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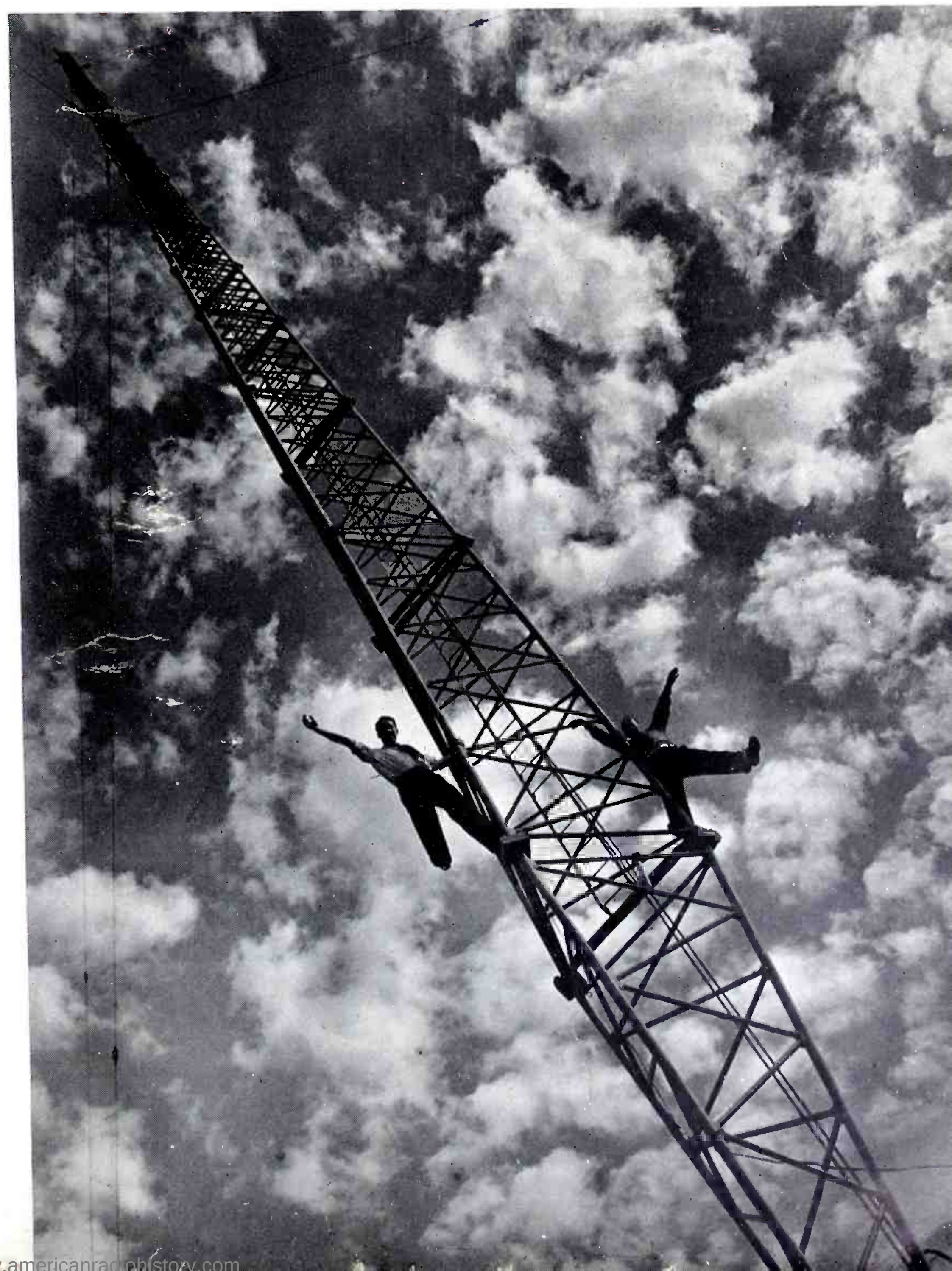

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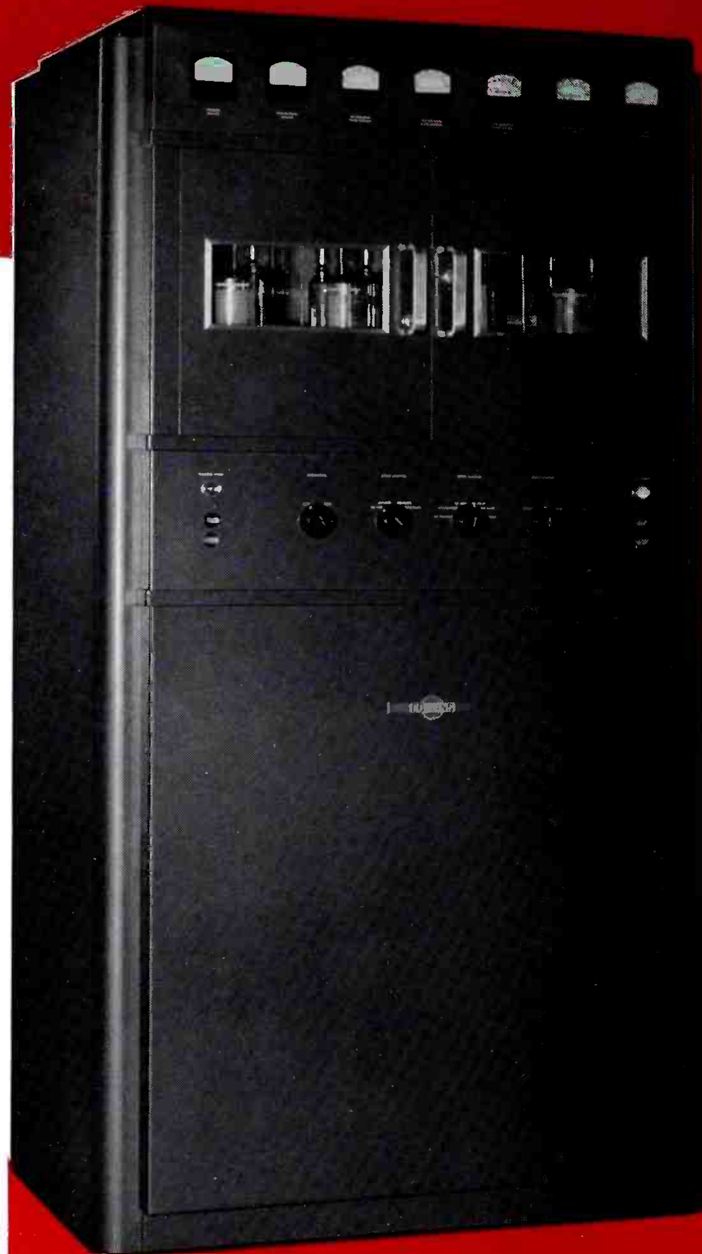

