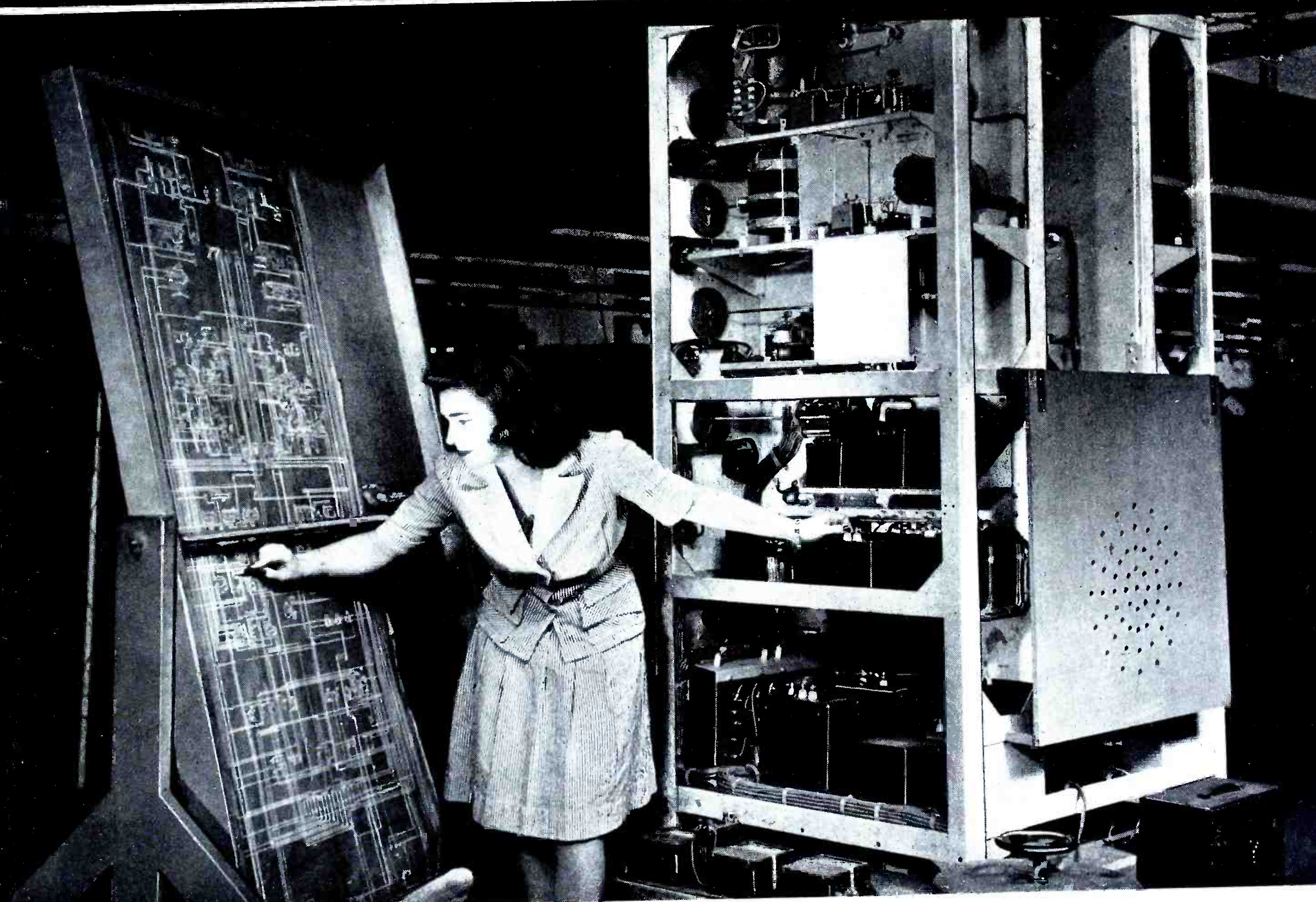
# COMMUNICATIONS



SEPTEMBER 1943

- ★ RADIO ENGINEERING
- ★ TWO-WAY LIFEBOAT RADIO
- ★ MULTIPLE BRIDGING NETWORKS
- ★ WARTIME CONTROL CONSOLE
- ★ COIL-CONDENSER CHECKS AT A-F
- ★ AIRCRAFT COMMUNICATIONS

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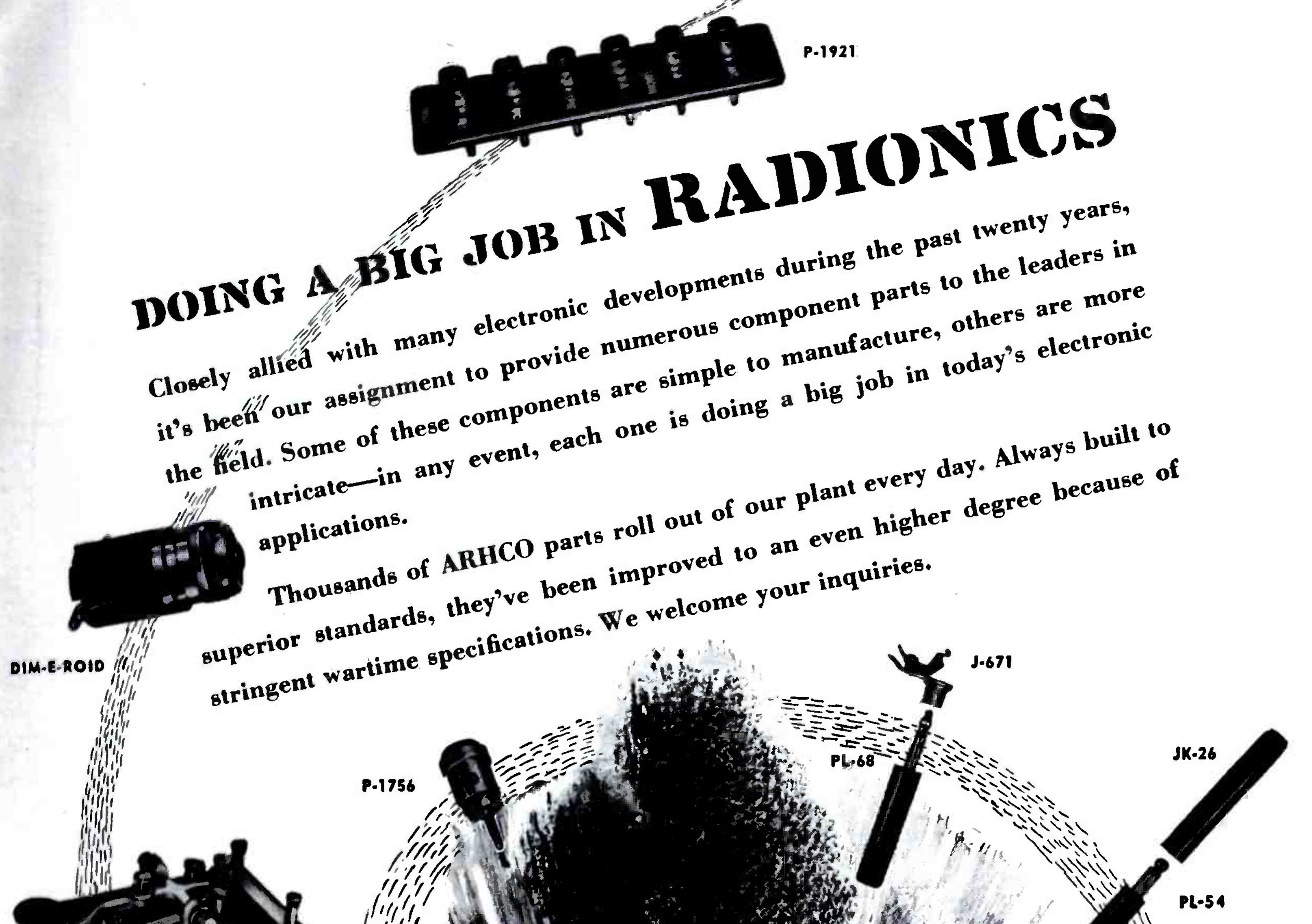


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SEPTEMBER, 1943

VOLUME 23 NUMBER 9

## We See...

THE IMMEASURABLE POWER of broadcasting has become an enthusiastic topic with everyone. Commentators, advertising writers, lecturers, authors . . . all are applauding the incomparable utility of broadcasting today.

Before a group of the nation's leading industrialists, one lecturer said that the rapidity with which broadcasting has assumed wartime responsibilities, in a technical and administrative way, has been truly amazing. Praise for the industry from advertisers, in fields entirely outside of radio, has also been common during the past months. Said one such advertiser recently in describing the virtues of broadcasting . . . to whose who are engaged in this difficult work so ably, America is forever indebted.

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To the FCC Committee on Critical Radio Materials goes the credit for this grand new ruling. Good work!

WE WERE SHOCKED TO LEARN of the death of David Grimes, one of the nation's leading radio specialists. He was killed while traveling in a transport plane in Ireland, on a special war mission.

Everyone will miss David Grimes.

REMEMBER THE THIRD WAR LOAN drive is now on. Don't forget to back the attack . . . with *more* War Bond purchases.—L. W.

### COVER ILLUSTRATION

Circuit checking of an aircraft communications transmitter with the aid of a giant blueprint.

*(Courtesy Federal Telephone & Radio Corporation)*



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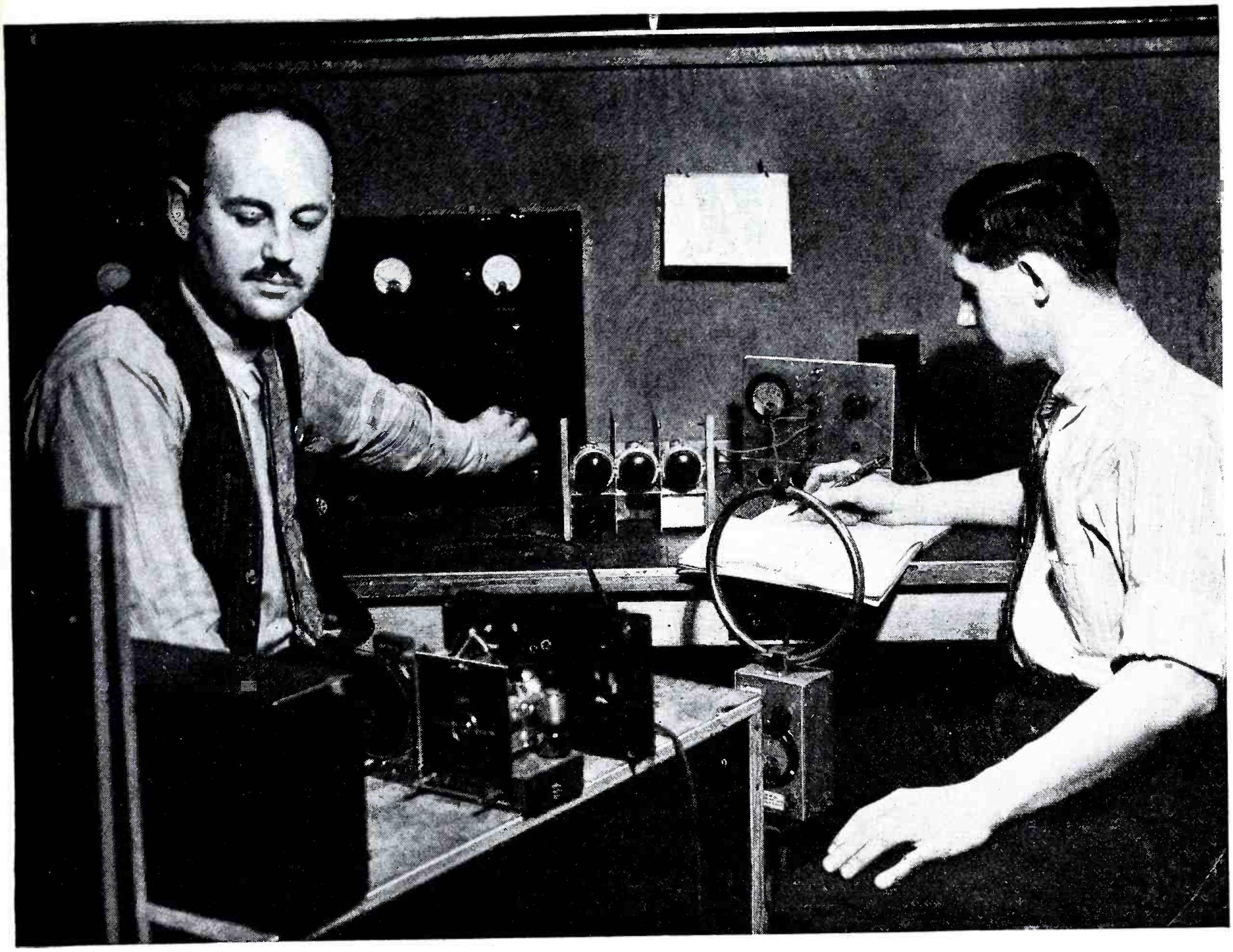
Advertising and Editorial offices, 19 East 47th St., New York, 17, N. Y. Telephone PLaza 3-0483. Cleveland, Ohio: James C. Munn, 10515 Wilbur Avenue. Pacific Coast Representative: Brand & Brand, 4310 Los Feliz Blvd., Los Angeles 27, Calif. Wellington, New Zealand: Te Aro Book Depot. Melbourne, Australia: McGill's Agency.  Entered as second-class matter October 1, 1937, at the Post Office at New York, N. Y., under the act of March 3, 1879. Yearly subscription rate: $2.00 in the United States and Canada; $3.00 in foreign countries. Single copies, twenty-five cents in United States and Canada; thirty-five cents in foreign countries.



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And it will prove no less valuable when victory widens the radio-electronics field. It will contribute to the development of FM radio and practical television. It will help to convert electronic military secrets of today into everyday miracles for better life and work tomorrow.

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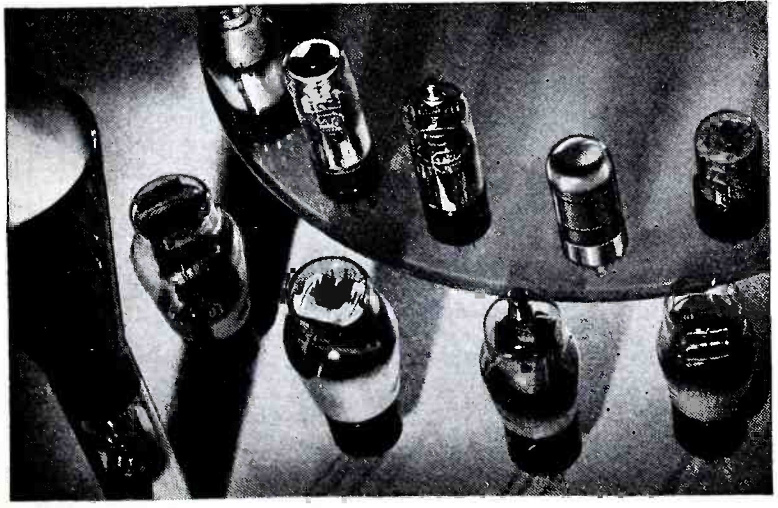

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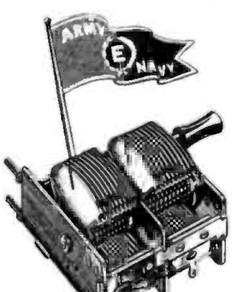


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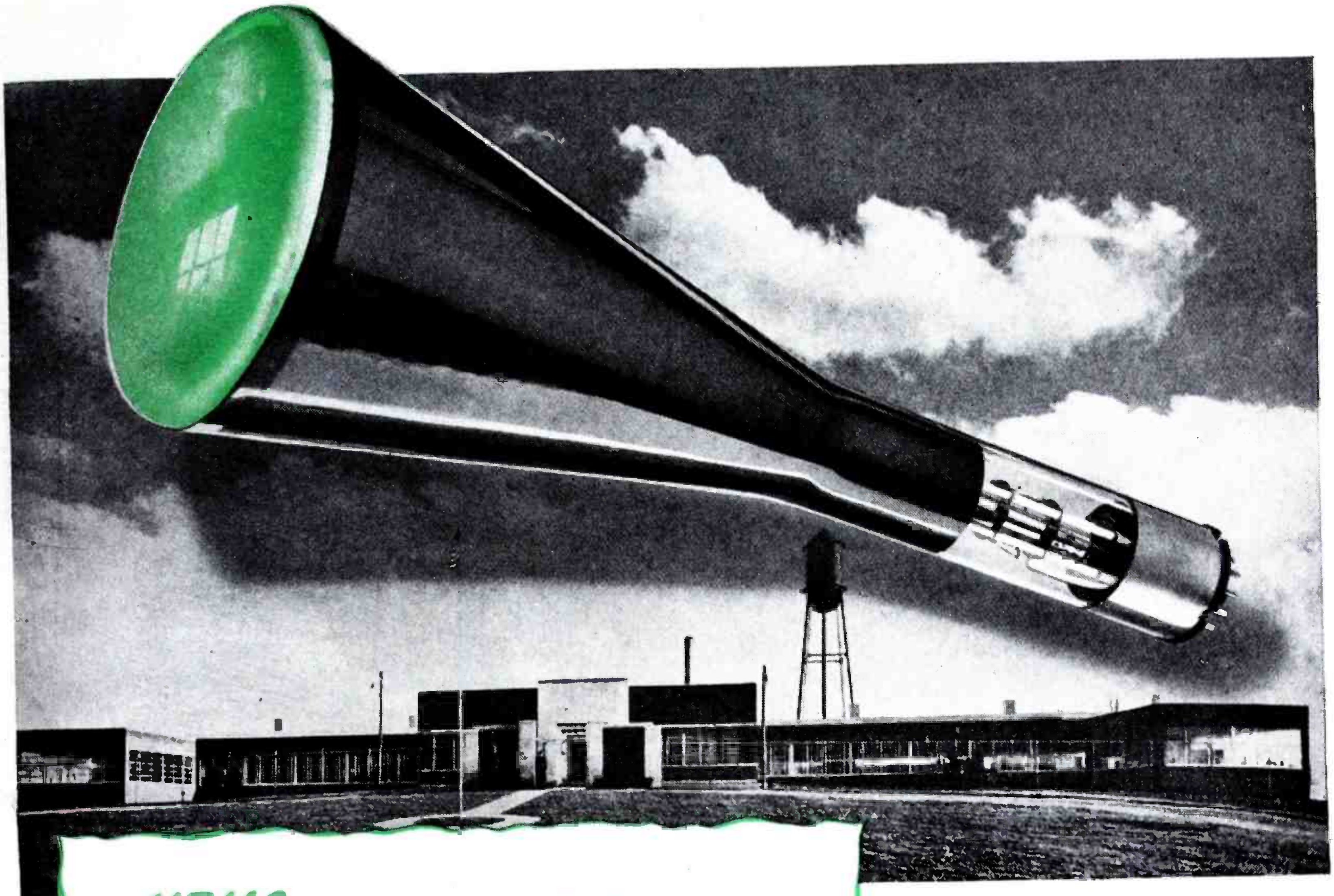

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*Count on National Union for the things you'll need—tubes, test equipment, engineering data—to keep your post-war service in step with electronics progress.*

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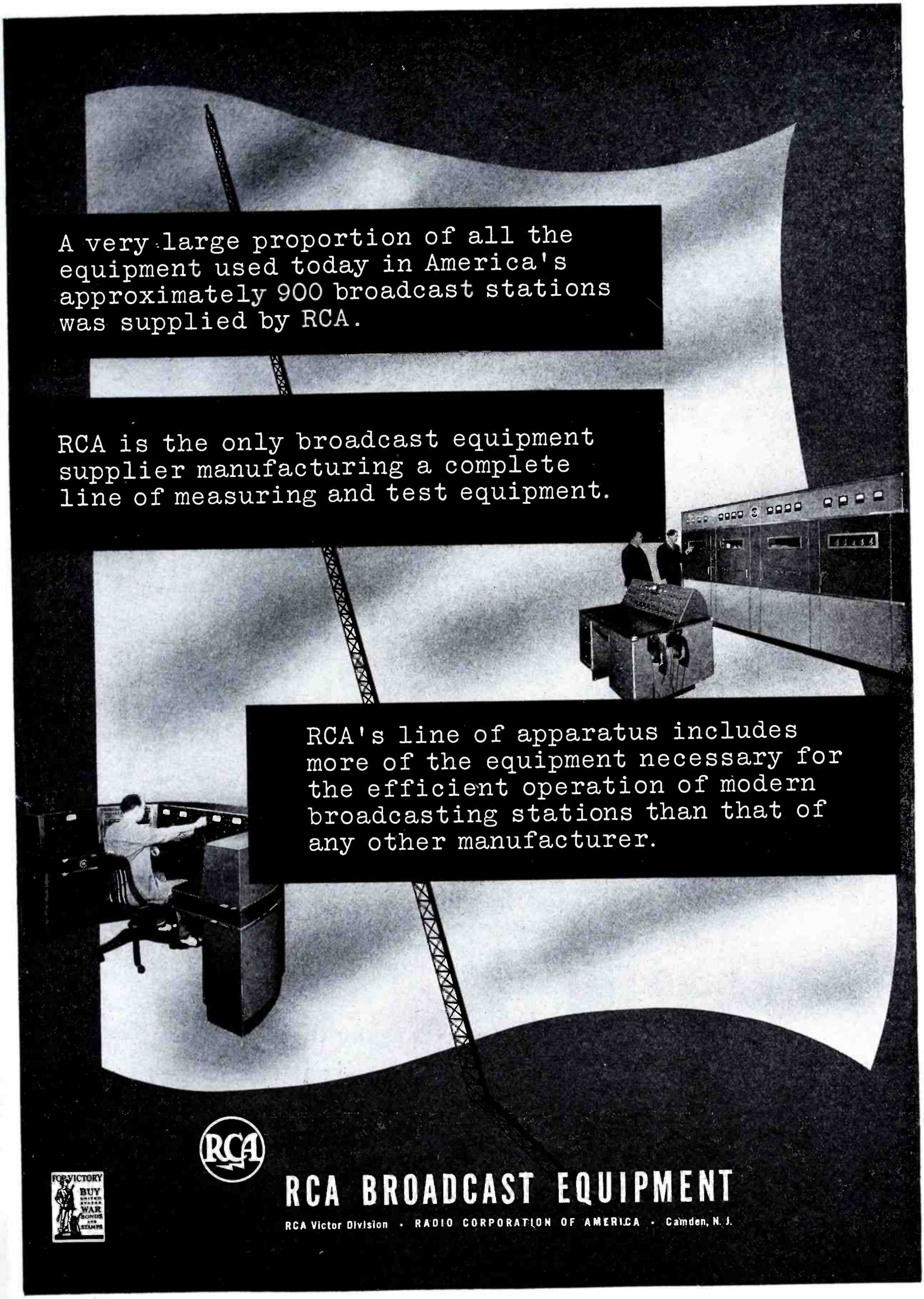
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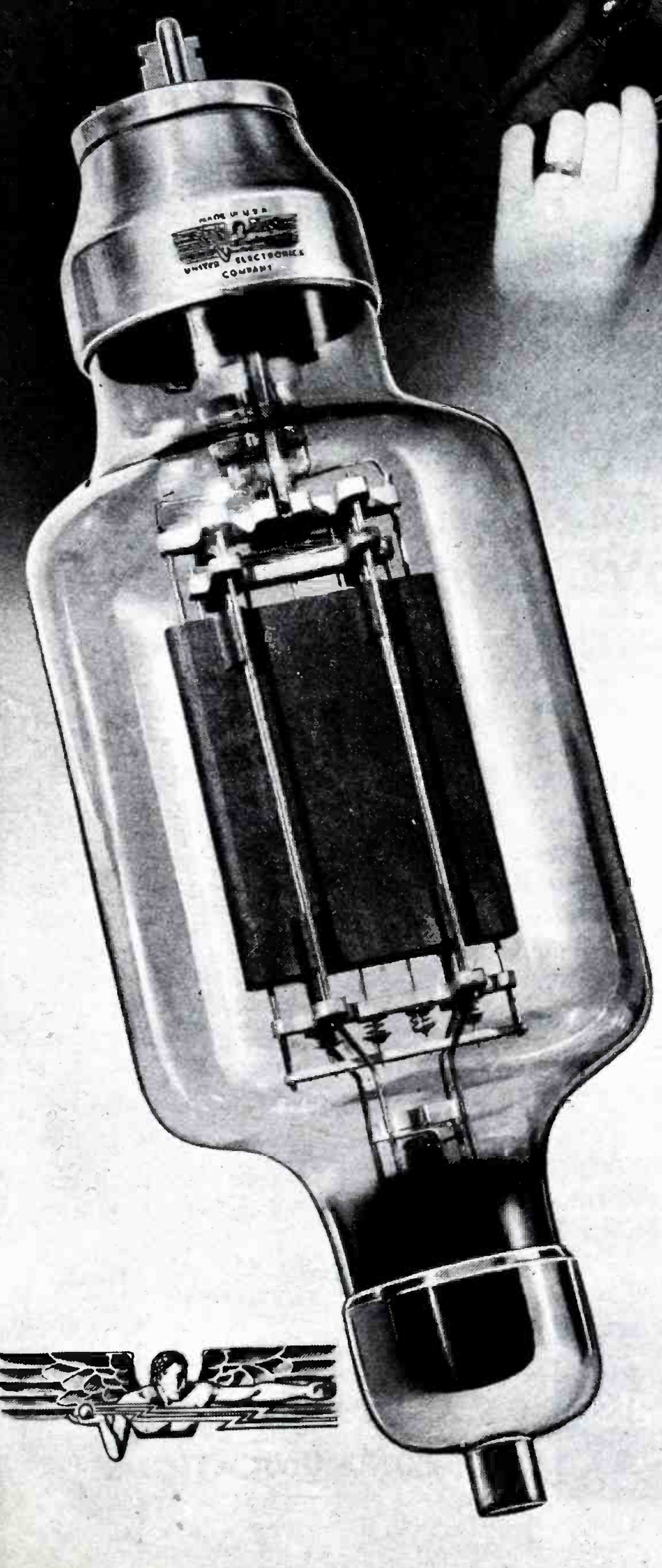

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On August 12th, 1943, United Electronics Company received the coveted Army-Navy "E" Award for excellence in production of war materials.

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Today about 30,000,000 wage earners, in 175,000 plants, are buying War Bonds at the rate of nearly half a billion dollars a month. Great as this sum is, *it is not enough!* So turn-to today! Get this new *family income plan working!*


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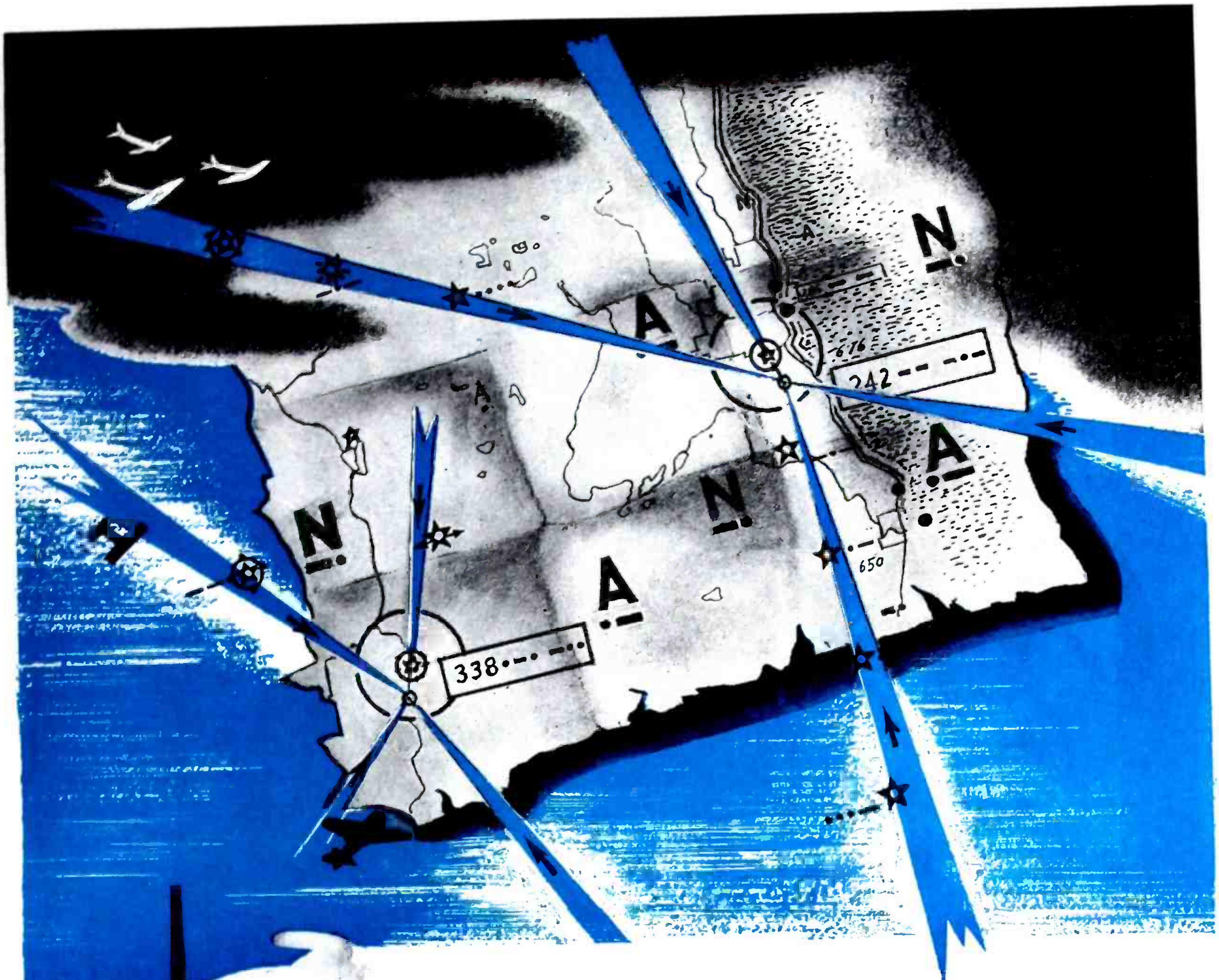
**COMMUNICATIONS**

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*We will send, on request, a copy of our revised brochure, "HIGHWAYS OF THE AIR", now in preparation. Please write on your business stationery to our Executive Offices.*

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General Electric S-T equipment permits complete FM program fidelity from 30 to 15,000 cycles . . . the total range of the human ear. This apparatus takes the place of technically inadequate or prohibitively expensive wire-line construction . . . for *no* connecting wires are needed! General Electric alone has pioneered and developed this wireless type of equipment . . . and G. E. is the only manufacturer who can supply it.

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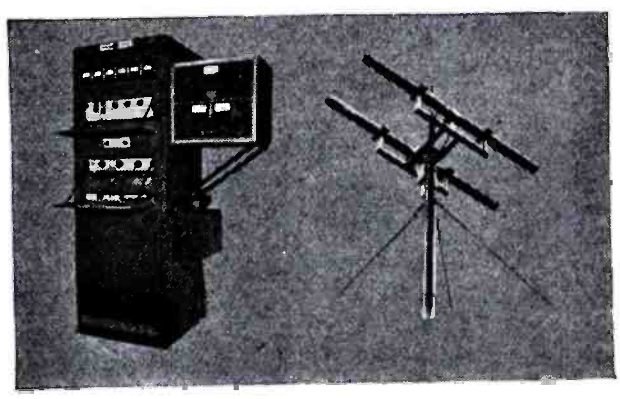

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COMMUNICATIONS

LEWIS WINNER, Editor

SEPTEMBER, 1943

# TWO-WAY LIFEBOAT RADIO

## Receiver-Transmitter Powered by Hand-Driven Generator Affords Telephony or Modulated Telegraphy Transmission

by IRVING F. BYRNES

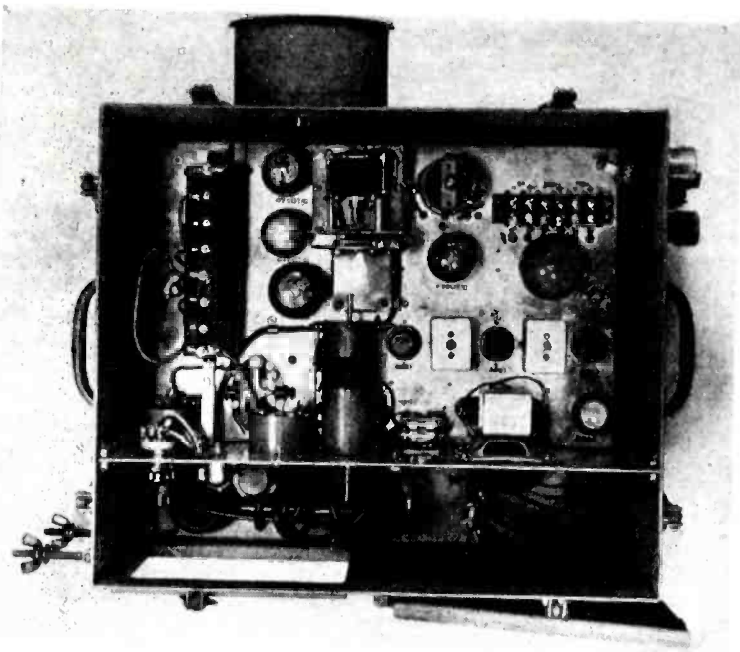
Chief Engineer
Radiomarine Corporation
of America

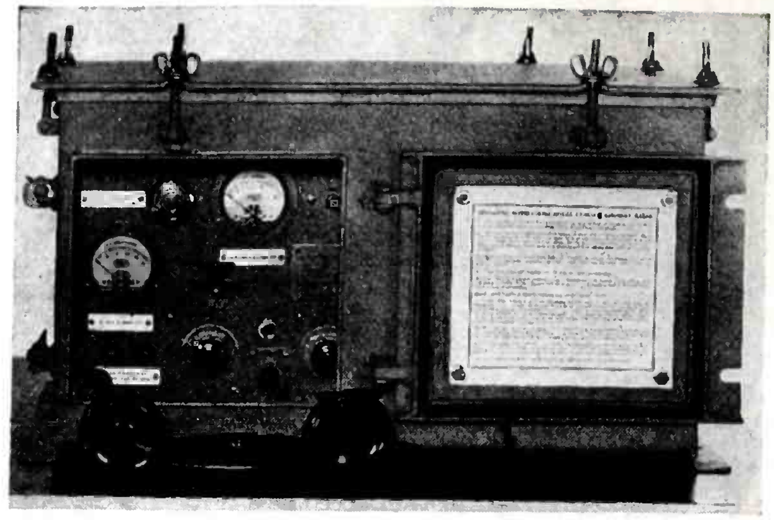
THE importance of providing radio communication from lifeboats in time of distress has been recognized for many years. Suitably designed equipment not only permits the use of the conventional *SOS* call, but also enables transmission of signals to actuate auto alarms and for direction finder bearings. Men who have been at sea in a lifeboat for a considerable period usually do not have accurate information on their position, and the direction finder on the rescuing ship is a valuable aid when taking radio bearings to locate the lifeboat.

Lifeboat radio apparatus may be considered in three general classifications. In the first class, we have so-called passenger ship equipment, permanently installed in the lifeboats and comprising a radiotelegraph transmitter and receiver which are powered by storage batteries. This class of equipment is operated by the ship's

Figures 1 (top, right) and 2 (bottom, right)

In Figure 1 appears a motor driven radio-equipped lifeboat. Figure 2 shows the lifeboat radio in operation.





Figures 3 (left) and 4 (above)

Top view of the transmitter-receiver appears in Figure 3, while the front view is shown in Figure 4.

radio personnel for normal two-way radiotelegraph communication.

#### Portable Transmitters

In the second class of lifeboat equipment, there is a portable radiotelegraph transmitter only, which is normally stowed aboard the ship and then carried into a lifeboat when the vessel is abandoned. This portable type is powered by a storage battery or hand driven generator and includes an automatic mechanism to permit unskilled personnel to transmit *SOS* and *long dashes*. It will be apparent that the portable class of lifeboat radio provides one-way transmission only as no receiver is built into the equipment.

#### Transmitter-Receivers

The third class, which is the type of equipment described in this paper, comprises a complete radiotelephone and radiotelegraph transmitter, with receiver, and a hand driven generator for power supply. Such equipment includes a telephone handset, an automatic SOS-long dash keying mechanism and a manual telegraph key. It is, therefore, capable of use by either unskilled personnel or by the radio operator. Permanently installed in port and starboard lifeboats, the equipment is always ready for immediate service in an emergency, and can, of course, be operated for indefinite periods since there are no batteries to be discharged.

#### Advantages of Two-Way Unit

The advantage of two-way lifeboat radio, with both telephone and telegraph facilities, on the morale of the men in a lifeboat is obvious. Lifeboats become separated after the vessel has been abandoned and the use of the telephone in providing interboat communication between the crew members is of considerable value. When distress calls are transmitted, the ability to receive a reply from rescuing vessels helps keep up morale even in cases where the rescuing vessel replies by telegraph using prearranged recognition signals. Furthermore, needless operation of the lifeboat transmitter is avoided when the men in the lifeboat are able to determine whether ships have picked up their signals.

#### General Construction

The general construction of the transmitter-receiver unit and its hand driven generator are shown in the illustrations. The transmitter-receiver unit is housed in a watertight cabinet approximately 12″ high, 22″ wide, and 22″ deep. The top cover of the cabinet, which is removable for inspection or repair, is clamped down by means of wing nuts to provide a watertight enclosure. The front of the cabinet is fitted with a watertight door which, when opened, provides access to the various transmitter and receiver controls, the telephone handset, and the manual telegraph key.

#### Hand Generator

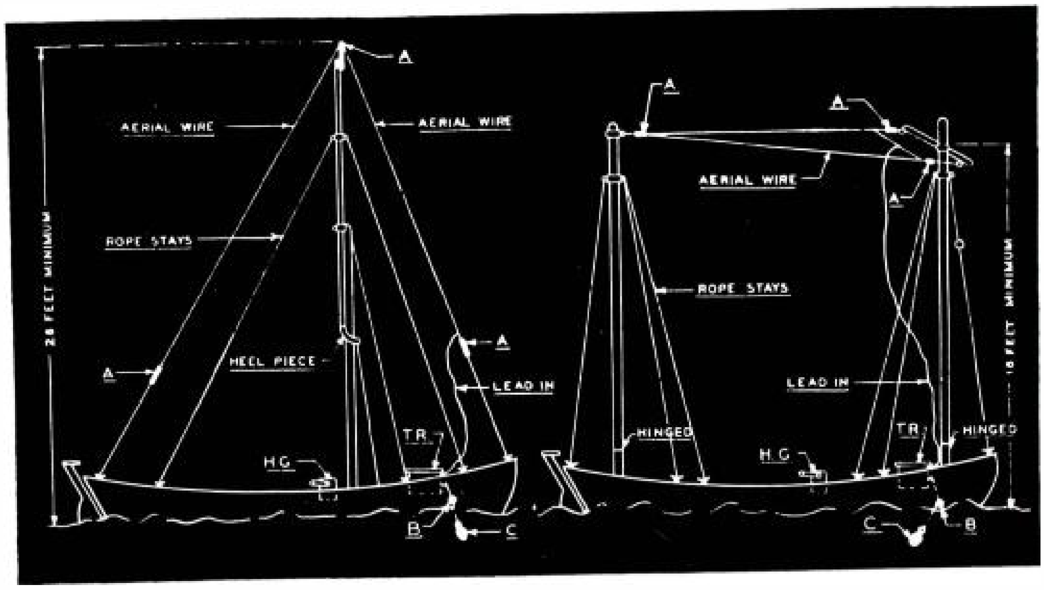
The hand generator, which is a compact watertight unit, delivers d-c voltages of 6 and 315 for the filament and plate supply of the transmitter-receiver unit. Two cranks are used with the generator so that either one or two persons may operate the machine. The cranks are removable and are stowed in clamps on the generator body when not in use. The manual energy required to turn the hand generator, when delivering its full rated load, is equivalent to approximately one-quarter horsepower. The load on the generator is, of course, greatest when the transmitter is in operation, being reduced to one-third of full load value when the receiver only is in use. Crank handles are turned at a speed of 60 rpm. A gear train, inside the machine, causes the generator armature to rotate at 3600 rpm. The generator output voltages are maintained constant with varying crank speeds by means of a built-in voltage regulator.

#### Frequency Used

The equipment operates on the international distress frequency of 500 kc. Both the transmitter and receiver circuits are pretuned and locked at this frequency, resulting in simplified controls when operated by the layman. The only receiver control used is that to adjust receiver sensitivity. The transmitter is resonated to the antenna, for maximum antenna current, by means of a single control, a meter being provided to indicate antenna current. The panel also includes a plate milliammeter as a check on overall operation and for initial installation adjustments. A panel controlled *manual-automatic* switch is used. In the automatic position of this switch, the keying mechanism is connected in circuit so that SOS and long dashes are transmitted continuously when the generator is cranked. In the manual position of the switch, either telephone or manual telegraphic keying may be employed.

#### Iron Core in Inductors

The illustration showing the top view of the transmitter-receiver unit discloses the general arrangement of the component parts. The oscillator tank inductor to the rear of the chassis, near the terminal block, is




Figures 5 (left) and 6 (right)

The two antenna arrangements that can be used with lifeboat radios are shown here. In Figure 5, the antenna is equivalent to an inverted *V*. This is supported by an extension to the lifeboat normal sailing mast so that the highest point of the antenna is approximately 26 feet above the water line. Figure 6 shows an *L* type antenna, supported by two masts, approximately 18 feet high. *A* are the insulators; *B* is the ground stud for a metal hull lifeboat; *C* is the ground lead with sinker for a wood hull lifeboat; *H.G.* is the hand driven generator and *T.R.* is the radio transmitter unit.

provided with an iron core for setting the oscillator frequency to 500 kc. The p-a tank inductor is a similar unit with the adjustable core brought out through the front panel for alignment purposes during installation. The antenna loading inductor comprises a tapped coil and an adjustable core for resonating the antenna circuit. All inductors are wound with litzendrath conductor, which is appreciably more efficient than solid conductor at 500 kc. The antenna lead-in insulator is located at the rear of the cabinet and is enclosed by a circular metal shield for drip-proofing and for mechanical protection. The telephone handset is stowed in clamps in the space between the front panel and the enclosing cabinet.

### Automatic Keying Mechanism

The automatic keying mechanism which transmits SOS and long dashes is mounted in the center rear section of the chassis. This device consists of a low drain 6 volt d-c motor operating at 600 rpm which is coupled through a gear train to the signalling cam, the latter rotating at a speed of 3 rpm. Each revolution of the signalling cam transmits SOS three times and a long dash having a duration of about 2.5 seconds. The six-volt driving motor is of interest in that it requires an input of only 1.5 watts.

### Antenna Systems

The antenna system used with this equipment may be either of the two types shown. In Figure 5 the antenna is equivalent to an inverted *V* supported by an extension to the lifeboat normal sailing mast so that the highest point of the antenna is approximately 26 feet above the water line. In Figure 6 an *L* type of antenna is shown supported by two masts approximately 18 feet high. With this type of antenna, the masts are hinged at the base so that they lie flat in the lifeboat prior to the erection of the antenna. In the case of lifeboats constructed with metal hulls, the ground connection is made directly to the hull. With wooden hull lifeboats, a 20-foot ground wire with attached sinker is placed in the water.

### Loading Problems

In the design of a lifeboat radio transmitter for operation on 500 kc with antenna arrangements such as described, one of the primary problems concerns the antenna loading system. The average antenna has a capacitance of 100 mmfd and a total resistance at 500 kc of about 10 ohms. Only a very small portion of the total resistance is effective radiation resistance. Moreover, to resonate the antenna to 500 kc, an inductor of one millihenry is required. Government regulations for this class of equipment require a minimum antenna power of 5 watts into a 100-mmfd, 10-ohm load, which corresponds to an antenna current of approximately 0.7 ampere. Since the capacitive reactance of the antenna is equivalent to 3200 ohms, the circulating volt-amperes with 0.7 ampere antenna current are 1568. The relatively high ratio of about 300, therefore, exists between antenna watts and antenna volt-amperes. These factors are reflected in the design of the antenna loading inductor. For example, a one-millihenry coil of practicable size will have a $Q$ to the order of 160, and, therefore, appears as an effective resistance of 20 ohms at 500 kc. Small improvements in coil $Q$ are of little benefit. If it were possible to double the $Q$ of the coil, resulting in 10-ohms effective resistance, it is obvious that half of the r-f power would still be lost in the loading inductor. Under practical conditions the designer must provide for the output tube to deliver approximately 15 watts in order to realize a net antenna power of 5 watts.

### Circuits

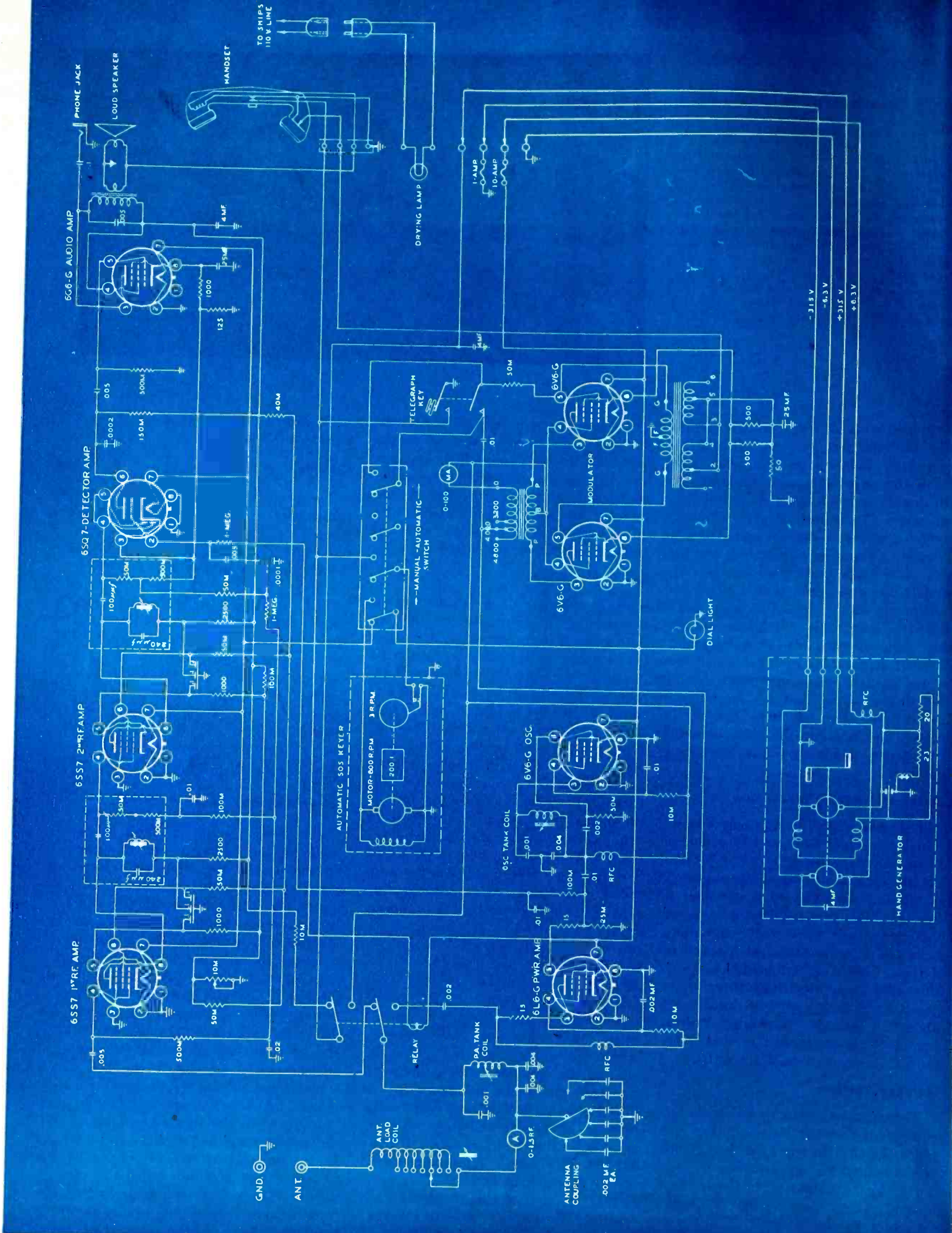
The schematic circuits of the radio transmitter and receiver are shown in Figure 7. The radio transmitter employs one 6V6-G oscillator, one 6L6-G power amplifier and two 6V6-G modulators.

The oscillator circuit uses a series pair of capacitors shunted by the oscillator tank coil with the midpoint of the capacitors grounded to form a Colpitts circuit. The oscillator grid potential is applied through a coupling capacitor to the power amplifier grid circuit. Oscillator and power amplifier screen circuits are connected in the conventional manner.

### Power Amplifier Tank

The power amplifier tank circuit comprises an inductor and a special arrangement of capacitors for resonating this circuit to 500 kc, and to couple into the antenna circuit. Part of the power amplifier capacitor leg consists of a group of .002-mfd units arranged so that one or more of these units may be connected in parallel through a panel controlled coupling switch. These coupling capacitors, therefore, carry power amplifier tank and antenna current. This arrangement provides an efficient method of transferring the energy to the antenna circuit. When the antenna coupling is adjusted at the time of installation, the power amplifier tank circuit may be thrown slightly off resonance because of the common capacitor elements. The p-a is then brought back into resonance by means of the panel controlled movable iron core which is then locked in the desired position.

For telephone transmission the microphone output is coupled through a suitable transformer to the push-pull




grids of the 6V6-G modulator tubes. The plate circuit of these tubes is in turn coupled, through a modulation transformer, to the plate and screen circuits of the 6L6-G power amplifier

(*Continued on page* 94)

Figure 7
Schematic of the transmitter-receiver.

# COIL AND CONDENSER MEASUREMENTS*

## At Audio Frequencies

## Without Commercial Instruments Specifically Designed For The Measurement


by IVAN G. EASTON

**Engineer**

**General Radio Company**


EVERY laboratory worker has probably been faced at one time or another with the problem of measuring the capacitance and dissipation factor[1] of a condenser, or the $Q$ and inductance of a coil, and has not had available a suitable bridge. The purpose of this discussion is to show that reasonably accurate measurements can be made at audio frequencies without a commercial instrument specifically designed for the measurement and without constructing permanently an instrument for the purpose. The availability in the laboratory of some standards of impedance and of such staple items as decade resistance boxes and calibrated variable condensers is assumed. An audio oscillator of reasonable output as a source of test voltage and a suitable sensitive detector is also naturally quite necessary before an audio-frequency impedance measurement can be made. In addition, a shielded transformer will be required.

The problem of stray capacitance in any *bread-board* layout of a circuit is always an important one, but can be particularly serious when measuring high impedances. Likewise electrostatic and magnetic pickup can be potential sources of difficulty. Considerable attention will consequently be paid to the problem of controlling stray capacitance, to measuring the capacitances that remain, and to taking them into account in computing results.

### Basic Bridge Circuits

Before entering a detailed discussion of methods and connections, some of the basic measuring circuits are reviewed. In Figure 1 is shown a table of eight circuits, four each for the measurement of inductance and capacitance. Each circuit is a simple four-arm bridge, involving only resistance and capacitance as standards. The identification of the various bridges is in terms of the method by which the loss component of the unknown impedance is measured.

### Capacitance Bridges

In the series resistance bridge, the loss component or resistance of the unknown capacitor is measured in terms of a resistance placed in series with the standard capacitor. The equations of balance for this bridge turn out to be most conveniently written in terms of the series component of the unknown impedance. A careful analysis will indicate that such a circuit is inherently best suited for measurements on capacitors whose dissipation factor is comparatively low. The resistance in series with the standard capacitor can be calibrated to read directly in dissipation factor (or $D$ can be calculated simply from that resistance).

As the name of the parallel resistance circuit implies, the resistive component of balance is made by a resistance in parallel with the standard

[1]Dissipation factor ($D$) is defined as the ratio of series resistance to series reactance and is equal to $R\omega C$ for a capacitance in series with a resistance. This quantity is the co-tangent of the power factor angle. For small values, power factor and dissipation factor are very nearly equal and are frequently used interchangeably.

The ratio of series reactance to series resistance is called storage factor and is designated as $Q$. For a capacitance in parallel with a resistance, we have $Q = R\omega C$. For an inductance and resistance in series, $Q = \frac{\omega L}{R}$.

