RADIO

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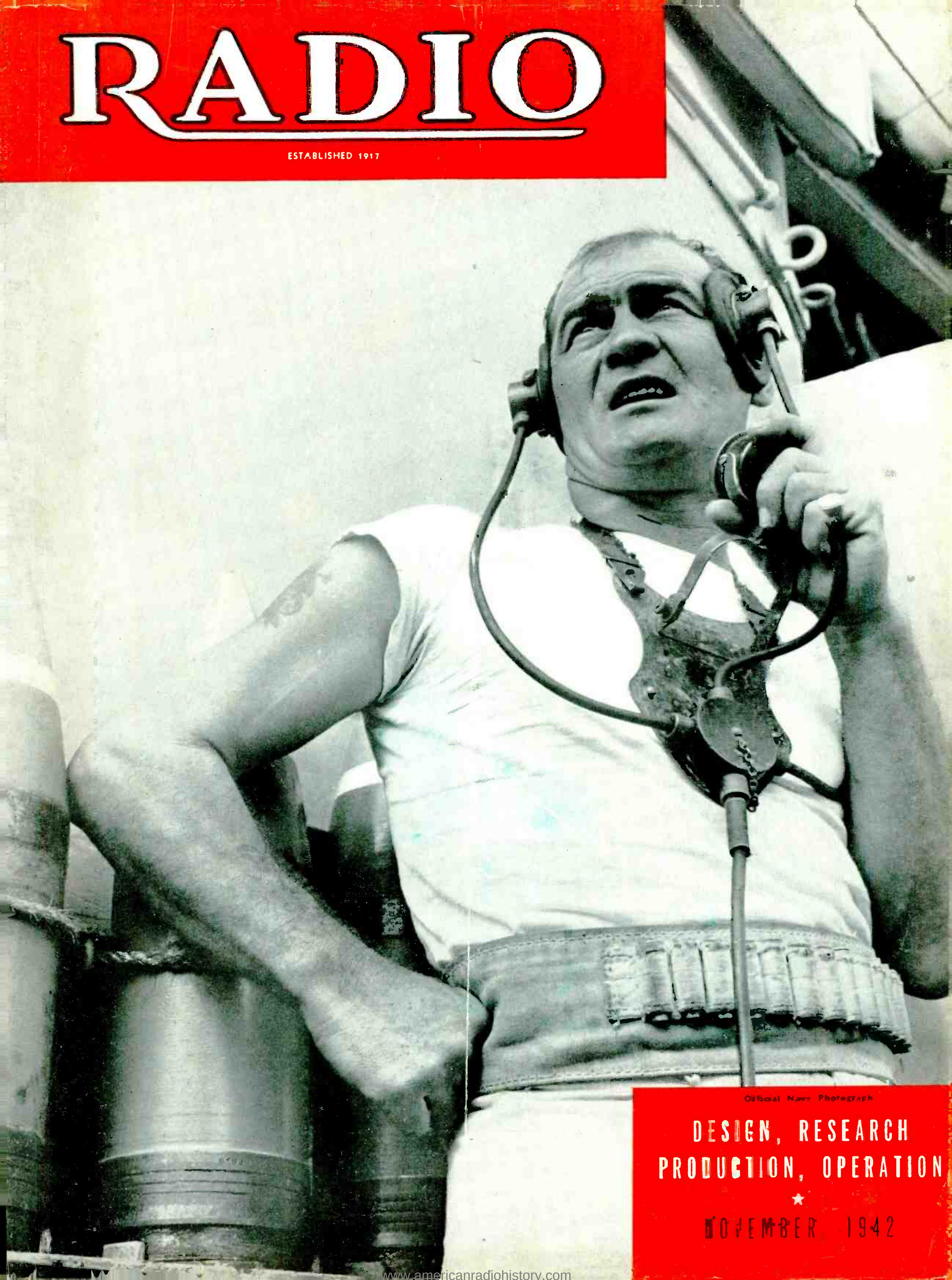
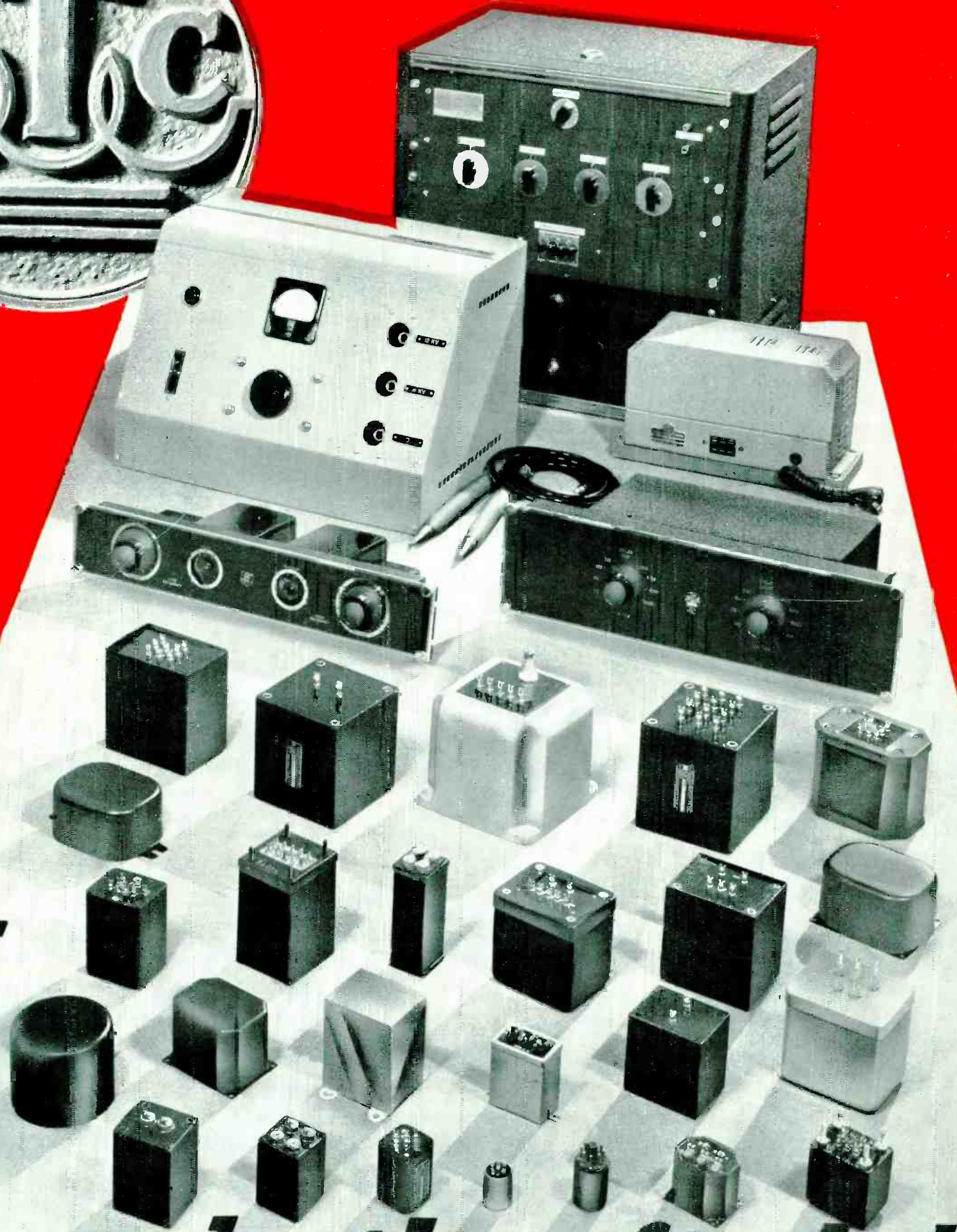


Official Navy Photograph

DESIGN, RESEARCH
PRODUCTION, OPERATION

★

NOVEMBER 1942



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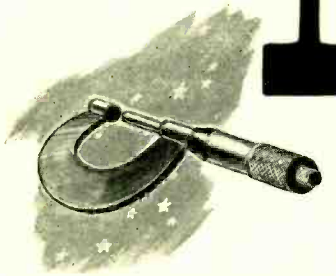

Military specifications, as applied to communications follow strict rules. Hallicrafters Communications equipment not only meet these rigid specifications . . . they surpass the requirements.

C-7. *Fixed Capacitors.* The maximum peak voltage applied on any of the fixed paper — [redacted] — dielectric capacitors shall not exceed the manufacturer's working voltage rating of that capacitor. All electrolytic capacitors shall be capable of continuous operation at a temperature of [redacted] degrees C. The normal working voltage applied on any fixed capacitor shall not exceed [redacted] per cent of the manufacturer's voltage rating. All fixed paper or [redacted] capacitors shall be [redacted] sealed.

C-8. *Resistors.* All resistors shall have their resistance values plainly and legibly marked on them, or as an alternative they may be color-coded in accordance with the Standard Resistor Color Code of the Radio Manufacturer's Association. All fixed resistors shall be of the [redacted] type and shall be capable of dissipating without damage to themselves or any other part of the equipment, at least [redacted] per cent more power than the maximum which they will dissipate in the normal use of the equipment.

C-9. *Transformers and Coils.* All audio and power [redacted] transformers and coils which carry direct current shall be designed (for normal use) to carry, for at least [redacted] hours, without damage to themselves or any other part of the equipment, at least [redacted] per cent more direct current than the maximum they carry in the normal use of the equipment. All [redacted] and coils shall be so designed that, when in their place in the equipment, they will safely handle their required power and peak voltage without damage to themselves or any other part of the equipment. All [redacted] and coils shall be capable of withstanding a [redacted] minute application of an [redacted] voltage (with frequency not greater than [redacted] cps.) with an rms value equal to [redacted] times the normal operating [redacted] voltage between any two [redacted] or any [redacted] and [redacted] parts or ground. However, if the operating voltage is greater than [redacted] volts, then the test voltage shall be [redacted] volts greater than twice the operating voltage. All transformers and coils shall be [redacted] and [redacted] so as to be capable of withstanding temperatures and humidity of both tropical and cold climates.

D-3a. Ambient temperatures outside the truck of [redacted] to plus [redacted]°C.

E-2f(6). *Frequency Stability.* There shall not be more than [redacted] cycles drift below [redacted]kc., nor more than .[redacted]% above, under the first [redacted] minutes of locked key operation after the filaments have been turned on for at least [redacted] minutes. This should hold where the ambient temperature is [redacted]° to [redacted]°F., and the line voltage is between [redacted] and [redacted] volts.

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RADIO

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COVER

An able-bodied seaman, Bill Williams of San Diego, California, captain of a gun crew who is now holding down a hot spot at sea. He can dish it out—and is in the process of doing so with the aid of communications equipment.

ARTICLES

MISCELLANEOUS

RADIO (title registered U.S. Pat. Off.) is published monthly at 34 N. Crystal Street, East Stroudsburg, Pa., by Radio Magazines, Inc., Executive and Editorial Offices at 132 West 43d Street, New York, N. Y. Subscription rates—United States and Possessions, $3.00 for 1 year, $5.00 for 2 years; elsewhere $4.00 per year. Single copies 35c. Printed in U.S.A. Entered as Second Class Matter October 31, 1942, at the Post Office at East Stroudsburg, Pa., under the Act of March 3, 1879.

EDITORIAL

THE GREMLINS

★ We wouldn't bother to mention the Gremlins at all, except that they have presumably invaded the radio field. We'd prefer to ignore them, as Gremlins and Fifinellas (female Gremlins) love to be talked about, particularly if it has to do with some mischief they've been up to. But we've received disturbing reports of Gremlins snapping rubber bands at mikes, sliding down radio beams, sending out false messages, and creating static interference.

The Gremlins are little folk and, according to *Time,* were first discovered by the R.A.F., the first one having been seen—if we are to believe the *Cosmopolitan*—by a pilot called Gus. More recently it has been reported by *The New York Sun* that Gremlins are an old story to the boys at Boeing Aircraft, which proves beyond contention that the little folk are not peculiar to Britain.

Usually, says *Time,* Gremlins are about a foot high, wear tight green breeches, red jackets and stocking caps, and have pointed ears. Other sources claim Gremlins have horns, like a bull, but the Boeing people insist that all Gremlins have a Pitot tube, which acts as an air-speed indicator, attached to the tops of their heads—which goes to show that no one really knows much about Gremlins anyhow.

An eminent radio engineer is of the belief that what the Boeing people have confused as a Pitot tube is nothing less than a quarter-wave Marconi; and he is of the opinion that the Gremlins originally sprung from the square root of minus one. He offers as a support of this theory the persistent reports that Gremlins drill holes into plane receivers, climb in, and have all sorts of sport playing b.f.o.

All sources, however, are agreed on two points; 1) that Gremlins can be seen and heard only by aircraft pilots and their associates, and, 2) they do not make their presence known to *any* of the enemies of the United Nations—so you can see that, as mischievous as Gremlins may be, they do not carry secrets to the Axis Powers.

The R.A.F. has instituted Training Schools for Gremlins and Fifinellas to make them good and helpful. No doubt training centers also will be opened over here; and it's about time! The little folk are multiplying like rabbits and over-running almost everything. There has, for instance, been a wave of errors in technical publications, and as early as August, *Electronics* reported on their editorial page the existence of a Jinx who threw some type away on them. It was unquestionably a Gremlin. In our own case, we had a Fifinella who played hob with Doppler's Principle (page 48, September RADIO) and left the impression that a plane flies backwards, like a Dodo Bird.

We wish to caution radio manufacturers that Gremlins have been using Widgets (baby Gremlins) to unscrew padders after receivers have come off the production testing line. If this difficulty is experienced, the solution is to spread Grape Nuts around on the test benches for the little folk to eat. What happens is, they glut themselves and fall asleep.

Bibliography

Battle of Europe, *Time,* September 14, 1942, page 37.
The Gremlins, *Cosmopolitan,* December, 1942, page 37.
American Gremlins, *New York Sun,* November 2, 1942, page 25.
The Gremlins, *Life,* November 16, 1942, page 93.

RELAXATION

★ We were surprised to learn recently that many of our readers, both in and out of the armed forces, often turn to RADIO for relaxation. Things they like best are, "Radio Design Worksheet" and "Q. & A. Study Guide." They're used as self-imposed quizzes, and woe to us if we make errors, as we sometimes do, for we soon hear about it—and from the strangest places.

Relaxation is very important these days. One friend of ours finds peace and diversion in walking his dog after dinner and solving equations up till bedtime. Another friend plays imagineering in his spare moments, and reports that he's sunk the Jap navy five times over with a special radio torpedo he cooked up in his head.

We go in for word games. If you have nothing better to do, take the word RESISTANCE and see how many four-or-more letter words you can extract from it, like "since", for instance. You ought to get one hundred, at least.

SNAFU

★ We live in a nation where one half doesn't know what the other half is doing. Most everything in radio, for instance, is hush-hush, and this makes for a situation where the boys in the know are miles out in front of the civilian.

This, of course, is for the best, but Americans have the delightful habit of attaching fond names to new things. Hence, when the war is over, the boys on the outside won't understand the language of the boys who've been on the inside, and everything will be what the Navy might well call Snafu.

M.L.M.


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NOTES ON FREQUENCY MODULATION

C. F. NORDICA

★ Modulation can be accomplished by operating on any of the three paramiters of a wave; namely, amplitude, phase, or frequency. All three types of modulation have been analyzed in the technical press. It is the purpose of this article to call attention to some of the pertinent characteristics of frequency modulation.

Modulation Distinctions

The generalized expression for an alternating current is:

$$I = A \cos(\omega t + \theta) \qquad (1)$$

This current may be modulated by arranging for the signal current to operate on the amplitude A of expression (1) while the frequency $\omega/2\pi$ and phase θ of the carrier current remain constant. This is called amplitude modulation.

In amplitude modulation the instantaneous amplitude of the carrier is at all times proportional to the instantaneous amplitude of the signal current. Likewise, in phase modulation, the phase θ is at all times proportional to the instantaneous amplitude of the signal current, amplitude and frequency of the carrier remaining constant. In frequency modulation the instantaneous amplitude of the signal current is employed to vary the instantaneous frequency of the carrier, while phase and amplitude are constant.

The expression for an amplitude-modulated current consisting of a carrier current modulated by a single frequency signal current (for simplicity) is well known. It may be derived by substituting the formula for the signal current for the peak value of the carrier current A in (1). Let the signal current be:

$$KA \cos pt$$

Substituting in expression (1) we have:

$$I = KA \cos pt \cos (\omega t + \theta) + A \cos (\omega t + \theta)$$

For simplicity assume: $\theta = 0$; then:

$$I = A\,(1 + K \cos pt) \cos \omega t = A \cos \omega t + AK/2 \cos (\omega - p)\, t + AK/2 \cos (\omega + p)\, t \qquad (2)$$

In expression (2), K is known as percentage modulation, the first term to the right of the equality sign is the carrier, and the two remaining terms the sidebands. It is obvious that the amplitude of the modulated wave varies between a peak of $(1 + K)\,A$ and a minimum of $(1 - K)\,A$ during modulation. If $K = 1$ (100% modulation):

$$(1 + K)\,A = 2A$$
$$(1 - K)\,A = 0$$

Obviously this is equivalent to a carrier of constant amplitude and two signal-bearing sidebands symmetrically disposed on either side of the carrier in the frequency spectrum, the frequency interval separating either sideband from the carrier being equal to the signal frequency. See *Fig. 1.*

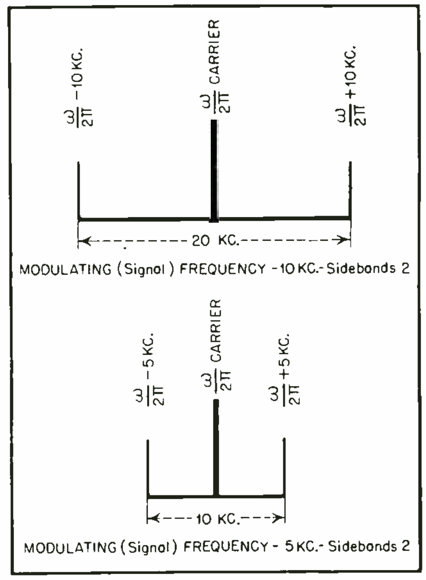


Fig. 1. Signal distribution for amplitude-modulated wave with constant percentage modulation for two modulation frequencies.

