RADIO NEWS

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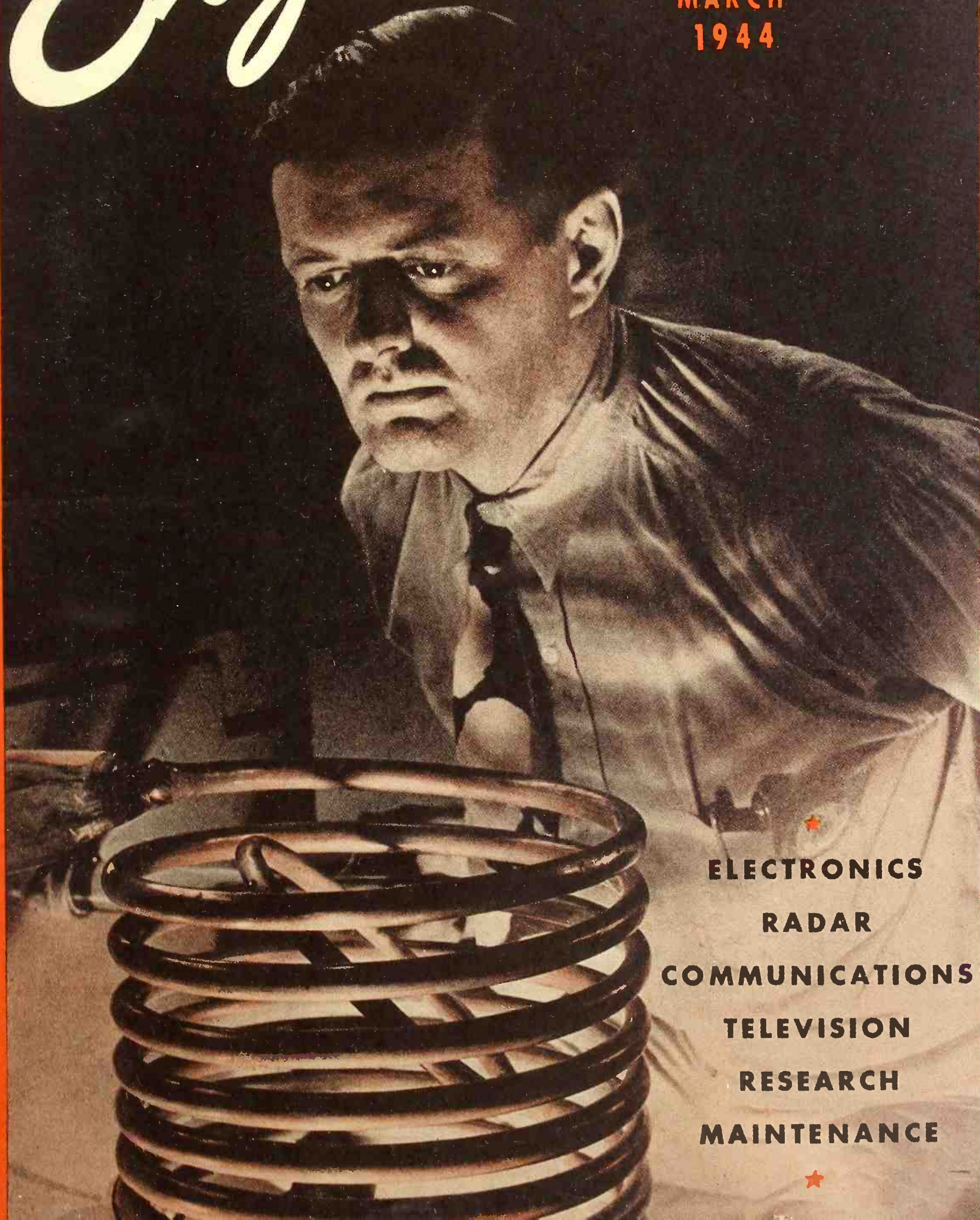
DEPARTMENT

MARCH 1944



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MARCH, 1944

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VOLUME 2 NUMBER 3

COVER PHOTO—BY HANS GROENHOFF

Operator "tunes" the large induction heating coil used in setting glues. Laminations for Fairchild Engine and Airplane Company's wooden aircraft, as described in this issue, are treated by this method of heat processing.

A typical standard-broadcast antenna of the type discussed in this article.

ANTENNA PERFORMANCE

By JOHN BARRON
Consulting Engineer
Washington, D. C.

An outline of the procedure for designing antennas to meet FCC requirements.

A SYSTEMATIC method of selecting coupling networks and testing antenna performance is extremely valuable in satisfying the strict requirements of the Federal Communications Commission. This article includes a detailed explanation of such a method of testing the performance of directional antennas for a 5 kw. station. Theoretical and practical data are given so that the installation considered is indicative of the requirements to be met and may therefore be used for such purposes.

This station under consideration first obtained a construction permit from the Federal Communications Commission to erect a new 5 kw. station operating on 1280 kc. The present station operated with 1000 watts power with a non-directional antenna. Inasmuch as the present station already operated on 1280 kc. all of the preliminary measurements, tuning and adjustments, had to be made during the period when the present station was not in operation, which was approximately from midnight to 6 a.m. However, under the terms of the construction permit, no power must be radiated from the antennas of a new station except during the equipment test period, which is from 1:00 a.m. to 6:00 a.m. local standard time, until special permission is obtained from the Federal Communications Commission upon completion of the initial adjustments.

The horizontal plane radiation pattern

determined for this station, together with the antenna arrangement is shown in Fig. 3. This pattern was decided upon as desirable for the double purpose of avoiding interference with co-channel stations and at the same time beaming a maximum signal having the effective power of 20 kilowatts toward the desired service area.

Of the various measurements necessary, the transmission line and antenna impedance measurements are fundamental.

First consider the properties of the transmission line and then those of the antenna array. The input impedance of the transmission line which has negligible losses is:

$$Z_i = \frac{Z_r \cos\beta + j\,Z_o \sin\beta}{Z_o \cos\beta + j\,Z_r \sin\beta} \qquad (1)$$

Where:

Z_r = Load impedance
Z_o = characteristic impedance
β = electrical-angular length of transmission line.

To measure the characteristic impedance, Z_o, of the transmission line simply measure the input impedance when the receiving end is open-circuited and short circuited. Let the values of these impedances be represented by Z_{oc} and Z_{sc} respectively. Then the characteristic impedance is given by:

$$Z_o = \sqrt{Z_{oc} \cdot Z_{sc}} \qquad (2)$$

It is this impedance, which of course is entirely resistive, that must be properly matched to the antenna. In this particular application each antenna is one of an array of three. Therefore, the effect of any two antennas upon the third must be considered in the most direct and practical manner.

When an antenna is driven so that it has current flowing in it, an induced voltage will exist in any other antenna in the vicinity. This effect resembles two circuits coupled together and the action may be best explained in terms of mutual impedance Z_{12}, which is defined by the relation:

$$Z_{12} = -\frac{E_2}{I_1} \qquad (3)$$

Where:

I_1 = current in first antenna
E_2 = voltage induced in second antenna

In defining mutual impedance, it is necessary to use a definite reference point in each antenna. This may be further clarified by realizing that mutual impedance represents the coupling effect between the antennas expressed in terms of the current at a definite point in the first antenna and the voltage at a corresponding point in the second antenna. If these points are not specified, it is assumed that they are at the current antinode. It is possible to calculate the mutual impedance between two antennas but in practice there are too many external influences which cannot be computed accurately. In this discussion, the value of Z_{12} shall be taken equal to Z_{21}, where the latter is the mutual impedance obtained by driving antenna number two and inducing a voltage in antenna number one.

With a three antenna array, the system equations become:

$$\begin{aligned} E_1 &= I_1 Z_{11} + I_2 Z_{21} + I_3 Z_{31} \\ E_2 &= I_1 Z_{12} + I_2 Z_{22} + I_3 Z_{32} \qquad (4) \\ E_3 &= I_1 Z_{13} + I_2 Z_{23} + I_3 Z_{33} \end{aligned}$$

Where:

E_1, E_2, E_3 = voltages applied to antennas
I_1, I_2, I_3 = currents flowing in antennas
Z_{11}, Z_{22}, Z_{33} = self impedances of antennas
Z_{12}, Z_{13}, Z_{23} = mutual impedances between antennas

When applying equation (4), it is important to note that if some of the antennas are not being driven, then the corresponding applied voltages are zero, and if some of the antennas are open-circuited so that they carry no current, then the currents in these antennas are assigned the value of zero.

The driving point impedance, which must be matched to the transmission line, for the first antenna is:

$$Z_{D1} = \frac{E_1}{I_1} = Z_{11} + \frac{I_2 Z_{21}}{I_1} + \frac{I_3 Z_{31}}{I_1} \qquad (5)$$

$$Z_{D1} = R_1 + j\,X_{a1} \qquad (6)$$

and for the second antenna:

$$Z_{D2} = \frac{E_2}{I_2} = \frac{I_1 Z_{12}}{I_2} + Z_{22} + \frac{I_3}{I_2} Z_{32} \qquad (7)$$

$$Z_{D2} = R_2 + j\,X_{a2} \qquad (8)$$

and for the third antenna:

$$Z_{D3} = \frac{E_3}{I_3} = \frac{I_1 Z_{13}}{I_3} + \frac{I_2}{I_3} Z_{23} + Z_{33} \qquad (9)$$

$$Z_{D3} = R_3 + j\,X_{a3} \qquad (10)$$

In order to match an antenna to a transmission line using a reactive four-terminal network, consider the transmission line impedance as Z_o and the resistive component of the antenna impedance as R. The position of the reactances in the four-terminal network are shown in Fig. 2 and their values are computed by applying the formulas:

$$X_1 = -\frac{Z_o \cos\beta - \sqrt{Z_o R}}{\sin\beta} \qquad (11)$$

$$X_2 = -\frac{R \cos\beta - \sqrt{Z_o R}}{\sin\beta} \qquad (12)$$

$$X_3 = -\frac{\sqrt{Z_o R}}{\sin\beta} \qquad (13)$$

where β is the phase-angle shift in the four-terminal network.

When nondirectional tests are being made on the antenna system, phase relationships are not important and a reactive "L" network may be used. The phase shift introduced by an "L" section is determined by the ratio of R to Z_o as shown in the following formulas. The design formulas for the "L" section are obtained from equations (11), (12), and (13) by assigning X_1 equal to zero. The new formulas become:

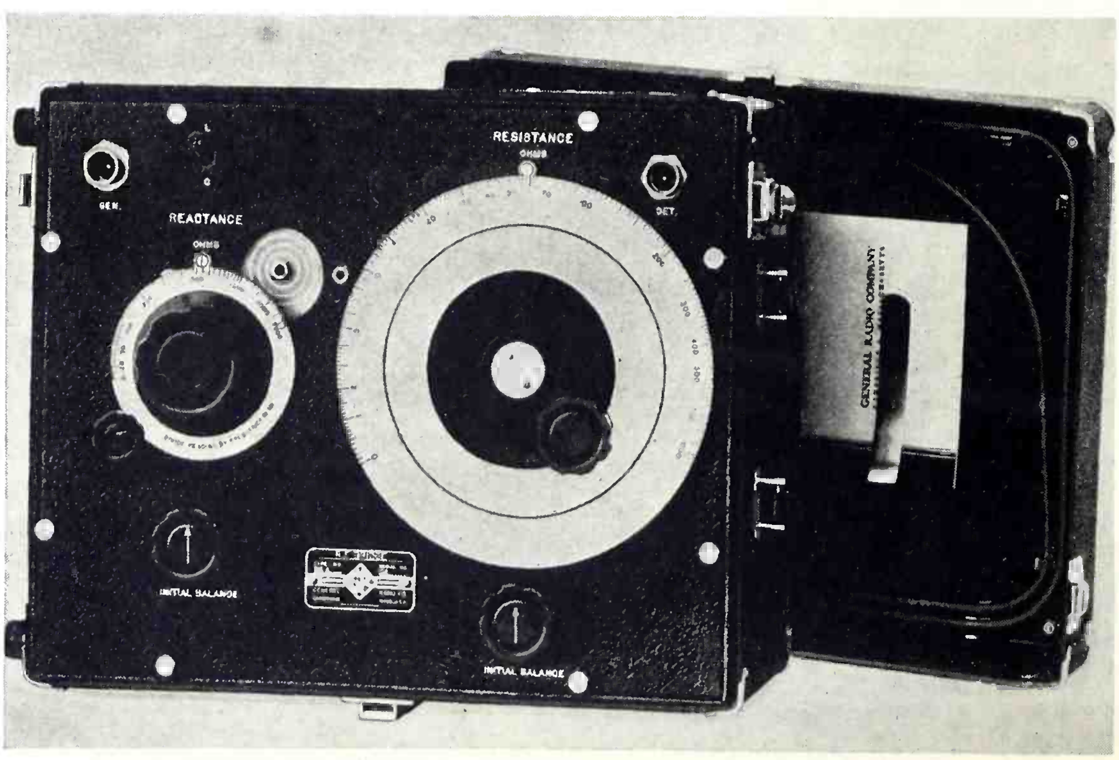
$$\cos\beta = +\sqrt{\frac{R}{Z_o}} \qquad (14)$$

$$X_2 = +\sqrt{Z_o R - R^2} \qquad (15)$$

$$X_3 = -\frac{Z_o R}{\sqrt{Z_o R - R^2}} \qquad (16)$$

With the aid of the foregoing formulas and discussion of basic fundamentals the test procedure and calculations follow in very logical sequence.

Fig. 1. An r-f bridge used for measuring antenna and transmission line impedances. Both resistive and reactive components are evaluated at the operating and adjacent band frequencies.



As a preliminary test, antenna and transmission line impedances should be made at 1280 kc. Measurements need not be made over a band of frequencies as the station is not intended to operate non-directionally except for test purposes. The impedance measurements made on each individual antenna should be repeated to ascertain whether the resistance and reactance changes appreciably when the lighting circuits are connected and disconnected. If a change of the order of 10 percent occurs, the cause must be removed. During the preliminary measurements, each antenna is allowed to "float" free (ungrounded). While the r-f bridge is connected to each antenna, determine the amount of reactance necessary to resonate the antennas at ¼ wavelength. The required reactance will probably be capacitive as it is expected that the antennas will have about 60 ohms. inductive reactance at 1280 kc.

Now check the impedances of all transmission lines, including the phase monitor sampling lines. The transmission line impedance is determined with the aid of the r-f bridge for open-circuit and short-circuit conditions. In accordance with equation (2) the characteristic impedance is

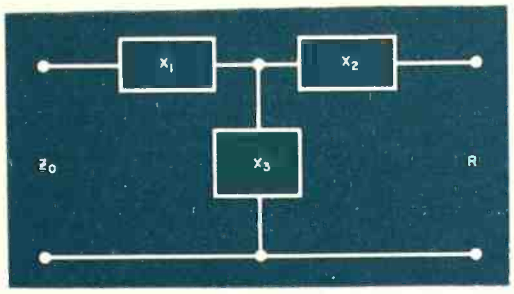


Fig. 2. Basic "T" impedance matching network.

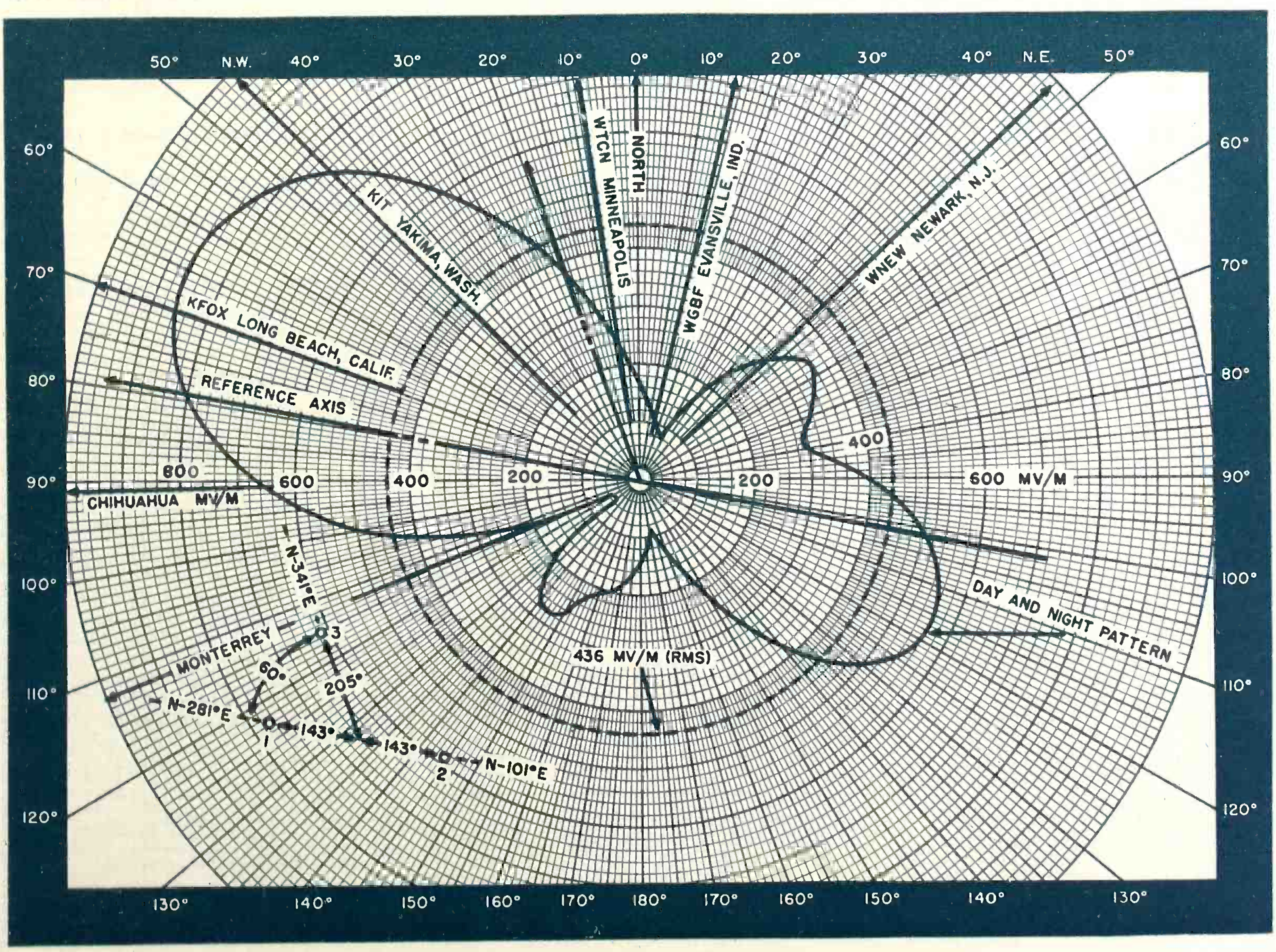
given by the square root of the product of these two figures. If any line should be approximately ¼ wavelength long at 1280 kc. or a multiple thereof, an erroneous result will be obtained or it will be impossible to balance the bridge. In such cases, the frequency should be changed by about fifty percent and a new set of readings taken. It is well to verify all transmission line impedance measurements by determining experimentally the resistance with which it is necessary to terminate the line so that the bridge reads a pure resistance with zero reactance when connected to the input of the line.

Next connect the input of the phase monitor to the bridge and check the input impedance which should be a pure resistance usually about 78 ohms. Also check the reading of the phase monitor by connecting any condenser of known value in series with the input to the monitor. The monitor will then read the phase shift which is the angle whose tangent is X/R, where R is the input resistance of the phase monitor and X the reactance of the condenser. For example, a 0.002 mfd. condenser will together with a 78 ohm resistance shift the phase 38.6 degrees and a 0.001 mfd. condenser will shift the phase 69 degrees at 1280 kc.

It is important to note that the bridge readings taken on the phase monitor sampling lines should be the same for each line, if they are of equal length as they should be. If these readings are not nearly the same, then the phase monitor will give erroneous phase readings.

In order to determine the driving point impedance of each antenna of the array, it is first necessary to measure the mutual impedance between two antennas while the third is not connected to ground. Apply a convenient value of power to antenna No. 1 with antenna No. 2 connected to ground through a resonating circuit. The currents in both driven and ex-

Fig. 3. Desired radiation pattern of three antenna array analyzed in this article. Relative position of radials and antenna array also shown.



cited antennas should be recorded and designated as I_1 and I_2.

Since antenna No. 2 has been tuned to resonance the impedance has been reduced to a pure resistance designated by R_{a2}. Then by definition the mutual impedance is given by:

$$Z_{12} = R_{a2}\frac{I_2}{I_1} \quad \ldots\ldots (17)$$

The amount of power supplied is not important in this test as the ratio of the currents is only necessary in addition to the value of R_{a2}.

A similar set of measurements should be made using antenna No. 3 as the coupled antenna instead of No. 2. This measurement will give the value of Z_{13} and another test should be made to detrmine the value of Z_{23}. The results selected for this example are:

$I_1 = 1.25$ amperes at $+ 30.5°$
$I_2 = 0.75$ amperes at $- 30.5°$
$I_3 = 1.6$ amperes at $+ 28°$

or by shifting the phase angles so they all appear as positive angles.

$I_1 = 1.67$ amperes at 61°
$I_2 = 1.0$ amperes at 0°
$I_3 = 1.6$ amperes at 58.5°

Realizing that the spacing between the three antennas is 182° from No. 1 to No. 3, 303° from No. 2 to No. 3 and 286° from No. 1 to No. 2, estimated values of the mutual impedance may be made by referring to the curves of G. H. Brown, page 86 of The Proceedings of The Institute of Radio Engineers, for January, 1937, shown in Figs. 5 and 6. These estimations are:

$Z_{13} = 22$ ohms at $- 118$ degrees
$Z_{12} = 15.4$ ohms at $+ 143$ degrees
$Z_{23} = 14.8$ ohms at $+ 129$ degrees

Where the self resistance, R_a of the antenna differs from the theoretical resistance, the estimated value may be obtained by the method of percentages, in the above array of mutual resistance term for Z_{13} is 44.2 percent of the self resistance; Z_{12} is 30.8 percent of the self resistance; and Z_{23} is 29.6 percent of the self resistance. Reactance values will also be computed using these same percentages, using either the theoretical or measured values as may be necessary. The self impedance of each antenna is assumed to be $50 + j60$ ohms.

With the aid of equations (5), (7) and (9) the driving point resistances are:

$$R_1 = 50 + \frac{15.4}{1.67}\cos(-61 + 143) + \frac{2.13 \cdot 22}{1.67}\cos(-2.5 - 118)$$

$R_1 = 37.02$ ohms

$$R_2 = 50 + 1.67 \cdot 15.4 \cos(61 + 143) + 2.13 \cdot 14.8 \cos(58.5 + 129)$$

$R_2 = - 4.7$ ohms

$$R_3 = 50 + \frac{1.67 \cdot 22}{2.13}\cos(2.5 - 118) + \frac{14.8}{2.13}\cos(-58.5 + 129)$$

$R_3 = 44.9$ ohms

The value of negative resistances for R_2 means that this antenna will be self-excited. Using the same set of equations, the operating reactances are:

$X_{a1} = 60 + 9.22 \sin 82 + 28.1 \sin(-120.5) = 44.9$ ohms
$X_{a2} = 60 + 25.7 \sin 204 + 31.5 \sin 187.5 = 45.4$ ohms
$X_{a3} = 60 + 17.23 \sin(-115.5) + 6.95 \sin 70.5 = 51.0$ ohms

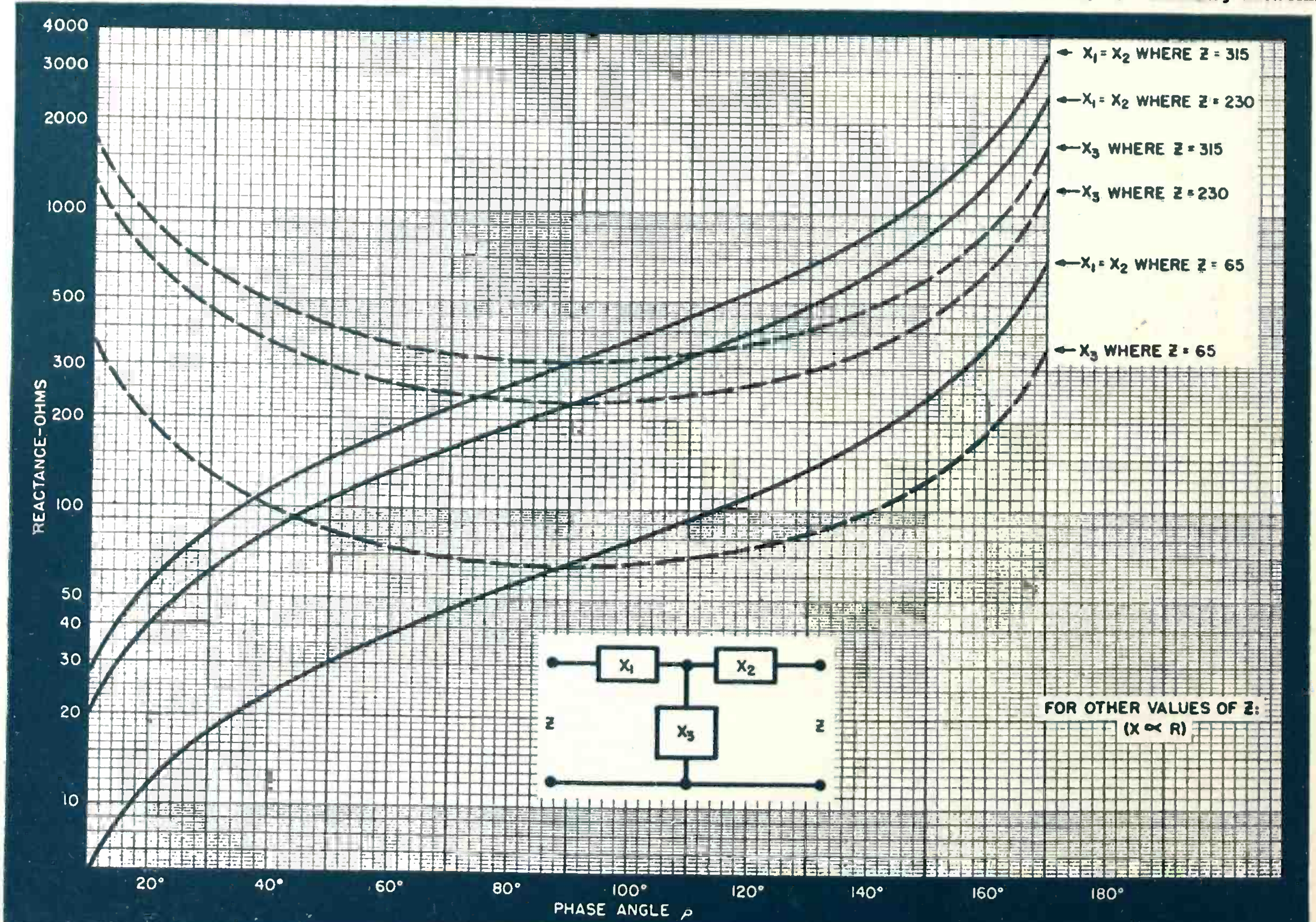
The power distribution will be as follows:

No. 1 antenna power $= (6.77)^2 \cdot 37.02 = 1698$ watts
No. 2 antenna power $= (4.07)^2 \cdot (-4.7) = -78$ watts
No. 3 antenna power $= (8.68)^2 \cdot 44.9 = 3380$

The total power amounts to 5000 watts with a negative power in the No. 2 antenna. Since the No. 2 antenna is nearly self-tuned, no transmission line is absolutely necessary but it is required by the FCC as tuning of the antenna will be aided with the connection.