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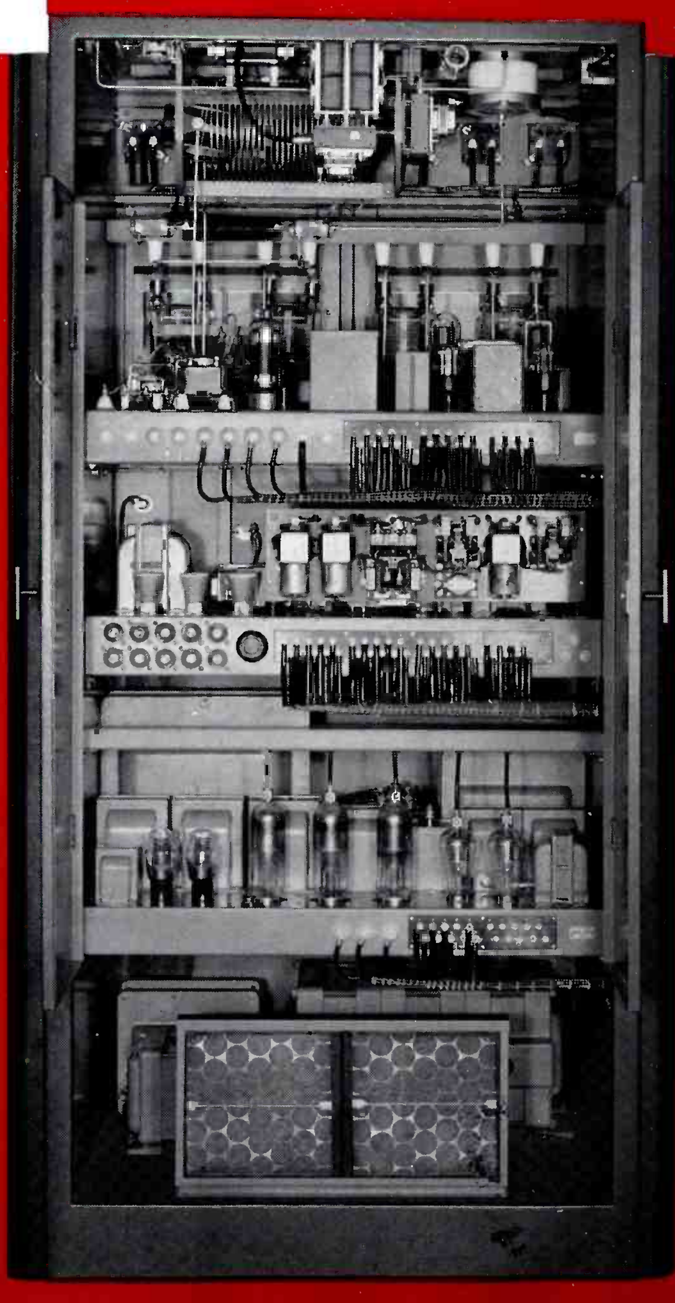

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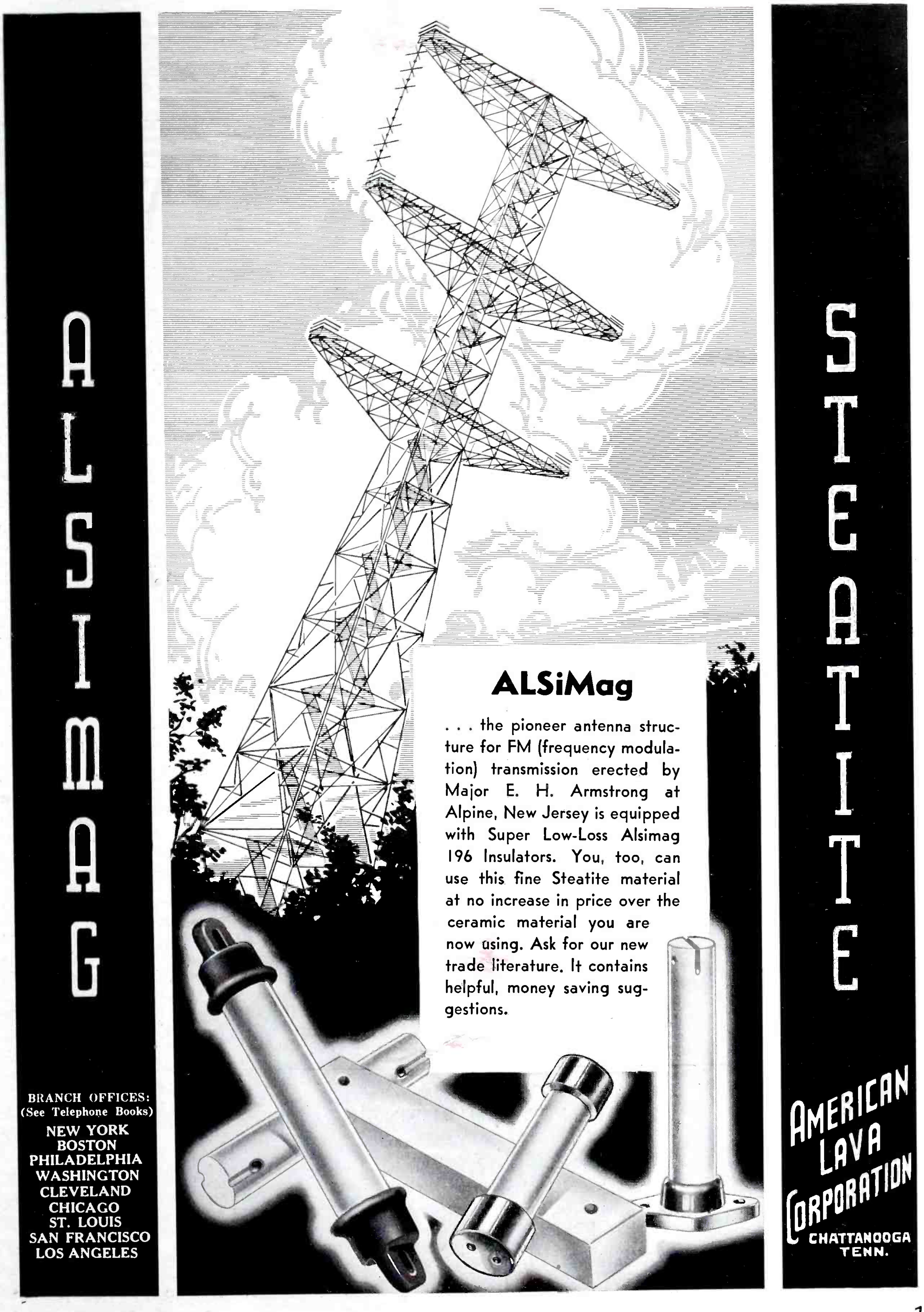
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DECEMBER 1939

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RAY D. RETTENMEYER
Editor

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COVER ILLUSTRATION

The 718-foot steel broadcast tower of station KDKA in Pittsburgh's suburban Allison Park district. This tower, originally erected at the station's Saxonburg transmitter, was dismantled and reassembled at the Allison Park site. Westinghouse photo.

•Editorial Comment•

THE Board of Governors of the Society of Motion Picture Engineers have announced that the forty-sixth semi-annual convention of the Society will be held April 22 through 25 at the Chalfonte-Haddon Hall Hotel in Atlantic City, New Jersey. W. C. Kunzman, Convention Vice-President, is completing tentative arrangements for the meeting, while the Papers Committee, under the direction of J. I. Crabtree, Editorial Vice-President, and Sylvan Harris, Papers Committee Chairman, has already begun its work of preparing the papers program. An excellent gathering is anticipated.

FEELING that the television industry had reached a "crucial stage" of development, the Television Committee of the Federal Communications Commission has recommended that the Commission adopt a more lenient policy towards the broadcaster. Specific recommendations were made towards the elimination of those regulations which may be interfering with proper business or economic processes. A definite suggestion in this respect was that under certain conditions the television broadcasters be permitted to obtain a specific amount of commercial sponsorship for their experimental broadcasts . . . to the point where operating expenses would be defrayed.

We believe this recommendation by the Television Committee to be a step in the right direction. Experimental television broadcasting is certainly a costly procedure, and a certain amount of commercial programs would do much to help these pioneers in television. An obvious objection, however, may be the costs of determining the operating expenses . . . a procedure which may be far from easy.

THE 1940 Radio Parts National Trade Show will be held at the Stevens Hotel, in Chicago, from June 11 through 14. The main exhibition will be held in the large exhibition hall in the Stevens Hotel, while the demonstration and conference rooms will be in both the Stevens and the Blackstone Hotels. From all indications the 1940 show promises to be bigger and better than the 1939 gathering.

