RADIO NEWS

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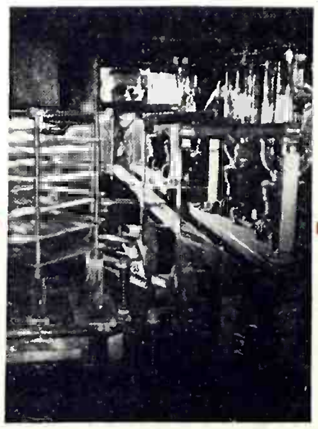

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VOLUME 2 NUMBER 5

Cover Photo—By HANS GROENHOFF

An interior view of the 30 kw high-frequency generator used for the electronic processing of the spar flanges for Fairchild's laminated wooden aircraft, the AT-21.

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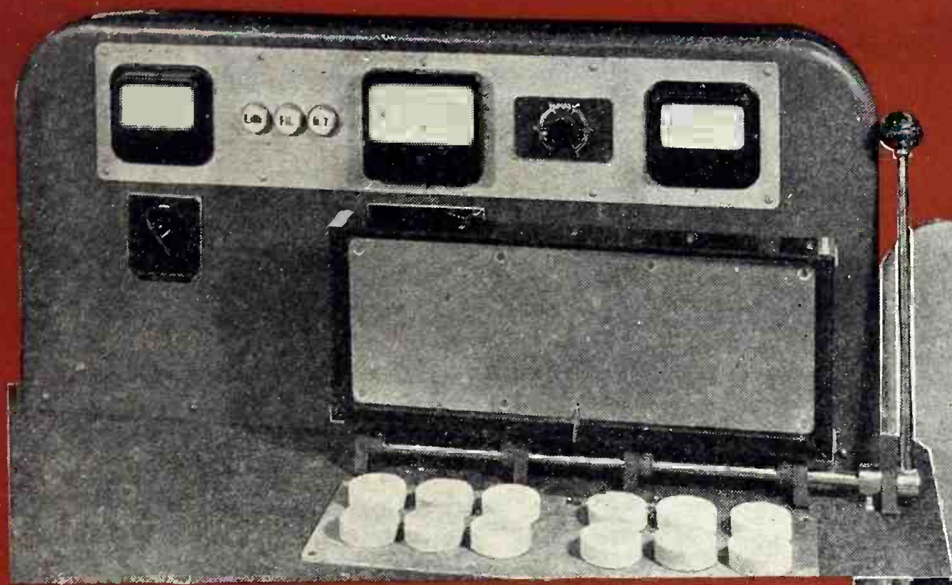
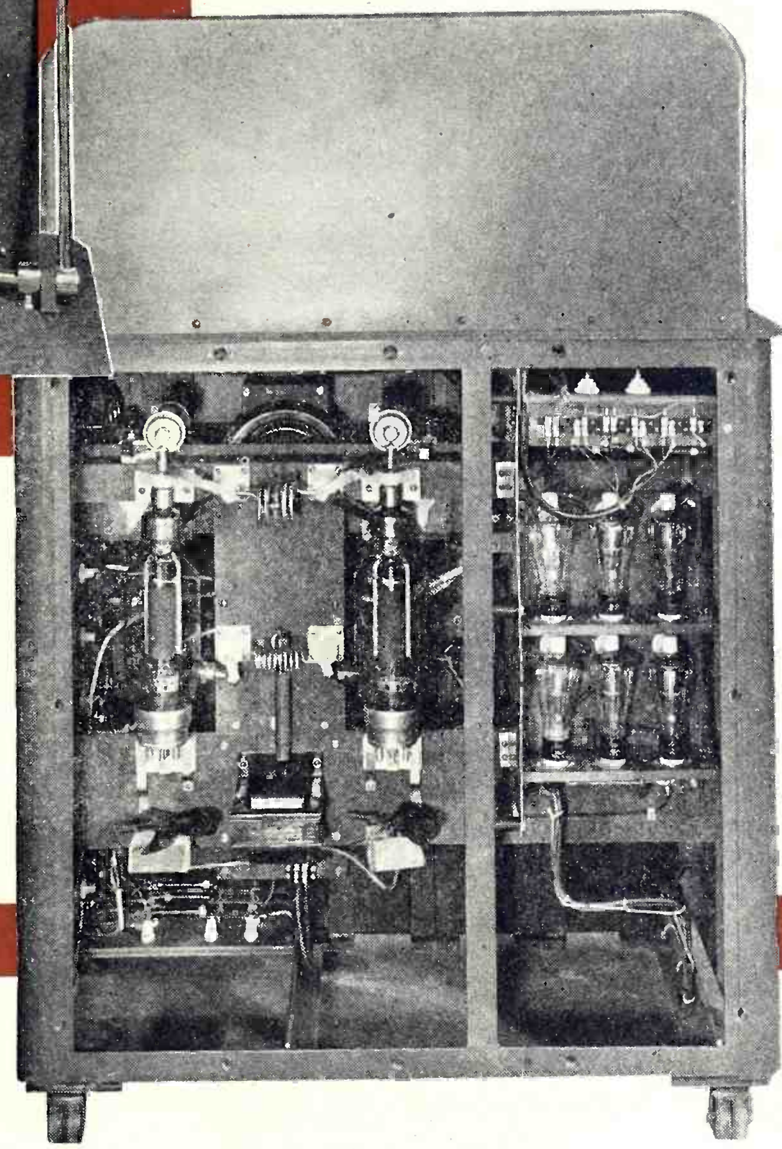
Left: Close up of instrument panel, controls, and the electrodes of the R-F heating unit.

Below: Rear view of R-F heating unit with back removed to show internal construction.





R-F HEATING OF PLASTICS

By DR. EUGENE MITTELMANN
Director of Research, Illinois Tool Works

The selection of the proper equipment for the high-frequency heating of plastics.

THE use of high-frequency power in the molding of plastics is rapidly becoming an accepted industrial technique. However, in spite of the fairly comprehensive literature on the subject of electronic heating, there are many questions which remain unanswered in the minds of plastic engineers. In the interest of clarification, this article will attempt to discuss and answer some of these questions.

Selection of Frequency

The first question that arises deals with matter of optimum frequency for any given material at which maximum power would be absorbed by the charge within the high frequency field. Because of the importance in selecting the proper frequency, this question will be answered in some detail. A similar problem arose several years ago in the field of electromedicine. At that time it was necessary to determine whether by the proper selection of frequencies it would be possible to heat certain portions of the human body to the exclusion of other parts. A simple analysis will help to clarify the problem both in the field of medicine and manufacturing.

Every dielectric material, which can be heated by high-frequency currents, must of necessity have losses associated with it. Hence, the electrical equivalent of any such material may be represented in a manner shown in Fig. 6. R represents the equivalent parallel-loss resistance of the material, and C the equivalent capacity. R is determined by the power factor (or loss angle), and C by the dielectric constant. The resulting impedance of this combination can be written as:

$$Z = \frac{1}{\sqrt{(\omega C)^2 + \frac{1}{R^2}}} \qquad (1)$$

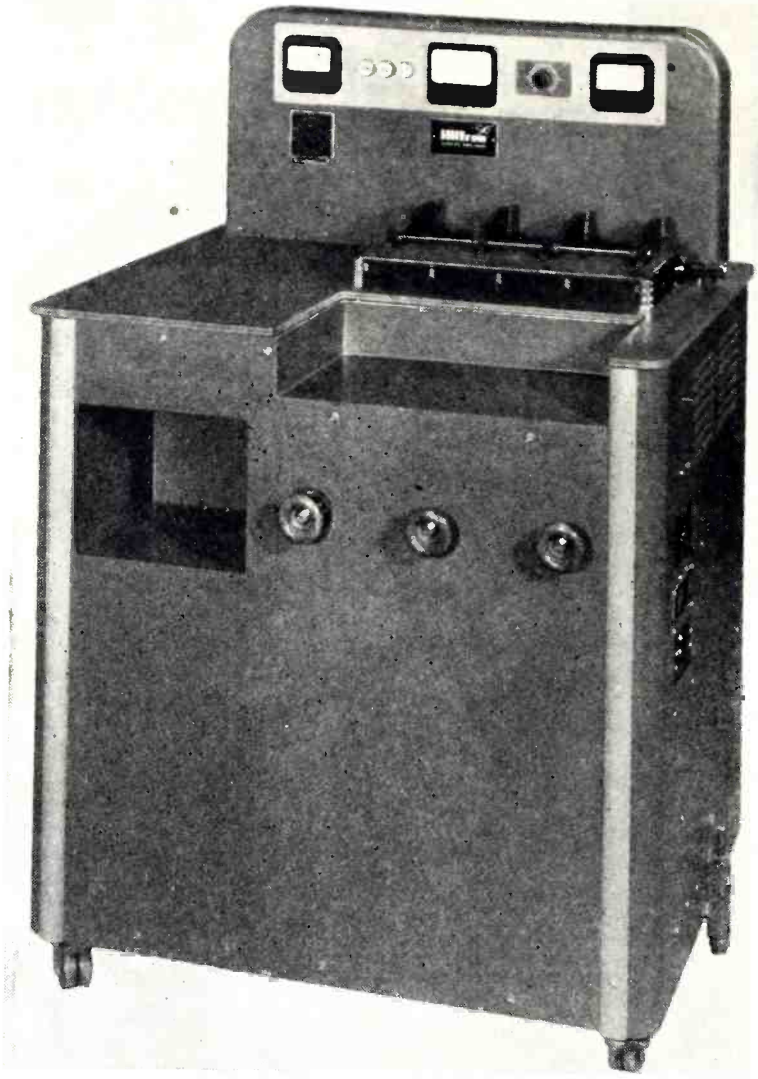
For a given current, I, the voltage across the terminals 1 and 2 will be:

$$E = I\,Z \qquad (2)$$

and hence, the power absorption will be:

$$P = \frac{E^2}{R} \qquad (3)$$

Or, after substituting for E, from equations (1) and (2):



Front view of the complete R-F heating unit showing relative location of controls, instrument panel and electrodes.

$$P = \frac{I^2}{\omega^2 C^2 R + \frac{1}{R}} \quad \dots\dots (4)$$

This last equation gives the power absorbed in a dielectric material for a constant current in the sample. To find the condition for maximum power absorption, equation (4) is differentiated with respect to R, with the frequency as a parameter:

$$\frac{dP}{dR} = \frac{I^2 \left[\frac{1}{R^2} - (\omega C)^2\right]}{\left(\omega^2 C^2 R + \frac{1}{R}\right)^2} \quad \dots\dots (5)$$

For a maximum value of P, the numerator on the right hand side of equation (5) must become zero. This will be the case for:

$$\frac{1}{R} = \omega C \quad \dots\dots (6)$$

This means that at any given constant frequency, for a constant current there does exist a value of the equivalent loss resistance for which the power absorption is a maximum. According to equation (6) this will be the case at a loss angle of 45 degrees or, its equivalent, at a power factor of .707.

The above condition for maximum absorption of power should not be confused with that case where certain given values of R and C are to be considered. In other words, the question often arises as to the possibility of finding a frequency at which the power absorption will become maximum for any given material. To find such a maximum, it is necessary to differentiate equation (4) with respect to frequency, which gives:

$$\frac{dP}{d\omega} = \frac{I^2\, 2\, \omega R C^2}{\left(\omega^2 C^2 R + \frac{1}{R}\right)^2} \quad \dots\dots (7)$$

For this equation to equal zero, the numerator must disappear, which will happen only when:

$$2\, \omega R C^2 I^2 = 0 \quad \dots\dots (8)$$

The condition of equation (8) cannot be satisfied except for a current of zero frequency, which means that no alternating current exists for which a maximum can be obtained for any given material.

It is important to note the conclusions reached for the two different conditions because the maximum power absorption which can be obtained for constant frequency and varying resistance was widely interpreted in earlier literature, to the extent that it was thought that specific effects could be obtained by the proper selection of the frequency.

The influence of the frequency on the proper absorption is best shown by the equation:

$$P = k\, E^2 f \tan \delta \quad \dots\dots (9)$$

which shows the amount of power absorbed as a function of the applied voltage, E, the loss angle δ, and the frequency. It should be noted that the amount of power absorbed by the material is proportional to both the frequency and the loss factor. This statement is again important as it can happen that the loss factor itself does have a maximum value as a function of the frequency. The product of frequency and loss factor, however, will not show a maximum. This is best illustrated in a group of graphs representing actual measurements. In the first group, the loss factors of three different materials of different dimensions are recorded as a function of the frequency. The third material shows a definite maximum of the loss factor, at around 45 megacycles (Fig. 4). The next set of curves, Fig. 3, shows the same material with the product of frequency and loss angle indicated as a function of frequency. It is evident that no maximum is obtained at any frequency.

The only instance where maximum power absorption could be expected would be in a material where not only the power factor has a maximum as a function of frequency, but where the power factor itself changes more rapidly than the frequency. This would mean that at that particular frequency, a lower voltage would be required for full power output.

However, the selection of the frequency is rather important for practical reasons. The higher the chosen frequency, the lower will be the required voltage across the sample. To indicate the influence of the frequency on the required voltage and to enforce the same amount of power absorption (one kilowatt) into the charge, the curves of Fig. 4 were calculated. It is evident that for all materials, irrespective of their loss angle, the use of higher frequencies reduces the required voltage across sample.

To select a frequency, then, a frequency with as high a value as possible is chosen, which value will be limited only by the tube efficiency and necessary circuit constants.

Impedance Matching

The amount of power which can be delivered to a load by a generator will depend, aside from its power rating, on the matching of the load impedance to that of the generator. In the case of practical applications involving the high-frequency heating of plastics, the load impedance will be determined not only by the electrical characteristics of the material, but also by the geometrical dimensions of this material. To illustrate the point, if the same weight (volume) of material is assumed to be distributed over a large surface in a thin layer, or if a small surface is spread with the material at a greater thickness, the first case will yield a low load-impedance while the second case will produce a high load-impedance. Hence, the unqualified statement that a certain generator is able to heat a certain volume of plastic material to a given temperature in a given time, is, as such, meaningless. Only when some provision is made to match loads of widely varying impedances to the internal impedance of the generator does such a statement assume any practical meaning.

One example of a variable coupling for the purpose of impedance matching is shown in Fig. 2, where the load is coupled through variable capacitors to the tank circuit of the generator. When designing the tank circuit and the coupling elements for the load, the two extreme conditions of impedance values for which matching must be possible, must be considered. The tank circuit must be able to deliver sufficient current to the load of the lowest impedance and a large enough voltage must be available when the highest impedance values of the charge are utilized.

In the generator illustrated in the photographs, an instrument is provided to measure the amount of high-frequency power delivered to the charge and to indicate whether matching is established between the load and the generator. The theory of this high-frequency wattmeter has been previously discussed. A brief explanation of the measurement of the matching conditions shall suffice.

The procedure is based on the following principles. In any oscillating circuit, which in this case may be identical with the tank circuit, all losses associated with the circuit can be fully represented either by a series resistance in one branch of the circuit, or by a parallel resistance shunting the tank circuit. For the purpose of this instrument, the method shown in Fig. 6 was selected, all equivalent losses being represented by an equivalent parallel resistance R_p. This parallel resistance includes all radiation losses, the losses in the circuit itself and in the case where the circuit is loaded by an external load coupled to the circuit, an additional parallel resistance R_1 is included to show the share of the external load. By indicating the value of R_p under no load conditions (without external load) as R_0, the resonance voltage e_0 across the circuit will be proportional to R_0:

$$e_0 = k R_0 \qquad (10)$$

If the excitation of the circuit is not changed, this voltage will change to:

$$e_1 = \frac{k R_0 R_1}{R_0 + R_1} \qquad (11)$$

in case a load is coupled to the circuit. Since k is a constant and R_0 itself is a characteristic constant for the circuit under consideration, e_1 becomes a single-valued function of the equivalent loss resistance R_1 representing all the losses associated with the external load:

$$e_1 = f(R_1) \qquad (12)$$

To match the loaded tank circuit to the generator, the tank circuit impedance must have a definite value,

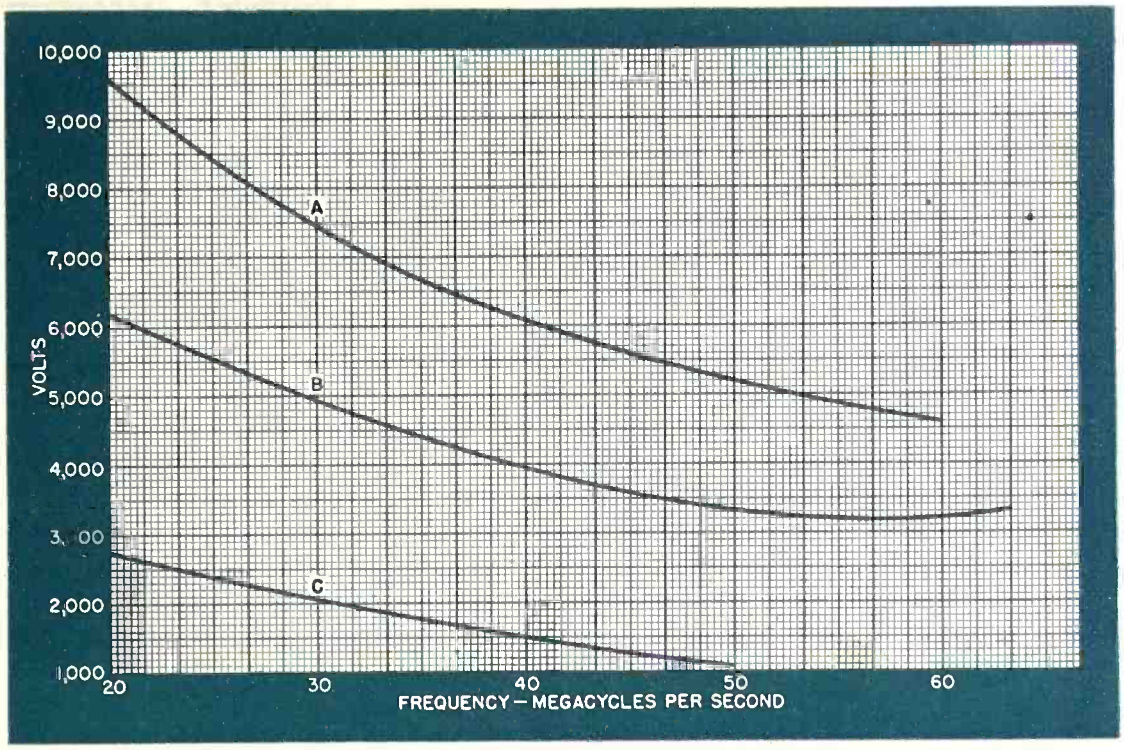


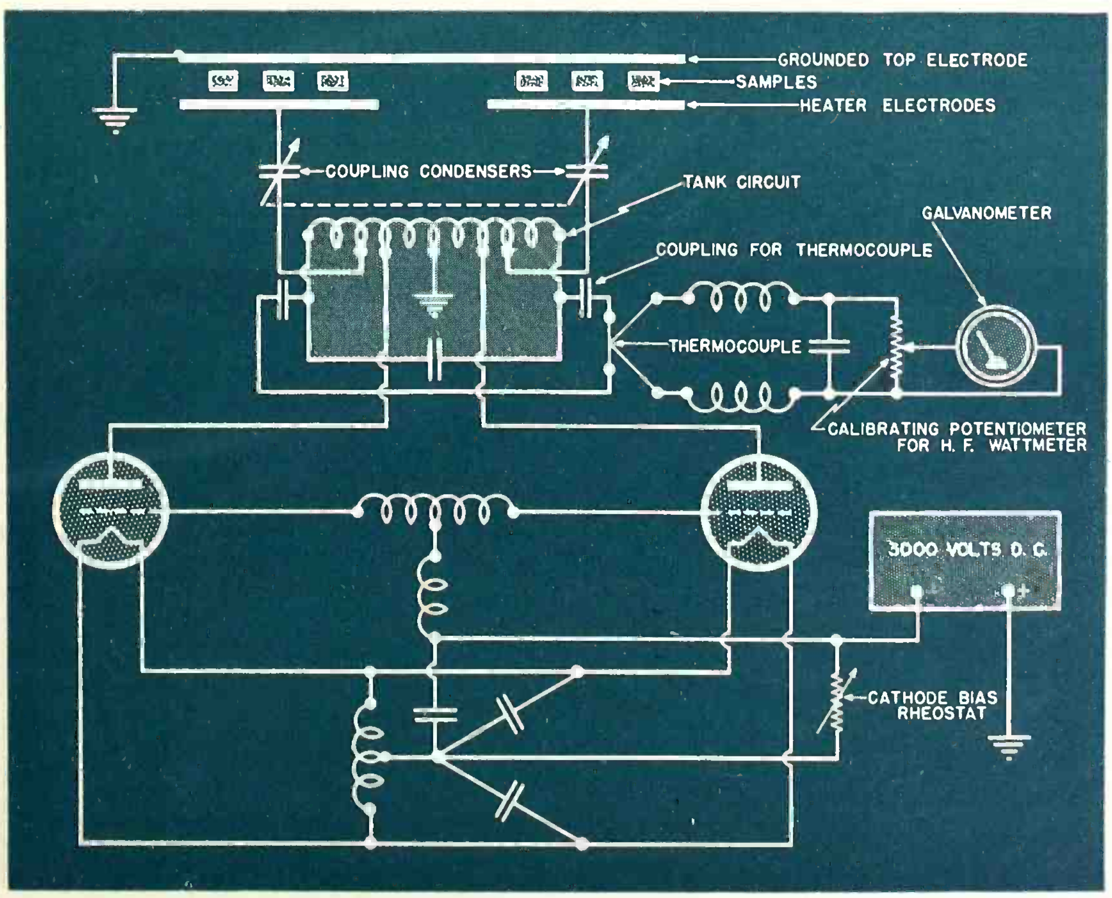
Fig. 1. Voltage required to enforce a power absorption of 1 kilowatt in three materials recorded as a function of the frequency. Curve A is for hemp, 2.7 x 3.8 x 1.2 cm. between parallel plates; curve B is for bakelite compressed powder 2" diameter and ⅝" thick between parallel plates; curve C is for black plastic 11⅛" x 1⅝" x 1/16" between plate 1⅝" wide and two strips ¼" wide. Plates are shown in photo, page 3.

which in turn will be determined by the total equivalent loss resistance across the tank:

$$R_P = \frac{R_1 R_0}{R_1 + R_0} \qquad (13)$$

However, there will be only one value of R_1 and thus only one value of e_1 for which this condition is satisfied. The procedure is very simple. The excitation of the unloaded tank circuit is so selected that the instrument measur-

Fig. 2. Schematic diagram of the complete R-F heating unit, showing the oscillator, electrode arrangement, method of coupling the load to the tank coil, and the thermal arrangement for measuring the power absorbed by the load. The galvanometer is the center instrument shown in the photograph on page 3, and is calibrated to read watts directly. The B plus of the power supply and the center tap on the oscillator coil are grounded for safety.



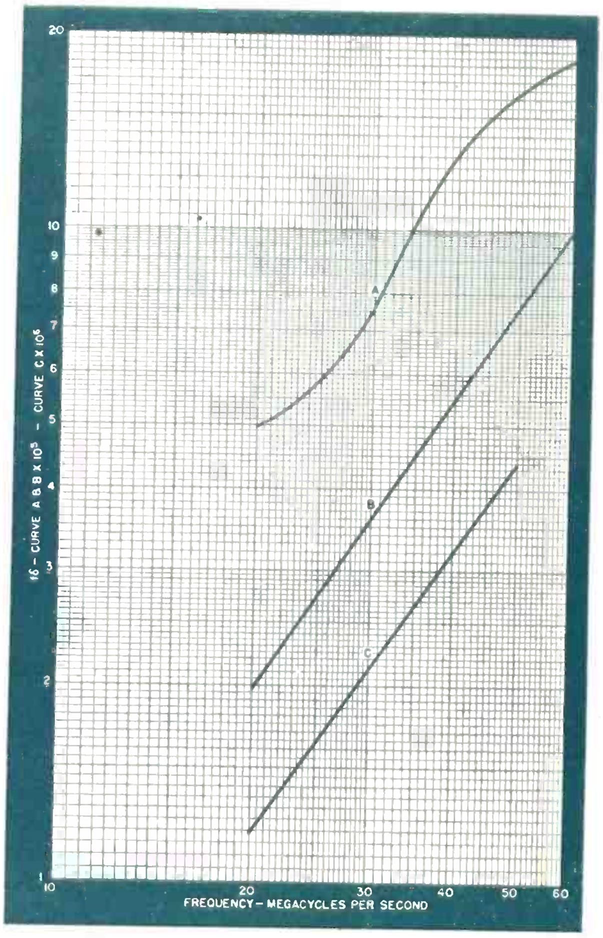


Fig. 3. Product of frequency and loss factor recorded as a function of frequency. Curve A is for bakelite, B for hemp and C for plastic. Samples are described in Fig. 1.

ing the voltage across the tank circuit indicates a certain arbitrary value. In practice this value is selected as the full scale deflection of the meter. Then the load is introduced into the circuit and the resonance voltage e_1 measured again. The coupling between load and tank will be changed by varying the coupling capacities until e_1 reaches a predetermined value corresponding to the proper load impedance. This value is marked on the scale of the instrument.

Power Absorption Measurement

The same instrument that is used to determine the proper matching conditions can be used for the measurement of the power absorbed by and converted into heat within the charge. The power absorbed by the charge will correspond to the square of the voltage across the equivalent loss resistance representing the charge, multiplied by the reciprocal value of that resistance:

$$P = \frac{E^2}{R_1} \qquad (14)$$

In order to measure the power absorption, and that alone, it is necessary to employ an instrument, the deflection of which will be proportional to the square of the voltage and to the reciprocal value of the equivalent parallel loss resistance introduced by the external load. This is accomplished by means of the instrument shown in Fig. 2. The h-f voltage is measured by a thermocouple which is connected to the tank circuit through the small capacitors. The d-c potential across the output terminals of the thermocouple will be proportional to E^2, if E denotes the h-f voltage across the tank circuit. A calibrated voltage divider VD is connected across the d-c terminals of the thermocouple. It was demonstrated above that R_1 is a single-valued function of e_1, therefore it is only necessary to mark the settings of the calibrated potential divider VD in terms of e_1 in such a manner that at that particular setting the sensitivity of the galvanometer and hence its deflection will be proportional to e_1. When this is done the galvanometer will read h-f watts, indicating the amount of power absorbed by the load.

This procedure appears to be complicated, but in actual practice this method is straightforward. The procedure for establishing the proper value of matching impedance has already been described. The same instrument can be used for measuring the power absorbed by the load, in which case the procedure is as follows: the sliding contact on the potential divider is set for the maximum value and the excitation (power input into the tank, in practice changed by the plate voltage or the grid bias providing a variable output control) is adjusted until the instrument reaches full scale reading. Then the coupling is adjusted as described above until the reading e_1 is obtained. The slider of the potential divider is then set to the mark identified with e_1 and the instrument reads in watts directly. The reading will be correct for any voltage, E, across the tank circuit. In other words, once the calibration is set, the power output may be adjusted to any desired power level by means of the power output control and the wattmeter will indicate the power absorption correctly.

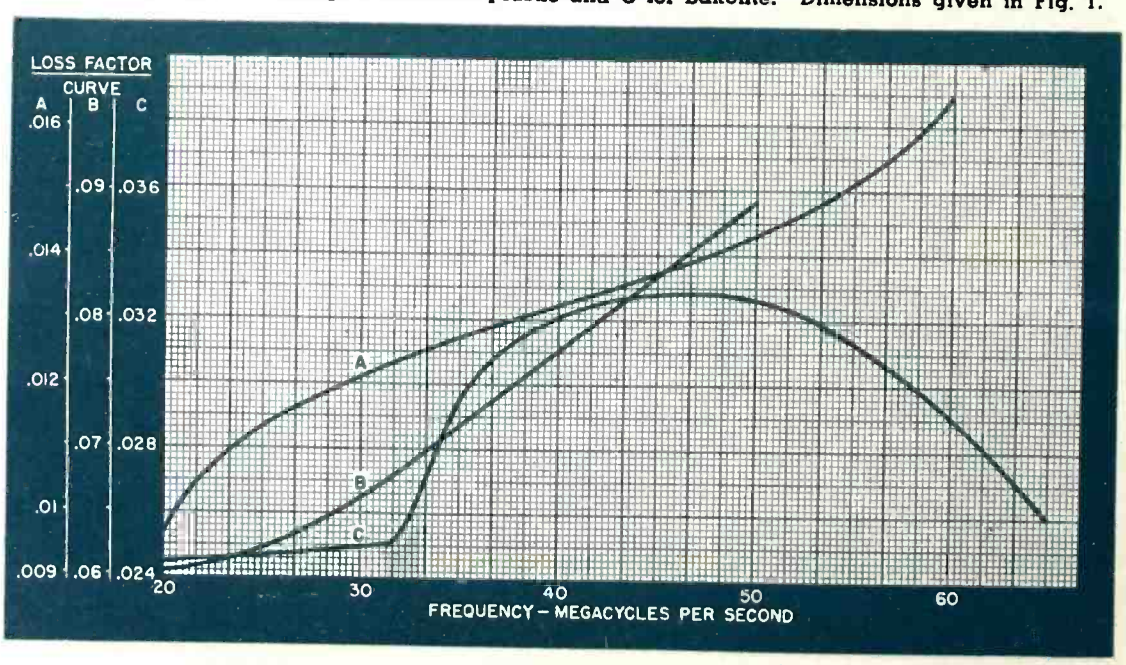
The importance of such an instrument, in the light of the above discussion, is obvious. Neither the plate current, nor the h-f current measured in the load circuit are an indication of the power absorbed by the load. If anything, the values so obtained are misleading, as the plate current may acquire identical values for various power outputs depending upon the instantaneous conditions of matching and efficiency. The h-f current in the load circuit may be the same for entirely different values of power dissipation, depending on the power factor of the load circuit.

2.5 kw. Heating Unit

A practical example of a unit in which the features of the above theoretical discussion were incorporated, is shown on page 3. The purpose of this unit is to provide a simple and convenient means for the simultaneous heating of a number of preforms for a multiple cavity mold. Although designed primarily for this purpose, a variety of forms and volumes can be heat-treated with this unit. The schematic diagram of the electrode arrangement is shown in Fig. 2. The heater circuit is coupled through variable capacitors to the tank circuit. The frequency of the tank circuit is determined by the inductance and capacitance between the plates of the tubes in the push-pull oscillator. The heater circuit itself is split into two halves. A common top electrode at ground potential establishes the reference point for the high-frequency po-

(Continued on page 35)

Fig. 4. Loss factors of three different materials recorded as a function of frequency. Curve A is for hemp, B for black plastic and C for bakelite. Dimensions given in Fig. 1.



GRAPHICS of RC Networks

By ROBERT C. PAINE
Production Test Engineer

Graphical method of analyzing networks containing resistance and capacity as applied particularly to various types of RC oscillators.

THERE are many types of audio oscillators, of which several make use of resistance capacity networks as the frequency determining element. Such oscillators are relatively simple and stable. As compared to beat frequency oscillators, the calibration remains more constant especially for low frequencies. These resistance capacity networks can be analyzed by graphical methods.

A type of network which can be used in making a one tube oscillator is shown in Fig. 1a. This network produces the reversal of phase between the plate and grid of the tube which is necessary to make oscillations self-sustaining. A circuit using this network is simple and has very good stability and low harmonics.[1] The oscillating frequency in cycles equals:

$$\frac{1}{2\pi RC\sqrt{6}}$$

Mathematically the analysis of this network is somewhat involved, but its operation can be readily analyzed graphically. The reactance, X_c, of each of the equal condensers, C_1, C_2, and C_3 of course varies with frequency, but at the frequency at which X_c equals 2.45 times the resistance of each of the equal resistors, R_1, R_2, and R_3, the phase shift between *f* and *a* is 180°. This point determines the oscillating frequency shown in the formula above.

