	Triode Detector Amplifier	M.	4F/4D	1.1	0.25	—	—	—	Class-A Amp.	135	−10.5	—	—	3.0	15000	440	6.6	—	—	11/12
20	Triode Power Amplifier	S.	4D	3.3	0.132	2.0	2.3	4.10	Class-A Amp.	135	−22.5	—	—	6.5	6300	525	3.3	6500	0.11	20
22	Tetrode R.F. Amplifier	M.	4K	3.3	0.132	3.5	10	0.02	Class-A Amp.	135	− 1.5	67.5	1.3	3.7	325000	500	160	—	—	22
26	Triode Amplifier	M.	4D	1.5	1.05	2.8	2.5	8.10	Class-A Amp.	180	−14.5	—	—	6.2	7300	1150	8.3	—	—	26
40	Triode Voltage Amplifier	M.	4D	5.0	0.25	2.8	2.2	2.00	Class-A Amp.	180	− 3.0	—	—	0.2	150000	200	30	—	—	40
50	Triode Power Amplifier	M.	4D	7.5	1.25	4.2	3.4	7.10	Class-A Amp.	450	−84.0	—	—	55.0	1800	2100	3.8	4350	4.6	50
71-A	Triode Power Amplifier	M.	4D	5.0	0.25	3.2	2.9	7.50	Class-A Amp.	180	−43.0	—	—	20.0	1750	1700	3.0	4800	0.79	71-A
99[10]	Triode Detector Amplifier	S.	4D	3.3	0.063	2.5	2.5	3.30	Class-A Amp.	90	− 4.5	—	—	2.5	15500	425	6.6	—	—	99
112A	Triode Detector Amplifier	M.	4D	5.0	0.25	—	—	—	Class-A Amp.	180	−13.5	—	—	7.7	4700	1800	8.5	—	—	112A
182B/ 482B	Triode Amplifier	M.	4D	5.0	1.25	—	—	—	Class-A Amp.	250	−35.0	—	—	18.0	—	1500	5.0	—	—	182B/ 482B
183/483	Power Triode	M.	4D	5.0	1.25	—	—	—	Class-A Amp.	250	−60.0	—	—	25.0	18000	1800	3.2	4500	2.0	183/483
485	Triode	S.	5A	3.0	1.3	—	—	—	Class-A Amp.	180	− 9.0	—	—	6.0	9300	1350	12.5	—	—	485
864	Triode Amplifier	S.	4D	1.1	0.25	—	—	—	Class-A Amp.	90	− 4.5	—	—	2.9	13500	610	8.2	—	—	864
954	Pentode Detector, Amplifier	A.	5BB	6.3	0.15	3.4	3.0	0.007	Class-A Amp.	250	− 3.0	100	0.7	2.0	1.5 meg.	1400	2000	—	—	954
									Bias Detector	250	− 6.0	100	—	Plate current to be adjusted to 0.1 ma. with no signal					—	
955	Triode Detector, Amplifier, Oscillator	A.	5BC	6.3	0.15	1.0	0.6	1.40	Class-A Amp.	250	− 7.0	—	—	6.3	11400	2200	25	—	—	955
										90	− 2.5	—	—	2.5	14700	1700	25	—	—	
956	Triple-Grid Variable-μ R.F. Amplifier	A.	5BB	6.3	0.15	3.4	3.0	0.007	Class-A Amp.	250	− 3.0	100	2.7	6.7	700000	1800	1440	—	—	956
									Mixer	250	−10.0	100	—	—	Oscillator peak volts—7 min.					
957	Triode Detector, Amplifier, Oscillator	A.	5BD	1.25	0.05	0.3	0.7	1.20	Class-A Amp.	135	− 5.0	—	—	2.0	20800	650	13.5	—	—	957
958 958-A	Triode A.F. Amplifier, Oscillator	A.	5BD	1.25	0.1	0.6	0.8	2.60	Class-A Amp.	135	− 7.5	—	—	3.0	10000	1200	12	—	—	958 958-A
959	Pentode Detector, Amplifier	A.	5BE	1.25	0.05	1.8	2.5	0.015	Class-A Amp.	145	− 3.0	67.5	0.4	1.7	800000	600	480	—	—	959
7E5/1201	U.h.f. Triode	L.	8BN	6.3	0.15	3.6	2.8	1.50	Class-A Amp.	180	− 3	—	—	5.5	12000	—	36	—	—	7E5/1201
7C4/1203	U.h.f. Diode	L.	4AH	6.3	0.15	—	—	—	Rectifier		Max. r.m.s. voltage—150				Max. d.c. output current—8 ma.					7C4/1203
7AB7/ 1204	U.h.f. Pentode	L.	Fig. 5	6.3	0.15	3.5	4.0	0.06	Class-A Amp.	250	− 2	100	0.6	1.75	800000	1200	—	—	—	7AB7/ 1204
1276	Triode Power Amplifier	M.	4D	4.5	1.14	—	—	—	Class-A Amp.				Characteristics similar to 6A3							1276
1609	Pentode Amplifier	S.	5B	1.1	0.25	—	—	—	Class-A Amp.	135	− 1.5	67.5	0.65	2.5	400000	725	300	—	—	1609
9004	U.h.f. Diode	A.	4BJ	6.3	0.15	—	—	—	Detector			Max. a.c. voltage—117. Max. d.c. output current—5 ma.								9004
9005	U.h.f. Diode	A.	5BG	3.6	0.165	—	—	—	Detector			Max. a.c. voltage—117. Max. d.c. output current—1 ma.								9005
EF-50	High-Frequency Pentode Amplifier	L.	Fig. 14	6.3	0.3	8	5	0.007	I.F.-R.F. Amp.	250	150*	250	3.1	10	600000	6300	—	—	—	EF-50
GL-2C44 GL-464A	U.h.f. Triode	O.	Fig. 17	6.3	0.75	—	—	—	Class-A Amp. and Modulator	250	100*	—	—	25.0	—	7000	—	—	—	GL-2C44 GL-464A
GL-446A GL-446B	U.h.f. Triode	O.	Fig. 19	6.3	0.75	—	—	—	Oscillator, Amp. or Converter	250	200*	—	—	15.0	—	4500	45	—	—	GL-446A GL-446B
559	U.h.f. Diode	O.	Fig. 18	6.3	0.75	—	—	—	Detector or trans.	5.0	—	—	—	24.0	—	—	—	—	—	559

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
NU-2C35	Special Hi-Mu Triode	O.	Fig. 38	6.3	0.3	5.2	2.3	0.62	Shunt Voltage Regulator	8000	—200	—	—	5.0	525000	950	500	—	—	NU-2C35
M54	Tetrode Power Amplifier	1	—	0.625	0.04	—	—	—	Class-A Amp.	30	0	30	0.06	0.5	130000	200	25	35000	0.005	M54
M64	Tetrode Voltage Amplifier	1	—	0.625	0.02	—	—	—	Class-A Amp.	30	0	—	—	0.03	200000	110	25	—	—	M64
M74	Tetrode Voltage Amplifier	1	—	0.625	0.02	—	—	—	Class-A Amp.	30	0	7.0	0.01	0.02	500000	125	70	—	—	M74
XXB	Twin-Triode Frequency Converter	L.	Fig. 9	2.8/ 1.4 3.2[6]/ 1.6	0.05/ 0.10 — —	—	—	—	Converter[5]	90[2]	0	—	—	4.5[7] 4.5[9]	11200[4] 11200[9]	1300[4] 1300[9]	14.5[2]	—	—	XXB
											— 3	—	—	1.4[7] 1.4[9]	1900[4] 1900[9]	760[7] 760[9]	14.5[2]	—	—	
XXFM	Twin-Diode Triode	L.	Fig. 10	6.3	0.3	—	—	—	Special Detector Amplifier	250[8]	— 1	—	—	1.9	6700	1500	100	—	—	XXFM
										100[8]	0	—	—	1.2	85000	1000	85	—	—	
										100[3]	—	—	—	4[4]	—	—	—	—	—	

* Cathode resistor—ohms.
[1] No base; tinned wire leads.
[2] Both sections.
[3] Diode plates (a.c. max. volts per plate).
[4] Max. d.c. output.
[5] Section No. 2 recommended for h.f.o.
[6] Dry battery operation.
[7] Section No. 1.
[8] Amplifier plate.
[9] Section No. 2.
[10] Same as X99. Type V99 is same, but socket connections are 4E.

TABLE XI—MINIATURE RECEIVING TUBES

Type	Name	Base	Socket Connections	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor[4]	Load Resistance Ohms	Power Output Watts	Type
1A3	H. F. Diode	B.	5AP	1.4	0.15	—	—	—	Detector F.M. Discrim.		Max. a.c. voltage per plate—117.					Max. output current—0.5 ma.				1A3
1L4	R.F. Pentode Amplifier	B.	6AR	1.4	0.05	3.6	7.5	.008	Class-A Amp.	90	0	90	2.0	4.5	350000	1025	—	—	—	1L4
1R5	Pentagrid Converter	B.	7AT	1.4	0.05	—	—	—	Converter	90	0	67.5	3.0	1.7	500000	300	Grid No. 1 100000 ohms			1R5
1S4	Pentagrid Power Amp.	B.	7AV	1.4	0.1	—	—	—	Class-A Amp.	90	— 7.0	67.5	1.4	7.4	100000	1575	—	8000	0.270	1S4
1S5	Diode Pentode	B.	6AU	1.4	0.05	—	—	—	Class-A Amp.	67.5	0	67.5	0.4	1.6	600000	625	—	—	—	1S5
									R-Coupled Amp.	90	0	90	Screen resistor 3 meg., grid 10 meg.					1 meg.	0.050	
1T4	Triple-Grid Variable-μ	B.	6AR	1.4	0.05	3.6	7.5	0.01	Class-A Amp.	90	0	45	0.65	2.0	800000	750	—	—	—	1T4
1U4	Pentode R.F. Amplifier	B.	6AR	1.4	0.05	3.6	7.5	.008	Class-A Amp.	90	0	90	0.45	1.6	1500000	900	—	—	—	1U4
1U5	Diode Pentode	B.	6BW	1.4	0.05	—	—	—	Class-A Amp.	67.5	0	67.5	0.4	1.6	600000	625	—	—	—	1U5
2E30	Beam Power Tetrode	B.	7CQ	6.0	0.7	10	4.5	0.5	Class-A_1 Single	250	450*	250	7.4[2]	44[2]	63000	3700	40[5]	4500	4.5	2E30
									Class-A_1 Amp.[3]	250	225*	250	14.8[2]	88[2]	—	—	80[5]	9000[6]	9	
									Class-AB_1 Amp.[3]	250	—25	250	13.5[2]	80[2]	—	—	48[5]	8000[6]	12.5	
									Class-AB_2 Amp.[3]	250	—30	250	20[2]	120[2]	—	—	40[5]	3800[6]	17	
3A4	Power Amplifier Pentode	B.	7BB	1.4 2.8	0.2 0.1	4.8	4.2	0.34	Class-A_1 Amp.	135 150	— 7.5 — 8.4	90 90	2.6 2.2	14.9[2] 14.1[2]	90000 100000	1900	—	8000	0.6 0.7	3A4
3A5	H.F. Twin Triode	B.	7BC	1.4 2.8	0.22 0.11	0.9	1.0	3.20	Class-A Amp.	90	— 2.5	—	—	3.7	8300	1800	15	—	—	3A5
3Q4	Power Amplifier Pentode	B.	7BA	1.4	0.1	Parallel Filaments			Class-A Amp.	90	— 4.5	90	2.1	9.5	100000	2150	—	10000	0.27	3Q4
				2.8	0.05	Series Filaments							1.7	7.7	120000	2000			0.24	
3S4	Power Amplifier Pentode	B.	7BA	1.4	0.1	Parallel Filaments			Class-A Amp.	90	—. 7.0	67.5	1.4	7.4	100000	1575	—	8000	0.27	3S4
				2.8	0.05	Series Filaments							1.1	6.1		1425			0.235	
3V4	Power Amplifier Pentode	B.	6BX	1.4	0.1	Parallel Filaments			Class-A Amp.	90	— 4.5	90	2.1	9.5	100000	2150	—	10000	0.27	3V4
				2.8	0.05	Series Filaments			Class-A Amp.	90	— 4.5	90	1.7	7.7	120000	2000	—	10000	0.24	
6AG5	Pentode R.F. Amplifier	B.	7BD	6.3	0.3	—	—	—	Class-A Amp.	250 100	200* 100*	150 100	2.0 1.6	7.0 5.5	800000 300000	5000 4750	— —	— —	—	6AG5
6AJ5	U.h.f. Pentode	B.	7PM	6.3	0.175	—	—	—	R.F. Amplifier	28	200*	28	1.2	3.0	90000	2750	250	—	—	6AJ5
									Class-AB Amp.	180	— 7.5	75	—	—	—	—	—	28000	1.0	
6AK5	H.F. Pentode	B.	7BD	6.3	0.175	—	—	—	R.F. Amplifier	180	200*	120	2.4	7.7	690000	5100	3500	—	—	6AK5
										150	330*	140	2.2	7.0	420000	4300	1800	—	—	
										120	200*	120	2.5	7.5	340000	5000	1700	—	—	