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IMPEDANCE MATCHING

By ALBERT PREISMAN
RCA Institutes, Inc.

I INTRODUCTION

A SOURCE of considerable controversy among engineers is the question of impedance matching, and it is the hope of this article to clear up this matter in its various aspects. Originally, impedance matching meant the matching on an equality basis of the source and load impedances to the characteristic impedance of the intervening link, such as the transmission line. While this is still of paramount importance in telephone practice, the communication art has become so ramified that this consideration is of no importance in many other applications, and other factors determine the basis upon which impedance matching is done. It appears that the various factors can be classified into the following groups.

II MATCHING OF LOAD AND GENERATOR TO INTERVENING LINK

In telephone practice—as mentioned above—a transmission line is interposed between the source and load. The line has certain characteristics that require to be catered to in order that successful transmission be accomplished. In particular, it has a certain characteristic or surge impedance—if of infinite length—given by the formula

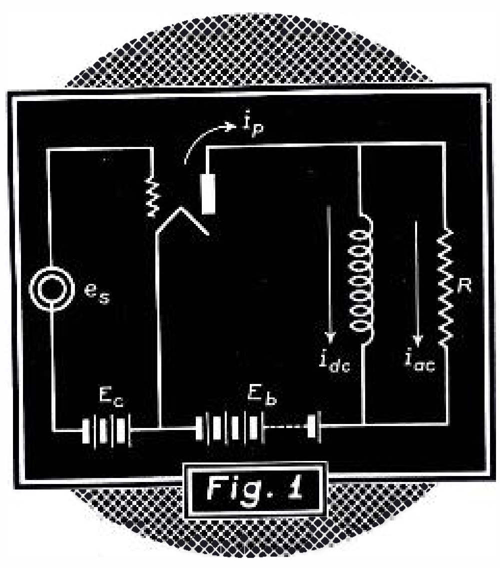
$$Z_o = \sqrt{\frac{R + jwL}{G + jwC}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where R, L, G, and C are respectively its resistance, series inductance, transverse conductance and transverse capacitance, per unit length. If $R = G = 0$ (which is approximately the case for an r-f transmission line), or if $R/G = L/C$ (the so-called distortionless line) then equation (1) becomes

$$Z_o = \sqrt{L/C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

or a pure resistance.

If a finite line is used, and it is terminated in a load impedance equal to its image impedance, given by equations (1) or (2), then it becomes equivalent to an infinite line, and its sending-end impedance becomes identical with its surge impedance. Furthermore, no reflections take place on such a line, and such effects as "echo" are avoided. Obviously, it is easiest to match a line whose image impedance is a pure resistance, hence every effort is exerted to make a line "distortionless," at least over the frequency range of transmission. This is usually done by adding lumped inductances in the form of loading coils in order to raise the ratio of L/C to as near equality with R/G as possible, since economic considerations determine how small R can be, and how small C can be (in the case of a cable). Unfortunately, loading coils make a line appear distortionless and hence easy to match up to a limiting higher frequency only, but this upper frequency limit can be extended as far as required within reasonable limits by spacing the loading coils closer together along the line. In short, the load is matched on an equality basis to the characteristic, surge, or image impedance of a line to avoid reflections, and particularly in the case of an ideal and also of a distortionless line, to insure flat frequency response.



Power-output tube transformer coupled to resistive load.

The generator, in order to maintain a flat frequency response, should have an internal impedance which is a pure resistance, and preferably one that is also equal to the surge impedance of the line. In this latter case we obtain maximum power transfer, and also any surges or disturbances originating on the line are absorbed not only at the load end, but at the generator end as well, and thus reflections of these at the latter end avoided.

Another case where the load and generator impedances are matched on an equality basis to the intervening link is where the latter is a filter section. Such a section can be designed so as to have a characteristic impedance which is practically a pure resistance over most of the pass band. If terminated at both ends by a pure resistance equal to its own characteristic impedance, it will have the desired pass and attenuation characteristics, although for theoretically perfect results, the terminating impedances should be more complex in nature in order to match more perfectly the characteristic impedance of the section, which impedance departs markedly from a pure constant resistance near the limits of the pass band.

It is interesting to note that while the terminating impedances (source and load) are matched to the characteristic impedance of the line or filter section, the latter impedance is made as nearly resistive in nature as is possible in practice in order to facilitate this matching.

Lack of space precludes any further discussion of these matters, but it is interesting to note in passing that due to the impossibility of perfect matching, equalizing networks are often required. For instance, in the case of a long line, undesirable phase shift may occur, which requires the further interposition of a phase-equalizing network between the line and load. The equalizing network when terminated in the load impedance, presents a matched impedance to the line, uniform amplitude transmission, and yet has a phase-delay characteristic which is the inverse of that of the line, so that the overall phase characteristic is linear with frequency.

III MATCHING OF LOAD TO GENERATOR

Matching under these conditions may or may not be on an equality basis, and is employed where the intervening link is so electrically "short" as to require no consideration with respect to its characteristics. While it is possible to treat this case as a limit case of a transmission-line practice, it is probably just as well to study this type of matching on the basis of ordinary circuit analysis.

The ordinary source or generator of

signal employed in communication work is characterized by a low conversion efficiency, and often is loosely coupled to its actuating source. As an example, the ordinary ribbon or dynamic microphone may be cited. Its acoustic to electrical efficiency is low, so that whether it is open or short-circuited makes little difference to the acoustic field in its vicinity. Furthermore, with reference to the source of the sound, its coupling is so low that its electrical loading has even less effect upon the source of sound. Hence there is everything to gain and nothing to lose in choosing an electrical load impedance which will draw maximum electrical power from it, and there is, in addition, no danger—due to design factors—that such a load will cause it to overheat. If the internal impedance of the generator is resistive in nature, and if its generated voltage is in proportion to the impinging acoustic energy regardless of frequency, then if the load be resistive in nature and equal to the internal generator resistance, maximum power output will result, and furthermore this power transfer will be independent of frequency and hence always proportional to the impinging acoustic power. Hence here too, matching is on an equality basis, but for a different reason from that for the transmission line.

On the other hand, if maximum voltage output is desired from the source, then the load may be any kind of an impedance provided it is many times that of the source, and in the above case the output voltage will be independent of frequency, since it is practically equal to the generated voltage of the generator. Thus, for maximum voltage output, the impedance matching is on an inequality basis, and rather indeterminate in nature: the load impedance has merely to be many times that of the generator over the required frequency range.

It is interesting to contrast this with the case of a power generator. Here maximum conversion efficiency is sought for, since the electrical energy as such is to be sold, and the only requirements as to its wave shape are that it be sinusoidal and of constant frequency. Hence the internal impedance is made as small a fraction of the load impedance as possible, and this also insures that the generator will not overheat. Were the load made as low as the generator in impedance, we should not only have excessive overheating, but the efficiency at best could be only fifty per cent.

