FEBRUARY, 1950

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DEPARTMENTS

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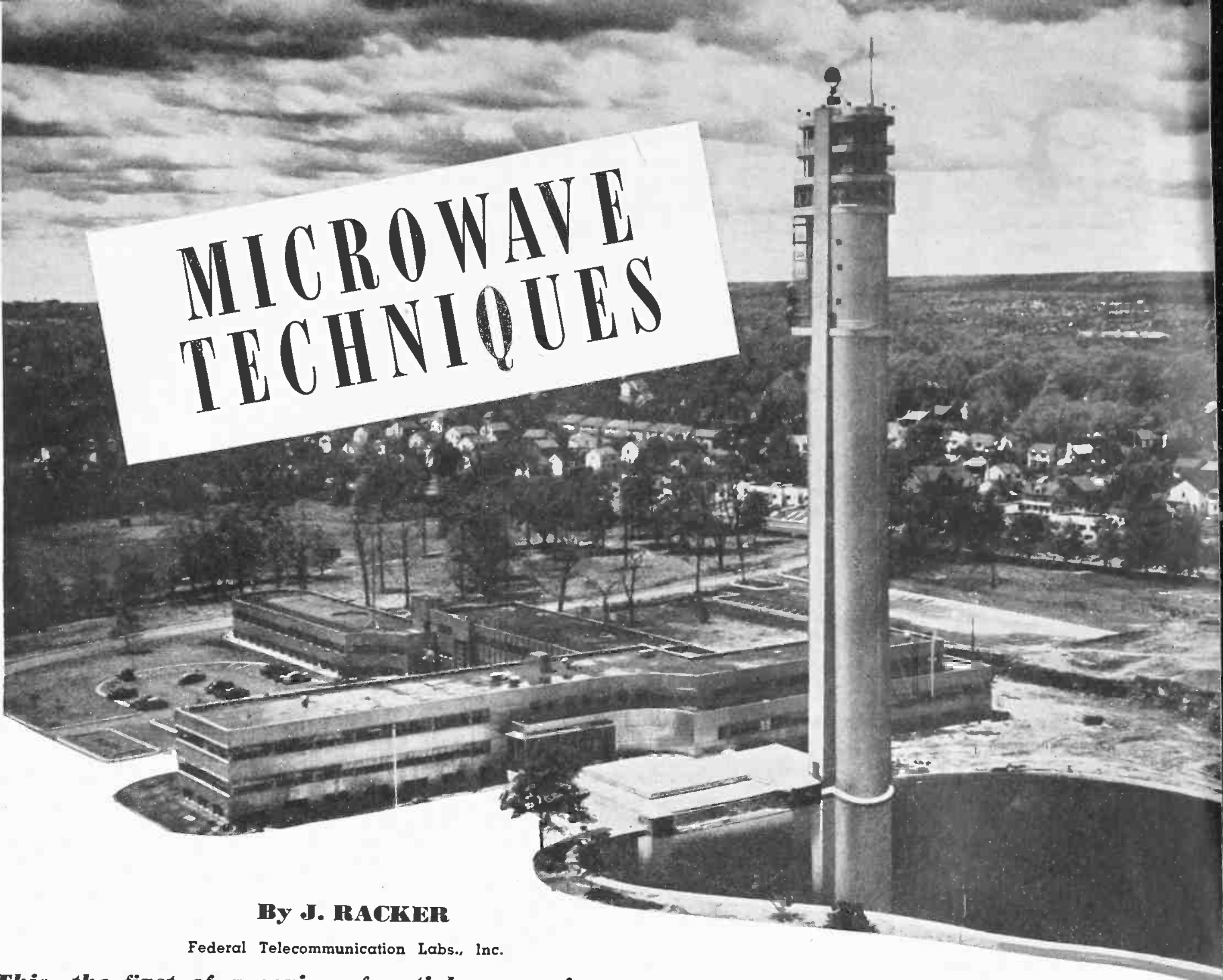
COVER PHOTO — By ACME

Dr. George Klotzbaugh of the Westinghouse Research Laboratories holds a "dry raindrop" in the path of a radar beam during experiments on the "scattering" produced by raindrops. The scattered beam is picked up by the horn receiver at the right and transmitted to the table where Edward J. Duckett calculates the amount of scattering. The plastic raindrop behaves electrically like real rain.



MICROWAVE TECHNIQUES

By J. RACKER

Federal Telecommunication Labs., Inc.

This, the first of a series of articles on microwaves, introduces the subject and gives some basic definitions.

Fig. 1. Microwave tower used by Federal Telecommunication Labs. for research and development of microwave equipment.

THE abundance of papers on microwaves that appear virtually every month in many technical periodicals bears witness to the tremendous activity in this field. The author, therefore, feels that it is unnecessary to delve into the importance of this new, but rapidly expanding, art in electrical engineering. However, one point that may have been overlooked by many readers is this: virtually every large organization operating in electronics has announced the construction of a "microwave tower", such as the one shown in Fig. 1, specifically for the purposes of studying and developing equipment utilizing the centimeter wavelength band.

It is reasonable to assume that the millions of dollars invested in these "microwave towers" represents only a fraction of the total cost of the research program. It is also a sound principle that for each dollar spent in research, many more will be expended in production and commercialization of this equipment. At present microwave activity is centered in the laboratory, but when the years of intensive study are translated into practical apparatus, the emergence of this field as a major industry is almost certain. Remember that the management of many organizations would have never erected elaborate structures such as the one shown in Fig. 1, unless they were firmly convinced of the commercial possibilities of equipment operating in this band.

Even today, more and more systems are being turned over to the factory from the laboratory, and for the main part, it is this equipment that provides the subject matter for the papers mentioned in the first sentence of this article. Many engineers who were "low-frequency" men all their lives are now being called upon to work on microwave units. Certainly from the foregoing it is obvious that this field offers good opportunities for the student or junior engineer.

This article serves as an introduction to a series on "Microwave Techniques" particularly directed to the engineer who is just starting in this art. On the whole the articles will be kept as simple and practical as possible, minimizing as much as possible the use of higher mathematics and advanced theory. This series will also provide the practicing microwave engineer with a reference, or handbook, for many useful, everyday design equations which he may now have to thumb through several volumes to locate. Nomographs and charts will be employed whenever they are available.

The subjects to be covered in this series of articles include: design of microwave transmitters; design of microwave receivers; microwave transmission lines and antennas; microwave propagation; microwave measurements; microwave television links; microwave communication systems and microwave system planning.

Definition of Microwaves

Two questions immediately arise. First, what are microwaves, and sec-

Fig. 2. One of the major advantages of the use of microwaves is that the energy can readily be "beamed" by dipole fed parabolic antennas like the one shown.

ond, why are microwave techniques different than conventional techniques. The answer to the first provides a clue to that of the second. Microwaves have been defined in various ways by different individuals, but the best definition, in the opinion of the author, is the following. Microwaves are those radio frequencies whose wavelengths are comparable to the dimensions of the apparatus in which they are used. This fact distinguishes microwaves from conventional radio frequencies, whose wavelengths are of a much higher order of magnitude than their equipment, and light waves, whose wavelengths are very small compared to normal sized units. Because of this unique position of microwaves in the frequency spectrum, it is sometimes convenient to describe certain circuits in conventional radio-frequency terms, while others are more readily visualized by comparing them to equivalent light phenomena.

In defining microwaves as those radio frequencies whose wavelength is comparable to the dimensions of the apparatus in which they are used, a wide latitude is available in establishing the exact frequency range implied, since both "comparable" and "dimensions of the apparatus" must still be precisely defined. No such definitions exist and, therefore, there is a considerable difference in opinion as to exactly where microwave frequencies start and end. Arbitrarily, the author will set the lower limit at about 900 mc. (wavelength of the order of 33 cm.) because at these frequencies parabolic reflectors such as the one shown in Fig. 2 become practical for many applications, while an upper limit of about 10,000 mc. will be assumed where wavelengths of about 3 cm. dictate use of equipment considerably smaller than that conventionally used. Some authorities set the upper limit as high as 100,000 mc., but for the purpose of these articles 10,000 mc. represents an ample limit, since even at these frequencies present-day activity is limited.

Now for the second question introduced previously, i.e., why are microwave techniques different than conventional techniques. The answer is derived from its definition, i.e., wavelengths are involved that are comparable to the size of the equipment. This fact immediately affects many of the basic circuit equations that were previously employed because these equations were derived with the assumption that the elements employed were small in comparison to the wavelength of the applied signal.

For example, let us consider one of the simplest and most commonly used relations that appears in classical circuit theory, i.e. Ohm's law. This law may be generalized so that it applies to an infinitesimal conducting cube and is then written as:

$$i = \sigma \overline{E} \quad \quad (1)$$

where i is the current density

σ is the conductivity of the material through which the current flows

$\overline{E}$ is the electric field intensity

Assume that we have a voltage V, across a loop of wire shown in Fig. 3A. When this voltage is d.c. the current, as expressed in Eqt. (1), flowing through this wire is:

$$I = V/R \quad \quad (2)$$

where R is the resistance of the wire (reciprocal of its conductivity) which is the familiar form of Ohm's law.

However, if the voltage is varying in time, but the wavelength is still very large compared to the length of the wire, then the current flowing through the wire becomes (assuming that the distributed capacitance can be neglected):

$$I = V/(R + j\omega L) \quad \quad (3)$$

where L is the inductance of the wire.

Finally if the frequency of the applied voltage is such that its wavelength is of the same order of magnitude as the length of the wire, the voltage equation becomes (again neglecting the distributed capacitance):

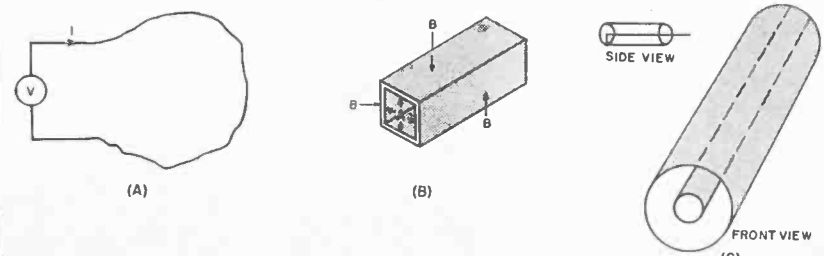
$$V = I[(R + R_r) + j\omega L] \quad \quad (4)$$

where R_r is the radiation resistance.

Thus we note that when the length of the wire becomes comparable to the wavelength of the applied voltage some of the energy is radiated. This idea is, of course, not really new to "low frequency" engineers, because they know that an antenna "radiates" more effectively as its length is increased. It is primarily due to this radiation effect that microwaves are transmitted and measured by means of electromagnetic waves rather than via currents and voltages. Thus instead of two-wire lines, wave guides are used and instead of lumped constant L-C resonant circuits, cavities are used. Impedance is measured by "standing waves", and inductive and capacitive elements become functions of wavelength.

Another important characteristic of microwaves is that the depth of current penetration in a good conductor is virtually negligible. The "skin" effect is well-known to most readers and at microwaves this effect reaches the point where, for all practical purposes, it is safe to assume that the current flows on the surface of (rather than in) the conductor. It is important to note that this current flows along the side of the conductor which excites the microwave energy. For example, in the wave guide shown in Fig. 3B, the current flows within the guide walls (A), and the current on the exterior walls (B) is zero. Therefore, no energy is radiated from a wave guide through which microwaves are directed.

Fig. 3. (A) Voltage applied across a loop of wire. (B) Cross-section of a wave guide showing inner walls A and outer surface B. (C) construction of a coaxial line. The outer conductor completely envelops the inner conductor.



Transmission Line Analysis

Reviewing briefly, the primary difference in approach between microwaves and standard radio frequencies is that the former must be analyzed in terms of flow of electromagnetic energy, rather than voltages and currents. It is not easy for the average reader to achieve this reorientation in approach unless a clear picture of wave propagation is obtained. The analysis of transmission line characteristics, to be covered in the following paragraphs,

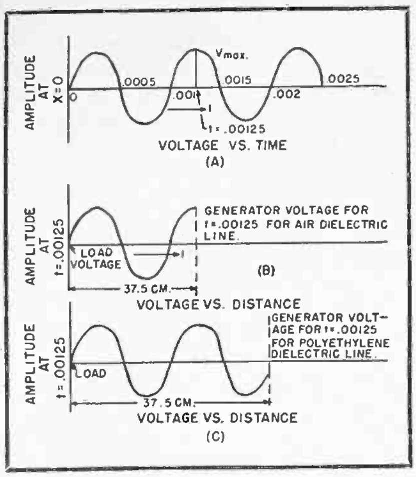


Fig. 4. Waveforms on 37.5 cm. short-circuited line including (A) voltage vs. time at x = 0, (B) voltage vs. distance from load with air dielectric, and (C), same as (B) with polyethylene dielectric.

should aid the reader in attaining this picture.

The coaxial line, shown in Fig. 3C, can be considered to be a transitional element between ultra-high frequencies (u.h.f.) and microwaves. Coaxial line elements are used extensively in u.h.f. equipment and find wide application in centimeter wavelengths up to about 10 cm. The reason for this can be understood by referring to Fig. 3C, where it is seen that the outer conductor acts as a cylindrical wave guide, i.e., prevents radiation of energy, while the presence of the inner conductor establishes the conventional two-wire line required for completion of a current path.

It is due to this unique construction of the coaxial line that its behavior can be analyzed in terms of voltage and current traveling waves. The subsequent analysis will, therefore, serve both to present important design information and to accustom the reader to thinking in terms of wave phenomena.

Fig. 5 depicts the output of a generator being applied to a finite length, l, of transmission line short-circuited at its far end. For simplicity this figure shows a parallel-wire transmission line, but in actuality a coaxial line (which can be assumed to be lossless for the purposes of this discussion) is usually used. In the future the author will refer to the two ends of the line as the sending end (generator) and load end.

In considering the characteristics of this line it is important to stress the difference between waveforms given as functions of length, l, (known as traveling waves), and those produced by the generator which are functions of time. In some cases these two waveforms seem to be identical but actually they are not. This will tend to confuse a person who is accustomed to thinking of sinusoidal voltages in terms of time rather than distance.

The difference between the two functions can best be brought out by working out a problem. Assume that the generator of Fig. 5 operates at a frequency of 1000 mc. and the transmission line is 37.5 cm. long. The voltage-versus-time curve of this generator at the point $x = 0$, shown in Fig. 4A, is the conventional sinusoid. However, it should be noted that this curve is valid only at a particular point on the line, i.e., $x = 0$. The significance of this fact will soon become apparent.

The voltage appearing at $x = 0$ is then transmitted down the line at a velocity (for an air dielectric) of 3×10^{10} cm./second and arrives at the load exactly 0.00125 microseconds later. Consider the voltage-versus-distance curve (forward wave) at the instant $t = 0.00125$. At this time the output of the generator, ($l^o = 0$) as indicated in Fig. 4A, is equal to $+V_{max}$. The voltage at the load, which is delayed by 0.00125 microseconds, is equal to the generator potential at $t = 0$, or as shown in Fig. 4A, is equal to zero. During the period between $t = 0$ and $t = 0.00125$, the generator has passed through a cycle and a quarter of operation. Hence, the voltage-versus-distance curve (forward wave) at $t = 0.00125$ is a duplicate of that portion of the curve in Fig. 4A between $t = 0.00125$ and $t = 0$, as shown in Fig. 4B.

This result could have been achieved directly by expressing the line length in terms of wavelengths, in this case 1.25 wavelengths. This indicates that the forward wave on the line (expressed as voltage versus distance) must cover a cycle and a quarter. If the line is very small compared to a wavelength, then the instantaneous (forward) voltage along the line is virtually equal to the instantaneous generator voltage since the voltage varies very little during the period of time required for the wave to travel down the line. In this analysis it is assumed that the length of the line is comparable to the wavelength of the generated signal.

There is another important point. In calculating the time required for the wave to reach the load end, the velocity 3×10^{10} cm./second was used which is correct as long as the dielectric between the conductors is air. In many coaxial cables this is not true, however, in which case the velocity (V_T) is equal to:

$$V_T = \frac{3 \times 10^{10}}{\sqrt{k}} \quad . \; . \; . \; . \; . \; . \; . \quad (5)$$

($= 2 \times 10^{10}$ for polyethylene, $k = 2.25$)

where k is the dielectric constant of the insulating material.

In a polyethylene dielectric line, a longer period of time is required for the wave to travel down the line, or conversely, the wavelength of the applied signal in the dielectric is shorter by a factor of 1.5. Hence, a 37.5 cm. polyethylene insulated line would be 1.875 wavelengths long and consequently the voltage versus distance of such a line would be the one shown in Fig. 4C at $t = 0.001875$.

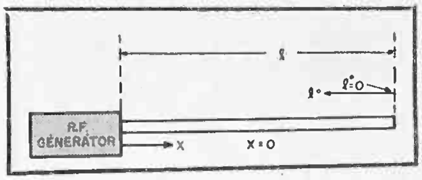


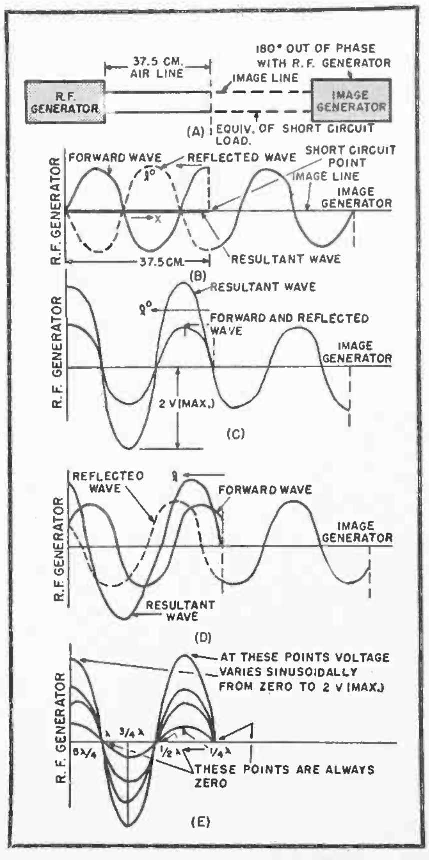
Fig. 5. R.f. generator feeding a line of length l short-circuited at its load end.

Standing Waves on the Line

The discussion covered thus far has carefully specified that the traveling wave considered is the forward wave. When the wave reaches the short-circuited end it is then reflected and the actual voltage versus distance on the line becomes the sum of these two waves.