TABLE XI—MINIATURE RECEIVING TUBES—*Continued*

Type	Name	Base	Socket Connections[1]	Fil. or Heater Volts	Fil. or Heater Amp.	Capacitance μμfd. In	Capacitance μμfd. Out	Capacitance μμfd. Plate-Grid	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance Ohms	Transconductance Micromhos	Amp. Factor[4]	Load Resistance Ohms	Power Output Watts	Type
6AK6	Power Amplifier Pentode	B.	7BK	6.3	0.15	3.6	4.2	0.12	Class-A Amp.	180	− 9.0	180	2.5	15.0	200000	2300	—	10000	1.1	6AK6
6AL5	U.h.f. Twin Diode	B.	6BT	6.3	0.3	—	—	—	Detector	Max. r.m.s. voltage—150. Max. d.c. output current—10 ma.[1]										6AL5
6AN6	Twin Diode	B.	7BJ	6.3	0.2	—	—	—	Detector	R.m.s. voltage per plate = 75 volts; d.c. output = 3.5 ma. with 25000 ohms and 8 μμf load; peak current per plate = 10 ma.; peak inverse voltage = 210.										6AN6
6AQ5	Beam Power Tetrode	B.	7BZ	6.3	0.45	7.6	6.0	0.35	Class-A1 Amp.	180	− 8.5	180	4.0[2]	30[2]	58000	3700	29[5]	5500	2.0	6AQ5
										250	−12.5	250	7.0[2]	47[2]	52000	4100	45[5]	5000	4.5	
6AQ6	Duodiode Hi-mu Triode	B.	7BT	6.3	0.15	1.7	1.5	1.80	Class-A Triode	250	− 3.0	—	—	1.0	58000	1200	70	—	—	6AQ6
										100	− 1.0	—	—	0.8	61000	1150	70	—	—	
6AR5	Pentode Power Amp.	B.	6CC	6.3	0.4	—	—	—	Class-A1 Amp.	250	−18	250	5.5[2]	33[2]	68000	2300	—	7600	3.4	6AR5
										250	−16.5	250	5.5[2]	35[2]	65000	2400	—	7000	3.2	
6AS6	Sharp Cut-off Pentode	B.	7CN	6.3	0.175	4.0	3.0	0.02	Class-A Amp.	120	− 2	120	3.5	5.5	—	3500	—	—	—	6AS6
6AT6	Duplex Diode Triode	B.	7BT	6.3	0.3	2.3	1.1	2.10	Class-A Amp.	250	− 3	—	—	1.0	58000	1200	70	—	—	6AT6
6AU6	Pentode R.F. Amp.	B.	7BK	6.3	0.3	5.5	5.0	.0035	Class-A Amp.	250	− 1	150	4.3	10.8	2000000	5200	—	—	—	6AU6
6BA6	Remote Cut-off Pentode	B.	7CC	6.3	0.3	5.5	5.0	.0035	Class-A Amp.	250	68*	100	4.2	11	1500000	4400	—	—	—	6BA6
6BD6	Pentode R.F. Amplifier	B.	7CC	6.3	0.3	—	—	—	Class-A Amp.	100	− 1	100	5	13	120000	2350	—	—	—	6BD6
										250	− 3	100	3.5	9	700000	2000	—	—	—	
6BE6	Pentagrid Converter	B.	7CH	6.3	0.3	Osc. Grid 20000 Ω			Converter	250	− 1.5	100	7.1	3.0	1000000	475	—	—	—	6BE6
6BF6	Duplex-Diode Triode	B.	7BT	6.3	0.3	1.8	1.1	2.0	Class-A1 Amp.	250	−9	—	—	9.5	8500	1900	16	10000	—	6BF6
6BJ6	Pentode Remote-Cutoff	B.	7CM	6.3	0.15	4.5	5.0	.0035	Class A1 Amp.	250	−1	100	3.3	9.2	1300000	3800	—	—	—	6BJ6
6C4	Triode Amplifier	B.	6BG	6.3	0.15	1.8	1.3	1.60	Class-A Amp.	250	− 8.5	—	—	10.5	7700	2200	17	—	—	6C4
6J4	U.h.f. Grounded-Grid R.F. Amplifier	B.	7BQ	6.3	0.4	5.5	0.24	4.0	Grounded-Grid	150	200*	—	—	15.0	4500	12000	55	—	—	6J4
									Class-A1 Amp.	100	100*	—	—	10.0	5000	11000	55	—	—	
6J6	Twin Triode	B.	7BF	6.3	0.45	2.2	0.4	1.6	Class-A1 Amp. Mixer, Oscillator	100	50*	—	—	8.5	7100	5300	38	—	—	6J6
6N4	U.h.f. Triode Amplifier	B.	7CA	6.3	0.2	3.0	1.6	1.10	Class-A Amp.	180	− 3.5	—	—	12.0	—	6000	32	—	—	6N4
12AL5	Twin Diode	B.	6BT	12.6	0.15	2.5	—	—	Detector	R.m.s. voltage per plate = 117; d.c. output = 9 ma. per plate; peak ma. per plate = 54; peak inverse voltage = 330.										12AL5
12AT6	Duplex Diode Triode	B.	7BT	12.6	0.15	2.3	1.1	2.10	Class-A Amp.	250	− 3.0	—	—	1.0	58000	1200	70	—	—	12AT6
12AU6	Sharp Cut-off Pentode	B.	7CC	12.6	0.15	5.5	5.0	.0035	Class-A1 Amp.	250	− 1.0	150	4.3	10.8	1 meg.	5200	—	—	—	12AU6
12AU7	Twin-Triode Amplifier	B.	9A	6.3	0.3	1.6[7]	0.5[7]	1.5[7]	Class-A1 Amp.	250	− 8.5	—	—	10.5	7700	2200	17	—	—	12AU7
				12.6	0.15	1.6[8]	0.35[8]	1.5[8]												
12AW7	Sharp Cut-off Pentode	B.	7CM	12.6	0.15	6.5	1.5	0.025	Class A1 Amp.	250	200*	150	2.0	7.0	0.8 meg.	5000	—	—	—	12AW7
12BA6	Remote Cut-off Pentode	B.	7CC	12.6	0.15	5.5	5.0	.0035	Class-A Amp.	250	68*	100	4.2	11.0	1500000	4400	—	—	—	12BA6
12BD6	Pentode Amplifier	B.	7CC	12.6	0.15	4.3	5.0	.004	Class-A Amp.	250	− 3	100	3.5	9.0	700000	2000	—	—	—	12BD6
12BE6	Pentagrid Converter	B.	7CH	12.6	0.15	Osc. Grid 20000 Ω			Converter	250	− 1.5	100	7.1	3.0	1000000	475	—	—	—	12BE6
12BF6	Duodiode Triode	B.	Fig. 37	12.6	0.15	1.8	1.1	2.00	Class-A Amp.	250	− 9	—	—	9.5	8500	1900	16	—	—	12BF6
26A6	Remote cut-off Pentode	B.	7BK	26.5	0.07	6.0	5.0	.0035	Class-A1 Amp.	250	125*	100	4	10.5	1000000	4000	—	—	—	26A6
26C6	Duplex-Diode Triode	B.	7BT	26.5	0.07	1.8	1.4	2	Class-A1 Amp.	250	− 9	—	—	9.5	8500	1900	16	—	—	26C6
26D6	Pentagrid Converter	B.	7CH	26.5	0.07	Osc. Grid 20000 Ω			Converter	250	− 1.5	100	7.8	3.0	1000000	475	—	—	—	26D6
35B5	Beam Power Amplifier	B.	7BZ	35	0.15	11	6.5	0.4	Class-A1 Amp.	110	− 7.5	110	7[2]	41[2]	—	5800	40[5]	2500	1.5	35B5
50B5	Beam Power Amplifier	B.	7BZ	50.0	0.15	13	6.5	0.50	Class-A Amp.	110	− 7.5	110	4.0	49.0	14000	7500	—	3000	1.9	50B5
9001	Triple-Grid Detector, Amplifier	B.	7PM	6.3	0.15	3.6	3.0	0.01	Class-A Amp.	250	− 3.0	100	0.7	2.0	1 meg.+	1400	—	—	—	9001
									Mixer	250	− 5.0	100	Osc. peak voltage 4 volts			550	—	—	—	
9002	Triode Detector, Amplifier, Oscillator	B.	7TM	6.3	0.15	1.2	1.1	1.40	Class-A Amp.	250	− 7.0	—	—	6.3	11400	2200	25	—	—	9002
										90	− 2.5	—	—	2.5	14700	1700	25	—	—	
9003	Triple-Grid Variable-μ R.F. Amplifier	B.	7PM	6.3	0.15	3.6	3.0	0.01	Class-A Amp.	250	− 3.0	100	2.7	6.7	700000	1800	—	—	—	9003
									Mixer	250	−10.0	100	Osc. peak voltage 9 volts			600	—	—	—	
9006	U.h.f. Diode	B.	6BH	6.3	0.15	—	—	—	Detector	Max. a.c. voltage—270. Max. d.c. output current—5 ma.										9006

* Cathode resistor—ohms.

[1] Per Plate.
[2] Maximum-signal current for full-power output.
[3] Values are for two tubes in push-pull.
[4] Also no-signal plate ma. when so indicated.
[5] No-signal plate ma.
[6] Effective plate-to-plate.
[7] Triode No. 1.
[8] Triode No. 2.

TABLE XII—CONTROL AND REGULATOR TUBES

Type	Name	Base	Socket Connections	Cathode	Fil. or Heater Volts	Fil. or Heater Amp.	Use	Peak Anode Voltage	Max. Anode Ma.	Minimum Supply Voltage	Operating Voltage	Operating Ma.	Grid Resistor	Tube Voltage Drop	Type
0A2	Voltage Regulator	7-pin B.	5BO	Cold	—	—	Voltage Regulator	—	—	185	150	5–30	—	—	0A2
0B2	Voltage Regulator	7-pin B.	5BO	Cold	—	—	Voltage Regulator	—	—	133	108	5–30	—	—	0B2
0A4G	Gas Triode Starter-Anode Type	6-pin O.	4V	Cold	—	—	Cold-Cathode Starter-Anode Relay Tube	With 105–120-volt a.c. anode supply, peak starter-anode a.c. voltage is 70, peak r.f. voltage 55. Peak d.c. ma = 100. Average d.c. ma = 25.							0A4G
1B47	Voltage Regulator	7-pin B.	—	—	—	—	Voltage Regulator	—	—	225	82	1–2	—	—	1B47
1C21	Gas Triode Glow-Discharge Type	6-pin O.	4V	Cold	—	—	Relay Tube	125–145	25	66 [6]	—	—	—	73	1C21
							Voltage Regulator		0.1 [6]	180 [4]				55	
2A4G	Gas Triode Grid Type	7-pin O.	5S	Fil.	2.5	2.5	Control Tube	200	100	—	—	—	—	15	2A4G
2B4	Gas Triode Grid Type	8-pin O.	6Q	Htr.	6.3	0.6	Sweep Circuit Oscillator	300	300	—	—	1.0	0.1–10 [7]	19	2B4
6Q5G		5-pin M.	5A	Htr.	2.5	1.4									6Q5G
2C4	Gas Triode	7-pin B.	5AS	Fil.	2.5	0.65	Control Tube	Plate volts = 350; Grid volts = −50; Avg. Ma. = 5; Peak Ma. = 20; Voltage drop = 16.							2C4
2D21	Gas Tetrode	7-pin B.	7BN	Htr.	6.3	0.6	Grid-Controlled Rectifier	650	500	—	650	100	0.1–10 [7]	8	2D21
							Relay Tube	400	—	—	—	—	1.0 [7]	—	
3C23	Gas and Mercury Vapor Grid Type	4-pin M.	3G	Fil.	2.5	7.0	Grid-Controlled Rectifier	1000	6000	—	500	1500	−4.5 [8]	15	3C23
										—	100	1500	−2.5 [8]	15	
6D4	Gas Triode	7-pin B.	5AY	Htr.	6.3	0.25	Control Tube	Plate volts = 350; Grid volts = −50; Avg. Ma. = 25; Peak Ma. = 100; Voltage drop = 16.							6D4
17	Mercury Vapor Triode	4-pin M.	3G	Fil.	2.5	5.0	Grid-Controlled Rectifier	7500 [5]	2000	—	—	500	200–3000	—	17
								2500		−5 [3]	1000	250	—	10–24	
874	Voltage Regulator	4-pin M.	4S	—	—	—	Voltage Regulator	—	—	125	90	10–50	—	—	874
876	Current Regulator	Mogul	—	—	—	—	Current Regulator	—	—	—	40–60	1.7	—	—	876
884	Gas Triode Grid Type	6-pin O.	6Q	Htr.	6.3	0.6	Sweep Circuit Oscillator	300	300	—	—	2	25000	—	884
							Grid-Controlled Rectifier	350	300	—	—	75	25000	—	
885	Gas Triode Grid Type	5-pin S.	5A	Htr.	2.5	1.4	Same as Type 884	Characteristics same as Type 884							885
886	Current Regulator	Mogul	—	—	—	—	Current Regulator	—	—	—	40–60	2.05	—	—	886
967	Mercury Vapor Triode	4-pin M.	3G	Fil.	2.5	5.0	Grid-Controlled Rectifier	2500	500	−5 [3]	—	—	—	10–24	967
991	Voltage Regulator	Bayonet	—	—	—	—	Voltage Regulator	—	—	87	55–60	2.0	—	—	991
1265	Voltage Regulator	6-pin O.	—	—	—	—	Voltage Regulator	—	—	130	90	5–30	—	—	1265
1266	Voltage Regulator	6-pin O.	4AJ	Cold	—	—	Voltage Regulator	—	—	—	70	5–40	—	—	1266
1267	Gas Triode	6-pin O.	4V	Cold	—	—	Relay Tube	Characteristics same as OA4G							1267
2050	Gas Tetrode	8-pin O.	8BA	Htr.	6.3	0.6	Grid-Controlled Rectifier	650	500	—	—	100	0.1–10 [7]	8	2050
2051	Gas Tetrode	8-pin O.	8BA	Htr.	6.3	0.6	Grid-Controlled Rectifier	350	375	—	—	75	0.1–10 [7]	14	2051
2523N1/ 128AS	Gas Triode Grid Type	5-pin M.	5A	Htr.	2.5	1.75	Relay Tube	400	300	—	—	1.0	300 [7]	13	2523N1/ 128AS
KY21	Gas Triode Grid Type	4-pin M.	—	Fil.	2.5	10.0	Grid-Controlled Rectifier	—	—	—	3000	500	—	—	KY21
RK61	Thyratron	— [9]	—	Fil.	1.4	0.05	Radio-Controlled Relay	45	1.5	30	—	0.5–1.5	3 [7]	30	RK61
RK62	Gas Triode Grid Type	4-pin S.	4D	Fil.	1.4	0.05	Relay Tube	45	1.5	—	30–45	0.1–1.5	—	15	RK62
RM208	Permatron	4-pin M.	—	Fil.	2.5	5.0	Controlled Rectifier [1]	7500 [2]	1000	—	—	—	—	15	RM208
RM209	Permatron	4-pin M.	—	Fil.	5.0	10.0	Controlled Rectifier [1]	7500 [2]	5000	—	—	—	—	15	RM209
OA3/VR75	Voltage Regulator	6-pin O.	4AJ	Cold	—	—	Voltage Regulator	—	—	105	75	5–40	—	—	OA3/VR75
OB3/VR90	Voltage Regulator	6-pin O.	4AJ	Cold	—	—	Voltage Regulator	—	—	125	90	5–40	—	—	OB3/VR90
OC3/VR105	Voltage Regulator	6-pin O.	4AJ	Cold	—	—	Voltage Regulator	—	—	135	105	5–40	—	—	OC3/VR105
OD3/VR150	Voltage Regulator	6-pin O.	4AJ	Cold	—	—	Voltage Regulator	—	—	185	150	5–40	—	—	OD3/VR150
KY866	Mercury Vapor Triode	4-pin M.	Fig. 8	Fil.	2.5	5.0	Grid-Controlled Rectifier	10000	1000	0–150	—	—	—	—	KY866