Run the non-directional radials as shown in Fig. 3 using 5 kw. power in No. 3 antenna during the daytime. (If it is more convenient to use No. 1 or No. 2 antenna, it is satisfactory to use

Fig. 4. Curves for graphically evaluating input and output series reactances as well as shunt reactance of the "T" matching network.



one of them. Begin measurements at 1.5 miles because of the wide spacing between towers). These measurements will enable the engineer to determine the exact field at any given point for any required value of unattenuated field intensity at one mile.

Ten measurements of 0.1 mile each should be made, beginning at 1.5 miles, then every 0.5 mile out to 6.5 miles; then for every two miles out to 15 or 20 miles. There should be at least 20 measurements on each radial. In case it is not possible to obtain accurate measurements at close distances, more measurements should be made at the greater distance. However, it is extremely important to obtain numerous readings between 1.5 and 2.5 miles, if at all possible, as these mean considerably more in the way of interpreting data than the more remote measurements, and these are more obscured by the conductivity effects.

All test points should be located on a map such as a U. S. topographic map or an accurate county map. For non-directional operation, the distance should be measured to the antenna being used and for directional operation the distances should be measured to the center of the array.

To illustrate the measurements graphically, plot the field intensity in microvolts per meter along the ordinate and distance in miles along the absicissa of log-log coordinate paper and determine the unattenuated field at one mile by matching the points with the FCC curves which fit the best. The conductivity curves for 1280 kc. are shown in Fig. 7. The unattenuated field at one mile for 5 kw. non-directional operation would be about 437 mv/m or 195 mv/m per kilowatt.

All field intensity measurements must be logged and identified on a map with a number in order to satisfy the requirements of the FCC.

The "L" type matching network required to feed the antenna for non-directional operation is computed on a basis of matching 300 ohms to 50 + j60 ohms. This is accomplished by using equations (15) and (16) for evaluating the series and shunt arm of the network. The series arm is given by:

$$X_2 = \sqrt{300 \cdot 50 - (50)^2} = 112 \text{ ohms}$$
(inductive)

Since the antenna supplies 60 ohms of inductive reactance, the series arm must have a reactance of 52 ohms.

The calculation for the shunt arm of the network is:

$$X_3 = \frac{300 \cdot 50}{112} = 134 \text{ ohms (capacitive)}$$

This may be obtained by using a 0.001 mfd. condenser since the capacity necessary at 1280 kc. is by calculation equal to 0.000928 mfd.

In order to obtain the desired radia-

TABLE I

FIELD INTENSITY RADIALS REQUIRED

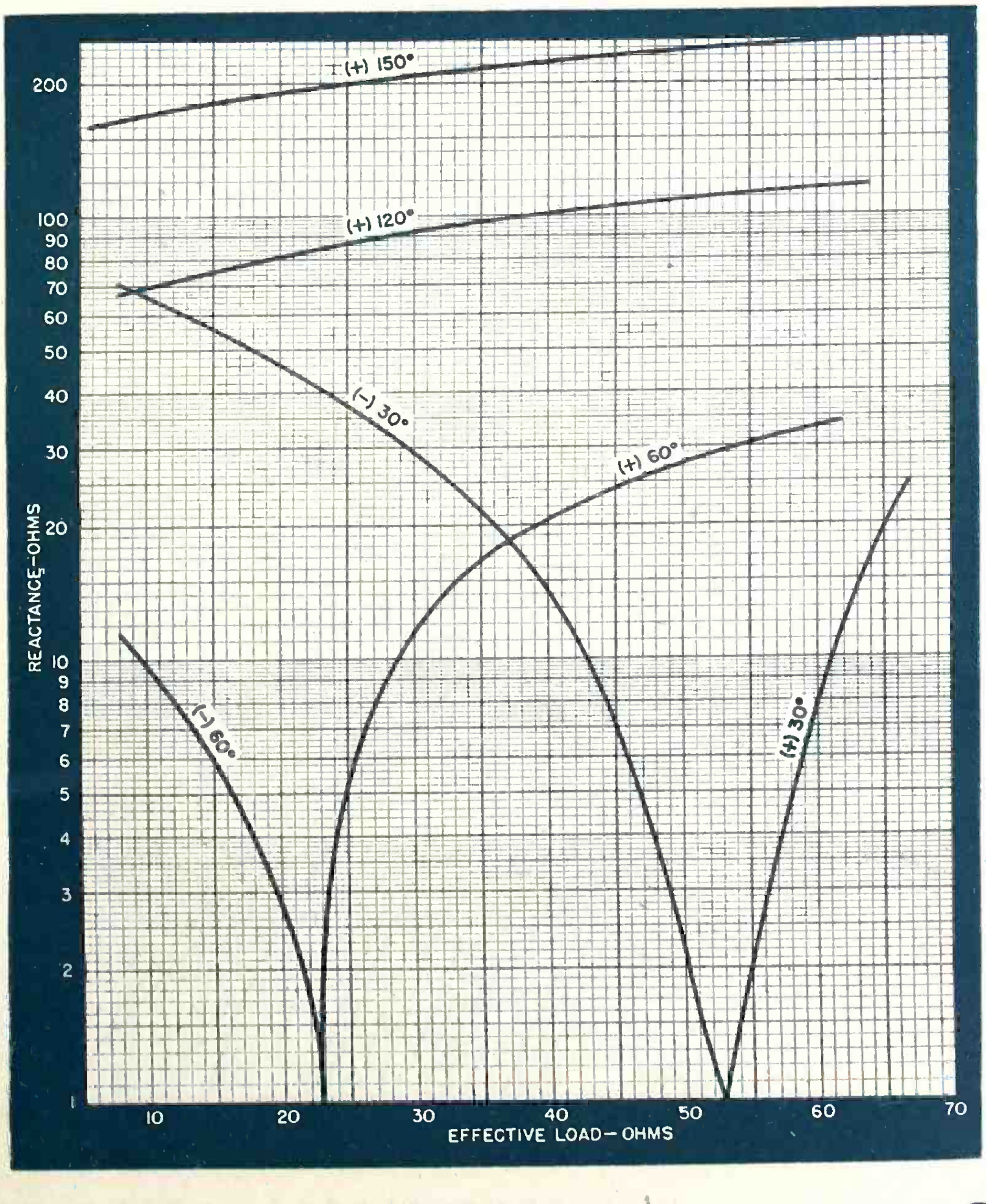
NON-DIRECTIONAL OPERATION WITH 5KW IN NO. 3 ANTENNA

Radial	Az	Towards
A	14	Evansville, Ind.
C	46	New York, N. Y.
I	248	Monterrey, Mexico
J	269	Chihuahua, Mexico
M	351.5	Minneapolis, Minn.

DIRECTIONAL OPERATION 5KW (5.4 KW COMMON INPUT)

Radial	Az	Towards	Unattenuated Field	Monitor Spot
A	14	Evansville, Ind.	118	X
B	23	Minimum	90 or more	
C	46	New York, N. Y.	305	X
D	58	Northeast Lobe	350 or more	
E	115	Southeast Lobe	560 or more	
F	168	Minimum	80 or more	
G	215	Southwest Lobe	270 or more	
H	241	Minimum	50 or more	
I	248	Monterrey, Mexico	180	X
J	269	Chihuahua, Mexico	650	X
K	294	Maximum	870 or more	
L	338	RMS	436 or more	
M	351.5	Minneapolis, Minn.	230	X

Fig. 5. Graphical data for determining the input arm of a "T" matching network for loads connected to a 70 ohm line. The algebraic signs refer to the reactance for a lagging phase shift and the opposite signs would be for a leading phase shift.



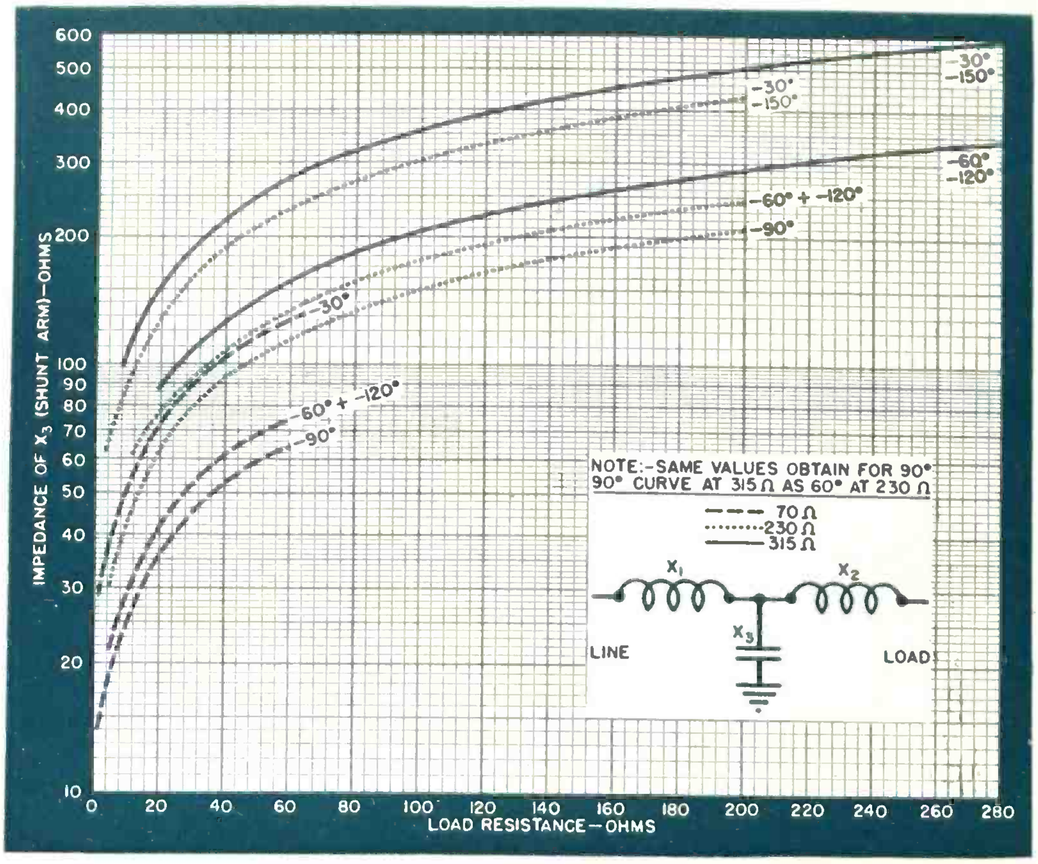


Fig. 6. Curves for determining shunt arm reactance of "T" impedance matching networks for various load resistances to 280 ohms and for phase shifts as indicated. The transmission line characteristic impedance is selected as 70; 230; and 315 ohms.

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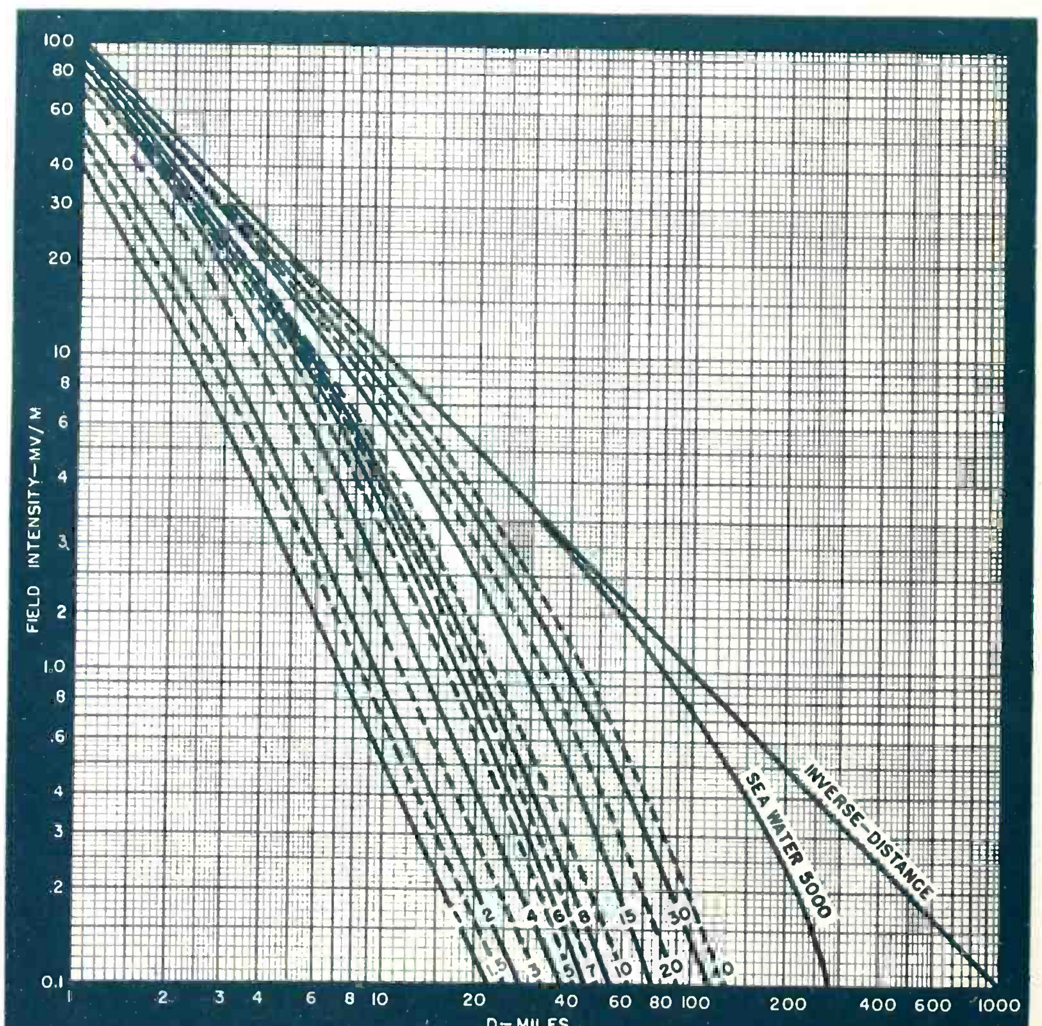
Fig. 7. Functional relation between field intensity in millivolts per meter and distance from antenna in miles. The curves are drawn with conductivity in cgs units as the parameter, with perfect conductivity for the line labeled "inverse-distance."



tion pattern, networks introducing a lagging phase shift of 80° were decided upon for the antennas. These coupling networks may be designed with the aid of equations (11), (12) and (13).

The networks for No. 1 antenna must match 300 ohms to 37.02 + j44.9 ohms. The shunt arm is given by:

$$X_3 = \frac{\sqrt{300 \cdot 37.02}}{\sin 80} = 107.2 \text{ ohms}$$

This amounts to a capacity of 0,00116 mfd. at 1280 kc. or a 0.001 mfd. condenser may be installed in the actual circuit. The input arm is computed by equation (11) and is:

$$X_1 = -\frac{300 \cos 80 - \sqrt{300 \cdot 37.02}}{\sin 80} = 54.3 \text{ ohms}$$

and is a fairly small coil. The output arm is computed by equation (12) and is:

$$X_2 = -\frac{37.02 \cos 80 - \sqrt{300 \cdot 37.02}}{\sin 80} = 100.6 \text{ ohms}$$

This antenna, however, will present a plus reactance of 44.9 ohms and a blocking condenser of 0.01 mfd. in series with the output arm will introduce a capacitive reactance of 12.4 ohms so that the coil necessary in the output will have a value of 100.6-44.9 + 12.4 or 68.1 ohms. This is a small coil.

The coupling network for antenna No. 2 must match 300 ohms to 4.7 + j 45.4 ohms. Then by applying equation (13) for the shunt arms, the value of X_3 becomes:

$$X_3 = -\frac{\sqrt{300 \cdot 4.7}}{\sin 80} = -38.1 \text{ ohms}$$

A capacity of 0.00327 mfd. will yield a reactance of 38.1 ohms at 1280 kc., but a 0.003 mfd. condenser will satisfy the requirements of a practical circuit.

For the same circuit the input arm must have a reactance as specified by equation (11) or:

$$X_1 = -\frac{300 \cos 80 \sqrt{300 \cdot 4.7}}{\sin 80} = -14.87 \text{ ohms}$$

A capacity of 0.01196 mfd. will give the required reactance, but a condenser of 0.01 mfd. used as a "blocking" condenser will be satisfactory and if no condenser is available, an "L" network may be used by eliminating the input arm. The phase shift will then be 84 degrees instead of 80 degrees which is within a reasonable tolerance.

The output arm of the "T" network is given by equation (12) and is:

$$X_2 = -\frac{4.7 \cos 80 - \sqrt{300 \cdot 4.7}}{\sin 80} = 37.3 \text{ ohms}$$

There is, however, an inductive reactance due to the antenna equal to 45.4 ohms. As a result, a condenser must be used in order to supply a capacitive reactance of 8.1 ohms. As such a large condenser would be required in order to produce the small reactance of 8.1 ohms, this arm may be eliminated also

(*Continued on page 28*)

Electrophysics of Hearing

By JOHN D. GOODELL

An analysis of human hearing which will aid the electro-acoustic engineer in designing effective audio equipment.

IN THE design of radio, recording, amplifying and associated equipment, an understanding of the limiting characteristics of human hearing is important to every engineer. No filter networks can be applied to the auditory nerve, and the presence of harmonic distortion is an uncontrolable factor, but the ear is the final link in every chain of devices dealing with audible sound.

This article deals with the functional operations of the auditory mechanism in terms of electrophysiology and associated phenomena of interest to electronic engineers.

A microphone may be defined as a device for transforming physical sound energy into electrical currents with patterns of amplitude and alternation in direct ratio to the mechanical vibrations. In accordance with this definition, the human ear is a microphone. An interesting demonstration may be obtained by attaching one electrode to the round window in the middle ear of a guinea pig and another to the back of the animal's neck. If connections are made to the input of an amplifying system, words spoken into the guinea pig's ear will be reproduced by the loudspeaker. Considering the complex chemical and electrical variables under which they are manufactured, the characteristics of these living devices are remarkably consistent. The human ear is an amazing example of mechanical engineering, and in addition to functioning as a microphone it performs the mechanical counterpart of Fourier transforms, analyzing complex waves in terms of sine wave components.

In order to refresh the memory of those who have not recently reviewed the nomenclatures applied to various components of the auditory mechanism, a semi-schematic drawing is provided in Fig. 1. The eardrum is cone shaped with the apex toward the middle ear. It is placed about two and a half centimeters in from the exterior opening of the auditory canal. The middle ear is a cavity approximately two cubic centimeters in volume which contains the ossicular chain. There are three sealed openings to the middle ear: (1) the eardrum covers the auditory canal; (2) the oval window leading to the inner ear is covered by the footplate of the stapes and supporting ligaments; and (3) the round window leading to the inner ear is sealed by a membrane. A fourth opening leads to the Eustachian tube which is normally closed at its lower end, opening during the act of yawning or swallowing to permit equalization of air pressures on the eardrum. The ossicles are mounted in close contact and held in place by ligaments and two muscles. Under normal stress they vibrate as a closed continuum. The muscles contract under the impact of loud sounds so as to increase the impedence of the structure, forcing the eardrum somewhat inwards under tension. This serves as a protective mechanism and also changes the frequency characteristics of the ear, discriminating against low frequencies and slightly increasing the sensitivity to higher frequencies. The stapes does not move like a piston but rocks on its base unless the stimulus is excessive, at which time it oscillates on a central axis.

The electrical effects are produced in the inner ear, to which sound energy may be transmitted in three ways: (1) from the eardrum through the ossicles to the oval window; (2) air-borne from the eardrum to the round window; and (3) by bone conduction through the skull.

It is apparent that the eardrum and ossicles may be completely inactivated without eliminating the ability to hear. Clinical data show that a considerable hole in the eardrum may not measurably affect hearing. This is comparable to a hole in the cone of a loudspeaker which often has no observable effect on performance. Some persons retain hearing within 20 db. of normal even after destruction of the eardrum, malleus and incus, but the usual result is a 50 to 60 db. reduction in efficiency.

There is one more method of conveying sound to the brain. The effects produced in most microphones are reversible, and this is equally true of the human ear. If an alternating current is applied to the head, the ear converts it into mechanical vibrations and a corresponding pitch is heard. This phenomenon is referred to as the electrophonic effect and results from actions which may be comparable to piezo-electric effects in crystals. It is important to point out that direct stimulation of the auditory nerve is not involved, in which case the mechanical pitch selectivity of the organ of Corti would be circumvented and only a sensation of noise would result. There is always a considerable percentage of distortion in electrophonic hearing, and while speech is recognizable as such, intelligibility is low and music reproduction of poor quality. It is generally believed that this distortion arises largely from partial rectification of the applied current. In support of this theory, it has been shown that a radio frequency current of high intensity modulated by an audio wave is sufficiently demodulated when applied to the head to permit the perception of the modulation frequency.

The sensitivity of the ear to minimum sound pressures is remarkable. At 3000 cps. a displacement of the eardrum, amounting to approximately one-thousandth of the wave length of visible light, will produce perceptible currents in the auditory nerve; movement of the basilar membrane may be as slight as 10^{-10} cm., which is comparable to one-hundredth of the diameter of a hydrogen molecule.

There is a generally accepted myth that some animals have more sensitive hearing than humans. This may be true for certain very high frequencies, but in the range up to 7000 cps. such sensitivity would appear worthless. In normal humans the minimum audible sound pressure is around 75 db. below one dyne per sq. cm., and in exceptional cases 85 db. The random thermal agitation of molecules in the air produces pressure variations which have been calculated in the frequency range from 1000 to 6000 cps. at the rms. value of 86 db. below one dyne per sq. cm. Considering this noise as

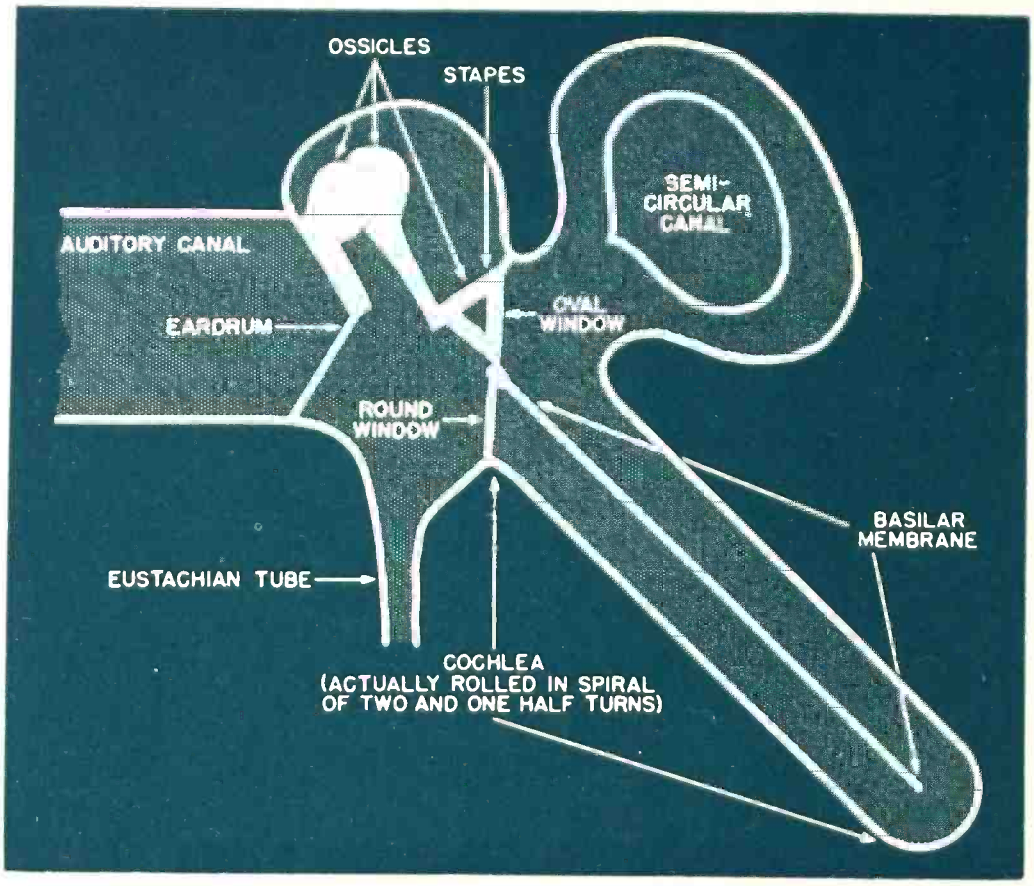


Fig. 1. A semi-schematic diagram of the inner ear showing the various component parts.

normally present, it is evident that nature has properly limited auditory acuity in terms of the characteristic signal to noise ratio of the transmitting medium.