The characteristics of the reflected

Fig. 6. Effect of reflection of voltage traveling waves caused by short circuit. (A) is equivalent circuit, (B), (C) and (D) are waveforms at different periods, and (E) depicts the over-all effect caused by the combination of the forward and the reflected waves. This is known as a standing wave.



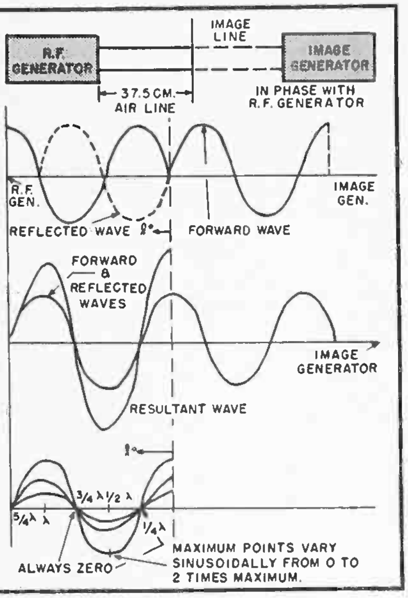
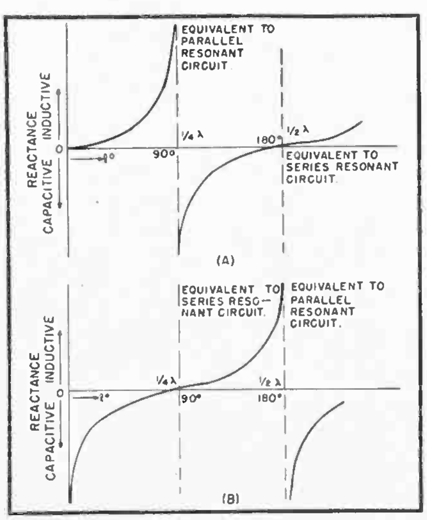


Fig. 7. Current equivalent circuit and waveforms on short-circuited line.

wave are determined by the load. For the short-circuited case it is known that the voltage across the load must be equal to zero. To obtain this potential at all times (assuming a lossless line) the reflected wave must be equal in amplitude and frequency but be exactly 180 degrees out of phase with the forward wave at the short-circuited point. The action of this circuit can best be analyzed by assuming the presence of another line and generator of exactly equal characteristics (with a phase difference of 180 degrees) feeding into the load end of the original line with the short-circuit removed. This equivalent circuit is shown in Fig. 6A. This image phenomenon is similar in principle to the reflection of light from a mirror.

Figs. 6B, 6C, and 6D plot the summation of the forward and reflected waves for several different periods. Fig. 6E depicts the over-all effect and as indicated on this figure, points along the line that are exactly one, or a multiple of half-wavelengths away from the load are always at zero potential. The points that are one or a multiple of quarter-wavelengths from the load vary sinusoidally in amplitude from peak values of $-2\,V_{max}$ to $+2\,V_{max}$. The intermediate points along the line vary sinusoidally at a peak amplitude somewhere between these two extremes (0 and $2V_{max}$) depending upon their relative position.

Fig. 8. Reactance curves for (A) short-circuited and (B) open-circuited lines.



The current waves in a short-circuited line can be determined in a similar manner. In this case the current is maximum across the short-circuit point. Consequently the reflected wave (and image generator) will be in phase with the forward wave. The over-all effect, shown in Fig. 7, is the same as developed for the voltage waves but shifted in position by a quarter of a wavelength.

Impedance at Different Points Along the Line

The impedance of any point along the line (looking toward the load) is determined by the ratio of voltage to current at that point. Since the voltage and current distributions are functions of distance from the load, it is obvious that the impedance will also be a function of distance, varying from zero (at points where voltage is zero and current maximum) to infinity (voltage maximum, current zero).

The instantaneous distribution along the line can be expressed as $V \sin \omega t$, where V is the maximum instantaneous amplitude, and t is the time required for wave to travel from load to point in question. Similarly the instantaneous current distribution is equal to $-jI \cos \omega t$. (The factor $-j$ accounts for the difference in phase between voltage and current.) It can be shown that the ratio V/I, at any instant, is always equal to Z_c, where Z_c is the characteristic impedance of the line.

The impedance at any point along this short-circuited line is therefore equal to:

$$Z_{sc} = \frac{V \sin \omega t}{-jI \cos \omega t} = j\, Z_0 \tan \omega t \qquad (6)$$

The same procedure can be employed to determine the impedance looking into a transmission line with an open-circuit termination. In this case the impedance equation becomes:

$$Z_{oc} = -j\, Z_0 \cot \omega t \qquad (7)$$

The factor ωt can be rewritten as:

$$\omega t = 2\pi f t = \frac{2\pi}{\lambda_T} V_T t = \beta_T l = l^\circ \qquad (8)$$

where λ_T is the signal wavelength in the transmission line

l° is the distance from load in terms of electrical degrees.

A nomograph which permits the user to obtain l° for any given distance and wavelength by means of a straight edge appeared on page 32 of the February issue of RADIO-ELECTRONIC ENGINEERING. Note that the frequency scale (at right) on this graph is valid only for an air dielectric line. A nomograph for determining the impedance looking into a short-circuited or open-circuited line is given on page 32 of the January issue. A quarter-wave matching section nomograph is scheduled for the March issue.

Eqts. (6) and (7) are plotted in Figs. 8A and 8B respectively. As indicated in this figure, Z_{sc} starting from a value of zero, at $l^\circ = 0$, becomes an increasingly larger positive reactance until at $l^\circ = 90°$, or $l = \lambda_T/4$, it approaches infinity. It is possible to express any point along this curve in terms of an equivalent inductance. Between the points $l^\circ = 90°$ and $l^\circ = 180°$, Z_{sc} is a negative, or capacitive, reactance decreasing exponentially until the point $l^\circ = 180°$ is reached. At $l^\circ = 90°$, the transmission line acts as a parallel tuned resonant circuit, while at $l^\circ = 180°$, the line is equivalent to a series tuned resonant circuit. Z_{oc} presents a similar series of curves but shifted by 90°.

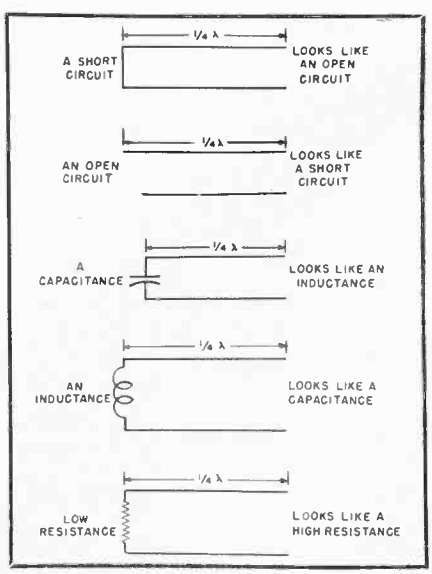
Transmission Line Equations

The short-circuited and open-circuited terminations are special solutions to the general transmission line equation. The derivation of this equation is considerably more complex and, for the purpose of this article, would not be very useful. The impedance Z_N, looking into a transmission terminated by Z_t is:

$$Z_N = \frac{Z_t + j\, Z_0 \tan \beta\, l}{1 + j\, \dfrac{Z_t}{Z_0} \tan \beta\, l} \qquad (9)$$

(*Continued on page 26*)

Fig. 9. Quarter-wave transformer action.



CRYSTAL OSCILLATOR PLATES For H. F. Use

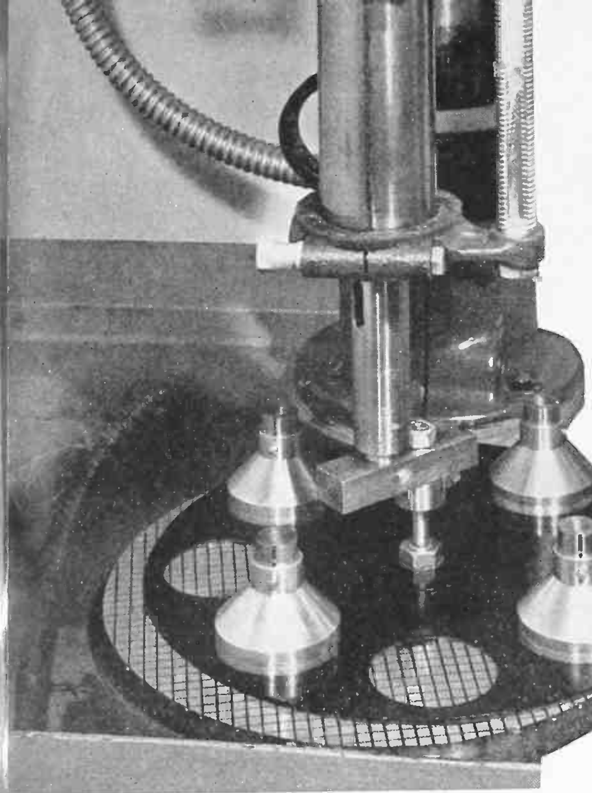


Fig. 1. The inkwell apparatus developed at NBS permits easier inspection of individual quartz crystals as they are ground to required thinness.

Precision grinding of quartz plates to .001 inch thick is possible with this new machine developed at NBS.

THE increasing interest in high frequencies for radio communication is accompanied by a demand for very thin quartz crystal oscillator plates having fundamental frequencies up to 100 megacycles or even higher. The usual crystal grinding methods and machinery, however, have proven inadequate for producing plates of the required thinness. In the course of an investigation of this problem, L. T. Sogn and W. J. Howard of the National Bureau of Standards have modified conventional techniques to overcome these difficulties.[1] The improved equipment, capable of producing 0.001 inch thick quartz crystals with a high degree of parallelism and flatness, can also be used for grinding equally thin wafers from a variety of other materials. A promising application, for example, is the production of extremely thin dielectric plates for miniature radio condensers.

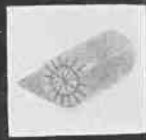
In crystals whose fundamental frequency is in the higher range, the thickness of the quartz plate determines the frequency. Since the frequency is inversely proportional to the thickness, the higher the frequency the thinner the crystal must be. For example, a crystal with a fundamental frequency of 100 mc. is about 0.001 inch thick. Moreover its surfaces must be parallel within a few millionths of an inch. To manufacture such crystals it has been necessary to modify the usual lapping procedures and to design equipment suitable to the modification.

Ordinarily, crystals are carried in a planetary path between two abrasive-charged plates by a thin apertured disk called a nest. Nests thinner than 0.005 inch do not have the strength required to carry the crystals. Because the nest must be thinner than the crystals to permit their abrasion, crystals produced by this method have maximum fundamental frequencies of about 20 mc.

The initial problem therefore was to make the crystal thickness independent of the nest thickness. The solution involved various replacements for the customary top lapping plate and related changes in the design of the nest.

In the first modification the crystals were individually cemented to small steel blocks which were used in place of the top plate to supply lapping pressure. A conventional nest carried the cemented units over the lower lap. Because of difficulties inherent in this method of mounting, the crystals became wedge-shaped. Crystals were next lapped, using the same equipment with the pressure blocks resting freely on the crystals. This process however did not correct contour defects and the rate of lapping had to be reduced to prevent the blocks from being separated from the crystals.

(*Continued on page* 30)



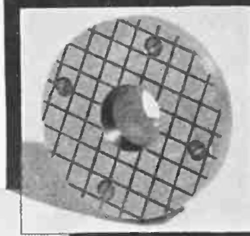


Fig. 2. (Above) Assembled and unassembled view of the inkwell type quartz crystal lapping apparatus.

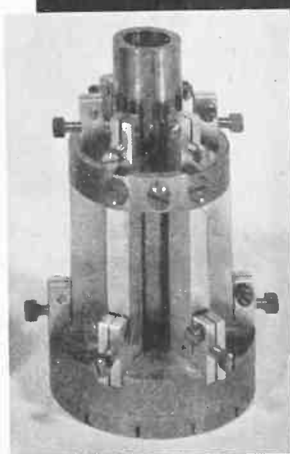
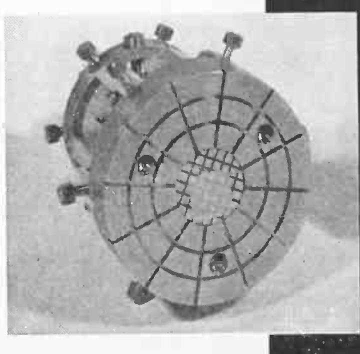


Fig. 3. The tall plunger apparatus developed at NBS to eliminate limiting factors of conventional lapping equipment. In this modification, bearing point screws replace the close fitting bore. Slots in the uprights permit the transverse screws to lock the bearing point screws in position.



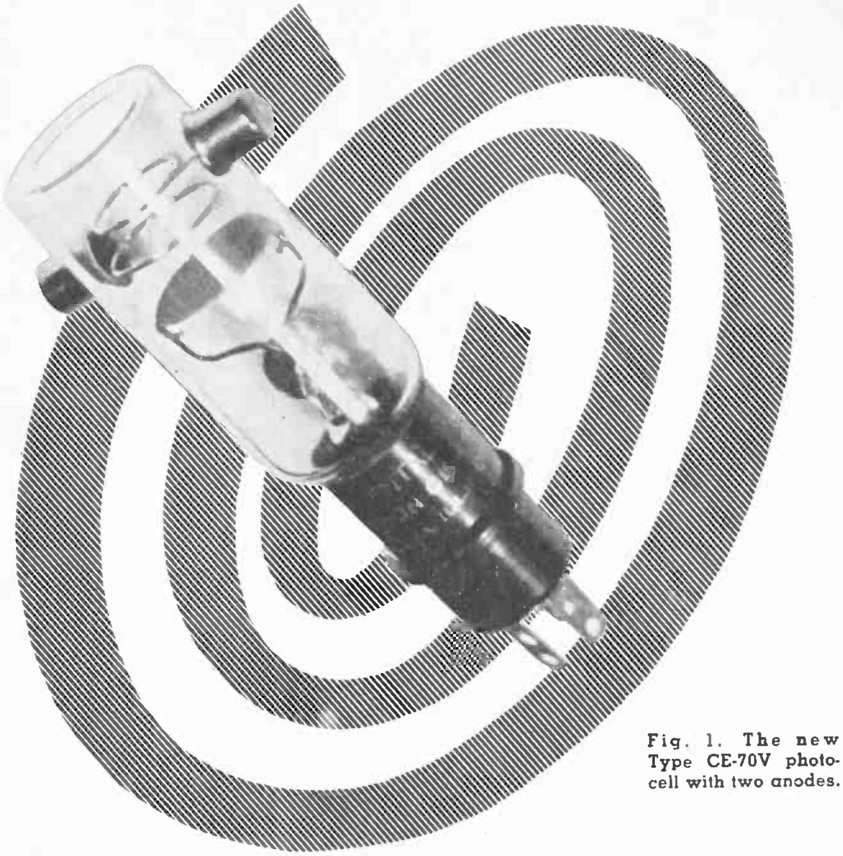


Fig. 1. The new Type CE-70V photocell with two anodes.

DESIGN FEATURES Of A New PHOTOCELL

By J. H. CROW and V. C. RIDEOUT
University of Wisconsin

A new vacuum-type photocell with two anodes for use where the transfer constant must be rapidly altered.

THE NEED for the new photocell to be described arose as a result of work on an electro-optical pyrometer. The basic form of the pyrometer [1,2] was devised by Professors Myers and Uyehara in the Mechanical Engineering Department of the University of Wisconsin in a fuel combustion research program initiated in 1942, and was used to measure the instantaneous gas temperature in the cylinder of a Diesel engine. As described below, this pyrometer is based on a ratio or dividing circuit which is made up of a feedback loop incorporating a multiplier. It was suggested at a conference in October 1948 that a phototube with two anodes might serve as the multiplier in the pyrometer, with some significant advantages.

This article is based on a paper which was presented at the 1949 National Electronics Conference.

The Two-Anode Photocell

Fig. 1 is a photograph of the new photocell, the CE-70V. This tube is a high-vacuum version of a gas photocell manufactured by the *Continental Electric Company* for quite a different purpose. It is an end-on type of tube with two ring anodes and a flat disc-type cathode. The outer ring is used as the main or load anode, and the inner control anode is used to vary the amount of emission current reaching the load anode.

Static response curves for this tube are shown in Fig. 5. The output is quite linear with control voltage over an appreciable range for the various values of light intensity used. Fig. 6 shows a combined curve of microamperes per foot-candle versus control voltage, and was obtained from the same data used in plotting Fig. 5. The control action resembles that in a tetrode where the control grid potential determines the cathode current and the screen grid potential determines the division of cathode current between the screen and plate. In the CE-70V the light striking the cathode plays the role of control grid potential, and the control anode functions somewhat as the screen grid in a tetrode. The small amount of current collected by the control anode will not affect its potential if a low-impedance source is used to drive it.

Frequency response tests were made to see if the transference of this photocell could be varied at frequencies well above the highest frequencies (10 to 20 kc.) which would be encountered in the pyrometer application. It was found that at frequencies above a few kilocycles the capacity coupling between anodes caused a signal to appear on the load anode that was independent of light intensity on the cathode. This problem was overcome by neutralization as shown in Fig. 2. Here a center-tapped transformer is used to apply the alternating voltage to the control anode and an equal and opposite neutralizing voltage to the main anode through a capacitance C_n which is adjusted to equal the inter-anode capacitance. With C_n so adjusted no capacity feed-through was detected at frequencies up to 200 kilocycles. In practice, a phase-inverter circuit may be used in place of the center-tapped transformer.

A tube with a third ring anode added between the control and main anodes was tested with this added anode held at radio-frequency ground. The shielding effect was not adequate, and the neutralized two-anode tube was used in the pyrometer circuit discussed below.

Circuit Applications

(a) Modulator

In electro-optical systems which must handle slowly-varying light intensities it is often desirable to avoid the problems inherent in direct-coupled amplifier design such as those of drift and fluctuation noise by using carrier modulation. Modulation schemes involving mechanical light-choppers or control of photocell conduction by means of magnetic fields are complicated and limited to low-frequency carriers and narrow-band signals. The CE-70V may be used as a combination modulator and photocell at carrier frequencies up to at least 200 kilocycles, and probably much higher. In this application the linearity of the control characteristic is not essential.