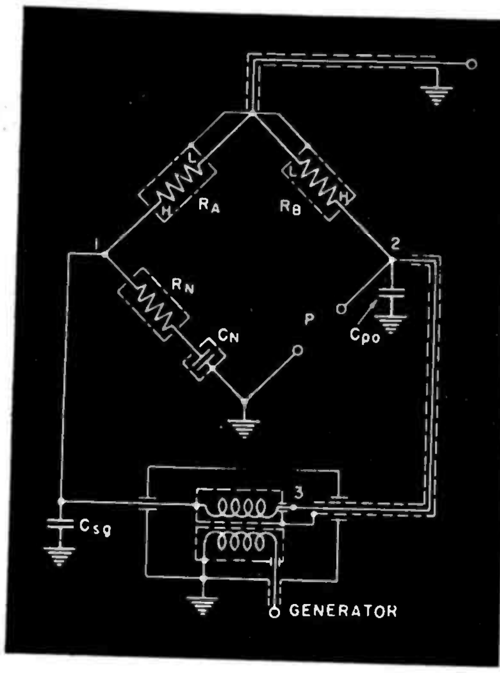
*This manuscript, specially prepared for COMMUNICATIONS, is based on a paper, "The Construction of Impedance Bridges," that was presented before the Basic Science Group of the New York Section, American Institute of Electrical Engineers.

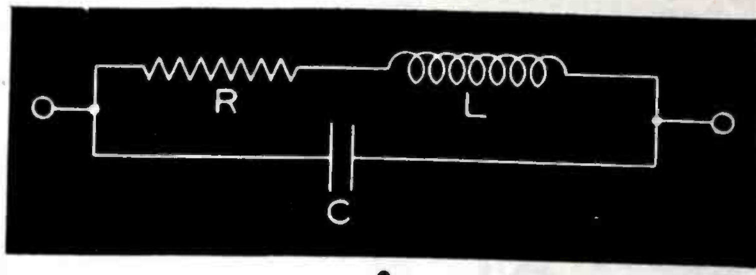
**Basic Capacitance and Inductance Bridges, Using Resistance and Capacitance**

| | *Type* | *Measures Components* | *Most Suitable for* |
|---|---|---|---|
| Capacitance | Series-Resistance | Series | Low $D$ |
| | Parallel-Resistance | Parallel | High $D$ |
| | Schering | Series | Low $D$ |
| | | Parallel | High $D$ |
| Inductance | Hay | Parallel | High $Q$ |
| | Maxwell | Series | Low $Q$ |
| | Owen | Series | Low $Q$ |
| | "Parallel Owen" or Schering | Parallel | High $Q$ |

Figure 1

A tabulation of several circuits for the measurement of inductance and capacitance in terms of capacitance and resistance. Each circuit is discussed in the text.




**Figures 2 (left) and 3 (top)**

**Figure 2 illustrates the connections for a bench layout of a series-resistance type of capacitance bridge. The approximate equations of balance are**

$$C_P = C_N \frac{R_A}{R_B}$$

$$D_P = D_N + \varphi_A - \varphi_B$$

**In Figure 3, we have a simple representation of a resistor having residual inductance and capacitance. The $Q$ of this circuit can be expressed as**

$$Q = \frac{\omega L}{R} - R\omega C$$

**provided that $\omega^2 LC << 1$.**

capacitor. In this case the equations of balance are most simply expressed in terms of parallel components of the unknown impedance. Furthermore, the circuit is likely to be most useful for measurements on capacitors with large dissipation factors.

These first two bridges are frequently called the simple impedance bridges, with an added designation to show the method of obtaining the loss balance.

In the Schering circuit, the resistive component of the unknown is balanced by a capacitor placed in parallel with the resistance arm opposite to the unknown. While it is not so readily apparent, it is easy to show that this circuit basically measures the series components of the unknown and that it is most suitable for low values of dissipation factors.

The fourth circuit listed is unnamed for the reason that it probably has never been used and has no particular usefulness, at least at audio frequencies. It is included here, however, to complement logically the other three. In this arrangement the quadrature balance is made with a condenser in series with the resistance arm opposite the unknown impedance. As indicated, the balance equations for this circuit are most simply expressed in terms of the parallel components of the unknown.

### *Inductance Bridges*

Turning now to the circuits for the measurement of inductance, we list four circuits which are analagous to the four circuits discussed for capacitance measurement. In these circuits the unknown inductance is measured in terms of a standard capacitor, but since inductance and capacitance have reactances of unlike sign, the two reactive elements must be placed in opposite arms of the bridge to make a balance possible.

In the Hay circuit, a resistance in series with the standard capacitor is used to balance the losses in the coil under measurement. If we write the balance conditions for this bridge, we find that the effective parallel component of unknown inductance is given by the triple product of the two resistance arms and the series capacitance in the standard arm. If, however, we write the expressions for the series components of the coil under measurement, we find that a term involving the square of the dissipation factor in the standard arm enters. In other words, this circuit fundamentally measures the parallel components in the unknown arm in terms of the series components in the standard arm. A consideration of limiting cases will show that this circuit is best suited for measurements of inductors with relatively high $Q$.

The circuit wherein we use a resistance in parallel with the standard capacitor is usually called the Maxwell bridge. With this arrangement the series components of the unknown are measured in terms of the elements in parallel in the standard arm.

In the Owen bridge the resistive component of balance is determined by a capacitance in series with one of the resistive arms (it does not matter which one). As indicated in Figure 1, the series inductance and resistance of the coil are the components measured by this circuit, and the circuit is basically best suited for inductors of relatively low $Q$.

The fourth circuit listed is again one that has received very little attention in the literature.[2] It utilizes a parallel capacitor across a resistance arm adjacent to the unknown, and fundamentally measures the parallel components of the unknown impedence.

### *Bridge-Sensitivity and Precision of Balance*

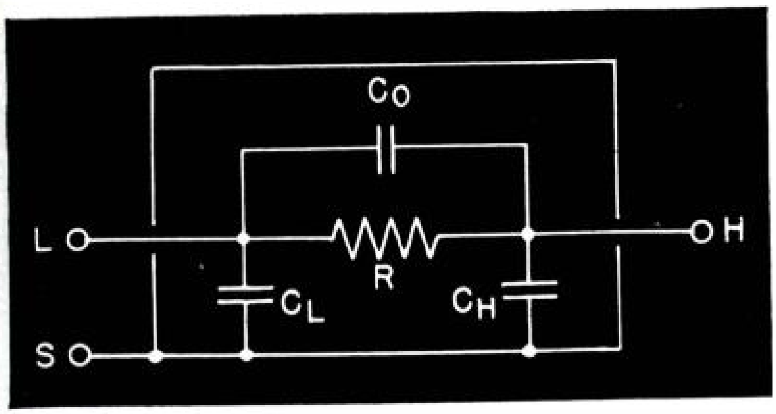
Once a suitable circuit has been selected for the desired measurement, the question of connecting generator and detector to it must be considered. Insofar as the balance conditions of the circuit are concerned, it is immaterial how the two are connected across the bridge. The sensitivity (defined as the minimum fractional change in impedance that can be distinguished), however, is dependent on the method of connection. The output voltage for a given circuit unbalance in the vicinity of balance can be expressed in terms of the following simple equations, which involve only the ratio of the impedances of the bridge arms across which the generator is connected:

$$E_{out} = E_{in} \frac{\left(\frac{A}{B}\right)}{\left(1 + \frac{A}{B}\right)^2} d \qquad (1a)$$

$$E_{out} = E_{in} \frac{\frac{A}{B}}{1 + \left(\frac{A}{B}\right)^2} d \qquad (1b)$$

Equation *1a* applies when $A$ and $B$ are similar impedances, and *1b* for the case of the generator connected across dissimilar impedances. The quantity

[2] Although mentioned in Hague's *Alternating Current Bridge Measurements*, fourth edition, with no name assigned to it.



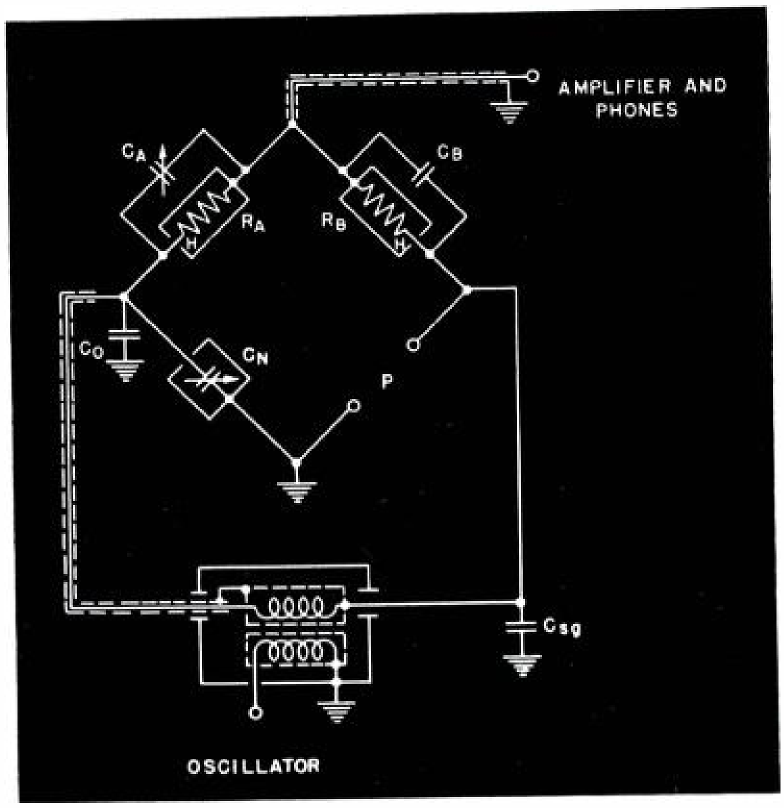




**Figure 4 (top) and 5 (right)**

**Figure 4 shows an equivalent circuit of a decade-resistance box with its associated capacitances. In Figure 5, we have the connections for a bench layout of a Schering bridge.**

*d* is the fractional unbalance of the circuit.

Maximum sensitivity is obtained when the two arms across which the generator is connected are equal in impedance. Considerable deviation from this ideal can usually be tolerated, however, because of the ease with which voltage amplification can be obtained with vacuum-tube amplifiers. It must be remembered, nevertheless, that if the ratio of the two impedances is extremely large, the effective sensitivity is markedly reduced, and it may not be possible to achieve the desired precision of balance.

Equation *1* may be used to estimate the output voltage for given conditions and to determine the possible precision of balance with a given detector and oscillator, or conversely, to determine the required amplification to realize a desired precision of balance. As an example, suppose we wish to measure a 1000-mmfd condenser and to be able to make a dissipation factor balance to 0.001. Suppose a 0.01-mfd standard condenser is used and the generator is connected across the two capacitive arms. The output voltage for a dissipation factor unbalance of 0.001 becomes:

$$E_{out} = \frac{10}{(1 + 10^2)} (0.001) E_{in}$$
$$\backsimeq 8 \times 10^{-5} E_{in}$$

Thus, if 10 volts is applied to the bridge, it will be necessary to detect 0.8 millivolt in order to distinguish the 0.001 unbalance of dissipation factor. This is somewhat beyond the range of ordinary head telephones, and a moderate amount of voltage amplification will be required.

As a matter of fact, however, we frequently will find that other considerations may dictate the type of connection to the bridge and we are forced to take what sensitivity we can get or to change our circuit impedence. We may, for example, have a circuit set-up for capacitance measurement using a 1-mfd standard condenser, that is entirely satisfactory for measuring capacitances ranging from 10,000 mmfd to 100 mfd. If we try to measure 100 mmfd with this circuit, we may find that the sensitivity has dropped too much. The sensitivity can be increased by changing to a smaller value of standard capacitance, say 10,000 mmfd.

### External Considerations

The principal requirements on the oscillator used as a power source are that it deliver an adequate voltage of reasonably sinusoidal wave form. The detector system should, of course, have the sensitivity necessary for the desired precision of balance, and in addition should preferably have a certain amount of discrimination against harmonics and other unwanted frequencies. The degree of discrimination necessary depends on the precision of balance that is desired. For moderate precision (1% or slightly better) this factor need not be given much attention.

Direct coupling between the voltage source and the detector must, of course, be avoided. Shielded units and leads should preferably be used, but if only unshielded ones are available, proper orientation and spacing will frequently reduce pickup to a satisfactory minimum.

Practically all oscillators and amplifiers, particularly if they are a-c operated, will require that one terminal be grounded for satisfactory operation. Since generator and detector cannot both be connected directly to the bridge and grounded at the same time, a shielded transformer will be required to isolate the bridge from one of them. This enables us to connect either one directly to the bridge with one terminal grounded and replaces the terminal capacitances of the other by the terminal capacitances of the shielded transformer. These terminal capacitances will be thrown across the grounded bridge arms and are a source of error, but it will be shown later that they can be measured and at least partially taken into account.

### The Series-Resistance Capacitance Bridge

To take a concrete example, let us consider the problem of measuring the capacitance and dissipation factor of reasonably good condensers (dissipation factors not exceeding a few per cent). Referring back to our compilation of basic circuits (Figure 1) it is evident that either the Schering or the series-resistance circuit will be suitable. If we have available a fixed standard capacitor and some decade resistance boxes, the series-resistance type is the most suitable circuit.

Figure 2 shows the connections for a typical circuit, and some of the problems will be discussed with particular reference to it. It will be noticed that the generator is connected across the capacitance arms of the bridge, through the shielded transformer, and that the junction of the two capacitive arms is grounded. This connection is chosen for two reasons. The terminal capacitances will have a less serious effect (or perhaps we should say, a more easily calculated effect) when placed across these arms, than if they were placed across the resistive arms. With the generator connected to the transformer, rather than to the de-

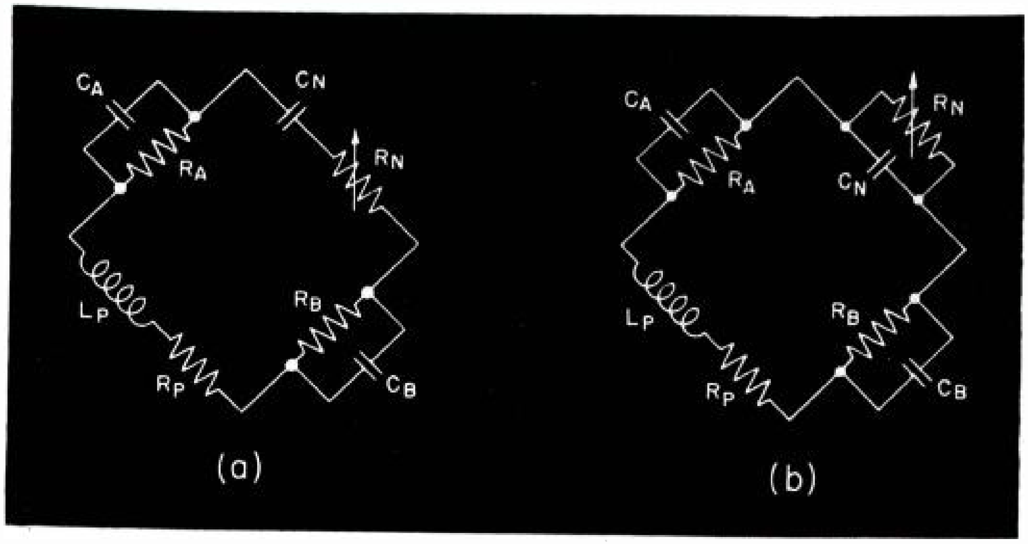



**Figure 6**

**The Hay *(a)* and Maxwell *(b)* bridges. The two circuits differ only in the method of balancing the resistive component of the unknown. The Hay circuit utilizes resistance in *series* with the standard condenser, while in Maxwell's arrangement a parallel resistance is used. The approximate equations of balance are:**

**Hay:** $L_P = \frac{R_A R_B C_N}{1 + D_N^2}$ $Q_P = \frac{1}{D_N + Q_A + Q_B}$ **Maxwell:** $L_P = R_A R_B C_N$ $Q_P = \frac{Q_N}{1 + Q_N(Q_A + Q_B)}$

tector, there is less likelihood of difficulty with magnetic pick-up. Were the transformer used to connect the detector to the bridge, it would be operating, at balance, at a voltage null and magnetic pickup would naturally have a more serious effect.

Consider now the transformer terminal capacitances, how they may be measured, and their effects on the circuit conditions. With the shield connections as shown, one of the terminal capacitances is considerably larger than the other. The larger capacitance is obviously the one on the left-hand side, as it includes the capacitance-to-ground of the secondary shield and of the shield surrounding the lead to the high side of the unknown terminals of the bridge. The magnitudes of the two terminal capacitances can be measured quite accurately by making two balances of the bridge; one with the connections as shown, the other with the leads from the transformer to the bridge transposed at the bridge. With the connections as shown, the capacitance designated as $C_{po}$ is measured directly, to a good degree of accuracy, if we assume the standard capacitance is large compared to the other terminal capacitance. With the leads reversed, a value for $C_{sg}$ is obtained. With the particular circuit shown, the values of terminal capacitance are of the order of 10 mmfd and 100 mmfd. It is felt that these can be measured to within a mmfd for the smaller and within about 5 mmfd for the larger. The capacitance connected across the unknown terminals is always measured as part of the *P* arm impedance and can be subtracted from observed values when we are making measurements, to obtain the true value of the unknown capacitance connected to that arm. The correction is important only when measuring small values of capacitance. The larger capacitance ($C_{sg}$) must be added to the known value of the standard capacitance. If, for example, the standard condenser is 10,000 mmfd, the correction is of the order of 1%, and a slight error in the determination of this correction is quite insignificant. If the resistance in series with the standard condenser is small compared to its reactance (this condition corresponds to our assumption that we are measuring a condenser of fairly small *D*) the shunting effect of the terminal capacitance will have no significant effect on the effective dissipation factor of that arm.

When these terminal capacitances have been determined, the accuracy of capacitance measurement will depend almost entirely upon the accuracy with which the bridge arms are known. If 0.1% components are used, the maximum possible error will be of the order of 0.3%.

### *Dissipation Factor Balance*

The determination of dissipation factor (or the resistance) of the unknown is subject to errors arising from residual impedances in the bridge arms. Neglecting the second-order terms, which can be shown to be ordinarily neglegible, the equation for the resistive balance can be written as

$$D_p = D_N + D_{NO} + Q_A - Q_B \quad (2)$$

where $D_{NO}$ is the dissipation factor of the standard condenser, $D_N = R_N \omega C_N$, $Q_A = R_A \omega C_A$ and $Q_B = R_B \omega C_B$. We wish to be able to compute $D_p$, the unknown *D-F* (dissipation factor) from the equation

$$D_p = D_N = R_N \omega C_N \quad (3)$$

That is, the terms $D_{NO}$, $Q_A$ and $Q_B$ are errors (although if they are accurately known, they introduce, not errors, but merely added inconvenience of calculation). The accuracy of the dissipation factor measurement depends upon the magnitude of these residual terms, and upon the accuracy with which they are known. The terms $Q_A$ and $Q_B$ are due to the stray capacitance shunting the resistive arms *A* and *B*. Residual inductance in these arms will give rise to similar terms. Figure 3 is a representation of a resistance showing both series inductance and shunt capacitance.

The *Q* of this circuit can be expressed as

$$Q = \frac{\omega L}{R} - R\omega C \quad (4)$$

provided that $\omega^2 LC << 1$. Hence the series inductance introduces a *Q* term opposite in sign to that introduced by the shunt capacitance, and the equations previously written may still be used by substituting for $Q_A$ and $Q_B$ their values modified by the presence of the series inductance. For high resistance settings of a decade box, the inductive *Q* is generally completely negligible compared with the *Q* contributed by the shunt capacitance. At low settings, however, the inductance will predominate, and the error in the dissipation factor due to that particular arm will change its sign.

The capacitances associated with the decade resistance boxes can be represented as shown in Figure 4. The terminal connected to the highest resistance decade is designated as *H*, while the terminal connected to the lowest resistance decade, and located nearest to the shield terminal, is designated as *L*.

The terminal capacitances $C_L$ and $C_H$ can be measured directly with the bridge, of which the decade box is a part. Consider the ratio arm *B* of Figure 2. It is shown with the *L* terminal and the shield connected to the junction of the ratio arms. Hence $C_L$ is short-circuited, and $C_H$ parallels the resistance $R_B$ and does not affect the capacitance balance. If the bridge is balanced with the *P* arm open circuited, a value for $C_{po}$ will be obtained, as previously. If the shield is connected to ground, $C_H$ is thrown across the *P* arm, in parallel with $C_{po}$, and the bridge at balance will indicate the value of $C_H + C_{po}$. The difference of the two readings is clearly $C_H$. By interchanging the *L* and *H* terminals of the box and following the same procedure, the value of $C_L$ is obtained. The value of $C_o$ cannot be measured by the bridge, but independent measurements indicate a value of about 5 mmfd for the General Radio type 602 decade boxes.

The series inductance ($L$ in Figure 3) cannot readily be determined, but approximate values are usually supplied by manufacturers of decade boxes.

The direct-reading accuracy of dissipation factor measurement is obviously limited by the sum of the residual $Q$'s and $D$'s of the circuit (equation 2). If $Q_B$ is negative, which occurs when series inductance predominates over shunt capacitance in the $B$ arm, all three *error* terms are additive. Let us examine the probable order of magnitude of the terms involved.

A good mica standard in the $N$ arm will of itself have a power factor less than 0.0005, but this may be nearly doubled by the losses in $C_{SG}$ shunting it. At one kilocycle the $Q$ of a type 602-J decade box (for instance) will vary roughly from —0.0008 at 10,000 ohms to +0.0007 at 10 ohms, so that the difference $Q_A - Q_B$ may range from zero to 0.0015. The maximum error to be expected, then, in measuring the total dissipation factor of the $P$ arm, will be of the order of 0.0025. If the ratio arms are nearly equal, however, the difference between their $Q$'s will be small, and the maximum value of $Q_A - Q_B + D_{NO}$ may be as low as 0.001. If $Q_B - Q_A$ be equal to $D_{NO}$ the error will approach zero. This condition may be approached by connecting a capacitor of known dissipation factor in the $P$ arm, setting the resistance box in the $N$ arm to the proper value, and balancing the bridge by means of a variable condenser across the $A$ or $B$ arm, as may be required. A known resistance in series with a known capacitance, or an air condenser of extremely small dissipation factor, may be used in the $P$ arm. This procedure must be followed through for each setting of $R_B$ that is to be used and is a relatively long and tedious procedure that is generally not justified. If it is followed with care, however, the only remaining error is that caused by the variation of the $Q$ of the $A$ arm (something of the order of ±0.0005 at 1000 cycles).

### The Schering Circuit

If a calibrated precision air capacitor is available, the Schering circuit offers several advantages for the measurement of capacitance and dissipation factor.

*(1)*—The resistances $R_A$ and $R_B$ can be fixed, the capacitance $C_N$ being varied for balance. This allows an almost infinitesimally precise adjustment of the capacitance balance.

*(2)*—An initial balance can be established for dissipation factor, so that the dissipation factor of the unknown can be measured in terms of an *increment* of a calibrated condenser across the $A$ arm.

*(3)*—It is possible to make a direct substitution measurement across the standard capacitor (for capacitance within the range of the standard).

In the design of commercial, shielded, self-contained Schering bridges it is customary to place the terminal capacitances of the shielded transformer across the ratio arms, where they are relatively innocuous, becoming a part of the initial dissipation factor balance. In a bench layout, however, this is generally not possible. Figure 5 shows an arrangement wherein the terminal capacitances are placed across the capacitance arms, in the same manner as in the series-resistance bridge.

A type 722-D precision condenser (direct reading in capacitance from 100 to 1100 mmfd, and from 25 to 110 mmfd) is ideal for use as the capacitance standard. Any shielded air condenser, such as the type 539-A, may be used for dissipation factor balance. An accurate capacitance calibration of this condenser can be obtained by a direct substitution method, with the type 539 condenser placed across the standard condenser, and with an appropriate condenser in the $P$ arm for balance. Any variable air condenser of suitable size can be used for the dissipation factor balance while $C_A$ is being calibrated.

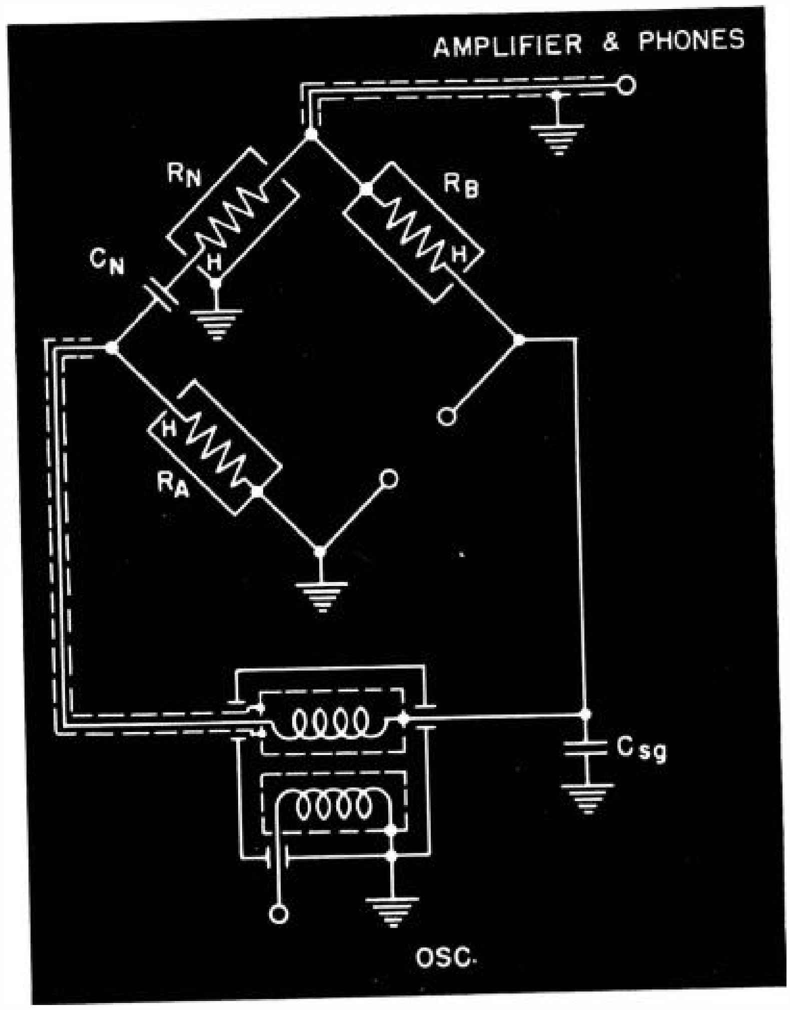



Figure 7

Here we have the connections for a bench layout of an inductance bridge. As shown, it is a Hay bridge, but can be converted to a Maxwell bridge by placing $R_N$ in parallel with $C_N$.

As shown, the larger terminal capacitance is placed across the unknown arm while the smaller (5-10 mmfd) is placed across the standard arm. Both of these terminal capacitances can be measured with good accuracy, as follows:

To measure $C_o$, the capacitance across the standard arm ($C_N$), balance the bridge with the ratio arms set equal and with a balancing condenser of from 100-1000 mmfd in the $P$ arm. Change the setting of the $A$ arm and obtain a second balance. Denoting the readings of the standard condenser by $C_{N1}$ and $C_{N2}$, respectively, the value of $C_o$ is given by

$$C_o = \frac{C_{N1} - \dfrac{R_A}{R_B} C_{N2}}{\dfrac{R_A}{R_B} - 1} \qquad (5)$$

The initial capacitance ($C_{SG}$) across the unknown arm is obtained by a direct measurement, it merely being necessary to add to $C_N$ the value of $C_o$ just obtained. That is

$$C_{SG} = \frac{R_A}{R_B}(C_N + C_o) \qquad (6)$$

After these quantities have been determined, a known constant capacitance can be added to the standard arm reading at all times. Similarly, the zero capacitance (approximately 100 mmfd) must be subtracted from the measured value of the unknown.

The dissipation factor of the zero capacitance across the *P* arm can be determined as follows: Establish an initial balance ($C_{SG}$, $D_{SG}$) with the *P* arm open, setting $C_A$ at some large value (an additional condenser across the *B* arm will be necessary). Place a 1000-mmfd condenser in the *P* arm, and rebalance the bridge by means of $C_N$ and $C_A$. The dissipation factor of the zero capacitance will then be given by

$$D_{SG} = \frac{\Delta Q_A - \dfrac{D_1 C_1}{C_2}}{1 - \dfrac{C_{SG}}{C_2}} \qquad (7)$$

In this equation, $C_{SG}$ is the zero capacitance, $C_2$ is the total *P* arm capacitance, and $D_1$ is the dissipation factor of the condenser $C_1$ placed across the *P* arm. If a good condenser is used for $C_1$, the ratio $D_1C_1/C_2$ will be very small and can be neglected.

To establish the initial balance for any setting of the ratio arms it is merely necessary to connect a capacitance of known dissipation factor (best obtained by a known resistance in series with a known capacitance) in the *P* arm, to set $C_A$ to the proper value, and to balance by means of $C_N$ and an additional condenser in parallel with *B*. After a reference point on $C_A$ has been thus determined, it will be possible to compute $D_p$ directly from any setting of $C_A$, or, at any given frequency $C_A$ can be calibrated directly in dissipation factor. The accuracy of measurement will be limited by *(1)*—the accuracy of calibration of $C_A$, by *(2)*—the accuracy with which the reference dissipation factor was known, and by *(3)*—the variation in the dissipation factor of the standard condenser in the *N* arm as its setting is varied. An accuracy better than 0.001 (at 1000 cycles) can be attained if care is taken.

### Substitution Method With the Schering Bridge

For the measurement of capacitance below 1000 mmfd, excellent accuracy for dissipation factor as well as capacitance can be attained by the use of a substitution method in the standard arm. Although the procedure for this type of measurement is fairly obvious, it is outlined here because of its importance.

An initial balance is made with a capacitance of about 1000 mmfd in the *P* arm, with the unknown in place and connected to the standard on the grounded side. The high-potential connection should be made with a bare self-supporting lead. For the initial balance this lead should be left ¼" or ½" from the high terminal of the unknown. The condenser $C_A$ must be set at some fairly large value, since its setting must be reduced when the unknown is connected. When the initial balance is made and the settings of $C_A$ and $C_N$ noted, the unknown is connected and the bridge rebalanced. Denoting the new settings by $C_N'$ and $C_A'$, the increments by $\Delta C_N$ and $\Delta C_A$ we have (provided $D_x$ is less than about 0.1):

$$C_x = C_N - C_N' = \Delta C_N \qquad (8)$$

$$D_x = R_A \omega \Delta C_A \left(\frac{C_N}{C_x}\right) \qquad (9)$$

The capacitance so determined will be accurate within ±2 mmfd, a possible maximum error of ±1 mmfd for each capacitance setting. The possible error in *D* will range from 0.00005 for a 1000-mmfd condenser to 0.0005 for a 100-mmfd condenser.

### Inductance Measurements

The circuits listed in Figure 1 for the measurement of inductance deliberately included only circuits which measure inductance in terms of capacitance, in order to make possible such measurements using the same circuit components that are used for the measurement of capacitance. The Hay and Maxwell Bridges can be set up using the same components that were used for the series-resistance-capacitance bridge, while a circuit utilizing a precision condenser is also described below.

### Hay and Maxwell Bridges

A close analogue of the series-resistance type of capacitance bridge is the Hay bridge, shown in Figure 6 with simplified equations of balance.

The expression for the storage factor may be written in reciprocal form as

$$\frac{1}{Q_P} = D_p = \frac{R_p}{\omega L_p}$$
$$= D_N + Q_A + Q_B + D_{NO} \qquad (10)$$

where $D_{NO}$ is the dissipation factor of the standard condenser itself, and $D_N$ that added by the series resistor $R_N$.

Equation *10* in this form is identical with the corresponding equation for the analogous capacitance bridge, except that all the residual factors add, whereas the *Q*'s of the ratio arms in a capacitance bridge are subtractive. This fact warns us immediately that, when the resistance arms are such that the effect of shunt capacitance predominates over that of series inductance, less accuracy can be expected in measuring *Q* than for the corresponding quantity for a condenser. It is also evident that the residuals cannot, under these conditions, be neutralized

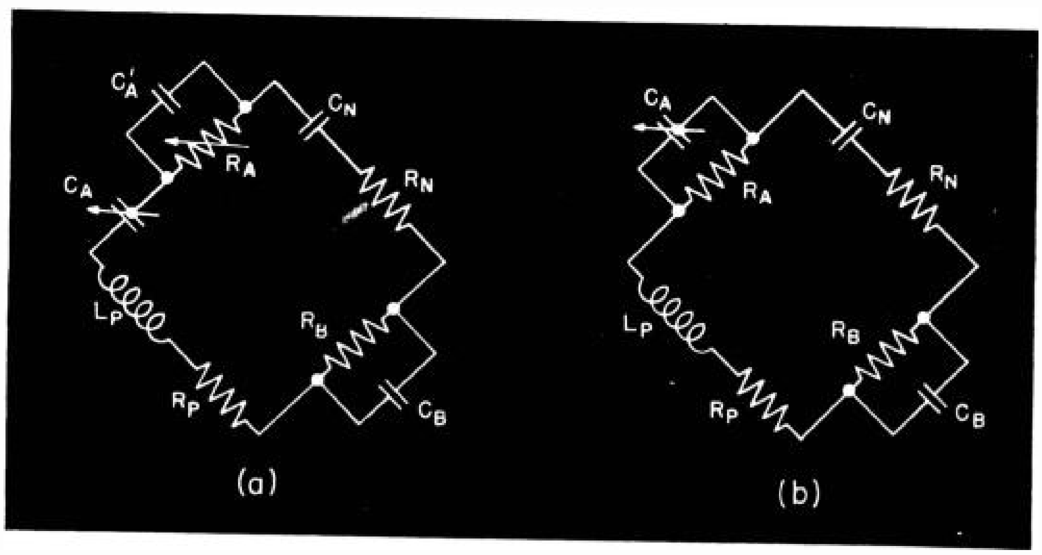



Figure 8

Schematic diagrams of (a) the Owen bridge, and (b) the Schering, or parallel, form of the Owen bridge. The conventional form of the Owen bridge balances the losses in the *P*-arm by a condenser in series with $R_A$, while the circuit shown in (b) utilizes a parallel condenser across the *A*-arm. Circuit residuals are represented by $R_N$, $C'_A$ and $C_B$ in both diagrams. The approximate equations of balance are

$$\text{Owen: } L_P = R_A R_B C_N;\ Q_P = \frac{D_A}{1 + D_A(Q_B + D_N + Q'_A)}$$

$$\text{Schering: } L_P = \frac{R_A R_B C_N}{1 + Q_A^2};\ Q_P = \frac{1}{Q_A + Q_B + D_N}$$

by adjusting capacitance across resistive arms.

### *Errors from Residual Impedances*

From our knowledge of the magnitude of the residuals we can readily estimate the order of magnitude of the error to be expected. Suppose we connect the bridge transformer in such a manner as to place the secondary shield-to-ground capacitance across the standard condenser (0.01 mfd), and set $R_A$ and $R_B$ to (say) 10,000 ohms. We may then use the values given in the previous discussion of the series-resistance capacitance bridge. These values were $Q_A = Q_B = 0.0008$, $D_{N_0} = 0.001$, which give approximately 0.0025 for the maximum value of $Q_A + Q_B + D_{N_0}$. This corresponds to an error of 25% in measuring a *Q* of 100, and to an error of 2% for $Q = 10$, if the simple relation $Q = \frac{1}{D_N}$ is used. This accuracy at high value of *Q*, is rather poor but in many practical cases a knowledge of the approximate value of *Q* is sufficient, even when it is desired to know the inductance quite accurately. The error in the indicated value of *Q* can always be reduced somewhat, of course, by inserting the estimated values of the residual terms into the equations of balance.

The accuracy of inductance measurement with the Hay circuit will be limited largely by the accuracy with which the capacitance standard is known. With the standard known to ± 0.1% an accuracy of approximately ±0.3% can be achieved. The factor $\frac{1}{1 + D_N^2}$ which appears as a multiplier in the expression for the series inductance $L_P$ is significant only when the *Q* of this inductance is low. Actually, however, this factor does not represent an error, but is the conversion factor between series inductance and equivalent parallel inductance. That is, even for low values of *Q*, the bridge reads correctly if the indicated result is properly interpreted as the effective parallel inductance of the unknown.

### *Hay, Maxwell Bench Layouts*

A bench layout utilizing the Hay and Maxwell circuits is shown in Figure 7. The components required are the same as those used for the series-resistance type of capacitance bridge already described. The disposition of the transformer terminal capacitances is different, however. The small (5-10 mmfd) capacitance is placed across a resistive arm, while the larger (approximately 100 mmfd) is placed across the unknown arm. The effect of this capacitance on inductors of 0.1 henry or less is negligible. For higher inductances, a satisfactory correction may be made, assuming a value of 100 mmfd for this capacitance.

For this particular configuration the sum of the residual *Q*'s and *D*'s is approximately 0.002.

A 100,000-ohm resistance box across $C_N$ (= 0.01 mfd) will balance *Q*'s up to 6.3, while the same box may be placed in series with $C_N$ for higher values of *Q*.

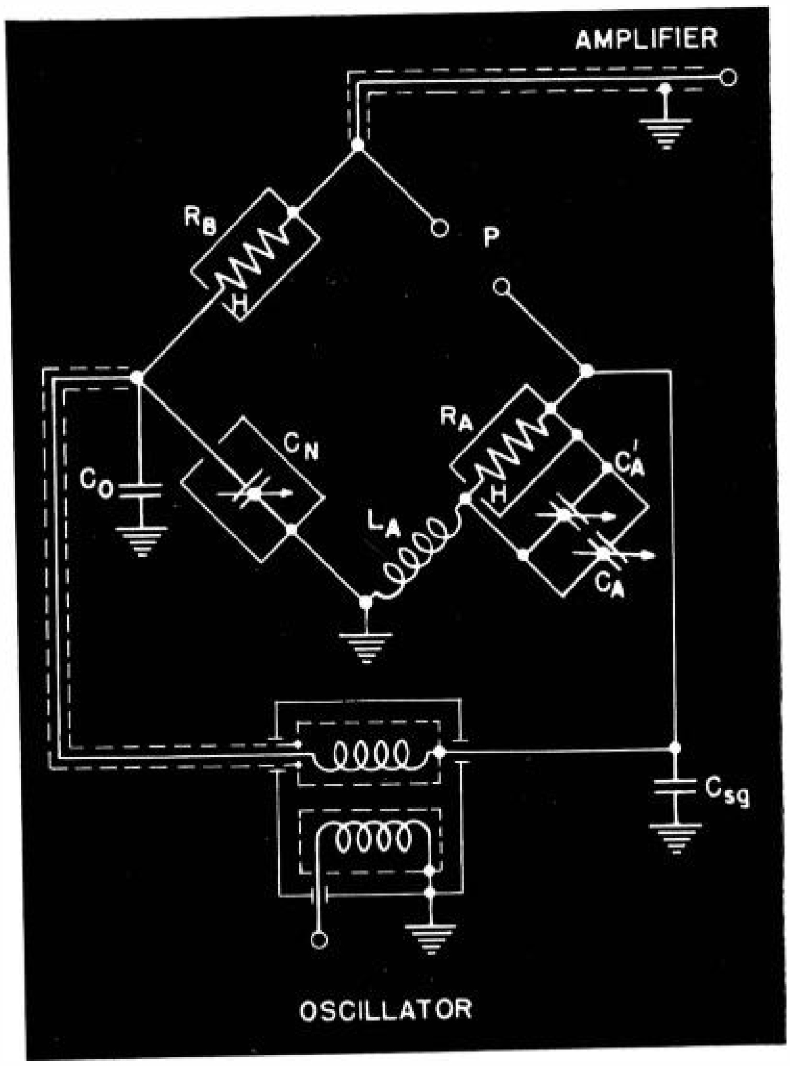



**Figure 9**

**Connections for a bench setup of a parallel form of Owen bridge. Here the inductance is balanced by a precision air condenser in the opposite arm, while the resistance of the unknown is balanced by a capacitance across one of the fixed resistance arms.**

### *The Owen Bridge*

In the Owen bridge the resistive component of the unknown impedance is balanced by a capacitance in series with one of the resistive arms. If the reactive balance is obtained by varying this resistive arm, the two balances are independent. For this circuit the variable condenser determines the resistance balance, whereas for the Maxwell bridge the variable condenser determines the inductance balance. A decade condenser, with its relatively poor accuracy (typically 1%), is generally satisfactory for the resistance measurement, however, as larger errors from other sources generally determine the accuracy of measurement of this component.

Another well recognized advantage of the Owen bridge is that it is a comparatively easy matter to pass direct current through the unknown coil. This bridge is consequently suitable for measuring iron-core inductors with polarizing current flowing.

The circuits so far discussed, however, are all subject to the same limitation in measuring coils of high Q, namely, that the error in the determination of *Q* (or of resistance) is directly proportional to *Q*, and an error of 25%, 50%, or even greater is not uncommon when *Q* is of the order of 100 or greater.

### *Circuit Using Precision Condenser*

In Figure 8 is shown a parallel form of the Owen bridge, while a bench layout of the circuit is given in Figure 9. Here the inductance is balanced by a precision air condenser in the opposite arm, while the resistance of the unknown is balanced by a capacitance across one of the fixed resistance arms.

For capacitance measurements, one of the advantages of the Schering circuit lies in the fact that it is a relatively simple matter to establish an initial balance by adjusting the difference $Q_A — Q_B$, using trimmer condensers across the ratio arms. For inductance measurements, however,

(*Continued on page* 99)

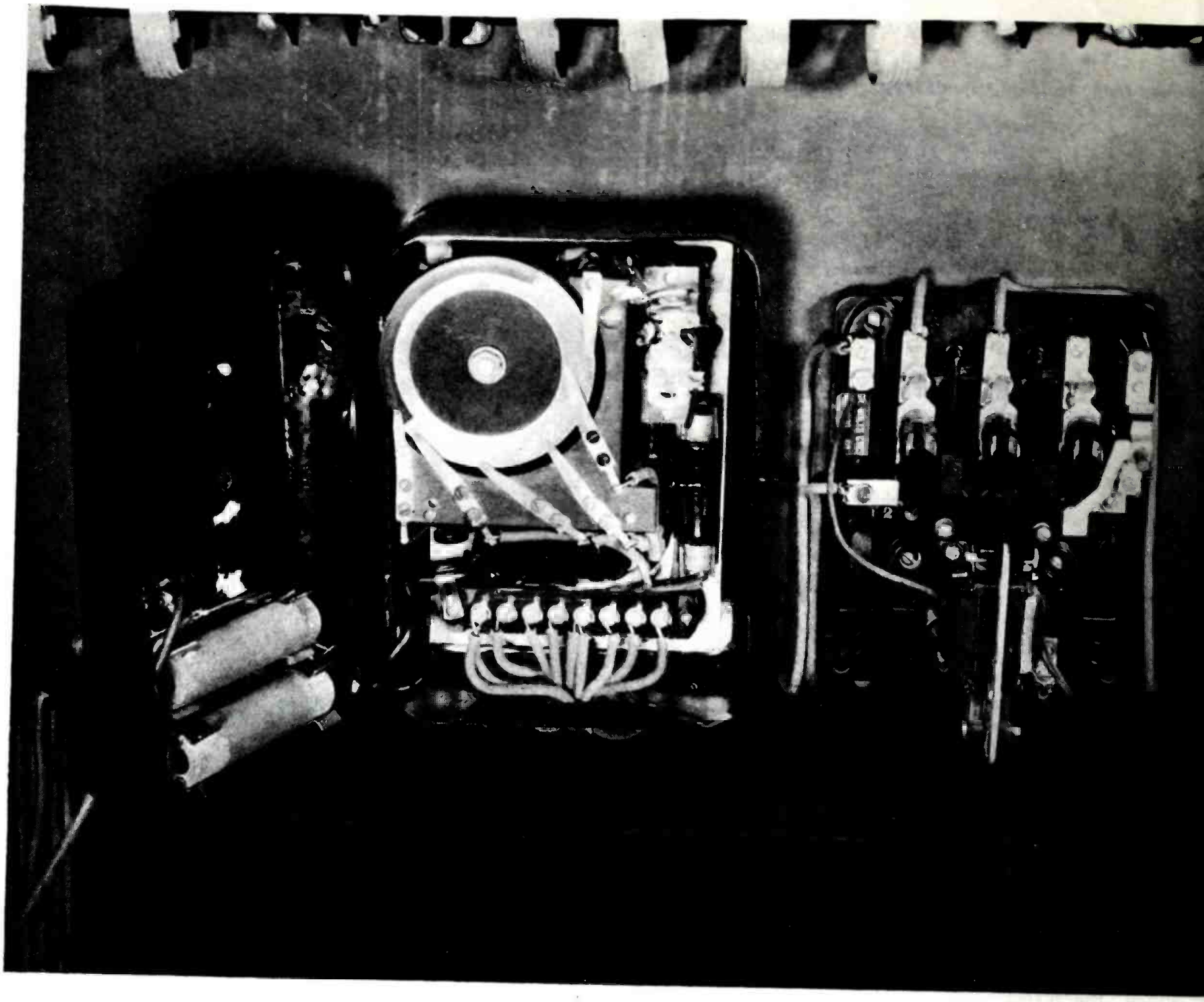


Figure 1
Closeup of the special relay device built at WCKY to afford a gradual reduction of filament voltages to 50-kw amplifiers and high voltage rectifiers.

# A FILAMENT "STEPPER DOWNER"

**by H. B. GLATSTEIN**

**WCKY Transmitting Chief Engineer**

To gradually reduce filament voltages applied to the 862 fifty-kilowatt amplifier tubes and the 857 high voltage rectifiers, a special relay was constructed at WCKY. Since the filament voltages are initially applied in three steps, the system provides for the removing of the voltages in the same sequence and at the same speed to lessen thermal shock to the tubes. This procedure fills the maintenance requirements at WCKY that call for all voltages being removed at each signoff period.

The relay was built at WCKY using castoff parts such as an old 1750 rpm fan motor, old telephone jacks and scrap bakelite. The heart of the relay is the motor that was taken from an old fan of the oscillating type, which had a geared-down shaft in the rear of the housing. This provided a speed of about 12 rpm and was originally used to oscillate the fan. This geared shaft was further geared down, using an old condenser drive gear. The final speed of the rotary contactor (*A*) is 1½ revolutions per minute. Since the rotary contactor makes only one revolution each day, the gears may be of fibre or any other light material.

***Push Button Operation***

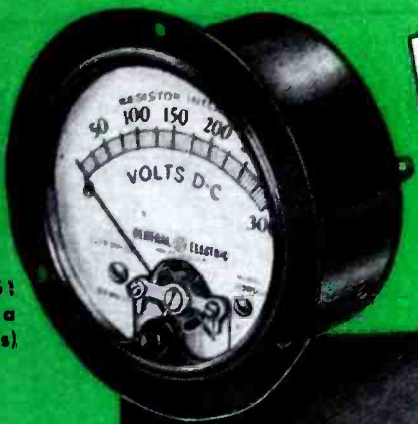
When the push button (*D*) is pushed in, relay (*C*) locks its contacts across the push-button contacts and the push button may be released.

As soon as the circuit of bus *1* is complete through the motor, the rotary contactor will start. As the edge of contact *X* passes contact *2*, the second step filament contactor will drop out; when *X* passes contact *3*, the first filament contactor will drop out.

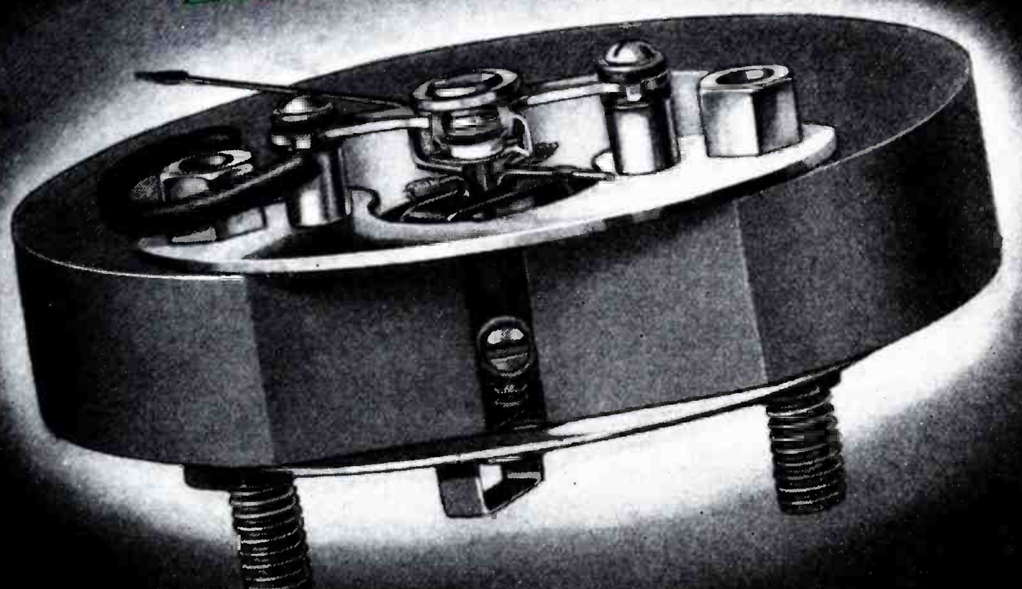
***Motor Control***

The motor will continue turning until *X* breaks contact with contact *5*. At this point, contact will be made with contact *1* at *Y*. The relay then becomes ready for resetting. However control bus *2* voltage is kept off by relay *E*, which is held in.

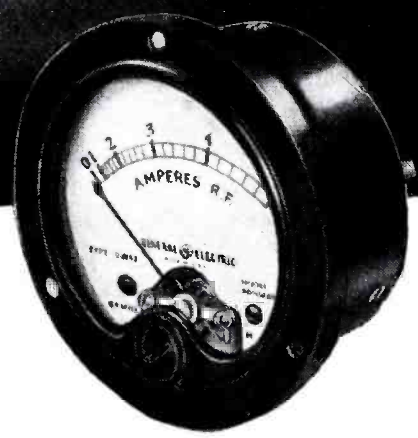
When the station start-stop switch (*Continued on page* 108)


VOLTS D-C



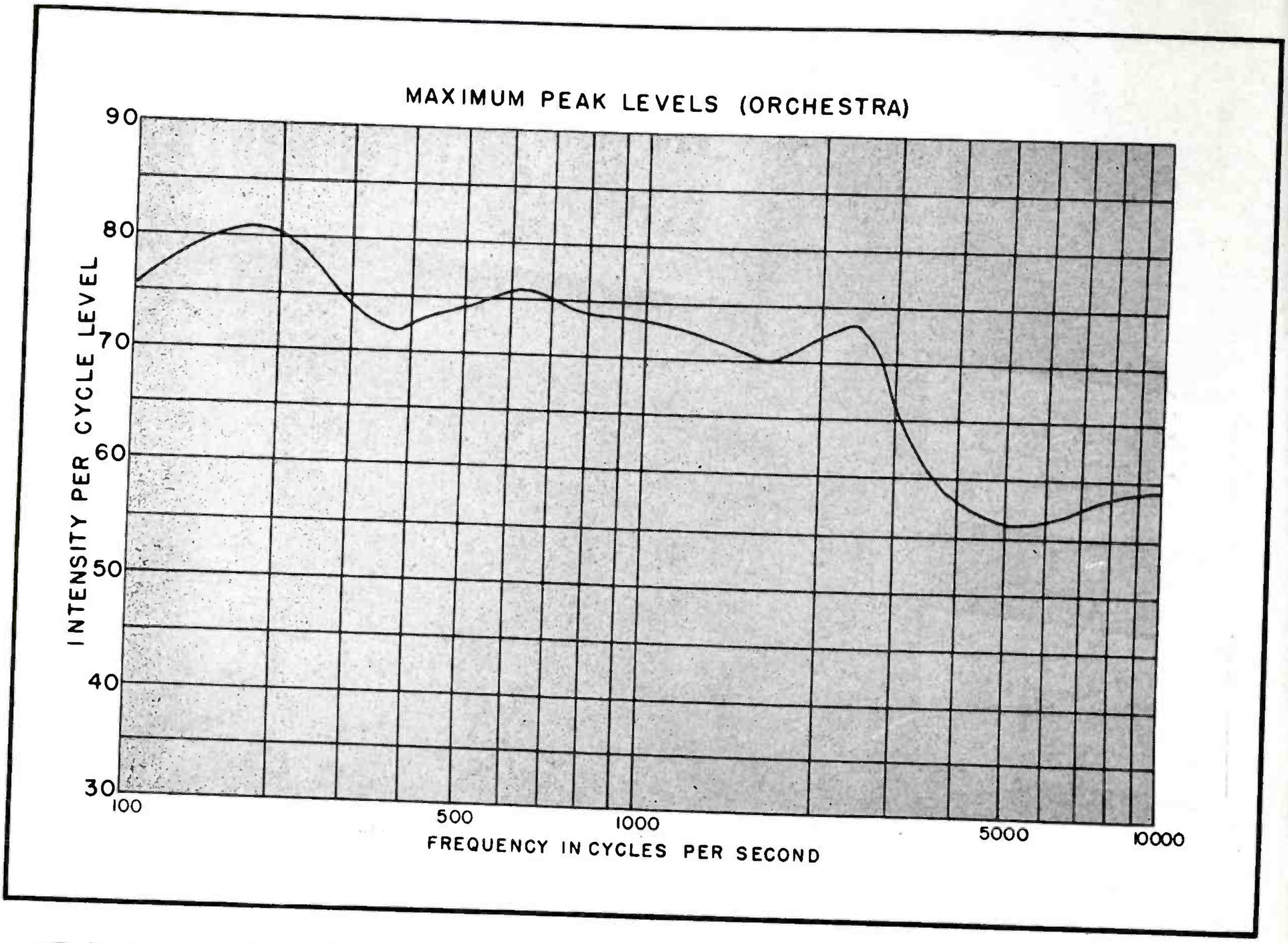





AMPERES RF

# FACTORS AFFECTING PRE-

by JOHN K. HILLIARD
Altec Lansing Corporation




OF the several factors influencing the type of transmission characteristics in radio and sound reproduction giving the best overall results, the most important is the reduction of background noise.