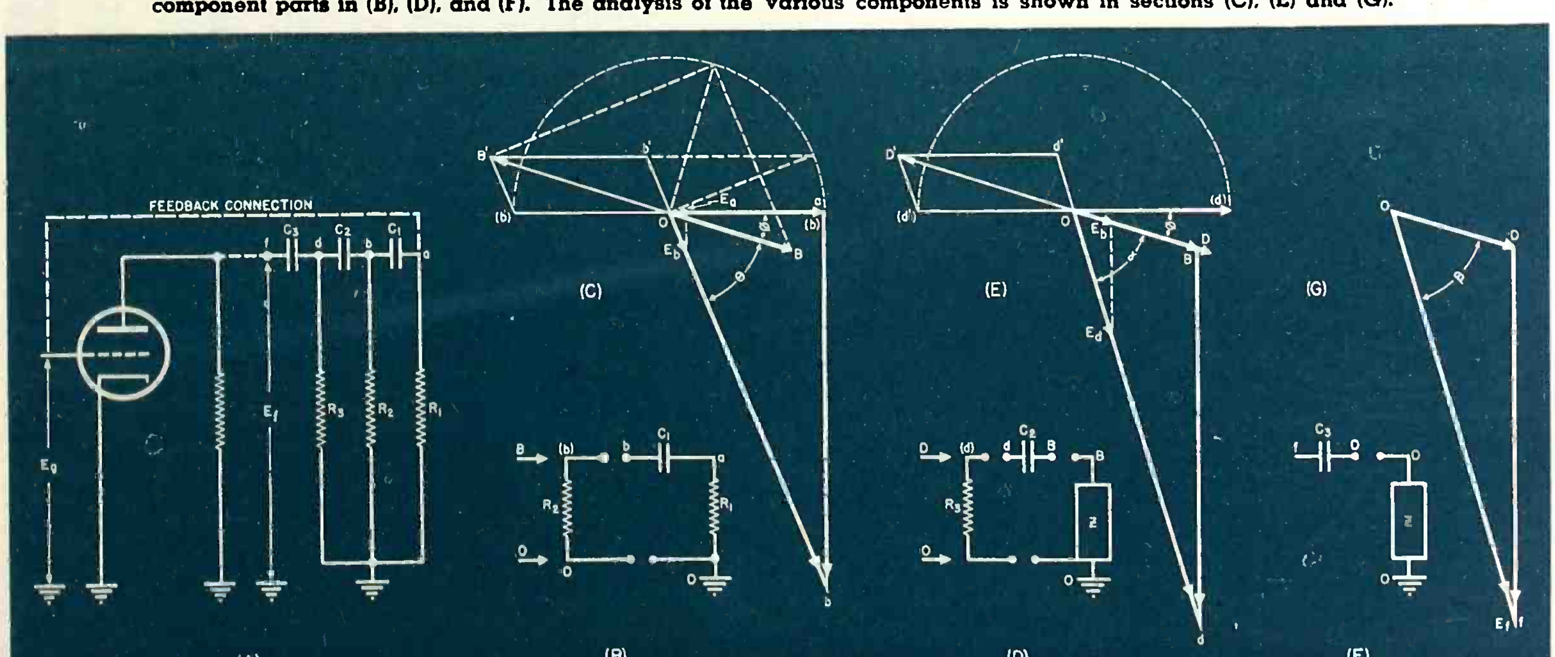
Graphic analysis on the basis of X_c equals 2.45 R proceeds by steps, in Fig. 1b the branch *baO* is first taken. Its series impedance vector, *Ob* is found in the usual way in Fig. 1c where the vector *Oa* representing R is added to the vector *ab* representing the reactance, X_c, of C_1. The series impedance vector, *Ob*, is then combined with the vector, *O(b)*, representing R_2. The reciprocal functions of these vectors are found, by aid of the circular arc, to be *Ob'* and *O(b)'*. These reciprocals are added in the parallelogram, *O(b)'B'b'*, to obtain the sum, *OB'*. The reciprocal of *OB'* is found to be *OB* which is the vector of the required parallel impedance looking into the circuit at *OB* in Fig. 1b. This method of obtaining the parallel impedance has been described in more detail in a previous article by the author.[2]

The impedance vector *OB* is then added to the vector *Bd*, representing the reactance of the condenser C_2, in Fig. 1e to obtain the series impedance, *Od*. The vector *Od* is combined in parallel with the vector *O(d)* representing the resistance R_3, by the aid of the parallelogram *O(d)'D'd'*, to find the parallel impedance, *OD*. This is the impedance seen from *OD* in Fig. 1d and it is only slightly greater than the vector *OB*, so these two vectors nearly coincide. The vector *OD* is then combined in series with the vector *Df*, representing the reactance of C_3, in Fig. 1g. This gives the impedance, *Of*, seen by the plate of the oscillator tube at *f* in Fig. 1f.

To determine the feedback voltage to the grid, let the audio voltage at the plate of the tube be represented by the vector OE_f, then the voltage to ground at *d* equals *OD*. The voltage *OD* is laid out as the vector OE_d on the impedance vector *Od*, then the voltage OE_b at *b* is found by drawing E_dE_b parallel to *dB*, since the voltages OE_d and OE_b are proportional to the impedances *Od* and *OB* respectively. In a similar manner the voltage OE_b is laid out on *Ob* and on the line *Od* the vector OE_a for the voltage which is fed back to the grid of the tube is found by drawing E_bE_a parallel to *ba*.

The three vector diagrams of Fig. 1 have been shown separately only to clarify the problem, but they are only portions of the complete analysis

Fig. 1. Graphical analysis of a one tube RC oscillator. The complete circuit (A) is shown broken down into its component parts in (B), (D), and (F). The analysis of the various components is shown in sections (C), (E) and (G).



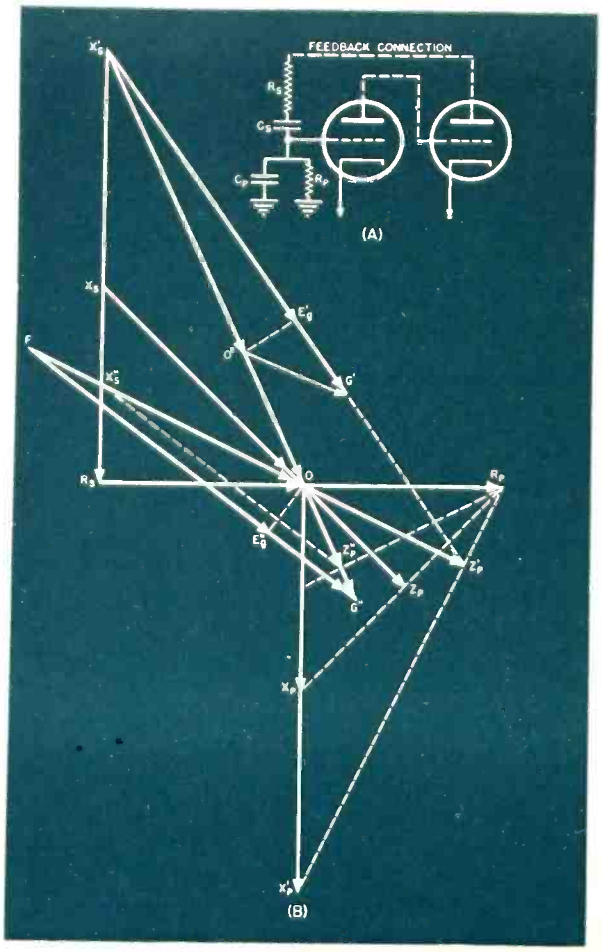


Fig. 3. Analysis of RC oscillator using tube to reverse phase of feedback voltage.

which has been worked out in Fig. 2. This figure has been lettered in the same manner as the separate figures of Fig. 1. To simplify its layout, it may best be drawn on polar coordinate paper which facilitates rotation of the construction lines through the proper angles. Fig. 1e is represented in Fig. 2 by rotating Fig. 1e through an angle of θ about O, then OB falls on Ob. This is done because the voltages on OB and Ob are in phase. In a similar manner, Fig. 1g is rotated about O through an angle of θ plus α. In Fig. 2 the plate voltage, E_f, and the grid voltage, E_a, are shown in their correct relation and it is seen that E_f/E_a equals about $29\angle{-180°}$, a complete phase reversal. The voltage gain between the grid and plate of the tube must be as great as this value to sustain oscillations.

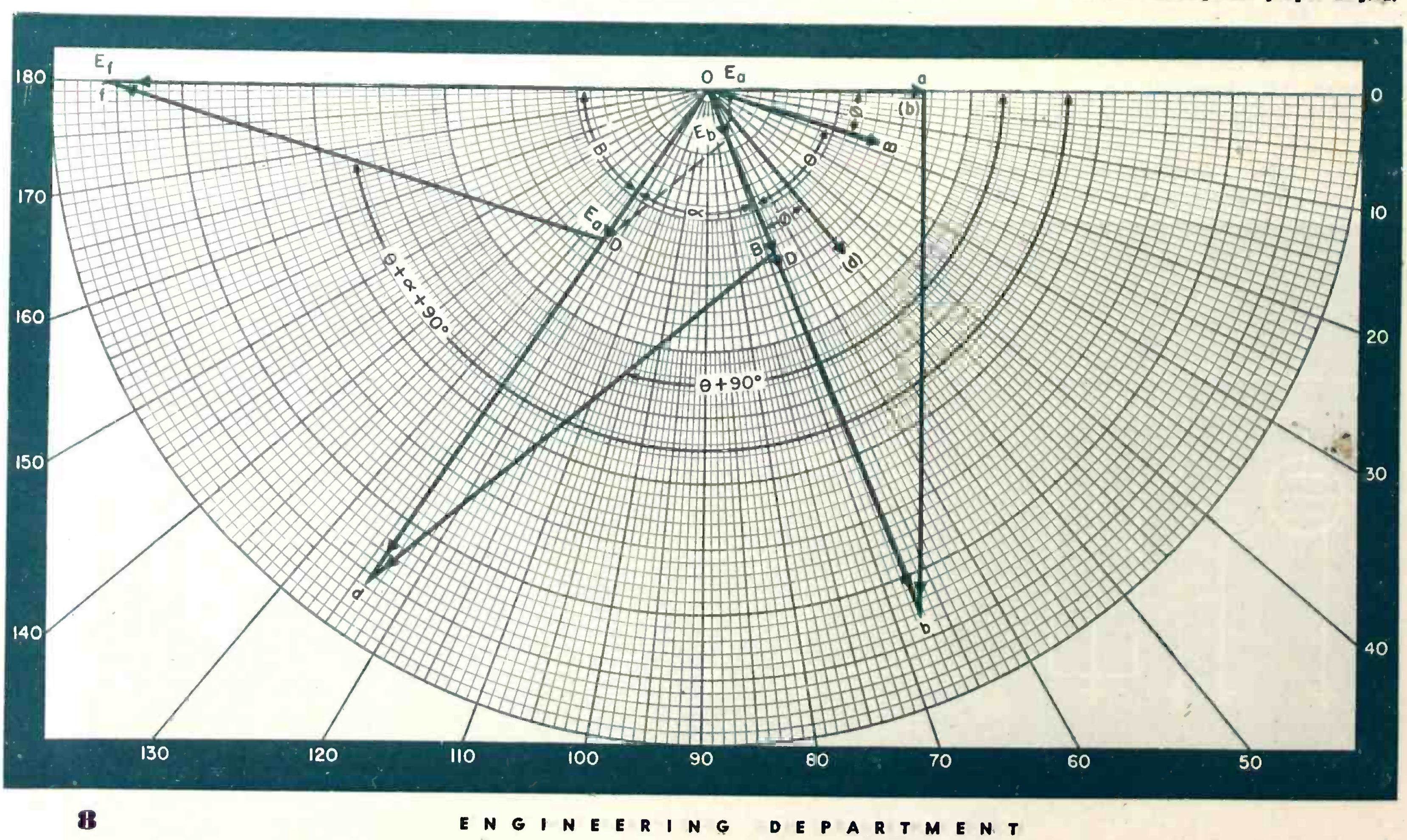
A more common type of network for a resistance-capacity oscillator is shown in Fig. 3a. This circuit requires a second tube to reverse the phase of the feedback voltage from the plate of the first tube to its grid. The network shown applies a portion of this voltage to the grid of the first tube. The circuit oscillates at the frequency which produces the greatest component of grid voltage in phase with the feedback voltage. This frequency equals $1/2\pi\sqrt{R_sR_pC_sC_p}$. It is convenient to have C_s equal C_p if variable condensers are used for tuning, and if $C_s = C_p$ and $R_s = R_p$, the oscillating frequency in cycles equals $1/2\pi RC$.

This network is analyzed in Fig. 3b in which R_s and C_s have been taken equal to R_p and C_p respectively. The vector R_sO represents the resistance R_s and OR_p represents R_p. The vector X_sR_s is drawn equal to the reactance of C_s, and OX_p equal to the reactance of C_p at the oscillating frequency, at which frequency $X_s = R_s$ and $X_p = R_p$. The vector sum X_sO of R_s and X_s equals the impedance, Z_s, of these elements in series. The vector sum of R_p and X_p in parallel, Z_p, is found by drawing OZ_p perpendicular to R_pX_p. This method of adding resistance and reactance in parallel has been described by the author in the article previously mentioned.[2] Z_s and Z_p are in phase and their sum equals X_sZ_p. This line can also represent the feedback voltage and it is seen that the grid voltage OZ_p is proportional to Z_p and in this diagram it equals one third of the feedback voltage and is in phase.

Assume a lower frequency at which the reactances of C_s and C_p are X_s' and X_p'. The impedance of the series elements is then equal to $X_s'O$ and of the parallel elements, OZ_p. The sum of these impedances is $X_s'Z_p'$. The feedback voltage $X_s'G'$ is laid out on this line equal to X_sZ_p as before. Then the voltage vector diagram $X_s'O'G'$ is formed by drawing $O'G'$ parallel to OZ_p'. The projection of $O'G'$ on $X_s'G'$ is the component of grid voltage $E_g'G'$ in phase with the feedback voltage. Since this is less than OZ_p, the assumed frequency represents an unstable condition, and the frequency of the oscillator will return to the frequency represented by OZ_p.

At some higher frequency the reactances of C_s and C_p are X_s'' and X_p''

Fig. 2. Complete analysis of a one tube RC oscillator. Parts (C), (E), and (G) of Fig. 1 are each rotated through the proper angle and superimposed to give the complete analysis. Polar coordinate paper is used to facilitate rotation of construction lines through the proper angles.



and the corresponding impedances are OX_g'' and OZ_p'', the vector sum of which is $X_g''Z_p''$. The voltage diagram for this condition is FOG'' in which FG'', the feedback voltage equals, X_gZ_p as before. The component of grid voltage in phase with the feedback voltage is $E_g''G''$. But this again is less than OZ_p and this frequency also represents an unstable condition. The frequency represented by OZ_p is the frequency which produces the greatest in-phase grid voltage and is the frequency at which the circuit must oscillate.

Another type of feedback network which might be called the "twin T" is shown in Fig. 4a. This circuit operates similarly to the Wein frequency bridge, but its input and output have a common connection (usually ground), making it a more practical circuit for use in an audio oscillator. At its frequency of balance no voltage at all is transmitted from input to output, this makes the circuit much more selective than those described above, so this circuit also finds use in other systems such as tuned amplifiers and harmonic analyzers. The audio oscillator is connected so that a positive feedback through another channel is neutralized by the negative feedback through this circuit, except at the oscillating frequency, at which there is no negative feedback and the circuit is allowed to oscillate freely.

The balance frequency of this network must satisfy the equations $X''' = X' = KR''$, $X'' = R''/2K$, also $R''' = R''$ and $R' = K^2R''/2$, where K may be any numerical factor required by the design, and X', X'', and X''' represent the reactance of the corresponding capacitors, C', C'', and C'''. In the case graphically analyzed below, K has been taken as 1, so $X''' = X' = R'' = R'''$ and $X'' = R' = R''/2$.

Assume the frequency at which the network balances and the voltage between *ef* and *gh* is zero. If the voltage between these points is zero, they are at the same potential and they can be connected at this one frequency without changing any of the voltages concerned. Thus, for analysis, R''' is effectively in parallel with C'', and C''', in parallel with R'. The impedance diagram for the upper branch is then as shown in Fig. 4b. In this figure *od* is laid out to a suitable scale to equal the resistance R'', *de* to equal R''' and *dg* to equal the reactance, X'', of C''. R'' and X'' are combined to find the parallel impedance dZ_g, by a method already referred to. Then the lines *od* and dZ_g are added vectorially to find the total impedance of the upper branch oZ_g.

The diagram for the lower branch is shown in Fig. 4c. In this figure *oc* equals the reactance, X', of the condenser C', *cf* equals the reactance X''' of C''', and *ch*, the resistance R'. The values X''' and R' combined in parallel equal the impedance cZ_h. The impedance diagrams odZ_g and ocZ_h are seen to be similar and oZ_g equals oZ_h. The equal vectors oZ_g and oZ_h can be taken to equal the voltage from *o* to *g*, or *o* to *h*, then the voltages across R'', C'', C', and R' will be represented by the impedance vectors *od*, dZ_g, *oc*, and cZ_h respectively. These two voltage diagrams are combined in Fig. 4d in which the voltage from *c* to *d* is found by drawing the vector E_cE_d.

The vector E_cE_d represents the voltage across the branch *cfed*. The impedance of this branch is found in Fig. 4e where *cf* represents the reactance X''' of C''' and *fe* represents the resistance R'''. The vector sum of these impedances is *ce*. The voltage across this path, E_cE_d, is laid out on *ce*, as cE_d, and $f'E_d$ is drawn parallel to the impedance vector *fe*. Then *cf'* is the voltage across C''', and $f'E_d$, the voltage across R'''. This voltage diagram cE_df' can be superimposed on the exactly similar diagram $E_cE_dE_g$ which represents the voltage across the path *chgd*. The voltage between *ef* and *gh* is then the vector between the points *f'* and E_g, but these points coincide so this voltage equals zero at the balance frequency. At any other frequency a

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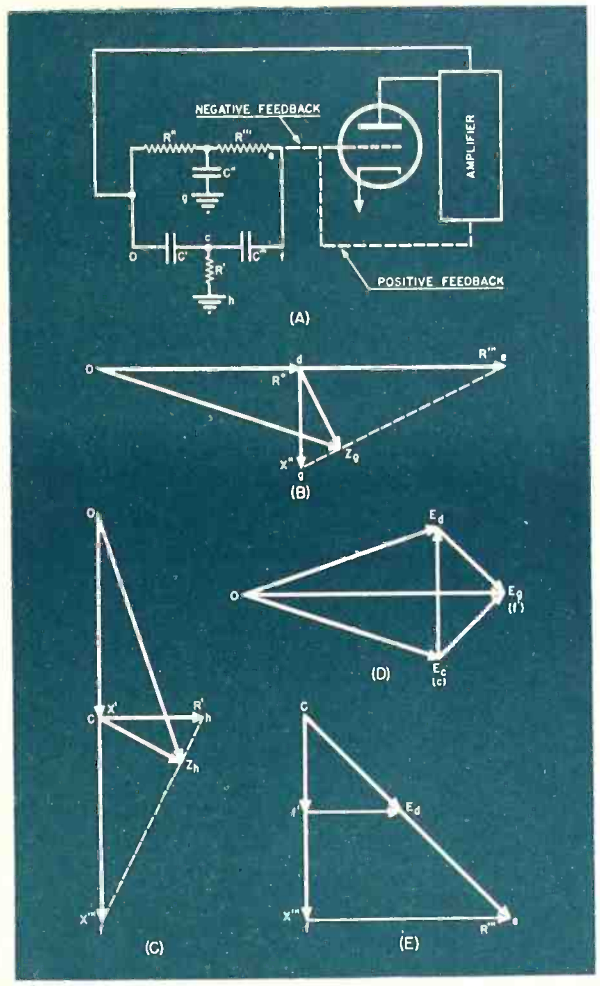
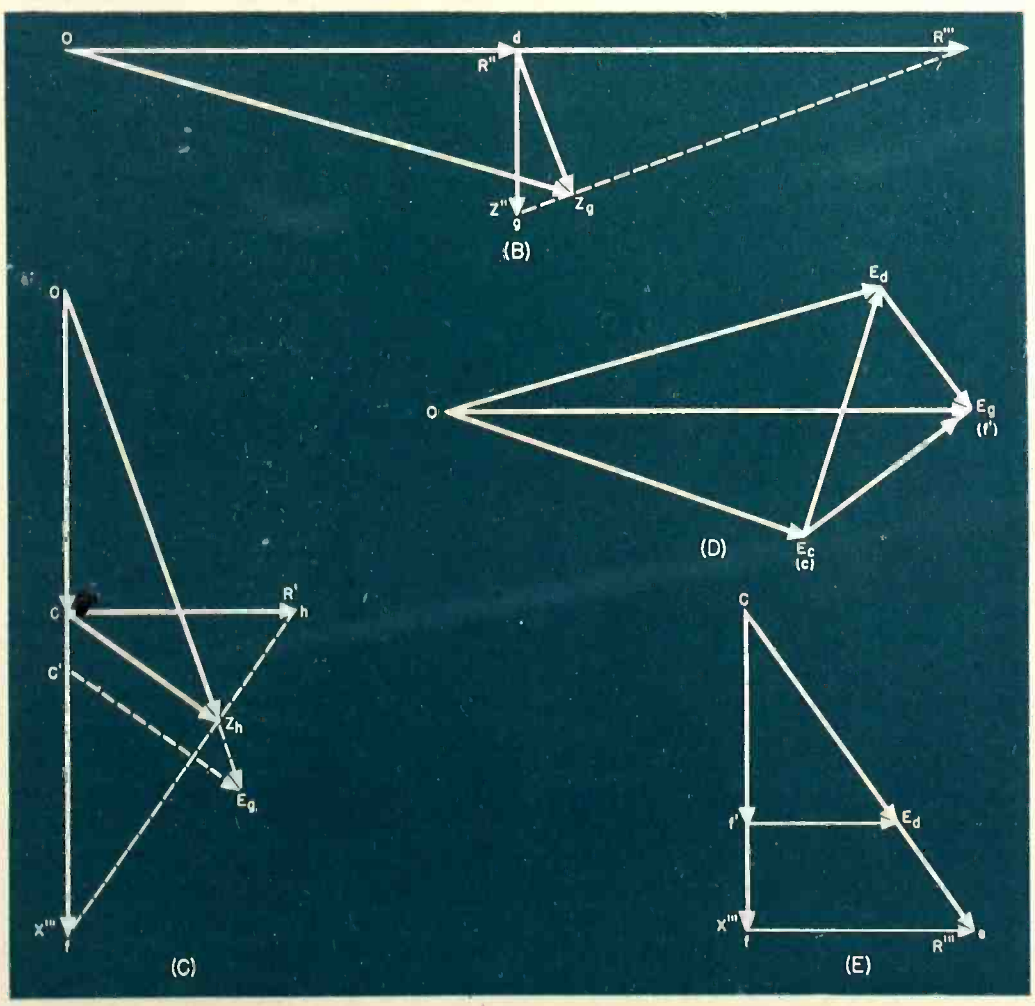


Fig. 4. "Twin T" feedback network with a graphical analysis of component parts.

Fig. 5. Graphical analysis of the twin "T" feedback network shown in Fig. 4A for $K = \sqrt{2}$. Vector diagrams are drawn to approximately twice the scale of Fig. 4 for greater accuracy.



HEAT DISSIPATION in TRANSMITTER TUBES

By HAROLD E. ENNES
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A discussion of the problems of heat dissipation encountered in the operation of broadcast transmitting tubes.

A water- and forced-air-cooled transmitting triode used in high-power broadcasting.

A RADIO engineer, particularly one associated with installation and operation of broadcasting equipment, often encounters the problem of heat dissipation in power tubes. This calls for a thorough understanding of tube characteristics with respect to the capabilities and limitations of cooling mediums. This article is designed to present the basic problems of handling heat dissipation, with sufficient co-ordinated data to enable the engineer to cope with this situation in its many varied forms.

Fundamentally, the power rating of a tube in free air is determined by three characteristics, namely:

1. Plate voltage that may be safely applied (dependent on physical parameters.)
2. Electron emission of filament.
3. Amount of heat that can be dissipated at anode without causing overheating (dependent on physical and electrical parameters.)

Thus it becomes apparent that from the standpoint of heat dissipation and voltage requirements, artificial cooling of the anode is necessary to eliminate prohibitive physical dimensions of the tube. In practice, all tubes over 2 kw output rating are cooled by water or, more recently, by forced-air cooling systems.

In order to get a workable picture of the problem at hand, assume an efficiency of 70% in a plate modulated stage, and consider the maximum output from a tube as being slightly more than twice the maximum plate dissipation. This maximum plate dissipation may be referred to a unit area of the anode, in which case the dissipation is limited to approximately 4 watts per cm^2 to prevent excessive temperature rise of the anode and adjacent glass bulb. Thus, it becomes obvious from this angle that the maximum output of the tube would be limited by plate area. An arbitrary increase in anode dimensions, however, must be avoided due to obvious mechanical difficulties, and also to keep the anode in proportion to the size of the filament, since for a given filament diameter there is a maximum allowable length to prevent sagging.

In calculating the value of plate dissipation for a given class of operation, consideration must be given to the peak current and voltage values as shown in figures 3-A and 3-B. Heat dissipation at grids of some higher power tubes is also a consideration since the construction of the grid is such as to establish a certain effect on the electrostatic field between the tube elements. R-f grid current as well as the d.c. on the grid must combine to produce not more than the I^2R loss that the grid lead (internal) can safely handle to prevent secondary emission. For this reason, some of the highest power tubes used in transmitters rated over 50 kw, are both grid and anode cooled by water systems.

Fig. 6 illustrates an X-ray view of a typical water-cooled tube, and Fig. 5 shows the schematic arrangement. With this type of cooling, a dissipation of 70 watts per cm^2 is allowable. Higher values are permissible with an increased rate of water flow through the tube jacket.

This type tube fits into a water jacket made of copper. The jacket must be designed to provide the correct clearance between plate and jacket walls, and adequate shielding against corona discharge.

It is obvious that the water jacket, being connected directly to the anode, must be insulated from the water pipe connection and ground. This is accomplished by means of 15 to 20 feet of rubber hose connected at the input and output connections of the jacket, and wound in cylindrical form under each water cooled tube used. In most instances, this rubber hose is being replaced by porcelain hose or pipe,

Fig. 1. An air-cooled transmitting triode showing the silver-soldered ventilating fins.

which provides better connection with the tube, and greater dielectric strength with resultant lower current leakage through the water supply system. This type hose, due to its great physical strength, may be used as the jacket mounting for the smaller sized water-cooled tubes. The cooling system itself consists of a reserve tank, preferably a copper tank, connected to the water jacket inlet through the porcelain reel or pipe. The outlet pipe carries the heated water into a radiator equipped with a blower for cooling. From there, the cooled water is carried back to the reserve tank.

The most important factor in the cooling of water-cooled tubes is the water velocity. The effect of increasing the flow of water is to increase the turbulency of flow. This increased turbulency breaks down the layer of steam present at the anode wall and increases the heat exchange between the wall and the water. The turbulency of the flow may be increased by mechanical means, such as baffles.

The turbulency of the water is indicated by the "Reynolds number." This constant was established about 65 years ago by Oliver Reynolds who determined by experimentation that with Re smaller than 2100 the flow is viscous while with the Re greater than 4000 the flow is turbulent. Between these limits the flow may alternate between viscous and turbulent.

The Reynolds number is a non-dimensional coefficient used as a measure of the dynamic scale of flow. The value is given by the formula:

$$R_e = \frac{DpV}{\mu}$$

Where:

D = equivalent diameter of the fluid channel cross section in cm.

p = density of fluid in grams per cm^3.

μ = viscosity of fluid in grams per cm second.

When the rate of water flow is fixed, a variation in the annular clearance between the anode and the jacket has a direct effect on the velocity of the water and the equivalent diameter. Both of these factors affect the turbulency of the water in an independent manner.

With either a large or small clearance, the turbulency remains the same if the number of gallons per minute remains constant. However, the heat transfer varies with the size of the clearance. Thus, the heat transfer becomes larger in inverse proportion to the size of the clearance. However, there is an optimum clearance possible in the design of transmitting tubes beyond which there is little improvement in cooling efficiency. The reason for this optimum clearance is due to the almost stationary film of liquid at the walls of the anode. When the water wall becomes comparable to the thickness of the film, the turbulency decreases and the flow becomes laminar.

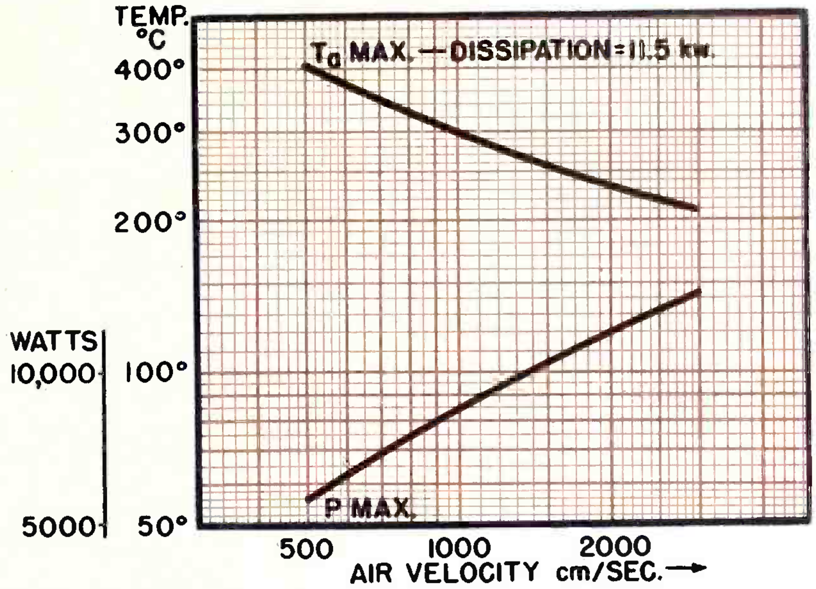


Fig. 2. Graphical analysis of the temperature plotted against air velocity for the 891-R air-cooled r-f power amplifier tube.

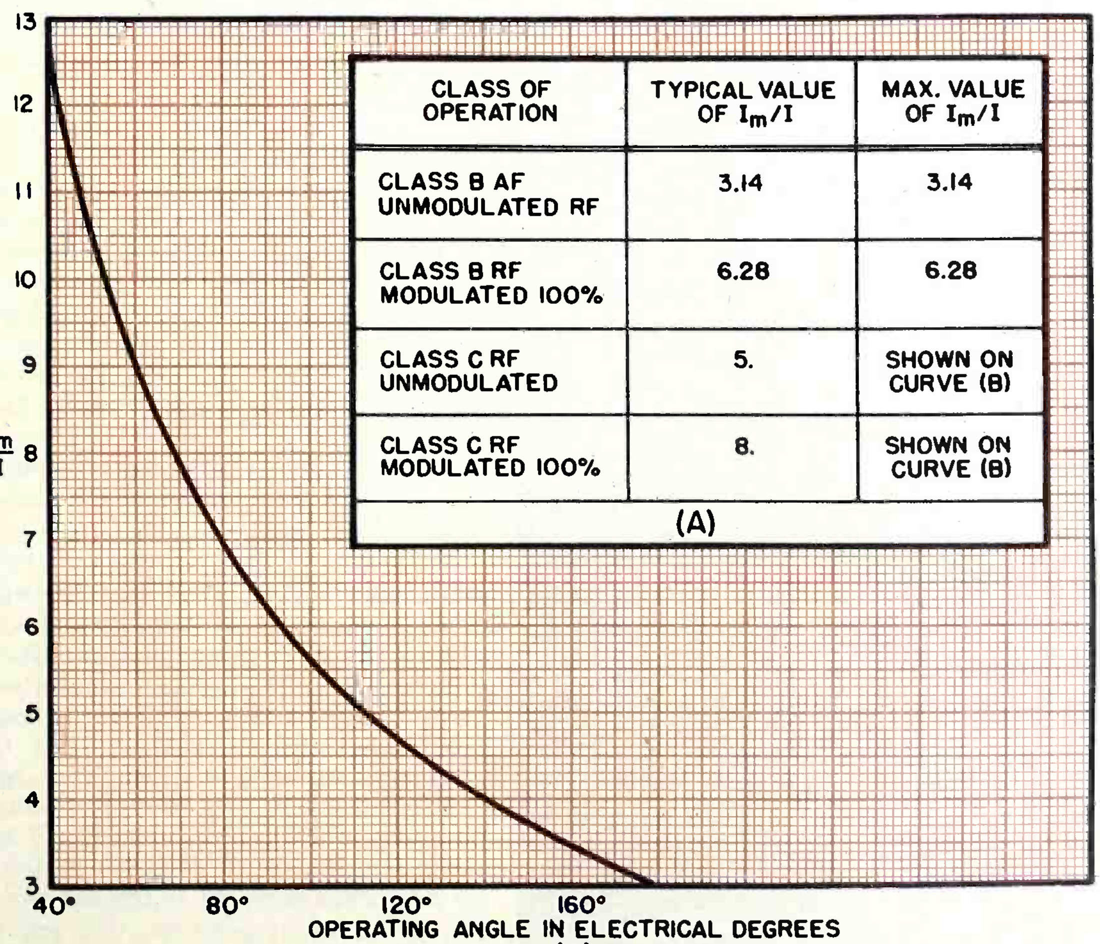
Installation and Maintenance

Several pertinent facts should be kept in mind when installation of

Fig. 3. Graph for calculating the value of plate dissipation for a given class of operation. Peak current and voltage values are plotted against operating angle in degrees.