[1] For use as grid-controlled rectifier or with external magnetic control. RM-208 has characteristics of 866, RM-209 of 872.
[2] When under control peak inverse rating is reduced to 2500.
[3] At 1000 anode volts.
[4] Grid tied to plate.
[5] Peak inverse voltage.
[6] Grid.
[7] Megohms.
[8] Grid voltage.
[9] No base. Tinned wire leads.

TABLE XIII—CATHODE-RAY TUBES AND KINESCOPES

Type	Name	Socket Connections	Heater		Use	Size	Anode No. 2 Voltage	Anode No. 1 Voltage	Cut-Off Grid Voltage	Grid No. 2 Voltage	Signal-Swing Voltage	Max. Input Voltage [1]	Screen Input Power [2]	Deflection Sensitivity [6]		Anode No. 3 Voltage	Pattern Color	Type
			Volts	Amp.										D_1 D_2	D_3 D_4			
2AP1 [7]	Electrostatic Cathode-Ray	11B	6.3	0.6	Oscillograph Television	2″	1000	250	— 60	—	—	660	—	0.11	0.13	—	Green	2AP1
							500	125	— 30	—	—			0.22	0.26			
2BP1-11	Electrostatic Cathode-Ray	12E	6.3	0.6	Oscillograph	2″	2000	300/560	—135	—	—	500	—	270 [3]	174 [3]	—	Green	2BP1-11
							1000	150/280	—67.5	—	—	500	—	135 [3]	87 [3]	—		
3AP1/906-P1-4-5-11 [7]	Electrostatic Cathode-Ray	7AN	2.5	2.1	Oscillograph	3″	1500	430	— 50	—	—	550	10	0.22	0.23		Green Blue White	3AP1/906-P1-4-5-11
							1000	285	— 33	—	—			0.33	0.35			
							600	170	— 20	—	—			0.55	0.58			
3BP1-4-11	Electrostatic Cathode-Ray	14A	6.3	0.6	Oscillograph	3″	2000	575	— 60	—	—	550	—	0.13	0.17	—	Green	3BP1-4-11
							1500	430	— 45	—	—			0.17	0.23			
3DP1	Electrostatic Cathode-Ray	Fig. 49	6.3	0.6	Oscillograph	3″	2000	575	— 60	—	—	550	—	200 [3]	148 [3]	—	Green	3DP1
							1500	430	— 40	—	—			150 [3]	111 [3]	—		
3EP1/1806-P1	Electrostatic Cathode-Ray	11A	6.3	0.6	Oscillograph Television	3″	2000	575	— 60	—	—	550	—	0.115	0.154	—	Green	3EP1/1806-P1
							1500	430	— 45	—	—			0.153	0.205			
3GP1-4-5-11	Electrostatic Cathode-Ray	11A	6.3	0.6	Oscillograph	3″	1500	350	— 50	—	—	550	—	0.21	0.24	—	White Green Blue	3GP1-4-5-11
							1000	234	— 33	—	—		—	0.32	0.36			
3JP1-2-4-7-11	Electrostatic Cathode-Ray	14B	6.3	0.6	Oscillograph	3″	2000	575	— 60	—	—	550	—	0.13	0.17	4000	Green Blue White	3JP1-2-4-7-11
							1500	430	— 45	—	—		—	0.17	0.23	3000		
3KP1	Electrostatic Cathode-Ray	11M	6.3	0.6	Oscillograph	3″	1000	300	— 45	1000	—	500	—	68 [3]	136 [3]	—	Green	3KP1
							2000	600	— 90	2000	—			52 [3]	104 [3]			
5AP1/1805-P1 5AP4/1805-P4 [7]	Electrostatic Picture Tube	11A	6.3	0.6	Oscillograph Television	5″	2000	575	— 35	—	—	500	10	0.17	0.21	—	Green White	5AP1/1805-P1 5AP4/1805-P4
							1500	430	— 27					0.23	0.28	—		
5BP1/1802-P1-2-4-5-11	Electrostatic Picture Tube	11A	6.3	0.6	Oscillograph	5″	2000	450	— 40	—	—	500	10	0.3	0.33	—	Green White Blue	5BP1/1802-P1-2-4-5-11
							1500	337	— 30	—	—			0.4	0.45			
5CP1-2-4-5-11	Electrostatic Cathode-Ray	14B	6.3	0.6	Oscillograph Television	5″	2000	575	— 60	—	—	550	—	0.28	0.32	4000	White Green Blue	5CP1-2-4-5-11
							1500	430	— 45	—	—		—	0.37	0.43	3000		
							2000	575	— 60	—	—		—	0.36	0.41	2000		
5FP1-2-4-11 [7]	Electromagnetic Cathode-Ray	5AN	6.3	0.6	Oscillograph Television	5″	7000	250	— 45	—	—	—	—	—	—	—	Green White Blue	5FP1-2-4-11
							4000	250	— 45	—	—		—	—	—			
5HP1 5HP4 [7]	Electrostatic Cathode-Ray	11A	6.3	0.6	Oscillograph	5″	2000	425	— 40	—	—	500	—	0.3	0.33	—	Green White	5HP1 5HP4
							1500	310	— 30					0.4	0.44	—		
5JP1-2-4-5-11	Electrostatic Cathode-Ray	11E	6.3	0.6	Oscillograph	5″	2000	520	— 75	—	—	500	—	0.25	0.28	4000	White Green Blue	5JP1-2-4-5-11
							1500	390	— 56	—	—		—	0.33	0.37	3000		
5LP1-2-4-5-11	Electrostatic Cathode-Ray	11F	6.3	0.6	Oscillograph Television	5″	2000	500	— 60	—	—	500	—	0.25	0.28	4000	White Green Blue	5LP1-2-4-5-11
							1500	375	— 45	—	—		—	0.33	0.37	3000		
							1000	250	— 30	—	—		—	0.49	0.56	2000		
5MP1-4-5-11	Electrostatic Cathode-Ray	7AN	2.5	2.1	Oscillograph	5″	1500	375	— 50	—	—	660	—	0.39	0.42	—	White Green Blue	5MP1-4-5-11
							1000	250	— 33	—	—		—	0.58	0.64			
5RP1-2-4-11	Electrostatic Cathode-Ray	14F	6.3	0.6	Oscillograph	5″	3000	—	— 90	—	—	1200	—	0.12	0.12	15000	Green White Blue	5RP1-2-4-11
							2000	575	— 60	—	—		—	0.18	0.18	10000		
5TP4	Projection Kinescope	Fig. 46	6.3	0.6	Television	5″	27000	4900	— 70	200	—	—	—	—	—	—	White	5TP4