Phase Modulation

The expression for a phase-modulated wave may be derived in a similar manner. Substituting in (1) we have:

$$I = A \cos \{\omega t + \theta\,(1 + K \cos pt)\} \qquad (3)$$

Which reduces to:

$$I = A \cos (\omega t + \theta) \cos (K\theta \cos pt) - A \sin (\omega t + \theta) \sin (K\theta \cos pt)$$

Expanding the sine and cosine terms in accordance with their power series:

$$\sin \theta = \theta - \frac{\theta^3}{\underline{|3}} + \frac{\theta^5}{\underline{|5}} - \frac{\theta^7}{\underline{|7}} + \dots$$

$$\cos \theta = 1 - \frac{\theta^2}{\underline{|2}} + \frac{\theta^4}{\underline{|4}} - \frac{\theta^6}{\underline{|6}} + \dots$$

yields:

$$I = A \cos (\omega t + \theta) - AK\theta \sin (\omega t + \theta) \cos pt - \frac{AK^2\theta^2}{2} \cos (\omega t + \theta) \cos^2 pt + \frac{AK^2\theta^3}{6} \sin (\omega t + \theta) \cos^3 pt + \dots \qquad (4)$$

A term-by-term comparison of expressions (2) and (4) indicates that the phase-modulated current contains a carrier $[A \cos (\omega t + \theta)]$ of constant amplitude, frequency and phase; two first-order sidebands $[AK\theta \sin (\omega t + \theta) \cos pt]$ essentially similar to those of expression (2); together with a number of higher order sidebands consisting of the carrier modulated by harmonics of the signal frequency. See *Fig. 2.* Here it may be recalled that:

$$\cos^2 pt = \tfrac{1}{2} \cos 2\,pt + \tfrac{1}{2}$$
$$\cos^3 pt = \tfrac{1}{4} \cos 3\,pt + \tfrac{3}{4} \cos pt$$
$$\cos^4 pt = \tfrac{1}{8} \cos 4\,pt + \tfrac{1}{2} \cos 2\,pt + 3/5$$

$$\sin^2 pt = \tfrac{1}{2} - \tfrac{1}{2} \cos 2\,pt$$
$$\sin^3 pt = \tfrac{3}{4} \sin pt - \tfrac{1}{4} \sin 3\,pt$$
$$\sin (pt + \pi/2) = \cos pt$$

It will be noticed that in the phase-modulated current the first and other odd-ordered sidebands are displaced $\pi/2$ radians from their position in an amplitude-modulated current. Thus the current of expression (4) applied to an ordinary detector would yield no signal output, until the phase of the carrier was shifted. Thus as the relative phase of the carrier was shifted to $\pi/2$ radians from its normal phase, the output would continually increase, being maximum for a carrier phase shift of $\pi/2$ and decreasing again as the phase was shifted beyond $\pi/2$.

Frequency Modulation

The expression for a frequency-modulated wave can be derived as were the expressions for amplitude and phase modulation by substituting for the frequency term. The common expression for a frequency-modulated current is:

$$I = A\,[J_o M \sin \omega t + J_1 M\{\sin(\omega + p)\,t - \sin(\omega - p)t\} + J_2 M\{\sin(\omega - 2p)\,t - \sin(\omega + 2p)t\} + \ldots \quad (5)$$

In this case the J's are Bessel functions of the first kind and of the order indicated by the subscript. The quantity M represents the variation of frequency of the carrier from the unmodulated mean value, divided by the modulating (signal) frequency. This is

$$M = \frac{\Delta f}{F}$$

$$\text{when } f = \frac{\omega}{2\pi}$$

$$\Delta = \text{variation of } f$$

$$F = \frac{p}{2\pi}$$

The quantity M is usually referred to as the modulation index and may be compared, with certain reservations, to percentage modulation in amplitude modulation. Of course the modulation index can be and frequently is greater than unity, whereas percentage modulation (K) never exceeds unity. Like phase-modulated currents, frequency-modulated currents consist of several sets of sidebands. See *Fig. 3*.

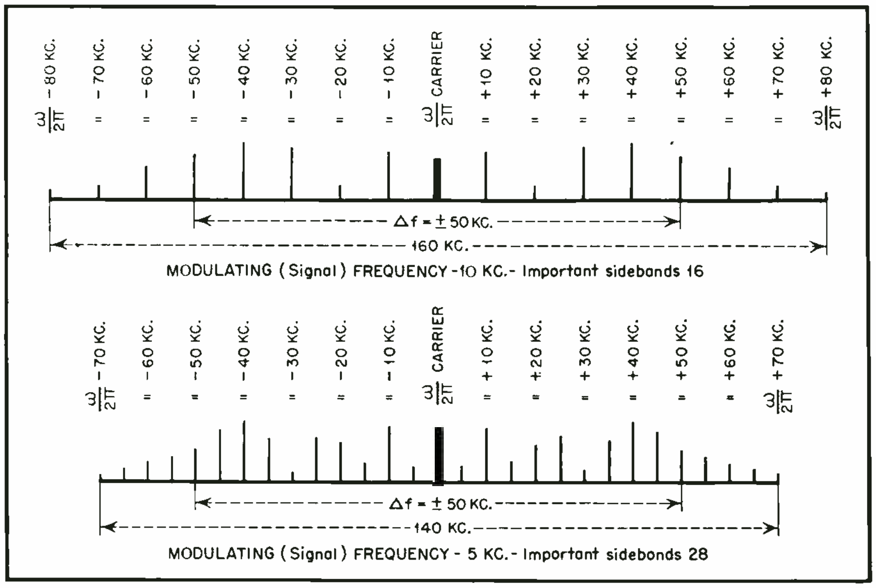


Fig. 3. Signal distribution for frequency-modulated wave with constant frequency variation for two modulation frequencies. Frequency deviation constant. Only important energy-bearing sidebands shown.

PM-FM Distinctions

If the modulation index is less than unity, then the amplitude of the first set of sidebands will be approximately proportional to M, while the amplitude of the higher order sidebands will be negligible. When the modulation index exceeds unity, the higher order sidebands become of more importance, in that they carry more energy, while the carrier amplitude drops rapidly.

From the foregoing it is apparent that phase modulation, while bearing many resemblances to frequency modulation, is by no means identical with frequency modulation. Or, to put the matter another way, phase and frequency modulation may be regarded as two somewhat dissimilar aspects of the same phenomena. In frequency modulation the extent of the frequency deviation is determined solely by the amplitude of the modulating signal. In pure phase modulation the extent of the phase deviation is proportional to both the amplitude and frequency of the modulating signal.

For example, in frequency modulation two modulating signals of 50 and 500 cycles of the same amplitude acting individually would produce identical frequency deviations. In phase modulation, however, the 500-cycle signal would produce 10 times the phase change of the 50-cycle signal. This situation was recognized by early investigators, and is corrected by pre-distorting networks which attenuate high signal frequencies with respect to low ones before modulation in so-called phase-frequency modulation transmitters. In a pure frequency-modulated transmitter such a network would not be required for this purpose. Such a network could, of course, be included in the receiver instead of the transmitter. An expedient frequently used in f-m systems to improve signal-to-noise ratio lies in pre-emphasizing high audio frequencies at the transmitter and employing a conjugate network at the receiver to emphasize the low audio frequencies with respect to those of a high order.

Inasmuch as the relative phase of the carrier in frequency modulation is in quadrature with respect to the carrier in amplitude modulation, interfering amplitude modulations, such as atmospherics, is much reduced in frequency-modulation systems. This is one of the noteworthy advantages of frequency modulation over amplitude modulation.

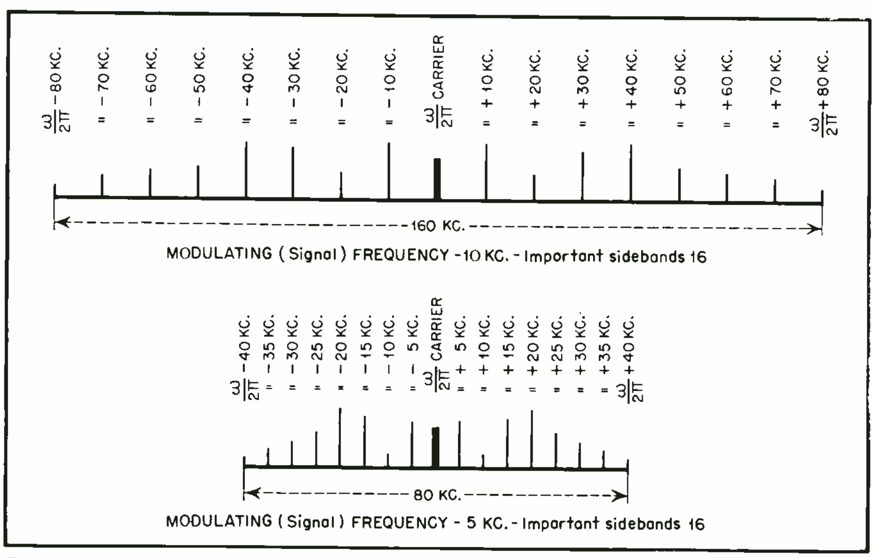


Fig. 2. Signal distribution for phase-modulated wave with constant phase variation for two modulation frequencies. Phase deviation constant. Only important energy-bearing sidebands shown.

Fundamental Differences

From the foregoing it is evident that

[*Continued on page 43*]

HIGH-FREQUENCY SWEEP CIRCUITS

M. VAN ARKEL

★ The popular sweep circuit employing a gas triode serves well in many applications, but it suffers from instability and frequency limitation. Due to the fact that the ionization in such a tube takes a small but definite length of time, the maximum frequency obtainable is somewhere near 25 kc. Even at these frequencies, the return stroke takes too great a proportion of the cycle.

Greater reliability and higher sweep frequencies can be obtained with circuits employing high-vacuum tubes. Such circuits, however, are more complicated and also have some disadvantages. For instance, it is very difficult to obtain the sudden large discharge current with ordinary vacuum tubes. This results in the back trace taking a longer time so that it becomes visible. Also, changing the frequency involves varying more circuit constants than in circuits with gaseous discharge tubes. As a result, the sweep circuit with high-vacuum tubes is employed when high sweep frequencies are required, or where high stability at a limited number of frequencies is needed.

Linear sweep circuits employing high-vacuum tubes may be divided into groups depending upon their principle of operation. In this article we shall describe four groups, as follows: 1) blocking an oscillator; 2) adapting the multivibrator; 3) using an oscillator with a discharge tube; 4) changing the shape of a sine wave.

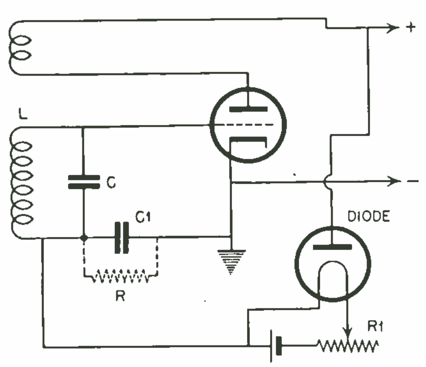


Fig. 1. Circuit of one of the simplest forms of blocked-oscillator sweep circuit.

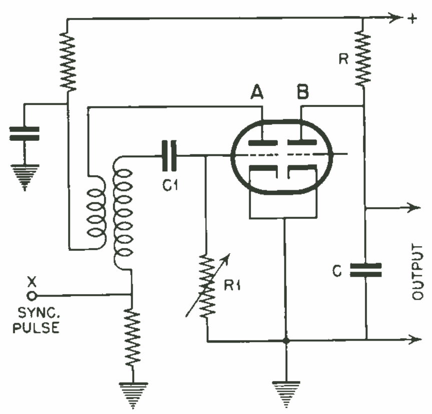


Fig. 2. Blocked-oscillator sweep circuit used in RCA television receivers.

Blocked Oscillators

One of the simplest forms of blocked-oscillator sweep circuit is shown in *Fig. 1*. This arrangement is due to Appleton, Watson-Watt and Herd (*Proc. Royal Soc. A.* Vol. 103, p. 84, 1923 and Vol 111, p. 615 and 654, 1926). The LC circuit of the oscillator is designed to resonate at a frequency much higher than the desired sweep frequency. Due to the large time constant of the grid-leak and condenser combination, the oscillator grid is blocked after the first or second cycle. The charge then leaks off through the grid leak until the grid bias becomes so low that oscillations can start again. After the first few cycles the grid is again blocked and the procedure repeated.

The sweep voltage is taken from across the grid condenser, *C1*. If an ordinary grid resistor *R* were used, the discharge voltage would fall exponentially. Therefore, a fixed rate of discharge is insured by the use of a saturated diode instead of a resistor. This diode is shown in the diagram and might be considered as being "biased" by the B-supply. The rate of discharge is adjusted by the diode filament rheostate *R1*.

Several variations and refinements of this system are in use. In *Fig. 2*, it is shown how this arrangement is employed in the RCA television receivers TRK-9 and TRK-12.

To explain the action let us begin at that part of the cycle where the triode oscillator *A* blocks. At that time the grids of both tubes are biased beyond cut-off and there is no plate current in triode *B*. Consequently, the condenser *C* will charge up through resistor *R* at an exponential rate. At the same time the charge on the grid condenser *C1* will leak off through *R1*. When the grid condenser has been so far discharged that plate current starts flowing, tube *A* breaks into oscillation. There is then a short positive pulse on the grids and a sudden large plate current in tube *B* which discharges condenser *C*. The cycle is then repeated.

The sweep voltage is taken from across the condenser *C*. The charging period should be adjusted so that it does not permit the condenser to charge to more than about 20% of the supply voltage before discharge occurs. The first part of the exponential curve being nearly straight, this is the easiest way of providing a linear rise of voltage.

The frequency of the circuit is entirely dependent on the time constant *C1-R1* in tube *A*, and may be slightly varied by the synchronization pulses applied at *X*. If the same voltage output and the same waveform are to be expected from the circuit, the ratio of *R-C* to *R1-C1* should remain fixed.

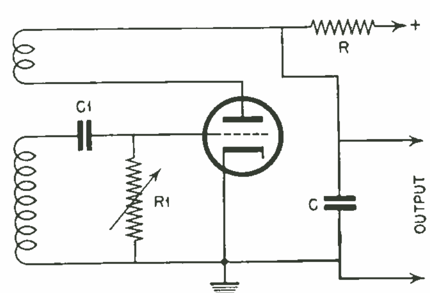


Fig. 3. Single-tube blocked-oscillator sweep circuit, otherwise the same as Fig. 2.

Sweep frequencies up to 500 kc are claimed for this circuit.

It is possible to have the two jobs which are performed by tubes *A* and *B* in *Fig. 2,* done by a single tube, as in *Fig. 3.* The same tube serves both as oscillator and as discharge tube. The action is practically the same as described above. Condenser *C* charges and is periodically discharged as the tube breaks into oscillation. Waveforms of the grid voltage and plate voltage are shown in *Fig. 4.*

Going one step farther in the evolution of the blocked oscillator, there is shown in *Fig. 5* a circuit which allows a push-pull voltage to be taken from a single blocked-oscillator tube. It is done by dividing the charging resistance in two parts, *R1* and *R2,* which are in the plate circuit and cathode circuit respectively. This oscillator is also interesting because of the coils *L1* and *L2* in series with the charging resistors. The presence of

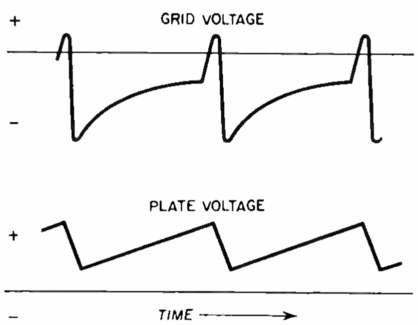


Fig. 4. Voltage waveform of Fig. 3 circuit.

the coils tends to keep the charging currents equal and aids in getting a linear charging rate. The condenser can then be charged to a higher voltage—more than 1/5 of the supply voltage—and still retain linearity. This circuit was described by Kallman in the *Proceedings of the IRE,* Vol. 28, No. 8, August, 1940.

Multivibrator Types

The ordinary multivibrator can be used as a sweep oscillator but a special arrangement has to be made to change the waveshape to a sawtooth form. One of these, due to Puckle, is illustrated in *Fig. 6.* It differs from a conventional multivibrator by the addition of the components *C, R* and *L* in the cathode lead of the second triode.

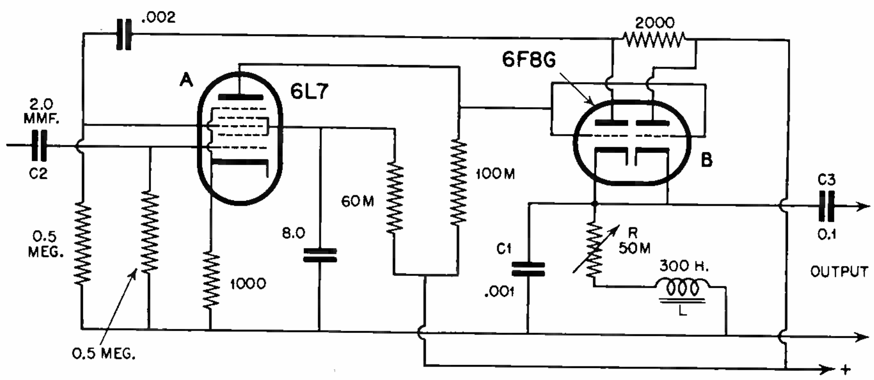


Fig. 7. Another multivibrator sweep oscillator. Values are for 13,230 cycles. At 60 cycles, C1 is .25 μf., L is 2000 h., R is 100,000 ohms, C2 is .005 μf., and C3 is .25 μf.

The operation is as follows: Assume that at a given time the plate current in tube *B* is rising. This increasing plate current causes a decrease in plate voltage at tube *B,* a decrease in grid voltage in tube *A* and a decrease of plate current in tube *A.* Therefore, the plate voltage of tube *A* rises and the grid voltage of tube *B* also rises, reinforcing the original increase in plate current in tube *B.* Due to the rise in plate current in tube *B,* the grid bias increases—since it consists of the voltage drop across *L* and *R*—until finally the tube is biased to the point of plate-current cutoff.

The charge on condenser *C* then leaks off through *R* and *L,* the proportion of these two constants keeping the discharge linear. This continues until the tube starts to draw plate current again. This sudden rise in plate current starts the same train of events as before, increasing the plate current until cutoff occurs again and the cycle repeats.

The frequency is determined approximately by the constants *R, L* and *C.* The synchronizing pulse allows some variation. The other constants of the circuit need not be changed with frequency. There is no objection to using a double triode for the purpose, a 6F8G being suitable.

This type of circuit has been employed for television deflection and was described in this connection by Wilder, in *QST,* for February, 1938. The sudden voltage surges occurring at the plate of tube *B* are suitable for blanking the return trace.