(b) Multiplier

In some applications, particularly in the field of instrumentation, it may be found necessary to obtain the instantaneous product of two quantities; one a light intensity, the other a voltage. This is possible with the two-anode photocell due to its linearity. Here the varying voltages must be limited to the linear range of the control anode characteristic and a constant term must be subtracted. The multiplier output current for the CE-70V characteristics shown in Fig. 5 is given by:

$$I = 3.9 \times 10^{-3} L(E - E_{CA}) \ \mu \text{ amps.} \quad (1)$$

where L is light intensity at the cathode in foot-candles, E_{CA} is the control anode voltage and E is a bias voltage dependent on the load anode voltage.

(c) Divider

The ratio of two voltages may be taken by means of a multiplier and a feedback loop as shown in Fig. 3. Here the multiplier is used as the β circuit so that:

$$\beta = KE_2 \quad (2)$$

The output is given by:

$$E_o = \frac{AE_1}{1 + A\beta} = \frac{AE_1}{1 + AKE_2} \quad (3)$$

If AKE_2 is large compared to unity:

$$E_o \approx E_1/KE_2 \quad (4)$$

Thus the accuracy of the process of division always depends upon the accuracy of the multiplier.

If the voltages are proportional to two light intensities, the output E_o will give the ratio of the light intensities, as in the pyrometer circuit described below.

Electro-Optical Pyrometer

The basic principle involved in the electro-optical pyrometer is that the absolute temperature of a luminous flame may be obtained from the ratio of the light intensities at two wavelengths if the ratio of the monochromatic emissivities is constant [1,2]. This follows from Wien's law which gives black body radiation intensity J as:

$$J = C\lambda^{-5}\varepsilon^{-c/\lambda T} \quad (5)$$

where λ is wavelength, T is absolute temperature, and C and c are constants.

Thus if the light from the incandescent soot particles in a Diesel engine cylinder is split up by means of a prism and the two narrow bands of light centered on properly chosen wavelengths are allowed to fall on photocell cathodes, the log of the ratio of their output voltages will give the reciprocal of the absolute temperature. It is necessary to obtain this ratio electronically because of the rapid changes in temperature which must be measured. The early form of the pyrometer, which is based on the divider circuit of Fig. 3, used a gain-controlled radio-frequency amplifier and two standard photocells as shown in Fig. 7. The approximate output, corresponding to Eqt. (4) is, in this case:

$$E_o \approx \frac{K_1 A_1 L_1}{K_2 K L_2} \quad (6)$$

It may be seen from Fig. 7 that large parts of the circuit such as A_1 are not included in the feedback loop, and thus appear in Eqt. (5) no matter how high the loop gain may be. The new photocell made it possible to include all amplifiers within the loop with attendant simplicity and freedom from drift problems.

A simplified circuit diagram of the new pyrometer using the new photocell is shown in Fig. 8. The light from the Diesel cylinder is split as before and the part L_1 falling on the cathode of the ordinary photocell gives:

$$E_1 = K_1 L_1 \quad (7)$$

The CE-70V is biased about 6 volts from cut-off so that it operates in the middle of its linear range. The output of this tube is:

$$E_2 = K_2 L_2 (E - E_o) \quad (8)$$

The difference $E_1 - E_2$ when amplified A times gives the output voltage E_o. We have, therefore:

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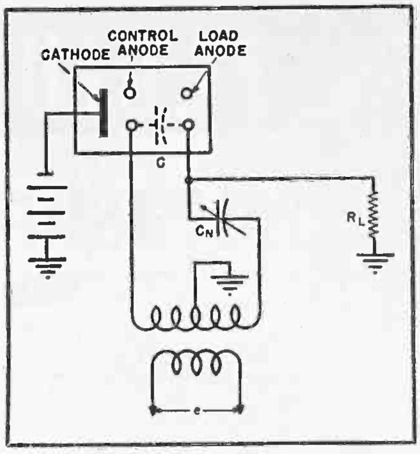


Fig. 2. Neutralization applied to prevent coupling between anodes.

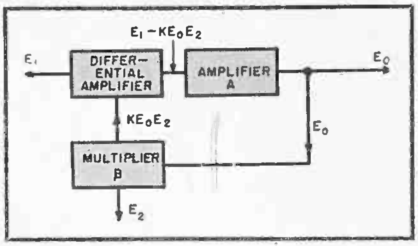
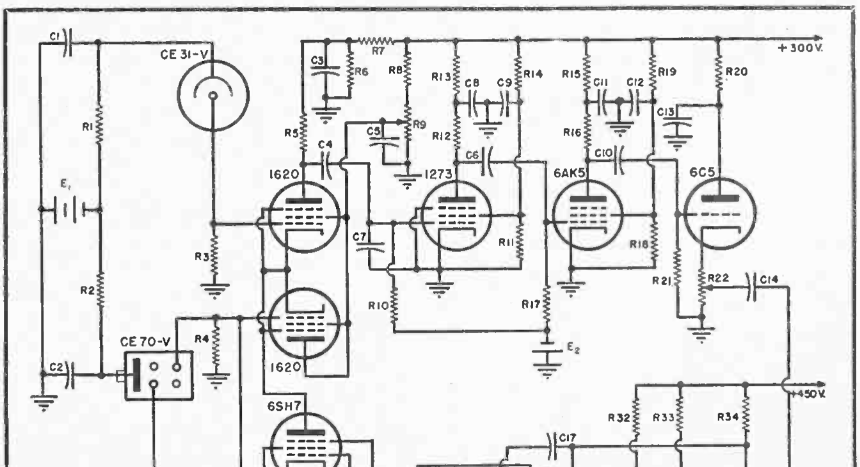


Fig. 3. Divider circuit used in an early form of the pyrometer.

Fig. 4. Circuit diagram of pyrometer using the new photocell.



FLUID VELOCITY Measurement And Control

If a fluid cuts magnetic lines of force, a voltage is induced which is proportional to the velocity of flow of the fluid.

By EDWARD M. BENNETT
Purdue University

IT IS only too common to find that the research on an idea with well recognized potentialities must be discontinued under pressure of more immediate matters. An idea of this nature may fail to gain its high commercial value until re-examined years later by other scientists. Due to a lack of available time, the writer has had to discontinue highly successful preliminary research on just such an idea. Some members of the faculty of Purdue University, including the writer, are vividly aware of the importance of the early results and the value of the completed instrumentation that can result from the basic principles developed. This article is the result of a desire to present the available information to the profession in order to prevent the loss of years before it is "rediscovered".

Design

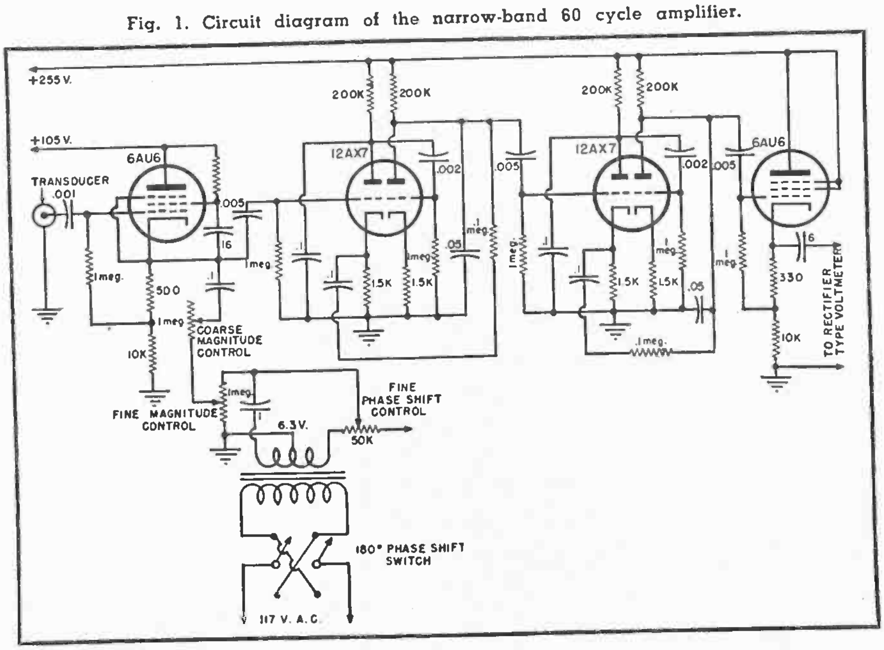
The measurement of the velocity, or of the quantity, of a fluid moving through an enclosed pipe has continually proved a problem due to the necessity of introducing some element of the measuring device into the fluid with accompanying distortion of the motion and a loss in accuracy. The difficulties of accurate measurement are the forerunners of the difficulties of control and regulation of the fluid flow. The electromagnetic velocity meter described below introduces no distortion producing element into the fluid, and obtains an electrical representation of the velocity, or of the quantity, of the fluid immediately without the necessity of conversion from mechanical to electrical representation.

Although it is common knowledge that a conductor moving through a constant magnetic field develops an induced voltage proportional to its velocity, the emphasis has been predominantly on the motion of a solid conductor. If a magnetic field is set up across a non-metallic pipe carrying a conducting fluid, a voltage will also be induced in the moving fluid. This voltage can be, and has been, detected by introducing two electrodes through the walls of the pipe at right angles to the direction of flow and the direction of the field. The appearance of a similar voltage from the motion of an ionized gas also seems logical.

In determining the voltage induced in a moving fluid, the electrodes can be either flush with the pipe walls or slightly recessed without loss of sensitivity; there will be no distortion of the fluid motion as a result of their presence. If a d.c. magnetic field is used, the voltage induced will be constant for, and proportional to, any velocity. However, the problems of d.c. amplification make it advisable to apply a 60 cycle a.c. magnetic field of constant r.m.s value, thus inducing an a.c. voltage with r.m.s magnitude proportional to the velocity.

The a.c. voltage that appears on the electrodes contains both fundamental and appreciable second and third harmonics. The magnitude is the result of both the velocity and stray inductive couplings. The problem of harmonics is easily corrected by a 60 cycle tuned amplifier. The extraneous voltage magnitudes can be removed completely by a hum-bucking circuit.

Fig. 1. Circuit diagram of the narrow-band 60 cycle amplifier.



Applications

The applications of this form of transducer are numerous. The voltage obtained can be amplified and transmitted to any number of voltmeters or voltage recording devices. More important perhaps than the ability to measure, is the ability to control fluid velocity. If two units are installed, the first can be adjusted by means of the hum-bucking circuit to give zero output reading for zero velocity. This first unit will give a

(*Continued on page* 27)

MICROWAVE DIRECTIONAL COUPLERS

By

SAMUEL FREEDMAN

Design, construction, and operation of directional couplers as used in various microwave measurements.

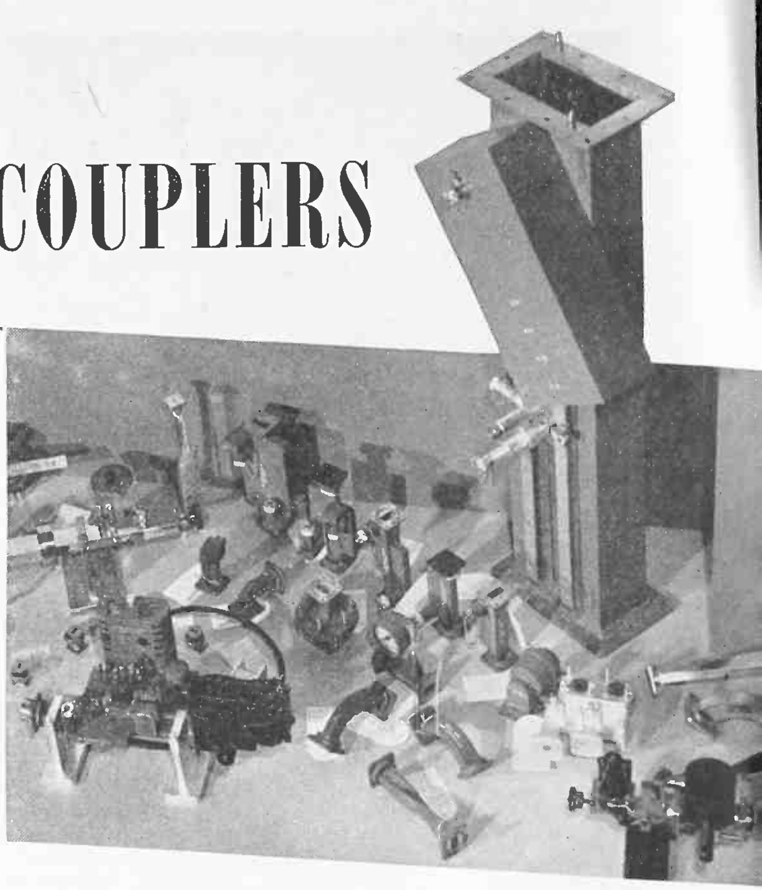


Fig. 1. Group of microwave components dominated by 1200 megacycle unidirectional coupler of the Bethe-Hole type.

ANY directional coupler is a stationary standing-wave detector which can separately sample either the direct or reflected waves, or both, in a wave-guide transmission line.

The usual form of directional coupler comprises two adjacent wave guides with one or more holes or slots serving as coupling provisions between them. Where two wave guides join together, the common practice is to mill off one wall so that the two wave guides have a common wall equal to the thickness of a single wave guide. One of these wave guides is the main or primary transmission line. A small fraction of the energy in that line is permitted to couple or escape through the coupling hole or holes to the other wave guide which is known as the auxiliary or secondary wave guide.

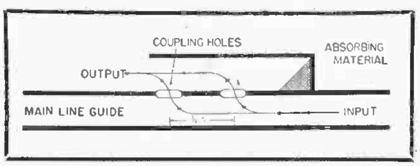
Being a wave selector device, the directional coupler is capable of differentiating between the incident and reflected energy in a microwave system. This facilitates the making of adjustments or modifications in a microwave communication or radar system so that the energy can be properly terminated into the antenna or load.

The coupling holes or slots between the two wave guides represent a fixed coupling loss which is unaffected by the standing-wave condition of the main wave guide. The ratio of the powers that flow in these two lines depends on the number, size, shape, placement, and separation between the holes or slots performing the coupling function. Since these remain fixed, they make possible high stability of measurement.

Essentially, every directional coupler uses the constructive addition of two waves in one direction and the destructive addition in the other direction. As illustrated in Fig. 2, the two holes or slots have to be a quarter wavelength apart. However, this would only be a true directional coupler for one frequency (the one which corresponds to a quarter wavelength). To have destruction in one direction for the other frequencies, a load in the form of absorbing material must be present for the other frequencies. This absorbing material is illustrated at the right-hand end of the auxiliary wave guide in Fig. 2. This still is essentially narrow in frequency but it is now a band coupler.

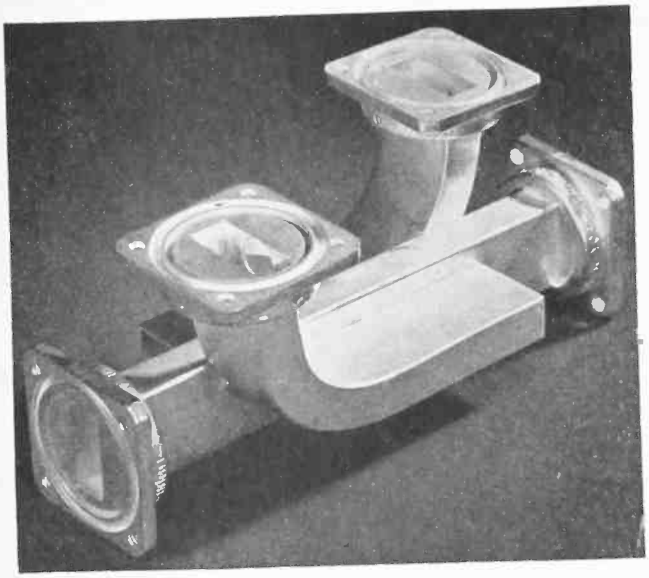
Fig. 8 illustrates a commercial version of a two-hole unidirectional narrow band wave-guide directional coupler with coaxial output connection for the frequency range of 8500-9400 mc. Fig. 9 is a narrow band bidirectional coupler or variation of Fig. 8. The latter consists of a primary wave guide attached to two secondary guides on the narrow side of the primary guide. Such a coupler may be permanently installed in a transmission line system to measure at all times both incident and reflected energy simultaneously. This particular model utilizes five holes on each side. The sizes of these holes vary, being largest for the middle hole and tapering down in size so that the first and fifth holes are smallest.

Fig. 2. Principle of two-hole directional coupler. Wave coming from left in main guide is absorbed on right-hand side of output guide and is canceled on left side of output guide. Cancellation is due to destructive interference of waves from the two coupling holes.



The absorbing material used in the auxiliary guide to keep the standing-wave ratio down may be a choice of types. Carbon impregnated bakelite is very popular because it holds its shape and does not absorb moisture. Resistor cards are also used but these have been known to deform or crack under service conditions. Another material is carbon impregnated rubber known by the trade name of "USKON." Metallized glass is highly efficient but has the disadvantage of being fragile and easily breakable.

When no directional coupler is employed in a microwave setup, the microwave transmitter or energy source sends signals down the wave-guide line to the load such as an antenna. If the antenna impedance matches the transmission line impedance, no reflection will occur at the load or antenna. Only the transmitted wave, the direct or incident one, exists in the line. If, however, the antenna impedance does not exactly match the transmission line impedance, part of the direct wave or incident en-



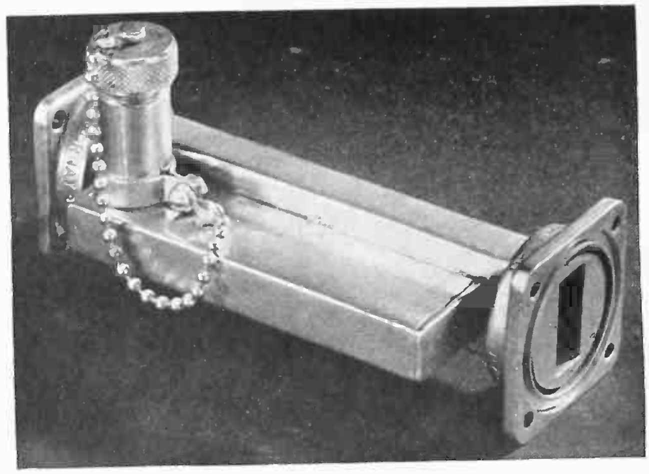


Fig. 3. (Left) Broad-band bidirectional coupler of the Schwinger type using two slots between main and each auxiliary guide. Fig. 4 (Above) Broad-band unidirectional coupler using two slots by the Schwinger method.

ergy will be reflected back to the transmitter or energy source and reduce the over-all energy available for propagation at the antenna. The presence of both direct waves or incident energy and reflected waves or reflected energy in a transmission line means that standing waves exist, reducing efficiency.