This reduction in noise by the pre-emphasis or equalization method accomplishes beneficial results for two basic reasons: First, the peak energy of audible signals for the most part lies in the lower portion of the audible spectrum; and second, the most objectionable noise from static impulse noise, film and disc background occurs in the upper portion of the audible spectrum.

Up to the present time, many degrees and types of pre-equalization characteristics have existed in transmission and recording circuits.

### High-Frequency Peaks

High-frequency peaks in earlier types of microphones provided a pre-

Figure 1
Maximum intensity levels produced by large and small orchestras, based on measurements made by Sivian, Dunn and White, are shown here.

equalization which tended to offset losses in radio receivers. Mechanical resonances in records for disc and film also provided another type of pre-equalization. These methods, however, were undesirable since the tuning of the mechanical system varied and caused a variable characteristic.

With the reduction of peaks in microphones and recorders, along with greater stability over a period of time, it is now practical to apply and achieve a large amount of pre-equalization for reduction of noise with little detrimental effect.

### Equalization Results

The reason for introducing pre-and-post equalization into an audible transmission channel or recording and reproducing system, is to obtain a better energy load factor than would be obtained with a normal characteristic of the system.

From measurements reported by Sivian, Dunn and White, information has been made available on the maximum intensity levels produced by large and small orchestras (Figure 1).

### Voice Characteristics

The average voice characteristics of both men and women have been determined by Loye and Morgan, and is shown in Figure 2. From these data, the average peak level intensity can be derived from the audible frequency band.

These curves show that the maximum energy occurs in the vicinity of 300 cycles for music and somewhere around 500-700 cycles for voice work,

# AND-POST EQUALIZATION

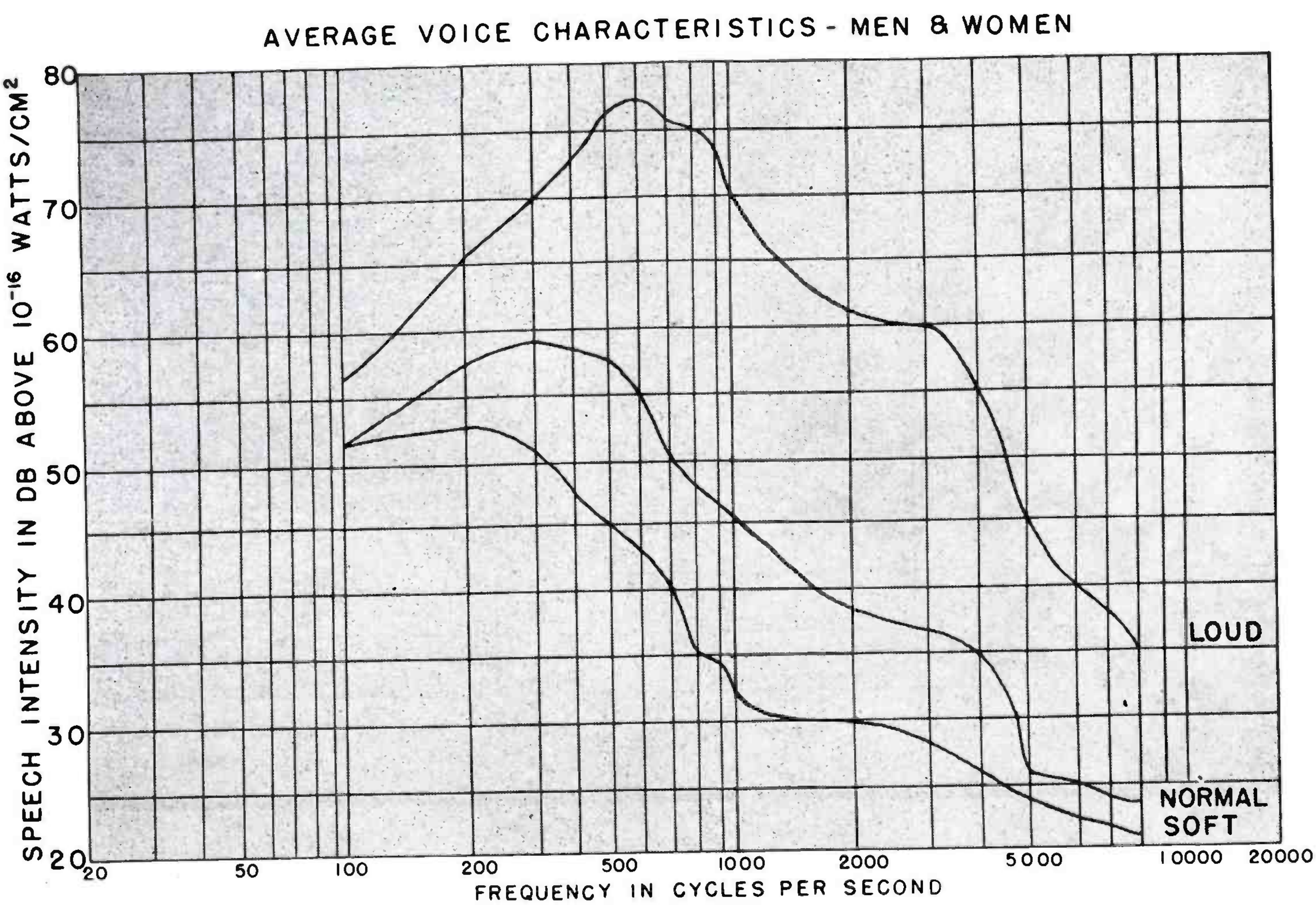



Figure 2
The average voice characteristics of both men and women as determined by Loye and Morgan. From these data, the average peak level intensity can be derived from the audible frequency band.

depending upon how much effort is expended in producing speech.

#### Pre-equalization Limit

Where the system must be designed to transmit both speech and music, the pre-equalization characteristic should be limited to start around 500-700 cycles. A limit of approximately 15 db equalization at 10,000 cycles appears to be a good balance to fit the load factor normally occurring in speech and music (Figure 3).

#### Restoration of Frequencies

The reduction in noise is accomplished by transmitting or recording the higher frequencies at this increased amplitude relative to the lower frequencies. In reproduction they are restored to normal by means of the reciprocal or post equalizer. For a very small percentage of the time, the amplitudes of the high frequencies may be such that the capacity of the system temporarily is not sufficient. During this time the penalty that must be paid is a temporary reduction in gain of the system. Normally, in orchestral sounds, no penalty is observed. Certain high frequency instruments such as cymbals and brass instruments, however, will overload. This overloading can be taken care of by the use of a limiting amplifier which reduces the gain for the short period required.

For several years, vertical transcriptions have utilized the pre-equalization method to a marked advantage, and more recently, the 33 1/3 rpm lateral transcriptions have used a similar method with equal results.

#### Television Sound Channels

Television sound channels, and frequency modulated systems employ this method to increase the signal to noise ratio. Tube hiss and impulse types of noise are apparently reduced to the same extent as is the noise on disc and film. Several motion picture studios use the pre-emphasis on original recording by the variable density method. It is generally agreed that approximately 10 db of noise reduction is obtained by this method.

#### High-Frequency Overloading

Objections have been raised to the use of pre-equalization on the basis that the high-frequency overloading would cause increased intermodulation and harmonic distortion. However, it has been observed throughout the past few years, in those systems that have utilized pre-and-post-equalization, that the reverse is true. Both dynamic and static tests indicate that the introduction of this method reduces the overall distortion very materially. The cleaner reproduction results also from the decreased inter-

(*Continued on page* 110)

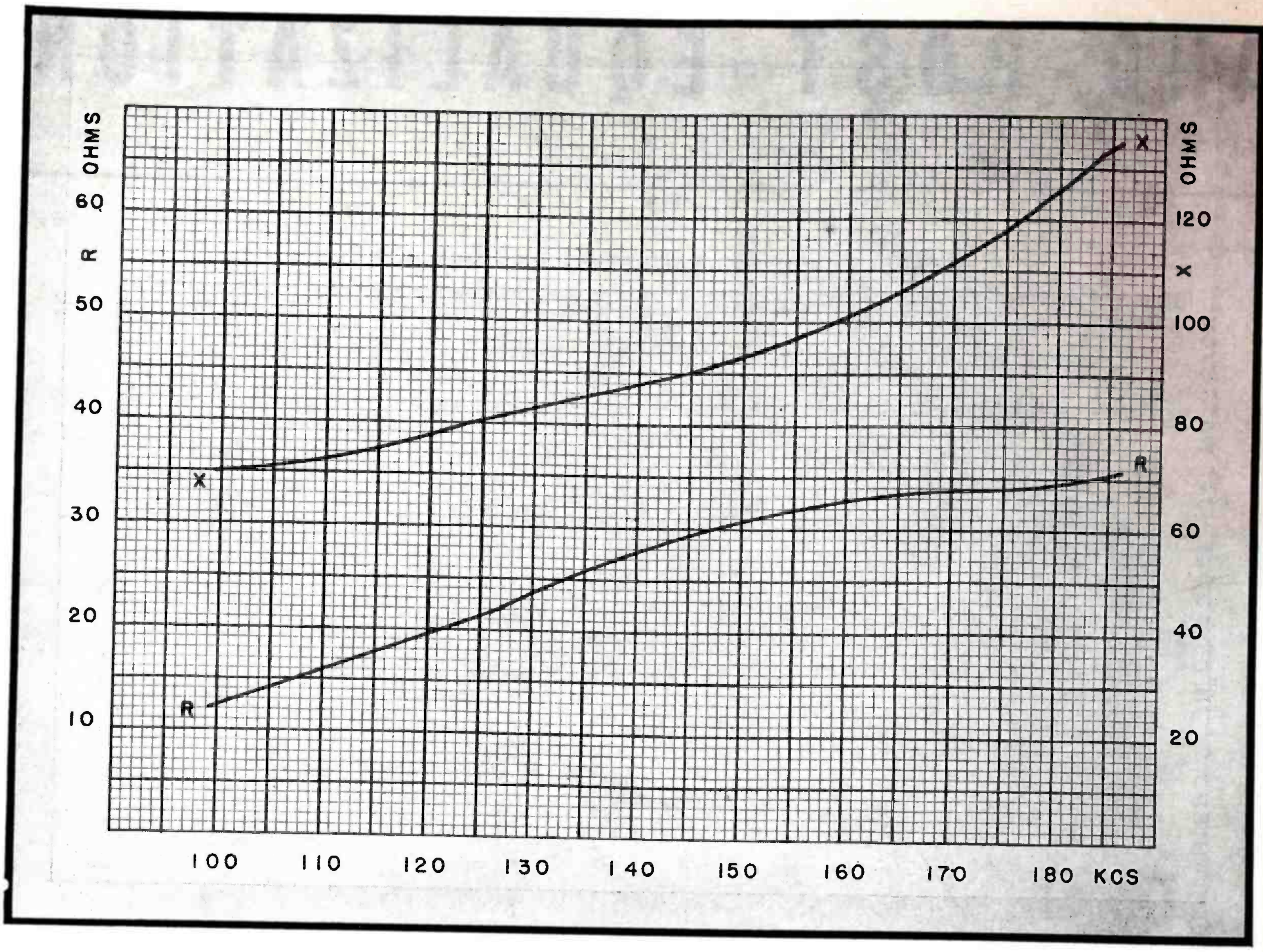



Figure 8

Resistance and reactance of supply lines single phase 3-wire 12/240 volt, 5 kva. Load side of service switch open. Left hand scale marked *R* to be used with curve *R*, right hand scale marked *X* for curve *X*.

# CARRIER CURRENT TRANSMISSION

## Impedance Measurements Data Offered In Concluding Instalment of Two-Part Paper*

**by PERRY E. WIGHTMAN and HENRY H. LYON**

**Radio Aide**
**Prince George's County, Maryland**

**Chief Engineer, WOL, Washington, D. C.**

DURING the period of experimental operation of several transmitters we noticed that it was necessary to adjust the tuning and loading when a transmitter was moved from one location to another. This was due to differences in the impedances into which the transmitter worked. A considerable number of impedance measurements were made at 5-kc intervals over a frequency range of forty kilocycles above and below the operating frequency. We used a radio frequency bridge with the usual driver and detector, to make these measurements. This was connected to the circuits at the point where a transmitter or receiver was to be installed.

*Part I appeared in August COMMUNICATIONS.

### Plots of Bridge Measurements

The results of the bridge measurements were plotted, four of the charts being shown in Figures 8 to 11. In Figure 8, it will be seen that the variation of resistance and reactance was rather smooth, rising with frequency,

(*Continued on page* 54)

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|---|---|---|---|---|
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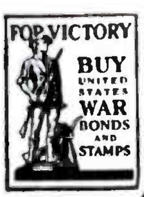
| 807 | Beam power amplifier; full power output with very low driving power. | 3.50 | 2.25 | 1.25 |
| 833-A | Amplifier and oscillator; one of RCA's most powerful glass-type triodes. | 85.00 | 76.50 | 8.50 |
| 837 | Heater-cathode type pentode r-f power amplifier, frequency-multiplier, oscillator; designed for exacting service. | 7.50 | 2.80 | 4.70 |
| 872-A/872 | Half-wave mercury-vapor rectifier; max. rating, 10,000 peak inverse volts. | 11.00 | 7.50 | 3.50 |

*October, 1941. Between Oct. 14, '41, and Mar. 15, '43, food prices have *increased* 24% (*U. S. Dept. of Commerce Bulletin*). RCA Transmitter Tube prices, on the other hand, have been materially *reduced* — an example of RCA's policy of passing the benefit of production economies on to its customers.

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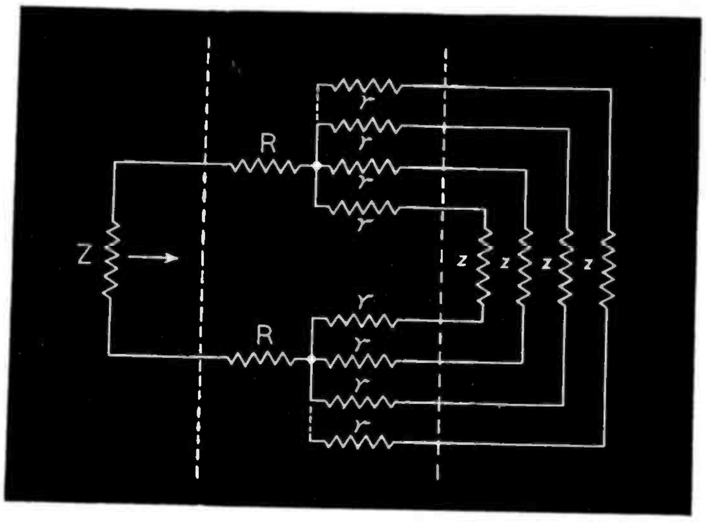
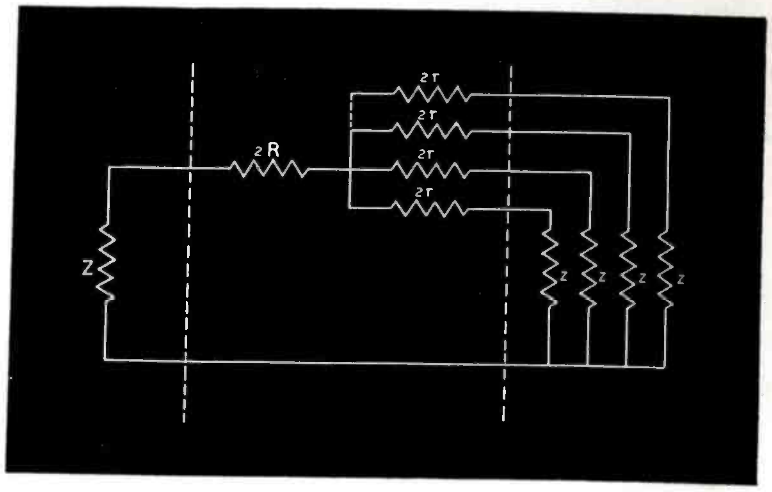
# RCA ELECTRON TUBES

TUBE & EQUIPMENT DEPT., RCA VICTOR DIVISION, RADIO CORPORATION OF AMERICA, CAMDEN, N. J.

# MULTIPLE




Figures 1 (left) and 2 (right)
In Figure 1, we have a multiple bridging network of the balanced form. Figure 2 illustrates a multiple bridged network of the unbalanced form.

THE communications engineer is frequently faced with the problem of supplying a number of branch points, loops, lines, or equipment from a common source of supply such as the output of an amplifier.

One very satisfactory manner of providing a solution to this problem would be to use one or a number of multi-winding transformers connected in such a way as to match all of the various loops and equipment impedances with their respective image impedances. This would keep amplitude distortion low by properly loading the amplifier output, and frequency distortion to a minimum partly for the same reason noted. In addition by keeping each of the windings and connected branches properly matched, the unpleasant effects to quality which would otherwise result are avoided. A further advantage gained by properly matching impedances, especially where there are other active circuits connected in the same cabling, is that of minimizing crosstalk which inevitably results when reflection of energy is permitted at the junction of two dissimilar impedances, one of which is supplying energy to the other.

### Transformer Drawbacks

Although the transformer can and does function very well to give an excellent means of matching impedances, and with very little loss from a transmission viewpoint, we find a serious drawback because of the high cost of such transformers. And at the present time, there is still a further question of priorities and availability. Each unit must be custom or especially built for any given installation. In addition to these disadvantages, there is one of either the replacement of the transformer or the rebuilding of the equipment around it, when making changes which involve rearrangments of the connecting lines and associated equipment. A simpler solution must therefore be sought.

### Multiple Bridging Networks

Fortunately, there is a simple solution. This is given by what is commonly known as a multiple bridging network. These are also called multiple pads, and splitting pads. A reduction in cost and an increase of flexibility with their usage is gained. To facilitate design and construction of a multiple bridging network for any desired ratio of impedances between input and outputs of the network and rapidly supply any number of branches desired, a series of tables, charts and examples, have been developed.

All resistive types of networks dissipate energy in the resistance elements of which they are composed. The multiple bridge is no exception to this general rule, and therefore a price is exacted for the advantages gained. The cost is an increased transmission loss over that obtained when using the transformer. This must be compensated for by increased gains at one or more points in the connecting system. A single stage amplifier will generally suffice for most applications, and for many installations, none at all will be needed since sufficient margin is frequently available in existent equipment. If additional gain must be added, it is best to add it at the input of the multiple bridge. This is especially true if the network impedance ratios are high and the number of branches being fed are numerous. The practical necessity for this procedure is determined by either excessive noise or crosstalk, or both. If the level of transmission at the output branches of the network is allowed to fall much in excess of twenty decibels below a power reference of one milli-watt into six hundred ohms, trouble from either or both of these causes may result. For flexibility of control, and the avoidance of these difficulties, the use of a separate amplifier associated with the network is to be highly recommended, although it is of course, not absolutely necessary.

The exact manner of application of the multiple bridge will vary with individual design tastes of the user; it will depend upon the impedances to be matched, the losses required to match them and upon the general economic situation of each installation.

### Applications

A few of the applications may be mentioned, although many more specific ones could be added to the list. Among them, we might include:

(1)—Integral usage with a separate amplifier to form what is commonly termed a multiple bridging amplifier.

(2)—Supplying numerous loops for music distribution systems in and to hotels, cafes, and entertainment clubs.

(3)—Distribution of incoming line energy to station transmitters, loops, monitors, and audition studios.

(4)—In recording studios, to supply a number of recording units, fader systems, and extra loops to various points.

(5)—Feeding speaker systems through-

# BRIDGING NETWORKS

## For Supplying Any Number Of Lines Or Units Of Equipment From A Common Source

### by PAUL B. WRIGHT

out large plants, railroad stations, automobile parking areas, football fields, sport events, etc.

In recent years, many groups, societies and interested persons have gone to considerable effort and expense to standardize a few impedance values for general purposes. However, one still finds many different pieces of equipment with other than the relatively few standard impedances. For the majority of voice frequency applications, the impedances most frequently encountered in connection with lines and amplifiers are 500 and 600 ohms. In addition to these, there are . . . amplifier inputs ranging over values like 50, 125, 133, 150, 175 and 250 ohms; amplifier outputs ranging from 3 or 4 ohms up to several thousand ohms; speaker voice coils from 3 to 20 ohms; fader systems of 50, 200, 250, 500 and 600 ohms. The desirability of having as few impedances as possible which will serve equally as well as an assorted lot seems quite reasonable and necessary on economic grounds, if for no other reason.

Since multiple bridging networks are designed normally on the basis of a common input impedance, and equal branch output impedances which are equal to or less than the common input impedance, it is necessary to use either a transformer for the odd values, or an impedance matching pad which is designed for minimum loss. Which of these is used will depend upon whether the additional loss of the pad is great enough to require an additional amplifier, or if the added cost of a transformer is the more economical. On the other hand, a mismatch of impedances may be allowed to occur without seriously impairing the quality to the branch considered, or, at the same time, causing any appreciable distortion at either the source or to the remaining branches of the network. The accompanying charts give the losses of the minimum loss pads, and the formulae for the determination of their elements; also the loss resulting from a mismatch of the given impedances. Since the loss of these networks is relatively high, the effects of interaction losses are neglected as being unimportant for most practical applications.

Equipment arrangements used in connection with multiple bridging networks should always provide for proper termination of the bridge at all times. If one or more branches are disconnected from the bridge, terminations should replace the branches removed. The effect of failing to do so is most serious when the impedance ratio approaches unity and the number of branches as few as two. In these cases, jumps in volume and impairment of quality will result. A convenient manner in which to provide the terminations is to terminate the resistances on the back contacts of jacks or keys, whichever is used; or some form of strapping may be utilized if desired.

[1] P. K. McElroy, *Designing Resistive Attenuating Networks*, Proceedings of IRE, Vol. 23, No. 3, March, 1935.

**Figures 3 (left) and 4 (right)**

**A multiple bridge network, equivalent of Figures 1 or 2, appears in Figure 3. In Figure 4, we have a dissymmetrical *T* network, the equivalent of Figure 3.**

#### Design

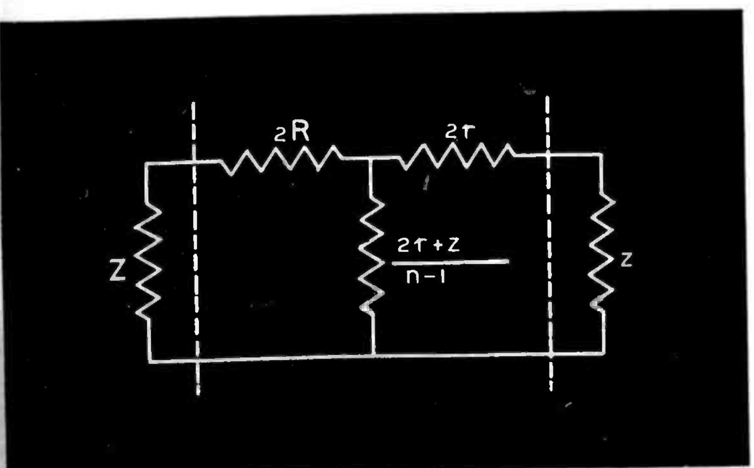
The general configuration of the multiple bridging type of network described in this paper is shown in balanced form (Figure 1) and in unbalanced form (Figure 2). For simplification, the usual equivalent generator frequently represented with zero impedance in series with the source impedance is omitted. It is assumed that power is supplied to the network from the source impedance in order to deliver power to each of the branches of the bridge.

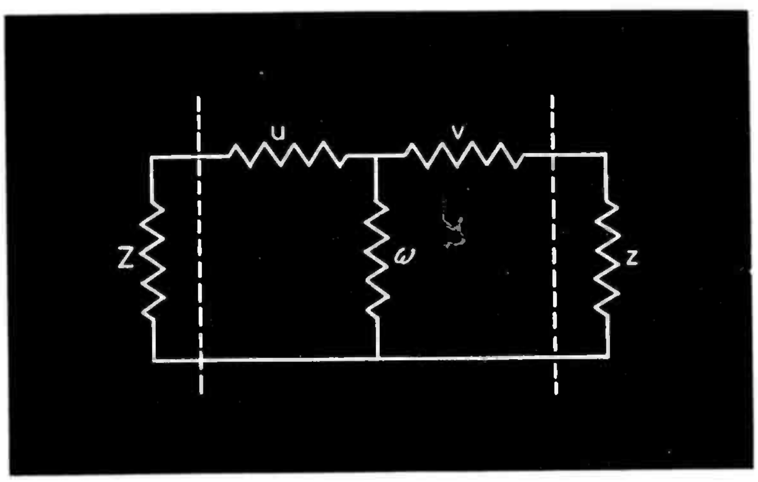
The definitions below will apply throughout the following analysis; using a portion of the nomenclature adopted in the work of McElroy[1].

$R = ZC_R$, where $Z$ is the source impedance and $C_R$ is a constant taken from Table 1.

$r = zC_r$, where $z$ is the load impedance of each of the $n$ branches of the network and $C_r$ is a constant taken from Table 2.

$k^2 = \log_{10}^{-1}(N/10)$ = ratio of the input power to the network and the output power delivered to each



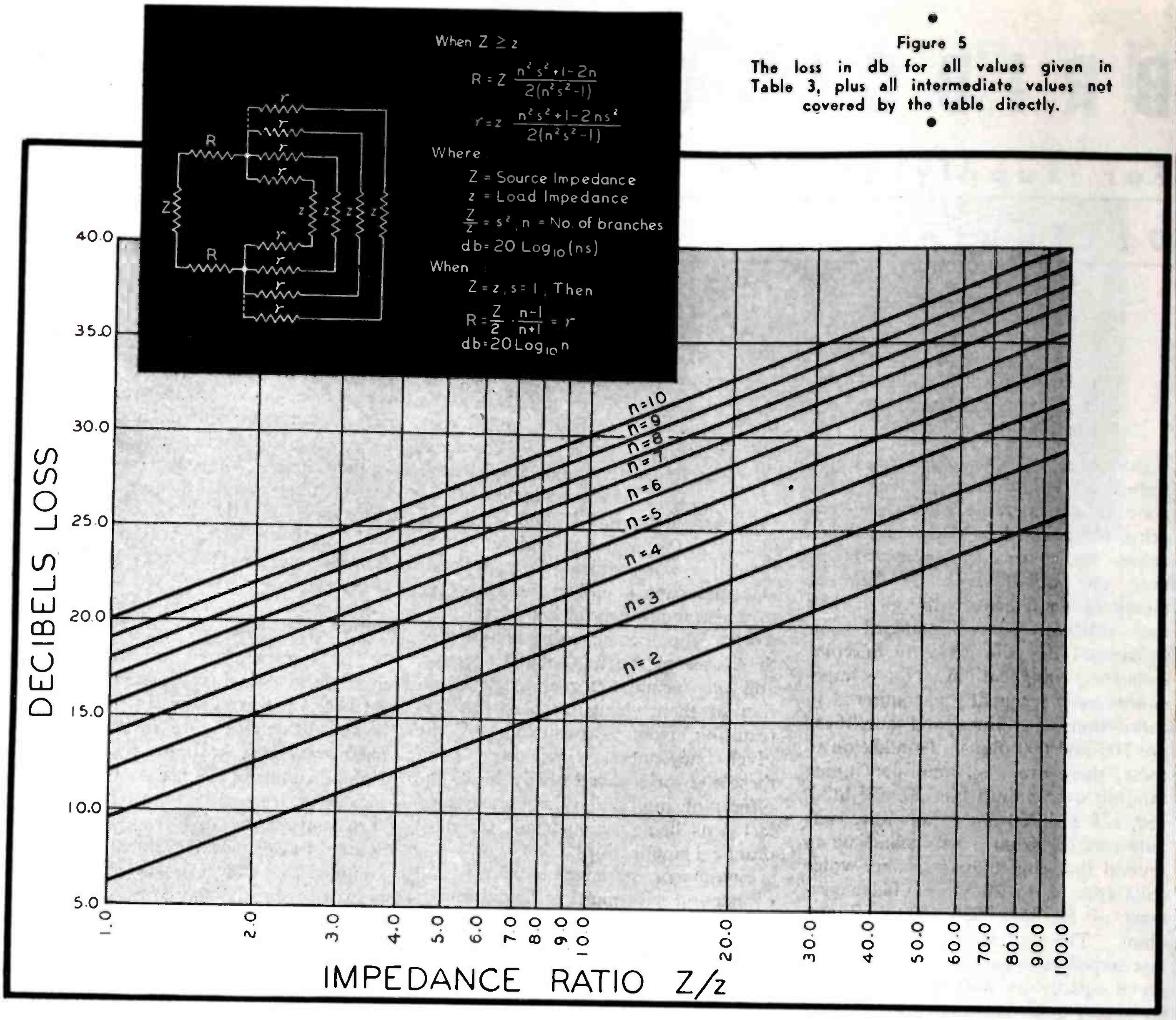



**Figure 5**
The loss in db for all values given in Table 3, plus all intermediate values not covered by the table directly.

load of impedance $z$, and causing a loss of $N$ decibels.

$k = \log_{10}^{-1}(N/20)$ = the square root of the power ratio taken positively, and equal to or greater than one.

$s^2 = Z/z$, the ratio of the source impedance to the load impedance of any one branch, and equal to or greater than one.

$n$ = number of load impedances or branches each having the value of $z$.

$u$, $v$, $w$ = resistive elements of the generalized $T$ network, and equivalent to 2R, 2r, and $(2r+z)/(n-1)$ respectively of the multiple bridge, of this paper.

$\theta = .115129 \times$ no. of decibels $= \log_e k$.

The equivalent form of Figures 4 or 5 is shown in Figure 3. This may be recognized as having the general form of the dissymmetrical $T$ network shown in Figure 4.

Utilizing the theory of the generalized $T$ structure for pure resistance networks, the ratio of the input and output power of Figure 4 is:

$$k^2 = \left[\frac{w + v + z}{w}\right]^2 s^2 \qquad (1)$$

The element values are given by

$$u = Z\left[\frac{k^2+1}{k^2-1} - \frac{2k}{s(k^2-1)}\right] \qquad (2)$$

$$v = z\left[\frac{k^2+1}{k^2-1} - \frac{2ks}{k^2-1}\right] \qquad (3)$$

$$w = z\left[\frac{2ks}{k^2-1}\right] \qquad (4)$$

These become, for $Z = z$, or $s = 1$,

$$u = \frac{Z}{2} \cdot \frac{k-1}{k+1} = v \qquad (5)$$

$$w = 2z \cdot \frac{k}{k^2-1} \qquad (6)$$

By comparing Figure 3 with Figure 4, it can be seen that

$$u = 2R \qquad (7)$$

$$v = 2r \qquad (8)$$

$$w = (2r + z)/(n-1) \qquad (9)$$

Substituting equations *8* and *9* into *1*, we obtain the simple and compact expression

$$k = ns \qquad (10)$$

Taking the logarithm of each side of this equation, and remembering that $s^2 = Z/z$,

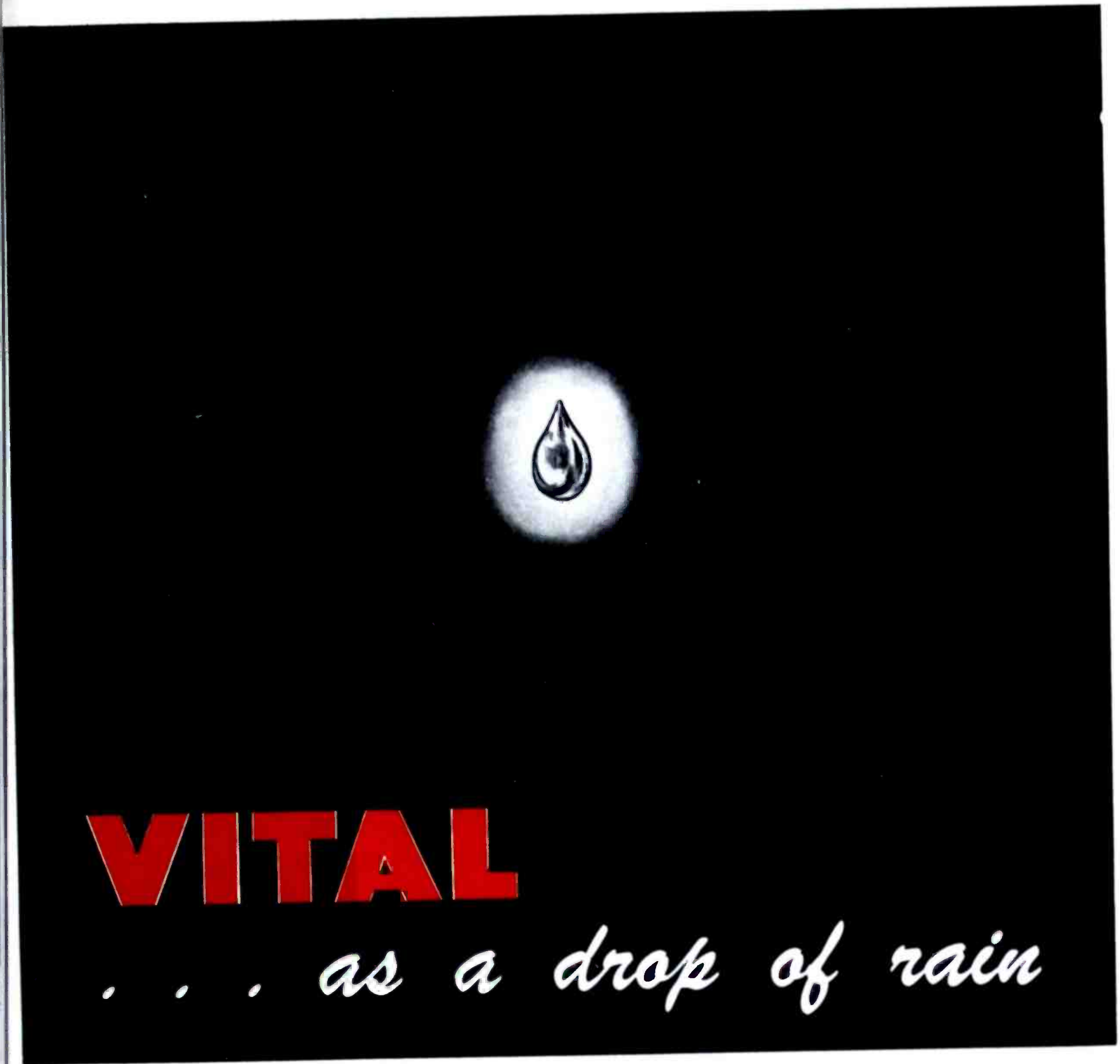
$$\log_{10}k = (1/2)\log_{10}(Z/z) + \log_{10}n \qquad (11)$$

which has the linear slope form familiar in analytical geometry of

$$y = mx + b \qquad (12)$$

where:

$y = \log_{10}k$
$m = (1/2)$
$x = \log_{10}(Z/z)$
$b = \log_{10}n$




**Spirit** . . . . Our enemies, who lack among their own peoples an idealism that motivates the individual from within rather than one forced upon him, are increasingly learning to count the cost of their gross ignorance and accordingly miscalculating that tremendous VITAL force — AMERICAN SPIRIT! Just as American Spirit is helping forge victories on the field of battle, so does American Spirit on the production front provide the priceless ingredient which, added to materials and skills, results in our unprecedented output.

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**Table 1**

$C_R$

| $\frac{Z}{z}$ | n 2 | n 3 | n 4 | n 5 | n 6 | n 7 | n 8 | n 9 | n 10 |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | .166667 | .250000 | .300000 | .333333 | .357143 | .375000 | .388889 | .400000 | .409091 |
| 1.2 | .236842 | .259919 | .335165 | .362069 | .381517 | .396193 | .407651 | .416839 | .424369 |
| 1.5 | .300000 | .340000 | .369566 | .390411 | .400159 | .417246 | .427836 | .433610 | .439597 |
| 2.0 | .357142 | .382352 | .403226 | .418868 | .429577 | .438145 | .444882 | .450310 | .454774 |
| 3.0 | .409091 | .423076 | .436170 | .445945 | .453271 | .458904 | .464103 | .470687 | .469899 |
| 4.0 | .433333 | .442857 | .452380 | .459595 | .465035 | .464231 | .472549 | .475232 | .477439 |
| 5.0 | .447369 | .454546 | .462024 | .467742 | .472067 | .475410 | .478057 | .480198 | .481964 |
| 6.0 | .456522 | .462263 | .468420 | .473154 | .476744 | .479522 | .482096 | .483506 | .485025 |
| 7.0 | .462962 | .467741 | .474973 | .477012 | .480079 | .482456 | .484341 | .485864 | .487126 |
| 8.0 | .467742 | .471831 | .476378 | .479950 | .482578 | .484653 | .486302 | .487636 | .488734 |
| 9.0 | .471428 | .475000 | .479021 | .482143 | .484521 | .486364 | .487826 | .489012 | .489990 |
| 10.0 | .474358 | .477500 | .481132 | .483935 | .486073 | .487730 | .489047 | .490104 | .490090 |
| 12.0 | .478723 | .481303 | .484293 | .486621 | .468400 | .489779 | .491060 | .491763 | .492493 |
| 16.0 | .484126 | .486014 | .488235 | .489975 | .491304 | .492327 | .493157 | .493821 | .494370 |
| 25.0 | .489899 | .491070 | .492482 | .493588 | .494439 | .495098 | .495622 | .496047 | .496398 |
| 36.0 | .493007 | .493809 | .494782 | .495551 | .496139 | .496596 | .496960 | .497250 | .497499 |
| 49.0 | .494872 | .495455 | .496169 | .496732 | .497164 | .497500 | .497767 | .497984 | .498162 |
| 64.0 | .496078 | .496521 | .497067 | .497498 | .497329 | .498086 | .498290 | .498456 | .498593 |
| 81.0 | .496905 | .497254 | .497683 | .498023 | .498284 | .498388 | .498649 | .498780 | .498888 |
| 100.0 | .497494 | .497776 | .498123 | .498399 | .498610 | .498775 | .498906 | .499012 | .499100 |

Equation *11,* when plotted on semi-logarithmic graph paper gives parallel lines having a slope of ½, and an intercept of log $n$ at $Z = z$ or $s = 1$.

From the definition for the loss in decibels and equations *10* and *11,* the loss of the network from the input to each of the $n$ loads or branches is obtained as:

$$db = 20 \log_{10} k = 20 \log_{10}(ns) \quad (13)$$

and

$$db = 10 \log_{10}(Z/z) + 20 \log_{10} n \quad (14)$$

For $Z = z$, or $s = 1$, the loss of the network becomes simply:

$$db = 20 \log_{10} n \quad (15)$$

***Element Values***

The element values of the network in terms of the number of branches and the ratio of the input and load impedances are obtained from using equation *10* in *2* and *3*; then combining with equations *7* and *8,* giving finally:

$$R = Z \left[ \frac{n^2s^2 + 1 - 2n}{2(n^2s^2 - 1)} \right] = ZC_R \quad (16)$$

and

$$r = z \left[ \frac{n^2s^2 + 1 - 2ns^2}{2(n^2s^2 - 1)} \right] = zC_r \quad (17)$$

where the bracketed quantities = $C_R$ in *16,* and $C_r$ in *17.* These become, for the special case of $Z = z$, or $s = 1$,

**The product of $C_R$ (from Table I above) and Z give the element R as shown in the figure at the right.**

the identities:

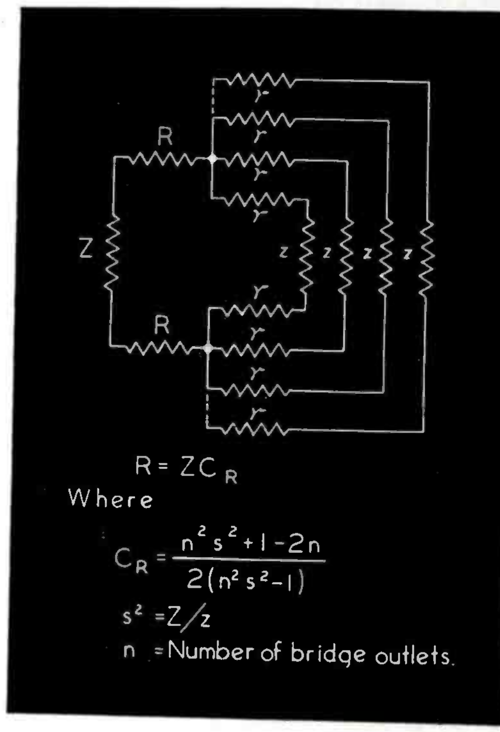
$$R = r = \frac{Z}{2} \frac{k-1}{k+1}$$

$$= \frac{Z}{2} \frac{n-1}{n+1} = ZC_R = ZC_r \quad (18)$$

Tables 1, 2, and 3 have been calculated to facilitate obtaining rapidly the losses and element values of the network. They have been calculated from the functions given in equations *16, 17* and *14* respectively. All of the common values of impedance ratios from 1 to 100 and of branches from 2 to 10 have been included. For any number of branches greater than 10, two bridging networks may be bridged together giving an additional loss of 6.02 db.

Figure 5 provides loss in db for all the values given in Table 3 plus all intermediate values not covered by the table directly. For greatest accuracy, the tables should be used. If intermediate values not given directly by the tables are desired, they may be obtained by interpolation or calculation. Although there will be probably few instances when such data will be necessary, all of the necessary formulae have been shown so that any desired degree of accuracy might be obtained.

An impedance matching pad is a



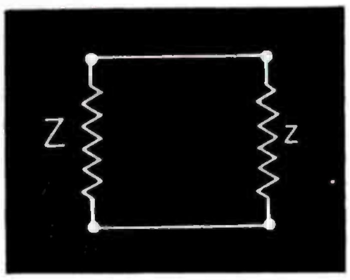

degenerated *T* pad in which the series arm next to the smaller terminating impedance has vanished and become equal to zero. From Figure 4 and equation *2,* the condition necessary for $u$ to equal zero is that

$$k = s + \sqrt{s^2 - 1} \quad (19)$$

The loss of the degenerate network is therefore:

$$db = 20 \log_{10} k$$
$$= 20 \log_{10}(s + \sqrt{s^2 - 1}) \quad (20)$$

The network has become an *L* type, or in the balanced form, a *U* type pad and capable of matching both of the impedances *Z* and *z* to which it is connected. Since the loss is a func-



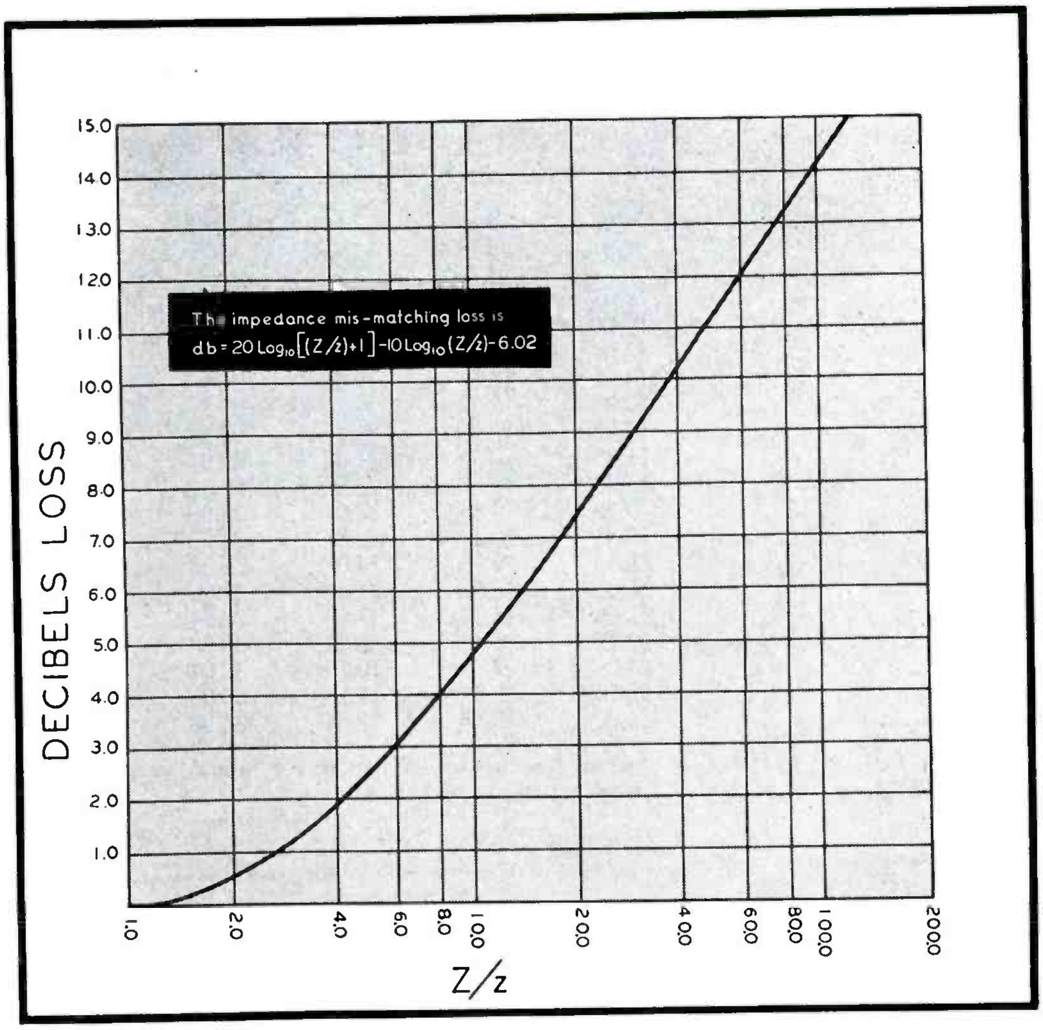




Figure 6 (a, top; b, right)

The curve gives the loss caused by an impedance mismatch where the ratio at the junction considered is Z/z. This loss must be added to the transmission losses to obtain the total loss.

tion of *s*, which is a function of the ratio of the two impedances, equation *20* shows that for each value of the ratio of the terminating impedances, there corresponds a given minimum loss which must be suffered in transferring energy from the one impedance to the other without reflection at the junctions of the network. Figure 6b shows the minimum loss that will be obtained in order to match the impedances of ratio Z/z, and the formulae for determining their elements.

If equation *19* and natural logarithms are used, we obtain a relationship which may be recognized as a hyperbolic function. Likewise equation *2* may be transformed into hyperbolic form by the placing of

$$k = e^{\theta} \qquad (21)$$

either form or method leads to the equation:

$$s = \cosh \theta \qquad (22)$$

Using equations *21* and *22* in equa-

**Table 2**

$C_r$

| $\frac{Z}{z}$ | n 2 | n 3 | n 4 | n 5 | n 6 | n 7 | n 8 | n 9 | n 10 |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | .166667 | .250000 | .300000 | .333333 | .357143 | .375000 | .388889 | .400000 | .409091 |
| 1.2 | .131579 | .234694 | .291209 | .327586 | .353081 | .371971 | .386543 | .398128 | .407563 |
| 1.5 | .100000 | .220000 | .282608 | .321918 | .349046 | .368965 | .386599 | .396265 | .406040 |
| 2.0 | .071428 | .205882 | .274193 | .316827 | .345070 | .365980 | .381889 | .394410 | .404523 |
| 3.0 | .045454 | .192307 | .265957 | .310810 | .341121 | .363014 | .382051 | .392562 | .403009 |
| 4.0 | .033333 | .185715 | .261904 | .308080 | .339161 | .361539 | .378431 | .391641 | .402256 |
| 5.0 | .026316 | .181818 | .259493 | .306452 | .337988 | .360656 | .377743 | .391089 | .401804 |
| 6.0 | .021739 | .179246 | .257895 | .305369 | .337209 | .360068 | .377285 | .390722 | .401552 |
| 7.0 | .018518 | .177419 | .256756 | .304598 | .336653 | .359649 | .376958 | .390458 | .401288 |
| 8.0 | .016129 | .176056 | .255906 | .304020 | .336236 | .359334 | .376712 | .390264 | .401125 |
| 9.0 | .014286 | .175000 | .255244 | .303571 | .335768 | .359091 | .376521 | .390111 | .401002 |
| 10.0 | .012820 | .173858 | .254714 | .303212 | .335655 | .358895 | .376370 | .389986 | .400900 |
| 12.0 | .010488 | .172897 | .253927 | .302675 | .335267 | .358604 | .376140 | .389806 | .400750 |
| 16.0 | .007936 | .171328 | .252941 | .302005 | .334782 | .358238 | .375855 | .389574 | .400562 |
| 25.0 | .005050 | .119643 | .251880 | .301281 | .334261 | .357843 | .375547 | .389328 | .400360 |
| 36.0 | .003496 | .118731 | .251304 | .300890 | .333977 | .357629 | .375380 | .389193 | .400250 |
| 49.0 | .002564 | .118182 | .250958 | .300653 | .333806 | .357292 | .375279 | .389113 | .400183 |
| 64.0 | .001961 | .11726 | .250733 | .300500 | .333478 | .357416 | .375213 | .389060 | .400140 |
| 81.0 | .001548 | .117583 | .250579 | .300395 | .333619 | .357359 | .375168 | .389029 | .400111 |
| 100.0 | .001253 | .117408 | .250469 | .300320 | .333565 | .357317 | .375136 | .388998 | .400090 |

$$r = z\,C_r$$

where

$$C_r = \frac{n^2s^2 + 1 - 2ns^2}{2\,(n^2s^2 - 1)}$$

$s^2 = Z/z$

n = number of bridge outlets.

**Table 3**

| Z/z | db n=2 | n=3 | n=4 | n=5 | n=6 | n=7 | n=8 | n=9 | n=10 |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 6.02 | 9.54 | 12.04 | 13.98 | 15.56 | 16.90 | 18.06 | 19.08 | 20.00 |
| 1.2 | 6.81 | 10.33 | 12.83 | 14.77 | 16.35 | 17.69 | 18.06 | 19.88 | 20.79 |
| 1.5 | 7.78 | 11.30 | 13.80 | 15.74 | 17.32 | 18.66 | 19.82 | 20.85 | 21.76 |
| 2.0 | 9.03 | 12.55 | 15.05 | 16.99 | 18.57 | 19.91 | 21.07 | 22.08 | 23.01 |
| 3.0 | 10.79 | 14.31 | 16.81 | 18.75 | 20.33 | 21.67 | 22.92 | 23.86 | 24.77 |
| 4.0 | 12.04 | 15.56 | 18.06 | 20.00 | 21.58 | 22.92 | 24.08 | 25.10 | 26.02 |
| 5.0 | 13.01 | 16.53 | 19.03 | 20.97 | 22.55 | 23.89 | 25.05 | 26.07 | 26.99 |
| 6.0 | 13.80 | 17.32 | 19.82 | 21.76 | 23.34 | 24.68 | 25.93 | 26.87 | 27.78 |
| 7.0 | 14.47 | 17.99 | 20.49 | 22.43 | 24.01 | 25.35 | 26.51 | 27.54 | 28.45 |
| 8.0 | 15.05 | 18.57 | 21.07 | 23.01 | 24.59 | 25.93 | 27.09 | 28.12 | 29.03 |
| 9.0 | 15.56 | 19.08 | 21.58 | 23.52 | 25.10 | 26.44 | 27.60 | 28.63 | 29.54 |
| 10.0 | 16.02 | 19.54 | 22.04 | 23.98 | 25.56 | 26.90 | 28.06 | 29.08 | 30.00 |
| 12.0 | 16.81 | 20.33 | 22.83 | 24.77 | 26.35 | 27.69 | 28.85 | 29.88 | 30.79 |
| 16.0 | 18.06 | 21.58 | 24.08 | 26.02 | 27.60 | 28.94 | 30.10 | 31.13 | 32.04 |
| 25.0 | 20.00 | 23.52 | 26.02 | 27.96 | 29.54 | 30.88 | 32.04 | 33.06 | 33.98 |
| 36.0 | 21.58 | 25.10 | 27.60 | 29.54 | 31.13 | 32.46 | 33.62 | 34.65 | 35.56 |
| 49.0 | 22.92 | 26.44 | 28.94 | 30.88 | 32.46 | 33.80 | 34.96 | 35.99 | 36.90 |
| 64.0 | 24.08 | 27.60 | 30.10 | 32.04 | 33.62 | 34.96 | 36.12 | 37.15 | 38.06 |
| 81.0 | 25.10 | 28.63 | 31.13 | 33.06 | 34.65 | 35.99 | 37.15 | 38.17 | 39.08 |
| 100.0 | 26.02 | 29.54 | 32.04 | 33.98 | 35.56 | 36.90 | 38.06 | 39.08 | 40.00 |

The loss in decibels from the source impedance $Z$ to any outlet $z$ is

$$db = 20 \log (ns)$$

where:

$n$ = no. of bridge outlets.
$s^2 = Z/z$.

when $Z > z$.