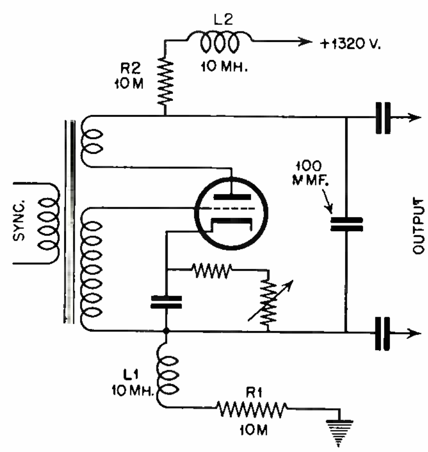


Fig. 5. Push-pull voltage blocked-oscillator.

A modification of the multivibrator circuit of *Fig. 6* was suggested by Dumont, and is illustrated in *Fig. 7.* Here a second tube is connected in parallel with tube *B,* except for the plate circuit. The result is that the rise in plate current passing through *R* and *L* is greater and the time of the return trace is reduced. Values of the constants for a 60-cycle sweep and for the horizontal sweep are given in the diagram caption.

Potter's Circuit

Another variation of the multivibrator, as shown in *Fig. 8,* was devised by Potter (*Proc. IRE,* Vol. 26, No. 6, June, 1938). It can operate at frequencies from a few cycles per second to about 100 kc.

The operation is rather complicated, but briefly it is as follows: When the plate voltage is applied (the tubes having no bias) there is a sudden rush of plate current in both tubes. Condenser

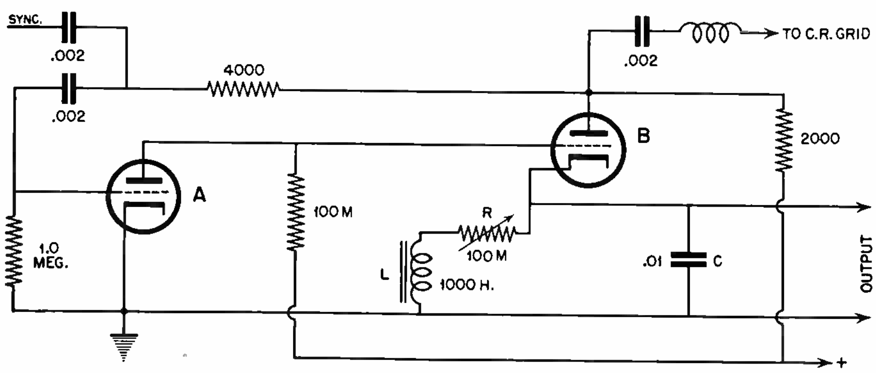


Fig. 6. Diagram of multivibrator used as sweep oscillator circuit.

C1 charges through *Rb* and *R1*, but shortly the charge passes through the grid circuit of tube *B* rather than through *R1*. Due to the voltage drop across the bias resistor and across *Rb*, the plate current in tube *A* is eventually cut off. However, tube *B* continues to draw plate current and *C1* therefore charges. During this charge the voltage drop across *Rb* and *R1* is progressively reduced until the grid voltage on tube *B* becomes negative and tube *A* starts drawing current,

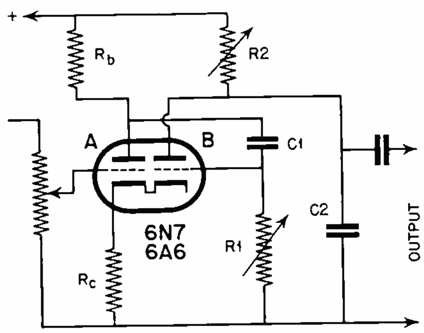


Fig. 8. Potter's sweep circuit.

thus discharging *C1*. During this period *C2* charges through *R2*; and this constitutes the forward stroke of the sweep.

The cycle is then repeated. The voltage across *C2* is practically a perfect sawtooth form. The frequency is approximately $f = .4R1/C1$, while the amplitude is determined by *R2* and *C2*. In the circuit shown by Potter, an amplifier tube is used after this oscillator. It was omitted in *Fig. 8* so as to avoid confusion.

Oscillator-Driven System

A high-frequency sweep circuit employing a discharge tube which is

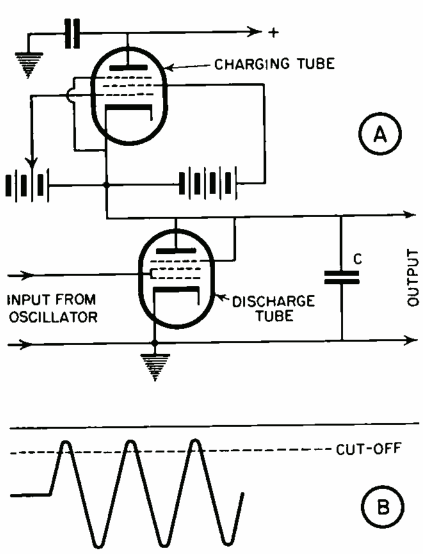


Fig. 9. High-frequency sweep circuit using discharge tube. Grid waveform shown at B.

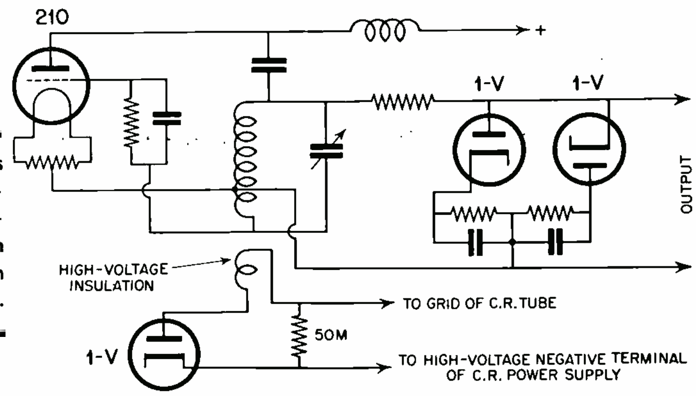


Fig. 11. In this sweep circuit, oscillator signal is clipped by diodes, with resultant waveform as shown in Fig. 12.

triggered off at the proper time by an auxiliary oscillator was originated by Goldsmith and Leeds (*Proc. IRE*, Vol. 23, No. 6, June, 1935). It consists of a condenser *C* that is charged through a constant-current device consisting of a pentode, as in *Fig. 9-A*. Periodically, the condenser is suddenly discharged by the power tube across it which is normally biased beyond cutoff, but is momentarily made conducting by a pulse from an oscillator.

In the example shown by Goldsmith and Leeds, the discharge tube consists of a type 59 operated Class B. It therefore has a high mu and is easily biased beyond cutoff. The con-

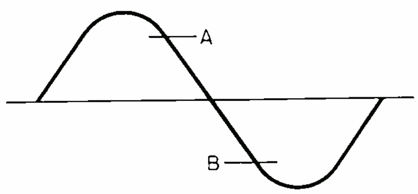


Fig. 10. Part of sine wave used as sweep.

stant-current device consists of four 58's in parallel.

If the discharge, which represents the return trace, is to be made as short as possible, the grid of the tube should be made conducting only at the positive peak of the oscillator cycle. This can be adjusted by properly proportioning the grid bias and the superimposed oscillator voltage. *Fig. 9-B* illustrates the waveform of the grid signal.

The frequency is dependent upon that of the oscillator; but at higher frequencies a smaller capacity is required so that the tube will be able to discharge it in the shorter time allotted. The authors used the stray circuit capacity as the condenser. Sweep frequencies of 4 mc and more are possible; there is also no reason why low frequencies cannot be obtained.

In order to interlock the sweep with the observed signal, some stray coupling between the control oscillator and the signal can be provided.

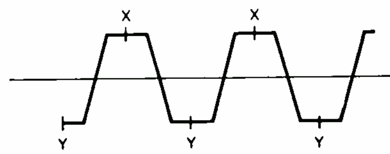


Fig. 12. Waveform of Fig. 11 sweep circuit.

Shaping the Sine Wave

Leeds (*Proc. IRE*, Vol. 24, No. 6, June, 1936) described an interesting way of changing the shape of a sine wave so that it can be used as a linear sweep circuit for higher frequencies.

The sine-wave shape (*Fig. 10*) is nearly straight for one-sixth of a cycle near the middle of its stroke from *A* to *B*. Leeds used only this part of the cycle as the forward stroke; the rest of the cycle is suppressed, and therefore the observed phenomenon must be at a frequency which is at least 6 times the sweep frequency.

The circuit is shown in *Fig. 11*. The signal from an oscillator is first fed through two diodes which clip off the peaks so that the resultant waveform is that of *Fig. 12*. The return trace from *X* to *Y* is suppressed by a voltage applied to the grid of the cathode-ray tube so as to suppress the beam. This voltage is picked from the oscillator in the correct phase, rectified, and applied to the grid.

Other Sweep Circuits

It is sometimes desirable to obtain a very long sweep, to observe transients, for instance. For this purpose.

[*Continued on page 44*]

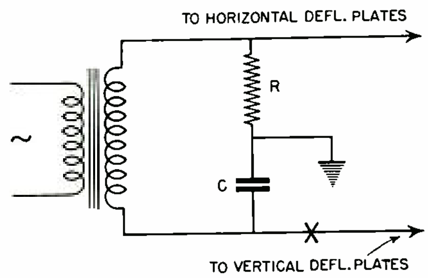


Fig. 13. Circuit providing circular sweep.

FM-STATION PERFORMANCE

C. H. WESSER

Chief Engineer, W45D

★ Paragraph 6 of the Application for High-Frequency Broadcast Station License (FM), FCC Form 320, has to do with Proof of Performance of Audio-Frequency Operating Characteristics, and appears quite easy to satisfy. Actually, with requirements that are much stiffer than AM station performance requirements, and with little precedent and measuring equipment now available, furnishing the required proof of performance in accordance with the Standards of Good Engineering Practice Governing FM Broadcast Stations is not entirely a simple matter.

Performance Requirements

The proof of performance requires that "All measurements shall be made with the equipment adjusted for normal program operation and shall include all circuits between the main studio microphone terminals and the antenna output, including telephone lines, pre-emphasis circuits and any equalizers employed, but excluding the compensated microphone amplifier, if used." The measurements required include the following:

(a) Audio-frequency response in decibels above and below response at 1000 cycles for frequencies of 30, 50, 100, 400, 1000, 5000, 10,000 and 15,000 cycles with modulation of 25, 50, 75, and 100 percent.

(b) Extraneous noise level (exclusive of microphone and studio noises), in decibels (unweighted r.m.s.) below 100-percent frequency modulation. (The noise-measuring equipment shall have substantially uniform response in the range from 30 to 15,000 cycles).

(c) Extraneous noise level as in *(b)*, except amplitude modulation.

(d) Audio-frequency distortion (r.m.s. harmonic) at 50, 100, 400, 1000, 5000, 10,000 and 15,000 cycles at 100-percent modulation.

Complete data, diagrams and graphs together with descriptions of measurement procedure must be furnished. For 100-percent modulation in connection with the above measurements, a frequency swing of ±75 kc shall be used.

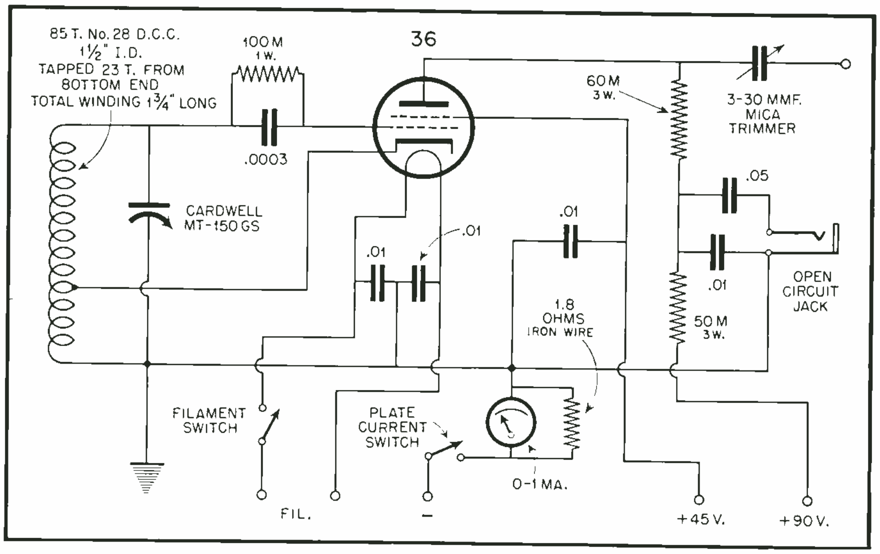


Fig. 1. Diagram, with parts values, of heterodyne meter. Variable condenser has 15 stator plates, but only 8 rotor plates, 3 of which are swung 180° on shaft in relation to remaining 5 plates, providing small tank capacity across coil.

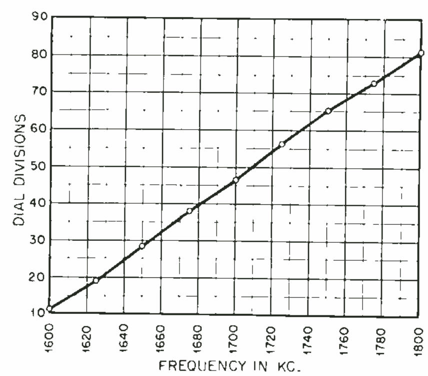


Fig. 2. Calibration curve of heterodyne meter.

To anyone familiar with performance requirements of AM broadcast stations, it is at once apparent that FM requirements are considerably harder to meet, except for the inherent advantages that FM offers over AM in several respects. Producing the proof of performance is sometimes difficult because FM station engineers must devise their own methods of making the required measurements, and for every piece of equipment used in making these measurements performance must be proved, if the equipment has not already been approved by FCC (Little of this equipment has been approved, or is commercially available.)

Audio-Frequency Response

Since a-f response must be measured at four different percentages of modulation, it is obvious that these modulation percentages must first be accurately established. At this writing there has been no modulation monitor approved for FM by the FCC, although one manufacturer offered such a monitor for sale last year. It is doubtful if these are still available.

If no monitor is available, the swing must be established by some other means. One way of measuring swing will be described here, since it has been used at W45D for some time, and is very satisfactory once the operator is thoroughly familiar with the method and procedure of measuring, and with the equipment involved. A comparatively simple and very stable heterodyne frequency meter was constructed with the midpoint of its frequency range at the intermediate frequency of the FM receiver with which it is used, and the high and low limits of its range at approximately 100 kc above and 100 kc below the midpoint, or i-f, frequency.

Fig. 1 shows the diagram of the heterodyne meter. As long as a reliable standard is available against which the calibration of this meter can be checked, it is only necessary that it hold calibration during the period that is required to make the actual swing measurements. Since the receiver used at W45D for all measurements is an REL 517 with an i.f. of 1700 kc, the range of the heterodyne meter was made to run from 1600 to 1800 kc, with an extra ten dial divisions or more at each end of this range to avoid having to operate too closely to the ragged edges of the tuning condenser.

The calibration curve of this meter, *Fig. 2,* was made against a General Radio type 620-A Heterodyne Meter-Calibrator. This meter was checked against WWV just prior to making the band-spread heterodyne meter calibration. It has since been found that the band-spread meter holds calibration over periods of months if it is handled carefully, and is treated as a piece of measuring equipment deserves to be treated. The fact that this meter holds calibration so well is undoubtedly due, in part, to its construction of heavy aluminum, reinforced with brass angles at all corners. Its A and B batteries are self-contained in another shielded compartment, and a check on total space current of the tube, each time it is used, is made to make sure that everything is in proper working condition.

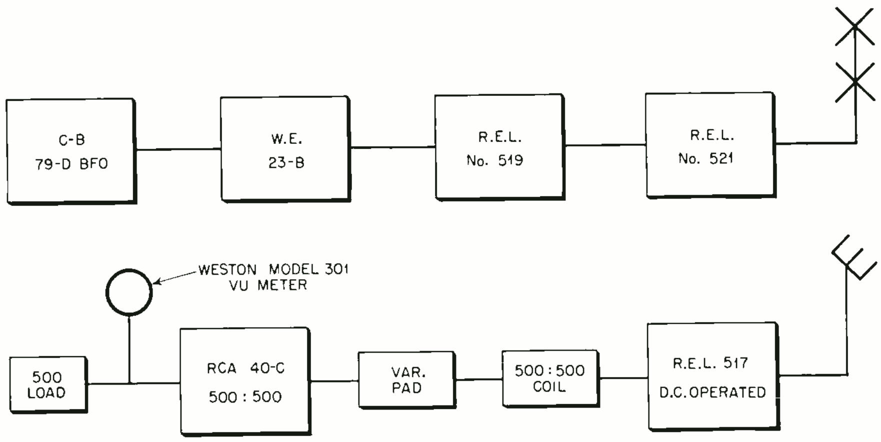


Fig. 4. Equipment line-up in block form, used for noise level checks and measurements.

Once the heterodyne meter is calibrated, we have a source of r.f. that can be used also for calibrating the discriminator of the receiver, to make certain that its operation is linear. The calibration of the discriminator is, in effect, the plotting of the r-f input to it at various frequencies within the range of the i-f ±75 kc, which is considered equal to 100-percent modulation. This is done by lightly coupling the output of the meter to the last i-f stage of the receiver, and at the same time reading the discriminator output voltage on a VT voltmeter, and repeating this process at small frequency intervals over the entire range of the i-f ±75 kc.

Fig. 3 shows the equipment line-up in block diagram, and the curve of the discriminator that resulted after careful adjustment of it and the receiver. It is interesting to note that the final curve of the discriminator of the REL 517 receiver is straight from 1620 kc to 1780 kc, and virtually straight from 1600 to 1800 kc.

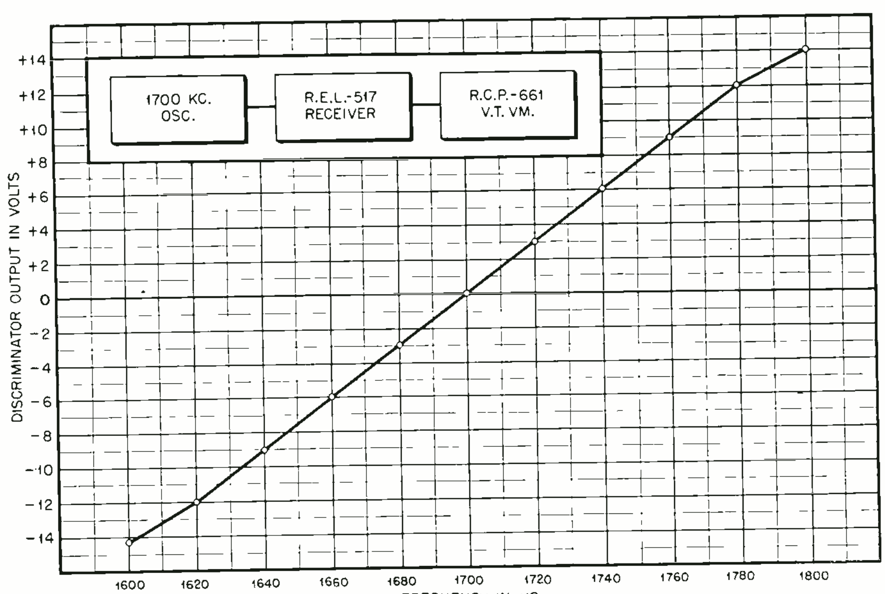


Fig. 3. Equipment line-up in block diagram form, and the discriminator curve resulting from careful adjustment.