TABLE XIII—CATHODE-RAY TUBES AND KINESCOPES—*Continued*

Type	Name	Socket Connections	Heater Volts	Heater Amp.	Use	Size	Anode No. 2 Voltage	Anode No. 1 Voltage	Cut-Off Grid Voltage	Grid No. 2 Voltage	Signal-Swing Voltage	Max. Input Voltage [1]	Screen Input Power [2]	Deflection Sensitivity [6] D_1 D_2	Deflection Sensitivity [6] D_3 D_4	Anode No. 3 Voltage	Pattern Color	Type
5UP1-7-11	Electrostatic Cathode-Ray	12E	6.3	0.6	Oscillograph	5″	2500	640	— 90	—	—	500	—	38.5 [3]	77 [3]	—	Green Yellow Blue	5UP1-7-11
							2500	340	— 90	—	—	500	—	28 [3]	56 [3]	—		
							1000	320	— 45	—	—	500	—	31 [3]	62 [3]	—		
							1000	170	— 45	—	—	500	—	23 [3]	46 [3]	—		
7AP	Electromagnetic Picture Tube	5AJ	2.5	2.1	Television	7″	3500	1000	−67.5	—	—	—	2.5	—	—	—	White	7AP4
7BP1-2-4-11	Electromagnetic Cathode-Ray	5AN	6.3	0.6	Oscillograph Television	7″	7000	250	— 45	—	—	—	—	—	—	—	White Green Blue	7BP1-2-4-11
							4000	250	— 45	—	—							
7CP1/1811-P1	Electromagnetic Cathode-Ray	6AZ	6.3	0.6	Oscillograph	7″	7000	1470	— 45	250	—	—	—	—	—	—	Green	7CP1/1811-P1
							4000	840	— 45	250	—			—	—			
7DP4	Kinescope	Fig. 46	6.3	0.6	Television	7″	6000	1430	— 45	250	—	—	—	—	—	—	White	7DP4
7GP4	Electrostatic Kinescope	Fig. 47	6.3	0.6	Television	7″	3000	1200	— 84	3000	—	—	—	123 [3]	102 [3]	—	White	7GP4
9AP4/1804-P4	Electromagnetic Picture Tube	6AL	2.5	2.1	Television	9″	7000	1425	— 40	250	25	—	10	—	—	—	White	9AP4/1804-P4
							6000	1225	— 38									
9CP4	Electromagnetic Picture Tube	4AF	2.5	2.1	Television	9″	7000	—	−110	—	25	—	10	—	—	—	White	9CP4
9JP1/1809-P1	Electrostatic-Magnetic Cathode-Ray	8BR	2.5	2.1	Oscillograph	9″	5000	1570	— 90	—	—	3000	—	0.136	—	—	Green	9JP1/1809-P1
							2500	785	— 45					0.272	—			
10BP4	Magnetic Kinescope	Fig. 48	6.3	0.6	Television	10″	—	9000	— 45	250	—	—	—	—	—	—	—	10BP4
12AP4/1803-P4	Electromagnetic Picture Tube	6AL	2.5	2.1	Television	12″	7000	1460	— 75	250	25	—	10	—	—	—	White	12AP4/1803-P4
							6000	1240										
12CP4	Electromagnetic Picture Tube	4AF	2.5	2.1	Television	12″	7000	—	−110	—	25	—	10	—	—	—	White	12CP4
12DP4	Electromagnetic Cathode-Ray	5AN	6.3	0.6	Television	12″	7000	250	— 45	—	—	—	—	—	—	—	White	12DP4
							4000	250	— 45	—	—	—	—	—	—	—		
902 [7]	Electrostatic Cathode-Ray	Fig. 1	6.3	0.6	Oscillograph	2″	600	150	— 60	—	—	350	5	0.19	0.22	—	Green	902
903 [5]	Electromagnetic Cathode-Ray	6AL	2.5	2.1	Oscillograph	9″	7000	1360	−120	250	—	—	10	—	—	—	Green	903
904	Electrostatic-Magnetic Cathode-Ray	Fig. 3	2.5	2.1	Oscillograph	5″	4600	970	— 75	250	—	4000	10	0.09	—	—	Green	904
905 [7]	Electrostatic Cathode-Ray	Fig. 6	2.5	2.1	Oscillograph	5″	2000	450	— 35	—	—	1000	10	0.19	0.23	—	Green	905
907	Electrostatic Cathode-Ray	Fig. 6	2.5	2.1	Oscillograph	5″	Characteristics same as Type 905							—	—	—	Blue	907
908 [7]	Electrostatic Cathode-Ray	7AN	2.5	2.1	Oscillograph	3″	Characteristics same as Type 3AP1/906P1							—	—	—	Blue	908
908-A	Electrostatic Cathode-Ray	7CE	2.5	2.1	Oscillograph	3″	1500	430	— 50	—		500	—	0.223	0.233	—	Blue	908-A
							1000	287	— 33	—		500	—	0.334	0.348	—		
909 [5]	Electrostatic Cathode-Ray	Fig. 6	2.5	2.1	Oscillograph	5″	Characteristics same as Type 905							—	—	—	Blue	909
910 [5]	Electrostatic Cathode-Ray	7AN	2.5	2.1	Oscillograph	3″	Characteristics same as Type 3AP1/906P1							—	—	—	Blue	910
911 [5]	Electrostatic Cathode-Ray	7AN	2.5	2.1	Oscillograph	3″	Characteristics same as Type 3AP1/906P1							—	—	—	Green	911
912	Electrostatic Cathode-Ray	Fig. 6	2.5	2.1	Oscillograph	5″	10000	2000	— 66	250	—	7000	10	0.041	0.051	—	Green	912
913	Electrostatic Cathode-Ray	Fig. 1	6.3	0.6	Oscillograph	1″	500	100	— 65	—	—	250	5	0.07	0.10	—	Green	913
914 [7]	Electrostatic Cathode-Ray	Fig. 12	2.5	2.1	Oscillograph	9″	7000	1450	— 50	250	—	3000	10	0.073	0.093	—	Green	914
1800 [5]	Electromagnetic Kinescope	6AL	2.5	2.1	Television	9″	6000	1250	— 75	250	25	—	10	—	—	—	Yellow	1800
1801 [5]	Electromagnetic Kinescope	Fig. 13	2.5	2.1	Television	5″	3000	450	— 35	—	20	—	10	—	—	—	Yellow	1801
2001	Electrostatic Cathode-Ray	Fig. 2	6.3	0.6	Oscillograph	1″	Characteristics essentially same as 913											2001
2002	Electrostatic Cathode-Ray	Fig. 1	6.3	0.6	Oscillograph	2″	600	120	—	—	—	—	—	0.16	0.17	—	Green	2002
2005	Electrostatic Cathode-Ray	Fig. 1 [4]	2.5	2.1	Television	5″	2000	1000	— 35	200	—	—	10	0.5	0.56	—	—	2005
24-XH	Electrostatic Cathode-Ray	Fig. 1	6.3	0.6	Oscilloscope	2″	600	120	— 60	—	—	—	10	0.14	0.16	—	Blue	24-XH

[1] Between Anode No. 2 and any deflecting plate.
[2] In mw./sq. cm., max.
[3] D.c. Volts/in.
[4] Cathode connected to Pin 7.
[5] Discontinued.
[6] In mm./volt d.c.
[7] Superseded by same type with letter "A."

TABLE XIV—RECTIFIERS—RECEIVING AND TRANSMITTING

See also Table XII—Control and Regulator Tubes

Type No.	Name	Base	Socket Connections	Cathode	Fil. or Heater		Max. A.C. Voltage Per Plate	D.C. Output Current Ma.	Max. Inverse Peak Voltage	Peak Plate Current Ma.	Type
					Volts	Amp.					
BA	Full-Wave Rectifier	4-pin M.	4J	Cold	—	—	350	350	Tube drop 80 v.		G
BH	Full-Wave Rectifier	4-pin M.	4J	Cold	—	—	350	125	Tube drop 90 v.		G
BR	Half-Wave Rectifier	4-pin M.	4H	Cold	—	—	300	50	Tube drop 60 v.		G
CE-220	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	3.0	—	20	20000	100	HV
OY4	Half-Wave Rectifier	5-pin O.	4BU	Cold	Connect Pins 7 and 8		95	75	300	500	G
OZ4	Full-Wave Rectifier	5-pin O.	4R	Cold	—	—	350	30–75	1250	200	G
1	Half-Wave Rectifier	4-pin S.	4G	Htr.	6.3	0.3	350	50	1000	400	MV
1-V	Half-Wave Rectifier	4-pin S.	4G	Htr.	6.3	0.3	350	50	—	—	HV
1B3GT/8016	Half-Wave Rectifier	6-pin O.	3C	Fil.	1.25	0.2	—	2.0	4000	17	HV
1B48	Half-Wave Rectifier	7-pin B.	—	Cold	—	—	800	6	2700	50	G
1Z2	Half-Wave Rectifier	7-pin B.	7CB	Fil.	1.5	0.3	7800	2	20000	10	HV
2B25	Half-Wave Rectifier	7-pin B.	3T	Fil.	1.4	0.11	1000	1.5	—	9	HV
2V3G	Half-Wave Rectifier	6-pin O.	4AC	Fil.	2.5	5.0	—	2.0	16500	12	HV
2W3	Half-Wave Rectifier	5-pin O.	4X	Fil.	2.5	1.5	350	55	—	—	HV
2X2/879	Half-Wave Rectifier	4-pin S.	4AB	Htr.	2.5	1.75	4500	7.5	—	—	HV
2X2-A	Half-Wave Rectifier	4-pin S.	4AB	Same as 2X2/879 but will withstand severe shock & vibration							HV
2Y2	Half-Wave Rectifier	4-pin M.	4AB	Fil.	2.5	1.75	4400	5.0	—	—	HV
2Z2/G84	Half-Wave Rectifier	4-pin M.	4B	Fil.	2.5	1.5	350	50	—	—	HV
3B24	Half-Wave Rectifier	4-pin M.	T-4A	Fil.	5.0 2.5 [9]	3.0 3.0	— —	60 30	20000 20000	300 150	HV
3B25	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	—	500	4500	2000	G
3B26	Half-Wave Rectifier	8-pin O.	Fig. 31	Htr.	2.5	4.75	—	20	15000	8000	HV
DR-3B27	Half-Wave Rectifier	4-pin M.	4B	Fil.	2.5	5.0	3000	250	8500	1000	HV
5R4GY	Full-Wave Rectifier	5-pin O.	5T	Fil.	5.0	2.0	900 [4] 950 [7]	150 [4] 175 [7]	2800	650	HV
5T4	Full-Wave Rectifier	5-pin O.	5T	Fil.	5.0	3.0	450	250	1250	800	HV
5U4G	Full-Wave Rectifier	8-pin O.	5T	Fil.	5.0	3.0		Same as Type 5Z3			HV
5V4G	Full-Wave Rectifier	8-pin O.	5L	Htr.	5.0	2.0		Same as Type 83V			HV
5W4	Full-Wave Rectifier	5-pin O.	5T	Fil.	5.0	1.5	350	110	1000	—	HV
5X3	Full-Wave Rectifier	4-pin M.	4C	Fil.	5.0	2.0	1275	30	—	—	HV
5X4G	Full-Wave Rectifier	8-pin O.	5Q	Fil.	5.0	3.0		Same as 5Z3			HV
5Y3G	Full-Wave Rectifier	5-pin O.	5T	Fil.	5.0	2.0		Same as Type 80			HV
5Y4G	Full-Wave Rectifier	8-pin O.	5Q	Fil.	5.0	2.0		Same as Type 80			HV
5Z3	Full-Wave Rectifier	4-pin M.	4C	Fil.	5.0	3.0	500	250	1400	—	HV
5Z4	Full-Wave Rectifier	5-pin O.	5L	Htr.	5.0	2.0	400	125	1100	—	HV
6W5G	Full-Wave Rectifier	6-pin O.	6S	Htr.	6.3	0.9	350	100	1250	350	HV
6X4	Full-Wave Rectifier	7-pin B.	7CF	Htr.	6.3	0.6	325	70	1250	210	HV
6X5	Full-Wave Rectifier	6-pin O.	6S	Htr.	6.3	0.5	350	75	—	—	HV
6Y5	Full-Wave Rectifier	6-pin S.	6J	Htr.	6.3	0.8	350	50	—	—	HV
6Z3	Half-Wave Rectifier	4-pin M.	4G	Fil.	6.3	0.3	350	50	—	—	HV
6Z5	Full-Wave Rectifier	6-pin S.	6K	Htr.	6.3	0.6	230	60	—	—	HV
6ZY5G	Full-Wave Rectifier	6-pin O.	6S	Htr.	6.3	0.3	350	35	1000	150	HV
7Y4	Full-Wave Rectifier	8-pin L.	5AB	Htr.	6.3	0.5	350	60	—	—	HV
7Z4	Full-Wave Rectifier	8-pin L.	5AB	Htr.	6.3	0.9	450 [1] 325 [4]	100	1250	300	HV
12A7	Rectifier-Pentode	7-pin S.	7K	Htr.	12.6	0.3	125	30	—	—	HV
12Z3	Half-Wave Rectifier	4-pin S.	4G	Htr.	12.6	0.3	250	60	—	—	HV
12Z5	Voltage Doubler	7-pin M.	7L	Htr.	12.6	0.3	225	60	—	—	HV
14Y4	Full-Wave Rectifier	8-pin L.	5AB	Htr.	12.6	0.3	450 [1] 325 [4]	70	1250	210	HV
14Z3	Half-Wave Rectifier	4-pin S.	4G	Htr.	12.6	0.3	250	60	—	—	HV
25A7G	Rectifier-Pentode	8-pin O.	8F	Htr.	25	0.3	125	75	—	—	HV
25X6GT	Voltage Doubler	7-pin O.	7Q	Htr.	25	0.15	125	60	—	—	HV
25Y4GT	Half-Wave Rectifier	6-pin O.	5AA	Htr.	25	0.15	125	75	—	—	HV
25Y5	Voltage Doubler	6-pin S.	6E	Htr.	25	0.3	250	85	—	—	HV
25Z3	Half-Wave Rectifier	4-pin S.	4G	Htr.	25	0.3	250	50	—	—	HV
25Z4	Half-Wave Rectifier	6-pin O.	5AA	Htr.	25	0.3	125	125	—	—	HV
25Z5	Rectifier-Doubler	6-pin S.	6E	Htr.	25	0.3	125	100	—	500	HV
25Z6	Rectifier-Doubler	7-pin O.	7Q	Htr.	25	0.3	125	100	—	500	HV
28Z5	Full-Wave Rectifier	8-pin L.	5AB	Htr.	28	0.24	450 [7] 325 [4]	100	—	300	HV
32L7GT	Rectifier-Tetrode	8-pin O.	8Z	Htr.	32.5	0.3	125	60	—	—	HV
35W4	Half-Wave Rectifier	7-pin B.	5BQ	Htr.	35 [2]	0.15	125	100 [8]	330	600	HV
35Y4	Half-Wave Rectifier	8-pin O.	5AL	Htr.	35 [2]	0.15	235	60 100 [8]	700	600	HV
35Z3	Half-Wave Rectifier	8-pin L.	4Z	Htr.	35	0.15	250 [5]	100	700	600	HV
35Z4GT	Half-Wave Rectifier	6-pin O.	5AA	Htr.	35	0.15	250	100	700	600	HV
35Z5G	Half-Wave Rectifier	6-pin O.	6AD	Htr.	35 [2]	0.15	125	60 100 [8]	—	—	HV
35Z6G	Voltage Doubler	6-pin O.	7Q	Htr.	35	0.3	125	110	—	500	HV