A dissymmetrical balanced *H* attenuation pad or network may be obtained having the losses given in *Table 3* with series arms of *R* and *r*, and shunt arm of $(2r + z)/(n - 1)$, as shown in Figure 3. When the network is unbalanced, it becomes a *T* pad having series arms of 2R and 2r, with a shunt of $(2r + z)/(n - 1)$, as shown in Figure 3.

When $Z = z$, the same configurations hold true, except that the network becomes symmetrical with series arms of $R = r$, and shunt of $(2R + Z)/(n - 1)$ for the *H* pad; and series arms of $2R = 2r$ and shunt of $(2R + Z)/(n - 1)$ for the *T* pad.

tions *3* and *4* and the relationships between the hyperbolic sine and cosine along with $s^2 = Z/z$, we obtain after some algebraic manipulation:

$$v = \sqrt{Z(Z - z)} \quad (23)$$

and

$$w = Zz/v \quad (24)$$

Another and perhaps much simpler method to obtain the element values is to equate each end of the *L* network to its image impedances and solve the simultaneous pair of equations resulting, giving the same values obtained above. These are the values required to match any source and load impedance to each other without reflections taking place. Note that as the value of *Z* aproaches that of *z* or conversely, the series arm *v* approaches zero; the shunt arm approaches infinity, and the pad vanishes.

#### Impedance Mis-match or Reflection Loss

The ratio of the power that would

(*Continued on page* 96)

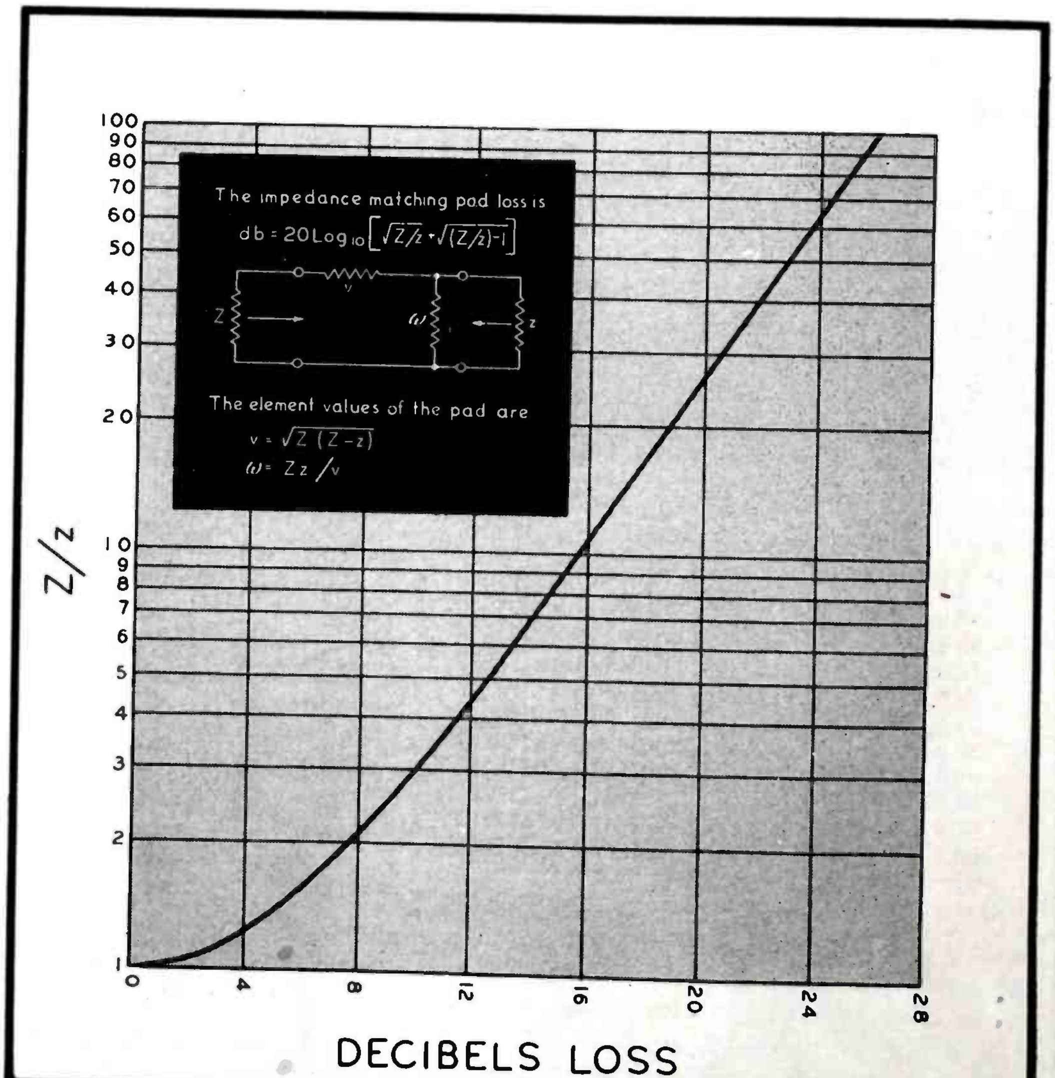



Figure 7
**This curve gives the minimum loss that will be obtained by the use of a matching network for the ratio of Z to z and still permit perfect matching at both ends of the network.**


The Hytron 807—peacetime all-purpose favorite—is now a veteran. Before it joins its battle-scarred brothers, however, like all Hytron tubes it must pass Hytron factory specifications which weed out the 4-F's as efficiently as Army doctors at an induction center. Unless a Hytron 807 is in top fighting condition, it never leaves the factory. Let's look at a few of the many test hurdles it must surmount.

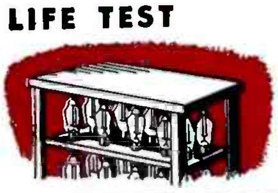
**BUMP TEST**

Ever stop to think of what a leaping, bouncing jeep or peep can do to a tube's "innards"? One answer to the question of a tube's ability to withstand such punishment, is the Bump Test. Several resounding smacks by a heavy, swinging hammer loosens up the weak sisters pronto!

**IMMERSION TEST**

A "PT" boat leaning back on its stern, and plowing a foaming furrow through steaming tropical waters would spell disaster to poorly-cemented bases and top caps. That is why Hytron 807's are thoroughly soaked in a hot bath, before they are O.K.'d.

**LIFE TEST**



Day and night, Hytron 807's on life-test racks are proving that they can give long, dependable service. Soaring skyward in our big bombers, these tubes have a big investment in men and matériel to protect. Long after the big fellows have been patched for the last time, these tubes are still doing their jobs.

**VIBRATION TEST**

Link-trainer for 807's aspiring to tank service is a motor-driven eccentric arm which shakes the tube like an angry terrier while a v.t. voltmeter in the plate circuit records the ability of the elements to take it like the iron men who ride those clanking, thundering monsters.

**HYTRON TOLERANCES tighter than CUSTOMER TOLERANCES**

No manufacturer makes all tubes of a given type exactly alike. Hytron does manufacture its tubes to tight specifications which insure against slight inaccuracies due to meters and the human element. Engineered to these narrower limits, Hytron tubes fit exactly the circuit constants with which they must operate.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

HYTRON RADIO TUBES

# HYTRON

ELECTRONIC AND RADIO TUBES **CORPORATION**

SALEM AND NEWBURYPORT, MASS.

# WARTIME MASTER CONTROL

by A. JAMES EBEL AND KENNETH GUGE
Chief Engineer, WILL
Engineer, WILL

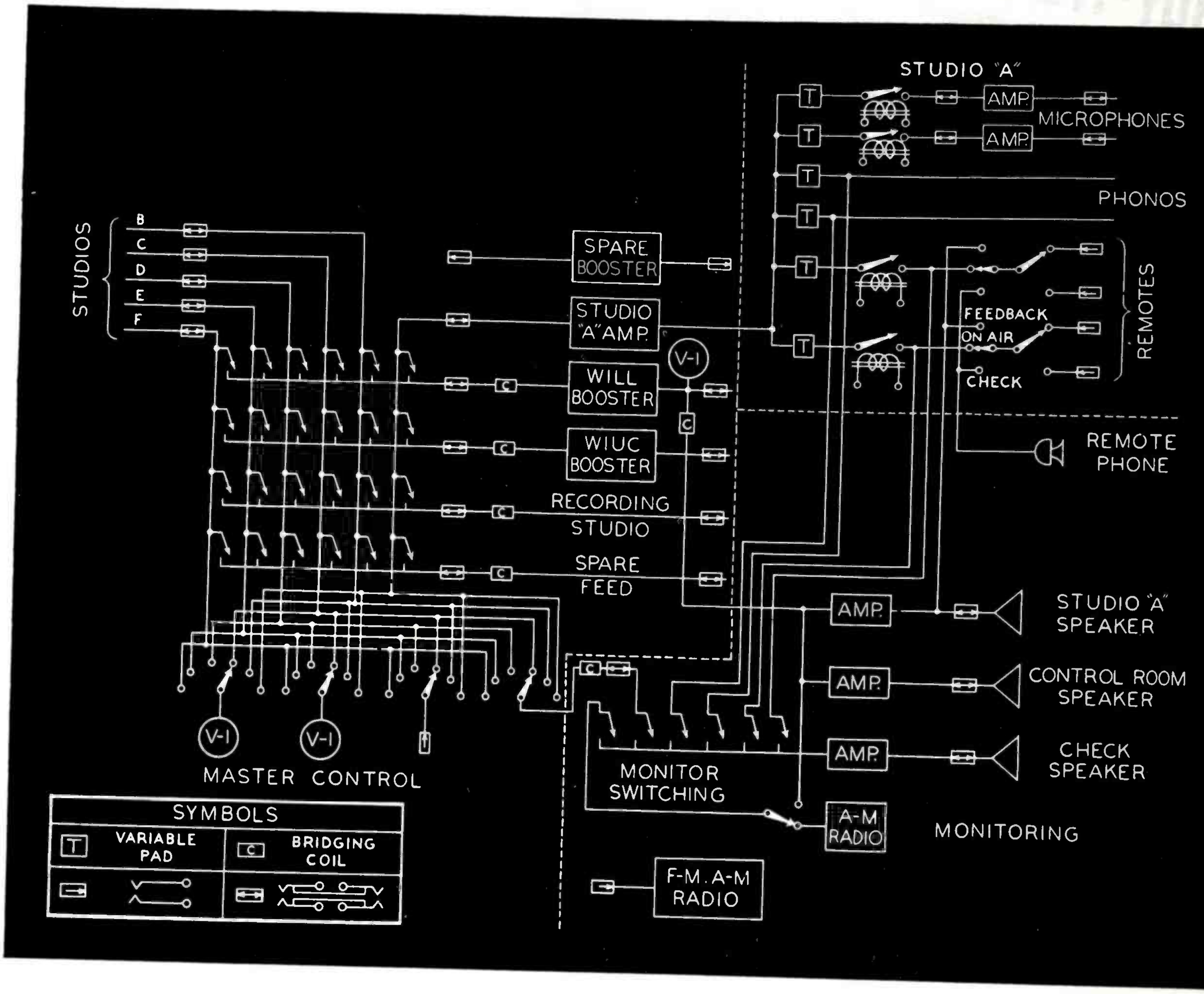



Figure 1

The high level bridging type switching system used in the WILL master control console.

CONTROL consoles represent a type of broadcast equipment which must be tailor-made for its particular application in the overall transmission system. Manufactured consoles, although standardized to a large extent, still provide for adaptation to individual conditions. Since any such equipment must serve to knit together all the various units of the transmission system, its design must be definitely dependent on the type of operation contemplated, the facilities available, and the operating philosophy of the engineer in charge. For this reason no successful paper may be written on how to build a control console. Rather, a *complete* description of existing equipment will add to the fund of information and ideas which the engineer can tap when designing a piece of equipment for his own application.

#### *Wartime Problems*

The equipment described here is interesting in that it had to be constructed during wartime from existing parts. When the University of Illinois Radio Service had to move its quarters, an old inadequate master control was remodeled into the equipment shown here. Certain components had to be obtained wherever available, but for the most part the components were salvaged from the old installation.

#### *System Requirements*

The requirements to be imposed on the new control system were as follows:

*(1)* It must provide a master control for a six-studio plant.

*(2)* It must provide facilities for feeding a standard broadcast station, an f-m station, a recording room, and other stations.

*(3)* Audition facilities must be

# CONSOLE

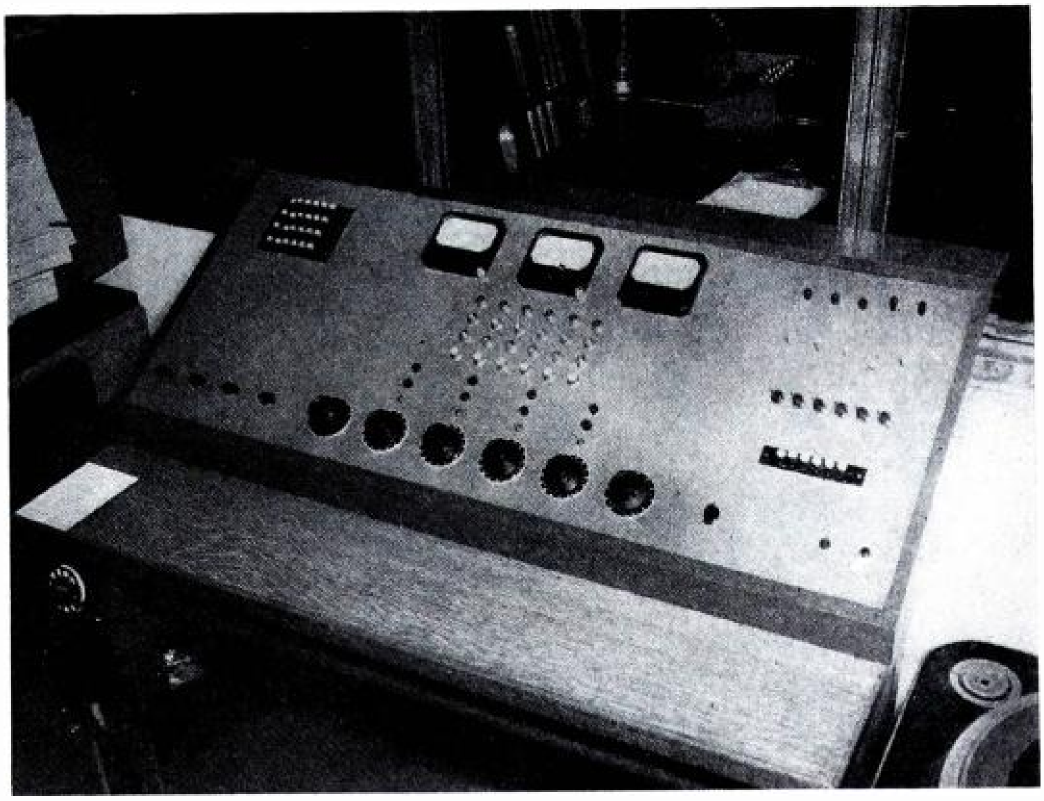


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Figure 2

**The console with its bank of varied-colored lights that serve to post the operator on the studios in use, which stations programs are going to, or whether the recording room or an outside station is being fed.**

•

established which can monitor any of the six studios.

In addition to the above requirements, since the University of Illinois Radio Service is a State operated organization it is imperative to effect economies in operation wherever possible. For this reason the studio control for studio *A*, the most used studio, was incorporated as part of the master control console. Thus with the control engineer operating master control, studio *A* control, and playing records at the same time, it became highly desirable that the operation of each of the units be simplified as much as possible. We feel that the console described meets these requirements satisfactorily.

### Switching System

In Figure 1 appears the switching system used. It is of the high level bridging type. While a pre-set system is highly desirable it was out of the question in this particular installation since the relays necessary could not be obtained. Instead direct push-button switching is used and is highly successful. The push-buttons are of the telephone interlocking type with six to the strip. One strip is assigned to each feed circuit, making four strips in all. All studio outputs come into the switching system at zero level and are terminated in a 500-ohm resistor. The switches provide bridges across any of the incoming program buses. The bridging loss is made up in booster amplifiers connected to the output feed circuits. Audition channels are provided by two rotary switches which swing the audition bridging coils across the various incoming program buses. Two additional rotary switches bridge v-u meters across the incoming buses.

### Pilot Light Indication

Pilot light indication of the switching is provided by an extra contact on each of the push-button switches. The photograph of the console, Figure 2, shows a bank of pilot lights in the center of the panel. Each feed circuit has a different color light so that the operator can tell at a glance which studios are feeding, and whether the program is going to WILL, the a-m transmitter; WIUC, the f-m transmitter; the recording room; or to another station. Also, taps are taken off of these lights and run to a standard indicator board in each of the studio control rooms.

### Indicating Panel

Figure 3 shows the standard indicating panel in the upper right corner of the studio *B* control console. The upper row of lights indicate which studio is feeding WILL, the a-m transmitter. The second row of lights indicates where the program from that particular studio is going. If a program is being fed to WILL, the red light comes on; if to WIUC, amber, etc. The lights used are the regular 6.3 v pilot lights operated on 5 volts a-c. By careful pilot wiring, no a-c induction can be detected. Running the lights at reduced voltage insures long life for the lights and still provides sufficient light for indication.

### Studio A Equipment

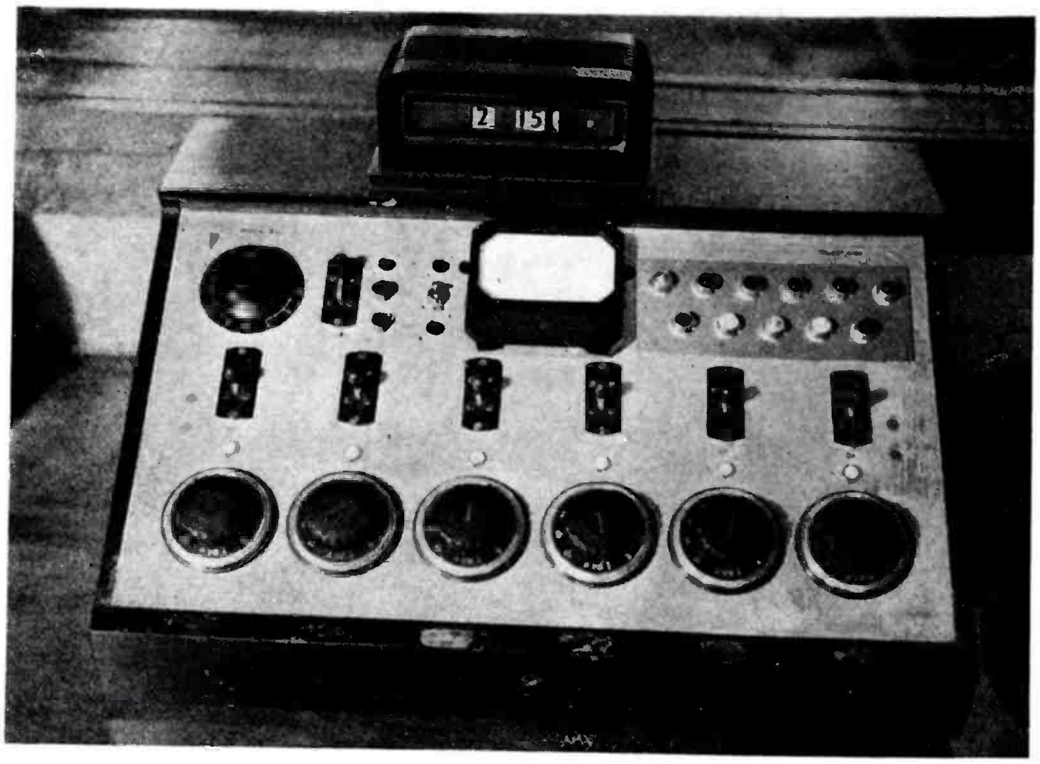
The rest of the equipment mounted on the master control console panel comprises the studio *A* control equipment. The first row of key switches in the upper right corner of the panel provide remote line switching and cueing and a monitor transfer. It is possible to patch up four remotes ahead of time at the operator's leisure and then cue and switch them entirely on this set of switches (see Figure 1 for circuit details). The second row of switches provides for four-order wires which can be patched in on the jack panel. The third row of twist switches are used for miscellaneous purposes where *on* and *off* switching is necessary.

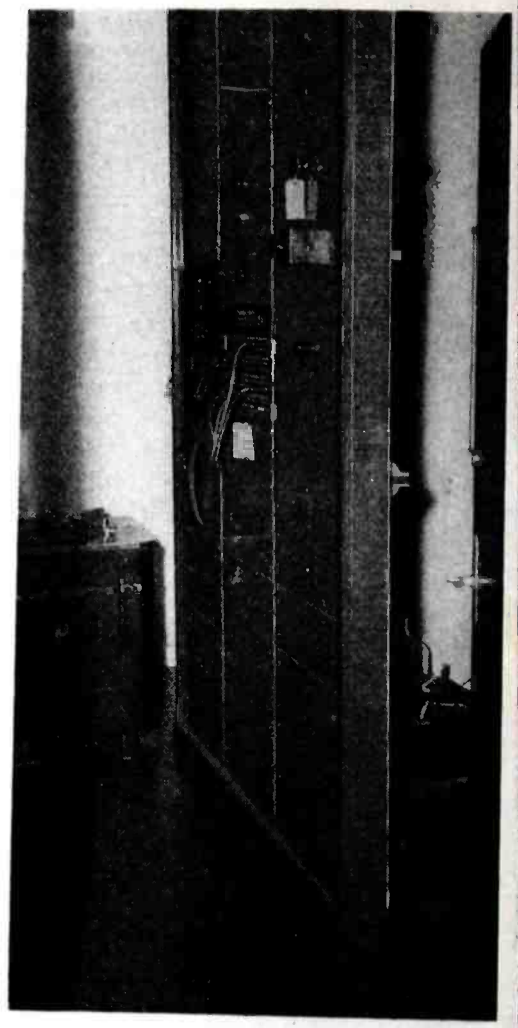
### Six-Channels

The six controls in the lower center of the panel, Figure 2, make up the six-channel mixer used in connection with studio *A*. It provides for two phono channels, two microphone channels, and two remote channels. The remote channels can be converted to microphone channels by appropriate patches on the jack panel. The next control to the right is the monitor gain control. The set of push-button switches in the lower right section of the panel provide for program checking by the operator. The first button connects the monitoring amplifier to the monitoring receiver. The second connects to one of the audition rotary switches so that any of the programs going through the master control can be monitored. The third bridges across the first remote channel providing a method for checking remote programs before broadcast. The fourth provides a similar service for the second remote channel, and the fifth and sixth positions check the two phono tables respectively. Thus it is possible for the operator to check all operations in connection with the board by using push-button switching.

### Push-Button Relays

The microphone and remote channels are switched by a push-button-relay system making it possible for the announcer in studio *A* to operate his or her own microphones. This is a decided advantage since it frees the operator's hands at the time of pro-





Figures 3 (left) and 5 (below)
The standard indicating panel is shown in Figure 3. The upper row of lights indicates WILL studio feeds. Second row reveals studio feeds. In Figure 5, appears the rack and panel mount of all amplifiers, etc.

gram changes or at the start of transcriptions. Figure 4 shows the announcer's control panel. Note that it also has a standard indicating panel showing the announcer which studio is on the air, and where that particular studio is feeding.

In Figure 5 we see the panel mounting of all the various amplifiers, jack panels, receivers, loudspeaker, and associated equipment. This rack is made from angle iron drilled and tapped for standard panels. There is some lack of standardization in the equipment since it has been assembled over a long period of time and is constantly rebuilt to keep ahead of advancing standards. All amplifiers were constructed by student employees of the University of Illinois Radio Service, giving them outstanding practical training in producing equipment to meet high technical standards. Conservative design and reliability are stressed in this equipment. The racks contain three pre-amplifiers, four program amplifiers, two standard booster amplifiers, and the f-m pre-emphasis booster amplifier. It also houses power supplies for the above, tone beat oscillator, an a-m receiver, an f-m receiver monitor speaker, terminal panels, and jack panels. The style strips intended for this installation had to be foregone because of material shortages.

By using twisted shielded wire throughout, good grounding practice with special care in determining low potential points, parallel mixers, and adequate wire separation where fields were anticipated, cross talk is more than 40 db down in all cases and the noise level is only that of the amplifiers in the various circuits.

A year's operation of this equipment has not revealed any major weaknesses. There have been cases where four programs have been going through the board coming from four different points of origination, yet an alert operator can handle the switching without difficulty. The board is not as easy for the untrained operator to learn to operate as some, but for the results to be accomplished it could not be simplified further. The only change contemplated when materials are again available is the installation of two more v-u meters to check the booster outputs so that feeds may be monitored more closely on the output side. The board has been made large enough to allow for ample expansion in the future as the situation seems to demand.

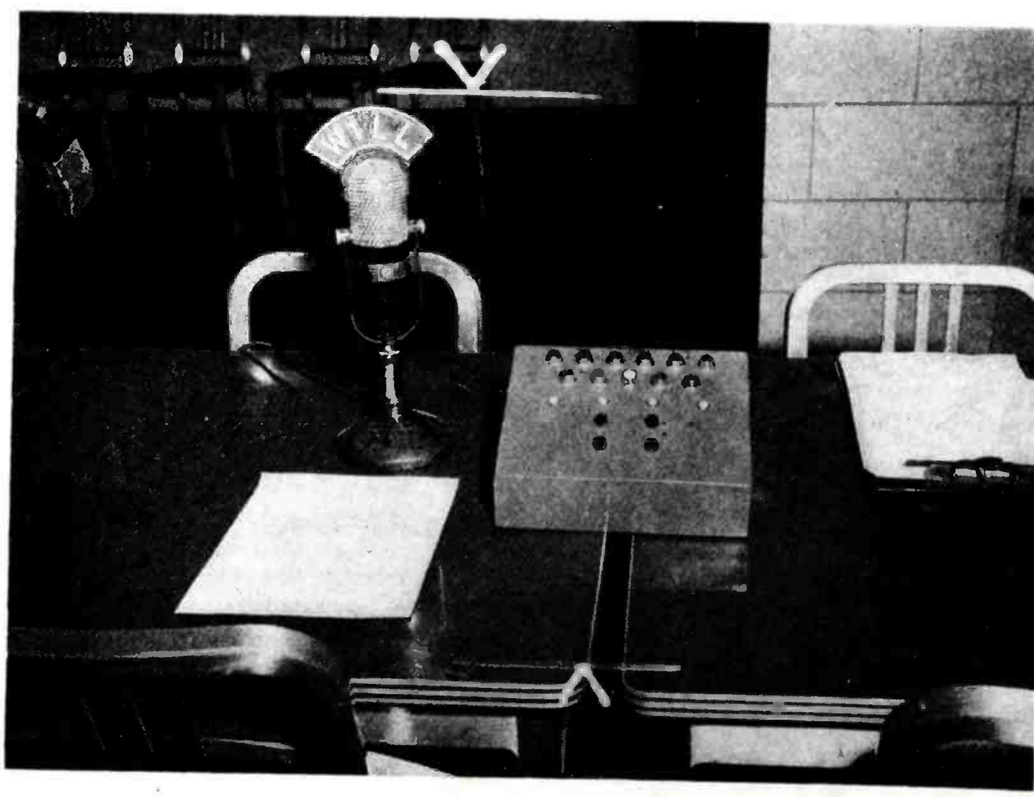
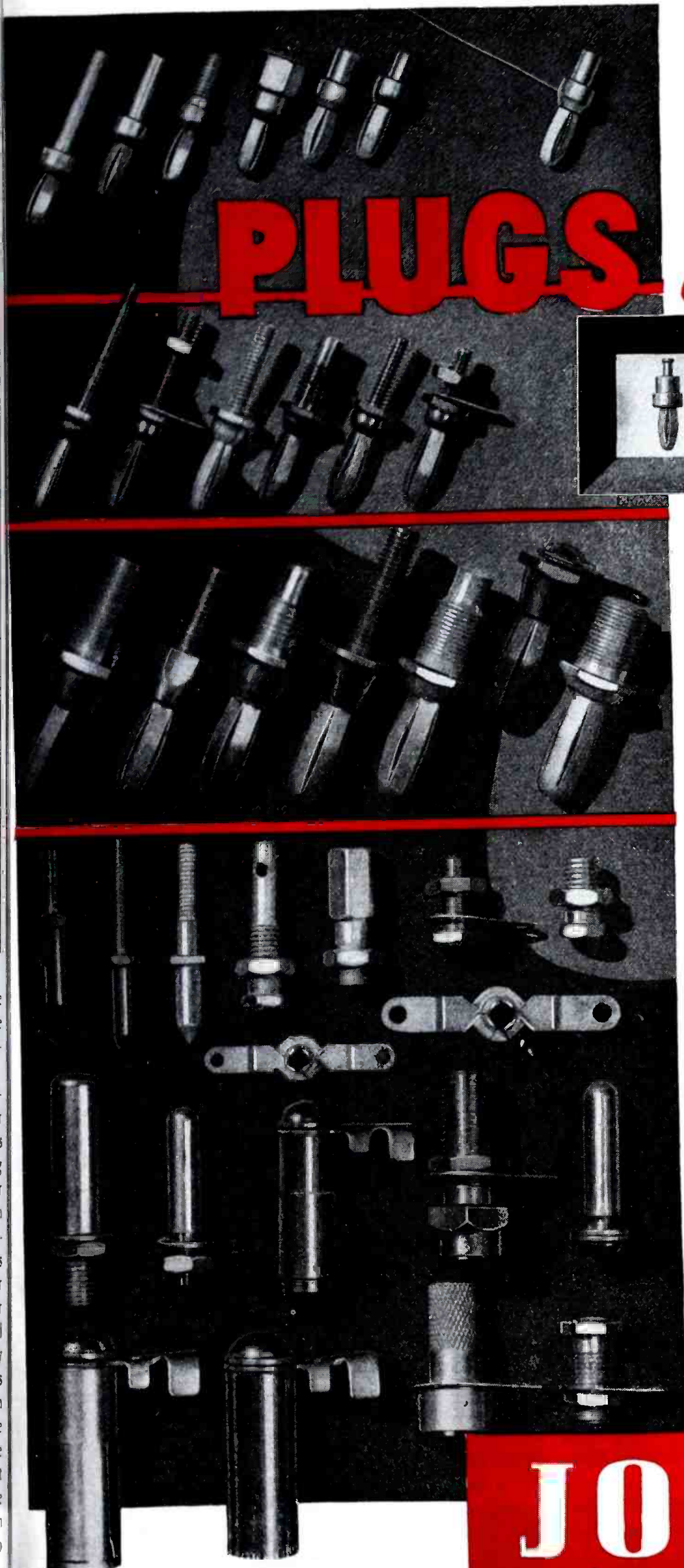


Figure 4
The announcer's control panel.



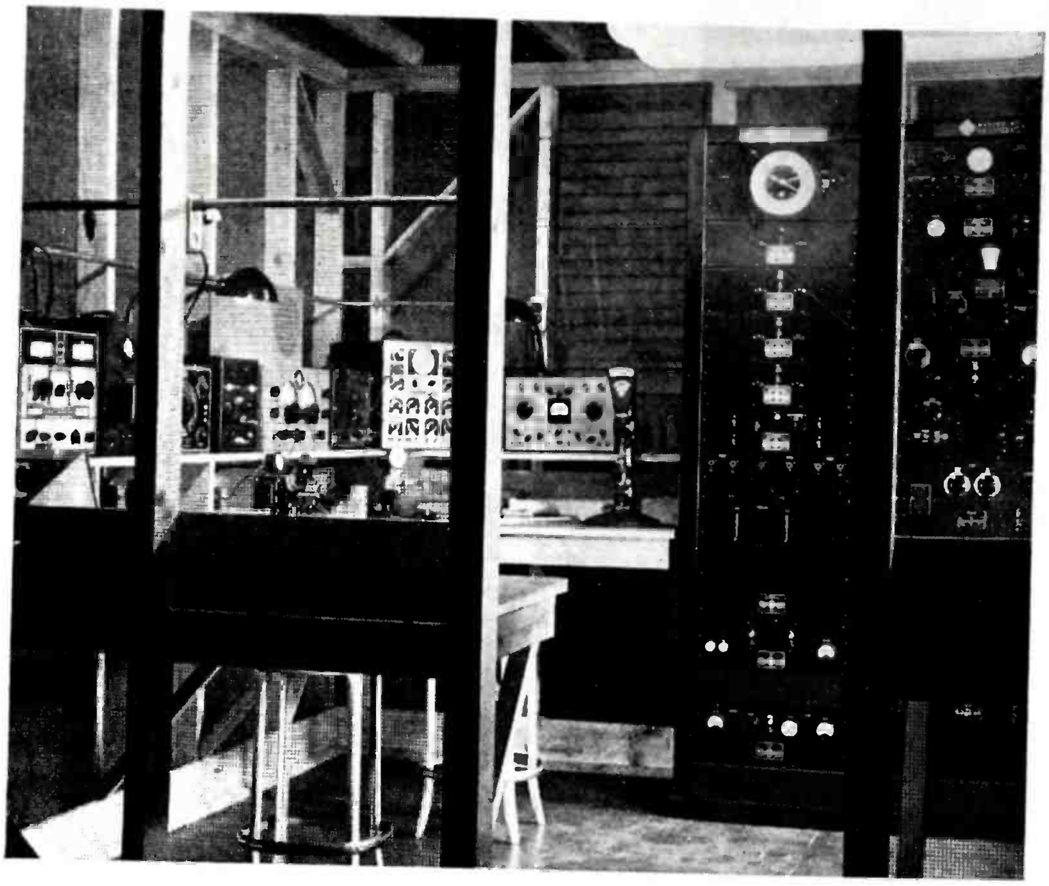


Figure 1
A section of the experimental laboratory, showing frequency standard and measuring equipment employed in research and production of crystals today. With the different cuts of crystals to consider for frequencies ranging from 25 kc up to 12 megacycles, it is necessary to employ a variety of precision laboratory equipment to judge effectiveness.

Quartz crystals have five principal modes of operation, which require extremely close study for effective application. These modes are known as the thickness mode, thickness shear mode, face shear mode, longitudinal mode and the flexure mode. In the thickness mode, the thickness determines the frequency, causing the crystal to expand and contract along the dimension of the thickness. The thickness shear mode prompts the major surfaces of the crystal to slide one with respect to the other and yet remain parallel. Angles formed by the side of the major surface which change and cause the crystal to lose its square and rectangular shape provide the face shear mode. Longitudinal mode consists of a periodic increase and decrease of crystal length. Flexure mode results in bending of crystal under action of the electric field applied to it.

# QUARTZ CRYSTALS

## Types, Modes of Vibration, Methods of Manufacture

by MAURICE A. A. DRUESNE
Chief Engineer, The James Knights Company

THE use of crystals in communication equipment and various industrial applications is based upon the piezoelectric property of certain crystalline materials which was originally discovered by Pierre Curie. And in radio, quartz crystal oscillators provide a simple and convenient means of frequency control.

### Different Crystals in Use

Quartz is an hexagonal crystal whose atomic structure is well known. It possesses an orthogonal system of crystallographic axes which comprise the optic, mechanical and electric axes. Quartz oscillators are cut at definite angles with respect to these crystallographic axes, and their orientation angles completely determine the electrical characteristics of the resulting crystal.

A great number of different cuts have been discovered, but they can all be classified according to their modes of vibration. Most crystals vibrate in several modes at once and, consequently, have several frequencies. Usually, however, one mode of vibration predominates and determines the frequency at which the crystal is used.

There are five principal modes of vibration. The thickness mode, where the thickness determines the frequency, causes the crystal to expand and contract along the dimension of the thickness. The thickness shear mode causes the major surfaces of the crystal to slide one with respect to the other and yet to remain parallel. In the face shear mode the angles formed by the side of the major surfaces change, causing the crystal to lose its square or rectangular shape. The longitudinal mode of vibration consists in a periodic increase and decrease of the length of the crystal. Finally, the flexure mode of vibration, as its name implies, results in a bending of the crystal under the action of the electric field applied to it.

### Modes of Vibration

For the above modes of vibration the frequency is given by the following expressions:

Thickness and Thickness shear $\left.\right\}$ $f = \frac{k}{t}$

Face shear $f = k\sqrt{\frac{1}{l^2} + \frac{1}{w^2}}$

Longitudinal mode $f = \frac{k}{l}$ (1)

Flexure mode $f = k\frac{w}{l^2}$

Where t = thickness
w = width
l = length
k is a proportionality constant.

The most important characteristics of a quartz oscillator are its temperature coefficient and its freedom from spurious frequencies.

### Spurious Frequencies

Spurious frequencies are determined by the coupled modes of vibration. The crystal may oscillate at different frequencies depending upon which mode of vibration is excited in it. Poor crystals have been known to jump fre-

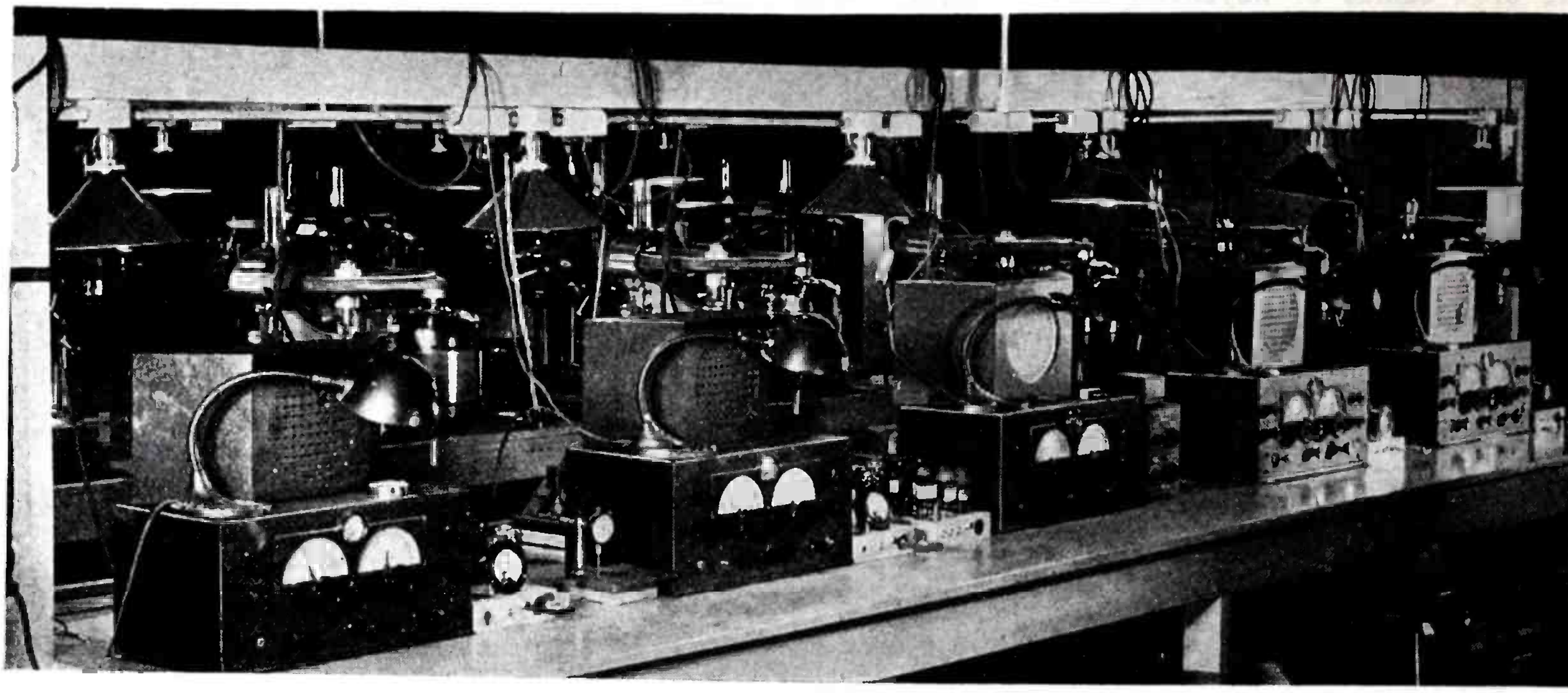


Figure 2
Radio lapping and calibrating positions where the frequency of the crystals is measured while being lapped. A beat note method provides a simple yet effective audio method of checking on the frequency response.

quency while in operation. In well designed, properly oriented crystals, the spurious frequencies are usually far removed from the nominal frequency and if need be they can be filtered out by a suitable circuit as an additional safety feature.

#### Temperature Coefficient

The temperature coefficient is also determined by the modes of vibration of the crystal which are in turn a function of the angles of orientation with respect to the crystallographic axes. Temperature coefficient simply means the change in frequency as a function of the change in operating temperature, and it is usually expressed in cycles per megacycle per degree Centigrade, or in parts per million per degree Centigrade.

For high precision work such as primary frequency standards the crystals are used in a constant temperature oven but in most applications the crystal is used at whatever temperature happens to prevail. It is, therefore, obvious that crystals having a low drift are much sought after, particularly for use in planes or tanks. Some cuts, such as the *BT, CT, DT* cuts, have a so-called *turning point;* this simply means that the frequency will increase with the temperature up to a certain point and then will decrease with a further increase in temperature. Fortunately, the temperature at which this turning point occurs can be controlled within certain limits. It follows, therefore, that if this reversal in drift can be made to take place at the temperature at which the crystal is most often used the frequency drift will thus be minimized.

#### Frequency Ranges

Due to their physical dimensions the various cuts can only be used within their specific frequency range. For example, in the range from 500 kc to 3500 kc, the *AT* cut is commonly used. From 3500 kc to 12 megacycles, the *BT* cut would be employed. For the low frequency field, from 100 kc to 200 kc, the *GT* and *JT* cuts are preferred because of their extremely low temperature coefficients. At present, crystals can be made from, roughly, 25 kc up to 12 megacycles with a minimum drift of about 1 part per million per degree Centigrade.

#### Fundamental Theory of Quartz Oscillators

As stated above piezoelectricity is the property that certain crystalline materials have to translate mechanical stresses into electric charges or vice versa. As a consequence, the electrical resonance of a piezoelectric oscillator is determined by the mechanical resonance of the body.

The complete theory of the modes of vibration involved in a quartz oscillator is too complex to be fully treated here, but the general concepts will be briefly outlined. It must be borne in mind that any theoretical analysis of the vibrations of a quartz oscillator is based on static equations; the dynamical analysis would be extremely difficult, if not impossible. All the theoretical work must obviously be based on the theory of elasticity coupled with relations between electric field and the resulting mechanical stresses and their attendant strains in the quartz.

General results are available for crystalline non-istropic media and can be directly applied to quartz when its atomic structure is taken into consideration. The fundamental relation is Hooke's law stating that within the elastic limit the deformation produced is proportional to the stress, the coefficient of proportionality being called the modulus of elasticity. The stresses of interest are of extensional character; tension or compression, or of shear character. Resulting shear strains often give rise to other modes of vibration such as flexure motion. As mentioned above, spurious frequencies result when several modes of vibration are coupled together, the quartz plate oscillating at several frequencies at the same time, either on the fundamental or on some harmonic.

#### Orientation

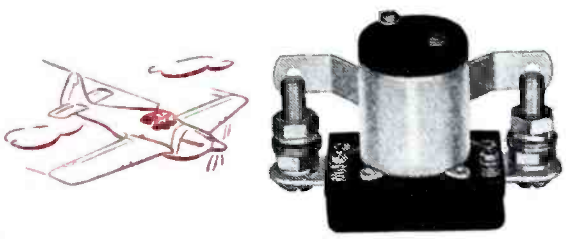
The most important mode of vibration of a crystal is determined by the orientation of the oscillator with respect to the crystallographic axes.

If the three tension components of the stress tensor are denoted by $X_1$, $X_2$, $X_3$ and the three shear components by $X_4$, $X_5$ and $X_6$, the three tension components of the strain tensor by $x_1$, $x_2$ and $x_3$ and the three shear components by $x_4$, $x_5$ and $x_6$, Hooke's law takes the very general form:

$$X_i = \sum_{j=1}^{6} c_{ij} x_j \qquad (2)$$

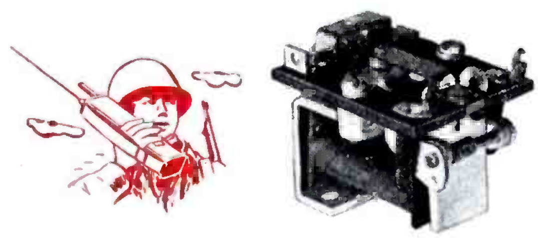
# Relays by GUARDIAN

FOR EVERY CONTROL NEED



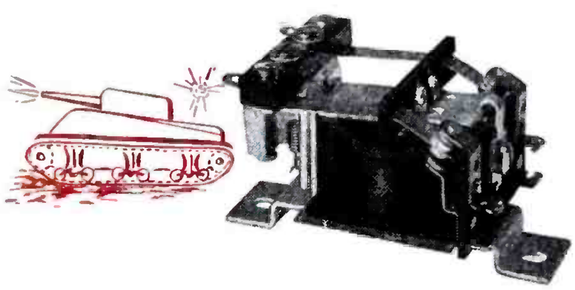
### SC-25 LIGHTWEIGHT CONTACTOR

A lighter, more efficient contactor for AAF type B-4 continuous duty applications. Double wound coil draws 2 amperes closing contacts firmly. Then an auxiliary switch cuts in a higher resistance reducing current to .18 amperes. Advantages are lighter weight, firm closing of contacts, smaller current drain. Weight: 21 oz. Write for bulletin SC-25.



### SERIES 195 MIDGET RELAY

One of the smallest of all relays. Built for aircraft and radio applications where space and weight are at a premium. Contact rating: 2 amps. at 24 volts D.C. Switch capacity up to double pole, double throw.



### SERIES 165 VIBRATION RESISTANT

Counterbalanced armature and sturdy construction throughout give this relay an unusual resistance to vibration. Silver contacts are rated at 12½ amperes in combinations up to double pole, double throw.

Rating for aircraft is 8 amperes at 24 volts D.C. Available with ceramic insulation for HF and UHF applications.


**GUARDIAN ELECTRIC**

1623-L WEST WALNUT STREET CHICAGO, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

Where $C_{ij}$ are the thirty-six elastic constants.

If $E(x_1, x_2, \ldots x_6)$ is the energy per unit volume of the crystal as a function of the strains it follows that:

$$E(x_1, \ldots, x_6) = \tfrac{1}{2} \sum_{i,j} C_{ij}\, x_i\, x_j \qquad (3)$$

Therefore,

$$C_{ij} = \frac{\partial^2 E}{\partial x_i\, \partial x_j} \qquad (4)$$

Consequently

$$C_{ij} = C_{ji} \qquad (5)$$

and only 21 of the 36 elastic constants are independent. Since quartz belongs to the trigonal group and is a hexagonal crystal with three-fold symmetry along the $Z$ or optic axis, and two fold symmetry along $X$, or electric axis, and the Y, or mechanical axis, the equations *1* for quartz can be written:

$$\left.\begin{aligned}
-X_x &= c_{11} x_x + c_{12} y_y + c_{13} z_z + c_{14} y_z + 0 + 0 \\
-Y_y &= c_{12} x_x + c_{11} y_y + c_{13} z_z - c_{14} y_z + 0 + 0 \\
-Z_z &= c_{13} x_x + c_{13} y_y + c_{33} z_z + 0 + 0 + 0 \\
-Y_z &= c_{14} x_x - c_{14} y_y + 0 + c_{44} y_z + 0 + 0 \\
-Z_x &= 0 + 0 + 0 + 0 + c_{44} z_x + c_{14} x_y \\
-X_y &= 0 + 0 + 0 + 0 + c_{14} z_x + c_{66} x_y
\end{aligned}\right\} \qquad (6)$$

Equations *6* apply to a quartz oscillator cut with its two plane faces parallel to one of the axes X, Y or Z.

The most commonly accepted values for the elastic constant are those given by Voight in *Lehrbuch der Kristalphysik.*

We can also write equations *6* as follows:

$$\left.\begin{aligned}
-x_x &= s_{11} X_x + s_{12} Y_y + s_{13} Z_z + s_{14} Y_z + 0 + 0 \\
-y_y &= s_{12} X_x + s_{11} Y_y + s_{13} Z_z - s_{14} Y_z + 0 + 0 \\
-z_z &= s_{13} X_x + s_{13} Y_y + s_{33} Z_z + 0 + 0 + 0 \\
-y_z &= s_{14} X_x - s_{14} Y_y + 0 + s_{44} Y_z + 0 + 0 \\
-z_x &= 0 + 0 + 0 + 0 + s_{14} Z_x + 2 s_{14} X_y \\
-x_y &= 0 + 0 + 0 + 0 + 2 s_{14} Z_x + s_{66} X_y
\end{aligned}\right\} \qquad (7)$$

### Crystal Stress

However, in a quartz oscillator the stresses are introduced by means of an electric field and the relations between the stresses and that applied field are expressed by the following equations, due to Voight:

$$\left.\begin{aligned}
-X_x &= e_{11} E_x + 0\, E_y + 0\, E_z \\
-y_y &= -e_{11} E_x + 0\, E_y + 0\, E_z \\
-z_z &= 0\, E_x + 0\, E_y + 0\, E_z \\
-y_z &= e_{14} E_x + 0\, E_y + 0\, E_z \\
-z_x &= 0\, E_x - e_{14} E_y + 0\, E_z \\
-x_y &= 0\, E_x - e_{11} E_y + 0\, E_z
\end{aligned}\right\} \qquad (8)$$

Where the $e$ are coefficients of proportionality between the stresses and the applied electric field, the strains resulting from the application of the voltage gradient are given by the following equations:

$$\left.\begin{aligned}
x_x &= d_{11} E_x + 0\, E_y + 0\, E_z \\
y_y &= d_{11} E_x + 0\, E_y + 0\, E_z \\
z_z &= 0\, E_x + 0\, E_y + 0\, E_z \\
y_z &= d_{14} E_x + 0\, E_y + 0\, E_z \\
z_x &= 0\, E_x - d_{14} E_y + 0\, E_z \\
x_y &= 0\, E_x - d_{11} E_y + 0\, E_z
\end{aligned}\right\} \qquad (9)$$

The third equation shows that no strain can be set up in quartz along the $Z$, or optic axis no matter how the electric field is applied.

In all the above equations the positive sign indicates an elongation while the negative sign indicates a compression. These equations are useful mainly when it is desired to design a crystal where there would not be any coupling between the modes of vibration or where the various oscillations would be far removed from one another so as to eliminate *hops* in frequency.