To measure the swing of the transmitter, the heterodyne meter is again loosely coupled to the i-f amplifier of the receiver while a steady tone is being fed into the transmitter, with the receiver carefully tuned to the transmitter frequency. By slowly scanning the entire frequency range of the heterodyne meter, "birdies" will be heard all across the range over which the carrier is swung. By carefully going to outer frequency limits of the meter that still barely give a beat between it and the frequency-modulated carrier, that limit of swing can then be read directly from the calibration curve of the meter, at once establishing swing in terms of kilocycles plus and minus unmodulated carrier, and therefore in percent.

Making frequency-response curves at 25, 50, 75 and 100-percent modulation is then a simple matter of reading meters at the mike input terminals of the speech input equipment that feeds the transmitter, and at the output of the test receiver.

Extraneous Noise Level Measurements

Fig. 4 shows the equipment line-up used for the noise-level checks and measurements. The speech input-transmitter arrangement is the one normally used for program transmission. The measuring set-up includes the REL 517 receiver, whose frequency response is known to be flat within less than 1 db from 25 to 16,000 cycles. This receiver

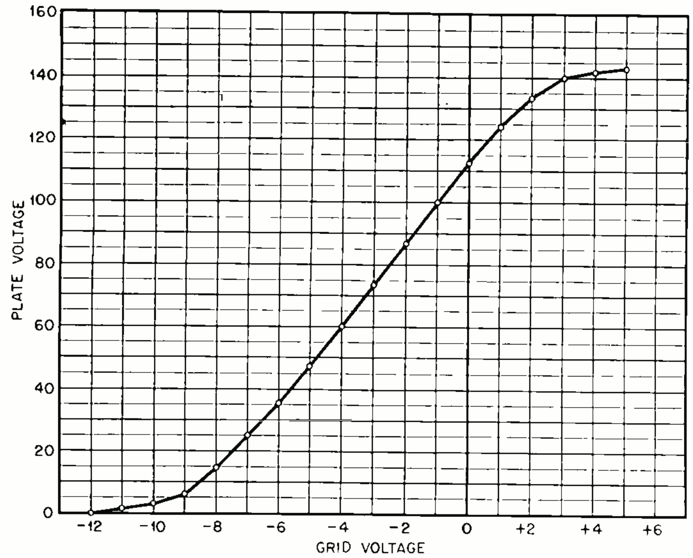


Fig. 5. Grid voltage-plate voltage curve of tuned grid circuit bias detector, as measured across plate load resistor, and used for AM noise-level measurements.

was worked into an RCA type 40-C amplifier through a matching coil and variable pad. The output of 40-C amplifier was terminated in 500 ohms, its intended load impedance, with a VI meter connected across its output. Since the response of the measuring equipment must be substantially uniform over the range of 30 to 15,000 cycles, a frequency run was made on this amplifier to prove its response, and was found to be safely within the required limits.

With all equipment set up, the transmitter was modulated at 100 percent with a 1000-cycle tone, and the 40-C amplifier gain control adjusted to give zero-level output. With no modulation, but with all controls set at normal program settings, the output at the 40-C was found to be 66 db below zero level output at 100 percent, thus establishing the overall noise level of the entire program channel, including the transmitter and measuring equipment. The receiver limiter grid was then grounded, and the noise level at the output of the 40-C checked. It was better than 90 db down, proving that the noise-measuring set-up did not materially contribute to the overall noise measured.

For the purpose of noise-level measurements the REL receiver was entirely battery-operated. Switches were installed permanently on the back of this receiver to allow similar operation whenever noise-level checks are made, and without any undue loss of time.

AM Noise-Level Measurements

For these measurements a simple 6L5 bias detector with a tuned grid circuit was assembled, and the grid voltage-plate voltage curve plotted (as measured across the plate load resistor). This curve is shown in *Fig. 5.* The RCA 40-C amplifier was used in connection with this detector and measurements were made as follows:

Sufficient r-f voltage from the radiator of the transmitter was picked up by the resonant grid circuit of the detector to give a d-c drop of 10 volts across the plate load resistor. A measured gain of 25 db was needed in the 40-C amplifier behind the detector to produce an output level of zero. From the curve in *Fig. 5* we find that a grid voltage of 3.5 is indicated when 10 volts is developed across the plate load resistor. Multiplying the grid voltage by 2 to simulate 100-percent (AM) modulation conditions of the carrier, the resulting 7 volts on the grid shows a corresponding plate voltage of 48, again taken from the curve. This corresponds to a level of approximately 34 db. The 25-db gain of the 40-C amplifier plus the 34-db level measured across the plate load resistor equals 59 db, which is the level of the AM noise below 100-percent conditions.

A-F Distortion Measurements

Since these measurements must be made at various frequencies from 50 to 15,000 cycles, there is no substitute for the use of a wave analyzer or regular distortion meter that covers the prescribed range. With the proper equipment available, these measurements are easily made. If no such measuring equipment is available, it appears that the only thing left to do is to request that the FCC waive this portion of the proof of performance until such time as the necessary equipment becomes available once again, which will not be until after the war. Under such circumstances the Commission may waive the requirements that cannot be met because of lack of proper equipment, under a Commission action of August 4, 1942. Of course, in cases where waiving of any portion of the requirements is requested, it becomes necessary that the applicant or licensee state, under oath, that he will comply with the Rules and Standards of the Commission just as soon as availability of equipment and material make it possible for him to do so.

Since the Standards require that the combined distortion does not exceed 2 percent at 100-percent modulation, it is impossible to make the measurements by any other means than with equipment designed for that purpose. To satisfy our own curiosity, photographs were taken of 'scope patterns of the output of a beat-frequency oscillator and the output of the test receiver while the transmitter was being modulated at 100 percent with the same frequency, and from the same b-f oscillator. It was interesting to note that no distortion shows on these photographs, indicating that the method (and particularly the 'scope) is incapable of showing up low percentages of distortion of the order of 2 percent and less—the reason why this method is not acceptable as part of the proof of performance.

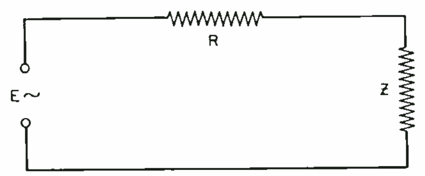
RADIO DESIGN WORKSHEET

No. 7—POWER & BRIDGING LOSSES

POWER LOSS

Problem 1: *Determine the formula relating the power loss in decibels and ratio between source and sink resistances.*

Solution: Assume a circuit in which sink resistance Z is equal to the generator resistance R. In the circuit shown:



$$\text{Current} = I_1 = \frac{E}{R+Z_1} = \frac{E}{2R} \text{ if } Z_1 = R$$

Let power dissipated in load $Z_1 = P_1$

$$P_1 = Z_1 I_1^2 = \frac{Z_1 E^2}{4R^2} = \frac{E^2}{4R} \text{ if } Z_1 = R$$

When Z is not $= R$ $\quad I_2 = \frac{E}{R+Z}$

$$P_2 = \frac{ZE^2}{(R+Z)^2}$$

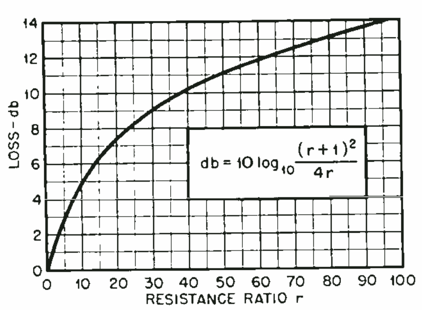
$$\frac{P_1}{P_2} = \frac{E^2}{4R} \times \frac{(R+Z)^2}{ZE^2} = \frac{(R+Z)^2}{4RZ} \quad (1)$$

Let $r = \frac{Z}{R}$ and substituting $Z = Rr$ in *(1)*

we have: $\frac{P_1}{P_2} = \frac{(R+rR)^2}{4R^2 r} = \frac{R^2(r+1)^2}{4R^2 r} = \frac{(r+1)^2}{4r}$

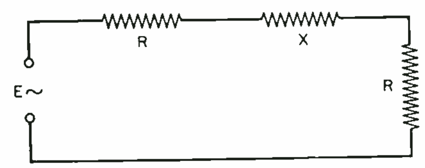
db loss is: $db = 10 \log_{10} \frac{(r+1)^2}{4r}$

A plot of this relation is shown in the accompanying graph.



BRIDGING LOSS

Problem 2: *Determine the bridging loss due to a series resistance inserted between source and sink. Assume source or generator resistance is equal to the sink or termination resistance (the usual case); and let X equal the series resistance inserted, as in the accompanying diagram.*



Solution: When $X = 0$

$$I_1 = \frac{E}{2R} \qquad P_1 = RI_1^2 = \frac{RE^2}{4R2} = \frac{E^2}{4R}$$

When X is finite

$$I_2 = \frac{E}{X+2R} \qquad P_2 = RI_2^2 = \frac{RE^2}{(X+2R)^2}$$

$$\frac{P_2}{P_1} = \frac{RE^2}{(X+2R)^2} \times \frac{4R}{E^2} = \frac{4R^2}{(X+2R)^2}$$

$$\text{loss in } db = 10 \log_{10} \frac{4R^2}{(X+2R)^2} = 10 \log_{10} \frac{4}{(r+2)^2} \text{ if } r = \frac{X}{R}$$

This relation is plotted in the graph of *Fig. 1.*

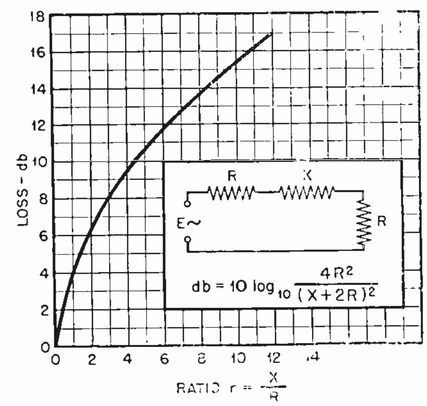


FIG. 1.

An application of Problem 2 may be found in the transmission of audio signals over short lengths of line, say under 1000 feet. This problem often arises in broadcast studios, public-address systems, etc.

The accompanying table shows the resistance per 1000 feet of various sizes of copper wire. This is d.c. resistance, but for relatively short circuits the audio a.c. resistance is equal to the d.c. resistance for all practical purposes.

Since a metallic circuit consists of two wires, the resistance per circuit foot is double the resistance per wire foot. Substituting the resistance for X in *Fig. 1,* we have the data shown in *Fig. 2* for a 5-ohm circuit.

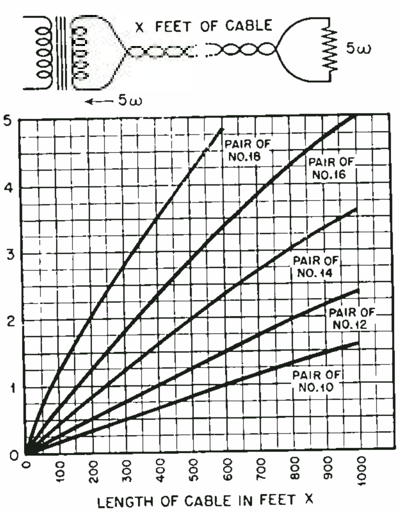


FIG. 2.

Wire Resistance Table

Wire size B & S gage	*Ohms per M ft.*	*Wire size B & S gage*	*Ohms per M ft.*
10	1.0	22	16.2
11	1.26	23	20.4
12	1.6	24	25.7
13	2.0	25	32.4
14	2.6	26	40.86
15	3.12	27	51.52
16	4.02	28	64.97
17	5.07	29	81.92
18	6.39	30	103.3
19	8.29	31	127.3
20	10.16	32	164.26
21	12.8	33	207.1

U. H. F. OSCILLATORS

C. R. STOLL

★ The term "ultra high frequencies" has been defined as that part of the radio spectrum between 30 and 400 megacycles.

Many suitable methods for generating these frequencies using vacuum tube oscillators have been devised, a few of which will be explained.

A brief review of circuits reveals that any one of four types of oscillators are commonly used in all standard radio equipment. There are, in the order of importance, the Hartley; Tuned Plate-Tuned Grid; Colpetts and Tickler Feedback Circuit *(Fig. 1)*. Of these, three are useful on ultra-high frequency. The Tickler Feedback Circuit, which has considerable merit on low and medium frequencies, becomes impractical on high frequencies because of the decreasing size of L/C circuits.

For ultra-high frequency superheterodyne receivers, the first three circuits illustrated in *Fig. 1* are often used as local oscillators with the conventional coil and condenser tuned circuit. This gives satisfactory results if high stability is not required, as is the case of narrow band beat-note reception. If cw reception is attempted, a very rough note will be heard due to small continual variations of the oscillator frequency. This results from minute mechanical vibrations of the tuned circuit and inefficient oscillator operation, since considerable energy must be fed back to the grid circuit to sustain oscillation on these frequencies with conventional tubes.

Requirements

Analyzing oscillator requirements we find that stability and/or power output are the two major points to strive for in all equipment. In an oscillator for a signal generator or superheterodyne, stability is usually the only requisite. For communication purposes we want both. It is not possible to get high stability and high power output simultaneously, so, when both are desired, a compromise must be reached. Methods for accomplishing this will be described later.

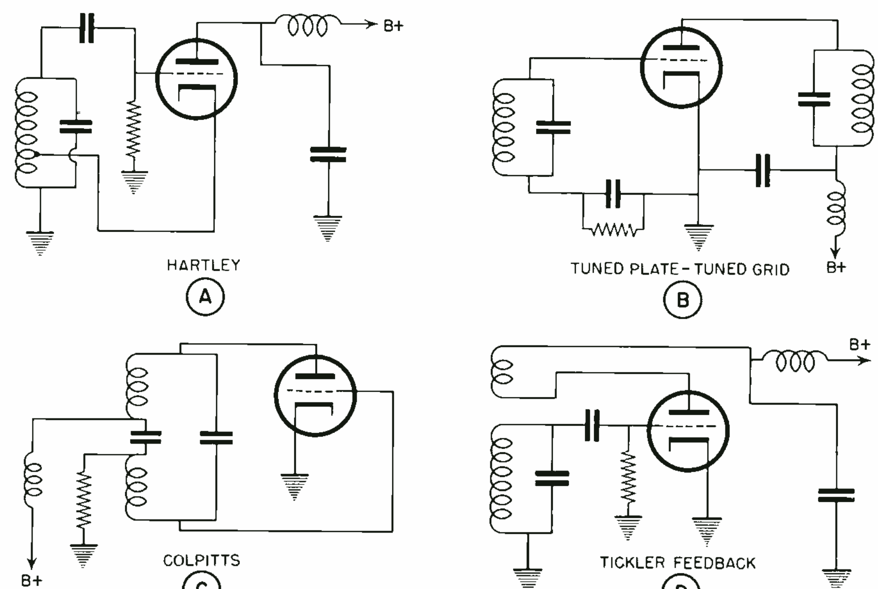


FIG.1

The four most commonly used oscillator circuits. Of these, three types are useful at ultra-high frequencies, the tickler feedback type not being satisfactory because of the decreasing size of the L/C circuits.

To analyze further, it is evident that the stability of an oscillator is a function of the "Q" of the oscillator tuned circuit. This also governs the power output, and this will be considered presently. Consequently, for high stability, the tuned circuit should be designed for the best "Q" possible.

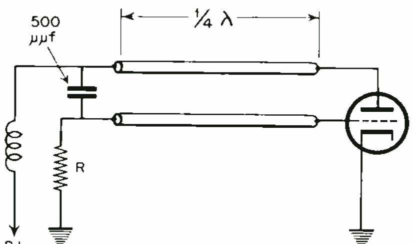


FIG. 2

Quarter-wave resonant line oscillator circuit.

This means that the r.f. resistance of the coil should be low, necessitating the use of a large conductor since high-frequency current flows only on the outer surface. Another essential is large inductance compared to the capacity of the circuit. This is the stumbling block in all ultra-high frequency oscillators since the tube capacity is the limiting factor as we go higher and higher in frequency. Even at best, the "Q" of a coil-condenser circuit leaves much to be desired.

The use of quarter-wave resonant lines as tuned circuits permits high values of "Q" which, if utilized correctly, will give stability comparable with crystal control. Several versions of these are shown in *Figs. 2, 3* and *4*.

It is possible to reach usable "Q" values in the neighborhood of 5,000 to 10,000 using resonant lines, since this construction minimizes skin effect. This may be easily seen since, as the frequency is increased, the length of the line decreases faster than the skin effect increases. As a result "Q" increases with frequency.

Two types of lines have been commonly used; the concentric *(Fig. 3)*, and the two-conductor type *(Figs. 2, 3* and *4-A)*.

In the construction of these it is desirable that large conductors be used. For the open-wire type, half-inch copper tubing will be sufficient for most applications. The spacing is critical for optimum results. A distance equal to the diameter of the tubes gives about the best performance for all-round use. For a concentric line, the inside diameter of the outer tube should be three or four times larger than the outside radius of the inside conductor. A quarter-inch tube inside a one-inch tube would work well. The tubes should be shorted together at the bottom end and supported concentrically at the top end by low-loss discs of polystyrene or similar insulation. Connection to the inner conductor is made through a hole in the outer tube *(Fig. 3)*.

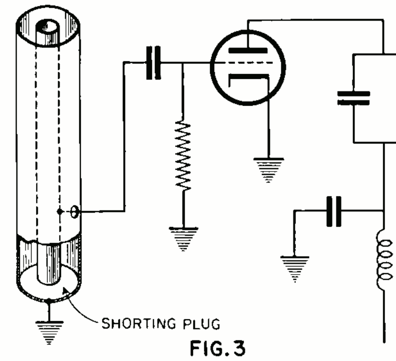


FIG. 3
Concentric-line tuned oscillator circuit

Line Considerations

Since resonant lines if properly constructed are high "Q" circuits, care must be exercised when they are coupled to the oscillator tube if the "Q" is to be preserved for stability reasons. *Fig. 2* shows a Colpitts type line oscillator in which the grid and plate are connected directly across the open end of the line. This permits the tube to work into a maximum impedance—since a high-"Q" circuit is a high-impedance device—and to deliver optimum power output. The shunt-loading effect of the tube, however, loads down the resonant line and reduces the "Q". Consequently, the full "Q" value cannot be realized for stability. The result is high output with moderate stability.