CLASS OF OPERATION	TYPICAL VALUE OF I_m/I	MAX. VALUE OF I_m/I
CLASS B AF UNMODULATED RF	3.14	3.14
CLASS B RF MODULATED 100%	6.28	6.28
CLASS C RF UNMODULATED	5.	SHOWN ON CURVE (B)
CLASS C RF MODULATED 100%	8.	SHOWN ON CURVE (B)

(A)



(B)

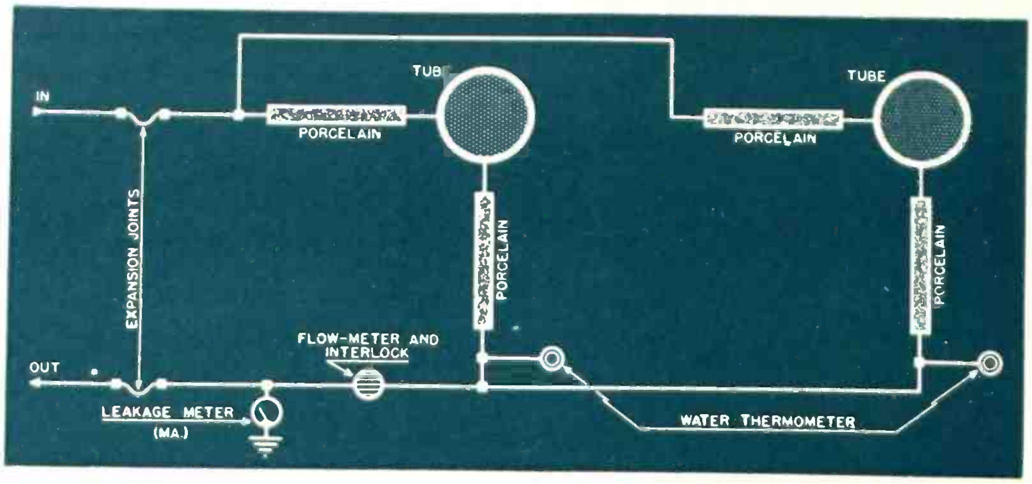


Fig. 4. Schematic diagram of the water-cooling system for transmitting tubes.

water cooled tubes is undertaken. The prevention of scale on the anode of the tube is one of the most important factors to be considered. For this reason, distilled water is highly recommended for use in the cooling systems. The system may be connected with the city water supply if the water conforms to these standards: Hardness of less than 10 grains per gallon, and a specific resistance of at least 4000 ohms per cubic cm. To show the relative importance of having a test made on the water to be used, a table showing an analysis of a typical sample from a water supply system is given in Table 1.

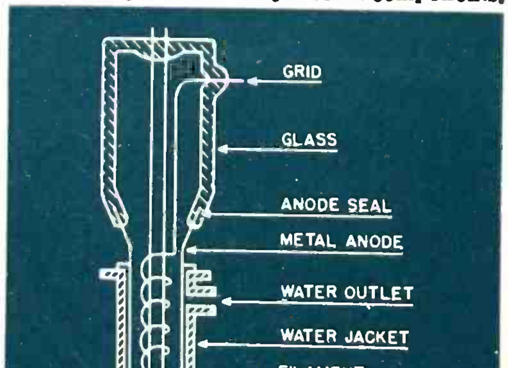
TABLE I

Content	*Grains per Gallon*
Silicia	0.63
Iron Oxide Alumina	0.15
Calcium Carbonate	1.26
Sodium Sulphate	2.14
Potassium Carbonate	2.25
Magnesium Carbonate	2.92
Sodium Chloride	8.17
Total grains per gallon	17.52

Specific resistance: 359 ohms.

Since proper functioning of the water cooling system is of prime importance (without cooling water the heat of the filament alone is sufficient to cause damage), indicating instruments and protective relays must be used in the circuit. An outlet water thermometer and water-flow meter indicated in Fig. 4, are used as indicators of water temperature and rate of water flow. The temperature should never exceed 70° centigrade (158° F) and the rate of flow should be at least 15 gallons per minute. Twenty gallons per minute is more beneficial in retarding accumulation of foreign matter in the jacket and the prevention of steam bubbles along the anode surface. Water-flow circuit breakers, or interlocks which open the circuit breakers in filament and plate power transformer primaries in case of water flow failures, are necessary protective features. A combination interlock and flow-meter is available on the commercial market. The direction of the water flow is in at the bottom and out at top of the jacket. This procedure prevents air traps in the jacket.

Fig. 5. Cut-away diagram of the water-cooled transmitting tube showing various components.



Extraordinary precautions must be taken in the installation of the tube in the jacket. The movable metal parts of the jacket should be coated with a light film of oil to help prevent corrosion. The tube should then be placed gently in the jacket, and after it is correctly seated, the retaining studs or jacket clamping device is fastened firmly into place to force the flange of the plate into solid contact with the water-tight gasket. The electrical connections may then be made. Care should be taken that the wires are not near or do not touch the glass bulb. Should this precaution be neglected, puncture of the glass from corona discharge is apt to occur. Particular care should also be observed in making the connection between hose and jacket tight and clean. Due to electrolysis, trouble may develop at this point, and close inspection every two or three weeks is advisable. Fig. 7 illustrates in schematic form a fairly recent development to combat trouble from electrolysis at this point. The electrolysis "target" is a length of large gauge copper wire soldered to the cap screw and projecting down into the water below the point of metal contact with the porcelain coil or pipe. By replacing these copper wires every 4 to 12 months (depending on the conductivity of the water) practically all trouble due to electrolysis on this positive end of the pipe is eliminated.

A reasonably rigid maintenance schedule should be observed on the entire system to forestall trouble from water leakage, scale formation or formation of steam bubbles, with resultant transmitter shut-down and loss of time on the air. Scale formation, if and when it occurs, will prevent adequate transfer of heat from anode to water. If it becomes necessary to remove the tube for this or any other reason, the tube should be lifted carefully from the jacket after the clamping device has been released. Sticking of the tube often occurs, and in this case a gentle twisting back and forth while lifting will free the tube. Immersion of the plate in a 10% solution of hydrochloric acid is usually recommended to dissolve scale formation. The anode should then be rinsed thoroughly in distilled water.

The formation of steam bubbles may be checked periodically by using a good insulating rod of at least six feet. This should be moved along the jacket while aural observations are made. Precautions should be taken to assure the operators' safety including grounding the testing tube between water jacket and the observer with a "hot-stick" or similar arrangement.

A convenient way for the operator to keep an approximate check on the heat dissipation of the tube is by use of the formula:

$$P(kw) = \frac{n(t_o - t_1)}{4}$$

where:

t_1 = known initial temp. of water °C.

t_o = temp. of water at jacket outlet °C.

n = rate of flow in gallons per minute.

A good check on the general condition of the water, as it affects leakage current back through the system, may be made by connecting a milliammeter to one of the pipes on the insulated side of the circuit as shown in the complete schematic of Fig. 4. This figure also shows "expansion loops" connecting the pipes to the pump.

Forced-Air Systems

Although the problems of deteriorating hose, leaky hose connections, electrolysis and troublesome flow-

(*Continued on page* 34)

Q of LC CIRCUITS

By Dr. F. M. BAILEY
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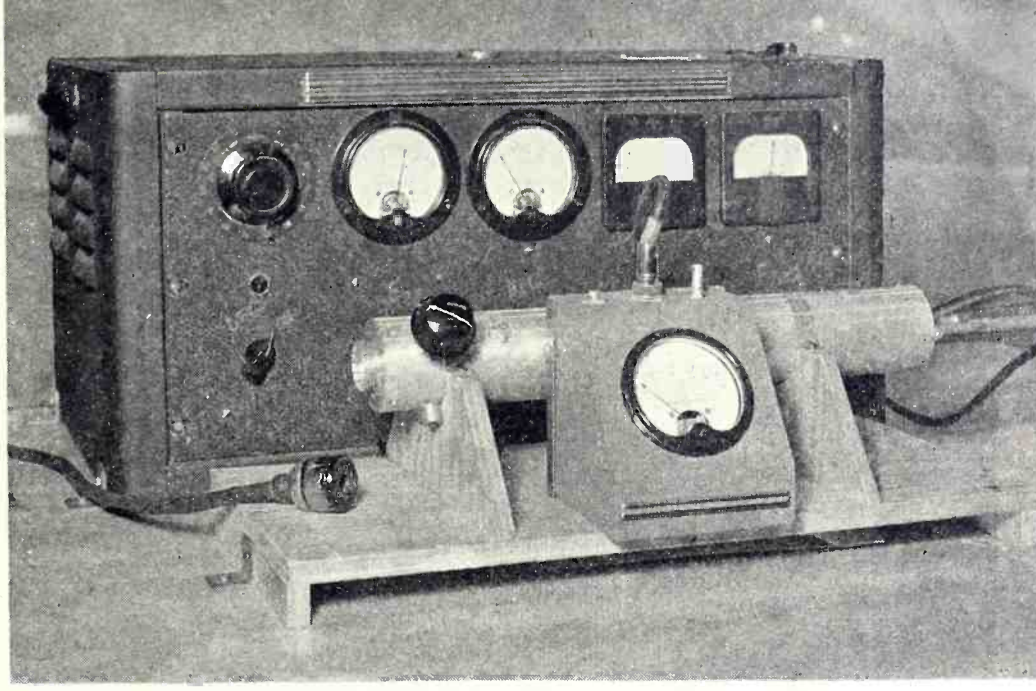
The calculation of Q in resonant circuits utilizing transmission lines as part of circuit.



Q-meter for the production testing of high-frequency resistance of tubes.

At radio frequencies the shunting reactance of the plate-cathode and grid-cathode capacitances of an electronic tube make it necessary to use parallel-tuned circuits at these points to provide a suitable impedance for the plate and grid loads. Impedances formed in this way are exceedingly frequency-sensitive, and in many cases a parallel resistance must be added to the resonant circuit to provide operation over a sufficient band of frequencies. It is of interest, therefore, to examine the parallel-tuned circuit with respect to its bandwidth and effective shunting impedance, using the ratio of reactance to resistance or "Q" of the inductance as a measure of the sharpness of resonance. A convenient way to do this is to consider the distribution of energy in a resonant system during a half cycle of operation.

If the condenser in a resonant circuit is charged to a voltage + V, the energy stored in it is ½ CV^2. Completing the circuit allows the charge on the condenser plates to flow through the inductance L, increasing the magnetic flux within the coil until the condenser is discharged. The energy formerly in the condenser is now in the coil and its value is given by ½LI^2. At this point the magnetic flux begins to collapse, inducing a voltage of opposite polarity across the condenser and eventually charging it to a voltage — V. The process then reverses, current flows through L, and L discharges its magnetic energy until C is again charged to + V. This produces the familiar sine-wave oscillation shown in Fig. 2. The presence of resistance R_L in the inductance L produces an I^2R loss as the current flows through it, extracting a certain amount of energy each cycle and eventually dissipating all of the original energy in the form of heat.

To calculate the energy lost during the passage of current through the resistance in one direction, for one-half cycle, the power lost for one-half cycle is integrated with respect to time, the instantaneous current being taken as $I = I_0 \sin \omega t$.

$$\text{Energy lost} = \int_0^{\frac{\pi}{\omega}} R_L I_0^2 \sin^2 \omega t dt$$

$$= I_0^2 R_L \frac{\pi}{2\omega} \qquad (1)$$

The ratio of the stored energy ($\frac{1}{2}LI_0^2$) to the dissipated energy per one-half cycle gives:

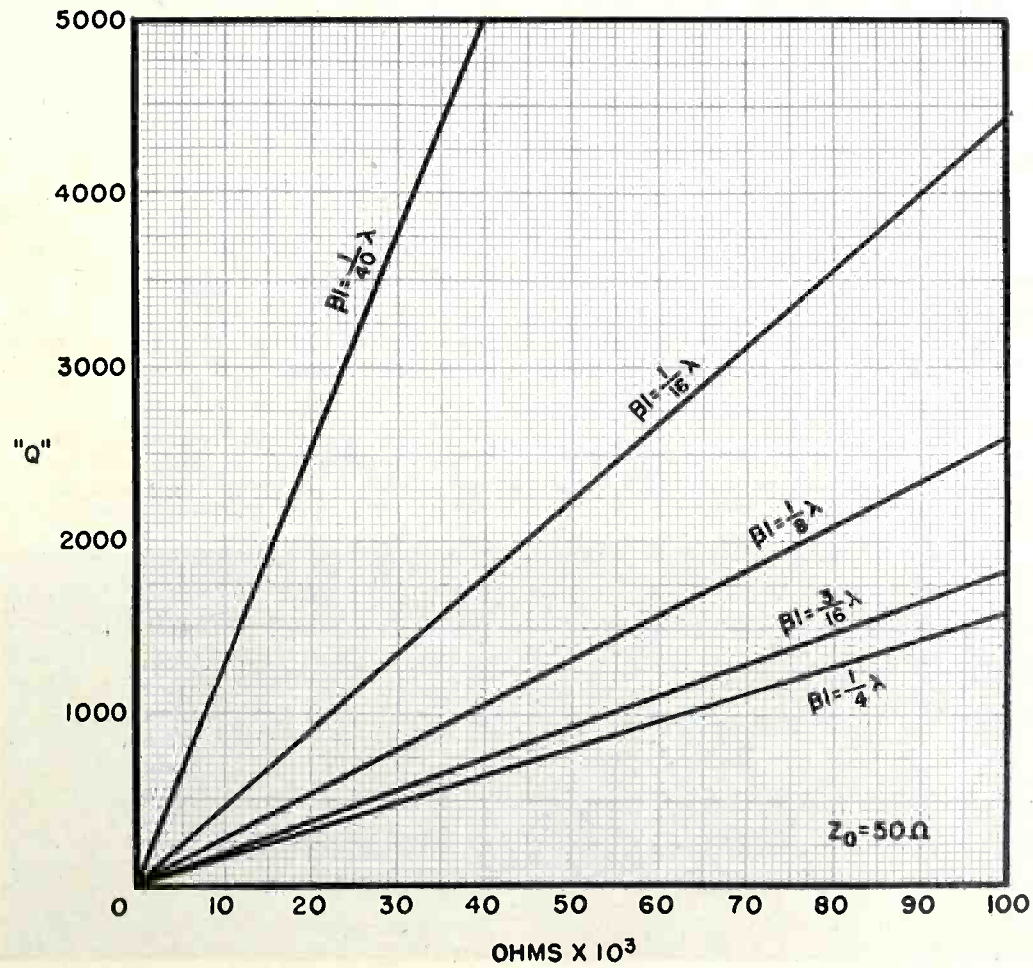
$$\text{Ratio} = \frac{\frac{1}{2} L_0 I_0^2}{\frac{\frac{1}{2} I_0^2 R_L \pi}{\omega}} = \frac{\omega L}{\pi R_L} \qquad (2)$$

Multiplying this ratio by π gives the familiar expression for Q or quality factor of a coil:

$$Q = \frac{\pi \times \text{stored energy}}{\text{energy dissipated per half cycle}}$$

$$= \frac{\omega L}{R_L} \qquad (3)$$

Fig. 1. Q as a function of the equivalent shunting R for a 50 ohm line. Line length is indicated, the remainder of the circuit being made up of the foreshortening capacitance.



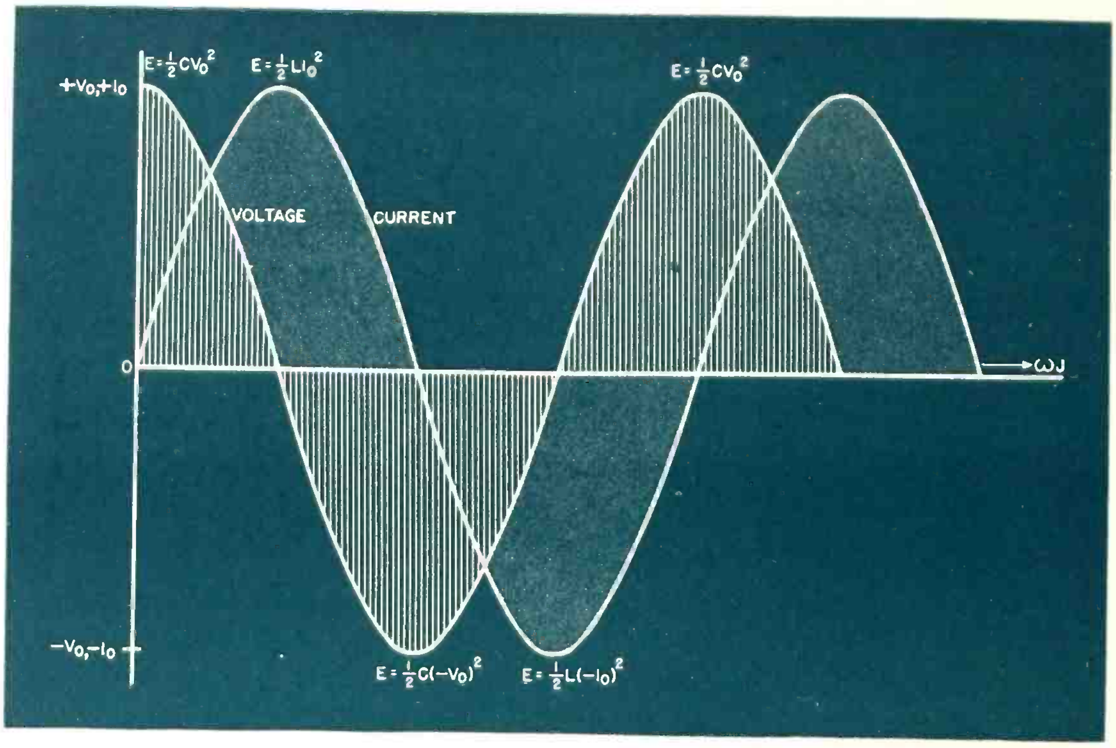


Fig. 2. A graph of the sine-wave oscillations in a resonant LC circuit. Both the voltage and current waves are shown with the energy stored in the capacity due to the voltage wave and the energy stored in the inductance due to the current wave indicated for both the positive and negative portions of the sine wave.

For a single tuned circuit it can be shown[1] that the quantity $\frac{R_L}{\omega L}$ equals $\frac{\Delta f}{f}$ or the bandwidth, where f equals the frequency at the center of the resonance curve and Δf equals the difference in frequency at the half-power points. Thus the bandwidth for a given frequency is proportional to $\frac{1}{Q}$. Since the energy dissipated per half cycle is $\frac{1}{2f}$ times the average power for a sine wave, the above ratio can then be written as:

$$Q = \frac{\omega \times \text{stored energy}}{\text{average power lost}} \quad \text{(4)}$$

To compute the Q of the circuit in Fig. 3B it is necessary to calculate the energy in terms of voltage. This gives:

$$Q = \frac{\omega \times \text{stored energy}}{\text{average power lost}} = \frac{\omega \frac{1}{2} C V_0^2}{\frac{\frac{1}{2} V_0^2}{R_C}} = \omega C R_C \quad \text{(5)}$$

If both circuits in Fig. 3 are resonant at the same frequency, that is, $\omega L = \frac{1}{\omega C}$, and it is assumed that the resulting Q for each is the same, the two expressions for Q may be equated:

$$\frac{\omega L}{R_L} = \omega C R_C \quad \text{(5a)}$$

$$R_C = \frac{L}{C R_L} \quad \text{(6)}$$

Thus a series resistance may be replaced by an equivalent shunt resistance. In other words, the resistance of the wire in a tuned circuit places in effect a shunting resistance across the tuned circuit and prevents the impedance of the parallel circuit from becoming infinite at resonance.

The trend toward higher frequencies has resulted in the discarding of lumped circuits in favor of resonant lines. In this case the energy method of calculating Q provides a convenient means for determining effective impedance.

In the ¼ λ resonant coaxial line in Fig. 4, there is a capacity C per unit length and an effective shunt resistance R due either to resistance of the material of the line or to a tube attached across the line. The voltage distribution along the line is sinusoidal, being zero at the closed end and a maximum at the open end. This causes the amount of stored energy in the line to increase gradually from the closed end to the open end. To get the stored energy, it is necessary to integrate the incremental energy per unit length over the length of the line. If the capacitance per unit length is C and the voltage at each point along the line is $V = V_0 \sin \theta$, then:

$$\text{Stored energy} = \int_0^\theta \tfrac{1}{2} C V^2 d\theta =$$

$$\tfrac{1}{2} C \int_0^{\frac{\pi}{2}} V_0^2 \sin^2 \theta d\theta = \frac{V_0^2}{2} C \frac{\pi}{4} = W_S \quad \text{(7)}$$

$$\text{Average power in R} = \tfrac{1}{2} \frac{V_0^2}{R} \quad \text{(7a)}$$

$$Q = \frac{\omega W_S}{\text{average power lost}} = \omega \frac{\pi}{4} CR \quad \text{(8)}$$

$$\text{Substituting } \omega = \frac{1}{\sqrt{LC}} \quad \text{(8a)}$$

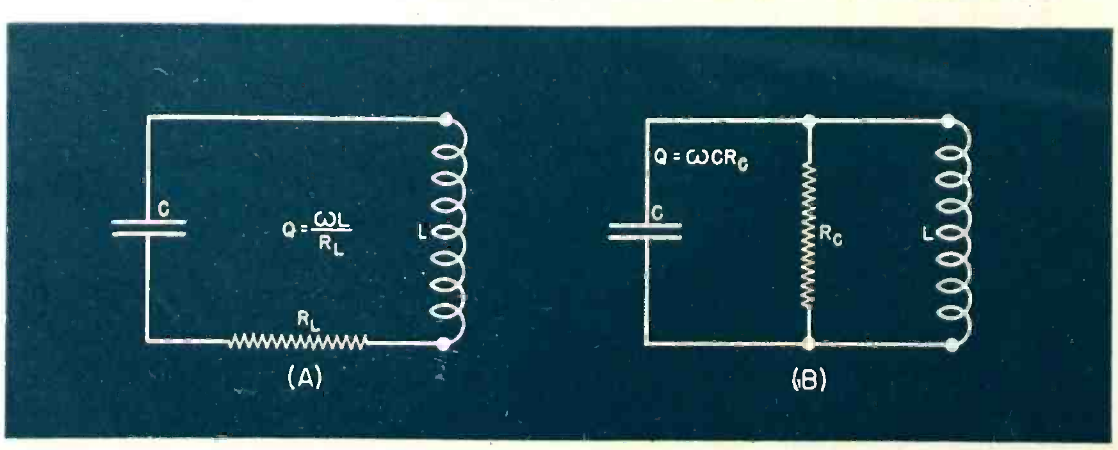
$$Q = \frac{\pi}{4}\sqrt{\frac{C}{L}} R = \frac{\pi}{4} \frac{R}{Z_0} \quad \text{(9)}$$

where Z_0 = characteristic impedance of the line.

$$\text{Thus } R = \frac{4}{\pi} Q Z_0 \quad \text{(10)}$$

A more complicated calculation of Q, but one which more nearly satisfies the practical case, is that of a quarter-wavelength resonant line foreshortened by an end capacitance C_1 and loaded with a resistor R. (See Fig. 5.) In this case one must calculate the energy stored in the line and add to it the energy stored in the foreshortening capacitance C_1 to obtain the total stored energy. Writing the angular position θ along the line in terms of the phase constant β times the distance Z, the stored energy W_s is:

Fig. 3. Equivalent methods of representing the losses in a parallel resonant LC circuit. In part (A) the losses are represented by a resistance R_L in series with the inductance and capacity, while in part (B) an equivalent circuit is shown with the losses represented by a resistance R_C in parallel with the inductance and capacity.



$$W_S = \tfrac{1}{2} C V_0^2 \int_0^l \sin^2 \beta Z \, d Z + \frac{C_1 V_l^2}{2}$$

$$= \tfrac{1}{2} \frac{C V_0^2}{\beta} \left[\tfrac{1}{2} \beta l - \tfrac{1}{4} \sin 2\beta l \right] + \frac{C_1 V_0^2 \sin^2 \beta l}{2} \quad \text{(11)}$$

At resonance the value of the capacitance C_1 can be expressed in terms of the length of the line βl by:[1]

$$\frac{1}{\omega C_1} = Z_0 \tan \beta l \quad \text{(11a)}$$

Solving for C_1 gives:

$$C_1 = \frac{1}{\omega Z_0 \tan \beta l} \quad \text{(12)}$$

Substituting (12) in (11) gives:

$$W_S = \frac{C V_0^2}{2\beta} \left[\tfrac{1}{2} \beta l - \tfrac{1}{4} \sin 2 \beta l \right] + \frac{V_0^2 \sin 2 \beta l}{4 \omega Z_0} \quad \text{(13)}$$

Remembering that for a transmission line the phase constant can be expressed as $\beta = \omega \sqrt{LC}$, or:

$$\frac{C}{\beta} = \frac{C}{\omega \sqrt{LC}} = \frac{1}{\omega} \sqrt{\frac{C}{L}} = \frac{1}{\omega Z_0} \quad \text{(14)}$$

The expression for W_s reduces to:

$$W_S = \frac{V_0^2}{2 \omega Z_0} \left[\frac{\beta l}{2} + \frac{\sin 2 \beta l}{4} \right] \quad \text{(15)}$$

The average power dissipated is given by:

$$W_D = \frac{V_l^2}{2R} = \frac{V_0^2 \sin^2 \beta l}{2R} \quad \text{(16)}$$

and the Q by:

$$Q = \frac{\omega W_S}{W_D} = \frac{R \left[\beta l + \frac{\sin 2 \beta l}{2} \right]}{2 Z_0 \sin^2 \beta l} \quad \text{(17)}$$

Examining this expression for the case where there is no foreshortening capacitance and $\beta l = \frac{\pi}{2}$, (17) becomes $Q = \frac{R\pi}{4Z_0}$ as obtained in the previous derivation.

In Fig. 1 is shown a plot of Q as a function of the equivalent shunting R for a fifty-ohm line and for different amounts of foreshortening. In each case the fractional part of the quarter wavelength represents the length of the resonant system which is line, the remainder being consumed by a suitable capacitance C_1 (Fig. 5). The increasing slopes of the lines with increased size of foreshortening capacitance is expected since in a parallel resonant coil and condenser circuit the Q increases with increasing $\frac{C}{L}$ ratio.

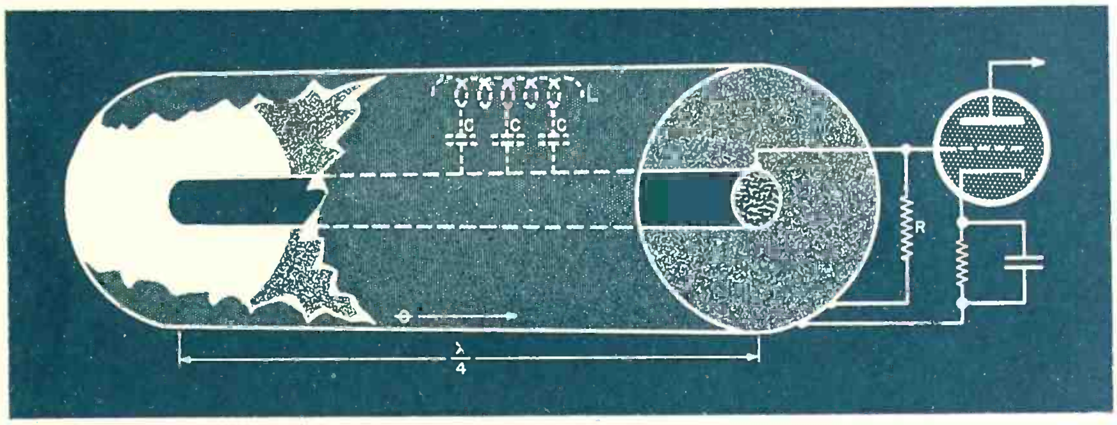


Fig. 4. A quarter wave-length resonant coaxial cable, showing the distributed inductance and capacitance and the equivalent shunting resistance.

A coaxial resonant line provides a practical means of determining resistance at high frequencies, for example, the effective resistance of an electronic tube. With the tube terminals placed across the end of the line the Q can be measured by plotting a resonance curve for the system. This is done by introducing a variable frequency signal into the line with a small loop and extracting enough energy on a second loop to measure the response. Such test equipment used for the production testing of tubes is shown in the photograph.

The limiting value of Q obtained in a resonant line depends of course on the loss of power in the conductors. This in turn depends on the dimensions of the conductors and the frequency, since frequency determines the skin effect and so the amount of conductor used. For a fifty-ohm copper line with an outer conductor diameter of three inches, a theoretical Q of 13,500 could be achieved at 200 megacycles. This represents an effective shunt resistance of 860,000 ohms. Since the resistance of most electronic devices at high frequencies is much lower than this, their resistance and not the resistance of the line will determine the Q.

In a strict analysis, the energy method of computing Q is valid only if the stored energy in the system is constant. This is true if the energy lost per cycle can be neglected to permit the inductive and capacitive energies to be approximately equal. Since most practical circuits have a Q sufficiently large to satisfy this condition, the bandwidth calculation can be made quite accurately by determining the stored and dissipated energies.

The above method for calculating the Q of a resonant circuit comprised of a section of transmission line, foreshortened by a capacitance is a valuable tool, in view of the extensive use of transmission lines at present.

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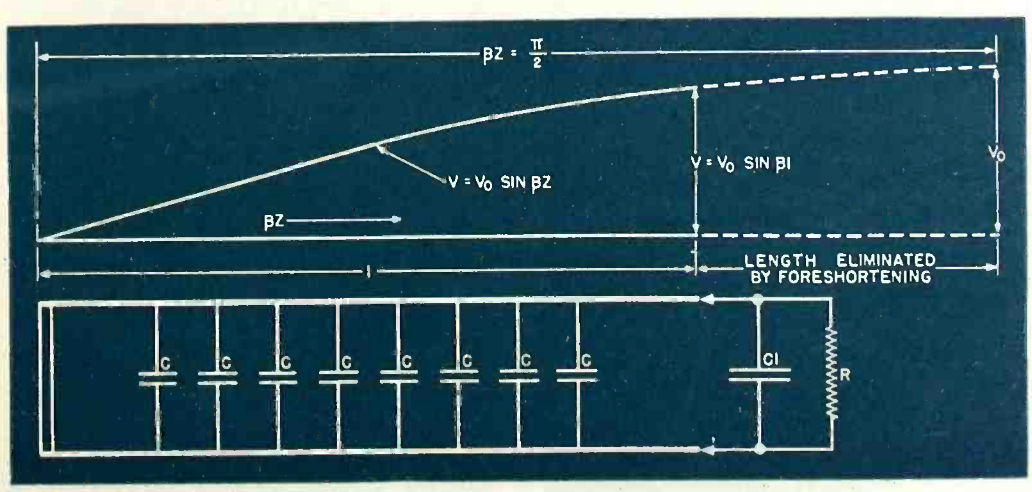
Fig. 5. Equivalent circuit of a line which has been foreshortened by a capacitance C_1. The actual length of the line is less than ¼λ, but the electrical length has been increased to ¼λ by the addition of the foreshortening capacitance C_1. Any type of line, such as a twisted pair, parallel spaced line, or coaxial cable may be represented in this manner.



MATRIX ALGEBRA in Network Theory

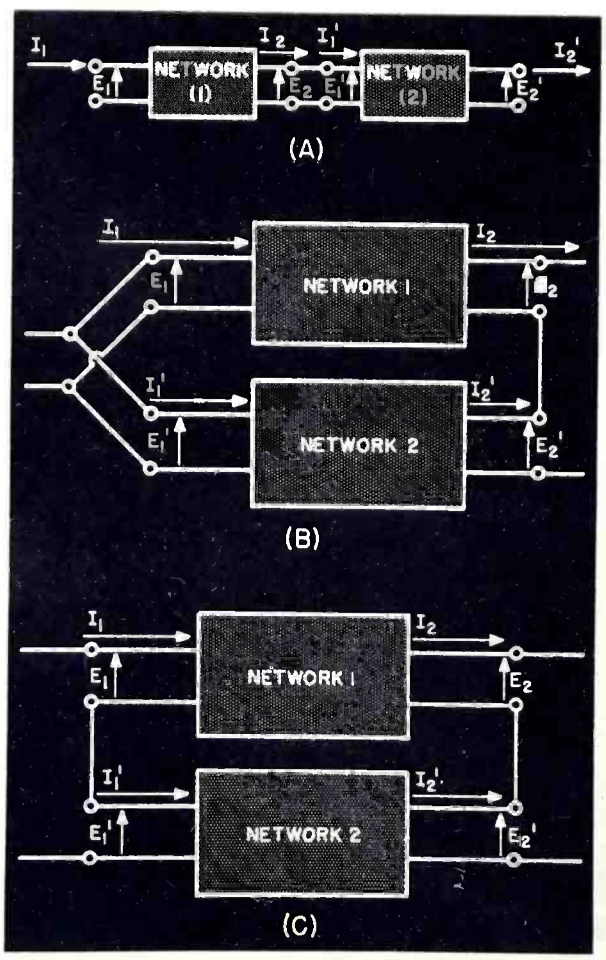
By D. FIDELMAN

A simplified method of solving network problems using matrix algebra instead of the more conventional mathematics.

IN THE study of electrical networks, the mathematical details tend to become quite complicated, even for the simplest problems encountered. In the case of more complex network manipulations, the algebraic computations become too involved to handle easily. By the use of matrix algebra it is possible to eliminate the major portion of this mathematical confusion.