The threshold of feeling is about 60 db. above one dyne per sq. cm. and represents the upper auditory limit. This corresponds to 120 db. in terms of loudness level measurements and is usually compared to intense thunder. The reference value for decibel loudness scales is 10^{-16} watts per sq. cm., which for sound waves in air equals the rms. pressure of 0.0002 dynes per sq. cm., and a particle velocity of 0.000005 cm. per second.

A diagram of the portion of the inner ear directly concerned with hearing is represented in Fig. 2. The semicircular canals are not indicated and the cochlea is shown unrolled. This entire structure is filled with incompressible fluids called "perilymph" in the outer, bony canal, and "endolymph" in the inner, membranous canal. It appears certain that the inner ear is an almost critically damped system. When an impulse is transmitted to the stapes through the ossicular chain, the rocking motion of this bone displaces the fluid in the cochlear canals. The energy is generated as a traveling wave which is impressed on the basilar membrane and eventually equalized by motion of the membrane covering the round window. The hydromechanical action must be considered in terms of fluid in a semi-elastic canal, and solution of the problem is not only mathematically complex but requires constants that have not yet been determined.

The fibres of the basilar membrane are believed to be under some tension; its width is least at the point of origin and becomes progessively greater toward the apex of the cochlea. At any rate, the structural dynamics of the inner ear function to produce mechanical tuning of the mode of vibration set up on the basilar membrane, and resonance for high and low frequencies is located as indicated in Fig. 2. Stresses appearing lengthwise along the basilar membrane inevitably establish a correlated gradient across its width.

The hair cells which are finally activated by this motion appear in groups of three or four on the outside of the triangular tunnel along the basilar membrane, and a single row is placed between the tunnel and the wall of the cochlea. These hair cells are the final discriminators that activate the auditory nerve fibres which conduct the intelligence to the brain. A "wiring" diagram is shown in Fig. 3. The external hair cells approximate eight microns in diameter and number about 20,000. There are some 3500 hair cells in the inner single row and these are about 12 microns in diameter. The indicated overall difference in diameter between inner and outer hair cells is the only such variation; there is no other dimensional difference between individual hair cells.

The preponderance of experimental evidence leads to the assumption of piezo-electric effects in the hair cells. In accordance with this principle, mechanical stresses in the basilar membrane communicated to the hair cells establish differences of potential in direct ratio to the amplitude and frequency of the sound wave. The voltages measured at the round window reach average peaks of one millivolt at 1000 cps., and readings as high as 2.5 millivolts have been reported. The hair cells are connected to fibres of the auditory nerve, and the voltages generated have a "trigger" action on these nerve fibres. Nerve fibres operate on the "all or none" law, and the magnitude of the electrical impulses (called action potentials) they generate and conduct bears no proportional relation to the magnitude of the stimulus. After a nerve fibre has been "fired," it goes through an absolute refractory period during which no stimulus has any effect. If the stimulus is sufficiently intense, it may refire early in the recovery period, while a weak stimulus may not produce a new action potential until complete recovery has taken place.

Considerable experimental work has been done with techniques using coaxial microelectrodes inserted in the auditory nerve to measure action potentials of single fibres. The results have shown that the upper limit of discharge rate is usually around 400 impulses per second for a single nerve. The rate per second is a function of both the intensity and frequency of the stimulus.

A single wave motion of the basilar membrane will encompass an area proportional to the intensity of the sound, and the resonant peak itself may shift under intense excitation. The latter effect may explain the perceived shift in subjective pitch for the same frequency at varying intensities. The greater the amplitude, and hence area, of a single form in the basilar membrane, the greater the number of hair cells that will be affected and the larger the number of nerve fibres through which action potentials will reach the brain. Thus (to reverse the order of statement), the loudness of a sound is communicated to the brain in terms of the number of nerve fibres generating action potentials as a result of piezo-electric effects produced in the hair cells by mechanical motion of the basilar membrane.

At low frequencies the rate of action potentials per second may follow the frequency of the original sound impulse, but as the upper time limit for the nerve fibre cycle of discharge, refractory period and recovery is exceeded, the nerve fibre is forced to respond to alternate and then still fewer of the potentials acting on it. It is apparent that the time constants may permit a group of fibres acting in rotation to follow a higher frequency, and the limitation for the arrangement has been shown to be 400 cps.

The subjective determination of pitch in the brain is correlated in terms of *which* nerve fibre or fibres bear the action potentials, which in turn relates to the *place* on the basilar membrane where maximum amplitude activates the hair cells.

A specific nerve fibre may be at frequencies of increased intensities above and below the specific frequency to which it is assigned. A particularly interesting feature of this phenomenon may reflect the characteristic shape of wave forms on the basilar membrane. For example, a nerve fibre which is excited with minimum stimulus at 2000 cps. will respond to increased intensities of stimulation down to 250 cps. and up to about 2500. At these extremes it requires a 90 db. rise in intensity over the threshold at 2000 cps. to produce action potentials. It is noteworthy that the range extends much further below than above the point of sharp tuning at minimum intensities.

An examination of the so-called "wiring" diagram in Fig. 3 will reveal the inner row of hair cells as connected to nerve fibres singly or in pairs. The outer groups of hair cells are connected in parallel, or series parallel, so that one fibre is associated with several cells, and one cell may connect to several fibres. It is noteworthy that the fibres connecting the outer groups of hair cells always turn toward the round window. It is conceivable that the time constants are such that generation and travel of action potentials at this point are slower than the rate of development for the wave on the basilar membrane. If this is the case it could explain the sharp cut-off of activation by higher as opposed to lower frequencies with respect to the characteristic frequency of a single fibre. This would follow from the "all or none" law, since activation of hair cells away from the round window might cut off the travel of action potentials generated closer to the nerve fibre end point.

The nerve fibres grouped in the auditory nerve are analogous to small batteries connected in parallel, but the internal resistance (approximately 100 megohms per cm. long varying inversely with the cross section) is large compared with the resistance of the surrounding tissues which function as a shunting circuit. When two nerve fibres are simultaneously active, the internal resistance of the source is halved and the current flow in the external circuit of the auditory nerve is approximately doubled. Experimental results show a near linearity in the arithmetical addition of action potentials in the auditory nerve as a whole, which would not be expected from a first consideration of the anatomical parallel connections.

Auditory nerve fibres measure about five microns in diameter. The velocity of conduction for action potentials is estimated at 30 meters per second and the refractory period 1.0 ms. The time factor between activation of the hair cell and the appearance of an action potential in the auditory nerve amounts to 0.5 ms. or more. The most acceptable explanation of this latency postulates a chemical mediator in the transfer of energy.

The effect of masking one tone by another is largely related to the refractory period of the nerve fibres. Immediately after generating an action potential, a nerve fibre may be compared to a "busy" telephone line. It will not respond to a new stimulus for a period of 1.0 ms., and since the frequencies which may activate it extend over a wide range at high intensities, any one of two or more competing frequencies may obtain control at the minimum recovery point, depending strictly on the time of their arrival.

In the higher auditory pathways, very little of practical importance is known, but strictly psychological factors merit some attention. Cerebral conditioning occurs with regard to all stimulation and follows the general law of adherence to established pathways. It is broadly true that human beings dislike change and exhibit a preference for familiar stimuli. Furthermore, memory "patterns" may be generated in the cerebral region to fill in factors lacking in a particular stimulus for conformance with a desired pattern. Unquestionably the improvement in pitch discrimination and recognition of harmonic content which many persons show as a result of "ear" training is actually "brain" training.

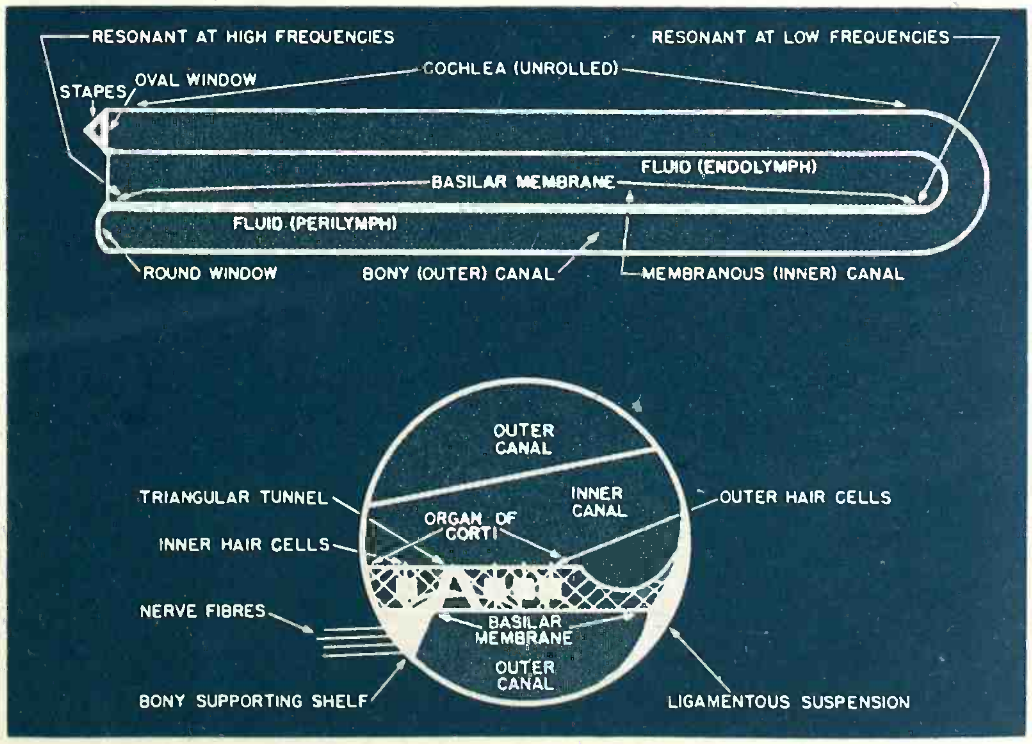
The following is a list of interesting response characteristics in the human auditory mechanism:

1. Frequency cross-over effects in the ear occur mechanically and electrically around 1000 cps. High tone deafness occurs above 1000 cps. The change in frequency response resulting from tension of the muscles in the middle ear rotates around 1000 cps. The absolute maximum rate of single fibre action potentials is around 1000 cps. The frequency considered as optimum, and least subject to masking, in listening to telegraph code signals is 1020 cps.

2. The frequency response of the average ear falls off at both high and low frequencies in a relatively smooth curve covering a difference range of 50 to 60 db. Maximum sensitivity is generally approached between 3000 and 4000 cps. Sudden dips may appear over sharply defined bands, i.e., a person with an otherwise normal response may show a hearing loss of 60 db. or more over a frequency range of from 3800 to 4000 cps.

3. Pitch, which is a subjective value, is largely, but not uniquely, determined by frequency. It is also affected by intensity. An increase in the loudness of a 200 cps. tone tends to lower the observed pitch, and the reverse effect is obtained at high frequencies. In the middle range both effects are observable at different intensities.

Fig. 2. A diagram of that portion of the inner ear which is directly responsible for hearing.



4. When a complex wave is formed from component frequencies separated equally by 100 cps. or more, the observed pitch is equal to the separating frequency. For example, a tone composed of 600, 800 and 1000 cps. is assigned a pitch of 200 cps. by the brain. A tone containing 600, 700 and 800 cps. is observed at a pitch of 100 cps. If a tone containing 600, 800 and 1000 cps. is sounded, and then the frequencies 700 and 900 are added, the effect is to lower the observed pitch one octave. Although many of the fundamentals carrying the melody in music are in the range of from 200 to 300 cps., the introduction of sharp cut-off filters at 300 cps. does not eliminate them from cerebral perception. The fundamentals are automatically filled in with respect to the pattern of the harmonics.

5. Very few people possess infallible, absolute pitch discrimination, but the ability does exist in rare individuals.

6. Loudness is a subjective measurement and is not to be confused with intensity. Summation of loudness occurs between the two ears of one person if the same frequency is led to both ears. If two tones of frequencies sufficiently different as to stimulate entirely separate portions of the basilar membrane are led to one ear, loudness summation occurs.

7. Considering only differences in pitch and loudness, the human hearing mechanism is capable of distinguishing between approximately 340,000 different pure tones. The permutations and combinations which the ear can discriminate is obviously a relatively high order of magnitude.

8. A great many experiments have been conducted to determine the mechanism of auditory localization. Although many factors have been shown to contribute, two are believed to be of greatest importance. If the crest of a sound wave arrives at one ear before the other, a phase difference is perceived. For frequencies below 1000 cps., this effect is translated into direction by the brain. Above this frequency the wave length in air is shorter than half the path between the ears, and confusion results. In the range of 1000 to 4000 cps. the percentage of error is greatly increased, but at higher frequencies discrimination improves, and at 8000 cps. is equally good as at 800 cps.

In localizing high frequencies, the difference of intensity between the two ears is the fundamental clue. Above 4000 cps. the head provides a distinct shadow effect, and the exterior ear creates shadows from back to front. Noises containing both high and low frequencies can be localized much more accurately than pure tones. When high frequencies in a complex noise are attenuated (as by the exterior ear shadow), the quality of the sound is greatly changed, and this contributes to localization. For complex sounds experiments indicate that monaural hearing provides enough data as to make localization almost as accurate as with binaural perception. Obviously, if the observer is permitted to move and rotate so as to perceive the sound from various angles, the ability to discriminate direction is greatly improved.

Distance is much more difficult to determine, and, except for a limited range of short distances, can only be judged in terms of intensity from experience with a known source.

In producing stereophonic effects with multiple speakers, it has been shown that a minimum of three is required to indicate depth. It is interesting to note that with single channel reproduction, an increased percentage of sound reaching the microphone directly as opposed to reflected energy causes the sound source to seem closer to the ultimate listener.

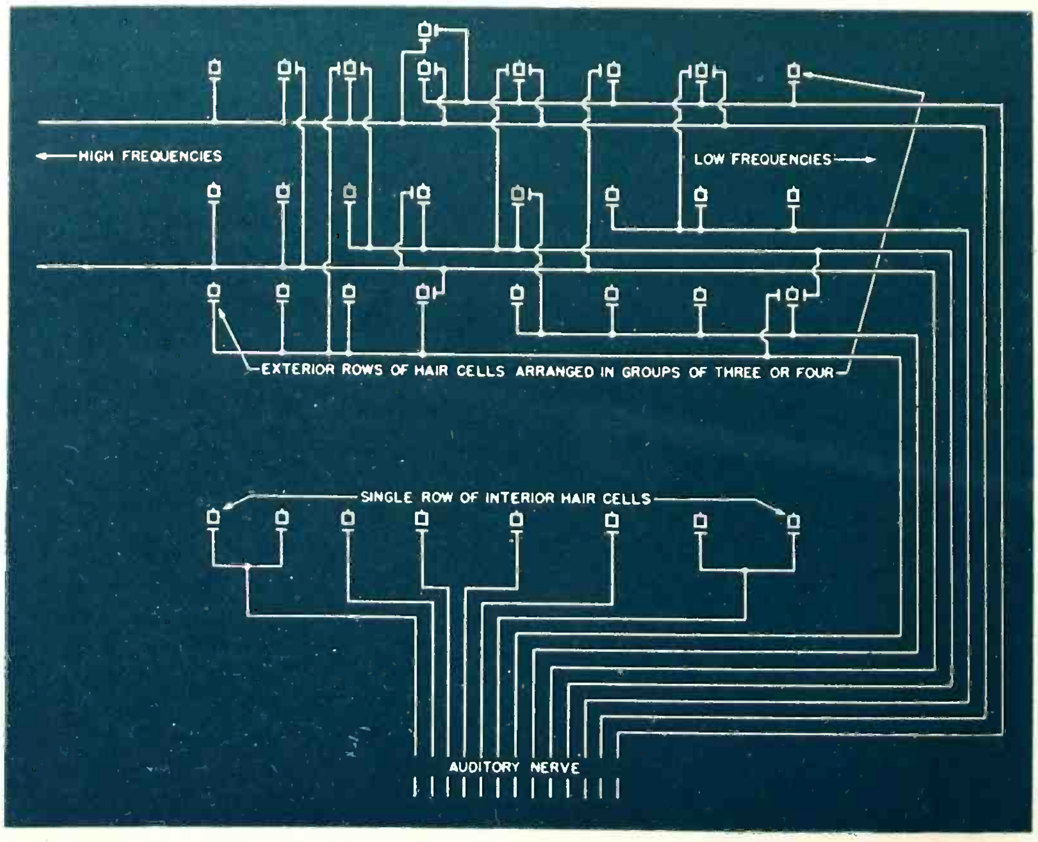
In the one instance where nature has been known to make use of auditory localization for an important practical purpose, the frequency used is around 65,000 cps. This is the ultrasonic tone generated by bats, from the reflected perception of which they determine the location of objects with amazing accuracy and speed. This sound is their "sight" for purposes of avoiding collisions with solid objects during flight.

9. The mechanism of the ear generates harmonics. This distortion is of greater magnitude for low than high frequencies, and above 1000 cps. does not appear at all up to 50 db. above sensation threshold. At high levels of increasing intensity, the magnitude of the harmonics relative to the fundamental increases rapidly. The odd harmonics finally reach a maximum, and even harmonics actually fall off beyond a certain critical increase in stimulus intensity. This latter phenomenon is associated with mechanical distortion in the middle ear, as well as the interactive effect of action potentials in the nerve fibres with the piezo-electric characteristics of the hair cells.

10. The approximate speed of travel for action potentials in the nerve fibre is 30 meters per second. This is curiously parallel to the slow travel of the mechanical wave on the basilar membrane, which has been calculated at precisely the same figure.

Scientists work under stringent, self imposed by-laws regarding the nature of proof. It is noted in closing this article that some of the content connected with processes in the inner ear is based on strongly indicative experimental evidence which has not yet been substantiated in terms of rigorous proof.

Fig. 3. A "wiring" diagram of the inner ear showing the arrangement of the hair cells.



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CALCULATOR—

For Distribution and Transmission Engineers

By V. W. PALEN
Westinghouse Elec. & Mfg. Co.

A mechanical calculator for determining the electrical power loss in single and three-phase distribution.

ENGINEERS and electricians who are interested in electrical distribution and transmission problems will find this power-loss calculator of value.

Considerable time can be saved while making routine calculations for I^2R losses in single-phase and three-phase transmission circuits.

The calculator operation is based upon the fundamental relation:

$W = I^2R$

Where:

W = power in watts

I = current in amperes

R = resistance in ohms per 1000 ft. of wire.

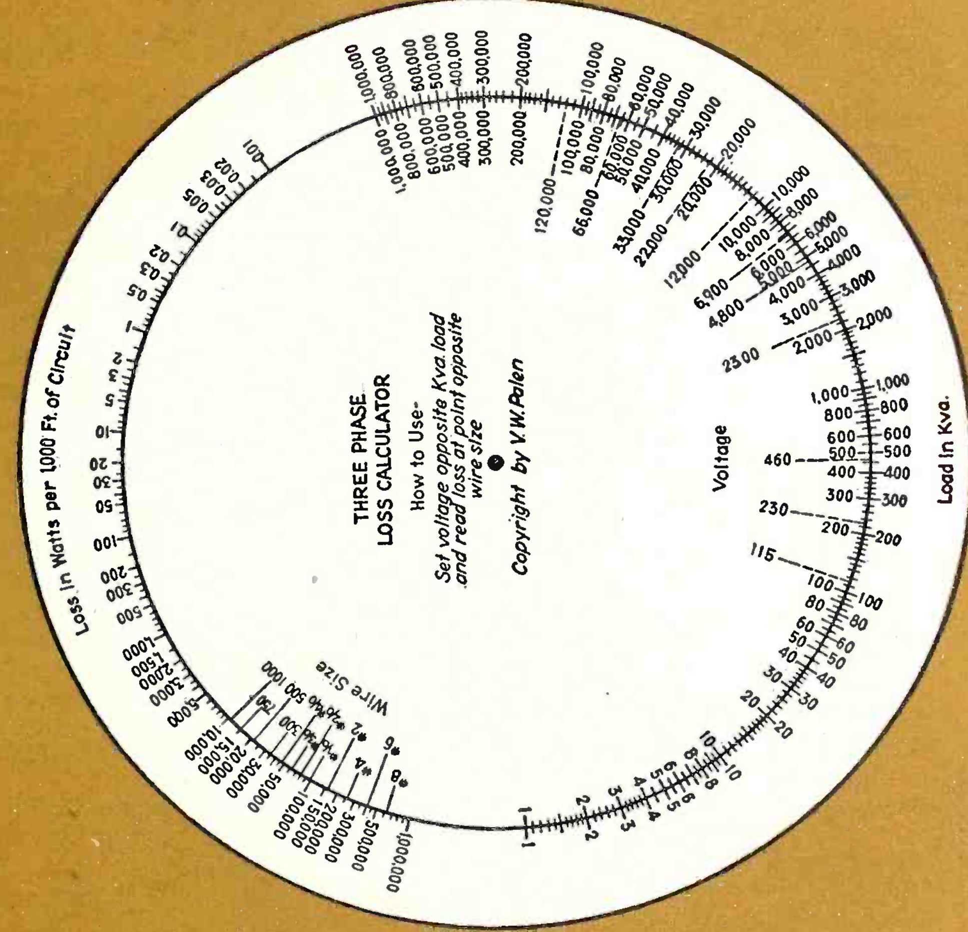
Then for a single-phase circuit, the current is equal to the Kva divided by Kv, and the resistance of 1000 feet of circuit is equal to 2R.

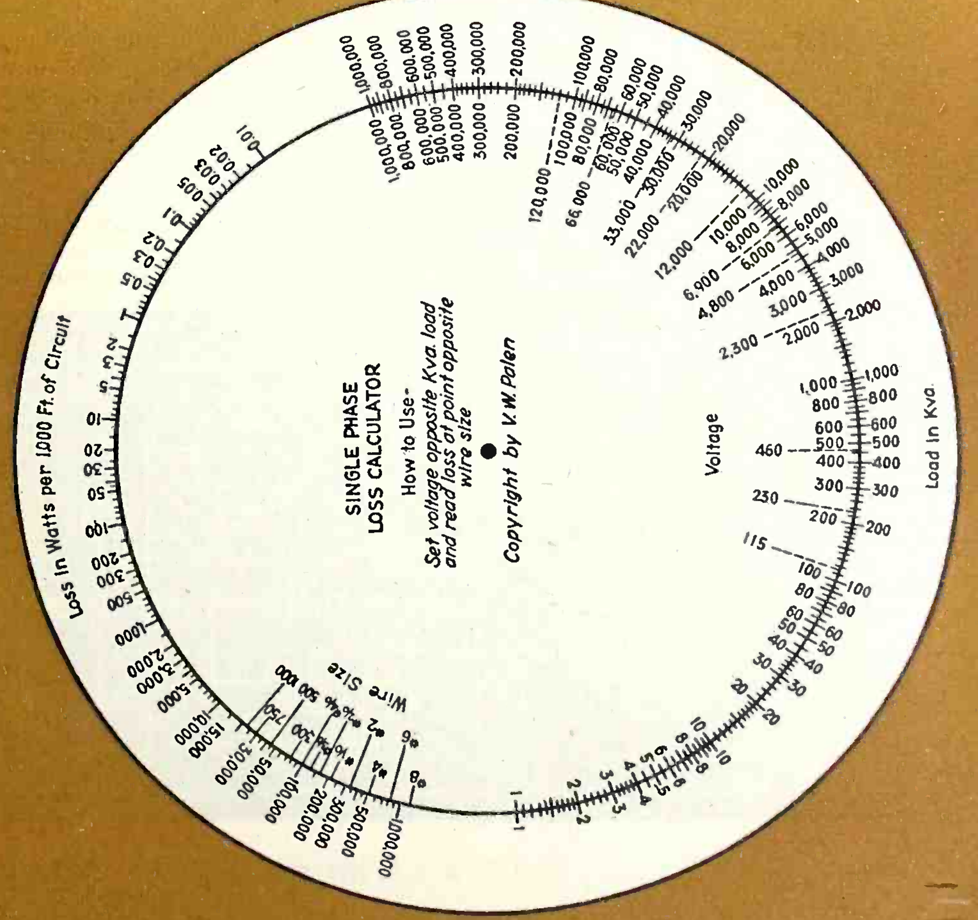
The formula, which includes the effect of power-factor variations, for the power loss of 1000 feet of circuit is:

$$W = \left(\frac{Kva}{Kv}\right) 2R$$

To use the single-phase or three-phase loss calculator, set the number corresponding to the delivered line voltage and marked "voltage" opposite the number on the scale marked "load in Kva". The loss in watts per 1000 feet of circuit is given on the scale opposite the wire size. The scales are designed on the basis of copper conductor and stranded copper wire for sizes No. 2 or larger.

The calculator may be conveniently constructed from the circles printed on the right hand side of this page. To construct this calculator, cut out the circles to form two dics and two rings. Next, mount these discs on cardboard. Punch the center holes as indicated and hold the discs in place by means of a brass brad or bolt.





ALPHA RECORDING

By [illegible]

A practical circuit for recording alpha radiations with an explanation of the unit's operational characteristics.