Fig. 3 illustrates a concentric tuned-plate tuned-grid version. In this case the line is placed in the grid circuit and the grid tapped off about ⅓ up from the shorted end. A decrease in line loading results and the operating "Q" is almost as great as the "Q" of the line by itself. This method gives maximum stability at some sacrifice in power output since full exciting voltage is not supplied to the grid. A condenser-coil combination is used in the plate circuit since this is not a controlling factor. The "Q," and naturally the impedance of the plate circuit, is lower than that which could be obtained with a resonant line and, as a result, the power output will be less than if a line plate circuit were used.

A push-pull oscillator making full use of lines is shown in *Fig. 4-A*. Here the grid circuit is the tapped version to give optimum stability; whereas the plate circuits take advantage of the maximum circuit impedance for optimum output. Even though the plates are direct connected to the ends of the line, the loading on the line is only half of that in *Fig. 2*, since the tubes are operated in series. This circuit is best suited for ultra-high-frequency operation.

One of the drawbacks of resonant lines is the necessity of adjusting "sliding bars" in the case of open-wire lines, or "tuning plugs" on concentric lines, to resonate them at the desired frequency. A practical arrangement is illustrated in *Fig. 4-B* to simplify tuning. A small split-stator condenser of 10 to 30 μμf per section is shunted across the line about 10 percent up from the shorted end. If the line has been designed to be slightly shorter than required, it can be resonated nicely with the condenser. The shunt capacity reduces the "Q" a small amount since it is across only a small portion of the line.

Coupling to resonant lines is best accomplished by a hairpin loop about one quarter the length of the line. This may be fed directly to an impedance-type feeder or tuned for Zepp antenna connection.

A word or two is in order about grid leaks. An old rule to find the best grid leak value is to multiply the grid leak resistance in ohms by the grid current. The resistance which gives the highest product is the best value. This applies for all tubes and circuits. Most tubes require values between 5,000 and 50,000 ohms.

Receivers

Since conventional receivers employ oscillators, it is fitting that some consideration be given them.

Resonant lines have been used extensively in all types of power oscillators and amplifiers, but receivers have been given little attention. Superregenerative receivers are ideally suited for lines since usually only one tuned circuit is employed. Needless to say, any of these receivers can use more selectivity. Lines will go a long way to sharpen up these "megacycle meanderers."

The circuit of *Fig. 2* is easily converted to a receiver simply by increasing the grid leak *R* to ½ or 1 megohm, using a 6J5 as a detector. Tuning may be accomplished by making the 500 μμf condenser at the far end variable. With this type of series tuning, signals will appear broad at the high-capacity end of the condenser and sharp at the other end. This is not an indication of selectivity, but simply a characteristic of this type of tuning. Actually there will be little difference in selectivity at either end. The virtue of this tuning method is that it is non-critical if operated at half setting, giving an excellent band-spread effect.

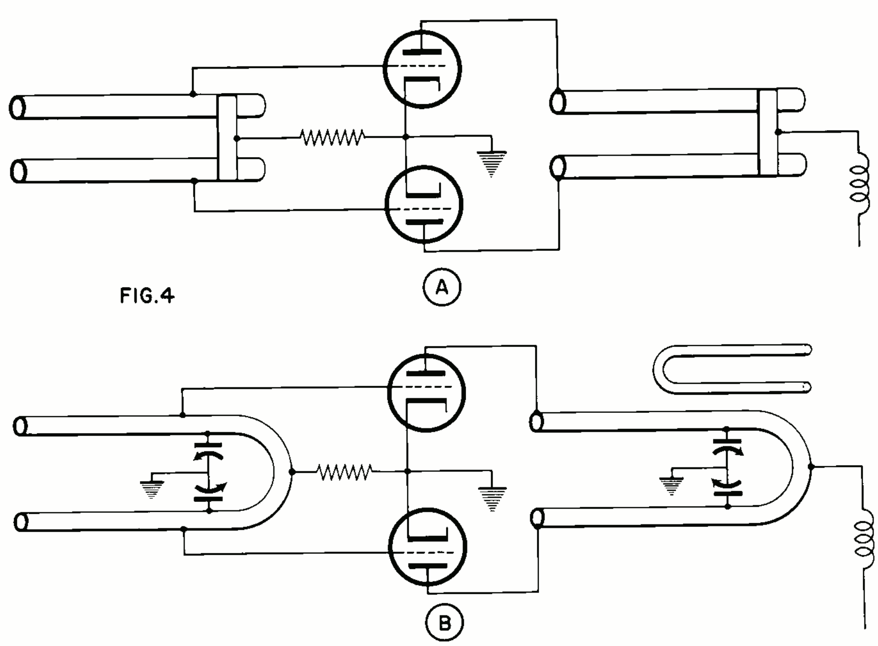


Fig. 4-A. Push-pull oscillator making full use of resonant lines. Fig. 4-B. An improved version of A, using tuning condensers rather than sliding shorting bars.

NEW TUBE TYPES

★ The RCA Manufacturing Co., Inc., are making available to equipment manufacturers seven new tube types for use in connection with WPB rated orders. In numerical sequence the types are: *1C21* Gas-Triode, *2AP1* High-Vacuum Cathode-Ray Tube, *5R4-GY* Full-Wave High-Vacuum Rectifier, *6AG5* (Miniature) R-F Pentode Amplifier, *6J6* (Miniature) Twin Triode, *934* Vacuum Phototube, *935* Vacuum Phototube.

The specific electrical and mechanical characteristics, and applications of these seven new types are as follows:

1C21 GAS-TRIODE

The RCA-1C21 is an ionic-cathode, glow-discharge triode designed for use primarily as a relay tube. The discharge can be initiated with a very small amount of electrical energy applied to the grid circuit. The 1C21 may also be used as a voltage regulator, or as a relaxation oscillator. The bulb is sprayed with an opaque coating so that incident light will not affect the breakdown characteristics.

Tentative Characteristics

Peak Anode Breakdown Voltage (Grid tied to cathode)	180 *min.*	Volts
Peak Positive Grid Breakdown Voltage	66 *min.* 80 *max.*	Volts Volts
D-C Anode Extinction Voltage	73 *approx.*	Volts
A-C Anode Extinction Voltage (RMS—60 cycles)	115 *approx.*	Volts
Grid Current (for transition of discharge to anode at 100 volts peak)	25 *av.* 150 *max.*	Microamp. Microamp.
Anode Voltage-Drop	73 *approx.*	Volts
Grid Voltage-Drop	55 *approx.*	Volts

Maximum Ratings

Maximum Ratings Are Design-Center Values

Peak Cathode Current	100 *max.*	Milliamp.
D-C Cathode Current	25 *max.*	Milliamp.
TYPICAL OPERATION AS RELAY TUBE:		
D-C Anode-Supply Voltage*	125-145	Volts
Peak Positive Grid-Bias Voltage	66 *max.*	Volts
Peak Grid-Signal Voltage	40 *min.*	Volts
Sum of Grid-Bias and Grid-Signal Voltages (Peak)	100 *min.*	Volts
D-C Grid Current	100	Microamp.

* If a-c supply is used, the rms voltage applied to the tube should not exceed 100 volts for a line-supply voltage of 117 volts.

Breakdown Characteristics

The voltage conditions necessary for breakdown between any two electrodes in the 1C21 are described by the closed curve of *Fig. 1.* Consider the test circuit shown with the curve. A voltage E_{cc} is applied to the grid through a high resistance R_1; a voltage E_{bb} is applied to the anode through a load impedance R_2. From the typical curve, it will be noted that for values of anode voltage less than approximately + 237 volts, no discharge is initiated until the grid voltage is approximately + 74 volts. When this value is reached, a discharge between cathode and grid is initiated. This condition is shown by section *A* (above zero ordinate) of the breakdown characteristics curve.

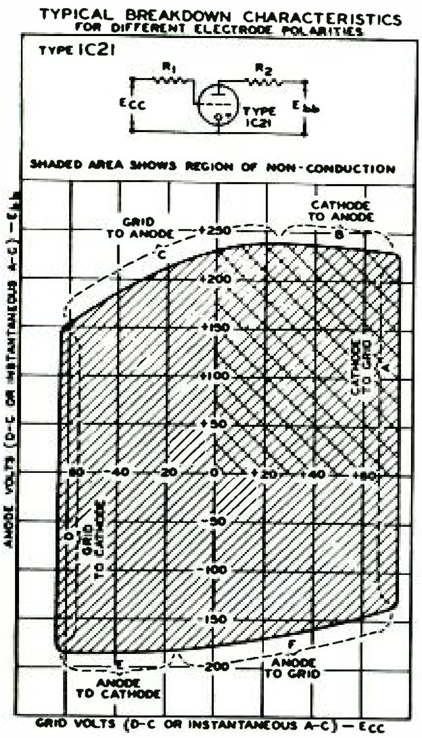


Fig. 1. 1C21 breakdown characteristics.

When the anode voltage is increased to + 237 volts, a breakdown occurs between cathode and anode. The value of anode voltage required for this breakdown is substantially independent of grid voltage for values of grid voltage greater than approximately + 25 volts, and less than + 74 volts. Section *B* shows the relation between anode voltage and grid voltage which is necessary for a cathode-anode discharge.

Section *C* shows the relation between anode voltage and grid voltage which is required for a grid-anode discharge. In this discharge, the grid acts as a cathode, so that the slope of section *C* would be approximately 45 degrees were there no third electrode in the tube. This discharge can occur with positive values of grid voltage, because the distance between anode and grid is less than that between anode and cathode.

Section *D* shows the relation between anode and grid which is required for a grid-cathode discharge. It should be noted that this discharge takes place between the same two electrodes as in section *A*. However, under the conditions of section *D*, the grid electrode acts as a cathode, because it is negative with respect to the cathode electrode.

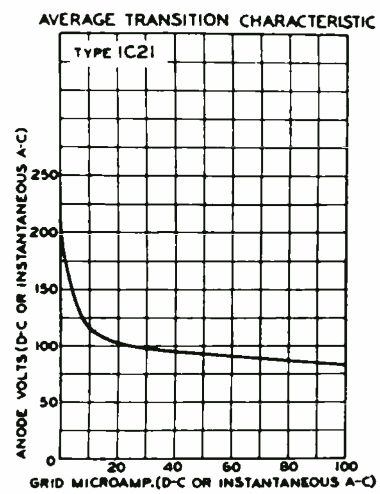


Fig. 2. 1C21 transition characteristic.

Sections *E* and *F* shows the relations between anode and grid which are required to initiate an anode-cathode discharge, and an anode-grid discharge, respectively. In these cases as in the previous ones, the first word of the term describing the discharge denotes the electrode acting as cathode.

The previous conditions, as indicated, are all on the basis that breakdown occurs between any two electrodes without the assistance of any ionic discharge current. For example, a discharge between cathode and anode is initiated when the anode voltage is + 237 volts and the grid current is zero. When the voltage applied to the grid is increased so that grid current flows, the discharge between cathode and anode can be initiated at values of anode voltage less than + 237 volts. For each value of grid current, there is a corresponding value of anode voltage necessary to initiate the main discharge between cathode and anode. Because it is convenient to think of the discharge to grid as transferred to the anode when sufficient anode voltage is applied, the relation is termed the *transition characteristic* and is given in *Fig. 2*. In practice, it is desirable to have a current of at least 100 microamperes flowing to the grid.

When the value of anode voltage is less than the voltage drop across the tube (anode voltage-drop), the transfer of the main discharge cannot take place.

The anode characteristic of the 1C21 is given in *Fig. 3*. This curve, obtained with a cathode-ray oscillograph, shows that over the useful operating range, the anode voltage-drop remains substantially constant at 73 volts. The curve also shows, because of its asymetrical shape, that the 1C21 can be used as a rectifier. In such use, the peak inverse voltage should not exceed 180 volts. Operation at d-c anode currents less than 5 milliamperes is not recommended because of instability.

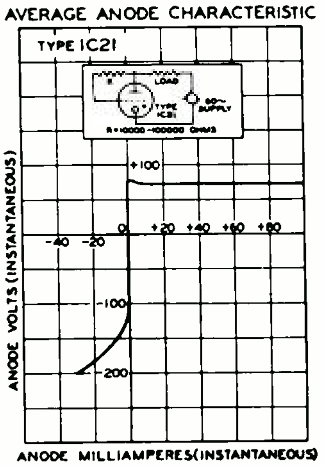


Fig. 3. 1C21 anode characteristic.

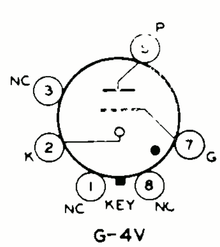


Fig. 4. 1C21 socket connections.

The 1C21 is designed for operation only in the area of the breakdown characteristics curve shown by double crosshatching. Although the tube will function in other regions, as previously described, its operation in these regions is unstable because of design characteristics.

Installation and Application

The *base* of the 1C21 fits the standard octal socket which may be installed to hold the tube in any position.

When the 1C21 is used in relay service, provision should be made to supply to the grid a signal voltage adequate to take care of voltage-supply regulation, tube variation, and manufacturing variation in the equipment tiself.

The typical operating data shown in the tabulation are for the 1C21 when used as a relay tube with a d-c voltage supply which may vary from 125 to 145 volts. The corresponding values of bias voltage and grid-signal voltage have been chosen to take care of this voltage range as well as other variations. The required amount of peak grid-signal voltage can be reduced substantially either by reducing the supply-voltage range, or by adjusting the equipment to take care of differences between individual tubes, or by utilizing a combination of these two methods. *Fig. 4* shows socket connections.

934 VACUUM PHOTOTUBE

The RCA-934 is a small high-vacuum phototube intended primarily for use in sound and facsimile equipment but it is also suitable for light-operated relays and light - measuring equipment. Its S-4 photosurface has exceptionally high response to blue and blue-green radiation and a negligible response to red radiation. Socket connections are shown in *Fig. 5*.

Tentative Characteristics

Cathode	Semi-cylindrical
Cathode Photosurface	S4
Cathode Window Area	0.4 sq. in.
Direct Interelectrode Capacitance	1.5 μμf
Bulb	T-5-½
Base	Peewee 3-Pin
Mounting Position	Any

Maximum Ratings

Maximum Ratings Are Absolute Values

Anode-Supply Voltage (D.C. or Peak A.C.)	250 max.	Volts
Anode Current[1]	10 max.	Microamp.
Ambient Temperature	50 max.	°C
Sensitivity[2]	30	Microamp./lumen
D-C Resistance of Load: For 250-volt anode-supply voltage	1 min.	Megohm

[1] On basis of the use of a rectangular sensitive cathode area 17 mm by 7.5 mm.

[2] Sensitivity value (see *Fig. 6*) is given for conditions where a Mazda Projection Lamp operated at a filament color temperature of 2870°K is used as a light source. The method of determining sensitivity employed a 250-volt supply and included a 1.0-megohm load resistance. With daylight, value is several times higher; to light from a high-pressure mercury arc, many times higher.

The *socket* of the 934 should be mounted so that light is intercepted by the concave surface of the cathode.

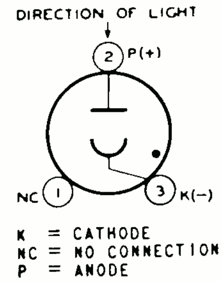


Fig. 5. 934 socket connections.

Exposure to intense light, such as direct sunlight, may decrease the tube's sensitivity even though there is no voltage applied. The magnitude and duration of the decrease depend on the length of exposure. Permanent damage to the tube may result if it is exposed to radiant energy so intense as to cause excessive heating of the cathode.

Shielding of the 934 and its leads to the amplifier is recommended when amplification is high. The leads from the phototube to the amplifier should always be as short as possible to minimize capacitance loss and pick-up from stray fields. Since the tube is a high-resistance device, it is important that insulation of associated circuit parts and wiring be adequate.

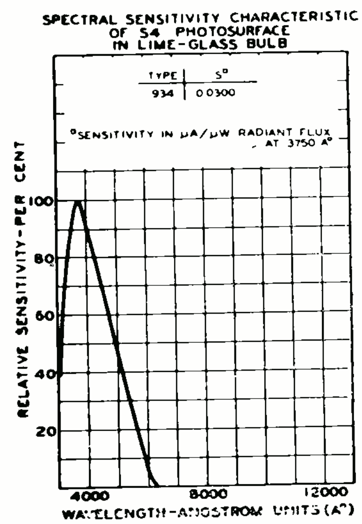


Fig. 6. 934 spectral sensitivity.

When *maximum sensitivity* of phototube circuits is important, special care should be taken to keep the leakage resistance of circuit parts and wiring insulation high.

935 VACUUM PHOTOTUBE

The RCA-935 is a high-vacuum phototube possessing extraordinarily high sensitivity to radiant energy rich in blue and near ultraviolet and will re-

[*Continued on page 42*]

Q. & A. STUDY GUIDE

—Theory and Practice

243. Why does the output of a d.c. generator generally require less filtering than the output of a rectifier system?

Though substantially a direct current, the output of a rectifier system contains an a.c. component, in the form of pulsations having definite waveform. This current, rising and falling at a definite frequency, constitutes an a.c. ripple. It is essential, therefore, to employ a fairly elaborate system of filtering, using condensers and chokes or resistors, to smooth out the a.c. ripples.

The output of a d.c. generator is an interrupted direct current of fairly constant value. Such slight variations as are present (commutator ripple) are readily smoothed out by a comparatively simple filter system.

244. When filter condensers are connected in series, resistors of high value are often connected across the terminals of the individual condensers. What is the purpose of this arrangement?

The two condensers, series-connected, may not have identical capacity and leakage values, causing unequal voltage distribution (and the possible breakdown of one of the condensers). By connecting resistors of high value across the terminals of the series-connected condensers, the voltage across each condenser is equalized.

245. Draw a diagram of a bridge type, single phase, rectifier employing mercury-vapor type tubes and connected to a choke-input, two-section filter system, including a bleeder resistance.

Such a diagram is shown in *Fig. 1.* Though separate filament power sources are required for tubes *V* and *V1*, and *V2-V3*, the filament windings of *T1* and *T2* could form a part of the high-voltage transformer *T*, with a single primary serving all secondaries. However, where high power is involved, separate transformers are more economical.

In a bridge rectifier of this type, the secondary voltage of transformer *T* is approximately equal to the desired load voltage, whereas in a full-wave rectifier system with center-tapped secondary, the desired load voltage is equal to one-half the total secondary voltage.

The choke-input, two-section filter consists of the chokes *L* and *L1*, and the condensers *C* and *C1*. Resistor *R* is the bleeder, which may be used as a voltage divider, for the purpose of providing different voltages to various circuits.