Some communication generators, however. do not have a resistive internal impedance. A phonograph pick-up, for instance, has an internal impedance which is mainly inductive in

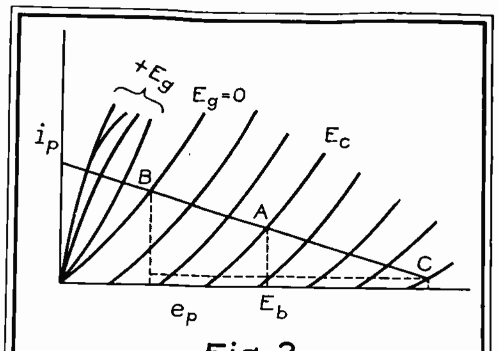


Fig. 2

The family of characteristics for the triode.

nature (balanced-armature type) or capacitive in nature (crystal type). For maximum power output, the load impedance should be the conjugate of that of the source, and equal to it in magnitude. This, however, can be done in practice at one frequency only, and is of no value for an extended frequency range of operation. Hence the load is usually made resistive in nature, but now the frequency response from a constant-velocity-cut frequency record will not be flat unless the generated voltage of the pick-up varies in a manner to produce this flat response. This the manufacturer may attempt to do, and he will then rate his pick-up as being of such an impedance—say 500 ohms—by which he means that a satisfactory frequency response will be obtained if the load be a 500-ohm resistance, since the resistance will not vary with frequency. Here, again, impedance matching is not on an equality basis, but rather on an empirical basis: the load impedance is such as to produce the best frequency response from the source.

The generators just considered are linear—i.e., their internal impedance is a linear parameter. When the source is a vacuum-tube or photocell, however, the impedance matching becomes an entirely different matter. We are now dealing with a non-linear generator, and in many cases the load impedance must be carefully chosen so as to obtain maximum power output consistent with a permissable distortion content.

The vacuum tube is not a generator of power in the ordinary sense of the word, but a variable resistance whose magnitude is controlled electrostatically by means of a grid, and which is capable of converting d-c energy (from the "B" supply) into the desired form of a-c energy. Since the differential equations expressing the circuit relations, or the simplified equations for steady-state conditions when the applied voltage is sinusoidal (Ohm's Law) are not amenable to solution if the circuit parameters are variable (or even periodic in nature), it has been found advisable to replace the vacuum tube with an approximately equivalent circuit whose impedances are linear, but which contains an a-c generator or generators as well as a d-c source. Such an equivalent circuit may form the basis of impedance matching, but the analytical expressions are usually so involved that recource is often had to graphical methods. Suppose, for instance, we have a circuit as shown in Fig. 1, which represents in essence a power-output tube transformer coupled to a resistive load R. The output transformer is assumed to be ideal, and the resistance shown is the reflected value of the actual load resistance connected to the secondary (not shown).

Suppose, first, that the tube is a triode having the family of characteristics shown in Fig. 2. The load line for the d-c component is drawn vertically upward through E_b to point A, since the primary of the transformer offers practically zero resistance to it. The reactance of the primary, however, is practically infinite to the a-c component, so that it is forced to flow through R, and accordingly, we draw through A a line BAC whose slope is 1/R, or the load line for R. The path of operation for the a-c component is along the latter line.

If the grid signal voltage is sufficiently great, the path of operation will include those portions of the tube characteristics which are curved, and as a result the current through R, hence voltage across R will not be a faithful copy of the grid signal voltage, e_s. Suppose the path of operation be confined to the portion BAC, for which segment the distortion is fairly small and permissable, and the output consists mainly of fundamental power. Assume further that the signal voltage is a sine wave, and that the operating point A (more correctly the quiescent point) is located midway in grid voltage between those corresponding to B and C. This merely means that the bias has been chosen half-way between the limits of grid swing defined by points B and C.

In this case it is easily shown that the fundamental power output, P, is approximately one-quarter of the area of the triangle BDC. This corresponds with the formula

$$P = \frac{(E_{max} - E_{min})(I_{max} - I_{min})}{8} \quad (3)$$

Now if R is varied, the length of path of operation (for the permissible amount of distortion) will vary, as will the bias, which must always be midway between the extremes of grid swing. Specifically if R be increased, its load line will be more nearly horizontal, and a greater negative grid swing is possible before the permissible amount of distortion is reached. This means, in turn, a greater grid swing and bias, and a different amount of power output (different triangle of different area).

There is one slope corresponding to one particular value of R which gives the maximum amount of fundamental power output for the given permissible amount of distortion, and this is the value of the load resistance to match the tube. If the characteristic were to consist of straight parallel lines equidistant in spacing (the so-called linear tube), then the above optimum slope would be one-half that of the slope of the tube lines, which corresponds to a load resistance which is twice the so-called plate resistance, r_p, of the tube. In actual triode tubes whose characteristics have appreciable upward curvature, it will be found that the optimum value of R is more than twice r_p. There is some small effect from the shifting of the load line due to self-rectification of the tube, but the results are still substantially as explained above.

The above can be explained on a physical basis. It was mentioned above that the tube can be replaced by an equivalent generator whose voltage is μe_s, and a linear resistance called r_p of the tube. The distortion can be approximately represented by a generator whose voltage is proportional to $\mu^2 e_s^2$. (This means that the distortion is assumed to be mainly second harmonic.) The magnitude of the second-harmonic voltage can be shown to depend upon R, and to decrease as R increases. Hence, as R is increased, e_s can be increased until the second-harmonic voltage is brought back to its original, permissible value. This means that the equivalent fundamental generator can be assumed to be generating a higher voltage μe_s.

For a linear generator the maximum power theorem states that maximum power output occurs when the load resistance is equal to the generator resistance. This is on the assumption that the generated voltage is constant. But in the case of the triode tube, it is possible to obtain a higher equivalent generated voltage if R is made greater than r_p, so that under these conditions more power output is obtained even though this means R is mis-matched to r_p. Since we are dealing with resistances, this state of affairs is true at all frequencies, so that mis-matching will not affect the frequency response, and hence can be employed in wide-frequency-range amplifiers. If the grid signal is fixed, however, so that the equivalent generated voltage cannot be varied, then the maximum power output is obtained when $R = r_p$, just as in the case of linear generators.

In Fig. 3 is shown the very non-linear characteristics of a pentode tube. For a given operating point, A, the distortion will vary with R in a very complex manner. For a low value of R, the output will contain more even harmonics, while for higher values, it will contain more odd harmonics. If R be sufficiently great, its load line for sufficient grid swing will cut through the characteristic where the plate current droops markedly, and a rich crop of harmonics will result.

The optimum value of R, and the maximum power output is now to a great extent, a matter of opinion or choice between even and odd harmonics, since a value of R which gives a minimum of one, will not give a minimum of the other. About the only rule for matching here is that R should not be so high that its load line cuts through the drooping portion of the characteristic. This is also true for the push-pull AB_2 operation.[1] For push-pull AB_1 operation, more even than odd-harmonic distortion can be tolerated for each tube, due to the cancellation of the former in the output, so that the value of R chosen is generally less than that for a single-side operation. In all cases, however, R is very much less than the r_p of a pentode tube, which is just the opposite of the case for a triode.

When we consider a Class C tube operating into a tank circuit, the analysis becomes indeed complicated, since the reactive load has to be chosen so that a maximum of the following contending factors are obtained:

(1) Fundamental power output, (2) freedom from harmonic output, (3) plate efficiency, (4) ease in driving the grid, (5) insurance against exceeding the plate dissipation.

The choice of load parameters is too involved to be discussed here, but we may summarize all the cases of matching a load to a non-linear generator by saying that this is usually on an inequality basis in order that optimum results be obtained. Specifically

[1]See "Balanced Amplifiers"—A. Preisman—*Communication and Broadcast Engineering.* Part IV, October, 1936.

Showing the non-linear characteristics of a pentode.

