# RADIO

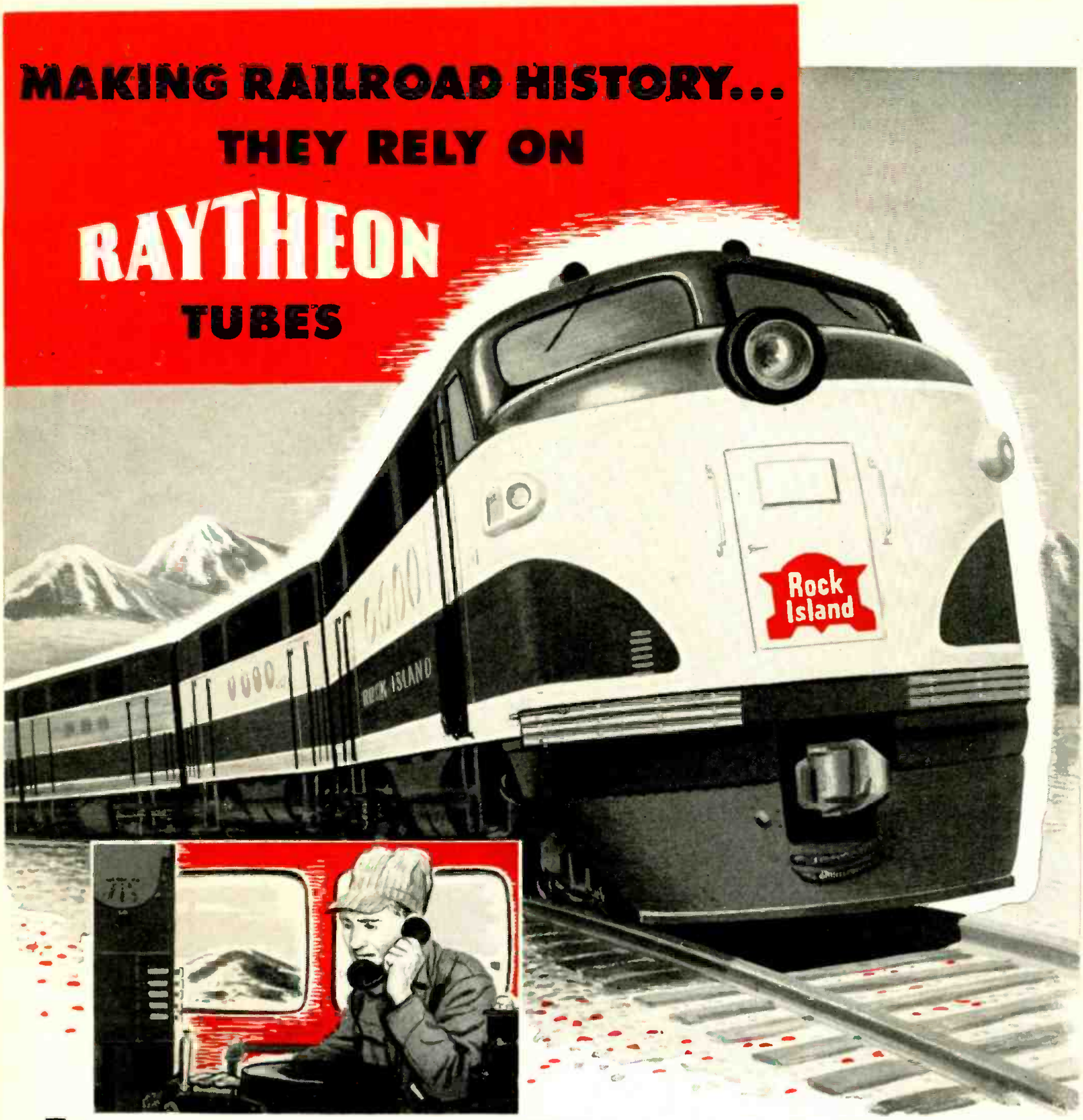
**Design • Production • Operation**

JULY, 1944

**Including: Impedance-Admittance Chart**

Winding a spiral filament for a transmitting tube

**The Journal for Radio & Electronic Engineers**




Taking a giant step forward in railroad history, paving the way for greater efficiency and added safety in railroad operation, THE ROCK ISLAND LINES, recognizing the importance and value of an electronic communications system have installed two-way radio in their trains ...and, because they want the best equipment, delivering peak performance at all times, THE ROCK ISLAND LINES are using RAYTHEON Tubes.

Because of its unique wartime experience, Raytheon will be in a better position than ever before to supply electronic tubes to radio manufacturers and industrial equipment users for the most exacting applications. Into RAYTHEON Tubes is built the finest engineering, as well as all the "Plus-Extra" performance qualities that have been synonomous with the name of Raytheon throughout the years.

*Raytheon Manufacturing Company*

RADIO RECEIVING TUBE DIVISION

Newton, Massachusetts • Los Angeles • New York • Chicago • Atlanta

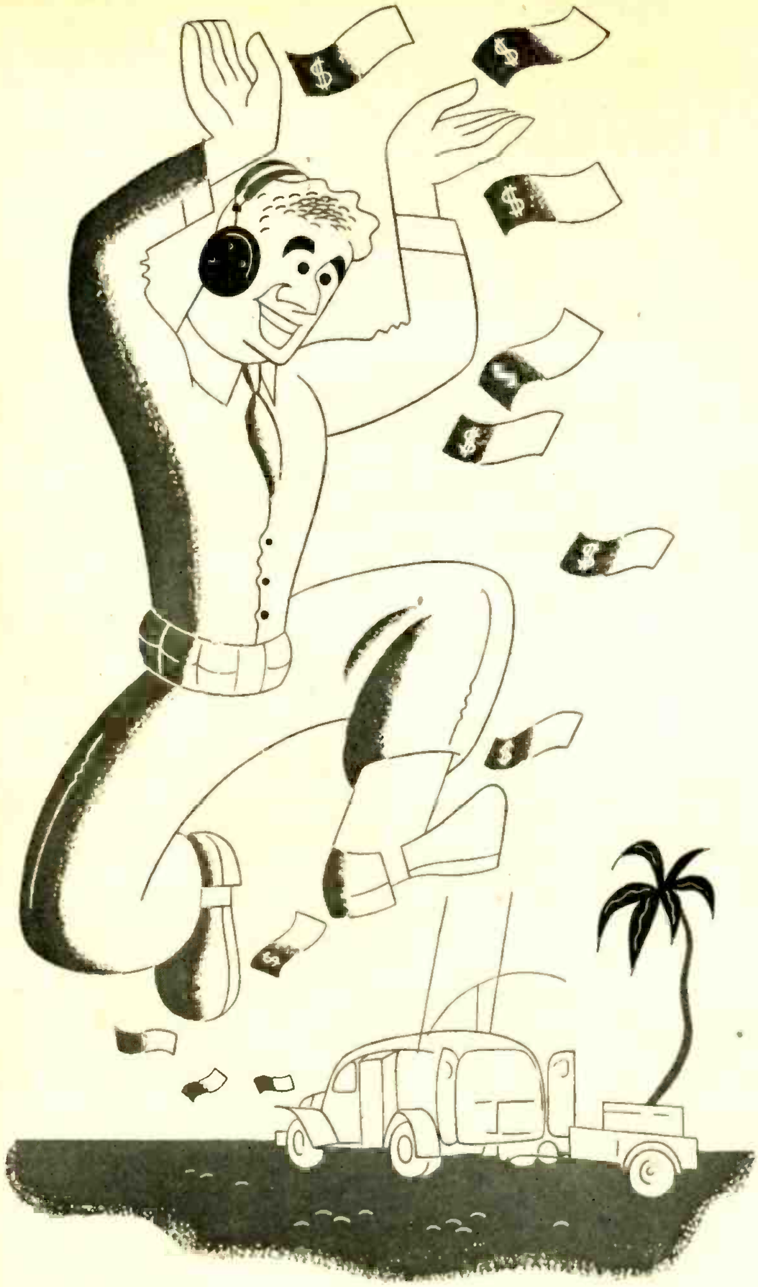
All Four Raytheon Divisions Have Been Awarded Army-Navy "E" Plus Stars

# RAYTHEON

*High Fidelity*

RADIO AND ELECTRONIC TUBES

DEVOTED TO RESEARCH AND MANUFACTURE OF TUBES FOR THE NEW ERA OF ELECTRONICS



# NEW LETTER CONTEST for SERVICEMEN!

### *ELEVEN 1st PRIZE WINNERS IN 5 MONTHS IN CONTEST #1!*

Yes sir, guys, the hundreds of letters received were so swell that *double* first prize winners had to be awarded each of the first four months and there were *triple* first prize winners the fifth and last month . . .

### *SO—HERE WE GO AGAIN!*

Get in on this NEW letter contest—write and tell us your *first hand* experiences with *all* types of Radio Communications equipment built by Hallicrafters including the famous SCR-299!

## RULES FOR THE CONTEST

Hallicrafters will give $100.00 for the best letter received during each of the five months of April, May, June, July and August. (Deadline: Received by midnight, the last day of each month.) . . . For every serious letter received Hallicrafters will send $1.00 so even if you do not win a big prize your time will not be in vain. . . . Your letter will become the property of Hallicrafters and they will have the right to reproduce it in a Hallicrafters advertisement. Write as many letters as you wish. V-mail letters will do. . . . Military regulations prohibit the publication of winners' names and photos at present . . . monthly winners will be notified immediately upon judging.

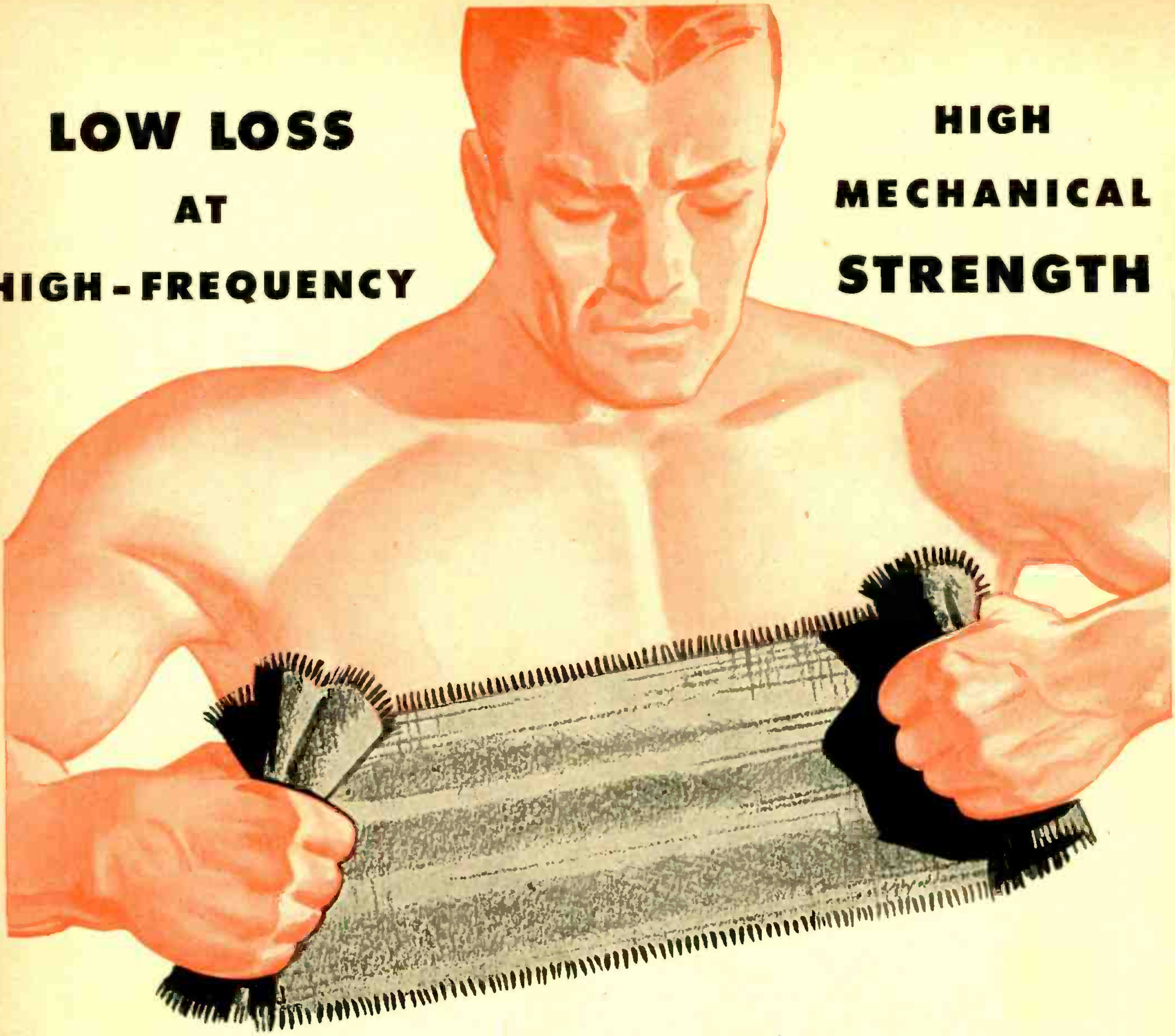
BUY MORE BONDS!

**hallicrafters RADIO**

THE HALLICRAFTERS CO., MANUFACTURERS OF RADIO AND ELECTRONIC EQUIPMENT, CHICAGO 16, U. S. A.

# LOW LOSS AT HIGH-FREQUENCY

# HIGH MECHANICAL STRENGTH



Until now most of the better high frequency insulators have been either brittle or subject to deformation at elevated temperatures. With the development of glass mat base Formica there is available an insulator that allows only minimum losses at high frequencies and at the same time retains the mechanical strength and machinability that is characteristic of other grades of Formica.

For low losses at high frequencies we suggest that you test Formica Grade MF 66 which has been found to be the answer for antenna insulators and coil forms on airborne and ground installations. It withstands the vibrations and mechanical stresses to which military radio equipment is subject. This material is resistant to attacks of fungus growth and can be used in the tropics.

Sample on request. "The Formica Story" is a moving picture showing the qualities of Formica, how it is made, how it is used. Available for meetings of engineers and business groups.

ARMY E NAVY

FORMICA

**THE FORMICA INSULATION COMPANY**
**4670 Spring Grove Avenue**
**Cincinnati, 32, Ohio**

# RADIO

Published by RADIO MAGAZINES, INC.

John H. Potts .................. Editor

Sanford R. Cowan ............ Publisher

JULY 1944 Vol. 28, No. 7

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### COVER

The photograph of the hands guiding the winding of a transmitting tube spiral filament was made and supplied to us by Eitel-McCullough, Inc

### ARTICLES



### MISCELLANEOUS



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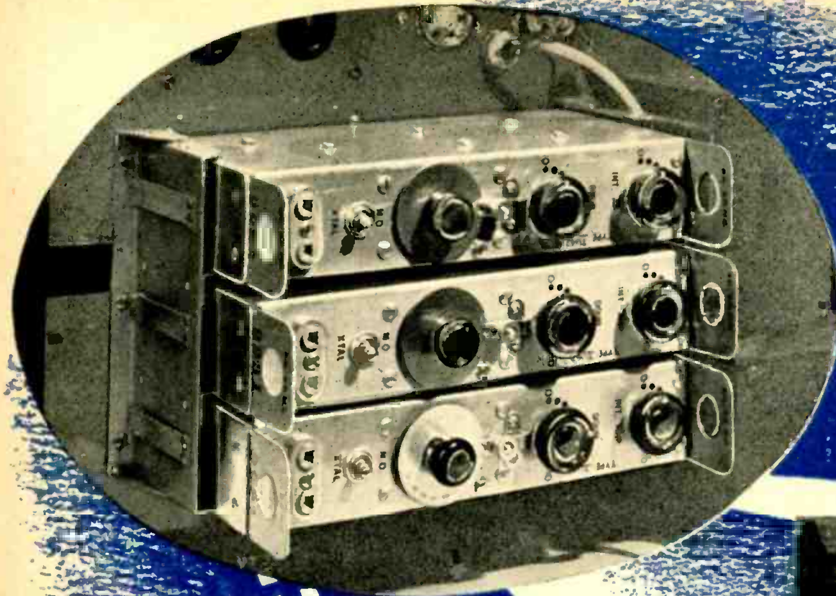


# GUTHMAN *Super Tuning Units*

## IN THE FAMOUS SCR-299 MOBILE TRANSMITTER

We at Edwin I. Guthman & Company are proud of the Super Tuning Units that we manufactured completely in our splendidly equipped plant for the Hallicrafters' SCR-299 mobile transmitter. Operating under most trying combat conditions on all Allied Fronts, the SCR-299 has distinguished itself amongst America's most vital "weapons" . . . and always the Guthman Super Tuning Units rendered dependable and accurate service.

"GUTHMAN . . . *Leader in INDUCTRONICS*"


**EDWIN I. GUTHMAN & CO.** INC.

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PRECISION MANUFACTURERS AND ENGINEERS OF RADIO AND ELECTRICAL EQUIPMENT

# Transients

## TELEVISION IN THEATERS

★ To those in the movie industry, the prospect that television may eventually displace to some degree the market for film movies in theatres is a consummation devoutly to be abhorred. This is, of course, a condition which is unlikely to happen practically overnight, as was the case when sound movies displaced silent films, but it is probable that a gradual integration of the best points of each form of entertainment presentation will ultimately take place.

The announcement of the organization of the RKO Television Corporation as a subsidiary of RKO may be interpreted as a move toward the integration of these two forms of entertainment. The immediate aim of this new company, as stated in the announcement, is to make available to the producers of television entertainment a program-building service whereby those situations which can be presented more effectively with film than with live talent, or by a combination of both, may be adequately handled. It is assumed that these presentations will be made in the usual manner, by broadcasting to home receivers.

But it is clear that the movie companies are alive to the possibilities of a partial transition from film projection to television broadcast presentations in theatres. Just as radio broadcasting has proved superior to newspapers for spot news items which need only be heard, so likewise is television broadcasting superior to films for such occurrences as football games, boxing matches, and the like. In each case radio eliminates the time lag inherent in other methods of presentation. And to this must be added the novelty and glamor which surround television in the public mind, both of which are of paramount importance in showmanship.

We'll see more movie companies hopping onto the television chariot.

## TWO-WAY RADIO SYSTEM FOR CABS

★ The announcement by the General Electric Company that a two-way taxicab radio system will be installed in Cleveland by the Yellow and Zone Cab Companies as soon as possible after the war, provided approval can be obtained from the FCC, may open up a new and wide field for postwar radios.

Advantages claimed for such a system are as follows:

Establish contact with any cab instantly at any place in the city.

Eliminate all present unattended call boxes, with their direct line connection to cab headquarters.

Reduce "dead" mileage and thus conserve gasoline, rubber, and extend the life of the taxicab itself.

It was also suggested that the taxicab industry in each city draw up an agreement with that city permitting the police department to commandeer its radio cars and headquarters station at any time that a major public disturbance should warrant.

Although not mentioned in the release, it would seem that this service might well be extended to include cars used by doctors, maintenance workers, and others who, on occasion, need to be communicated with while in transit.

## POLLS—GOOD AND BAD

★ All polls prove something, even though that something may be far different from the information which the survey was organized to gather. What brings this to mind is a recent survey conducted by a reputable organization for the electrical industry, in which a small segment of the population was asked what new inventions would raise their living standards after the war. The majority of those answering this question said "Television," which is nice to know, but the payoff comes when we find that "Radar" took second place. To most of us this survey merely indicates that the general public is perfectly willing to express opinions on subjects about which they know nothing, provided these subjects are sufficiently publicized and glamorized.

Far more informative is the 1944 Consumer Analysis of the Greater Milwaukee market, a poll conducted by the *Milwaukee Journal*. The questions asked call for answers which the party being polled can give exactly; they do not ask for opinions. Furthermore, they do not inquire as to whether the party intends to buy the item under consideration, because they have found such polls, as well as hell, are paved with good intentions. When we learn, for example, that 27.5% of the radio in the home of 62,168 families in the Greater Milwaukee area are in need of major repair or replacement, we have concrete data to think about. And, further, it is interesting to learn that this percentage is higher than that of any other defective home equipment. Also, it is stated that approximately the same percentage of families have no home equipment needing replacement.

Of course, this survey covered a great number of items besides radios and other home equipment. And, in the event that you have become fed up with radio surveys, in the city which made beer famous, you will find that the name of Schlitz leads all the rest.

—*J. H. P.*

# TECHNICANA

## GRAPHICAL SOLUTION OF TRANSMISSION LINE PROBLEMS

★ An article entitled "Loss-Less Transmission Lines," written by Dr. A. Bloch of the Research Lamoratories of the General Electric Co., Ltd. appears in the April, 1944 issue of *Wireless Engineer*.

Analysis of input impedance and admittance, and voltage and current distributions in no-loss lines is possible by the use of two simple types of diagrams.

A "Clock" diagram employed to determine input impedance for a reactively-loaded open-circuited line is shown in *Fig. 1*.

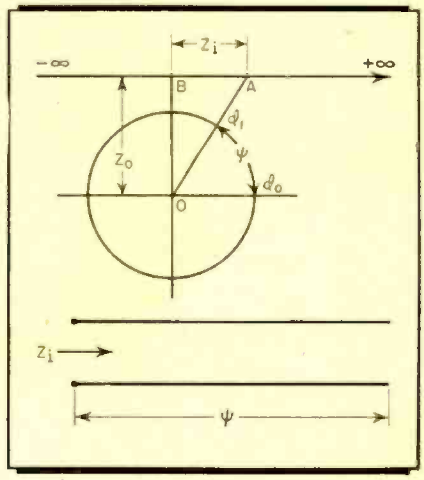



**Figure 1**

The input impedance of an open-circuited line with zero losses is given by $|Z_i| = Z_0 \cot \psi$ from which *Fig. 1* is drawn. The angle $\psi = 2\pi x/\lambda$ where $x$ is the length of line from the open end and $\lambda$ is the wave length of propagation. The intercept *BA* is obviously $|Z_i|$ of this equation.

The diagram shows how an increase of $\psi$ causes $Z_i$ to pass through zero to negative values, returning through infinity to positive values.

If a given value of $Z_i$ is supplied, the length of an open-circuited line which will replace this reactance can be obtained from the diagram.

Elaboration of this method leads to a solution of the input impedance of an open-circuited line containing an intermediate section of different characteristic impedance. This is illustrated in *Fig. 2*.

$Z_{01}$ and $Z_{02}$ are the characteristic impedances of the different sections of

[*Continued on page 8*]

# wherever a tube is used...

*for example* **THE ELECTRONIC CALIBRATOR**

A recently designed automatic calibrator for frequency meters used in conjunction with adding machines largely eliminates tedious hand calibration, saves man hours, reduces element of human error, speeds production.

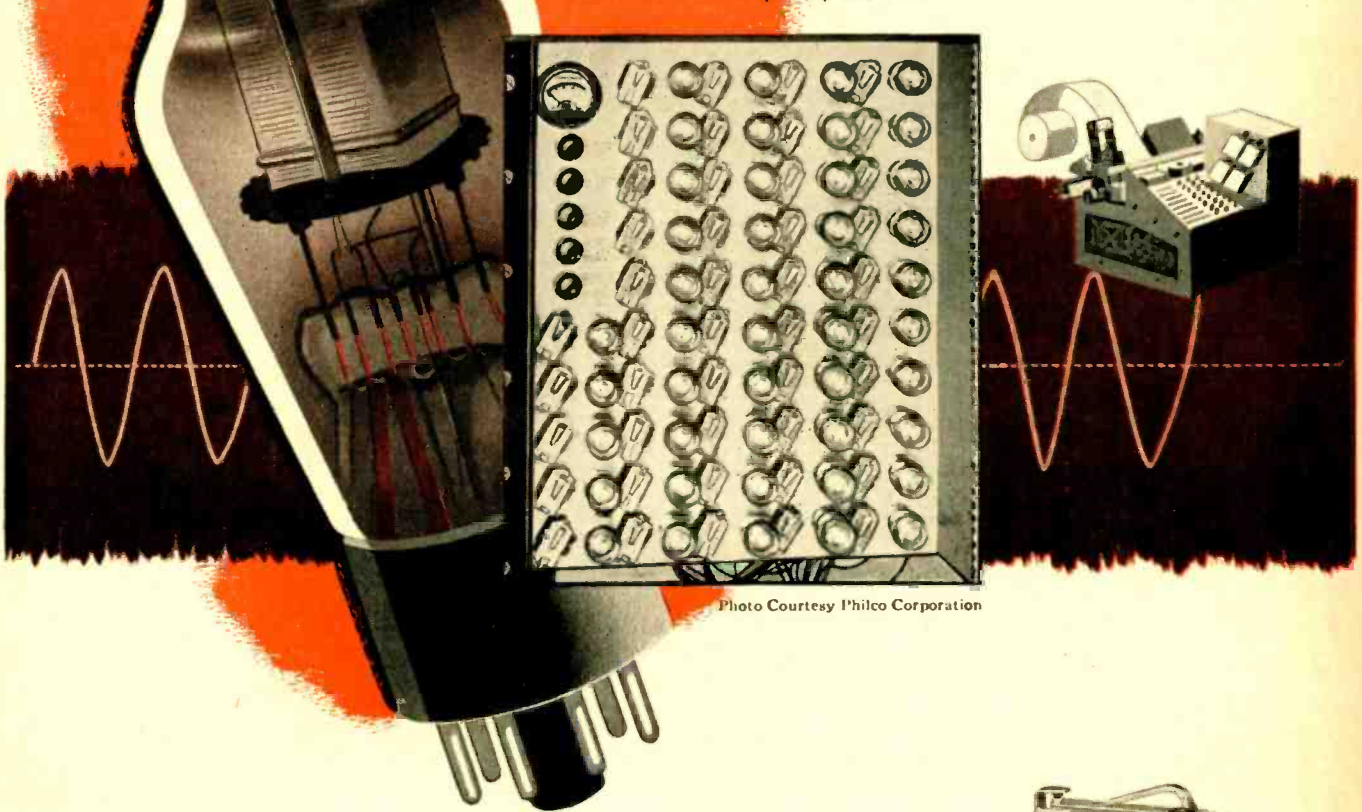


Photo Courtesy Philco Corporation

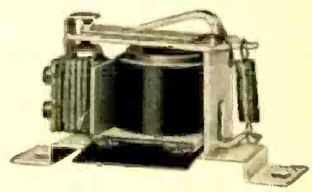
**THERE'S A JOB FOR**

# *Relays* BY GUARDIAN

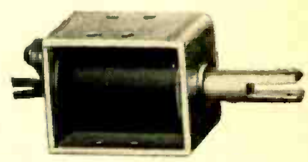
The Philco 126-tube Electronic Calibrator employs a system of fast and slow-acting relays and solenoids to bring about desired end actions. One application is the transferring of readings from the storage bank (shown above) to the keyboard of the adding machine. Operated by the plate current of OA4G tubes the relays on the storage bank energize the adding machine solenoids which press the proper number key of the adding machine.

The Guardian Series 120 relay used in this application is a small, sensitive unit having a minimum power requirement of 0.5 VA and an average of 2 VA. Coils are available in resistances from .01 to 6,000 ohms. Contact combinations up to single pole, double throw with 12.5 amp. points. Send for Bulletin 120.

The solenoid is Guardian Series 4 available for either A.C. or D.C. use. Series 4 A.C. at a maximum stroke of 1" permits a pull of 14 oz. intermittent duty, 3 oz. continuous duty. Series 4 D.C. at a maximum stroke of 1" permits a pull of 6 oz. intermittent duty, 1 oz. continuous duty. Send for information.



Series 120 Relay



Series 4 Solenoid

Consult Guardian whenever a tube is used—however—Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

**GUARDIAN ELECTRIC**

1605-H W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

## TECHNICANA

[*Continued from page 6*]

the line. Radial line $\phi_1$, given the input impedance of the first section of the line (nearest the open end) as FA. Ray $\phi_2$ gives the length of line of characteristic impedance $Z_{02}$ which could replace the first section of line. By adding $\phi_2$, the length of the second section, we reach point $C$. Going back to axis $Z_{01}$, point $D$, there is now added the last length of line, $\psi_3$, and the final ray $\phi_5$ gives the resultant $Z_i$ = FE.

This method indicates clearly how a change in the characteristic impedance of a line affects the electrical length. In particular, an increase in impedance, from $Z_{01}$ to $Z_{02}$ corresponds to a change in electrical length which is not in general equal to the change in going from $Z_{02}$ to $Z_{01}$.

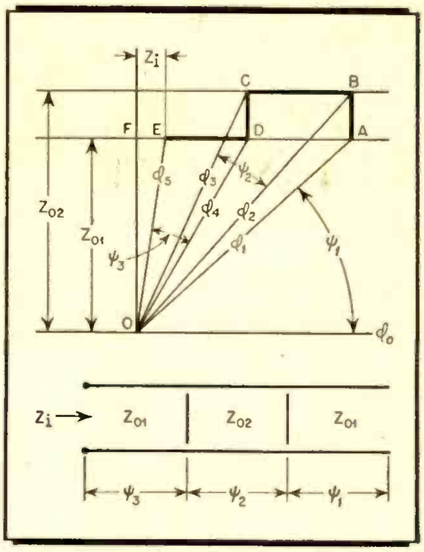



Figure 2

If it is decided to determine input admittance, as when a line is shunted by a capacitance, the expression is $|Y_i| = Y_o \tan\psi$, when $Y_o = 1/Z_o$. A graphical solution can be obtained by plotting $Y$ on a vertical coordinate and $Y_o$ on the horizontal axis.

For a short-circuited line $|Z_i| = Z_o \tan\psi$ and $|Y_i| = Y_o \cot\psi$, so that the axes used in the diagram are the reverse of those used for the open-circuited line.

The voltage and current distribution can be determined by use of the equations $|U| = U_o \cos\psi$ and $|i| = I_o \sin\psi$, where $U_o$ and $I_o$ are the amplitudes of the voltage and current waves. When voltage is plotted horizontally and current vertically an ellipse can be drawn with the horizontal semi-major axis equal to $U_o$ and the vertical semi-minor axis equal to $I_o$. The voltage

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and current for any angular distance $\psi$ are represented by the coordinates of the point of intersection of the radial intercept and the ellipse. By suitable choice of scale we can obtain $I_o = U_o/Z_o$.

By combination of the above principles, when a line consists of several sections with different impedances, and possibly loaded with shunt or series reactances, we can plot the voltage and current patterns along the line.

In the "Crank" diagram, *Fig. 3*, the voltage and current distribution is determined if the values are known for one point of the line.

This graph considers both the forward and reflected waves.

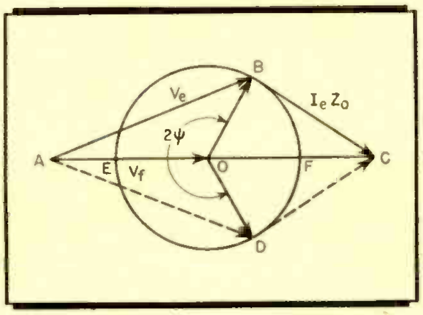


**Figure 3**

All vectors shown are voltage vectors. The vectors $V_1$ = AB and $I_1Z_o$ = BC are known for a certain point in the line. Point *O* is constructed midway between *A* and *C* and the circle is drawn through *B*. This circle is the locus of all voltage values along the line. For example, point *D* represents the condition at a counterclockwise distance 2 $\psi$ from the first vector, i.e., a distance $\psi$ on the line closer to the load. This fact is proved in the original article.

In a combination of the "Clock" diagram and the "Crank" diagram the "Crank" diagram can be inverted to obtain the impedance or admittance of the line.

### IMPEDANCE OF THIN-STRIP TRANSMISSION LINES

★ The impedance of a transmission line in which one conductor is a thin strip can be roughly computed as that of the equivalent line having a circular conductor of equal perimeter.

It is frequently desirable to use odd cross-sectional shapes for resonant lines at high frequencies. When a minimum attenuation is required the use of a flat strip is suggested.

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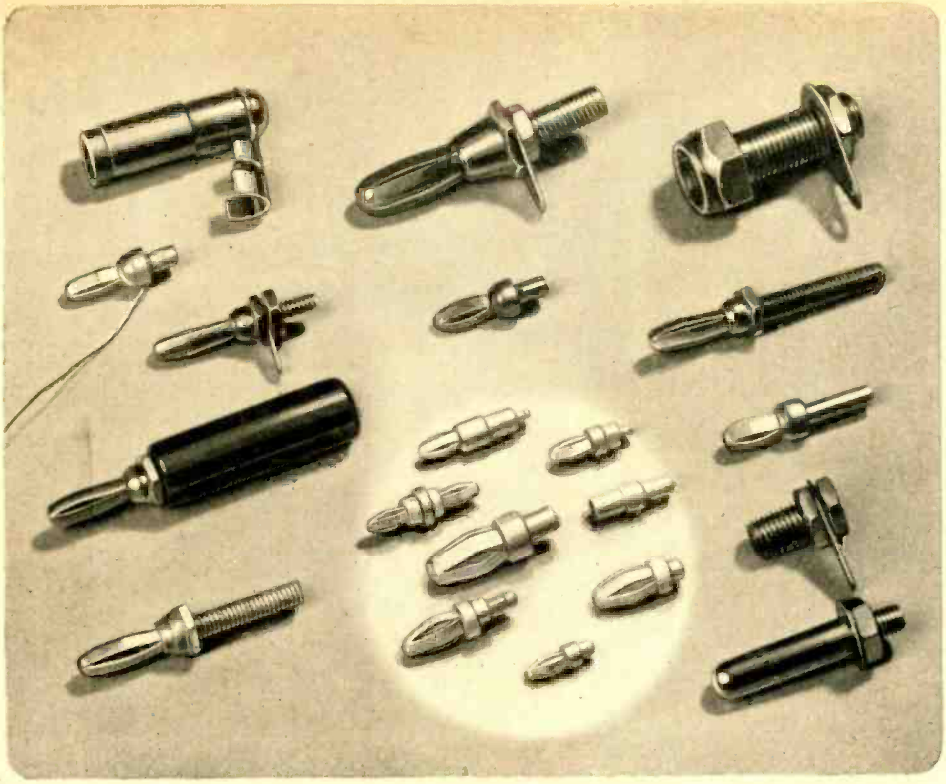

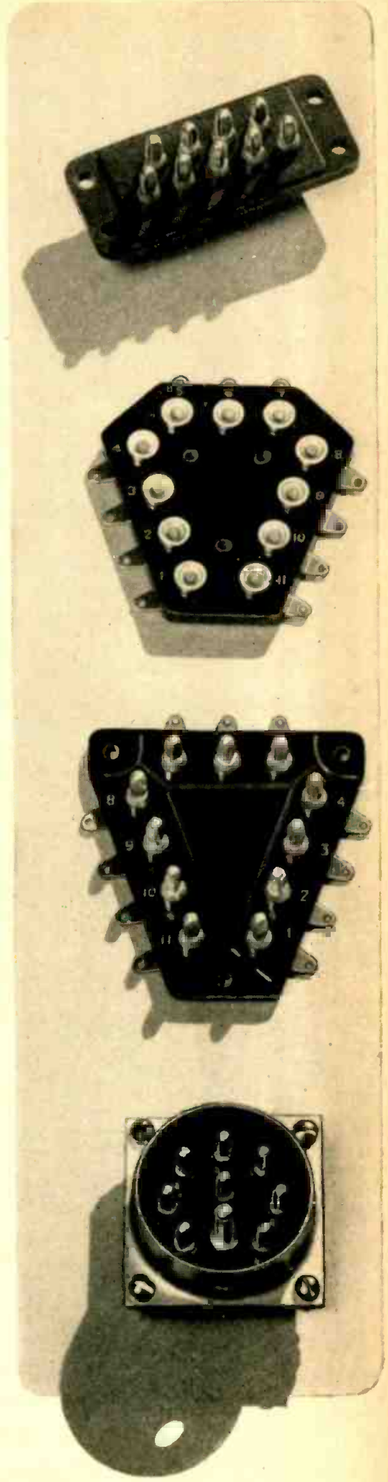

# *and it's* JOHNSON

That is the plus element you get at no extra cost.* Many manufacturers are producing plugs and jacks, some are very clever copies and some are not so clever. Some of these manufacturers are experienced in making electrical parts and many are not.