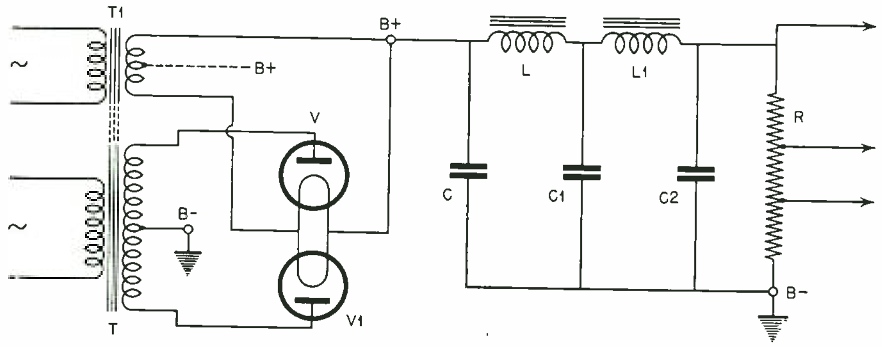


Fig. 2. Diagram of full-wave, single phase thermionic rectifier power supply.

246. Draw a diagram of a full-wave, single-phase, rectifier employing thermionic vacuum tubes, connected to a condenser-input, two-section filter, and including a bleeder resistance.

The diagram of such a rectifier system is shown in *Fig. 2.* The transformers *T* and *T1* may be separate units, or may be one transformer with single primary, as indicated by the dotted core lines.

The high voltage may be taken from one side of the filament transformer winding, or from a center tap on this winding, as indicated by the dotted line. If considerable current is drawn, and a single, full-wave rectifier tube employed, it is preferable to take the high voltage from a center tap on the filament transformer winding, for the sake of distributing the load current on both sides of the filament. This is also good practice where two half-wave rectifier tubes are used in a full-wave circuit, as in *Fig. 2.*

The two-section, condenser-input, filter in this circuit consists of the chokes *L* and *L1*, and the condensers *C, C1* and *C2*. The bleeder resistor *R* may be used as a voltage divider.

247. Draw a diagram of a half-wave rectifier system employing a thermionic rectifier tube and a two-section, condenser-input, filter system.

Such a diagram is shown in *Fig. 3.* The units *T* and *T1* may be a single power transformer, with one primary. The filter system is the same as that shown in conjunction with the full-wave rectifier *(Fig. 2)*, but does not necessarily have the same values of inductance and capacitance; for in the full-wave rectifier, which makes use

[*Continued on page 41*]

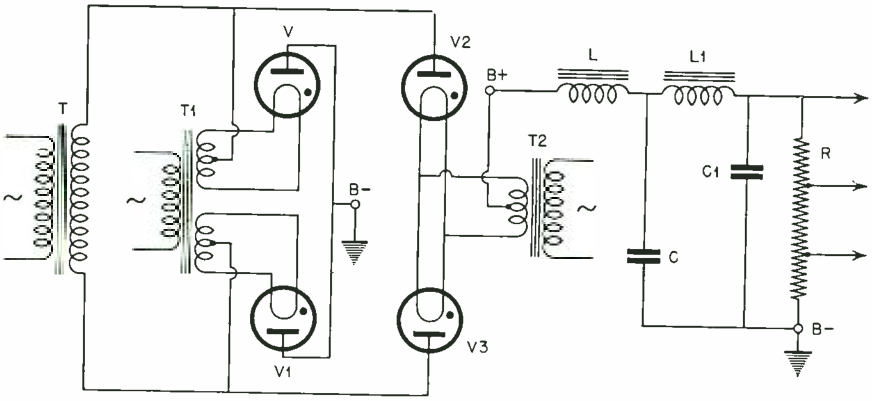


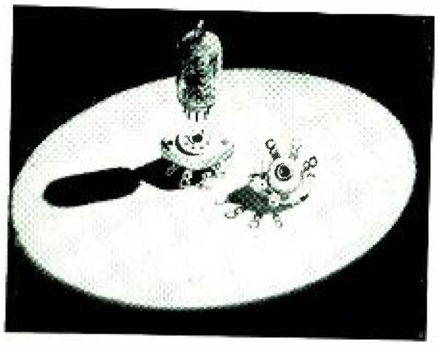
Fig. 1. Diagram of bridge type, single phase mercury-vapor rectifier power supply.

Echophone Model EC-1 6 tubes, 3 bands. Tunes from 550 kc. to 30 mc. Beat frequency oscillator. Bandspread logging scale. Self-contained speaker. Electrical bandspread on all bands. AC/DC. 115-125 volts. ECHOPHONE RADIO CO., 201 EAST 26TH ST., CHICAGO, ILLINOIS

NEW PRODUCTS

MINIATURE-TUBE SOCKET

The E. F. Johnson Co., Waseca, Minn., is now producing a new socket for miniature tubes featuring government grade G steatite insulation. Listed



as No. 267 (Navy type designation CEJ-49401), it is designed for use with the 9000 series and Miniature series tubes including RCA 1S4, 1S5, 1T4, 1R5, etc.

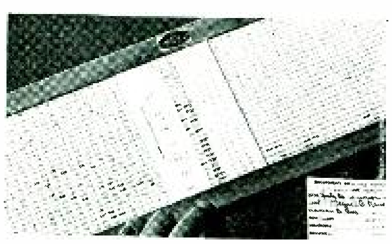
Contacts are phosphor bronze, heavily silver plated, and are self-aligning so that they receive the tiny tube prongs without danger of fracturing the glass base of the tube. Other features include orientation of contacts for minimum capacity effect and a center shield for grounding to chassis. Steatite insulation is glazed top and sides and the bottom wax impregnated.

For additional information, write to the manufacturer for folder K and general products catalog 967K.

★

PAY-ROLL CALCULATOR

Pay rolls and job costs can be figured in a fraction of the usual time through the use of a new calculator, according to the manufacturers, the Berger - Bricker Company of 433



South Spring Street, Los Angeles, California.

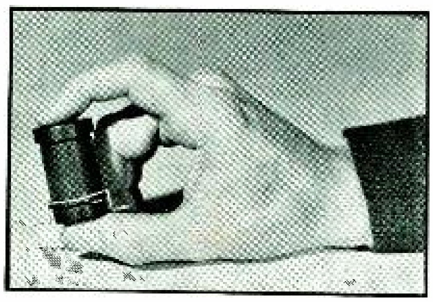
Operating on a simple new principle, this device includes all hourly rates of pay from $0.50 to $1.75 with a half-cent spread between rates. It covers all time periods up to 104 hours with divisions of one-tenth of an hour. It is handsomely made of lacquered wood and easily fits into a desk drawer.

★

DUST-TIGHT AIRCRAFT RELAY

A new dust-tight relay especially designed for aircraft applications requiring high current-carrying capacity without sacrifice of compactness and light weight has been announced by the General Electric Company.

The new relay is a solenoid-operated device with the normally-open contacts rated at 10 amperes direct current. These contacts will make or break 30 amperes at altitudes up to 40,000 feet. The coil, contacts, and plunger are enclosed in a dust-tight housing, and the unit is corrosion-proof, meeting 200-hour salt-spray



tests as stipulated by various government agencies.

The relay can be furnished in a single-pole, single-circuit form with normally-open contacts or in a single-pole, two-circuit form with one normally-open and one normally-closed contact. The operating coil can be furnished for either 12- or 24-volt d.c. operation. The relay can be mounted in any position on a metal or non-metallic base.

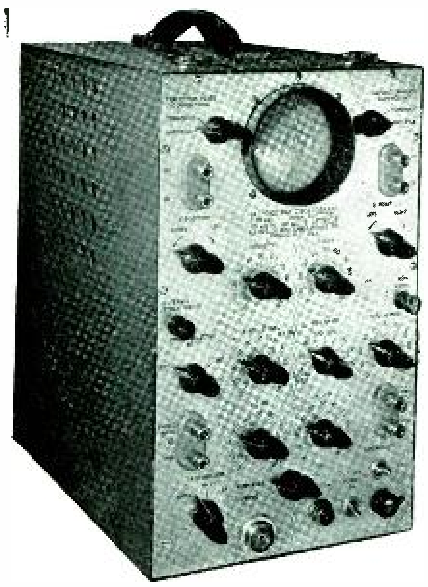
When the relay is in the energized or de-energized state, the contacts will remain in the open or closed position without chattering, even when subjected to mechanical frequencies of from 5 to 55 cycles per second at 1/32-inch amplitude (1/16-inch total travel) applied in any direction. The relay is designed for use in an ambient temperature range of from 95 C. to minus 40 C., and will withstand 95 percent humidity at 75 C. on 48-hour tests and operate immediately thereafter.

★

EXPANDED RANGE OSCILLOGRAPH

Critical wartime requirements are responsible for a new cathode-ray oscillograph characterized essentially by a greatly extended frequency range, more versatility in the handling of applied signals, and special pickup means whereby input capacitance is reduced and stray pickup eliminated. Removable front cover protects panel, controls and tube screen, and also holds the shielded-cable test probe, when instrument is not in use.

Known as Type 224, this new oscillograph is now offered as a standard instrument by Allen B. Du Mont Laboratories, Inc., Passaic, N. J. One of its outstanding features is the Y-axis or vertical deflection response which is uniform from 20 to 2 million cycles. It has a comparably faithful square and sinusoidal wave response. The X-axis or horizontal deflection amplifier has a uniform characteristic from 10 cycles to 100 kilocycles. Both amplifiers have distortionless input attenuators and gain controls.



The widest variety of signal input connections are available. In addition to the conventional amplifier connections, signals can be applied directly

[Continued on page 39]


AS GIFTS OF PEACE GIVE WAY TO WAR

the resistors that knocked tradition into a cocked hat

BY DOING THE JOBS CONVENTIONAL WIRE-WOUND RESISTORS COULDN'T HANDLE

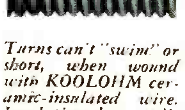
THE unique and exclusive construction of KOOLOHM resistors has completely revolutionized previous conceptions of wire-wound resistor design. It has freed engineers from use limitations which a few years ago they regarded as "necessary evils."

KOOLOHMS are the only resistors made with wire that is ceramic insulated *BEFORE it is wound.* This one feature alone provides you with advantages that no other wire-wound resistor can give you. It furnishes absolute protection against shorts and changed values. It makes possible extremely high resistance values in amazingly small-size units. It permits the use of larger, safer wire sizes. It permits full-rated wattage dissipation regardless of resistance value. This ceramic insulation on KOOLOHM wire is heat-proof to 1000° C. It is moisture-proof and flexible and can either be layer wound or progressively wound in high density patterns. It allows perfect Ayrton-Perry windings, thus reducing inductance to negligible values, and also permits the design of units with predetermined inductance values. It makes possible the use of an *extra* outer protection in the form of chip-proof ceramic or shock-proof sealed glass casing. Thus *doubly* protected they can be easily and cheaply mounted directly to or against metal or grounded parts with *complete* resistor circuit insulation.

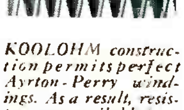
Thus, KOOLOHM superiority is not a matter of hair-splitting differences—it is *conspicuously* evident in any test you care to name.

Send for free samples and catalog—today!

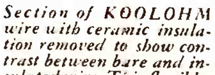
SPRAGUE SPECIALTIES COMPANY (*Resistor Division*), **North Adams, Mass.**



Turns can't "swim" or short, when wound with KOOLOHM ceramic-insulated wire. Insulation has a dielectric strength of 350 volts per mil at 400° C.!



KOOLOHM construction permits perfect Ayrton-Perry windings. As a result, resistors are available having negligible inductance, even at 50 to 100 Mc.!



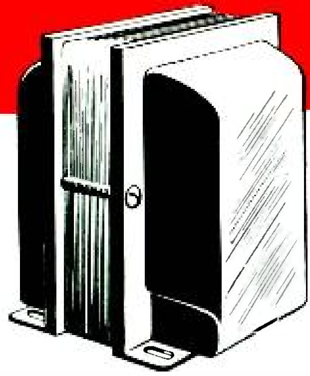
Section of KOOLOHM wire with ceramic insulation removed to show contrast between bare and insulated wire. This flexible, heat-proof insulation is actually applied to wire at a temperature of 1000° C.!

SPRAGUE

KOOLOHM

WIRE-WOUND RESISTORS

Transformers for Radio, Sound, Public Address, Television and Geophysical Applications



THERMADOR

A FAMOUS NAME IN ELECTRICAL PRODUCTS

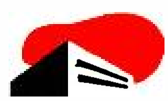
A New Name in TRANSFORMERS

THERMADOR is well known in the field of electrical appliances—well known for engineering and quality built into numerous products serving the electrical industry all over America. Thermador now expands its services into the field of transformers.

Thermador combines the machinery, dies, equipment, inventory and many of the personnel of the well-known Los Angeles Inca Division of Phelps-Dodge Corporation with the facilities of their modern plant and now offers the industry transformers for radio, sound, public address, television and geophysical applications.

THERMATITE TREATED TO WITHSTAND HUMIDITY and EXTREME HEAT

Thermador transformers are Thermatite treated, which is a well tested and approved form of impregnation. This treatment, proved on thousands of transformers under severe climatic conditions, gives these units the resistance to constantly withstand extreme conditions of humidity and heat. This is particularly important at this time with their widened use in foreign countries where extreme temperatures and humidity exist.



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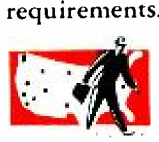

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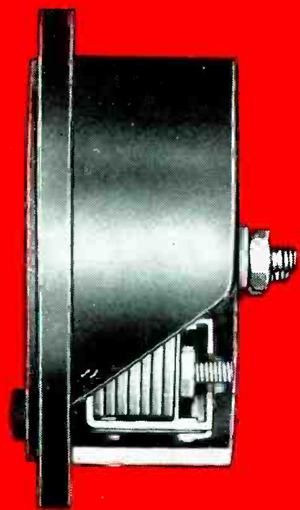

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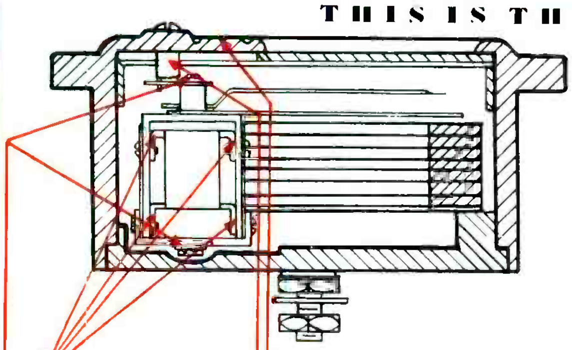

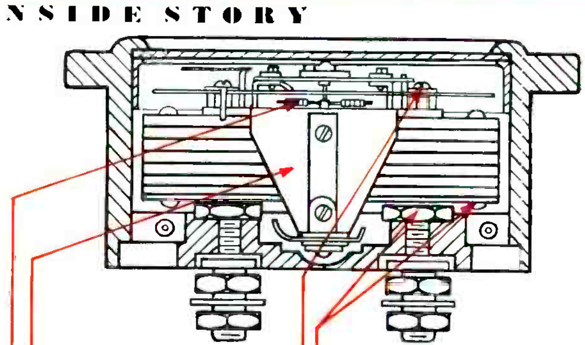

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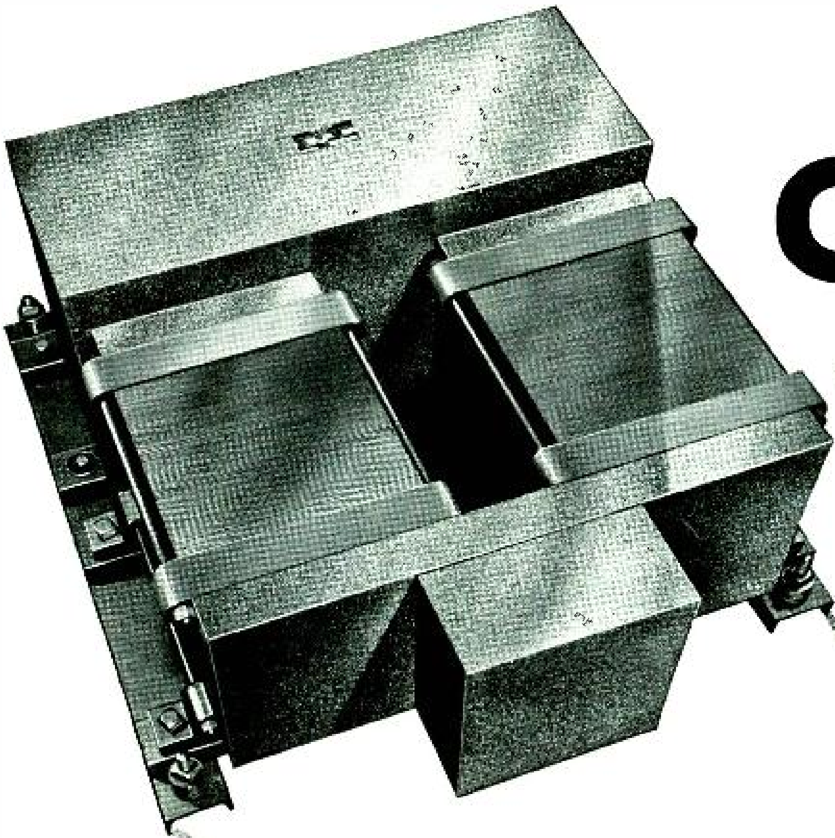

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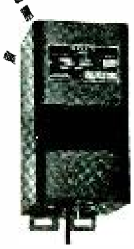

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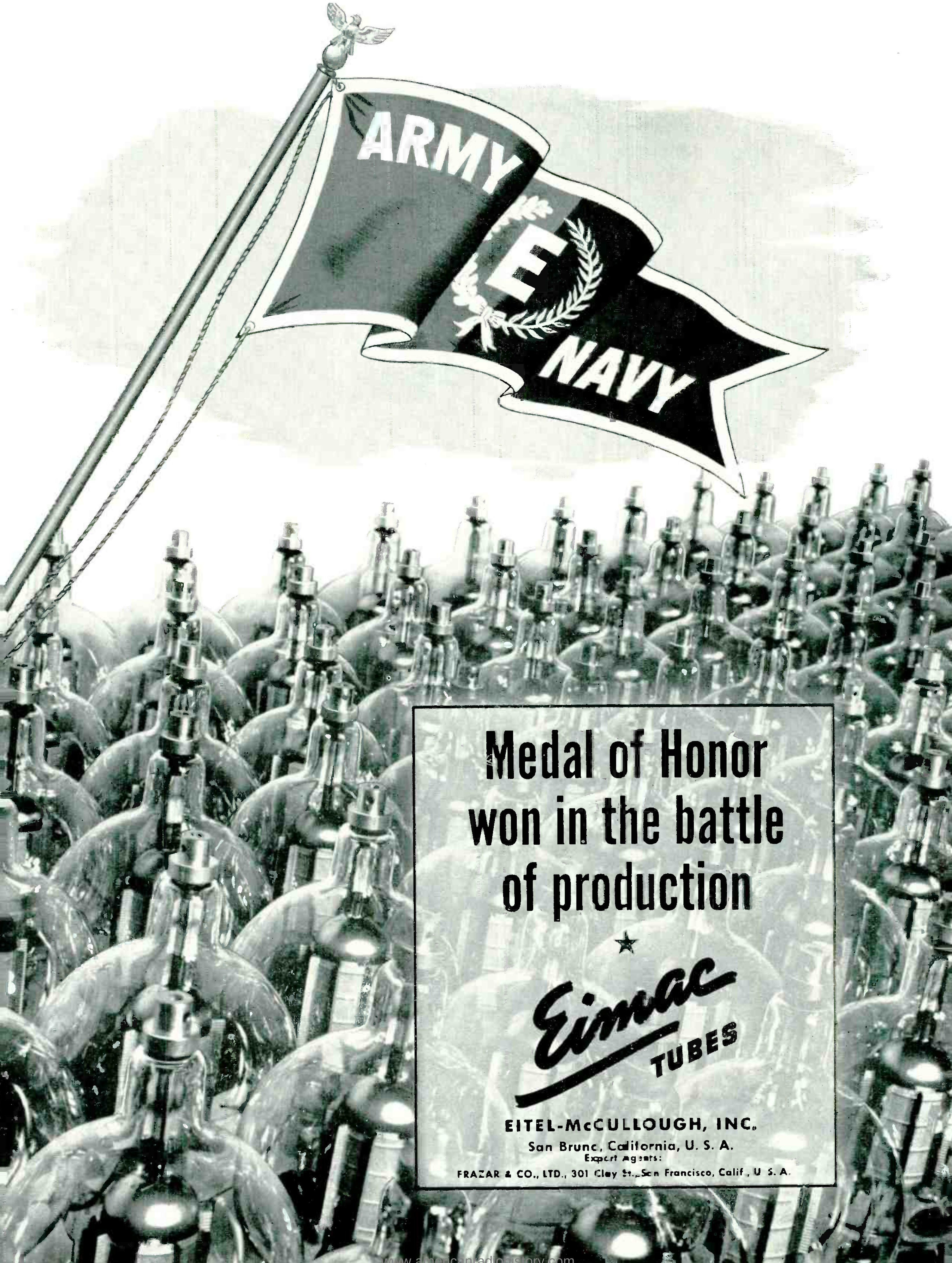
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Men of 18 and 19 may choose enlistment in the Signal Corps without any previous training or experience.