IN 1912 Geiger and Rutherford originated a device for measuring the alpha radiation from radioactive sources. A few years later Mueller improved the instrument and today it is called the "Geiger Mueller Counter" or simply "Geiger Counter." It's true utility, however, was not fully realized until electronics made possible its automatic, high speed counting action for manifold applications in biology, chemistry and physics. Salient features of the latest readaptation of this type of recording system is the topic of this article.

The over-all hook-up comprises four major parts of which three are fully illustrated herewith. The general layout of the equipment is shown in Fig. 1.

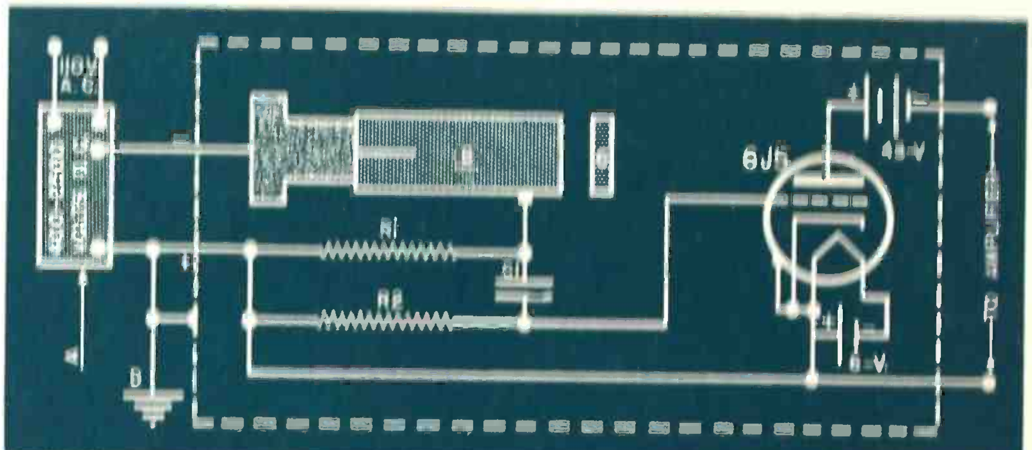


Fig. 2. Detail arrangement of Geiger counter circuit with variable d-c power supply, (A) variable high-voltage (d-c) source, (B) ionization chamber (See Fig. 3), (C) radio-active source, (R_1) 10 megohm grid leak, (R_2) 1 megohm grid leak, (C_1) 0.001 mfd. condenser, (D) positive side of high potential and apparatus shielding both grounded.

Fig. 2 indicates the variable d-c power supply necessary for the apparatus and gives in detail the circuit immediately supporting the ionization chamber or Geiger counter. The latter comprises a 6J5 detector-amplifier tube, with its related battery supply, connected between the ground and one side of the chamber case via appropriate grid leaks and a condenser. The positive side of the high potential is connected to the shield-ground. It will be noticed that all the parts in this chamber unit are shielded from high frequency disturbances or other interferences that might disrupt the sensitively adjusted system. This is accomplished with copper screen painting non-conductive parts with a fairly concentrated solution of colloidal graphite and water. Separation of this part of the circuit from the other sections is also advisable.

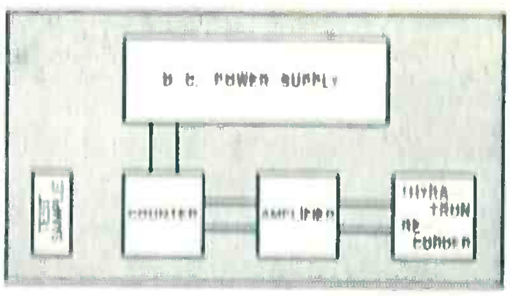
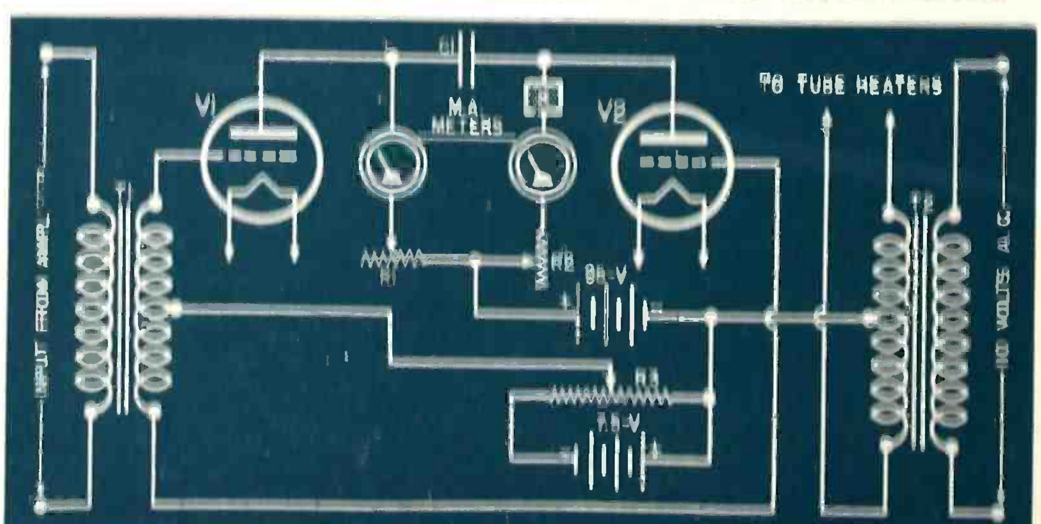


Fig. 1. Layout of Thyratron recording unit.

A standard two-stage wide band audio amplifier supplements the first unit. The input from the counter circuit feeds through a transformer to two 6J5 tubes with their related filament controls and battery supplies. Headphones or a loudspeaker may be connected across the output of this amplifier to demonstrate and check audibly the entrance of alpha particles into the chamber. This unit should also be separated from the other two for undisturbed action.

Fig. 3. Thyratron recording circuit, (R_1) 910 ohm variable resistance, (R_2) 1800 ohm variable resistance, (C_1) 20 mfd. condenser, (K) Cenco impulse counter, type 80, (V_1) and (V_2) FG-17 Thyratron tubes, (T_1) filament transformer, (R_3) 890 ohm resistance.



The final or recording circuit makes use of the hot-cathode, mercury vapor-grid controlled rectifier tube developed by Hull. The features of this tube, exemplified by the FG-17 thyratron, include: (a) arc starting time in the order of 5 seconds, (b) negligible inertia assuring certain control, and (c) impulses separated by as little as 1/500th second can be separately recorded. In the present circuit the grids are connected to the secondary side of the input transformer. A 110 a-c fed filament transformer supplies the filaments, while variable resistances of appropriate value control the plate outputs to sufficient value to actuate the impulse counter.

The mechanics of the actual counting action is quite evident. The d-c potential between the counter point and the chamber case is carefully adjusted below the sparking over value. This "threshold" potential varies with the sharpness of the point, its distance from the inside face of the chamber and most markedly with the pressure of the air surrounding the counter parts as shown in Fig. 4. Once critically adjusted, however, the ionic charge produced by the entrance of a single alpha particle into the high potential field within the case is sufficient to alter the grid bias of the first 6J5 tube. This voltage impulse is amplified by the two-stage amplifier producing a surge from the last 6J5 tube

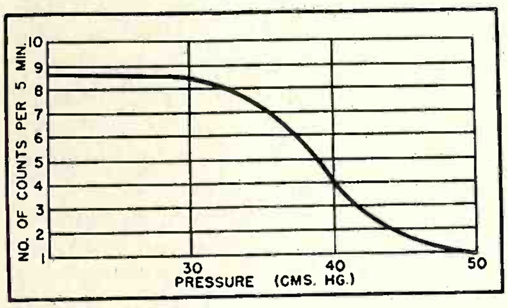


Fig. 4. Relation of ion counts to pressure.

of the order of several tenths of a volt. It is this impulse, applied to the grid of the first thyratron, that causes discharge, provided the tube has been carefully adjusted above the background of hum from outside disturbances. The resulting anode current, limited to just sufficient strength to move the armature of the automatic recorder, causes a ratchet to move one tooth forward where upon stopping a contact is opened which extinguishes the arc and resets the thyratron for the next impulse. With the thyratrons alternately glowing at each discharge the counter registers every other alpha particle entering the chamber. Thus, when the arc current of one tube alters the grid bias potential of the adjacent thyratron, counting speeds can be increased by as many tubes as are employed. Fig. 5 depicts the results that can be obtained with the counter mounted in space of varying air pressure. If the air pressure is above 40 cm. of mecury, the unit is fairly insensitive.

In order to have the electrical circuits operate satisfactorily as a unit, the ionization chamber must be constructed with extreme care. By referring to Fig. 6 the detail dimensions and mode of construction for a satisfactory chamber may be seen. Turned brass stock, closed at one end with brass and a bakelite stopper at the other, are the salient features of this unit. Equally important is the tungsten collector point, which is employed because it restores itself with fewer heating and cleaning treatments and can operate continuously for intervals from three to five hours. With alternate periods of rest and operation, such electrodes will function satisfactorily from two to three weeks and, upon being found useless, can be reground. They will, moreover, operate consistently well as the impressed voltages are decreased with changes in atmospheric pressure.

The operation of the ionization chamber is quite simple and can be best understood by again referring to Fig. 6. The end-face of the chamber which has a small hole of 0.139 cm. diameter drilled in its center is faced toward the sample under test. A high-velocity alpha particle which passes through the small hole of the chamber will strike gas molecules and produce ionization of the gas by impact. The ionization becomes progressive and in a short time, measured in microseconds, the chamber has become a sufficiently good conductor to affect the thyratron circuit. The sharply pointed electrode aids the progressive ionization, since it is connected to one side of the power supply and thereby produces a very high electric gradient in the vicinity of the needle point. Since the needle is negative, the electrons pass from the tip of the needle point to the walls of the chamber completing the circuit during the discharge period.

The portion of the counter circuit which includes the thyratrons serves as a relay and not as an amplifier. The relay action is extremely fast but must be electronically "reset" for each new cycle to be counted. This may be accomplished by reducing the anode voltage and current to zero by utilizing an alternating supply voltage for the anode so that the polarity of the anode with respect to the cathode alternates periodically. Experiment and practice indicate that the time of deionization of gas in an average sized tube is approximately 10^{-6} seconds, which is, of course, negligible compared with the period of the electronic cycle generally used in this type of circuit. The time of ionization is also measured in microseconds and depends upon the tube structure, gas pressure and electrode supply voltages.

After ionization of the gas the grid has practically no control upon the anode current. If the grid does become negative, a sheath or cloud of positive ions forms around the grid neutralizing the effect of the electric field in the neighborhood of the grid. As the potential of the grid becomes more negative the density of the posi-

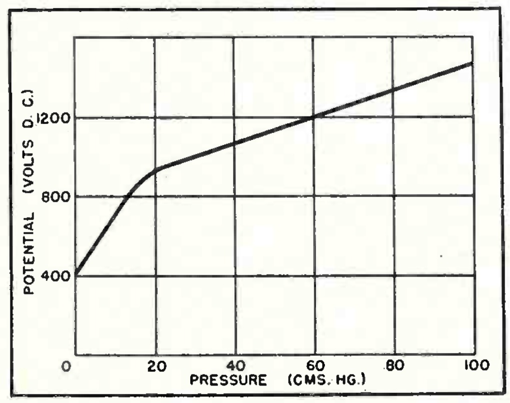
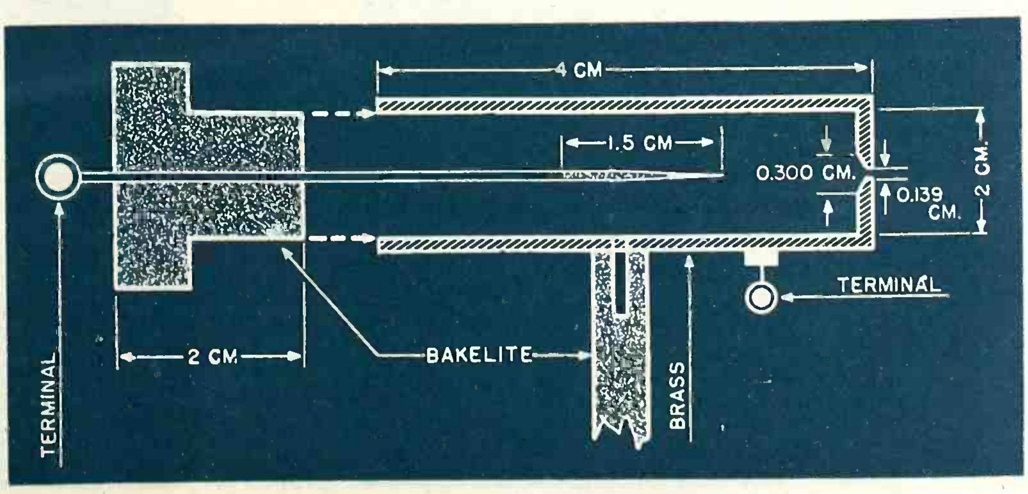


Fig. 5. Dependence of ionization on pressure.

tive ions increases keeping the electric field neutralized. Under these conditions the electrons as well as the positive ions are unaffected by a negative grid or a varying negative potential on the grid. The operation of the thyratron may not be compared with the high vacuum triode and therefore should be considered as a separate unit in the general layout as shown in Fig. 1.

By connecting the various units together, to form the system shown in the block diagram of Fig. 1, the circuit will automatically count the ionizations that take place.

Fig. 6. Detail of ionization chamber showing position of tungsten collector point.



X-RAYS in Aviation Medicine

By JOHN L. BACH
General Electric X-Ray Corp.

A survey of the vital role being played by electronic equipment in modern medical research for the armed services.

WORLD WAR II is opening new vistas for the study of medical X-ray. It has been recently revealed that for the first time in the history of aviation-medical research X-ray films have been taken of the bodily changes which take place at altitudes of 38,000 feet, or a distance of better than seven miles, by means of X-ray equipment built into special decompression chambers which simulate conditions of high-altitude flying.

Pioneer work in this field is being carried on at Northwestern University in Evanston, Illinois under the direction of Dr. A. C. Ivy, Professor of Physiology. Working with Dr. Ivy, are Drs. H. F. Adler, William Burkhart and A. J. Atkinson, of the Northwestern Medical School and seven young men who are acting as subjects for this experimental investigation.

Films taken in this high-altitude test chamber disclose marked and significant changes in the heart, lungs, joints and muscles of the subjects, thus providing flight surgeons and medical men with new material and information regarding the physiological reactions of the body to high-level flying. From the information obtained, it has become possible to analyze the causes of the "bends", one of the most common and most painful of the disabilities experienced by flyers operating in the stratosphere.

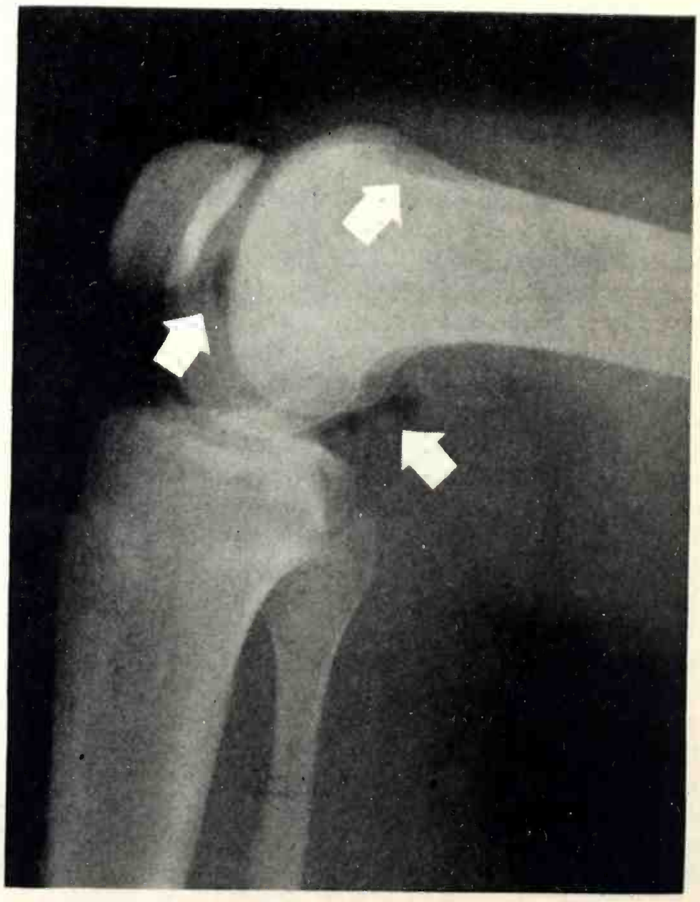
The cause of discomfort, experienced at high levels, is the expansion of the gases of the body. Prior to the use of X-rays it was impossible to determine the penalty exacted on the body by the rarified atmosphere. A solution of these problems is vital because air travel through the stratosphere offers many operational advantages, especially in war-time. Planes flying at stratospheric levels are less likely to run into anti-aircraft fire or be intercepted by enemy aircraft.

Scientists have pointed out that the gases in body fluids have normal channels for expulsion at sea level but such gases that lodge in fat tissues and the joints expand as the outside pressure decreases causing a condition described as more painful than rheumatism. In many cases the gas in the stomach of a man flying at 38,000 feet expands six times.

The exact gaseous composition of the bubbles and pockets which form in the joints and muscles is not known, but scientists believe that it is made up, in a large part, of nitrogen.

In Fig. 1 actual X-rays of the knee joint taken before the "ascent" and under atmospheric pressure are

Fig. 1. X-rays showing knee joint (left) at sea level and (right) at high altitude. Note gaseous bubbles formed at joint.



shown. It can be easily seen in the X-ray taken in the pressure chamber that a gaseous bubble appears back of the knee joint. This bubble disappeared when the subject was returned to sea-level pressure. The appearance of the phenomenon at high levels and its disappearance at normal levels is, as yet, a riddle to the scientist, but it is hoped that this problem may be solved in the near future through the continued use of X-ray.

Prior to the introduction of the X-ray as a research tool for this type of work, it was necessary for physicians to make their observations under actual flying conditions. This proved to be unsatisfactory as it was impossible to study the results carefully and thoughtfully and often no permanent record of the disability was possible. Now with the advent of the decompression chamber and the X-ray film taken under simulated conditions, it has become practical to make thorough studies of the evidence. In this manner, it is possible for scientists, working independently on the problem, to collaborate and pool their knowledge and data.

The method of making the X-ray exposures within the chamber is an interesting one, and is shown in Fig. 2. The X-ray transformer is situated, together with the operator's control panel, immediately outside of the small test chamber. Shockproof, high-voltage cables running through sealed channels connect the X-ray tube, which is mounted on an adjustable stand within the chamber. Since the tube is immersed in oil, within a hermetically sealed casing, its operation is free from any of the high-altitude effects.

The subjects within the chamber are supplied with "cassettes" containing 14 x 17 inch X-ray film. After the door is bolted and the men have donned their oxygen masks, they take their seats and wait until the desired "altitude" is reached. The X-ray technicians are able to give instructions to the subjects by means of microphones attached to a speaker within the chamber. When the subject is ready for his radiograph, he steps in position in front of the X-ray tube, places the "cassette" to his chest, knee, or stomach as directed, and the operator on the outside of the chamber operates the X-ray controls and timer switch to make the exposure. The films are developed immediately upon the subjects' release from the chamber.

In the past, X-ray has received some of its greatest impetus during war times and this period of present conflict is no exception. The British used X-ray extensively during the

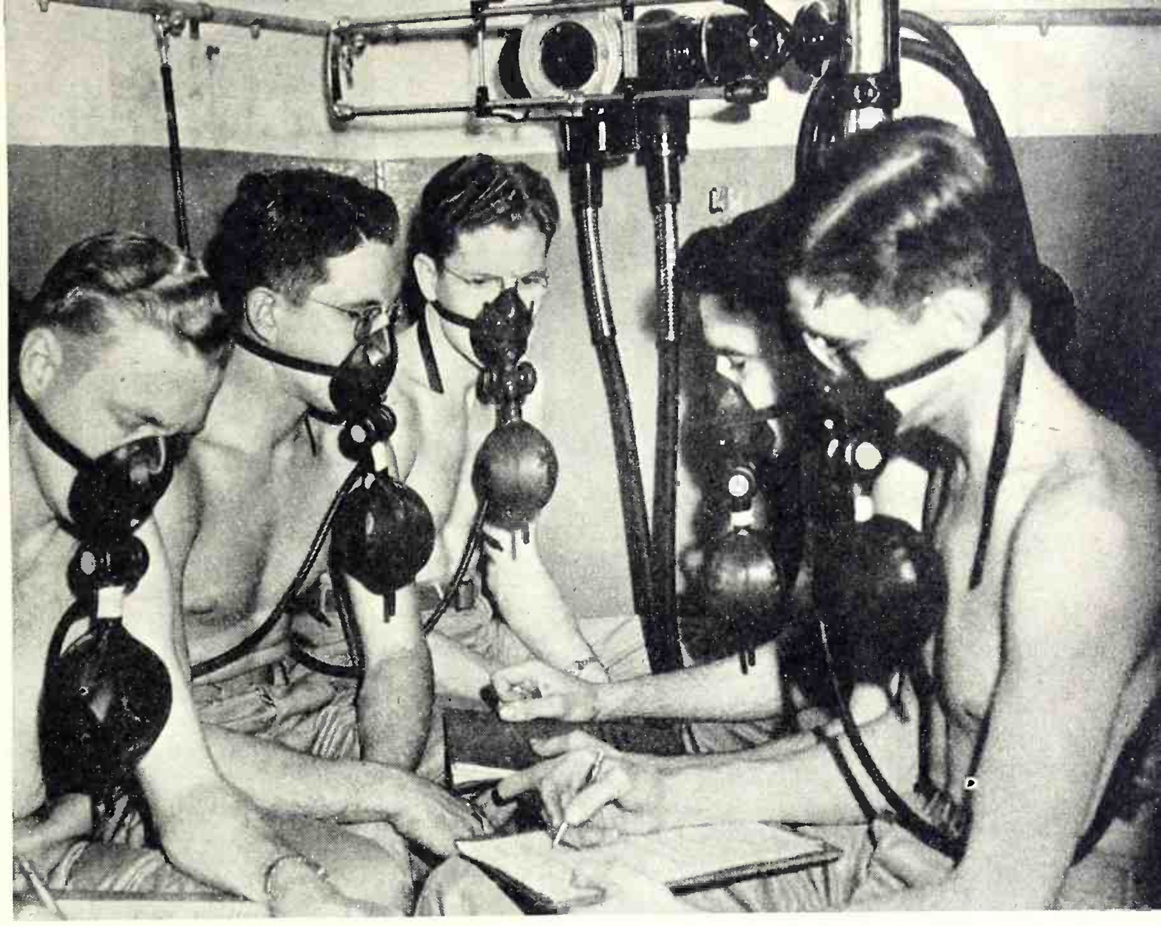


Fig. 2. Subjects undergoing tests in decompression chamber. X-ray equipment is shown at top.

Boer War, just four years after Professor Wilhelm Roentgen's discovery and the Americans used it during the Spanish-American War.

However, it was not until the first World War, that X-ray was given its first serious consideration, and served as a training school for many of the ablest roentgenologists in practice today.

When the United States entered the World War in 1917, the Army and Navy had no apparatus except that in use at the regular army posts or hospitals. There were very few well-trained technicians in either branch of the service. Doctors, with little experience in X-ray, developed their technique while serving with the hospital units, or acquired the skill in hastily established schools of roentgenology.

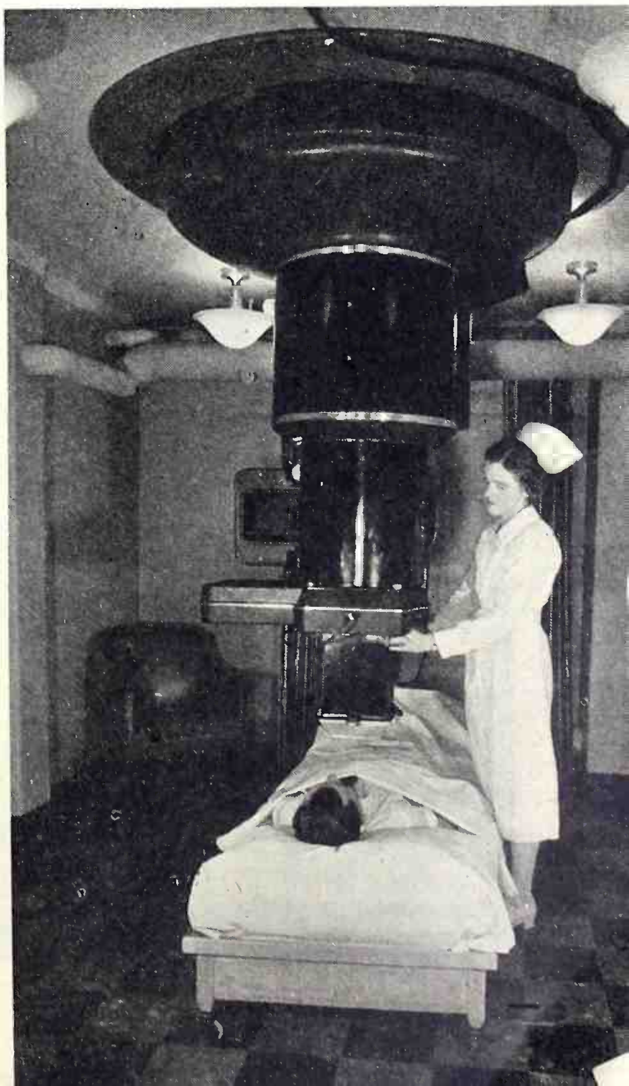
Upon cessation of the hostilities, the doctors returning to their private practice demanded X-ray in the hospitals with which they were associated. Thus, the development of roentgenology, both from the use of a diagnostic point of view, as well as the improvement in existing equipment, was stimulated by the various schools of military X-ray.