In Johnson you get the benefit of a quarter of a century of experience in manufacturing radio transmitter components and assemblies—a manufacturer who knows transmitter parts requirements and in fact, to assist the war effort, is actually building transmitters for the armed forces. Johnson engineers are therefore thoroughly familiar with the applications and functional requirements of all transmitter parts and these parts become more than mere mechanical assemblies. Many products are original Johnson designs and considered standard for comparison by the industry.

Whether the new "miniature" plugs featured above, the "standard" plugs manufactured by Johnson for years, or "specials" for particular applications, Johnson plugs and jacks are designed by the same engineers, produced by the same skilled hands, and carry the same Johnson guarantee of quality.

If you have a plug or jack problem, write or call for Johnson's recommendations and quotation. Johnson is especially well equipped to furnish complete assemblies of plugs and jacks, using any insulating materials, and in combination with other metal parts.

*In most cases Johnson plugs and jacks are actually less because of quantity production.

Do you have the new catalog 968K?

ARMY E NAVY

# JOHNSON

*a famous name in Radio*

E. F. JOHNSON COMPANY • WASECA • MINNESOTA

## TECHNICANA

[Continued from page 10]

Mr. C. C. Eaglesfield discusses two examples of flat strip lines in an article entitled "Transmission Lines" appearing in the May 1944 issue of *Wireless Engineer*. In one type of line the thin strip is a center conductor within a hollow square. In the second example the thin strip runs parallel to an infinite plane.

In measuring the characteristic impedance for the first type the formula

$$Z_0 = \frac{1}{\pi C f_1} \tan \left[ \left( \pi/2 \right) \left( \frac{f_0 - f_1}{f_0} \right) \right]$$

was used, in which $f_0$ is the resonant frequency of the line, $f_1$ the resonant frequency with a loading condenser $C$ at the center of the line.

The value of the capacitance presented measurement difficulties, due to end effects. A commercial 2 $\mu\mu$f ceramic condensor was used. In a conventional line of known impedance the exact capacitance value can be measured.

Measurements were made upon the thin strip enclosed within the square tube, for several strip widths, $a$. The characteristic impedance $Z_0$ is plotted against the value of $a/b$, in which $b$ is the inside width of the square tube. This graph is shown in *Fig. 4* by the solid line.

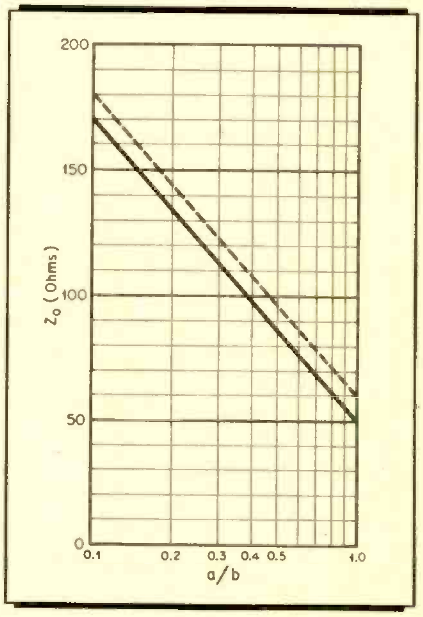


**Figure 4**

The dotted line of *Fig. 4* is the graph of $Z_0 = 60 \log_e 2b/a$ which is the suggested formula using perimeter ratios.

A better empirical formula, which

[Continued on page 14]

# Smooth Action with Smooth Power motors

★ Whatever kind of a job you may have for small motors, you'll probably find General Industries *Smooth Power* motors doing similar types of work. They may be operating turntables or record changers, powering motion displays or driving recording mechanisms or industrial controls. Whatever the work may be, these *Smooth Power* motors do it smoothly, quietly and according to specifications.

Quite likely, the motors you need will be found in the long line of standard *Smooth Power* motors. But if they're not—if your product calls for special service or characteristics, then our engineering staff can adapt a standard model or design a new one for your specific needs.

Or, if you're planning new electrical or mechanical devices of comparatively small size, that call for motors or metal fabrication, or both, we suggest you remember General Industries as a source of reliable assistance. Right now, our plant and facilities are at work for Uncle Sam, but when his present business is satisfactorily concluded, we'll be ready again to start designing and building peacetime products. We'd like to have you call upon us.

**THE GENERAL INDUSTRIES COMPANY**
ELYRIA OHIO

THE GENERAL INDUSTRIES COMPANY

*Smooth Power*

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[*Continued from page 12*]

duplicates the measurements exactly is $Z_0 = 124 \log_{10} 2.4b/a$.

Similarly good comparison was obtained using the thin strip of width a, distance h from the infinite parallel plane.

The formula is $Z_0 = 60 \log_e (1 + 2h/a)$ which is derived from the formula for a single circular wire, $Z_0 = 60 \log_e 4h/d$. where $d$ is the wire diameter.

The selectivity of the flat strip resonant line can be made to approach the maximum selectivity of a circular line. The maximum selectivity of 100% was determined to occur when $a/b = 0.5$ in the case of the hollow square tube, at a frequency of 250 mc, using a line 60 cm. long.

The bandwidths for the open line are measurably greater and there is considerable radiation.

When an elliptical outer conductor is used the impedance can be calculated by means of an hyperbolic transformation, and leads to confirmation of the perimeter rule.

## SHIELDING OF LOOP ANTENNAS

★ The need for obtaining an electrostatic balance to ground in a loop antenna has led to the use of a shielded loop. This also has the advantage of preventing induction fields from affecting the loop, but has practically no effect upon the performance of the loop otherwise.

The theory of the shielded loop has been given by Mr. R. E. Burgess in Vol. 16 of *Wireless World*, 1939. In the current issue of *Wireless World*, May 1944, Mr. Burgess renews the discussion by analyzing the case of a single-turn loss-free loop by means of the transmission line equations with unifromly distributed constants.

The loop is indicated in *Fig. 5.* It is assumed that the gap is narrow, and the cross sectional area is small compared with the wavelength.

When a given signal is applied to the loop the potential and current distributions within the shield are determined with due regard for the boundary conditions at the terminals and gap. There are two modes of propagation represented by waves inside and outside the shield. The outer mode corresponds to a current flowing on the outer surface of the shield and corresponding shield potentials. The velocity is that of free space.

The inner mode corresponds to a circulating current flowing in the loop and the inside surface of the shield, and corresponding potential differences

[*Continued on page 16*]

# WINNING THE BATTLE OF STANDARDIZATION

SYLVANIA was first to introduce a line of 6.3-volt radio tubes and to propose their universal use in not only automobile but home receivers.

That was back in the early 1930's. Prior to the introduction of these tubes, there was no agreement as to what types of radio tubes should be used for automobile service. Existing 2.5- or 5-volt types were either wasteful of battery current or did not have the efficiency needed. Standardization on 6.3-volt tubes of high efficiency would make it possible to effect manufacturing economies, to avoid complicated filament wiring arrangements, to save automobile battery drain, and to improve operating efficiency.

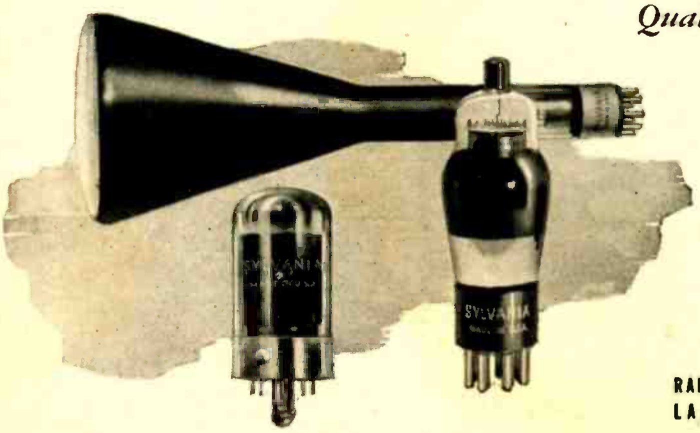
Sylvania's proposal met with opposition, but its common sense won the day. More and more radio-set manufacturers specified 6.3-volt tubes in all types of new equipment. And, in time, 2.5-volt tubes became practically extinct except for replacements.

Winning this battle of radio tube standardization, furthermore, proved to be a boon to radio broadcast listeners. Elimination of the transformer in AC-DC sets reduced both the size and the cost of radio receivers. Millions who otherwise would not have been able to afford sets were able to take full advantage of broadcast information and entertainment.

You will always find Sylvania, exemplar of radio tube quality, on the side of standardization for the mass market.

That is why it pays to sell Sylvania.

*Quality that Serves the War Shall Serve the Peace*



RADIO DIVISION — EMPORIUM, PENNSYLVANIA

**SYLVANIA**

**ELECTRIC PRODUCTS INC.**

RADIO TUBES, CATHODE RAY TUBES, ELECTRONIC DEVICES, FLUORESCENT LAMPS, FIXTURES AND ACCESSORIES, INCANDESCENT LAMPS

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[*Continued from page 14*]

between the loop and shield. The velocity will be less than the free-space velocity.

These modes are expressed in terms of capacitance and inductance coefficients which depend upon the geometry of the system.

The characteristic impedance of the outer mode is independent of the loop and is given by $Z_{01} = 30\ L_{11}$ ohms, where $L_{11}$ is the inductance coefficient of the shield. $L_{11} = 2\ (\log p/r_0 - 1.76)$ for a circular shield, where $p$ is the perimeter of the shield and $r_0$ is the outer cross-sectional radius of the shield conductor. For a square os side $a$, $L_{11} = 2\ (\log p/r_0 - 2.16)$.

The inner mode for a circular loop has a characteristic impedance of $Z_{02} = 30\ (L_{22} - L_{11})$. where $K_2$ is the $\sqrt{K_2}$ dielectric constant of the inner medium, and $L_{22} = 2\ (\log p/r_2 - 1.76) - 2 \log r_0/r_1$, in which $r_2$ is the cross-sectional radius of the loop, and $r_1$ is the inner cross-sectional radius of the shield.

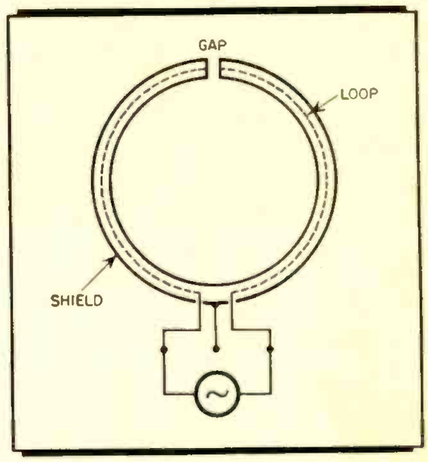


**Figure 5**

The term $-2 \log r_0/r_1$ is the reduction in self inductance of the loop due to eddy currents induced by the loop current in the shield cross section The effect of the eddy currents is to neutralize the field within the shield conductor.

For examples, the author finds that for a screened loop 200 cm. square for which $r_0 = 2.5$ cm, $r_1 = 2.0$ cm., and $r_2 = .05$ cm, the total inductance $L_2$ of the loop is 11.6 microhenrys, $Z_{01} = 220$ ohms, and $Z_{02} = 220$ ohms, for $K_2 = 1.0$. For a second loop 25 cm. square, with $K_2 = 2.0$, $r_0 = 1.25$ cm, $r_1 = 1.0$ cm, $r_2 = 0.25$ cm, the inductance $L_2$ is 0.7 microhenry, $Z_{01} = 135$ ohms, and $Z_{02} = 55$ ohms.

[*Continued on page 16-B*]

**W. J. HALLIGAN, *President, Hallicrafters Radio . . .***

*Mr. Halligan says, "Those of us who are building radio communications equipment in this war anticipate a tremendous demand in the future for radios and radio telephones for plane to ground, ship to shore use, and many other applications."*

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## TECHNICANA

[*Continued from page 16*]

For a balanced loop, in which the terminal potentials are symmetrical with respect to the shield, and for an air-spaced gap, the resonant frequency $f = nc/2p$ where $p$ is the perimeter of the shield, $n$ is an integer, and $c$ is the velocity of light. At a resonant frequency the impedance appearing at the loop terminals is zero for a loss-less system.

The nth anti-resonant frequency ($Z_2 = \infty$) is given by $f = (n - 1) c/p \pm f$, where $f$, is the lowest anti-resonant frequency. For a coefficient of coupling, k, between the shield and the loop, such that $k^2 = 0.5$ to 0.6 the first anti-resonant wavelength $\lambda_1 =$ 4.0p to 4.6p. In the special case of $k^2 = 0.5$ the characteristic impedances $Z_{01}$ and $Z_{02}$ are equal and the loop impedance $Z_2 = jcL_{22} \tan 2/\beta s$. This is the reactive impedance of a short-circuited loss-free line of length $2s$ and characteristic impedance $cL_{22}$ and is approximately equal to that of an unshielded loop of twice the dimensions.

The author discusses the effect of a small capacitance such as would be normally found across the gap. This effect is to modify the odd resonant frequencies but to leave the even resonant frequencies unaltered. The anti-resonant frequencies are also slightly modified.

The impedances of balanced and unbalanced loops are expressed in terms of all variables. In the case of the unbalanced loop the resonant and anti-resonant frequencies are unevenly separated.

The effective height of a single-loop antenna, in terms of the height of a linear antenna producing an equivalent field at a distant point, is given as $h_o = Bs$, where $s$ is the area of the loop and $B = \omega/c$. This applies to frequencies such that $\beta s \ll \frac{\pi}{2}$ where $s$ is half the perimeter of the loop.

For higher frequencies the effective height is shown in *Fig. 6*, where $h =$ effective height, $h_o = \frac{2\pi \times \text{area}}{\lambda}$, for the case of $k^2 = 0.6$.

Since the antenna impedance is identical for reception and transmission, by the Reciprocity Theorem, all equations developed apply to both cases.

The author presents experimental data on a square shielded loop to sub-

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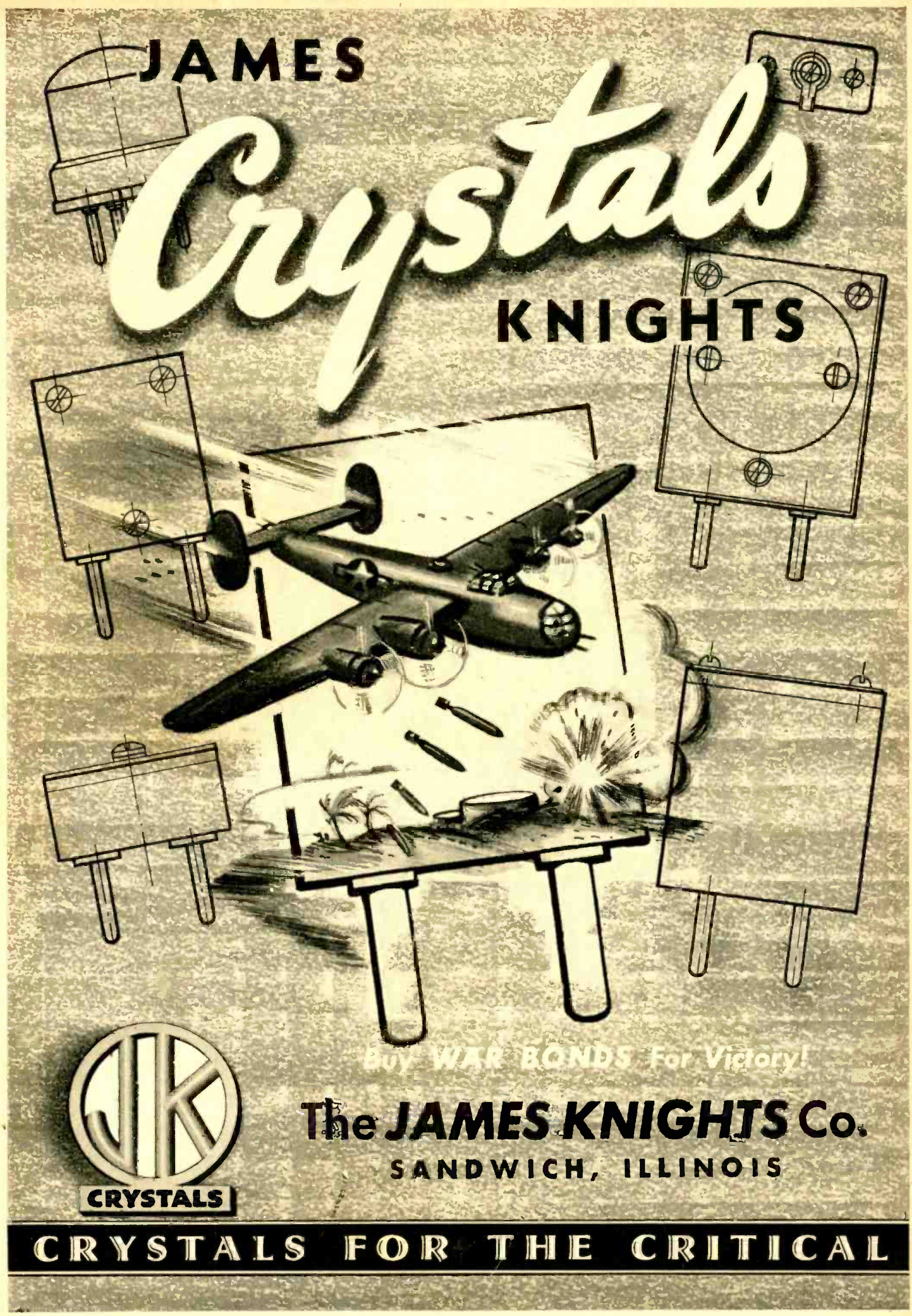
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## TECHNICANA

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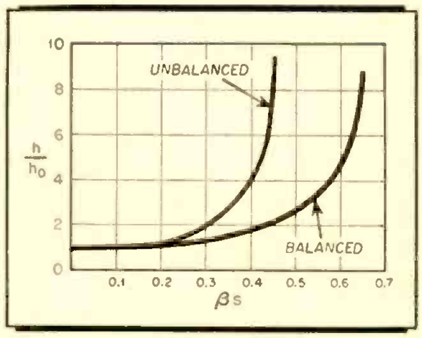


**Figure 6**

stantiate the theoretical results obtained. The comparison is good.

He concluded, however, that any exact treatment is difficult because of deviations from the ideal. These are (a) non-uniformity of the inductance and capacitance coefficients around the loop, (b) width of gap, and (c) ohmic and dielectric losses.

### TRANSIENT RESPONSE IN FREQUENCY MODULATION

★ The response of transients in both amplitude modulated and frequency modulated carriers is examined by Mr. D. A. Bell in an article appearing in the March, 1944, issue of the *Philosophical Magazine* which uses the above title.

Mr. Bell assumes the use of square-wave modulation for an examination of transients. He develops the conclusion that f.m. gives better response than a.m. for a given band-width-to-frequency ratio when limited by a simple *LCR* resonant circuit.

This conclusion differs from that of Salinger* which was that the transient response is similar in an FM system to that in an a.m. system.

The author uses the operational method to determine the transient response of the f.m. circuit. The results are compared with those obtained using the side-band analysis of the response to a sinusoidal modulation of an f.m. signal, giving indirect confirmation.

The f-m transient, or sharp change from one frequency to another, is expressed as the sum of two amplitude transients. One corresponds to the impressed emf; the other corresponds to the natural frequency of the circuit.

An f-m system is more effective than an a-m system in discriminating in favor of the stronger of two signals of different frequencies. So that the f-m circuit gives more faithful re-

* *Proc. IRE*, p. 378 (1942).

[*Continued on page 20*]

## TECHNICANA

[*Continued from page 18*]

sponse by reproducing the predominance of the impressed emf over the free circuit oscillation.

In an amplitude-modulated system the response to the transient amplitude change is dominated by an exponential expression,

$$1 - \epsilon^{\frac{-RT}{2L}}$$

When the tuned circuit band width is narrower than the carrier frequency band, including wide side-bands produced at high modulation frequencies severe harmonic distortion is produced, so that the general conclusions do not then apply. This condition is examined for sinusoidal modulation and compared to the case of square-wave modulation.

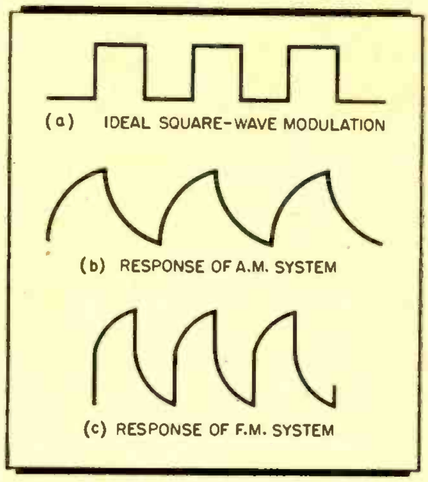


**Figure 7**

The curves of *Fig. 7* illustrate the response to a square wave in both circuits. The relation of the circuit band width to the period of the square-wave modulation is the same in each case. Since curve (c) is given for a frequency deviation large compared with the circuit band width, it is considered to be a fair comparison, showing that f-m response is better than a-m response.

### BROWN NAMES HIERMEIER

V. H. Hiermeier has been named industrial manager of the St. Louis office of the Brown Instrument Co., Philadelphia precision industrial instrument division of Minneapolis-Honeywell Regulator Co.

Mr. Hiermeier, who succeeds I. K. Farley, has had 15 years experience in the industrial instrument field. For the past few years he has been with the Brown Company in its Chicago office. Mr. Hiermeier is credited with doing much to help Purdue University establish and operate an instrumentation course.

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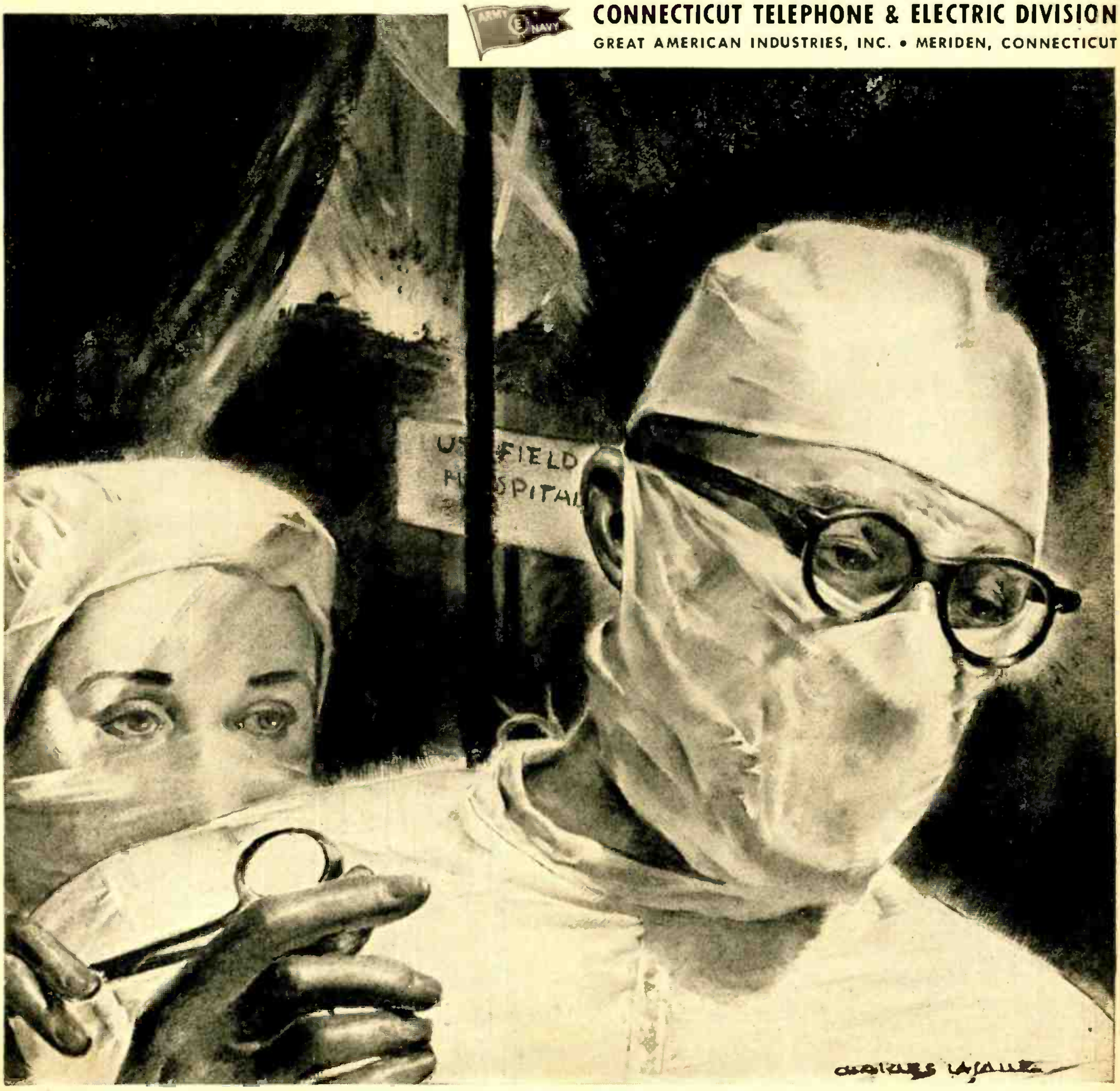


# WAVE GUIDE

# Junctions and Terminations

**V. J. YOUNG**
Engineer,
Sperry Gyroscope Company, Inc.

**Types of wave guide junctions and terminations, suitable methods of attacking design problems, and phenomena associated with wave guide terminations are discussed**

THE most difficult part of the design of any wave guide system is that of constructing proper terminations, bends, and junctions between sections. The requirements that have to be met by such parts are numerous and even the job of visualizing the way in which the currents flow and in which the electric and magnetic fields are oriented may be far from easy. The present discussion is by no means exhaustive as to the results achievable nor is it necessarily a listing of fittings and junctions most commonly used; instead, it is an examination of various approaches which are best suited to lead to optimum designs plus a rather thorough discussion of certain phenomena common to many wave guide terminations.

To see how difficult the situation may be, we will first examine the problem of T joints. The cross section of a wave guide may be circular, elliptical, or rectangular in shape; for that matter, there are undoubtedly even more complicated shapes which will support a traveling electromagnetic wave without great attenuation. A rectangular wave guide is often chosen because it is relatively easy to manufacture to accurate dimensions and because its operation is the simplest to understand and denote by algebraic equations. The possibilities of making fittings, such as T joints, for more complicated types of guides have not yet been explored very thoroughly.

### T Joints in Wave Guides

As shown in *Fig. 1*, there are at least two ways of joining a rectangular wave guide to form a T. In *Fig. 1A*, the wider side comes at the joint while, in *Fig. 1B*, the connection is on the shorter side. If sources and loads are connected to these junctions as shown, then for operation of these guides in the $TE_{1,0}$ mode, the cases are roughly analogous to the series and shunt connection of two loads across a single source. In *Fig. 1A*, it is clear that the electric field does not need to change direction at the junction and that its value there is the value impressed across the entrance to the two legs leading to the loads. With the magnetic field, however, the longitudinal component of the source leg becomes the transverse component in one load leg and remains a longitudinal component in the other. This is like a wired circuit of two loads in parallel where the voltage across the loads must be the same although the currents may differ.

Similarly, in *Fig. 1B*, the transverse component of the magnetic field is common to both load legs and the electric field has to change in direction to be propagated to one of the loads. This is similar to two wired loads in series with a source. There the current to each load is the same but the voltages across the loads may be different. Unfortunately, however, this is about where the similarities end. If the impedances[1] of the two load lines are known, it may be possible to combine them in such fashion as to predict the desired impedance of the source to fair accuracy, but the method of combination is not the same as with wired circuits and moreover, it is rather complicated.

### Electric Field Values

In *Fig. 2* the series-connected T is shown again in a side view. If the dimensions of the guide are such that only the $TE_{1,0}$ mode of propagation can be transmitted without appreciable attenuation and all other modes are rapidly attenuated then, at a distance of several wavelengths away from the junction, the electric field will have

[1] Wave Guide Impedance, RADIO, May, 1944.

instantaneous values as shown. This will be true if the width of the guide (dimension into the paper in *Fig. 2*) is between one-half and one wavelength, and if the height of the guide is less than that width. Under such conditions, the energy propagation which interests us is accomplished by the motion along the guide of a sinusoidally varying electric field like the one shown. When the wave carrying energy from the source reaches the junction the electric field is distorted, because there is no top surface to the guide which can hold a charge at the terminations of the electric lines of force. Thus, in an overly-simplified illustration, the electric lines are forced to terminate at or near the corner of the junction as shown in *Fig. 2.* This provides a proper component of the electric field for propagation up into the vertical leg of the T but also forces a high electric field strength to appear at the corners. Consequently, these corners are subject to the periodic presence of high charge densities which cause a certain amount of dissipative power loss.

The electric field shown at the junction in *Fig. 2* is overly simplified for at least two reasons. In the first place, the traveling wave from the source is, in general, not the only one present; there may be waves reflected from the loads and from each connection of a wave guide with the junction. Also, the irregularities in the field at the junction will cause the excitation of higher modes in any or all of the connected wave guides; the fact that these higher modes are rapidly attenuated and do not extend far into the wave guides does not lessen their presence at the junction or prevent energy loss into them. With these complications it is easy to see that the problem is a difficult one to solve in a purely theoretical manner. As always, the need is to satisfy Maxwell's equations at all boundaries for each possible mode and to superimpose the resulting functions to give a complete solution of the problem.

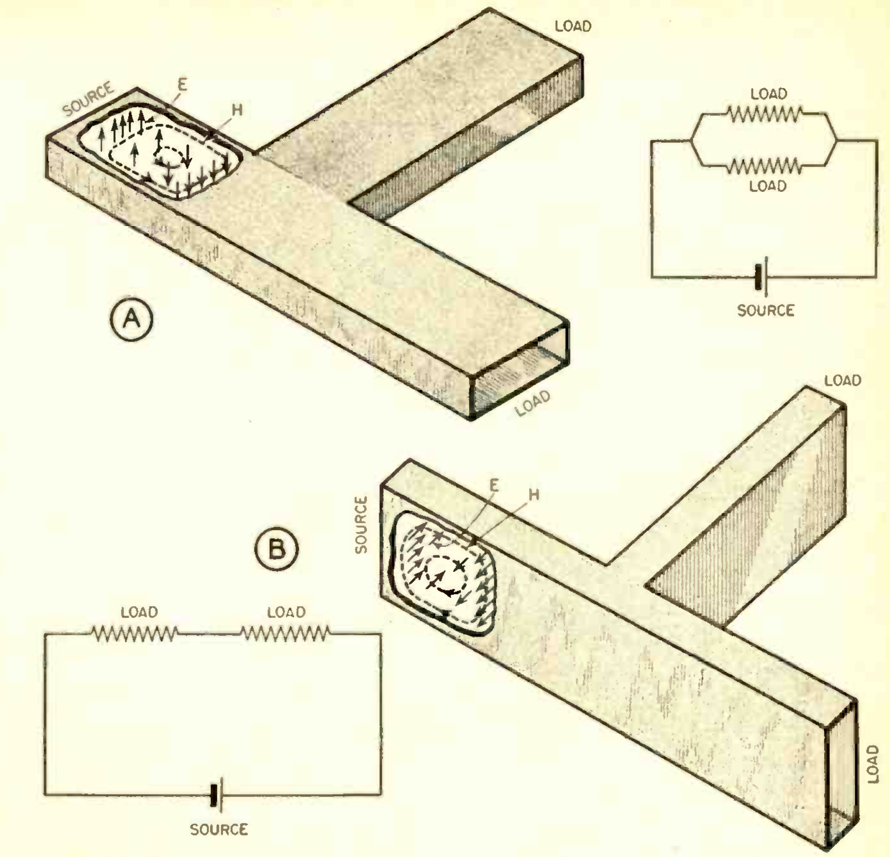



Fig. 1. Shunt and series wave-guide-connected loads across a single source

#### Impedance Determination

However, once such a solution is obtained either theoretically or empirically, it is most convenient to express it in terms of impedance. That is, graphs or algebraic expressions connecting the desired impedance of any two of the legs and that of the third are needed to show the relation which will cause energy to be transferred through the junction most efficiently. To follow a standard method, it is necessary to choose points at which the impedance is to be evaluated. It is convenient to make the measurement for both of the horizontal guides of *Fig. 2* at a cross section indicated by *A* or its equivalent; for the vertical wave guide, the impedance may be computed or measured at *B*.

Reference to *Fig. 3* makes it clear that, in general, the impedance of a wave guide line depends upon the position at which the measurement is made. The component of the field due to a standing wave alone represents an $E/H$ value or impedance that varies from infinity at a point like *A* to zero at a point like *B*. Superimposing *E* and *H* values from the traveling wave on this standing wave modifies the ratio but does not remove the dependence of impedance on distance along the line. This situation is the same as that which prevails in other electrically long transmission lines and is the reason why matching criteria for a device like a T junction must specify the impedance of each leg at a particular point. Any other point an integral number of wavelengths away from the given point and back into the leg in question will give an equivalent measure. For that matter, if the wavelength is known and the impedance at any given point on the wave is measured it is easy to calculate the impedance at any other point. Charts for making such calculations are commonly used.