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Civilians over 16 years of age may attend a Signal Corps School, and will be paid not less than $1020 per year for full-time training and future service with the Signal Corps. Apply U. S. Employment Bureau or U. S. Civil Service.

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NEW PRODUCTS

[*Continued from page 24*]

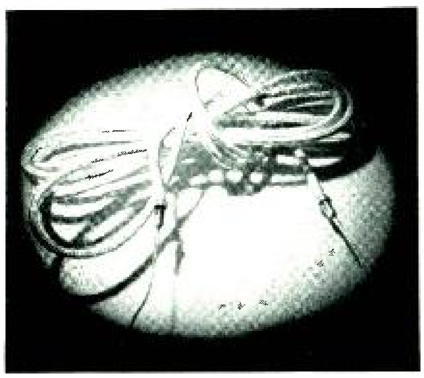
to the deflection plates of the 3-inch cathode-ray tube, when it is desirable, by means of terminals at the front panel of the unit. The Y-amplifier has an input connection for the Shielded-Cable Test Probe Type 242A, supplied with the instrument. This reduces input capacitance and eliminates stray pickup. All high-voltage electrolytic condensers are eliminated from circuit.

Type 224 Oscillograph weighs 49 lbs., and measures $14\frac{1}{8}$" high, $8\frac{5}{8}$" wide, $15\frac{1}{8}$" deep. Operates on 115 volts, 60 cycles a.c.

★

FLEXIBLE HEATING ELEMENT

Available in any length, by the inch, foot or yard, a low-power flexible heating element now finds many uses particularly in very limited space. Known as the Glasohm, and also widely used as a flexible power resistor, this product is made by Clarastat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.



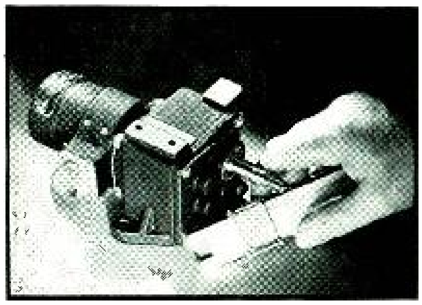
In the Glasohm construction the resistance wire is wound on a fibre-glass core and is protected by a fibre-glass braided covering. The fibre-glass, while providing the desirable properties of unbreakable and virtually indestructible glass, is almost as flexible as silk, so that the unit can be readily bent and compacted to fit snugly about parts to be heated, or again jammed into very tight spots, in either case providing an efficient heating means. Typical Glasohm heating elements range from a few inches to several feet in length. They can be made to any required length and provided with any type terminals. Wattage ratings are from 1 to 4 watts per body inch depending on the application. Operating temperatures up to 750° F.

★

NEW POWER PACKAGE FOR AIRCRAFT SUBASSEMBLIES

A new driving mechanism—the power package—has been announced

by the General Electric Company for use in aircraft subassemblies. The design of a particular power package depends upon the application for which it is built. Designs are available for applications including bomb-door operation, landing-gear and wing-flap operation, and operation of control and protective devices.



The power package combines in one compact unit as many items as a motor, brake, clutch, and limit switch as well as indicators, gears, and whatever else is required to do a specific job. They are designed for 24-hour service, and can be obtained in ratings from about 1/100 hp to 3 hp.

Each element in the power package is reduced to its simplest terms to save weight and space. For instance, where either a brake or a clutch could be used, the brake is chosen because it has one moving part while the clutch has two.

A new planetary gear system permits the use of a magnetic brake in the power package for some applications. The brake is of the quick-acting friction type and stops the motor quickly to prevent overtravel and consequent jamming of the driven plane assembly. When the power is off, driven equipment is locked in place by the brake, to eliminate creeping of such subassemblies as landing gear.

★

Q. & A. STUDY GUIDE

[*Continued from page 22*]

of both halves of the cycle, the ripple voltage is 120 cycles, whereas the ripple voltage at the output of the half-wave rectifier tube is 60 cycles, since only one-half of the cycle is rectified, assuming a 60-cycle source.

248. What is the primary purpose of a "bleeder" as used in a filter system?

The primary purpose of a bleeder resistance is to provide some load on the rectifier output, to prevent excessive voltage excursions when no other load at the output is present; and to hold down initial voltages in rectifier circuits employing swinging chokes. A bleeder resistor also provides a means of discharging the filter condensers when the equipment is shut down; otherwise there would be the danger of shock, even though the equipment were idle.

The resistance of a bleeder is normally higher than the total dynamic load resistance; and is of such a value as to draw around 10 per cent of the total load current.

[*Continued on page 42*]

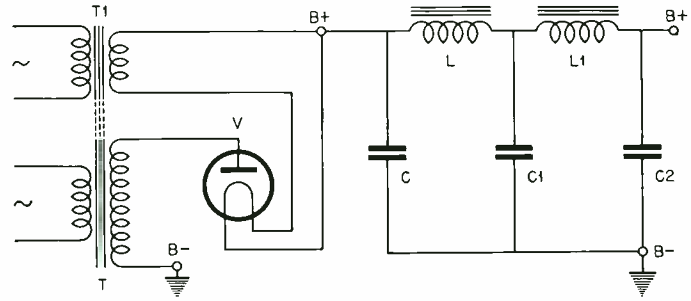


Fig. 3. Circuit diagram of a half-wave rectifier system with two-section condenser-input filter. Output ripple is equal to line frequency.

249. If the frequency of the supply source is 60 cycles, what is the output ripple frequency of a three-phase, full-wave rectifier?

The ripple frequency of a three-phase, full-wave rectifier is 6 times the line frequency; in this case, 360 cycles. Hence, with this type of rectifier system, a simple filter will suffice to suppress the ripple.

250. If the frequency of the supply source is 60 cycles, what is the output ripple frequency of a single phase, full-wave rectifier?

The ripple frequency of a single-phase, full-wave rectifier is 2 times the line frequency; in this case 120 cycles. This is evident, since a full-wave rectifier rectifies both halves of each cycle.

251. If the plates of a full-wave, high-vacuum rectifier tube become red hot while in operation, what may be the cause(s) of this condition?

This condition would indicate an abnormal load on the tube, said high current drain being due to a shorted filter condenser, a short in the dynamic load, or incorrect tuning in the case of a transmitter. The condition could also indicate an internal short or a "soft" tube.

252. List the primary characteristics of a high voltage plate supply as compared to a low voltage plate supply considering the capacity of the filter condensers required to provide a given degree of filtering.

In a low-voltage plate supply (up to approximately 500 volts), high-capacity electrolytic condensers may be used in the filter, and the filter may be either of the choke- or condenser-input type. Since the working voltage of an electrolytic condenser is restricted to about 600 volts, it cannot be used in a high-voltage plate supply unless two are connected in series (in which case the capacity is halved).

Paper and oil dielectric condensers with considerably higher working voltages are therefore customarily used in the filter circuits of high-voltage plate supplies, with values from 2 to 4 μf as against 8 μf or so for electrolytics. An equal degree of filtering is gained in the high-voltage plate supply by using condensers of lower capacity and chokes having higher values of inductance, a customary arrangement being a two-section, choke-input, filter with an input choke of the swinging type.

253. How may radio-frequency interference from gaseous rectifier tubes be minimized?

Radio-frequency "hash" can be minimized by connecting appropriate radio-frequency chokes in series with each tube plate lead, said chokes being wound of wire of sufficient gauge to handle the total rectifier plate current involved.

CORRECTION

The answers to Questions *220* and *223* in the Q. & A. Study Guide, September, 1942, RADIO, are incorrect.

The formula involved should have been $f = PS/120$ rather than $f = PS/60$. The answer, then, to Question *220* should be 1200 rpm for a 6-pole alternator, and the answer to Question *223* should be 100 cycles for a 10-pole generator with a speed of 1200 rpm.

NEW TUBE TYPES

[*Continued from page 21*]

spond in the region down to about 2000A°. It employs a bulb of special glass featuring a high transmission factor for ultraviolet radiation, and top-cap construction to provide high resistance to leakage currents between electrodes. Because of its excellent stability, consistency of spectral response, and extremely high sensitivity, the 935 is particularly suited for use in measuring ultraviolet absorption of gases and liquids. In such applications, lack of response of the 935 to the infra-red radiation may be an important advantage. Socket connections are shown in *Fig. 7*.

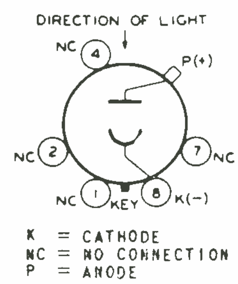


Fig. 7. Socket connections for type 935 tube.

Tentative Characteristics

Cathode	Semi-cylindrical
Cathode Photosurface	S4
Cathode Window Area	0.9 sq. in.
Direct Interelectrode Capacitance	0.6 $\mu\mu$f
Bulb	T-9
Cap	Skirted Miniature
Base	Intermediate Shell Octal 5-Pin
Mounting Position	Any

Maximum Ratings

Maximum Ratings Are Absolute Values

Anode-Supply Voltage (D.C. or Peak A.C.)	250 max. Volts
Anode Current[1]	20 max. Microamp.
Ambient Temperature	50 max. °C
Sensitivity[2]	30 Microamp./lumen
Sensitivity at 2537 Angstroms	0.02 approx. Microamp./Microwatt
D-C Resistance of Load: For 250-volt anode-supply voltage	1 min. Megohm

[1] On basis of the use of a sensitive cathode area ½" in diameter.

[2] Sensitivity value is given for conditions where a Mazda Projection Lamp operated at a filament color temperature of 2870°K is used as a light source. The method for determining sensitivity employed at 250-volt anode supply and included a 1.0-megohm load resistance. With daylight, value is several times higher; to light from a high-pressure mercury arc, many times higher.

Installation

The *base* of the 935 fits a standard octal socket which should be mounted so that the light is intercepted by the concave surface of the cathode.

Exposure to intense light, such as direct sunlight, may decrease the tube's sensitivity even though there is no voltage applied. The magnitude and duration of the decrease depend on the length of the exposure. Permanent damage to the tube may result if it is exposed to radiant energy so intense as to cause excessive heating of the cathode.

Shielding of the 935 and its leads to the amplifier is recommended when amplification is high. The leads from the phototube to the amplifier should always be as short as possible to minimize capacitance loss and pick-up from stray fields. Since the tube is a high-resistance device, it is important that insulation of associated circuit parts and wiring be adequate.

When *maximum sensitivity* of phototube circuits is important, special care should be taken to keep the leakage resistance of circuit parts and wiring insulation high. Leakage across moisture films on the surface of the glass can be prevented by coating the glass with pure white ceresin wax, or other non-hygroscopic wax. It is not necessary to coat the whole bulb. A continuous band of wax, approximately a half-inch wide, around the top-cap or around the bulb is sufficient to interrupt all external leakage paths across the phototube surface. Under these conditions, a minimum leakage resistance of 500,000 megohms may be expected.

(Characteristics of the remaining four tube types will be published next month.)

FREQUENCY MODULATION

[*Continued from page 10*]

there are three essential fundamental differences between amplitude and frequency modulation. First, there may be a number of sidebands bearing appreciable energy in a frequency-modulated wave against two for an amplitude-modulated wave. Secondly, the energy in the sidebands adjacent to the carrier may be negligible in frequency modulation compared to higher order sidebands. Thirdly, the amplitude of the sidebands in an amplitude-modulated wave can never be greater than half the carrier amplitude (100% modulation) whereas the amplitude of some of the frequency-modulated sidebands very materially exceeds that of the carrier. See *Figs. 1* and *3*.

In phase modulation the number of important energy-bearing sidebands is a function of phase deviation only and is independent of the modulating frequency. However, as previously indicated, the essential bandwidth or the frequency difference between the carrier and any given sideband, say the 5th, is a function of the modulation frequency. Thus for a given phase deviation the 5th-order sideband is equally important in energy content whether the modulation frequency is 50 cycles or 10,000 cycles. However, for the 50-cycle case the 5th sideband is separated from the carirer by 250 cycles, whereas for 10,000 cycles the 5th sideband is removed from the carrier by 50,000 cycles. This is not the case in frequency modulation, where the number of important sidebands is larger for lower modulating frequencies than for higher modulating frequencies for a constant frequency deviation. The bandwidth required for both frequency and phase modulation is a function of the modulation index. See *Figs. 2* and *3*.

The aforementioned characteristics of phase and frequency modulation are not necessarily defects, and when properly understood and used can generally be turned to advantage. Indeed, it is because of some of these characteristics of phase and frequency modulation, so long unappreciated, that these systems are destined to play a major role in communication systems of the future.

H. F. SWEEP CIRCUITS

[*Continued from page 13*]

the sweep can be in the form of an ellipse or a circle. This form of trace is very easily obtained from any alternating voltage through the circuit of *Fig. 13*. The trace will be a circle if the reactance of the condenser C equals the resistance of the resistor R. In all other cases, the trace is an ellipse.

The signal can be applied to one pair of c-r plates and all deflections from the signal will then be in one direction only, either vertical or horizontal. It is also possible to obtain a radial deflection. This is best done by connecting the voltage to be observed in series with the plate supply; the sensitivity is then changed and the diameter of the circle varies with the applied signal.

If the circular trace is combined with a sawtooth sweep applied to one set of plates, the resulting sweep is in the form of a helix. This is just another way of providing a longer sweep. The sawtooth sweep circuit should be connected in series with one of the c-r plates, as at X in *Fig. 13*.

It would be better still to obtain a

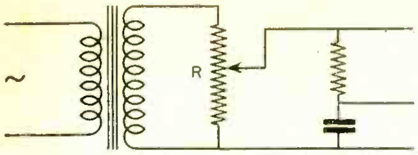


Fig. 14. Spiral sweep circuit.

true spiral as a sweep. This can be obtained by means of the circuit shown in *Fig. 14.* If the potentiometer *R* is rotated manually, a spiral trace is had. If the potentiometer is replaced by the plate resistance of a tube in series with a fixed resistance, the spiral trace can be contrived automatically. Applying a sawtooth wave to the grid of the tube will vary its plate resistance, thereby causing the tube to function as an automatic potentiometer.

Another possible method is the use of a variable-mu tube as an amplifier for the original deflection voltage, and the variation of the gain of this tube by the application of a sawtooth voltage to its control grid. An example of this is shown in *Fig. 15,* where a 6L7 is used for the purpose.

BOOKS ON CATHODE-RAY TUBES

American

The Cathode-Ray Tube at Work, by John F. Rider.

Cathode-Ray Tubes and Allied Types. RCA Technical Series TS-2.

British

The Low-Voltage Cathode - Ray Tube, by G. Parr.

Cathode-Ray Tubes, by Manfred von Ardenne (translated from the German).

Cathode-Ray Oscillography, by J. T. MacGregor-Morris and J. A. Henley.

Cathode-Ray Oscillographs, by J. H. Reyner.

The Cathode-Ray Oscillograph in Radio Research, by R. A. Watson-Watt.

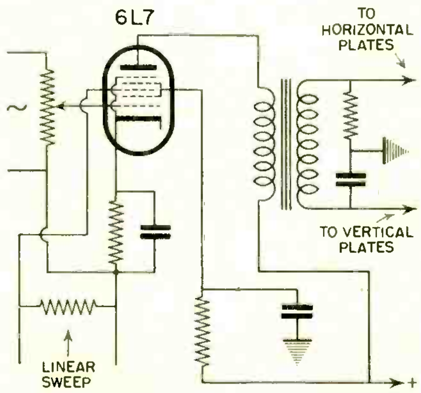


Fig. 15. Automatic spiral sweep circuit.

NEWS

RADIO DRAFT DEFERMENT

According to a recent RMA Bulletin, thirty-five general occupations of radio and radar manufacturers were designated as "essential" in the directive of Selective Service System headquarters, issued October 30th.

Although Occupational Bulletin No. 32 is dated October 23, the formal order of SSS National Headquarters was not issued until the 30th, following weeks of development by the WPB Radio and Radar Branch, under Deputy Director Ray C. Ellis and his staff, and Army and Navy branches. The Selective Service System action, upon certification from the War Manpower Commission, does not automatically provide a deferment for any employees in the specified 35 occupational classifications, but is a guide sent to all local draft boards for their consideration of occupational deferment of persons in the designated classifications. Such deferment is limited to a six-months' period.