In this war, similar advancement is being made. A field unit is now serving army casualties on the battle field. This unit can be dismantled in a few minutes and packed for convenient portability. By means of this X-ray, bullets and shell fragments can be located quickly at the scene of the injury and thus save precious time which might otherwise be wasted in transporting the injured to the base hospitals before beginning treatment.

In another application of the Photo-Roentgen unit, the chests of draftees have been examined for evidence of tuberculosis ever since the Selective Service System was organized. In this way, it is possible to weed out inductees, whose care after the last war cost the United States government

(*Continued on page* 35)

Fig. 3. Million volt X-ray therapy equipment.



A Multiple Converter Unit

By HERBERT L. LIPSON
Radio Engineer, Border Patrol

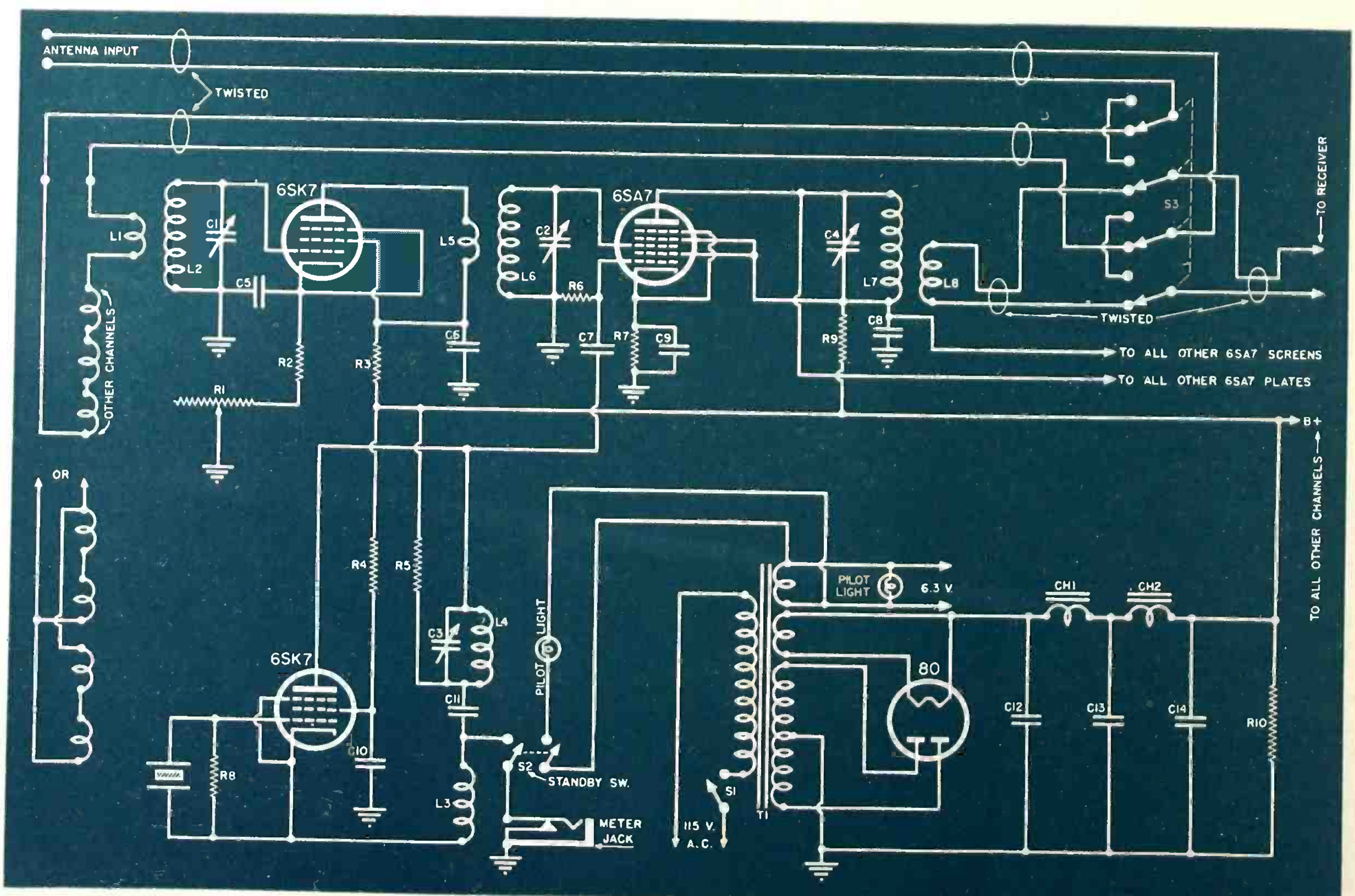
A crystal controlled unit intended for police and aircraft short-wave multichannel communication systems.

POINT to point communication is becoming more and more important in ship-to-shore, police, and aircraft radio. The usual receiver layout in a point-to-point service generally has too many components, consisting as it does of four separate speakers, four separate audio and I.F. channels, separate power supplies, sixteen or more sets of idle coils, and four tuning condensers that are never moved. All of this construction represents a useless expenditure of valuable time, money and vital materials.

In order to conserve on these materials, and to overcome the shortage of communications receivers, the Multiple Converter was designed. This Multiple Converter is a modernized version of a short-wave converter designed a few years ago. The equipment described in this article consists of four fixed-frequency detector-oscillator units operating from a single power supply. The outputs of these detector-oscillator units are fed into a single intermediate frequency channel, consisting of a standard communications receiver set to a predetermined frequency. The advantages of such a system for a point-to-point station can be readily appreciated when you consider that only one receiver is needed, thus elimination of three receivers is possible as well as a saving of approximately five hundred dollars is effected. Beside the above mentioned advantages, a more compact layout is obtained because two units (a converter and receiver) replace a six-foot rack of receivers.

Comprehensive tests have shown that nothing has been sacrificed in performance, in fact, the combination yielded a receiver that gave excellent results. Since fixed-frequency operation permitted crystal oscillators to be used, there is no frequency instability. Double conversion and six tuned stages give far better selectivity than a receiver alone. The gain of the converter unit in conjunction with the gain of the receiver gives a high degree of sensitivity. Tested by IRE standards, the sensitivity was so far below one microvolt that it could not be measured, likewise with one microvolt input and a degree of

Fig. 1. The superheterodyne principle applied to a converter unit using a crystal controlled local oscillator.



modulation of thirty per cent, an audio output well over one watt was obtained, and the signal-to-noise ratio was over 15 db.

The Multiple Converter is not too difficult to construct as no special parts are needed other than the coils, whose construction will be fully described in this article. Since fixed-frequency operation is used, there are no gang condensers, which eliminates any tracking difficulties. Idle amateur bands may be utilized by choosing the proper intermediate frequency.

A complete four-channel unit was constructed on a standard 12 x 17 x 3 inch chassis. Fig. 1 shows the approximate physical layout, which may be rearranged to accommodate the size of individual components. The actual layout is not critical providing it conforms to standard construction procedure and ordinary precautions are taken in the matter of short leads, shielding, and spacing. Because of their availability, metal tubes were used in the actual construction but GT types give satisfactory performance.

The front panel layout is shown in Fig. 2, but here again, this may be changed to suit individual requirements. It will be noted that each channel is equipped with its own gain control, standby switch and pilot light. The need for the pilot light was indicated when it was discovered that the operators would forget to close the standby switch after handling traffic on another channel. The pilot light eliminated this difficulty.

In the center of the panel of the master controls is a line switch, pilot light for the power supply and an antenna changeover switch. This changeover switch connects the antenna to the receiver and disconnects the converter when frequencies other than those in the converter are to be used.

The circuit of the basic channel is shown in Fig. 3. Standard R.F. and mixer circuits are used, similar to those found in any communications superheterodyne receiver. The special oscillator uses a doubler circuit so that it becomes necessary to grind the crystal to only half of the required frequency. Since this unit is used primarily for the reception of code, there is no provision for AVC, however it was found that the receiver itself had enough AVC to amplify most signals when receiving voice. An R.F. gain control is used to control any tendency on the part of the unit to block on strong signals.

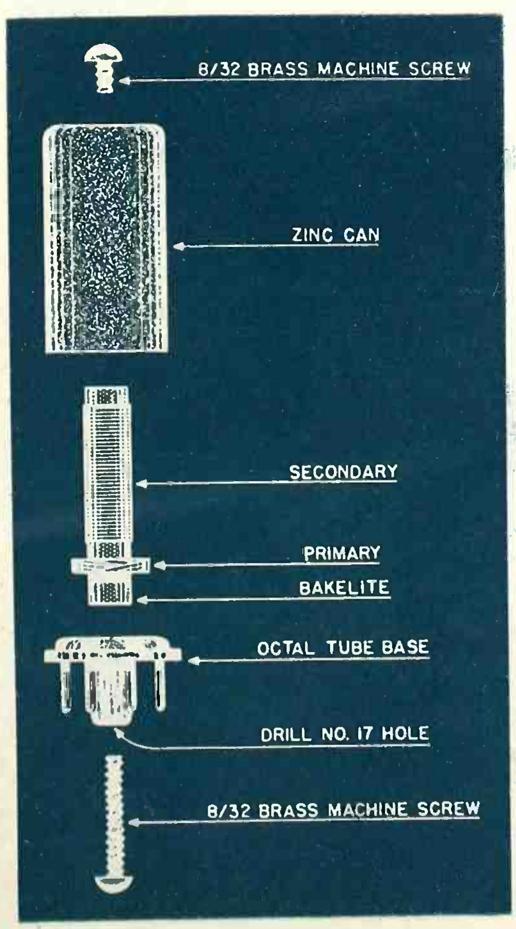
Special care must be exercised in the construction of the coils as they must be designed individually to tune to the assigned frequency. Those familiar with the standard methods of computing inductance will experience little difficulty in making these calculations.

In calculating the inductance of the r-f and detector coils, it may be assumed that the value is 15 mmfd. for the circuit capacity and 5 mmfd. tuning capacity, or a total of 20 mmfd. This low-C circuit is used in order to give maximum gain. Since it will be necessary to prune the coils in order to achieve optimum results, precise calculation is not essential. The windings for the primary coils must also be determined by experimentation, but a good approximation may be made for the initial coil assuming it to be a pi-wound coil of 10% of the number of turns on the secondary with one-eighth inch spacing between windings.

The necessity for removing the coils many times during their adjustment resulted in the unusual mechanical design shown in Fig. 4. A shortage of shield cans led to a unique substitution plan. Flashlight batteries shells were utilized before the zinc shells had become corroded from use. After the material is removed from the battery, the shells are washed, first with a solution of acetic acid and then with ammonia, after which they should be thoroughly rinsed with hot water and soap. This treatment will arrest any further tendency toward chemical reaction. A dozen or so shells can be processed in this manner in half an hour.

The mechanical layout in Fig. 4 is

Fig. 3. Physical layout of r-f transformer.



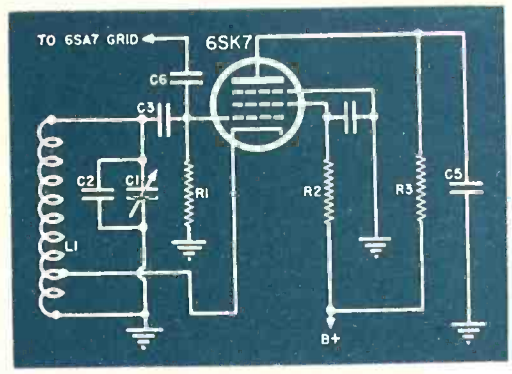


Fig. 2. Local oscillator circuit of tritet type if crystal is unavailable.

self-explanatory. Although the ½ inch bakelite rod was available, any material could have been used with equal success, such as a hard wood rod boiled in paraffin. The octal bases from a metal tube will fit into this battery shell. No provision was made to mount the trimmer condensers inside of the can, since it is possible to mount these at the sockets with very little difficulty. Care should be taken to assure the proper grounding of the metal shells through one of the tube-base pins.

Inasmuch as the facilities for grinding crystals were available, crystal controlled oscillators were incorporated in this unit, a feature which simplifies the oscillator and yields good stability. The circuit used is a variation of the familiar tri-tet circuit, in which the output is tuned to twice the crystal frequency. As the required frequency increases, the grinding of the quartz crystal becomes more difficult and when operating in the 8 to 10 megacycle range it is advisable to use a frequency doubler circuit.

By using capacitive coupling between the crystal controlled local oscillator and the converter tube, ample voltage is obtained. In fact, the coupling should be reduced to less than 10 mmfd. to avoid overloading the mixer grid.

The cathode resonant circuit, which includes L_3, should be designed to resonate at a higher frequency than that of the crystal. The resonant circuit should be adjusted until it operates on the upper portion of the resonance curve and the crystal oscillates with satisfactory stability. This coil may be wound on a piece of bakelite or other rod and placed at the socket of the 6SK7 oscillator tube.

In this particular application, the plate tuned circuit must be tuned to twice the crystal frequency. The crystal frequency is determined by the formula:

$$f_c = \frac{f_s + f_1}{2}$$

Where

f_c = crystal frequency in kc.

f_s = signal frequency in kc.
f_i = intermediate frequency in kc.

The standby switch is inserted in the oscillator circuit because the removal of the high voltage from any of the mixer plates tends to detune the output transformer. When the oscillator is the only circuit which has its voltage removed, the mixer tubes remain loaded and do not unbalance the currents in the primary of the output transformer.

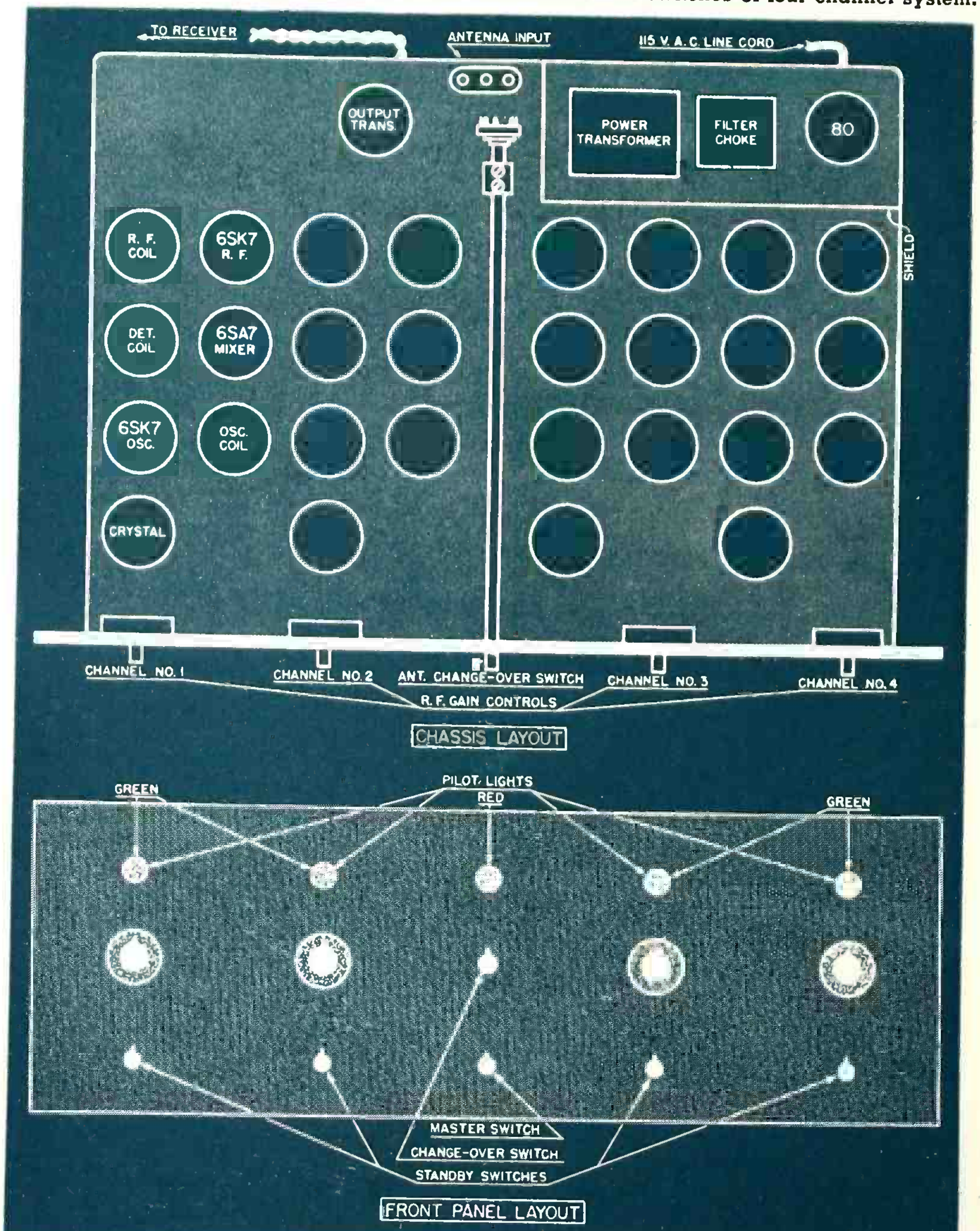
Since the coils are generally constructed, they may be wound to satisfy the requirements of the particular application. If it is desired to use an amateur band receiver, a frequency between 1750 and 2050 kc. will be very satisfactory. Since receivers are quite sensitive at the high frequency end of the spectrum, an attempt to use the higher frequency is preferred. If, however, an average communications receiver is used, a frequency between 1600 and 2000 kc. should be chosen. If crystal control is used, since the intermediate frequency cannot be changed after the crystal has been ground, considerable care should be used when choosing this frequency.

After the IF has been determined the output transformer should be wound with a tuned primary. The secondary matches the antenna input impedance of the receiver used in this application. The primary tuned circuit is constructed to resonate at the chosen intermediate frequency while the secondary consists of 8 or 10 turns spaced one eighth of an inch from the primary. An exact match to the receiver is not necessary, since there is ample gain in the converter stage to overcome a slight mismatch.

It should be noted that a common output transformer may be used for all four stages, the plates of the mixer tubes being connected in parallel. This may seem to be violating good engineering practice, but with sufficient gain in the system operation is satisfactory.

For better matching conditions, four separate transformers may be used with the output windings connected in series-parallel.

Fig. 4. Chassis and panel layout of tubes, transformers and switches of four channel system.



In order to align the Multiple Converter, an accurate signal generator is essential. If the receiver has no "S" meter, an output indicating device should be included. The aligning procedure should proceed from the receiver end of the circuit and progress toward the high-frequency or antenna end. The first step in the alignment procedure, of course, is to connect the converter to the receiver, and set the receiver to the chosen intermediate frequency as accurately as possible. With the receiver volume controls adjusted about half-way and the signal generator coupled to the plate of the 6SA7 through a .001 mfd. condenser, attempt to tune the output transformer with the signal generator adjusted to the intermediate frequency. The transformer inductance should be increased or decreased if necessary as indicated by the setting of the trimmer condenser.

After the output transformer has been properly tuned insert the quartz crystal in the appropriate oscillator circuit. As a preliminary check upon the operation of the oscillator circuit, it might be well to measure the r.f. crystal current with an r.f. milliameter to insure that it does not exceed 75 ma. When the crystal appears to operate properly, plug in a d.c. 0-25 ma. meter in the jack provided and adjust the plate circuit by observing the dip in the milliameter deflection.

A wavemeter will aid in determining whether the circuit is operating as a frequency doubler or tripler. The doubling action, of course, is preferable in this application.

After the crystal controlled oscillator is operating satisfactorily, the signal generator should be adjusted to a frequency within the reception band. The signal generator should be capacitively coupled to the antenna terminal of the converter through a .001 mfd. condenser. If, with this connection, no signal is observed, couple the output of the signal generator directly to the grid of the 6SK7 tube and tune the following grid-trimmer condenser. Now by connecting the signal generator to the antenna terminal and repeating this procedure with the tuned r.f. circuit of the 6SK7 tube, maximum voltage will be obtained.

The adjustments which have been completed are not accurate due to frequency errors of the signal generator. To obtain a greater accuracy, in the final alignment of the converter unit, couple an antenna to the converter and arrange for aligning the unit with a signal from one of the network stations. With this test sig-

(*Continued on page 33*)

ELECTRONIC PROCESSING

By C. B. F. MACAULEY
Fairchild Engine and Airplane Corp.

A description of electronic equipment used in processing laminated aircraft.

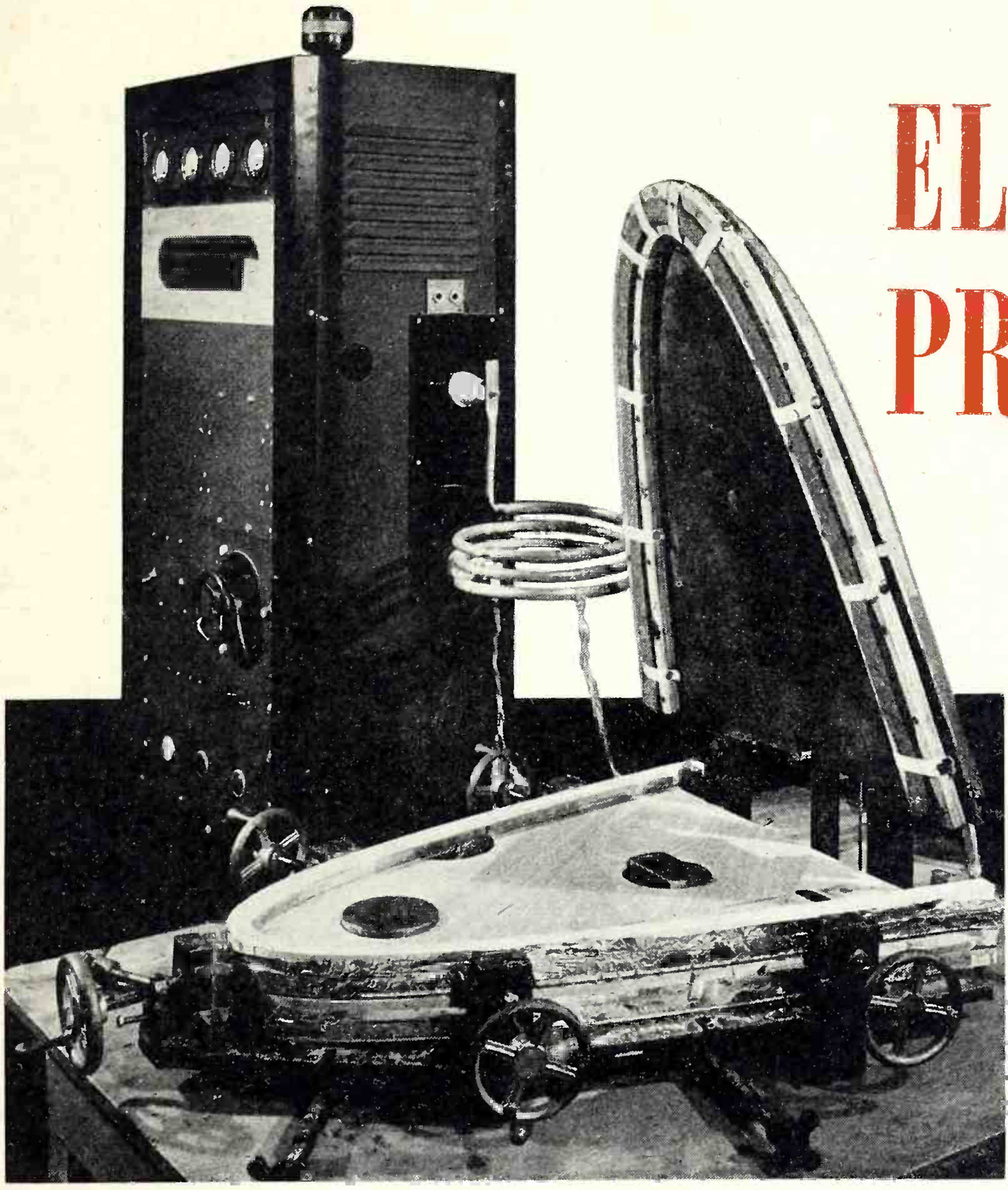


Fig. 1. Small high-frequency generator and jig used for bonding cap strips to bulkhead web.

ELECTRONICS, is performing still another great war job in the electronic processing of molded wood airplanes. By means of an application of the science of electronics, it is now possible to secure a uniform degree of heat to all of the glue lines in a thick laminated section of the aircraft.

The scarcity of aluminum has promoted wood to a position of prime importance in the construction of aircraft. The use of this material has resulted in a lightweight yet durable plane which can be turned off of the production lines rapidly and efficiently. Wood as an aircraft material has been subjected to criticism, but a careful examination of the facts show that most of the criticism is directed not toward the use of the material itself but the materials and methods for fastening or bonding the pieces of wood together and the finishes used for protecting the wood. Like many other materials used in the fabrication of airplanes, wood proved to be stronger than the joints in the wood, and it was this factor that was responsible for much of the disagreement concerning wood among aeronautical engineers.

Roughly, the glues used to laminate wood parts may be divided into three classifications, casein glue, urea formaldehyde resins, and phenol formaldehyde resins. The first two classes will set at room temperature 70° F-90° F in about six to eight hours, although this time can be reduced by the application of heat. The last class, and the most durable, requires either room temperature, 75° F to 100° F. coupled with a long setting time (measured in hours), or high temperatures ranging from 200° F to 280° F for the rapid setting (measured in minutes) necessary for production.

Casein glue, unless fortified with strong preservatives, loses its strength and molds when exposed to moisture. Although there are many airplanes with parts fastened together with casein glue, many of which are flying after 14 years of continuous and satisfactory service under unfavorable climatic conditions, this glue has been practically discontinued because of the difficulty, found in modern monocoque structures, of providing drainage and surface protection over the glue joint so that there is no possibility of the joint being subjected to accumulated moisture. Failure of casein glue, because the joints were allowed to be exposed to moisture, is one of the main reasons for a lack of confidence in wood airplanes.