Fig. 5 shows the functioning of a

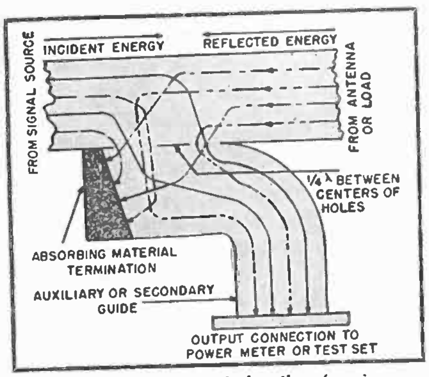


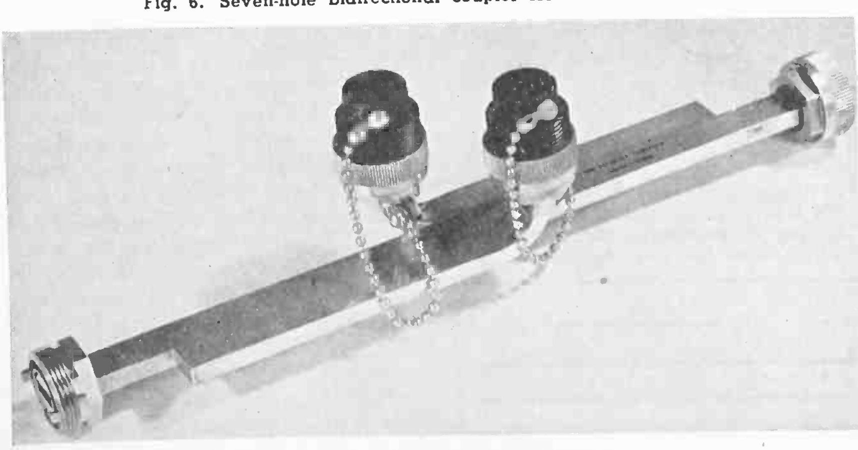
Fig. 5. Functional details of unidirectional coupler. Solid lines are in phase and add at output. Dashed lines are half-wavelength apart at termination and cancel. Same happens in case of dash-double-dot lines. Dash-single-dot lines arrive in phase and add.

directional coupler like that illustrated in Fig. 8 which is useful where standing waves are present. The presence of both direct and reflected waves is indicated. The main and auxiliary wave-guide lines are coupled to each other by two identical holes, the centers of which are a quarter wavelength apart. A portion of the direct wave couples through those two holes into the auxiliary wave guide. One portion of the direct energy comes through the first hole and then passes to the auxiliary wave-guide output flange or coaxial cable connection to a measuring device or indicator. Another equal portion of the direct energy comes through the second hole and passes to the same measuring device or indicator. The path lengths through the holes are equal in the case of direct waves. This means that the energies escaping through each of the coupling holes are in phase and will add with each other. Another path available for the direct waves through the two coupling holes to the absorbing material is self-canceling since the direct wave energy that travels from the second hole has a path which is a half wavelength longer than through the first hole. These two components arrive at the absorbing material termination out of phase so that none gets to that termination.

The reflected wave is subject to the same phenomena with none of its energy reaching the measuring device or indicator. All of the reflected energy is absorbed in the absorbing material termination. The measuring device only has a definite portion of the direct wave energy to measure and is not influenced by the reflected wave. If the position of the unidirectional coupler is reversed with respect to the load or antenna and the transmitter or signal source, the measuring device will only measure the reflected wave and will not be influenced by the direct wave. The use of a bidirectional coupler, as illustrated in Fig. 9, makes it possible to measure the reflected wave and the direct wave simultaneously by two indicating devices.

Fig. 7 is a curve showing the theoretical variation in coupling versus frequency (or wavelength) for a narrow band unidirectional coupler similar to that illustrated in Fig. 8 in the 3 centimeter band. A narrow band coupler has about a 3% bandwidth in such a band. A broad-band coupler is considered to be one with about a ten per-cent bandwidth. Such couplers of the unidirectional type are illustrated in Fig. 4 and the bidirectional type in Fig. 3. The graph of Fig. 7 shows a coupling loss of 19 to 21 db. over the 3% region with an over-all nominal rating of 20 db. coupling.

Fig. 6. Seven-hole bidirectional coupler for the 1-cm. band.



Broad Band Directional Coupler

Figs. 3 and 4 show the Schwinger broad-band type of directional coupler. As shown in Fig. 10, this type of coupler takes the two slots of Fig. 2 and places one above and one below the center line of the wave guide. In this reversed phase type of coupler, the coupling is between the longitudinal magnetic field in one guide and the transverse magnetic field in the other. This is achieved by placing the wide side ("a" dimension) of the primary guide against the narrow side ("b" dimension) of the secondary guide. The use of a slot about a quarter wavelength long results in broad-band coupling. The magnetic field is zero in the center and maximum near the walls in the guide. By using a slot type of coupling hole, more field lines are cut. In any case, regardless of the type of directional coupler, no coupling hole is really round when fabricated. It is always an ellipse to the very high frequencies involved in microwaves, as a minute deviation from "perfectly round" (such deviation always exists in mechanical practice) is appreciable

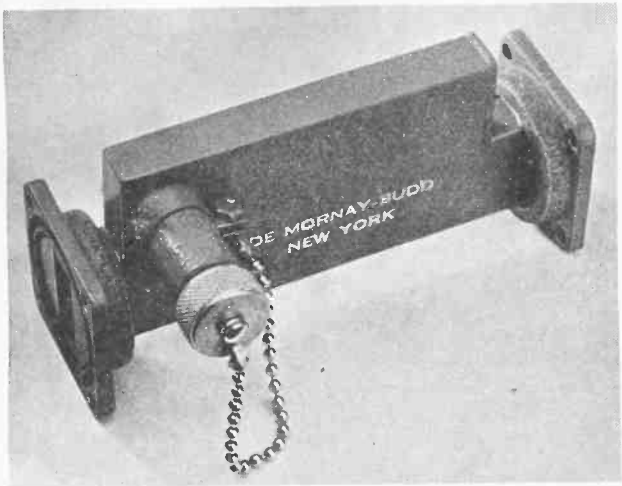


Fig. 8. Two-hole narrow band unidirectional coupler for 3 cm. band.

with respect to the wavelength. The up and down dimensions determine the coupling power into the auxiliary guide. If the two slots are closer to the center line, less power will transfer.

The longer the slots, the more closely is the resonant point of the slot approached. Approach of resonance is undesirable because it disturbs the broad-band property of this coupling. It would then tend to resonate or peak on one frequency and really have no attenuation for that frequency. The resonance of the slot would cause all power to couple out from the main guide. If the slot is too short, the attenuation is too high and coupling becomes too low. If the slots are made too wide, the directional properties will be disturbed or damaged by the coupling of the electric field component usurping that of the magnetic field. The reason that holes are used instead of probes for coupling between two guides is because the probes would be resonant at a single frequency. Fig. 11 shows the energy distribution for the dominant mode in a rectangular wave guide and where the coupling must be for maximum or minimum magnetic or electric lines of force.

Fig. 6 is a 7-hole bidirectional coupler, i.e., seven holes on each side between primary and auxiliary guides. In this case, the wavelength (1 centimeter) is so short that the wave-guide size is only ½" x ¼" outside dimensions (.42 x .17 inches inside). Smaller holes are necessary because of the reduced wave-guide pipe dimension and also because larger holes could approach the resonant point for such a short wavelength. In order to get enough coupling power for directivity functions, more holes are employed but of smaller size than at the lower frequencies.

The very large upended unit in Fig. 1 is a Bethe-Hole type of directional coupler. This particular unit uses wave-guide rectangular pipe 4" x 2" in the region of about 1200 mc. (known as the *L* band). The two wide faces of the wave guide are coupled together by a single coupling hole. This hole provides coupling to both the electric and the transverse magnetic field components.

The transverse electric and magnetic fields are in phase for a true traveling wave in the main wave guide. The magnetic dipole moment will be opposite in phase while the electric dipole moment will be in phase. The reversal of phase of one type of coupling with respect to the other results in cancellation in the forward direction relative to the direction of propagation in the main guide for the waves in the auxiliary guide. Reinforcement takes place in the backward direction. The wave in the auxiliary wave guide travels opposite in direction to the wave in the main wave guide. Cancellation and directivity are

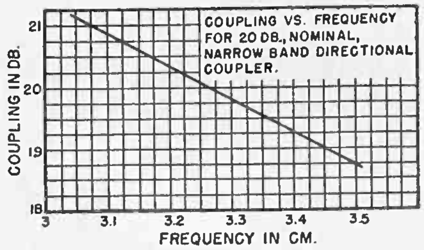


Fig. 7. Theoretical curve for coupling loss vs. change in wavelength for the 3 cm. or X band.

dependent on how nearly equal in amplitude are the waves generated by the two types of coupling (electric and magnetic). To equalize the couplings, the axis of one guide (auxiliary) is tilted with respect to the other guide as shown in Fig. 1. The magnetic coupling is reduced by an amount equal to a cosine function while the electric coupling is unchanged. The coupling hole may be considered to be a very short section of circular wave guide beyond cutoff. The wall thickness of the coupling hole has the effect of reducing the coupling and attenuating the magnetic and electric couplings by different amounts. The effect of wall thickness is to increase the proportion of magnetic coupling between the primary and secondary guides.

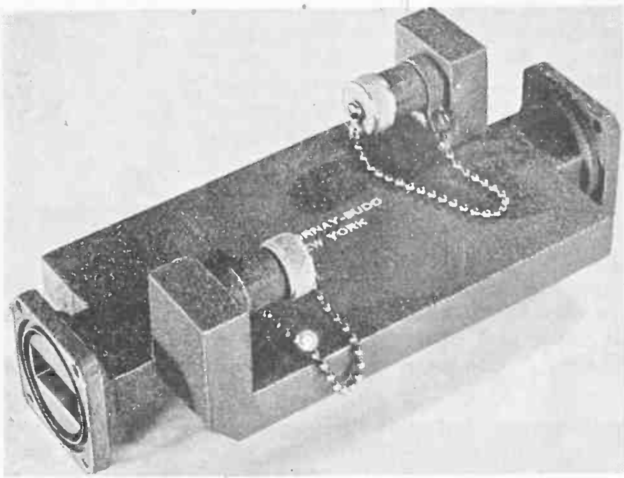


Fig. 9. 5-hole narrow band bidirectional coupler for the 3 cm. band.

Applications of Directional Couplers

A directional coupler is primarily a standing-wave detector that is independent of variations in probe coupling which normally exist where a probe is moved back and forth in a slotted wave guide (the usual standing-wave detector). It is not subject to the variations of a moving probe which result from minute mechanical imperfections. Variations in probe couplings are confused with the variations of the standing-wave pattern to an extent that they

(*Continued on page* 24)

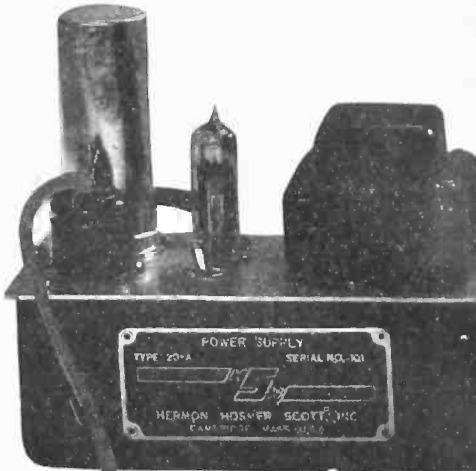
Measurement Of STUDIO And ROOM ACOUSTICS

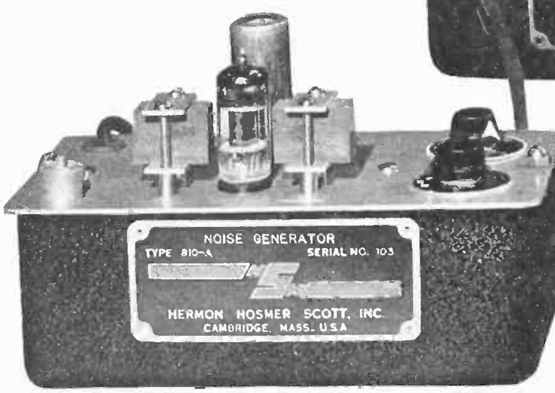
By DAVID FIDELMAN

The second and concluding part covers measurements of sound level, power output, and room acoustics.

NOISE LEVEL and sound power output are measured by use of a sound-level meter. The basic block diagram of the standard type of sound-level meter is shown in Fig. 1. The sound is picked up by a unidirectional microphone with a known frequency-response characteristic. The output of the microphone is then amplified and passed through a calibrated attenuator which serves to set the meter range. The signal is then passed through a frequency weighting network which can be set for either flat response or for either of the standard noise-measurement response curves. The output of the frequency weighting network is then amplified and measured by a vacuum-tube voltmeter calibrated to read logarithmically in decibels. The output signal is also available before rectification for operation with graphic recorders or with various types of analyzers. The meter reading is accurately calibrated in decibels relative to the standard 1000 cycle/sec. reference level of 10^{-16} watts per square centimeter.

When noise level is being measured, a truly objective measurement is impossible because of the complexity of the human hearing mechanism and because of the wide variety of noises which may





Noise generator and power supply made by H. H. Scott, Inc.

NBC studio 8-H in New York City.

be encountered. However, a reliable indication of the noise level is obtained by taking into account the frequency response of the human ear, and making the over-all response of the noise meter approximately the reciprocal of the ear response characteristic. This condition is approximated by using three different frequency characteristics for the meter for different sound levels. The three response curves which are chosen by the American Standards Association as the standard curves for noise level measurements are shown in Fig. 3. Curve A is recommended for measurement of low levels around 40 db.; curve B for levels around 70 db.; and curve C, which is flat, for very loud sounds around 80 to 100 db. The actual measurement of the noise level is performed simply by having no source of sound in the room and reading the sound level on the meter.

The sound power output of the reproducing system is measured by feeding steady tone (warbled if necessary to reduce standing waves) into the reproducing system and measuring the resulting sound intensity, with the sound-level meter set for flat frequency response. The electrical signal at the auxiliary output of the sound-level meter can also be fed to any of the standard instruments for measuring the various characteristics of audio-frequency electrical signals—harmonic analyzers, intermodulation analyzers, etc. Measurements of this type performed at various frequencies will give the characteristics over the entire audio frequency range.

The frequency response of the complete system including the loudspeaker can be measured by using the basic measurement system in the manner shown in Fig. 2A. The method is the same as for measuring frequency response of any electrical circuit, except for the warbled frequency. The electrical signal is applied to the input of the system under test. The sound output of the loudspeaker is measured by means of a microphone, amplifier and meter whose frequency characteristics are accurately known. The frequency of the test signal is then set as desired, and the meter read, to give the response characteristic over the entire audio frequency range. The microphone can also be placed in various locations throughout the room to give the spatial radiation pattern as well.

Another method of measuring frequency response is by means of a thermal noise generator and a tunable filter in the microphone amplifier circuit, as shown in Fig. 2B. The signal is supplied by a source of thermal noise, such as a diode, and is applied to the input of the reproducing system. The output of the loudspeaker is then picked up by the standard microphone, amplified and passed through a narrow band pass filter, whose band width should be independent of frequency. The output of the filter is then measured by the meter. At the present time, suitable apparatus for the generation of thermal noise, and band pass filters of the type mentioned, are commercially available and this type of measurement will in the future become very important for acoustic measurements.

Results of Acoustic Measurements in Practice

The methods which have been described have been used to determine the acoustic characteristics of rooms and auditoriums in order to obtain a measure of their performance, to aid in their redesign and improvement when they do not give optimum performance, and to obtain information to aid in new constructions.

Many measurements of reverberation time have been made in the past, and much data has been accumulated on this subject. There is no theoretical basis for the choice of desirable reverberation times, but experience has shown what is most pleasing to the ear, and standards have thus been determined subjectively. Early experience with broadcast studios has shown that when there is no reverberation the room gives a dull, lifeless effect to sounds. However, when there is too much reverberation, the energy from successive sounds tends to overlap and reduce intelligibility. The optimum reverberation time is a function of the volume of the room, and rooms for listening to reproduced music should

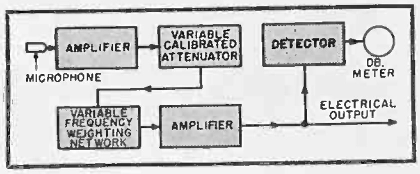


Fig. 1. Basic block diagram of a sound-level meter.

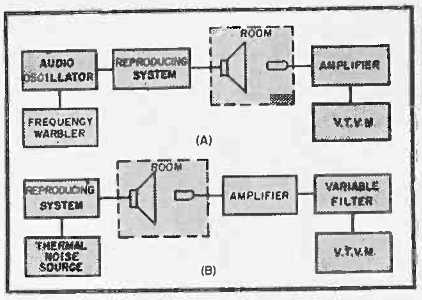
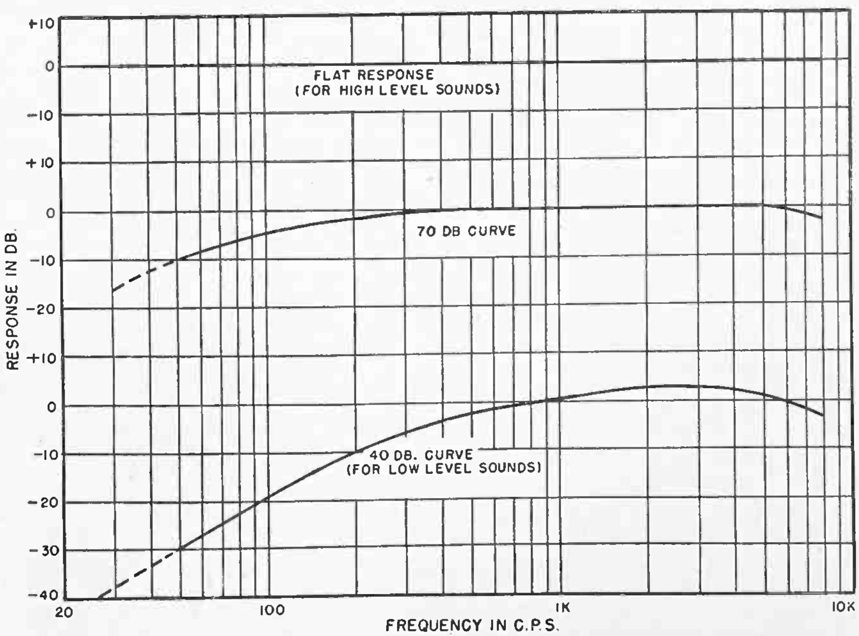


Fig. 2. Measurement of frequency response by means of (A) single-frequency method, and (B) a thermal noise generator.

have shorter reverberation times than those for live production of the same type of music because the reproduced music will already contain some reverberation from the production studio.