The advantage of this system may be illustrated by the simple case of the linear, passive four-terminal network shown in Fig. 2a. It is known that for such a circuit the following relations are true:

Fig. 1. Possible interconnections of a pair of dissimilar four-terminal networks.



$$\left.\begin{aligned} E_1 &= AE_2 + BI_2 \\ I_1 &= CE_2 + DI_2 \end{aligned}\right\} \quad \text{(1)}$$

where A, B, C, and D are called the general circuit parameters and obey the relation

$$AD - BC = 1$$

If it becomes desirable to connect this network in cascade with another similar four-terminal network as shown in Fig. 2b, then the output current and voltage of network 1 become the input current and voltage of network 2. In order to find E_1 and I_1 in terms of E_2' and I_2' it is necessary to substitute the results of equations (1) into similar equations for network 2. When this is done and the terms are regrouped in a form similar to that of equations (1), the result is found to be:

$$\left.\begin{aligned} E_1 &= \alpha E_2' + \beta I_2' \\ I_1 &= \gamma E_2' + \delta I_2' \end{aligned}\right\} \quad \text{(2)}$$

where:

$$\left.\begin{aligned} \alpha &= AA' + BC' \\ \beta &= AB' + BD' \\ \gamma &= CA' + DC' \\ \delta &= CB' + DD' \end{aligned}\right\} \quad \text{(3)}$$

In order to appreciate the amount of work involved, the algebraic steps of the above transformation should be worked out. It can be seen easily how complicated this procedure becomes when more than two such networks are cascaded, or when it is necessary to manipulate more complex types of networks.

However, such transformations can be represented very simply by the use of matrix operators. By referring to equations (1), the following arrangement of coefficients may be made:

$$\left\|\begin{matrix} A & B \\ C & D \end{matrix}\right\| \quad \text{(3a)}$$

This is called the *matrix*, or the *transformation matrix*, of the system. In matrix form, equations (1) would be rewritten thus:

$$\left\|\begin{matrix} E_1 \\ I_1 \end{matrix}\right\| = \left\|\begin{matrix} A & B \\ C & D \end{matrix}\right\| \left\|\begin{matrix} E_2 \\ I_2 \end{matrix}\right\| \quad \text{(4)}$$

The cascade connection of the two networks is represented by substituting the matrix representation of network 2 into equation (4), which gives as a result:

$$\left\|\begin{matrix} E_1 \\ I_1 \end{matrix}\right\| = \left\|\begin{matrix} A & B \\ C & D \end{matrix}\right\| \left\|\begin{matrix} A' & B' \\ C' & D' \end{matrix}\right\| \left\|\begin{matrix} E_2' \\ I_2' \end{matrix}\right\| \quad \text{(5)}$$

Thus, the transformation is obtained in a more simple and direct manner than before. This same transformation may be extended to any number of additional networks connected in cascade.

Before continuing with the development of this method, it is desirable to set down the various rules and definitions that have been developed for the manipulations of matrix operators.

Fundamentals of Matrix Algebra

Although a matrix is similar in appearance to a determinant, their dissimilarity should be kept clearly in mind. A determinant represents a definite value obtained by a process of expansion, while a matrix is simply a rectangular array of elements representing a set of operations that involve these elements.

A matrix is usually denoted as:

$$\|a\| = \left\|\begin{matrix} a_{11} & a_{12} & \dots & a_{1N} \\ a_{21} & a_{22} & \dots & a_{2N} \\ \dots & & & \dots \\ a_{M1} & a_{M2} & \dots & a_{MN} \end{matrix}\right\| \quad \text{(5a)}$$

where the quantities a_{ij} are called the elements of the matrix, and may be any algebraic constants or operators. The number of rows M need not necessarily be equal to the number of columns N. However, a rectangular matrix, i.e., one in which $N \neq M$, can be considered a square matrix in which the elements of the missing rows or columns are set equal to zero.

Two matrices are defined as being equal when they have the same number of rows and columns and each element of one is equal to the corresponding element of the other.

The fundamental operations of matrix algebra are defined in the following manner.

Matrices are added (or subtracted) by adding (or subtracting) their corresponding elements, thus:

$$\begin{Vmatrix} a_{11} & a_{12} & \dots & a_{1N} \\ a_{21} & a_{22} & \dots & a_{2N} \\ \cdot & \cdot & \cdot & \cdot \\ a_{N1} & a_{N2} & \dots & a_{NN} \end{Vmatrix} + \begin{Vmatrix} b_{11} & b_{12} & \dots & b_{1N} \\ b_{21} & b_{22} & \dots & b_{2N} \\ \cdot & \cdot & \cdot & \cdot \\ b_{N1} & b_{N2} & \dots & b_{NN} \end{Vmatrix} =$$

$$\begin{Vmatrix} a_{11}+b_{11} & a_{12}+b_{12} & \dots & a_{1N}+b_{1N} \\ a_{21}+b_{21} & a_{22}+b_{22} & \dots & a_{2N}+b_{2N} \\ \cdot & \cdot & \cdot & \cdot \\ a_{N1}+b_{N1} & a_{N2}+b_{N2} & \dots & a_{NN}+b_{NN} \end{Vmatrix} \quad (6)$$

The elements of the product of two matrices $\|a\|$ and $\|b\|$ are defined in the following manner:

$$\|a\,b\|_{jk} = \begin{Vmatrix} \sum_{l=1}^{N} a_{jl}\, b_{jl} \end{Vmatrix} \quad \dots\dots (7)$$

That is, the elements of the j^{th} row of $\|a\|$ are multiplied by the corresponding elements of the k^{th} column of $\|b\|$. This should be compared with equations (2), (3) and (5) for the specialized case of two four-terminal networks connected in cascade. Equation (2) is obtained from (5) by equating corresponding elements on both sides of the equality.

It can be seen from equation (7) that multiplication of two matrices is not commutative. That is, in general,

$$\|a\|\;\|b\| \neq \|b\|\;\|a\| \quad \dots\dots (8)$$

Matrices for which this product does happen to be commutative are said to be *symmetrical* matrices.

A matrix is multiplied by a factor when each of its elements is multiplied by this factor:

$$k\,\|a\| = \begin{Vmatrix} ka_{11} & ka_{12} & \dots & ka_{1N} \\ \cdot & \cdot & \cdot & \cdot \\ ka_{N1} & ka_{N2} & \dots & ka_{NN} \end{Vmatrix} \quad \dots\dots (9)$$

The inverse, or reciprocal, of a matrix $\|a\|$ is defined as that matrix which, when multiplied by $\|a\|$, gives the product unity. That is:

$$\|a\|^{-1}\,\|a\| = \|a\|\,\|a\|^{-1} = \|I\| \quad \dots\dots (10)$$

where the unit matrix $\|I\|$ is defined as the matrix having the elements along its principal diagonal equal to 1, and all the others equal to zero:

$$\|I\| = \begin{Vmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \dots & 1 \end{Vmatrix} \quad \dots\dots (10a)$$

The inverse matrix is formed by first replacing each element by its minor in the corresponding determinant formed from the elements of the matrix $\|a\|$, then dividing each minor by this determinant, and interchanging rows and columns. Applying this rule:

$$\begin{Vmatrix} a_{11} & a_{12} & \dots & a_{1N} \\ a_{21} & a_{22} & \dots & a_{2N} \\ \cdot & \cdot & \cdot & \cdot \\ a_{N1} & a_{N2} & \dots & a_{NN} \end{Vmatrix}^{-1} =$$

$$\begin{Vmatrix} \frac{A_{11}}{|a|} & \frac{A_{12}}{|a|} & \dots & \frac{A_{1N}}{|a|} \\ \frac{A_{21}}{|a|} & \frac{A_{22}}{|a|} & \dots & \frac{A_{2N}}{|a|} \\ \cdot & \cdot & \cdot & \cdot \\ \frac{A_{N1}}{|a|} & \frac{A_{N2}}{|a|} & \dots & \frac{A_{NN}}{|a|} \end{Vmatrix} \quad \dots\dots (11)$$

where $|a|$ is the determinant composed of the elements of $\|a\|$ and A_{ji} is the minor of the element a_{ji} in this determinant.

A matrix is said to be singular if the determinant of its elements is zero. Such a matrix has no inverse. If the determinant of the elements does not vanish, the matrix is said to be non-singular.

The inverse matrix derives its significance from the process of solving simultaneous equations. For instance, in equation (5) it might be necessary to know the output current and voltage in terms of the input, instead of in the form in which it has been given. This would then be:

$$\begin{Vmatrix} E_2' \\ I_2' \end{Vmatrix} = \begin{Vmatrix} \alpha & \beta \\ \gamma & \delta \end{Vmatrix}^{-1} \begin{Vmatrix} E_1 \\ I_1 \end{Vmatrix} \quad \dots\dots (12)$$

The transpose $\|a\|_t$ of the matrix $\|a\|$ is defined as that matrix derived from $\|a\|$ by interchanging the rows and columns.

With the exception that multiplication of matrices is not in general commutative, the laws of matrix algebra are similar to those of ordinary algebra. That is:

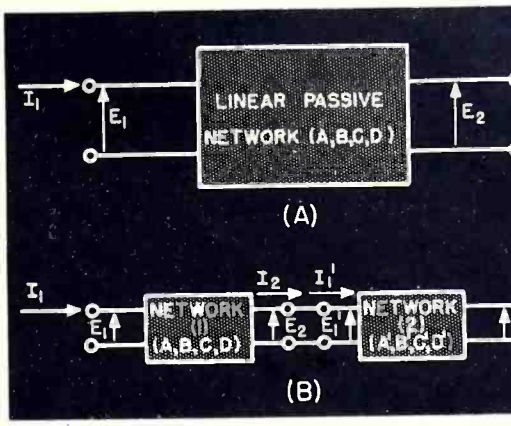


Fig. 2. Four terminal networks, showing reference directions for voltage and current.

$$\|a\| + \|b\| = \|b\| + \|a\| \quad \dots\dots (12a)$$

$$\|a\| + [\|b\| + \|c\|] = [\|a\| + \|b\|] + \|c\| \quad \dots\dots (12b)$$

If k and l are scalars:

$$k\,\|a\| + k\,\|b\| = k\,[\|a\| + \|b\|] \quad \dots\dots (12c)$$

$$k\,\|a\| + l\,\|a\| = [k + l]\,\|a\| \quad \dots\dots (12d)$$

If $\|c\|$ and $\|d\|$ are matrices;

$$\|c\|\,\|a\| + \|c\|\,\|b\| = \|c\|\,[\|a\| + \|b\|] \quad \dots (12e)$$

$$\|c\|\,\|a\| + \|d\|\,\|a\| = [\|c\| + \|d\|]\,\|a\| \quad \dots (12f)$$

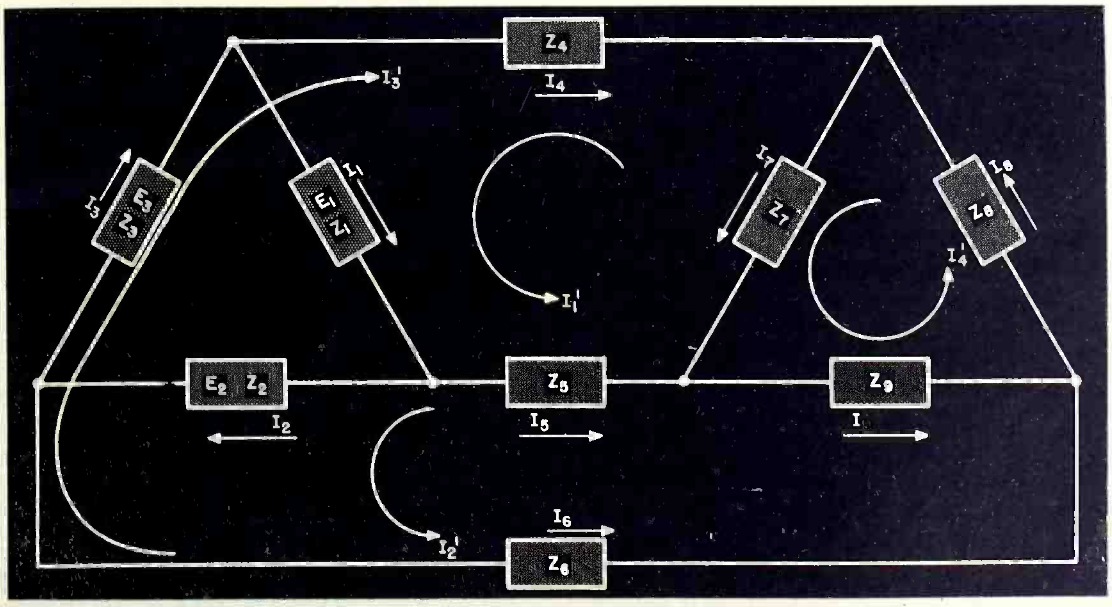
Matrices in Network Theory

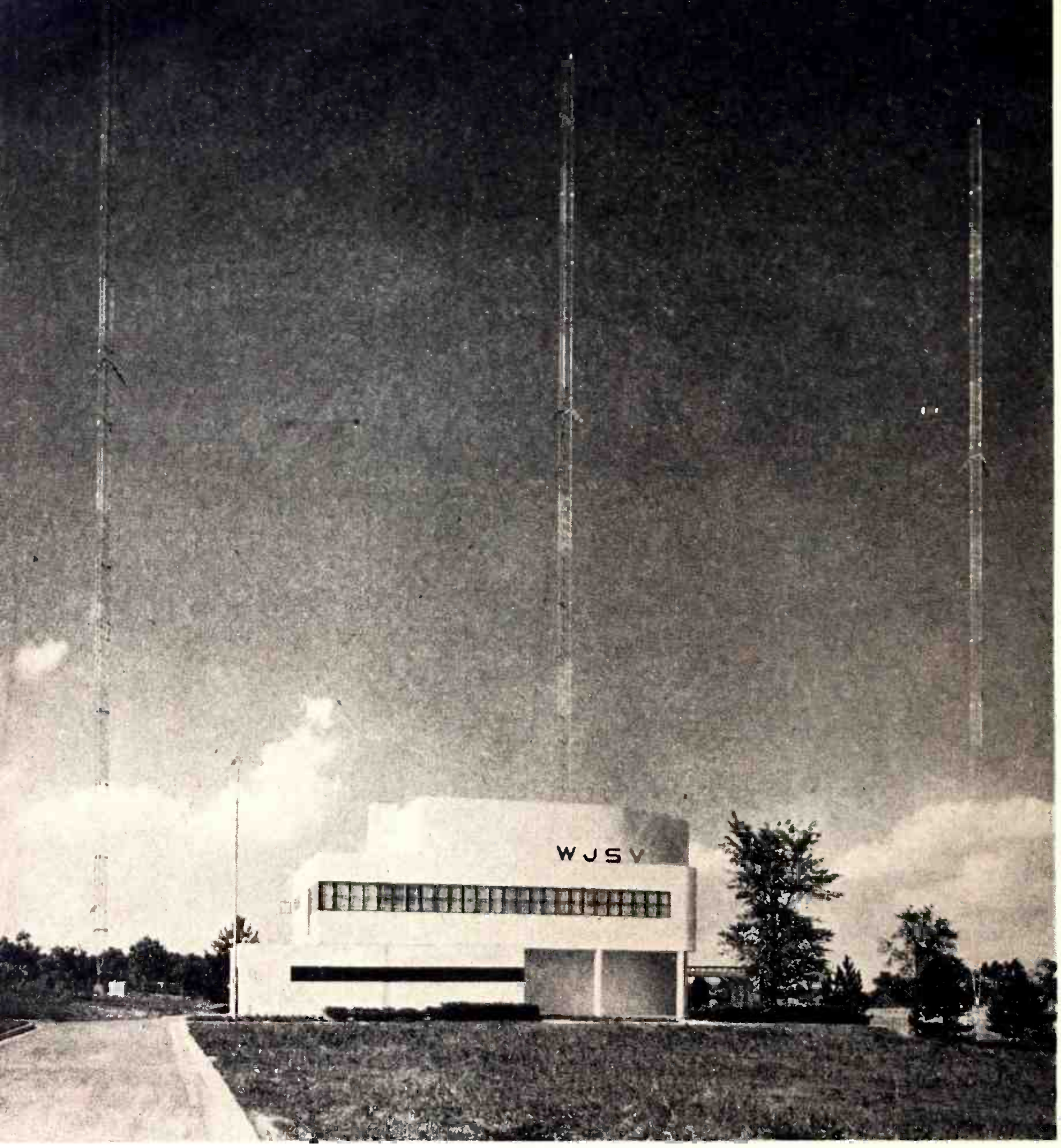
Fundamentally, all electrical network problems must be formulated from five basic laws:

1. Ohm's law.
2. The relation between current through and voltage across an inductor.
3. The relation between current through and voltage across a capacitor.
4. Kirchhoff's voltage law.
5. Kirchhoff's current law.

(*Continued on page* 42)

Fig. 3. Three-phase circuit delta-delta connected, with assumed directions of current flow.





A three-antenna array used in directional transmitting for standard broadcasting.

Broadcast Transmitter Maintenance

By PAUL A. BERG
Broadcast Engineer, Station WJJD

An analysis of common transmitter failures in the commercial broadcast field with suggestions for easy correction.

THE operational engineering of radio frequency transmitting equipment is one of the specialized fields of electronics. While this art is not new, it has become an ever increasingly important one both in war and peace. However, it has been only recently that technical information about transmitting equipment has been available through technical publications and texts although information regarding receivers has been covered thoroughly.

The operation of receiving equipment is in some respects comparable to the operational methods used in transmitter work. The hazards of high operating potentials utilized in transmitter equipment are not a problem of the receiver or communications operator. Point to point measurements with equipment familiar to the communications operator, is impossible on transmitter equipment unless the equipment is shut down.

In transmitting, time is the most important factor. A station must be kept on the air, hence long periods of time are not available to the station engineer for determining and correcting the trouble. The cost of time lost on commercial stations may run into four figures within an hour, while on non-commercial transmitting, this loss may be transferred into loss of human lives and damage to property. This is particularly true under war-time conditions.

Keeping the station on the air, is the problem of the station engineer and good performance by the station depends in a large part, on the ability of the engineers to judge the cause of failure and make the decisions regarding repair work, rapidly and accurately.

It is important that all equipment used in transmitting include protective devices to prevent serious accident to the operating personnel.

A thorough knowledge of the transmitter circuit, is a primary requisite for the station engineer. Inasmuch as the average transmitter operates with controls in sequence, the location of trouble may be made quickly and accurately, if the engineer is familiar with the transmitter.

These control circuits may be divided into two operational categories, first, those which open and close the primary circuits of the respective power supplies and second, those whose function is purely protective.

The controls of the first classification while serving as remote controlled contactors are also interlocked in such a manner that they may be energized only in the proper sequence. The protective controls are placed at various points between the contactors to prevent the sequence from continuing beyond a given point if the respective protective control is not in its proper operating position.

Fig. 2 illustrates a basic transmitter control circuit. In this diagram, the contacts have been placed on one side of the power line only and simple switches have been drawn instead of contactors. Regardless of the complexity of the system, the principle illustrated in Fig. 2, will provide the basic knowledge necessary to understand the proper sequence in tracing faults. The approximate location of trouble may be made by observing the pilot lights. Thus if pilot 5 ceases to light although pilot 3 is still in operation, it is obvious that the bias voltage has failed.

Once the operational sequence of the control system has been committed to memory, the cause of the failure may be traced with a minimum of time and trouble. Where polyphase rectifiers are employed a failure of a specific rectifier may be located through the control circuit by means of the knowledge of the relative phase in which a particular holding coil is located. Thus the failure of a tube in phase "B" would be unlikely to drop any of the relays in the other phases due to the momentary overload on the line when such a tube inverses.

The first type of control, as discussed above, may be classed as a remote-control switch, differing from the usual type in one respect, that the starting button may be energized only when the preceding contactor is closed. Where power requirements are large, a master contact breaker is employed and its holding coil derives its energy from the control relay. This feature permits the proper grouping of equipment with all control circuits located on a single panel.

Fig. 1 shows a complete working diagram of the control circuits used in a modern high-power transmitting station.

Relay (Ry) 1, in this diagram, serves both as a sequence control and a master contactor for the motor operating the forced-cooling system, which in the case of a water-cooled installation would be the water pump and in the case of a forced-air system, would be the air-duct blower. The power for the holding coil of Ry2 is derived from the load side of the contacts of Ry1 and from a pressure relay, not shown in Fig. 1. Thus, Ry2 cannot be energized unless Ry1 and the pressure switch are both closed. While identical in operation with Ry1, Ry2 operates the master contact breaker which carries the actual filament power.

Time delay #1 (TD1), whose function is to close Ry3 after a pre-determined length of time, is the next control in the sequence. Ry3 merely completes the sequence after TD1 has closed as the power rating of the Ry3 is extremely low. The door switches for the protection of the operating personnel are interposed at this point. After Ry3 closes, providing the doors are all properly closed, the holding coil of Ry4 becomes energized. This in turn will close the primary circuit of the oscillator power supply and carry the sequence to Ry5. MCB #2, whose contacts operate in the primary of the bias supply, is controlled by Ry5.

Between Ry5 and Ry6, a protective relay Ry7 is inserted. Its function is to permit the closing of Ry6 only if the intermediate amplifier-bias voltage is of sufficient value to prevent damage to the tube in that circuit.

Ry6 is of the sub-control type, as are Ry2 and Ry5, and serves to apply the intermediate high voltage through MCB #3.

Referring again to Fig. 1, it will be noted that in the starting button circuit of Ry8, whose function it is to energize the high voltage contact, is interposed several protective devices. These devices are the contacts of Ry9 and Ry10, the contacts of the d.c. overload relay, an emergency stop button, and an additional set of terminals for the insertion of other protective devices.

The holding coil of Ry9 is in series with the grid return of the driving amplifier and the closing of the contacts depends upon the presence of sufficient grid current. The value of this type of interlock is questionable when certain types of grid bias are employed. Where grid-leak bias is used in sufficient quantities, this type of protection is adequate for the purpose of preventing excessive plate overloads due to insufficient bias. Besides its use as a protective device, Ry9 also serves to warn of any failure in the oscillator or intermediate amplifier circuits by means of a drop in the high voltage contact and its corresponding pilot. The closing of Ry10 is dependent upon the presence of sufficient d.c. bias voltage.

Voltages in excess of 10,000 volts are usually applied in two steps. Contact Ry11, through Time Delay #2 shorts out the primary reactor within a few seconds of the closing of Ry8. Ry12 serves no purpose in the control system other than that of operating the pilot lights of Ry8 and Ry12.

Control systems vary with the station and manufacturer, hence the system shown in Fig. 1 does not have a universal application but may be considered typical of any large transmitter. The adoption of additional protective devices may be made when the local conditions warrant.

While the present trend in transmitter construction is toward the use of the relay system, there are still many transmitters in operation in which the circuits are protected by fuses. It is recommended that the testing of fuses as a possible source of transmitter failure be disregarded in favor of the replacement of suspected fuses. Installation of new fuses will result in a lower time loss than the testing would involve, especially with those fuses lying directly behind the interlocking doors. These fuses cannot be reached while the transmitter is in operation, and a station shut-down results in serious time losses.

Where polyphase power supplies are used, the replacing of fuses is preferable to the testing of these fuses in all cases where the station engineer is not thoroughly familiar with the equipment with which he is working. Testing against ground results in confusion and in the case of the three-phase circuit, the fuses should be replaced in all three phases and the removed cartridges tested later.

Both fuses and magnetic relays are subject to mechanical or electrical failure due to imperfect contacts within the cartridges, or oxidized contacts and sticking mechanisms within the relays.

The holding coil in any relay presents a potential source of failure and must be considered when clearing any difficulty.

Transmitter power supplies differ little from those used in receivers and other electronic devices except in the matter of size. The tubes used in the transmitter power supply are usually of the mercury-vapor type to conserve

A 50-kilowatt transmitter installed at WJSV, CBS outlet in Washington, D. C.

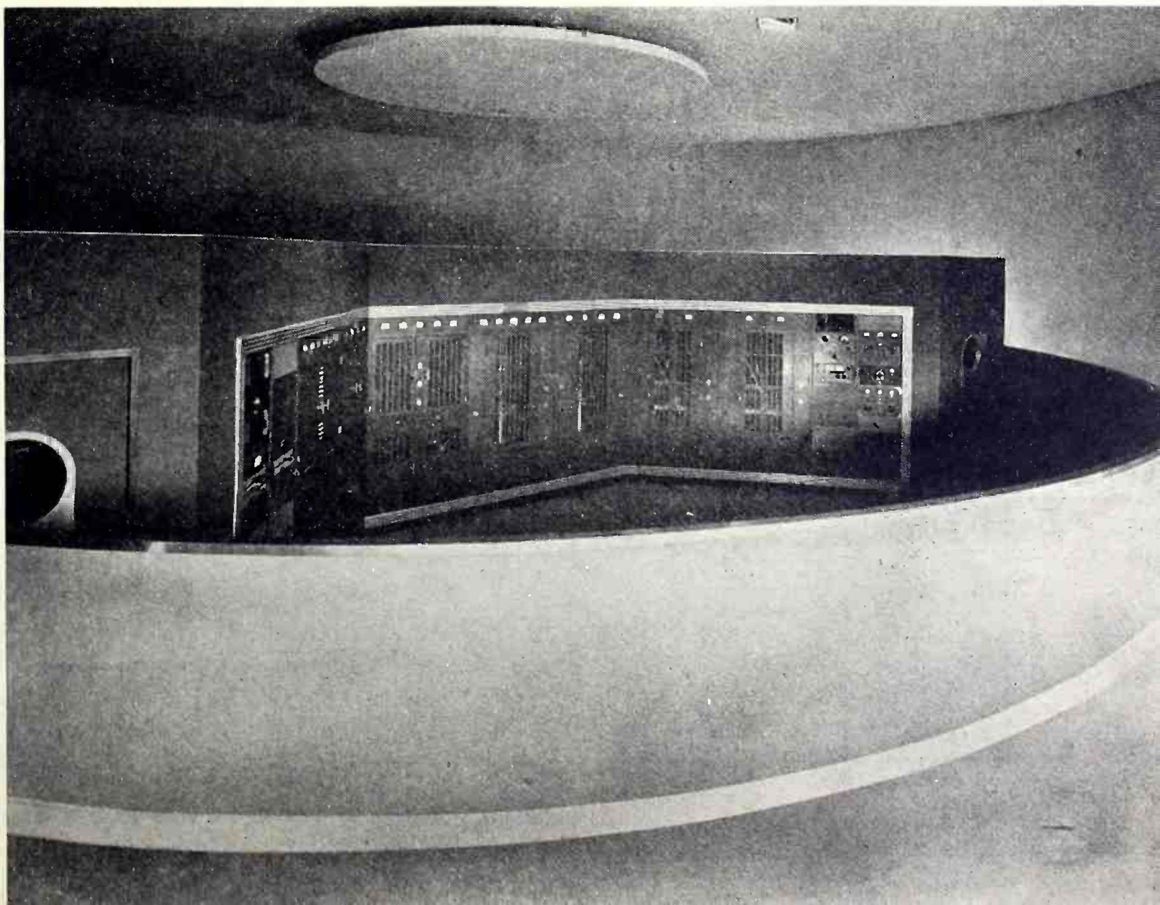
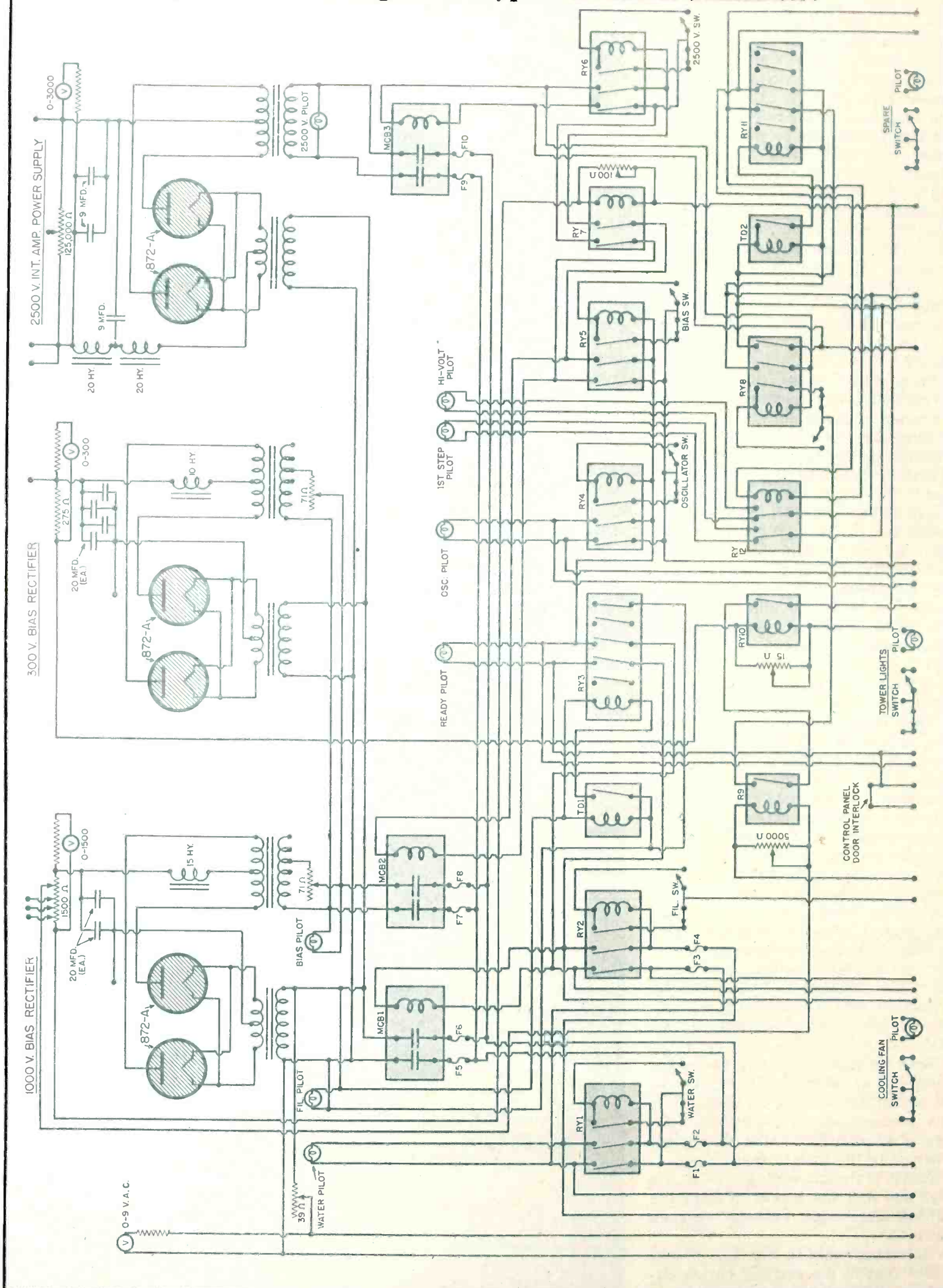
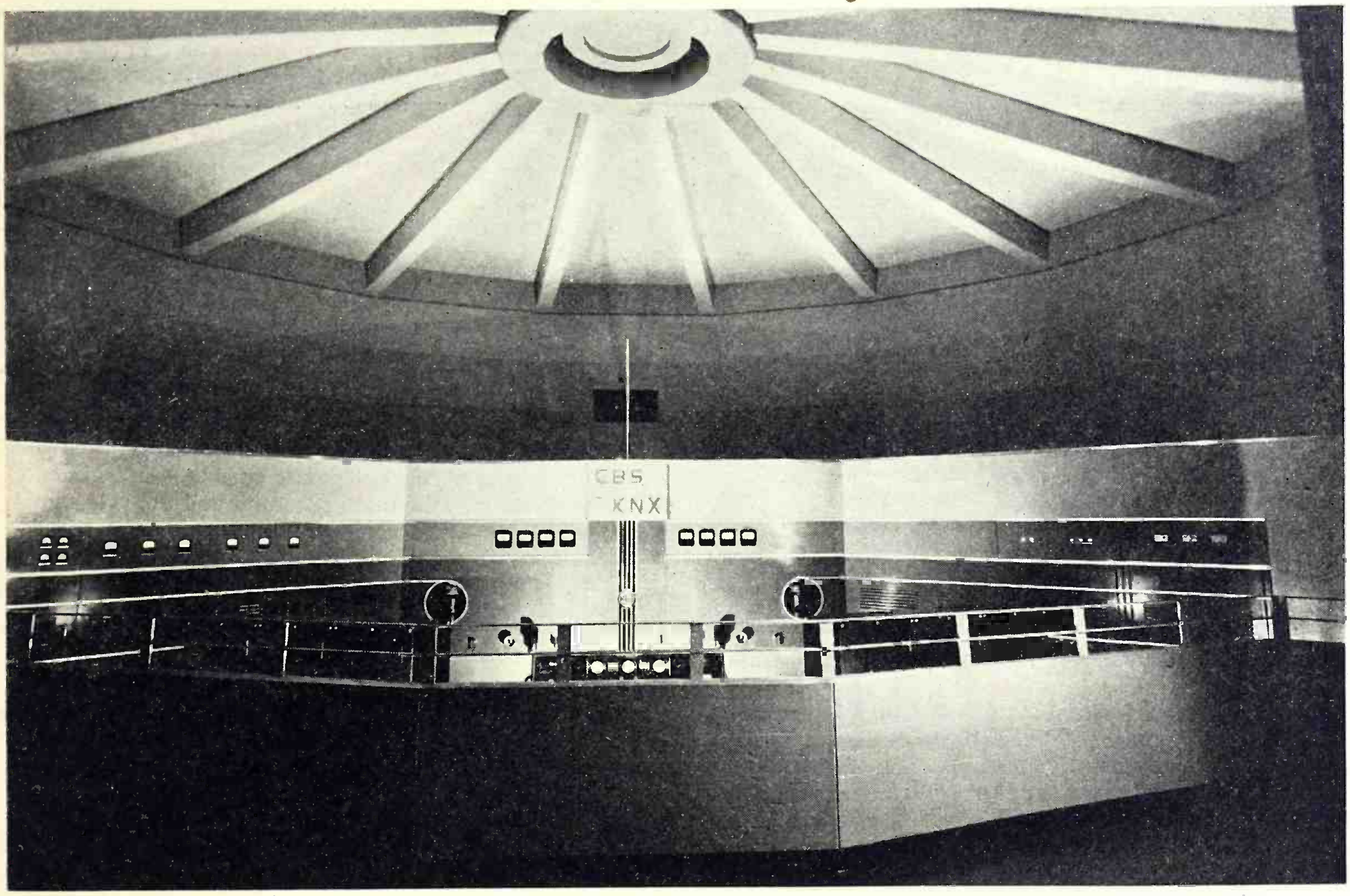


Fig. 1. Schematic diagram of a typical broadcast transmitter.