Urea formaldehyde resins are moisture resistant and thus the main objection to wood structures bonded with casein glue is overcome. However, the processing of structures with this resin, has certain inherent difficulties in that thick glue lines will "craze" with time. The small cracks in the "crazed" glue line and the internal stresses set up by the "crazing," will materially weaken the complete structure.

In order to avoid the production of thick glue lines, a process has been developed whereby a fluid pressure is used to push the parts into such close contact that thin glue lines are assured. Heat is usually used with this process by means of external-heating strips attached to the jigs. This reduces the time in the jig from six to eight hours to 15 to 40 minutes. This process results in a saving in the cost of production by eliminating the need for building new jigs to supplement those tied up by the long processing.

The phenol formaldehyde resins are the most durable and require the least care in their application. In fact, they are an ideal bonding material in every respect, except that they require long setting periods at room temperatures, or extremely high temperatures for fast setting. It is this requirement for the application of high heating that constitutes the main disadvantage of the two resins.

There are two methods, whereby heat may be applied to the glue line. The first method is to apply a heated platen to the surface of the wood, and depend upon conduction to bring the heat to the innermost glue line. The second, the electronic process, is to cause a current to flow through the wood and by electrical agitation cause the wood to heat uniformly throughout its thickness. Because of the poor conducting qualities of wood, the length of time for the conduction of the heat, coupled with a limitation placed on the heat of the platen before the wood is burned, makes this process undesirable when the distance of the glue line to be processed is increased beyond ½" from the surface. Even where time was not a factor, attempts to heat thick pieces of wood from the surface results in the drying out of the surface layers to a greater extent than the center. When, in time, the surface layers stabilized themselves and reached the same moisture content as the center, these layers would expand with resulting stresses in the wood itself and in the glue lines.

Therefore, when the problem of processing the glue lines in laminated spar flanges arose, it was necessary to devise a different method for the application of the required heat. Electronic processing was the answer to the problem. However, the electronic heating equipment available was mostly of the diathermy type used extensively for the treatment of arthritis and other diseases requiring a deep heating of the bodily tissues. These units, while they were capable of heating wood uniformly, could not develop temperatures sufficiently high to process and set the glue line for aircraft. In the diathermy equipment, was the nucleus of the proper approach to the problem.

Diathermy equipment was available with average powers of 100-150 watts and maximum temperatures of 110° F., while apparatus capable of producing temperatures up to 280° F. with powers of 1000 to 30,000 watts was needed.

Conversion of existing equipment was necessitated by the lack of available units suitable for the purpose. In some instances, high-frequency generators were converted and rebuilt as was a 15kw frequency-modulated radio station, which was built before the war but not installed. From this miscellany of equipment three units were produced. Two of the units, the 1kw and 5kw, designed for scarfing, edge-gluing and small assemblies, were portable so that they could be moved to the jig where the heating was to be applied. The advantage of this type of unit, besides its portability, lay in its adaptability to existing jigs, thus avoiding the necessity of redesigning and constructing new jigs. A stationary unit, rated at 30kw, has the jigs laid out around it like the spokes of a wheel.

Wood, sometimes thought of as a non-conductor, is in reality a very poor conductor of heat. Its resistance to the passage of direct or 110 volt alternating current is very high. It would require tremendous electrical pressure, on the order of millions of volts, to cause enough current to flow through wood of appreciable thickness sufficient to heat it. As the 60 cycle current, found in most factories, is increased to 3 to 8 megacycles, used in electronic processing, the effective resistance drops.

In electronic processing the desired heat can be obtained either by a combination of low frequencies in the electronic range, on the order of 3 megacycles in combination with voltage of 15,000 to 18,000 volts, or higher frequencies of from 15 to 20 megacycles in combination with lower voltages of 3,000 to 4,000 volts. In either case, it is evident from the voltages in operation that the apparatus and guards must be carefully designed from a safety standpoint. The selection of the proper combination of voltage and frequency is a complicated one, for as the thickness of the piece being processed is reduced, the voltage must be reduced below a value which would result in arcing between the electrodes.

Uniform power distribution, or its resultant, uniform temperature distribution is more difficult to obtain in a large piece than in a small one. The reason for this is that when the dimensions of the work become comparable to a wave length corresponding to that of the frequency used, standing wave effects appear. These effects cause non-uniform power distribution. This non-uniformity can be minimized to a satisfactory degree by introducing the current to the electrodes at a number of points, which results, in effect, in breaking the large piece into a number of smaller pieces. The necessity for doing this is practically eliminated by lowering the frequency which increases the wave length.

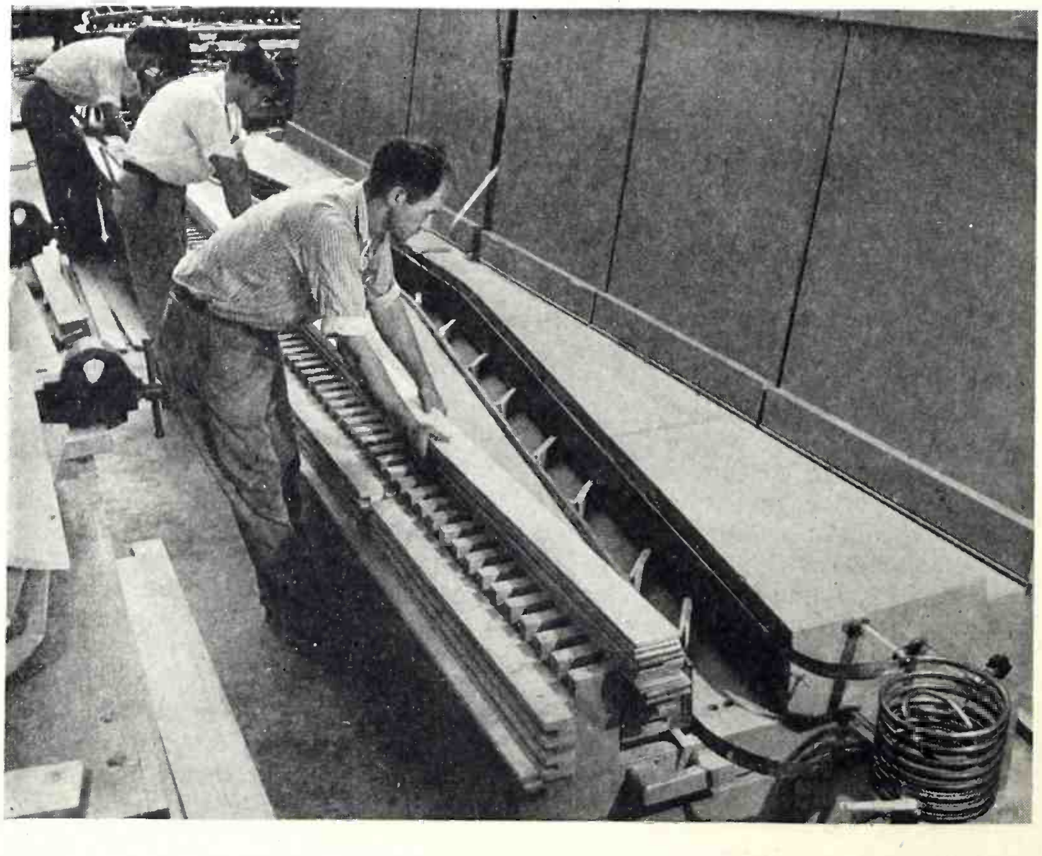
Naturally the frequency cannot be reduced below the point where the voltage required would arc between electrodes. With small pieces, such as cap strips for ribs and bulkheads, there is no problem of uniform heating.

Another item which must be considered in any application of high frequency heating to wood, is power factor. Materials containing water, such as wood at high moisture content or wet formaldehyde glues, generate more heat from the passage of a high frequency current than dry materials. For this reason, with a given power, the time required is less with wet glues than with dry glues. If a wet glue line can be placed at right angles to the electrodes there is a concentration of current in the glue line and the relative heating effect in the glue line as compared to that in the wood is further increased. With this arrangement voltages as low as 200 volts at 5 megacycles are used with glue lines 1 inch wide.

Most bonding agents, like casein glues or cold or warm setting adhesives have a fairly short allowable time between applying the glue and getting the glued part under pressure.

(*Continued on page* 38)

Fig. 2. Shows assembly detail in processing spar flanges. Note heating coil and copper strips.



GUTHMAN *Inductronics**

INDUCTORS AND ELECTRONICS

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PRECISION MANUFACTURERS AND ENGINEERS OF RADIO AND ELECTRICAL EQUIPMENT

Industrial Review

New Developments

AT A RECENT meeting held in New York, the Westinghouse Electric and Mfg. Company demonstrated laboratory models of what may be post-war illumination for homes, factories and public buildings.

Lamps, unconnected to any wires, and lighted by high-frequency radio beams, generated by a diathermy set, were shown.

Fluorescent lamps in new shapes and sizes were also exhibited. It is now no longer necessary to confine this shadowless and cool light in tubular forms because it has been found possible to make fluorescent lamps in circular and spiral shapes. This innovation was possible because of a new and better understanding of the physical properties of glass tubing.

The common phosphors used to coat the inside of fluorescent lamps, are also aiding in the war effort. Fabrics impregnated with them line parachute cases so that a pilot downed at sea or in the jungle may be spotted by rescue craft; miles of phosphor-coated cloth tape provide luminous markings on invasion beaches while phosphor-coated controls glow on submarines and luminous signs mark escape hatches of merchant ships.

Further improvement in incandescent lamps for heavy duty in ship yards and on aircraft carriers and other places where a shatterproof bulb is necessary was demonstrated at this same meeting. Developed as an answer to the accident hazard produced by shattering bulbs broken by welding sparks, this lamp utilizes a coating of special lacquer as a "jacket" and contains a sturdy filament which adds to its shock resistance. While the lamp may be broken, it will not shatter. This feature makes it of particular value aboard aircraft carriers below decks where bulbs often were broken by the shock of landing aircraft on the flight deck.

An all-glass lamp used as a sealed beam landing light for army bombers was also shown to the audience. This lamp may be converted to a heater unit by removing its light filament and replacing it with a special high-resistance element which will produce 95% heat and only 5% light. This is the type of filament used in the infra-red or radiant heat lamps now being used to dry paint in three minutes. The post-war uses of this element in homes and public buildings is practically unlimited as the lamp may be screwed into an ordinary socket and will produce heat where and as it is needed.

All of these developments described in this item are the product of Westinghouse research and while many of the pieces of equipment are not available to the public as yet, it is the desire of Westinghouse to have them ready for post-war building and remodeling.

* * *

Synthetic Insulation

AN increased use of plastics and synthetics in place of natural rubber as insulation for electrical wires, cables and cordage is forecast by Mr. H. W. Clough of the Belden Manufacturing Company of Chicago, Illinois.

Faced with a serious shortage of rubber, Belden's research laboratory adapted plastics to the job of insulating wires, thus effecting a saving of rubber amounting to 95% of the pre-Pearl Harbor requirements for natural rubber, which amounted to over 1,500,000 pounds.

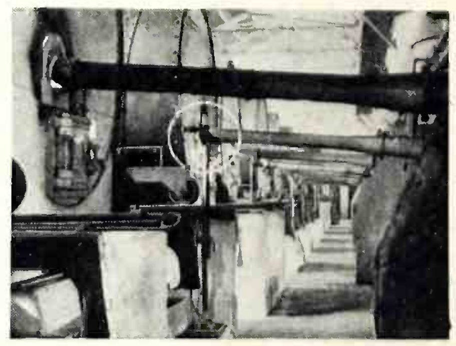
In many applications, the new plastics and synthetics are superior to natural rubber, in others they are equally efficient. Resistance to acids and oils, ability to withstand high and low temperatures, and extreme flexibility were listed among their favorable characteristics. Considering these desirable qualities, the cost compares favorably with that of natural rubber and its widespread use after the war is expected. This insulation will be available in a variety of colors after the war.

Photoelectric Pyrometer

THE photoelectric pyrometer is a radiant-energy-responsive device for indicating or recording the temperature of incandescent bodies. This instrument, a product of General Electric Company of Schenectady, New York, is being widely used as a temperature control as well as a recording device for kilns and furnaces.

The phototube mounted near the material to be measured, is focused on the clinker or molten metal. This phototube is then connected either to control devices or to a chart recording instrument, or both.

The relationship of temperature to energy radiation (Wein's Law) is utilized in the operation of the pyrometer. In the pyrometer a vacuum-type phototube with a caesium-



oxygen-silver cathode is employed. While it is far less sensitive than the gas-filled phototube, it is much more stable in its sensitivity and is not appreciably affected by voltage variations. Data taken on a number of vacuum-type phototubes indicate that variations in sensitivity over a period of 1000 hours are around ten percent and that these variations are relatively slow. A ten percent variation in phototube response corresponds to a small error in temperature.

High amplication of the minute phototube is obtained by using a pentode amplifier tube. The phototube circuit and the amplifier circuit are supplied with direct current from a small rectifier and filter included with the equipment. The amplifier-tube grid voltage is determined by the phototube current and by the position of the bias adjustment potentiometer. The anode current passes through a resistor which is in series with the indicating or recording instrument.

Since voltage variations would affect the accuracy of the equipment to a serious degree, it is necessary to incorporate means for maintaining the voltage constant. For this purpose a voltage regulator tube is employed. This is a two-element gas-filled tube which is connected with a series resistor across the filtered d-c output of the rectifier tube. Since the tube has a substantially constant arc drop,

(*Continued on page* 36)

NEWS BRIEFS

FIVE R.T.P.B. COMMITTEES NAMED

In a recent release by Mr. W. R. G. Baker of General Electric Company and chairman of the Radio Technical Planning Board, the names of the men who will serve on five of the thirteen committees was announced.

At the same time Mr. Baker also announced the appointment of Dr. Alfred N. Goldsmith to the post of vice-chairman of the board. He will also serve in the capacity of chairman of Panel No. 1 on Spectrum Utilization.

Lists of the committees will be released as soon as the appointments are made public.

In the following (M) designates member, (A) alternate, (O) observer.

PANEL NO. 1—SPECTRUM UTILIZATION

Dr. A. N. Goldsmith, Chairman, 580 Fifth Avenue, New York
Dr. R. H. Manson, Vice-Chairman, Stromberg-Carlson Co., Rochester
George Grammer (M), ARRL, West Hartford, Conn.
K. B. Warner (A), ARRL, West Hartford, Conn.
A. C. Peterson (M), Bell Telephone Labs., 436 West Street, New York
W. G. Richardson (M), Canadian Broadcasting Corp., Montreal
E. K. Cohan (M), CBS, 485 Madison Avenue, New York
W. B. Lodge (A), CBS, 485 Madison Avenue, New York
P. C. Goldmark (M), CBS, New York
Robert Serrell (A), CBS, 485 Madison Avenue, New York

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Lt. Col. A. G. Simson (M), War Department, Pentagon Building, Arlington, Va.
C. J. Burnside (M), Westinghouse Elec. & Mfg. Co., Baltimore
R. N. Harmon (A), Westinghouse Elec. & Mfg. Co., Baltimore

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Dr. A. N. Goldsmith (M), 580 Fifth Avenue, New York
G. E. Gustafson (M), Zenith Radio Corp., 6001 Dickens Avenue, Chicago
Frank Gunther (M), Radio Engineering Lab., Inc., 35-54 36th Street, Long Island City 1, N. Y.
Dr. D. E. Noble (A), Galvin Corp., 4545 Augusta Boulevard, Chicago
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William B. Lodge (M), CBS, 485 Madison Avenue, New York
Walter Merkle (M), Television Engineering Dept., Philco Corp., Philadelphia
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K. B. Warner (M), ARRL, West Hartford, Conn.
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N. P. Case (O), Hamilton Radio Corp., 510 6th Avenue, New York
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John H. Barron (M), Earle Building, Washington
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(*Continued on page 39*)

Ant. Performance

(*Continued from page 8*)

so that the network may be only a single 0.003 mfd. condenser across the transmission line. No blocking condenser is absolutely necessary in series with this antenna as series condensers are provided in the phase shifter to the transmission line.

The coupling network for antenna No. 3 is computed in a similar manner using equations (11), (12) and (13) and allowing a phase shift of 80 degrees. This network must match 300 ohms to 44.9 + j 51.0 ohms. The shunt arm as given by equation (13) is:

$$X_3 = -\frac{\sqrt{300 \cdot 44.9}}{\sin 80} = -118 \text{ ohms}$$

A capacity of 0.001053 mfd. corresponds to a reactance of 118 ohms at 1280 kc. which means that a 0.001 mfd. condenser may be used.

The reactance of the input arm of this circuit is given by equation (11) and is:

$$X_1 = -\frac{300 \cos 80 - \sqrt{300 \cdot 44.9}}{\sin 80}$$
$$= 112.7 \text{ ohms}$$

A coil having an inductive reactance of 112.7 ohms at 1280 kc. is a good sized coil.

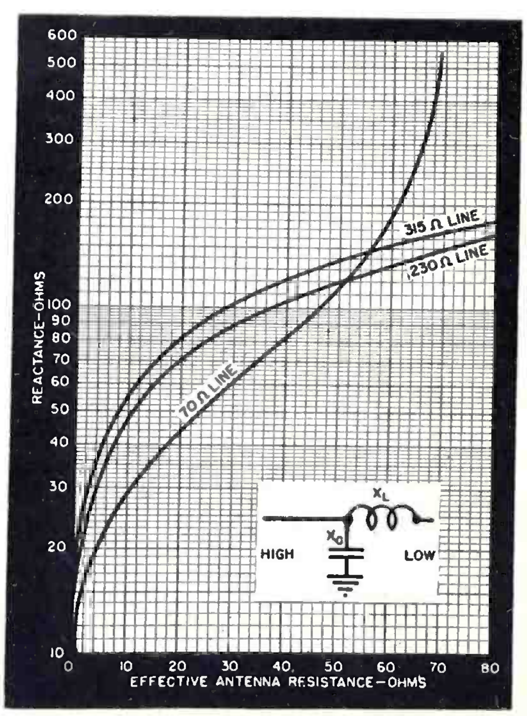
Now the output arm of this network as given by equation (12) is:

$$X_2 = -\frac{44.9 \cos 80 - \sqrt{300 \cdot 44.9}}{\sin 80}$$
$$= 110.7 \text{ ohms}$$

There will, however, be an inductive reactance of 51 ohms present due to the antenna impedance as well as a capacitive reactance of 12.4 ohms due to a locking condenser of 0.01 mfd. The actual coil required should therefore provide an inductive reactance of 10.7 — 51 + 12.4 or 72.1 ohms.

In order to test the coupling networks, dummy antennas must be used

Fig. 8. Graph of shunt arm for "L" network.



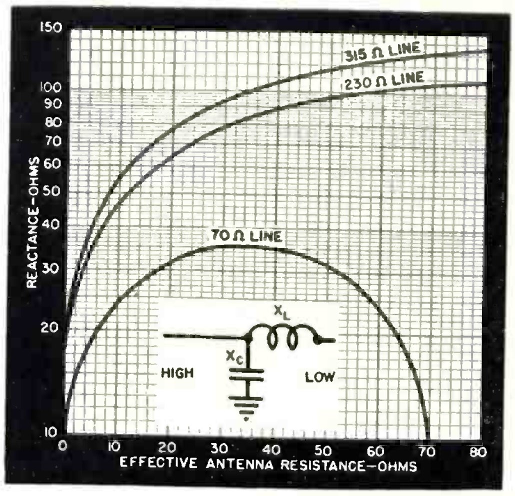


Fig. 9. Graph of series arm for "L" network.

having the correct impedances to correspond with those of antennas No. 1, 2 and 3.

The phase shifting networks, which should be connected at the sending end of each transmission line are to match 300 ohms and shift the phase by 107.5 degrees for line No. 1 and —105 degrees for line No. 3 and +104 degrees for line No. 2. By applying equations (11), (12) and (13) and realizing Z_0 and R are equal to 300, the specifications for the phase shifting networks reduce to the following:

1. For lines No. 1 and No. 3 the shunt arm is a capacitive reactance of 313 ohms while the input and output arms have an inductive reactance of 400 ohms.
2. For line No. 2, the shunt arm is an inductive reactance of 309 ohms while the input and output reactances are capacitive and equal to 384 ohms.

The phase shifting networks should be checked experimentally and adjusted to provide resistance of 300 ohms when terminated by a non-inductive resistance of 300 ohms.

The group of curves accompanying this article provide a graphical method of solving certain network problems and may be used as a guide for checking the results of similar calculations. It is obviously impractical to prepare a set of curves which will include all possible conditions as there are an infinite number of solutions to the problem.

After checking the coupling and phase-shifting networks, it is necessary to make a preliminary test on the complete system by applying low power to the array. The power should be increased gradually and observing carefully for overheating of coils and condensers.

Note that the currents in antennas No. 1 and 3 are almost in phase and that the current is approximately the same. These two antennas together without antenna No. 2 would produce a radiation pattern resembling the figure eight. The minimum on the north side would be located along A_1 23 degrees and A_2 357 degrees with the specified phase angle difference of 2.5 degrees. The formula for the determination of this pattern is:

$$e = E \left[\cos \left(\frac{\theta}{2} - \frac{d}{2} \cos \phi \right) \right]$$

where:

e = field intensity along the radial
θ = relative phase angle
d = spacing of antenna measured in terms of an angle
ϕ = angle measured from line of towers and determines direction of radial
E = maximum field intensity

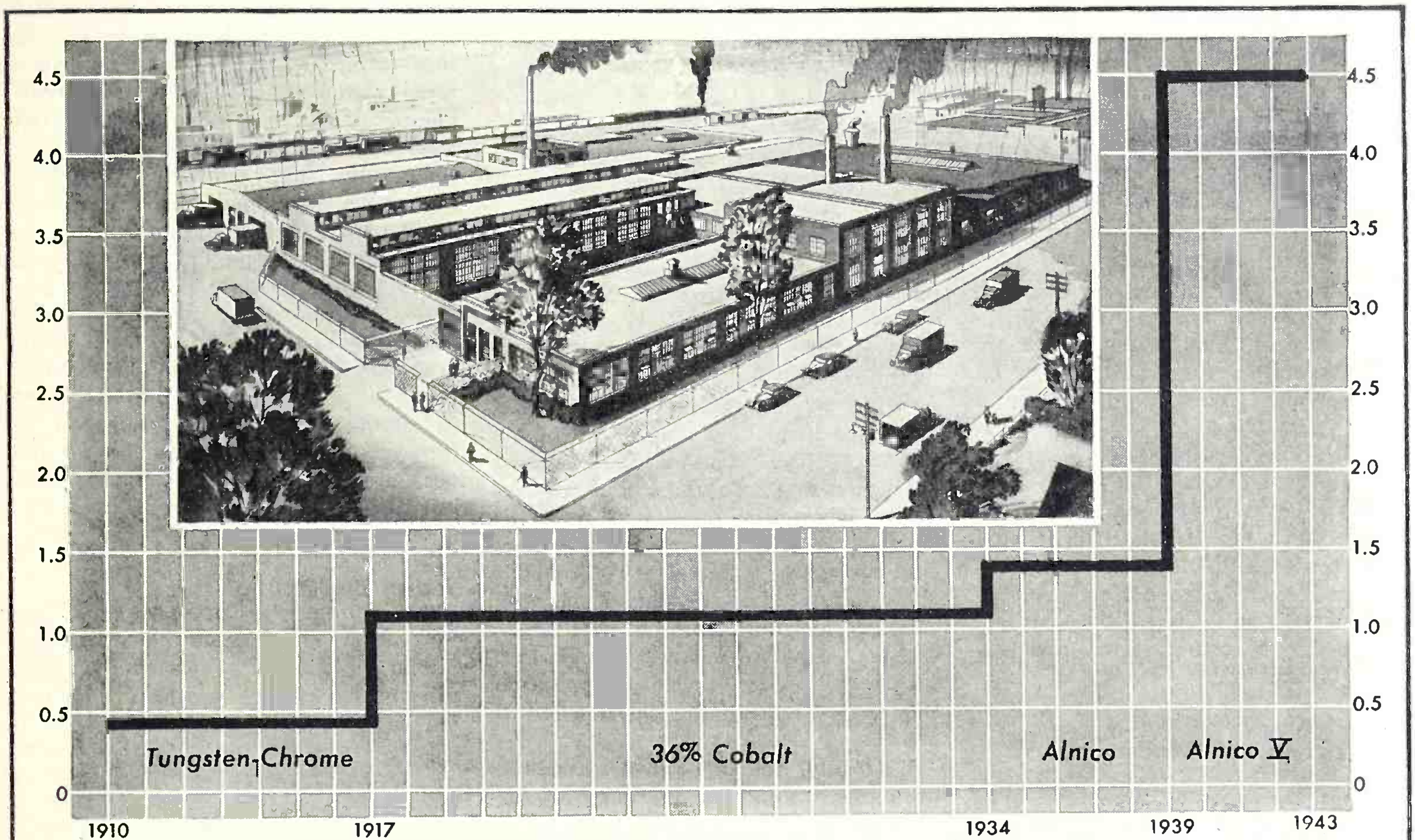
In order to check the field intensity, it is desirable to establish a remote monitoring station about 3 miles distant from the antennas on the radial directed with A_1 23 degrees. The resulting measurement may then be telephoned to the transmitter station while final adjustments are being made. The power division may be accomplished by changing taps on an autotransformer. This produces some unknown phase shift which has to be corrected with the aid of the phase-shifting networks. All phase shifting should be accomplished at such networks rather than at the antennas, unless the transmission line currents are badly out of balance. The autotransformer should be matched to the transmitter by using an "L" matching network. It is at this part of the system that the power should be determined by direct measurement using a resistance of 92.5 percent of the measured value at 1280 kc. for a 5 kw. output or a power of 5.4 kw. using 100 percent of the measured value as required by the FCC.