TABLE XIV—RECTIFIERS—RECEIVING AND TRANSMITTING—*Continued*

See also Table XII—Control and Regulator Tubes

Type No.	Name	Base	Socket Connections	Cathode	Fil or Heater		Max. A.C. Voltage Per Plate	D.C. Output Current Ma.	Max. Inverse Peak Voltage	Peak Plate Current Ma.	Type
					Volts	Amp.					
40Z5GT	Half-Wave Rectifier	6-pin O.	6AD	Htr.	40 [2]	0.15	125	60 100 [8]	—	—	HV
45Z3	Half-Wave Rectifier	7-pin B.	5AM	Htr.	45	0.075	117	65	350	390	HV
45Z5GT	Half-Wave Rectifier	6-pin O.	6AD	Htr.	45 [2]	0.15	125	60 100 [8]	—	—	HV
50X6	Voltage Doubler	8-pin L.	7AJ	Htr.	50	0.15	117	75	700	450	HV
50Y6GT	Full-Wave Rectifier	7-pin O.	7Q	Htr.	50	0.15	125	85	—	—	HV
50Z6G	Voltage Doubler	7-pin O.	7Q	Htr.	50	0.3	125	150	—	—	HV
50Z7G	Voltage Doubler	8-pin O.	8AN	Htr.	50	0.15	117	65	—	—	HV
70A7GT	Rectifier-Tetrode	8-pin O.	8AB	Htr.	70	0.15	125 [5]	60	—	—	HV
70L7GT	Rectifier-Tetrode	8-pin O.	8AA	Htr.	70	0.15	117	70	—	350	HV
72	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	3.0	—	30	20000	150	HV
73	Half-Wave Rectifier	8-pin O.	4Y	Fil.	2.5	4.5	—	20	13000	3000	HV
80	Full-Wave Rectifier	4-pin M.	4C	Fil.	5.0	2.0	350 [4] 500 [7]	125 125	1400	375	HV
81	Half-Wave Rectifier	4-pin M.	4B	Fil.	7.5	1.25	700	85	—	—	HV
82	Full-Wave Rectifier	4-pin M.	4C	Fil.	2.5	3.0	500	125	1400	400	MV
83	Full-Wave Rectifier	4-pin M.	4C	Fil.	5.0	3.0	500	250	1400	800	MV
83-V	Full-Wave Rectifier	4-pin M.	4AD	Htr.	5.0	2.0	400	200	1100	—	HV
84/6Z4	Full-Wave Rectifier	5-pin S.	5D	Htr.	6.3	0.5	350	60	1000	—	HV
117L7GT/ 117M7GT	Rectifier-Tetrode	8-pin O.	8AO	Htr.	117	0.09	117	75	—	—	HV
117N7GT	Rectifier-Tetrode	8-pin O.	8AV	Htr.	117	0.09	117	75	350	450	HV
117P7GT	Rectifier-Tetrode	8-pin O.	8AV	Htr.	117	0.09	117	75	350	450	HV
117Z3	Half-Wave Rectifier	7-pin B.	4BR	Htr.	117	0.04	117	90	330	—	HV
117Z4GT	Half-Wave Rectifier	6-pin O.	5AA	Htr.	117	0.04	117	90	350	—	HV
117Z6GT	Voltage Doubler	7-pin O.	7Q	Htr.	117	0.075	235	60	700	360	HV
217-A	Half-Wave Rectifier	4-pin J.	T-3A	Fil.	10	3.25	—	—	3500	600	HV
217-C	Half-Wave Rectifier	4-pin J.	T-3A	Fil.	10	3.25	—	—	7500	600	HV
Z225	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	—	250	10000	1000	MV
249-B	Half-Wave Rectifier	4-pin M.	Fig. 53	Fil.	2.5	7.5	3180	375	10000	1500	MV
HK253	Half-Wave Rectifier	4-pin J.	T-3A	Fil.	5.0	10	—	350	10000	1500	HV
705A RK-705A	Half-Wave Rectifier	4-pin W.	T-3AA	Fil.	2.5 [9] 5.0	5.0 5.0	— —	50 100	35000 35000	375 750	HV
816	Half-Wave Rectifier	4-pin S.	4P	Fil.	2.5	2.0	1750	125	5000	500	MV
836	Half-Wave Rectifier	4-pin M.	4P	Htr.	2.5	5.0	—	—	5000	1000	HV
866A/866	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	3500	250	10000	1000	MV
866B	Half-Wave Rectifier	4-pin M.	4P	Fil.	5.0	5.0	—	—	8500	1000	MV
866 Jr.	Half-Wave Rectifier	4-pin M.	4B	Fil.	2.5	2.5	1250	250 [3]	—	—	MV
HY866 Jr.	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	2.5	1750	250 [3]	5000	—	MV
RK866	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	3500	250	10000	1000	MV
871 [10]	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	2.0	1750	250	5000	500	MV
878	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	7100	5	20000	—	HV
879	Half-Wave Rectifier	4-pin S.	4P	Fil.	2.5	1.75	2650	7.5	7500	100	HV
872A/872	Half-Wave Rectifier	4-pin J.	T-3A	Fil.	5.0	7.5	—	1250	10000	5000	MV
975A	Half-Wave Rectifier	4-pin J.	T-3A	Fil.	5.0	10.0	—	1500	15000	6000	MV
OZ4A/ 1003	Full-Wave Rectifier	5-pin O.	4R	Cold	—	—	—	110	880	—	G
1005/ CK1005	Full-Wave Rectifier	8-pin O.	T-9F	Fil.	6.3	0.1	—	70	450	—	G
1006/ CK1006	Full-Wave Rectifier	4-pin M.	4C	Fil.	1.75	2.25	—	200	1600	—	G
CK1007	Full-Wave Rectifier	8-pin O.	T-9G	Fil.	1.0	1.2	—	110	980	—	G
CK1009/BA	Full-Wave Rectifier	4-pin M.	—	Cold	—	—	—	350	1000	—	G
1275	Full-Wave Rectifier	4-pin M.	4C	Fil.	5.0	1.75	Same as 5Z3				HV
1616	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	—	130	6000	800	HV
1641/ RK60	Full-Wave Rectifier	4-pin M.	T-4AG	Fil.	5.0	3.0	—	50 250	4500 2500	— —	HV
1654	Half-Wave Rectifier	7-pin B.	Fig. 41	Fil.	1.4	0.05	2500	1	7000	6	HV
8008	Half-Wave Rectifier	4-pin [6]	Fig. 11	Fil.	5.0	7.5	—	1250	10000	5000	MV
8013A	Half-Wave Rectifier	4-pin M.	4P	Fil.	2.5	5.0	—	20	40000	150	HV
8016	Half-Wave Rectifier	6-pin O.	4AC	Fil.	1.25	0.2	—	2.0	10000	7.5	HV
8020	Half-Wave Rectifier	4-pin M.	4P	Fil.	5.0	5.5	10000	100	40000	750	HV
					5.8	6.5	12500	100	40000	750	
RK19	Full-Wave Rectifier	4-pin M.	T-3A	Htr.	7.5	2.5	1250	200 [4]	3500	600	HV
RK21	Half-Wave Rectifier	4-pin M.	4P	Htr.	2.5	4.0	1250	200 [4]	3500	600	HV
RK22	Full-Wave Rectifier	4-pin M.	T-4AG	Htr.	2.5	8.0	1250	200 [4]	3500	600	HV

[1] With input choke of at least 20 henrys.
[2] Tapped for pilot lamps.
[3] Per pair with choke input.
[4] Condenser input.
[5] With 100 ohms min. resistance in series with plate; without series resistor, maximum r.m.s. plate rating is 117 volts.
[6] Same as 872A/872 except for heavy-duty push-type base. Filament connected to pins 2 and 3, plate to top cap.
[7] Choke input.
[8] Without panel lamp.
[9] Using only one-half of filament.
[10] Discontinued.

TABLE XV—TRIODE TRANSMITTING TUBES

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
958-A	0.6	1.25	0.1	135	7	1.0	12	0.6	2.6	0.8	500	A.	5BD	Class-C Amp.-Oscillator	135	− 20	7	1.0	0.035	—	0.6
RK24	1.5	2.0	0.12	180	20	6.0	8.0	3.5	5.5	3.0	125	S.	4D	Class-C Amp.-Oscillator	180	− 45	16.5	6.0	0.5	—	2.0
6J6[2]	1.5	6.3	0.45	300	30	16	32	2.2	1.6	0.4	250	B.	7BF	Class-C Amp. (Telegraphy)	150	− 10	30	16	0.35	—	3.5
9002	1.6	6.3	0.15	250	8	2.0	25	1.2	1.4	1.1	250	B.	7TM	Class-C Amp.-Oscillator	180	− 35	7	1.5	—	—	0.5
955	1.6	6.3	0.15	180	8	2.0	25	1.0	1.4	0.6	250	A.	5BC	Class-C Amp.-Oscillator	180	− 35	7	1.5	—	—	0.5
HY114B	1.8	1.4	0.155	180	12	3.0	13	1.0	1.3	1.0	300	O.	2T	Class-C Amp.-Oscillator	180	− 30	12	2.0	0.2	—	1.4[3]
														Class-C Amp. (Telephony)	180	− 35	12	2.5	0.3	—	1.4[3]
3A5[2]	2.0	1.4 2.8	0.22 0.11	150	30	5.0	15	0.9	3.2	1.0	40	B.	7BC	Class-C Amp.-Oscillator	150	− 35	30	5.0	0.2	—	2.2
6F4	2.0	6.3	0.225	150	20	8.0	17	2.0	1.9	0.6	500	A.	7BR	Class-C Amp.-Oscillator	150	− 15 550* 2000[4]	20	7.5	0.2	—	1.8
HY24	2.0	2.0	0.13	180	20	4.5	9.3	2.7	5.4	2.3	60	S.	4D	Class-C Amp. (Telegraphy)	180	− 45	20	4.5	0.2	—	2.7
														Class-C Amp. (Telephony)	180	− 45	20	4.5	0.3	—	2.5
RK33[1,2]	2.5	2.0	0.12	250	20	6.0	10.5	3–2	3–2	2.5	60	S.	T-7DA	Class-C Amp.-Oscillator	250	− 60	20	6.0	0.54	—	3.5
12AU7[2]	2.75[6]	6.3	0.3	350	12[6]	3.5[6]	18	1.5	1.5	0.5	54	B.	9A	Class-C Amp.-Oscillator	350	−100	24	7	—	—	6.0
6N4	3.0	6.3	0.2	180	12	—	32	3.1	2.35	0.55	500	B.	7CA	Class-C Amp.-Oscillator	180	—	—	—	—	—	—
HY6J5GTX	3.5	6.3	0.3	330	20	4.0	20	4.2	3.8	5.0	60	O.	6Q	Class-C Amp.-Oscillator	330	− 30	20	2.0	0.2	—	3.5
														Class-C Amp. (Telephony)	250	− 30	20	2.5	0.3	—	2.5
2C22/7193	3.5	6.3	0.3	500	—	—	20	2.2	3.6	0.7	—	O.	4AM	Class-C Amp. (Telegraphy)	—	—	—	—	—	—	—
HY615 HY-E1148	3.5	6.3	0.175	300	20	4.0	20	1.4	1.6	1.2	300	O.	T-8AG	Class-C Amp.-Oscillator	300	− 35	20	2.0	0.4	—	4.0[3]
														Class-C Amp. (Telephony)	300	− 35	20	3.0	0.8	—	3.5[3]
GL-446A[1] GL-446B[1]	3.75	6.3	0.75	400	20	—	45	2.2	1.6	0.02	500	O.	Fig. 19	Class-C Amp.-Oscillator	250	—	—	—	—	—	—
GL-2C44[1] GL-464A[1]	5.0	6.3	0.75	500	40	—	—	2.7	2.0	0.1	500	O.	Fig. 17	Class-C Amp.-Oscillator	250	—	—	—	—	—	—
6C4	5.0	6.3	0.15	350	25	8.0	18	1.8	1.6	1.3	54	B.	6BG	Class-C Amp.-Oscillator	300	− 27	25	7.0	0.35	—	5.5
1626	5.0	12.6	0.25	250	25	8.0	5.0	3.2	4.4	3.4	30	O.	6Q	Class-C Amp.-Oscillator	250	− 70	25	5.0	0.5	—	4.0
2C21/ RK33[2]	5.0	6.3	0.6	250	40	12	—	1.6	1.6	2.0	—	S.	T-7DA	Class-C Amp.-Oscillator	250	− 60	40	12	1.0	—	7
6N7[2]	5.5[3]	6.3	0.8	350	30[6]	5.0[6]	35	—	—	—	10	O.	8B	Class-C Amp. Oscillator	350	−100	60	10	—	—	14.5
2C40	6.5	6.3	0.75	500	25	—	36	2.1	1.3	0.05	500	O.	Fig. 19	Class-C Amp.-Oscillator	250	− 5	20	0.3	—	—	0.075
5556	7.0	4.5	1.1	350	40	10	8.5	4.0	8.3	3.0	6	M.	4D	Class-C Amp. (Telegraphy)	350	− 80	35	2	0.25	—	6
														Class-C Amp. (Telephony)	300	−100	30	2	0.3	—	4
2C43	12	6.3	0.9	500	40	—	48	2.9	1.7	0.05	1250	O.	Fig. 19	Class-C Amp.-Oscillator	470	—	38[7]	—	—	—	9[7]
2C26A	10	6.3	1.10	—	—	—	16.3	2.6	2.8	1.1	250	O.	4BB		—	—	—	—	—	—	—
2C34/ RK34[2]	10	6.3	0.8	300	80	20	13	3.4	2.4	0.5	250	M.	T-7DC	Class-C Amp.-Oscillator	300	− 36	80	20	1.8	—	16
205D	14	4.5	1.6	400	50	10	7.2	5.2	4.8	3.3	6	M.	4D	Class-C Amp.-Oscillator	400	−112	45	10	1.5	—	10
														Class-C Amp. (Telephony)	350	−144	35	10	1.7	—	7.1
2C25	15	7.0	1.18	450	60	15	8.0	6.0	8.9	3.0	—	M.	4D	Class-C Amp.-Oscillator	450	−100	65	15	3.2	—	19
														Class-C Amp. (Telephony)	350	−100	50	12	2.2	—	12
10Y	15	7.5	1.25	450	65	15	8	4.1	7.0	3.0	8	M.	4D	Class-C Amp.-Oscillator	450	−100	65	15	3.2	—	19
														Class-C Amp. (Telephony)	350	−100	50	12	2.2	—	12