The main operating room for the 50-kc broadcast transmitter at station KNX located at Torrance, California.

potential and power loss, which factors become increasingly important as the power demand becomes greater.

Three-phase rectifiers are used since, in addition to requiring only a small amount of filtering, the steady state values very nearly approach the peak value which permits maximum tube economy.

In general, failures in large power supplies are fairly obvious through physical evidence of damage to the component involved in the failure, such as a sustained arc, or a smoking part. Voltage dividers, bleeder resistors and capacitors which have failed usually may be recognized by visual inspection because of the physical damages to the part.

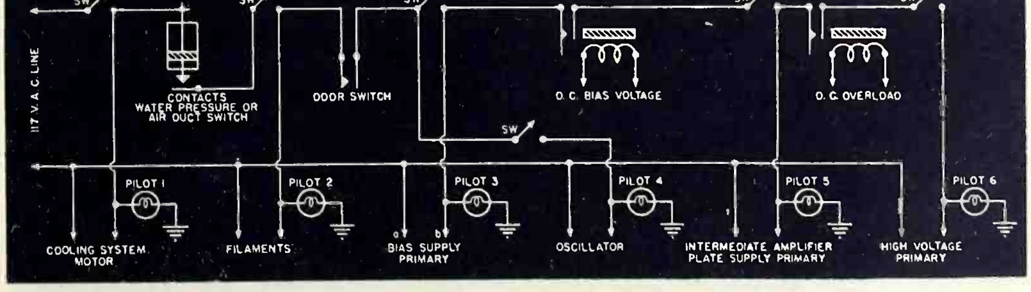
One of the first of suspected causes of failure in power supplies should be the rectifier tubes. The amount of current flowing in the tubes may be approximated by the amount of glow in such tubes. While this method precludes a certain familiarity with these particular tubes, the amount of time saved by this visual inspection will make the time spent in mastering this technique worthwhile. Where an extremely large current is seen to flow through the rectifier, the filament transformer or the first section of the filter should be investigated. A lesser degree of overload might indicate a certain resistance in the circuit and the load side of the supply is the cause. The failure of the rectifier tube to show any ionization will clearly indicate an open circuit. An instantaneous ionization flash will indicate a charging of a capacitance.

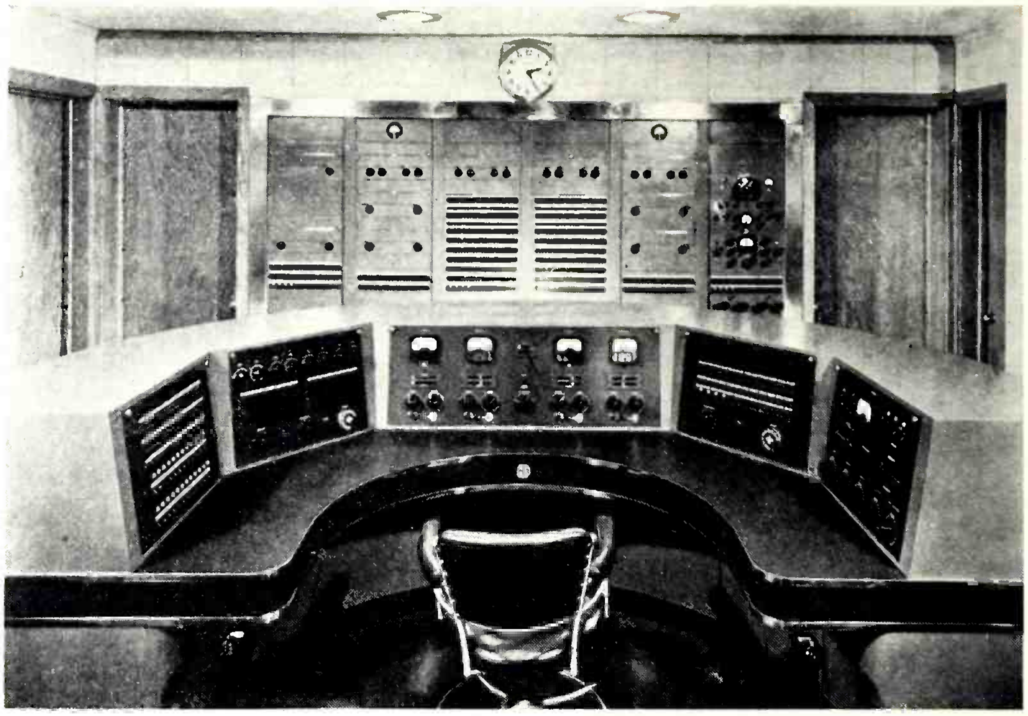
Another rapid and effective method of locating trouble caused by short circuits in power supplies is to remove the fuses from the circuit, replacing them with shorting bars or a limiting resistance. The point of short is then clearly ascertainable, although this method should be used only by the experienced station engineer.

Since rectifier tube failures constitute the major fault in power supplies, under certain conditions it may be deemed advisable to replace these tubes upon expiration of their rated life. If additional service from these tubes is necessary, they may be used longer than rated and this saving used to compensate for time loss while off of the air. Replacement time, except in the case of polyphase rectifiers, is a matter of a few seconds, however in three-phase rectifiers the circuit is more complex and it may require some discrimination to determine which is the faulty tube and make the necessary replacement.

In the operation of high-powered circuits, the duration of any short circuit is extremely slight, as the control circuits and protective devices will react almost instantly. Fortunately, mercury vapor tubes seldom fail instantaneously, since they usually arc-back several times before failing completely. Thus by careful and continued observation, a defective tube may be observed and replaced in advance

Fig. 2. Basic transmitter control circuit indicating operating sequence.





Master control desk, completely RCA equipped, at station WLS in Chicago.

of its actual failure. In some cases, increasing the ambient temperature will increase the mercury pressure sufficiently to allow uninterrupted service until the end of the broadcast period.

Where arc-back indicators are used, the solution presents no particular problem as these devices are designed to indicate any momentary flow of current which passes in the opposite direction. Where these devices are not used, the problem of locating a faulty tube in a three phase rectifier is one of the more perplexing problems in station maintenance. The only solution in this matter is experience in handling such failures.

A knowledge of control circuits may make an analysis of short-circuits in the secondary of the 10 to 20 kv. transformer clear. The control circuits are commonly confined to two phases which are designated A and C. An elimination of one source of the difficulty may be made by the fact that a very heavy primary overload in either of these phases would drop all of the holding coils, thus cutting of the entire installation completely. The same phenomenon in the other phase would open the primary fuse or circuit breaker in that phase. Where the overload has been sufficient to open the primary protective device, this will occur in the two phases simultaneously thus the phase not involved in the breakdown may be eliminated completely.

In order to provide a rapid method of determining the circuit in which the failure occurs, consider all circuits, which are functioning properly, as constants in the relationship given below. Then, when one circuit or component of the transmitter is not functioning properly, this circuit or component becomes the variable in the relationship and the source of the trouble may be quickly and accurately traced.

Since the number of equipment failures which will not affect the d.c. plate current in a radio frequency amplifier are few in number, one relationship may be expressed as:

$$I_b \longrightarrow \frac{E_b E_s}{R_L r_p (-E_c)} \quad \ldots\ldots\ldots (1)$$

Where:

E_b = d-c plate voltage
E_s = effective signal voltage
R_L = load resistance
r_p = plate resistance
E_c = bias voltage

While this relation is accurate only within certain limits, the following deductions may be made from the results obtained. The factors which will cause the plate current to increase are the plate potential and the grid-signal voltage, while an increase in the denominator will effect a decreased plate current. Any serious deviation from normal plate current thus indicates a total of five factors, which may be eliminated in turn and the cause of the failure be determined. The d.c. values are directly interpretive, while R_L, E_s, and r_p, are complex factors representing specific circuits.

Of still greater value than relation (1) in aiding the detection of failures is the value of the circulating current in the plate load circuit. This relation becomes:

$$I_t \longrightarrow \frac{E_b E_s R_L}{r_p (-E_c)} \quad \ldots\ldots\ldots (2)$$

While an r-f ammeter is not always employed in the circuit, it is a valuable adjunct to proper circuit operation. The simultaneous comparison of the relationships given in formulas (1) and (2) provides a means of determining the definite circuit in which the fault lies.

The applications of these proportions to the inoperative radio-frequency amplifier circuits may be illustrated by the following examples.

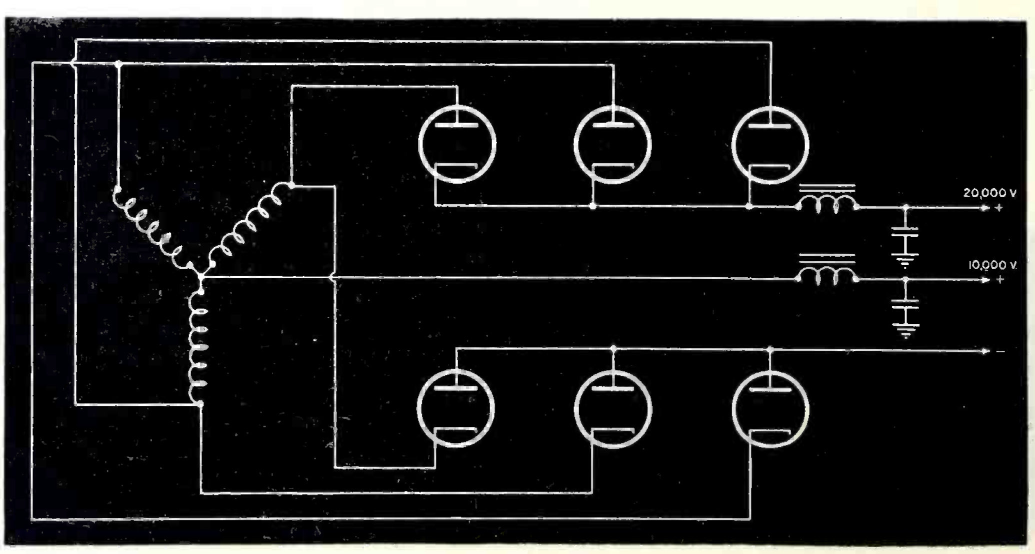
The amplifier in this case consists of two 8½ kilowatt water-cooled tubes which operate as a class B linear amplifier coupled to a transmission line and terminated in its characteristic impedance.

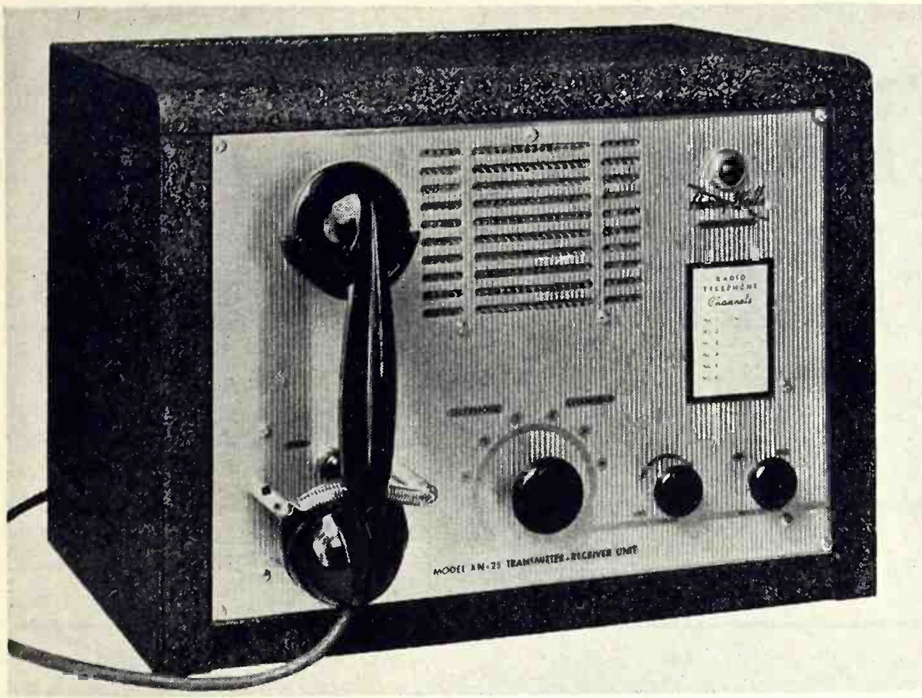
The first indication that the amplifier was inoperative was when the plate voltage was applied. The plate current ammeters indicated a flow of a few milliamperes when the normal flow should have been several amperes.

Applying relation (1), it may be observed that all of the factors upon which the plate current are dependent are embodied into this single formula and further that in the amplifier at least one of the constants has deviated from the rated value. The solution of the equation with a value of zero, re-

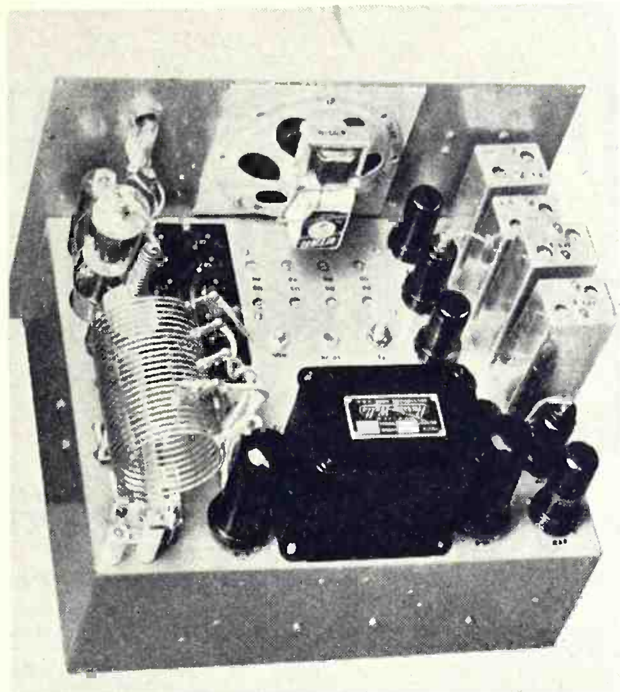
(*Continued on page* 46)

Fig. 3. Full-wave, three-phase rectifier used in modern broadcast transmitters.





The marine transmitter-receiver being produced for the U. S. Navy and Coast Guard.



Rear view of the same marine transmitter-receiver.

Aircraft Radio Equipment

Recently designed multiple-purpose receiver for application to commercial and private aircraft.

THE field of electronics, as applied to the many aviation needs, presents a real challenge to the post-war engineer. Interplane and ground communications will receive a great impetus in the coming age of air where commercial and military aviation will be increased and private aircraft will take to the air in larger numbers than ever before.

For all of these planes, new and improved radio equipment will be necessary. The *Harvey-Wells Communications, Inc.,* believing that there is a real and vital need for lightweight and compact radio equipment, have developed a new aircraft receiver known as the AR-10-A.

This development was the result of direct requests made by one of the commercial airlines for a multiple purpose receiver that is small, light and easily accessible for maintenance.

The receiver combines three units in the space ordinarily required to house a single unit. Frequency coverage in the beacon band is 195 to 415 kilocycles continuously variable tuning, with provision for quick shift "spot tuning" on 278 and 271 kilocycles or any other two specific frequencies in the beacon band. In the communications band, continuously variable tuning from 2500 to 8000 kilocycles, with provision for twelve crystal-controlled frequencies anywhere in the 2500 to 15,000 kilocycle band is provided.

The sensitivity of the AR-10-A is such that an input of 2 microvolts, modulated 30% at 400 cycles will produce an output of 50 milliwatts at a signal to noise ratio of 6 db.

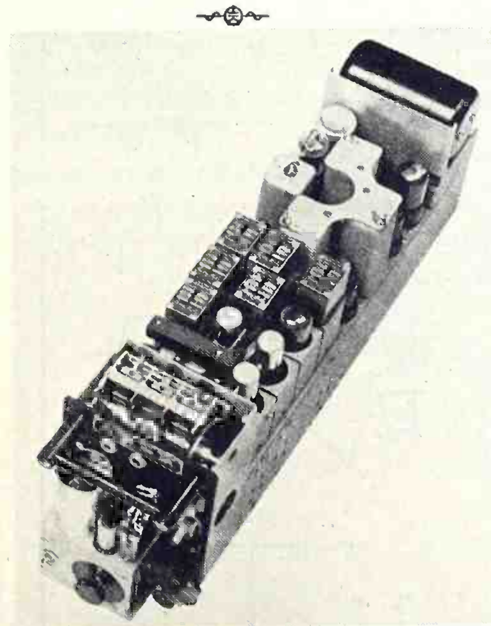
Three antenna input terminals are provided, one for the low frequency beacon antenna, one for the high frequency communication antenna and one for the loop input on the beacon band.

The low frequency antenna input circuit is designed for a low impedance line (70 ohms). The high frequency input circuit is matched to a 200 mmf antenna. The loop circuit includes a coupling transformer and trimmer, so designed as to operate on an RCA-Sperry or other similar loop as specified by the airline. A tuned loop amplifier is provided between the loop input and the RF amplifier of the receiver. High impedance loops can be used with the equipment with a maximum of 1060 mmf available for tuning the loop when using the proper type of coupling transformer.

Two stages of intermediate frequency amplification are provided with six tuned circuits operating at a frequency of 455 kilocycles. The receiver also incorporates a beat frequency oscillator, thus making possible the reception of CW signals. Two independent audio output channels are available.

The AR-10-A may be installed anywhere in the aircraft since all electrical circuits and the frequency tuning control can be operated from the cockpit by means of remote control units furnished with the receiver.

In order to describe this and other developments in the electronic field as applied to aircraft, the engineers of Harvey-Wells have coined and registered a new word. The word "Airionics" is designed to convey to the reader the whole field of aviation radio and the new horizons of aircraft electronics of the future.



Model AR-10-A aircraft receiver chassis, showing component arrangement.

DIFFERENTIATING and INTEGRATING NETWORKS

By C. H. FOELL

An analysis of the important part being played by differentiating and integrating networks in modern electronics.

THE usefulness of differentiating and integrating networks in many electronic applications, including television, has been firmly established.

The names of these networks are derived from their important properties. A differentiating network is one in which the charging and discharging current flow in a capacitor is utilized. Since the current is a differential function of a small change in voltage per unit time and because the network also has the property of differentiating between two signals, it is so-named. In an integrating network, the ultimate result is the integral of a small change in charging current during a small period of time.

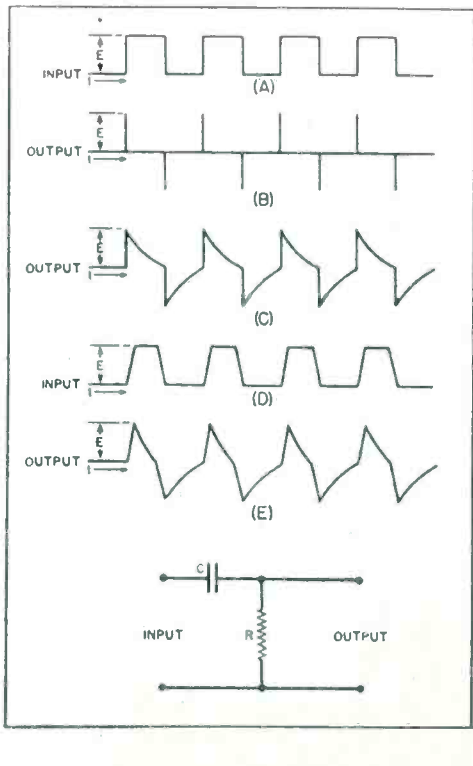
The Differentiator

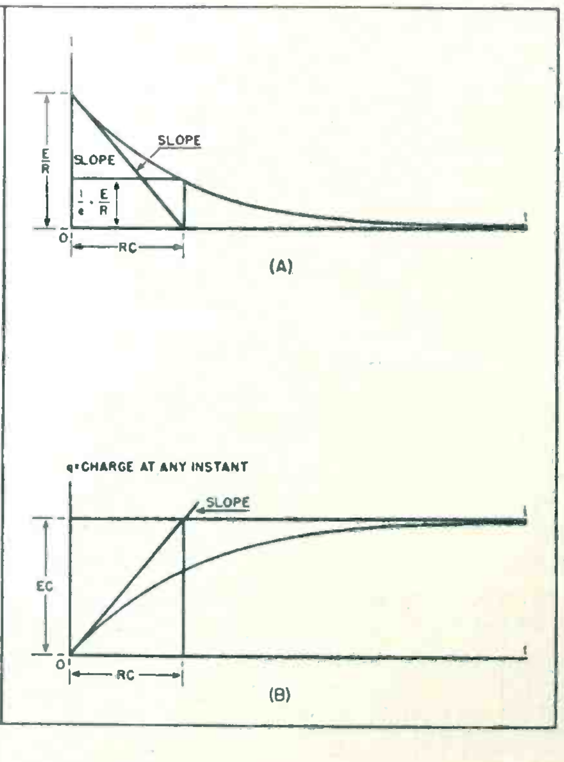
When a square wave is applied to a differentiating network, which consists of a series capacitor and shunt resistance, the resultant output is a short, sharp pulse or "pip." The sharpness of this "pip" depends upon the waveform of the applied signal and the time constant of the network. For best results the input signal should be a true square wave, that is, the leading edge of the applied signal should rise from zero instantaneously. Fig. 1-A shows the ideal square waveform and Fig. 1-B the resulting ideal waveform. The usual result produced by a tapering input signal such as 1-D is shown in 1-C. However, the true representation is indicated by 1-E. Note that any sloping of the leading edge of the applied waveform lengthens the time during which the "pip" is developed. The usual practice is to employ some form of clipping circuit ahead of the differentiator, so that a true square wave is secured.

As soon as the signal is applied to the RC combination shown in Fig. 1, the leading edge of the applied signal quickly charges the capacitor to a maximum voltage. This voltage is determined by the amount of applied voltage and the time constant of the network. That is, with a constant applied potential, a circuit using a small time constant quickly charges to a maximum voltage, while the same circuit using a larger time constant will charge only up to a small percentage of this value, during the same interval of time. In Fig. 1, it may be noted that the differentiator produces two "pips" for each imput signal. It is evident that one "pip" is produced by the leading edge of the input signal and another "pip," in the negative direction, is produced by the trailing edge of the signal. In between the leading and trailing edges the "pip" falls to the zero base line. These facts lead to another conception of a differentiator, namely, that this type of network can be considered as a high-pass filter. Since X_c varies inversely with frequency, the high frequency components of the signal are offered little opposition and the low frequency components are offered a high reactance. The input signal, if a true square wave, contains a great number of high and low frequency components. Calculation of X_c at the lowest and highest frequencies to be passed, is an easy method of determining whether a network is a coupling network or a possible differentiator.

Fig. 2 shows the exponential charge and discharge curve for any capacitor. The differentiator shown in Fig. 1 charges and discharges in this fashion. The "pip" previously discussed is produced by the charging and discharging current flowing through the resistance. By mathematical analysis, it can be shown that the current flow

Fig. 1 (left). Differentiating network, showing ideal output (B) and actual output (C) resulting from square-wave input (A), while (E) shows output resulting from input (D).
Fig. 2 (right). Condenser discharge (A) and charge (B) with time constant indicated.





through the capacitor at any instant is:

$$i = \frac{E}{R} \epsilon^{-\frac{t}{RC}} \qquad (1)$$

Fig. 2 shows that as soon as an input signal is applied to the differentiator, the current starts at its full value E/R and falls to zero at an exponential rate. When t equals RC, the current will have fallen to 1/e of its initial value. The quantity RC is called the time constant of this circuit. The rate of decrease of the current at any instant is given by:

$$\frac{di}{dt} = \frac{E}{R^2C} \epsilon^{-\frac{t}{RC}} \qquad (2)$$

by inserting t equal to zero:

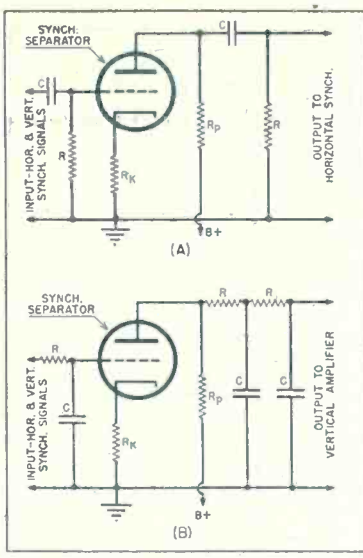
$$\left(\frac{di}{dt}\right)_{t=0} = \frac{E}{R^2C} \qquad (3)$$

as the initial decrease of current. Had the current continued to decrease at this rate for a length of time equal to RC it would have fallen through the value:

$$\frac{E}{R^2C} \times RC = \frac{E}{R} \qquad (4)$$

Hence, the time constant may be expressed as the time it would take the current to fall to zero if it continued to decrease at its initial rate. Since the tangent to a curve equals the slope or rate of increase or decrease at any instant it can be seen from Fig. 2 that as the RC product approaches zero the slope gets steeper, and when RC is infinitely small, the slope would be a maximum. Thus a very small time constant allows the capacitor to charge and discharge quickly. Note that if a small resistor is used in the differentiator only a small voltage will be developed across it. Thus, in designing a network of this type the ultimate result is secured by choosing an optimum value that gives the desired result.

As a typical example of how values vary in practice several suspected differentiators were examined and a table compiled. By referring to table 1 it will be noted upon examination that combinations Nos. 2 and 4 are coupling networks. While the No. 3 combination might be considered as a differentiator, the time constant is a bit too large. This network was located at the input to the "synch" separator tube of a television receiver, shown in Fig. 3. The first combination is a true differentiator, and the network was located at the input to the horizontal "synch" oscillator shown in Fig. 3A.



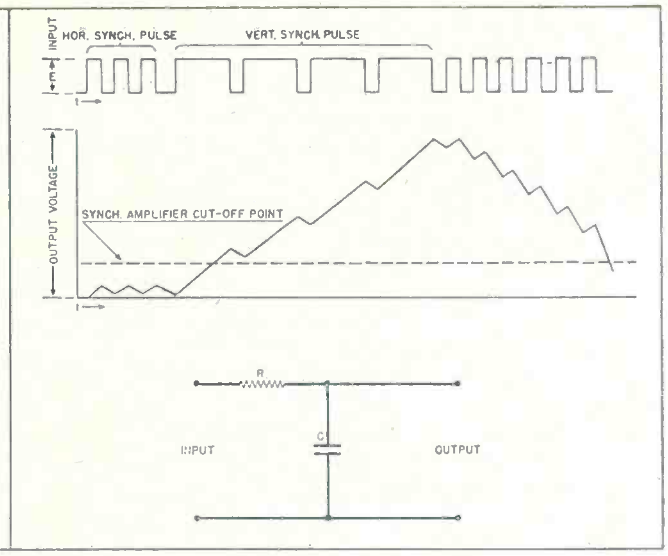


Fig. 3 (left). (A) is a typical differentiating network, (B) a typical integrating network.
Fig. 4 (right). Comparison between the input and output signals of an integrating network.

It is recommended that a differentiator used in a television receiver for horizontal "synch" separation should have a charging time equal to one half of one per cent of the line scanning interval. The line scanning interval for 441 lines is 75 microseconds and for 525 lines is 63.5 microseconds. The recommended value of charging time would therefore be .375 microseconds and .32 microseconds respectively. By referring to table 1, it becomes evident that the first combination does not meet this requirement. Column five shows a combination which does meet this requirement. Since the horizontal blanking pulse width is approximately 14 microseconds on a 525-line system, it is evident that a greater charging voltage can be developed across the No. 5 combination.

As a rule, with a time constant of less than one microsecond, good results may be obtained. In most instances differentiators used in television circuits employ series resistors of less than 10,000 ohms, while the capacity varies according to the relative frequency components to be expected in the applied signal. Generally speaking, it can be said that where a form of hi-pass filter is observed using small R and small C (considering the maximum frequency component of the pulse), then in most cases, closer analysis will prove it to be differentiator. Where absolute accuracy is needed then the calculation must be made. Tabulating such calculations, as illustrated in table 1, will be helpful.

The modern television practice is to employ a differentiator at the input to the "synch" separator tube and apply the "synch"-separator horizontal output to another differentiator either in the plate circuit of the separator or at the input to the horizontal "synch" amplifier.

It is important to keep in mind that where a differentiator is used to secure accurate synchronism, the leading edge of the "pip" must occur at the desired time and as quickly as possible, otherwise synchronism will be impaired. On the other hand, where the network is used to furnish a means of time base calibration, less slope and hence larger RC combinations can be tolerated. In the latter case, for industrial applications where trigger pulses need occur only at the line frequency, satisfactory results have been secured by using saturable reactors or transformers. The same results may be secured by substituting an inductance for the series resistor in a differentiator. However, this complicates the calculation of values, is usually more costly, and not as convenient. Discussion has, therefore, been limited to the capacitor-resistor type.

Integrating Networks

The integrating circuit operates in an inverse manner to the differentiator. A typical integrator is shown in Fig. 3B. Fig. 4 shows a comparison of the input and output signals. A study of this figure shows that when the leading edge of the applied input

TABLE I

	1	2	3	4	5
RC	2×10^{-6}	.01	8×10^{-5}	5×10^{-3}	1.7×10^{-7}
99% charge	60 μs	.05 sec.	.0035 sec.	.03 sec.	.8 μs
E	2. μs	.01 sec.	80 μs	.005 sec	.17 μs
Xc at 60 ~(ohms)	$.5 \times 10^6$	23,000	3.4×10^6	23,000	105×10^6
Xc at 1 Mc (ohms)	26	1.6	200	1.6	6500

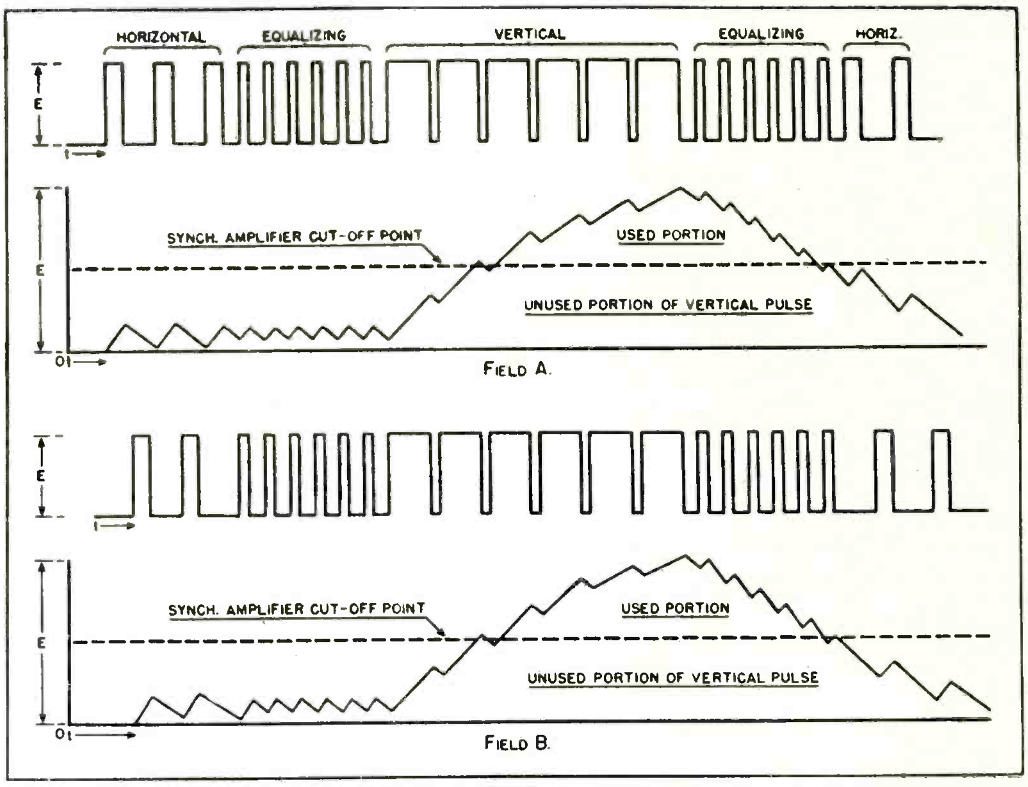


Fig. 5. Illustrating the integrating action for two fields spaced half a line apart.

signal reaches C, very little opposition is offered and the high frequency components of the signal are shunted to ground. Since the input is a square wave containing a number of frequency components, each component will meet a different impedance, dependent upon the reactance of C at that frequency. The net result will be that a small charge is developed in C, and will appear in the output of the circuit. On the other hand, the low frequency (flat top) component of the input signal will meet with a higher reactance and consequently a higher voltage will be developed across C and appear in the output.