#### Open-Ended Wave Guides

Mechanically, the simplest termination that can be imagined for a wave guide is none at all. Because of its

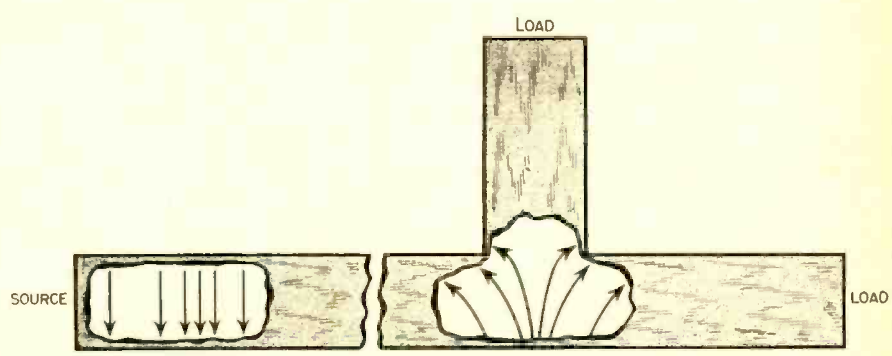



Fig. 2. Simplified illustration of a series T wave guide junction, showing how the electric field is distorted at the junction

very simplicity there is considerable interest in what happens when a long wave guide whose far end is well removed from other obstructions is left with just an open end. Qualitatively, the answer is that some energy is radiated and some is reflected back into the guide. Moreover, of that which is radiated, some moves straight ahead, some appears as side lobes and a considerable amount is radiated backward along the outside of the guide.

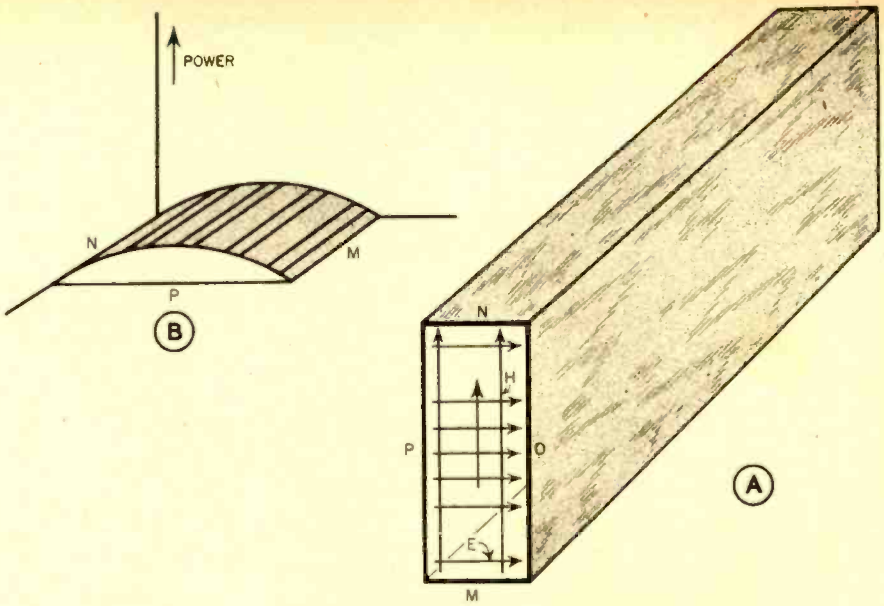



Fig. 4. Instantaneous values of E and H fields at exit of an open-ended wave guide operating in the $TE_{1,0}$ mode

In *Fig. 4A* is shown the electric and magnetic fields which as a first approximation we may expect to find at the open end of a rectangular wave guide that is operating in the $TE_{1,0}$ mode. The electric field which runs uniformly across the narrow dimension has maximum intensity at the center and shades off to zero at walls *M* and *N*. The magnetic field which is perpendicular to the electric field is also uniform in the *OP* direction and varies in the *MN* direction in the same way as does the electric field. Thus since we know that the energy flow in an electromagnetic field depends upon *E* and *H*, we expect the energy flow out of the guide as radiation to be given in strength by a function something like the one drawn in the three dimensional plot of *Fig. 4B*. Our desire is to find how this energy proceeds out into space.

Huygen's principle at first seems to offer us a method of solution. It seems to say that we need only to imagine the electromagnetic wave at the end of the wave guide to be replaced by an array of point sources which vary in strength in accord with the plot of *Fig. 4B*; to construct spherical waves about each of these sources; and to add these waves in proper strength at various points in space so as to determine the pattern of the radiation. This type of calculation, however, neglects radiation which arises from currents flowing in the outer surface of the wave guide and although it approximates the forward radiation it does not predict the backward component which is experimentally observed and which is nearly as strong as the forward component when the wave guide is operated near cut-off.

Because of the skin effect, wave guide currents flow only in a very thin layer of metal and are quite unable to penetrate through the walls of the guide. But when the end of the guide is left open, electric and magnetic fields which appear at the plane of the opening cause currents to flow in the exterior of the guide in the neighborhood of the open end. These currents are, of course, very rapidly changing ones and contribute to the radiation field around the guide end. This argument alone indicates qualitatively why horns or cone terminations are so helpful in matching wave guides to free space. As in the acoustical case, very specially shaped horns give the best results but only as a matter of degree. Almost any sort of flange or cone which prevents these exterior currents from propagating energy backward will greatly improve the desirability of the wave guide termination as a radiator.

S. A. Schelkunoff has demonstrated a method of calculation for an open-ended rectangular wave guide which overcomes the difficulty encountered in the naïve use of Huygen's principle. The argument is based upon the use of a so-called equivalence theorem. A sheet of electric current and a sheet of magnetic current are imagined to be flowing in the plane of the wave guide opening and over the outer surface of the guide. If such currents are adjusted so as to just cancel out the aperture fields and the outer surface currents which are present when the guide is radiating, then the cancellation completely stops any flow of energy from the guide. If now no energy is fed into the source end of the guide, these simulated currents must duplicate the radiation field except for a reversal of sign. Maxwell's equations are sufficient to calculate the field arising from this equivalent current distribution. The great advantage accruing from such an equivalent type of calculation lies in the fact that the current sheet distribution does not have to be one that is physically realizable. It may be as imaginative as we desire so long as it does provide the necessary cancellation and lend itself to use in the field calculation. It may allow these calculations to be simpler than would the actual currents in the interior of the wave guide which in any event may not be accurately known and are difficult to compute or measure.

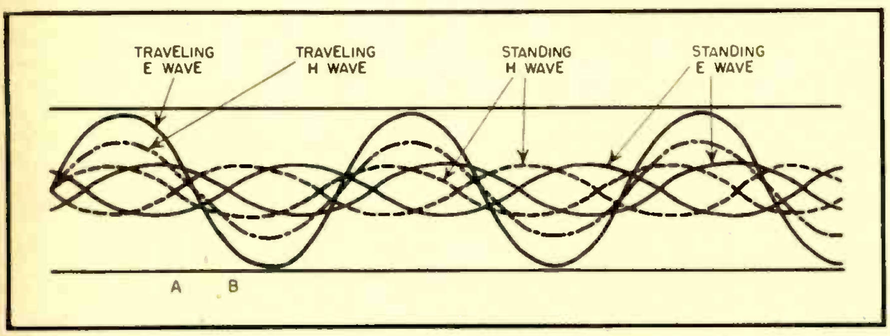



Fig. 3. A section of a wave guide or other type of transmission line carrying a traveling wave and a standing wave. The curves represent the field strength in the guide by their distance above or below an imaginary cnter line. As a function of time, the traveling waves move to the right; the standing waves take on successive values between the extremes shown

### Design Considerations

Reflections back inside of the wave guide occur not only at an open end but in general are found wherever there is any sudden discontinuity such as a change in shape or size or a change in the dielectric inside the guide. It is only when very careful designs are ar-

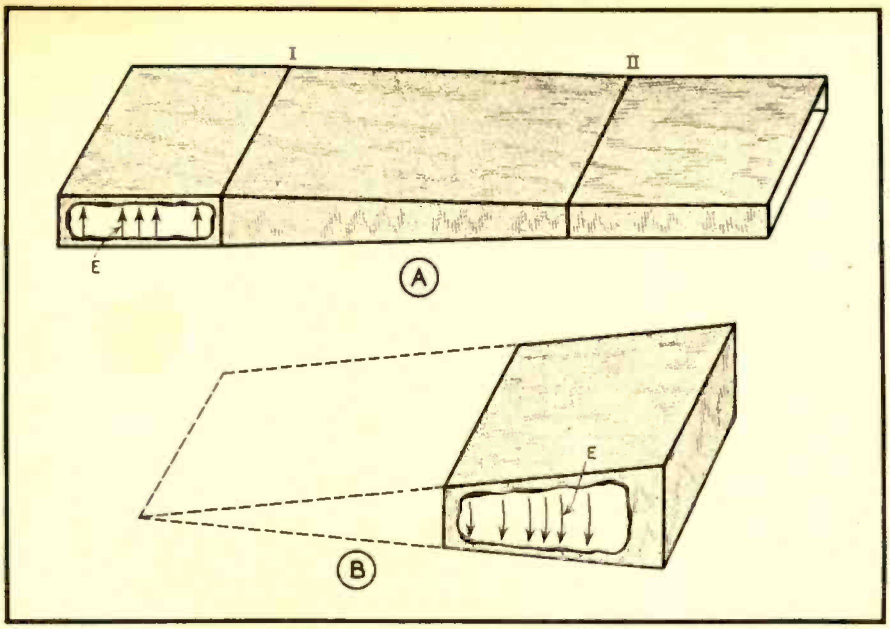



Fig. 5. Tapered section to connect wave guides of different sizes

ranged that these reflections can even be minimized. When space is available, it is therefore often advisable to avoid sharp discontinuities and use tapered sections to connect wave guides of different size or to use bends of not too small a radius of curvature to replace right angle junctions.

To see qualitatively why a tapered section like that shown in *Fig. 5* is superior to a sudden change in cross section, it is only necessary to realize that the wedge-shaped connecting piece will propagate approximately cylindrical electric waves without much attenuation and that the reflections at the entrance and exit to the tapered connector can be negligible because the discontinuities in the wave guide size can be kept small. In *Fig. 5B* an exaggerated wedge-shaped section is shown to indicate that cylindrical waves are the natural ones for such a piece. The broken lines indicate that if the wedge were continued, it would converge to a line. If this line were a wave source then cylindrical waves might surely be expected to emerge from it just as circular waves spread out about a pebble dropped into a quiet pool of water. A more practical tapered connector, as shown in *Fig. 5A*, is evidently two or more wavelengths long for frequencies which allow the guides shown to operate in the $TE_{1,0}$ mode. The discontinuities shown at cross-sectional surfaces *I* and *II* are so mild as to cause little reflection. If energy traverses the system from left to right, we will have at the boundary *I* incident and reflected plane waves to the left, and incident and reflected cylindrical waves to the right. At the boundary *II* we will have incident and reflected cylindrical electric waves to the left and a transmitted plane wave to the right. It is not too difficult to express these waves algebraically and match them at the surfaces to allow for continuity of energy flow. Such a calculation can yield the amount of reflected power back into the wave guide at the left as a function of the ratio of the wave guide sizes and the length of the tapered line. The result indicates in agreement with experiment that, for all usual cases, a tapered section more than two or three wavelengths long will yield quite satisfactory results. Moreover, we can be sure in any event that a sufficiently tapered line will be non-reflecting. This applies to coaxial lines and non-rectangular wave guides as well as to the case discussed.

### Wave Guide Bends

The arguments concerning bends in wave guides are in the main similar to those for tapered sections except that a change in direction of the electric or magnetic field is also involved just as it was in our discussion of T junctions. The change here, however, is gradual and much less difficult. The creation and attenuation of higher modes is not at all a serious problem. In *Fig. 6* are shown two types of bends in a rectangular wave guide which are often respectively referred to as *E* and *H* bends. The assumption is that these pieces are to be operated at such a frequency that only the $TE_{1,0}$ mode can be transmitted without rapid attenuation. That is, it is assumed that the wavelength of the energy in free space will be less than twice the wider dimension of the guide but not so little as to be less than or equal to that dimension. Under these conditions the electric field vectors will be oriented approximately as shown. With the *E* bend the electric vector is forced to change its direction while, with the *H* bend, it is not. In the *H* bend, it is the transverse component of the *H* field which must turn as it proceeds along the wave guide.

If the bent portion of either of the guides shown in *Fig. 6* is considered as a section of a wave guide toroid, it is possible to show that in either type of bend the attenuation in the toroid section itself can be as small as in a straight section of wave guide. For example, in the case of the *E* bend the toroid section of the wave guide serves only to cut out a portion of a radial field whose center is at the center of curvature of the bend. Since the walls of the wave guide partition off this section by virtue of conductors placed normal to the field, at least the boundary condition of the electric field is adequately met.

We can write algebraic expressions for the waves in the bent section and match them up to the plane waves in the straight sections, paying due attention to the higher modes. Out of such calculations can be obtained expressions for the amount of reflected energy to be expected at the discontinuities where the two types of guide are joined. It turns out that the loss due to such bend junctions are fairly negligible even if the radius of curvature is only a few times as great as the wider dimension of the wave guide. Experimental results are usually somewhat worse than the calculated performances. This is presumably due to the mechanical difficulty of making truly smooth bends. Actually, some reflections do occur at points along the bend as well as at the joints. But even then the loss is so small that bending a wave guide is generally considered an easy and very efficient way to turn a corner. This applies both to *E* and *H* bends and to bends in circular wave guides as well.

### Junctions

When we come to the problem of constructing junctions between wave guides of different shapes or between a hollow wave guide and a coaxial line, a great many fairly complicated arrangements are possible. So far as guide-to-guide connections are concerned, the procedure is quite often only of academic interest because there is seldom a valid reason for changing from one type of wave guide to another. When there is a reason, the change can be made by the use of sections which gradually change from one shape to another and by the use of grids or resonant slots which correspond to the desired electric field dis-

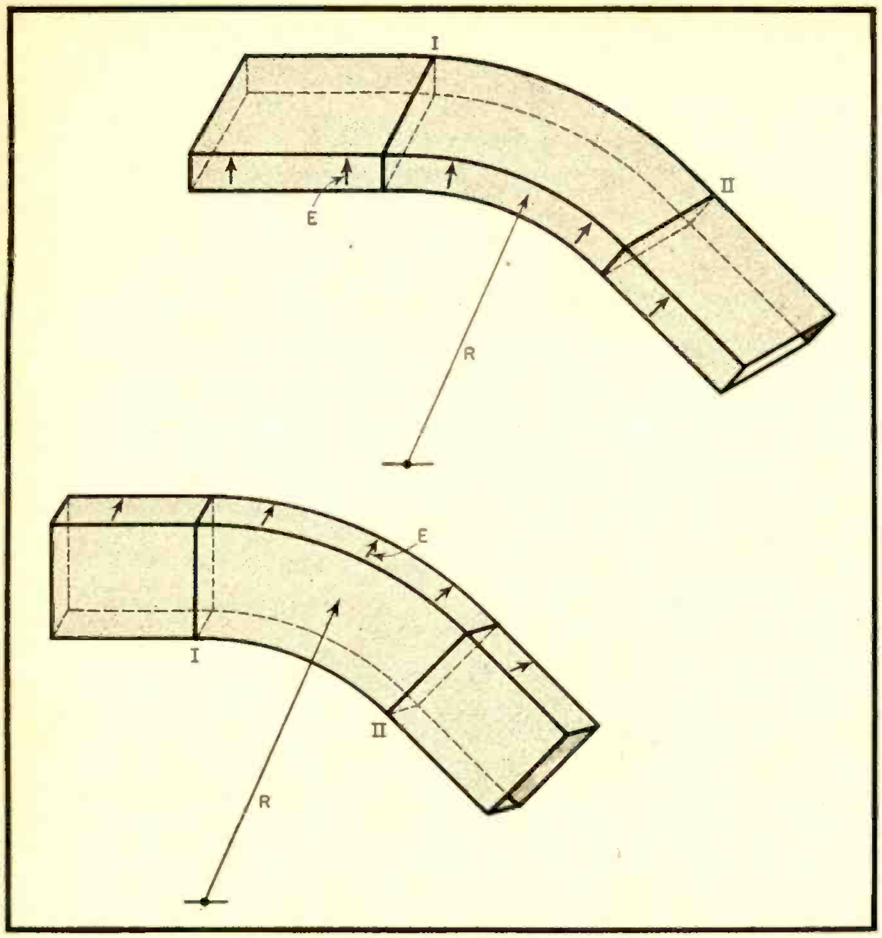



Fig. 6. E and H bends in a wave guide

tribution in the new shape. Detailed analyses and computations are doubtless possible for at least the simpler cases of such transitions, and would follow along the lines that have been described for bends and T joints. Junctions between coaxial lines and hollow wave guides are much more frequently used. It is often more convenient to bring the energy out of a vacuum tube generating device with coaxial fittings than with a hollow wave guide because the coaxial line is smaller. On the other hand, for transmission over distances greater than a foot or so, a hollow guide is preferred on the basis that the losses can be limited to a smaller amount.

In *Fig. 7* is shown a schematic representation of one method of introducing a signal from a coaxial line into a wave guide. The left-hand end of the wave guide and the upper end of the coaxial line are closed off or shorted. Here, the shorts are shown as being adjustable to indicate that the impedance of the wave guide and the coaxial line may be matched within certain limits by proper adjustment. Once the characteristics of the wave guide and coaxial line are known, these adjustments can of course be fixed.

The wave guide in *Fig. 7* is assumed to be proportioned so that only the $TE_{1,0}$ mode can be propagated without great attenuation, and is represented as being seen from the narrower side of the rectangle. Thus we desire that energy from the coaxial line shall set up an electric field in the wave guide which is oriented as we have shown it. Qualitatively, this seems to be just what is to be expected from the way the coaxial center wire is inserted. Voltage waves between the two conductors of the coaxial line must appear between the center wire and the wave guide walls when the wave guide is reached. Currents in the center wire at the wave guide likewise seem to create the right sort of magnetic field.

The main problem is that of tuning the two stubs. Energy coming up the coaxial line to the wave guide will also energize the coaxial stub section; energy reflected from the shorted coaxial end must return without loss so as to keep the net energy flow into the stub at zero and yet not pass backward along the line to the generator. Likewise, energy radiated from the coaxial center wire antenna into the wave guide must be reflected from the wave guide short and proceed to the load without causing interference at the antenna wire that will prevent further energy radiation. In brief, all this means matching the coaxial line impedance to that of the wave guide. It turns out that, in a junction like the one shown in *Fig. 7*, we can match the wave guide to any coaxial input whose resistance is less than twice the characteristic impedance of the wave guide. Adjustment of the coaxial stub

[*Continued on page 74*]

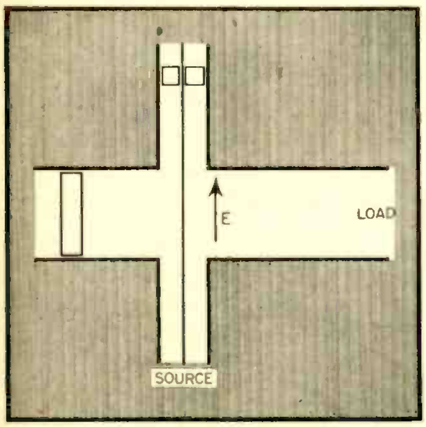



**Fig. 7. A transition junction from coaxial line to wave guide**

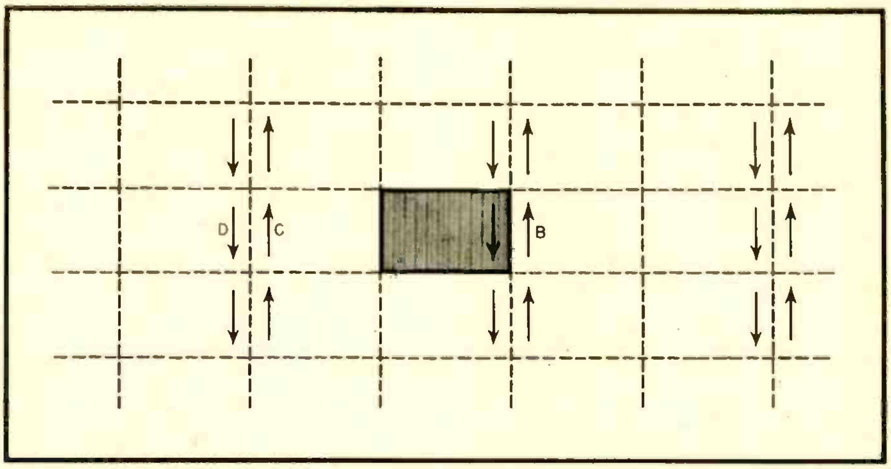



**Fig. 8. Image array to simulate field in a rectangular wave guide arising from excitation by a single electric dipole**

# RESISTORS

## Their Construction & Behavior

**A. P. HOWARD**

**PART I**

**Factors which enter into the manufacture of composition resistors, and their characteristics, are described**

THE basic phenomenon of resistance has been explained in terms of the freedom of the material's molecular structure to adapt itself readily to the passage of electrical current. From this explanation, arbitrary distinctions have been made among conductors, semi-conductors, and insulators.

The criterion of a material's resistance is its resistivity. It is this quality which defines the ability of the molecular construction to adapt itself electrically.

Resistance then becomes a dimensional expression of resistivity, directly proportional as related in the following equation:

$$R = c\rho L/A$$

where $R$ is the resistance in ohms; $c$ is the dimensional constant depending on the units of measurement; $\rho$ is the resistivity of the material; $L$ is the length of the body; $A$ is the cross-sectional area of the body.

Designers of commercial resistors have confined themselves primarily to the field of conductors. These conductors have been defined as materials whose volume resistivity is less than 10 megohms per circular mil foot.[1] Some of the more commonly used materials are the subject of Table A.

As a result of these limitations of conducting materials, resistors have been constructed of two general groups of materials:

a.) Composition—a resistor whose resistance element is composed of a granular carbonaceous material.

b.) Wire-wound—a resistor whose resistance element is composed of one or more alloy wires connected in series or parallel.

The former group will be considered first.

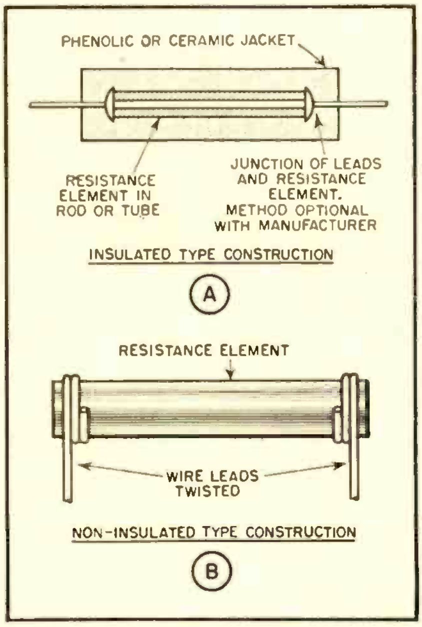



**Fig. 1. Resistor construction**

### Composition Resistors

Commercially, a distinction has been made between the insulated and non-insulated forms of the composition resistor. This distinction is necessary from a functional and a constructional viewpoint. The insulated type permits contact with the resistance element only through the lead wires; the non-insulated type is essentially a bulk of resistance where, theoretically at least, contact can be made with the resistance element at any place along the resistor body.

The composition resistor industry today has become a chemically-minded industry. The composition, today a closely guarded trade secret, has changed much from the early days but is based on carbon and its forms or a similar conducting material.

The resistance element material is capable of being expressed mathematically. Certain formulae have been found empirically on the basis of continuous test data by the resistor manufacturers. The generalizations below are based on these formulae.

Finely-granulated carbon is mixed with a synthetic resinous binder. This material, when the binder is dry, is the heart of the resistor.

The variables in the carbon composition and the control of these variables represents the problems of resistor construction. Analyzing first the material as received, it is known that carbon, as indicated in *Table A,* will have a resistivity of approximately 21 kilohms per circular mil foot (abbreviated cmf), graphite will vary between 400 and 5000 ohms per cmf. Again the addition of certain ceramic forms or metallic oxides or the silicon compounds which readily combine with carbon products affect the resistivity.

After pulverizing the selected carbon stock, the material can be mixed in different proportions with the binder. The resistor, carbon and binder, is fired at high temperatures. Since the carbon tends to contain water not easily thrown off in an evaporation process, an increase in temperature past the boiling point of water will drive off varying portions of the water of crystallization.

The driving off of the water of crystallization is more important in the case of the non-insulated resistor, where talc or equivalent ceramic is introduced for mechanical and electrical reasons.

There is one additional property of carbon, apart from the water of crystallization described above, which affects the finished resistor. This also is a determining factor in deciding the temperature at which the resistance is to be cured. The property of changing resistivity with temperature of curing is known to electrical engineers since the introduction of the compressed carbon rheostat. It has been known that an increase of temperature, past the point where the material was originally fired, will bring about a permanent decrease in resistivity.

It is these properly controlled variables—the purity and composition of the material, the mixing proportions with binder, the firing temperature—that lead to proper composition resistor design. It is these variables that have led to design formulae.

### Resistor Elements

It has been customary to build the insulated composition resistor with a minimum of extraneous or non-carbonaceous material. Because the resistance path is characteristically small, the elements consist only of carbon or similar conductor and binder. *(See Fig. 1A).*

This conducting material is painted or sprayed on a small glass rod or tube, or similar ceramic form. This tube or rod in lengths is baked at elevated temperatures and the now-baked coating shrinks around the tube. The finished tube, cut to size, is press-fitted to the wire leads and molded into a phenolic case.

It would seem well to note that there are some exceptions to the above generalizations in today's resistor market. Sometimes the ceramic tube or rod is not used, but a solid rod of carbon replaces it. Usually, the carbon content is altered to include other conducting material whose temperature coefficient or other properties are more desirable than carbon's. Sometimes the outer jacket is a ceramic-like material with resin-cement-sealed ends.

The non-insulated type, shown in *Fig. 1B,* uses talc or the metallic oxides or silicon forms in combination with the carbon and binder, as has already been indicated. The absence of an outer jacket would lead to mechanical instability were not talc or a similar agent added. Additionally, the increase in resistor body diameter would limit the top resistance obtainable since resistance is inversely proportional to the body cross-sectional area. Thus the ceramic added increases the non-condusting paths present in the body and adds to the total resistance.

Carbon, powdered ceramic, and binder are the start of the non-insulated resistor. Poured into forms and fired or continuously extruded and fired, the resistance body is then wrapped with wire leads. The finished product of either type is then measured and painted in accordance with standard color codes.

Each of these types has separate and distinct limitations. Overall, the composition resistor has one distinct disadvantage: its comparative lack of stability. Temperature, humidity, voltage, current, and other factors—all have a marked effect on the composition resistor. In general, the wire-wound resistor, to be discssed later, offers greater stability.

### Limitations

The limitations of the composition resistor with humidity exposure have become the criteria for selection under the American War Standard, which outlined two grades: resistant to humidity exposure, or resistant to humidity exposure and salt-water immersion cycling. The resistor which can meet salt-water immersion cycling has proven to have a more impervious coating and should be used in those circuits where maximum stability is demanded.

Non-insulated forms, at the time of the writing of the War Standard, were not sufficiently impregnated to withstand the rigorous immersion cycling. It is doubtful if any today can meet these requirements. This failure does not reflect on the product of any one manufacturer, but is inherent in the design of the resistor. Since the resistance element is at all times exposed, it would be expected that the resistor would fail under such a severe test, though satisfactory in general applications.

Even the resistor, insulated and resistant to humidity and salt-water immersion cycling, is no match for high humidity conditions. Under continuous exposures to relative humidities in excess of 95%, a contiguous film of moisture forms across the jacket. This film effectively shunts the resistance element and will have a marked effect above the following resistance values:

| *Power Rating (watts)* | *Maximum Resistance (megohms)* |
|---|---|
| ¼ | 1 |
| ½ | 2 |
| 1 | 3 |
| 2 | 5 |

The above rules, of course, are arbitrary. They have been based on typical wattage sizes available commercially and on the decrease of surface resistivity under extreme humidity conditions.

The other limitation which is imposed on the insulated type resistor is the comparative lack of thermal conductivity of a phenolic or ceramic jacket as opposed to a resistor free to dissipate its heat through open air.

### Power Rating

The power rating of any resistor is based on its ability to dissipate heat. The power rating, although a combination of a number of variables, is basic-

**RADIO CONDUCTOR CHARACTERISTICS**

| Material | Relative Conductivity | Specific Resistance (ohms/cmf) | Temperature Coefficient (ohms/ohm/°C.) |
|---|---|---|---|
| Copper | 1.00 | 10.37 | .0039 |
| Silver | 1.06 | 9.80 | .0038 |
| Carbon * | .0005 | 21,000 | —.0006 |
| Nichrome V | .016 | 650 | .00013 |
| Constantin | .035 | 295 | ±.00002 |
| Manganin | .036 | 290 | ±.000015 |
| Ohmax | .014 | 1,000 | —.00035 |

* Values given for carbon vary depending on the form. Graphite specific resistance values vary from 400 to 5000 ohms/cmf. Values given above are typical for amorphous carbon.

## TABLE B

**POWER RATINGS OF FIXED COMPOSITION RESISTORS**

**Insulated Types**

| Wattage (Max) | Length (Max) | Diameter (Max) | Working Voltage (Max) |
|---|---|---|---|
| ¼ | 0.406 | 0.170 | 250 |
| ½ | 0.468 | 0.249 | 350 |
| ½ | 0.655 | 0.249 | 350 |
| 1 | 0.718 | 0.280 | 500 |
| 1 | 1.28 | 0.310 | 500 |
| 2 | 1.41 | 0.405 | 500 |
| 2 | 1.78 | 0.342 * | 500 |

* The diameter is being changed to 0.405 max. under current specifications.

**Non-Insulated Types**

| Wattage (max) | Length (max) | Sepaartion of Leads (min) | Diameter of Leads (max) | Working Voltage (max) |
|---|---|---|---|---|
| ¼ | 0.350 | .... | 0.120 | 200 |
| ¼ | 0.655 | 0.376 | 0.248 | 250 |
| ½ | 0.780 | 0.407 | 0.280 | 350 |
| 1 | 1.16 | 0.814 | 0.280 | 500 |
| 1 | 1.84 | 1.45 | 0.436 | 1000 |
| 2 | 2.12 | 1.45 | 0.592 | 500 |
| 4 | 2.66 | 2.06 | 0.730 | 500 |
| 5 | 3.16 | 2.47 | 0.780 | 500 |

Based on American War Standard C75.7—1943

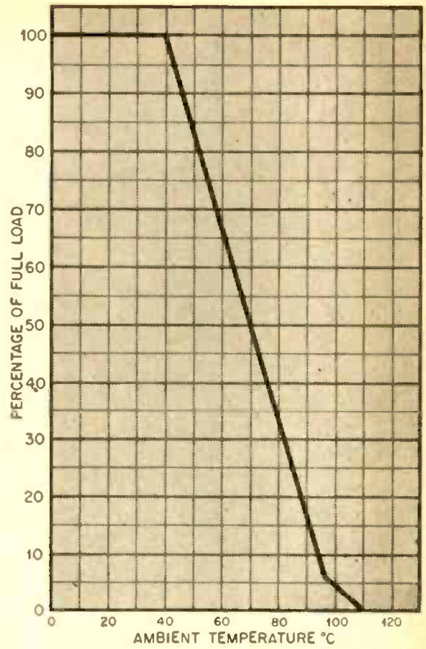



**Fig. 2. Graph showing proper derating for operation of composition resistors at elevated temperatures**

ally the measure of the amount of power the unit can dissipate before marked deterioration of the unit will set in. In general, insulated resistors can be operated without damage to 100°C. and perhaps to 110°C. This is based on the limitations of the typical phenolic and typical binder, both organic in nature.

Since the hottest point of the jacket is not on the resistor surface, one cannot tell from surface temperature rise measurements what damage is being done to the jacket internally. Some typical resistors examined showed a rise from 50°C. to 110°C. over a 25°C. ambient when operated at 100% load, and from 60°C. to 125°C. at 150% load.[2]

The dissipation of heat will vary with many factors: the type, construction, and shape of the rod; the type of joint with the wire leads; the thickness, type, and length of the outer jacket. Since all these factors are unpredictable, results such as described above are usual.

The same considerations apply for the non-insulated resistor, with the exception of the outer jacket.

It can easily be seen that there is no predictable conclusion to the problem of size versus wattage. As a result, certain sizes have grown up to be standard. But size in itself does not indicate the resistor's ability to dissipate power. Therefore, the indication of a resistor's ability to dissipate power has become its satisfactory operation through 1000 hours of intermittent full-load operation. This in itself has become the standard way of rating resistors, replacing the nebulous temperature rise or size considerations.

This power-handling ability tends to decrease with an increase in temperature, as shown in *Fig. 2.* This arises from the limitations of the organic materials present. Note that at about 110°C. no load can be handled.

Despite the limitations imposed by the phenolic jacket, the War Standard resistor sizes of the insulated types are smaller than the non-insulated types of the same wattage rating. This is because the rating of the resistor is based on performance rather than temperature rise and, in general, the insulated resistor is more stable under ageing. The mattage and voltage ratings are shown in Table B.

### Voltage Rating

Voltage rating, as a by-product of wattage rating, has been based on two considerations: creepage length and power rating. Each resistor size has been assigned a maximum rated continuous working voltage or critical voltage. This rating has been based on previously established manufacturer's ratings and on safe creepage distances predicated on the several ambient conditions the resistor may encounter.

Below the point where the critical voltage is reached, the working voltage is based on power:

$$E = \sqrt{PR}$$

where $E$ is the safe working voltage, $P$, the nominal power rating in watts, and $R$, the nominal resistance in ohms.

These, then, are the important characteristics of the composition resistor. Sizes, color coding, voltage and power rating have become standard through usage and through efforts of such groups as the R.M.A. Also standardized are the preferred resistance sizes, subject to Table C. These values have been selected because the entire range of resistance can be conveniently cov-

## TABLE C

**PREFERRED RESISTANCE VALUES**

Over the range from 10 ohms to 20 megohms, the following values and these values multiplied by any multiple of 10 are preferred resistance values:

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

Example: 7500 ohms is available in 5% tolerance only; but 2.2 megohms is available in 5%, 10%, or 20% tolerance.