The optimum reverberation times for rooms as a function of volume, for a 1000 cycle test signal, are shown in the graph in Fig. 6A. The optimum reverberation time as a function of frequency relative to the 1000 cycle value is shown in the graph of Fig. 6B. The values shown in these curves do not, of course, take into account the possibilities of microphone placement and synthetic reverberation systems which are used to increase the apparent reverberation

Fig. 3. Frequency-response characteristics recommended as standard curves for noise level measurements.



Photograph of the interior of the Esquire Theater in Chicago.

time and "presence" in the reproduction of speech and music.

For a long time the acoustic qualities of rooms and auditoriums were judged primarily on the basis of reverberation times. However, experience began to show that it was possible for rooms to have the same reverberation time and still to have quite different acoustic properties. Measurements of the diffusive and the transient characteristics show that at times these facts are considerably more important than the reverberation time, and at the present time these are being given increasing importance in acoustic measurements.

The pulse method of measuring transient characteristics is an extremely important method, and often gives much more valuable data than the reverberation time and other methods. In many cases it is the only method of correlating measured data with the results observed by the listener, when other methods fail. The results of such measurements upon a number of typical auditoriums show the type of information that can be obtained. The pulse patterns shown in Fig. 4 show the results of measurements on a number of moving-picture houses whose acoustic qualities had received different degrees of acceptance by listeners over a period of several years.

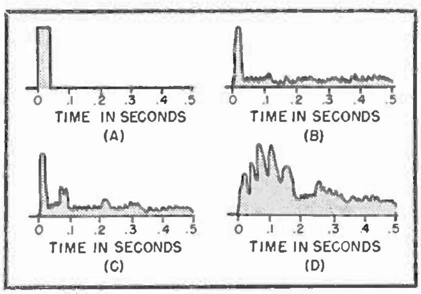
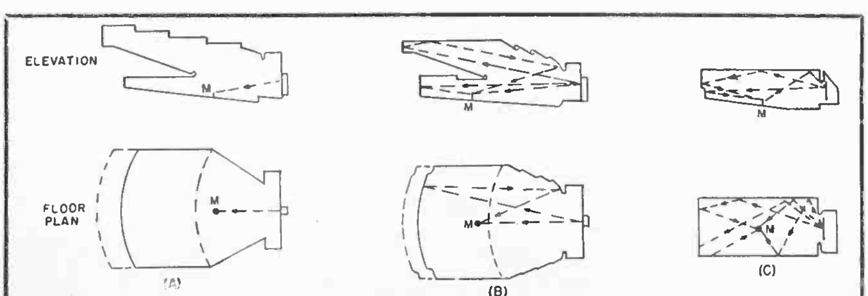


Fig. 4. Pulse patterns showing results of transient characteristic measurements on several different theaters.

An investigation was undertaken to determine the causes of the acoustic differences, since the theaters had identical sound reproducer installations, and in all cases the measured frequency characteristic and the reverberation time were found to be satisfactory. The pattern (A) (Fig. 4) shows the pulse output of the loudspeaker, which is what the microphone would pick up in a room with no reverberation. Pattern (B) is the sound picked up by the microphone in a theater with uniformly good acoustics; the physical structure of the theater is shown in Fig. 5A, showing that there are no undesirable reflections. The pulse pattern represents a bad spot in an otherwise good theater whose layout is shown in Fig. 5B. The measurement shows a reflection from the back wall at 80 milliseconds delay, and a further reflection at 220 milliseconds delay which seems to be due to a multiple reflection as shown. Pulse pattern (D) was taken in an auditorium of inferior quality, whose layout is shown in Fig. 5C. Large reflections are found at both short and long time intervals, and are the reason for the bad quality.

Fig. 5. Physical layout of theaters measured in Fig. 12, showing reflection paths for the various pulse echos.



In general, reflections with less than 45 milliseconds delay can be tolerated, but reflections with more than 50 milliseconds delay lead to a deterioration in sound quality due to lack of intelligibility. When there are large reflections at short time delays which arrive to the listener at large angles from the path of the direct sound, the directional effects of the sound are lost, resulting in a loss of "presence". In auditoriums where acoustic conditions are not optimum, the pulse technique also gives good indications of the possible locations of the reflections, and thus aids in correcting any defects in the acoustic design.

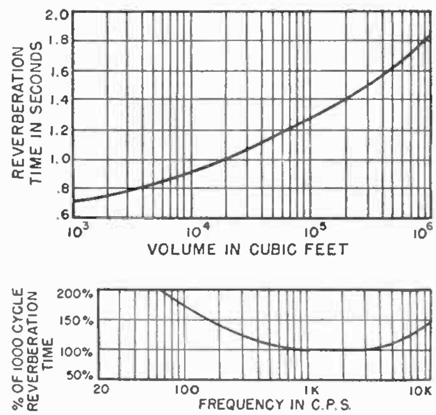


Fig. 6. Optimum reverberation time as a function of (top) room volume, for a 1000 cycle test signal, and (bottom) frequency.

These measurements have indicated what the basic points in good acoustic design are, and what rules should be followed in the design of rooms, studios and auditoriums. Some of these rules are:

(a) Maximum sound diffusion should be aimed for in all acoustic designs.

(b) The room should be as unsymmetrical as possible (with no lines or planes of symmetry), and if possible there should be no walls parallel to one another, and no concave surfaces.

(Continued on page 24)

NEW PRODUCTS

VIEWFINDER FOR TV CAMERAS

General Electric Company, Syracuse, N. Y., has announced an electronic viewfinder for *GE's* television studio cameras

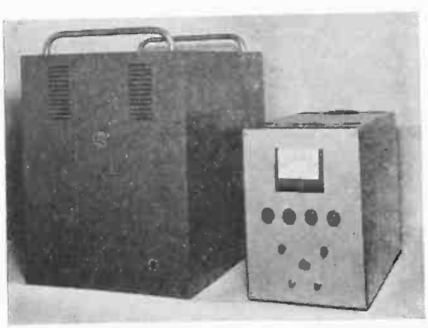
capable of giving 500 lines definition. Video response is uniform to 7.0 mc. within ±0.5 db.

According to reports, the newly developed circuits show improved performance in eliminating distortion and give the operator a brighter image as well as an exact reproduction of the scene being televised. The unit is easily serviced and has a focus coil which is adjustable in all directions.

Earl Revercomb, a *GE* Engineer, is shown looking at the new electronic viewfinder (with cover up). Further information on the viewfinder may be obtained from the Transmitter Division at Electronics Park, Syracuse, N. Y.

POWER SUPPLY

A highly regulated d.c. power supply, designed for any application requiring a voltage between 10 and 50 kilovolts with a maximum current requirement of two milliamperes, is the latest of *RCA's* scientific instruments announced



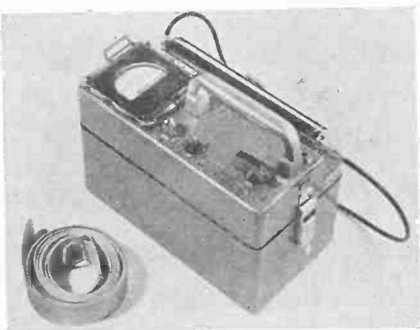
by the Scientific Instrument Section, Camden, N. J.

Pictured are the rectifier and driver units comprising the new equipment. The new power supply, *RCA* Type EME-2, makes an ideal accelerating supply for cathode-ray tubes in experimental equipment or as a permanent setup for the testing of these tubes. It is also designed for use in nucleonics.

The final output voltage is taken from the rectifier unit and can be continuously varied, by means of the controls on the driver unit, between 10 and 50 kilovolts. A meter on the front panel of the driver unit indicates the output voltage for any particular setting.

SURVEY METER

Tracerlab Inc., 130 High St., Boston 10, Mass., has just developed a Beta Gamma Survey Meter which is portable, battery operated, and weatherproof and which will serve the dual purpose of



a radiation dosage rate meter and a monitoring instrument.

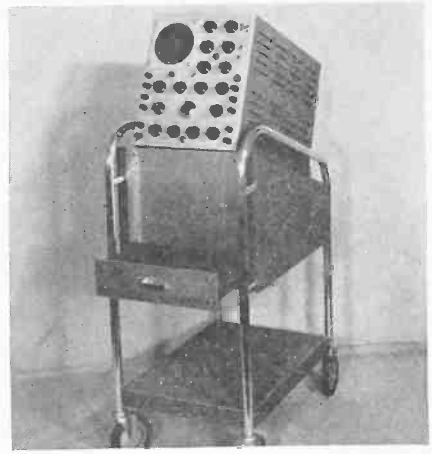
The SU-5 Beta Gamma Survey Meter uses a sensitive thin-wall Geiger tube mounted in a waterproof detachable probe and is sensitive to gamma radiation and to medium and high energy beta radiation. A removable probe shield with a wall of 1300 mg/cm^2 permits the separate measurement of gamma radiation in the presence of beta radiation with maximum energies of up to 2.5 MEV.

This meter, which uses the new *Tracerlab* TGC-5 plug-in type glass-wall Geiger tube, has a phone jack on the front panel permitting the connection of high impedance headphones for audible indications of the counting rate.

SCOPE-MOBILE

Tektronix, Inc., 712 S. E. Hawthorne Blvd., Portland 14, Oregon has especially designed Type R-500 Scope-Mobile to accommodate the *Tektronix* Type 511, 511-A, 511-AD, 512 and X-513 cathode-ray oscilloscopes. Convenient and easy observation of the CRT face is achieved by a 20° tilt back.

A blank panel, 11" x 15", fronting a mounting space of approximately 1½ cubic feet allows for auxiliary built-in equipment as an aid in meeting special-



ized requirements. A drawer is provided for storage of cords, probes, etc. The unit is constructed of aluminum alloy materials and the total "dry" weight is approximately 42 pounds.

VOLTAGE STABILIZERS

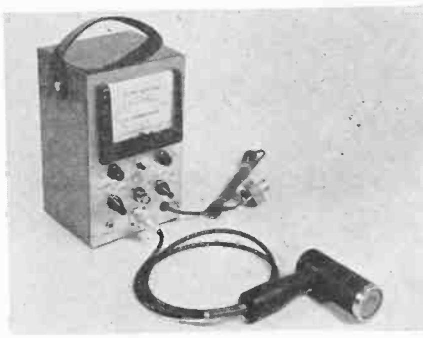
Multiple-unit type voltage stabilizers for capacities in excess of 2 kva. have been announced by *Raytheon Manufacturing Company*, Waltham 54, Massachusetts.

Multiple sections of 500 or 625 watt capacities are built up on rails and connected in parallel with input and output connections located in a separate junction box. Capacities can be built up to 10,000 watts.

Further information and typical layout drawings are available by writing to Department 6460-NR1.

RADIATION METER

The Scientific Instrument Section of the *RCA* Engineering Products Depart-

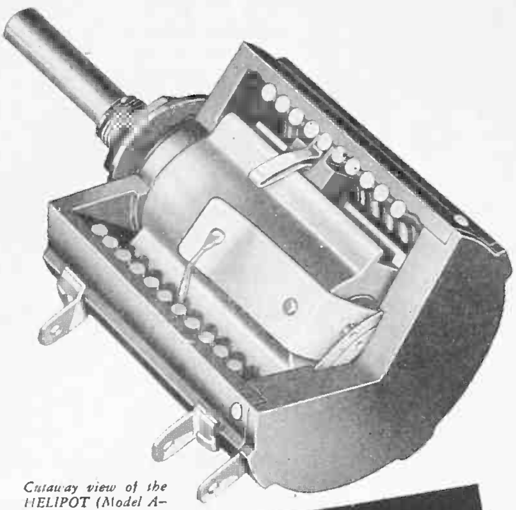


ment, Camden, N. J., has developed a meter for measuring nucleonic radiations.

The Count Rate Meter, *RCA* Type

(Continued on page 30)

For new simplicity, wide range, and high accuracy in the control of modern electronic circuits . . .



Cutaway view of the HELIPOT (Model A–10 Turn–1¾" Diameter)

THE BECKMAN Helipot

(Trademark of the HELical POTentiometer)

Provides *many times* greater resistance control in *same* panel space as conventional potentiometers!

IF YOU are designing or manufacturing *any type* of precision electronic equipment be sure to investigate the greater convenience, utility, range and compactness that can be incorporated into your equipment by using the revolutionary HELIPOT for rheostat-potentiometer control applications . . . and by using the new DUODIAL turns-indicating knob described at right.

Briefly, here is the HELIPOT principle . . . whereas a conventional potentiometer consists of a *single* coil of resistance winding, the HELIPOT has a resistance element *many times* longer coiled *helically* into a case which requires no more panel space than the conventional unit. A simple, foolproof guide controls the slider contact so that it follows the helical path of the resistance winding from end to end as a single knob is rotated. Result . . . *with no increase in panel space requirements*, the HELIPOT gives you as much as 12 times* the control surface. You get far greater accuracy, finer settings, increased range—with maximum compactness and operating simplicity!

COMPLETE RANGE OF TYPES AND SIZES

The HELIPOT is available in a complete range of types and sizes to meet a wide variety of control applications . . .

MODEL A: *5 watts, 10 turns, 46" slide wire length, 1¾" case dia., resistances 10 to 50,000 ohms, 3600° rotation.*

MODEL B: *10 watts, 15 turns, 140" slide wire length, 3¼" case dia., resistances 50 to 200,000 ohms, 5400° rotation.*

MODEL C: *3 watts, 3 turns, 13½" slide wire length, 1¾" case dia., resistances 5 to 15,000 ohms, 1080° rotation.*

MODEL D: *15 watts, 25 turns, 234" slide wire length, 3¼ case dia., resistances 100 to 300,000 ohms, 9000° rotation.*

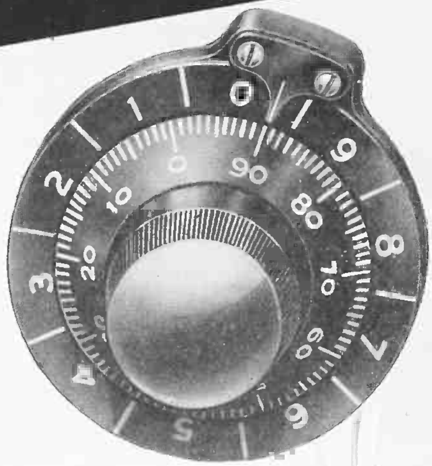
MODEL E: *20 watts, 40 turns, 373" slide wire length, 3¼" case dia., resistances 150 to 500,000 ohms, 14,400° rotation.*

Also, the HELIPOT is available in various special designs . . . with double shaft extensions, in multiple assemblies, integral dual units, etc.

Let us study *your* potentiometer problems and suggest how the HELIPOT can be used — possibly is already being used by others in your industry — to increase the accuracy, convenience and simplicity of modern electronic equipment. No obligation, of course. Write today outlining your problem.

**Data for Model A, 1¾" dia. Helipot. Other models give even greater control range in 3" case diameters.*

THE BECKMAN Duodial



The inner, or Primary dial of the DUODIAL shows exact angular position of shaft during each revolution. The outer, or Secondary dial shows number of complete revolutions made by the Primary dial.

A multi-turn rotational-indicating knob dial for use with the HELIPOT and other multiple turn devices.

THE DUODIAL is a unique advancement in knob dial design. It consists essentially of a primary knob dial geared to a concentric turns-indicating secondary dial—and the entire unit is so compact it requires only a 2" diameter panel space!

The DUODIAL is so designed that—as the primary dial rotates through each complete revolution—the secondary dial moves one division on its scale. Thus, the secondary dial counts the number of complete revolutions made by the primary dial. When used with the HELIPOT, the DUODIAL registers *both* the angular position of the slider contact on any given helix as well as the particular helix on which the slider is positioned.

Besides its use on the HELIPOT, the DUODIAL is readily adaptable to other helically wound devices as well as to many conventional gear-driven controls where extra dial length is desired without wasting panel space. It is compact, simple and rugged. It contains only two moving parts, both made entirely of metal. It cannot be damaged through jamming of the driven unit, or by forcing beyond any mechanical stop. It is not subject to error from backlash of internal gears.

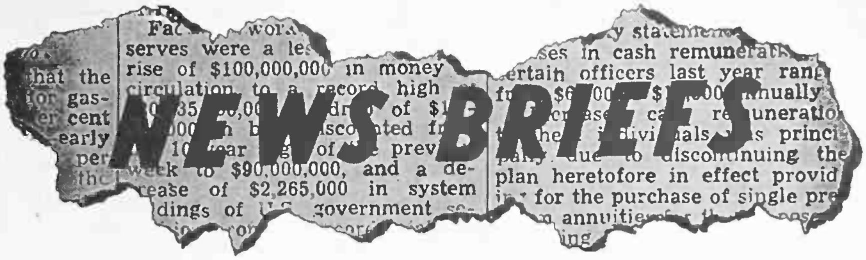
TWO SIZES—MANY RATIOS

The DUODIAL is now available in two types—the Model "R" (illustrated above) which is 2" in diameter, and the new Model "W" which is 4¾" in diameter and is ideal for main control applications. Standard turns-ratios include 10:1, 15:1, 25:1 and 40:1 (ratio between primary and secondary dials). Other ratios can be provided on special order. The 10:1 ratio DUODIAL can be readily employed with devices operating *fewer* than 10 revolutions and is recommended for the 3-turn HELIPOT. In all types, the primary dial and shaft operate with a 1:1 ratio, and all types mount directly on a ¼" round shaft.

Send for this HELIPOT AND DUODIAL CATALOG!

Contains complete data, construction details, etc., on the many sizes and types of HELIPOTS . . . and on the many unique features of the DUODIAL. Send for your free copy today!