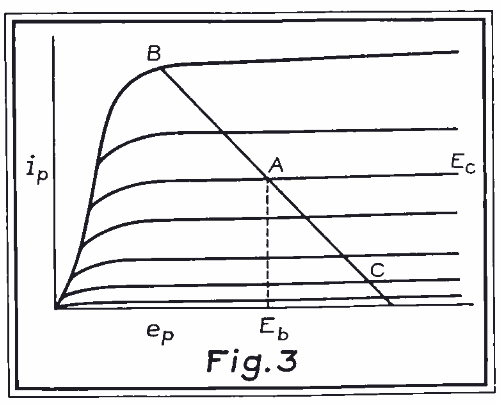


Fig. 3

for an audio-amplifier power-output stage, this means choosing that value of load resistance which gives maximum fundamental power output consistent with a permissible amount of distortion. If this value produces a plate dissipation which exceeds that permitted for the tube, or if this value will demand an unreasonable degree of regulation of the "B" power supply, or if self-bias is desired, then another value of R, or a change in operating voltages, or both, may result in better results. Hence in this type of operation, impedance matching is determined by a variety of factors, and therefore is quite a different matter from impedance matching for a transmission line.

IV MATCHING OF GENERATOR TO LOAD

In many instances the load must be catered to instead of the generator, and impedance matching is determined therefore, by the characteristics of the load. Three examples of this will be cited here, although there are many other instances.

The first is the audio transformer. If this be of the input or interstage type, it may be represented by an equivalent T-network, which at low frequencies reduces to an (primary open-circuit) inductance, L_m, paralleled by a resistance, R_c (see Fig. 4-a). At high frequencies the equivalent T-network reduces to a series resonant circuit (Fig. 4-b), in which L_L is the total leakage inductance as viewed from the primary side, and C is the reflected lumped equivalent of the secondary capacities.[2]

Let us first study the unloaded case, i.e., R_L is infinite. We can also usually ignore R_e as being very high. The voltage across L_m at low frequencies (Fig. 4-a) is evidently

$$e = e_g \frac{j\omega L_m}{r_g + j\omega L_m} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

and the voltage across the secondary is "a" times this, where "a" is the turns ratio. It is evident from equation (4) that as the frequency decreases, e decreases, so that a flat frequency response is not possible. But if the permissible drop in e is 5%, for instance, at the lowest frequency desired to transmit, then if r_g is made one-third of ωL_m at this frequency, the desired results will be obtained.

At the high-frequency end of the spectrum, the voltage across C (Fig. 4-b) will be

$$e = e_g \frac{-j/\omega C}{r_g + j\,(\omega L_L - 1/\omega C)} \quad \ldots\ldots (5)$$

[2]See, for instance, Terman, *Radio Engineering*, pp. 188-202—Second Edition.

At resonance, where $\omega_o L = 1/\omega_o C$, this reduces to

$$e = e_g \frac{-j/\omega_o C}{r_g} = e_g Q \quad \ldots\ldots\ldots(6)$$

where $Q = \omega_o L_L/r_g$. If $Q = 1$, then $e = e_g$, and the secondary voltage is ae_g. This means that r_g must be chosen equal to $\omega_o L_L$. In a well designed transformer, L_m, C, and L_L are such that the optimum value of r_g for the low-frequency response is the same as that for the high-frequency response, and the resulting curve will be as shown by the solid line in Fig. 5, where f_l and f_h are respectively the lowest and highest frequencies to be transmitted.

If a lower value of r_g is employed, the low-frequency response will be improved, but a resonant peak will develop at the high-frequency end, whereas if r_g is increased, both the high and low frequencies will be reduced. This is shown respectively by the broken line curves A and B in Fig. 5.

If the secondary be loaded, then we can combine the reflected resistance R_L at low frequencies with r_g (by Thevenin's Theorem) to give rise to an equivalent generator of lower generated voltage, but also of lower internal resistance. This results in an improvement in the low-frequency response. At the high frequencies, however, R_L appears as a shunt across C, and produces two effects: (1) it lowers the resonant frequency—even down to zero—and (2) it decreases the peak—even down to a drooping characteristic—so that the response curve looks like a composite of A and B, Fig. 5. In practice the transformer is usually designed so as to have a slight resonance peak when unloaded, and a flat or slightly drooping response when loaded with a specific value of R_L.

If, on the other hand, the primary be loaded with a resistance R_L, then it acts to make the generator resistance appear lower over the entire frequency range. As such, it produces a response which is similar to A of Fig. 5, but of reduced gain. It is therefore evident that by a judicious choice of r_g, and of the loading on both the primary and secondary, it is possible to flatten out the response of a transformer, albeit at the expense of its gain. It may also be mentioned that an output transformer is similar in its action, except that C is practically negligible, so that there is a droop both at the high and low end, and that it is almost invariably loaded on the secondary end.

It may seem that the example has been presented backwards: that the transformer is really designed to fit r_g, and not r_g chosen to fit the transformer. While in a sense this is true, the author prefers to regard the transformer as designed to operate from a certain source impedance, and that the tube (the usual source) is then chosen so that its r_g fulfills this requirement. From this viewpoint, impedance matching means choosing the proper tubes to give the desired frequency response from a given transformer.

The next example is that of a loudspeaker. It is usually connected to the output stage through a coupling or output transformer, and thus reflects a load impedance to the tube or tubes of value correct for their proper operation. This has been discussed previously with respect to impedance matching of a load to a non-linear generator. Thus, a 15-ohm secondary means a secondary to which 15 ohms should be connected in order to reflect back to the tubes the proper value for their correct operation: maximum power output for a permissible amount of distortion, plate dissipation, etc.

Consideration, however, should be given to the internal output impedance of the tubes, i.e., the apparent source impedance which the loudspeaker load sees when looking back into its secondary terminals. This is of particular importance with respect to the transient repsonse of loudspeaker, which importance is being noticed more and more.

It is customary to study the reaction of the mechanical system of the loudspeaker upon the electrical source, and this reaction is called its motional impedance. It is possible, however, to transform the electrical impedance into an equivalent mechanical form to be inserted into the mechanical circuit representing the acoustic properties of the speaker. Thus, suppose the total electrical resistance of the source (as viewed from the loudspeaker terminals) plus that of the voice coil is R, and the total inductance is L. Further let B be the flux density in the air gap, and, l, the total length of wire on the voice coil. Then R and L may be replaced, in the mechanical circuit, by a mechanical resistance R_m in parallel with a compliance, C_m, and instead of electrical source impedance, we may regard the speaker as being fed by a constant-velocity mechanical source (infinite-impedance generator), in parallel with the shunt combination of R_m and C_m. The latter are given by the following expressions:

$$R_m = 10^{-9}(Bl)^2/R \quad \ldots\ldots\ldots\ldots(7)$$

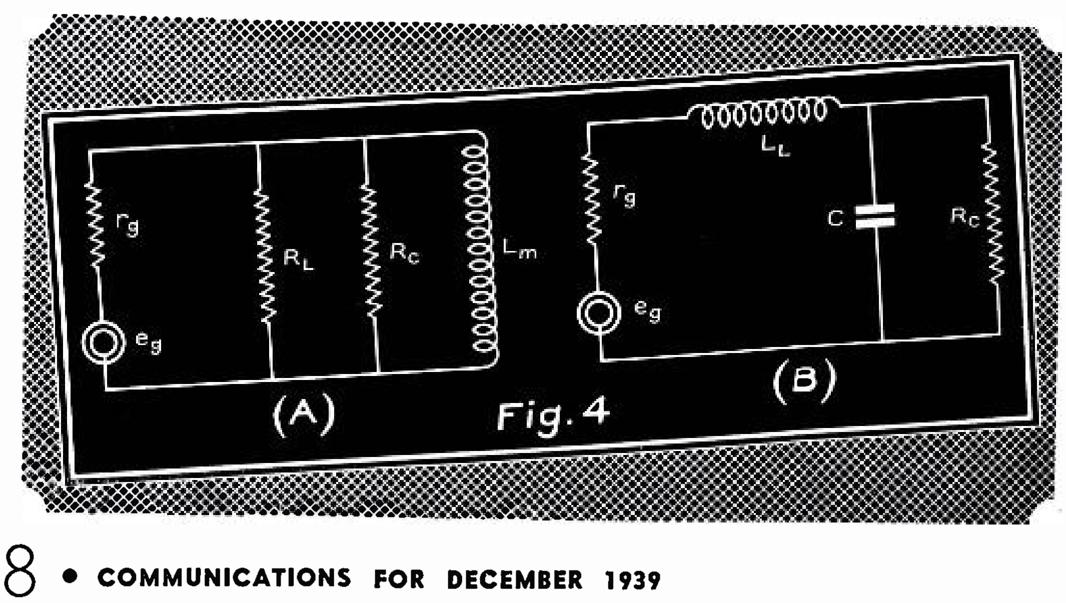
$$C_m = 10^9 L/(Bl)^2 \quad \ldots\ldots\ldots\ldots(8)$$