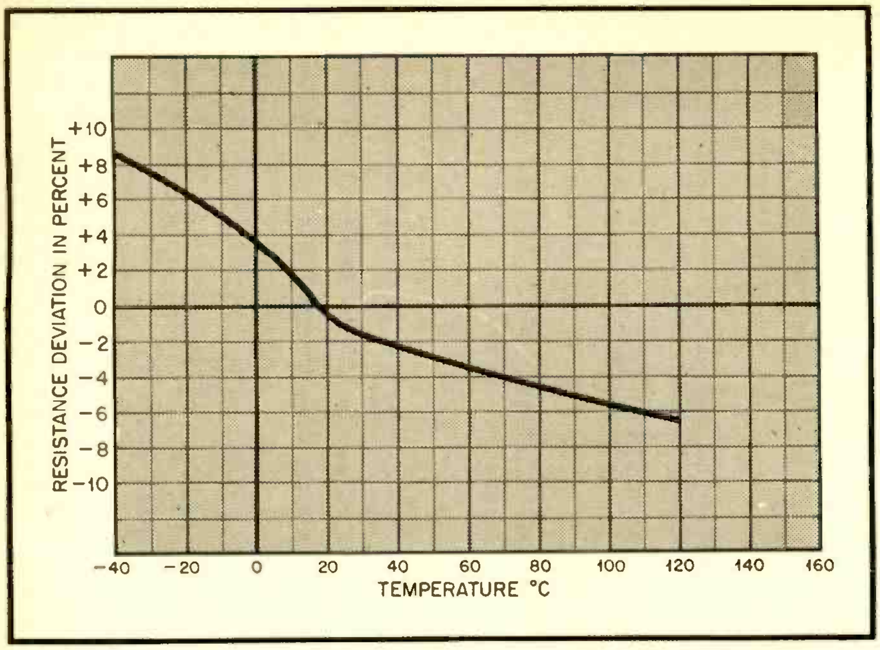



**Fig. 3. Percentage resistance deviation at various temperatures**

ered in each of the common 5%, 10%, and 20% tolerance groups.[3]

Manufacturers, in pre-war days, stocked these preferred sizes. Today, the selection of composition resistors in accordance with this system of preferred values is virtually mandatory, in view of the procurement situation.

### Temperature Coefficient

A characteristic of the fixed composition resistor is the temperature coefficient of resistance. Practically all known substances have a change in resistivity with temperature. Resistance will vary with temperature as follows:

$$R = R_o\,(1 + \alpha\,[T - T_o])$$

where $R$ is the resistance in ohms at temperature $T$, $R_o$ is the resistance in ohms at temperature $T_o$, and $\alpha$ is the temperature coefficient.

A typical temperature characteristic curve is shown in *Fig. 3*. The resistors examined were commercial resistors which did not claim special temperature-coefficient characteristics. Special results have been achieved with such negative temperature coefficient materials as the metallic oxides (barium, strontium, etc.) or the silicon carbides.

It has been found, however, that the normal temperature coefficient varies with resistance. This follows from our previous discussion where we stated that resistance is often varied by changing the "mix" of carbon with binder or by changing the firing temperature.

Expected variations because of temperature, based on the War Standard, are as follows:

| *Nominal Resistance* | *Maximum Allowable Per Cent Change from Resistance at 25°C.* At —55°C. E | F | At 105°C. E | F |
|---|---|---|---|---|
| $10^3$ ohms and below .... | +13 | + 6.5 | ±10 | ± 5 |
| $10^3$ to $10^4$ ohms | +20 | +10 | ±12 | ± 6 |
| $10^4$ to $10^5$ ohms | +25 | +13 | ±15 | ± 7.5 |
| $10^5$ to $10^6$ ohms | +40 | +20 | ±20 | ±10 |
| $10^6$ to $10^7$ ohms | +52 | +26 | ±36 | ±18 |
| $10^7$ to $10^8$ ohms | +70 | +35 | ±44 | ±22 |

This temperature coefficient, upon examination, is basically negative. This arises from the fact that the main constituent of the resistance coating is carbon, one of the few common materials with a temperature coefficient.

It is this coefficient working in combination with the voltage coefficient which has contributed greatly to the instability of composition resistors. The latter coefficient appears to be caused by two isolated actions working together: heating of the resistance under load, therefore causing a temperature coefficient-inspired change and a partial—but temporary—breakdown of the individual resistance particles.

This property has been utilized in the building of protective resistors of the negative temperature coefficient type. Resistances have been constructed to vary as the exponent of the current to as high as the seventh or eighth power.

A typical voltage-coefficient curve is shown in *Fig. 4*. This data has been secured recently. It is important to note, however, that some of the major advances in making a more stable composition resistor have been in the field of temperature and voltage coefficients. Data of five to ten years ago would yield greater coefficients.

Limiting values on the part of the War Standard, values which most every manufacturer can meet, are:

¼ and ½-watt sizes .035%/*V*. rated load
Above ½-watt sizes .020%/*V*. rated load

It is expected that values under one megohm will cause no difficulty, according to the language of the specification.

Other characteristics, other than the high-frequency characteristics and those mentioned above, appear to be of lesser importance, such as noise, shelf life, and the effect of soldering.

### Noise

A more careful control of the compounding and better lead structure cause a reduction in thermal agitation, the source of noise. Typical measured values of noise, employing a highly shielded circuit, battery-controlled, were in the order of 1.5 microvolts at rated load for commercial ½-watt com-

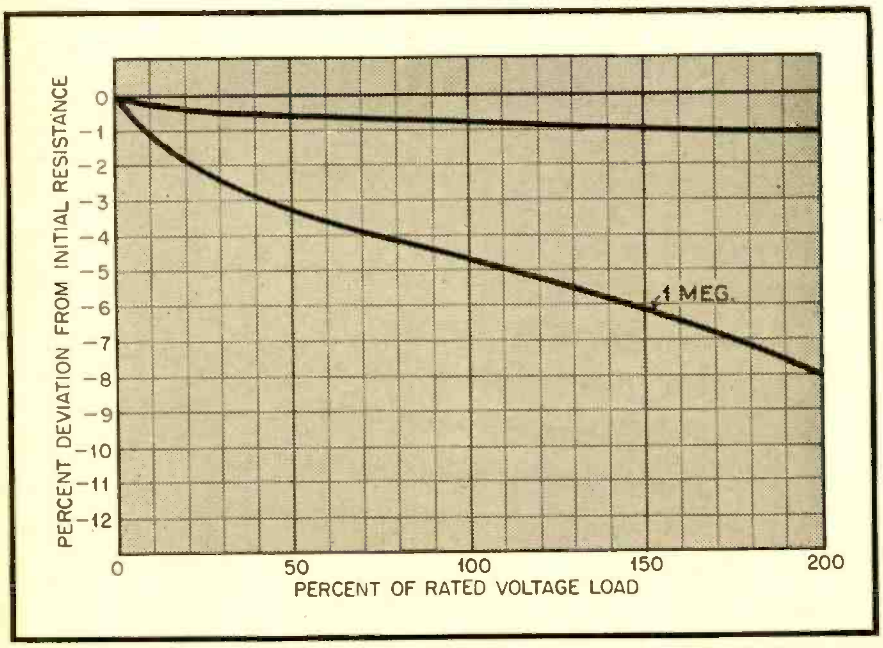



**Fig. 4. Voltage characteristics of ½-watt, 10,000-ohm resistor (upper curve) and 1-megohm resistor expressed as percentage resistance deviation**

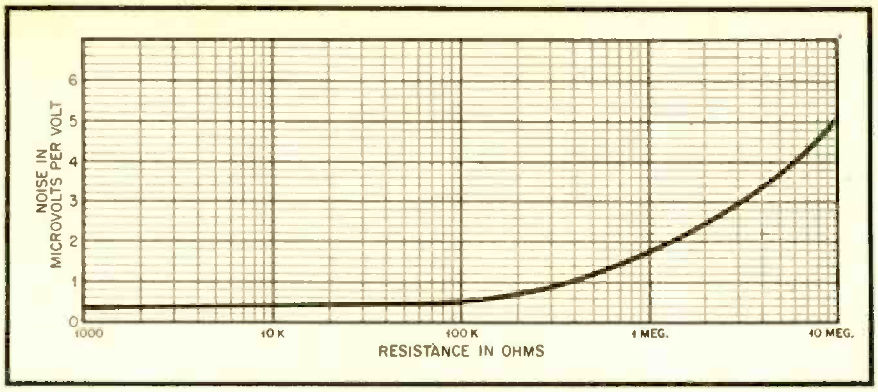



**Fig. 5. Noise characteristics of typical ½-watt resistor**

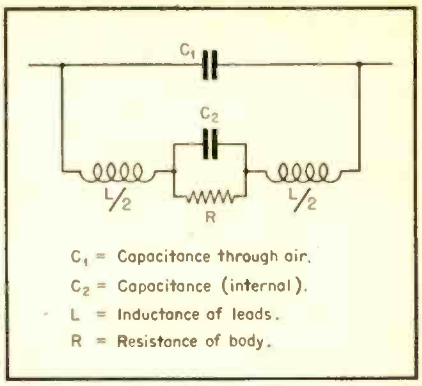



**Fig. 6. Equivalent circuit of composition resistor at high frequencies**

position resistors. War Standard limits, again an indication of what most manufacturers can produce, are 3.0 microvolts at rated continuous working voltage for ¼ and ½-watt sizes, 1.2 microvolts for power rating above ½-watt. A representative curve is shown in *Fig. 5.*

Shelf life, a factor unmeasurable under usual test accelerated conditions, varies with the manufacturer. Little change can be expected if the resistor has been properly cured. The proper drying-out of both the binder and the jacket is the answer to the problem. Speed in manufacturing with insufficient time for moulding or firing has caused resistors of lesser quality to depart greatly from rated tolerance.

The other factor involved in shelf life is the ambient temperature of the stock room. Resistors, like any other component, should be handled with care, even if their cost is fractional. High temperature and high humidity will by themselves cause changes in resistance.

Accelerated ageing tests are indications of the curing of the resistor, but not the final answer. There are several variations of this test in use: overload and operation at elevated temperatures.

Overload operation of the composition resistor will materially shorten its life. However, in testing for approximately 200 hours at 150% load at 40°C., the average change for typical quality commercial resistors is less than 5%.

Operation at elevated temperatures (85°C.) for the same amount of time with 100% load applied caused resistance changes of approximately 7%.

Operation under high humidity and under intermittent full load conditions will also have an effect on the resistance. Variations up to 10% can be expected over prolonged periods of time.

### Effect of Soldering

Soldering, essentially the application of a sudden and short-lived high temperature to the resistance element, has its most adverse effects on the smaller size units. Because the resistance element is nearer the part soldered, the effect is more important. Changes of resistance of the average of 3% were experienced in testing ¼-watt sizes. Average change of 1-watt resistors was less than 1%. At least half the resistance change was a temporary change, since the units continued to change back to the original value after the initial change due to soldering.

So far in our discussion, we have concerned ourselves with the d-c characteristics of a composition resistor. The resistor, however, should be considered as part of a high-frequency circuit.

The resistor at high frequencies looks to the alternating current wave as a complex impedance, as shown in *Fig. 6.* It has a resistance which decreases with frequency (again, a characteristic of carbon). With increasing frequency, an increasing proportion of the current travels on the "skin" of the resistance coating.

Additionally, the resistor has in inductance of its leads. Since the construction of the leads varies from manufacturer to manufacturer, there is no fixed value for this inductance.

The most troublesome reactance is the capacitive reactance of the resistor body and of the internal lead separation. Values plotted in *Fig. 7* show the decreasing effective resistance with frequency of one commercial type resistor. Here the leads are relatively close together inside the body and since capacitance is inversely proportional to lead separation, the capacitance is the dominating element at high frequency.

The capacitance in the case of the composition resistor is in the neighborhood of 0.5 $\mu\mu f$. for 1-watt resistors; 1 $\mu\mu f$ for ½-watt resistors.

The answer to the high-frequency resistor problem hinges upon several things: design of the leads so that the maximum internal separation is achieved; designing the leads so that the minimum bending is used; finding a resistance material which does not change with frequency.

In the meantime, the radio designer of high-frequency equipment can only hope to make measurements at the deseries with its resistance element, the

[*Continued on page 76*]

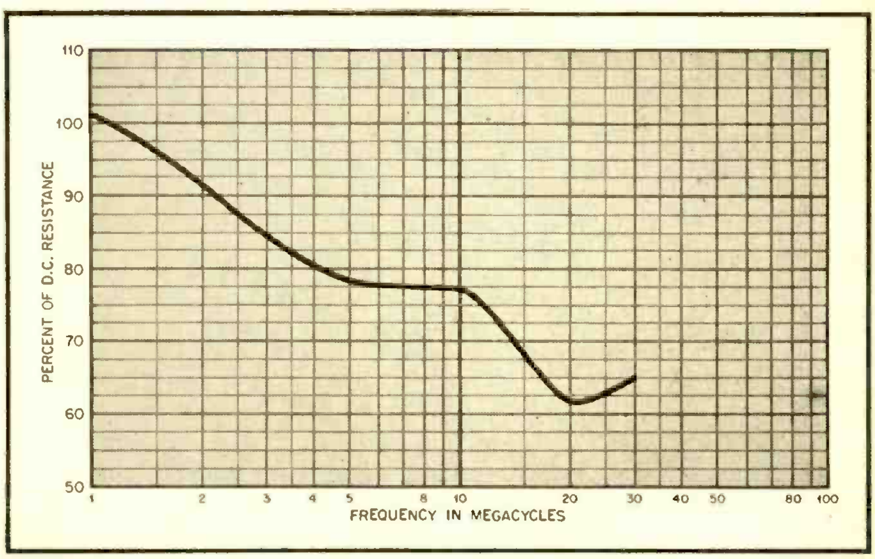



**Fig. 7. Frequency characteristic of 0.1-meg., ½-watt resistor**

# IMPEDANCE ADMITTANCE CHART

**ROBERT C. PAINE**

**Many network problems requiring admittance to be converted into impedance, and vice versa, may be more speedily solved by graphical means, using the accompanying chart**

In network problems it is frequently necessary to convert impedance to admittance and vice versa, and to avoid the use of somewhat complex mathematical solutions, graphical charts are useful. Such a chart is *Fig. 1*, which is designed to make this conversion easier.

In this chart impedance, $Z\theta$, is given in the polar form, absolute values being shown by the $Z$ circles concentric about the point 0, designated 0—10, and phase angle, $\theta$, by the radial lines marked in degrees from —90° to +90°. Each value of $Z$ corresponds to a value of admittance, $Y$, equal to $G \pm jB$, shown by the $G$, $+B$, and $-B$ circles. The conductance is shown by the $G$ circles having their centers on the line 0 —0° and designated 1.0 to .01. The susceptance is shown by the circles having their centers on the line —90° to +90° and designated 1.0 to .01. The $+B$ circles correspond to capacitive impedance and the —B circles to inductive impedance.

Only one decade of impedance is shown, 0—10, and for values outside this range the values of $G$ and $B$ must be multiplied by appropriate figures. For example, if the impedance considered is 10 times as great as the figures on the $Z$ circles, lying between 10 and 100, the corresponding values of $G$ and $B$ as read from the chart must be multiplied by 1/10, or 0.1.

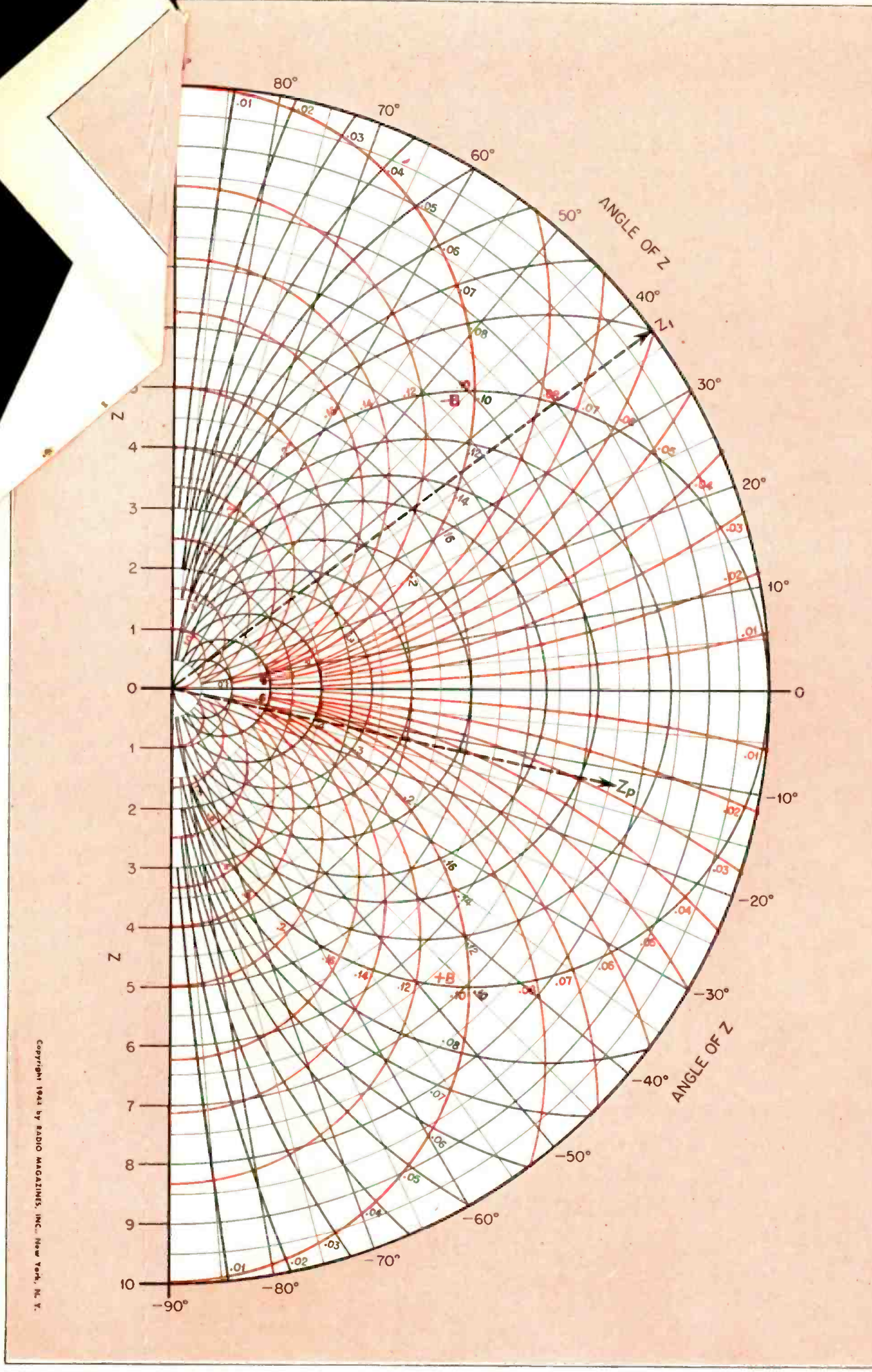
As an example of the use of this chart, consider a circuit of $Z'$ equal to 10 | 36.8° in parallel with $Z''$, equal to 10 | —60°, in which it is desired to find the equivalent impedance. These illustrative values have been plotted as vectors on the chart where it is seen that corresponding to $Z'$, $G'$ = .08 and $B'$ = —.06, and corresponding to $Z''$, $G''$ = .05. $B''$ = + .088. The net conductance $G$ then equals $G' + G''$ = .13, and the net susceptance, $B$, equals $B' + B''$ = +.028. These values of $G$ and $B$ on the chart are seen to correspond to a parallel impedance, $Z_p$, equal to 7.6 | —12°. The equivalent mathematical computation gives the value of $Z_p$ as 7.55 | —11.7°, which is a reasonably good agreement of values.

Suppose the value of $Z''$ is 100 | —60°, then $G''$ and $B''$ equal .005 and .009 respectively, and the sum, $G$, of the conductances $G'$ and $G''$, equals .085, and the sum, $B$, of the susceptances $B'$ and $B''$ equals —.051. The corresponding point for $Z$ lies outside of the chart. To take care —.051. The corresponding point for $Z$ lies outside of the chart. To take care of this difficulty $G$ and $B$ could be multiplied by 10, giving a value of $Z$ which must also be multiplied by 10 for the correct answer; however, this results in a point so close to the center as to be difficult to read accurately. A better way is to multiply by 2, giving $G$ = .17 and $B$ = —.102, which gives a value of $Z$ of 5.05 | 31°, the absolute value of which multiplied by 2 gives the correct value of $Z_p$ = 10.1 | 31°. This chart can also be used for the solution of many other problems.

The method of deriving these curves may be of interest to the reader. Admittance, $Y$, equals the reciprocal of impedance, $Z$, that is $Y = 1/Z$, or in polar coordinates $Y = 1/Z$ (cos $\theta$ + j sin $\theta$). This expression can be rationalized by multiplying the numerator and denominator by cos $\theta$ — j sin $\theta$, obtaining $Y$ = cos $\theta/Z$ — j sin $\theta/Z$ $G \mp jB$. Equating the real terms, G = cos $\theta/Z$, which is the polar equation of a circle for any given constant value of $G$ of radius $Z/2$. the center of which is at $Z/2$. | 0°. This gives a family of circles for varying values of $G$. Equating the imaginary terms, $-jB$ = — j sin $\theta/Z$, which is the equation of two equal circles for any given constant value of $B$, of radius $Z/2$, with centers at $Z/2$ | —90° and at $Z/2$ | 90°. Since physical impedances only have angles in the 1st and 2nd quadrant, semicircles are shown on the chart for values of $B$.

[*See chart on opposite page*]

# IMPEDANCE - ADMITTANCE CHART



# TONE ARM DESIG

**ROY DALLY**
Consulting Engineer, The Electrovox Co., Inc.

**PART I**

**Fundamental principles of tone arm design and practical considerations to be observed in their application are discussed**

Modern phonograph tone arm design should be divided into two categories, those used on manually operated equipment, and those which form an inherent part of the changer mechanism. Certain fundamental facts however, apply to both types. These facts we will cover before discussing specific problems presented by the individual types.

### Resonance

The number one problem in any tone arm is resonance. The frequency or frequencies at which a tone arm will resonate are determined by a number of factors, among them being mass, stiffness, mechanical design or shape, and material used. Mass, and the positioning of mass, may be controlled to a large extent by the designer. Mass produces inertia, which is both essential and a nuisance in a tone arm. Lateral inertia is essential in order that the reciprocating mechanism of the pickup be forced to follow the groove modulations without imparting like motion to the tone arm, which sometimes happens at frequencies below 100 cycles if the tone arm is too light to properly complement the pickup compliance. If this condition exists, poor tracking, loss of voltage, harmonic distortion, and even groove jumping will result. The lateral inertia however, should never be greater than is necessary to insure proper tracking with the particular pickup mechanism that is to be used, since the mass necessary to produce such inertia is effective also in producing vertical inertia, the undesirable componant.

Vertical inertia cannot be completely done away with, but it may be minimized by careful design. It appears when a warped record is played, or the turntable has a regular rise and fall, which most of them have during each revolution, or where there is dancing, particularly of the jitter-bug category, which produces severe vibrations through the floor to the turntable. In the case of the warped record and uneven turntable, as the record surface below the needle point rises, the entire pickup must rise with it. The amount of additional vertical pressure existing between the needle point and record during this part of the cycle depends entirely on the vertical inertia presented by the pickup. If this be great, both needle and record are subjected to greater wear, and in addition, the amount of surface noise being reproduced will increase, since noise is largely a function of friction.

This may be proven by listening carefully to a pickup tracking at one ounce vertical pressure, and then adding an additional ounce of pressure. On the other half of the cycle, as the record surface falls away from the needle, the vertical inertia of the pickup tends to maintain the needle point at its highest level, with the result that there is little and improper contact between the needle point and the groove, resulting in poor quality, and in extreme cases, disengagement of the point and groove entirely, whereupon the pickup skates merrily across several grooves or the entire record. That record will spend the balance of its life ticking each time the needle point crosses the scratch thus produced.

### Floor Vibrations

In the case of floor vibrations, which coin machines have to contend with in particular, the results are very bad indeed. If the phonograph record drops out under a high vertical inertia head, the lad who dropped his nickel in the slot loses most of his dance music. Record life is important in juke box operation, also.

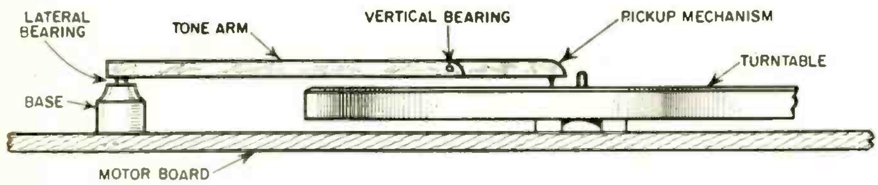



**Fig. 1. Side view of manually operated tone arm design**

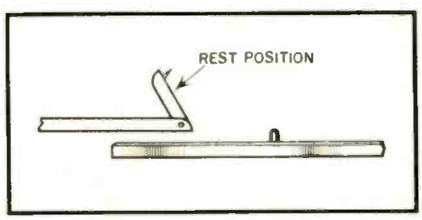



**Fig. 2. Tone arm in "rest" position**

Oddly enough, designers of tone arms for coin machines have depended on weight in the tone arm to prevent skating due to floor vibration, where as a matter of fact, that very weight produced the vertical inertia which permitted skating. Try placing a feather and a pencil on a loose board, side by side, and see which leaves the board the greatest distance when the board is struck sharply from underneath. Therefore, when considering mass and inertia in tone arm design, incorporate just enough to insure proper tracking at low frequencies with the pickup to be used, but no more. Concentrate the mass at the extreme end around the mechanism where it is most effective, and reduce it to a minimum from that point back to the base assembly.

It becomes obvious from this discussion that the use of weight for counterbalancing, where the normal vertical pressure is too great, is decidedly undesirable. If you must counterbalance, use a spring system. Much better is to choose a tone arm material which is sufficiently light to produce the desired vertical pressure when combined with the cartridge weight. Or a material may be used that produces less than the desired pressure, and lead pellets may be added in the head assembly in exactly the right spits to give proper pressure and effective inertia. Treat mass carefully, it is both your friend and enemy.

Stiffness is a product of cross section, length, and material. Proper design will produce an arm which is both light and stiff by ribbing and re-inforcing. Cast or molded arms are best from this standpoint, arms drawn from sheet metal, unless re-enforced, usually have a considerable degree of torsional resonance.

### Material

Which brings us to consideration of material. Die-cast aluminum and magnesium offer many advantages, such as stiffness, light weight, relatively inert metals, and appearance. Magnesium in particular is desirable where very light pressures are desired. Molded phenolics and plastics too, may be considered. However, phenolic materials are usually hard and brittle, making them subject to breakage. Most plastic materials tend to change their shape and dimensions in forms such as tone arms require. Caution is necessary if this type of material is to be considered.

The mechanical design or shape of a tone arm is important, but in reality, has been maligned and mistreated more than any other part of the pickup design. The customary procedure is to determine how long the arm must be to function properly, how it must fit in with the mechanical lay-out, and turn the balance of the work over to a commercial designer for shaping and embellishment. This procedure comes mostly from the Sales Department's desire that the tone arm have distinctive appearance, beauty, if such a thing can be had from a tone arm, in other words, "eye appeal." Even the material specified is usually chosen with the same thought in mind.

### Good Design Practice

This is strictly in opposition to good design practice. One should bear in mind that a tone arm is functional, just as much so as a round turntable, or a gear, and whoever heard of beautifying a turntable or a gear. Certainly the first step in designing a tone arm is to select or design the pickup mechanism, or cartridge, whichever it may be. This cartridge must do the things desired, produce a satisfactory voltage output, track at the desired vertical pressure, and be capable of reproducing the necessary range of frequencies. One should not overlook the importance of the needle to be used in the cartridge, since it has a great bearing on the pickup characteristics.

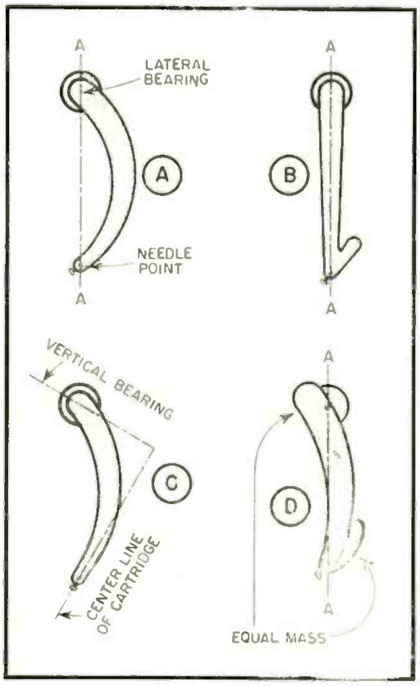



**Fig 3. Typical manually-operated tone arm designs. See text**

When this selection or design is completed, the tone arm then should be laid out around this particular mechanism, made to complement the cartridge, to supply just the right amount of inertia; in general, to assist in getting the exact performance desired from the completed pickup. The tone arm is basically functional, and should be an engineering problem from start to finish. Only after the engineer is satisfied with performance may the arm be turned over to a designer for artistic embellishment, with the caution that the material, shape and size shall not be tampered with. It is obviously unfair to permit a designer to completely design a tone arm with an eye only to appearance, plop the completed thing of beauty in the lap of an innocent cartridge manufacturer, and expect him to supply a cure-all cartridge that will give the required results, in spite of the tone arm. Any manufacturer who follows such a procedure will handicap his product with added cost and lesser performance, and will live to regret it if a more alert competitor follows the rules.

As mentioned previously, all the above factors determine tone arm resonance. Obviously, we must have mass, stiffness, material, etc., therefore it stands to reason that since the pickup may be expected to cover a frequency range of from 50 to 10,000 cycles, resonance will certainly appear at some frequencies. Some tone arm designs have been mechanically tuned so that the fundamental resonance appears below the lowest frequency to be reproduced.

This requires added mass which serves no other function, and usually a torsionally free arm which further complicates the design; certainly undesirable in a light pressure pickup. Or the tone arm at the base end may be supported in a flexible coupling system, which permits the arm to resonate as a unit at some relatively low frequency. Such designs however, never resonate below 50 cycles, usually much higher, and the bass response sounds like anything but music, assuming that there is anything left of the grooves after a few plays that could have been musical. The other alternative is to use a rigid arm and bearing system. This results in resonance at a much higher frequency, usually between 200 and 500 cycles, but is much less obnoxious than the disturbance which occurs with a flexibly coupled system.

### Compliant Cartridges

There remains one avenue of approach. A tone arm will not resonate unless energy is fed to it at its resonant frequency. Since this energy originates in the pickup, through the needle and moving parts of the cartridge, a highly compliant cartridge will do much to overcome the problem. If the needle and moving parts of the cartridge could move without restriction, obviously there would be no energy transferred to the tone arm to excite it to resonance. This condition can be realized to a practical degree. Pickups which really track at less than one ounce, coupled with sensible tone arm design, are remarkably free from tone arm resonance, and will give quiet, distortionless performance, adequate for most usage. Do not overlook the importance of using a low pressure, high compliance type of pickup mechanism.

Now we are ready to discuss manually operated and changer type tone arms. Since the manually operated pickup is not a part or linkage of a mechanical system, such as the changer, it is considerably more flexible. Here one can apply the lessons learned previously about vertical inertia, lateral inertia, and a few new thoughts as well. Refer to *Fig. 1*. A side view is shown of a pickup in playing position. The base assembly contains a suitable lateral bearing which permits the tone arm to move across the record. The tone arm proper does not move in any other than a lateral plane. The pickup made of relatively heavy material to obtain adequate lateral inertia. The proper amount of mass and the material chosen must be determined by the cartridge to be utilized. Other mechanical details, such as stops, rests and handles, can be very readily worked out in a tone arm of this type. No other arm comes so nearly to answering all the requirements of good design.

The changer arm is a different problem. Here we have a link in a mechanical chain, forced to function in ways other than a tone arm, and usually considered as strictly a mechanical device. It is customary for the mechanical engineer who designs the changer to design the tone arm as well, since it is a part of the finished assembly, and usually little attention is given the electrical problems involved. The cartridge manufacturer seldom sees

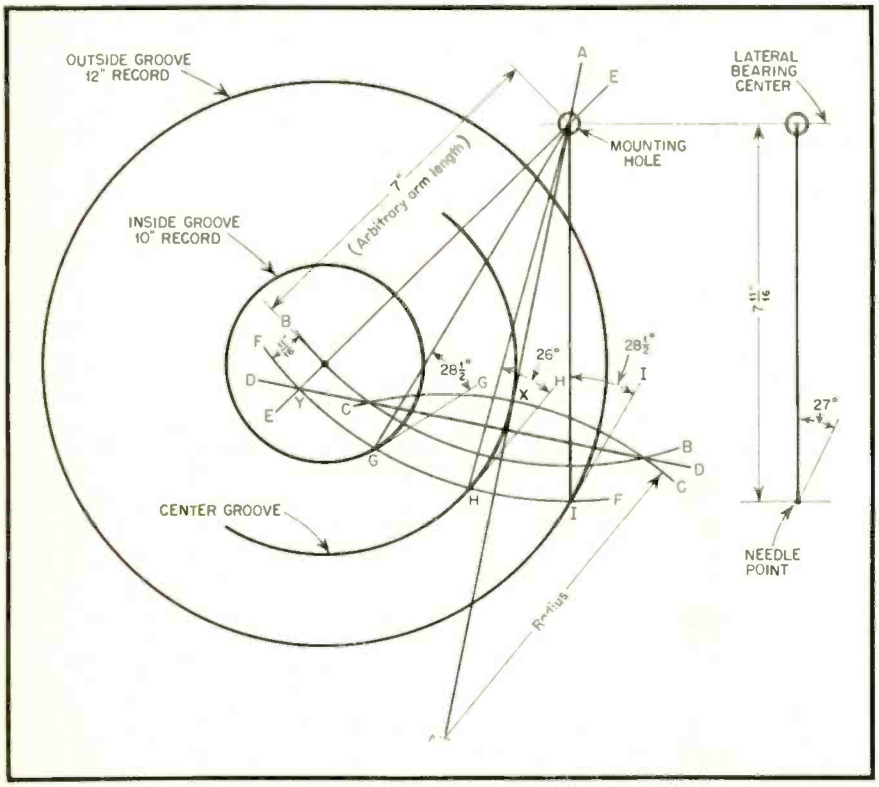



**Fig. 4. Method of laying out tone arm mounting. See text**

mechanism is pivoted to the tone arm in such a manner that it may move in a vertical plane only. This design is not new, but its possibilities have been overlooked completely in recent years. Proper consideration of weight will give exactly the right vertical pressure desired without counter-balancing. A minimum of vertical inertia is thus obtained, while as much lateral inertia as is necessary can be had.