THE Helipot CORPORATION, SOUTH PASADENA, 4, CALIFORNIA



TV TUBE MANUFACTURING

An operator is shown mounting a 16 inch metal-cone TV tube on the

exhaust machine at the *General Electric Co.* tube plant, Electronics Park, Syracuse, N. Y.

Quick exhaust is obtained by means of a conventional vacuum pump, and a diffusion pump completes the process. While pumping is in progress, the tubes are heated to drive out occluded gases. Both the 8½ in. and 16 in. metal-cone tubes can be accommodated on this machine.

REPORT GAIN IN ELECTRONICS IN THE WEST

Figures revealed by the West Coast Electronic Manufacturers' Association, sponsors of the annual convention, show heavy gains in attendance, interest and participation. The 1949 exhibit, held early in September at San Francisco, drew nearly 6,500 delegates.

Attendance totals alone were better than 20% above 1948 figures, and over 25% gain was registered in terms of commercial exhibitors.

A breakdown of participation in the 1949 exhibit showed 17% manufacturers, 12.9% distributors, 13.0% Government operation, other than research, 10.5% educational institutions, and 12.4% miscellaneous, including publishers, students, etc.

ARCHITECTURAL AWARD

Dr. Bennett S. Ellefson, Director of *Sylvania's* Central Engineering Laboratories, has received a bronze annual award plaque for "excellence in architectural design and civic value" of *Sylvania's* new physics laboratory at Bayside.

The plaque is one of eight first prize annual awards by the Chamber of Commerce of the Boro of Queens for different classes of buildings. The laboratory, located on Cross Island Parkway overlooking Long Island Sound, is

of two story brick and steel construction which includes a penthouse, basement, and 38,000 square feet of working space for long-term research and development of electronic and lighting products.

1950 IRE OFFICERS ANNOUNCED

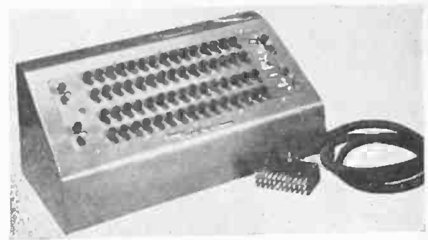
Raymond F. Guy, Manager of Radio and Allocations Engineering for *NBC*, and Sir Robert Watson-Watt, Governing Director of *Sir Robert Watson Watt and Partners, Ltd.*, of London, England, have been elected president and vice president, respectively, of the IRE for 1950.

Candidates elected as Directors-at-Large for the 1950-51 term are: William R. Hewlett, Vice President of *Hewlett Packard Company* of Palo Alto, Calif.; and James W. McRae, Director of Electronic and Television Research of *Bell Telephone Laboratories, Inc.*, Murray Hill, N. J.

PUSH-BUTTON TWO-WAY RADIO SYSTEM INSTALLED

A new two-way radio system with a 60 button selective calling box was recently installed by *Taxicab Service, Inc.*, of Newark, N. J. The unit, called the Quik-Call system and manufactured by *Motorola Inc.*, Chicago, Illinois, makes it possible for the dispatcher to talk to each cab individually, without transmitting to the rest of the fleet.

Many additional ways to extend the area of operation with this system are said to be possible; such as control of a



remote transmitter and receiver from the dispatcher's desk, intercom facilities between dispatchers at separated points, and provisions for making group calls when desired.

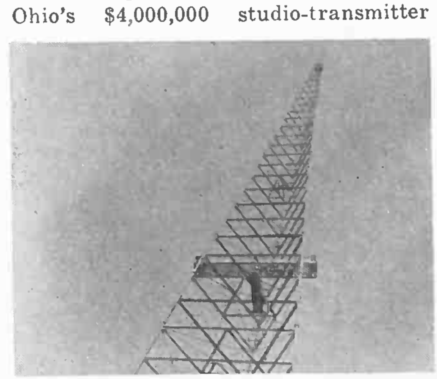
MACHINE ANALYZES TELEMETRY RECORDS

A machine which has been described as being able to read, count, sift, scan, decode, correct and plot multiple quantitative instrument records taken from line pictures on film has been developed by *Douglas Aircraft*. The development of this machine and its labor and time saving merits in analyzing telemetry records from a V-2 flight were announced at the annual meeting of the American Society of Mechanical Engineers in New York recently.

Heretofore, in the ground recording of the performance of missile-borne instruments, hundreds of thousands of recorded lines and their lengths had to be measured and the values calibrated and plotted to suitable scales manually, which is a slow and costly process. According to Bernard S. Benson, research engineer with *Douglas*, this machine effected a savings of more than $9,000 for a single record as compared with the cost of manual analysis.

WXEL TO ERECT 438-FT TV TOWER

Finishing touches on Cleveland, Ohio's $4,000,000 studio-transmitter



building are now being completed with the erection of a 438-foot television

(*Continued on page* 28)

NEWS!

SYLVANIA 16-INCH *RECTANGULAR* TELEVISION TUBE

New short-necked picture tube in rectangular bulb makes possible smaller TV cabinets—better pictures!

At last . . . the tube that presents 100% of the transmitted picture and eliminates all unused viewing screen area. The Sylvania 16TP4. Made of special lighter weight glass, this rectangular shaped tube in the new glass is 30% lighter than round 16" glass tubes. This is a new opportunity for set makers to design TV sets customers have been waiting for . . . sets designed to match the depth and height of other home furniture without loss of picture size.

Sylvania 16TP4 rectangular tubes have a relatively flat face . . . incorporate neutral gray filter which gives better picture contrast. New slanted electron gun design requires only single ion trap magnet . . . helps to reduce length of tube . . . permits use of shorter deflection coils!

See your local Sylvania Distributor or write to Sylvania Electric Products Inc., Department R-2302, Emporium, Pennsylvania.

SYLVANIA ELECTRIC

RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES, SIGN TUBING; LIGHT BULBS; PHOTOLAMPS

NEW TUBES

"RUGGEDIZED" TUBES

Sylvania Electric Products Inc., New York, N. Y., has announced five types of radio tubes specially designed to

provide dependable communications service under conditions of severe vibration and shock.

The first of approximately twenty types being designed include 6X5WGT, a full wave rectifier; 6L6WGA, a beam power amplifier; 28D7W, a double beam amplifier; 6SL7W, a high-mu duotriode; and 6SN7W, a medium-mu duotriode.

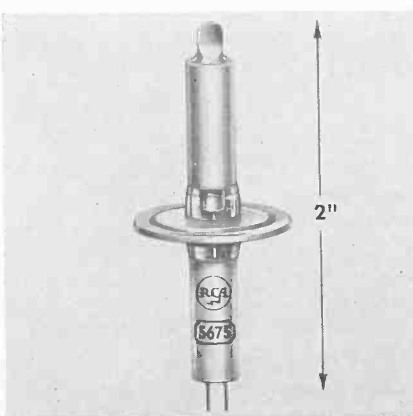
Electrical characteristics and circuit applications of these tubes are similar to corresponding types.

RCA TUBES

"Pencil-type" Triode

The Tube Department of the *Radio Corporation of America*, Harrison, N. J., has now available the 5675 medium-mu triode for use in grounded-grid circuits at frequencies as high as 3000 mc.

The 5675 utilizes "pencil-type" construction and employs a coaxial-electrode structure of the double-ended type in which the plate cylinder and the



cathode cylinder, each only ¼" in diameter, extend outward on opposite sides of the grid flange. The over-all length of the structure is only 2⅜ inches maximum.

As a local oscillator, the 5675 is claimed to be capable of giving a power output of 475 milliwatts at 1700 mc. and about 50 milliwatts at 3000 mc.

Multiplier Phototube

The 1P21 Multiplier Phototube has now been improved by the reduction of the equivalent noise input to 5×10^{-13} lumen as the result of an intensive development program by *RCA*. This value shows a 6 times improvement over that of 1P21's previously available.

In addition, the improved 1P21 features a combination of extremely high photosensitivity, very high secondary-emission amplification, and very small d.c. dark current. It is recommended for applications involving extremely low light levels such as in the use of specialized scientific equipment; namely, photoelectric spectrometers, astronomical telescopes, and scintillation counters utilizing "light piping."

Miniature Pentode

A sharp-cutoff pentode of the 7-pin miniature type has also been announced by *RCA*. The 6CB6 is designed espe-

cially for video i.f.-amplifier service at frequencies in the order of 40 mc., as well as for use as an r.f. amplifier in v.h.f. television tuners.

The 6CB6 features high transconductance combined with low interelectrode capacitances, and separate base-pin terminals for grid No. 3 and cathode.

GE TUBES

Custom Miniature Tubes

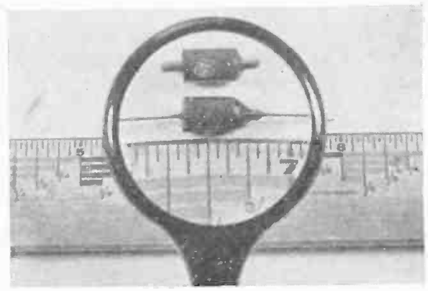
The Tube Divisions of the *General Electric Company* at Schenectady, N. Y. have announced the third and fourth in a series of custom miniature tubes for use in altimeters, radio compasses, radio control equipment and h.f. aircraft radio receivers and transmitters.

The GL-5814 is a heater-cathode type medium-mu twin triode and is designed for dependable operation where conditions of severe shock or prolonged vibration are encountered. Heater voltage is 6.3 volts at 0.350 ampere for parallel operation and 12.6 volts at 0.175 ampere for series operation. Maximum plate voltage is 330 volts and the plate dissipation is 3.03 watts.

The GL-5751 is a high-mu twin triode designed for long life under conditions of intermittent operation. Cathode heater voltage is 6.3 volts at 0.350 ampere or 12.6 volts at 0.175 ampere. The maximum plate voltage is 330 volts and the plate dissipation is 1.1 watts.

TV Germanium Diodes

GE at Electronics Park has announced a u.h.f. welded germanium



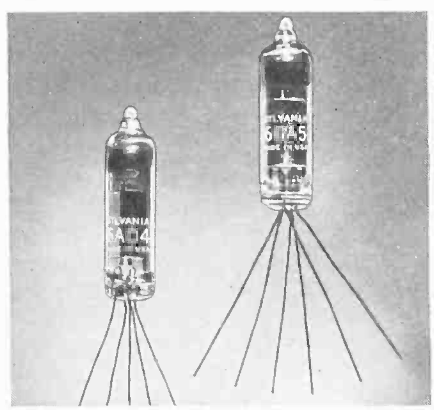
diode and two new types for use in v.h.f. television receivers.

The u.h.f. germanium diode is currently available for use in the 500 to 1000 mc. range and is designed for use as a converter. It is self-healing under temporary over-voltage conditions.

The two new diodes for use in present v.h.f. television receivers are the 1N64 and the 1N65. The 1N64 is designed and selected for optimum efficiency in video detector circuits and the 1N65 is designed for use as a d.c. restorer in TV circuits and is especially selected to provide high back resistance.

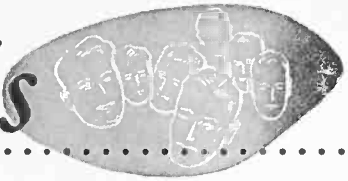
AMPLIFIER TUBES

Sylvania Electric Products Inc., New York, N. Y., has designed two new subminiature tubes for use as Class A a.f. amplifiers or resistance coupled a.f. amplifiers.



Type 6AD4 triode has a mutual conductance of 2700 micromhos. The 6BA5 pentode rating is 3300 micromhos. Both tubes are enclosed in T-3 envelopes and are supplied with 6.3 volt, 150 milliampere heaters.

Personals



ROBERT FULTON has been appointed superintendent of the Plastic Metals Division plant of *The National Radiator Co.*, Johnstown, Pa., where he will supervise all phases of the production of metal powders which are used in the fields of powder metallurgy, electronics and chemistry. For the past four years, Mr. Fulton has been affiliated with *The Indiana Steel Products Co.*, as production manager of the Eastern Division at Chauncey, N. Y.

NICHOLAS E. GOLOVIN has been appointed Assistant to the Director of the National Bureau of Standards and will assist the Director in analysis in planning related to technical program matters. Mr. Golovin was formerly Head of the Management Division on the Staff of the Commander, Naval Ordnance Test Station, Inyokern, Calif. A member of the American Economic Association and the APS, he received an A.B. in mathematics from Columbia.

ANTHONY H. LAMB has been appointed vice president of the *Weston Electrical Instrument Corp.*, Newark, N. J. to assume responsibility for the operation of the Tagliabue Division of the company. Mr. Lamb is credited with eighty U. S. and foreign patents and is well-known for his pioneering activity in the field of photoelectricity. He is a member of the AIEE; IES; ASTM, ISA, and the National Society of Professional Engineers.

MAX M. LEE has joined the research staff of the National Bureau of Standards as a chemist. Before joining the Bureau, Mr. Lee was a senior research chemist with the *Hercules Powder Company*. He received the degree of Bachelor of Chemical Engineering from Ohio State University and the degree of Master of Science in organic chemistry from the University of Rochester. He is a member of the American Chemical Society and Sigma Xi.

LUCIEN P. TUCKERMAN, formerly chief engineer for the *International Industrial Development Company*, has joined the staff of the National Bureau of Standards as liaison engineer in the Guided Missiles Laboratory. During the war he served as a Commander at the U. S. Navy Bureau of Ordnance and was also project officer for the "Bat" Guided Missile. Mr. Tuckerman is a senior member of the IRE and holds a patent for a peak limiting amplifier.

WILLIAM VASSAR, engineering assistant at *Emerson Radio and Phonograph Corp.*, New York, N.Y., has been named Chief Engineer. Mr. Vassar joined *Emerson* in 1934 and rejoined the company in 1944 after working with the Chemical Warfare Services during the war. He is Chairman of the Safety Committee of the Receiver Section of RMA; and a member of the Underwriters' Laboratories Industry Advisory Conference.

Acoustic Meas.

(*Continued from page* 16)

(c) Large surfaces should be broken up by randomly distributed irregularities such as convex spherical bumps and cylinders, and serrated surfaces. Absorbing material broken into small patches also aids diffusion. At the present time, radio broadcasting studios, theaters, and auditoriums are being built according to these rules for best acoustic qualities.

The measurement methods which have been described in this article are being more and more widely used to give an objective indication of acoustic quality, and their application will result in continuing improvements in acoustic design and construction.

REFERENCES

1. *Mason, C. A. & Moir, J. "Acoustics of Cinema Auditoria"; J. Inst. of Electr. Eng.; v. 88, part III, p. 175-190; Sept. 1941.*
2. *Moir, J. "Acoustics of Small Rooms and Studios"; Electronics, p. 286, Feb. 1945.*
3. *Bolt, R. H. "Studio Acoustics"*; RADIO-ELECTRONIC ENGINEERING; *p. 5-7, Dec. 1945; p. 8-10, Jan. 1946.*
4. *Olson, H. F. "Elements of Acoustical Engineering" (D. Van Nostrand Co., New York, 1947).*

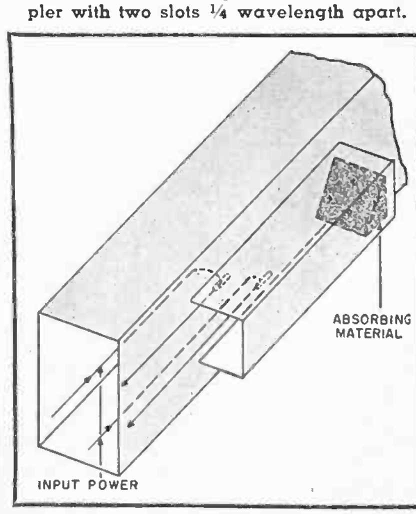
Directional Couplers

(*Continued from page* 13)

cause errors in measurement. Where a standing-wave pattern is of low amplitude, probe coupling variations of a slotted line type of standing-wave detector can even exceed the standing waves under measurement so that such measurements become meaningless or impossible. A coupling hole or slot eliminates the need for the probe entirely, which is a great advantage.

Another great advantage of the directional coupler is that it can measure the direct and reflected waves separately whereas a slotted line type of standing-wave detector must measure them together. It is actually possible to couple to one and not to the other of these two types of waves in the case of a unidirectional coupler, or

Fig. 10. Schwinger type directional coupler with two slots ¼ wavelength apart.



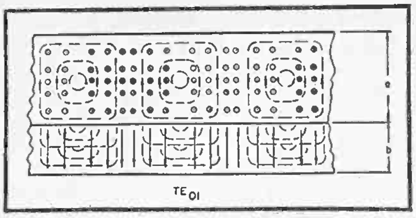


Fig. 11. Electric and magnetic lines of force for the dominant ($TE_{0,1}$) mode.

to separately couple to both in the case of a bidirectional coupler. The same equipment used to measure the output of a standing-wave detector may also be used to measure the output of a directional coupler.

When a unidirectional coupler is used instead of a bidirectional coupler, connecting the flange ends of the primary wave guide in one direction may measure the reflected wave, while reversing it may measure only the incident wave. The relative magnitude of the reflected wave can be determined by the ratio of these two responses. Determination of the magnitude of the reflected wave is sufficient to know how well a transmission line is matched to its load, before, during and after transmitter, line or load adjustments.

Directional couplers are actually fixed attenuators. Since the amount of attenuation varies with change of frequency or wavelength, these couplers may also serve as narrow band frequency or wave meters.

Directional couplers can be used to measure the amplitude but not the phase of the voltage standing-wave ratio. In order to measure the phase also, a probe would have to be inserted into the directional coupler. This is not normally done. Elaborate microwave systems employ both a standing-wave detector of the slotted line type and a directional coupler. The latter is much simpler and cheaper to construct. Some setups which cannot afford a standing-wave detector will rely on the directional coupler costing a tenth as much.

Innumerable variations of the coupling apertures between the primary and auxiliary wave guides are conceivable and even feasible. The aperture must be able to radiate or leak a small portion of the energy into the auxiliary wave guide from the total energy flowing in the primary wave guide. It should do this without having a resonant dimension or an aperture thickness which disturbs the desired coupling effect.

It offers interesting opportunities to experimenters in modifying existing types developed during World War II or being commercially produced during the postwar period. It can very well be a poor man's most useful tool in getting one entrenched in the microwave portion of the radio spectrum.

TECHNICAL BOOKS

"ELECTRONICS MANUAL FOR RADIO ENGINEERS" by Vin Zeluff and John Markus. Published by *McGraw-Hill Book Company*, 330 West 42nd St., New York 18, N. Y. 879 pages. $9.50.