At low frequencies the speaker, if of the cone flat baffle type, appears as a series-resonant mechanical circuit, due to the mass of the cone and voice coil resonating with the compliance of the suspension. The mechanical damping of the speaker is very low. Also, we may neglect C_m, and thus obtain the circuit shown in Fig. 6. If the constant current of the equivalent mechanical generator be applied, and particularly if it is of the above resonant frequency, and then suddenly removed, the speaker will continue to vibrate with a damped sinusoidal motion. This results in a "hangover" of the sound which is very annoying in its effects.

If the resonant circuit is critically damped, then a single pulse will result of negligible effect. The damping is mainly that of R_m, as given by equation (7), and indicates that the higher the electrical circuit resistance, the smaller will be the equivalent mechanical damping.

The power stage should therefore represent a low impedance to the speaker. At the same time we are faced with the fact that the speaker should reflect a low impedance to the tubes if they are of the pentode type, which is considerably lower than their impedance (see Fig. 3), which is turn means that the tubes will appear as a high impedance to the speaker. In this instance of conflicting requirements, the tubes win out because the distortion products at all frequencies is more important than the "hangover" at the

Characteristics of transformer load at low (A) and high (B) frequencies.



low-frequency resonance point. However by an ingenious arrangement, both load and source can be satisfied. The solution is to employ inverse feedback of the voltage type. This makes the source appear as a low impedance to the load, and yet the load can actually be a low impedance compared to the source. In the case of a triode tube or tubes, however, we have seen (Fig. 2) that the load should be higher than the tube in impedance, and thus both can usually be matched without requiring inverse feedback.

The third example is that of a driver stage furnishing grid power to a Class AB_2 power-output stage. This has been covered in a previous article,[3] and it will suffice to state here that the load in this case is very non-linear: the grids of the two power tubes, which grids draw current during only a fraction of the excitation cycle, so that the driver (source) impedance must be sufficiently low in order that the regulation be not excessive. This means that a sine wave, for instance, must not be deformed to an excessive degree, which would occur if the driver impedance were too high. While an exact analysis is prohibitively difficult, an approximate analysis is given in the article cited for determining the maximum value of the driver resistance for a permissible amount of distortion (assumed all third harmonic). The problem of impedance matching here is the reverse of that cited earlier in this article—that of the non-linear generator feeding the linear load—but in both cases it is to be noted that the basis of impedance matching is the obtaining of maximum voltage or power for a permissible amount of distortion, and that the non-linear element is the one catered to.

V VOLTAGE AMPLIFICATION

Heretofore we have discussed impedance matching mainly from the viewpoint of obtaining maximum power transfer. When we wish to obtain maximum voltage across the load, however, our impedance matching proceeds along different lines. Ordinarily, the load is made as many times the source impedance as possible, since the ratio of load (terminal) voltage to generated voltage is the same as the ratio of load to total impedance of the circuit. The matching is therefore on an inequality basis, and is used in the case of the ordinary linear generator, and also the triode type of non-linear generator.

When we consider the pentode tube, however, we must take more fully into account both the question of distortion products and maximum voltage output. Thus, referring once again to Fig. 3, we note that for a large grid swing, if a high load resistance be employed, the path of operation will carry over into the "knee" of the plate-current curves, and the distortion will be high. Hence a lower load resistance must be employed. If the signal level is low, however, a higher load resistance is permissible, with consequent greater gain. To obtain both high gain and high voltage output, a higher "B" supply voltage must be employed, since this shifts the intersection of the load line with the voltage axis farther to the left. Another factor which influences the value of load resistance is the frequency range of signal to be handled, and the output capacity. Thus, in video amplifiers, where frequencies up to 3 megacycles or more have to be amplified, a low load resistance in series with a peaking coil must be employed to counteract the deleterious effects of the output capacity, and thereby insure flatness of response and linearity of phase shift.

[3] "Balanced Amplifiers," by Albert Preisman. Parts V, VI, VII, Nov. 1936, Dec. 1936, Jan. 1937, *Communication & Broadcast Engineering*.

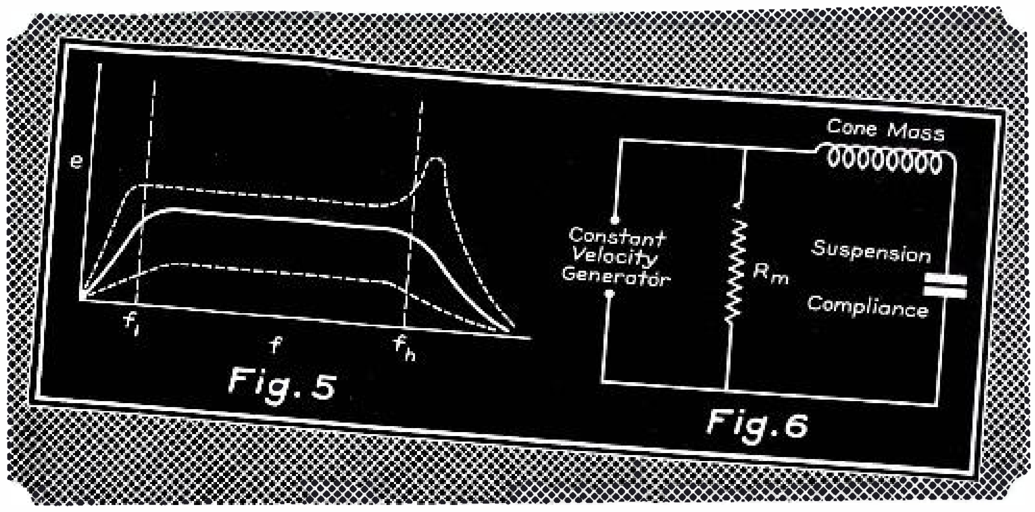


Fig. 5. Curves for various r_g.
Fig. 6. Equivalent circuit of speaker.

VI USE OF PADS

Many occasions arise where a resistance attenuation pad is of great use in impedance matching. Its utility lies in the fact that the greater its attenuation, the less consequence has the magnitude or nature of the impedance connected to one end, upon the impedance seen looking into its other end. Thus, a 10-db 500-ohm attenuation T-pad, when open-circuited at the far end, has an input impedance of 610 ohms, and when short-circuited at the former end, an input impedance of 408 ohms. Moreover, this input impedance is a pure resistance, and is practically so when terminated at its far end by a pure reactance, such as an inductance.

Suppose a phonograph pickup is to be connected to an unloaded input transformer of a fairly high-gain audio amplifier. Suppose that both have been designed to give the best frequency response when facing a pure resistance. By inserting a pad between the two, this can be accomplished, and in many practical instances the insertion loss of the pad is of no great consequence. Other examples can be given, such as the use of a pad between a broadcast line amplifier and the telephone line, etc., but it is believed that the above example will adequately illustrate the use. In all such cases the pad serves as a buffer, and prevents variations in impedance with frequency of the network connected to one end from affecting the constancy of impedance seen by the network connected to its other end.