It is apparent that an integrating network can be considered as a low-pass filter.

The ratio between the horizontal scanning and vertical scanning frequencies of a television system determines the frequency difference over which the "synch" separator circuits must work, for example about 220 to 1 in a 441-line system. While for purposes of explanation the above suffices, on closer examination, it is found that an integrating network does not respond to the frequency difference to the same extent that it does to the width of the applied pulse. Since the voltage developed across a network of this type is equal to:

$$E = \int \frac{i\,dt}{C} \qquad (5)$$

it is apparent that the result of an integrating network is really the summing up of a series of small charges from time t=0 to t'. The charge at any instant is:

$$q = \int_0^t i\,dt = \int_0^t \frac{E}{R}\,\epsilon^{-\frac{t}{RC}} = EC\left(1 - \epsilon^{-\frac{t}{RC}}\right) = Q\left(1 - \epsilon^{-\frac{t}{RC}}\right) \qquad (6)$$

This is true for the first instant where the condenser has no charge. However, any time after the initial charge, a voltage exists between the plates of the condenser. In the time between "synch" pulses, the voltage dies down exponentially to a lower value and when the next pulse arrives, the charge placed on the capacitor depends upon the current flow and this in turn depends upon the difference between the applied voltage and the voltage present, that is:

$$I_0 = \frac{E - \frac{Q_0}{C}}{R} \qquad (7)$$

where I_0 equals the initial current flow and Q_0 equals the initial charge on the capacitor. The charge at any instant equals:

$$q = Q_0 + \frac{EC - Q}{RC}\int_0^t \epsilon^{-\frac{t}{RC}}\,dt$$

$$= EC + (Q_0 - EC)\,\epsilon^{-\frac{t}{RC}} \qquad (8)$$

which may be written as:

$$q = Q_\infty + (Q_0 - Q_\infty)\,\epsilon^{-\frac{t}{RC}} \qquad (9)$$

where Q_∞ is the total final charge and Q_0 is the initial charge at $t = 0$. This proves mathematically what is shown in Fig. 4 and leads to the result shown by Fig. 5, that is, the final output waveform of an integrating network is a sawtooth wave-shape. The general shape of the sawtooth depends on the RC value and the width of the input pulses, and distance between them. It is the usual practice to use a number of integrating networks in cascade. As a matter of practical interest, it might be noted that the above action can be observed on an oscilloscope applied to the output of the vertical "synch" separator of a television receiver. Since the integrating network is slightly responsive to the horizontal "synch" pulse present in the television "synch" separator, the vertical synchronizing amplifier is usually biased so that only signals above a certain amplitude will act on the amplifier. Thus only that portion of the vertical "synch" (integrated) pulse, shown above the dotted lines in Figs. 4 and 5, is utilized. In order to synchronize the horizontal circuit properly, it is necessary to continue the horizontal "synch" pulses during the period of the vertical "synch" and blanking. This is done by means of the equalizing pulses and by breaking the vertical "synch" pulse up into a series of pulses whose leading edges correspond with those of the horizontal "synch" pulse. Fig. 5 shows an exaggerated picture of the integrating action for two fields, one of which is spaced a half line apart from the other. It may be seen that the equalizing and horizontal "synch" pulse have little effect on the action of the vertical synchronization, thus the vertical pulse always occurs at the proper time. Fig. 6 shows how the leading edge of the vertical pulse appears in the horizontal differentiator circuit, in order to maintain the horizontal synchronization.

It is also possible to use a series inductance in place of the series resistor of the integrating network. However, this method is not used because the same results can be secured more easily and at less expense by means of a resistor. For circuit applications where an integrator is needed and where frequency discrimination is important, a tuned filter with the proper time constant may be used. The latter method is not employed in television and seldom in other electronic applications. One important point that should be remembered when using inductance for either "pip" production or sawtooth waveshapes is that while in a capacitive circuit the charge may not change instantly from one value to another, the current may and does, whereas, in the inductive circuit the current before a signal is applied is the same as the current the instant after the signal is applied. That is why the inductance type cir-

(*Continued on page* 36)


More Leaders in Radionics
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GUTHMAN Super-Made CHOKES
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Again, Guthman experience, engineering, skill and complete manufacturing facilities are co-ordinated to produce a wide variety of Guthman Super-Made Chokes. Universal Guthman Chokes are available in unlimited ranges of inductances. They are wound on ceramic or bakelite with pigtail connections or standard resistor mountings
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PRECISION MANUFACTURERS AND ENGINEERS OF RADIO AND ELECTRICAL EQUIPMENT

NEW PRODUCTS

GE FLUXMETER

A light-beam instrument for measuring either flux density or the total magnetic flux in magnetic circuits has been announced by General Electric's Meter Division.

The fluxmeter, applicable wherever permanent magnets or d-c electromagnets are used, is similar to a light-beam galvanometer and has a suspension-type element. A wide variety of magnetic measurements may be handled by this instrument by means of search coils, which may be constructed by the user. Different sensitivities may be obtained by using galvanom-

eters of various characteristics. These galvanometers are interchangeable, and the instrument has a scale of 50-0-250 millimeters.

The control box, which contains a dry cell, resistors, rheostat, push button and a switch provides a means of introducing a voltage into the electric circuit to compensate for small but undesirable spurious voltages that may otherwise cause errors in high-sensitivity instruments of this type.

Bulletin GEA-4157 describing the fluxmeter may be obtained from *Dept. RE-5, General Electric Company, Schenectady, New York.*

MASS SPECTROMETER

In order to furnish accurate control over various materials and processes, Westinghouse has provided a new industrial tool, known as the mass spectrometer.

While not of recent design, this instrument has just made its first appearance outside of the laboratory where it has been used in exploring the field of nuclear physics. The spectrometer determines both qualitatively and quantitatively the constituents of a gas. With substances that are alike chemically and differ only slightly in weight, chemical analysis is extremely difficult. The mass spectrometer ionizes a small quantity of gas, by means of the impact of electrons from a hot filament in an evacuated tube, draws the stream of charged molecules into a magnetic field, where it is bent into an arc-shaped path. The heavier the ion, the larger the radius of curvature of its path. As a result, different molecules emerge from the field at various locations, but all ions of the same kind leave at one particular spot. Different charged molecules are collected successively at an exit slit into a current that can be amplified and measured. In this way, constituents of any gas can be determined as to kind and proportion.

The mass spectrometer is designed for use in refineries, chemical plants and similar industrial applications. The instrument is self-contained and requires 110 volt, 60 cycle power supply. Measurements as small as one-billionth of one microampere may be measured.

Other industrial uses include checking of gases in protective-atmosphere furnaces, completeness of evacuation processes, or detection of some undesirable constituent in process gas.

Further data on the spectrometer and its applications will be furnished by *Westinghouse Electric and Manufacturing Company, Dept. RE-5, East Pittsburgh, Pennsylvania.*

TORSIOMETER

An interesting example of industrial co-operation is found in the development of the torsiometer, which is now being produced by the Sheffield Corporation of Dayton, Ohio, as a result of collaboration with the Gruen Watch Company and the Manross Division of the Associated Spring Corporation.

This instrument is a comparator which provides a means of precision measuring the torsion of small spiral springs. A direct reading of the torsion measurement of the spring being checked can be made in millimeter grams on a graduated Manross scale. This permits the indentifying and classifying of springs as to torsion before assembling in instruments.

The torsiometer will accommodate springs up to 2⅞ inches in diameter with a maximum torsion measure-

ment of 49.5 millimeter grams. This is sufficient capacity to cover the complete range of springs used in most instruments.

In addition to the savings effected in instrument assembly costs, the torsiometer can be used by the manufacturer to supply springs of a known uniform quality to a definite classification specified by his customer.

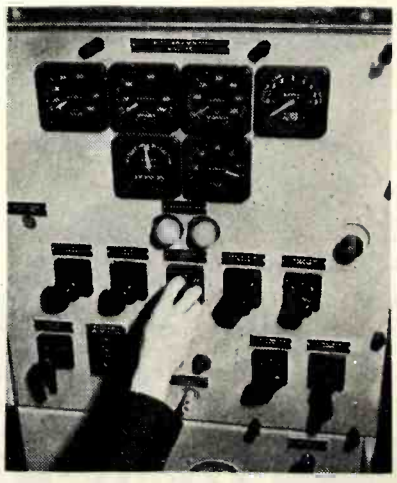
Additional information on the torsiometer is available to interested persons, by writing *Dept. RE-5, The Sheffield Corporation, Dayton, 1, Ohio.*

250 DEGREE INSTRUMENTS

New long-scale instruments required by the Navy have been designed and manufactured by Westinghouse to meet this need.

In engineering this job, it was necessary to redesign all instruments, a-c and d-c ammeters, volt meters, a-c watt meters, power-factor meters, frequency meters and synchroscopes. As a byproduct of this redesigning program, these instruments have now been standardized and unified, which allows for uniform sizes in frames and other components.

Although inherently more complex



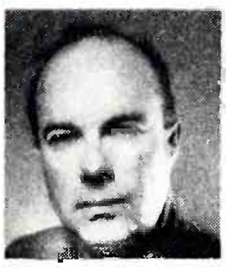
than the 100-degree type, the new long-scale instruments are outstanding because they can be disassembled and repaired easily. Regular repair-

(*Continued on page* 36)

Personals

R. L. ANDERSON has been appointed to the post of chief engineer at the Franklin Transformer Company of Minneapolis. His present position is that of engineer-in-charge of the new developments on Army and Navy equipment. Mr. Anderson came to the Franklin Company in 1942 from the Rockefeller Foundation at the University of Minnesota where he was working in the field of visual education and photographic studies.

LUDWIG ARNSON, one of radio's pioneer engineers has received the Marconi Memorial Medal of Achievment. This award comes as a recognition of more than forty years of contribution to radio engineering. Mr. Arnson has pioneered in the field of aircraft radio and his work along this line has added to the safety of airplane travel for many years. He is a development engineer for Radio Receptor Company of New York.



DR. W. L. BARROW of Sperry Gyroscope Company is the recipient of this year's Morris L. Liebmann Memorial Prize awarded at a banquet of the IRE held in New York. His work in the field of theoretical and experimental investigation of ultra-high-frequency propagation of wave guides and radiations from horns is well known in the engineering field. Dr. Barrow joined the Sperry Engineering staff in 1943.

HENRY C. BONFIG has resigned his position as vice-president of RCA to join the executive staff of Zenith Radio Corporation of Chicago. He will be in charge of the company's greatly expanded household radio sales division which is just one phase of Zenith's post-war expansion in the field of radionics. Mr. Bonfig has had wide experience in the radio distribution field, as well as an impressive record in radio design and sales.

EDMOND M. DELORAINE, director in charge of the Laboratories Division of Federal Telephone and Radio Corporation of New York, has been elected to the position of Director of the corporation. Mr. Deloraine's contributions to the radio field are well-known not only in his native France, but also in England and on the continent as well as in the United States. His best known work is in the field of ultra-high frequency.

JOHN H. SENNOTT, formerly a supervising accountant for Ernst and Ernst in Chicago, has been appointed controller of Detrola Radio Division in Detroit. Mr. Sennott has recently returned from active duty as a lieutenant (senior grade) in the Navy where he served from March, 1941 until June of 1943. This appointment is in line with Detrola's program of expansion for the new post-war program being developed.

Graphics

(Continued from page 9)

definite voltage will exist between these points and negative feedback will occur to neutralize the positive feedback. The circuit therefore oscillates at the frequency of greatest positive feedback at which the network analyzed transmits no negative feedback voltage.

A convenient arrangement of the "twin T" network for variable frequencies uses three ganged matched rheostats for the resistors. Such an arrangement requires the value of K to be $\sqrt{2}$, then $R' = R'' = R'''$, $X''' = X' = \sqrt{2}R''$, and $X'' = R''/2\sqrt{2}$. The corresponding diagrams are shown in Fig. 5b, c, d and e which are lettered to correspond with similar diagrams of Fig. 4.

The impedance diagram for the upper branch, Fig. 5b has been drawn to a scale twice as great as the other impedance figures for greater accuracy. This diagram is also used as the voltage diagram for this branch and its impedance vector oZ_g has been taken as the voltage vector of the total voltage from o to g. In the diagram for the lower branch, Fig. 5c, oE'_g has been taken equal to the voltage vector oZ_g and $c'E_g$ has been drawn parallel to cZ_h to find the voltages oc' and $c'E_g$ across X' and the impedance cZ_h respectively. The two voltage diagrams odZ_g and $oc'E_g$ have been combined in Fig. 5d to find the voltage vector E_cE_d for the path *chgd* and this vector is used in Fig. 5e to form the voltage diagram $cf'E_d$ for the path *cfed*. It is again seen that the diagram $cf'E_d$ will coincide with the vector triangle $E_cE_gE_d$, resulting in zero voltage between f' and E_g at the balance frequency.

The analysis of regenerative feedback in RC oscillator circuits presented in this article aids in visualizing the phase relationships of the various voltages. Such a visualization is somewhat more difficult when the analysis is purely analytical and therefore the advantages of graphical constructions are again exemplified. The procedure outlined above is not only applicable to oscillator circuits but also to amplifier circuits with or without inverse feedback networks. The generality of the method is as important as the specific application presented here.

Procedures, as outlined in this article, should be filed for future reference on the graphic method.

REFERENCES

1. *Ginzton and Hollingsworth, "Phase Shift Oscillators", Proceedings of the I.R.E., February, 1941.*
2. *Paine, Robert. C., "L Type Matching Networks", Radio-Electronic Engineering, January, 1944.*

Industrial Review

RF Coupling Devices

INDUSTRIAL heat-processing, which is receiving wide application, is being facilitated by means of special harnesses that couple electronic power to unusual work loads.

The design and application of such coupling devices are receiving considerable attention in the laboratories of Radio Corporation of America.

By utilizing the characteristic of high-frequency currents for travelling along the surface of the metal under processing and the characteristic of concentrated heating, new applications have been adopted using certain types of specially designed transformers and coils as coupling devices.

Specific application, of course, depends on the type of work being done and the material under processing. Problems in induction heating may be referred to *Radio Corporation of America, Camden, New Jersey* for definite suggestions as to their solution.

* * *

HF Heat for Plastics

MANY new uses for high-frequency dielectric and induction heating for plastics and plywoods are being developed by Westinghouse Electric and Manufacturing Company.

Already, the process has received wide application in the fabrication of war-necessary equipment, but the post-war period should produce even greater advancement, according to the company.

The dwindling supply of timber in the United States, will give new impetus to the use of plywoods. This material, now being used in the construction of PT boats, is both strong and adaptable. By means of induction heating, glue lines may be set in plywoods, rapidly and safely.

Two types of high-frequency heating are used in the curing of plastics and the ease with which this material may be processed makes this an active contender for post-war material prestige.

Engineering problems in which dielectric or induction heating may be applied should be submitted to *Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.,* for suggested solutions.

* * *

Black Light

A NEW application of invisible ultra-violet rays has been made by the Lion Manufacturing Corporation. This phenomenon is being utilized in their new line of plastic filters which may be adapted to control knobs, switches and door handles as well as dashboard panels for automobiles.

The plastic filter can be used with any size fluorescent tubular or circular lamp as well as with the special airplane lamps of the two and four watt sizes. The filter and the lamp combination produce the required black light effect. The elimination of glare and an increased ease with which important controls may be located are but two of the advantages of this type of illumination.

According to the manufacturer, the introduction of many color combinations for both decorative and utility purposes is possible. Radio dials, so treated may be changed readily and accurately by means of this adapter.

Varied suggestions as to the possible uses of this plastic filter will be furnished to interested readers by addressing inquiries to Dept. RE-5, *Lion Manufacturing Corporation,* 135 South LaSalle Street, Chicago, 3, Illinois.

* * *

Automatic Recording

AN INSTRUMENT which records data and results of tests automatically and permanently, has been announced by General Electric Company.

Of particular interest, at the present time, in the recording of the performance of test models of military aircraft in wind tunnels, this instrument has many applications in industry where accuracy and constant reading of meters and indicators is necessary.

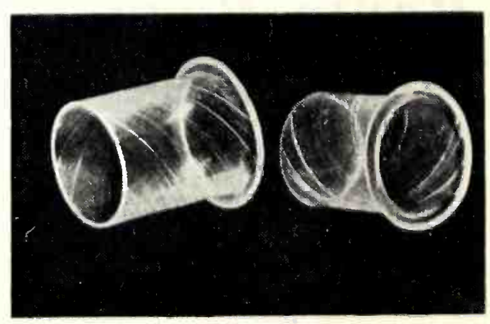
The mechanism of this instrument may be adjusted to give precision readings equivalent to readings that might be obtained on a scale more than eight feet long. The indications picked up by electron tubes, cause the rotation of a tiny thyratron-controlled motor, which in turn drives wheels carrying type for numbers. When the operator wants to take a reading, he presses a button and the type wheels print their setting at the moment.

The General Engineering Laboratory of *General Electric Company, Schenectady, New York,* is responsible for this development.

* * *

Acetate Grommets

NEW light-weight spun acetate grommets are rapidly replacing those made of scarce and critical materials. These grommets are made of acetate film, spirally wound and laminated for greater strength. Their insulating properties combined with the non-shatterable quality of the material, makes these grommets particularly adaptable to aircraft and hydraulic applications.



The grommets are supplied with one end spun, inserted in place and subsequently spun over on standard drill press equipment with special tools supplied by the manufacturer.

The heat of the spinning operation shrinks the thermo-plastic material, so that a tight fitting insulation results. Special spinning tools are available for inaccessible places.

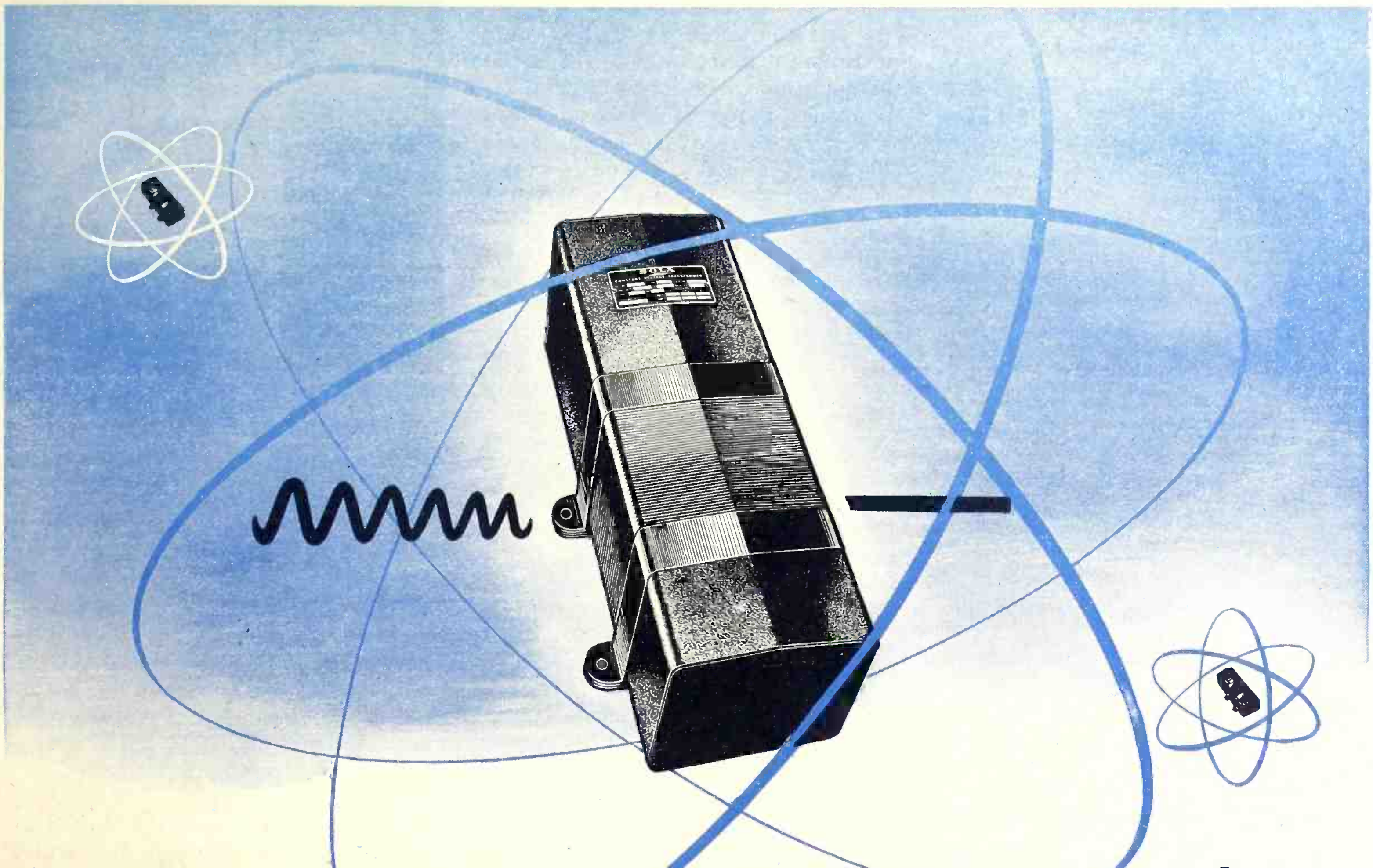
Details and samples of these grommets are available from the manufacturer, the *Precision Paper Tube Company,* 2035 W. Charleston Street, Chicago, 47, Illinois.

* * *

Recording Devices

THE resumption of production on sound recording devices has been announced by the Fairchild Camera and Instrument Corporation. Manufacture of sound equipment was halted when this company went into exclusive production of Army and Navy

(*Continued on page* 44)



ELECTRONIC PERFORMANCE is always exactly predictable with built-in CONSTANT VOLTAGE

Constant, stable voltage comes first in design consideration if the electronic miracles promised for the post-war world are to be realized.

Perfect performance cannot be guaranteed if delicate electronic devices, too sensitive to tolerate ordinary voltage fluctuations, are left vulnerable to the sags and surges of commercial power lines.

FM and television transmitters and receivers, food sorting and testing devices, scientific instruments, X-ray, sound and projection equipment, precision machinery—these are but a few of the products, once requiring frequent adjustments and constant attention by watchful operators, whose performance is now automatic and exactly predictable with *built-in* Constant Voltage.

Many new products that have not yet progressed beyond the laboratory stage because of critical voltage problems will be available to the post-war world, with built-in Sola Constant Voltage Transformers reducing their operation to a simple "just plug in" basis.

Engineers and sales executives who are responsible for product design should bear this fact in mind—that the precisely controlled voltages of the research laboratory *are not* the voltages that will be encountered once the product reaches the user. An otherwise perfect piece of engineering may be headed for trouble at the hands of less experienced operators.

Dependably close voltage control to within ±1% can be made available to all electronic devices, or electrically operated equipment, with built-in automatic Sola Constant Voltage Transformers.

Without manual adjustments or supervision, they instantly reduce voltage fluctuation as great as 30% to the rated voltage required for successful operation. They protect themselves against short circuit damage. Capacities and sizes are available to meet any design requirements.

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Heat Dissipation

(*Continued from page* 12)

interlocks have been largely overcome by porcelain reels, reliable flow-interlocks and completely non-ferrous circulating systems (all copper tank and pipes); the familiar problems of scale formation, gradual water evaporation and relatively large time consumption in changing tubes have remained.

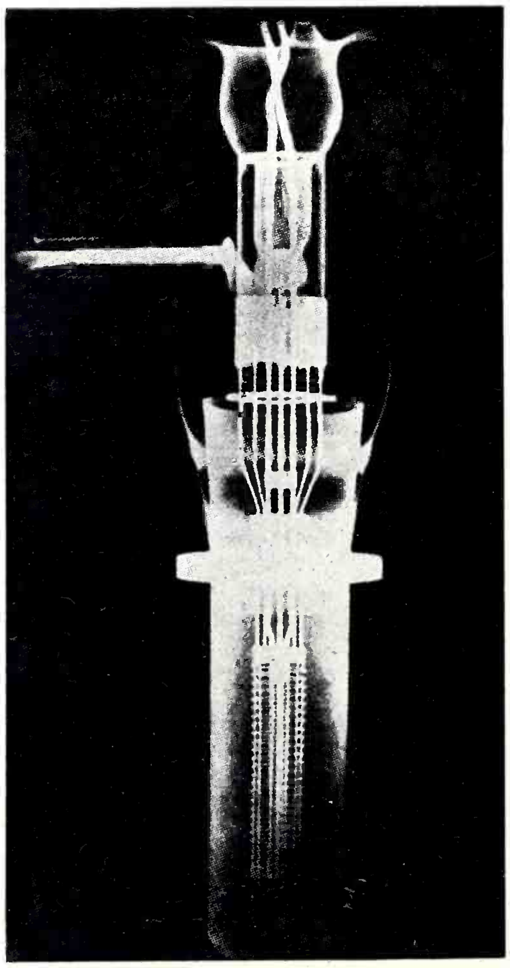
In recent years, the elimination of the water cooling system has been accomplished for transmitters up to and including 50 kw rating, by the development of forced-air cooling systems.

Air-cooled tubes may be used to advantage where ambient temperatures may drop below the freezing point, also in conditions where it is desirable to eliminate the water piping and water coils.

The conventional air-cooler consists of a core and a set of fins set radially and soldered to the outer surfaces of the core.

Fig. 1 illustrates a tube of the forced air type, which shows the large number of copper fins which are silver-soldered directly to the anode of the tube. The method of mounting and cooling is considerably simplified. The water jacket has been replaced by a hollow porcelain mounting into which the tube with its attached fins is placed. No clamping device is necessary, and the anode connection is on the chrome plated rim at top of porcelain mounting which forms the seat for the anode. Since only the electrical connections to grid and filament are used, this results in less time expended for replacing a defective tube. Just below the mounting is the air blower and canvas ducts which forces the air through the large surface exposed by means of the copper fins, and out through the top of the transmitter. Blowers are equipped with dust filters to prevent the deposit of dust particles on tube and transmitter components.

Fig. 6. X-Ray view of the water-cooled tube.



Air-cooled tubes offer a number of advantages over the water cooling systems, namely:

1. No accumulation of scale on the anode.
2. Complete elimination of all inherent troubles of water cooling systems.
3. Glass seal and press more evenly cooled.
4. Heat dissipation surface is larger, which helps to prevent formation of hot spots.
5. Much less space required in initial installation of entire transmitter.

However, there are certain inherent disadvantages in using the air-cooled rather than the water-cooled type of transmitting tubes. Water jackets are more compact than the air coolers and replacements may be made in the jackets thus permitting the water-cooling jackets to be built into the transmitters. Air-cooled tubes cannot be inserted in this manner. They must be carefully soldered into the cooler core to form contact between the anode and the cooler. Generally, the actual replacement of the burned out tube is not considered to be within the province of the broadcast station personnel, hence the air-cooled tubes usually must be handled and transported with the cooler as a unit.

Various attempts have been made to separate the cooling unit from the tube to facilitate easy handling, but the reassembly of this unit involves careful and painstaking work done with intricate tools, used in a skillful manner. The stationary cooler must be cleaned mechanically each time a tube is replaced.

Control circuits for this type of cooling system are simplified, consisting as they do of an air interlock damper on top of blower motor, which prevents application of filament and plate voltages until normal air-flow pressure is present, and a blower motor "keep-alive" relay which is a time-delay relay keeping blower motors functioning for 4 to 7 minutes after filament voltage is removed.

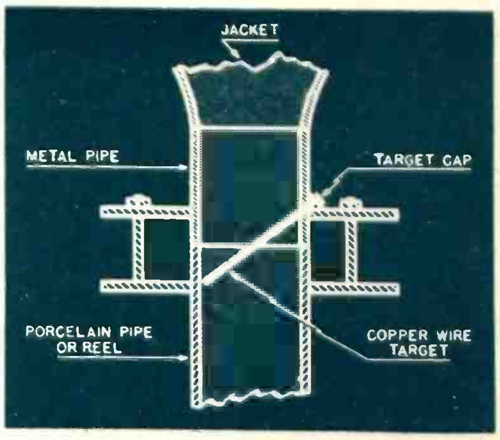


Fig. 7. Position of electrolysis target for water-cooled tubes.

The comparative design of an 891 (water-cooled) tube, and an 891-R (modified for air-cooled use) is exemplified by charts, together with the comparative temperature distribution for maximum dissipation operation of the tube. As may be observed from these charts, the anode of the tube in both cases runs considerably hotter than the boiling point of water at the maximum dissipation point of operation. This characteristic underlines the relative importance of velocity of water-flow which establishes a turbulency of flow through the water jacket. The water in a water cooling system is kept from boiling by the velocity of water flow, and by the characteristic rise of the boiling point of water under pressure. Usually at least 30 pounds of pressure exists in the water jacket, at which value the boiling point of water rises above 135° C.

In observing the comparative anode temperatures of the two methods of cooling, the conclusion might be made that this comparison proves a greater efficiency for water cooling systems, since T_a for air-cooled operation is 230° C. at maximum dissipation. Paradoxically, however, the "higher efficiency" of the water cooled method is not a contributing factor to the design of cooling systems. The anode of a water cooled tube runs cooler than the adjacent glass bulb, which, under certain conditions results in condensation of residual gases. When this occurs, the gases are apt to be released under tube operation and cause local instantaneous increases in pressure which results in the formation of an arc back in the tube. This trouble is almost non-existent in the operation of forced-air cooled tubes since the anode is hotter than the adjacent glass wall, which results in a more even temperature distribution of absorbed gases within the tube.

Fig. 2 is a graph showing maximum T_a and power dissipation limit plotted against air velocity for the 891-R tube. Since the physical constants of water

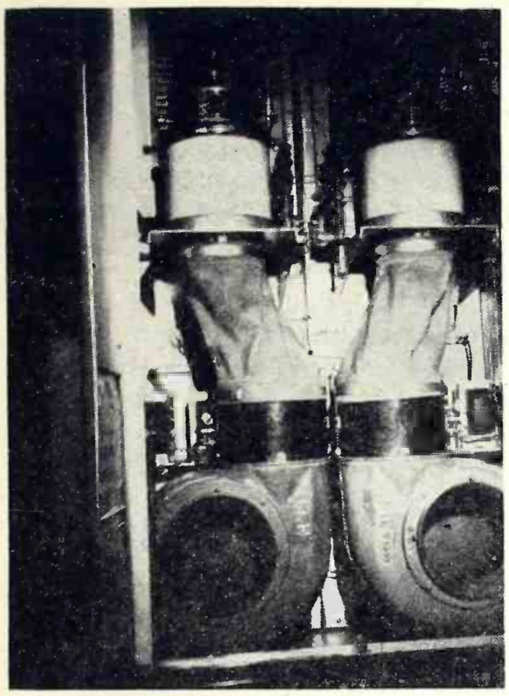


Fig. 8. Air ducts used in air-cooling system.

(viscosity and heat conductivity) vary with a change of water temperature, the dissipation limit for a water-cooled system varies somewhere between the 0.4th and 0.8th power of water velocity. When Prestone or alcohol is used in the water to prevent freezing at the blower radiator, the turbulency of the water flow is lowered. The rate of flow must be increased 2 or 3 times to maintain a given turbulence when anti-freeze is used.

While the discussion of heat dissipation given in this article does not cover all of the problems involved in the installation and maintenance of broadcast transmitting tubes, certain of the fundamental problems have been suggested for the guidance of station engineers and technicians. From the suggestions given, it will be possible to combat many of the more troublesome elements encountered in the field of broadcast tube maintenance.

With the many factors involved in the selection and operation of transmitting tubes, it becomes the duty of every broadcast engineer to be thoroughly familiar with the operating characteristics of both water-cooled and air-cooled transmitting tubes. It is in the interest of stimulating a healthy curiosity regarding this important broadcast element that this article is addressed to the broadcast engineer.

REFERENCE:

1. *Mouromtseff, I.E. "Water and Forced-Air Cooling of Vacuum Tubes," Proceedings of the I.R.E. April, 1942, page 190.*

2. *"Water-Cooled Transmitting Tubes, Installation and Operation," General Electric Company, Manual No. GEH-1152B.*

3. *Chevigny, G. "Tubes for High-Power Short-Wave Broadcast Stations," Proceedings of the I.R.E. July, 1943. Page 331.*

R-F Heating of Plastics

(*Continued from page* 6)

tential. The two heater electrodes, HE1 and HE2 are separated by mycalex sheets from the material to be heated, as is the top grounded electrode. This arrangement provides sufficient electrical flexibility for the various sizes of preforms, the thickness of which may be varied within the mechanical limits of the available space.