This volume, like the first of its kind published several years ago under the title of "Electronics for Engineers", is intended to solve the problems of engineers in their time-consuming process of research through technical literature for desired information.

289 articles which have been published in *Electronics* during the years 1940-48 are cross-indexed for quick and easy reference and contents are arranged according to the major interests of those in the radio field: Antennas; Audio; Circuit Theory; Components; etc. Practicing engineers will find practical circuit information among the many articles. Mathematical foundation needed by radio design engineers and researchers is covered, and articles on the subjects of measuring and operating techniques for radio operators, technicians and maintenance men are included.

This handy reference volume containing the significant work of other engineers will save engineers in the radio broadcasting, communications, manufacturing and research fields, hours and even days of searching for material.

"RADAR SYSTEMS AND COMPONENTS" by Members of the Technical Staff, *Bell Telephone Laboratories*. Published by *D. Van Nostrand Company, Inc.*, 250 Fourth Ave., New York, N. Y. 1042 pages. $7.50.

Typical of the response of American scientists and development organizations to the nation's critical need, one-half of *Bell Laboratories*' total war effort was devoted to radar. This compilation of papers, originally published in the *Bell System Technical Journal*, is a result of the development and research conducted at the Laboratories.

Mr. E. Peterson describes power pulse coils and their applications in his paper on "Coil Pulsers for Radar." Sealed-gap units developed at the Laboratories are described by F. S. Goucher, J. R. Haynes, W. A. Depp, and E. J. Ryder in "Spark Gap Switches for Radar." The gas-discharge tube used in the single antenna application is discussed by A. L. Samuel, J. W. Clark, and W. W. Mumford in "The Gas-Discharge Transmit-Receiver Switch." H. T. Friis and W. D. Lewis present the story of the radar antenna research and development at *Bell Laboratories.*

The fifteen papers included in this volume present a clear and complete record of the scientific advances achieved in the field of radar, and scientists and engineers working in that field will find this a valuable reference book.

"FREQUENCY MODULATED RADAR" by David G. C. Luck, *RCA Laboratories*. Published by *McGraw-Hill Book Company*, 330 W. 42nd St., New York 18, N. Y. 466 pages. $4.00.

In conjunction with a program of research and development in the field of FM radar initiated by *RCA Laboratories*, the original form of this book was prepared as a final report to the Navy covering the principles and possibilities of FM radar. The production equipment described in this volume is based on engineering prototypes developed at *RCA Laboratories.*

The general principles of distance and speed determination by FM radar is discussed in this practical reference book and radio apparatus found useful in this field is described, as well as certain indicating or control devices suitable for utilization of FM radar data.

Although the author has assumed that the reader is familiar with the normal techniques of radio engineering, the material is complete enough to be of value to readers entirely unfamiliar with the specialized subject of FM radar. Simple concepts are used to develop theory and apparatus is described in terms of generally useful techniques.

"FUNDAMENTALS OF RADIO-VALVE TECHNIQUE" by J. Deketh. Published by N. V. Philips' Gloeilampenfabrieken, Netherlands. Distributed by *Elsevier Book Co. Inc.*, 215 Fourth Ave. New York, N. Y. 535 pages. $5.00

This book has been written to give engineers and technicians, not specialized in radio and allied techniques, an impression of the construction and functioning of radio valves and their applications in receiving sets and other electronic apparatus. The physical fundamentals of electronic valves are given with a brief description of their construction and manufacture. Valves of very recent design, and the all-glass Rimlock valves, are included.

The author explains such notions as valve noise, short-wave properties, low-frequency inverse feedback and emphasizes the more important aspects. An appendix which gives an important collection of definitions, formulae, tables and graphs is included to be of help in designing electronic apparatus.

Microwave Techniques

(*Continued from page 6*)

Several other special solutions are of interest, namely the case where $Z_t = Z_0$, and the general solutions for a quarter-wavelength and half-wavelength lines. Substituting these values in Eqt. (9) we obtain:

$$Z_{in} = Z_0 \text{ for } Z_t = Z_0 \qquad (10)$$

$$Z_{in} = \frac{(Z_0)^2}{Z_t} \text{ for } \beta l = \lambda/4 \qquad (11)$$

$$Z_{in} = Z_t \text{ for } \beta l = \lambda/2 \qquad (12)$$

Eqt. (10) indicates that when a line is terminated in its characteristic impedance, the impedance looking into this line is independent of l^o and is always equal to Z_0. This means that no reflections or standing waves occur. The line is, therefore, matched to the load since all the energy transmitted down the line is absorbed by the terminal resistance.

Eqt. (11) indicates that a quarter-wave line "inverts" the load impedance. As shown in Fig. 9, a short-circuited quarter-wave line looks like an open circuit; an open circuited line like a short; an inductance like a capacitance; and a capacitance like an inductance. This characteristic of the quarter-wave line is used to match two lines or other sources of different characteristic impedance. The quarter-wave line is connected between the two lines. A nomograph for calculating quarter-wave matching sections will appear in the March issue. The impedance looking into the quarter-wave line, Z_1, using Eqt. (11) is:

$$Z_1 = \frac{(Z_{02})^2}{Z_{01}} \qquad (13)$$

If Z_1 is made to be equal to the characteristic impedance of the second line, Z_{03}, then the system will be perfectly matched. This is achieved by making the characteristic impedance of the quarter-wave line equal to:

$$Z_{02} = \sqrt{Z_{03} Z_{01}}, \quad \therefore \frac{(Z_{02})^2}{Z_{01}} = Z_{03} \qquad (14)$$

Eqt. (12) indicates that when the transmission line is exactly one (true also for a multiplex of) half-wavelength long the input impedance is exactly equal to the terminal impedance.

Conclusion

In examining the characteristics of transmission lines whose lengths are comparable to the wavelengths of the applied signal, it has been shown that it is possible to simulate an inductance, capacitance, series or parallel tuned circuit, or a resistance by properly choosing the line parameters. It is important to note, however, that the equivalence may hold only for one particular frequency, since the reactance of a lumped element, such as inductance, varies linearly with frequency, while the reactance of a transmission line varies exponentially with frequency as indicated in Fig. 4. Selection of line parameters should therefore be made on the basis of matching reactance curves over the complete frequency band for which the equipment is designed.

Fluid Velocity

(*Continued from page* 10)

direct reading of velocity. The second unit can be adjusted to give zero output reading for any finite value of velocity by bucking out both the extraneous voltages and the voltage generated in the fluid by the specific velocity. This second unit will then deliver an amplified voltage output proportional to the absolute change in velocity above or below the reference velocity. In addition, the amplified output voltage will shift phase by 180 degrees when the velocity moves from below the reference to above it. This phase indication of the direction of change, and the magnitude indication of the magnitude of change supply the ideal input voltage for a servomechanism regulator to keep the velocity at the predetermined value.

The pilot model developed at Purdue consisted of a 60 cycle electromagnet that supplied 5000 lines per square inch flux density across a glass tube of 10 millimeters inside diameter. The glass tube was electrostatically shielded by winding magnet wire around it, leaving the ends of the wire free, and grounding the midpoint. This produced an eddy-current free shield. The two test electrodes were bonded into the glass and one was grounded to the wire shield. The second electrode supplied the grid of a pentode cathode-follower designed for maximum input impedance. The hum-bucking circuit was of conventional design, and supplied a variable magnitude and variable phase 60 cycle signal directly to the cathode of the pentode cathode-follower. The combined input signal and hum-bucking signal were delivered to a two-stage triode amplifier with inverse feedback. This output was fed to another identical two-stage amplifier and then to a triode cathode-follower. The output voltmeter was capacitively coupled to the output of the cathode-follower. The total amplifier design was such as to produce a second harmonic gain of 27 per-cent, third harmonic gain of 8 per-cent, of the fundamental 60 cycle gain of 8000. Results of tests with the pilot model indicated that the voltage output of the transducer was perfectly stable and linear at 0.195 millivolts per foot per second before amplification. The amplifier supplied an output voltage of 1.42 volts per foot per second. The harmonic frequencies were reduced to less than one per-cent of the fundamental. No extraneous voltages were noted, and a zero output could be adjusted and held for zero velocity, or for any other finite velocity.

The results indicated that little, if any, of the generated voltage could be assigned directly to *IR* losses in the fluid. Calculations indicated that an ideal conductor would have produced a voltage only 0.02 millivolts per foot per second more than that noted experimentally. As the input impedance of the input tube is raised, the current drain from the transducer is lowered, and the conductivity of the fluid should become less and less relevant. Future research is required to determine to what extent the conductivity of the fluid can be ignored under actual application conditions. Investigation of the possibility of applying the principles discussed to the measurement and control of gases might also be attempted.

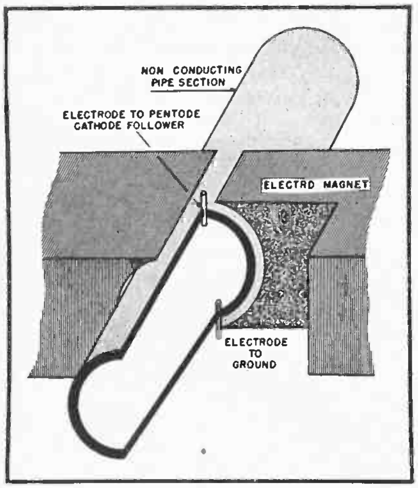
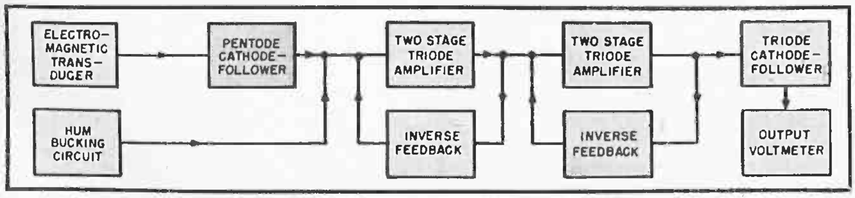


Fig. 2. Electromagnetic transducer for measuring fluid velocity.

Fig. 3. Block diagram of the electromagnetic fluid velocity meter.



New Photocell

(*Continued from page 9*)

$$E_o = A\,[K_1L_1 - K_2L_2\,(E - E_o)]\ . \quad (9)$$

Solving for E_o gives:

$$E_o = \frac{AK_1L_1}{1 + AK_2L_2} - \frac{AK_2L_2E}{1 + AK_2L_2}\ . \quad (10)$$

If $AK_2L_2 >> 1$ then:

$$E_o \approx \frac{K_1L_1}{K_2L_2} = E\ . \quad (11)$$

At low values of L_2 this relation breaks down, but where it holds true it depends only on the phototube constants K_1 and K_2 which are quite stable. In practice the instrument is calibrated by use of a tungsten filament set at a known temperature and followed by a mechanical light-chopper.

A complete circuit diagram is shown in Fig. 4. The differential amplifier uses two 1620 tubes operated at low voltages to reduce grid current. A pentode was used in the common cathode circuit to give a very high effective cathode resistance without excessive voltage drop. With the aid of a potentiometer which varies the μ of one of the tubes by varying its plate voltage, good suppression (over 70 db.) of the common mode was obtained.

The main amplifier was a.c. coupled with low frequency compensation used to give corner frequencies below one cycle so that Diesel engine firing rates of 5 per second could be handled. The high frequency corner frequencies were all above 1 mc. except for one which was set at 3 kc. in the interests of loop stability. It should be noted that because the differential equation describing this circuit has variable coefficients the frequency response requirements are somewhat more stringent than if the coefficients were constant as in the ordinary feedback amplifier. A phase inverter was used in the last stage of the amplifier to provide push-pull output for the indicating oscilloscope and to provide a neutralizing voltage.

The pyrometer feedback loop was found to be stable for a gain of 104 db. exclusive of the phototube. This, together with Eqt. (1) and the value of the phototube load resistor (1 megohm) gives the loop gain as:

$$A = 618\,L\ . \quad (12)$$

Thus a minimum light intensity of the order of 0.15 foot-candles is necessary for one per-cent accuracy. This must be corrected for spectral response of the phototube, in practice. Noise calculations indicate that if light intensity is reduced to 0.016 foot-candles *or* one tenth of the above value the signal-to-noise ratio will still be a safe 30 db. Thus some improvement of the loop gain characteristics to permit higher gain and the measurement of lower light levels is permissible before noise troubles become serious.

The initial adjustments on this circuit were made with the aid of two independent sources of light and a mechanical light-chopper. Preliminary tests of the complete device including the prism have been made with light from a Diesel cylinder and have indicated that it operates satisfactorily.

Acknowledgements

The development of this phototube and pyrometer circuit would not have been possible without the encouragement and assistance of Professors P. S. Myers and O. A. Uyehara. The phototubes were obtained through the cooperation of Dr. Pakswer and others of the *Continental Electric Company*.

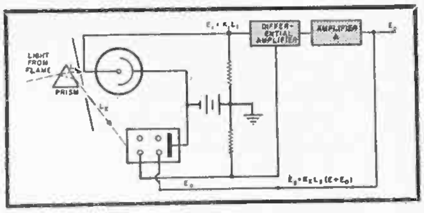
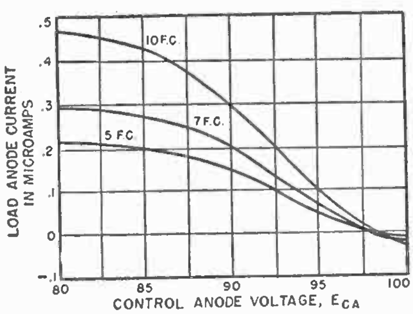


Fig. 8. Simplified diagram of the new pyrometer using the new photocell.

REFERENCES

1. *Uyehara, Myers, Watson and Wilson, "Flame-Temperature Measurements in Internal Combustion Engines". Trans. A.S.M.E., Vol. 68, No. 1, 1946, pp. 17-30.*
2. *Myers and Uyehara, "Flame-Temperature Measurements—Electronic Solution of the Temperature Equations", S.A.E. Quart. Trans., No. 1, 1947, pp. 592-611.*



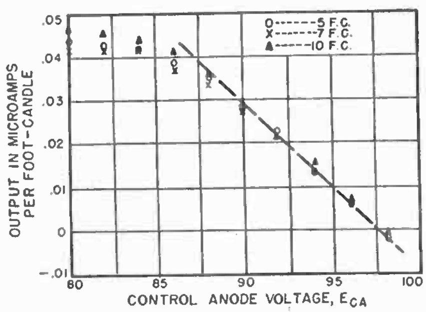
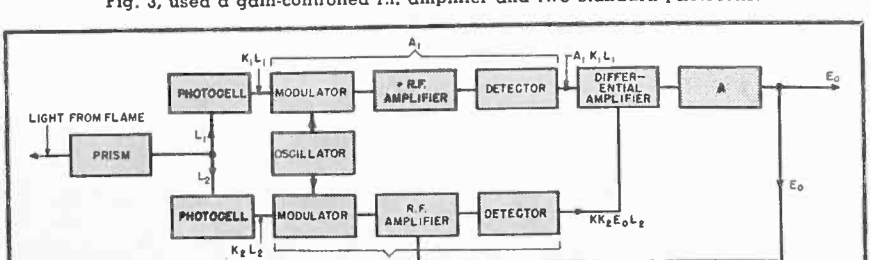


Fig. 5. (Left) Static response curves for the new tube. Fig. 6 (Right) combined curve of microamperes per foot-candle vs. control voltage, from data of Fig. 5.

Fig. 7. The early form of the pyrometer, based on the divider circuit of Fig. 3, used a gain-controlled r.f. amplifier and two standard photocells.



News Briefs

(*Continued from page 20*)

tower with its 6-bay high band *General Electric* antenna. The new Cleveland station will also use *GE's* 5-kw. high band television transmitter and studio equipment.

Shown is the television tower with its 6-bay high band antenna made at Electronics Park in Syracuse.

Herbert Mayer, President of *Empire Coil Company*, is manager of Cleveland's third TV station and Tom Friedman is chief engineer.

HARBOR RADAR INSTALLED

The third major port in the world to put into operation a harbor radar system is Baltimore Harbor. The equipment will be used in a navigational aid research program designed to assist ships entering and leaving the port in fog and bad weather, to provide continuous observation of harbor shipping, and to give immediate information on the location of any shipping casualties in the harbor.

The radar equipment, a *Westinghouse* commercial marine radar unit, provides operators with a 12½-inch radar chart of harbor shipping movements at ranges from 80 yards to 40 miles. It is installed at the City Recreation Pier in the radio control room and radar observations are transmitted directly to harbor shipping over stations WMH and WJY, the city's ship-to-shore radio stations.

The radar unit consists of three major parts, one of which, the console, is located in the transmitter room. The antenna, protected by a large mushroom-like plastic dome, is located atop one of the radio towers. The radar scope picture is shown on the disc-like face of a 12½" cathode-ray tube similar to those used in television, mounted in the console. Water surfaces are dark while any objects such as ships, buoys, shore lines, etc., are indicated in a bright fluorescent pattern. A special feature of the equipment is an "electronic ruler," an adjustable circle on the radar scope which can be set to measure and report the exact distance of objects from the pier with an accuracy better than one-tenth of a mile. This information relayed to a plotter enables him to establish the exact position of a vessel on a chart of the harbor.

The only other ports in the world equipped with radar are Long Beach, California, and Liverpool, England. Manufactured at the Wilkens Avenue plant of *Westinghouse's* Electronics and X-Ray Division, the radar was made available to the city on a long-term loan.

NEW LITERATURE

Code Rules on Electric Lines

Handbook H43, Installation and Maintenance of Electric Supply and Communication Lines-Safety Rules and Discussion, published by the National Bureau of Standards, combines the code rules on electric lines (Handbook H32) with the discussion thereof (Handbook H39).

The Handbook includes three appendices giving technical data useful in making computations of the strengths of supporting structures and in determining crossing clearances. In some cases, engineering short cuts are suggested which give approximately the same results as formulas covered in the code.

Handbook H43 is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of $1.50 a copy.

High-Frequency Voltage Measurements

National Bureau of Standards has just published a booklet which deals with measurements at frequencies in the upper audio- and radio-frequency ranges, including part of the ultra-high frequency range.

Measurements discussed are high precision methods based on d.c. measurements, moderate precision methods, including thermionic and other rectifiers, pulse-peak voltage measurements, and miscellaneous methods.