The use of a taper or unsymmetrical pad enables one to match two different impedances to their images, just as a matching transformer does, but with a greater insertion loss, particularly if the magnitudes of the two impedances differ greatly. This is a cheap and satisfactory method of matching on an equality basis if the system has an excessive gain. This may be the case, for instance, where stock amplifier units are to be connected in cascade for some very special purpose.

VII MIS-MATCHING OF IMPEDANCES

Occasions arise where a mis-matching of impedances is desirable. Such applications are quite special, however. and can not be covered in any detail here. But one example will be given to illustrate this point. The ordinary telephone line of a mile or so in length, while considerd as having a characteristic impedance of 600 ohms nominal value, acts more like a simple condenser. If connected to a source and load impedance of 600 ohms, it will attenuate the higher frequencies. If, however, we choose such taps on the repeater transformer as make the load and source impedance about 300 or 250 ohms, we shall obtain a loss of the lower frequencies sufficient to provide an essentially flat frequency transmission without the use of a special equalizer network. While in one sense this is not

(Continued on page 12)

New U-H-F Transmitters

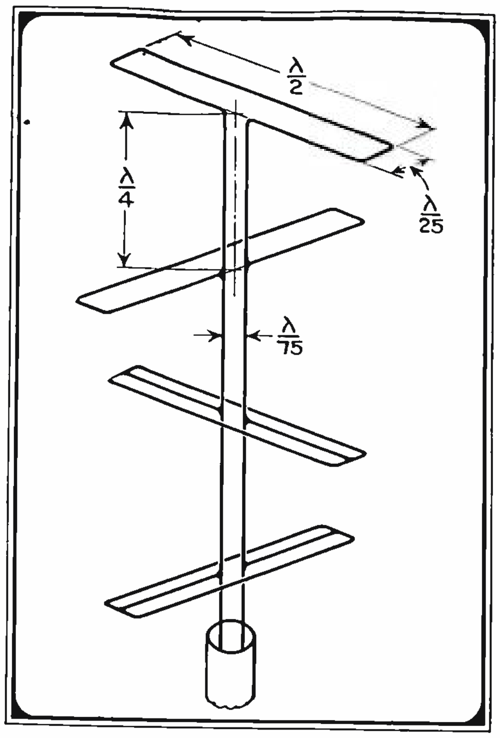
Frequency-Modulation

During the past year engineers of the General Electric Company have carried out many field tests on the frequency modulation system of radio transmission. As a result of this development there have been offered for sale a 250-watt transmitter and a one kilowatt transmitter, and designs will soon be made available for transmitters rated at three, ten, and fifty kilowatts.

These transmitters have been designed to provide a harmonic distortion of less than one and a half per cent for modulating frequencies between 30 and 7500 cycles, and less than three per cent up to 15,000 cycles; deviation in response of less than plus or minus one decibel between 30 and 15,000 cycles with the high-frequency pre-accentuation filter omitted; and a frequency-modulated carrier noise level at least 60 decibels below 100 per cent modulation.

A pre-accentuation filter for the higher audio frequencies is included similar to the R. M. A. standard for the television sound channels in order further to increase the ratio of signal to noise at the relatively weaker higher frequencies. An input of minus ten decibels is sufficient to produce 100 per cent frequency modulation. In addition, the mean assigned carrier frequency is maintained within a deviation of plus or minus 0.01 per cent by a new electrical circuit.

The characteristics stated are obtained at any assigned mean frequency in the 30 to 44 megacycle band. The frequency swing to be used for "100 per cent modulation" will probably be plus or minus 60 kilocycles, but the equipment will produce a swing linear with the modulating voltage up to plus or minus 80 kilocycles.



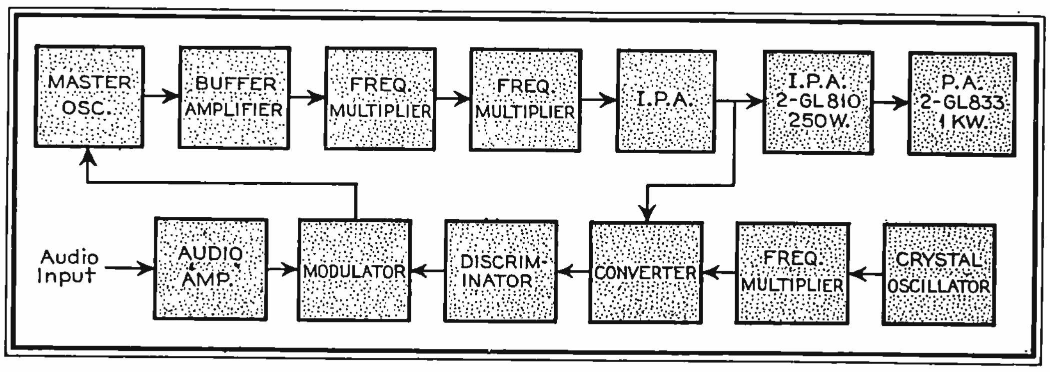
A proposed turnstile antenna in which vertical spacing between elements is an electrical quarter wave. Two elements are in one plane, two others in 90° plane.

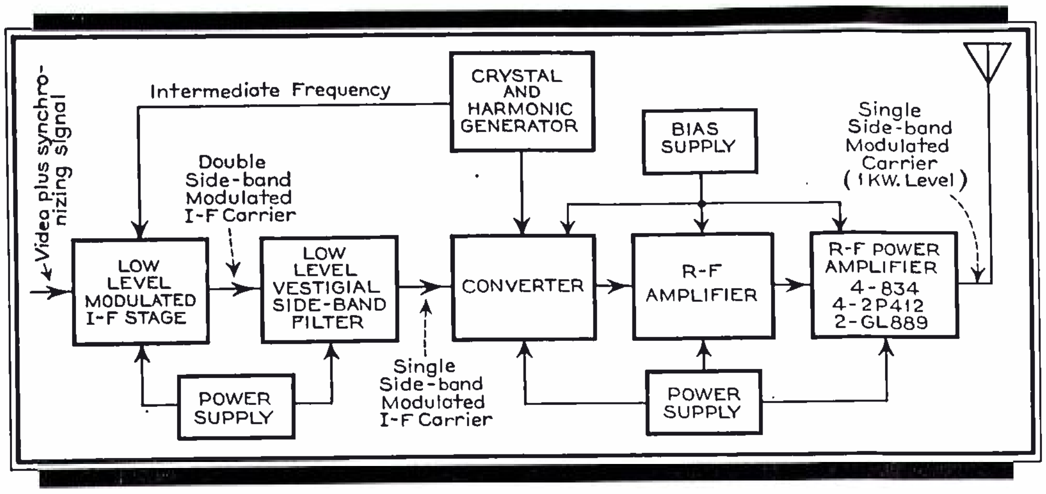
Due to the use of newly developed circuits, the vacuum tube complement is minimized (a total of 31 tubes are used in the 1-kw transmitter), high efficiency is obtained, and relatively low cost tubes are employed. Wide-band frequency-modulated signals are obtained in a single stage through the modulation of the output of a low-power radio-frequency oscillator by a "reactance tube" circuit. Stability of the mean carrier frequency is produced through the employment of electron tube voltage regulators and a stabilizing circuit controlled by a temperature-controlled crystal oscillator which continuously monitors the mean carrier-frequency and produces the correction necessary to maintain it within stated limits. All i-f amplifier stages operate under Class C telegraph conditions, and therefore are highly efficient and non-critical in adjustment. Power output can be easily increased by the addition of the proper amplifier or set of amplifiers. Since the design is such that elaborate shielding and filtering of power circuit leads between units is unnecessary, and since the line of equipment is wholly coordinated, the edition of amplifiers is simple and good appearance is maintained.