The cartridge and housing should be as light as possible, consistent with desired pressure, which assures low vertical inertia. Since the tone arm proper does not enter into the consideration, the tone arm itself may be the tone arm until the entire changer design, including the arm is completed, and he again is expected to supply a cartridge that will cure all the ills that may be inherent in the arm design. This is another example of the cart before the horse.

At best, the changer arm must be a compromise, in order to fill its many functions. It must be rigid to maintain adjustments; for the same reason it should be rigidly coupled to the base. It must be strong and light in weight. Counter-balancing is not desirable. The most obvious answer is a die-cast one-piece magnesium arm. A high compliance type of cartridge should take care of the balance of the problems to an acceptable degree of performance. Again, however, the design should be made around the cartridge to be used, and should be under the supervision of a sound engineer, working in conjunction with the mechanical engineer, with electrical performance uppermost in mind. After all, a phonograph is intended to reproduce music, and the mechanical details are incidental to the prime purpose.

**Bearings**

The subject of bearings is an important one. There are two involved, the lateral and the vertical. Both should function smoothly, with a minimum of friction, and no loose play. The problem of friction becomes increasingly important with low pressure, high compliance pickups. Bearings which do not permit free movement will certainly cause poor quality and groove skipping, since the moving system in a low pressure cartridge is not stiff enough to force the tone arm to overcome friction. Nor should the bearings have free enough play to permit chatter. Such play will result in noise and resonance. Give the bearings a great deal of thought. Some added cost here is well worth while.

Tangential tracking has always been somewhat of a controversial subject. The English adopted the use of tangent type tone arms long before American manufacturers saw fit to do so. From a theoretical standpoint, it is desirable to maintain tangency with the groove being reproduced, since the cutter moves in a straight line across the wax when recording. A pivoted arm will, of course, scribe an arc across the record, and a straight arm can be tangent only at one point, depending on how the pickup is mounted. Pantograph types of arms have been designed so that, through a system of levers and mechanical linkages, the reproducer head is revolved about a pivot as the tone arm moves across the record, thus maintaining a substantially tangent position with respect to the groove. The drawbacks of such a design however, outweigh the advantages. More parts to resonate, more bearings to add friction, more work to be done by the groove, and considerably added cost hardly make it worth while. Some attempts have been made to design a pickup traveling on a rail system, which would permit the reproducer to move across the record in a straight line, but the mechanical problems involved have not permitted any marked success.

The best approach has been a curved arm, an off-set head, or a combination of the two. When carefully worked

[*Continued on page 72*]

**INDUSTRIAL ELECTRONIC CONTROL,** by W. D. Cockrell. Published by McGraw-Hill Book Co., New York, N. Y. 247 pages. Price $2.50.

This book is addressed to the sales, installation and service engineers who are not familiar with the use of electronic devices in industry. It deals with industrial applications of electronic devices and tends to emphasize a few basic circuits and their application. The functions of the various types of electron tubes are stressed rather than the phenomena taking place within the tubes themselves. In general, explanations are brief but adequate and mathematical formulae avoided. Each section is provided with sufficient bibliographical material that the reader desiring more detailed treatment of specific topics can pursue any specific topic further.

The book is divided into four sections and has five appendices. The first section deals with electron tubes devoting a chapter to each of the following:

- vacuum rectifiers
- gas-filled rectifiers
- special tubes (secondary emission sion and cathode ray)
- grid controlled vacuum tubes
- grid controlled gas filled tubes

In addition a short chapter (5 pages) is devoted to the mechanical construction of electron tubes. This section contains 38 figures and although the descriptions are brief and generally elementary in nature, the section is remarkably complete.

Section 2 is concerned with circuit components, devoting a chapter to each of the following:

- instruments and meters
- resistance and capacitance
- inductance
- transformers, reactors, non-linear elements
- combined circuit elements

This section contains 32 figures which serve to illustrate by photographs and charts the appearance and electrical characteristics of the various components. The chapter dealing with combinations of circuit elements is especially well written and complete.

Section 3 has five chapters devoted to basic electronic circuits, as follows:

- rectifier circuits and filters
- amplifiers
- oscillator circuits
- timing circuits and a-c switches
- phase shift circuits

The chapter on phase shift circuits is especially well done and timely. Some of the material presented is not readily found in the literature. This section contains 69 figures and is probably better illustrated than any other section of the book.

Section 4 relates to industrial electronic circuits and is concerned mainly with applications of the circuits and components discussed in earlier sections of the book. It contains four chapters as follows:

- elementary diagrams
- d.c. photoelectric and motor control circuits
- a.c. relay and power circuits
- resistance welder controls and welder current regulation

This is the longest section in the book and probably will be the most interesting to many readers.

This book is well written in a logical and concise manner. The elementary style permits the reader to grasp the principles involved rather quickly. The book is well annotated and has an excellent index. Appendix 5, dealing with photoelectric phenomena, is especially noteworthy. This book should be of interest to most radio engineers as a reference book, since it deals with many topics which they either do or could use frequently. It is highly recommended to the audience to which it is directed and to communication technicians as well.

**BASIC RADIO,** by C. L. Boltz. Published by the Ronald Press Company, New York, N. Y. 272 pages. Price $2.25.

This is a beginner's textbook which provides in simple language an explanation of the fundamentals of electricity and radio. The order of the subject matter follows the syllabus used for British Air Training Cadets and approximately one-third of the book is devoted to elementary electrical theory. It is assumed that the student has had no preliminary technical training whatsoever, and the author is careful to clarify each point by using familiar analogies.

As the author points out in his preface, many subjects (such as the superheterodyne receiver) have been omitted in order to compress into a small text the basic knowledge required before one can go on to advanced work.

Although British tubes and terminology are employed in the discussions devoted to tubes and circuits, the subjects are so simply and clearly explained that American students should have no difficulty in understanding them.

*Official U. S. Navy Photograph*

**Navy Provides Radio Network With Equipment for Eyewitness Broadcasts—Lt. Marvin Royston, USNR, of Chicago, Ill., adjusting the dials of U. S. Navy recording equipment of the type now being operated by the four major radio networks on a pool basis to provide the nation with eyewitness accounts of invasion action. Installed aboard U. S. warships operating in the English Channel, the equipment records observations made by network announcers during combat.**

# Factors Involved In

# CHOOSING TUBE TYPES

**A. C. MATTHEWS**

**PART III**

**Practical considerations in the selection of proper vacuum-tube types for various applications are discussed**

### Frequency Converter

The most important characteristic of a converter is the conversion transconductance, which is equal to the quotient of the i-f component of the plate current divided by the r-f signal voltage on the control grid, with no impedance in the plate circuit but with constant d-c voltages on all the electrodes.

The converter stage usually employs a square-law device because of the greater sensitivity obtained. A comparison of a linear vs. square-law detector is shown in *Fig. 10*. With the linear converter it can be seen that the output is directly proportional to the signal amplitude, since the oscillator voltage merely shifts the operating point on the characteristic curve. With a square-law detector however, it is possible to choose the point on the operating characteristic (by adjusting the oscillator voltage) so as to operate on a portion of the curve where the slope is greater (higher $G_m$) resulting in more amplification. It is evident then that the applied oscillator voltage should be of sufficient magnitude to permit operation on the steep part of the curve. The limiting factor being the point where the amplitude of the incoming signal will cause grid current to flow. Triodes, tetrodes and pentodes have been successfully used in this type of service.

The pentagrid converter is more popular because it combines the frequency mixer and the oscillator in one envelope and provides high conversion gain. By virtue of the electrode positions the electron stream is effectively modulated at the oscillator frequency. Since the signal grid also controls the electron stream, the plate current is varied by both voltages. The strength of the local oscillator, as mentioned previously must be adequate if good gain is to be obtained since the conversion efficiency is a function of the local oscillator strength.

Several other combined mixer-oscillator tubes are available, and since these are adequately described in the literature no further mention will be made at this time.

### Amplifier Service

Two general types of amplifiers are used in radio equipment; high-frequency amplifiers for radio and intermediate frequencies, and low-frequency amplifiers for audio frequencies. Low frequency amplifiers may be operated as Class A or B, while high frequency amplifiers are operated Class A, B, or C. The class of operation is determined by (see *Fig. 11*) the fraction of the a-c cycle during which plate current flows. For Class A operation, plate current flows during the complete a-c cycle and the output wave is essentially the same shape as the input signal. The grid bias is usually fixed at one-half cut-off value and no grid current is permitted. The plate efficiency is of the order of 25%.

In Class B operation plate current flows during a considerable portion of the a-c cycle. Bias is fixed at approximately twice cut-off and some grid current is permitted. The plate efficiency is of the order of 60%.

The plate current in a Class C amplifier only flows during a fraction of the a-c cycle because sufficient bias is used to reduce the plate current to zero with no excitation applied. In Class C operation the grid may swing sufficiently positive to allow saturation plate current to flow. The output wave is therefore rich in harmonics and the plate circuit efficiency is usually high. (65 to 85%).

### General Considerations

In the selection of tube types for a specific class of service the following items should be kept in mind.

Tubes for audio-frequency voltage amplifiers (particularly resistance coupled) should have a high amplification factor and be of the sharp cut-off variety. Triodes or pentodes are both satisfactory. Combination diode-triodes or diode-pentodes are often used as the second or audio detector since the triode or pentode section can be used as the first audio stage, thereby in many cases, eliminating the necessity of a separate audio tube. For audio power output the beam type tube is recommended.

Video-frequency amplifiers require tubes having a high ratio of transconductance to tube capacity. In general the transconductance is of the order of 5000 micromhos.

R-f and i-f voltage amplifiers usually employ pentode type tubes with a remote cut-off grid characteristic. Such tubes permit the use of automatic volume control without serious cross-modulation effects. The pentode has a very low grid-plate capacity and therefore does not require neutralization. The gain per stage is high and the circuit is not seriously loaded because the plate resistance of the tube is higher than the ordinary tuned circuit impedance.

*Table 1* has been arranged to assist in the selection of a tube type for a specific application. While it is by no means complete it includes most of the tubes now on the Preferred List and therefore is an excellent guide for the designer.

### Ultra High Frequency Tubes

There are four general types of vacuum tubes available for UHF applications, namely: (1) negative grid, (2) positive grid, (3) velocity modulated and (4) magnetrons.

*Negative Grid Tubes:* Of these, the negative grid tube is by far the most common. Some of the factors influencing its behavior at ultra high frequencies are particularly interesting since although they are present at the lower radio frequencies no deleterious effects are noticed. In order to efficiently utilize a negative grid type vacuum tube at ultra-high frequencies the physical structure must be especially designed for such service. The interelectrodes capacities should be small, the lead inductances low, the dielectric losses minimized, the transit time short and the cathode emission relatively large. At these frequencies the triode equivalent circuit appears somewhat like *Fig. 12*.

The interelectrode capacitances should be as small as is consistent with other factors affecting u-h-f operation, since the capacity and the lead inductance together with a short circuit between terminals, form a resonant circuit which is known as the resonant frequency of the tube. This is usually given by the manufacturer as part of the tube data. Obviously, if there is very little external circuit, nearly all of the tube output will appear within the envelope and is useless for all practical purposes. Thus, if the capacities are large the upper frequency limit is restricted as it is impossible to use any appreciable external circuit capacity. The reduction of interelectrode capacitance also results in decreased capacity charging current through the leads with its attendant $I^2R$ loss.

Short, heavy leads are therefore a necessity since their use also minimizes the lead inductance and skin effect. In some designs, multiple leads are employed for this purpose. The lead material should be chosen for low resistivity, thereby decreasing the losses.

### Dielectric Losses

Dielectric losses are a contributing factor in the relatively poor efficiency of tubes when operating at high frequencies. Dielectric losses increase rapidly with frequency due to dielectric polarization, so it is desirable to eliminate as much insulation as possible in the tube design. Insulating supports between elements must be able to withstand high electric fields without disintegration at high ambient temperatures, and whenever possible the elements should be so mounted that no auxiliary supporting members other than those actually required for leads are employed. The leads themselves are then brought through the glass at a point where a potential node on the conductor is not present, otherwise the seal might in time become defective. The actual tube base is eliminated in most designs except for heater connections.

Another desirable design feature is one where the ends of the tube structure are closed or shielded in such a manner as to prevent stray electrons from bombarding the glass envelope. Such bombardment is likely to cause decomposition of the glass and result in softening of the bulb and finally tube failure.

As mentioned previously, the transit-time of the electron stream between grid to cathode and grid to plate has an appreciable effect on the efficiency unless it is shorter than approximately one-tenth of a cycle at the operating frequency. With a large transit time the electrons will not reach the grid but will turn back to the cathode, thus bombarding it and thereby producing additional heat. Applying higher plate potentials will speed up the electron stream and thereby reduce the transit time. Another method is to decrease the spacing between elements. Such an expedient, however, will reduce the voltage breakdown point of the tube and increase the temperature of the grid which might result in grid emission, so it can be seen that any improvements along this line must of necessity result in a compromise design. The electrode itself may be designed with high thermal conductivity

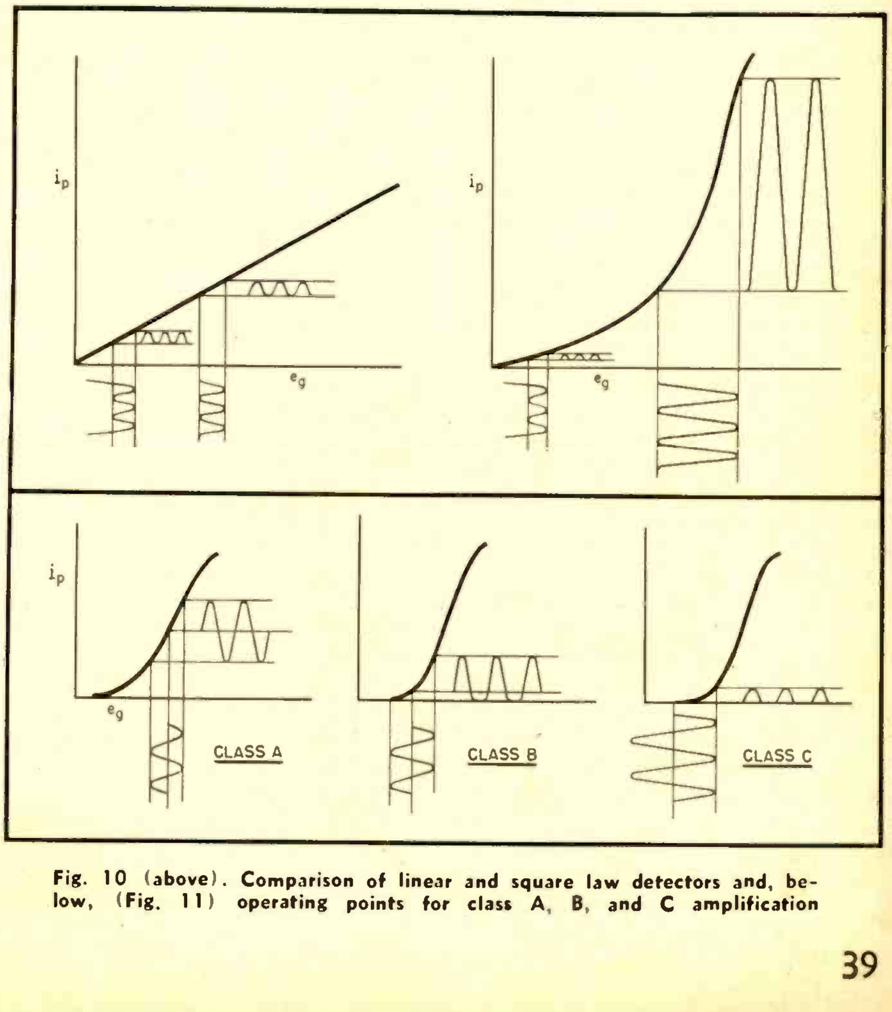



**Fig. 10 (above). Comparison of linear and square law detectors and, below, (Fig. 11) operating points for class A, B, and C amplification**

material and radiating fins can sometimes be employed. Carbonization of parts to increase heat radiation is also employed.

Because of their smaller dimensions, u-h-f tubes require a high specific cathode emission. The total available emission must also be high, due to the fact htat the load impedance at these frequencies is relatively low and therefore high peak currents are likely to be required.

For additional information, see bibliography.

*Positive Grid Tubes:* While it is possible to generate extremely high frequencies with this type of tube, the efficiency and power output are low and therefore these tubes are seldom used. It is interesting to note however, that the electron transit time determines the frequency of oscillation with this type of operation.

*Velocity Modulated Tubes:* A velocity modulated tube may consist of six main parts: (1) electron gun, (2) control grid, (3) buncher grids, (4) catcher grids, (5) collector and (6) resonant cavity (not always part of the tube).

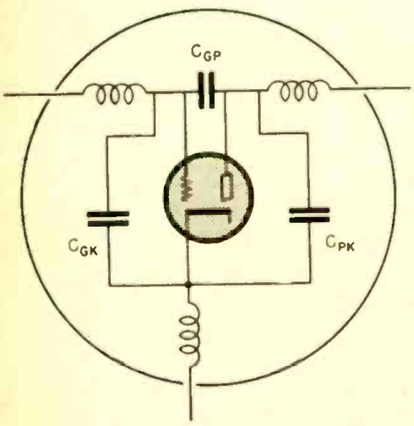



**Fig. 12. Equivalent circuit of triode when operated at uhf. Capacitances and lead inductances must be kept low**

A narrow beam of electrons is emitted by the gun. These electrons have a uniform velocity after passing through the first grid. The electrons having been accelerated, due to the positive potential on the grid, now pass through the buncher grids. Across these grids an alternating potential is impressed so that the electron is accelerated or retarded depending upon the position of the electron with respect to the amplitude of the alternating potential. By this means some electrons are accelerated while others are slowed down and the result is a "bunching" of electrons, known as velocity modulation.

The bunched electrons next proceed through a drift space before entering the catcher grids, where, if the catcher resonator or cavity is tuned to the frequency of the bunched electrons, power will be delivered to it. The useful power output may be obtained by coupling into the cavity with small wire loops. The operation of a velocity-modulated tube is not limited by the length of the transit time, in fact, long transit time is sometimes desirable. Since all of the energy of the electron stream is not given up to the catcher cavity some electrons pass through the catcher to the collector and are returned to the cathode; otherwise these electrons might return through the cavity and possibly reduce the power output.

The efficiency of this type of tube under perfect conditions as an oscillator is 58%. Actually, this value is never realized in practise, but the efficiency compares favorably with other types of generators at these frequencies. There are several modifications of the velocity-modulated tube The reflex type, for instance has only one cavity which acts as both the buncher and catcher. Here the electrons, after having passed through the cavity, are reversed in direction by a negative electrode and made to pass back through the cavity at the proper time so as to deliver power to the cavity.

Velocity-modulated tubes may be used as amplifiers, detectors, oscillators or harmonic generators and are particularly suitable for very high frequency operation. See bibliography.

*Magnetrons:* The magnetron provides the most satisfactory means of producing ultra high frequency oscillations, particularly in the microwave region.

In its simplest form it consists of a cylindrical anode and a concentric filament in a highly evacuated envelope. The tube must be operated in conjunction with a high magnetic field, which should be nearly parallel to the magnetron filament. Unlike the velocity-modulated tube just discussed, the electron stream, instead of being accelerated linearly, describes a curved path according to the magnitude of the anode potential and the strength of the magnetic field, as shown in *Fig. 13.*

High anode potentials and strong magnetic fields are necessary if good efficiency is to be obtained.

Two basic types of oscillation may be obtained with the magnetron: (1) negative resistance and (2) transit time oscillation. The operation of the first type (negative resistance oscillation) depends upon a negative slope in the static current-voltage characteristic and a low-loss parallel resonant frequency determining circuit. Efficient operation is limited to frequencies which are low with respect to the electron transit time.

**Magnetron Oscillations**

Magnetron oscillations of the transit-time type depend mainly, as its name implies, on the electron transit time from the cathode to the anode. Other factors influencing the frequency are the mode of operation, magnetic field strength, tube type (number of anode segments) and the external tuned circuit. By carefully adjusting the anode potential and the electric and magnetic fields, so that the time required for the electron to travel from the cathode toward the anode and return again, is nearly equal to the frequency of the tuned circuit, oscillations will result.

A well-regulated voltage supply and an essentially constant magnetic field are prerequisites for stable operation. In some cases the cathode may receive sufficient energy from the anode circuit, after oscillation has started, to permit operation of the tube without its usual heater supply voltage. This is probably due to bombardment of the cathode by electrons having excess energy and can result in the burning out of the heater or filament unless precautions are taken to provide protective devices to guard against such action.

As mentioned previously there are several varieties of magnetrons available and many new improvements are being made from time to time, so the designer should thoroughly acquaint himself with the latest developments of the tube manufacturer before specifying a definite type for a particular application.

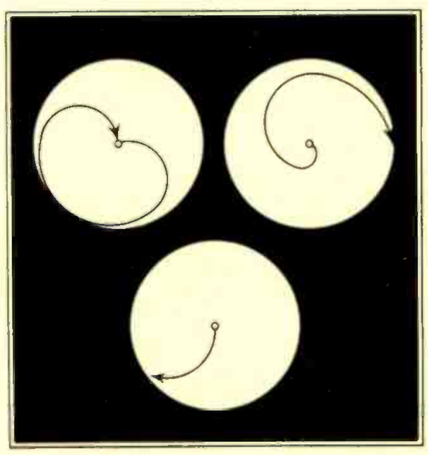


**Fig. 13. The electron steam in a magnetron describes a curved path which varies with anode potential and magnetic field strength**

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[*Continued on page 66*]

# RADIO DESIGN WORKSHEET

## NO. 27 — SINES AND COSINES OF MULTIPLE ANGLES EXPRESSED AS POWERS; SERIES TUNED CIRCUITS; EXPRESSIONS FOR $\sin^n \theta$ AND $\cos^n \theta$

### SINES AND COSINES OF MULTIPLE ANGLES EXPRESSED AS POWERS

★ In Radio Design Worksheet No. 12[1], there was derived the formulae for expressing the sines and cosines of multiple angles as a function of a series of powers of the sine and cosine of the unit angle. While not as generally useful as the opposite theorem, such formulae do find considerable use in trigonometric transformations. It is proposed here to illustrate how such formulae may be applied. Thus:

$$\sin n\theta = 2^{n-1} \sin\theta \cos^{n-1}\theta - (n-2)2^{n-3} \sin\theta \cos^{n-3}\theta + \frac{(n-3)(n-4)}{2} 2^{n-5} \sin\theta \cos^{n-5}\theta + \ldots$$

Let $n = 4$

Then:

$$\sin 4\theta = 2^3 \sin\theta \cos^3\theta - (4-2)2 \sin\theta \cos\theta$$
$$= 8 \sin\theta \cos^3\theta - 4 \sin\theta \cos\theta$$

If $n = 3$, then:

$$\sin 3\theta = 2^2 \sin\theta \cos^2\theta - (3-2)\, 2^0 \sin\theta \cos^0\theta$$
$$= 4 \sin\theta \cos^2\theta - \sin\theta$$

For odd values of $n$, it was also shown in Radio Design Worksheet No. 12 that:

$$\sin n\theta = n \sin\theta - \frac{n(n^2-1)}{2\times 3} \sin^3\theta + \frac{n(n^2-1)(n^2-3^2)}{2\times3\times4\times5} \sin^5\theta + \ldots$$

If $n = 3$, we have:

$$\sin 3\theta = 3\sin\theta - \frac{3(9-1)}{2\times 3} \sin^3\theta$$
$$= 3\sin\theta - 4\sin^3\theta$$

Whence, in like fashion, it may be shown that:

$$\sin 2\theta = 2\sin\theta\cos\theta$$
$$\sin 5\theta = 16\sin\theta\cos^4\theta - 12\sin\theta\cos^2\theta + \sin\theta, \text{ etc.}$$

Likewise, it has been shown that:

$$\cos n\theta = 2^{n-1}\cos^n\theta - 2^{n-3}\, n\cos^{n-2}\theta + \frac{n(n-3)}{2} 2^{n-5}\cos^{n-4}\theta + \ldots$$

Let $n = 4$:

$$\cos 4\theta = 2^3\cos^4\theta - (2\times4)\cos^2\theta + \frac{4\times1}{2\times2}\cos^0\theta$$

Since $\cos^0\theta = 1$.

Let $n = 3$:

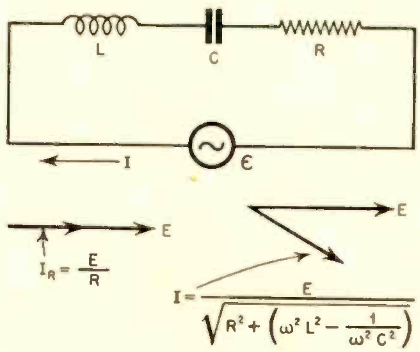
$$\cos 3\theta = 2^2\cos^3\theta - 2^0 \times 3\cos\theta$$
$$= 4\cos^3\theta - 3\cos\theta$$

Likewise:

$$\cos 2\theta = 2\cos^2\theta - 1$$
$$\cos 5\theta = 16\cos^5\theta - 20\cos^3\theta + 5\cos\theta, \text{ etc.}$$

### SERIES TUNED CIRCUITS

★ In Radio Design Worksheet No. 25[2], the phase angle of the current through a series tuned circuit was shown to be:




Phase angle of current in series tuned circuit

[*Continued on next page*]

$$\theta = \pm \tan^{-1} \frac{\sqrt{1-A^2}}{A}$$

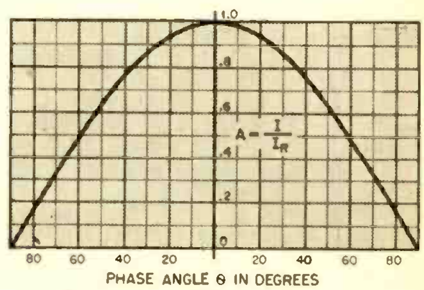
where

$$A = \frac{I}{I_R}$$

$I_R$ = current at resonance—in phase with applied voltage

$I$ = current at resonance—out-of-phase with applied voltage

From this relation an extremely useful curve showing the relative amplitude of I with respect to $I_R$ can be derived. Thus:




Curve plotted from data below

| $A$ | $\sqrt{1-A^2}$ | $\frac{\sqrt{1-A^2}}{A}$ | $\theta$ |
|---|---|---|---|
| 0 | 1.0 | ∞ | 90° |
| .2 | .98 | 4.9 | 78° 30′ |
| .3 | .95 | 3.1 | 72° 10′ |
| .4 | .91 | 2.3 | 66° 30′ |
| .5 | .86 | 1.7 | 60° 20′ |
| .6 | .8 | 1.3 | 53° 20′ |
| .7 | .7 | 1.0 | 45° |
| .8 | .6 | .75 | 36° 50′ |
| .9 | .43 | .48 | 25° 50′ |
| 11.0 | 0 | 0 | 0 |

1. RADIO, April, 1943.
2. RADIO, May, 1944.

## EXPRESSIONS FOR SIN$^n$ θ and COS$^n$ θ

★ In Radio Design Worksheet No. 13[2], there was derived the expression for $\sin^n \theta$ as a series of multiple angles. Likewise in Radio Design Worksheet No. 12[1] the derivation of $\cos^n \theta$ function of multiple angles appears. These expressions are extremely useful in mathematical analyses, particularly of modulated waves. One use of these expressions appeared in Radio Design Worksheet No. 16[3] in the derivation of the expression for a phase-modulated wave. It is proposed here to illustrate the use of these expressions.

$$\sin^n \theta = \frac{j^{n-1}}{2^{n-1}}\Big[\sin n\theta - n\sin(n-2)\theta + \frac{n(n-1)}{2!}\sin(n-4)\theta$$

$$-\frac{n(n-1)(n-2)}{2\times 3}\cos(n-6)\theta + \ldots \frac{j^n}{2}\,\frac{n!}{\left(\frac{n}{2}\right)!\left(\frac{n}{2}\right)!}\Big]$$

where $n$ is an even integer, $n!$ in factorial $n$, i.e., $1\times 2\times 3\times 4\times 5\times \ldots n$, and $j=\sqrt{-1}$

Suppose $n=4$

Thus:

$$\sin^n \theta = \sin^4 \theta$$
$$\cos n\theta = \cos 4\theta$$

And:

$$\sin^4 \theta = \frac{(\sqrt{-1})^4}{2^3}\Big[\cos 4\theta - 4\cos(4-2)\theta + \frac{4\times 3}{2}$$

$$\cos(4-4)\theta + \frac{(\sqrt{-1})^4}{2}\times\frac{(4)!}{\left(\frac{4}{2}\right)!\left(\frac{4}{2}\right)!}\Big]$$

Whence we have for the final term

$$+\frac{1}{2}\times\frac{2\times3\times4}{2\times2}=3$$

and

$$\sin^4\theta = +\frac{1}{8}(\cos 4\theta - 4\cos 2\theta + 3) = \frac{1}{8}\cos 4\theta - \frac{1}{2}\cos 2\theta + \frac{3}{8}$$

If $n$ is an odd integer:

$$\sin^n\theta = \frac{j^n}{2^{n-1}}\Big[\cos n\theta - n\cos(n-2)\theta + \frac{n(n-1)}{2}\cos(n-4)\theta$$

$$+\frac{j^{n-1}\times n!}{\left(\frac{n-1}{2}\right)!\left(\frac{n-1}{2}\right)!}\sin\theta\Big]$$

Then, evaluating the last term, we have:

$$\frac{(\sqrt{-1})^2\times 2\times 3}{\frac{2}{2}\times\frac{2}{2}}\sin\theta = \frac{(-1)\times 2\times 3}{1\times 1}\sin\theta = -6\sin\theta$$

And:

$$\sin^3\theta = \frac{(\sqrt{-1})^2}{2^2}(\sin 3\theta - 3\sin\theta)$$

$$= -\frac{1}{4}(3\sin\theta - \sin 3\theta) = \frac{1}{4}(\sin 3\theta - 3\sin\theta)$$

The expression for $\cos^n\theta$, where $n$ is an even integer, is:

$$\cos^n\theta = \frac{1}{2^{n-1}}\Big[\cos n\theta + n\cos(n-2)\theta + \frac{n(n-1)}{2!}$$

$$\cos(n-4)\theta + \ldots\frac{1}{2}\times\frac{n!}{\left(\frac{n}{2}\right)!\left(\frac{n}{2}\right)!}\Big]$$

Let $n=4$

$$\cos^4\theta = \frac{1}{2^3}\Big[\cos 4\theta + 4\cos 2\theta + \frac{4\times3}{2}$$

$$\cos(4-4)\theta + \frac{1}{2}\times\frac{2\times3\times4}{2\times2}\Big]$$

$$=\frac{1}{8}(\cos 4\theta + 4\cos 2\theta + 3) = \frac{1}{8}\left(\cos 4\theta + \frac{1}{2}\cos 2\theta + \frac{3}{8}\right)$$

The expression for $\cos^n\theta$, where $n$ is an odd integer, is:

$$\cos^n\theta = \frac{1}{2^{n-1}}\Big[\cos n\theta + n\cos(n-2)\theta + \frac{n(n-1)}{2!}$$

$$\cos(n-4)\theta + \ldots\frac{n!}{\left(\frac{n-1}{2}\right)!\left(\frac{n-1}{2}\right)!}\cos\theta\Big]$$

Let $n=3$

Then:

$$\cos^3\theta = \frac{1}{2^2}(\cos 3\theta + 3\cos(3-2)\theta)$$

$$=\frac{1}{4}(\cos 3\theta + 3\cos\theta) = \frac{1}{4}\left(\cos 3\theta + \frac{3}{4}\cos\theta\right)$$

In like fashion we might evaluate:

$$\sin^2\theta = \frac{1}{2} - \frac{1}{2}\cos\theta$$

$$\sin^3\theta = \frac{3}{4}\sin\theta - \frac{1}{4}\sin 3\theta$$

$$\sin^4\theta = \frac{1}{8}\cos 4\theta - \frac{1}{2}\cos 2\theta + \frac{3}{8}$$

$$\sin^5\theta = \frac{1}{16}\sin 5\theta - \frac{5}{16}\sin 3\theta + \frac{5}{8}\sin\theta$$

$$\cos^2\theta = \frac{1}{2}\cos 2\theta + \frac{1}{2}$$

$$\cos^3\theta = \frac{1}{4}\cos 3\theta + \frac{3}{4}\cos\theta$$

$$\cos^4\theta = \frac{1}{8}\cos 4\theta + \frac{1}{2}\cos 2\theta + \frac{3}{8}$$

$$\cos^5\theta = \frac{1}{16}\cos 5\theta + \frac{5}{16}\cos 3\theta + \frac{5}{8}\cos\theta$$

1. RADIO, April, 1943.
2. RADIO, May, 1943.
3. RADIO, Aug., 1943

# This Month

## NEW MICROCOPY PROCESS

A simple and economical method of condensing and preserving vital records for an indefinite period is announced by Microcopy Corporation, 2800 West Olive Avenue, Burbank, California.

The Microcopy Translite Hi-Reduction process is the application of microfilming to engineering drawings, as well as any other valuable record, document, drawing, map or material kept in industrial manufacturing plant files. Because of the high-fidelity translite feature, it is particularly adaptable to engineering drawings, in pencil or transparent paper.