By referring to the close-up photograph shown in Fig. 1, the preforms can be seen on the mycalex holding plate above the two heater electrodes. The top electrode, separated by a mycalex sheet, can be lifted by means of the lever shown on the right hand side. The top arrangement is so designed that within certain limits the top electrode will always press against the preforms to be heated. A slight pressure is provided by the weight of the top electrode. A heat insulating guard, which may be seen in Fig. 1, surrounds the electrode and it is provided with sufficient openings to allow for the escape of fumes and gases during the heat-treating process. The lifting lever operates a micro-switch, which in turn closes or opens the coil of the high voltage relay switch. Thus, when the cover electrode is lifted, the high voltage is removed automatically from the circuit. This arrangement simplifies the operation of the unit

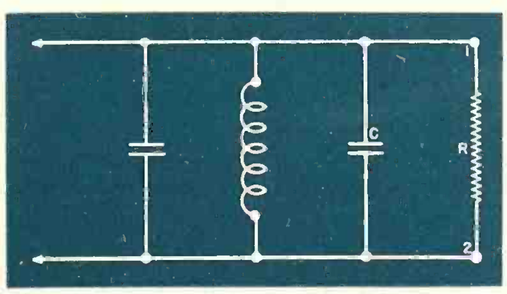


Fig. 5. Resistance and capacity of load.

because the filament voltage is maintained while loading the heater so that it is necessary to just close the top electrode and then open it after a predetermined time. The length of time for this operation is established by the automatic timer on the left hand side of the instrument panel. This timer is in series with the micro-switch which is connected with the lever arrangement and acts immediately on the high voltage switch.

A switch, the first dial on the front of the panel to the left, insures the proper sequence when the power to the filaments of the oscillators and the rectifier is applied, and to the high voltage circuit. A time delay switch is inserted between the filament and

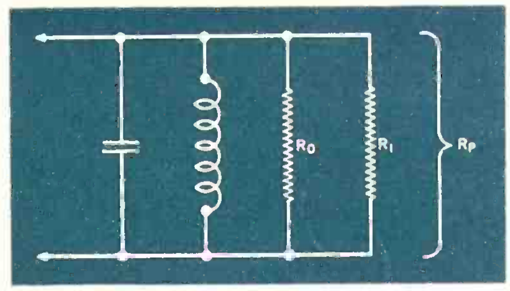


Fig. 6. Load and tank circuit resistance.

high-voltage positions of the switch to insure a sufficiently long warming up period for all of the filaments. A center dial operates the initial setting of the coupling condensers. The last dial on the right operates the power output control rheostat. The output is controlled by varying the grid bias and by changing the value of the cathode resistance of the oscillator tube. A smooth and continuous control of the power output may be obtained in this manner from an almost zero level up to the full rating of the unit, 2.5 kw. high-frequency output.

The wattmeter used to measure the power output, with its associated calibrated potentiometer, is shown in the photograph on page 3, between the grid and plate current measuring instruments.

All circuits are protected by automatic overload switches, and the primary of the three-phase high-voltage transformer is controlled by a d-c overload switch operated by the plate current of the oscillator tubes.

To insure maximum safety for the equipment, the center tap of the tank circuit and the positive pole of the 3000 volt d-c supply, is kept at ground potential.

A well-shaped opening is provided, adjacent to the heater platform, to accommodate the loading tray used in the transfer of the preforms from the high-frequency heating unit to the presses. An opening in the front of the cabinet provides storage space for materials and tools.

On page 3 is shown a photograph of the unit with the back removed. As can be seen, it is constructed in two main sections, one section containing the high frequency oscillator and the other the three-phase, full-wave rectifier circuit. Both the oscillator section and the rectifier section are built in standard subassembly units. This allows great flexibility if changes in operating characteristics of the unit are required.

The unit illustrated handles about one pound of preform material a minute.

While the discussion in this article is concerned primarily with the high-frequency heating of plastics, the equipment and methods described are applicable to many other materials in which dielectric heating may be the solution to the problem of producing a higher quality product at a lowered labor and material cost.

REFERENCES

1. *Mittelmann, E., "Dosimetry in Short Wave Therapy, An Instrument for Dosage Determination in Patient's Circuit," Arch. Phys. Therapy, 18:613 October 1937*
2. *Mittelmann, E., "Dosimetry in Short Wave Therapy," Electronics, 12:52 November 1939*
3. *Mittelmann, E. and Holmquest H.J., "The Useful Power Output of Short Wave Therapy Generators," Quarterly Bulletin, Northwestern University Medical School, August 1940*
4. *Kraus, J.D. and Teed, R.W., "Diathermy Measurement Technique," Electronics 13:39 December 1940*
5. *U. S. Patent Re 22,258*

Integrating Networks

(*Continued from page* 26)

cuit does not lend itself readily to popular applications.

In applications of the integrating network, it is important to remember that synchronization by means of the accumulating of charge depends upon the assumption that all charging pulses have the proper width and separation between them so that the accumulated charge will be the same at the time of synchronization. This assumption does not necessarily occur, therefore, a more accurate means of attaining this synchronization is by means of the proper selection of amplitude for operation.

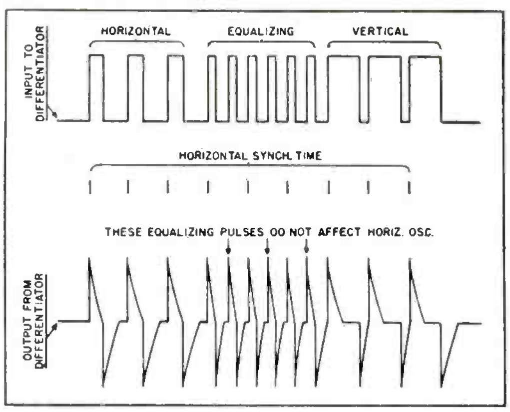


Fig. 6. Showing the effect of equalizing pulses on output of the differentiator.

In summarizing the above discussion, differentiators are trigger pulse generators of simple RC form, whose time constant and band-pass determine the waveform of the output pulse, while integrating networks are simple RC networks that function to build up a sawtooth output signal by charging a capacitor whose time constant is large compared to the spaces between the input pulses, and short compared to the width of the input pulses.

New Products

(*Continued from page* 28)

men can handle this job without retraining or further instruction.

These instruments must pass a 2,000-foot-pound shock test, while the steel test panel, on which the instruments are mounted, must withstand a blow from a 500-pound weight dropped from a height of four feet. This test momentarily increases the weight of part by 3,000 times, which is equivalent to supporting the weight of two light automobiles. Following this test the instruments must continue to operate with acceptable accuracy.

The entire output of these instruments will be required by the Navy for some time. However, it is expected that the new design will have considerable application on land, when the instruments become available.

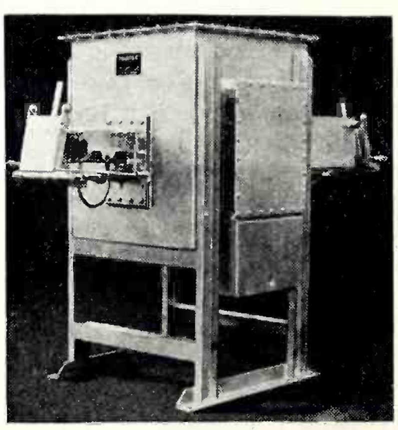
Further information regarding these instruments may be obtained by writing to *Westinghouse Electric and Manufacturing Company, Dept. RE-5, East Pittsburgh, Pennsylvania.*

ELECTRIC FURNACE

Electric furnaces for sintering powdered metal, are now being produced by Harper Electric Furnace Corporation, for general distribution. Capable of producing temperatures between 1800° and 2750° F, these furnaces put the manufacture of powdered metal products on a mass production basis. They are equipped with a pre-heat tunnel and the exit on the cooling tunnel is equipped with automatic flame curtains.

The gas-tight construction of this furnace permits the use of protective atmospheres, such as hydrogen, dissociated ammonia and mixtures of carbon monoxide, hydrogen and nitrogen.

Applications include high temperature cementing of tungsten carbide dies and sintering of powdered ferrous and non-ferrous metal parts, heating of electronic tube parts and for other uses where powder metallurgy is applicable. In addition, these furnaces provide correct temperature and atmosphere conditions for high temperature hydrogen brazing.

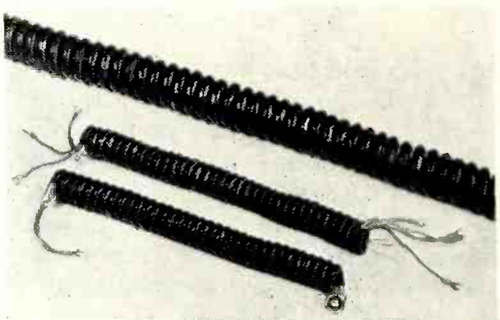


Sizes are available ranging from laboratory equipment size to furnaces used in volume production requirements. Complete data may be obtained from the *Harper Electric Furnace Corporation, Niagara Falls, New York.*

RETRACTILE CORDS

A new company devoted exclusively to the manufacture of rubber-jacketed and retractile electric cords, has been formed as a subsidiary of Kellogg Switchboard and Supply Company, and will be known as Cordage, Incorporated.

This process, which involves the spiral molding of the rubber jacket assures retention of the cord's normal position. As a consequence maximum retractability is acquired without the use of wire springs or similar separate mechanical devices. Recently, both Neoprene and Buna-S have been used in place of rubber for the outside covering of Kellogg Koiled Kords with satisfactory results.



All orders for the new company will be handled through the Kellogg Company. While the largest percentage of this output is being absorbed by the armed services, a small number of these cords is available for applications by manufacturers of electrical equipment and appliances.

Further information is available from the *Kellogg Switchboard and Supply Company,* Dept. RE-5, 6650 South Cicero Avenue, Chicago, Illinois.

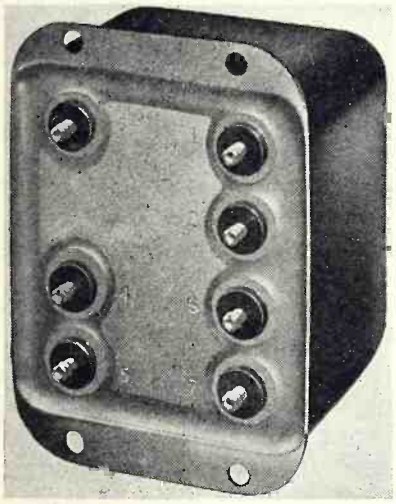
SEALED TRANSFORMER

A new hermetically sealed transformer, designated "Type S," has been developed by engineers of the Peerless Electrical Products Co., Los Angeles, manufacturers of transformers for aircraft, marine and ordnance installation.

Designed for use in all theatres of war operation and on all types of equipment, the new transformer recently approved by the United States Navy is of extremely rugged construction having a case of cold drawn copper cadmium plated steel. It uses a terminal molded into a plastic block which has a metal flange molded into its periphery. This flange is then soldered into the case. This new construction offers great flexibility in number and arrangement of terminals.

As in all Peerless transformers, their exclusive "Vac-sealing" impregnation process is used, insuring absolute impregnation without solvents or other deleterious material present inside the coil.

Increased plant facilities permit



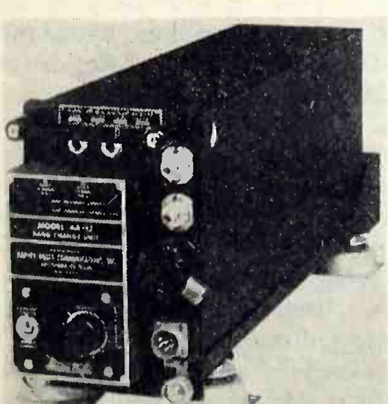
production of the new Type S transformer in any desired size or capacity to customers' specification.

Further information may be obtained by writing *Dept. RE-5, Peerless Electrical Products Company, McKinley Avenue, Los Angeles, Cal.*

AIRCRAFT RECEIVER

A new small sized communications receiver for aircraft has been announced by the Harvey-Wells Communications, Inc. This receiver is an all-purpose, all frequency receiver whose dimensions and weight (24 pounds) represent a saving in valuable airplane space and help to increase the payload.

This unit features beacon-band coverage from 195 to 425 kc. with "spot-tuning" on 278 or 271 or any other two specific frequencies, communications band coverage from 2500 to 4500 kc. and from 450 to 8000 kc. with pre-tuned circuits for twelve crystal con-



trolled frequencies anywhere in the 2500 to 10,000 kc. band. The receiver also carries two r-f channels for day frequencies of from 4.5 to 10 mc, and night frequencies from 2.5 to 4.5 mc. The makers claim an image attenuation greater than 65 db. and a sensitivity such that an input of two microvolts modulated 30 per cent at 400 cycles produces an output of 50 milliwatts at a signal to noise ratio of 6 db.

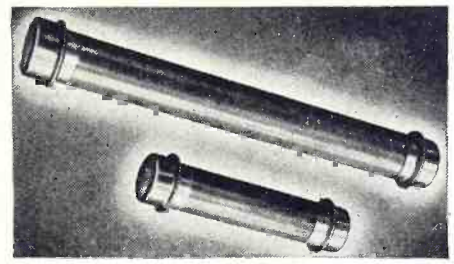
This receiver incorporates all of the necessary aircraft radio equipment. This permits wide coverage while saving valuable space and the operator's time.

Detailed information regarding the engineering advantages of this type of installation will be furnished upon application to *Dept. RE-5, Development Laboratories, Harvey-Wells Communications, Inc., Southbridge, Massachusetts.*

HIGH VOLTAGE RESISTORS

A new resistor, utilizing an absolute minimum of critical materials, is being manufactured by the Sprague Specialties Company, under the name of Meg-O-Max Resistors. These resistors are capable of operating at high voltages and ambient temperatures and serve as well to dissipate power.

Meg-O-Max resistors are formed of a series of pressed and sintered ring-shaped segments electrically joined in such a way as to cause the units to be non-inductive. Finished units are encased in a hermetically sealed, rugged glass envelope which is provided with ferule terminals. This unit is capable of withstanding aircraft



vibration tests, salt water immersion tests and mechanical shocks produced by rapid acceleration.

Data sheets on these resistors are available from the *Sprague Specialties Company,* Resistor Division, Dept. RE-5, North Adams, Massachusetts.

AIRCRAFT TRANSFORMER

A new transformer intended for use in aircraft applications where a high temperature component will not afford satisfactory service is being manufactured by the New York Transformer Company.

The unit weighs 8 ounces, which is 40% lighter than other transformers of

(*Continued on page* 39)

NEWS BRIEFS

INFORMATION CENTER

In an effort to make information regarding the electrical industry available to qualified persons, the National Electrical Manufacturers Association has opened a central information bureau for the dissemination of information to trade publications and the press.

A complete photograph file and various data will be available to these groups and up-to-date information will be distributed periodically. The new center is located at 155 East 44th Street, New York and began serving the public on March 15th. Mr. John M. Moorhead, formerly of the New York Herald Tribune, is in charge of the new center.

Mr. Leonard Kebler, president of the NEMA emphasized that prices of electrical appliances, equipment or securities would not be given by this center, but that human interest stories, pictures and technical data would be furnished promptly.

JOSEPH GALVIN DIES

Joseph E. Galvin, Executive Vice-President of the Galvin Manufacturing Corporation, makers of Motorola Radios, died suddenly at his home in Oak Park, Illinois on March 7, 1944.

Mr. Galvin had served in an executive capacity with the Galvin organization since its founding in 1928. Mr. Joseph Galvin's brother, Paul Galvin is the president of the company and president of the Radio Manufacturer's Association.

SOUND LABORATORY

The Library of Congress has received a grant of $41,520 from the Carnegie Corporation for the purpose of establishing a complete sound laboratory for duplicating phonographic recordings and for making master recordings of all types, which may be distributed.

In addition, with the purchase of a sound truck and six portable recorders, it will be possible for the Library to record, in the field, material which cannot be recorded in the studio. Operation of the laboratory will start in the fall.

When complete, the Music Division of the Library will be in a position to furnish recordings of American folk music, unpublished string quartets, as well as readings of poetry to schools, libraries and individuals.

Most of the material which the Library plans to reproduce is available at the present to those persons who have access to the Library in Washington. By means of reproductions, this extensive musical library will be available to thousands of persons who are unable to make the trip to Washington to secure the records desired.

NORTH AMERICAN PHILIPS

At the opening of the North American Philips Company's new showroom at 100 E. 42nd Street, New York, Mr. Pieter van den Berg, Vice-president of the company announced the appointment of Dr. Ora Stanley Duffendack, professor of physics at the University of Michigan to the post of Research Director of the company.

North American, formerly a Dutch corporation, whose entire business was moved to this side of the Atlantic when Holland was invaded, is specializing in the manufacture of electronic equipment for the Armed Forces.

The laboratories of the company, of which Dr. Duffendack is the director, will be located at Richmond Hill, Irvington, New York, which is within two miles of the Dobbs Ferry Plant of North American.

An elaborate booklet describing the physical equipment of the company, its personnel, and products is being prepared for early distribution.

FM SURVEY

Maxon, Inc. has recently completed a survey among FM receiver owners for the General Electric Company and the results have been released by the company.

The names of the owners were obtained from the FM stations in four cities surveyed, New York, Philadelphia, Detroit and Milwaukee. Letters containing the questions were sent out to the listeners through the stations assisting with the survey.

Of particular interest to the engineer in the electronic field is the listener response to the questions. More than 40% of the FM receiver owners listed higher quality reproduction as their primary reason for enjoying FM broadcasting, while the fact that higher types of programs were offered on FM stations was given as a further reason for the use of FM reception.

The majority of the listeners agreed that FM has lived up to the expectations for which they purchased their equipment and a vast majority prefer their FM reception to the AM reception for the same program. The survey further indicated that the majority of the users were making use of their FM receivers only three or four hours a day. This of course, is due in part to the fact that some FM stations are not on a twenty-four hour a day basis at the present time.

Copies of the complete report are available from the Electronics Department of *General Electric Company,* Schenectady, New York, the company which sponsored this survey.

BARUCH REPORT

The long-awaited "Report on War and Post-War Adjustment Policies" by Bernard M. Baruch and John M. Hancock has been released by the government for distribution.

This booklet will be of vital interest to all manufacturers of war material, who hold either direct or indirect governmental contracts. In this report Mr. Baruch has presented his views on the proper termination of war contracts and the problem of readjustment.

While Mr. Baruch's position is that of observer and special advisor to the President, without authority to enforce, many of his plans and suggestions have been adopted in the past, hence the preview of his ideas should be widely read by those whose companies will be directly affected by any contract terminations as well as by the public seeking information.

The distribution of this booklet is being made by the Government through the Office of War Mobilization, of which James F. Byrnes is the Director.

NEW CORPORATION

The Zenith Radionics Corporation of New York, a subsidiary of Zenith Radio Corporation has been formed and offices opened in the Empire State Building in New York City.

Mr. H. J. Wines, formerly with General Motors has been appointed general manager and director of the New York Corporation. E. F. McDonald, Jr., president of the parent company is serving as president.

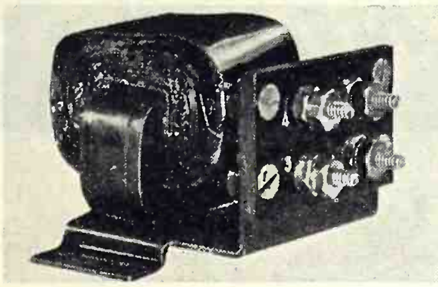
The Radionics Corporation will serve as distributor for Zenith's line of radionic products. The radionic hearing aid, most familiar item of the line, will be handled by Mr. Toni Strassman.

New Products

(*Continued from page* 37)

this type. The temperature rise of 30 degree C. permits operation over all ambient temperatures from minus 65 degrees C. to plus 70 degrees C. and altitudes up to 50,000 feet.

For special applications, the output

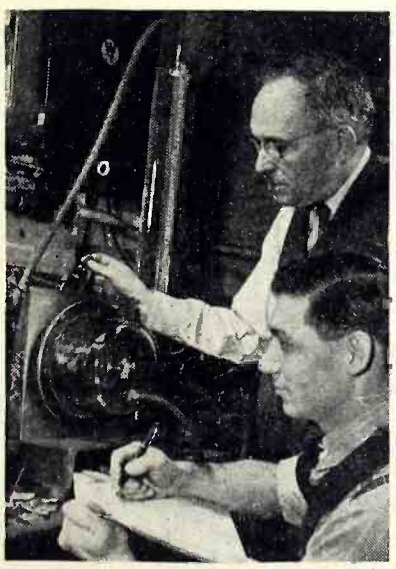


voltages and currents may be varied without affecting size and weight, if the output is held to 30 V.A.

Further information of this unit is available from the *New York Transformer Company*, 26 Waverly Place, New York, New York.

FOUR-IN-ONE DYNAMOTOR

A dynamotor which provides four closely regulated voltages, +14½,-150, +300 and 450 is one of the new developments of Westinghouse. This machine requires four separate comutators. Ordinarily the output voltage of a dynamotor bears a fixed relation



to the supply voltage. In this dynamotor, all output voltages are held constant for all normal input-voltage variations.

This constant voltage is accomplished by means of a regulator field which weakens when the input voltage rises and strengthens when the voltage drops. The regulator utilizes a separate core. The complete armature has four commutators, two cores and four windings. The dimensions of the dynamotor are 11 inches in length by 2.8 inches in diameter.

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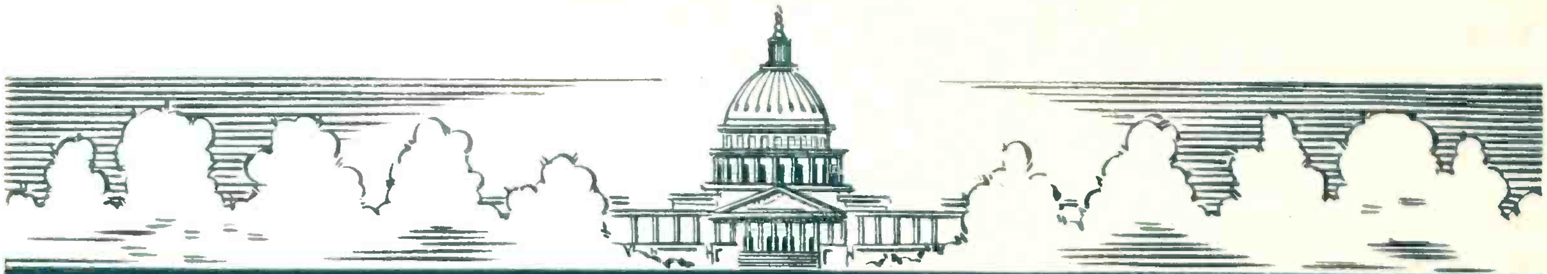

★★★★ Washington Directory ★★★★

Government Agency Personnel . . . Locations

O.E.M., 101 Indiana Ave., NW, REpublic 7500

Wayne Coy, Liaison Officer, Rm. 252 State Dept. Bldg., Ext. 5181

W.P.B., Social Security Bldg., REpublic 7500

Donald M. Nelson, Chairman, Rm. 5055, Ext. 2113
Stephen E. Fitzgerald—Div. of Inf., Rm. 5525A, Ext. 5242

Radio and Radar Division

R. C. Ellis, Director, Rm. 4332, Ext. 2566
F. H. McIntosh, Civilian Radios, Ext. 72119
E. R. Crane, Electronic Components, Ext. 71946
P. M. Deeley, Capacitors, Ext. 71278
M. Bakst, Coaxial Cables, Ext. 75604
H. P. Rockwell, Jr., Measuring Instr., Ext. 75675
W. L. Bond, Quartz Crystals, Ext. 74365
J. M. Coffeen, Relays, Ext. 75587
D. Connor, Resistors, Ext. 73389
E. A. Capelle, Instruments, Ext. 71992
G. C. Henry, Sound Systems, Ext. 4667
H. P. Rockwell, Jr., Test Equip., Ext. 75604
Lt. Col. J. Proctor, Microphones, Ext. 73389
C. Burmaster, Meters, Ext. 74487
F. C. Bash, Electronic Tubes, Ext. 73149
H. Gaston, Radio Hdwr., Ext. 72527
L. J. Chatten, Electronic Equip., Ext. 71828
A. T. Stanton, Vibrators & Scanners, Ext. 73631

WAR DEPARTMENT, Pentagon Bldg., REpublic 6700

Henry L. Stimson, Sect. of War, Rm. 3E880, Ext. 3211
Lt. Col. D. W. Stirling Wright, Aide, Rm. 3E880, Ext. 3214
Lt. Gen. Wm. Knudsen, Production, Rm. 3E606, Ext. 71361
Robt. P. Patterson, Undersecretary, Rm. 3E714, Ext. 2696
John J. McCloy, Asst. Secty., Rm. 4E886, Ext. 2385
Robt. A. Lovett, Asst. Secty. (Air), Rm. 3E980, Ext. 3718
Gen. George C. Marshall, Chief of Staff, Rm. 3E921, Ext. 2077
Lt. Gen. J. T. McNarney, Deputy Chief, Rm. 3E936, Ext. 4371
Brig. Gen. M. G. White, Asst. Chief (G-1), Rm. 3B929, Ext. 2851
Maj. Gen. G. V. Strong, Asst. Chief (G-2), Rm. 2E776, Ext. 2968
Maj. Gen. T. T. Handy, Asst. Chief (Operations), Rm. 3E800, Ext. 2904

Bureau of Public Relations

Maj. Gen. Alexander D. Surles, Director, Rm. 2E880, Ext. 2716
Col. Stanley J. Grogan, Deputy Dir., Rm. 2E872, Ext. 5135
Lt. Col. Robt. E. Kintner, Exec. Officer, Rm. 2E868, Ext. 74200
Col. Robert A. Ginsburgh, Chief (Ind. Serv.), Rm. 2E867, Ext. 2513
Col. R. E. Dupuy, Chief (News Div.), Rm. 2E865, Ext. 3494
Col. F. V. Fitzgerald, Intelligence Div., Rm. 2E873, Ext. 6358

Army Air Forces

Gen. Henry H. Arnold, Commanding Gen., Rm. 3E1009, Ext. 2766
Col. Horace W. Shelmire, Asst., Rm. 3E1012, Ext. 2964

Army Ground Forces

Lt. Gen. Lesley J. McNair, Commanding Gen., Rm. 25, Ext. 280
Col. James G. Christiansen, Chief of Staff
Col. William J. Mitchell, Deputy Chief of Staff

Army Service Forces

Lt. Gen. B. Somervell, Commanding Gen., Rm. 3E672, Ext. 4102
Maj. Harold K. Hastings, Aide, Rm. 3E672, Ext. 4102
Maj. Gen. W. D. Styer, Chief of Staff, Rm. 3E664, Ext. 71814

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Ralph A. Bard, Asst. Secty. of Navy
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Artemus L. Gates, Asst. for Air
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V-Adm. Russell R. Waesche, Commandant
R-Adm. L. T. Chalker, Asst., Rm. 7002, Ext. 4310
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U. S. PATENT OFFICE, Dept. of Comm. Bldg.

Conway P. Coe, Commissioner of Patents
Leslie Frazer, First Asst. Commissioner

New Products

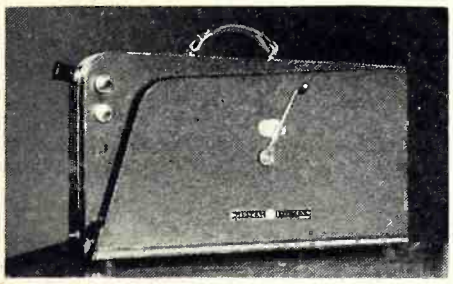
(*Continued from page* 39)

Specific applications and further information will be furnished by *Westinghouse Electric and Manufacturing Company, Dept. RE-5, East Pittsburgh, Pennsylvania.*

ELECTRON MICROSCOPE

A new unit, for demonstration purposes only, was exhibited and explained to the members of the Radio Club of America at a recent meeting in New York, by the engineers of General Electric's Electronics Division.

This instrument is a portable electron microscope, which is capable of



being transported in a suitcase. This instrument weighs 78 pounds and the vacuum pump for the operation of the microscope is carried in another suitcase-sized unit weighing 55 pounds.

This microscope operates on standard 110 volt a-c power and has ten times the enlarging power of a light microscope.

While this unit is not in production at the present time, its post-war possibilities as a handy laboratory tool for scientist and physician alike is foreseen by *General Electric Company* of Schenectady, New York.

DIPPING TANK

A portable heating and dipping tank, which includes an acid compartment, has been developed by the Heil Engineering Company.

The tank is divided into three compartments, which may be used for etching, plating, metal coloring, waxing or rust removing. An unusual feature of this tank is the dual purpose cover and shelf, which is thoroughly acid proofed and arranged in such a manner as to drain into the tank. Operation of the tank is from the standard 110-220 volt circuit and connection is made by means of a flexible extension cord with which the tank is equipped.

Compartment 1 is furnished with a standard heating unit for hot alkaline degreasing compounds and similar materials, while compartment 2 is for cold rinsing and the third compartment is lined with an acid resistant coating which makes it suitable for pickling acid processes, electroplating chemicals and acid cleaners. Heating

units are available for all three of the compartments if so desired.

Further information on specific applications is available from *Heil Engineering Company,* 12901 Elmwood Avenue, Cleveland, Ohio, Dept. RE-5.

HANDI-TRAY

A space and time saver for busy assembly lines, known as the Handi-Tray is being offered by the Handi Equipment Company. This equipment is easily adaptable for a variety of production uses wherever accessibility of small component parts is a primary consideration.

The tray is seventeen inches high and occupies an area of twenty square inches. It contains three tiers of shelves which revolve about a central pivot. All of the twelve trays are removable, allowing for interchangeability and locating on work benches and assembly tables where the minimum space occupied by the complete unit is not available.

The unit is equipped with a top handle for easy portability. Prices and further information are available from the *Handi Equipment Company,* 105 New York Boulevard, Dept. RE-5, Jamaica, 5, New York.

FRACTIONAL HP MOTORS

A new line of bantam fractional horse-power motors, built to special order for installations requiring maximum power per ounce of weight has been announced by Small Motors, Inc.

Of value in solving space problems inherent in the design of cooling fans, blowers, vacuum pumps, and remote control of radio and instruments, this motor operates at speeds from 2,000 to 20,000 RPM. Both a.c. and d.c. motors are available.

Windings are of high grade magnet wire, impregnated with varnish, while the commutator is mica insulated. Voltages ranging from 6 to 230 volts are available.

Specifications and engineering data may be forwarded to *Small Motors,*

Inc., 1308 Elston Avenue, Chicago, 22, Illinois for quotations.

CAPACITOR

A specially designed capacitor for use in electron microscopes is one of the new products announced by the Industrial Specialty Company.

The capacitor is rated at .01 mfd., 40,000 volts d.c. and is capable of continuous operation at 80 degrees Centigrade. It will also withstand total submersion and heavy surges.

The case is welded steel, measuring 4$^{11}/_{16}$" x 5¾" x 7" high with a stand-off insulator 8½" high.

Further information may be obtained by writing *Dept.RE-5, Industrial Specialty Company, 1725 West North Avenue, Chicago, 22, Illinois.*

Matrix Algebra

(*Continued from page* 17)

The application of these laws leads to the system of simultaneous equations which are ordinarily idealized into the linear equations used in circuit analysis. Matrices were developed by mathematicians for the express purpose of establishing the properties of systems of linear equations. Basically, therefore, the properties of electrical networks must all be deducible from a system of equations which are most simply and easily symbolized by matrices.

If the variables ($e_1, e_2, \ldots\ldots e_N$) are allowed to represent the alternating voltages impressed in the various meshes of an N-mesh network, and $\|Z\|$ and $\|i\|$ represent the impedance and current matrices, respectively, then the behavior of the most general possible linear network can be characterized by the equation:

$$\begin{Vmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{Vmatrix} = \begin{Vmatrix} Z_{11} & Z_{12} & \ldots & Z_{1N} \\ Z_{21} & Z_{22} & \ldots & Z_{2N} \\ \vdots & & & \vdots \\ Z_{N1} & Z_{N2} & \ldots & Z_{NN} \end{Vmatrix} \begin{Vmatrix} i_1 \\ i_2 \\ \vdots \\ i_N \end{Vmatrix} \ldots (13)$$

If the voltages are alternating of angular frequency ω, then:

$$Z_{ij} = J\,\omega\,L_{ij} + R_{ij} - \frac{J}{\omega C_{ij}} \ldots\ldots\ldots (14)$$

where $J = \sqrt{-1}$. In general $Z_{ij} = Z_{ji}$. Therefore, if $\|Z\|$ is not singular, equation (13) can be written in the form:

$$\|i\| = \|Z\|^{-1}\,\|e\| = \|Y\|\,\|e\| \ldots\ldots\ldots (15)$$

where $\|Y\|$ is the admittance matrix.