The general method of attack, as outlined by Mr. Koga in *Physics,* August, 1932, and Dr. W. P. Mason, of the Bell Telephone Laboratories, to eliminate some undesired coupling, is to orient the quartz oscillator with respect to the crystallographic axes so that the unwanted coefficient of elasticity does not contribute to the oscillations in this new orientation. Let us denote the direction cosines of the new orientation axes X′, Y′, Z′, of the oscillator with respect to the original axes, $X$, $Y$, $Z$, in the quartz by the following table:

| | $X$ | $Y$ | $Z$ |
|---|---|---|---|
| $X'$ | $l_1$ | $m_1$ | $n_1$ |
| $Y'$ | $l_2$ | $m_2$ | $n_2$ |
| $Z'$ | $l_3$ | $m_3$ | $n_3$ |

(10)

A. E. H. Love, in *Mathematical Theory of Elasticity,* gives the following expressions for the stresses in the original system of axes as functions of the stresses in the new system:

$$\begin{aligned}
X_x &= l_1^2 X'_x + l_2^2 Y'_y + l_3^2 Z'_z + 2 l_2 l_3 Y'_z + 2 l_3 l_1 Z'_x + 2 l_1 l_2 X'_y \\
Y_y &= m_1^2 X'_x + m_2^2 Y'_y + m_3^2 Z'_z + 2 m_2 m_3 Y'_z + 2 m_3 m_1 Z'_x + 2 m_1 m_2 X'_y \\
Z_z &= n_1^2 X'_x + n_2^2 Y'_y + n_3^2 Z'_z + 2 n_2 n_3 Y'_z + 2 n_3 n_1 Z'_x + 2 n_1 n_2 X'_y \\
Y_z &= m_1 n_1 X'_x + m_2 n_2 Y'_y + m_3 n_3 Z'_z + (m_2 n_3 + m_3 n_2) Y'_z + (m_3 n_1 + n_1 n_3) Z'_x + (m_1 n_2 + m_2 n_1) X'_y \\
Z_x &= n_1 l_1 X'_x + n_2 l_2 Y'_y + n_3 l_3 Z'_z + (n_2 l_3 + n_3 l_2) Y'_z + (n_3 l_1 + n_1 l_3) Z'_x + (n_1 l_2 + n_2 l_1) X'_y \\
X_y &= l_1 m_1 X'_x + l_2 m_2 Y'_y + l_3 m_3 Z'_z + (l_2 m_3 + l_3 m_2) Y'_z + (l_3 m_1 + l_1 m_3) Z'_x + (l_1 m_2 + l_2 m_1) X'_y
\end{aligned} \qquad (11)$$

Similarly the strains in the new coordinate system, X′, Y′, Z′, are given in terms of the strains in the old coordinate system $X$, $Y$, $Z$ by the following expressions:

$$\begin{aligned}
x'_x &= l_1^2 x_x + m_1^2 y_y + n_1^2 z_z + m_1 n_1 y_z + n_1 l_1 z_x + l_1 m_1 x_y \\
y'_y &= l_2^2 x_x + m_2^2 y_y + n_2^2 z_z + m_2 n_2 y_z + n_2 l_2 z_x + l_2 m_2 x_y \\
z'_z &= l_3^2 x_x + m_3^2 y_y + n_3^2 z_z + m_3 n_3 y_z + n_3 l_3 z_x + l_3 m_3 x_y \\
y'_z &= 2 l_2 l_3 x_x + 2 m_2 m_3 y_y + 2 n_2 n_3 z_z + (m_2 n_3 + m_3 n_2) y_z + (n_2 l_3 + n_3 l_2) z_x + (l_2 m_3 + l_3 m_2) x_y \\
z' &= 2 l_3 l_1 x_x + 2 m_3 m_1 y_y + 2 n_3 n_1 z_z + (m_3 n_1 + m_1 n_3) y_z + (n_3 l_1 + n_1 l_3) z_x + (l_3 m_1 + l_1 m_3) x_y \\
x'_y &= 2 l_1 l_2 x_x + 2 m_1 m_2 y_y + 2 n_1 n_2 z_z + (m_1 n_2 + m_2 n_1) y_z + (n_1 l_2 + n_2 l_1) z_x + (l_1 m_2 + l_2 m_1) x_y
\end{aligned} \qquad (12)$$

By substitution among the above transformation equations, the strains in the new coordinate system can be expressed in terms of the directions cosines and the stresses in that same system. All that remains to be done is to eliminate the coefficient of elasticity which contributes undesired oscillations by setting it equal to zero. This condition then yields values of the direction cosines which determine the orientation of the quartz oscillator with respect to the crystallographic axes of the mineral.

This method yields rather complicated equations, which, however, become much simplified when the quartz oscillator is rotated about one axis only.

The method applies to tourmaline, which is also an important piezoelectric material.

The second important characteristic of a crystal, that of a low temperature coefficient, can also be calculated approximately for the simpler modes of vibration. A change in temperature affects the density of the quartz and, consequently its dimensions and elastic constants.

Since the frequency of a particular mode of vibration depends upon one or two dimensions of the oscillator, its density, and one elastic constant, the method consists in determining the effect of the temperature on each of these factors and finding the proper orientation with respect to the crystallographic axes that will make the sum of all these individual temperature effects equal to zero.

When these calculations are carried out for the high-frequency shear mode or the low-frequency face shear mode, a great many cuts are found. It must be borne in mind, however, that a good

(*Continued on page* 109)

# VETERAN WIRELESS OPERATORS ASSOCIATION NEWS

W. J. McGONIGLE, President — RCA BUILDING, 30 Rockefeller Plaza, New York, N. Y. — GEORGE H. CLARK, Secretary

### PERSONALS

ARTHUR STOCKELBURG, holder of the first commercial radio license in Boston, and longtime member of the Yankee chapter of VWOA, recently completed his tenure as class instructor of the U. S. Signal Corps Training School at the Medford Vocational School, Medford, Mass. At the closing of the Signal Corps school, instructor Stockelburg was given a silver plaque, inscribed with the names of the members of his class, nineteen in number.

Arthur Cohen is now stationed for an indefinite period as radio operator in Rio de Janeiro, Brazil.

G. B. Angle, based at station WAX, Miami, Fla., writes: "If you know of any commercial or coastal station wireless operators between the ages of 38 and 45 who would like to settle down in Miami *for the duration,* ask them to write me at P. O. Box 488, Hialeah, Fla."

### Radio Inspector No. 1 Retires

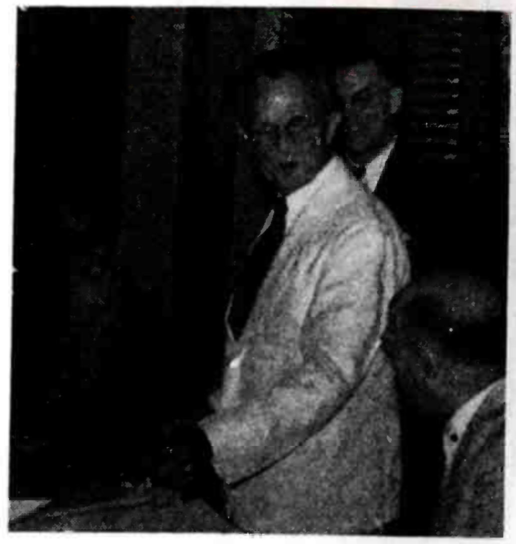
William D. Terrell, first Radio Inspector in the United States Government Service, appointed in 1911, was retired at his request on August 31, 1943. His colleagues in the Federal Communications Commission — where he served as Chief of the Field Division—tendered him a banquet on the evening of his retirement. It was attended by 66 of his associates and coworkers, and by George Bailey, representing the American Radio Relay League, and F. P. Guthrie, representing the Veteran Wireless Operators Association. Mr. Terrell has been an honorary VWOA member for many years.

All of the FCC Commissioners were present at the dinner, with the exception of Chairman Fly, who was out of town, and Gov. Case, who had another engagement. FCC chief engineer Jett presided.

Among the tributes to the retiring veteran, chief was a letter from the President of the United States, congratulating him on his forty years of government service. Our Mr. Guthrie followed, reading the following citation:

> "To W. D. Terrell, honorary member of the Veteran Wireless Operators Association, old-timer de luxe of the art of wireless, earliest exponent of the registration and regulation of wireless activities within our Government, the Veteran Wireless Operators Association extends, on the occasion of his retirement from public office, its sincerest congratulations on the achievements of his long career, and its hope that the future may be none the less pleasant, although cast in more quiet waters."
>
> *W. J. McGonigle, president.*

In somewhat similar vein, the ARRL through Mr. Bailey presented to the retiring expert a scroll expressing the appreciation and best wishes of the League.



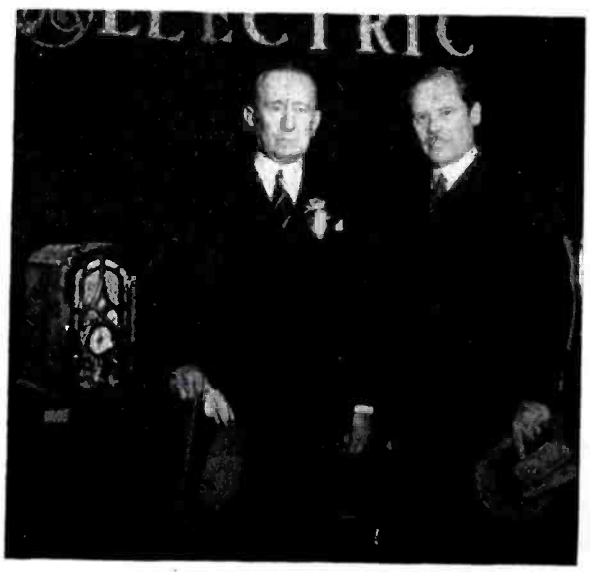
W. D. Terrell, retiring FCC executive, receiving the good wishes of his colleagues on a silver platter.

More tangible gifts were a gold watch and chain, presented by Mr. Terrell's ex-colleagues through Charles C. Kolster, FCC chief inspector at Boston, Mass., and the oldest man in its service; also a silver tray, appropriately handed to Mr. Terrell by Mr. Sterling, assistant chief engineer of FCC. Lastly, a scroll with the names of every one at the dinner was handed over by George S. Turner, long Mr. Terrell's assistant, and named to succeed him.

How about inviting the entire membership of VWOA to your diamond anniversary, Bill?

### Army Air Force Tribute

During a recent broadcast over NBC, during which Colonel A. W. Mariner, director of Communications of the Army Air Forces, was given the Marconi Memorial Award of Honor, Colonel Mariner said: "The Marconi Memorial Award of Honor is a splendid tribute to the officers and men who are operating the vast system of Army Air Force Communications throughout the world. The story of Air Force Communications is a story of men whose skill, bravery and devotion to duty are playing an indispensable part in the struggle for victory. The names of many brave men will be inscribed on the plaque."



An unusual photograph of the late Guglielmo Marconi and F. W. Alexanderson. Note the antiquated table model receiver which dates this memorable meeting. The WVOA has been one of the outstanding radio groups to perpetuate the name, honor and work of Marconi by donating the annual Marconi Memorial Awards of Honor and Scholarship Awards.

# CARRIER CURRENT TRANSMISSION

(*Continued from page 32*)

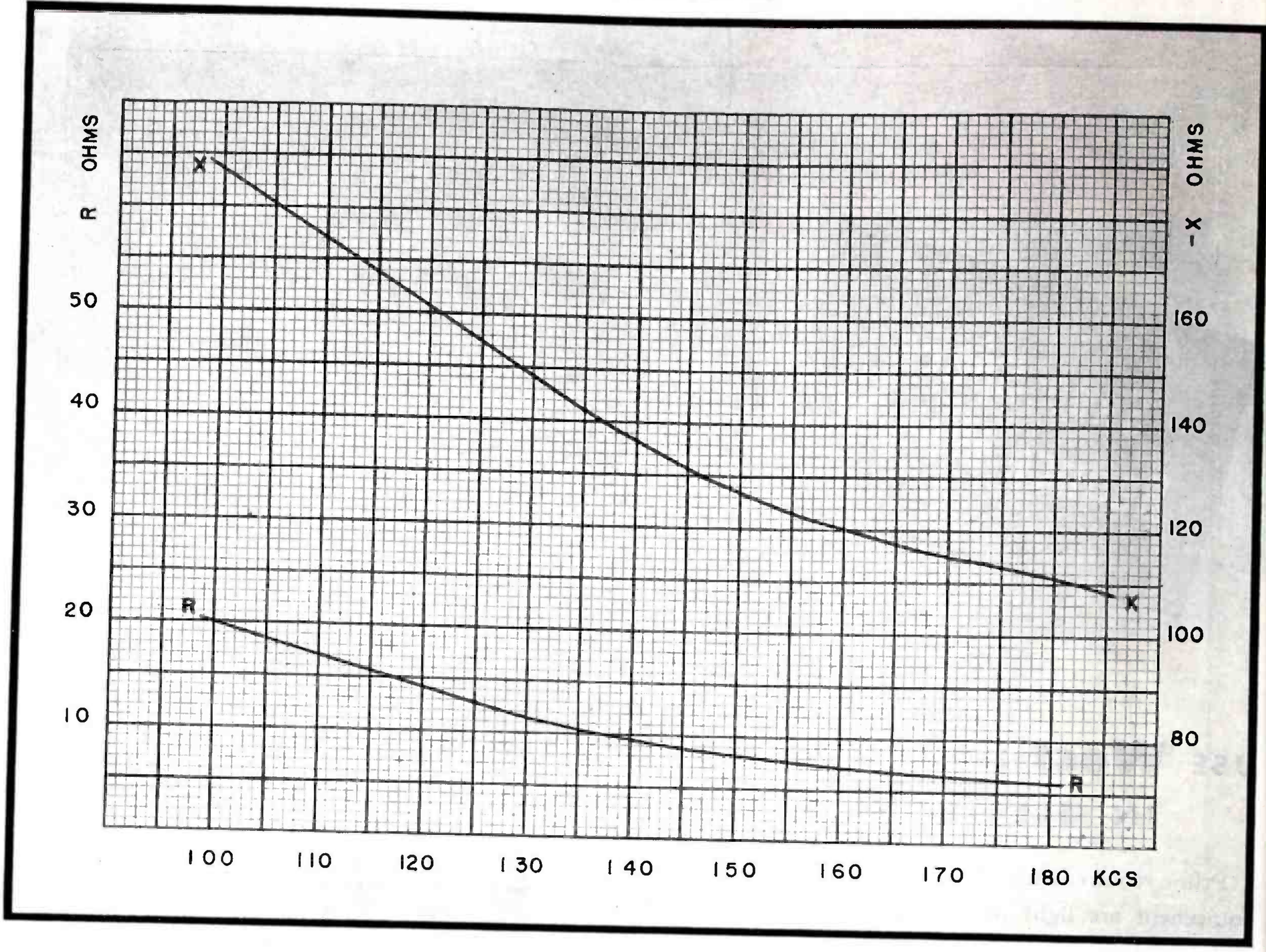



Figure 9
Resistance and reactance of load side of same service shown in Figure 8. Note reactance is negative in sign.

while in Figure 9 which shows the impedance of the load side alone, it will be noted that the resistive and reactive components fall with rising frequency and the sign of the reactance is negative.

#### Reactance Rise

In Figure 10, we see that the resistance rises rather rapidly while the reactance rises rather steadily until it has a maximum value 140 kc, falling again at higher frequencies.

#### Large Building Results

The curves in Figure 11 were plotted from the measurements made on the power service of a rather large office building. This building has a single transformer with a capacity of 50 kva, installed on a pole at a distance of about one hundred and fifty feet from the service entrance which is overhead. These curves are much flatter than the others shown and are believed to be typical of rather large building services.

It should be pointed out that variations in the amount of the connected load will affect the impedance values to be found at the feed point. This is to be expected but our experience indicates that the effect of the variations on the practical operation is in most cases not too serious. In the case of receivers with automatic volume control no noticeable deterioration of service is noticed except where the received signal is not sufficient to override the line noise. The result then is an increase in line noise from the receiver.

#### Operating Frequency Choice

The choice of operating frequency is usually determined by factors other than the impedance characteristics of the line involved but no great difficulty should be experienced in adjusting the transmitter to work at any point in the band. Since only low powers are employed, rather small and relatively inexpensive components may be used, provided adequate fuse protection is available.

#### De-coupling Networks

The use of simple de-coupling networks as previously mentioned is strongly recommended. They are not critical in adjustment and do not require much material. Our tests on one of our installations indicate that the improved efficiency obtainable by this means alone will result in a carrier power saving of from 50 to 90 per cent. The reduction of the power in the transmitter certainly justifies the expense of the filter. The filter also serves to reduce impedance variations under varying house loads thus making adjustments of the transmitter output circuits unnecessary.

#### Applicable to C-W and I-C-W

While the foregoing discussion has applied to voice frequency transmission it is entirely feasible to use c-w and

# BETTER BANK ON THE *HUMAN* ELEMENT, TOO

In the excitement of electronic discoveries and predictions, one great and important factor—the *human* element—stands forlorn. Machines and uses are, after all, only the offspring of man's experience and ingenuity. The more capable the man, the more dependable his product.

This is the *human* element upon which the Electronic Corporation of America places a high evaluation. And this, we suggest, is the element you should seek when planning your future program. Find out more about your man and his background. Is he an old-timer or a "war baby"? Does he have the ability and facilities to produce? How high are his standards? These are questions we'll gladly answer. We're 100% in war work now . . . but, occasionally production schedules enable us to accept additional contracts . . . *communicate with us.*

**A CALL FOR GREATER EFFORT . . .** *The WPB reports that war production has fallen off considerably. This is a challenge to industry and labor, and it's up to us to find the reason, whether it be optimism, internal strife, working conditions, discrimination, etc. The roar of battle is thousands of miles away, but, if you listen closely, you can hear the screams of a dying soldier. Can it be because we failed him?*

ECA

**ELECTRONIC CORP. OF AMERICA**

**45 WEST 18th STREET • NEW YORK 11, N.Y. • WATKINS 9-1870**

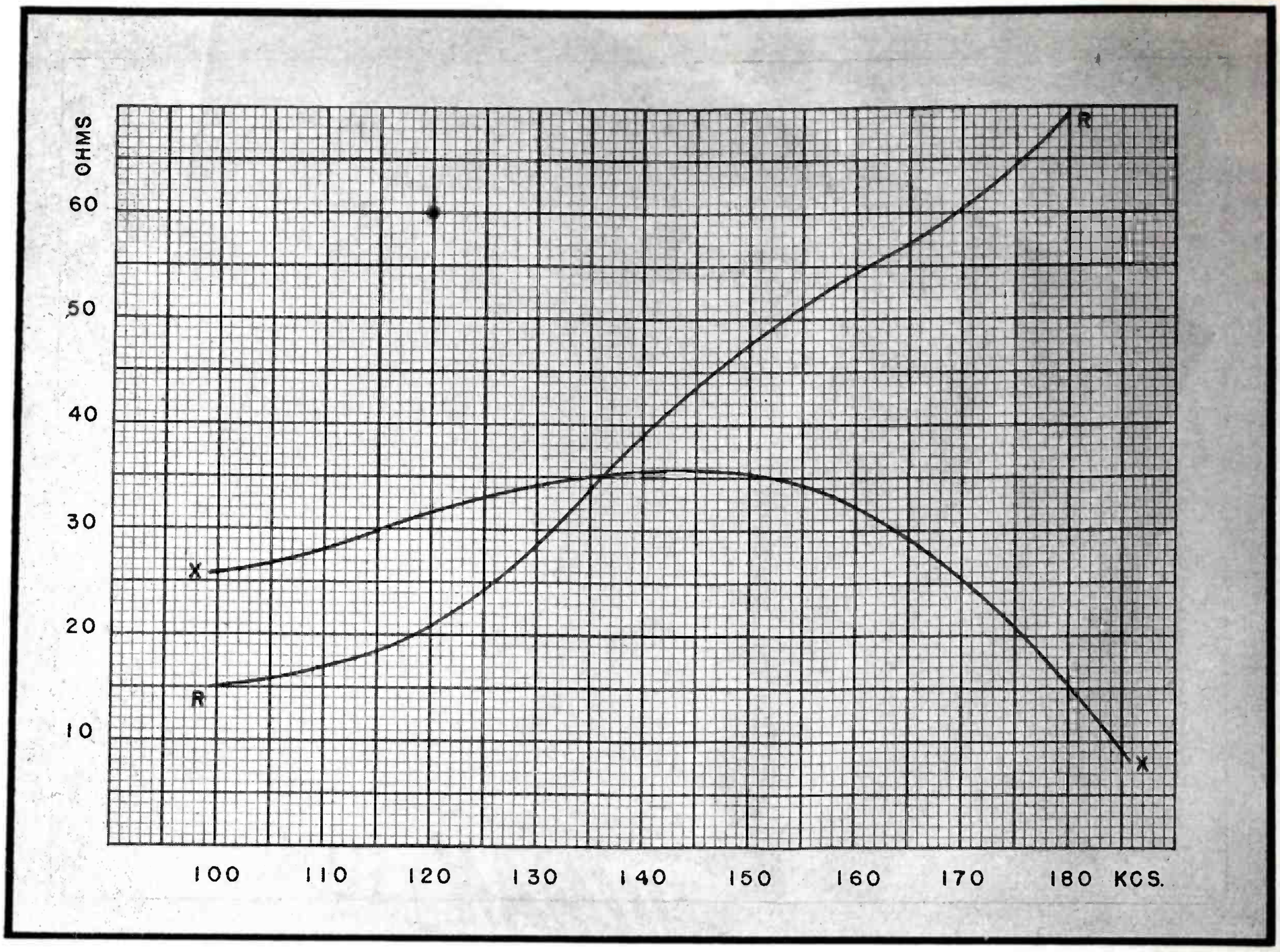



Figure 10

Resistance and reactance of a residence supply circuit 3-wire 120/240 volt with service switch closed. No load on house wiring. *R* and *X* read on same scale.

i-c-w telegraphy; in fact we have found it possible to work greater distances and with less power when c-w telegraphy is used. Other types of signals which may be suitable to actuate relays may, of course, be employed.

### Civilian Defense Uses

In civilian defense there is need for a means of communication which may be used when telephone circuits have been rendered inoperative due to bombing or sabotage. Carrier current transmission over power lines can be used if the transmitters and receivers are supplied from battery or standby emergency generating sets and the power lines are not entirely wiped out. While the line power supply may fail, it will often be possible to keep the carrier equipment in operation during the period of emergency thereby supplementing space radio circuits, which should also be available.

### Little Equipment Required

Carrier current equipment requires relatively small amounts of critical materials and is quite inexpensive to construct and operate, and for these reasons should find a rather wide field during the war and the immediate post-war period.

### Power Line Problems

It should be remembered that power lines were intended primarily for the transmission of power and that they are designed and constructed for that purpose. The insulating materials and conductors which may be of excellent low frequency construction may be rather poor from a high frequency viewpoint as compared with a specially engineered communication circuit. However, in most instances these power lines can and are being used to serve this additional purpose.

### Network Behavior

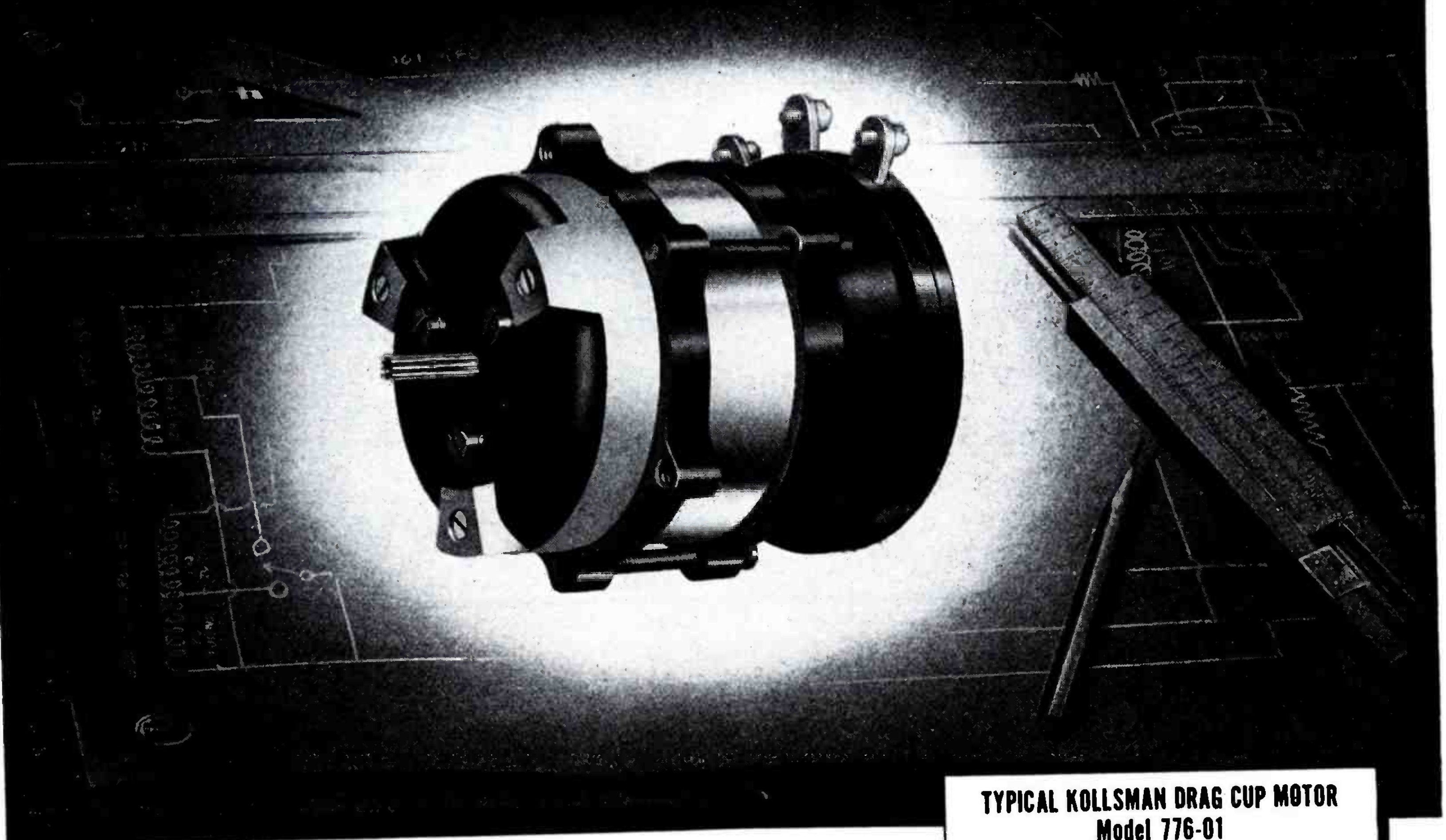
An accurate analysis of the behavior of complex power line network circuits at frequencies of from one-hundred to two-hundred kilocycles per second is extremely difficult. This can be better understood when it is realized that the frequencies for communication are about two-to-three-thousand times the power frequency. The effective impedance of circuit elements such as transformers, motors and generators is found to be quite different when taken at several thousand times the frequency for which they were designed. Reactances change from inductive to capacitive and vice versa, while resistive components of the impedances are of different magnitude. The length of the line between the desired communication points is often considerable in terms of the signal wavelength, and branch circuits are to be expected which by accident are even and odd multiples of a quarter wavelength. The voltage and current relations are consequently rather complicated and it is to be expected that losses due to reflections caused by impedance variations are almost impossible ot evaluate.

### Experiments Suggested

We believe that an experimental approach to the problems is more effective as well as less difficult. Tests can be readily carried out at the ter-

# ATTENTION: DESIGN ENGINEERS!

## Do any of these new miniature motors fit into your design plans?



**TYPICAL KOLLSMAN DRAG CUP MOTOR**
**Model 776-01**
*(Illustrated above actual size)*

Frequency—400 cycles
Voltage Phase 1—24 volts
Phase 2—35 volts
Speed, no load—5700 RPM
Torque, stalled—.70 in./oz.
Weight—Complete Motor—12 oz.
Shaft Assembly— .53 oz.

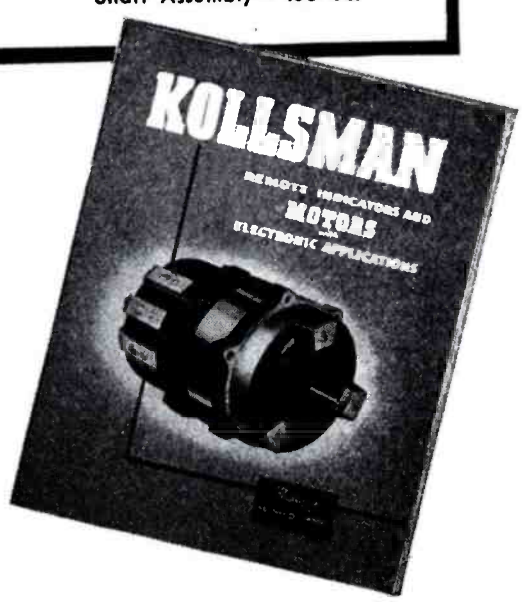
Of interest to design engineers of many electrical and electronic manufacturers will be the new line of miniature motors with special remote indication and control applications, just released by Kollsman Instrument Division of Square D Company.

Typical of these new units is the Drag Cup Motor illustrated actual size above. It is specially designed for installations requiring quick-starting, stopping and reversal characteristics. This is obtained by an extremely lightweight rotor having correspondingly low inertia. Extensive tests have shown it to have definite performance advantages over other motors of this type.

Similar design and operational advantages are to be found in the other Kollsman Motors described in the catalog pictured at right.

★ ★ ★

Complete information and performance data on Kollsman remote indicators and motors with electronic applications now available in catalog form. Please write for copy on your letterhead. Address: Kollsman Instrument Division, Square D Company, 80-22 45th Ave., Elmhurst, New York.




ELECTRICAL EQUIPMENT • KOLLSMAN AIRCRAFT INSTRUMENTS

**SQUARE D COMPANY**

ELMHURST, NEW YORK • GLENDALE, CALIFORNIA

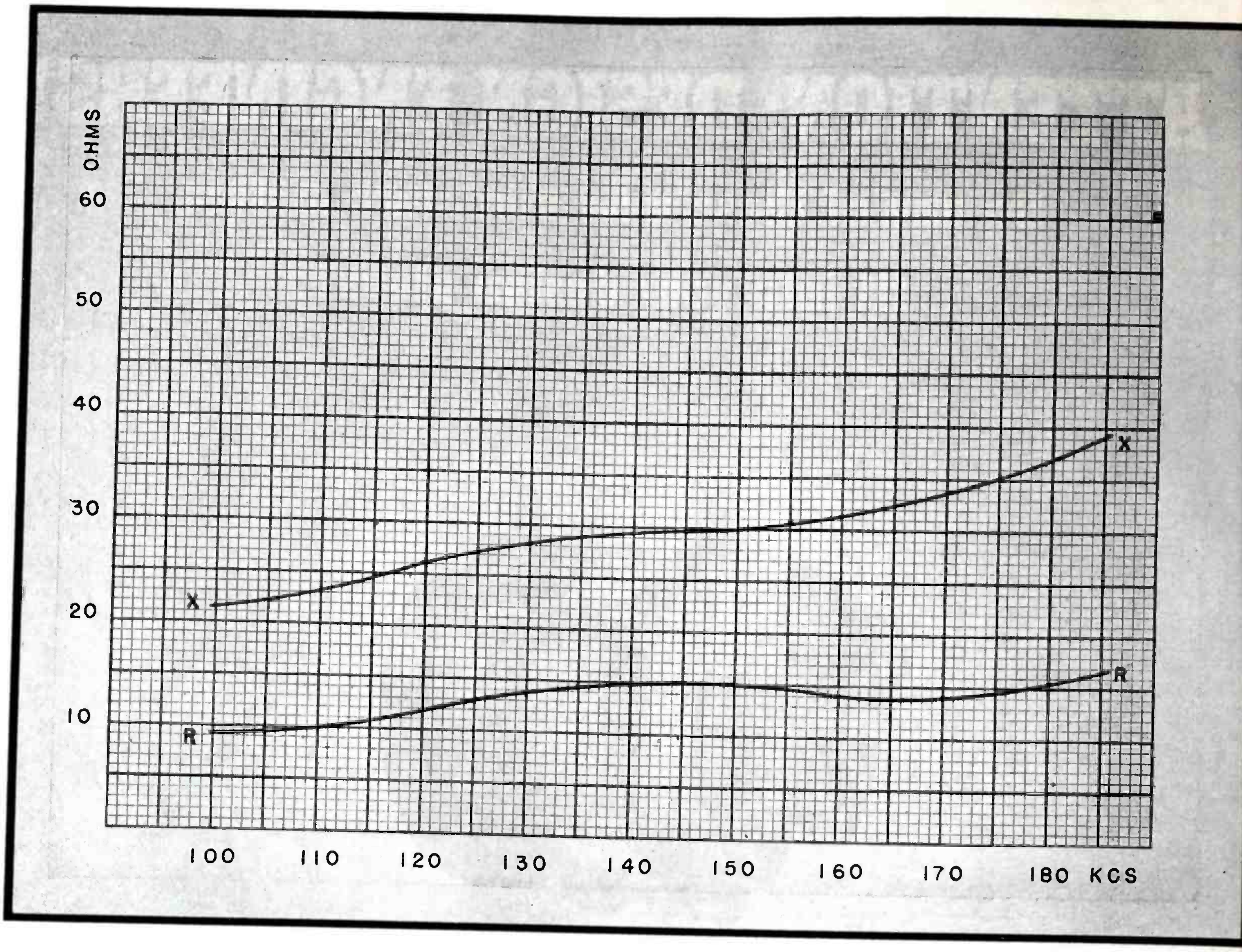



Figure 11
Resistance and reactance measured near meter on 3-wire 120/240 volt 50 kva public building service. *R* and *X* read on same scale.

minal points by the temporary installation of a transmitter of adjustable power and frequency. A receiver can then be connected at the receiving location and from a few tests with various frequencies and power outputs the optimum frequency and the required power may be ascertained. During these tests, observations of the effects of the transmitter on broadcast receivers in the immediate vicinity should be made as well as the effect of line noise levels. Always use the least power which will give the required quality of transmission.

#### Dual Frequencies Used

The use of a squelch circuit in the receiver is recommended where due to the action of the avc, line-noise may rise when the carrier is not present. Almost any of the well known circuits may be used to silence the receiver during the time the transmitter is off.

Two-way communication may be carried on by the use of two frequencies separated sufficiently in the band which will permit transmission and reception simultaneously. This will be more convenient as neither *push-to-talk* nor voice-controlled relays will be needed. The use of such relays or switches unnecessarily complicates the equipment and should be avoided. This arrangement is also adaptable to remote control where it may be desirable to locate the receiver and transmitter some distance away from the point at which the user is situated. Needless to say the receivers must be kept turned on all times but the transmitters energized only when needed.

#### National Electrical Code

Due consideration should be given to the National Electrical Code and such local regulations governing the installation as may apply. These regulations are generally reasonable and should be complied with in the permanent installation. Radiation into space should be kept to a minimum to conform with the Rules and Regulations of the Federal Communication Commission and in any event must not cause interference with any established power or protection type services.

Radiation effects prevent complete privacy in carrier communication due to the existence of some radio receivers which may be tuned to the carrier frequency and some receivers, which while not capable of tuning to the carrier frequency, may pick up harmonics. Profane or indecent language therefore should be carefully avoided.

We have endeavored to set forth some of the information gained by us over several years of experience and it is thought that while some changes may be necessary to adapt to local conditions, the system which we have described will be of considerable utility in most instances.

(In the first part of this paper, Whiteman and Lyon discussed the various frequencies that were tested before arriving at the 150 to 160 kc range. In the 550 kc to 3000 kc tests, as 1200 kc was approached, and on up to 3000 kc, radiation became a real problem. In fact at 3000 kc, it was all radiation. Frequencies above 500 kc did not pass through the transformer coupling but by induction from feeders. The frequency chosen seemed to fit all requirements for a minimum of interference and radiation.)

# AN ALIGNMENT CHART

## For Finding The True Inductance of A Coil With Distributed Capacity

**by ROBERT C. PAINE**

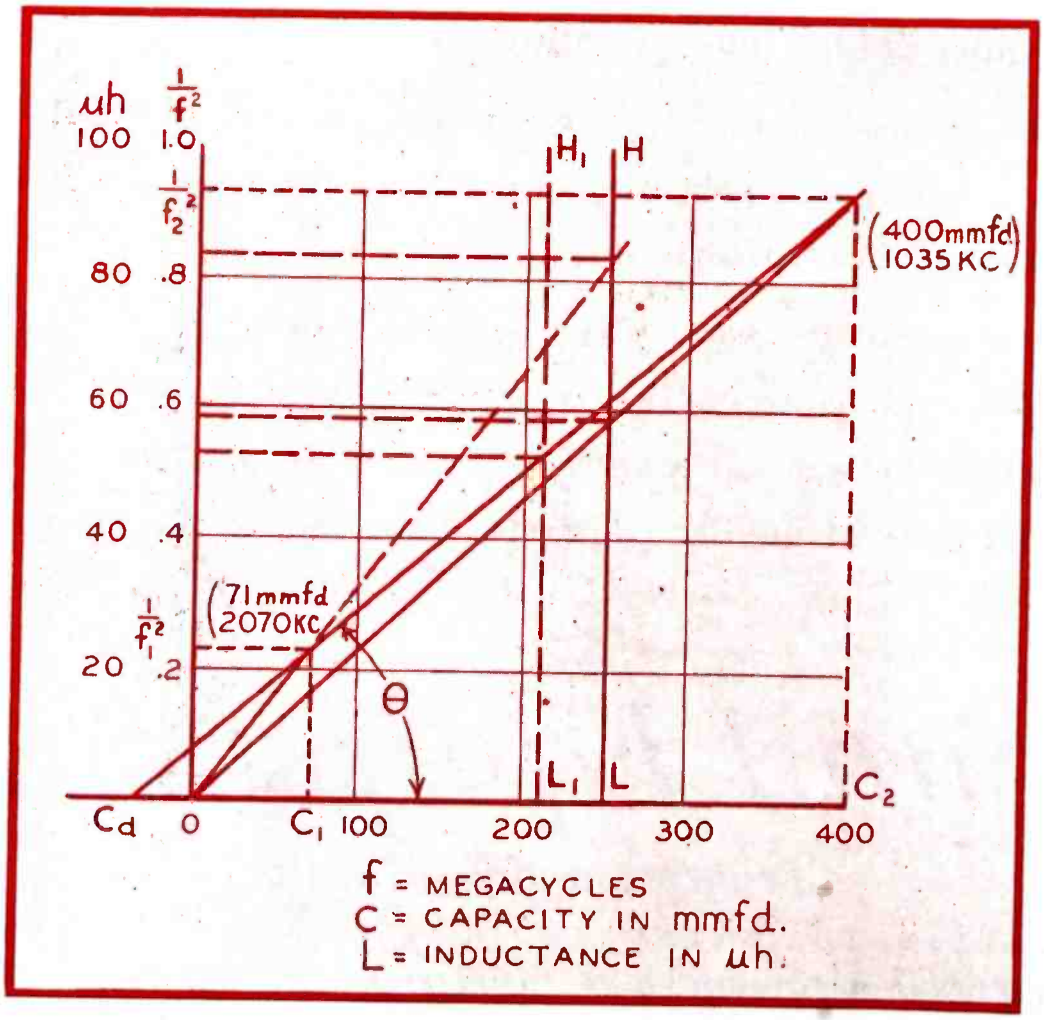
THERE are various well known methods of measuring radio frequency inductance which generally depend on resonating the inductance with a known capacity at a known frequency. The inductance can readily be calculated from the formula $L = 1/(4\pi^2 f^2 C)$. A factor sometimes overlooked, however, is that the *C* of this formula also includes the distributed capacity. If this is not considered in the calculations, the inductance, found by the above formula using as *C* the capacity of the condenser used to resonate the coil, will be the apparent inductance which may vary considerably from the true inductance, especially when low capacities are used in measurement.

As shown in many textbooks, the distributed capacity can be found by taking two or more observations with different capacity values and plotting these capacities against 1 (frequency)$^2$. This is shown in Figure 1. These points will lie approximately in line. And a straight line through them will intersect the *X* axis to the left of the origin at a distance equal to the distributed capacity, $C_d$.

This same plot can also be used to indicate true inductance directly. The slope of the line through the observed points is equal to the tangent of the angle $\theta$, equals $(1/f^2)/(C + C_d)$ or $1/[f^2(C + C_d)]$. This multiplied by the constant $\frac{1}{4}\pi^2$ is the formula given above for the inductance. If inductance is given in microhenries, capacity in micro-microfarads, and frequency in megacycles, the formula becomes $25300/[f^2(C + C_d)]$. In Figure 1 the capacities of the resonating condenser are plotted on the *X* axis from *O* at $C_1$ and $C_2$. The reciprocals of the corresponding frequencies in megacycles squared, $1/f_1^2$ and $1/f_2^2$ are plotted on the *Y* axis. A straight line is drawn through these two points intersecting the *X* axis at $C_d$. The distance $OC_d$ indicates the value of the distributed capacity, $C_d$. The point $L_1$ is plotted at a distance equal to 253.0 on the capacity scale from $C_d$ on the *X* axis. A vertical line $H_1L_1$ through this point will be intersected by the line through the observed points at a height above the *X* axis which indicates the true inductance on the µh scale.

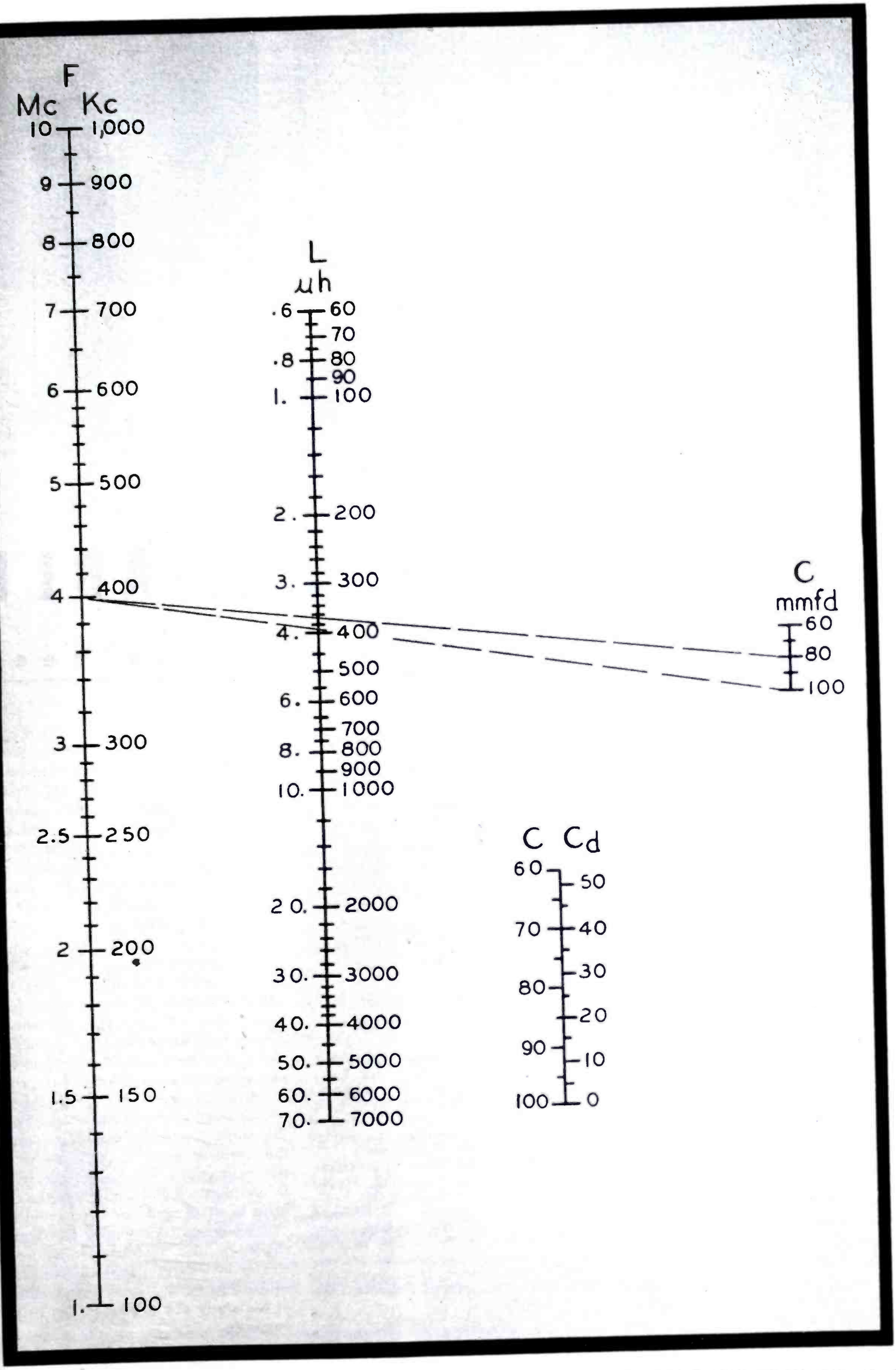
The example given shows an ordinary coil of 54 microhenries with a distributed capacity of about 12 mmfd. To exaggerate the effect of distributed capacity, this has been artificially increased to about 40 mmfd to represent a very poor coil. Under this condition two measurements were taken, indicating resonance at 1035 kc with 400

(*Continued on page* 104)




**Figures 1 (left) and 2 (opposite page)**

**In Figure 1 appears a diagram used to find the true inductance and distributed capacity of a coil when resonated with two different capacities, $C_1$ and $C_2$. In Figure 2 is the alignment chart for finding the true inductance and distributed capacity of a coil which resonates with 400-mmfd capacity at a frequency *F*, and with a capacity *C* at a frequency 2F. In the chart, the lines *F* and *L* are parallel, and at a distance of 2 units apart. *C* is parallel to *L* and at a distance of 4 units from it. (The unit in the drawing is one inch.) Scales *F*, *L* and *C* are logarithmic and not necessarily measured in the same unit as are their distances apart. Scale *F* can be the same as a 10" slide rule (*C* or *D* scale). Scale *L* is ⅓ the scale of scale *F*. That is 100-1000 on *L* equals ⅓ of 100-1000 on *F*. (The *K* scale on a 10" K & E slide rule would do.) Scale *C* is a portion of the same scale as used for *F*; *100* on this scale equals 300 on the logarithmic scale and *60* equals 340 (this appears in the formula as [400-C]).**


F
Mc Kc
10 1,000
9 900
8 800
7 700
6 600
5 500
4 400
3 300
2.5 250
2 200
1.5 150
1. 100
L
μh
.6 60
70
.8 80
90
1. 100
2. 200
3. 300
4. 400
500
6. 600
700
8. 800
900
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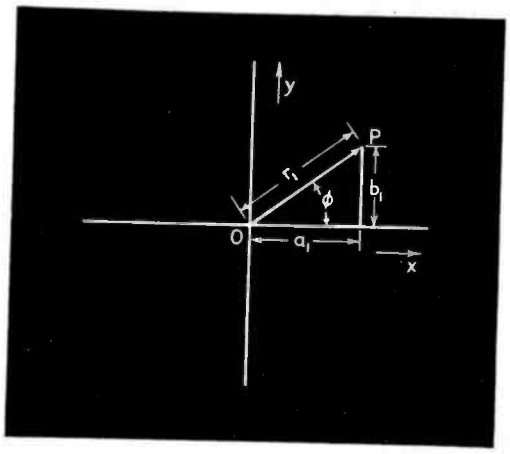



Figure 1 (left)
Geometric representation of a complex quantity. The origin, *O*, is a point in the *complex plane* located at the intersection of the *x* and *y* axes. A point, *P*, is located by means of its *x* and *y* coordinates ($a_1$ and $b_1$), respectively, and designated as the point $z_1 = a_1 + jb_1$, or as $z_1 = r_1\varepsilon^{j\phi_1}$ as explained in the text.

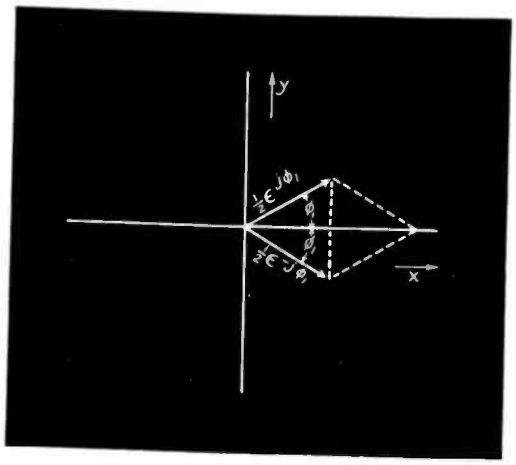



Figure 2 (right)
The trigonometric quantity $\cos\phi_1$ is represented in this Figure as the sum of two complex quantities equal in magnitude and symmetrically disposed with respect to the *x* axis. One quantity may be said to be the mirror image of the other, the mirror being the *x* axis. If the mirror is removed, one quantity, say $\frac{1}{2}\varepsilon^{j\phi_1}$, is sufficient to represent $\cos\phi_1$.

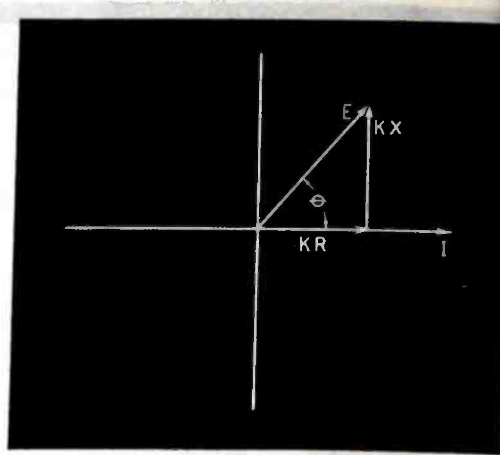



Figure 3 (above)
The Argand, phasor, or vector diagram as it is variously called for the current (*I*) in a circuit consisting of resistance (*R*) and inductive reactance (*X*) in series when a voltage (*E*) is applied across its terminals. The angle Θ is readily determined as explained in the text. *K* is a proportionality factor.

# THE COMPLEX VARIABLE

## And The Communications Engineer

*(PART ONE OF A TWO-PART PAPER)*

by SIDNEY FRANKEL

**Radio Engineer, Federal Telephone & Radio Corp.**

THAT branch of mathematical analysis known as the *Theory of Functions of a Complex Variable* has, in recent years, attained a position of vital importance in the solution of practical electrical problems. The designing engineer who wishes to make efficient use of existing analytical tools cannot afford to omit a working knowledge of the subject from his repertoire.

As a few examples of electric theory concepts which fall into or approach this category we can mention: *(1)*—the well-known *Argand,* or *vector* diagram, most powerful tool of steady-state alternating current theory[1]; *(2)*—The circle diagram of the induction motor and a host of other circle diagrams; *(3)*—The solution of two-dimensional electrostatic problems (determination of capacitance, voltage gradient, characteristic impedance, etc.) by means of conformal transformations, particularly the *Schwarz-Christoffel* transformation[2,3,4,5]; *(4)*—the evaluation of certain types of definite integrals of functions of real variables[6,7]; and finally *(5)*—The establishment of the Heaviside method of operational analysis on a rigorous basis, and extension of its methods, by means of the *Bromwich-Wagner* formulation employing contour integration in the complex plane[8].

The purpose of this paper is to arouse the curiosity of those engineers who may not yet have established contact with these various applications, so that they may have an incentive to pursue the subject further by themselves. For this purpose rigorous proofs are unnecessary, and even undesirable, since they burden the reader with so much detail as to obscure completely the general perspective which it is desired to attain in a paper of this general nature.

Furthermore, the practising engineer, anxious to proceed with the solution of practical problems, lacks the patience to make his way through delicate proofs, and is usually content to assume that the professional mathematician, who proves the theorems in the first place, has done at least as rigorous a job as he could have done himself.

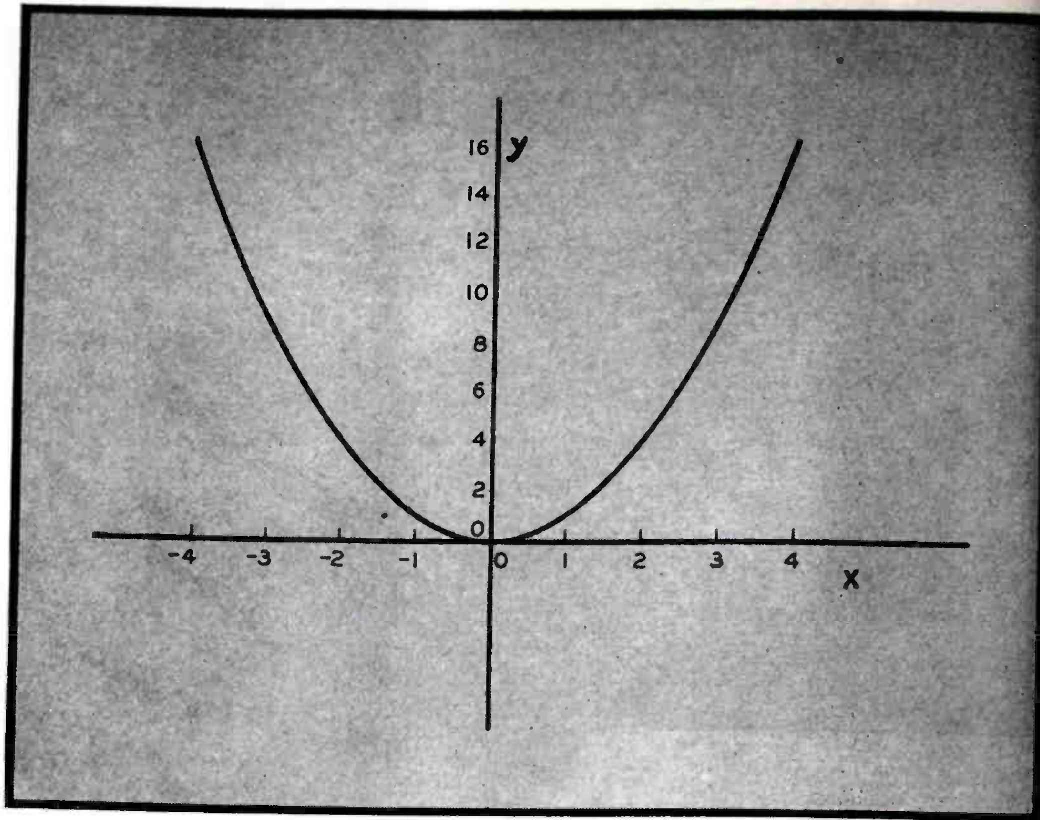
One word of caution is necessary at this point. In making use of a theorem the engineer must be fully aware of the restrictions imposed in deriving it, and must confine himself to the domain of these restrictions to avoid inevitable errors. Very often the significance of the restrictions is made clearer by a careful study of the proof of the theorem. This is the advantage of the study of rigorous proofs to the engineer.