After the above adjustments and measurements are made, special permission from the FCC should be obtained in order to measure the field intensity using a power input of 5.4 kw. The measurements should be made during the day and included arc measurements across the minimum located at 241 degrees.

The required monitor spots are shown in table 1 and are located between 3 and 4 miles from the transmitter.

In order to have the modified system approved by the FCC, it is necessary to submit completed forms 302, 306 and 335 in triplicate including manufacturer's name, type number and full scale reading of each antenna ammeter and common input ammeter. The forms should be accompanied by a complete diagram of final layout including phase network and antenna-network systems, arrangement of lighting choke coils and a description of the r-f power transmission lines as well as the phase monitor sampling lines. This information is required by the FCC.

PERMANENT MAGNETS MAY DO IT BETTER



INCREASE OF MAGNETIC ENERGY OUTPUT SINCE 1910

GOING UP . . . . THROUGH DEVELOPMENT!

THIS CHART shows the increase in permanent magnet energy due to metallurgical research during the past 33 years.

From 1910's conventional horseshoe magnets to today's intricate rotor magnets, we've constantly developed new shapes and new applications from these new metals. And doing this one job especially well has made possible countless new products, including some of the war's most complicated devices.

If you are planning war or post-war products, we'd like to suggest that you consider incorporating the principle of the permanent magnet—and that you utilize the services of the largest exclusive maker in this field. Chances are that permanent magnets will improve the functions and increase the uses of your products, and they may even bring to light possibilities that you hadn't thought of before.

Though our plant is devoted entirely to war orders, our engineers will be glad to consult with you. Write for the address of our office nearest you and a copy of our 30-page "Permanent Magnet Manual."

Two Ways to Back the Attack: Buy More War Bonds and Increase Production!

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★ SPECIALISTS IN PERMANENT MAGNETS SINCE 1910 ★

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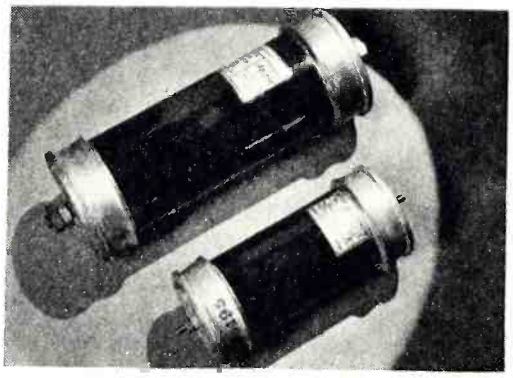
NEW PRODUCTS

NEW CAPACITORS

For high voltage d-c applications where space is limited, new solder-sealed porcelain-clad type FPC Inerteen Capacitors are announced by Westinghouse Electric and Manufacturing Company.

From 7,500 volts up to and including 200,000 volt class, the capacitor elements are hermetically-sealed in a tubular, wet-process porcelain body with solder sealed end closures. The end closures act as the capacitor terminal by connecting the element leads at opposite ends, utilizing the porcelain tube as insulation.



By eliminating the large metal case and bushings required by metal case capacitors, the new porcelain-clad capacitors help maintain minimum over-all dimensions. Larger types are furnished with or without case mounting flanges. Where castings are used, the capacitors are solder-sealed, then castings are cemented on with mineral-lead compound.

Additional information on type FPC Capacitors may be secured from Dept. 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna.

TISSUE THIN STEEL

Tiny, tightly wound coils of paper-thin steel have a big place in this war. In fact, according to Westinghouse engineers, without the development that led to super-thin transformer steels some of the radio-detecting devices of great military importance would not be possible, because insufficient power would be available.

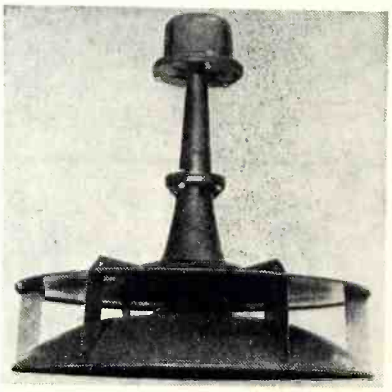
Just a few months before the attack on Pearl Harbor, Westinghouse research and transformer engineers announced a new kind of cold-rolled silicon-steel, called Hipersil, in which the grains are oriented or aligned in one predominant direction. This grain orientation results in a much higher permeability at high transformer inductions. Also, with this steel it is possible to make transformer cores by an entirely new and much faster method. The old method utilized punched laminations laboriously stacked by hand. Now, ribbons of Hipersil are wound into a core shape that resembles a flattened roll of adding-machine tape. This steel and core construction had been used with great success in power and distribution transformers. In this role it increased the output obtainable from a given amount of material.

With the advent of war and the need for radio and communication sets—tens of thousands of them, scores of new types were created by radio engineers. Some had to operate on 400 and 800 cycle power supplies while others utilized or delivered frequencies far higher than had been dreamed of a few years ago. Transformers losses and heating effects increase enormously as frequencies go up. To keep these losses within acceptable limits the transformer-core laminations must become thinner. Conventional Hipersil cores before the war were 29 gauge—about fourteen mils (0.014 inch) thick. Rolling-mill, transformer, and metallurgical engineers immediately tackled and solved the problem of producing 7-mil Hipersil cores to meet the new war demand. This permitted a reduction of one-third to one-half in the space and weight requirements for choke coils, reactors, and transformers. Weight and size are important indeed where radio sets carried by planes or men are involved during actual combat duty.

But that achievement was still not enough. To obtain satisfactory outputs at extra high frequencies, the laminations had to be thinner. After much research and development work, engineers can now produce steel two mils thick. Entirely new rolling-mill techniques and annealing practices had to be developed. This ultra-thin transformer steel (half as thick as ordinary magazine paper) has made today's highly efficient apparatus possible. Cores are used which weigh from one-fifth of an ounce up to seven pounds. The technique of winding these cores from a continuous ribbon of steel (instead of thousands of flimsy L- or E-shaped punchings) not only made the applications possible but also saved thousands of war-production man hours.

SOUND DISTRIBUTOR

The Langevin Company, Inc. has just announced a new type of Annular Sound Distributor, Type L-360. This distributor utilizes a different principle of sound distribution in that it



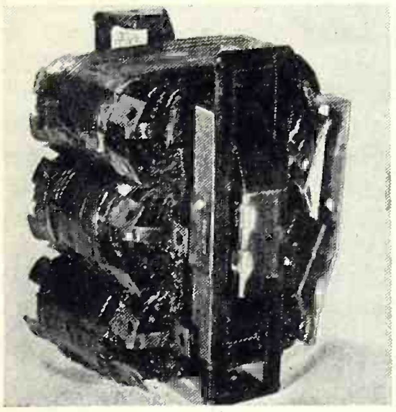
combines molecular reflection and collision instead of collision alone as in other speakers. The use of this principle results in a uniformity of sound distribution both as to frequency and power over a horizontal plane of 360 degees and a vertical plane of approximately 40 degrees.

The Type L-360 Distributor is 23″ in diameter with an over-all height of 25″. It will safely handle power imput of 20 watts when equipped with Jensen U-20 Drive Unit. Further information on this sound distributor may be obtained by writing direct to the Langevin Co., 37 West 65th Street, New York, N. Y.

MIDGET TRANSFORMER

Small and light, a tiny transformer about five inches wide and weighing but 25 pounds has been developed by Westinghouse. The ordinary single-phase, 37½-Kva transformer weighs 680 pounds, while one with a Hipersil core weighs 430 pounds. According to Westinghouse engineers, the most important factor in the creation of this midget is the frequency, 400 cycles.

Having a rating of 250/30-volts, the transformer is a member of a whole new family 400 cycle electrical devices that were brought into being for a-c systems on aircraft. This transformer uses class-B insulation, is air-cooled, and could be lighter in weight, except for the fact that a compromise is desirable between losses and weight.



Another group of 400-cycle transformers displays even more startling weight savings. A 7½-Kva, three-phase, 208-190/21-26.5-volt transformer weighs but nine and a third pounds. It is forced air-cooled, and has a regulating winding by which the secondary voltage is maintained constant over a 30 percent range. By added control equipment, constant d-c voltage can be maintained, compensating for voltage drop in the rectifier, transformer, and supply circuit. Cores are made of new thin-gauge Hipersil steel which provides low losses and lighter weight at this higher frequency. The three-phase core is wound in a novel manner. Two small cores are wound first. Then a third core is wound around these first two, giving the necessary core-type transformer having two windows and three legs for the three-phase windings.

A family of 400-cycle, self-cooled auto-transformers is correspondingly small. A five-kva, 120/30-volt unit weighs eight pounds, while a one-kva version weighs 2½ pounds. Both are capable of operation at 200 degrees C temperature rise. Another 1500-watt, 180/110-volt auto-transformer (with air blast) weighs slightly less than a pound. Thin-gauge Hipersil makes a major contribution to the light weight of all these aircraft designs.

CENTRAL STATION

Modern war is responsible for the design of a complete 5000-kw central station, completely assembled to make a railroad train of eight cars. This power train is suitable for use in almost any part of the world. It has been designed to use coal of unusually low quality. It is suitable for arid or devastated regions where water may be so scarce it would have to be de-

(*Continued on page* 32)

livered in tank cars. It will work where temperatures range from 110 degrees above to 40 degrees below zero F. According to Westinghouse engineers, this rolling power plant can be hauled by a locomotive to any spot where railway tracks exist—in about 48 hours it can be made ready to deliver power.

In wartime such power trains can follow victorious armies into recaptured areas to rehabilitate local industry. Conversely, it can be removed from areas about to fall into the hands of an advancing enemy. In peacetime the trains can furnish power for flooded plants and for other similar emergencies.

The first two cars carry the air-cooled condensers while third car carries the turbine generator with switchgear equipment. Number four and five cars take care of auxiliary equipment and water storage. The water storage supply will run the train, under most severe conditions, for more than a full day without replenishment. Number six and seven cars are for the boilers while car number eight provides quarters for the crew and storage for lubricating oils, spare parts, etc.

The two boilers produce steam at 600 pounds gage, 750 degrees F from available coals—even lignite, having a heat content of only 7000 Btu per pound will work satisfactory. Boilers are of water-tube, double-drum construction, have both forced and induced draft fans and have air-operated locomotive-type stokers. The single turbine-generator unit delivers to the bus 6250 kva at 80 percent power factor, 6300 volts. Power is delivered to a six-cubicle, metal-clad switchgear for distribution. Because intake ventilating air may be dusty or dirty, the generator is provided with a self-cleaning air filter. A Diesel-driven generator provides 75 kw capacity for plant and auxiliary purposes.

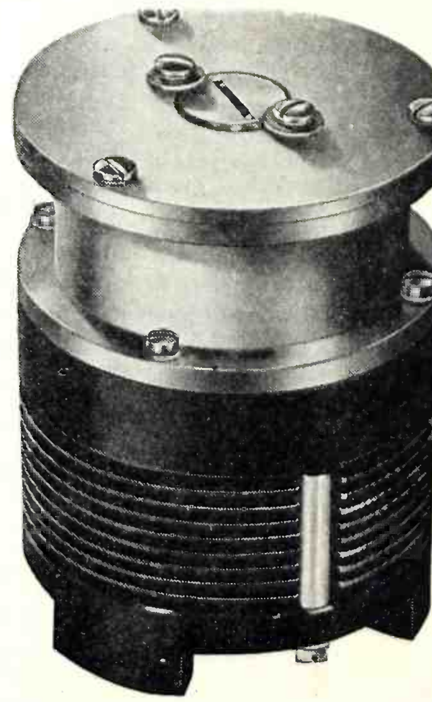
In many places where such a rolling power unit is needed, cooling or boiler water may be virtually nonexistent or may be of poor quality. To meet this condition the condenser is air cooled and the condensed steam is reused. Four motordriven propeller fans draw air over eight coolers in each of the condenser cars. Even with cooling air at 95 degrees F the condensers are able to condense the full amount of steam; the condensed water is then pumped back into the feed-water tank car. By this method it is expected that less than three percent make-up water will be required. All make-up water is filtered, softened, and evaporated in the auxiliary car.

Placing a modern 5000-kw plant into a train of eight cars presented scores of engineering problems. The trucks were designed specially rigid so that no torsional movement of the frame in transit can rupture pipe connections. All apparatus — meters, shafts and gauges —are braced so as not to be injured by a sudden stop of the train. Pipe and electrical circuits between cars are disconnected while the train is en route. This necessitates having some means of aligning the cars preparatory to going into service. Because of the tight fit in the turbine-generator car, the sides are removable to give access to the generating unit should dismantling be necessary. Therefore, supports for a crane, overhead piping and conduit are all built up independently from the floor. Many problems of unequal expansion had to be solved since the train must operate in air whose temperature varies over a wide range.

VOLTAGE REGULATORS

Data on a new, high-wattage voltage regulator has just been released by Webster Products, 3825 W. Armitage Ave., Chicago 47, Ill. Known as the VR-2200 Series, these carbon pile voltage regulators were developed of air-borne applications by Webster Products. They dissipate 300 to 400% more power than previous conventional designs, yet occupy the same chassis space, with 8% less cubic volume, only 6% heavier.

Many different applications are possible. In one, the resistance of the carbon pile is in one side of the line and the regulator operates to vary this resistance automatically so as to produce constant voltage across the load. In another typical application, the voltage regulator varies the field



excitation of an inverter, alternator or special dynamotor in such a manner as to produce constant output voltage across the load. Where the machine is delivering a-c, a rectifier may be provided.

The VR-2200 Series units will handle 100 watts in the pile with an air flow through the fins of approximately 25 cubic feet per minute, and up to 50-75 watts without air blast. Piles can be provided with a resistance range of the order of 20 to 1.

SQUARE WAVE GENERATORS

The newly organized Reiner Electronics Company of New York announces the development and production of a low-priced square wave gen-

(*Continued on page* 38)

Multiple Converter

(*Continued from page* 20)

nal passing through the unit, an accurate readjustment of the dial on the receiver is possible. Then by readjusting the trimmer condensers on the r-f and i-f transformers, one channel of the converter unit is properly tuned. The dial setting of the receiver corresponds to the intermediate frequency of the converter unit. If this setting is to remain fixed for each channel, the local oscillator crystals will have to be ground very accurately to the required frequency.

If the crystal controlled oscillator is not available, an electron coupled oscillator will be a fairly good substitute. A representative electron coupled oscillator circuit is shown in Fig. 5. To obtain satisfactory stability for this oscillator circuit, a high capacity circuit was produced by connecting a 100 to 300 mmfd. condenser across the trimmer condenser. The formula for the frequency of the oscillator is:

$f_o = f_s + f_i$

Where:

f_o = oscillator frequency

f_s = signal frequency

f_i = intermediate frequency

The tuning procedure for the unit with the electron-coupled oscillator is slightly different from that used with the crystal controlled unit. After the output transformer has been peaked, a strong signal of a frequency within the reception band should be fed into the grid of the 6SK7 r-f tube, and the oscillator trimmer adjusted until the signal is heard. The remainder of the procedure is the same, except that the oscillator trimmer should be adjusted instead of the receiver dial when a test signal is received from a network station.

The power supply for the converter unit should be capable of delivering 250 volts d.c. with a current of 15 ma. for each channel. The corresponding heater supply should be able to supply 1 ampere at a voltage of 6.3 volts for each channel.

The Multiple Converter is not limited to four channels but may be constructed to accommodate five, six or ten channel units. For a police installation, for instance, nine channels might be provided, one for each of the six working frequencies and one for each of the three calling frequencies. A two or three channel unit with a six volt power supply and a standard automobile receiver as an intermediate unit would make a very satisfactory aircraft receiver. In fact, any service which must monitor two or more frequencies simultaneously either fixed or mobile, will find the Multiple Converter principle very useful.

★ ★ ★ ★ TECHNICAL BOOKS ★ ★ ★ ★

"THE RADIO HANDBOOK, NINTH EDITION," by Editors and Engineers. Published, 1942, by *Editors and Engineers,* 1422 North Highland Avenue, Los Angeles, California. 640 pages. Price $2.00.

This book is written for the serious radio technician and presents theory, design and construction of radio circuits.

The introductory chapter reviews the activities and services of the amateur together with hints for the study of radio code. The first chapter is followed by several chapters which present the fundamentals of electrical and radio circuits.

The three chapters on radio receiver theory, receiving tube characteristics and receiver construction include detailed explanations of design, operation and construction. The chapter on receiver theory includes an analysis of detection by first presenting the fundamental principles and then applying them to practical examples, such as the autodyne, grid-leak detector and the diode detector.

A discussion of the superheterodyne receiver, including methods of aligning and testing, covers fifteen pages. The comparison of various mixer-oscillator combinations is very valuable and also illustrates the important methods of producing the heterodyning action with the use of one and two triode, tetrode and pentode combinations. The chapter on receiving tube characteristics is very complete with a supplementary explanation of the meaning of some of the letters used in vacuum tube designations. In addition to the characteristics of the individual tube types, there is a portion of this chapter which gives the layout of the receiving tube socket connections as well as those for the cathode-ray tube socket.

In order to utilize the material given in the chapters on receiver theory and tube characteristics, there is a chapter devoted to receiver construction. Many useful circuit diagrams and parts lists are given for two, three and five tube receivers. Supplementary data generally accompanies the circuit diagram which gives the dimensions and number of turns required for ten, twenty, forty and eighty meter bands.

The chapters on radio transmitters parallels the general presentation on radio receivers by discussing theory and design of the component parts before attempting construction of the entire transmitter. Such component parts include oscillators, crystal controlled oscillators, class "A," "B" and "C" r-f amplifiers, frequency multipliers, neutralized amplifiers, tank circuit design, grid-bias circuits, inter-stage-coupling methods, keying circuit, suppression of parasitics, etc.

The chapters dealing with radiotelephony include discussions and circuits relating to amplitude modulation with grid, cathode and plate modulated circuits. Other circuit elements include microphones, speech amplifiers, and inverse feedback systems both for audio amplifiers and for entire transmitters. The subject of amplitude modulation is followed by a section on frequency modulation which includes the reactance tube modulator as well as phase modulated circuits.

The chapter on transmitting tubes lists characteristics of many tubes and their corresponding socket connections.

The sections dealing with transmitter design and construction include constructional layouts for filament and plate power supplies, as well as for low power exciter units and medium and high power r-f amplifiers. Of the numerous r-f power amplifiers, one is of particular interest since it is arranged in an unconventional chassis layout, thereby providing extremely short r-f leads. This unit uses two TW-150 tubes in push-pull and may be mounted on a standard 19 inch rack panel.

Following the chapters on modulation amplifiers is a series of chapters on ultra-high-frequency circuits including receivers and transceivers for operation on the 1, 1¼ and 2½ meter bands and one circuit using the 825 tube as a 500 megacycle amplifier.

The final chapters explain the phenomena involved in the transmission of radio waves through the ionized layers of the ionosphere and their radiation from various types of antennas both from single antennas and from directive antenna arrays. Transmitter adjustment as well as test and measuring equipment provide a very practical section of the book for those interested primarily in maintenance and operation of transmitter equipment.

This book should provide an excellent reference for those experienced in receiver and transmitter performance in order to obtain suggestions and hints for practical arrangements.

"TIME BASES," by O. S. Puckle. Published, 1943, by *John Wiley and Sons, Inc.,* New York. 204 pages. Price $2.75.

This book analyzes the important electronic devices which are available for producing the time axis in television receivers, cathode-ray oscillographs, engine indicators and similar apparatus involving precise timing or the measurement of time intervals.

The time base is being put to new uses daily, and it is very likely that it will have greater importance in the future. However, some of the most useful devices in this field were invented more than twenty years ago although they were almost unknown to the majority of electronic engineers. With the advent of the cathode-ray tube and its subsequent development new opportunities for its exploitation were presented to the engineer. Within a few years, interest in time bases, trigger circuits and relaxation oscillators has grown rapidly and inventors have produced many new circuits and modifications of existing ones with the result that their historical background has been somewhat obscured.

It is quite possible that the circuit arrangements which are popular today may become obsolete almost overnight, but the fundamental principles of the technique are well established and anyone who masters these fundamentals will have no difficulty in understanding new developments as they may arise.

With this in mind, the author has attempted to provide an introduction to the principles, rather than a comprehensive discussion of inventions, and has further enhanced the value of the work by including a discussion of the historical aspects of the work accomplished. Long-forgotten devices which never have been successfully applied often become extremely valuable when improvements in other fields make their utilization practical. Every engineer should make a point of learning something of what has been attempted in the past.

In order to obtain a knowledge of time bases and to apply that knowledge to a particular purpose or to develop new methods, a study of the effects of the time constants and other vacuum tube and circuit parameters is essential. These subjects are discussed in this book together with a short account of the cathode-ray tube and its application in providing time bases. In addition to a study of linear time bases, the author introduces polar coordinate as well as spiral time bases. The study of pulse generators naturally leads to the multivibrator and trigger circuits with special components as the differentiating and integrating circuits.

X-Rays in Aviation
(*Continued from page* 17)

more than a billion dollars in claims and hospitalization.

During the last war, an X-ray chest examination of inductees was not a routine procedure, with the result that thousands of draftees with unrecognized latent lesions filtered into the ranks. Many of these men later developed active and disabling cases of tuberculosis, with the result that they became a financial burden to the government at an estimated cost of from $10,000 to $15,000 per man.

The Army now has several hundred units operating at induction stations throughout the country, eight units being used in the Grand Central Terminal Building in New York. Four such X-ray machines are used in the Army Recruiting and Induction Station in Chicago where more than 1,400 double (stereoscopic) exposures are made daily.

Here is how the Photo-Roentgen unit operates. In conventional X-ray procedure, the X-rays pass through the patient's chest, throwing the image directly upon a photographic film. The film, usually 14 x 17 inches, must be the size of the chest because it is not possible to focus X-rays by means of lenses. The Photo-Roentgen device makes use of the customary type of X-ray apparatus to throw the image of the chest on a standard size fluorescent screen. A powerful camera, equipped with an extremely fast lens, equivalent in size to that used in a six-inch astronomical telescope, is then used to photograph the image on the fluorescent screen. With the aid of this lens the image of the chest is photographed upon a supersensitive film 4 x 5 inches in size.

A further saving is made in the developing of these films, both in time and chemical solutions used. Considering the problem of making such X-rays for a large number of persons and the subsequent filing of such records, this innovation represents a real dollars and cents saving to the government. Since this induction record is maintained in the inductee's file, and is further supplemented by similar chest X-rays upon his release from service, the government is protected against future unwarranted claims for compensation.

Peacetime uses for this simplified technique are unlimited, as it will become possible for such equipment to be installed in trailers, and transported to rural areas and sections of heavily populated areas where the need for tuberculosis control is great but the facilities are lacking. The need for the early diagnosis of tuberculosis is well known and it should not be necessary to enlarge on the subject further in view of the wide spread publicity given to the importance of preventive care.

Medical science has made many strides since Dr. William D. Coolidge first developed the Coolidge hot-cathode X-ray tube, which is the basis of the modern X-ray practice.

By radiography, physicians and surgeons may examine the skull, bones of the hand, the spine and chest, while by fluoroscopy they study the internal organs in function.

One of the mightiest weapons against cancer and deep-seated malignancies is the giant 1,000,000 volt X-ray unit such as used at St. John's Hospital, Cleveland, Ohio, Mercy Hospital, New York City and the State Institution for the Study of Malignant Diseases at Buffalo, New York. This unit is shown in Fig. 3.

In the war against heart disease, an electronic instrument, the electrocardiograph, detects and amplifies electric currents generated by heart actions and records these variations on photographic paper. From this record, the physician may learn much about the heart's condition. This instrument, which employs vacuum tubes to amplify the minute electrical impulses of the heart, is likewise contributing importantly to war medicine.

In one series of tests, for example, electrocardiograms of air pilots were made at levels up to 20,000 feet in order that the effect on the heart due to anoxia might be studied. Significant changes noted in these electrocardiograms were the basis of resulting suggestions as to the minimum level at which oxygen should be used.

With the electron microscope, newest electronic instrument to come to the aid of medical science, physicians can look at typhoid or anthrax germs in structural form. Thus it may be possible that science will be able to reveal the life processes of these germs and the battle against the disease will have received a new impetus.

The contributions of the electronic engineer to the field of medical research and diagnosis are increasing yearly while new applications for old equipment are being made daily. This unanimity of purpose on the part of great scientists, each working in his own field, will bring new health standards to the people of the world and freedom from debilitating diseases.

Personals

J. W. BRYANT, who was formerly associated with the Radio Division of the Missouri State Highway Patrol has recently joined the Electronics Staff of General Electric's Chicago Office. He will assist users of emergency communications equipment in the selection and installation of equipment for their needs. His experience in the actual building and operation of short-wave station equipment will be invaluable in his new position.

FRANK M. FOLSOM, until recently, served as Chief of Navy Procurement, but has resigned that post to accept the position of Vice-President and Director of RCA according to an announcement made by David Sarnoff, President of RCA. Mr. Folsom will be in charge of the company's manufacturing division, RCA Victor, which maintains plants in six cities. Since RCA Victor is geared to 100% War Production his appointment is of interest.

JERRY KANE has resigned his position with the Turner Company's Research Department to accept the post of electro-acoustic engineer at Universal Microphone Co. of Inglewood, California. His duties will include microphone design in the current war microphone production as well as design problems for postwar production. An extensive program along this line is under way at the Universal Company's Inglewood plant.

TED POCKRANDT'S new position with Universal Microphone Company of Inglewood, California is that of supervisor of the department manufacturing the Signal Corp's lip microphone. Mr. Pockrandt was formerly associated with the precision assembly division of the North American Aviation Corporation and a Los Angeles aircraft parts manufacturer. Production of the lip microphone is on the increase due to heavy demands.