Circular 481, "High-Frequency Voltage Measurement" by Myron C. Selby, priced at 20c a copy, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Fabricated Natural Mica

The *Mica Fabricators Association,* 420 Lexington Ave., N. Y., has announced publication of its "Handbook On Fabricated Natural Mica" which presents pertinent facts on natural sheet and block mica with particular emphasis on characteristics required for its use in the electrical industry.

The book is designed to help manufacturers of electrical, radio and electronic equipment to select the best and most economical grade and quality of mica for any given application.

Report on Infrared Detector

An infrared detector, designed to locate faulty joints in overhead power line conductors, is described in a report now available from the Office of Technical Services, Department of Commerce.

The Radio and Engineering Division of the Council describes progress in fields of electronics, radar, radiophysics and electrical engineering during 1948 in a 42-page report. PB 95441, *N.R.C.C. Progress Report April-June 1948,* is available at $6.25 in photostat, $2.50 in microfilm. PB 95410, An Infra-Red Detector for Faulty Joints in Power Lines, is $1.25 per copy in either photostat or microfilm.

Orders should be addressed to: Library of Congress, Photoduplication Service, Publication Board Project, Washington 24, D. C.

Atomic Energy Levels

A compilation of all known data on the energy levels of elements of atomic number 1 through 23 has recently been published by the National Bureau of Standards.

The present volume is the first of a series being prepared at the Bureau and is designed to meet the needs of workers in nuclear and atomic physics, astrophysics, chemistry, and industry.

Volume 1 (containing Sections 1-3) of the National Bureau of Standards Circular 467, entitled Atomic Energy Levels, by Charlotte E. Moore, may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of $2.75 a copy.

Telemetering Systems

General Electric Company has just released a 20-page, illustrated bulletin which describes its newest telemetering equipment for electric power distribution and industrial applications.

The bulletin gives detailed information on the frequency-type, torque balance-type, and photoelectric-type telemeters manufactured by *GE*. Included also are simple wiring diagrams of typical telemetering installations for various services, and descriptions, dimensions, and specifications of telemeters and auxiliary equipment.

Bulletin GEA 5233 is available from *General Electric Co.,* Schenectady 5, N. Y.

Oscillator Plates

(*Continued from page 7*)

To permit faster lapping with some control of the movements of the block and crystal relative to each other, both were closely confined in an accurately machined opening of a small steel plate. When this assembly was carried by the nest through the lapping operation, abrasive which worked into the narrow clearance between the block and plate caused binding. For this reason the plate opening was enlarged and the pressure block was centered by means of an apertured zinc sheet cemented to the top side of the retaining plate, thus eliminating binding and permitting the crystal to move laterally with respect to its pressure block. Although crystals lapped this way were wedge-shaped, experience which led to more successful models was gained.

The wedge-shaped crystals emphasized the need for designs which would assure parallelism. The attacks on this phase of the problem resulted in three variations of a model in which small blocks were rigidly attached to a lapped ring. The assembled blocks were trued against the lap until they were coplanar and parallel to the lap so that wedged crystals could be corrected to parallelism. To prevent uneven abrasion caused by the adhesion between the crystals and the blocks, the surfaces of the latter were broken up by cross-channels. In the first apparatus of this type, pentagonal blocks fitted into pentagonal nest openings. In the second variation, cylindrical plugs were used and the nest was eliminated by using a close-fitting collar around each plug to confine its crystal and by using spokes to drive the ring directly. The third variation was similar to the first except that round rather than pentagonal plugs and holes were used, and its nest was thicker and channeled to reduce sticking.

Of the three forms just described the nestless type was least satisfactory, chiefly because its excessive weight caused breakage. The third variation gave better results than the first because the plugs and holes were a more precise fit. Consequently crystals produced with the round plugs had less pronounced rims. Deviations from parallelism in crystals produced by both lapping units were radial rather than wedge-like. The rims accounted for most of the deviation, which did not exceed 0.00004 inch.

Because of the difficulty in removing the ring and handling very thin crystals, a lapping method which permits much easier inspection of individual crystals has been evolved. The apparatus employed is an improved form of the square block and cell method and exists in two slightly different models—the inkwell and the tall plunger. The inkwell type has a conical exterior and is essentially a keyed and closely fitting plunger and cylinder. The crystal is attached to the plunger by means of a drop of oil; the unit is then inverted and placed on the lapping plate. The crystal is thus confined between the piston and plate by the cylinder walls. A nest drives a number of such units over the lapping plate. The tall plunger model differs mainly in having a taller piston sliding on bearing screws by which the amount of wobble can be precisely controlled.

Crystals have been lapped at the National Bureau of Standards to 0.001 inch with both these models. Breakage is almost nonexistent and the surfaces are quite flat and parallel. The limiting thickness for this equipment is not yet known since the difficulties of handling and properly measuring such crystals impose many new problems which remain to be solved.

REFERENCE:

1. *Sogn, L. T., and Howard, W. J., "The Mechanical Production of Very Thin Oscillator Plates," NBS J. of Research, Vol. 43, (Nov. 1949) RP 2037.*

New Products

(*Continued from page 18*)

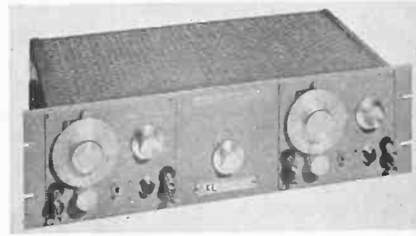
EMA-6, will indicate by meter readings the average number of pulses per unit of time produced by a Geiger-Mueller counter, or other suitable detector in the presence of nuclear radiations. Designed as a testing and safety device for use in biological or chemical laboratories, or industrial plants where radioactive material is likely to be present, it may be used as an assaying device to determine the activity of nuclear fuels or isotopes, or to study the rate of decay and the decay scheme of radioactive isotopes.

The meter is self-calibrating, making use of rectified pulses from the 60-cycle power line, and weighs approximately 10 pounds.

ELECTRONIC FILTER

The Model 302 Variable Electronic Filter announced by *Spencer-Kennedy Laboratories, Inc.*, 186 Massachusetts Ave., Cambridge 39, Mass., has a continuously variable cutoff from 20 cycles per second to 200 kilocycles. Each of the two sections has a range switch which selects the type of selection to be used, i.e., high-pass or low-pass, as well as four decade frequency ranges.

Compact in construction and reliable



in operation, the *SKL* Series 300 Filters are designed for use in sound analysis in conjunction with sound level meters, psycho-physical and physiological measurements.

PHOTO CREDITS

3 .....Federal Telecommunication Labs.
7, 11 (bottom)...National Bureau of Standards
11 (top), 12, 13..DeMornay-Budd, Inc.
14 (top)........H. H. Scott, Inc.
14 (bottom)..National Broadcasting Co.
16...............Better Theatres

R.F. HARDENING EQUIPMENT

Equipment for the continuous, r.f. selective induction hardening of cylindrical parts at feed rates to six inches per second is available from *Westinghouse Electric Corporation*, P. O. Box 868, Pittsburgh 30, Pa.

The equipment consists of three major components; an Automatic Loading Device, a Horizontal Rotating Scanner, and an Industrial Radio-Frequency Generator. Work is passed through an inductor coil and spray quench ring and uniformity of case depth is obtained by controlled feeds.

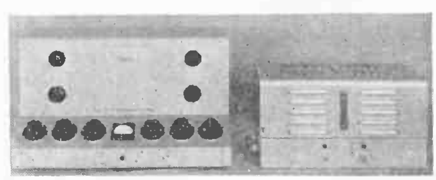
According to reports, this equipment can be used to harden a wide variety of cylindrical parts in any desired hardness pattern by simple adjustment of electronic timing circuits. Additional information may be obtained by writing the company.

VARIABLE AREA RECORDER

The development of variable area recording and reproducing instruments suitable for recording and reproducing vibrations has been announced by *Seismograph Service Corporation*, 709 Kennedy Building, P. O. Box 1590, Tulsa 1, Oklahoma.

Model CCC Variable Area Recorder is designed to translate electrical signals into corresponding amplitude variations on a variable area film.

It picks up reflections and records them on film using the movie sound-

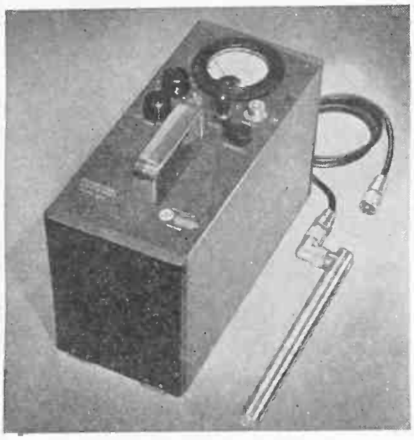


track principle. Special geophones, amplifiers and gain-control apparatus are used for recording and reproducing.

The Model CCD Variable Area Reproducer is a five-channel system designed to translate the amplitude variations of a variable area film into corresponding electrical signals. It consists of an exciter lamp providing light that is passed by mirrors through a five-trace variable area film, travelling on a rotating transparent drum, to five photocells.

PORTABLE ALPHA COUNTER

A portable monitoring instrument for determining alpha activity on table tops, hands, clothing, and other possibly



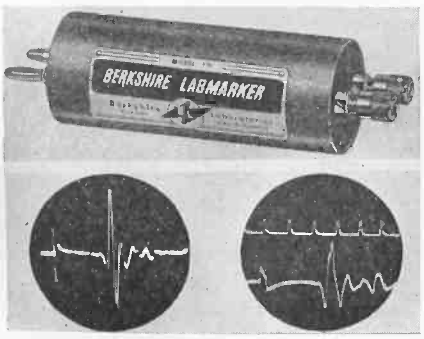
alpha contaminated locations is now available from *Nuclear Instrument and Chemical Corporation*, 223 West Erie St., Chicago, Illinois.

Model 2111, which includes an integrating circuit to show the average count rate on a built-in meter, detects only alpha radiation in the presence of other radiation. Several types of probes are available, and a pushbutton is provided to immediately reset the meter after exposure to a strong alpha source. An unusual feature is the plug-in four tube circuit which is easily removed for servicing and batteries are replaced through a hinged door on the end of the case.

The instrument weighs 16 pounds and is well-balanced for ease in carrying.

TIMING DEVICE

A wave shaping device used to produce time marks in cathode-ray oscil-



lography is available from *Berkshire Laboratories*, P. O. Box 70D, Concord, Mass., under the tradename Labmarker.

A sinusoidal input voltage is converted by the Labmarker into a series of sharp unidirectional pulses. These pulses may be displayed directly on the face of a cathode-ray tube by connecting the output of the Labmarker to the vertical input. It is a compact, self-contained unit which may be plugged into the terminals of an audio frequency oscillator and no other power source is required. The output binding posts of the unit may be used with leads having single or double banana plugs, spade tips, phone tips, or plain wire ends.

Two types of Labmarker are available; the Model 1N, giving negative pips; and the Model 1P, giving positive pips.

PERCENTAGE BRIDGE

Specialties, Inc., Skunks Misery Rd., Syosset, L. I., N. Y., has announced the development of a resistance percentage bridge designed for testing and calibrating precision potentiometers. This bridge measures the percentage of total potentiometer resistance tapped in at any mechanical setting of the potentiometer wiper arm.

The instrument incorporates a modified Wheatstone bridge circuit, match-

ing the voltage drop across selected standard resistors against the voltage drop across a potentiometer under test. The equipment operates from 110-volt, a.c. power or from a low-voltage d.c. source, and plug-in connections are provided for an external galvanometer.

GAMMA SURVEY METER

A 5-range Ionization Chamber Type Gamma Survey Meter covering the unusually wide range from 0-5 mr/hr to 0-50,000 mr/hr is manufactued by *The Kelley-Koett Mfg. Company*, 12 E. 6th St., Covington, Kentucky.

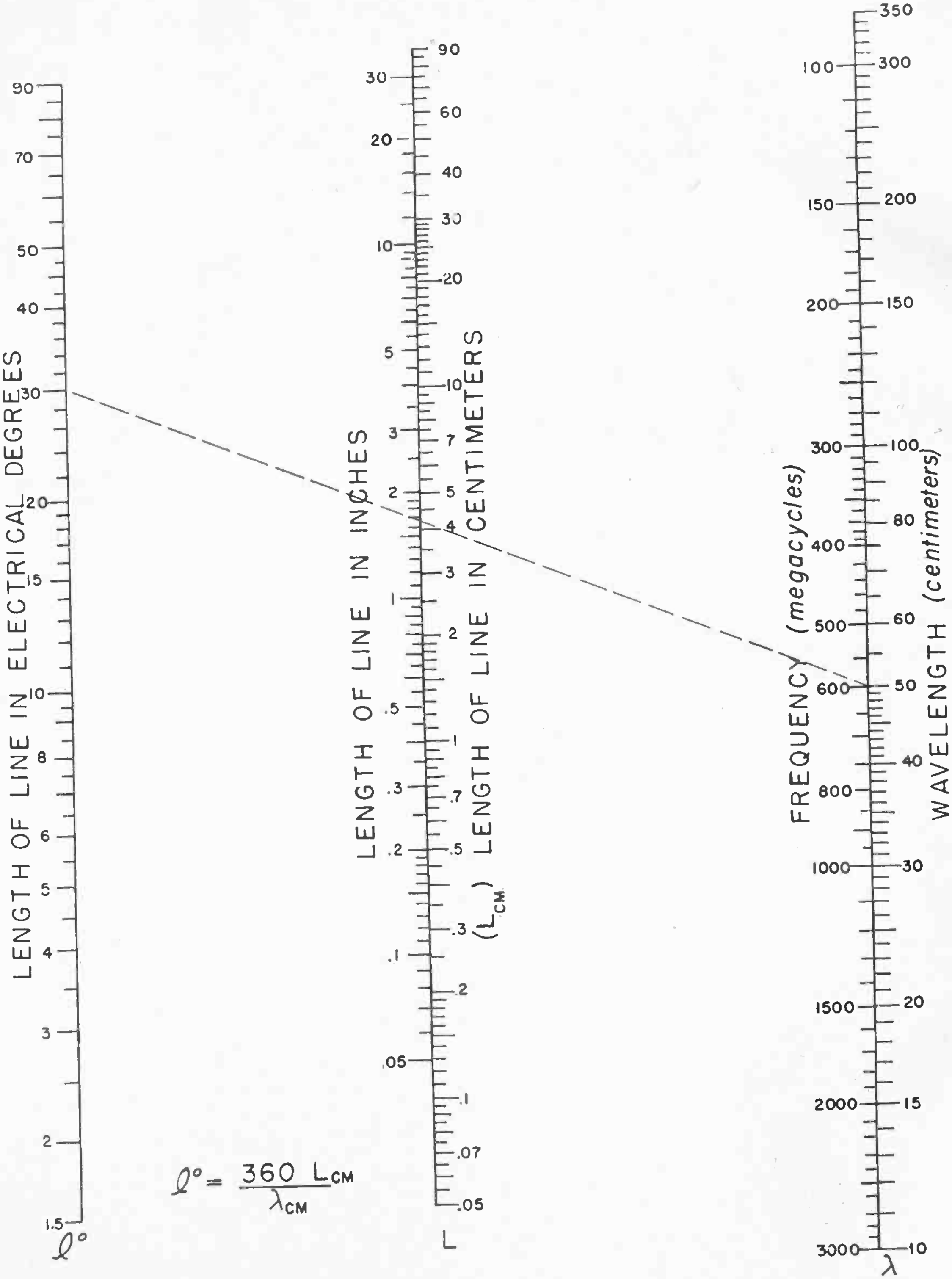
According to the manufacturer, the Model K-350 Gamma Survey Meter is the only instrument of its type offering a scale changing meter with only one range visible at a time. There are separate scales for the five ranges: 0-5, 0-50, 0-500, 0-5,000 and 0-50,000 mr/hr. Built to strict military specifications, the K-350 has a ± 10% accuracy over an operating range from —10° to 125° F.

Warm-up time is negligible and the instrument is non-microphonic.

LENGTH OF TRANSMISSION LINE

Chart for determining actual length of line in centimeters and inches when given the length in electrical degrees and the frequency.

The length is given on the *L* scale intersection by a line between λ and *l*°.



$$l^\circ = \frac{360\ L_{CM}}{\lambda_{CM}}$$

Courtesy of Federal Telephone and Radio Corporation.

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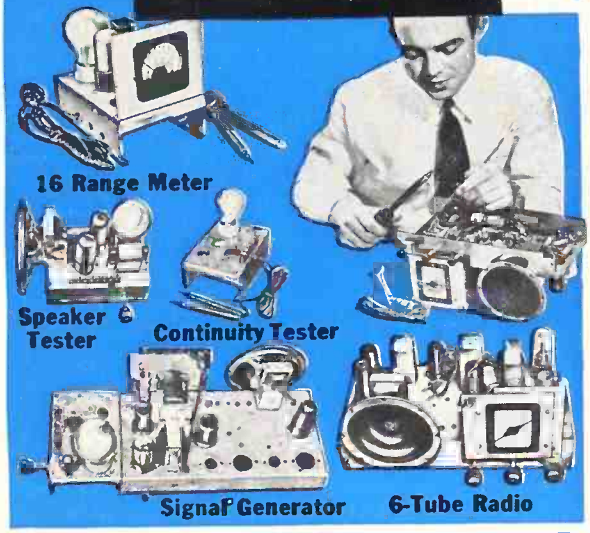

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Soon after you start training I send you my famous BUSINESS BUILDERS that show you how to make money in spare time doing interesting Radio jobs. Look at the useful and valuable equipment you get while training with me (illustrated at left)—I send you these 8 big kits of Radio parts and equipment and help you build step-by-step a powerful 6-tube superhet radio, a 16-range test meter, plus other mighty useful equipment for Radio and Television servicing. You will perform over 175 fascinating experiments while training. You will learn about Television—so that you will be qualified to step into this fast growing, profitable field. I also send you many valuable service manuals, diagrams and my book telling exactly how to set up your own Television and Radio shop. *I want you to learn all about my training*—and that is why I urge you to clip and mail the coupon below for my two big FREE Radio books. I employ no salesmen—and nobody will call on you. The important thing is to act now and get the facts.

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Each of the hundreds of Radio parts and other items I send my students is theirs "for keeps." You may use this equipment in your Radio and Television service work and save many dollars by not having to buy expensive "ready-made" test equipment. Each of my 8 kits will help you advance and learn important steps in Radio and Television servicing.

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