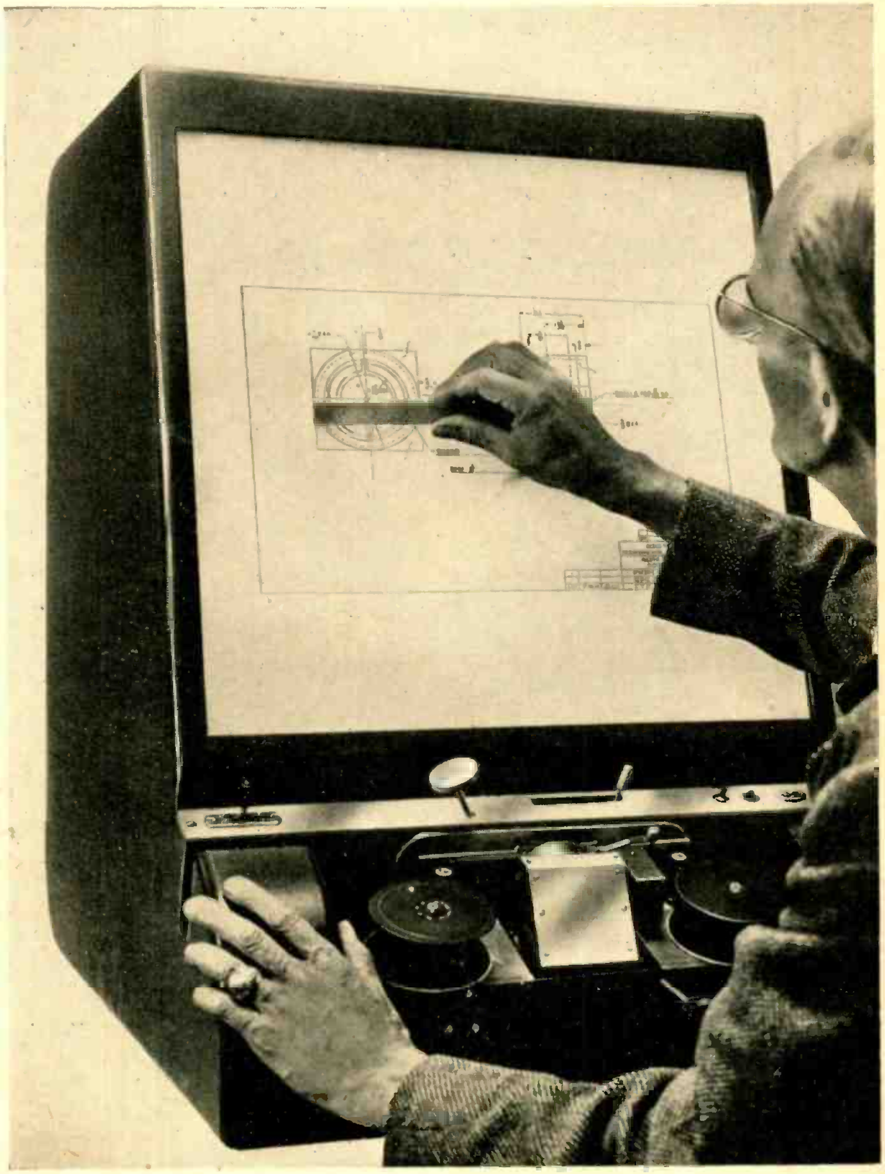
Millions of dollars' worth of intelligence, education and training are recorded each year on engineering drawings in plants throughout the nation. The loss of any of these drawings can represent the loss of hundreds of hours of time and many dollars in salaries and wages.

While insurance for records can be bought in the conventional manner, this insurance does not provide for duplication of lost material. At best, duplication can be obtained only by starting the job all over again, and in many cases, where original inspiration and enthusiasm was a predominant factor, duplication cannot be provided at any cost.

Microcopy, being a photographic record, is a faithful copy of the material microfilmed. The negative can be used to make copies on other pieces of film. The negative can be used to enlarge and make copies of the original in any size desired, whether actual, larger or smaller. These copies may be made on tracing paper, cloth or film. As many film duplicates as desired may be made. Thus, duplicates made may be transmitted to branches, service depots and other points.

From 90 to 98 percent filing space is saved by this process, effecting a decided savings in storage cost. This microfilm provides the fastest, most economical duplicating method obtainable. Duplicates may be reproduced quickly on film, paper, tracing paper or cloth, in case of destruction of the originals.

A multiple-magnification viewer is supplied in various models. This viewer, operated on a motion picture film projector principle, facilitates finding locations on films by permitting enlargements to be made on the screen, as well as permitting any portion of the frame to be centralized within the frame for easier reading.



## KEOGH JOINS WEBSTER

R. J. Keogh, E. E., is the newest addition to the engineering staff of Webster Products, 3825 W. Armitage Ave., Chicago 47, Ill.

Mr. Keogh has a background of nearly 20 years of practical experience in the radio industry since his graduation from Purdue University. He was issued patents for early developments of the vibrator for auto radios.

Ten years ago Mr. Keogh joined the Sears, Roebuck organization. For the last two and a half years he has been assigned to work with Colonial Radio Corporation, Buffalo, and comes to Webster Products from there.

## UNIVERSAL NOTES

"Micro Topics," bi-weekly house organ of the Universal Microphone Co., Inglewood, Cal., has started to reprint the series of full page history of communications advertisements that are appearing currently in RADIO.

The Universal Microphone Company has fashioned a set of salon pictures of its "History of Communications" advertising series at the request of the Chicago Army Signal Corps Depot for display in their permanent exhibit of electronics sources of supply, and the possible inclusion of the series in their projected traveling educational exhibit.

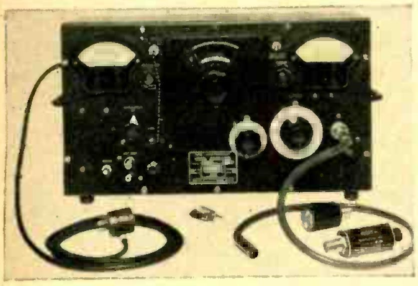
## WESTINGHOUSE APPOINTS DONLEY

Walter Evans, Vice President in charge of Westinghouse radio activities, recently announced the appointment of Harold B. Donley as manager of the Westinghouse Radio Receiver Division, which will manufacture and market home radio receivers as soon as they can be made again.

Mr. Donley, who before his new appointment was general appliance manager for the Westinghouse Electric Supply Company, with headquarters in New York City, has been with Westinghouse for 22 years.

"Mr. Donley will take over immediately supervision of the planning and

# New Products



accurately calibrated attenuator network which allows control from 1 microvolt to 20,000 microvolts.

This output is arranged so that an internal source of modulation at a frequency of 1,000 cycles may be used, or, by use of an incorporated switching arrangement, external sources of modulation may be used between 30 cycles and 20,000 cycles, adjustable from 0 to 60%, indicated by a direct-reading modulation meter.

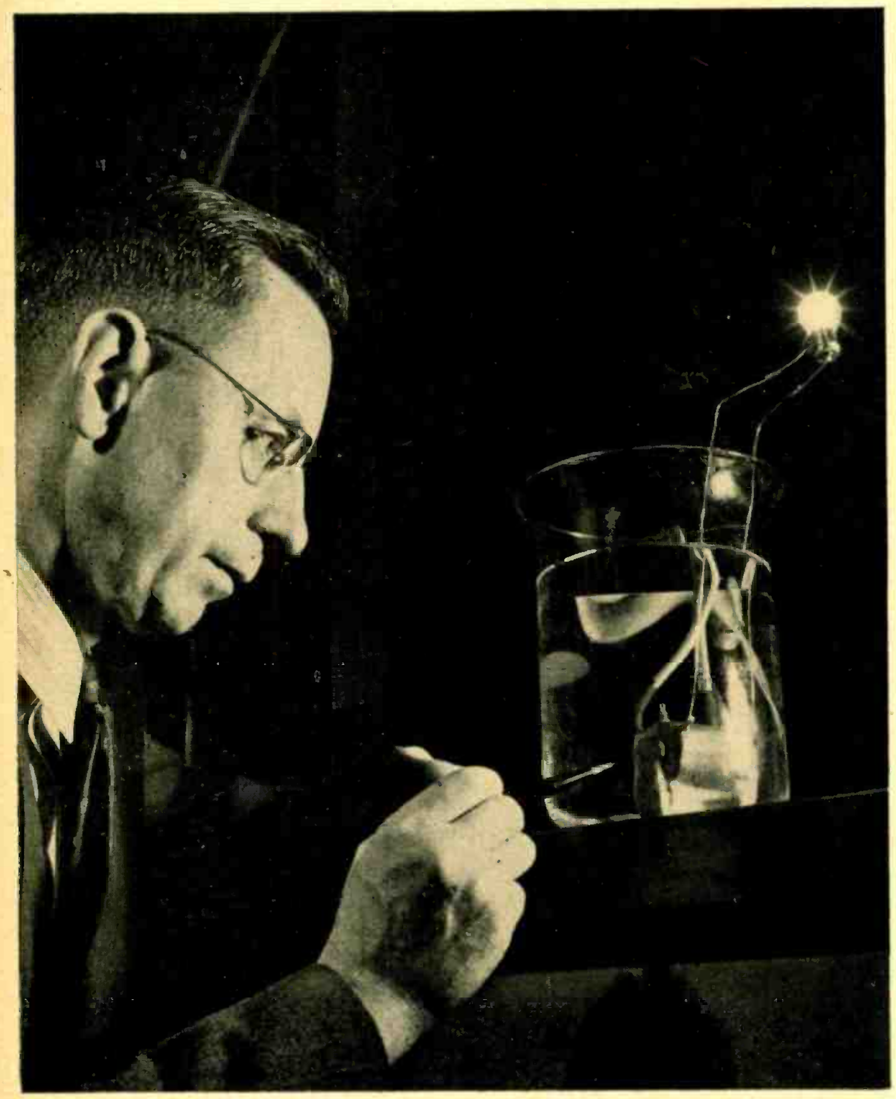
A special input circuit is also incorporated so that, by a circuit-switching device incorporated in the panel control assembly, it is possible to modulate the generator from an external source, with a pulse modulation having very steep wave fronts and extending in rapidity to pulses of about 20 micro-seconds.

Stray field leakage is held to a minimum by improved shielding and R. F. filters.

A stabilized power supply incorporated in the unit for operation at either 115 volts or 230 volts a.c., 40 to 60 cycles, single phase, insures an absolute minimum of frequency change due to power line fluctuations.

Enclosed in a polished walnut cabinet with black crackle metal panel, weighs less than 35 lbs., and comes provided with a special 3 foot coaxial output cable of 75 ohms impedance, a fixed 10:1 attenuation reduction unit, a special terminal unit, an adapter plug, line cord, extra blank plug-in coil form, spare pilot lamps, fuses, one set of 4 operating tubes installed as standard equipment.

For further information regarding Signal Generators and their availability, write to the Federal Mfg. & Engineering Corp., 211 Steuben Street, Brooklyn 6, N. Y.



Power to operate the glowing lamp is supplied by a submerged transformer, impregnated with Fosterite. Demonstrated by Dr. C. F. Hill of Westinghouse

## SYNTHETIC RESINS

Basic chemical research accelerated by the war is responsible for the development of two synthetic resins, according to Dr. C. F. Hill, Manager, Insulation Department, Westinghouse Research Laboratories. These resins are new, they have unusual properties, they are important now, and they promise to be even more important in post-war applications. They are so secret that what they are chemically can not be told. The first, now being applied to radio and radar units, is Fosterite, a remarkable solventless impregnant giving 100 per cent fill and, in addition, a moisture-proofing material. The second is a synthetic resin to replace shellac, surprisingly strong and definitely superior to natural shellac for some very important applications.

### Fosterite

For twenty years the electrical industry has been talking about the ideal impregnating material for insulation in coils and apparatus. It is quite evident that solvent type varnishes which are 50 per cent solvent cannot give more than 50 per cent fill. The two most desirable but elusive properties of such materials are (1) usability without a solvent and (2) a 100 per cent filling of all space within the insulation. We have now obtained these properties in a new resin, Fosterite. During the impregnation of the coil or device, Fosterite is in a liquid state, but the "solvent" reacts with another resin dissolved in it, and the whole mass turns to a tough solid. It is solventless in that the whole of the liquid resin reacts under heat to form the infusible solid: there are no by-products of the reaction that must escape as in most resin reactions.

The additional problem of keeping the resin from running out while it is being polymerized to a solid has also been solved, and we now have both a satisfactory material and a satisfactory processing method. Actually, this resin is not just one resin, but a family which makes it possible to obtain a wide range of properties by suitable modifications.

This family of resins is giving some very interesting results in application, both for the filling and coating of insulation. The complete filling allows much higher voltage gradients to be used than for normal materials. On one small radio transformer, for example, Fosterite provides 4 to 5 times the dielectric strength that was obtained with former materials. This permits a radical re-

[Continued on page 56]


## ECHOPHONE MODEL EC-1

(Illustrated) a compact communications receiver with every necessary feature for good reception. Covers from 550 kc. to 30 mc. on 3 bands. Electrical bandspread on all bands. Six tubes. Self-contained speaker. 115-125 volts AC or DC.

**ECHOPHONE RADIO CO., 540 NORTH MICHIGAN AVE., CHICAGO 11, ILLINOIS**

# The Terminology of

# ELECTROMAGNETIC THEORY

**Because recent developments in the field of microwave radiation and generation have greatly widened the engineer's interest in electromagnetic theory, the following alphabetical list of terms, ideas, and theorems is presented. It is not so much intended that the discussions be rigorous definitions as that they shall give interesting ideas and serve as an introduction to the concepts.**

**Admittance-Y**—If an a-c voltage is impressed across a load a certain alternating current will flow. In the same way that Ohm's law for d.c. allows us to define the resistance or conductance of a load by $R = V_{dc}/I_{dc}$ or $G = I_{dc}/V_{dc}$, so impedance or admittance may be defined for a.c. by $Z = V_{ac}/I_{ac}$, or $Y = I_{ac}/V_{ac}$, where the $V$'s and $I$'s are, for example, peak values. More than that, however, it is often desirable that $Y$ also tell about the phase relation between the current and voltage. To accomplish this it is more usual to write $Y = G + jB$. $G$ then represents the ratio of the in-phase component of current to the voltage and $B$ tells the ratio of the out-of-phase current to the same voltage. The number $j = \sqrt{-1}$ is of the nature of a signpost which distinguishes between the two.

This is possible because a sine-wave plot of the actual current as a function of time may be replaced by the sum of two sine waves, one in phase and the other out of phase with the voltage. In other words, it is possible to consider the current as made up of two currents, one of which is in phase with the voltage and gives a ratio $G$ to the voltage while the other is out of phase and is $B$ times as large as the voltage. *The admittance of an electrical load is a vector quantity whose magnitude is the ratio of the a-c current to the a-c voltage and whose direction in reference to a vector representing the voltage is at an angle equal to the phase between the current and voltage; Y is commonly written in the form Y = G + jB where G and B respectively represent ratios to the voltage of the in-phase and out-of-phase currents.*

When $Z$ is said to be equal to $1/Y = 1/(G + jB) = [G/(G^2 + B^2)] - j[B/(G^2 + B^2)] = R + jX$, more is implied than just a relation between the vector magnitudes of $Y$ and $Z$. If $Y$ represents a vector $\theta$ degrees counterclockwise from the reference voltage vector lying along the positive $x$ axis of a Cartesian coordinate system on which imaginary quantities are plotted along the ordinate and real quantities along the abscissa, then $Z$ automatically comes out to be a vector $\theta$ degrees clockwise from a reference current vector also imagined to lie along the abscissa. Thus even in terms of complex notation, $Y$ and $Z$ are rigorously reciprocals of each other. It is necessary, however, to remember that while the conductance $G$ and the susceptance $B$, which go to make up admittance, are ratios of current components to the total voltage, resistance $R$ and reactance $X$ are ratios of voltage components to the total current. Hence, except in the case of a pure reactance or pure resistance, $G$ is not the reciprocal of $R$ nor is $B$ the reciprocal of $X$.

**Ampere's Circuital Law** — The Biot-Savart law for determining the value of a magnetic field $H$ requires a knowledge of conditions in all of space or at least in all that portion of space which can appreciably affect the computation. It does not easily lend itself to the examination of a region in a space which elsewhere contains unknown currents. Ampere's circuital law, on the other hand, specifies a relation that depends upon only a single current or current distribution and, while it alone does not directly yield a value of $H$ nor in general apply to other than steady currents, nevertheless it is useful and does add to our knowledge of the nature of $H$.

If any closed path is traversed in a direction so as to keep the enclosed area on the left and, if for every incremental length of that path the tangential component of $H$ in the direction of travel is noted and multiplied by the incremental length, then the sum of these products taken all the way around the path is called the magnetomotive force of that circuit. In calculus notation this is written

$$\text{m.m.f.} = \oint H_s\,ds$$

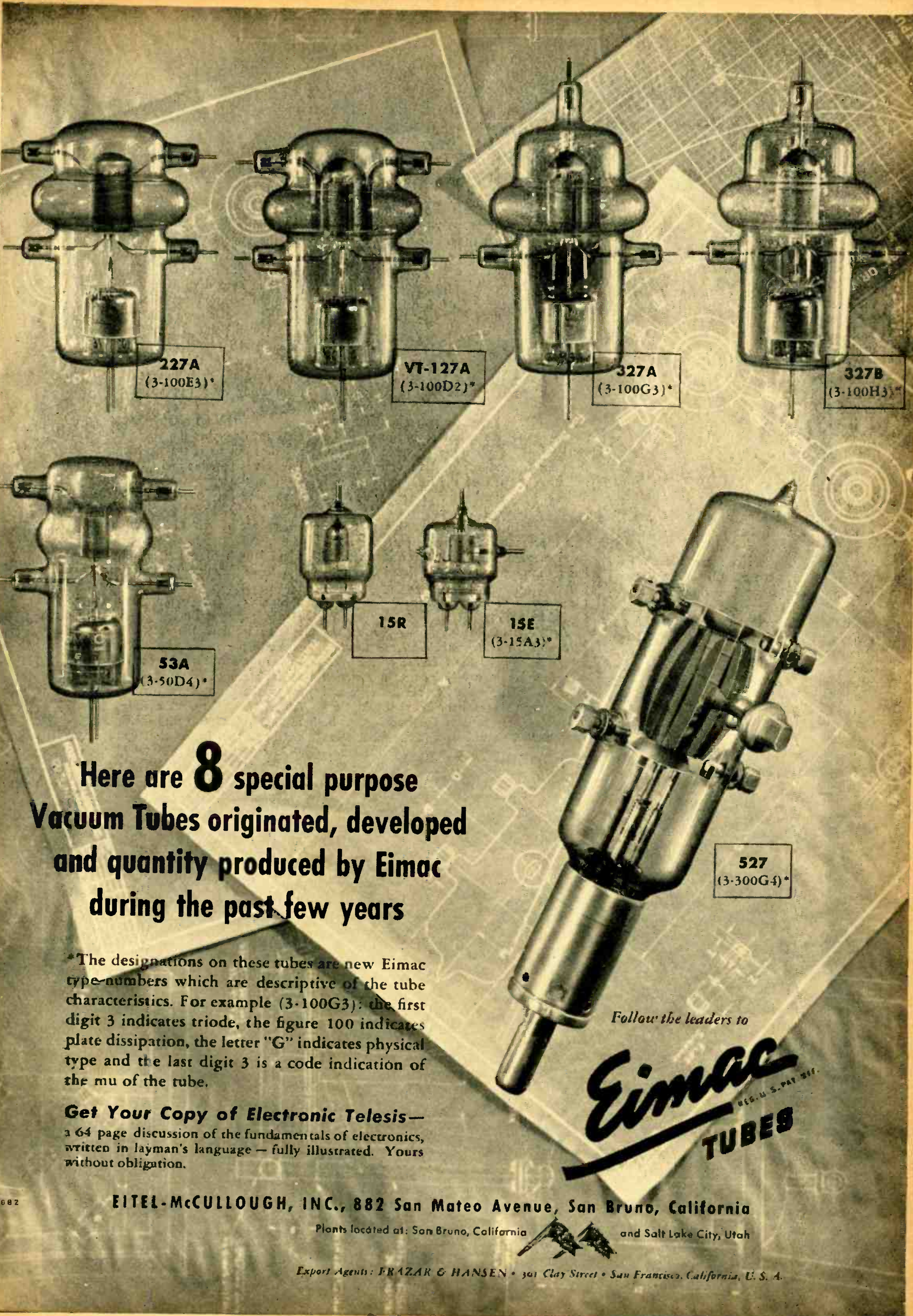
More simply, *m.m.f.* is of the nature of a magnetic field multiplied by a distance; the rest of the rigorous definition just given simply requires the field considered to be in the direction of the distance, allows for the field to have varying values along the distance, and indicates our interest in closed magnetic circuits. In terms of *m.m.f.* the circuital law may be simply stated. *The magnetomotive force around any closed path is $4\pi$ times the current crossing any surface of which the path is the boundary and is independent of all other currents.* Symbolically this may be stated as

$$\oint H_s\,ds = 4\pi i$$

In MKS units, $H$ is in amperes per meter, $i$ in amperes, and $ds$ in meters; in e.m.u, $H$ is in oersteds, $i$ in e.m.u amperes, and $ds$ in cm. If a wire carries a current which is distributed uniformly throughout the cross section, we may easily find the $H$ field within the wire. By symmetry the magnetic lines of force within the wire must be circles concentric with the wire and the field must be of equal intensity around any one of these circular paths. Thus if $r$ is the distance of a path from the axis of the wire, the *m.m.f.* must be $2\pi rH$. The current within the circle of radius $r$ is just the fraction of the total current given by the ratio of the area of that circle to cross section area of the wire. Hence, by the circuital law $2\pi rH = 4\pi i(\pi r^2)/(\pi R^2)$ where $R$ is the radius of the wire. Solving for $H$, this gives $H = (2ir)/R^2$ for the field inside the wire as compared to the well-known relation, $H = 2i/r$, for the field outside.

**Ampere's Rule**—Whenever electric charge passes through a magnetic field it is in general subject to a force which tends to move it in a direction perpendicular to both the magnetic field and its own motion. Only in the special case in which the charge is moving in the same or opposite direction from that indicated by the magnetic field does this force become zero although it is a maximum when the motion

[Continued on page 50]




# Here are 8 special purpose Vacuum Tubes originated, developed and quantity produced by Eimac during the past few years

*The designations on these tubes are new Eimac type-numbers which are descriptive of the tube characteristics. For example (3-100G3): the first digit 3 indicates triode, the figure 100 indicates plate dissipation, the letter "G" indicates physical type and the last digit 3 is a code indication of the mu of the tube.

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# TERMINOLOGY

[*Continued from page 48*]

is at right angles to the magnetic field. Ampere's rule gives a method of calculating this force. It is $F = BQV \sin \phi$ *where F is the force in newtons on a charge of strength Q coulombs which is moving V meters per second in a field of strength B webers per square meter in a direction φ degrees away from the direction of motion.* These are the units which apply when the MKS system is used. In the electromagnetic system of units $F$ is in dynes, $B$ in gauss, $\phi$ in e.m.u coulombs (a unit 10 times as large as a practical coulomb), and $V$ in cm. per sec.

Ampere's rule is also often stated for a wire carrying current through a magnetic field. It is then $F = BIL \sin \phi$ where, in the MKS system, $I$ is in amperes, and $L$ is in meters and represents the length of the wire. $F$ may then be considered as the force on the wire.

**Antenna Gain**—In a sense no antenna can have the effect of giving a gain in power. The energy radiated certainly can never exceed that fed to the antenna and practically it is somewhat less. Antenna gain is therefore not like a gain which describes the operation of a vacuum tube amplifier stage but rather it represents only an increase in transmission efficiency in a certain direction at the expense of the efficiency in another direction. An antenna having a high gain is always one which is highly directional. Microwaves particularly lend themselves to the use of highly directional antennas and therefore allow a high gain to be practically realizable. *Antenna gain is best defined as the ratio of the intensity of radiation in the direction of maximum intensity, to the intensity that would be had if the antenna emitted the same total power, but in a manner so as to spread it out uniformly in all directions.*

Suppose, for example, an antenna pattern is obtained which radiates a signal whose strength is completely independent of the azimuth angle and which depends upon the elevation angle in a fashion that may be approximated by $P = P_o \epsilon^{-18\theta^2}$ where $P$ is the power emitted per unit solid angle at an angle $\theta$ radians above or below the horizontal. Such a pattern is of pancake shape. It has a maximum radiative power of $P_o$ at zero degrees elevation and falls off to about one-half that amount at ±11 degrees of elevation. The total solid angle contained between the elevation angles $\theta$ and $\theta + d\theta$ is $2 \cos\theta \, d\theta$ so the total radiation through that element of elevation angle is $2 P_o \cos \theta \, e^{-18\theta^2} d\theta$.

To find the average power per solid radian it is only necessary to perform an integration and divide by the $4\pi$ radians contained in a complete sphere. Actually, the integration is difficult. It may be easily approximated from tables of the normal error function by taking $\cos \theta$ equal to unity under the assumption that the exponential term is small for all other values. $P_{av}$ comes out in this case to be $(1/24) P_o$.

**Antenna Reciprocity Theorem**—When applied to a pair of antennas or to any other four-terminal network containing only linear impedance elements, the essential idea of the reciprocity theorem is that an impedanceless voltage source and an impedanceless ammeter may be interchanged in position without affecting the reading of the ammeter. This theorem was first discovered by Rayleigh and was extended to include radio communication by John R. Carson. Stated for antennas alone it says that *if an alternating voltage from a zero-impedance source is connected to one antenna and a zero-impedance ammeter is connected into another antenna remote from the first, the alternating current in the ammeter will be unchanged in both magnitude and phase if its position is traded with that of the source.*

The only exceptions occur to the extent that radio waves are appreciably affected by the earth's magnetic field in conjunction with an ionized atmosphere. If one antenna is moved about another antenna and an impedanceless ammeter imagined to be read in series with the portable antenna, then from readings of that ammeter the radiation pattern of the fixed antenna can at least be plotted for distances which are large compared to the antenna dimensions. By the reciprocity theorem this plot will also represent the receiving pattern of the fixed antenna. Thus the reciprocity theorem has an important corollary that *the receiving and transmitting patterns of any antenna array must be identical.*

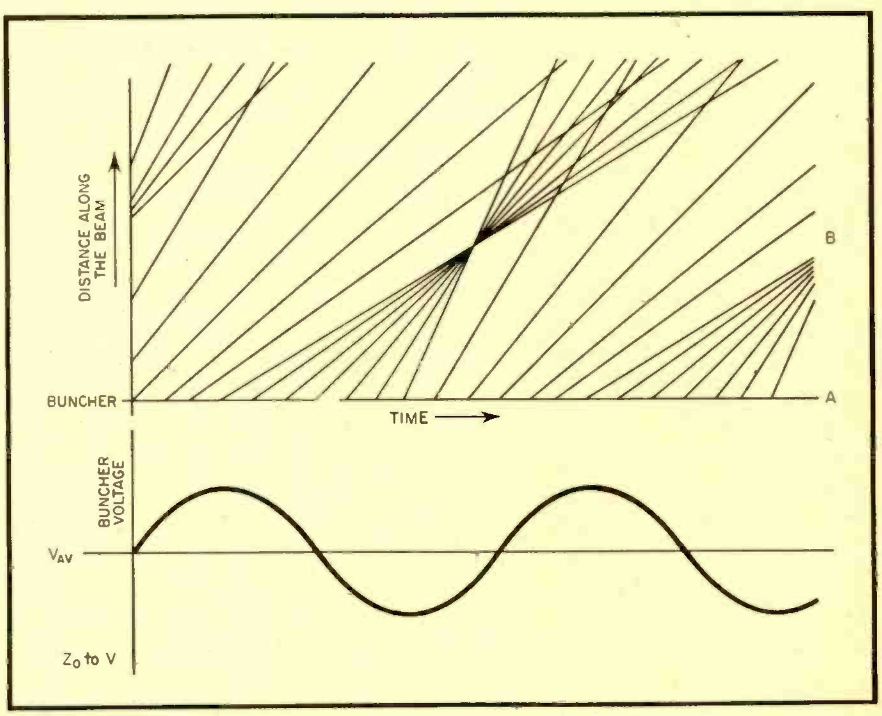
**Applegate Diagram** — *An Applegate diagram is a geometrical construction which determines the location of the electron bunches in a Klystron as a function of time.* The abscissa represents time and the ordinate shows distances along the electron beam away from the buncher. The lines plotted show how velocity modulation is possible, how a varying voltage somewhere along the beam can cause a periodic appearance of a high charge density further along the beam.

The voltage across the buncher grids varies in some such manner as is shown in the lower part of the diagram. This voltage accelerates the electrons and hence determines the velocity with which they travel through the drift space. In the diagram the velocity is represented by the slope of a line. Thus each line represents the path followed in space-time by an electron leaving the buncher at a given time. If the buncher grid voltages are known then the electron path lines may be assigned proper slopes in accord with that voltage and the optimum position for the catcher located. In the case shown maximum bunching occurs at a point $B$ along the beam. The distance $AB$ represents the field free drift space between the buncher and catcher. The diagram does not take into account debunching caused by space charge.

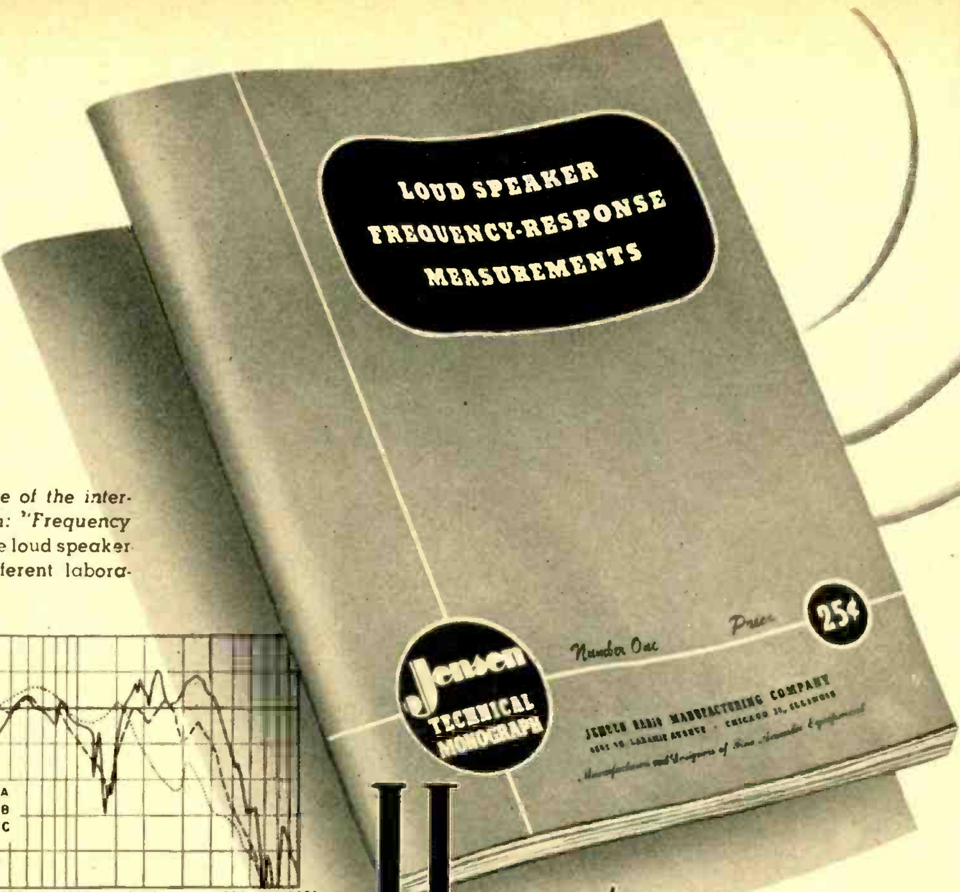
**Attenuation Constant**—α—This constant describes the way in which a signal dies out as it travels along a uniform line. It is possible and convenient to make such a description with a single factor containing only one disposable constant because of the special properties of the number ε (base of natural logarithms = 2.7183) and because the loss of signal in any very small length of a uniform line is always the same fraction of the signal entering that element of line.

Suppose, for example, a signal of strength $P$ enters a line 20 inches long and is attenuated at the rate of 1/20th of its strength per inch. If we naively interpret this to mean that in each 2 inches the signal strength is reduced by 1/10th, then after the first 2 inches the strength is $0.90P$, after the next 2 inches only $0.81P$, at the end of 6 inches $0.729P$, and so on until after 20 inches the signal strength is

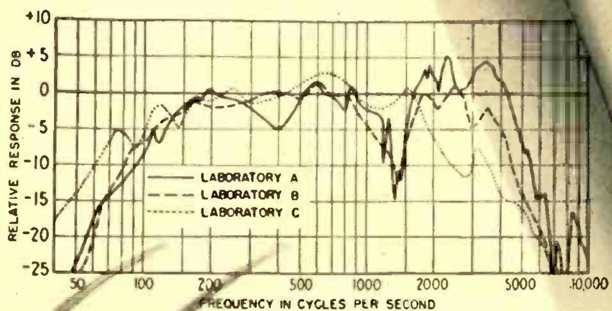
[*Continued on page 52*]




**Applegate Diagram**




*The graph shows only one of the interesting points of discussion: "Frequency response curves of the same loud speaker as measured in three different laboratories."*




# How to judge Loud Speakers from Frequency Response Curves

For years we at Jensen have keenly felt the need of dependable and useful information to guide both the professional and the layman in their selection, purchase, installation and use of loud speakers. Now we are going to meet that need by a series of informative technical Monographs prepared by the Jensen Technical Service Department. ¶ The first Monograph in the series deals with one of the most interesting and controversial subjects in the field of acoustics, "LOUD SPEAKER FREQUENCY RESPONSE MEASUREMENTS." It discusses thoroughly the practical aspects of this subject in such a way that the material is unhesitatingly recommended to the whole profession: the engineer, the trade, the student, and even the layman. The first Monograph is ready now. Copies are available from Jensen jobbers and dealers everywhere, or fill out the coupon below and send it with 25c to

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I am interested in the monograph, "Loud Speaker Frequency Response Measurement." Enclosed is 25c for my copy.

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# TERMINOLOGY

[*Continued from page 50*]

$0.349P$. On the other hand, if we work in one-inch steps saying that a 5% loss takes place in each inch, then at the ends of the 1st, 2nd, 3rd, and 20th inches, respectively, the signal strength is $0.95P$, $0.9025P$, $0.857P$, and $0.358P$.