Inasmuch as such prooffs are unde-

[1]E. A. Guillemin, Communication Networks, Wiley, New York; Vol. 1.
[2]W. R. Smythe, *Static and Dynamic Electricity,* McGraw Hill, New York.
[3]J. H. Jeans, *Mathematical Theory of Electricity and Magnetism,* Cambridge University Press (Macmillan).
[4]S. Frankel, Parallel Wires in Rectangular Troughs, Proc. IRE, Vol. 30, No. 4, p. 182, April, 1942.
[5]H. A. Schwarz, *Ueber einige Abbildungsaufgaben,* J. für Reine u. Angewandte Mathematik, Vol. 70, p. 105, 1869.
[6]E. J. Townsend, *Functions of a Complex Variable,* Henry Holt, New York.
[7]F. S. Woods, *Advanced Calculus,* Ginn and Company.
[8]N. W. McLachlan, *Complex Variable and Operational Calculus,* Cambridge University Press (Macmillan).



Figure 4
Typical example of a quantity, $y$, plotted as a function of a real variable, $x$. The function plotted is $y = x^2$. The problem of plotting functions of a complex variable is more awkward on the one hand, but on the other leads to interesting practical results.




sirable for our present purposes we shall confine ourselves instead to rudimentary arguments.

***The Argand Diagram***

We can approach the subject of *functions* of a complex variable by discussing, first, a concept which involves only the complex variable by itself and which is completely familiar to electrical engineers. We consider a plane (Figure 1) which we designate as the $z$-plane. We establish a rectangular coordinate system with coordinates $x$ and $y$, and locate the point $P$ as

$$z_1 = a_1 + j\, b_1$$

where $j = \sqrt{-1}$, and $a_1$ and $b_1$ are any real quantities. By using the quantity j we are able to distinguish when to measure along the $x$-axis and when to measure along the $y$-axis. If $z_2$ is another complex quantity

$$z_2 = a_2 + jb_2$$

then the sum of $z_1$ and $z_2$ is

$$z_3 = (a_1 + a_2) + j\,(b_1 + b_2) \qquad (1)$$

From Figure 1 we can also write

$$\left.\begin{array}{l} a_1 = r_2 \cos\phi_1 \\ b_1 = r_1 \sin\phi_1 \end{array}\right\}$$

so that

$$z_1 = r_1 (\cos\phi_1 + j \sin\phi_1) = r_1 \varepsilon^{j\phi_1}$$

Similarly,

$$z_2 = r_2\, \varepsilon^{j\phi_2}$$

so that the product of two complex quantities is

$$z_p = z_1 z_2 = r_1 r_2\, \varepsilon^{j(\phi_1 + \phi_2)} \qquad (2)$$

Let us consider the real quantity $\cos\phi_1$. We can write this as

$$\cos\phi_1 = \tfrac{1}{2}\,(\varepsilon^{j\phi_1} + \varepsilon^{-j\phi_1})$$

This is the sum of two complex quantities as indicated in Figure 2.

Looking at Figure 2, we can see that it is symmetrical with respect to the $x$-axis. For any cosine function this would always be true. It is also true for a sine function, because a sine function is merely a cosine function displaced by 90 degrees. Now we can simplify the appearance of Figure 2 by omitting the quantity $\tfrac{1}{2}\varepsilon^{-j\phi_1}$, if we agree that, whenever we see a diagram with the quantity $\tfrac{1}{2}\varepsilon^{j\phi_1}$ on it, we can assume that the quantity $\tfrac{1}{2}\varepsilon^{-j\phi_1}$ was omitted to simplify the picture.

By this means we substitute a diagram like Figure 1 for the quantity $\cos\phi$, and call it an *Argand* or *phasor* diagram. For purposes of a-c theory we multiply the scale of our diagram by $\sqrt{2}$. There can be no question about this, since we are at liberty to choose any scale we like.

If $\phi_1 = \omega t$, where $\omega = 2\pi \times$ frequency of an alternating voltage, and $t$ = time, then $z_1$ (Figure 1) rotates counterclockwise at a constant rate. We can stop this rotation if we make the further assumption that the rotation should be there, and that we should re-insert it whenever we wish to make use of any property of the quantity $\cos\omega t$ that depends on time.

Finally, if we wish to represent $E\cos\omega t$ rather than $\cos\omega t$, we merely make the complex quantity $E$ — *times* as large. Inasmuch as we can stop rotation in any position, $E\cos\omega t$ may be represented in any direction. But if two quantities, $E_1 \cos(\omega t - \theta_1)$ and $E_2 \cos(\omega t - \theta_2)$ are involved, then $E_2$ must be represented as *lagging* $E_1$ by an angle $\theta_1 - \theta_2$. If there is a possibility that a series of quantities may be added, subtracted, or compared, they must be drawn to the same scale. For example all voltages must be drawn to the same scale and so must all currents. However, currents need not be drawn to the same scale as voltages unless they are to be compared to determine impedances. Even then, the same scale is unnecessary provided the ratio of scales is accounted for in determining impedances, etc.

If we suppose we have a circuit of resistance $R$ and inductive reactance $X$ to an applied emf, $E\cos\omega t$, the steady-state current $I$ is

$$I = \frac{E}{\sqrt{R^2 + X^2}} \cos(\omega t - \theta),$$

$$\theta = \tan^{-1}\frac{X}{R} \qquad (3)$$

The Argand diagram is constructed as in Figure 3. $I$ is laid off to any convenient scale. A quantity $KR$ proportional to $R$ is laid off parallel to $I$ and $KX$ is laid off perpendicular to $I$ as shown. $E$ is then drawn from the *tail* of $KR$ to the *head* of $KX$. Clearly, $I$ lags $E$ by an angle $\theta$ required by equation *3*.

This discussion is sufficient to indicate the basis of the Argand diagram in its application to a-c theory. A more complete discussion is beyond the scope of this paper.

***Circle Diagrams***

To proceed further in a discussion of the applications of function theory we must introduce the function concept itself. A quantity $w$ is said to be a function of a quantity $z$ for some or all values of $z$ when, corresponding to some or all values of $z$ there exist one or more values of $w$. Sometimes such relationships can be expressed by mathematical formulas, in which case we can say that the functions are analytical. To take a simple example, the function

$$y = x^2 \qquad (4)$$

is a relationship expressing $y$ as an analytical function of $x$. To every value of $x$ corresponds one, and only one value of $y$. The function is, there-

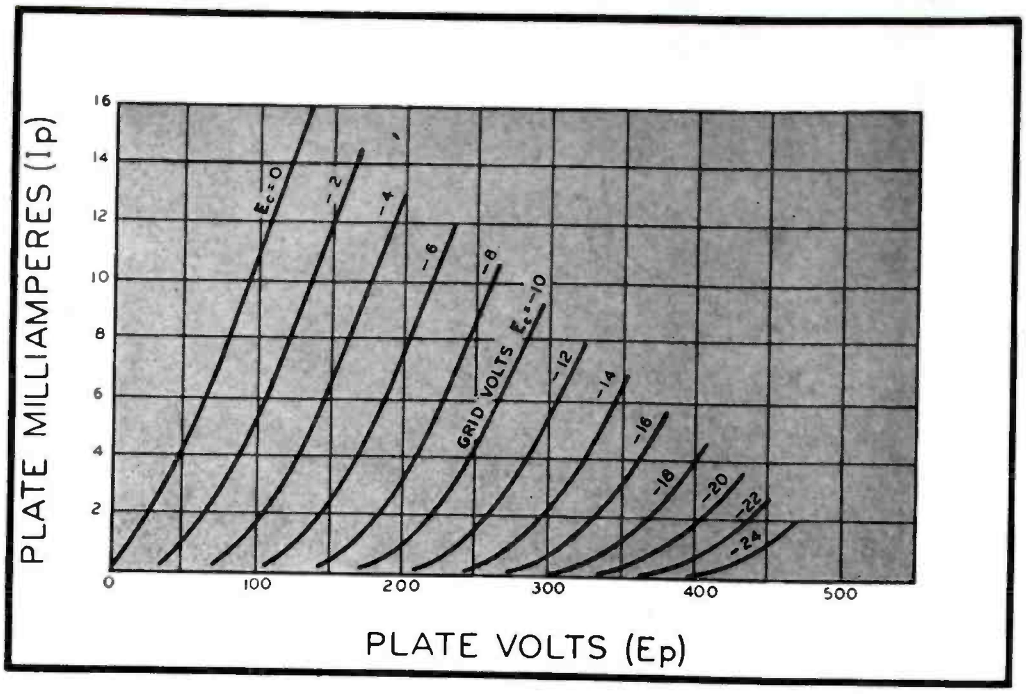



**Figure 5**

**The plate characteristic of a vacuum tube represents a typical use of the concept of a parameter to plot a function of two real variables.**

fore, *single-valued*. For any value of $x$ we can compute the corresponding value of $y$. Very often we are satisfield to stop when we have performed this calculation. Sometimes we wish to go further and get a pictorial representation of $y$. We *plot* $y$ as a function of $x$ (Figure 4). For a function of a single real variable this is easy. Only two dimensions, one for independent variable, $x$, and one for dependent variable, $y$, are required for a complete picture. If we have two independent variables, a three-dimensional picture is required. This is still possible to construct, though somewhat clumsy. In such cases the engineer usually is satisfied to draw a series of two-dimensional pictures using one independent variable as a *variable* and the other as a *parameter*. For example the plate characteristic of a vacuum tube (Figure 5) plots the dependent variable $I_p$ as a function of $E_p$, with $E_c$ as the parameter. Actually of course, $I_p$ is a function of both $E_p$ and $E_c$.

When it comes to functions of a complex variable we are in a similar difficulty. Let us again consider an analytical function of the form

$$w = z^2 \tag{5}$$

where, now, however, $z$ is the complex independent variable

$$z = x + jy$$

To begin with, the independent variable $z$ really consists of the two independent variables $x$ and $y$, and so already absorbs two dimensions, leaving nothing for the independent variable $w$. Furthermore, $w$ leads us into additional difficulties, for, since it is a function of a complex variable, it is generally also complex, and therefore, like $z$, two different variables. Thus, in the case of equation 5

$$w = z^2 = (x + jy)^2 = x^2 + j2xy - y^2 = (x^2 - y^2) + j2xy = u + jv \tag{6a}$$

so that $w$ is the complex quantity $u + jv$, and

$$\left.\begin{aligned} u &= x^2 - y^2 \\ v &= 2xy \end{aligned}\right\} \tag{6b}$$

The problem of representing these functions pictorially is often handled in function theory by making $u$ and $v$ parameters. This makes it possible to plot the functions in the *z-plane*.

Thus we assign a series of values to $u$ and $v$ and plot the corresponding functions in the $z$-plane. For example, for $u = 1$, we get

$$x^2 - y^2 = 1$$

which is readily plotted. The results of such a procedure are shown in Figure 6. This figure will be discussed again later in connection with electrostatic problems.

The expression for Ohm's law is

$$I = \frac{E}{Z} \tag{7}$$

If $Z$ is a given complex impedance and $E$ is real, it would be considerably simpler to compute $I$ from

$$I = YE \tag{8}$$

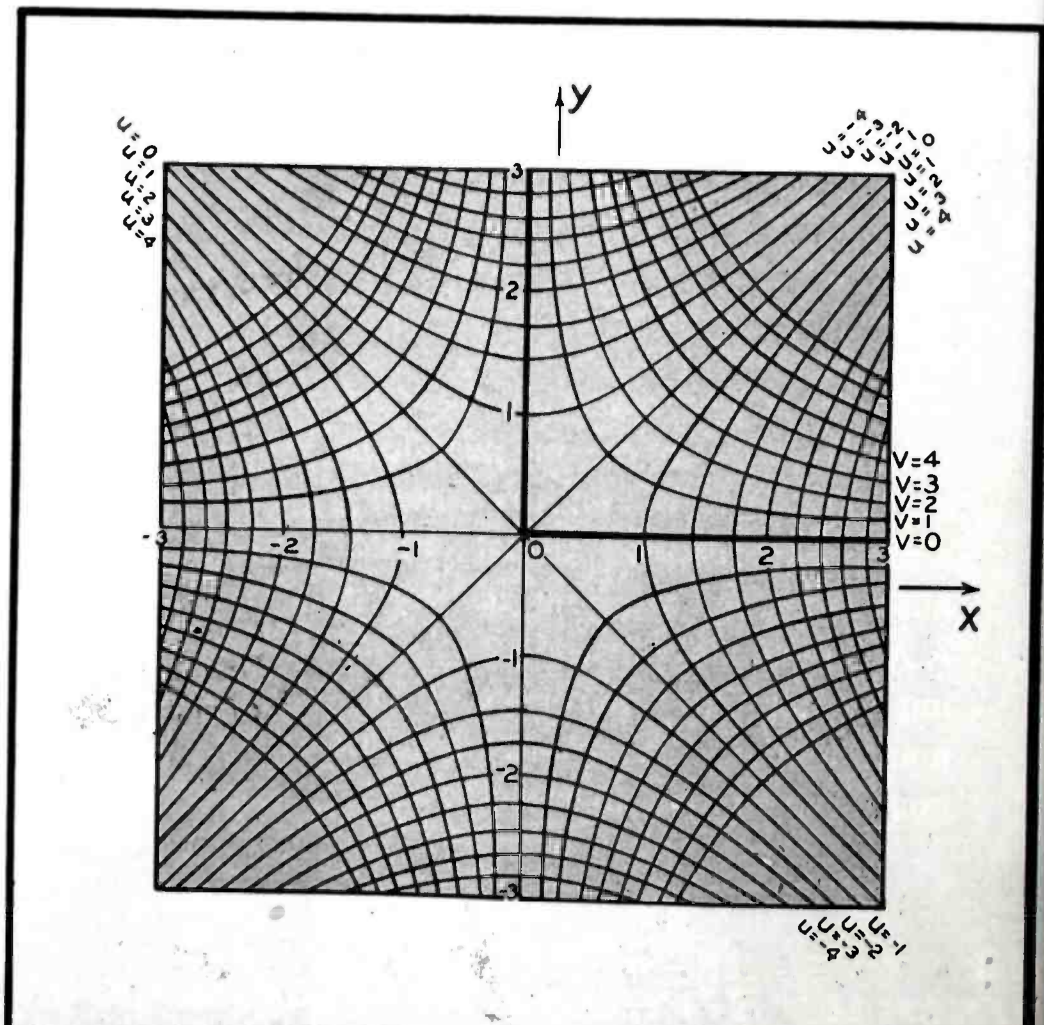
where the complex admittance $Y$ is

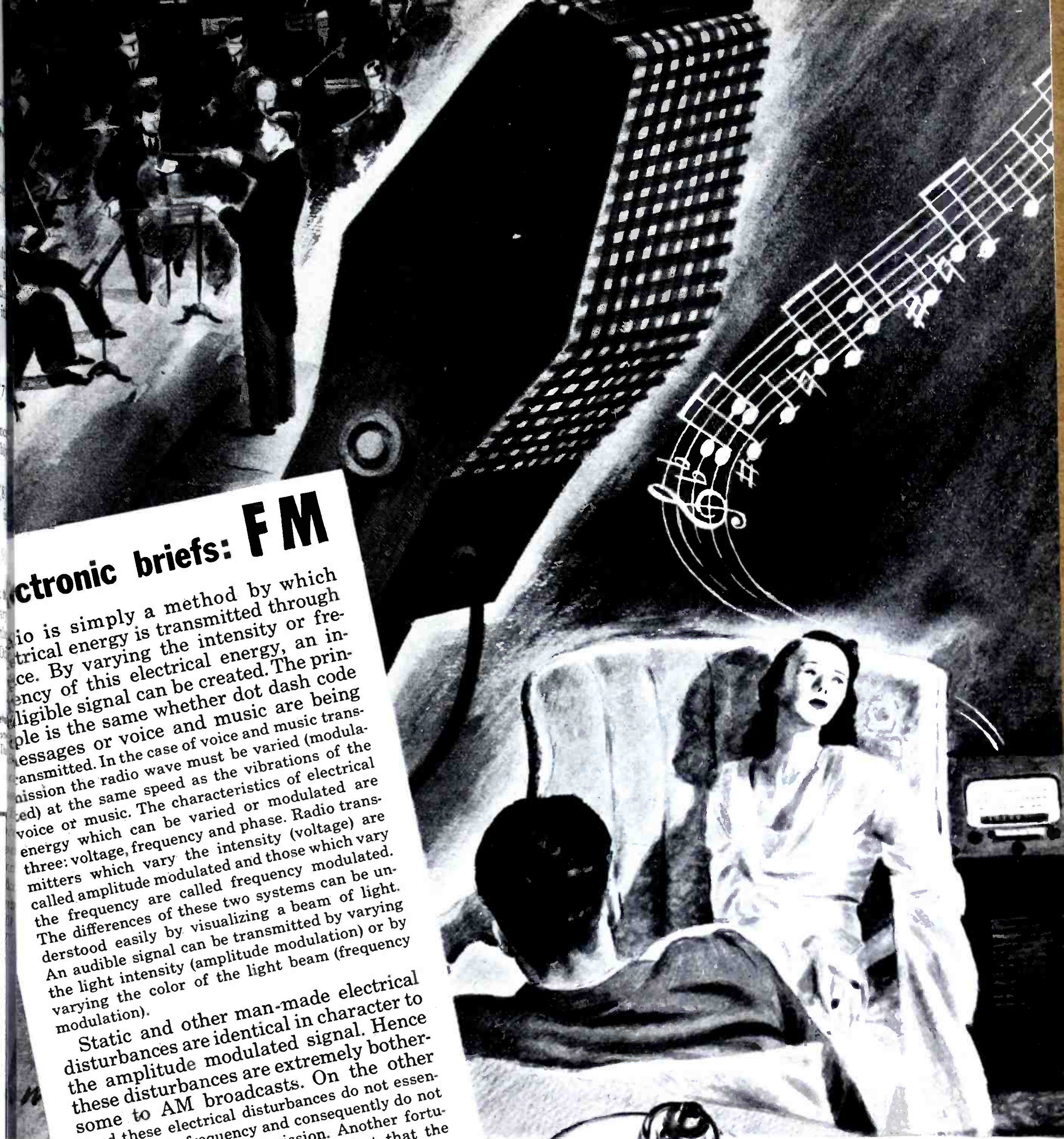
$$Y = \frac{1}{Z} \tag{9}$$

It would, therefore, be convenient to have curves of the real and imaginary parts of $Y$ plotted as functions of the real and imaginary parts of $Z$. Off

**Figure 6**

**Typical example of the use of the parameter concept to plot the components of a complex function $w = u + jv$ on a plane. The function is $w = z^2$.**





# ctronic briefs: FM

io is simply a method by which trical energy is transmitted through ce. By varying the intensity or fre- ency of this electrical energy, an in- ligible signal can be created. The prin- ple is the same whether dot dash code essages or voice and music are being ansmitted. In the case of voice and music trans- nission the radio wave must be varied (modula- ed) at the same speed as the vibrations of the voice or music. The characteristics of electrical energy which can be varied or modulated are three: voltage, frequency and phase. Radio trans- mitters which vary the intensity (voltage) are called amplitude modulated and those which vary the frequency are called frequency modulated. The differences of these two systems can be understood easily by visualizing a beam of light. An audible signal can be transmitted by varying the light intensity (amplitude modulation) or by varying the color of the light beam (frequency modulation).

Static and other man-made electrical disturbances are identical in character to the amplitude modulated signal. Hence these disturbances are extremely bothersome to AM broadcasts. On the other hand these electrical disturbances do not essentially vary in frequency and consequently do not interfere with FM transmission. Another fortunate characteristic of FM is the fact that the stronger of two signals predominates, thus eliminating much inter-station interference and cross-talk. Further, and of great importance, the fidelity of tone can be made nearly perfect even when the heaviest of musical scores is being broadcast.

In frequency modulation as in all things in the field of electronics, vacuum tubes are the most important component. Eimac tubes have the distinction of being first choice of most of the leading electronic engineers throughout the world. They are consequently first in the most important new developments in electronics... FM for example.

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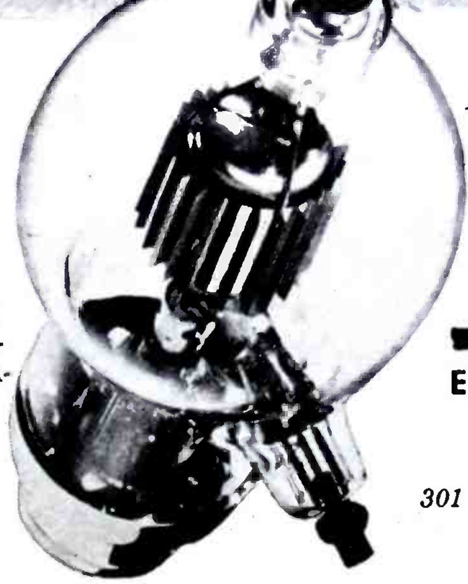

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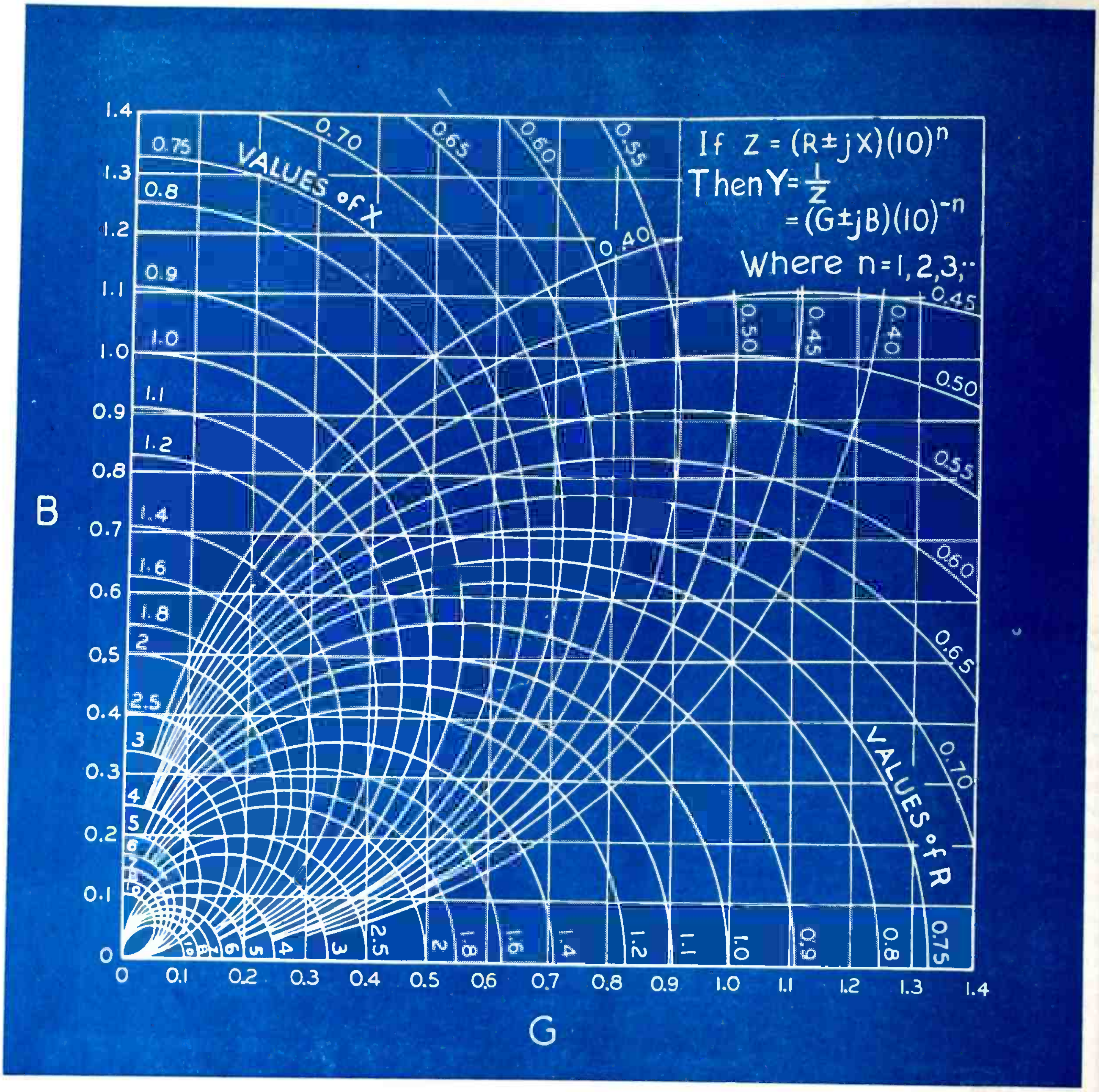



hand, calculating these curves would appear to be a tedious proposition. But let us view the problem as that of plotting a function of a complex variable

$$w = \frac{1}{z} = \frac{1}{x + jy}$$

$$= \frac{x}{x^2 + y^2} - j\frac{y}{x^2 + y^2} = u + jv \qquad (10)$$

so that

$$\left.\begin{aligned} \frac{x}{x^2 + y^2} &= u \\ -\frac{y}{x^2 + y^2} &= v \end{aligned}\right\} \qquad (11)$$

If we plan to plot these functions treating $u$ and $v$ parameters, we can re-write them as

$$\left.\begin{aligned} y^2 + \left(x - \frac{1}{2u}\right)^2 &= \left(\frac{1}{2u}\right)^2 \\ \left(y + \frac{1}{2v}\right)^2 + x^2 &= \left(\frac{1}{2v}\right)^2 \end{aligned}\right\} \qquad (12)$$

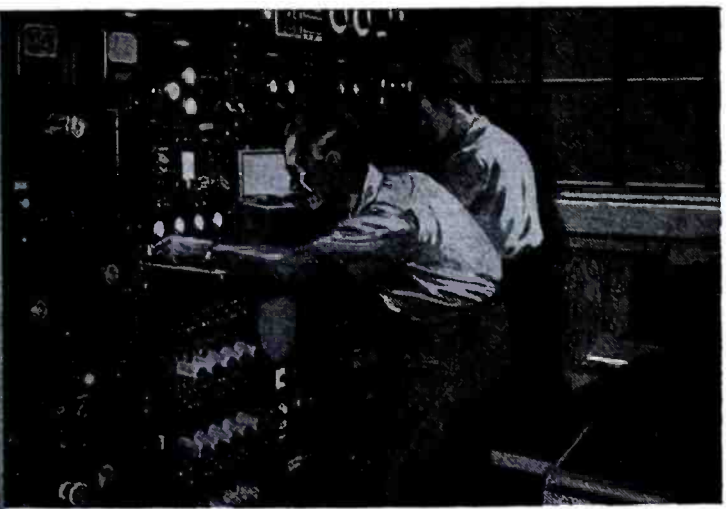
But these equations represent circles and are very easily drawn. Thus, in the first equation, all centers are on the x-axis distant $\frac{1}{2u}$ from the origin and tangent to the y-axis. In the second equation, all centers are on the y-axis distant $-\frac{1}{2v}$ from the origin and tangent to the x-axis. From this information we readily obtain the conversion chart of Figure 7, in which resistance and reactance are converted to conductance and susceptance, and vice-versa.

This is a first and fundamental type of circle diagram based on the inverse transformation. Another type of problem is posed by the following question: The current in a circuit consisting of resistance $R$ and reactance $X$ is given by

$$I = \frac{E}{R + jX} \qquad (13)$$

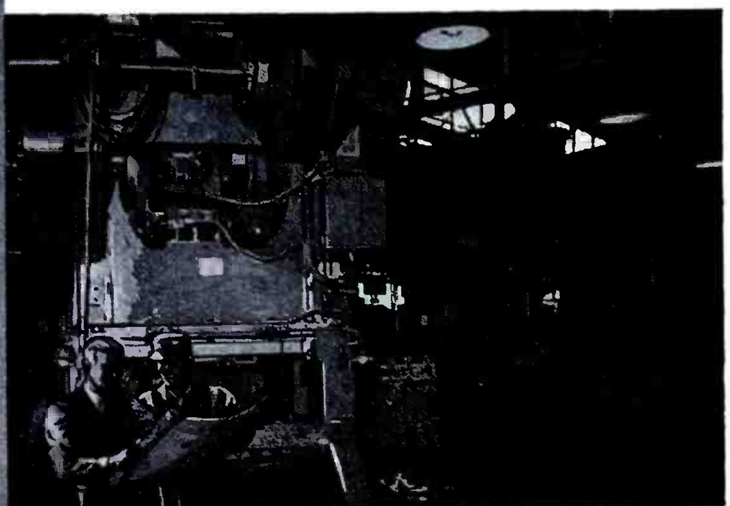
where $E$ is the applied voltage, taken

**Figure 7**
Conversion chart for calculating admittance $Y = G \mp jB$ when impedance $Z = R \pm jX$ is known. Since this conversion depends on the *inverse transformation* $w = 1/z$, it is apparent that all curves are circles.



**ELECTRONICS RESEARCH**

**Technicians of Delco Radio are carrying forward pioneer research in the field of radio and electronics.**



**PROCESS ENGINEERING**

**Delco engineers are equipped through years of experience to translate swiftly the product of research and design into practical, useful products.**

**PRECISION ON A PRODUCTION BASIS**

**Delco specializes in the ability to mass-produce highly intricate products. Years of experience in the automotive radio field qualify Delco for vehicular radio production for war.**

# PROBLEMS

## were made to be solved

For many years before the war, Delco Radio engineers were meeting and solving the problems of automotive radio . . . and putting their answers into mass production on the assembly line.

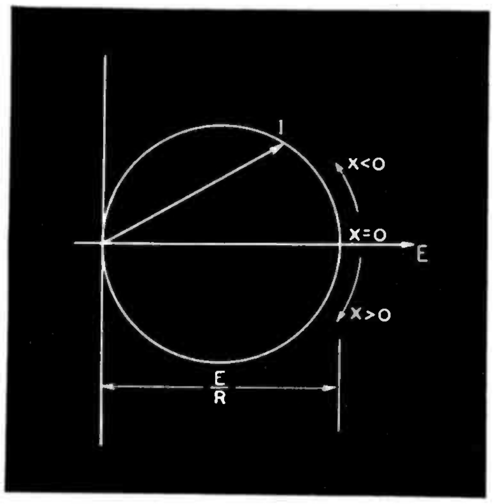
This practice gave Delco Radio technicians a head start on the problems of automotive radio for war, and prepared Delco Radio for the task of producing intricate war radio parts, components and assemblies in large quantity and of uniformly high quality of manufacture at a lower cost. Ability quickly to combine research engineering with mass-production methods has been applied in full measure to meeting the needs of the armed forces.

Whether the task at hand is one of pure research, or of mass-production methods, or a combination of both, Delco Radio is adequately equipped and experienced to do the job. Delco Radio Division, General Motors Corporation, Kokomo, Indiana.

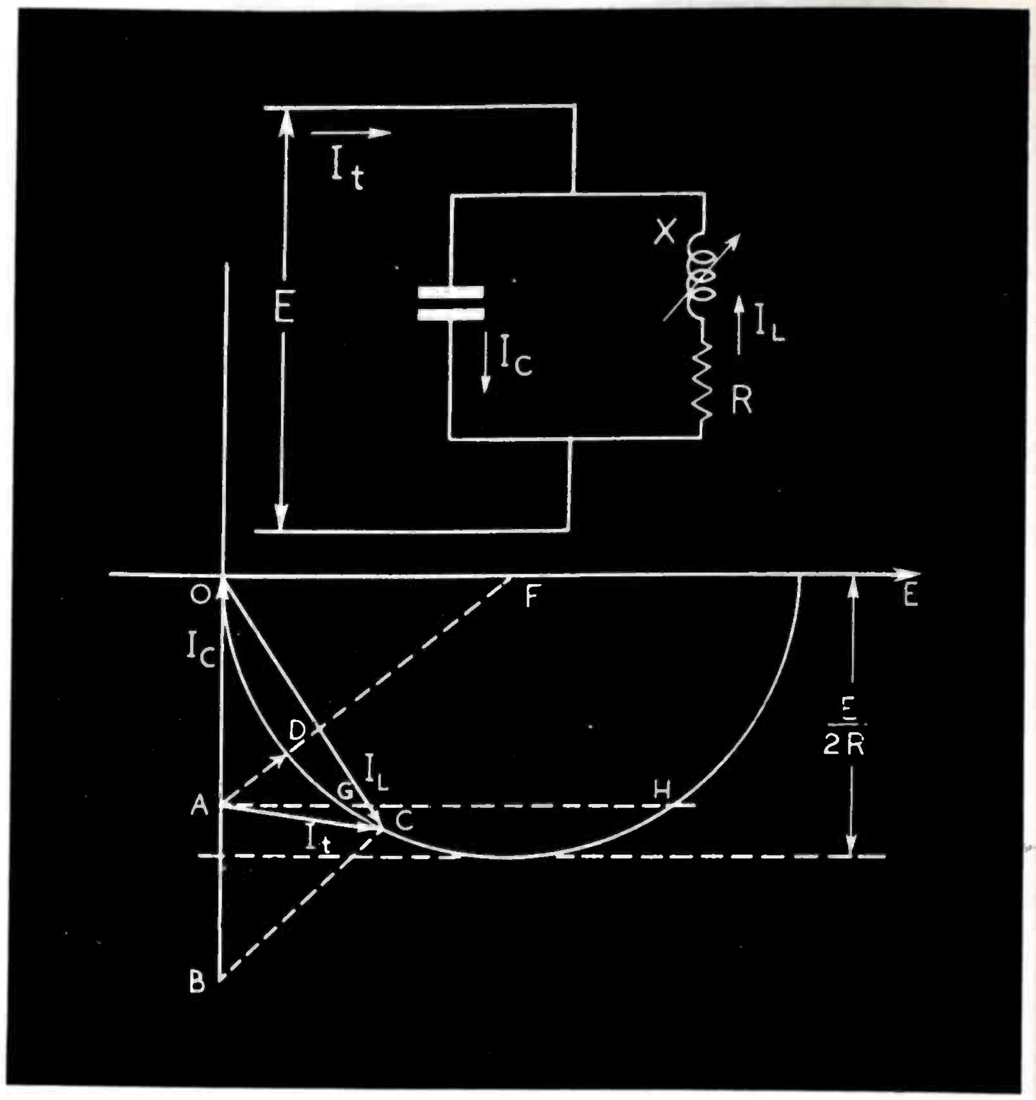
★ ★ ★ ★ ★ ★ ★

***Back the Attack—***
**WITH WAR BONDS**

**Delco Radio**
**DIVISION OF**
**GENERAL MOTORS**




Figures 8 (above) and 9 (right)
The locus of the impedance of a series circuit is a circle tangent to the *y* axis at the origin (Figure 8). Figure 9 shows the locus of current flowing into a typical parallel circuit when the inductive reactance in one branch is varied.




as a real constant. Then if $I$ represents a point in the complex plane, what is the locus of $I$ as $X$ is varied from $-\infty$ to $+\infty$?

Converting this to function-theory language the problem is stated as follows: In the $z$-plane, where $z = x + jy$, the locus of $x = R =$ const. is a straight line parallel to the y-axis, distant $R$ from and to the right of that axis, and running from $-\infty$ to $+\infty$. To what does this locus transform under the transformation

$$w = \frac{E}{z} \quad ?$$

We have

$$z = \frac{E}{w} = \frac{E}{u + jv}$$

$$= \frac{Eu}{u^2 + v^2} - j\frac{Ev}{u^2 + v^2} = R + jy$$

From this,

$$\frac{Eu}{u^2 + v^2} = R$$

$$v^2 = \frac{E}{R}u - u^2$$

This is a circle whose center is on the *real-*, or *u-axis*, and which is tangent to the *imaginary-*, or *v-axis*, (Figure 8). Its diameter is E/R and is the value of $I$ when $X = 0$. As $X$ increases in the positive direction, $I$ decreases in magnitude, and lags increasingly in phase until $X = \infty$, the phase angle is 90° and the magnitude is zero. Similarly, as $X$ increases in the negative direction, $I$ decreases again in magnitude, but now *leads* increasingly in phase until, as $X = -\infty$, the phase angle is 90° and the magnitude is again zero.

This diagram may be used to demonstrate, in a simple manner, certain interesting phenomena occurring in parallel resonant circuits. Thus, consider Figure 9 which shows such a circuit. Here one branch has $X$ variable, as in the example just discussed, but, inasmuch as we now limit this to positive reactance, only the lower half-circle is used. In addition we have the capacitor current, $I_c$, leading $E$ by 90°. We ask: how does the total current, $I_t$, vary as $X$ is varied? Suppose first that $I_c = OA < \frac{E}{2R}$. Then $I_t = AC$, and as $X$ is varied from $\infty$ to zero, the point $C$ moves from the origin $O$ along the perimeter of the circle. $I_t$ starts at the value $OA$ and decreases to a minimum value readily determined by constructing $AF$ through the center $F$, of the circle, and measuring $AD$ as the minimum value of $I_t$. This is the condition for maximum impedance of the circuit; yet, as can be seen, the input current may be badly out of phase with the applied voltage. In fact it will only be close to being in phase at the maximum impedance point if $I_c$ is much smaller than the diameter of the circle. Practically this boils down to having a high-Q circuit, since, in that case, the reactance of the capacitor is much greater than the resistance of the coil, so that $I_c << \frac{E}{2R}$.

Continuing around the circle after passing the minimum point $D$ we find two points at which the input current is in phase with the applied voltage, namely the points $G$ and $H$. In case $I_c = \frac{E}{2R}$, there is only one such point, while if $I_c > \frac{E}{2R}$, there are none. In that case no value of inductive reactance exists to give unity power factor for the tuned circuit.

Examples of circle diagrams could be multiplied endlessly, since every time an impedance is inverted into an admittance a new circle diagram is implied. We will not pursue this subject further, but go on to other applications of function theory.

#### Electrostatics in Two Dimensions

Before proceeding with further applications we have to discuss certain interesting properties of analytic functions of a complex variable.

We saw previously (equation *6a*)
(*Continued on page* 98)

# SQUELCH SYSTEMS

## Their Design And Operation

by LOUIS PRESSMAN

Radio Supervisor, WNYF
New York Fire Department

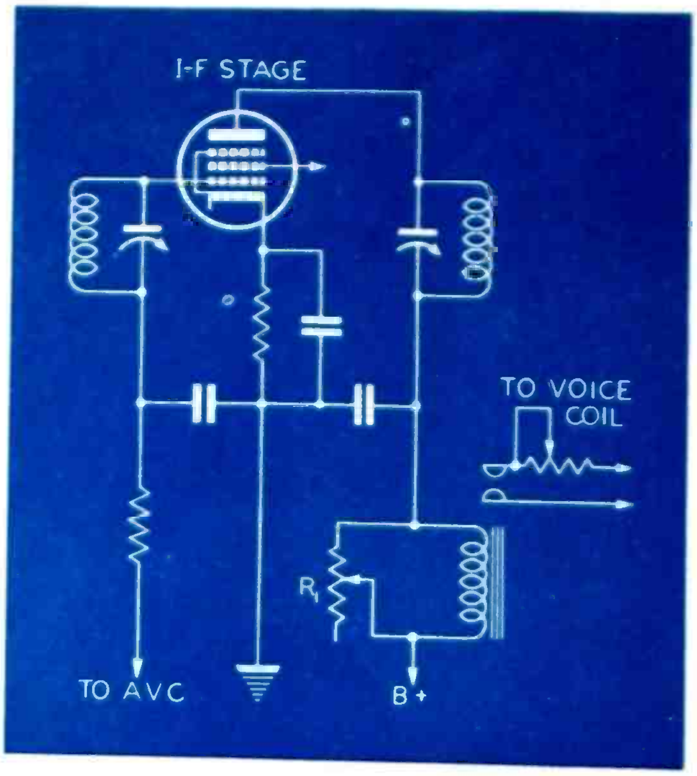



Figure 1
The relay type of squelch system. Although the relay shown provides muting only, addition of extra contacts provide interesting possibilities useful for other purposes.

A RECEIVER employing automatic volume control will deliver very large noise outputs between stations or channels. This is due to the lowering of the control voltages or biases to the r-f and i-f stages of the receiver resulting in increased sensitivity when tuning away from a carrier. In a fixed-tuned receiver for police or fire department service, for example, this condition exists when the transmitter goes off the air after completion of a message.

### Manual Methods

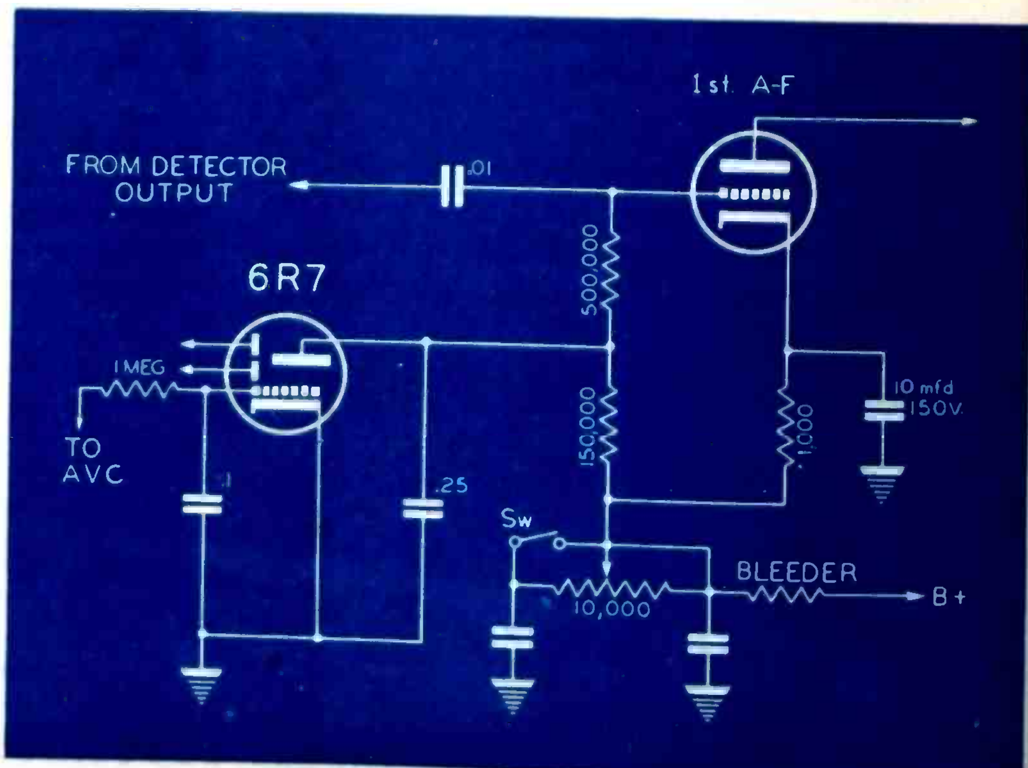
Manual methods of disabling the audio stages may be utilized for broadcast or short-wave tuning, but for other listening services, an automatic method is necessary, if a noise suppression system is to be used. Circuits designed to provide this service automatically are known as squelch, quiet avc or just qavc, muting, codan (for carrier-off device anti-noise), interchannel noise suppression, channel control, etc.

Aside from the manual method, electro-mechanical methods such as relays may be used. In addition complete electronic methods using vacuum tubes and glow-discharge tubes may be utilized, too.

Muting, of course, is not new. Around 1930, manual quieting was used in a number of broadcast receivers. A push button on the front panel was depressed while tuning over the band. Obviously both hands were necessary for manipulation of the controls and the system did not remain popular. In 1930, the Marconi Company received a patent for an automatic squelching circuit utilizing a relay in the intermediate frequency stage. In this system, when a carrier was being received, then the receiver functioned normally, while with no carrier, one audio stage was shorted out by the relay contacts. Relays have been used since then in some fixed-frequency receivers, but this method has been superseded largely by electronic circuits.

Figure 2
The blocked-audio type of squelch system. In the potentiometer bypass circuit, the left end of the potentiometer may be tied to ground.

Actual muting is possible by causing receiver sensitivity to be reduced between channels or carrier-off conditions or by disabling the audio system. The former has the disadvantage of greatly reduced sensitivity between channels and may cause missing of a carrier altogether in a tunable receiver. For a fixed-tuned receiver, this method is also impracticable. The blocked audio system (or shorted type) does not affect the r-f sensitivity of the receiver, but must provide the squelch circuit with a definite carrier amplitude for unblocking or unshorting. Since signals below the r-f input necessary to operate the squelch are not

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reproduced, the receiver sensitivity is reduced somewhat. This of course depends on the adjustment of the muting level control. This means that signals below or at the same level as the noise will not be heard. Actually, this may be an advantage or disadvantage depending on the particular service in which the receiver is being used.

Squelching may be used to advantage in many applications, such as fixed-tuned receivers for police, fire and public utility service, and marine service in tugs, private cruisers, etc. It has its place, too, in high-fidelity broadcast receivers and frequency modulation receivers with or without avc.

Manual methods of muting are usually applicable only in continuously tuned receivers where an operator manipulates the controls. Modification of the manual method may be utilized in push-button tuned receivers, whereby extra contacts on the push-buttons act to disable the audio system while the button is being depressed. Actually, this may be considered a form of mechanical squelching.

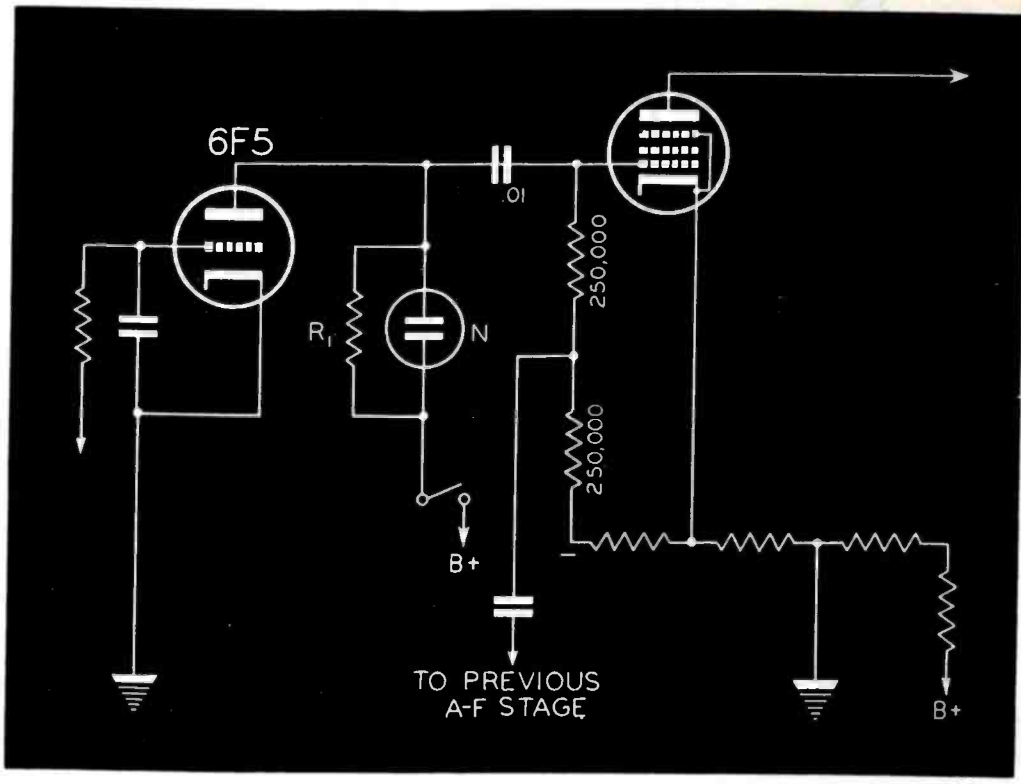


Figure 3

**The shunted audio type of squelch, wherein a neon tube is used to effectively short circuit the audio signal. Receiver sensitivity control also acts to control muting level.**

#### *Common Methods*

The most common methods act to short the loud speaker voice coil, short some audio grid to ground, or bias one of the audio stages beyond cut-off, in the absence of carrier. When muting manually the former two methods are normally utilized, and for satisfactory operation of such a system some form of tuning indicator must be supplied or the station calibration must be well fixed. It is possible to provide for only partial shorting so that a weak signal is heard between channels eliminating the necessity of the tuning indicator.

Automatic squelching is usually preferable and is most commonly used. This type may be incorporated in practically any type of receiver, tunable or fixed-tuned. However, the a-m receiver must use avc; the f-m receiver may or may not.

Basically the principle of operation depends on making use of the change in operating current or voltage from carrier to no carrier conditions as a control source. In an amplitude modulation receiver a controlling voltage may be obtained from some point in the avc system or a controlling current may be obtained from the plate circuit of an avc controlled stage. In frequency modulation receivers, not using avc, a controlling voltage may be obtained from the grid circuit of a limiter stage. An unusual arrangement in a f-m unit is to pick off amplitude variations from plate circuit of last i-f, rectify with a diode and use the resultant d-c component as a controlling voltage. This method is used by General Electric in some of their f-m receivers.

Circuits incorporating electro-mechanical devices (relays) usually arrange to short the voice coil or a grid circuit through the relay contacts. This method may only partially short the signal so that the effective sensitivity of the receiver is not reduced. However complete muting is not obtained.