DR. GREGORY TIMOSHENKO who is Associate Professor of Electrical Engineering at the University of Connecticut has joined the research staff of Templetone Radio Company located at Mystic, Connecticut. He has long specialized in electrical measurement work and his new position will enable him to further expand his research along this line as well as do original investigation in the specialized field of radio measurements.

FRANK W. WARNER has again received a promotion in General Electric's Plastic Division. Mr. Warner is now serving as the Chief Engineer for the Division. As an employee of the General Electric Company since 1930 he has had the diversified experience in the various departments of the company which further enhances his value to the company and the public he will serve indirectly through the new developments in plastics.

Industrial Review

(*Continued from page 24*)

any variations of the applied d-c voltage must be absorbed by the IR drop in the series resistor. The voltage for operating the amplifier circuit is taken directly across the two electrodes of the tube.

To further insure amplifier stability, a ballast tube is connected in series with the pentode cathode heater. The resulting constant heater temperature minimizes the possibility of changes in mutual conductance due to changes in line voltage. The resistors employed in the system and particularly the phototube resistor are of low-temperature-coefficient material and are so mounted as to make the leakage current negligible.

Thyratron-tube relay circuits are used in conjunction with the amplifier circuit when it is desired to operate control equipment at predetermined temperature points. The voltage drop across the resistor is introduced into the thyratron-tube grid circuit which is provided with a suitably adjustable bias voltage to permit setting the point at which the voltage across the resistance will cause the thyratron-tube to conduct. Gas-filled thyratrons are employed in this arrangement because their characteristics are little affected by variation in ambient temperatures. When the thyratron-tube conducts, it energizes a contractor which may be either normally closed, or normally open, thus providing complete flexibility in the control arrangements which may be operated from the photoelectric pyrometer system. One or more thyratron relaying circuits may be used in conjunction with the photoelectric-pyrometer amplifier and each circuit can be independently adjusted to close or open a control circuit at any desired temperature indication.

The photoelectric recorder is employed to make a continuous record of temperatures. One or more recording instruments may be connected in series if desired. The recording instrument usually has a specially ruled chart marked in degrees F or C and a recorder with suppressed zero is usually employed since that part of the amplifier characteristic below 0.5 milliamp is not used.

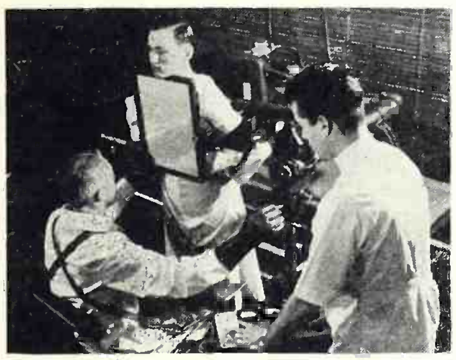
This equipment is available through the General Electric Company of Schenectady, N. Y.

* * *

X-Rays Aid Army

WHEN an aviator is hit by flak or a soldier has been shot, the field-hospital surgeon must know the exact location of the buried metal. If the doctor knows its shape, position and relation to vital organs and boney structure, the injured fighter has a chance of more rapid or more complete recovery.

To provide Army surgeons with this invaluable information, Westinghouse X-ray engineers have developed a locating device that serves as an adjunct to the Army's field X-Ray equipment.



The wounded man is brought into the X-ray room (or tent) on a stretcher. Without moving him from the stretcher the fluoroscope is used to examine him from head to toe for buried steel—if necessary X-Ray pictures are taken on film. If metal is found, the locating device (called a Biplane Marker) is brought into action. Consisting of graduated scales, sighting cross-hairs and an iodine marker, it is used in conjunction with the X-Ray tube and fluoroscope screen of the field unit. By taking a "sight" with the fluoroscope on the object and establishing its position with respect to two reference iodine marks on the skin (in two planes), the patient is made ready for the operating table.

If the patient is placed on the operating table in a different position than he assumed on the stretcher, the re-orientating device takes care of the situation. This device is a right angle caliper with two pointers and a spirit level at the right angle. Each pointer is placed on a skin spot and the patient is gently adjusted until the bubble in the spirit level is at dead center—the patient's original position is thus duplicated.

The re-orientation caliper, mounted on a support fitted with a calibrated probe, can be used by the surgeon to establish depth of incision during the operation. By comparing this depth with the known depth of the foreign body he can tell the distance he has yet to cut; he can also determine if the angle of his incision is correct.

An auxiliary probe can be employed with the reorientating calipers to indicate foreign body depth and correct angle of incision from any third point of entry.

Westinghouse Electric and Mfg. Company is at present making this device for the Armed Services.

Ignitron Converter

THE use of the mercury-arc rectifier to convert alternating current to direct current is one of the earliest applications of electronics. Almost all power is generated today in the form of alternating current and most of this power is supplied to alternating-current loads. There are, however, some loads which must be supplied with direct current and others where direct current affords advantages which dictate its selection.

Direct current is necessary for electro-chemical processes. Power for our war production of aluminum, magnesium and chlorine is supplied almost entirely by rectifiers, a high perecentage of which are Ignitrons. All conversion units sold to direct-current traction systems in recent years have been rectifiers. The mining industry is purchasing rectifiers almost exclusively to furnish direct current. The steel mills are purchasing rectifiers in increasing volume. All of the direct-current auxiliary power in one new western mill will be supplied by 14,000 kilowatts of *Westinghouse* Ignitrons. In an installation in another western steel mill, a 2500 kilowatt Ignitron will supply variable voltage to the motors of a tandem structural mill, the first installation of its kind.

Ignitron rectifiers are also in service supplying power to general industrial loads and to small isolated loads in cities where the a-c network is replacing the Edison systems. Rectifiers are supplying high voltage for radio transmitting stations. They are applicable as variable ratio frequency changers to tie two d-c systems of different and fluctuating frequencies together.

If high-voltage, direct-current transmission should prove to be economical after the present problems associated with this form of transmission are solved, Ignitron rectifiers will undoubtedly find their place in the system.

Compared with electronic devices for communication and control, the principle of mercury-arc rectification for power conversion is not new. The rectification properties of a mercury-vapor arc were discovered and patented by a *Westinghouse* Engineer, Peter Cooper Hewett, in 1902.

Current flows in a mercury arc with ease from the cathode to anode and with reluctance from anode to cathode. Occasionally a cathode spot will form on the anode that results in counterflow of current. This destroys the valve action of the rectifier, places a short circuit on the rectifier transformer and permits reverse current to flow from the d-c system. This phenomenon is known as arc back and its prevention is the major rectifier design problem.

Although the causes of arc back are not definitely known there are certain design factors which will keep them at a minimum. Unfortunately, for a given type of rectifier, the measures taken to minimize arc back, increase the rectifier losses and decrease the unit efficiency.

Dr. Joseph Slepian of the *Westinghouse Research Laboratory* and his associates, conceived and developed the Ignitron rectifier. This is a single anode tube rectifier with a synchronous ignition system. This type of rectifier has reduced the arc back rate and at the same time reduced the rectifier loss with resultant increase in efficiency. It has made the multi-anode rectifier obsolete. Since 1937, when Ignitron rectifiers became commercially available, the *Westinghouse Company* and its Canadian associates alone have sold in excess of 2,250,000 kilowatts, or well over half of the total rectifier market. The installation of this capacity represents a saving, due to its efficiency advantage, of the equivalent of a 60,000-kva generator over the same installed capacity of multi-anode rectifiers. As for the future, application of Ignitron rectifiers will continue in the industries where it has already found wide usage. New markets, difficult to visualize at this time, will undoubtedly be developed.

New Products

(*Continued from page* 32)

erator, Model 530 designed for production testing. This generator incorporates a new feature, the facility of synchronization with any external frequency source.

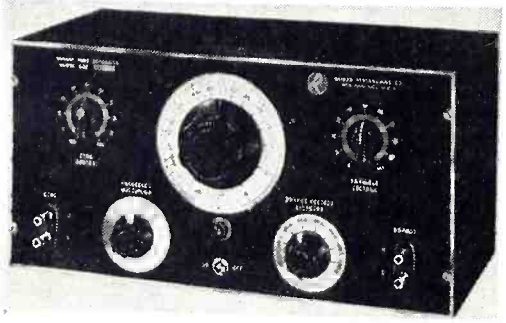
The generator has a hand-calibrated frequency scale reading from below 10 cycles to more than 100 kilocycles. The decade multiplier has four steps. The actual frequency output is the dial reading multiplied by the setting of the frequency multiplier. The accuracy of the frequency callibration, according to the company, is 5% over extended periods.

In cases where great accuracy of frequency is desired, the instrument can be made to synchronize with any standard frequency generator, providing that a synchronizing voltage of at least 0.1 volt is available. The synchronization can be made to any other external frequency source.

The output impedances available are 100-200-500-600-1,000-2,000 ohms. Output voltages may be varied either in fixed steps or may be continuously varied by means of the variable-voltage potentiometer. When the later is used, the output impedance is from 2,000 ohms.

If the output voltage is varied in steps, the output impedance is indicated by the output-voltage selector setting. The maximum voltage output is approximately 200 volts.

The power supply of this generator is designed to operate on 110-120 volts, 60 cycle a-c. It is also available for other voltage or line frequency at slight additional cost. The power consumption is 30 watts and a 1 amp. fuse is used for protection.



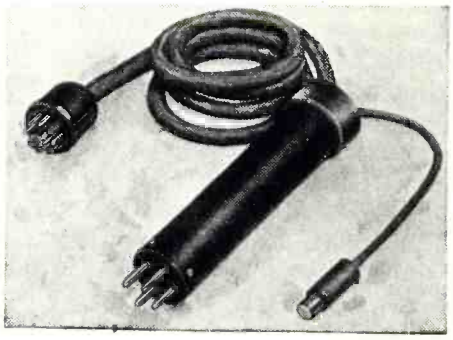
The Reiner Company, who also manufacture oscilliscopes, vacuum-tube volt meters and general electronics equipment, is located at 152 West 25th Street, New York, N. Y.

PRODUCTION PLUGS

Communication Measurements Laboratory have developed a new production plug for use with the Roto-bridge in testing electronic equipment. These plugs are 5 inches long and 1¼ inches in diameter so that the handle will project above the average IF transformer, condenser, making it readily accessible. They are made with a heavy steel barrel and are fitted with a wooden handle to permit ready removal from the socket. All pins are case hardened steel to assure long life, yet are easily removable when worn or broken.

In both the octal and loktal plugs, center keys extend through in the form of a threaded rod to permit the cable to be fastened firmly in position without strain on the pin connections. A flat-head-machine screw serves the same purpose in the other plugs.

This plug is now available for electrical manufacturers, and further information should be obtained direct from the makers, Communications Measurements Laboratory, 116 Greenwich Street, New York, N. Y.



NEW RELAY

A new type sensitive relay known as No. 5 has been announced by the Sigma Instruments, Inc., of Boston, Mass. More sensitive than the well-known No. 4, this relay is more resistant to shock and vibration although the No. 4 is desirable where high speed and close operating differential is important.

When vibration is limited to less than 5 g's and contact load is light, the Series 5 relay may be operated at a sensitivity of 0.0005 watts (½ mw.). For the most rigorous conditions met in aircraft applications, 0.005 watts (5mw.) is usually adequate.

In this relay, loss of adjustment at extreme temperatures is completely eliminated. The Series 5 relay preserves its adjustment from —60° to +90° C. Another requirement in its design was stability under shock, as dictated by certain military needs. Shocks of 500 g's will not affect its adjustments or in any way damage it.

These relays operate on d-c but where the source is a-c a midget selenium rectifiers are provided.

Further information, including engineering data and characteristic operating curves are available from Sigma Instruments, Inc., 76 Freeport Street, Boston, Mass.

Electronic Processing

(*Continued from page* 22)

sembly time. As the temperature required for setting the bonding agent is increased, the permissible open assembly time is lengthened. With an upper limit of 230° F, with wood not completely under fluid pressure, it can be seen that uniform current through the wood must be obtained to give uniform heating because the heating effect varies as the square of the current.

An installation used to cure the flanges of the center section of spars consists of a powerful high frequency generator and a large jig which holds the laminated assembly while it is being "set." In the bed of the jig is a long channel, shaped to the flange's form. One side of the jig, as well as the block on which the flange rests, is movable. Thin laminations of wood, smeared with dried phenolic resin are assembled edge to edge at the proper thickness. The flexible blocks on which the laminations rest are made of two pieces joined by a rubber hinge. Since the rubber is under tension, it holds each support open to the full width of the open jig, yet allows for compression as the jig is closed.

When the sides of the jig are clamped together, the thin laminations are pressed into the proper shape. Each side of the jig is lined with a copper plate or electrode. The two electrodes extend from end to end along opposite sides of the spar and the high frequency current completes a circuit through the laminations of wood and plastic.

Along one side of the jig, behind the copper plate and its support, is a high pressure air hose. The use of air pressure not only achieves accurate control, but provides the required uniformity of pressure. The thickness of wood laminations cannot be controlled with the accuracy, for example, of the machining of metal, consequently, if extremely rigid platens were used to apply pressure it would result in crushed wood fibers or either open or thick glue lines.

This process brings the internal heat of the flange up to the desired temperature in approximately 20 minutes, with remarkably uniform heat throughout the adhesive lines. The whole heating operation is done in about 30 minutes.

High frequency heating will play its part in the future of fabricated items as it may soon become possible to imbed fine wires or foil deep in a complicated assembly and then weld the whole into an integral unit with the snap of a switch.

Newsbriefs

(*Continued from page* 26)

T. C. Kenney (M), Station KDKA, Pittsburgh
D. D. Cole (M), RCA, Victor Division, Camden, N. J.
K. A. Chittick (A), RCA, Victor Division, Camden, N. J.
J. B. Coleman (M), RCA, Victor Division, Camden, N. J.
V. E. Trouant (A), RCA, Victor Division, Camden, N. J.
A. D. Ring (M), Ring & Clark, Munsey Bldg., Washington
Lynne C. Smeby (M), 4801 Connecticut Ave., N. W., Washington
C. W. Finnigan (M), Stromberg-Carlson Co., Rochester
Benjamin Olney (A), Stromberg-Carlson Co., Rochester
G. Porter Houston (M), Station WCBM, Baltimore
K. J. Gardner (M), Station WHAM, Rochester
H. W. Holt (M), Station WOV, 730 Fifth Ave., New York
F. M. Doolittle (M), Station WDRC, Hartford, Conn.
Frank McIntosh (O), WPB Radio and Radar Division, Washington
H. B. Canon (M), Wells-Gardner & Co., 2701 N. Kildare Ave., Chicago
Gordon T. Bennett (A), Wells-Gardner & Co., 2701 N. Kildare Ave., Chicago
R. E. Poole (M), Bell Telephone Lab., 463 West St., New York
J. C. Bayles (A), Bell Telephone Lab., 463 West St., New York
M. R. Briggs (M), Westinghouse Elec. & Mfg. Co., Baltimore
A. C. Goodnow (A), Westinghouse Elec. & Mfg. Co., Baltimore
Karl B. Hoffman (M), Stations WGR-WKBW, Buffalo
I. R. Lounsberry (A), Stations WGR-WKBW, Buffalo
Ronald J. Rockwell (M), Station WLW, Cincinnati
Clyde M. Hunt (M), Station WTOP, Washington
Walter A. Brester (A), Station WTOP, Washington
E. B. Paso, Zenith Radio Corp., 6001 Dickens Ave., Chicago

PANEL NO. 6—TELEVISION BROADCASTING

David B. Smith, Chairman, Philco Corp., Philadelphia
I. J. Kaar, Vice-Chairman, General Electric Co., Bridgeport, Conn.
Dr. George Town, Secretary, Stromberg-Carlson Co., Rochester
G. L. Beers (M), RCA-Victor Division, Camden, N. J.
F. J. Bingley (M), Philco Corp., Philadelphia
N. F. Smith (A), Philco Corp., Philadelphia
B. Ray Cummings (M), Farnsworth Radio & Tel. Co., Fort Wayne, Ind.
Allen B. DuMont (M), Allen B. DuMont Labs., Inc., Passaic, N. J.
Dr. T. T. Goldsmith, Jr. (A), Allen B. DuMont Labs., Inc., Passaic, N. J.
O. B. Hanson (M), NBC, RCA Bldg., New York
R. E. Shelby (A), NBC, New York
John D. Reid (M), Crosley Corp., Cincinnati
R. Serrell (M), CBS, 485 Madison Avenue, New York
C. A. Priest (M), General Electric Co., Syracuse
R. Longfellow (A), General Electric Co., Syracuse
Dr. Ray H. Manson (M), Stromberg-Carlson Co., Rochester
A. E. Newlon (A), Stromberg-Carlson Co., Rochester
J. E. Brown (M), Zenith Radio Corp., 6001 Dickens Avenue, Chicago
Donald G. Fink (M), Room 4E936, Pentagon Bldg., Arlington, Va.
Harry R. Lubcke (M), Don Lee Broadcasting System, 3800 Mount Lee Drive, Hollywood
W. A. MacDonald (M), Hazeltine Electronics Corp., 1775 Broadway, New York
T. B. Grenier (M), Metropolitan Television, Inc., 654 Madison Avenue, New York
L. L. Thompson (A), Metropolitan Television, Inc., 654 Madison Avenue, New York
W. Blacksher (A), Metropolitan Television, Inc., 654 Madison Avenue, New York
C. E. Nobles (M), Westinghouse Elec. & Mfg. Co., Baltimore
C. E. McClellan (A), Westinghouse Elec. & Mfg. Co., Baltimore
Jean Brand (M), Raytheon Mfg. Co., Waltham, Mass.
Howard Gates (O), Warwick Mfg. Corp., 4640-50 W. Harrison Street, Chicago
N. P. Case (O), Hamilton Radio Corp., 510 Sixth Avenue, New York
J. A. Ouimet (O), Canadian Broadcasting Corp., 1440 St. Catherine Street, West Montreal
Norman Snyder (O), Ansley Radio Corp., 21-10 49th Avenue, Long Island City, N. Y.

PANEL NO. 8—RADIO COMMUNICATION

Haraden Pratt, Chairman, Mackay Radio & Telegraph Co., 67 Broad Street, New York
H. H. Beverage, Vice-Chairman, RCA Communications, Inc., 67 Broad Street, New York
C. W. Latimer (M), RCA Communications, Inc., 67 Broad Street, New York
A. J. Costigan (M), Radio Marine Corp. of America, 75 Varick Street, New York
I. F. Byrnes (A), Radio Marine Corp. of America, 75 Varick Street, New York
Charles C. Harris (M), Tropical Radio Telegraph Co., 1 Federal Street, Boston
P. D. Zurian (M), Press Wireless, Inc., 435 N. Miichigan Avenue, Chicago
Carl E. Scholz (M), Radio Corporation of Porto Rico, 67 Broad Street, New York
W. I. Harrington (M), Mutual Telephone Co., Honolulu, T. H.
G. P. Bosomworth (M), United States-Liberia Radio Corp., Akron, Ohio
T. P. Kinn (M), Westinghouse Elec. & Mfg. Co., 2519 Wilkens Avenue, Baltimore
P. R. Sears (A), Westinghouse Elec. & Mfg. Co., 2519 Wilkens Avenue, Baltimore

NEW COMPANY FORMED

The formation of a new company for metal plating of plastics and dielectrics has been announced by Mr. William Stahl, General Manager. The firm will operate under the name of Electro Plastic Processes at 2035 West Charleston Street, Chicago 47, Illinois, and is a division of Precision Paper Tube Company. Operation started on January 25th.

Of particular interest to engineers in the electronics industry is the use of the Freund Plastic Plating Process whereby the bond coat is eliminated and in its place a process for depositing a miscroscopic metallic film by chemical means is used. So fine are the particles deposited that they penetrate the pores of the material itself.

The plating is done on this light metallic coating and the plated film becomes homogeneous with the plastic itself.

A few of the advantages of this process are pointed out by Mr. Stahl including, increased electrical conductivity, decreased moisture absorbtion, increased heat resistance, non-corrosive, dimensional stability, solderability.

Possible uses for this process include plating of outside cases of contactors, switches, motor controls, which will eliminate the need for extra inner insulating parts. Plastic tubing may be plated in part to be used for wiring or conduit applications. Radio chassis may be made of plastics which have been plated and aircraft and marine fittings may be molded of this material because of its resistance to moisture, heat and cold.

R.M.A. ACOUSTICS

In a recent meeting of the R.M.A. Committee on Acoustic Devices, a sub-committee was appointed by the committee chairman, Mr. S. J. Klapman of Utah Radio Products Company of Chicago, Illinois.

This group will carry on investigations leading to the standardization of Alinco "V" magnets for PM loudspeakers. This is being done at this time in an effort to utilize in full, the advantages of Alinco "V," in order that the public may obtain higher quality permanent magnet speakers in the post-war period.

The work of this committee, which has the full cooperation of all of the loudspeaker manufacturers, is progressing rapidly and a préliminary report on their findings is expected shortly.

PHOTO CREDITS

Pages
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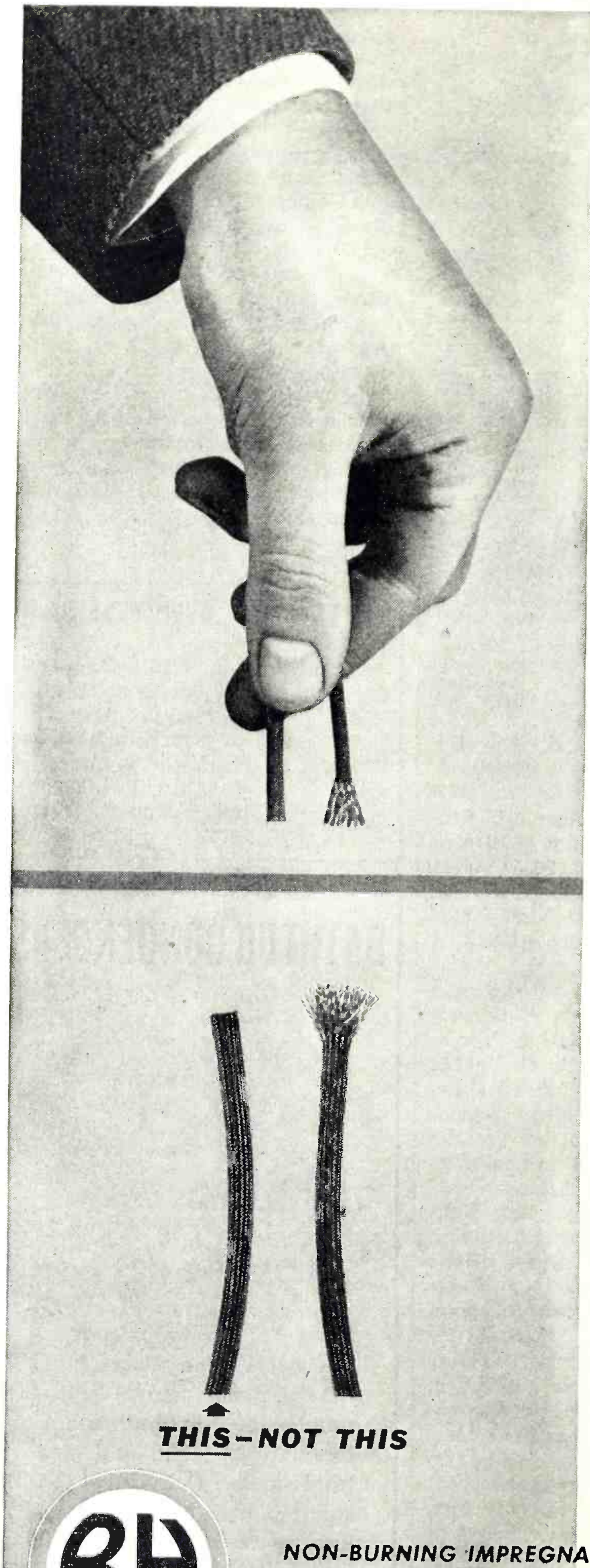
22....... Knickerbocker. Courtesy of Fairchild Engine and Airplane Company.



SNUB TEST

Proves non-fray feature of new BH Fiberglas Sleeving

NEW, BH Extra Flexible Fiberglas Sleeving *will not fray,* even under severe conditions. You can prove this *right at your desk*. It's easy as snubbing out a cigarette. Here's how:

Write us for a sample of BH Extra Flexible Fiberglas Sleeving equal in size to the saturated sleeving you use now.

Hold short pieces of both BH Fiberglas Sleeving and the usual saturated sleeving between your thumb and index finger, and snub the ends of both sleevings against your desk, similar to the way you would snub out a cigarette. Do this five to ten times, pressing hard.

BH Flexible Fiberglas Sleeving will spread slightly under this pressure, may fuzz a little, but *will not fray*. The usual saturated sleeving will break down at the edges and separate.

Continued snubbing will not noticeably affect the BH Extra Flexible Fiberglas Sleeving, whereas the saturated sleeving will readily unravel and become progressively worse.

NON-FRAYING • FLEXIBLE • HEAT-RESISTANT
NON-INFLAMMABLE • WATER-RESISTANT
NON-CRYSTALLIZING at LOW TEMPERATURES

The new BH Extra Flexible Fiberglas Sleeving is woven from the choicest continuous-filament Fiberglas yarns. It possesses high dielectric strength, is water-resistant and, like all BH Sleeving and Tubing—is non-inflammable.

All sizes from No. 20 to 5/8", inclusive, are available. Write for samples of this radically new and different sleeving today—in the sizes you desire. Seeing is believing! Bentley, Harris Manufacturing Co., Dept. R, Conshohocken, Pa.

BH PRODUCTS

NON-BURNING IMPREGNATED MAGNETO TUBING • NON-BURNING FLEXIBLE VARNISHED TUBING • SATURATED AND NON-SATURATED SLEEVING

BENTLEY, HARRIS MANUFACTURING CO.
Conshohocken, Penna.