Actually, to obtain a correct result the loss in an infinitesimal length must be used and calculations made on that basis. When that is done the signal present at the end of the 20 inches turns out to be $0.3679P$. This number 0.3679 is just $\epsilon^{-1}$. Furthermore, $P\epsilon^{-0.5}$ gives the signal strength half way along the line, $P\epsilon^{-0.25}$ at the quarter-way point, etc., so that $P\epsilon^{-x}$ can tell the strength at any point $x$ inches along the line where $\alpha$ is the attenuation rate in terms of the fraction of the signal lost per inch. *The attenuation constant $\alpha$ expresses a rate of signal loss in terms of the fraction of the signal lost per unit length.*

**Bessel Functions-J and Y.** — Although somewhat less familiar than ordinary trigonometric functions, Bessel functions serve much the same kind of purpose. Sines and cosines lend themselves to particularly simple definitions in terms of right triangles. Although no similar description can be given for Bessel functions, that is after all a relatively minor point. The important thing is that in certain physical problems such as a pendulum swinging through a small angle, a descriptive differential equation baesd on physical laws may be written in the form

$$\frac{d^2x}{dt^2} = Ax.$$

When solved in conjunction with proper boundary conditions such an equation involves trigonometric functions in specifying the action of the physical apparatus. In another large class of physical problems the differential equation is

$$\frac{d^2x}{dt^2} + \frac{1}{t}\frac{dx}{dt} + (1 - \frac{k^2}{t^2})x = 0.$$

This is called Bessel's equation. *Solutions of Bessel's equation are known as Bessel functions.* Every value of the parameter $k$ is associated with a pair of solutions called Bessel functions of order $k$. One of them, which is finite at $t = 0$, is called a Bessel function of the first kind and often represented by $J_k$; the other is called a Bessel function of the second kind and is sometimes represented by $Y_k$. Just as with sines and cosines, tables of values of $J_0$, $Y_0$, $J_1$, $J_{3/2}$, etc., are available which give numerical values of the functions for various values of their argument, $t$.

Many other functions which are well known to mathematicians also represent solutions of differential equations that are occasionally encountered in physical problems. Among these are hyperbolic and elliptic functions, Legendre polynomials, Henkle functions, Tesseral harmonics, and others.

The propagation of energy in a circular wave guide with attenuation and the calculation of antenna patterns especially from horn radiators are examples of microwave problems which involve Bessel functions.

**Biot-Savart Law** — Generally the magnetic field $H$ at any point in the neighborhood of a wire carrying a current can be found by computing a vector sum of the field components arising from each incremental length of the wire. The components are individually given by $dH = (i\ dl\ sin\ \theta)/r^2$ *where $i$ is a current, $dl$ is the incremental length, $r$ is the distance from $dl$ to the point in question, and $\theta$ is the angle between $r$ and a tangent to the wire at $dl$; each of the components is perpendicular to $r$ and $dl$ and is directed in accord with a right hand rule in which the thumb shows the direction of the current through $dl$.*

The law is most clearly justified by differentiating the rigorously obtainable expression for the magnetic field produced by a single closed circuit. It must always give a correct result if the summation of incremental currents is carried around one or more closed paths. The principle of summing over multiple closed circuits may even be extended to the case of current distributions which are considered to be made up of an infinite number of closed current filaments. When only portions of a current carrying wire are considered, however, it is not certain that there may not be false contributions to the field which would cancel out for a closed path integration.

Of great practical importance is the fact that while the Biot-Savart law is strictly true only for closed circuits or an infinite straight filament, it is approximately true for wire bent into any shape provided the point at which it is desired to calculate $H$ is close to the wire in comparison to the linear dimensions of the whole circuit.

**Black Body Radiation** — J. C Slater has pointed out that an independent proof of the equivalence of the receiving and transmitting patterns of an antenna can be obtained from the well known properties of black body radiation. *A black body is defined in the study of optics and thermodynamics as one which absorbs all radiation incident upon it and reflects none.* Thus a small hole in a hollow box approximates a perfect black body. All energy reaching the hole passes on into the box and is indefinitely subject to multiple reflections. When thermal equilibrium is reached, however, the interior of the box, like any ordinary body, must emit energy at the same rate that it is received. *The energy emitted from a black body is characterized by a perfectly random direction of travel and depends only upon temperature.*

It is possible to imagine the space around a given antenna to be so filled with this sort of radiation that there is thermal equilibrium between the transmission and reception properties of the antenna. In that case it is relatively easy to show that the transmitting and receiving efficiencies of the antenna must be equal. It remains only to particularize about emission and absorption in definite directions to confirm the pattern equivalence established by the reciprocity theorem.

The theory of black-body radiation is also useful in the calculation of noise due to the finite temperature of resistances used in electronic circuits.

**Boundary Conditions** — An algebraic equation has a single and perfectly definite solution if it contains only one unknown and if that unknown appears only in the first power. The solution is a number which can be used to replace the symbol representing the unknown and which will thereupon cause the equation to reduce to an identity. A quadratic equation or an algebraic equation of still higher degree has similar properties except that more than one number may fulfill the mathematical qualities of a solution. When such cases arise in connection with physical phenomena it is usual to choose among the solutions on the basis of experimental knowledge.[1] In the case of differential equations the same sort of situation exists except that the number of possible solutions is often infinite. *Boundary conditions are those known relations in a given physical problem which allow us to select the proper solution of one or more differential equations which describe a class of such problems.* When the variables of the problem are distances the boundary conditions may well take the form of numbers which represent the value of the variable at some outer boundary of the space under consideration; when a variable of the problem is time, part of the boundary conditions may be initial and final values of the unknowns.

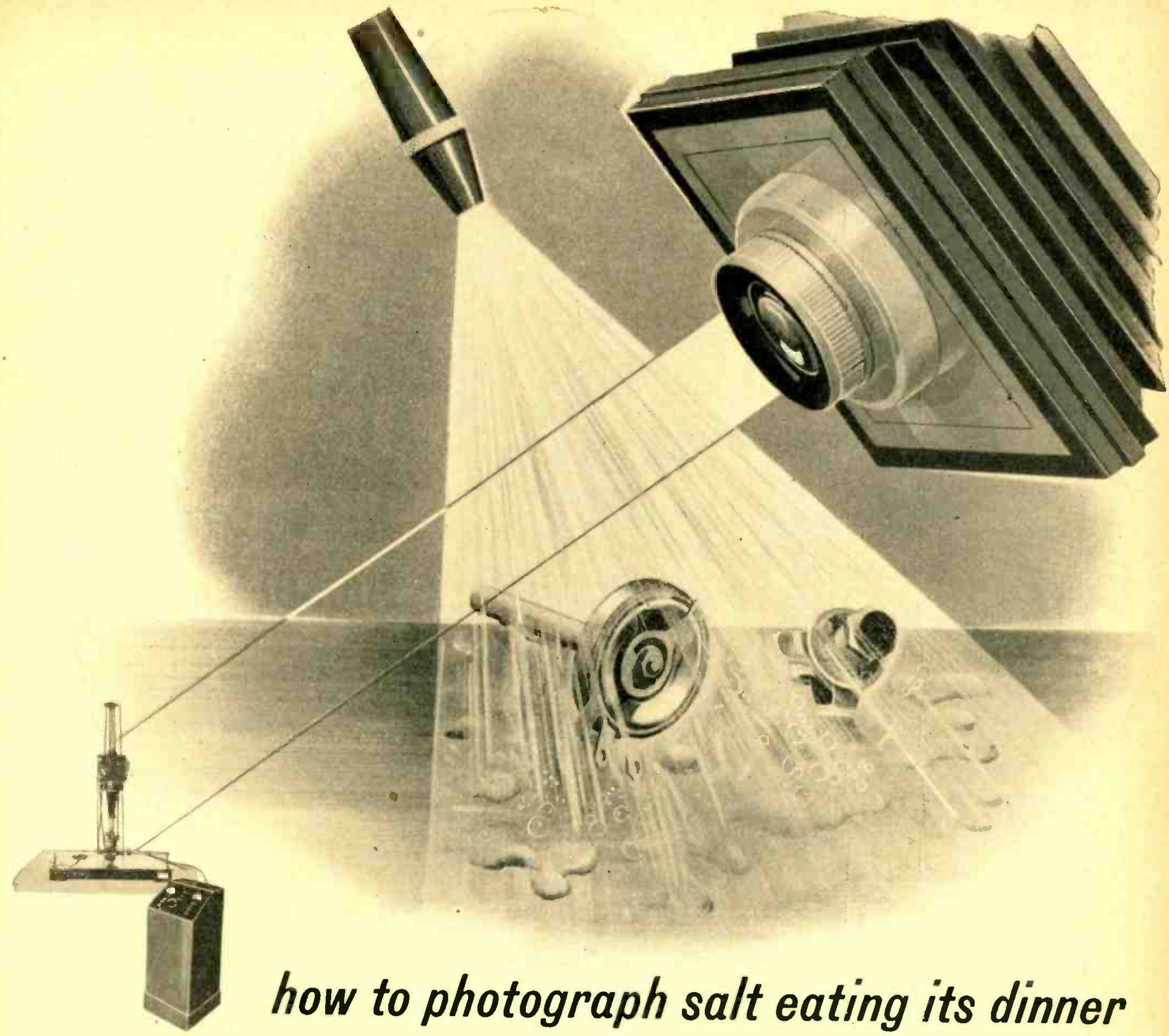
It is because of the role of boundary conditions that we are able to write down a set of equations as general as Maxwell's equations and say that they cover all of the phenomena of macroscopic electricity and magnetism. We mean that whenever proper boundary conditions can be formulated and mathematics carried through to cause these conditions to select a proper solution of the equations, then that solution will indeed describe the results of the physical experiment we had in mind. We believe this because we can see that Maxwell's equations contain the general conditions of magnetic induction, field orthogonality, continuity, etc., and because no case has ever been found in which proper methods have yielded a wrong answer.

The job of the theorist working with Maxwell's equations is to formulate boundary values of the variables in accordance with the nature of the apparatus at hand and to seek a solution of the equations which satisfies proper boundary values of the variables. This is possible in many cases but also impracticably laborious in others.

**Characteristic Impedance-Zo** — *The characteristic impedance of a transmission line or of a series of recurring networks is by definition the impedance of an infinitely long line or of a network*

[1] For example, $h = \frac{1}{2}gt^2$ used to calculate the time of fall of a body. If the body falls 64 feet with $g = 32$ ft. per sec.$^2$ then the solution of $t = -2$ sec. is disregarded and $t = +2$ sec. accepted as the proper answer.

[*Continued on page 54*]



# *how to photograph salt eating its dinner*

Salt, from the sea and air, has a tremendous appetite for many metals—eating them away unless they're protected. The exact effect of its gluttony and the success of the means used in preventing this costly damage are measured accurately by Utah's salt-spray test. One of the stages in Utah's *complete* circuit of radio and electronic tests.

Immediately after the parts have been subjected to the salt spray, microphotographs are taken and developed in the especially equipped Utah dark room. Thus, it is possible to make a microscopic inspection of the actual condition of the metal *before* other atmospheric changes take effect. Since metal surfaces exposed to salt-spray tests change rapidly *after tests are completed*, it is necessary and possible, by this photographic method, to determine and *accurately* record corrosion in metals.

As a result of this and other Utah tests, efficient performance of Utah parts is assured under any and all conditions normally encountered—the failures due to inadequate, inaccurate testing are avoided.

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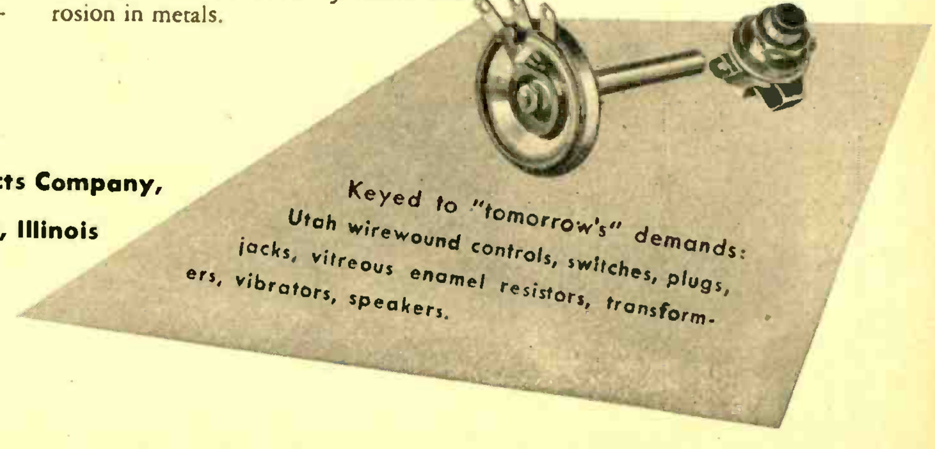


# TERMINOLOGY

[*Continued from page 52*]

*made up of an infinite number of sections.* Practically, of course, a truly infinite line is never realized but if the line is sufficiently long so that a voltage versus current measurement can be made before energy is reflected from the far end, the effect of an infinite line is obtained. Impedance of this sort is also often referred to as surge impedance.

If an infinite line is cut at some point and terminated by some impedance $Z$, then the amount of energy flowing in the line which will be reflected back along the line at that point is uniquely determined by the complex value of $Z$. In particular, if $Z = Z_o$ no reflection occurs and all the energy is absorbed in the termination. This is generally the desired condition for filters, electrically long wired circuits, and wave guides.

With constant voltage lines (i.e., electrically short lines in which a wave length is long compared to the physical length) the characteristic impedance does not usually play an important role. The input impedance to the line which must match the impedance of the source in order to obtain a maximum transfer of energy into the line is primarily dependent upon the load impedance. With electrically long lines, however, this is not true. The input impedance to the line depends upon both the load impedance and upon the characteristic line impedance and when the load end of the line is perfectly matched the input impedance becomes just equal to the characteristic impedance.

**Constant Voltage Line**—In contradistinction to an electrically long line, *a constant voltage transmission line is one whose length is short compared to the wave length of the electrical energy traveling in it.* Most ordinary power lines and other common electrical connections are of this type. Electrical energy travels so rapidly that at ordinary frequencies an electric current has ample time to travel completely around most circuits before the source voltage can appreciably change. A line has to be extremely long at audio frequencies if there is to be time for the source voltage to change while the current previously generated is still enroute to the load. That is what happens when an electrically long line is encountered and an appreciable fraction of a wave length or even several wave lengths are contained within the extent of thetransmission system.

The velocity of electromagnetic waves in a transmission line of negligible resistance is given by $1/\sqrt{L'C'}$ where $L'$ and $C'$ are respectively inductance and capacitance per unit length. For any pair of parallel straight conductors of uniform cross section, the product of $L'$ and $C'$ is just $1/C^2$; hence the velocity is just that of light. In ordinary circuits carrying audio frequencies as high as 10,000 cycles per second, a wave length would be 18.6 miles long so any connection less than several miles in length qualifies as a constant voltage line.

**Coulomb's Law**— In 1875, Coulomb made a series of measurements designed to find how the force of attraction or repulsion between point stationary electric charges varies with the distance between them. He found the force to fall off as the inverse square of the distance. The force also depends upon the medium in which the charge is located. *Analytically, the law may be stated as* $F = Q_1Q_2/\epsilon r^2$ *where* $F$ *is measured in dynes,* $Q_1$ *and* $Q_2$ *are in e.s.u coulombs,* $r$ *is the distance between the charges in cm, and* $\epsilon$ *is the dielectric constant in the electrostatic system of units.*

In this system of units $\epsilon$ is unity for a vacuum and Coulomb's law serves as a convenient definition of an e.s.u coulomb. In media other than a vacuum, $\epsilon$ is more than one and the force $F$ is decreased. This is because the polarized charges of the medium which are more or less symmetrically distributed around the free charges screen part of the force from the charges.

Coulomb's law is also approximately true for the electrostatic force between two charged metallic balls. It is true to the extent that the charge remains spread smoothly over the surface of each ball instead of being bunched up from interaction with the other ball. This approximation is usually considered valid if $r$ is large compared to the diameters of the balls.

[*To be continued next month*]

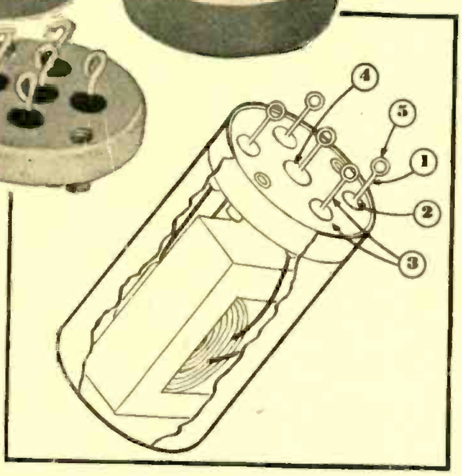
# PROVED IN SERVICE

# FOSTER TRANSFORMERS

MEET EVERY NEW NEED WITH THE SAME DEPENDABLE PERFORMANCE THAT HAS MADE THEM *"FIRST"* IN ELECTRONIC REQUIREMENTS.


## FOSTER IS FIRST AGAIN WITH THEIR NEW "VITROSEAL" TERMINAL

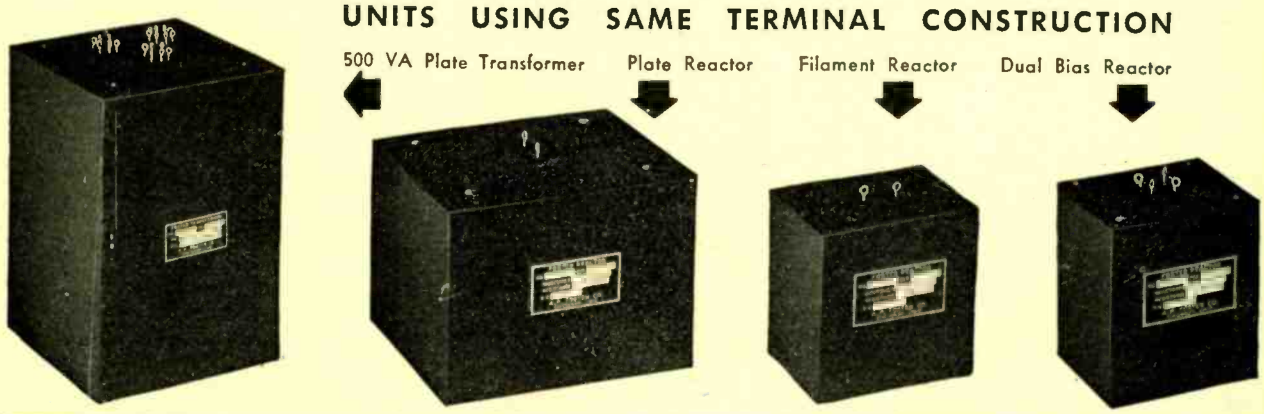
a development that has definite advantages over other types of hermetic seals for tropical use.




1. The electrode can be bent at an angle 90° from the upright position without breaking the glass in the seal. In fact, it can be bent and straightened several times and then the terminal will break *before* the glass is damaged.
2. Extremely high resistance to thermal shock.
3. The metallic parts are cold rolled steel, rather than expensive alloys.
4. The terminals are fused directly into the metal in multiple. Ordinary seals are made up individually and are soldered into holes in the transformer case.
5. A loop is provided for easy hook-up.

### UNITS USING SAME TERMINAL CONSTRUCTION

500 VA Plate Transformer — Plate Reactor — Filament Reactor — Dual Bias Reactor



SPECIALISTS IN BUILDING TRANSFORMERS SINCE 1938

# A. P. FOSTER COMPANY

TRANSFORMER ENGINEERS & MANUFACTURERS
719 WYOMING AVENUE, LOCKLAND 15, OHIO

[*Continued from page 46*]

duction in size and weight.

Moreover, the elimination of voids in coils increases the heat conductivity of the structure. Preliminary experiments have shown that certain coils impregnated with Fosterite Resin will dissipate as much as one-fourth more heat as coils impregnated with ordinary solvent-type varnishes. In addition, a sample of Fosterite, heated in transformer oil at a temperature of 185°F. (85°C) to 194°F. (90°C.) for one year, swelled less than 1½ per cent—indicating that it is insoluble in transformer oil and hence suitable for treating oil insulated coils.

While Fosterite was developed as a solventless varnish for use in standard electrical equipment, it is also finding application in highly specialized communication equipment for the armed services—both in radio and radar—where moisture proofing is the most critical factor. The Fosterite method now promises to solve this important problem of moisture proofing.

In a test of Fosterite moisture proofing, radio and radar components are subjected to hot and cold water submersion. The components are first placed in 149°F. (65°C.) saturated salt water solution for two hours, then in a 32°F. (0°C.) solution for another two hours, and the cycle is repeated five times. The insulation resistance must not be less than 75 megohms; the leakage current not more than 3 milli-amperes.

Surface coating has also provided a radical improvement in moisture resistance of such apparatus. By means of the coating and impregnation, the moisture proofness is 100 to 1000 times better than by the use of the best previous materials.

Fosterite is going as rapidly as possible into radar and radio communication equipment for the armed forces, but we can also anticipate its wide use after the war. At present, our efforts are confined to war time applications not only at Westinghouse but at other companies to which it will be furnished.

### Replacing Shellac

Fosterite is an example of the development of an entirely new material. Older materials, on the other hand, stimulate scientific efforts to discover improvements or similar but better materials. Typical of this latter kind of development is the discovery of a synthetic resin, a strong and new resin superior to natural shellac.

At the beginning of the war, we were faced with the prospect of losing our shellac supply since all of it comes from India. Moreover, made by small insects from the saps of several kinds of trees and varying in quality with the seasons, natural shellac is an extreme example of a product full of impurities. Yet one highly important and troublesome electrical device, the commutator of rotating machines, has depended completely on shellac as a bonding insulating agent.

While shellac had given much trouble, extensive research provided no substitute. The war, however, stimulated more research and again a discouraging search for substitutes began. Our chemists again took the shellac molecule apart theoretically and postulated another hypothesis as to the type of the desired resin; the result was the strong, new synthetic resin.

Mechanically and electrically, the synthetic resin appears to have all the properties desired; indeed, the new resin appears to be an improvement over shellac at its best for commutators and in certain other electrical insulations. This material now promises not only to eliminate shellac but also its associate, mica (used in combination with shellac in commutators), thus eliminating another headache.

The unusual elasticity and strength of this resin indicate that it will find other applications. For example, fiberglass bonded with this resin has a tensile and bending strength equal to that of rather strong metals—75,000 to 80,000 pounds per square inch. In other words, this plastic is stronger than cast iron which has a tensile strength of 15,000-50,000 pounds per square inch, stronger than sheet brass with a tensile strength of 40,000-70,000 pounds per square inch, and as strong as many steels (tensile strength: 80,000-300,000 pounds per square inch).

With these two resins, basic research has solved three important problems of the electrical industry. The problems were to find (1) a solventless impregnant to give 100 per cent fill, (2) a moisture proofing material, and (3) a shellac substitute. These are three very important problems to the industry, and they were solved by basic chemical re-

[*Continued on page 58*]

# THE SPHERE OF ELECTRONICS

The sphere of electronics is increasing constantly . . . it now encompasses practically all industries. Electronic devices are being applied to do old jobs quicker and more efficiently, and to accomplish tasks heretofore considered impossible.

At I. C. E. new methods of solving radio-electronics problems are being developed . . . and these developments will be ready to serve you when the peace is won. The time is coming when I. C. E. can help put your post-war blue-prints into action. One of the precision-engineered tubes ready now is the I. C. E. 257B . . . Beam Pentode transmitter tube . . . 75 watt plate dissipation . . . 200 watt output and 0.1 watt driving power. Send your inquiries now.

ICE

ELECTRONIC TUBES

**INDUSTRIAL & COMMERCIAL ELECTRONICS**

BELMONT, CALIFORNIA

# NEW PRODUCTS

[*Continued from page 56*]

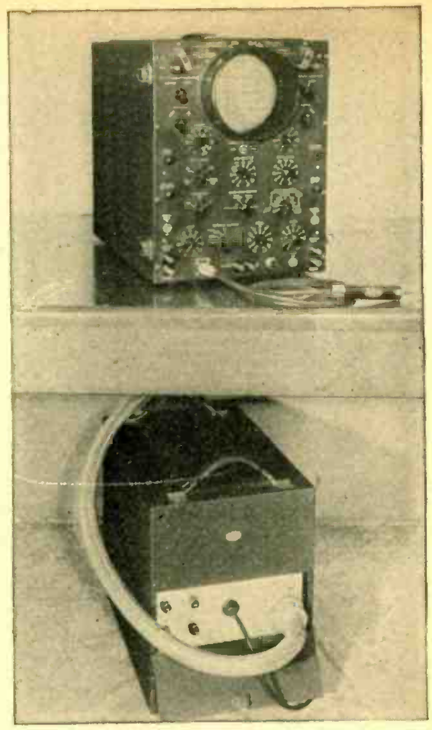
search. Fosterite and the synthetic resin replacing shellac in many critical applications are typical products of systematic, basic research in industry.

### WIDER-RANGE OSCILLOGRAPH

Those heretofore restricted in their oscillographic studies by the inadequate performance or the prohibitive cost of existing equipment will be especially interested in the new Type 248 oscillograph just announced by Allen B. Du Mont Laboratories, Inc., Passaic, N. J. The designers claim that this instrument removes the obvious deficiencies in commercial test equipment performance as brought to light by recent advances in electronic equipment, and yet is made available at moderate cost.

Du Mont Type 248 is a portable instrument suitable for lab or production-test purposes. Two units—the oscillograph and the power supply connected by a 6-foot plug-in shielded cable—facilitate handling and installation. A removable cover protects the oscillograph panel when instrument is not in use. The power supply weighs 80 lbs.; oscillograph, 30 lbs. Units each measure 14" x 18" x 21" deep.

This instrument reproduces either transient or recurrent phenomena. Also accommodates phenomena of inconstant



repetition rate. Leading edge of short pulses is not obliterated. The accelerating potential applied to cathode-ray tube is great enough to permit study of extremely short pulses with low repetition rates, usually observed only with specialized and costly oscillographic equipment. Timing markers are available for quantitative or calibration purposes.

Among the many interesting features of this oscillograph are: Wide band vertical axis amplifier usable to 10 mc; 4000 volts accelerating potential applied to cathode-ray tube, allowing observations of fast writing rate phenomena; extremely flexible time base generator to display signals which heretofore required special sweep circuits; delay network in vertical channel, permitting observation of entire wave shape of short-duration phenomena; useful timing oscillator for quantitative analysis; trigger output signal useful for "synchroscope" applications.

### NEW SPOT WELDING TIMER

Suitable for welding small objects of high conductivity such as aluminum or copper, a new precise welding timer with heat control for timing intervals of one-half cycle or less is announced by Westinghouse Electric and Manufacturing Company.

Precise, because the welding current is made to start at the same point on the voltage wave for every operation, the new SP-18, ½ cycle timer is designed for welding of such items as radio tube parts and sockets, pig-tail resistors to terminal lugs, watch and instrument parts, contact tips on electrical relays and other small parts.

The timer is furnished as a separate control for use with existing small bench welders and also in combination with a small welding transformer. Only

[*Continued on page 68*]


COMMUNICATION
AVIATION
EQUIPMENT
QUARTZ RADIO CRYSTALS
RB
MANUFACTURING · DESIGNING
ENGINEERING TO ORDER
ELECTRONIC EQUIPMENT
RADIO TRANSMITTERS
RADIO RECEIVERS
TESTING EQUIPMENT
HIGH & ULTRA HIGH
FREQUENCY UNITS
AMPLIFIERS
STANDARD PRODUCTION
of
AIRCRAFT · MARINE
POLICE · MOBILE
OR BASE RADIO
EQUIPMENT
REX BASSETT
INCORPORATED
FORT LAUDERDALE, FLORIDA.

## THIS MONTH

[*Continued from page 44*]

the latter. He will have charge of sales through the jobbing trade and states that he plans full continuance of the distribution policy that, for years, has made Cornell-Dubilier the world's largest capacitor manufacturer.

### POWERS SECURES TERMINATION ORDERS

Dr. Ralph L. Powers, Los Angeles counsellor, has received termination orders from his duties as an administrative inspector in the San Francisco Signal Corps Inspection Zone. He relinquished control of his own office in 1942 to become an inspector. Early in 1944 he was placed on a part-time basis and allowed to devote a portion of time to his clients. When the invasion was launched he was given final termination.

He is now editing Hoffman Transmitter, monthly house organ of the Hoffman Radio Corp., Los Angeles, which was recently changed from the name of the Bell Ringer, so named when the organization was known as the Mission Bell Radio Mfg. Company.

Micro Topics, bi-weekly house journal of the Universal Microphone Co., Inglewood, is also under his editorial supervision. Veteran of World War 1 with 15 months in the AEF, he was in Australia when World War II broke out. He is a Companion of the Australian Institution of Radio Engineers and onetime co-director with Dr. Lee de Forest on the Los Angeles chapter of the IRE.

Dr. Ralph L. Powers

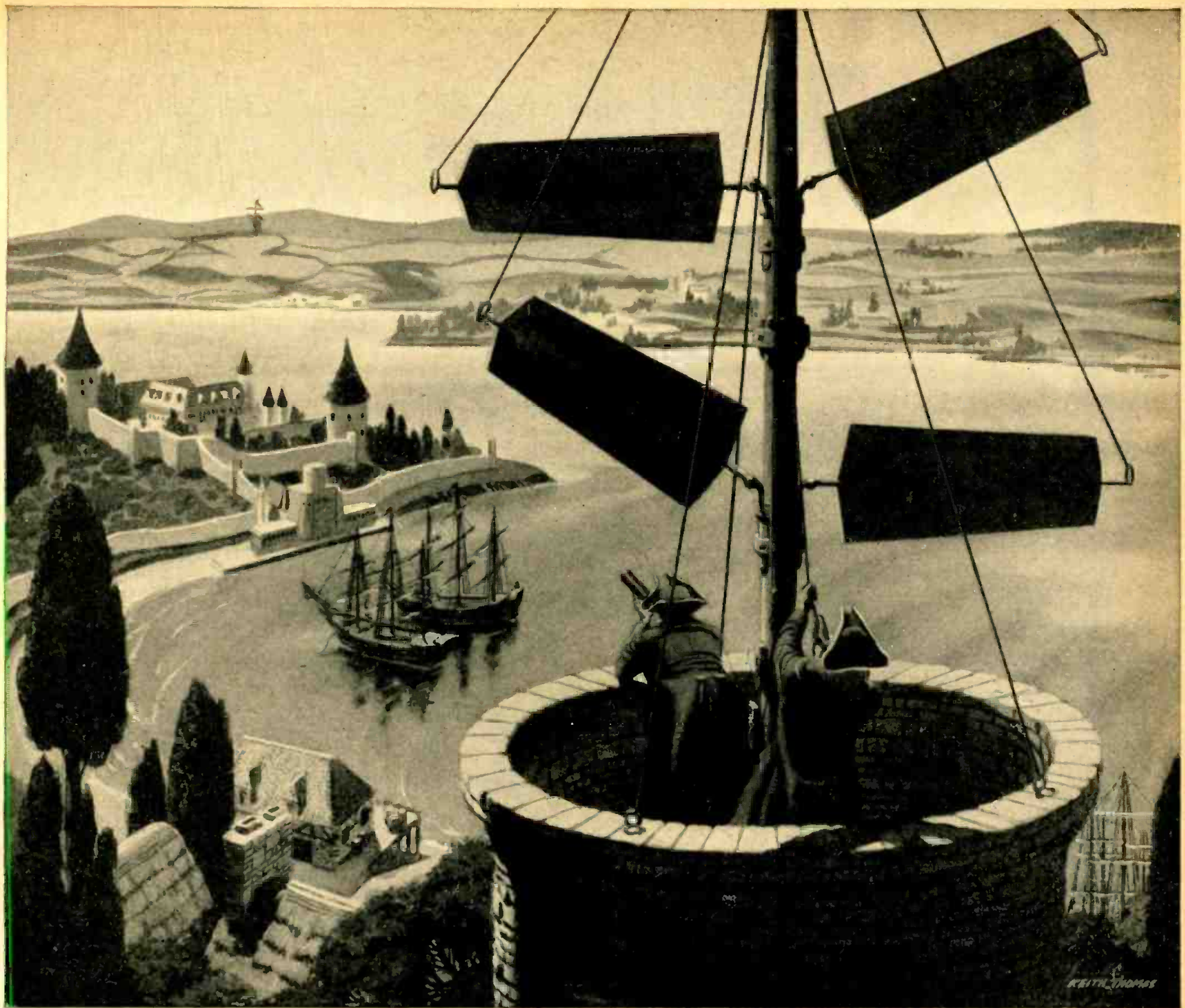
### ELECTRONIC INSTRUMENTS FOR MERCHANDISING

Electronic instruments, in their successful use as mediums for demonstrating postwar products, have assumed a role that may result in radically new and advanced promotion and merchandising methods, according to George M. Muschamp, vice-president in charge of engineering for the Brown Instrument Co., Phila., division of Minneapolis-Honeywell Regulator Company.

Mr. Muschamp pointed to a recent demonstration, using an electronic potentiometer, as an apt illustration of the forcible and dramatic in emphasizing the advantages and superiority of a new product. The example cited was the public demonstration of a new type, built-in transparent window-insulation developed by Libbey-Owens-Ford Glass Co. In this instance, he said, a Brown electronic potentiometer, a similar instrument to that used to test flight conditions for bombers and fighters, was employed to record temperatures of cold test cabinet windows. One of the windows tested had a single pane of glass, the other a light of Libbey-Owens-Ford Thermopane.

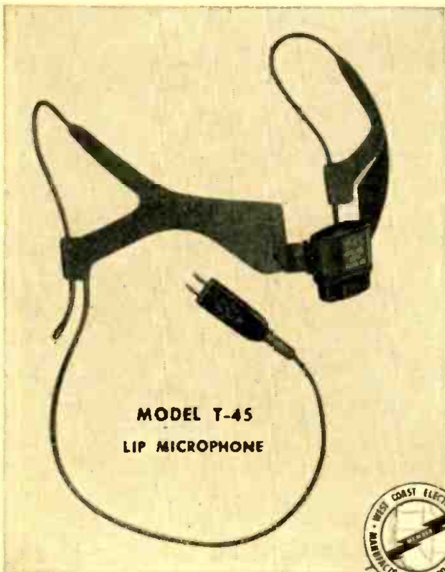
The advantages of this new product, said Mr. Muschamp, were demonstrated through use of thermocouples which were attached to inside and outside surfaces of both windows, while the inside temperature of the cabinet was near

[*Continued on page 62*]



*History of Communications Number Six of a Series*

# COMMUNICATION BY SEMAPHORE




The Semaphore, as a means of communication, met first commercial acceptance in France under the authority of Napoleon in 1792. Restricted by "line of sight" and low power eye pieces, excessive numbers of relay stations, as pictured above, were required for "directional broadcasting" over rough terrain. Weather conditions, too, were a handicap. Because of the code used and its necessary translation, delays and errors were continually encountered.

Today, in the era of applied electronics, Universal microphones are being used to expedite messages on every battle front in the service of the Allies. Universal is proud of its contribution in the electronic voice communications and its every effort to our ultimate Victory.