Completely electronic methods usually provide a blocking bias to the audio system and do not lend themselves to partial squelching. A control is normally provided so that the squelching level may be set for particular noise levels, with provision for making the circuit inoperative. The application of a carrier to the receiver will operate the qavc and restore the audio system to normal provided the carrier is greater in amplitude than

(*Continued on page* 102)

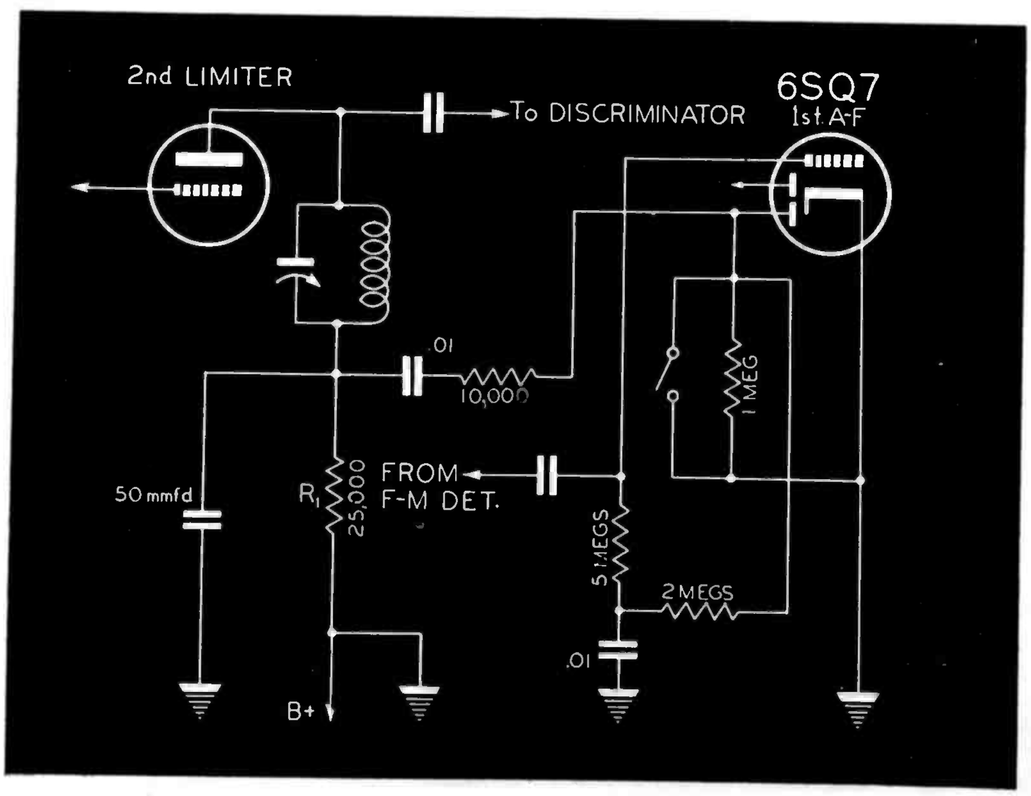


Figure 4

**An arrangement effective in an f-m receiver, whereby amplitude noise level provides blocking bias to the audio amplifier.**

# RADIOTELEPHONE EQUIPMENT
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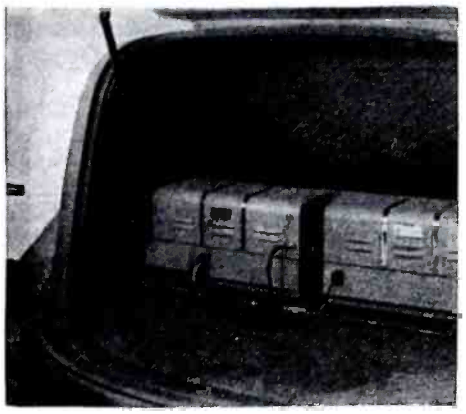

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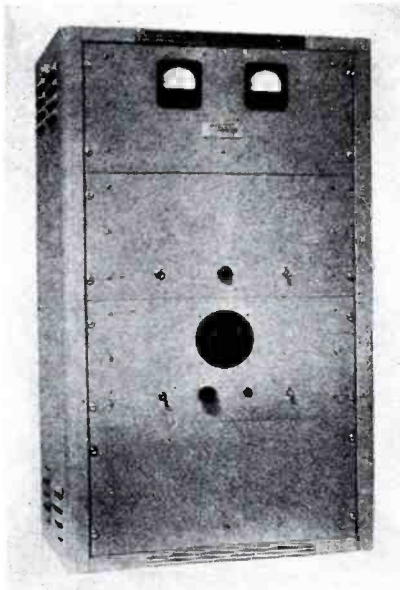

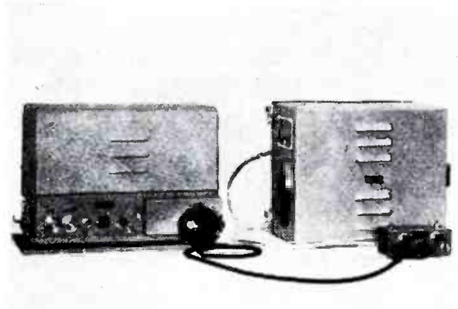

Type 11X Receiver and PTL-10X Transmitter for Mobile Applications.

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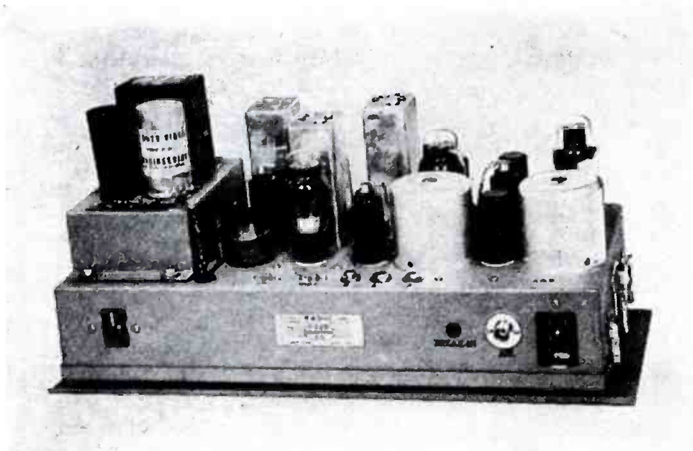
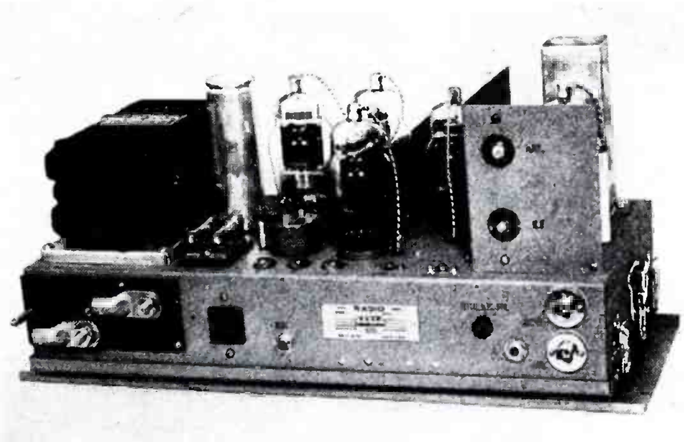


Type PRS-9X, 30-40 MC Mobile Receiver with Dust Cover Removed.



Type PTS-22X, 30-40 MC Mobile Transmitter with Dust Cover Removed.

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## PARTIAL LIST OF TYPICAL PRODUCTION MODELS

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|---|---|
| **SERIES 17** | 10 Watt Multi-Channel Transmitter, Receiver and Power Supply in 8¾" x 15" x 11" Cabinet. 6 and 12 Volt DC and 117 Volt AC Models available. |
| **SERIES 26** | 20 Watt Multi-Channel Transmitter and Receiver available for operation from 6, 12, 32 and 110 Volts DC or 117 Volts AC. |
| **SERIES 56** | 50 Watt Multi-Channel Transmitter and Receiver available for operation from 12, 32 and 110 Volts DC or 117 Volts AC. |
| **SERIES 6** | Includes Tunable and Multi-Channel Fixed Tuned Receivers for Mobile, Marine or Central Station application. |
| **TYPE 11A** | Single Frequency Crystal Controlled Station Receiver for frequency ranges up to 8,000 KC. |
| **TYPE 11X** | Crystal Controlled Mobile Receiver, for frequency ranges up to 8,000 KC. |
| **TYPE PTL-10X** | Instant Heating 10 Watt Mobile Transmitter, for frequency ranges up to 8,000 KC. |
| **TYPE PTL-22X** | Instant Heating 22 Watt Mobile Transmitter for frequency ranges up to 8,000 KC. |
| **TYPE PTS-22X** | Instant Heating 22 Watt Mobile Transmitter, range 30-40 MC. |
| **TYPE PR-9X** | Crystal Controlled Mobile Receiver, range 30-40 MC. |
| **TYPE PRS-9A** | Crystal Controlled Station Receiver, range 30-40 MC. |

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# NEWS BRIEFS OF THE MONTH . . . —

### ILLINOIS INSTITUTE OPENS NEW TRAINING COURSE SERIES

Twenty-nine courses in radio and electrical engineering, ranging from fundamental circuit study to industrial electronics on a post-graduate level, will be offered at Illinois Institute of Technology in Chicago this fall, when the school will open its eighth series of tuition-free radio war training courses.

The courses will cover seven fields: radio engineering, electrical engineering power, engineering electronics, power systems, telephony, illumination engineering and mathematics.

To accommodate war plant workers on night shifts, some of the free classes will be offered during the day for the first time. The program, which is primarily one of evening courses, will now include elementary radio classes in the morning and afternoon.

A refresher course for graduate electrical engineers also will be given on Saturday mornings and one night weekly. Instruction will cover modern developments in application of electronics and recent developments in power systems engineering.

All classes in the free program will meet twice a week, with an average of five and a half hours of lectures and conference and two and a half hours of laboratory work weekly.

Only prerequisite for enrollment is a high school education or the equivalent in industrial experience. Thus far a total of 3453 men and women have completed the free radio training at Illinois Tech.

* * *

### R. T. BARTLEY JOINS NAB

Robert T. Bartley, vice president of the Yankee Network, joined the National Association of Broadcasters in Washington, D. C., as coordinator of war activities.

Mr. Bartley was with Yankee for the past four and a half years.

* * *

### G. E. INSULATING MATERIAL CATALOG

A 60-page catalog covering the entire line of G. E. insulating materials has been announced by the resin and insulation materials division of General Electric's appliance and merchandise department. The catalog lists and describes varnished cloths, varnishes, glyptals, tapes, cords, cotton sleeving, varnished tubings, mica, wedges, soldering materials, cements and compounds.

Tab sheets separate the catalog sections, each of which is devoted to a different type of material. Copies are available on request.

* * *

### CLAROSTAT MOVES OFFICES

The Clarostat Mfg. Co., Inc., has moved its general offices to 130 Clinton Street, Brooklyn, N. Y. The new 'phone number is MAin 4-1190-1-2-3-4-5.

* * *

### NEW ARMY REGULATIONS ON TERMINATED CONTRACTS

The War Department has issued a new procurement regulation *15* giving Army field personnel instructions as to methods to be followed when war contracts are cancelled.

### UNITED ELECTRONICS "E" CEREMONIES

Colonel C. O. Bickelhaupt, Commanding Officer, Eastern Signal Corps Replacement Training Center, Fort Monmouth, presented the "E" flag to R. H. Amberg, president of United Electronics Company at ceremonies held in Newark recently.

Among others in attendance were Secretary of State of New Jersey, Joseph A. Brophy, and C. A. Rice, vice-president of United Electronics.

The ceremonies were broadcast over WOR and WAAT.


* * *

### "E" TO CANNON

The Army-Navy "E" has been awarded to the Cannon Electric Development Company and Cannon Manufacturing Corporation, Los Angeles, Calif. Lieutenant-Colonel William H. Dayton, U. S. Army Air Forces, presented the "E" flag to James H. Cannon, founder of Cannon Electric.


* * *

### FIVE INDUSTRY MEN ON OPA PLASTIC GROUP

Five members of the plastics industry have been appointed to serve on a national OPA Industry Advisory Committee for Plastic Thermosetting Laminates.

The committee will advise and consult with OPA on pricing problems of the industry.

Those named to the committee, which will meet in Washington, D. C., in the near future, are: D. J. O'Conor, president, Formica Insulation Company, Cincinnati, Ohio; C. C. Steck, president, Spaulding Fibre Company, Tonawanda, N. Y.; William H. Milton, Jr., manager, Plastics Dept., General Electric Company, Pittsfield, Mass.; R. R. Titus, president, Synthane Corporation, Oaks, Pa.; and C. R. Mahaney, general manager, Panelyte division, St. Regis Paper Company, Trenton, N. J.

### PARTS DUMPING THREAT CAN BE AVOIDED, SAYS GOLENPAUL

The post-war dumping of surplus radio parts need not be a serious threat to the trade if manufacturers and jobbers co-operate in maintaining price structures and brand reputations, pointed out Charley Golenpaul, sales manager of the jobber division, Aerovox Corporation and chairman of the Eastern Group, Sales Managers Club, recently.

He explained that while radio parts are now being produced in fantastic quantities, such parts are just as rapidly assembled into radio and electronic equipment for our armed forces. Much of that equipment will be used by our armed forces or placed in reserve after fighting ceases. Thus completed equipment, much of it of a vital military character, will hardly be dumped into civilian hands.

Nevertheless, the fact remains that radio parts are now being produced on a fantastic scale, he said.

Mr. Golenpaul pointed out that a sharp distinction can be drawn between such surplus parts and regular items produced for the jobbing trade. Manufacturers and jobbers should collaborate in making that distinction clear to the trade. Thus parts made for set or equipment manufacturers are usually not individually packaged. That is the first distinction.

Again, manufacturers' parts usually carry an entirely different part number or type designation to the confusion of the jobbing trade. That is the second distinction.

Still again, parts sold to manufacturers are protected by a blanket guarantee covering the initial buyer only. In other words, if such parts are resold to others as parts, the guarantee no longer holds. That is the third distinction, explained Mr. Golenpaul.

Our main job, continued Mr. Golenpaul, is to win the war. We cannot afford to spend valuable time worrying and fretting about postwar problems. However, without detracting one iota from the all-out war effort, both manufacturers and jobbers alike can and must do a little thinking and planning as to how the postwar dumping situation can be met, by drawing that sharp distinction between regular goods and dumped goods. There is a place for both kinds of goods.

Now is the time to be doing a little thinking and planning before the storm breaks, stressed Mr. Golenpaul.

* * *

### WICKENDEN NOW HEADS INCO DEVELOPMENT AND RESEARCH

T. H. Wickenden has been appointed manager of the development and research division of the International Nickel Company, 67 Wall Street, New York City. H. J. French was named assistant manager.

* * *

### STRONGER TIN ALLOYS DATA

A further contribution to the development of stronger tin base alloys suitable for use as bearing metals was reported in a paper by Dr. W. T. Pell-Walpole, in the *Journal of the Institute of Metals*, June 1943.

In the Oct., 1942 issue of the *Journal* it was revealed that the hardness of tin-

*(Continued on page 78)*——


**_Echophone Model EC-1_**

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

***ECHOPHONE RADIO CO., 201 EAST 26th ST., CHICAGO, ILLINOIS***

## NEWS BRIEFS

(*Continued from page* 76)

base alloys in the range, antimony 9 to 10 per cent, cadmium 1 to 1½ per cent, balance tin, can be appreciably improved by heat treatment. In the present paper, it is shown that the same range of alloys has improved tensile strength after quenching from the highest practicable annealing temperature followed by prolonged tempering at 140°C. The best alloy from this point of view contains 9 per cent antimony, 1½ per cent cadmium, balance tin. The tensile strength of the alloy reaches 6 tons per square inch as quenched and tempered, and this strength is retained at 140°C. This temperature was chosen as being near the maximum at which tin-base bearings may have to operate continuously.

Reprints of Dr. Pell-Walpole's paper (Publication 114.A) may be obtained on request to the Tin Research Institute, Fraser Road, Greenford, Middlesex, England.

* * *

### ARMY PRICING MANUAL

The War Department has issued a new manual, *M601*, of procedure for procurement officers entitled *Pricing in War Contracts*. It was prepared by the Director of Purchases, Army Service Forces.

* * *

### NANCE OF ZENITH ON RMA POSTWAR COMMITTEE

J. J. Nance, vice president of Zenith Radio Corporation, has been appointed to the new committee on postwar planning of the Radio Manufacturer's Association.

* * *

### W. H. HEICHER JOINS RCA'S INFORMATION DEPARTMENT

Winchester H. Heicher, writer, has joined the staff of the Department of Information of the Radio Corporation of America.

Mr. Heicher formerly served as research consultant for the Senate Committee on Affairs of Cities of the State of New York, of which Senator Thomas C. Desmond is Chairman.

* * *

### HAZELTINE WINS "E"

The Hazeltine Electronics Corp., Little Neck, L. I., has been awarded the joint Army-Navy "E".

* * *

### I. T. & T. INAUGURATES RADIOPHOTO SERVICE TO BRAZIL

The first radiophoto service between the United States and Brazil was inaugurated recently by the Mackay Radio and Telegraph Company, an associate of the International Telephone and Telegraph Corporation. In Brazil the operating unit will be the Companhia Radio Internacional do Brasil at Rio de Janeiro, I. T. & T. associate.

* * *

### PLASTIC MATERIALS COST LOWERED

The cost of laminated plastic sheets, rods and tubes, has been reduced about 10 per cent, the Office of Price Administration announced recently.

OPA stated that 10 manufacturers in the industry, accounting for virtually the entire $72,000,000 annual production, have agreed to restore price levels that prevailed in 1939 and 1940. Most of the manufacturers have signed individual vol-

(*Continued on page* 80)


A Great Family
A GREATLY magnified picture of a few Stewart parts—vitally important although small in size, as practically all assemblies would be useless without them. A "Great" Family in every sense. Great in coverage—meets virtually every Terminal requirement in the electrical field. Great because every part is made to highest precision standards—accurately dimensioned and to full standard gauge. Great by reason of the quality of the metals used, assuring maximum strength, durability and long life.
Odd shaped pieces stamped and formed from wire or strip on high speed machines.
Hundreds of items in stock.
Complete Hot Tinning and Plating facilities for handling large orders.
Send for samples and quotations. Let us have your prints and specifications.
Quick Response to Inquiries!
STEWART STAMPING COMPANY
621 East 216th Street, 67 New York
★
BUY MORE WAR BONDS!
STEWART TERMINALS

# NEWS BRIEFS

(*Continued from page 78*)

untary agreements formalizing the new schedule of prices. The reduction will be effected by cancelling a price increase of 10 per cent announced generally by the industry early in 1941 and which was reflected in current maximums established under maximum price regulation No. 406.

The lowered maximum prices set forth in the individual agreements will be continued in a regulation, to be drafted soon, providing uniform prices of sheet rods and tubes for the entire industry. An industry advisory committee, recently appointed by OPA, will advise and consult with OPA in preparing the proposed measure.

* * *

### *ALL MASS. POLICE NOW USING F-M*

There are now 105 f-m-equipped cars and seven 250-watt fixed transmitters situated on strategic hilltops throughout Massachusetts (also 25-watt transmitters on the islands).

* * *

### *HALLICRAFTERS ADDS NEW PLANT*

Another plant has been added by the Hallicrafters, Inc., Chicago, Ill. The new plant covers a block square.

A surprise visit was paid to the new plant soon after its opening by Major General Harry C. Ingles, Chief Signal Officer, and Brigadier General Edgar L. Clewell, commanding officer of the Chicago Signal Depot, accompanied by staff officers.

* * *

### *4TH DISTRICT NAB POST TO HUNT*

The chairmanship of the engineering committee for the fourth district of NAB has been accepted by Clyde M. Hunt, chief engineer for station WTOP, Washington, D. C.

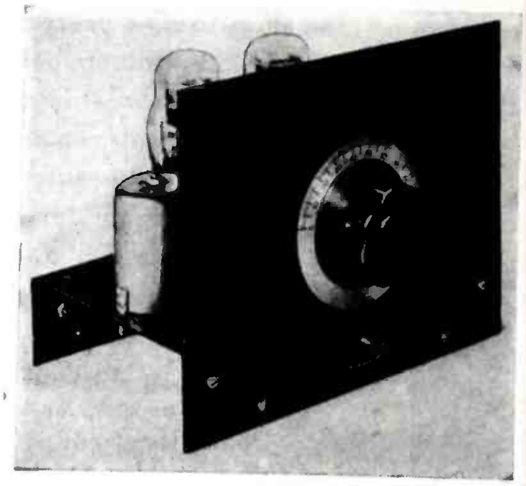
In this capacity, Mr. Hunt will coordinate the activities on behalf of the industry of chief engineers of member stations. Mr. Hunt's term of office runs through the next annual NAB Convention. He has been with CBS-WTOP for more than ten years.

* * *

### *LAFAYETTE KITS FOR WAR TRAINING*

One and two-tube regenerative kits designed to provide complete basic receiver training in wartime programs are now available from Lafayette Radio Corporation, Chicago and Atlanta.

The one tube kit, when assembled, demonstrates grid leak detector operation and the effects of regeneration on a detector circuit. With the addition of a minimum of parts an r-f stage can be added without redrilling the chassis or moving any component parts of the detector circuit. Alignment procedure can then be demonstrated in its simplest form. These kits may be operated either from power supplies or from batteries.



* * *

### *NBC APPOINTS POSTWAR TELEVISION COMMITTEE*

Niles Trammell, president of the National Broadcasting Company, has announced the creation of a postwar television planning committee to formulate plans for the company's postwar expansion. Essential technological studies and the surveys of the problems involved are to be initiated now and the conclusions held in readiness for the first days of peace.

The committee consists of John Royal, vice president in charge of International shortwave and television, as chairman; William S. Hedges, vice president in charge of stations; O. B. Hanson, vice president and chief engineer, and C. L. Menser, vice president and manager of the program department. John T. Williams, assistant to Noran Kersta, now in the Marine Corps, was named secretary.

Currently, NBC is operating its Empire State television transmitter four hours weekly: Mondays, 4:00 to 5:00 p.m., and 7:30 to 10:30 p.m. Hereafter programming will be under the direction of NBC's program department, with Williams and his staff reporting to Menser.

* * *

### STAR ADDED TO "M" PENNANT OF RADIOMARINE

A star for continued achievement in completing wartime schedules has been added to the maritime "M" pennant, which was presented Radiomarine Corporation of America on March 8, 1943.

* * *

### HUNDRED-MILLION VOLT X-RAYS PRODUCED

According to the research laboratory of the General Electric Company, 100,000,000 volt x-rays were produced recently for the first time in the history of science.

They were obtained from the large induction electron accelerator recently completed. The characteristics of this new type of radiation will be published as fast as they can be determined. The first few observations suffice to show that these characteristics differ radically from those with which physicists are familiar.

* * *

### QUAM NOW STEEL WIRE COMPANY DIRECTOR

James Quam, president and general manager of Quam-Nichols Company, Chicago, Illinois, has been elected a director of the Nichols Steel and Wire Company.

* * *

### CAPACITOR SUBSTITUTION DATA IN SPRAGUE FOLDER

A folder recently issued by the Sprague Products Company, North Adams, Mass., illustrates and describes a *Victory Line* of Sprague atom midget dry electrolytic capacitors and TC tubulars to be supplied through distributors in conformity with wartime limitations on capacitor production for civilian use.

Although the *Victory Line* is necessarily limited to only nine Atom types and nine TC tubulars, these have been carefully selected as to capacities and voltages to enable servicemen to handle practically any replacement job. An article included as part of the folder *How to Use Victory Line Capacitors,* contains many helpful hints on how to substitute the few *Victory* capacitors for the many varieties of standard types. Subjects covered include *Connecting Capacitors in Parallel to Make Capacity Values Not Available in a Single Unit; Replacing Filter Applications Higher Than* 450 *V D-C with Victory Line* 450 *V Capacitors;* and *Replacing Wet Electrolytics with Dry Electrolytics.*

Copies may be obtained direct from the company or through authorized Sprague distributors.

* * *

### "E" TO WEBSTER

The Webster Electric Company, Racine, Wisconsin, has been given the Army-Navy "E".

* * *

### F-M BROADCASTERS TO USE NEW CALL LETTER SYSTEM

A new system of call letters for f-m broadcast stations, similar to that currently used by standard broadcast and commercial television stations, has been adopted by the Federal Communications Commission. The change, effective November 1, next, will affect approximately 45 high frequency broadcast stations in operation and all future licensees.

This system replaces the present com-

(*Continued on page* 82)

## NEWS BRIEFS

(*Continued from page* 81)

bination of letter-numeral calls presently used. Under the old system the first letter of an f-m call, either K or W, indicated the geographical position of the station in relation to the Mississippi River, the number designation showed the frequency on which that station was operating and the last letter or letters gave a clue to the city from which the broadcast emanated.

Where a licensee of an f-m station also operates a standard broadcast station in the same city, he may, if he so desires, retain his standard call letter assignment followed by the suffix "FM" to designate broadcasting on the f-m band. Thus, if the licensee of a standard broadcast station with the call letters "WAAX" (hypothetical) also operates an f-m station in the same location, he will have the choice of using the call "WAAX-FM" or he may, on the other hand, be assigned a new four-letter call.

F-M licensees may inspect at the FCC a list of the approximately 4,000 four-letter calls which are available for assignments. This number appears ample to supply calls for all additional standard, commercial television, f-m stations and non-broadcast classes for some time to come. (The Commission wishes to call attention to the fact, however, that all three-letter calls have already been assigned.)

All call letters beginning with *W* are assigned to stations east of the Mississippi River; all station calls beginning with *K* are located west of the Mississippi and in the territories. A breakdown of the 4,000 four-letter calls available shows approximately 2,900 *K* calls and 1,100 *W*'s still unassigned.

* * *

### GALVIN POSTWAR FOLDER

A 4-page folder discussing postwar plans that will be distributed among some 40,000 dealers has been issued by the Galvin Manufacturing Company, 4545 Augusta Boulevard, Chicago, Illinois.

* * *

### McELROY CODE EQUIPMENT BULLETIN

A 12-page bulletin in color, describing high speed radiotelegraph asemblies, wheatstone code tape perforators, automatic transmitters, high speed recorders, school tape recorders, tape pullers, keyers, and radio beam keyers has been issued by the McElroy Manufacturing Corporation, 82 Brookline Avenue, Boston, Massachusetts. Included, too, in this bulletin is a full-page reproduction in color of the McElroy chart of codes and signals.

* * *

### HUMIDITY EFFECTS EXPLAINED IN G. R. EXPERIMENTER

In the August issue of the General Radio Experimenter appears an interesting discussion of the effect of humidity on electrical measurements, by Robert F. Field.

* * *

### INDUSTRIAL PUMP CATALOG

A 64-page catalog describing Westco turbine type pumps for field and plant service has been released by the Joshua Hendy Iron Works, Pomona Pump Company Division, St. Louis, Missouri.

Tandem units, hot oil pumps, condensation return units, and pump accessories are also described. Included too are engineering data on types of heads, units of measurements, etc.

* * *

### WHITE STAR TO STROMBERG-CARLSON

The Stromberg-Carlson Company of Rochester, N. Y., has been granted a renewal of its Army-Navy "E" Award for an additional six months' period. A white star has been placed on the "E" pennant as evidence of this award.

* * *

### FISCHER OF WESTINGHOUSE WINS AWARD

Eugene H. Fischer, manufacturing engineer in charge of ceramics in the porcelain department, who developed a new type porcelain, *Prestite,* was awarded the Westinghouse *Order of Merit.*

Prestite is a mixture of feldspar, flint and clay of low water content moulded in steel dies under high pressure. Said to be many times stronger than earlier porcelains, Prestite can easily be shaped into intricate designs. A one-pound steel ball dropped from three feet will bounce harmlessly off a one-inch thick piece of Prestite, it is said.

Prestite is now being used in bushings which seal radio transformers against trouble-causing moisture; in radio tube bases which protect airplane radio systems from violent temperature changes; and in insulators which guard radio condensers against electrical flashovers.

* * *

### GLASS-BONDED MICA INSULATORS STANDARDS

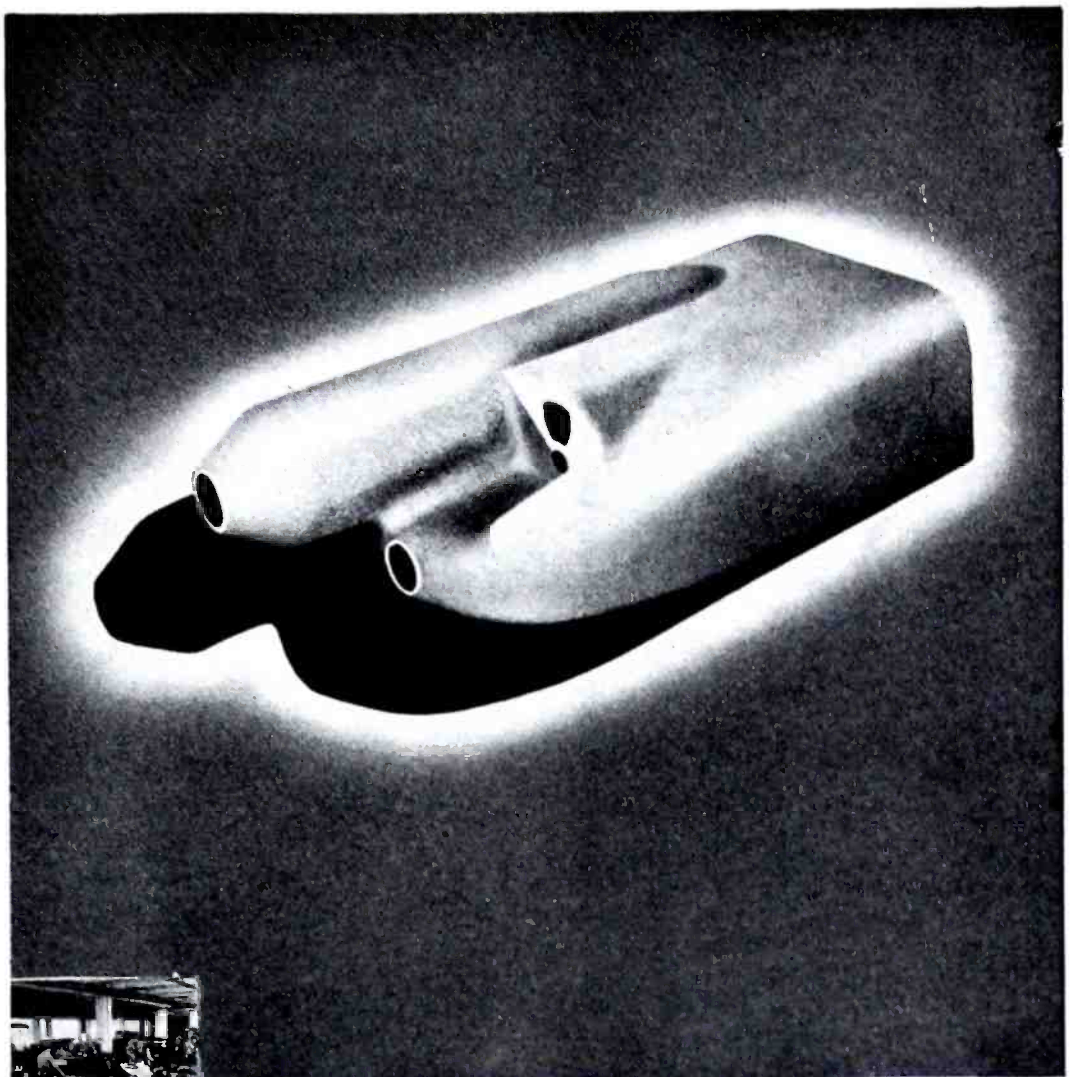
The American War Standard for glass-bonded mica radio insulators (C75.6-1943) has been officially approved.

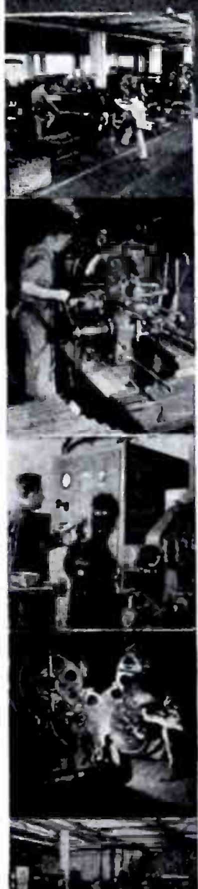
The chief feature of the standard is that it provides engineers and draftsmen with specific information about the machining of glass-bonded mica items. How holes are to be tapped, how corners are to be cut, and what thicknesses are available, are some of the design criteria set forth. Informative diagrams are included which indicate the correct and incorrect ways to machine glass-bonded mica.

The new standard differs from the other American War Standards on military radio components inasmuch as no standard shapes or type designations thereof are set up. Only the procedure for machining glass-bonded mica radio insulators and recommended practice for the handling and machining of such insulators are indicated.

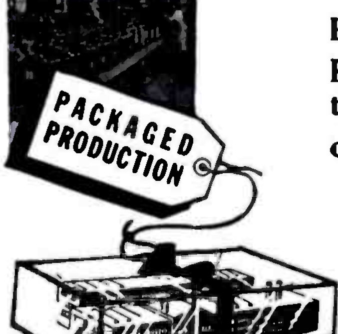
The new War Standard was prepared through the coordinated efforts of representatives of industry and the Armed

(*Continued on page* 84)









# NEWS BRIEFS

(*Continued from page* 83)

Forces at the request of the War Production Board. The committee that developed this standard was headed by L. J. Cavanaugh, General Electric Company. Its membership included: L. C. Athy, International Products Corporation, (P. C. Stufft, *Alternate*); B. R. Boymel, Navy Department, Bureau of Ships, (J. R. O'Brien, *Alternate*); T. M. Caven and G. M. Heckel, Camp Evans Signal Laboratory; D. E. Replogle, Electronic Mechanics, Inc., (Robert Goldsmith, *Alternate*); W. A. Evans, Bell Telephone Laboratories, (K. G. Coutlee, *Alternate*); H. E. Froberg, Colonial Kolonite Company; A. T. Krogh, Westinghouse Electric & Manufacturing Company, (L. T. Mallette, *Alternate*); Harold Miller, Aircraft Radio Laboratory; A. J. Monack, Mycalex Corporation of America, (S. D. Haberle, *Alternate*); H. R. Terhune, Radio Corporation of America; H. R. Wilsey, American Standards Association, *Secretary*.

Copies of the new American War Standard (C75.6-1943) may be obtained from the American Standards Association at 25 cents each.

* * *

## 1943 ACCIDENT BULLETIN

The National Safety Council, 20 North Wacker Drive, Chicago 6, Illinois, has issued an interesting 100-page bulletin covering accidents, their causes and methods of prevention.

In this 1943 edition are presented vital statistical data.

* * *

## NAB ISSUES WOMEN TECHNICIAN BROCHURE

An attractive 16-page brochure covering the story of women in the broadcasting industry today, has been prepared by Arthur Stringer, secretary of the NAB War committee, and Howard S. Frazier, NAB director of engineering.

According to this presentation, women now have a variety of important posts ranging from studio to transmitter control. There are some sixty cases cited. Many of the women received their initial training in stations. Others were trained at NYA classes or in the ESMWT program. The stations listed range from Alaska to New York.

* * *

## E. F. PETERSON IN CHARGE OF G.E. RECEIVING TUBE DESIGN ENGINEERING

E. F. Peterson has been placed in charge of design engineering of receiving tubes, according to O. W. Pike, engineer of the G. E. tube division.

K. C. DeWalt, tube division designing engineer, will continue his responsibility for design engineering of all other product lines of the division.

* * *

## SMPE SEMI-ANNUAL MEETING IN HOLLYWOOD

The fifty-fourth semi-annual technical conference of the Society of Motion Picture Engineers will be held from October 18 to 22 inclusive at the Hollywood-Roosevelt Hotel in Hollywood, Calif.

* * *

## TOWNSEND PROMOTED BY AIRCRAFT ACCESSORIES

Calvin K. Townsend has been appointed assistant general manager of Aircraft

Accessories Corporation, Kansas City, Kansas.

Before his promotion, Mr. Townsend was director of contract administration, which included supervision of the procurement department as well as jurisdiction over all contracts entered into by Aircraft Accessories Corporation, including those of the sales department.

Mr. Townsend is a partner in the Jennings Radio Company, San Jose, California, manufacturers of radio tubes.

* * *

### ECA PUBLISHES HOUSE ORGAN

A house organ, the ECA Trans-Ceiver, is now being published by the Electronic Corporation of America, 45 West 18th St., New York City.

Samuel J. Novick is president of ECA, now engaged in the production of numerous communication devices for war use.

* * *

### CAPACITRONS, INC., FORMED

A new manufacturer of capacitors, Capacitrons, Inc., with M. F. Laycock as president, was formed recently. Located at 318 West Schiller, Chicago 10, Illinois, the company is specializing in oil and wax capacitors for Army, Navy and industrial applications.

R. F. Laycock is secretary and Al Sklar is treasurer and in charge of production and engineering.

* * *

### G. E. TELEVISION STATION ISSUES PROGRAMS

A 4-page program is now being issued weekly by the General Electric Television Station, WRGB, Schenectady, New York. The program contains space for program rating and technical reception data.

* * *

### SYLVANIA BEAM POWER AMPLIFIER DATA

A data sheet on the 6L6GA beam power amplifier has been released by the Commercial Engineering Department of Sylvania Electric Products Inc., Emporium, Penna.

* * *

### MALLORY WINS THIRD STAR

The P. R. Mallory Company, Indianapolis, Indiana, has been awarded a third white star for the "E" pennant, first won in January, 1942.

* * *

### W. L. FATTIG SUCCEEDS P. R. BUTLER AT G. E.

W. L. Fattig has been appointed acting supervisor of the Technical Service section of G. E. receiver division. P. R. Butler, former manager of the section, is now a lieutenant in the U. S. Navy.

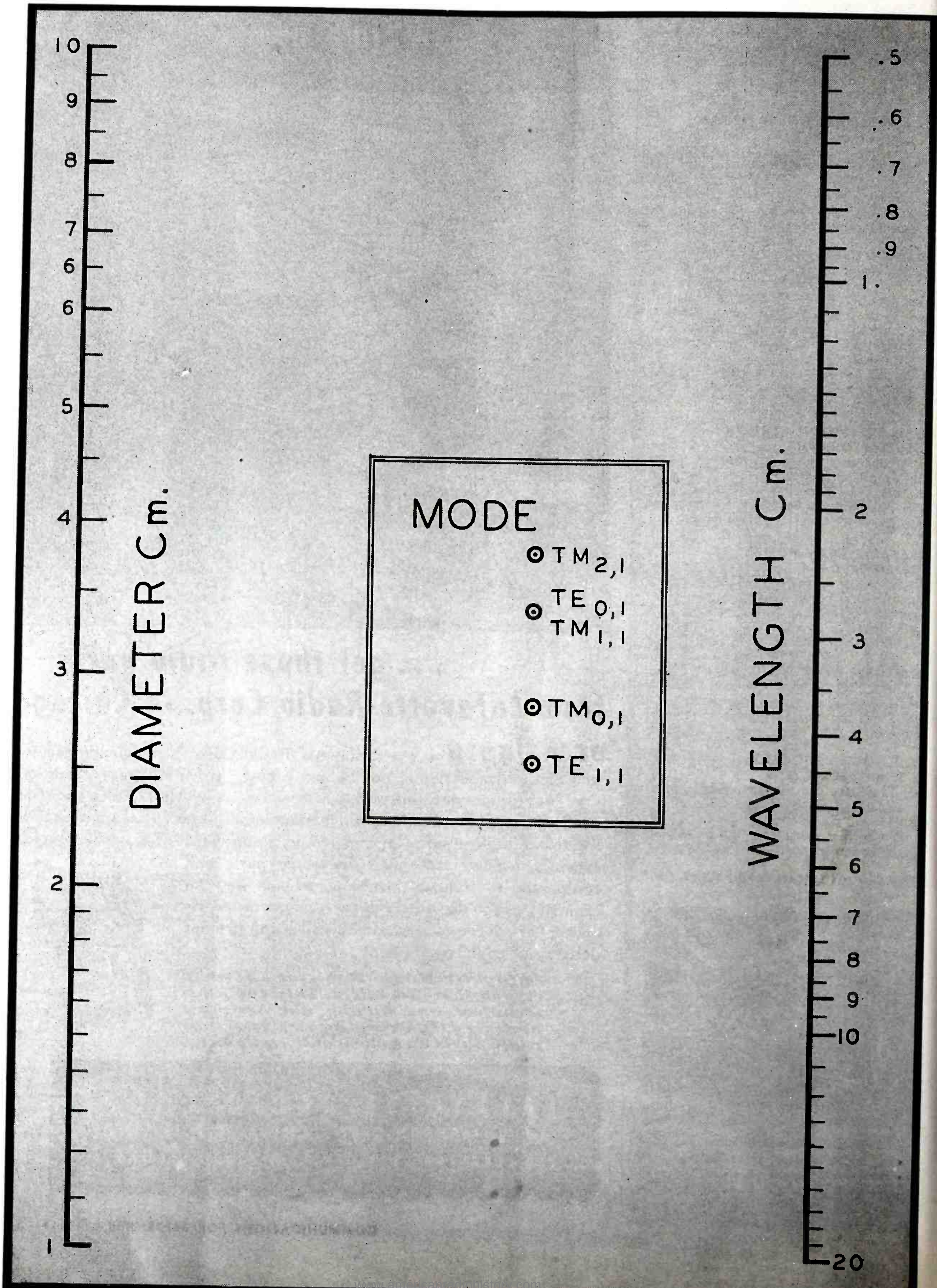
* * *

### HEINTZ & KAUFMAN, LTD., WINS "E"


John Fernandez, Nelson Klingler, W. Noel Eldred, and president Jack Kaufman with the Army-Navy burgee awarded the men and women of Heintz & Kaufman, Ltd., South San Francisco, Calif.

# CIRCULAR WAVE GUIDES

by FREDERICK C. EVERETT
Transmitting Engineer, WTAM



VERY high frequency waves can be sent down wave guides with circular and elliptical cross sections as well as rectangular ones. In the circular guide we have only one dimension, the diameter, as compared with two for the rectangular wave guide, but various modes of operation are also possible with the circular tube. There are transverse magnetic and transverse electric waves and a number of modes for each class. The nomogram shown here gives the five longer modes. (The subscripts refer to the various roots of the mathematical functions used to derive the various modes of transmission and will not be considered here.)

Like the rectangular wave guide, the circular wave guide also functions as a high pass filter, so that the propagation down the tube is imaginary until the wavelength becomes short enough, that the cut-off wavelength is reached. It is apparent that the $TE_{1,1}$ wave requires the smallest tube of any of the modes of operation. And if the tube is made large enough for this wave, but not large enough for the $TM_{0,1}$ wave, only the $TE_{1,1}$ wave will be propagated in the tube. However, this will not be the size of the tube which will give the minimum attenuation.

Although for many purposes the guide requiring the smallest tube might be expected most desirable for use, there are other considerations such as symmetry, characteristic impendance and attenuation which may enter. The $TE_{0,1}$ wave is of interest because its attenuation decreases with an increase of frequency. For utilization this requires either large tubes or quite short wavelengths.

The mode depends upon the dimensions of the wave guide and the method of excitation. Extraneous modes may be filtered by means of constrictions in the tube or by means of grids arranged to short circuit the undesired field, without much affecting the method of propagation desired.

In using the nomogram a straight line drawn through the points labeled with the various modes will give the cut-off wavelength for a given size tube, or conversely the size tube necessary for any frequency desired. A little consideration will show how it can be used to determine the maximum size without entering the province of the next mode. Either dimension or wavelength may be multiplied by a suitable factor to bring the desired dimension onto the scale, provided the other dimension is also multiplied by the same factor.

**See opposite page for the Circular Wave-Guide Nomogram**

# THE INDUSTRY OFFERS...

### HIGH-VOLTAGE BAKELITE-CASED TUBULAR CAPACITORS

High-voltage capacitors for x-ray, impulse generator and other intermittent d-c or continuous a-c high-voltage applications such as indoor carrier-coupler capacitors, test equipment and special laboratory work, have been announced by Aerovox Corporation, New Bedford, Mass.

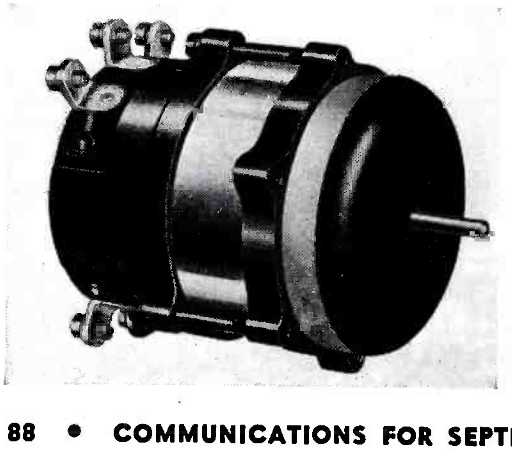
These capacitors, type '26, are oil-impregnated oil-filled with Aerovox hyvol vegetable oil. Equal voltage stresses are said to be maintained for all sections, with a uniform voltage gradient throughout the length of each capacitor. High-purity aluminum foil with a generous number of tab connectors is said to provide high conductivity with low inductive reactance. Capacitor sections are dried and impregnated under high vacuum in a closely-controlled long cycle.

The case is of special laminated bakelite tubing, protected by a high-resistance insulating varnish for high dielectric strength and maximum safety from external flashover.

* * *

### ROTATABLE TRANSFORMER

A lightweight rotatable transformer has been developed by Kollsman Instrument Division of Square D Company, Elmhurst, N. Y. Operating with either 32 volts 60 cycles, or 110 volts 400 cycles a-c, the transformer may be continuously rotated at speeds up to 1800 rpm. With a 110 volt input the voltage varies from 0 to 193 volts, according to the position of the rotor. Its weight is 10 ounces and overall length of less than 3 inches.



### TRAV-LER CORD SET

A cord set, which consists of an intercommunication switch, jack, plug, cordage and neck strap is being produced by the Trav-Ler Karenola Radio and Television Corp., 1036 West Van Buren Street, Chicago 7, Ill. The switch is a two-position, two-pole switch, and comes in either bakelite or tenite case. Contact springs are of spring temper phosphor bronze with silver contact points. This switch assembly is said to have been tested to withstand more than 100,000 operations.


* * *

### TEMPERATURE INDICATOR

An electronic temperature indicator is announced by North American Philips Company, Inc., Dobbs Ferry, N. Y. through its Industrial Electronics Division, 419 Fourth Avenue, New York.

A switch on the front panel of the instrument allows instantaneous selection of three temperature *spread ranges*. The standard limits of the instrument are from 100° below to 1000° above zero centigrade (-212° F to 1832° F) with a normal accuracy of plus or minus 2%.

Five pairs of terminals for five thermocouples are provided, any one of which can be switched into the circuit so that the temperature at five different points can be read.

Since the connecting wires between thermocouple and instrument carry only the small fractional voltage from the thermocouple, no special provisions are necessary for insulation, while varying lengths of thermocouple leads do not affect the calibration.

The instrument can be operated with as much as 100 feet of connecting wire between thermocouple and indicator. The apparatus is said to be so designed that it cannot be damaged by overload or wrong application. It is particularly adapted for permanent use, without supervision.

It is designed in a standard radio relay rack and panel built into a metal cabinet with black crackle finish; weighs 24 lbs.

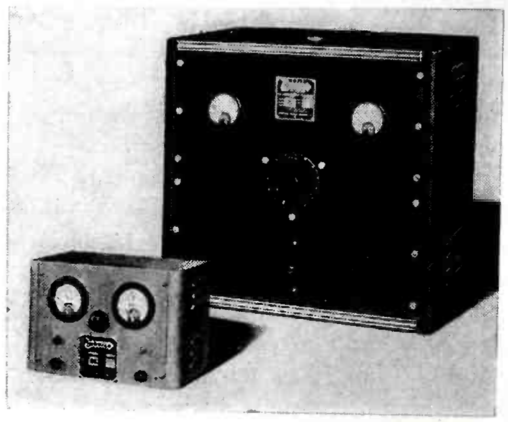
### FEDERAL BATTERY CHARGERS

A complete line of wide voltage and practically unlimited current range battery chargers, with selenium rectifiers are now being supplied by the Selenium Rectifier Division, Federal Telephone and Radio Corporation, East Newark, N. J.

Federal's battery charger line is divided into three general classes. It includes the low voltage type for automotive, vehicular, aircraft, high rate and radio uses, featured by ready portability, wide charging rate control, and equipped, if desired, for switching from 6 to 12 volts for operation with equal efficiency at either voltage.

The communications type is in the next class. This type is for telephone, telegraph, signaling and alarm systems ranging from 24 to 48 volts. These chargers are provided with filters to eliminate ripple and are available for floating or cyclic charging as well as with taper charge or automatic regulation.

The third class includes the general utility types for central power stations, machine tools, control circuits.



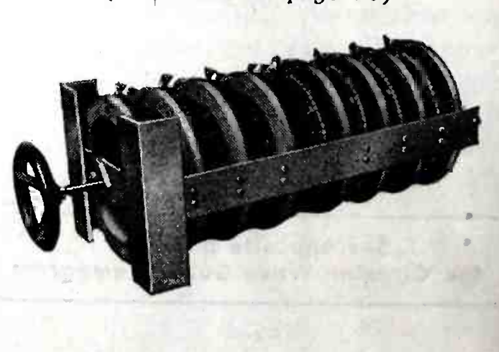
* * *

### OHMITE TANDEM RHEOSTAT ASSEMBLIES

Tandem units of Ohmite rheostats mounted on a sturdy steel frame, have been developed by the Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago 44, Illinois. Control is by a single hand wheel. Units of from two to eight have been produced, ranging in power rating from 25 watts to 1000 watts and in diameter from 1 9/16 inches to 12 inches. Rheostats in tandem are insulated from each other so that they may be used for simultaneous control of several circuits or phases of a circuit by means of one knob.

Two rheostats can be separately controlled by means of concentrically located knobs. This may be done to conserve panel space or where it may be desired to use one rheostat as a vernier for another. In this type of unit two rheostats

(*Continued on page* 90)




The bulk of UTC production today is on special units designed to specific customers' requirements. Over 5,000 new war designs were developed this past year. These designs ran from open type units to hermetically sealed items capable of many cycles of high and low temperature and extreme submersion tests. They included units from 1/3 ounce in weight to 10,000 lbs. in weight and from infinitesimal voltages to 250,000 volts. It is impossible to describe all these thousands of special designs as they become available. Our staff of application engineers will be more than pleased to discuss your problem as related to special components.

# UNITED TRANSFORMER CO.

**150 VARICK STREET • NEW YORK 13, N. Y.**

**EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N. Y., CABLES: "ARLAB"**

## THE INDUSTRY OFFERS . . . —

(*Continued from page 88*)

are mounted in tandem with the shaft of the rear unit extending through the hollow shaft of the front unit. For increased capacity, the front or back units can consist of several rheostats connected together.

Tandem rheostats are also available in taper windings and the same range of resistance values as individual units.

* * *

### COMPCO PROJECTORS

Two new sound system projectors have been announced by Commercial Metal Products Co., 2251 W. St. Paul Ave., Chicago, Ill. Speaker baffles are made for 12", 8" and 6" projector horns. Each size projector can be mounted vertically and horizontally to meet all requirements. The speaker baffles are of two-piece construction.

* * *

### THERMEX HIGH FREQUENCY HEATING UNITS

Thermex high frequency heating units for preheating and molding have been developed by the Girdler Corporation, Louisville 1, Kentucky. The plasticity, or flow properties, of the material are said to be improved by Thermex' uniform and speedy heating. Heating is said to be uniform throughout the mass of material, regardless of size, thickness or shape. Lower mold pressures are said to be permitted with Thermex, often 80% lower.

The types of machines best suited for use in molding plastics have single knob control and one meter and are semi-automatic. The Thermex unit is completely

nclosed within a compact safety cabinet nd is available in both stationary and ortable models.

* * *

## ITTELFUSE EXTRACTOR POST

'use extractor posts with anti-vibration ide terminals mechanically connected by lectrical welding to the metal shell inide the bakelite body and backed up by oft solder have been produced by Littelise Incorporated, 4747 Ravenswood Ave., Chicago 40, Illinois. The new welding rocess makes the terminal connection in ffect one-piece, integral with the metal arts. The terminal is said to be proof gainst heat and severest vibration.

The new Littelfuse Extractor Post 075 for fuses to 15 amps., is used for adios, auto-radios, amplifiers, fractional p motors, magnets, control circuits, relys, rectifiers, plate circuits, etc. Overll length is 2½". Length from front panel 2⅛"; mounting hole ½"; naximum current, 15 amps. It is furished for screwdriver operation meeting Underwriters' specifications, or for finger peration.

Knob and body are molded of black akelite. Spacing between live parts ives adequate protection against elecrical leakage. The tool-operated types ave a red knob.

A fuse grip permits full visual shockroof inspection of fuse; spring-activated up at the bottom is said to insure posiive and continuous electrical contact.

The knob not only pulls the fuse, it olds it. A specifically designed grip prerents the fuse from ever dropping out. The fuse can be taken from the knob only y hand.

* * *

## HARVEY UNIT CELL COMMUNICATION RECEIVER

The *unitized* cells which are self-conained, replaceable circuit elements are eing used in a new model ground staion and shipboard communication receiver now in production by the elecronics division of Harvey Machine Co., Inc., Los Angeles. Eight cells mounted on a common chassis constitute the reeiver, with an additional power supply ell based on individual installations. The ntire receiver is enclosed within a dust ight case, and designated as the model HM-10.

In the receiver are four r-f cells on he right side of the chassis, in which four ands of tuned radio frequency are proided; two i-f cells and two audio cells re on the left side of the chassis. Conecting each cell to the other are nine bus bars which eliminates the need for conventional wiring between circuit elements.

Another feature of the receivers are the radio frequency coil assemblies of the rotating turret type. In the four r-f bands, are four r-f coils wound over molded lucite forms. Each coil is proided with solid-silver contacts, turned from hard-drawn pure-silver wire. The contact points on the coils wipe against matching tumblers supported by the cellbox.