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
843	15	2.5	2.5	450	40	7.5	7.7	4.0	4.5	4.0	6	M.	5A	Class-C Amp.-Oscillator	450	−140	30	5.0	1.0	—	7.5
														Class-C Amp. (Telephony)	350	−150	30	7.0	1.6	—	5.0
RK59[2]	15	6.3	1.0	500	90	25	25	5.0	9.0	1.0	—	M.	T-4D	Class-C Amp.-Oscillator	500	− 60	90	14	1.3	—	32
HY75A	15	6.3	2.6	450	90	25	9.6	1.8	2.6	1.0	175	O.	2T	Class-C Amp. (Telegraphy)	450	−140	90	20	5.2	—	26
														Class-C Amp. (Telephony)	400	−140	90	20	5.2	—	21
HY75	15	6.3	2.5	450	80	20	10	1.8	3.8	1.0	60	O.	2T	Class-C Amp.-Oscillator	450	− 50	80	12	—	—	21[3]
														Class-C Amp. (Telephony)	450	− 60	80	12	—	—	16[3]
1602	15	7.5	1.25	450	60	15	8.0	4.0	7.0	3.0	6	M.	4D	Class-C Amp. (Telegraphy)	450	−115	55	15	3.3	—	13
														Class-C Amp. (Telephony)	350	−135	45	15	3.5	—	8.0
														Class-B Amp. Audio[7]	425	− 50	110[8]	260[9]	2.5[8]	8000	25
841	15	7.5	1.25	450	60	20	30	4.0	7.0	3.0	6	M.	4D	Class-C Amp. (Telegraphy)	450	− 34	50	15	1.8	—	15
														Class-C Amp. (Telephony)	350	− 47	50	15	2.0	—	11
10 RK10[1]	15	7.5	1.25	450	65	15	8.0	3.0	8.0	4.0	— 60	M.	4D	Class-C Amp. (Telegraphy)	450	−100	65	15	3.2	—	19
														Class-C Amp. (Telephony)	350	−100	50	12	2.2	—	12
														Class-B Audio[7]	425	− 50	55[8]	130[9]	2.5[8]	8000	25
RK100[1]	15	6.3	0.9	150	250	100	40	23	19	3.0	—	M.	T-6B	Class-C Oscillator	110	—	80	8.0	—	—	3.5
														Class-C Amplifier	110	—	185	40	2.1	—	12
TUF-20	20	6.3	2.75	750	75	20	10	1.8	3.6	0.095	250	O.	2T	Class-C Amp.-Oscillator	750	−150	75	20	1.5/2.5	—	40
1608	20	2.5	2.5	425	95	25	20	8.5	9.0	3.0	45	M.	4D	Class-C Amp. (Telegraphy)	425	− 90	95	20	3.0	—	27
														Class-C Amp. (Telephony)	350	− 80	85	20	3.0	—	18
														Class-B Amp. Audio[7]	425	− 15	190[8]	130[9]	2.2[8]	4800	50
310	20	7.5	1.25	600	70	15	8.0	4.0	7.0	2.2	6	M.	4D	Class-C Amp. (Telegraphy)	600	−150	65	15	4.0	—	25
														Class-C Amp. (Telephony)	500	−190	55	15	4.5	—	18
801-A/801	20	7.5	1.25	600	70	15	8.0	4.5	6.0	1.5	60	M.	4D	Class-C Amp. (Telegraphy)	600	−150	65	15	4.0	—	25
														Class-C Amp. (Telephony)	500	−190	55	15	4.5	—	18
														Class-B Amp. Audio[7]	600	− 75	130	320[9]	3.0[8]	10000	45
HY801-A	20	7.5	1.25	600	70	15	8.0	4.5	6.0	1.5	60	M.	4D	Class-C Amp. (Telegraphy)	600	−200	70	15	4.0	—	30
														Class-C Amp. (Telephony)	500	−200	60	15	4.5	—	22
T20	20	7.5	1.75	750	85	25	20	4.9	5.1	0.7	60	M.	3G	Class-C Amp. (Telegraphy)	750	− 85	85	18	3.6	—	44
														Class-C Amp. (Telephony)	750	−140	70	15	3.6	—	38
TZ20	20	7.5	1.75	750	85	30	62	5.3	5.0	0.6	60	M.	3G	Class-C Amp. (Telegraphy)	750	− 40	85	28	3.75	—	44
														Class-C Amp (Telephony)	750	−100	70	23	4.8	—	38
														Class-B Amp. Audio[7]	800	0	40/136	160[9]	1.8[8]	12000	70
15E	20	5.5	4.2	—	—	—	25	1.4	1.15	0.3	600	N.	T-4AF	—	—	—	—	—	—	—	—
3-25A3 25T	25	6.3	3.0	2000	75	25	24	2.7	1.5	0.3	60	M.	3G	Class-C Amp.-Oscillator	2000	−130	63	18	4.0	—	100
															1500	− 95	67	13	2.2	—	75
															1000	− 70	72	9	1.3	—	47
														Class-B Amp. Audio[7]	2000	− 80	16/80	270[9]	0.7[8]	55500	110
3-25D3 3C24 24G	25	6.3	3.0	2000	75	25	23	2.0 1.7	1.6 1.5	0.2 0.3	60	S.	2D	Class-C Amp.-Oscillator	2000	−170	63	17	4.5	—	100
															1500	−110	67	15	3.1	—	75
															1000	− 80	72	15	2.6	—	47
														Class-B Audio[7]	2000	− 85	16/80	290[9]	1.1[8]	55500	110
3C28	25	6.3	3.0	2000	75	25	23	2.1	1.8	0.1	100	S.	Fig. 56	Class-C Amp. Oscillator	Characteristics same as 3C24						
3C34	25	6.3	3.0	2000	75	25	23	2.5	1.7	0.4	60	S.	3G	Class-C Amp. Oscillator	Characteristics same as 3C24						

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
RK11[1]	25	6.3	3.0	750	105	35	20	7.0	7.0	0.9	60	M.	3G	Class-C Amp. (Telegraphy)	750	−120	105	21	3.2	——	55
														Class-C Amp. (Telephony)	600	−120	85	24	3.7	——	38
RK12	25	6.3	3.0	750	105	40	100	7.0	7.0	0.9	60	M.	3G	Class-C Amp. (Telegraphy)	750	−100	105	35	5.2	——	55
														Class-C Amp. (Telephony)	600	−100	85	27	3.8	——	38
HK24	25	6.3	3.0	2000	75	30	25	2.5	1.7	0.4	60	S.	3G	Class-C Amp. (Telegraphy)	2000	−140	56	18	4.0	——	90
														Class-C Amp. (Telephony)	1500	−145	50	25	5.5	——	60
HY25	25	7.5	2.25	800	75	25	55	4.2	4.6	1.0	60	M.	3G	Class-C Amp. (Telegraphy)	750	− 45	75	15	2.0	——	42
														Class-C Amp. (Telephony)	700	− 45	75	17	5.0	——	39
8025	30	6.3	1.92	1000	65	——	18	2.7	2.8	0.35	500	M.	4AQ	Class-C Amp. (Grid. Mod.)	1000	−135	50	4	3.5	——	20
	20				65	20								Class-C Amp. (Telephony)	800	−105	40	10.5	1.4	——	22
	30				80	20								Class-C Amp. (Telegraphy)	1000	− 90	50	14	1.6	——	35
HY30Z[1]	30	6.3	2.25	850	90	25	87	6.0	4.9	1.0	60	M.	4BO	Class-C Amp.-Oscillator	850	− 75	90	25	2.5	——	58
														Class-C Amp. (Telephony)	700	− 75	90	25	3.5	——	47
HY31Z[2]	30	6.3	3.5	500	150	30	45	5.0	5.5	1.9	60	M.	T-4D	Class-C Amp. (Telegraphy)	500	− 45	150	25	2.5	——	56
HY1231Z[2]		12.6	1.7											Class-C Amp. (Telephony)	400	−100	150	30	3.5	——	45
316A	30	2.0	3.65	450	80	12	6.5	1.2	1.6	0.8	500	N.	——	Class-C Amp. (Telegraphy)	450	——	80	12	——	——	7.5
														Class-C Amp. (Telephony)	400	——	80	12	——	——	6.5
809	30	6.3	2.5	1000	125	——	50	5.7	6.7	0.9	60	M.	3G	Class-C Amp. (Telegraphy)	1000	− 75	100	25	3.8	——	75
														Class-C Amp. (Telephony)	750	− 60	100	32	4.3	——	55
														Class-B Amp. Audio[7]	1000	− 9	40/200	155[9]	2.7[8]	11600	145
1623	30	6.3	2.5	1000	100	25	20	5.7	6.7	0.9	60	M.	3G	Class-C Amp.-Oscillator	1000	− 90	100	20	3.1	——	75
														Class-C Amp. (Telephony)	750	−125	100	20	4.0	——	55
														Class-B Amp. Audio[7]	1000	− 40	30/200	230[9]	4.2[8]	12000	145
53A	35	5.0	12.5	15000	——	——	35	3.6	1.9	0.4	——	N.	T-4B	Oscillator at 300 Mc.	Approximately 50 watts output						
RK30[1]	35	7.5	3.25	1250	80	25	15	2.75	2.5	2.75	60	M.	2D	Class-C Amp. (Telegraphy)	1250	−180	90	18	5.2	——	85
														Class-C Amp. (Telephony)	1000	−200	80	15	4.5	——	60
800	35	7.5	3.25	1250	80	25	15	2.75	2.5	2.75	60	M.	2D	Class-C Amp. (Telegraphy)	1250	−175	70	15	4.0	——	65
														Class-C Amp. (Telephony)	1000	−200	70	15	4.0	——	50
														Class-B Amp. Audio[7]	1250	− 70	30/130	300[9]	3.4[8]	21000	106
1628[1]	40	3.5	3.25	1000	60	15	23	2.0	2.0	0.4	500	N.	T-4BB	Class-C Amp.-Oscillator	1000	− 65	50	15	1.7	——	35
														Class-C Amp. (Telephony)	800	−100	40	11	1.6	——	22
														Grid-Modulated Amp.	1000	−120	50	3.5	5.0	——	20
8012 GL-8012-A	40	6.3	2.0	1000	80	20	18	2.7	2.8	0.35	500	N.	T-4BB	Class-C Amp.-Oscillator	1000	− 90	50	14	1.6	——	35
								2.7	2.5	0.4				Class-C Amp. (Telephony)	800	−105	40	10.5	1.4	——	22
														Grid-Modulated Amp.	1000	−135	50	4.0	3.5	——	20
RK18[1]	40	7.5	3.0	1250	100	40	18	6.0	4.8	1.8	60	M.	3G	Class-C Amp. (Telegraphy)	1250	−160	100	12	2.8	——	95
														Class-C Amp. (Telephony)	1000	−160	80	13	3.1	——	64
RK31	40	7.5	3.0	1250	100	35	170	7.0	1.0	2.0	30	M.	3G	Class-C Amp. (Telegraphy)	1250	− 80	100	30	3.0	——	90
														Class-C Amp. (Telephony)	1000	− 80	100	28	3.5	——	70
HY40[1]	40	7.5	2.25	1000	125	25	25	6.1	5.6	1.0	60	M.	3G	Class-C Amp. (Telegraphy)	1000	− 90	125	20	5.0	——	94
														Class-C Amp. (Telephony)	850	− 90	125	25	5.0	——	82
														Grid-Modulated Amp.	1000	——	125	——	——	——	20