*Model T-45, illustrated at left, is the new Lip Microphone being manufactured by Universal for the U. S. Army Signal Corps. Shortly, these microphones will be available to priority users through local Radio Jobbers.*

**UNIVERSAL MICROPHONE COMPANY**
INGLEWOOD, CALIFORNIA

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## THIS MONTH

[*Continued from page 60*]

zero. The electronic potentiometer picked up and recorded instantaneously a 20-degree difference between the surface of the ordinary single pane, compared with the new Thermopane.

Mr. Muschamp said that this and similar demonstrations will provide manufacturers of varied lines with a factual and impressive means of emphasizing the advantages of their products. The electronic principle incorporated in the new instrument, he added, will provide many other demonstration possibilities for products requiring close temperature, pressure or flow control in manufacture, and for products requiring close or specific temperatures while in use.

### BELL RINGER RENAMED

"Bell Ringer," monthly house organ of the Hoffman Radio Corp., Los Angeles, has chnaged its name to the "Hoffman Transmitter." Margaret Tylle, of final assembly, was awarded a war bond for suggesting the winning name to the employee-management committee.

### NEW RADIO PHENOMENON

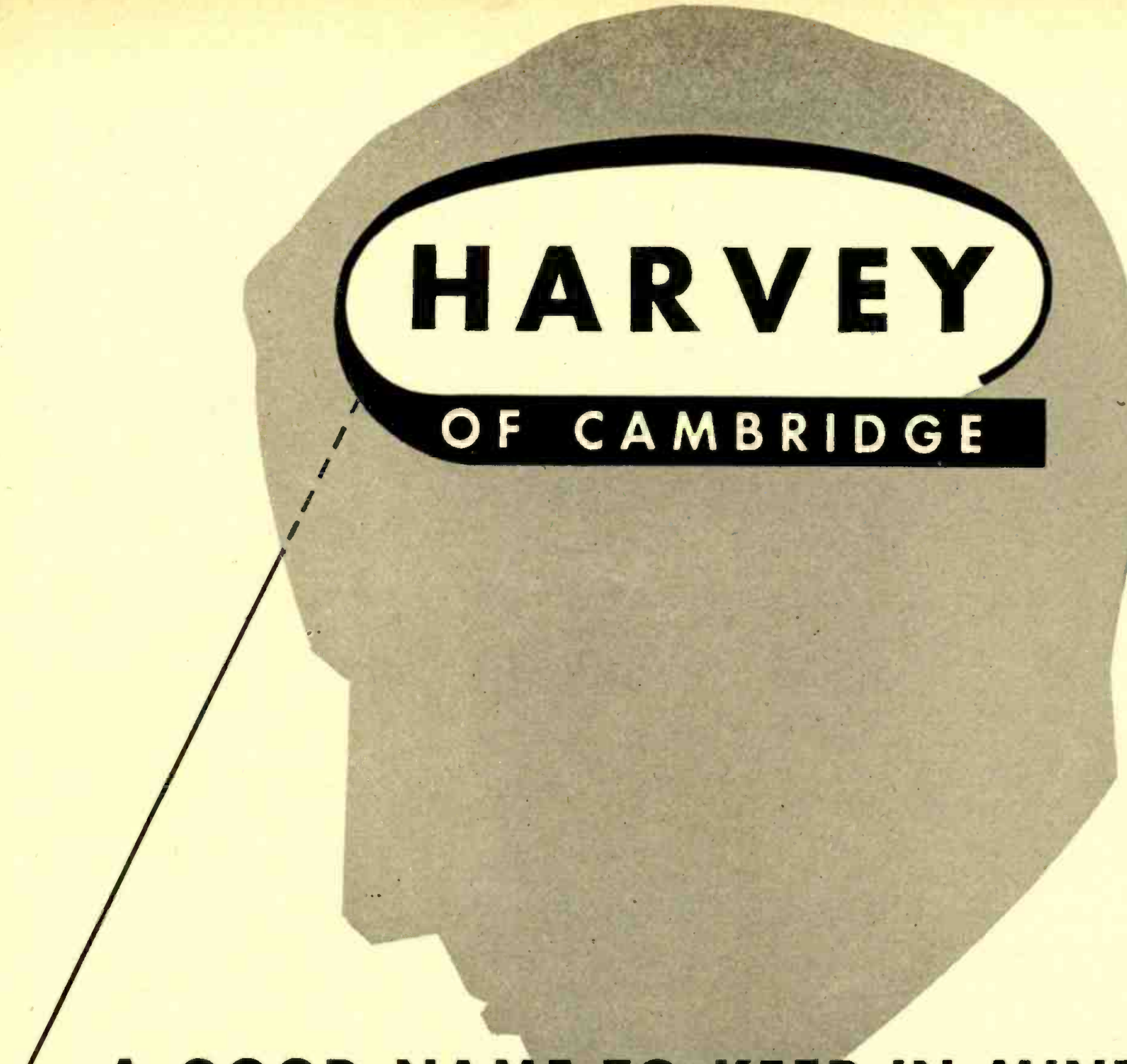
Observations on a phenomenon in radio propagation hitherto not reported—long-distance bursts causing interference in the very high frequency band which includes the band 42-50 megacycles now assigned to FM broadcasting—were announced today by the Federal Communications Commission.

The amplitudes of the bursts, according to FCC engineers, have varied from the lowest levels which can be measured up to levels well in excess of that required to render a satisfactory FM broadcast service. During periods of maximum activity they may occur at the rate of several hundred per hour. However, the amplitudes of but few of the bursts are sufficient to cause serious interference to a receiver operating within the protected area of an FM station under present FCC standards.

A "burst" is defined as a sharp increase of signal strength of very short duration—seldom covering more than the time consumed by a single spoken word or a note or two of music—from an FM station located at a considerable distance from the observer. Since February 1943, FCC engineers have been recording reception from certain FM stations to determine the nature and extent of the interference.

The bursts were observed from the higher powered FM stations only. This may account for the failure of amateurs, experimenters and others to have reported this type of interference in this frequency range. The bursts are not normally observed from nearby FM stations, since the steady ground wave signal is of sufficient strength to obscure them, but they may be observed in such instances by a system of pulsing or by a directional antenna which discrim-

[*Continued on page 64*]

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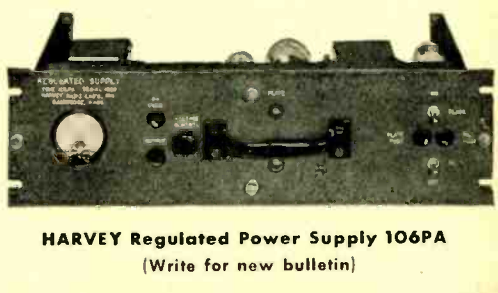

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## THIS MONTH

[*Continued from page 62*]

inates against the ground wave. At greater distances where the steady signal is absent or of low intensity, the bursts may be heard through the loudspeaker or may be recorded by a suitable recorder.

### Covers Long Distances

Bursts have been observed by both methods at distances up to 1400 miles from certain FM stations, but are neither so intense nor so numerous at the longer distances as they are at distances of 300 to 700 miles. Commission engineers observed a systematic variation in the relative numbers of bursts which occur from hour to hour during the day, the highest number occurring near sunrise and the fewest near sunset.

It was pointed out these bursts may be related in some way to bursts of somewhat longer duration and greater frequency of occurrence which have been reported by other engineers on frequencies blow 20 megacycles. The distances over which the FM bursts are received, as well as certain measurements of signal path length, indicate they are ionospheric in origin, just as are the bursts at the lower frequencies. There is also substantial agreement between the daily variations in the FM bursts and the lower frequency bursts which is further evidence that they are related and may perhaps be due to a common cause.

Bursts were also observed by Commission engineers on certain television stations at 72 megacycles, but insufficient data have been collected on these to make any determination of the relative amplitudes, frequencies of occurrence, and durations as compared with the bursts in the FM band.

In accordance with a commitment made when the FCC met November 17, 1943, with representatives of the Radio Technical Planning Board, the Interdepartment Radio Advisory Committee, and the Board of War Communications to discuss organization and procedure to be followed in post-war planning, the Commission has made a preliminary report on bursts in the FM band to the RTPB.

Commission engineers are continuing their observations and it is hoped data will be obtained which may serve as a basis for approximating the amplitudes and numbers of the bursts to be expected at various distances from a transmitter at any given time. This determination involves not only a long-time measurement of burst amplitudes from FM stations, but measurements as well of the path lengths and directions of arrival of the signals, in order to identify the medium causing the bursts.

In addition to the burst signal interference described above, there is another distinctly different kind of interference to Very High Frequency reception which has been recognized for some

[*Continued on page 66*]


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## THIS MONTH

[*Continued from page 64*]

years. It happens occasionally that a normally unheard station will come in with sufficient signal strength to operate a receiver satisfactorily for a considerable length of time—many minutes or even hours. This effect, easily distinguishable from the burst phenomenon by its duration, can be produced by transmitters of low power and has been known to produce a signal sufficiently strong to take control of a receiver tuned to a local station on the same frequency. The cause of this phenomenon has been traced to abnormal "patchy" ionic densities in the lowest of the ionospheric layers—the "E" layer, and is known as "sporadic E transmission." While much data on this effect has been accumulated at lower frequencies, more are needed for the Very High Frequency region of the spectrum and it is hoped that the present recording program of the Commission will help to supply the need.

Both of these interference effects are being studied by the appropriate Panels of the Radio Technical Planning Board and with this cooperation and that of other interested organizations, it is believed the Commission will find a satisfactory solution of the problems involved.

## Choosing Tube Types

[*Continued from page 40*]


2. Thompson & Rose—"Vacuum Tubes of Small Dimensions for Use at Extremely High Frequencies." *Proc. I.R.E.*, Dec., 1933.
3. Thompson—"Review of UHF Vacuum Tube Problems." *RCA Review*, Oct., 1938.
4. Wagener—"Two New UHF Triodes." *Proc. I.R.E.*, April, 1938.
5. DeWalt—"Three New UHF Triodes." *Proc. I.R.E.*, Sept., 1941.
6. Haller—"The Design and Development of Three New UHF Transmitting Tubes." *Proc. I.R.E.*, Jan., 1942.
7. Kilgore—"Magnetron Oscillator for the Generation of Frequencies between 300 and 600 Megacycles." *Proc. I.R.E.*, Aug., 1936.
8. Haeff—"An UHF Power Amplifier of Novel Design." *Electronics*, Feb., 1939.
9. Lindenblad—"Development of Transmitters for Frequencies above 300 Megacycles." *Proc. I.R.E.*, Sept., 1935.
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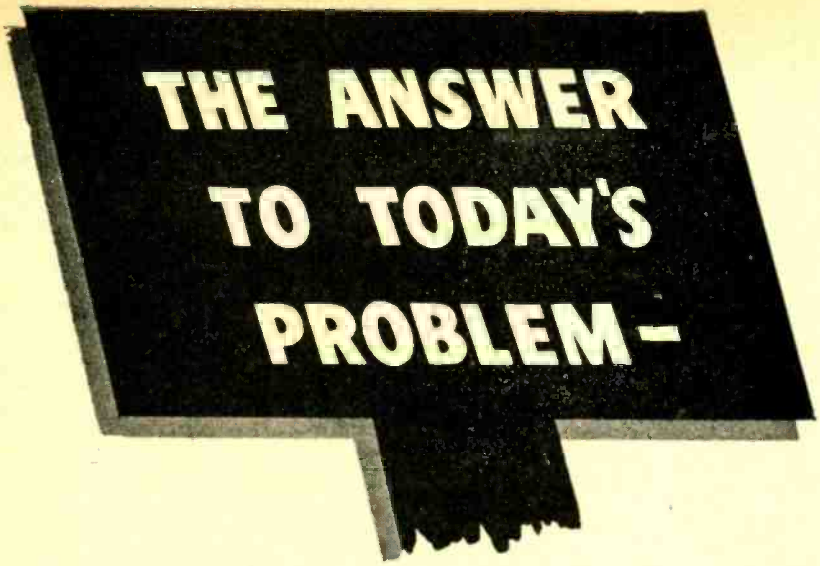
12. UHF Technique — Reprints from *Electronics*, 1942.
13. UHF Techniques — Brainerd — D. Van Nostrand Co., New York.
14. Radio Engineers' Handbook—Terman—McGraw-Hill Book Co., New York.
15. Klystron Technical Manual—Sperry Gyroscope Co., Brooklyn 1, N. Y.

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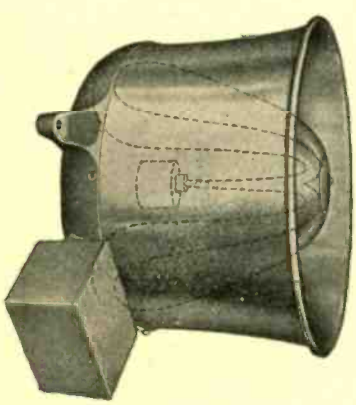
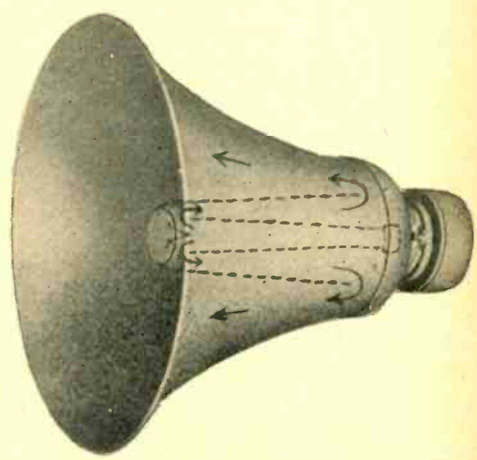
WPB will now accept applications for industrial war plant sound installations. Use WPB Form 617. Specify RACON's.



*Left:* MARINE HORN Speaker, approved by the U. S. Coast Guard. Several sizes available, Stormproofed, of the re-entrant type, suitable for indoor or outdoor use—may be used as both speaker and microphone. *Right:* RE-ENTRANT TRUMPET; available in 3½', 4½' and 6' sizes. Compact. Delivers highly concentrated sound with great efficiency over long distances.



**RACON ELECTRIC CO. 52 EAST 19th ST. NEW YORK, N. Y.**

# NEW PRODUCTS

[*Continued from page 58*]

one control tube is used, this thyratron serving the dual purpose of rectifying alternating current to charge a firing capacitor and also firing the small ignitron power tube. Heat control is accomplished by a phase shift method, the adjustment dial for which is mounted on the cabinet door.

Further information on this timer, rated at 230/460 volts, 50/60 cycles, may be secured from Department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

### CETRON CE-303

The Continental Electric Company, Geneva, Illinois, announce another new tube to their line of electronic tubes—the CETRON CE-303.

The CE-303 is a 1-ampere Xenon-filled thyratron tube especially designed for the industrial field and suitable for use in a wide variety of equipments including the following:

1. Industrial control including welding control.
2. Motor control.
3. Controlled rectifiers.

Being gas-filled, this tube is quick heating and is free from the effects of


large temperature changes. The inverse peak voltage rating of the tube is 700 volts.

Because of its special design, the CE-303 draws very low critical grid current, the maximum limit being 5 microamperes.

The tube uses a standard 4-pin base. Other technical details are covered by bulletin No. 114, which will be sent on request to manufacturer.

### FREE TRAINING COURSES

Special free training in radio and electronics for technical workers in California war industries will be given in a series of short courses which the University of California will start in August in major war production centers throughout the state, as part of the Engineering, Science, and Management War Training Program of the United States Office of Education.

The instruction is designed for full-time workers who are willing to devote two hours a week to class lectures and an equal amount of time to home study. The training will be offered in both elementary and advanced levels, to meet the needs of those of varying degrees of experience.

The program will include evening lecture courses in radio and industrial electronics, meeting weekly for eighteen weeks, and an evening elementary electronics laboratory, meeting three hours a week for sixteen weeks. An advanced lecture-demonstration course in industrial electronics is also planned for later in the year. For instructors, the University will draw upon members of its own faculty as well as leading engineers in the electrical industry.

The prerequisites for enrolling for this instruction are employment in a war industry and high school graduation or equivalent education. To facilitate their class attendance, students may apply under OPA regulations for supplementary gasoline allowances.

Detailed information regarding time and place of class openings and course descriptions may be obtained from the following University of California War Training Centers:

201 California Hall, Berkeley 4, Calif. (THornwall 5377)
405 Hilgard Avenue, Los Angeles 24, Calif. (BRadshaw 2-2171)
1302 First Avenue, San Diego 1, Calif. (Main 2037)

### FLIGHT TEST RECORDER

A flight test recorder which records 144 points in testing aircraft in about the same number of seconds, is now being exhibited publicly for the first time at the Franklin Institute in this city.

In addition to the flight test recorder, first public showing is being made of the Disney animated films which depict the basic principles of the famed electronic automatic pilot which is given considerable credit for the safe return of many otherwise disabled war planes, and with the amazing accuracy of American bombing. The flight test recorder, product of the Brown Instrument Co., has been used for flight tests for the past two years. The automatic pilot is produced by Minneapolis-Honeywell Regulator Co. of which the Brown company is the industrial division.

The amplifier is under a glass case, having two thermocouple junctions protruding to permit visitors to grasp first

[*Continued on page 70*]

# "MICROMETER CONSCIOUS"

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We welcome conversations with all companies who intend to be postwar factors in their fields and will be glad to discuss the matter of applying Wadsworth skills to your special needs.

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# NEW PRODUCTS

[*Continued from page 68*]

one, then the other, between two fingers. The amplifier reflects its high sensitivity by setting into immediate motion a fan in either a clock or counter-clockwise direction, according to which junction is grasped.

### USERS' GUIDE FOR SELF-TAPPING SCREWS

Much useful engineering and production data about the application of Self-tapping Screws is given in the new Users' Guide, offered by Parker-Kalon Corp. to design engineers, chief draftsmen and production executives.

The eighteen pages are file size, tab-indexed, spiral bound, and arranged with a strong wall hanger. The guide includes a selector chart which tells at a glance which of nine types of Self-tapping Screws to use in various materials. Clear tables give recommended hole sizes, stock sizes and data on use of each type of P-K Self-tapping Screw under different conditions.

Application information covers use of Self-tapping Screws in sheet metal, steel, castings, plastics, plywood, asbestos and other compositions.

Also shown are special heads and special forms of P-K Self-tapping Screws which can be made for specific needs.

Because of the paper shortage and the costliness of the unit, distribution must be limited to engineering and production executives, who can obtain copies of the Users' Guide from Parker-Kalon Corp., 204 Varick St., New York 14.

Dr. Harold H. Beverage, Associate Director of RCA Laboratories in charge of communications research, receives the U. S. Army Signal Corps Certificate of Appreciation for his contribution in furnishing the Army with the greatest communications system

### ELECTRONICS CONFERENCE

Scheduled to be held at the Medinah Club of Chicago, 505 N. Michigan Ave., Chicago, Illinois, on October 5, 6, and 7, 1944 the National Electronics Conference will offer a symposium of papers covering the communications, industrial, measurements, and medical applications of electronics. Within the limits of national security every attempt is being made to assure that the papers to be presented will reflect recent progress and will be outstanding in their field. Nationally known speakers have been invited to address the Conference at its banquet on October 5, and at luncheons on October 5 and 6.

Described as "a national forum for electronic developments and their engineering applications" by Dr. J. E. Hobson, Head of the Engineering Department of the Illinois Institute of Technology, and Chairman of the National Electronics Conference, Executive Committee, the Conference has as its aim a means of providing free discussions of the application of electronics in various fields of technical endeavor.

The program for the Conference is under the direction of Professor A. B. Bronwell, Technological Institute, Northwestern University, Evanston, Illinois. While the general plan of the program has been reasonably well outlined, those desiring to submit papers are invited to communicate with Prof. Bronwell, Chairman of the Program Committee.

Advance registrations may be made with Professor P. G. Andres, Illinois Institute of Technology, 3300 Federal Street, Chicago, Illinois, Chairman of the Arrangements Committee.

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## TONE ARM DESIGN

[*Continued from page 36*]

out, such pickups have less than three degrees of error on either side of tangency, and are quite acceptable. When designing such an arm, however, certain factors must be given thought. Reference to *Fig. 3 (a)* shows a curved arm with a line of support *A-A* passing through the lateral bearing in the base assembly, and the needle point. Obviously, the greater portion of the tone arm mass lies outside the line of support, and an unbalanced condition exists, wherein the needle point tends to lie at an angle with respect to the groove, instead of in a perpendicular plane. This condition is particularly aggravated if a flexible coupling is used between the tone arm and base assembly.

A somewhat better design appears in *(b)*, known as the off-set type, which has considerably less mass off the line of support. One helpful device is illustrated in *(c)*. The vertical bearing line is so laid out in the tone arm as to be at right angles to the center line of the cartridge. This tends to support the off-center mass of the tone arm to avoid sagging. However, somewhat greater friction results in the vertical bearing, due to the added work being done.

The proper approach is so to proportion the tone arm mass with reference to the support line *A-A*, that equal mass lies on each side. In addition, the bearing system illustrated in *(c)* may be used. See illustration *(d)*.

### Graphical Method

*Fig. 4* illustrates a graphical method developed by the writer to arrive at the proper over-all length of the tone arm, and the included angle of off-set. Any shape or design of arm may be laid out over this backbone, so long as the essential dimensions are not disturbed.

First lay out full size, the inside groove of a twelve-inch record. This averages 11½ inches in diameter; then the inside groove of a ten-inch record, which is about 4 inches. The only factor that must be known beforehand is the distance from the center of the record and the lateral bearing, which is usually the center of the mounting hole. This is an arbitrary distance, depending on the space available, etc. For sake of illustration we are using seven inches. Locate this point with reference to the record center. Then construct a center groove, which lies equidistant between the outer and inner grooves. Lay in line *A-A*, which is a tangent to the center groove. Construct the arc *B-B*, whose radius is the distance from the mounting hole to the record center. Using this same radius, locate the compass needle on tangent line *A-A*, so that the compass point intersects the tangent point *X* on the center groove.

Construct arc *C-C* so that both ends interesect *B-B*. Draw straight line D-D which passes through the arc intersections and line *E-E*. The point *Y* then represents the needle point, and the distance from *Y* to the mounting hole center becomes seven and eleven-sixteenths inches. Eleven-sixteenths inch is the distance the needle point must be beyond the record center when the pickup is mounted to insure proper tracking. Now construct the arc *F-F* whose radius is seven and eleven-sixteenths inches. Draw tangents *G-G*, *H-H*, and *I-I*, using a right triangle between the record center and intersection points of grooves and tangent lines. Then draw lines from the mounting hole center to the same points. The three included angles shown indicates the degree of off-set necessary to have perfect tracking at those respective grooves. An average included angle would be about twenty-seven degrees, which would permit an error on one side of one degree, and the other side one and one-half degrees. This gives a total tracking error of two and one-half degrees.

Such a layout should be done to full scale, and as accurately as possible to avoid error. The full-size backbone drawing illustrated may then be used to design the tone arm in the required shape. Obviously the arm may be curved, off-set or a combination of the two, without disturbing the tracking if the basic dimensions are held.

Pickups that will function at less than one ounce vertical pressure will require careful attention to every detail, and the tone arm is certainly no exception. Give it your best and you will be rewarded with a quiet, smoothly operating reproducer, a pleasure to both the designer and the user.

### FUNGUS-PROOF RESISTORS AND SWITCHES

Matching the growing demand from the armed services for components protected against fungus growth, Shallcross Mfg. Co., Collingdale, Pa., announces that Shallcross Akra-Ohm accurate fixed wire wound resistors, Shallcross switches, etc., are now available treated with anti-fungus materials which meet Signal Corps Specifications #71-2202A. These units are supplied without any manufacturing delay occasioned by the special treatment.

Complete details, as well as copies of the Shallcross resistor and switch catalogs, will gladly be sent on request.

# JUNCTIONS and TERMINATIONS

[*Continued from page 26*]

allows the coaxial line to be tuned to any reactance.

### Analytical Methods

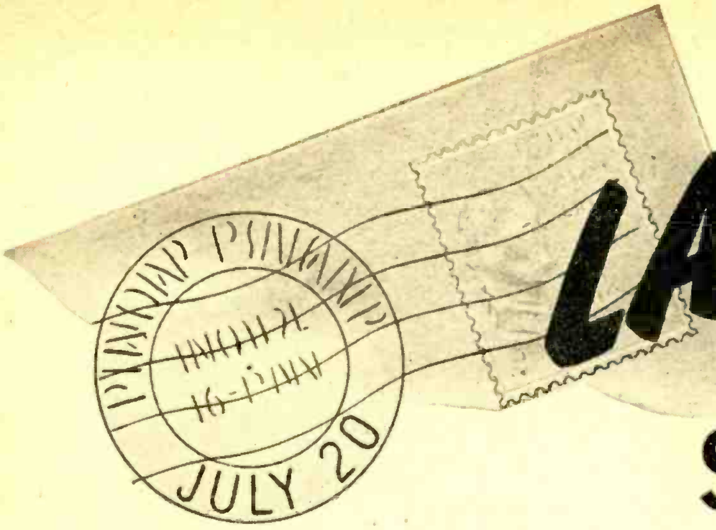
The method of making a theoretical study of this type of coaxial antenna in a wave guide is rather interesting. As has just been said, the reactive component of the coaxial line impedance can be anything that is desired; the resistive impedance depends entirely upon the dimensions of the coaxial line and must be accommodated by adjustment of the wave guide stub. Apparently, then, the job of theoretical analysis is one of finding how fields spread out from a voltage which periodically appears along a wire running across the inside of the guide.

J. C. Slater has solved this problem exactly for a dipole radiator by using a method of images. *Fig. 8* serves to show how he proceeded. The rectangle shown by heavy lines represents a cross section of a rectangular wave guide at the point where an electric dipole has been inserted. The vector shown there is an instantaneous value of an electric field caused by the charge in that dipole. This field varies continually with a frequency equal to that of the energy with which we are concerned and, in conjunction with an accompanying magnetic field, radiates toward both side walls of the guide as well as along the length of the guide. But the energy reaching the side of the guide is reflected. Now, if for a moment we imagine the right-hand side of the guide to be removed and a second dipole to be placed at *B*, first-order reflections are simulated by that image source. Anywhere along the line where the right wall did exist there is now zero energy because the source and image *B* just cause complete interference there; in other words, such a simulated arrangement satisfies the same boundary conditions as does an actual wall.

### Image Sources

Likewise, it at first seems that we could remove the left wall of the wave guide and know all the reflections from it by assuming another image source at *C*. So far as first reflections go, we can, but in removing that second wall we must also make provisions for reflections from the image source installed at *B*. This requires a second image at *D* and so on, so that a whole array of image sources is required to simulate the actual radiation field with

[*Continued on page 76*]

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All 5th War Loan Drive WINDOW DISPLAY CONTEST photographs must be in the mails not later than July 20. Address to: WAR BOND DISPLAY CONTEST, c/o The Display World, 1209 Sycamore Street, Cincinnati, Ohio.

This distinguished jury of five will judge this contest and all decisions will be final: Commander Edward J. Steichen, U.S. Navy, Washington; Walter K. Nield, V.P., Young & Rubicam, N.Y.C.; Lew Hahn, Gen. Mgr., NRDGA, N.Y.C.; Irma Ericsson, Adv. Mgr., Shulton, Inc., N.Y.C., and R. C. Kash, Editor of Display World, Cincinnati.

All contest photographs must be 8x10 and plainly marked *on the face* with the name of the store and city—as plans are now being made to prepare an exhibit of all contest photographs for public view in cities throughout the country. Later, this exhibit will become a part of the U.S. Treasury's archives in the history of the financing of World War II.

Remember! Get your entries in the mails by July 20. Win or lose, you've earned your Country's thanks. You've backed the attack—you've helped to sell more than before!

*This is an official U. S. Treasury advertisement prepared under the auspices of Treasury Department and War Advertising Council. The Treasury Department acknowledges with appreciation the publication of this message by:*

**RADIO**

### WINDOW CONTEST PHOTOGRAPHS

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1st PRIZE . . . . . $500
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4th PRIZE . . . . . $100
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5TH WAR LOAN

## JUNCTIONS and TERMINATIONS

[Continued from page 74]

the walls of the wave guide in place. Because of its regularity this is fairly easy to represent mathematically. The line of sources presents the same problem as does an infinite optical diffraction grating and allows an easy computation of the radiation distribution to be made. Once it is known for an unobstructed wave guide, we can close one end and add the reflected wave from that end to get the actual situation, analogous to the junction of *Fig. 7*.

## RESISTORS

[Continued from page 31]

sired frequency on a sufficient number of samples to obtain average characteristics. The resistor manufacturers today are vigorously attacking the problem, but the results to date indicate but little progress.

### References

1. A circular mil foot is defined as a wire of one foot length and of .001 inch diameter. It is not based on square mils.

To convert from ohms/mil foot to ohms/cm., multiply by 166 × $10^{-9}$.

2. Temperature rise varies with size and manufacturer. Average test data is as follows:

| *Wattage Size* | *Full Load* | *150% Load* |
|---|---|---|
| ¼-Watt (25) | 65° C. | 85° C. |
| ½-Watt (100) | 65° C. | 80° C. |
| 1-Watt (75) | 80° C. | 95° C. |
| 2-Watt (25) | 85° C. | 100° C. |

(Average characteristics, approximate number of samples in parentheses.)

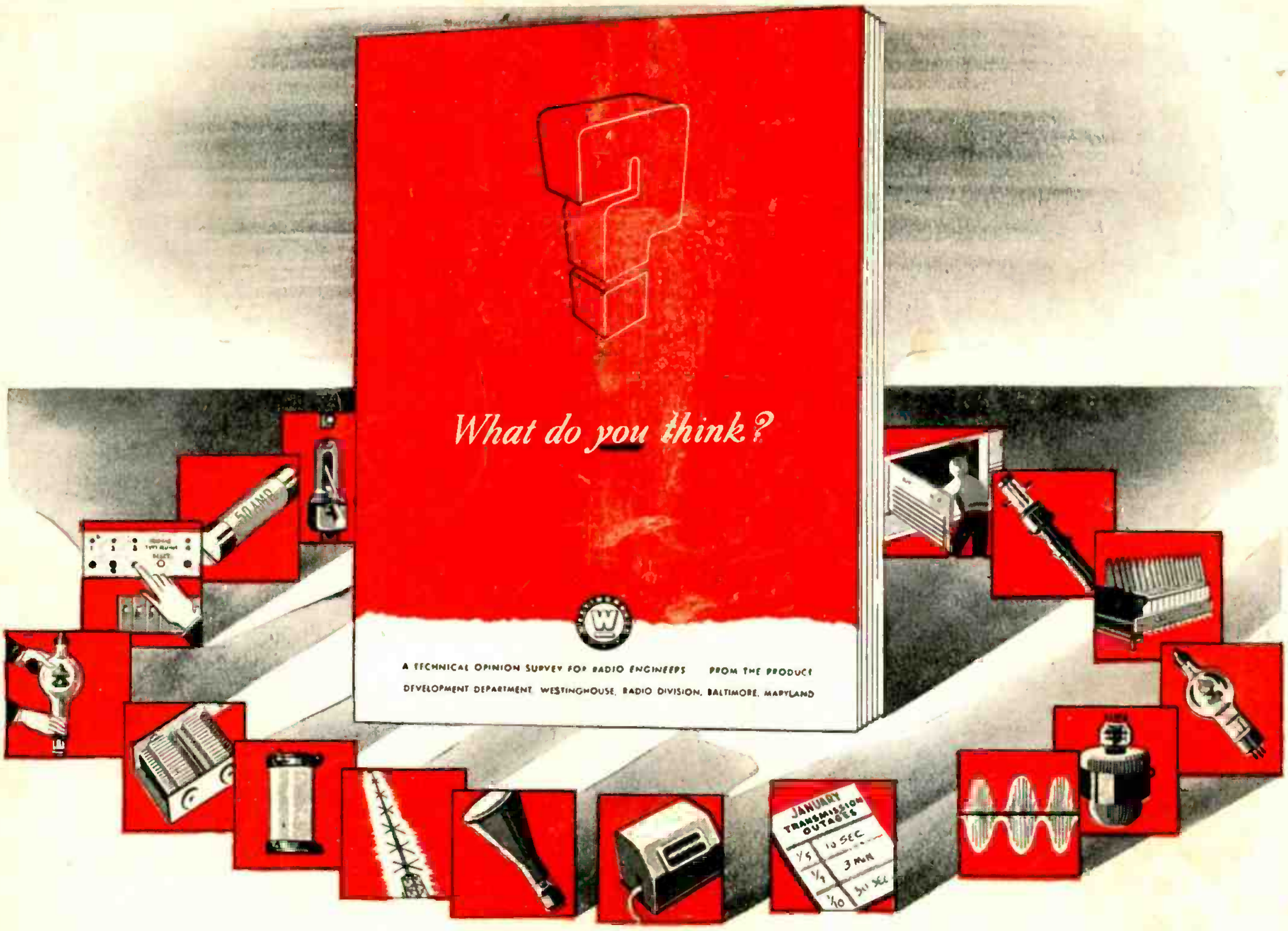
3. "E" and "F" are designations appearing in the American War Standard.

### GERSTENBERGER NOW WESTON VICE-PRESIDENT

*H. Leigh Gerstenberger*, formerly general sales manager of the Weston Electrical Instrument Corporation, Newark, N. J., recently has been made Vice President in charge of sales of that company, succeeding Mr. Caxton Brown who now is President. Mr. Gerstenberger has been associated with the Weston organization since 1917, shortly after his graduation from Stevens Institute of Technology. He served in both export and sales departments prior to his appointment as general sales manager in 1932. He is a member of the National Electrical Manufacturers' Association.

**UNIT CONVERSION TABLE ISSUE**
**A limited number of copies of May "RADIO" are still available at $1 each.**

## ADVERTISING INDEX




## CALLING ALL RADIO ENGINEERS!

In the interest of better broadcasting . . . and as a check on the features we are incorporating in our new transmitter designs . . . Westinghouse would like to know what radio engineers think about transmission equipment, feature by feature.

There's more than one way to "skin a cat", but there's one *best* way. You men who are responsible for operating the equipment are interested, we believe, in these factors:

**HIGH FIDELITY SIGNALS . . . CONTINUITY OF SERVICE**
**SIMPLICITY OF CONTROL . . . LOW OPERATING COST**
**EASE OF MAINTENANCE**

We will appreciate knowing what you consider the best way to incorporate these advantages in postwar transmitters. To facilitate this, the questionnaire booklet pictured above will be distributed to all stations in the near future. If you do not receive your copy . . . write Westinghouse Electric & Manufacturing Company, Dept. 7-N, East Pittsburgh, Pennsylvania.

J-08075

**Westinghouse** RADIO DIVISION
PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

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