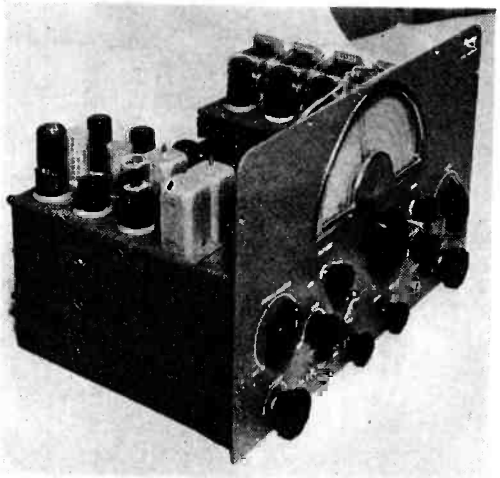
The four standard bands of the model

(*Continued on page* 92)

## THE INDUSTRY OFFERS . . . —

(*Continued from page* 91)

HM-10 are 1.49 to 2.67 mc, 2.625 to 4.55 mc, 4.50 to 7.80 mc, and 7.70 to 12.55 mc. The i-f selectivity is said to be not less than 6 kc for a 10 db antennation with the crystal in "off" position.



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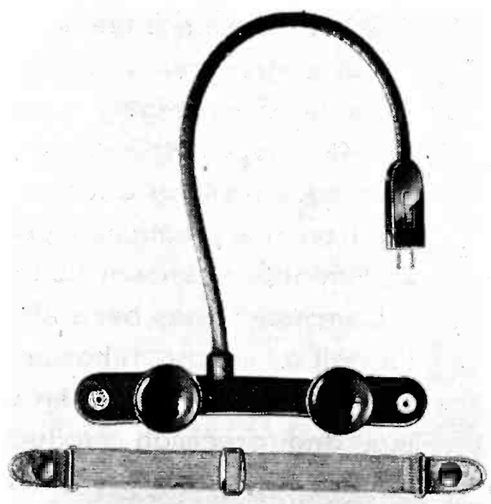
### UNIVERSAL THROAT MICROPHONE

Universal Microphone Co., Inglewood, Cal., is now making its T-30 throat microphone available in bulk orders to subcontractors and prime government contractors. It was originally designed and engineered to specifications for the U. S. Army Signal Corps communications circuits.

The T-30 is a carbon type, dual element, mounted in synthetic rubber neckpiece complete with elastic neckband. This microphone allows the use of both hands by the operator, such as in the case of pilots, dispatchers, etc.

The plug is a midget two-prong breakaway type PL-291. It is non-locking.



* * *

### KEY SWITCHES

Key switches are now available from Audio Development Company, 2833 Thirteenth Avenue, South, Minneapolis, Minnesota.

Allowing for a maximum of seven springs in each quadrant of the switch, these switches are said to provide a wide variety of locking and non-locking switching combinations. Silver alloy contacts are standard. Special contact materials can be supplied when desirable; are supplied with or without mounting plates.

Also available are the new telephone type jacks. They feature welded box construction assuring rigid alignment of



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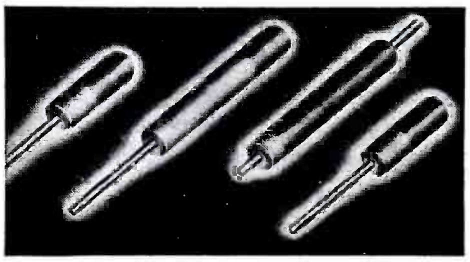
all parts. Non-aging springs are said to provide permanent tension. Additional springs allow for the switching of auxiliary circuits as desired. They can be supplied for all standard two and three circuit telephone type plugs.

* * *

### STACKPOLE HIGH RESISTIVITY INSULATED CORES

Iron cores having high unit resistivity have been developed by the Electronic Components Division of the Stackpole Carbon Company, St. Marys, Penna. These cores are recommended for applications where a resistance of 150 megohms or greater is required, and where voltages do not exceed the breakdown value.



* * *

### INDUSTRIAL CONDENSER HEAVY DUTY CAPACITORS

The Industrial Condenser Corp., Chicago, Ill., is now in production on a new line of heavy duty, high voltage capacitors for continuous operation up to 150,000 volts working.

Illustrated is a 5-mfd, 50,000-volt d-c capacitor. It is 28 inches high and weighs 175 pounds.

## LIFEBOAT RADIO

(*Continued from page* 20)

tube. For telegraph transmission, it is necessary to emit a modulated (A2) wave. This is accomplished in an ingenious manner by introducing a feed-back circuit between the modulator grids and plates. An auxiliary contact mechanically connected to the telegraph key closes the feed-back circuit each time the key is depressed. This arrangement automatically provides modulated telegraphy without the necessity, on the part of the operator, to transfer circuits from telegraph to telephone conditions. The telephone handset is fitted with a conventional push button for send-receive operation.

### Send-Receive Relay

A fast operating send-receive relay provides break-in operation when the telegraph key is used, or normal send-receive operation when the telephone handset is in service. One set of contacts on this relay transfers the antenna circuit to the transmitter or receiver while another set of contacts controls the plate and screen supply. The transmitter is capable of delivering 5 watts to the antenna with 100 per cent modulation on either telephone or telegraph.

### Receiver

The radio receiver employs conventional circuits with a 6SS7 in the first r-f amplifier and another 6SS7 in the second r-f amplifier. In the detector-first audio is a 6SQ7. The second audio has a 6G6-G.

The input to the grid of the first r-f amplifier is obtained from the transmitter amplifier tank circuit. There are, therefore, a total of four tuned receiver circuits made up of the antenna circuit, the power amplifier tank circuit and the two receiver interstage units. The receiver is capable of delivering 50 milliwatts audio output with an input of approximately 20 microvolts. Receiver bandwidth is 15 kc at 10 times down and 60 kc at 1000 times down. Of interest are the three means for listening to the receiver output. This may be done with the loud speaker on the front panel, the telephone receiver in the handset, or with a pair of headphones which may be plugged into the phone jack.

### Drying Lamp

A 25 watt, 120 volt *Drying Lamp* will be noted in the circuit diagram.

This lamp is located in the upper section of the transmitter-receiver chassis and is for the purpose of maintaining a moderate temperature inside the unit to inhibit condensation of moisture. The lamp burns at all times when the lifeboat is on the davits and is connected to the shipboard 120-volt supply through a plug connector which automatically disengages when the lifeboat is launched.

### Field Strength

The field strength delivered by the transmitter with the antenna arrangements previously described is of interest. At one nautical mile a field strength to the order of 400 to 600 microvolts per meter may be expected. At 50 nautical miles the ground wave follows closely the inverse distance law, resulting in a field of approximately 10 microvolts per meter. The effective height of the average shipboard main antenna, at 500 kc (such as would be used on the rescuing ship), is about 13 meters. Therefore, the lifeboat transmitter may be expected to deliver approximately 130 microvolts to the receiver of a rescuing ship 50 miles away.

### Effectiveness of Equipment

The practical utility of lifeboat equipment may be illustrated with the case of the S. S. Stag Hound which was torpedoed and sunk off the coast of South America. This vessel had two lifeboats equipped with the apparatus. The Stag Hound was abandoned. And during the night two lifeboats from this abandoned ship lost sight of each other but were able to maintain telephone communication at all times. Distress calls were transmitted and replies received from four ships which decided amongst themselves the ship that was nearest and which should effect the rescue. This was accomplished two days later, resulting in the rescue of the entire ship's crew and the naval gun crew. The radio operator, Edward F. Wall, who was in one of the lifeboats, made the following comments:

"Too much praise cannot be given the simplicity and efficiency of the set we had in the two lifeboats. The beauty of these sets is that they can be worked by telephone or telegraph so that in case the operator is missing or injured anyone in the lifeboat can work the set. Another feature—no batteries have to be bothered with, and naturally the set could be used day after day without its source of power being reduced."

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**BACK THE ATTACK**
**BUY WAR BONDS**

## BRIDGING NETWORKS

(*Continued from page* 40)

be received by an impedance $z$ when equal to Z, to that received when it is different from Z, is termed the reflection loss and is therefore a measure of the amount of mismatch of the two impedances.

Since the factor $k$ is equal to the square root of the power ratio, the reflection loss is

$$db = 20 \log_{10} k = 20 \log_{10} \left((Z + z)/2\sqrt{Zz}\right) \quad (25)$$

which may also be written in terms of $s$:

$$db = 20 \log_{10}\left((s^2 + 1)/2s\right) \quad (26)$$

Equation *25* has been plotted and is shown as Figure 7. This chart shows that for moderate values of mismatch, no serious reflections will take place.

### Examples

The following three examples were chosen as illustrative of the methods employed in the actual design of multiple bridging networks.

**Example 1.** It is desired to feed the output of an amplifier whose impedance is nominally 500 ohms to five branches, each having an impedance of 500 ohms. Find $R$ and $r$; also, determine the loss from the output of the amplifier to each of the branches.

*Solution 1.* From either Table 1 or 2, since $Z/z = 1$, and the value of $n = 5$, we find the value of the constant to be used. The values of $R$ and $r$ are equal because the constants are equal, and $Z$ and $z$ are equal. $R = r = 500 \times .333333 = 166.666$ ohms. From either Table 3 or Figure 5, the loss is found to be 13.98 db.

**Example 2.** Given a source impedance of 2,000 ohms from which it is necessary to supply eight outlets or branches each having a nominal impedance of 500 ohms. What values of $R$ and $r$ should be used, and what loss will be obtained from the source to each load?

*Solution 2.* In this case the ratio $Z/z = 2{,}000/500 = 4$, and $n = 8$. Using Table 1, $R = 2{,}000 \times .472549 = 945.098$ ohms. From Table 2, $r = 500 \times .378431 = 189.215$ ohms. From Table 3 or Figure 5, the loss to each load will be 24.08 decibels.

**Example 3.** Assume that it is necessary to distribute program material from a 600-ohm source to five branches. Three of the branches have impedances of 500 ohms. One has an impedance of 600 ohms, and the remaining one has an impedance of 700 ohms. How can all of these be properly matched, and what losses will be obtained to each of the branches?

*Solution 3.* The bridge is first designed on a 600 to 500-ohm basis for the five branches. Then minimum loss pads are inserted in each of the 600 and 700 ohm branches. The loss is then determined for each of the outlets. A further refinement and a saving in elements results if the matching pad elements are combined with the bridge elements. This, however, decreases the flexibility of the bridge.

#### Loss Data

Table 1 shows $Z/z = 1.2$ and $n = 5$; $R = 600 \times .362069 = 217.2414$ ohms. Table 2 shows $r = 500 \times .327586 = 163.7930$ ohms. Table 3 shows the loss to each of the 500-ohm outlets from the 600-ohm source as 14.7 db. Figure 5 may also be used to obtain the same value. Figure 7 shows the formulae for obtaining the element values of the matching pads required. For the 600-ohm branch from one of the 500-ohm outlets, we obtain from the given formulae, $v = 244.949$ ohms; $w = 1224.745$ohms. The minimum loss pad for this transformation is 3.77 db. For the 700-ohm branch, the ratio is $700/500 = 1.4$, thus from Figure 7 we have a minimum loss pad of 5.18 db. The elements from the formulae on this chart are, $v = 374.1657$ ohms; $w = 935.414$ ohms.

#### Mismatching

If the mismatch that is caused by connecting the 600 and 700-ohm loads directly to the bridge without matching pads is taken into account, reflections will be set up at each and every junction pair of terminals of the bridge. The magnitude of the losses caused by mismatching of impedances is shown in Figure 6. This does not show the interaction factor, however, but takes account of only one junction at a time as shown.

#### Small Angle Impedances

The impedances treated in this paper have been assumed as having small angles approaching or equal to zero. For a more complete and thorough account of the effects of reflections and mismatching, the reader is referred to standard textbooks such as that of Shea[2].

The degree of precision required is seldom greater than one percent for

(*Continued on page* 98)

## COMPLEX VARIABLE

(*Continued from page* 70)

that a function of a complex variable is, itself, generally a complex variable of the form.

$$w = u\,(x, y) + jv\,(x, y) \qquad (14)$$

where the notation u (x, y), v (x, y) indicates that *u* and *v* are functions of *x* and *y*.

Now when we say that *w* is a function of a complex variable *z*, we mean that its component parts, *u* and *v* must be such that they can be derived by taking some function of x + jy. This excludes independent functions of *x* or *y*, and also excludes functions of x — jy. Thus, as we have seen, if for example

$$\left.\begin{array}{l} u = x^2 - y^2 \\ v = 2xy \end{array}\right\} \qquad (6b)$$

then w = u + jv is a function of x + jy; in fact, $w = z^2$. On the other hand, for the functions

$$\left.\begin{array}{l} u = x^2 - y^2 \\ v = -2xy \end{array}\right\} \qquad (15)$$

no such function of z = x + jy exists.

Now there are certain interesting relationships among the partial derivatives of *u* and *v* with respect to *x* and *y* which exist only for analytic functions of a complex variable. For example, in equations *6b,* we have

$$\frac{\partial u}{\partial x} = 2x\,, \quad \frac{\partial u}{\partial y} = -2y$$

$$\frac{\partial v}{\partial x} = 2y\,, \quad \frac{\partial v}{\partial y} = 2x$$

A brief examination of these equa-

(*Continued on page* 106)

## BRIDGING NETWORKS

(*Continued from page* 97)

the resistances of the multiple bridge. Therefore the resultant calculations provided may be rounded to a value close to the given one, without causing any noticeable impairment to quality as judged by ear, or any change which can be detected by commercial volume indicators.

[2] T. E. Shea, *Transmission Networks and Wave Filters,* D. Van Nostrand Co.

## AUDIO MEASUREMENTS

(Continued from page 27)

the $Q$'s of the resistance arms and the condenser are directly additive, as pointed out previously. Thus, in this case, it is not possible to use parallel capacitance across the resistance arms. The possibility suggests itself, however, of using series inductance in one of the resistance arms to compensate for the residual $Q$'s of the circuit. The establishment of the initial balance requires an inductance of high $Q$, the value of which is known to a moderate accuracy, or, alternatively, a moderate value of $Q$, accurately known. This, in turn, requires an independent method of measuring resistance accurately, but fortunately such a method is available in the series-resonance bridge.

#### Compensation for Circuit Residuals

The secondary shield-to-ground capacitance of the transformer is placed across the resistance arm $A$, with the smaller (10 mmfd) terminal capacitance across the capacitive arm $N$ (722-D precision condenser). A fixed inductance, $L_A$, is used, with an additional trimmer capacitor $C'_A$, to make the final adjustment in establishing the initial balance. For an $A$ arm resistance of 20,000 ohms, a 50 or 100-mh choke* may conveniently be used for $L_A$, together with a 100-mmfd condenser used for $C_A$.

The stray capacitance placed across the standard condenser can be determined by a method similar to that used with the capacitance bridges. If two balances are made for a given $L_p$, one with the standard condenser disconnected at its high terminal, the other in the usual manner, with $C_N$ set at about 100 mmfd, the stray capacitance $C_o$ will be given by

$$C_o = C_N \frac{1}{\frac{B_2}{B_1} - 1}$$

Here $B_1$ is the reading of the $B$ arm resistance box with $C_N$ disconnected, $B_2$ its reading with the standard set at a value of $C_N$.

With this arrangement an initial balance was established against a $Q$ of 20 (known to about ±1%, from resonance bridge measurements). The $Q$'s of several other coils were then measured, the results checking the known values within essentially the accuracy of reading of the condenser $C_A$.

Additional correction terms are in-

*The resistance of the choke must, of course, be added to $R_A$. The choke resistance is small compared to $R_A$, however, and the d-c value may be used without introducing any appreciable error.

troduced into the inductance equation by the transformer capacitance shunting the series inductance $L_A$. For the case cited, this correction is negligible, but it can become significant if large inductances are used in the *A* arm.

#### Accurate Measurement of Coil Resistance

The resonance bridge, shown in series form in Figure 10, is one of the most accurate methods available for measuring coil resistance at audio frequencies. Since the reactance of the *P* arm is reduced to approximately zero, the resistance balance becomes the dominant one, and the circuit residuals have only a second-order effect on it, while having a comparatively large effect on the reactance balance. This method, then, although quite accurate for resistance measurements, is not very accurate for inductance measurements.

To obtain the coil resistance, when the total *P* arm resistance is known, obviously requires a knowledge of the effective resistance of the tuning condenser. Additional measurements are thus required, unless condensers of known dissipation factor are used, or unless $R_C$ is negligible with respect to $R_L$.

#### Independence of Balance

In any alternating-current bridge there are two conditions that must be simultaneously satisfied to obtain a true null balance. For maximum convenience in the use of the bridge it is desirable that the two adjustments for balance be independent of each other, so that the element that is varied to secure one balance shall not affect the other balance. Otherwise, the condition commonly known as a *sliding zero* occurs. It is characterized by the fact that balance must be approached by comparing a number of successive adjustments for minimum. The degree of dependency of the two components of balance on each other (i.e., the amount of *sliding*) is dependent on the storage factor, *Q*, of the unknown impedance. The higher the storage factor of the unknown impedance, the less pronounced is the sliding effect.

It can be shown that truly independent balances are obtained only when the two adjustments for balance are made in the same arm, or when one adjustment is made in each complex arm. An example of the first method is the Owen bridge, while a bridge devised by Sinclair[4] illustrates the second.

The two elements that provide independent balances can be made direct reading for the resistive and reactive (or conductive and susceptive) components of the unknown impedance, independent of each other. On the other hand, if any element is made direct-reading in *Q* or *D*, the bridge will have a *sliding zero balance.* All of the actual setups described fall into the latter category. In practice, however, the sliding balance is not seriously annoying unless the *Q* of the component being measured is extremely low (approaching unity).

### *The Shielded Transformer*

The transformer used to couple the generator to the bridge must be extremely well shielded, or serious errors may be introduced into the bridge measurement.[5] Ordinary single-shield transformers of the type commonly used in communication systems will not usually be satisfactory, as the requirement on reduction of electrostatic coupling between the two windings is more severe for the bridge transformer. The transformer used in all the circuits described is the General Radio 578-A, which is specifically designed for bridge use.

[4]General Radio 916-A radio-frequency bridge.
[5]A partial analysis of the errors introduced is given in the General Radio Experimenter, September, 1941.

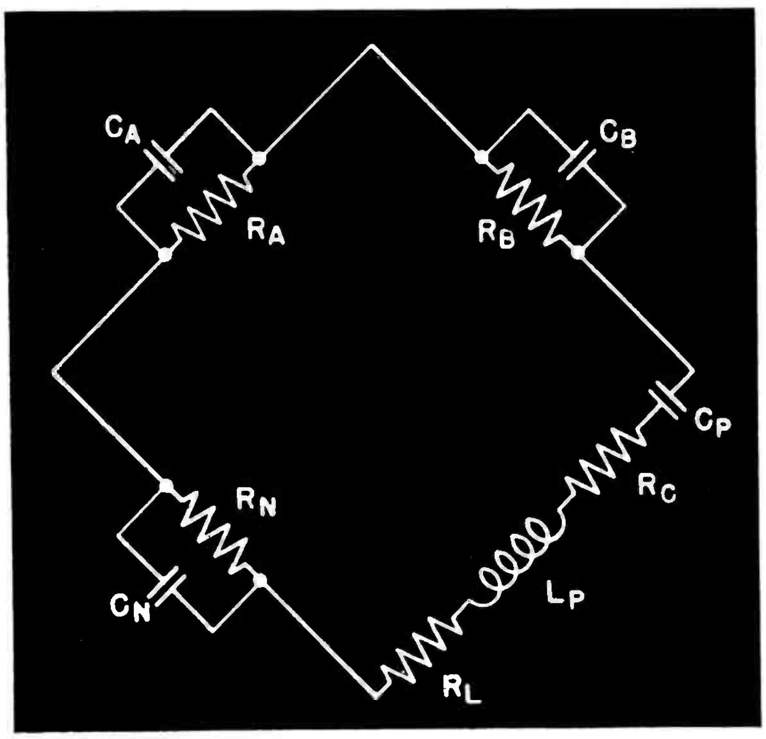


Figure 10
The series-resonance bridge. The capacitances $C_A$, $C_B$ and $C_N$ are circuit residuals. The equations of balance are

$$R_P = \frac{R_B R_N}{R_A} \; \frac{1 - Q_A^2}{1 + Q_N(Q_A + Q_B) + Q_A Q_B}$$

$$L_P = \frac{1}{\omega^2 C_P} \text{ (approximately)}$$

## SQUELCH SYSTEMS

(*Continued from page 74*)

the noise level for which the circuit was adjusted. If the carrier amplitude is less, then the receiver will provide no output. It is evident, therefore, that it is not possible to make full use of the inherent receiver sensitivity. For the exact reduction in sensitivity depends on the setting of the squelch control, which in turn depends on noise conditions at the receiver point. This means that signals below or at the noise level will not be heard. For a high quality a-m or f-m receiver this is an advantage since signals down in the noise level will not produce much enjoyment. For a *DX* listener the reduction in sensitivity is a disadvantage. In fact, even strong carriers may be missed if the tuning is too rapid. With the squelch in operation, tuning must be done very slowly. This results in an apparent increase in selectivity, but, of course, this is not so. If the squelch controlling voltage is obtained from a more selective point than the detector, the effect is to force the operator to tune the signal *on the nose*. This method was employed in a Wurlitzer receiver, around 1931. In single frequency receivers found in marine installations, police and fire department services, squelch is used extensively.

### Relay Type Squelch

A circuit using an interesting relay arrangement is shown in Figure *1*. In operation, if no carrier is being received, the tube plate current increases and operates the relay, the contacts shorting the loudspeaker voice coil. Variable resistor $R_1$ in series with the contacts may be adjusted for partial muting if desired. When a carrier is applied, the avc system biases the tube more negatively, reducing its average plate current and causing the relay to drop out, removing the speaker short. Variable resistor across the relay coil adjusts the squelch level.

### Electronic QAVC

In Figure 2, we have an example of an electronic type qavc circuit. The audio amplifier receives the audio signal through the coupling condenser as usual. Its grid resistor is divided into two parts, and the lower section of the 150,000-ohm resistor is connected to the plate of the squelch control triode. This may very well be the triode section of the duo-diode-triode detector and avc tube, type 6R7. When no carrier is being received no bias appears on the 6R7 grid, so that its plate current is maximum. The plate current IR drop across its plate resistor develops a polarity of negative upward and positive downward. Since the 6R7 plate resistor is common to the grid circuit of the audio amplifier, the IR drop acts to bias the grid. This bias is sufficient to cut off the audio amplifier plate current thereby blocking the audio signal in this stage. Application of a carrier develops a negative voltage in the avc circuit which is applied to the 6R7 grid as bias, reducing or cutting to zero its plate current. This removes the blocking bias from across the 150,000-ohm resistor and restores the audio amplifier to normal allowing the audio signal to pass through. The 1,000-ohm resistor in the amplifier cathode provides self-bias for this stage. The 10,000-ohm potentiometer adjusts the plate voltage to the 6R7. This determines the avc bias necessary to be applied to the 6R7 grid to cut off its plate current, thus acting as the muting level control. To prevent making the audio amplifier grid positive with respect to its cathode, the cathode is returned to the bottom end of the grid resistors. The .25-mfd condenser at the 6R7 plate in conjunction with the 150,000-ohm resistor provides the proper time delay so that instantaneous high amplitude noise peaks will not open the squelch. The squelch becomes inoperative if the switch *s* is thrown to the *on* position. If a pentode is used instead of a 6R7, the level control may be a screen grid potentiometer, instead of control shown.

### QAVC Circuit

A circuit with a qavc tube used in f-m appears in Figure 3. With no carrier, the qavc 6F5 plate current is relatively high so that an IR drop appears across resistor $R_1$. This drop is great enough to ignite the neon tube *N*. When *N* glows its a-c resistance is very low. Since the 6F5 plate is connected to the audio tube grid through capacitor *C*, the neon tube acts in series with *C* as a low shunt path for audio frequency signals across the audio tube grid circuit, reducing the signal output of this stage to a negligible value. When a carrier appears, the 6F5 plate current is reduced or dropped to zero, the IR drop across $R_1$ disappears and the neon tube is deionized. In this condition, the neon tube offers a high resistance path to a-c and thus no longer shunts out the signal.

When no f-m carrier is present, the limiters pass high noise voltages. These appear across $R_1$ in the plate of the second limiter, and are coupled via

(*Continued on page* 110)

## ALIGNMENT CHART

(*Continued from page* 60)

mmfd and at 2070 kc with 71 mmfd. These two points have been plotted and the line drawn through them intersects the $X$ axis at $-40$ mmfd, indicating a distributed capacity (artificial) of 40 mmfd. The true inductance as indicated by the intersection with the line $H_1L_1$ is 54 microhenries.

Let us consider the results if the apparent inductance is computed using either one of these measurements alone. This amounts to assuming that the distributed capacity is equal to zero. The apparent inductance is found by drawing the line $HL$ at distance of 253.0 from *0* on the $X$ axis. A line from *0* through either of the observed points will intersect the line $HL$ at a height indicating the corresponding apparent inductance for that point. The apparent inductance for the 400-mmfd point will be seen to be about 59 microhenries and for the 71-mmfd point about 83 microhenries. These results are far from the true inductance and for the measurement with the lower capacity the error is over 50%.

In the above measurements the effects of distributed capacity have been purposely exaggerated. Measurements of the same coil without artificially changing its distributed capacity indicated resonance at 1070 kc with 400 mmfd and 2140 kc with 91 mmfd. By the same method shown above the true inductance was found to be 54 microhenries. These measurements taken individually indicated 55 microhenries and 61 microhenries respectively. It is evident that the later measurement is more than 10% higher. Single measurements with lower capacities will be in even greater error.

The following table summarizes the preceding results:

| | kc | C | 1/f |
|---|---|---|---|
| Bad Coil.... | 1035 | 400 mmfd | .93 |
| | 2070 | 71 mmfd | .234 |
| Good Coil... | 1070 | 400 mmfd | .875 |
| | 2140 | 91 mmfd | .218 |

| | $C_d$ | True L |
|---|---|---|
| Bad Coil... | 39 mmfd | 54 microhenries |
| | 39 mmfd | 54 microhenries |
| Good Coil. | 12 mmfd | 54 microhenries |
| | 12 mmfd | 54 microhenries |

| | Apparent L | Error |
|---|---|---|
| Bad Coil.... | 59 microhenries | + 9% |
| | 83 microhenries | +54% |
| Good Coil... | 55 microhenries | + 2% |
| | 61 microhenries | +13% |

These results show that, if the inductance is to be calculated from a single observation, the resonating capacity should be reasonably high to avoid serious errors.

The inductance can be computed from Figure 1 for greater accuracy. In microhenries, inductance equals 25300 (very nearly) times the tangent of angle $\theta$, when the frequency is in megacycles and the capacity is in micro-microfarads.

This equals $25300\ (1/f_2^2 - 1/f_1^2)/(C_2 - C_1) = 25300\ (f_1^2 - f_2^2/[(f_1f_2)^2 (C_2 - C_1)]$. The distributed capacity, $C_d$, equals $1/f_2^2 \cot\theta - C_2 = 1/f_2^2\ [\ (f_1f_2)^2\ (C_2 - C_1)\ /\ (f_1^2 - f_2^2)\ ] - C_2 = f_1^2\ (C_2 - C_1)\ /\ (f_1^2 - f_2^2) - C_2$. These equations can be simplified if $f_1$ is twice $f_2$, as would be the case if a strong second harmonic is used for $f_1$. The equations then become $\mu h = 75900/[f_1^2(C_2 - C_1)]$ and $C_d = (C_2 - 4\ C_1)/3$.

By using, for $C$, a definite value such as 400 mmfd, the equation for inductance becomes $\mu h = 19000/[F^2\ (400 - C)]$, where $F$ is the resonant frequency for 400 mmfd and $C$ is the capacity required for resonance at a frequency of 2F. This equation can readily be solved by the alignment chart shown in Figure 2. To use this chart, the unknown inductance should be resonated at a frequency $F$ with 400 mmfd. It should be again resonated at twice this frequency either by using a strong second harmonic of the test frequency or by resetting the test oscillator. This gives the value of $C$. The points $F$ and $C$ are spotted on the chart and a straight edge placed between them to intersect the inductance scale, $L$, at the required value. For greater range two sets of scales are shown. The left hand scale of frequency in mc corresponds with the left hand scale of inductance and the right hand scale of frequency in kc corresponds with the right hand scale of inductance.

The value of distributed capacity depends only on the value of $C$.

A separate enlarged scale for $C$ shows the corresponding distributed capacity $C_d$ for each value of $C$.

In Figure 2 two examples are shown by the dotted lines. The upper line shows a tuning capacity of 80 mmfd at the second harmonic of 400 kc. The corresponding inductance has a value of 371 microhenries and the distributed capacity is about 27 mmfd. The lower line shows a tuning capacity of 100 mmfd at the same frequency, corresponding to an inductance of 396 microhenries and a distributed capacity of zero. This is, of course, impossible and given only for purpose of illustration.

The value 253 has been derived from $\frac{1}{4}\pi^2$ in the formula $L = \frac{1}{4}\pi^2 f^2 C$ after fixing the decimal points by making proper allowance for the units used.

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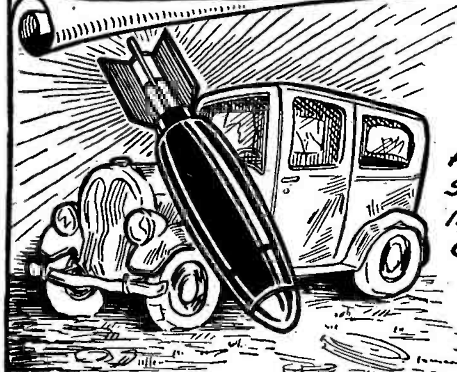

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## COMPLEX VARIABLE

(*Continued from page* 98)

tions quickly shows that the following conditions hold:

$$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} \qquad (16)$$
$$\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$$

These equations obviously do not hold for equations *15* since the signs of the derivatives of *v* are reversed.

Are equations *16* true only for the function $w = z^2$ or do they also hold for other functions? Let us consider an entirely different type of function

$$\begin{aligned} w &= \sin z = \sin (x + jy) \\ &= \sin x \cos jy + \cos x \sin jy \\ &= \sin x \cosh y + j \cos x \sinh y \\ &= u + jv \end{aligned} \qquad (17)$$

sinh *y* and cosh *y* being the hyperbolic sine and cosine, respectively. Thus

$$\left.\begin{aligned} u &= \sin x \cosh y \\ v &= \cos x \sinh y \end{aligned}\right\}$$

and the partial derivatives are

$$\frac{\partial u}{\partial x} = \cos x \cosh y$$

$$\frac{\partial u}{\partial y} = \sin x \sinh y$$

$$\frac{\partial v}{\partial x} = -\sin x \sinh y$$

$$\frac{\partial v}{\partial y} = \cos x \cosh y$$

Again it is seen that equations *16* are satisfied. These equations are, in fact, fundamental in function theory and are known as the *Cauchy-Riemann* conditions[6, 7]. Their derivation is based on the following simple definition of an analytic function: A function of a complex variable, *z*, is analytic at any point, *z*, if the first derivative of the function exists at that point, and is unique.

This definition also implies that the derivative is finite.

To obtain a derivative starting from first principles we can proceed as in the case of functions of real variables[7]. Writing

$$w = f(z)$$

we apply an increment Δz, to z, and obtain the corresponding increment Δw, in w,

$$\begin{aligned} w + \Delta w &= f(z + \Delta z) \\ \Delta w &= f(z + \Delta z) - w \\ &= f(z + \Delta z) - f(z) \\ \frac{\Delta w}{\Delta z} &= \frac{f(z + \Delta z) - f(z)}{\Delta z} \end{aligned}$$

and, finally

$$\frac{dw}{dz} = \lim_{\Delta z \to 0} \frac{\Delta w}{\Delta z}$$

Now if $\frac{dw}{dz}$ is to be unique, it must be possible to take Δz in any direction and, after letting $\Delta z \to 0$, arrive at the same result for dw/dz. Thus if Δz takes place in the *x-direction*, $\Delta y = 0$ so that

$$\frac{\Delta w}{\Delta z} = \frac{\Delta w}{\Delta x}$$

while if $\Delta z$ is in the y-direction, $\Delta x = 0$, so that

$$\frac{\Delta w}{\Delta z} = \frac{\Delta w}{j\Delta y}$$

In any case we have

$$\Delta w = \Delta u + j\Delta v$$

since $w = u + jv$. Therefore

$$\frac{\Delta w}{\Delta x} = \frac{\Delta u}{\Delta x} + j\frac{\Delta v}{\Delta x}$$

$$\frac{\Delta w}{j\Delta y} = \frac{\Delta u}{j\Delta y} + \frac{\Delta v}{\Delta y}$$

Equating

$$\frac{\Delta u}{\Delta x} + j\frac{\Delta v}{\Delta x} = -j\frac{\Delta u}{\Delta y} + \frac{\Delta v}{\Delta y}$$

Equating real and imaginary parts and letting $\Delta x$ and $\Delta y$ tend to zero we get

$$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$$
$$\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x} \qquad (16)$$

so that these equations are seen to hold generally for analytic functions.

From this abstract theory one more formal step takes us into a realm of extremely important applications. In equations *16*, take the derivative of the first with respect to $x$, the derivative of the second with respect to $y$, and add

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

Similarly, take the derivative of the first with respect to $y$, the derivative of the second with respect to $x$, and subtract

$$\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} = 0$$

$u$ and $v$ both satisfy the same partial difference equation. This is a special case of Laplace's equation

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0$$

For the case where $\frac{\partial^2 \phi}{\partial z^2} = 0$

This equation is one of the most important in mathematical physics.[2, 3] For electrical purposes it represents the equation that must be satisfied by the equation of potential for any electrostatic field at every point in the field where no charge exists. To cite a simple example consider the field due to a single point charge $q$ located at the origin of coordinates (Figure 10). The potential at any point P (x, y, z) is usually given as

$$\phi_P = \frac{q}{r}, \; r = \sqrt{x^2 + y^2 + z^2}$$

(*Continued on page* 109)

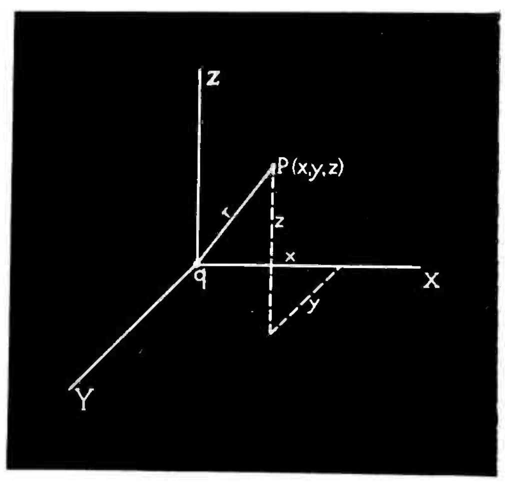


Figure 10
**Coordinate system to illustrate the potential of an electrostatic point charge. The charge, of magnitude *q*, is located at the origin of coordinates and the potential is evaluated at the point *P*.**

## FILAMENT STEPPER-DOWNER

(*Continued from page* 28)

is thrown to the *Stop* position to remove the low power filaments and to start the pump timing cycle, relay *E* drops out and the motor will run until *X* breaks contact with contact *1*. The rotary contact is then ready for operation during the subsequent operation period. The filament control switch then is opened. This drops out lock in relay (*C*).

### Relay Has Three Contacts

The relay, as built for this transmitter, which is an RCA 50D, has three contacts operating on the rotary contactor. This removes control voltage from the three filament contactors. Also, since the first and second step contactors drop out when the third step contactor comes in, it was necessary to install another contactor to pick up the first two contactors, before the third step contactor is opened when the rotary contactor operates. This contactor may be seen on the right of the illustration. The coil of this contactor, if required, may be installed in parallel with relay (*C*).

In addition, in the WCKY setup, a relay was installed with its coil parallel with the second step *plate* contactor and its contacts in series with the push button (*D*). With this emergency precaution, if plate voltage is applied to the transmitter, if the push-button is accidently pushed, the step-off system will not operate.

### Relay Circuit

In Figure *2* we see how the relay might be applied for use with a typical transmitter control circuit which uses two relays or contactors to step on the filament power.

### Credits

This relay system was designed and constructed by the author and William Heitzman of the WCKY technical department.



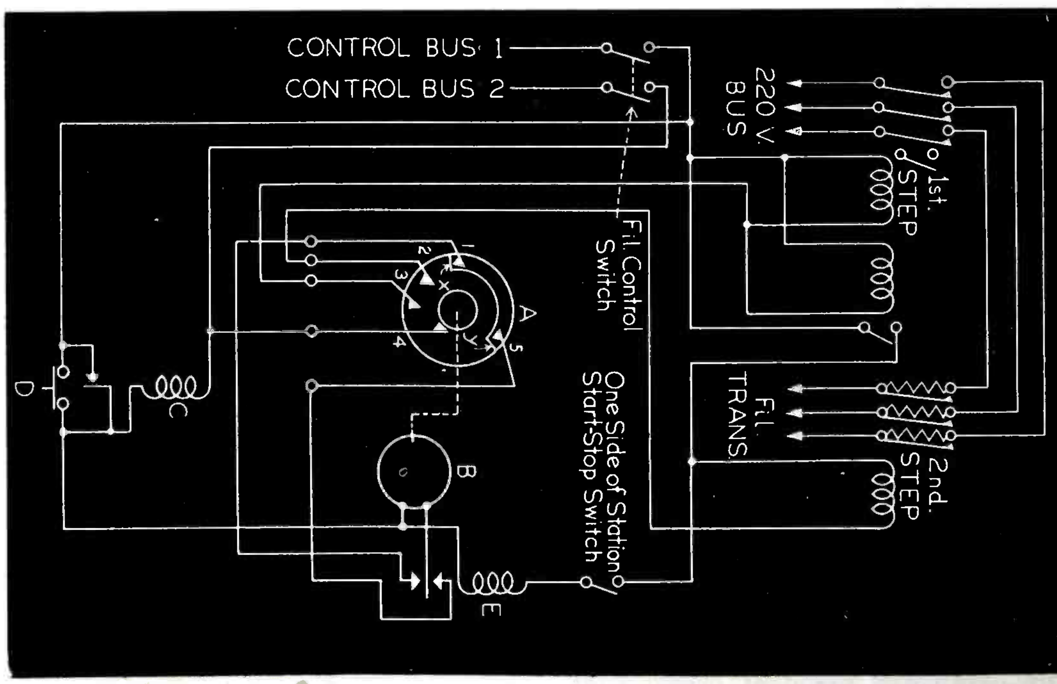


Figure 2
A 2-relay "stepper-downer" circuit.

## COMPLEX VARIABLE

(*Continued from page* 107)

More exactly it should be written

$$\phi_P = \frac{q}{r} + C \qquad (19)$$

where $C$ is any constant. Now

$$\frac{\partial \phi_P}{\partial x} = -\frac{q}{r^2}\frac{\partial r}{\partial x} = -\frac{qx}{r^3}$$

$$\frac{\partial^2 \phi_P}{\partial x^2} = -\frac{q}{r^5}\left[r^2 - 3x^2\right]$$

By symmetry, it is readily seen that

$$\frac{\partial^2 \phi_P}{\partial y^2} = -\frac{q}{r^5}\left[r^2 - 3y^2\right]$$

$$\frac{\partial^2 \phi_P}{\partial z^2} = -\frac{q}{r^5}\left[r^2 - 3z^2\right]$$

$$\frac{\partial^2 \phi_P}{\partial x^2} + \frac{\partial^2 \phi_P}{\partial y^2} + \frac{\partial^2 \phi_P}{\partial z^2} = -\frac{q}{r^5}\left[(r^2 - 3x^2) + (r^2 - 3y^2) + (r^2 - 3z^2)\right] = 0$$

So that Laplace's equation is satisfied.

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## CRYSTALS

(*Continued from page* 50)

crystal must not only have a low temperature coefficient, but must also be free from spurious or coupled frequencies. Moreover, the crystal should also have a relatively high piezoelectric driving constant insuring good output. Usually, therefore, the design of a good crystal must necessarily be a compromise between all the various requirements.

***Methods of Manufacture***

Due to the enormous demands for crystals created by the war, new methods of mass production had to be developed. New techniques to locate orientation angles also had to be evolved, for cutting quartz crystals without any natural faces.

Among all the new methods developed, the use of x-rays for the correct orientation of the cut may be considered as the most important from the point of view of speeding up production. While the Western Electric Company had been using this method for several years, no x-ray equipment was commercially available when the crystal bottleneck developed early in 1942. With x-rays it is possible to find the correction for the angle of cut in a few minutes. It was formerly necessary to finish a crystal and test it for drift in order to find that same correction.

Furthermore, by means of x-rays it is possible to locate the crystallographic axes in totally unfaced quartz. The importance of this method of cutting unfaced quartz cannot be overestimated since quartz with natural faces is becoming extremely scarce.

To take advantage of the accuracy of x-rays, new cutting machinery has been designed with two and even three degrees of freedom on the orientation table in order to secure three dimensional motion. Most cutting machines have had, as a result, to be equipped with angular verniers giving correction within one minute of arc.

Grinding machines have also been evolved from drill presses for the lapping simultaneously of a number of crystals on both sides at the same time.

Electronic crystal duplicators have been put on the market in which the frequency of a blank being finished, is rapidly and conveniently compared to a standard crystal plugged into the instrument.

New machines and methods are constantly being brought forward by both

(*Continued on page* 111)

## SQUELCH SYSTEMS

(*Continued from page* 103)

the filter network to the diode plate of the 6SQ7 where rectification occurs. The d-c component is fed to the grid of the triode section blocking it. When an f-m carrier appears, the amplitude noise drops to a low level removing the blocking bias. The switch disables the *q* system for reception of weak, noisy carriers.

Much use of qavc circuits is made in fixed-tuned receivers used by police and fire departments and similar services in addition to certain marine installations. The major difference between these and household receivers is the necessity for absolute reliability of received signal on the emergency units. Quality is unimportant — the message must go through, even if the signal is noisy. Squelch circuits do reduce the sensitivity of the receiver (if the control is set too high). It is conceivable that in high noise, weak signal areas, the operator may set the level so that he is not bothered by the noise and thereby lose some messages. This fact has caused some to use equipment not provided with muting, thereby reducing the efficiency of the operators who must listen to varying degrees of noise for extended periods of time.

Attempts have been made to retain receiver sensitivity and still obtain muting. The writer proposes a system whereby both may be practically retained. While this entails added equipment, it may be feasible under some conditions. Generally, it is proposed to make use of the attention signal (tone) usually provided with emergency systems—the tone to be amplified by a tuned stage and caused to actuate a thyratron or latching relay for disabling the audio system. Preliminary calculations indicate a favorable increase in the ratio of useable receiver sensitivity without muting, to sensitivity with muting.

## PRE-AND-POST EQUALIZATION

(*Continued from page* 31)

modulation of the signal and the noise.

The effectiveness of the post equalizer in reducing noise and distortion is well demonstrated in the manner in which the tone control is usually set when listening to commercial phonograph records. The average listener will always sacrifice frequency range to obtain decreased noise and distortion whenever a control is placed at his disposal.

A more general application of this overall principle in all sound transmission and recording systems will result in a substantial increase in signal-to-noise and quality improvement.

•

**Figures 3 (below) and 4 (right)**
**In Figure 3, we note that a limit of approximately 15 db equalization at 10,000 cycles appears to be a good balance to fit the load factor normally occuring in speech and music. Figure 4 shows the RMA post- and pre-equalizer setups.**

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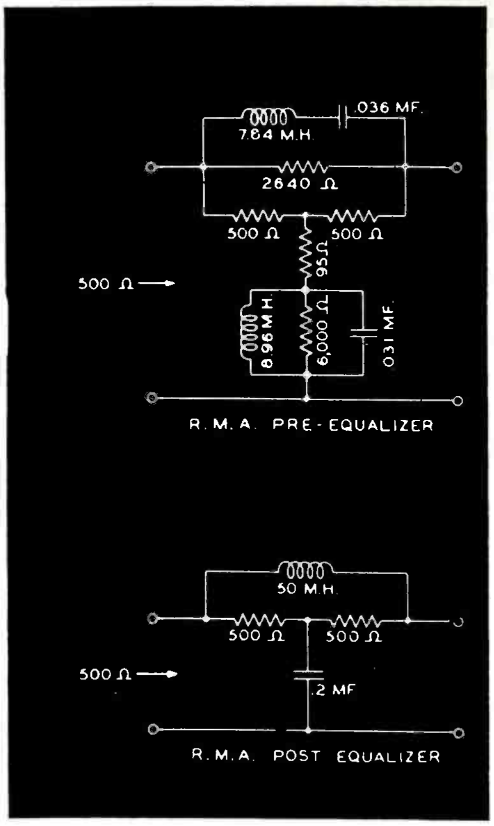
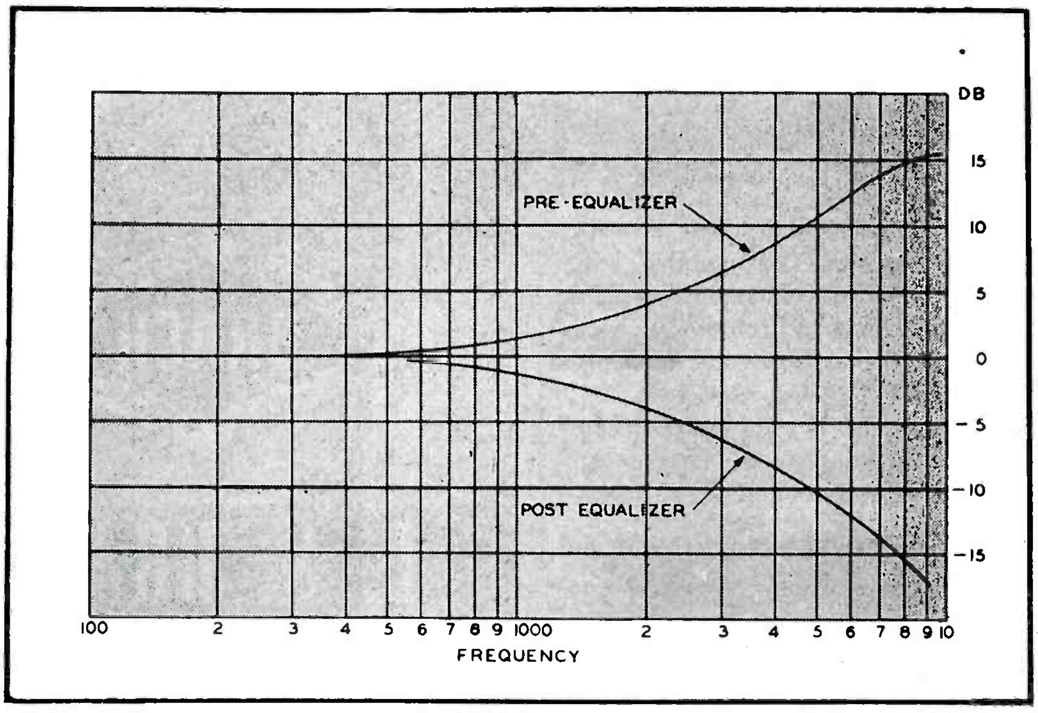


# QUARTZ CRYSTALS

(*Continued from page* 109)

manufacturers of crystal machinery and the crystal manufacturers themselves.

Due to the exchange of ideas and the development of all these recent techniques the crystal industry has become quite standardized during the last few months.

#### The War Effort and the Crystal Industry

The war created a demand for crystals which the industry was not ready to meet. As a matter of fact, crystals were such a bottleneck early in 1942 that the government had to persuade some manufacturers to increase their production enormously and requested many others to enter this field.

The year 1942 was, therefore, marked by a tremendous expansion which finally succeeded in catching up with the demand. This rapid increase in production was helped by the dissemination of information, the exchange of ideas and methods, the design of new machinery and the creation of equipment pools by the government or large prime crystal contractors from which the crystal manufacturers could obtain whatever they needed to make good crystals efficiently.

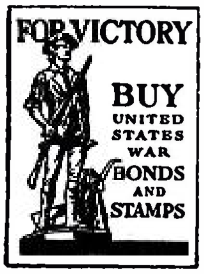
#### Strides of Industry

As it was to be expected, the crystal industry has made great strides in learning how to produce crystals efficiently. Most of the efforts during 1942 and 1943 so far have been directed toward production. Very little time has been available to devote to extensive research and improvement of the crystals themselves. As a matter of fact, the whole production has practically consisted of *AT* and *BT* cuts.

American ingenuity has shown that it can solve production problems efficiently and fast. Crystals are now made by the millions where a year ago a few thousands only were leaving the factories. Naturally, the place of crystals in the postwar electronic industry has been the subject of a good deal of debate.

Amateur and professional short-wave receivers were the major type of popular equipment in which crystals were used in any quantity prior to wartime. They were used to provide an effective means of retaining signal consistency on c-w signals. A few broadcast types of receivers used crystals for frequency control.

If the use of crystals should spread to broadcast receivers there is absolutely no doubt that the industry will be well prepared to take care of any requirements.



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## COMMUNICATIONS—SEPTEMBER, 1943

# STANDARD-SIGNAL GENERATORS

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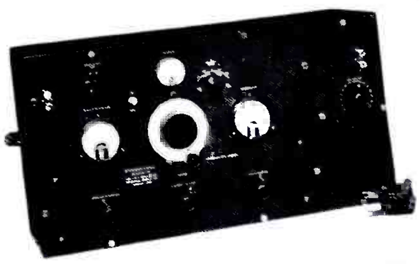

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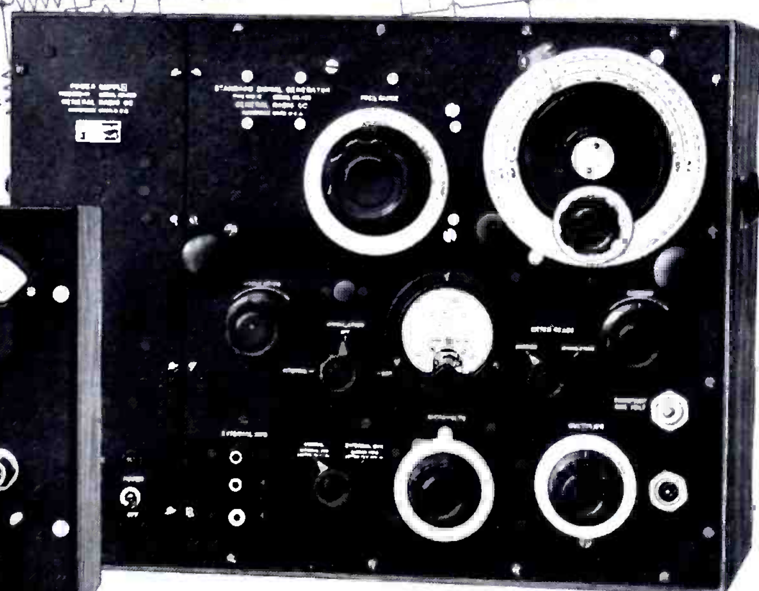

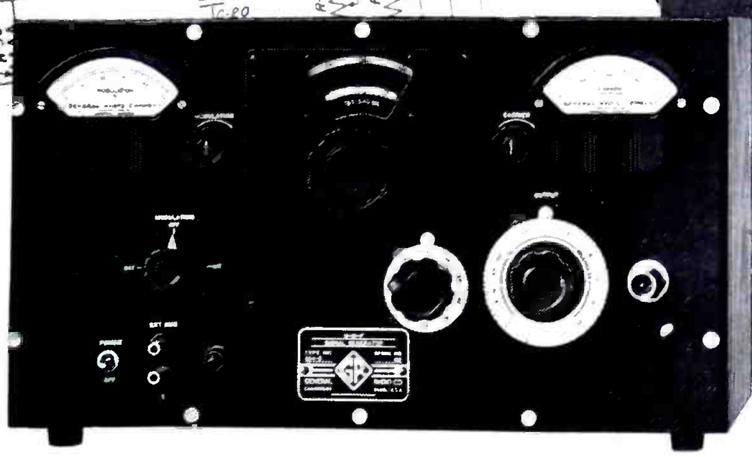

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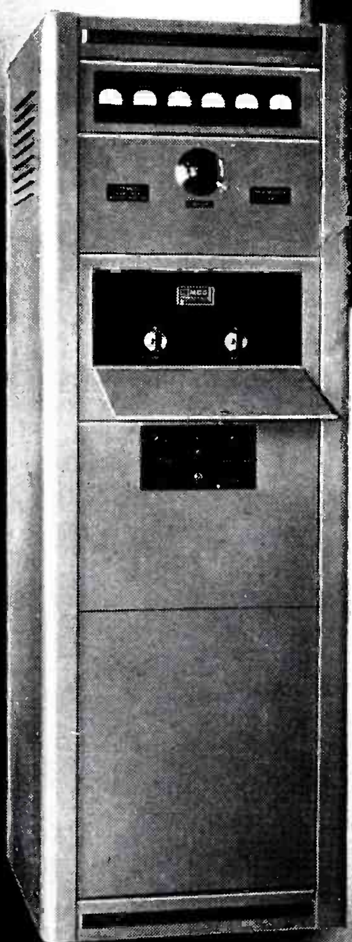

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