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
HY40Z[1]	40	7.5	2.6	1000	125	30	80	6.2	6.3	0.8	60	M.	3G	Class-C Amp. (Telegraphy)	1000	− 27	125	25	5.0	—	94
														Class-C Amp. (Telephony)	850	− 30	100	30	7.0	—	82
														Grid-Modulated Amp.	1000	—	60	—	—	—	20
T40	40	7.5	2.5	1500	150	40	25	4.5	4.8	0.8	60	M.	3G	Class-C Amp.-Oscillator	1500	−140	150	28	9.0	—	158
														Class-C Amp. (Telephony)	1250	−115	115	20	5.25	—	104
TZ40	40	7.5	2.5	1500	150	45	62	4.8	5.0	0.8	60	M.	3G	Class-C Amp.-Oscillator	1500	− 90	150	38	10	—	165
														Class-C Amp. (Telephony)	1250	−100	125	30	7.5	—	116
														Class-B Amp. Audio [7]	1500	− 9	250 [8]	285 [9]	6.0 [8]	12000	250
HY57	40	6.3	2.25	850	110	25	50	4.9	5.1	1.7	60	M.	3G	Class-C Amp. (Telegraphy)	850	− 48	110	15	2.5	—	70
														Class-C Amp. (Telephony)	700	− 45	90	17	5.0	—	47
														Grid-Modulated Amp.	850	—	70	—	—	—	20
756[1]	40	7.5	2.0	850	110	25	8.0	3.0	7.0	2.7	—	M.	4D	Class-C Amplifier	850	—	110	25	—	—	—
830[1]	40	10	2.15	750	110	18	8.0	4.9	9.9	2.2	15	M.	4D	Class-C Amplifier	750	−180	110	18	7.0	—	55
														Grid-Modulated Amp.	1000	−200	50	2.0	3.0	—	15
3-50A4 35T 3-50D4 35TG	50	5.0	4.0	2000	150	50	39	4.1	1.8	0.3	100	M.	3G	Class-C Amp. (Telegraphy)	2000	−135	125	45	13	—	200
								2.5	1.8	0.4	100	M.	2D	Class-C Amp. (Telephony)	1500	−120	100	30	5.0	—	120
														Class-B Amp. Audio [7]	2000	− 40	34/167	255 [9]	4.0 [8]	27500	235
8010-R	50	6.3	2.4	1350	150	20	30	2.3	1.5	0.07	350	N.	—	Class-C Amplifier	—	—	—	—	—	—	—
RK32[1]	50	7.5	3.25	1250	100	25	11	2.5	3.4	0.7	100	M.	2D	Class-C Amp. (Telegraphy)	1250	−225	100	14	4.8	—	90
														Class-C Amp. (Telephony)	1000	−310	100	21	8.7	—	70
RK35[1]	50	7.5	4.0	1500	125	20	9.0	3.5	2.7	0.4	60	M.	2D	Class-C Amp. (Telegraphy)	1500	−250	115	15	5.0	—	120
														Class-C Amp. (Telephony)	1250	−250	100	14	4.6	—	93
														Grid-Modulated Amp.	1500	−180	37	—	2.0	—	25
RK37	50	7.5	4.0	1500	125	35	28	3.5	3.2	0.2	60	M.	2D	Class-C Amp. (Telegraphy)	1500	−130	115	30	7.0	—	122
														Class-C Amp. (Telephony)	1250	−150	100	23	5.6	—	90
														Grid-Modulated Amp.	1500	− 50	50	—	2.4	—	26
3-50G2 UH50	50	7.5	3.25	1250	125	25	10.6	2.2	2.6	0.3	60	M.	2D	Class-C Amp. (Telegraphy)	1250	−225	125	20	7.5	—	115
														Class-C Amp. (Telephony)	1250	−325	125	20	10	—	115
														Grid-Modulated Amp.	1250	−200	60	2.0	3.0	—	25
UH51[1]	50	5.0	6.5	2000	175	25	10.6	2.2	2.3	0.3	60	M.	2D	Class-C Amp. (Telegraphy)	2000	−500	150	20	15	—	225
														Class-C Amp. (Telephony)	1500	−400	165	20	15	—	200
														Grid-Modulated Amp.	1500	−400	85	2.0	8.0	—	65
HK54	50	5.0	5.0	3000	150	30	27	1.9	1.9	0.2	100	M.	2D	Class-C Amp. (Telegraphy)	3000	−290	100	25	10	—	250
														Class-C Amp. (Telephony)	2500	−250	100	20	8.0	—	210
														Class-B Amp. Audio [7]	2500	− 85	20/150	360 [9]	5.0	40000	275
HK154[1]	50	5.0	6.5	1500	175	30	6.7	4.3	5.9	1.1	60	M.	2D	Class-C Amp. (Telegraphy)	1500	−590	167	20	15	—	200
														Class-C Amp. (Telephony)	1250	−460	170	20	12	—	162
														Grid-Modulated Amp.	1500	−450	52	—	5.0	—	28
HK158	50	12.6	2.5	2000	200	40	25	4.7	4.6	1.0	60	M.	2D	Class-C Amp.-Oscillator	2000	−150	125	25	6.0	—	200
														Class-C Amp. (Telephony)	2000	−140	105	25	5.0	—	170
WE304A[1] 304B	50	7.5	3.25	1250	100	25	11	2.0	2.5	0.7	100	M.	2D	Class-C Amp. (Telegraphy)	1250	−200	100	—	—	—	85
														Class-C Amp. (Telephony)	1000	−180	100	—	—	—	65

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
356A	50	5.0	5.0	1500	120	35	50	2.25	2.75	1.0	60	N.	T-4BD	Class-C Amp. (Telegraphy)	1500	— 60	100	—	—	—	100
														Class-C Amp. (Telephony)	1250	—100	100	35	—	—	85
808	50	7.5	4.0	1500	150	35	47	5.3	2.8	0.15	30	M.	2D	Class-C Amp. (Telegraphy)	1500	—200	125	30	9.5	—	140
														Class-C Amp. (Telephony)	1250	—225	100	32	10.5	—	105
														Class-B Amp. Audio [7]	1500	— 25	30/190	220 [9]	4.8 [8]	18300	185
834	50	7.5	3.1	1250	100	20	10.5	2.2	2.6	0.6	100	M.	2D	Class-C Amp. (Telegraphy)	1250	—225	90	15	4.5	—	75
														Class-C Amp. (Telephony)	1000	—310	90	17.5	6.5	—	58
841A [1]	50	10	2.0	1250	150	30	14.6	3.5	9.0	2.5	—	M.	3G	Class-C Amplifier	—	—	—	—	—	—	85
841SW	50	10	2.0	1000	150	30	14.6	—	9.0	—	—	M.	3G	Class-C Amplifier	—	—	—	—	—	—	—
T55	55	7.5	3.0	1500	150	40	20	5.0	3.9	1.2	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—170	150	18	6.0	—	170
														Class-C Amp. (Telephony)	1500	—195	125	15	5.0	—	145
811	55	6.3	4.0	1500	150	50	160	5.5	5.5	0.6	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—113	150	35	8.0	—	170
														Class-C Amp. (Telephony)	1250	—125	125	50	11	—	120
														Class-B Amp. Audio [7]	1500	— 9	20/200	150 [9]	3.0 [8]	17600	220
812	55	6.3	4.0	1500	150	35	29	5.3	5.3	0.8	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—175	150	25	6.5	—	170
														Class-C Amp. (Telephony)	1250	—125	125	25	6.0	—	120
														Class-B Amp. Audio [7]	1500	— 45	50/200	232 [9]	4.7 [8]	18000	225
RK51	60	7.5	3.75	1500	150	40	20	6.0	6.0	2.5	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—250	150	31	10	—	170
														Class-C Amp. (Telephony)	1250	—200	105	17	4.5	—	96
														Grid-Modulated Amp.	1500	—130	60	0.4	2.3	—	128
RK52	60	7.5	3.75	1500	130	50	170	6.6	12	2.2	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—120	130	40	7.0	—	135
														Class-C Amp. (Telephony)	1250	—120	115	47	8.5	—	102
														Class-B Amp. Audio [7]	1250	0	40/300	180 [9]	7.5 [8]	10000	250
T-60 HF60	60	10	2.5	1600	150	50	20	5.5	5.2	2.5	60 / 30	M.	2D	Class-C Amp.-Oscillator	1500	—150	150	50	9.0	—	100
826	60	7.5	4.0	1000	125	40	31	3.7	2.9	1.4	250	N.	T-9A	Class-C Amp.-Oscillator	1000	— 70	125	35	5.8	—	86
														Class-C Amp. (Telephony)	800	— 98	94	35	6.2	—	53
														Grid-Modulated Amp.	1000	—125	65	9.5	8.2	—	25
830B 930B	60	10	2.0	1000	150	30	25	5.0	11	1.8	15	M.	3G	Class-C Amp.-Oscillator	1000	—110	140	30	7.0	—	90
														Class-C Amp. (Telephony)	800	—150	95	20	5.0	—	50
														Class-B Amp. Audio [7]	1000	— 35	20/280	270 [9]	6.0 [8]	7600	175
HY51A [1] HY51B [1]	65	7.5 10	3.5 2.25	1000	175	25	25	6.5	7.0	1.1	60	M.	3G	Class-C Amp. (Telegraphy)	1000	— 75	175	20	7.5	—	131
														Class-C Amp. (Telephony)	1000	—67.5	130	15	7.5	—	104
														Grid-Modulated Amp.	1000	—	100	—	—	—	33
HY51Z [1]	65	7.5	3.5	1000	175	35	85	7.9	7.2	0.9	60	M.	4BO	Class-C Amp. (Telegraphy)	1000	—22.5	175	35	10	—	131
														Class-C Amp. (Telephony)	1000	— 30	150	35	10	—	104
														Grid-Modulated Amp.	1000	—	100	—	—	—	33
5514	65	7.5	3.0	1500	175	60	145	7.8	7.9	1.0	60	M.	4BO	Class-C Amp. (Telegraphy)	1500	—106	175	60	12	—	200
														Class-C Amp. (Telephony)	1250	— 84	142	60	10	—	135
														Class-B Audio [7]	1500	—4.5	350 [8]	88 [8]	6.5 [8]	10500	400
UH35 [1]	70	5.0	4.0	1500	150	35	30	1.4	1.6	0.2	60	M.	3G	Class-C Amp. (Telegraphy)	1500	—170	150	30	7.0	—	170
														Class-C Amp. (Telephony)	1500	—120	100	30	5.0	—	120
V70 V70B	70	10	2.5	1500	140	25	14	5.0	9.0	2.3	—	J. M.	T-3AB 3G	Class-C Amp. (Telegraphy)	1500	—215	130	6.0	3.0	—	140
														Class-C Amp. (Telephony)	1250	—250	130	6.0	3.0	—	120

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
V70A V70C	70	10	2.5	1500	140	20	25	5.0	9.5	2.0	—	J. M.	T-3AB 3G	Class-C Amp. (Telegraphy)	1000	−110	140	30	7.0	—	90
														Class-C Amp. (Telephony)	800	−150	95	20	5.0	—	50
50T[1]	75	5.0	6.0	3000	100	30	12	2.0	2.0	0.4	—	M.	2D	Class-C Amplifier	3000	−600	100	25	—	—	250
3-75A3 75TH	75	5.0	6.25	3000	225	40	20	2.7	2.3	0.3	40	M.	2D	Class-C Amp. (Telegraphy)	2000	−200	150	32	10	—	225
														Class-B Amp. Audio [7]	2000	− 90	50/225	350 [9]	3 [8]	19300	300
3-75A2 75TL						35	12	2.6	2.4	0.4			2D	Class-C Amp. (Telegraphy)	2000	−300	150	21	8	—	225
														Class-B Amp. Audio [7]	2000	−160	50/250	535 [9]	5 [8]	18000	350
HF75	75	10	3.25	2000	120	—	12.5	—	2.0	—	75	M.	2D	Class-C Oscillator-Amp.	2000	—	120	—	—	—	150
TW75	75	7.5	4.15	2000	175	60	20	3.35	1.5	0.7	60	M.	2D	Class-C Amp.-Oscillator	2000	−175	150	37	12.7	—	225
														Class-C Amp. (Telephony)	2000	−260	125	32	13.2	—	198
T-100 HF100	75	10	2.0	1500	150	30	23	3.5	4.5	1.4	30	M.	2D	Class-C Amp. (Telegraphy)	1500	−200	150	18	6.0	—	170
														Class-C Amp. (Telephony)	1250	−250	110	21	8.0	—	105
														Grid-Modulated Amp.	1500	−280	72	1.5	6.0	—	42
														Class-B Amp. Audio [7]	1750	− 62	40/270	324 [9]	9.0 [8]	16000	350
UE-100	75	10	2.5	1750	150	30	23	3.5	4.5	1.4	30	M.	2D	Class-C Amp. (Telegraphy)	1500	−200	150	18	6.0	—	170
														Class-C Amp. (Telephony)	1250	−250	120	21	8.0	—	105
														Class-B Audio [7]	1750	− 62	540 [8]	—	9.0	16000	350
111H	75	10	2.25	1500	160	—	23	—	4.6	—	25	M.	2D	Class-C Osc.-Amp.	1500	—	160	—	—	—	175
ZB120	75	10	2.0	1250	160	40	90	5.3	5.2	3.2	30	J.	4E	Class-C Amp. (Telegraphy)	1250	−135	160	23	5.5	—	145
														Class-C Amp. (Telephony)	1000	−150	120	21	5.0	—	95
														Grid-Modulated Amp.	1250	—	95	8.0	1.5	—	45
														Class-B Amp. Audio [7]	1500	− 9	60/296	196 [9]	5.0 [8]	11200	300
327B	75	10.5	10.6	—	—	—	30	3.4	2.45	0.3	—	N.	T-4AD	—	—	—	—	—	—	—	—
242A	85	10	3.25	1250	150	50	12.5	6.5	13	4.0	6	J.	4E	Class-C Amp. (Telegraphy)	1250	−175	150	—	—	—	130
														Class-C Amp. (Telephony)	1000	−160	150	50	—	—	100
284D	85	10	3.25	1250	150	100	4.8	6.0	8.3	5.6	—	J.	4E	Class-C Amp. (Telegraphy)	1250	−500	150	—	—	—	125
														Class-C Amp. (Telephony)	1000	−450	150	50	—	—	100
														Class-B Amp. Audio [7]	1250	−250	30/200	—	—	11200	140
812-H	85	6.3	4.0	1750	200	45	—	5.3	5 3	0.8	30	M.	3G	Class-C Amp. (Telegraphy)	1750	−175	170	26	6.5	—	225
															1250	−125	125	25	5.0	—	116
														Class-C Amp. (Telephony)	1500	−125	165	21	6.0	—	180
															1250	−125	125	25	6.0	—	120
8005	85	10	3.25	1500	200	45	20	6.4	5.0	1.0	60	M.	3G	Class-B Amp. Audio [7]	1500	− 46	42/200	—	—	18000	225
														Class-C Amp.-Oscillator	1500	−130	200	32	7.5	—	220
														Class-C Amp. (Telephony)	1250	−195	190	28	9.0	—	170
														Class-B Amp. Audio [7]	1500	− 70	40/310	310 [9]	4.0 [8]	10000	300
V-70-D	85	7.5	3.25	1750	200	45	—	4.5	4.5	1.7	30	M.	3G	Class-C Amp. (Telegraphy)	1750	−100	170	19	3.9	—	225
															1500	− 90	165	19	3.9	—	195
														Class-C Amp. (Telephony)	1500	− 90	165	19	3.7	—	185
															1250	− 72	127	16	2.6	—	122
RK36[1]	100	5.0	8.0	3000	165	35	14	4.5	5.0	1.0	60	M.	2D	Class-C Amp. (Telegraphy)	2000	−360	150	30	15	—	200
														Class-C Amp. (Telephony)	2000	−360	150	30	15	—	200
														Grid-Modulated Amp.	2000	−270	72	1.0	3.5	—	42