The matrix representation is especially valuable in representing transformations of networks into other equivalent networks. In the case of an N-mesh network interconnected in some manner to form a transformed system, by this transformation there will be formed new meshes, and consequently new mesh currents will be required to specify the new system. If $\|A\|$ is the transformation matrix and $\|i'\|$ is the matrix of the currents of the new system, then the transformation is represented by:

$$\|i\| = \|A\|\,\|i'\| \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

In general, $\|A\|$ is an N-rowed matrix of constants, and need not be a non-singular matrix. Once this transformation equation is known, the other electrical parameters of the circuit are known from the following relations:

$$\|e'\| = \|A\|_t\,\|e\| \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

$$\|Z'\| = \|A\|_t\,\|Z\|\,\|A\| \ldots\ldots\ldots\ldots (18)$$

As an application of this theory, consider the complete delta-delta circuit shown in Fig. 2. This circuit may be considered as made up by synthesizing a nine-mesh circuit which is interconnected to form the required four-mesh delta-delta circuit. Assuming no mutual inductance or capacitance, the transformation equation is:

$$\begin{Vmatrix} I_1 \\ I_2 \\ I_3 \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ I_9 \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 1 \\ 0 & -1 & 0 & 1 \end{Vmatrix} \begin{Vmatrix} I_1' \\ I_2' \\ I_3' \\ I_4' \end{Vmatrix} \ldots (18a)$$

By use of equations (17) and (18) the equation of the new four-mesh network becomes:

$$\begin{Vmatrix} E_1 \\ E_2 \\ E_3 \\ 0 \end{Vmatrix} = \begin{Vmatrix} Z_1+Z_5+Z_7+Z_4 & -Z_5 & -Z_9 & -Z_7 \\ -Z_5 & Z_2+Z_6+Z_9+Z_5 & -Z_6 & -Z_4 \\ -Z_4 & -Z_6 & Z_3+Z_4+Z_8+Z_6 & -Z_8 \\ -Z_7 & -Z_9 & -Z_8 & Z_7+Z_8+Z_9 \end{Vmatrix} \begin{Vmatrix} I_1' \\ I_2' \\ I_3' \\ I_4' \end{Vmatrix} \ldots (19)$$

Relations may be set up from this equation to handle any particular problem. In this case the transformation from the original nine-mesh network accomplishes no essential simplification, since equation (19) could have been derived from Kirchhoff's laws directly. However, in cases where there are mutual couplings between the various impedances, this procedure is extremely useful in preventing possible errors involving the mutual inductances and capacitances.

The general theory can be readily specialized to the case of the four-terminal network. Referring to the circuit of Fig. 1a, the relationship between the input and output currents and voltages can be expressed:

$$\begin{Vmatrix} E_1 \\ E_2 \end{Vmatrix} = \begin{Vmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{Vmatrix} \begin{Vmatrix} I_1 \\ I_2 \end{Vmatrix} \quad (20)$$

$$\begin{Vmatrix} E_1 \\ I_1 \end{Vmatrix} = \begin{Vmatrix} A & B \\ C & D \end{Vmatrix} \begin{Vmatrix} E_2 \\ I_2 \end{Vmatrix} \quad (21)$$

$$\begin{Vmatrix} I_1 \\ E_2 \end{Vmatrix} = \begin{Vmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{Vmatrix} \begin{Vmatrix} E_1 \\ I_2 \end{Vmatrix} \quad (22)$$

In addition each of these three equations can be expressed in the inverse form. All of these modes of representation have their particular usefulness in the analysis of four-terminal network performances. There are several ways in which four-terminal networks may be interconnected. For purposes of illustration only, the following three will be considered:

a. cascade
b. series
c. parallel-series

as shown in Fig. 3. The methods discussed here also apply when more than two component networks are involved.

a. Cascade connection. This case has already been discussed in this article. Application of equation (21) results in the equation that has been derived previously.

$$\begin{Vmatrix} E_1 \\ I_1 \end{Vmatrix} = \begin{Vmatrix} A & B \\ C & D \end{Vmatrix} \begin{Vmatrix} A^1 & B^1 \\ C^1 & D^1 \end{Vmatrix} \begin{Vmatrix} E_2' \\ I_2' \end{Vmatrix} \quad (22a)$$

b. Series connection. In this case, since $I_1 = I'_1$ and $I_2 = I'_2$ the use of equation (2) gives as the resulting equation of the new system:

$$\begin{Vmatrix} E_1 + E_1' \\ E_2 + E_2' \end{Vmatrix} = \begin{Vmatrix} Z_{11} + Z_{11}' & Z_{12} + Z_{12}' \\ Z_{21} + Z_{21}' & Z_{22} + Z_{22}' \end{Vmatrix} \begin{Vmatrix} I_1 \\ I_2 \end{Vmatrix} \quad (22b)$$

c. Parallel-series connection. In this case, since $E_1 = E'_1$ and $I_2 = I'_2$ the use of equation (22) gives as the resulting equation of the new system:

$$\begin{Vmatrix} I_1 + I_1' \\ E_2 + E_2' \end{Vmatrix} = \begin{Vmatrix} g_{11} + g_{11}' & g_{12} + g_{12}' \\ g_{21} + g_{21}' & g_{22} + g_{22}' \end{Vmatrix} \begin{Vmatrix} E_1 \\ I_2 \end{Vmatrix} \quad (22c)$$

The few examples given above should suffice to illustrate how matrix methods can be applied.

★ ★ ★ ★ TECHNICAL BOOKS ★ ★ ★ ★

"FUNDAMENTALS OF RADIO COMMUNICATIONS," by Austin R. Frey. Published by *Longmans, Green and Company,* 55 Fifth Avenue, New York. 385 pages. Price $4.00.

Contrary to the implication carried in the title of this book, Dr. Frey's *"Fundamentals of Radio Communications"* is in no sense of the word, an elementary text.

This book covers the subjects of resonant circuits, thermionic emission, diodes, voltage amplifiers, oscillators, r-f transmission lines, and radiation. The subjects are treated in a systematic manner, with examples and problems for self-examination.

For the engineer interested in r-f feeders, this book amplifies material covered in the April issue of Radio-Electronic Engineering on that subject. Dr. Frey has made a thorough analysis of the problem under varying line conditions. He has included the open-circuited lines of even wavelengths and odd wavelengths, lines terminated in a load, and a discussion of a line of infinite length.

The mathematics of the text are of calculus level and high, hence, the text is of no value to the beginning radio student, but should prove to be a valuable reference work for the engineer or engineering student.

The chapters on vacuum tubes and vacuum-tube circuits have been brought up-to-date and engineering data and characteristics of the Klystron, ignitron and several of the new control tubes is given.

"COMMUNICATION CIRCUITS," by L. A. Ware and H. R. Reed. Published by *John Wiley and Sons,* New York. 325 pages. Price $3.50. Second Edition.

In this second edition, published originally in 1942, Mr. Ware and Mr. Reed have made notable additions to their original work. Entirely new material has been added to provide the student with new working tools. Emphasis has been placed on impedance matching, especially as applied to the higher frequencies. The circle diagram method for determining conditions for impedance matching is introduced.

A new chapter, treating the more practical aspects of waves guides, such as the selection of tube sizes, modes of transmission for specific purposes, and methods of excitation, has been added.

An effort has been made, on the part of the authors, to clarify explanations which might cause confusion in the mind of the reader.

As in the first edition of "Communication Circuits" both wired and wireless transmission is covered. Transmission-line parameters, infinite lines, impedance transformation, and electromagnetic theory of coaxial lines, are but a few of the subjects discussed in this book.

The appendices number nine, and give necessary information on the Fourier series, loop equations, hyperbolic functions, and natural hyperbolic function tables as well as other subjects.

This book cannot be classed as a home-study text as the authors have presupposed a thorough knowledge of a-c theory and a practical working mastery of calculus. However, to the engineer or advanced student seeking a reference book for various transmission line problems, this book will prove most valuable.

"ELECTRON OPTICS," by Paul Hatschek, translated by Arthur Palme. Published by *American Photographic Publishing Co.,* Boston, Mass. 156 pages. Price $3.00.

Electron optics is a science which is just beginning to receive the attention of the engineer. Applications of this art have given the world a new tool, the electron microscope.

Although this book was originally published in Europe in 1936, it is making its first appearance in this country in a translation by Arthur Palme.

The concepts, as presented in this text are elementary but serve as a foundation on which to build further investigation. This work may be read and enjoyed by the layman as well as the engineer because the textual material is presented without the use of mathematics.

The structure and function of lenses is fully described along with the electron-flow theory. The wedding of the lens makers art to the discoveries of the research physicist has produced many laboratory tools whose value have been only partially realized.

Mr. Palme has added a chapter to this book to bring Dr. Hatschek's material up-to-date with the new uses and instruments which will make electron-optics a valuable science for the postwar world.

Industrial Review

(*Continued from page* 32)

materiel, but it is expected that two items in the sound line will be on the market by late summer and other items will follow shortly thereafter.

The models to be released are the portable recorder and a portable amplifier-equalizer. The recorder, now in production, has a new magnetic cutter head, replacing the crystal cutter formerly used. An improved low-pressure pickup, with a choice of crystal or dynamic type has also been included, while the overall weight has been reduced 70 pounds.

This recorder is designed for portable field service and meets the requirements for direct lateral recording and reproducing of sound from 78 RPM or 33.3 RPM discs up to 16 inches. The equipment may be set up in a few minutes by means of plug-in connectors.

Further details of this line and delivery are available from the *Fairchild Camera and Instrument Corporation* of New York.

* * *

Electronic Controls

An increase in the use of electronic controls in a variety of ways as a component of systems partly mechanical and partly electrical has been noted by the Westinghouse Electric and Mfg. Co.

Many motor drive problems, particularly those connected with machine tools are best solved by the characteristics inherent in a shunt wound d-c motor. The universal use of a.c.

has made it more difficult to use the d-c motor for these drive applications. An electronic control has now been developed which will operate a d-c motor from an a-c line with added features not possible before.

An adjustable speed motor drive

consists of a d-c shunt wound motor whose field and armature are energized by separate thyratron rectifier circuits. These rectifiers are so controlled as to vary the input to the motor, regulate the motor speed to a preset value and limit the maximum current furnished the motor during acceleration and reversal.

This control permits smooth stepless adjustment of motor speed over a range 20/1 below the base speed of the motor, and over an additional field control range of as much as 4/1 above the base speed of the motor. This speed control is obtained over the full range by means of a small dial located in the pushbutton station convenient to the operator. Normal variations in a-c voltage have only a small affect on the speed regulation.

This thyratron control equipment for a-c rectification is available from *Westinghouse Electric and Manufacturing Company.* Information may be obtained by writing Dept. RE-5, East Pittsburgh, Pennsylvania.

* * *

Fluorescent Lamps

DUE to the increased popularity of the fluorescent lamp for industrial lighting, the Westinghouse Company has developed and is manufacturing an instant-starting 40 watt fluorescent lamp having the same rated life as the standard type fluorescent lamp using conventional ballasts and starters.

The new lamp will eliminate the need for starters and will operate on a special type of instant-starting ballast. Limited quantities of these lamps will be available after May 1.

Further information on this type of lighting is available to interested persons upon application to the *Westinghouse Electric and Mfg. Co.,* Dept. RE-5, East Pittsburgh, Pa.

* * *

Steatite

A NEW technique for applying metal coatings to steatite insulator surfaces has been developed by the General Ceramics and Steatite Corporation.

These metal coatings are composed of a layer of silver fixed at a high temperature to the surface of the steatite plus an electro-copper plate on top of the silver to increase the thickness of the metallic plate.

This method of application assures a permanent bond between the steatite and the metal. This combination also provides a method of solder sealing metal parts to ceramic over limited temperature ranges.

The metallic surface being in intimate contact with the insulating surface provides a convenient method of adding shields to reduce corona effect in high-frequency circuits at high altitudes.

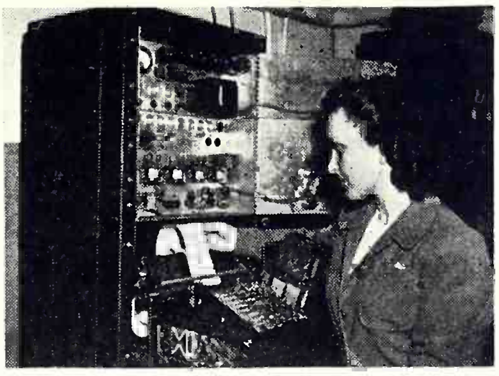
This development is by the *General Ceramics and Steatite Corporation* of Keasbey, New Jersey.

* * *

Philco "Master Mind"

A NEW piece of electronic equipment, designed for the calibration of Signal Corps apparatus, has been announced by Philco Corporation.

By means of this instrument, which utilizes 126 vacuum tubes, the government effected a saving of 144,000 manhours and $1,170,000 during 1943. In the manufacture of precision instruments, such as the Signal Corps frequency meter, it was necessary to calibrate this instrument by hand. This method involved a great expenditure of time and was subject to human error all along this line.



This "master mind" calibrates, calculates and records dial readings many times faster than a human being without the possibility of error. This calibrator consists of three parts, the first supplies a source of standard frequencies against which the Signal Corps frequency meters are calibrated. The second part provides a means of driving the dial of the frequency meter and generating a sharp impulse every time the frequency meter is turned through "zero beat" with the standard signal. This standard signal is derived from WWV, the United States Standard frequency station in Washington. The third unit automatically records and tabulates the dial reading.

In order to produce this instrument, it was necessary to develop a special type of FM detector, because of the problems arising in exact calibration. Philco plans many peacetime applications for this instrument when the "master mind" has completed its wartime duty. *Philco Corporation* of Philadelphia is responsible for this instrument.

* * *

New C-R Tube Packing

IN AN effort to save time and material, National Union Radio Corporation has instituted a new method of packing their cathode-ray tubes for shipment to the Army and Navy.

The advantage of this type of packing lies in the 25% saving in labor as well as a sizable reduction in corrugated packing material used. The filler is made of one piece of corrugated board which is folded and die cut to replace the four pieces of critical material formerly required.

The size of the cartons has been reduced materially, thus indirectly saving valuable shipping space.

This method of packing is being used extensively at *National Union Radio Corporation's* plant in *Newark.*

CALENDAR of Coming Events

APRIL

25-26-27—Technical Conference.

The Society of Motion Picture Engineers, Hotel Pennsylvania, New York. Julius Haber, Pub., Chairman.

26—**Institute of Industrial Engineers & Executives,** Business Meeting, 7:00 P.M. Chicago Engineers Club, Chicago, Illinois.

28—**American Institute of Chemists,** Dr. A. A. Potter speaks on *Patent Problems in America,* Dinner at 6:15 P.M. Huyler's Restaurant, Chicago, Illinois.

28-29—**Society for the Advancement of Management,** National Conference, Drake Hotel, Chicago, Illinois.

27-29—**American Physical Society,** Pittsburgh, Pa.

MAY

12-13—**Acoustical Society of America,** New York.

* * * *

MONTHLY MEETINGS

Association of Electronic Parts & Equipment Mfrs. L. G. Groebe, Secy., 77 W. Washington St., Chicago, Illinois.

2nd Thursday each month.

* * * *

Sales Managers Club. Hotel New Yorker, New York. Walter Jablon, Secy., Hammarlund Mfg. Co.

Lunch meeting on the 4th Wednesday each month.

* * * *

The Representatives. R. Edward Stemm, Secy. Chicagoland Chapter, Chicago, Illinois.

Luncheon meeting 1st Monday each month.

* * * *

I. R. E., Chicago Section. William O. Swinyard, Secy., 325 W. Huron Street, Chicago, Illinois. Del. 3055.

Meeting May 19, 1944, Central Y.M.C.A., 19 South LaSalle St., Chicago, Illinois. 6:45 P.M., Kendall Clough, Pres., Clough-Brengle Company, Chicago, speaks on *Specialized Problems of Electronic Instrument.*

Transmitter Maintenance

(*Continued from page 22*)

quires that one of the quantities in the numerator must be zero, or one of the factors in the denominator must have acquired a greatly increased value.

Since the plate voltmeter is indicating, the only factor remaining in the numerator is an open r-f choke coil. Since the operation of the amplifier is in push-pull, this factor was discarded since rarely do both coils open simultaneously without some obvious indication. A rapid check for the presence of high frequency at the grid of the tubes, eliminated all of the factors in the numerator.

With the use of two tubes in the circuit, with respect to the direct current component, the possibility of the internal resistance of both tubes reaching infinity at the same time, is very improbable. The load impedance was checked by changing the value of the tank capacitance. This eliminated all of the components in the denominator with the exception of the negative bias voltage, the cause of the failure was proven to be an excessive negative bias condition.

Shorting the terminals of the grid current meter restored normal operation, since the grid circuit of this particular amplifier was such that before the grid return was shorted, the excitation voltage from the preceding amplifier produced a high value of negative bias through rectification in the tube grids.

In the second practical example, the overload relay in the plate circuit of the intermediate amplifier opened. Upon resetting the relay, it was noted that the d.c. plate current was excessive. It was also noted that the flow of current in the tank circuit was zero. By means of relations (1) and (2) the value of the a.c. load circuit was determined to be zero. A mechanical inspection disclosed that a section of the mica tank capacitance was defective.

Although many of the causes of failure in transmitter circuits are easily determined by visual inspection, there are still many instances in which testing, experimenting and mathematics must be combined to give a satisfactory answer to the problem.

In such instances as, for example, when equipment which has been operating in a satisfactory manner for a long period of time, suddenly begins to show deviations caused by such conditions as seasonal changes of antenna resistance. The key to the solution of these problems lies in the proper interpretation of the tank-current ammeter readings.

Proper adjustment may be established by attention to two factors, namely, power output and efficiency. The input power may be interpreted directly by means of the direct current plate components. If the high frequency circulating current can be established as a function of the operating efficiency, a test for the efficiency and output can be established.

The use of Class C amplifiers provides a maximum efficiency within the physical limitations of the components consistent with the necessary harmonic attenuation. However, Class B amplifiers exhibit a lower efficiency which is independent of the percentage of modulation.

$$\eta = \frac{E_p I_p}{2 E_b I_b} \quad (3)$$

Where:

η = plate circuit efficiency
E_b = d-c plate circuit value
I_b = d-c plate circuit value
E_p = fundamental peak component a-c output
I_p = fundamental peak component a-c output

The ratio of I_p/I_b is a function of the angle of operation, thus the plate efficiency becomes:

$$\eta = \frac{E_p k}{2 E_b} \quad (4)$$

Where:

$$k = \frac{\theta - \sin\theta\cos\theta}{\sin\theta - \theta\cos\theta}$$

θ = one half of the angle of operation.

When the reactance of the tank condenser is a known quantity, X_c; E_p to a fair degree of approximation becomes $I_t X_c$ and the formula becomes:

$$\eta = \frac{I_t X_c k}{2 E_b} \quad (5)$$

For the class B operation, where the efficiency is the basis of design,

$$\theta = \frac{\pi}{2}$$

$$\text{Max. } \eta = \frac{E_p \pi}{4 E_b} \quad (6)$$

From this equation the maximum efficiency is determined to be approximately 78%. Since an analysis of the plate characteristics, as well as practical considerations place the practical linear limits at approximately 66%, the unmodulated operation is at an efficiency of 33%.

$$.33 = \frac{E_p \pi}{4 E_b} \quad (7)$$

but:

$$E_p = 0.707\, I_t X_c \quad (8)$$

and I_t becomes:

$$I_t = \frac{.33 \cdot 4\,E_b}{0.707\,\pi\,X} \qquad (9)$$

For a plate voltage of 10,000 volts, and a tank condenser reactance of 250 ohms, the tank current must approximate 24 amperes in order to give an efficiency of 33%.

In order to readjust an amplifier of this type, the operating angle is fixed by establishing the bias at cut-off, thus only the excitation voltage must be compensated to satisfy the relationship $I_t = E_b k$.

Vacuum tube circuits which are properly designed generally remain free of operational difficulties with the possible exception of tube failures. In most instances, actual interruptions may be attributed to the associated circuits rather than trouble appearing in the radio-frequency circuits.

Records kept by a large broadcasting station over a several year period indicate that the station failures may be roughly classed as follows, power interruptions, 27; tube failures, 28; minor failures, 51; storms, 8; mechanical failures, 36; for a total of 150 interruptions.

Power failures are classed as those which do not originate within the station but are the fault of the supplying utility. While the proportion of such failures appears to be large in comparison with the total interruptions, it must be realized that momentary surges and interruptions which in themselves are not serious or of long duration, may trip one of the controls on the transmitter which has to be reset before operation may be continued.

Tube replacements, with the exception of those used in polyphase-rectifier circuits or tubes of the water-cooled type, may be made easily and quickly. Tracing failures in the polyphase circuit has been discussed previously in the article. While the replacement of water-cooled tubes involves the expenditure of greater amounts of time than those required for other types of tubes, the actual operation is no more difficult. Certain electrical connections must be made and care exercised to assure the proper seating in the cooling jacket, and the location of the water gasket. Before the potential is applied, all water which has been spilled must be wiped up carefully, so that when the power is applied arcing to ground will not result.

In the case where a new tube is installed with imperfect seals, the fault may be corrected by allowing the tube to operate with the water circulating, but without the cooling medium for a period of from several minutes to a half hour until the inlet temperature of the cooling water reaches approximately 130 to 150 degrees F. This operation results in a slight expansion of the parts, which will aid in sealing a minor leak.

In the classification of "minor failures" are included those which require the repair or resetting of overload relays and other controls, which are often caused by a temporary overload.

The eight interruptions attributed to storms, were recorded in the earlier years when vertical radiators were first being installed. Since then adequate protective devices have been developed and the record of interruptions caused by storms has improved materially. Probably the most vulnerable of all the components to lighting are the radio-frequency indicating instruments which are used on the antenna or transmission lines. Wherever possible, these instruments should be protected by heavy conductors shunting the termals during normal operation. The shunts should be of the switch type to permit the instruments to be inserted into the circuit when desirable.

The mechanical failures were recorded, in order of the frequency of occurrence, as resistors, condensers, water-cooling system, contacts and connections, breakdown of insulating material, and open current meters.

Repair of water-cooling systems involves time consuming work, hence, if at all possible leaks should be temporarily sealed by the use of rubber or friction tape. This is a temporary expedient only, and permanent repairs should be made as soon as the station is "off" of the air.

Preventive maintenance and periodic inspection of the transmitter is the best possible solution to the problem of station failures. Familiarity with the circuits still remains as a primary requisite of the station engineer in order that speed replacements and repair of failures may be made in the shortest possible time. Thus keeping the station on the "air" proves to be a combination of knowledge, common sense, and experience.

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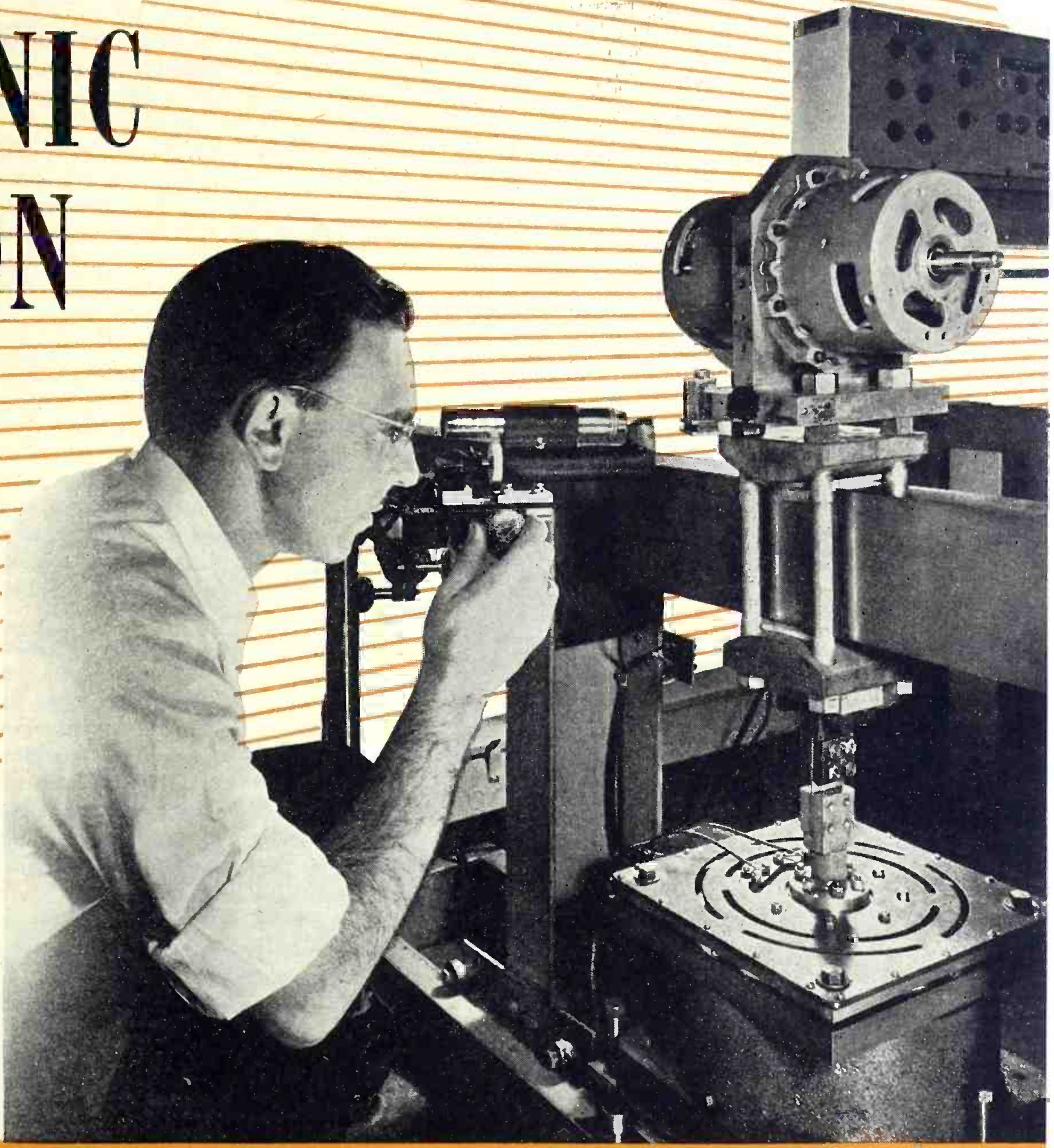
ELECTRONIC VIBRATION TESTER

By
FORREST DORMAN
Curtiss-Wright Corp.

A discussion of equipment used in vibrating materials and measuring the resulting stresses by electronic devices.



A technician examining the vibratory cycle of a propeller motor mounted on a resonance bar.

FORREST DORMAN

Research specialist in charge of experimental stress analysis and vibration fatigue testing in the Propeller Division of Curtiss-Wright Corporation.

VIBRATION fatigue testing today is becoming increasingly important to the manufacturers of machines or parts which are to be subjected to vibratory stresses or forces in service. To these manufacturers, the value of such testing is so well known as to require no mention, and the industry has for several years been developing better means of producing these types of tests.

In previous years a mechanical means of producing vibratory forces has normally been used. This usually consisted of whirling unbalanced weights of one arrangement or another. In more recent years, however, a newer type of vibrator utilizing the principle of the electro-dynamic speaker has been under development by several concerns. This, of course, required the development of specialized a.c. electric power generators for driving and controlling these vibration motors as well as the development of the motor itself.

It is well to consider the applications of such vibration machines which have justified their development.

The value of endurance testing of structural materials and the determination of fatigue limits is well known and the testing that has been done has been so extensive that there is hardly a structural material whose fatigue characteristics have not been investigated.

However, the knowledge of the fatigue limit of the material is only part of the consideration. Endurance testing of finished structures or component parts is of at least equal importance. Nevertheless, this type of testing has been given much less attention in the literature, perhaps because results of such tests, unlike those run on materials, are of interest only to the individual manufacturer. Much of this type of testing is performed on proving

Assembling strain gages on airplane propeller.

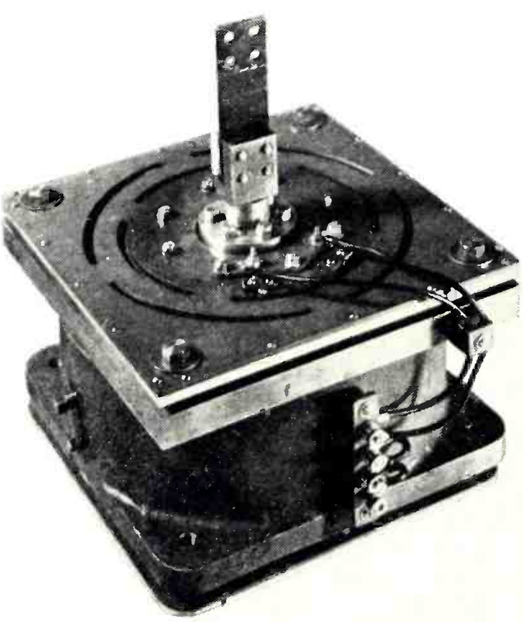
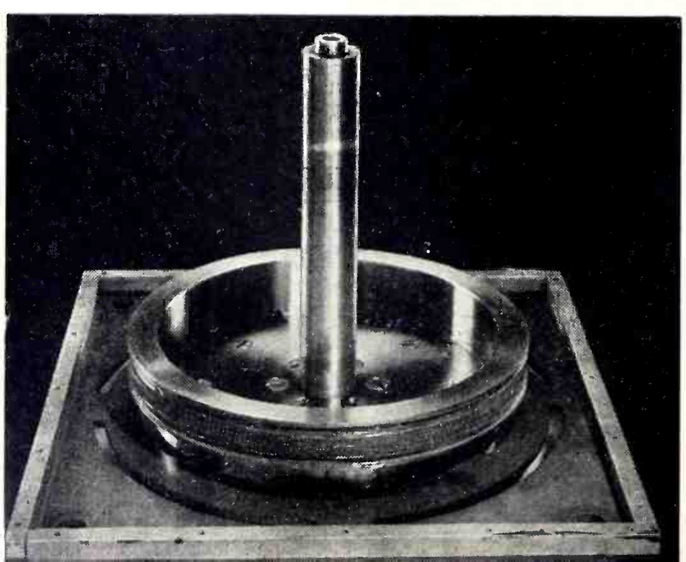


Fig. 1. Completely assembled vibration motor.

Fig. 2. Stainless steel armature or "voice coil" used in vibration motor shown in Fig. 1.



grounds, in test houses and under actual service conditions, but although this constitutes the nearest approach to a final test of the durability of a product, many more uncontrollable variables are involved than are present in a laboratory test. Furthermore, the laboratory permits testing of individual parts without requiring the testing of the complete assembly, which results in savings in both time and expense.

Unfortunately, the type of machine ordinarily used for fatigue tests of materials is generally unsuited for endurance tests of finished structures for two reasons. First, the machine is designed to accommodate only a test specimen of simple shape and more or less standardized dimensions. Second, it usually does not operate at high enough speed.

The latter comment calls for some amplification. It is well known that fatigue testing of steels requires approximately 10^7 cycles of reversed stress at each stress level and aluminum alloy 10^8 cycles or more before it can be determined that the endurance limit lies above this level. When such testing is performed on a machine which reverses the stress at 30 cycles per second, 93 hours of testing are necessary to reach 10^7 cycles, and a complete test on one material may require five weeks or more, even if the machine runs continuously. Machines of the rotating beam type may operate at considerably higher speeds, but are unsuited for testing of anything except standardized specimens of materials.

Most fatigue test machines are of the "brute force" type; that is, they contain rotating or reciprocating parts which apply, to the object under test, a momentary force comparable in magnitude to, and often larger than, the force required to produce a static stress of equal magnitude. The vibratory forces produced by these machines are normally carried by bearings, and consequently the machine is, of necessity, of rather heavy construction in order to outlive enough test specimens to justify its cost. The stress produced in the specimen in forced vibrations at a frequency appreciably lower than the lowest frequency of resonance is dependent only on amplitude, whereas the forces necessary to accelerate the moving parts of the machine are proportional to the square of the speed. Hence, conventional type machines are generally limited rather seriously as to speed range.

In fatigue testing of finished assemblies it is economically desirable to approach the fatigue stress limit from below. In the case of experimental assemblies, which constitute most of the testing, there is often only a single specimen available. Performed at 30 cycles per second, a test would last perhaps 10 weeks or even longer if the stress level increments were small. But the time element is not the only reason for developing a machine with a wider speed range.

Fatigue failures under service conditions do not usually occur at the lower frequencies of forced vibration. Elastic systems containing relatively little damping are much more likely to fail if they are vibrated at a frequency equal to one of their own natural frequencies.

In a system of more than a single degree of freedom the stress distribution at resonant frequencies above the lowest one, is entirely different from the stress distribution under static stress or low frequency forced vibration, so that failures in tests at low frequency would have no bearing on failures which might occur in service at much higher frequencies.

Not only are vibration stresses at resonant frequencies a more realistic representation of service conditions, but also they are much easier to produce. Forces for accelerating the vibrating parts are non-dissipative and at resonance are supplied by the vibrating system itself. The vibrator then needs to furnish only enough power to replace the energy lost through friction, windage, noise radiation, and mechanical hysteresis. Hence, a vibrator with a very moderate thrust output may create high stresses in the test specimen.

To summarize, there are a number of arguments in favor of endurance testing machines which operate at resonance, particularly when testing finished parts. These include accelerated testing through higher speed operation, more realistic stress distribution, and decreased vibrator thrust requirements.

Only a few machines for testing materials have been designed which make use of resonance phenomena. One difficulty encountered in operation of resonance, and perhaps the reason why such machines have not been more widely used, is the problem of maintaining constant exciting frequency. In a sharply tuned system, a change in frequency of a fraction of one percent can cause a change in stress level much greater than is allowable. Consequently, it was necessary to design a different type of equipment to do this job which employed electronic driving and controlling apparatus.

Basically, the system employs an electro-dynamic translational vibrator powered by a large vacuum tube amplifier which is in turn excited by a stable electronic oscillator. Other auxiliary