The Selective Service order for radio and radar manufacturers follows issuance, on October 12, of a similar bulletin, Occupational Bulletin No. 27, covering communications services, including radio broadcasting, telephone, telegraph and newspapers. The important basic clause in the radio manufacturers' Occupational Bulletin No. 32 is its general application, in clause 2(a), covering production of all communication equipment, and also the certification of the War Manpower Commission that production of such communication equipment is "an activity essential to the support of the war effort." Clause 2(a) will afford a general basis for appeal, in connection with local draft boards and Boards of Appeal, for deferment of such employees of radio manufacturers as are not included among the 35 general classifications of the Selective Service bulletin.

WPB officials have officially advised RMA that the Selective Service Occupational Bulletin No. 32 does not provide for automatic deferment of any employees among the 35 classifications. Manufacturers still must apply on SSS Form 42-A for deferment of essential, or "key" employees, and manufacturers' personnel managers should handle appeals to local draft boards, based on the essential employment of employees as covered by Occupational Bulletin No. 32.

Information to RMA from trade associations of other industries, which have had similar Selective Service deferment classifications, is that the Selective Service bulletins to local draft boards have not been largely effective in securing deferment. Therefore, the Selective Service action in connection with employees of radio manufacturers does not insure draft deferment, merely because of the issuance of Occupational Bulletin No. 32. This is merely official information and guidance to local draft boards of the classifications of radio manufacturers' employees considered essential, and which should be given due consideration by local draft boards. A detail of the classification of "repairman" is that this is limited to repair and servicemen of manufacturers, and does not apply nor extend to servicemen of distributors and dealers, nor to individually operating radio servicemen.

Radio manufacturers having difficulties in connection with deferment of important, fundamental "key," essential employees are promised assistance by the WPB Radio and Radar Branch, and also by the Army and Navy agencies in any important individual deferment cases.

The matter of amending Occupational Bulletin No. 32 by extending Selective Service action to a class of employees not included in the bulletin should be taken up with the WPB Radio and Radar Branch, for submission to and discussion with the War Manpower Commission.

★

NEW CORPORATION FORMED FOR AIRCRAFT PRODUCT DEVELOPMENT

Announcement has been made of the formation of the Aircraft Parts Development Corporation, with offices, laboratories, and shops in Summit, New Jersey.

This organization will handle research and development work on parts and materials for the Aircraft Industry, especially in the fields of fastening devices, powdered metals, and plastics. It is planned to solicit ideas and untested projects from engineers and inventors, and to carry them through complete development to the point of release for commercial manufacture. The activity will extend to the designing and tooling of any special machinery required for the manufacture of products evolved.

Facilities include a fully equipped tool room, special experimental machinery, a powdered metal experimental laboratory, and a pilot thermoplastics plant. The executive and technical personnel of the organization will be announced in a few weeks.

★

CLAROSTAT PRODUCT CONTROL EARNS "A" CLASSIFICATION

The inspection routine or quality control practiced in the Clarostat plant has won the rare recognition of an "A" classification granted by the Eastern Procurement District, Army Air Force. This means that Clarostat's own inspectors, having demonstrated a high degree of quality control to the satisfaction of the Air Force, are now entrusted with full responsibility of meeting all requirements as established. Duplication of inspection during fabrication by Air Corps inspectors can thus be eliminated, and the latter can now confine their activities to general supervision of the inspection system and the final approval and stamping of completed assemblies.

★

SYLVANIA AWARDED ARMY-NAVY E

Lieut. General Joseph T. McNarney, deputy chief of staff, U. S. Army and Rear Admiral Charles Fisher, director of Shore Establishments, U. S. Navy, on the occasion of the awarding of the Army-Navy E flag to the Emporium, Pa. plants of Sylvania Electric Products, Inc., jointly complimented the workers and the management for record breaking production of radio tubes and electronic equipment for war. Ceremonies were held during the afternoon of November 5th on the lawn facing the main plant.

★

ARMY-NAVY "E"

The Army-Navy "E" for excellence in production was awarded Clarostat Mfg. Co., Inc., of 285-7 N. 6th St., Brooklyn, N. Y., with impressive ceremonies held in the Grand Ballroom of the St. George Hotel, followed by a dinner and entertainment for several hundred honored guests, officials and employees.

★

G.E. MOTOR FITNESS MANUAL

Motor fitness requirements is the subject of a new 40-page illustrated bulletin (GED-1017) recently issued by the General Electric Company. Although primarily intended for plants converted to war production, the bulletin will prove valuable in all plants in which motors are widely used.

The bulletin discusses the following subjects in a highly comprehensive and informative manner: How to get the most service out of old and new motors, "switching" motors from one job to another, and equipping old machines with new motors.

Also, selection and application of motors, various types of motor enclosures, secondary ratings of standard integral-hp. motors, ways to determine WR^2, motor maintenance, full load currents of motors, selection of a.c control, and the use of the hook-on volt-ammeter. A supplement explains how to save critical motor materials, including WPB recommendations, and information on the use of load-time-temperature charts.

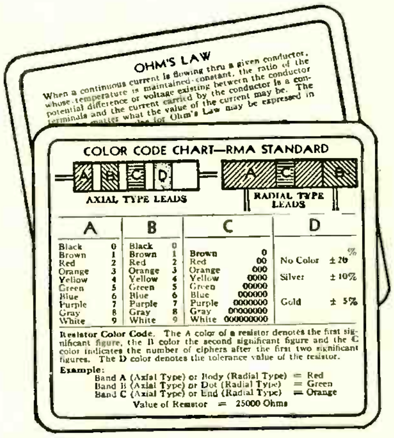
The bulletin is arranged throughout for quick reference.

★

COLOR CODE RESISTOR CARD

Sylvania announces a Color Code Resistor card for radio technicians issued at this time as a help in the War-time radio servicing job. It is free to all Sylvania radio servicemen.

In handy pocket size form, the Sylvania Color Code Resistor Card should prove to be a most valuable aid in circuit revision work. It clearly shows



OHM'S LAW

When a continuous current is flowing thru a given conductor, whose temperature is maintained constant, the ratio of the potential difference or voltage existing between the conductor terminals and the current carried by the conductor is a constant, no matter what the value of the current may be. The ...

COLOR CODE CHART—RMA STANDARD

AXIAL TYPE LEADS — RADIAL TYPE LEADS

A		B		C		D	
Black	0	Black	0				%
Brown	1	Brown	1	Brown	0	No Color	± 20
Red	2	Red	2	Red	00		
Orange	3	Orange	3	Orange	000	Silver	± 10%
Yellow	4	Yellow	4	Yellow	0000		
Green	5	Green	5	Green	00000		
Blue	6	Blue	6	Blue	000000	Gold	± 5%
Purple	7	Purple	7	Purple	0000000		
Gray	8	Gray	8	Gray	00000000		
White	9	White	9	White	000000000		

Resistor Color Code. The A color of a resistor denotes the first significant figure, the B color the second significant figure and the C color indicates the number of ciphers after the first two significant figures. The D color denotes the tolerance value of the resistor.

Example:
Band A (Axial Type) or Body (Radial Type) = Red
Band B (Axial Type) or Dot (Radial Type) = Green
Band C (Axial Type) or End (Radial Type) = Orange
Value of Resistor = 25000 Ohms

the A, B, C, and D color denotations of a resistor, explains the resistor color code and gives examples. On the reverse side of the card is Ohm's Law, one of the basic radio circuit formulas. Its definition and explanation is a helpful reference for every radio man.

They are available through Sylvania jobbers or can be secured by writing directly to Sylvania News, Emporium, Pa.

★

BULLETIN ON SOLENOIDS

Two new laminated solenoids are described in a bulletin released by Dean W. Davis & Co., 549 W. Fulton St., Chicago, Illinois. No. 2861 pull type and No. 2923 push-pull type, are covered.

They are particularly designed for specification by engineer-designers for hydraulic valves and general industrial purposes. Maximum magnetic force for given electrical input is effected by design, laminated frame and plunger and other features. More work per watt input is demonstrated.

Coils may be paper section wound, cloth-taped and treated to make impervious to cutting oils and coolant. Installation is easy for either direct or remote control, and quick short thrusts. For a.c. or d.c. All voltages. Stroke ⅞". Bulletin may be had free by addressing the manufacturer.

ADDRESS CHANGE?

Notify RADIO's Circulation Department at 132 West 43rd Street, New York, N. Y., of your new address two or three weeks before you move. The Post Office Department does not forward magazines sent to a wrong address unless you pay additional postage. We cannot duplicate copies mailed to your old address. Thank you!

ADVERTISING INDEX

FIRST AID INDEX

A First Aid Index in handy pocket size form is being issued by Sylvania for radiomen to use with local war emergency volunteer groups. It measures 6½ x 3 inches folded, and fits into pocket, purse or auto compartment. They are available at 5c each; minimum quantity for imprinting by Sylvania is one hundred.

The Sylvania First Aid Index is authoritative, bearing the approval of the Commander-in-Chief of the U.S. Volunteer Life Saving Corps.

★

WOMEN AT WORK

Universal Microphone Co., Inglewood, Cal., was the first factory in the southwest to use women inspectors of the Army Signal Corps inspectors division. The entire inspection staff will ultimately be composed of women, with a male supervisor.

★

TUBE CONNECTION CHART

"Tube Base Data Connections and Chart," the new issue just released by Weston Electrical Instrument Corporation, assembles in convenient folder form the element connection and base layout of over 600 different types of radio tubes. Originally designed for use with the Weston method of selective analysis, but now used with all methods of servicing, this folder permits rapid socket selection for practically any tube now in commercial use.

Tube base connections are illustrated by diagrammatic sketches of the bottom view of socket or base of tubes; constituting valuable reference material on tube circuits. A tube base chart is also included which indicates the proper base to use for any of the various tubes listed. A copy of this folder may be obtained by writing to Weston Electrical Instrument Corporation, Newark, N. J.

★

MANDERNACH NAMED G-E REPLACEMENT TUBE S.M.

H. J. Mandernach has been appointed sales manager of the Replacement Tube Section of General Electric's Radio, Television and Electronics Dept., at Bridgeport, Conn., according to an announcement by A. A. Brandt, Sales Manager of the Receiver Division.

In his new position, Mr. Mandernach is responsible for replacement sales of all types of electronic tubes handled through distributors, including tubes for radio receivers, transmitters, industrial control and power applications.

★

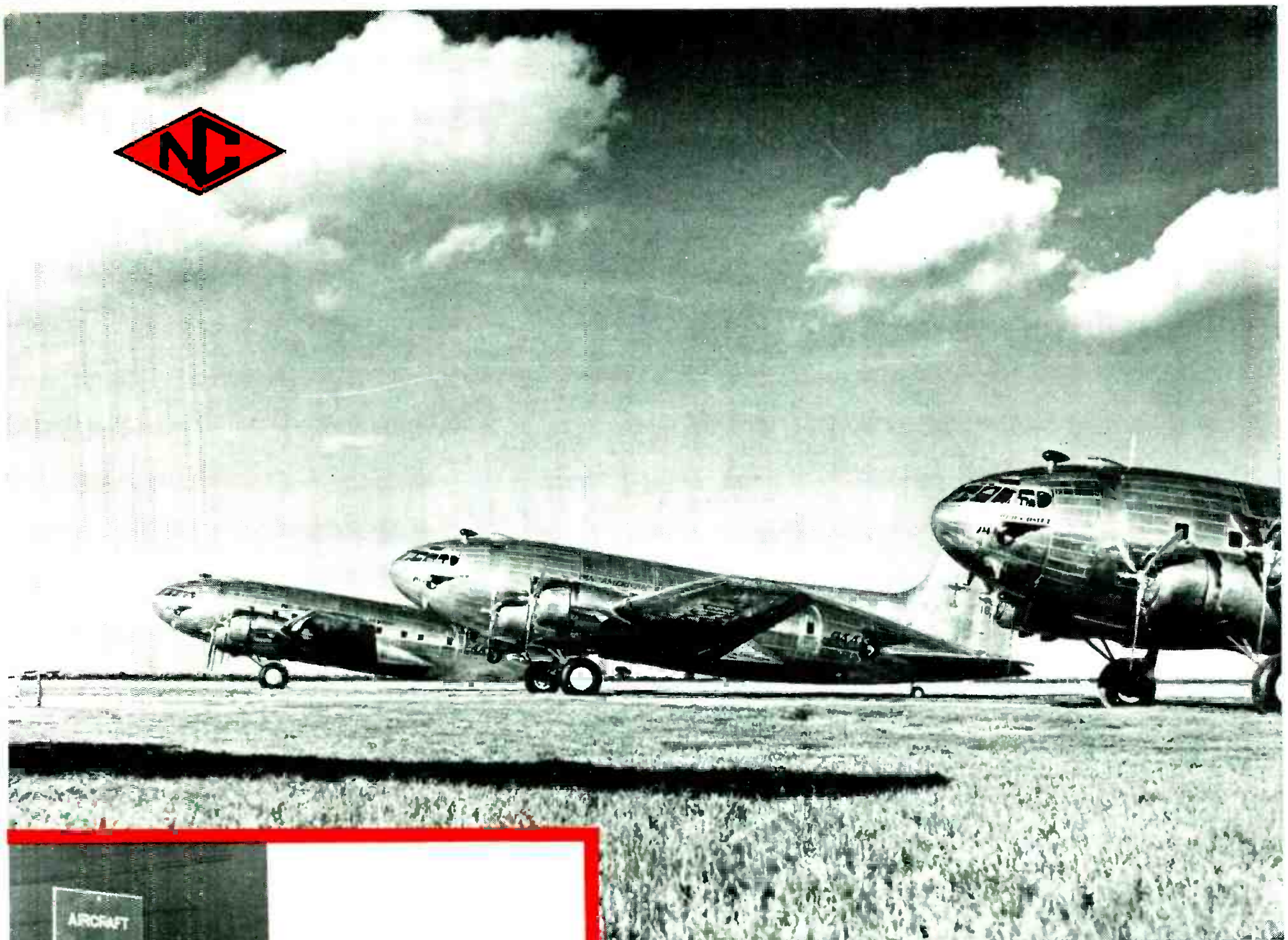
HALF PRICE SUBSCRIPTIONS . . .

for Men in the U. S. Armed Services

Subscriptions to "RADIO" addressed to men in the U. S. Army, Navy, Marine Corps, or Coast Guard will be accepted at the below-cost rate of $1.50 per year. Subscriptions at this rate (whether ordered by the addressee or a donor) should be accompanied by a remittance in full; addressee's rank and military address must be given. This rate applies wherever domestic U. S. postal service extends, including naval units at sea and overseas army postoffices. No cancellations or refunds.

Simply write rank, name, and military address on a slip of paper and send, accompanied by remittance, to

Radio Magazines, Inc., 132 W. 43rd St., New York, N. Y.



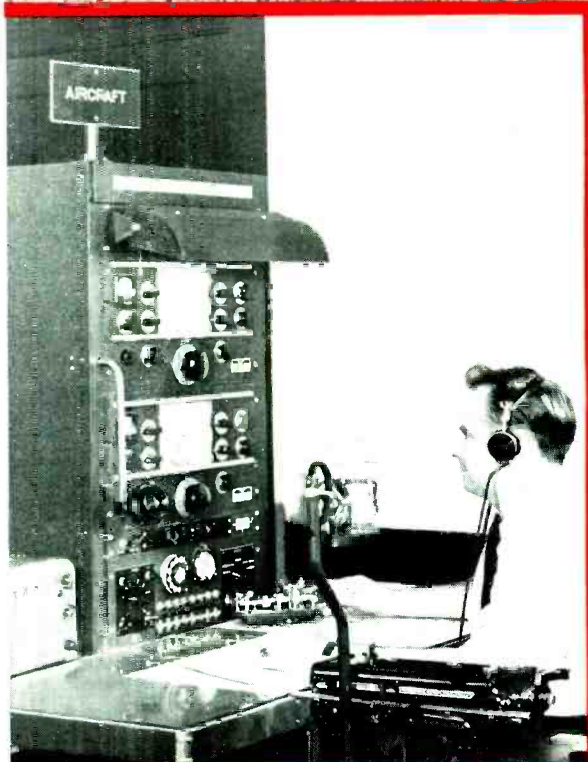


PHOTO COURTESY OF PAN AMERICAN AIRWAYS SYSTEM

Upper photo: Pan American Strato-Clippers.

Lower photo: A Pan American radio installation using National Receivers.

IT is not too much to say that Pan American Airways has invented the technique of trans-oceanic air transport; a technique based on superb skill, meticulous maintenance, and thoroughly reliable equipment.

National and Pan American Airways have never been strangers, but we are particularly proud that year by year Pan American has turned increasingly to National communication Equipment.

NATIONAL COMPANY, INC.
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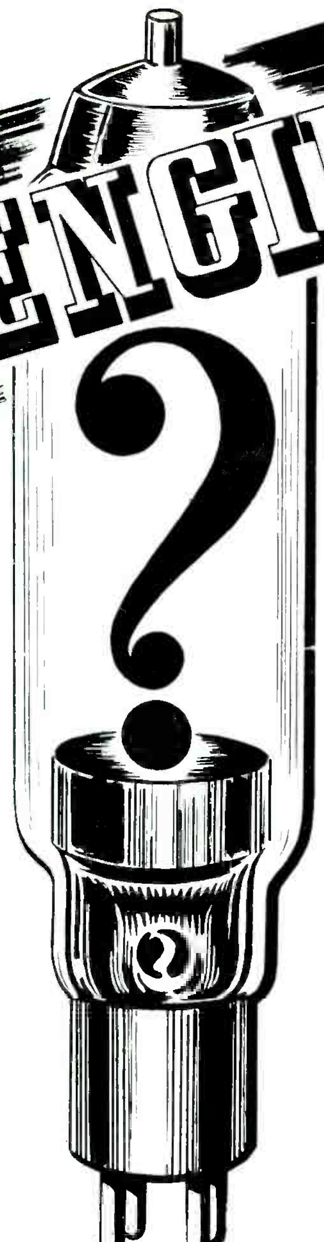
ENGINEERS



Do you have a development problem that could best be solved by a new electronic tube with characteristics not now available?

The Raytheon Laboratories are prepared to undertake such development assignments provided only that (a) The new tube would make possible new or greatly improved equipment for the successful prosecution of the war either on the field of battle or on production lines. (b) The tube would have wide enough uses to warrant the development expense.

Address correspondence to:
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RAYTHEON MANUFACTURING COMPANY
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DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES FOR THE NEW ERA OF ELECTRONICS