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
RK38[1]	100	5.0	8.0	3000	165	40	—	4.6	4.3	0.9	60	M.	2D	Class-C Amp. (Telegraphy)	2000	−200	160	30	10	—	225
														Class-C Amp. (Telephony)	2000	−200	160	30	10	—	225
														Grid-Modulated Amp.	2000	−150	80	2.0	5.5	—	60
3-100A4 100TH	100	5.0	6.3	3000	225	60	40	2.9	2.0	0.4	40	M.	2D	Class-C Amp. (Telegraphy)	3000	−200	165	51	18	—	400
														Class-C Amp. (Telephony)	3000	−210	167	45	18	—	400
														Grid-Modulated Amp.	3000	−400	70	3.0	7.0	—	100
														Class-B Amp. (Audio)[7]	3000	− 65	40/215	335[9]	5.0[8]	31000	650
3-100A2 100TL	100	5.0	6.3	3000	225	50	14	2.3	2.0	0.4	40	M.	2D	Class-C Amp. (Telegraphy)	3000	−400	165	30	20	—	400
														Class-C Amp. (Telephony)	3000	−600	167	35	18	—	400
														Grid-Modulated Amp.	3000	−560	60	2.0	7.0	—	90
														Class-B Amp. (Audio)[7]	3000	−185	40/215	640[9]	6.0[8]	30000	450
VT127A	100	5.0	10.4	3000	—	30	15.5	2.7	2.3	0.35	150	N.	T-4B	Class-C Amp.-Oscillator	Characteristics similar to 100TL						
227A	100	10.5	10.7	—	—	—	31	3.0	2.2	0.30	—	N.	T-4B	Oscillator at 200 Mc.	—	—	—	—	—	—	—
327A	100	10.5	10.7	—	—	—	31	3.4	2.3	0.35	—	N.	T-4AD	Oscillator at 200 Mc.	—	—	—	—	—	—	—
HK254	100	5.0	7.5	4000	200	40	25	3.3	3.4	1.1	50	J.	2N	Class-C Amp. (Telegraphy)	4000	−380	120	35	20	—	475
														Class-C Amp. (Telephony)	3000	−290	135	40	23	—	320
														Grid-Modulated Amp.	3000	—	51	3.0	4.0	—	58
														Class-B Amp. (Audio)[7]	3000	−100	40/240	456[9]	7.0[8]	30000	520
RK58	100	10	3.25	1250	175	70	—	8.5	6.5	10.5	—	J.	T-3AB	Class-C Amp. (Telegraphy)	1250	− 90	150	30	6.0	—	130
														Class-C Amp. (Telephony)	1000	−135	150	50	16	—	100
HF120	100	10	3.25	1250	175	—	12	—	10.5	—	20	J.	—	Class-C Amp.-Oscillator	1250	—	175	—	—	—	150
HF125	100	10	3.25	1500	175	—	25	—	11.5	—	30	J.	—	Class-C Amp.-Oscillator	1500	—	175	—	—	—	200
HF140	100	10	3.25	1250	175	—	12	—	12.5	—	15	J.	—	Class-C Amp.-Oscillator	1250	—	175	—	—	—	150
203A 303A	100	10	3.25	1250	175	60	25	6.5	14.5	5.5	15	J.	4E	Class-C Amp. (Telegraphy)	1250	−125	150	25	7.0	—	130
														Class-C Amp. (Telephony)	1000	−135	150	50	14	—	100
														Class-B Amp. (Audio)[7]	1250	− 45	26/320	330[9]	11[8]	9000	260
203H	100	10	3.25	1500	175	60	25	6.5	11.5	1.5	15	J.	T-3AB	Class-C Amp. (Telegraphy)	1500	−200	170	12	3.8	—	200
														Class-C Amp. (Telephony)	1250	−160	167	19	5.0	—	160
														Class-B Amp. (Audio)[7]	1500	− 52	30/320	304[9]	5.5[8]	11000	340
211 311 835[1]	100	10	3.25	1250	175	50	12	6.0 6.0	14.5 9.25	5.5 5.0	15	J.	4E	Class-C Amp. (Telegraphy)	1250	−225	150	18	7.0	—	130
														Class-C Amp. (Telephony)	1000	−260	150	35	14	—	100
														Class-B Amp. (Audio)[7]	1250	−100	20/320	410[9]	8.0[8]	9000	260
242B 342B	100	10	3.25	1250	150	50	12.5	7.0	13.6	6.0	6	J.	4E	Class-C Amp. (Telegraphy)	1250	−175	150	—	—	—	130
														Class-C Amp (Telephony)	1000	−160	150	50	—	—	100
242C	100	10	3.25	1250	150	50	12.5	6.1	13.0	4.7	6	J.	4E	Class-C Amp. (Telegraphy)	1250	−175	150	—	—	—	130
														Class-C Amp. (Telephony)	1000	−160	150	50	—	—	100
														Class-B Amp. (Audio)[7]	1250	− 80	25/150	—	25[8]	7600	200
261A 361A	100	10	3.25	1250	150	50	12	6.5	9.0	4.0	30	J.	4E	Class-C Amp. (Telegraphy)	1250	−175	125	—	—	—	100
														Class-C Amp. (Telephony)	1000	−160	150	50	—	—	100
														Class-B Amp. (Audio)[7]	1250	− 90	20/150	—	25[8]	7200	200
276A 376A	100	10	3.0	1250	125	50	12	6.0	9.0	4.0	30	J.	4E	Class-C Amp. (Telegraphy)	1250	−175	125	—	—	—	100
														Class-C Amp. (Telephony)	1000	−160	125	50	—	—	85
														Class-B Amp. (Audio)[7]	1250	− 90	20/125	—	25[8]	9000	175

TABLE XV—TRIODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode		Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances ($\mu\mu$fd.)			Max. Freq. Mc. Full Ratings	Base	Socket Connections	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts	Class B P-to-P Load Res. Ohms	Approx. Output Power Watts
		Volts	Amp.					Grid to Fil.	Grid to Plate	Plate to Fil.											
284B	100	10	3.25	1250	150	100	5.0	4.2	7.4	5.3	—	J.	T-3AB	Class-C Amp. (Telegraphy)	1250	−500	150	—	—	—	125
														Class-C Amp. (Telephony)	1000	−430	150	50	—	—	100
														Class-B Amp. (Audio) [7]	1250	−245	15/150	—	10 [8]	7200	200
295A	100	10	3.25	1250	175	50	25	6.5	14.5	5.5	—	J.	4E	Class-C Amp. (Telegraphy)	1250	−125	150	—	—	—	125
														Class-C Amp. (Telephony)	1000	−125	150	50	—	—	100
														Class-B Amp. (Audio) [7]	1250	− 40	12/160	—	20 [8]	9000	250
838 938	100	10	3.25	1250	175	70	—	6.5	8.0	5.0	30	J.	4E	Class-C Amp. (Telegraphy)	1250	− 90	150	30	6.0	—	130
														Class-C Amp. (Telephony)	1000	−135	150	60	16	—	100
														Class-B Amp. (Audio) [7]	1250	0	148/320	200 [9]	7.5 [8]	9000	260
852	100	10	3.25	3000	150	40	12	1.9	2.6	1.0	30	M.	2D	Class-C Amp. (Telegraphy)	3000	−600	85	15	12	—	165
														Class-C Amp. (Telephony)	2000	−500	67	30	23	—	75
														Class-B Amp. (Audio) [7]	3000	−250	14/160	780 [9]	3.5 [8]	10250	320
8003	100	10	3.25	1500	250	50	12	5.8	11.7	3.4	30	J.	T-3AB	Class-C Amp.-Oscillator	1350	−180	245	35	11	—	250
														Class-C Amp. (Telephony)	1100	−260	200	40	15	—	167
														Class-B Amp. (Audio) [7]	1350	−100	40/490	480 [9]	10.5 [8]	6000	460
3X100A11 2C39	100	6.3	1.1	1000	60	40	100	6.5	1.95	0.03	500	N.	—	"Grid Isolation" Circuit	600	− 35	60	40	5.0	—	20
311-CH	125	10	3.25	1750	200	50	12	5.5	8.0	4.5	30	J.	Fig. 57	Class-C Amp. (Telegraphy)	1750	−200	200	20	4.5	—	260
														Class-C Amp. (Telephony)	1250	−200	166	8	3.5	—	148
														Class-B (Audio) [7]	1500	−110	400 [8]	—	—	8200	400
3C22	125	6.3	2.0	1000	150	70	40	4.9	2.4	0.05	500	O.	Fig. 30	Class-C Amp.-Oscillator	1000	−200	150	70	—	—	65
4C36	125	5	7.5	4000	—	—	29	3.2	3.0	0.4	60	J.	Fig. 56	Class-C Amp.-Oscillator	—	—	—	—	18	—	480
F-123-A DR-123C	125	10	4.0	2000	300	75	14.5	6.5	8.5	3.3	—	J.	Fig. 26	Class-C Amp. (Telegraphy)	1500	−250	250	30	11	—	300
														Class-C Amp. (Telephony)	1500	−290	160	25	10	—	200
														Class-B Amp. (Audio) [7]	2000	−130	30/175	217 [9]	3.4 [8]	13800	522
RK57/805	125	10	3.25	1500	210	70	—	6.5	8.0	5.0	30	J.	T-3AB	Class-C Amp. (Telegraphy)	1500	−105	200	40	8.5	—	215
														Class-C Amp. (Telephony)	1250	−160	160	60	16	—	140
														Class-B Amp. (Audio) [7]	1500	− 16	84/400	280 [9]	7.0 [8]	8200	370
T125	125	10	4.5	2500	250	60	25	6.3	6.0	1.3	60	J.	2N	Class-C Amp. (Telegraphy)	2500	−200	240	31	11	—	475
														Class-C Amp. (Telephony)	2000	−215	200	28	10	—	320
HF130	125	10	3.25	1250	210	—	12.5	—	9.0	—	20	J.	—	Class-C Amp.-Oscillator	1250	−210	—	—	—	—	170
HF150	125	10	3.25	1500	210	—	12.5	—	7.2	—	30	J.	—	Class-C Amp.-Oscillator	1500	—	210	—	—	—	200
HF175	125	10	4.0	2000	250	—	18	—	6.3	—	25	J.	—	Class-C Amp.-Oscillator	2000	—	250	—	—	—	300
GL146	125	10	3.25	1500	200	60	75	7.2	9.2	3.9	15	J.	T-4BG	Class-C Amp.-Oscillator	1250	−150	180	30	—	—	150
														Class-C Amp. (Telephony)	1000	−200	160	40	—	—	100
														Class-B Amp. (Audio) [7]	1250	0	34/320	—	—	8400	250
GL152	125	10	3.25	1500	200	60	25	7.0	8.8	4.0	15	J.	T-4BG	Class-C Amp.-Oscillator	1250	−150	180	30	—	—	150
														Class-C Amp. (Telephony)	1000	−200	160	30	—	—	100
														Class-B Amp. (Audio) [7]	1250	− 40	16/320	—	—	8400	250
805	125	10	3.25	1500	210	70	40/60	8.5	6.5	10.5	30	J.	T-3AB	Class-C Amp. (Telegraphy)	1500	−105	200	40	8.5	—	215
														Class-C Amp. (Telephony)	1250	−160	160	60	16	—	140
														Class-B Amp. (Audio) [7]	1500	− 16	84/400	280 [9]	7.0 [8]	8200	370