Turnstile Antenna

The proposed antenna consists of four radiating elements of the folded wire type arranged so that two of the elements are in one plane and the other two in a plane at ninety degrees. The vertical spacing between the elements is an electrical quarter wave, so the currents in successive elements have a ninety degree time phase relation. The two upper radiating elements are designed to have a feeding point impedance of three hundred ohms, and are connected together by a 300-ohm surge impedance line. The line interconnecting the two center elements has a surge impedance of 212 ohms so that the impedance which is presented across the third element by the two upper elements is 300 ohms. The two lower radiating elements have an impedance of 600 ohms, and are interconnected by a 200-ohm impedance line. The impedance of the entire antenna at the feeding point will then be 150 ohms, and can consequently be used directly connected to a 150-ohm balanced transmission line.

Right: The one-kilowatt frequency modulation transmitter. Below: A block diagram of the one-kilowatt frequency-modulation transmitter.





The radiation pattern of this antenna in the horizontal plane will be essentially circular, the radiation being horizontally polarized.

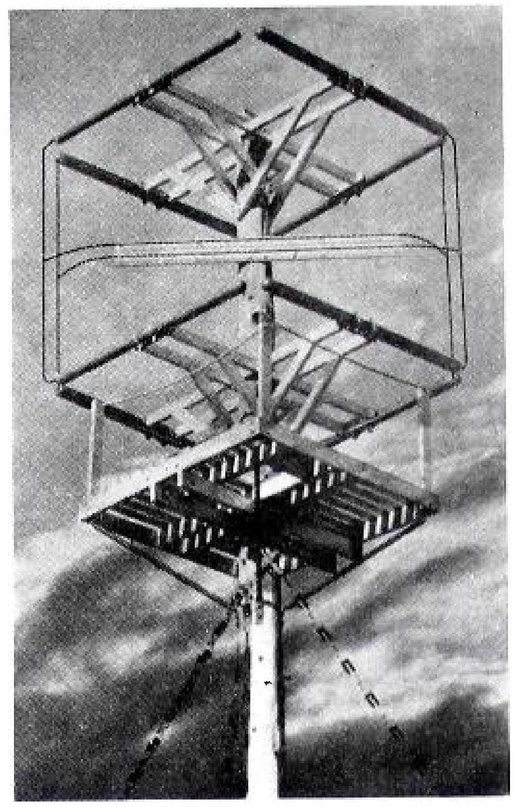
Television

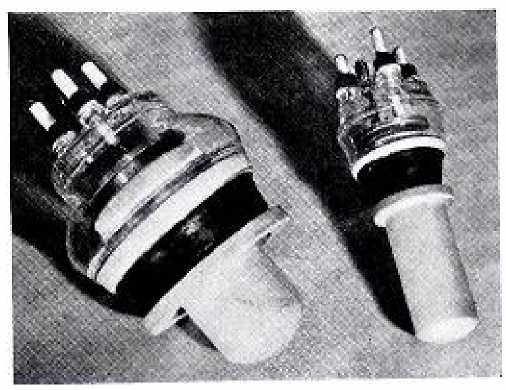
With the crystallization of its work in television, begun in 1925, General Electric has announced a flexible studio equipment and a one-kilowatt transmitter. This equipment includes cameras, microphones, a film projector, studio and control room apparatus, picture transmitter, sound transmitter, and antennas. In full compliance with the R. M. A. standards for perfection of picture detail, this equipment also incorporates outstanding exclusive features.

The camera and its mount provide means for the quick, accurate focusing and easy, smooth maneuvering necessary if action is to be well followed in close quarters. Sweep amplifiers are located within the camera housing to improve sweep linearity and render operation independent of camera cable length up to 200 feet. The studio microphone is a high-fidelity velocity type, having adjustable bi-directional, uni-directional, and non-directional characteristics to care for the various contingencies which arise in program production.

The television moving picture film projector is of special design which synchronizes automatically and provides rock-steady pictures. The machine converts the standard motion picture film speed of 24 frames per second to the television standard of 30 frames per second, with two field interlacing at a

Above: Block diagram of 1-kw television transmitter. Right: Cubical television antenna designed for W2XB (Helderberg station). Two are used: one for picture, one for voice.





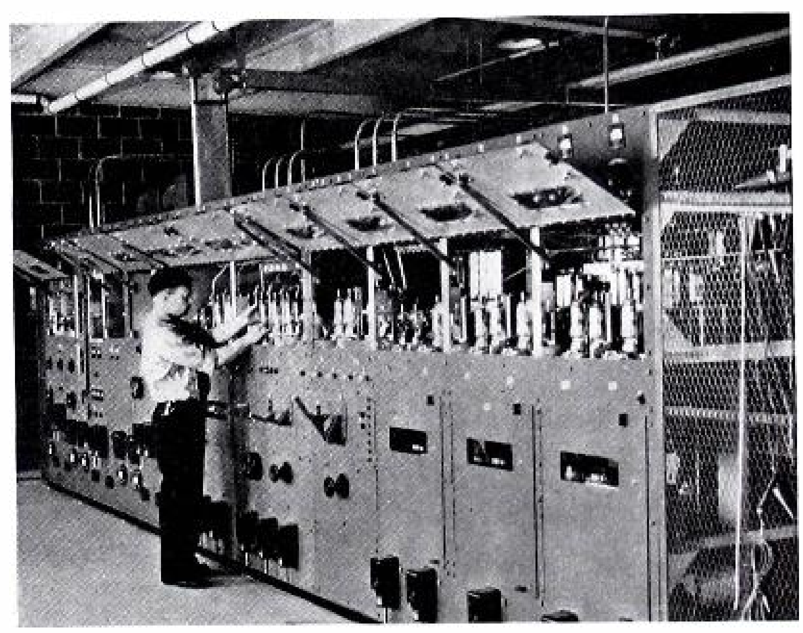
Two G-E high-pressure radio transmitting tubes designed for the television transmitter.

vertical picture stability of ⅛ of one per cent. Separate shutter and film loading is provided, and care has been taken to minimize vibration.

The studio control equipment which provides a picture definition of 441 lines corresponding to a frequency band from zero to four megacycles, provides for a maximum of six channels and the means for switching instantly or for fading gradually from one channel to another. Provision is made for full monitoring. The operator's burden is reduced by means of an automatic brightness control which supplements the manual control and maintains the "black" level during sudden background changes. The unit type of construction employed permits the expansion of camera facilities to six complete channels without altering the existing equipment.

Low-level modulation, employed in the picture transmitter, reduces equipment size and power loss. That portion of the lower sideband which is not to

Lower left: The one-kilowatt television picture transmitter. Lower right: Main control board of G-E television station W2XB



be transmitted is removed at low power level in the vestigial sideband filter, and consequently the high-power amplifiers are required to pass only that band of frequencies which is radiated as useful power; the duty on the amplifiers is reduced and large filter equipment in the high-power circuits is eliminated. When the transmitter is operated in conjunction with a picture relay transmitter, the conversion of the radio frequency of the picture signal at low power level eliminates distortion which might be caused by detection and remodulation. The sound transmitter is a high-fidelity unit having an audio channel extending from 20 to 15,000 cycles.

The cubical type antenna used with this equipment is comparatively easy to adjust and feed; it can be adapted to melt sleet from itself in the colder climates, and—if desired—both the sound and the picture antenna can be mounted one above the other on the same mast.

As in the case of the control equipment, in which flexibility has been stressed, engineers have provided for the future in transmitters. If it is later desired to increase a station's rating from one to ten kilowatts, no equipment need be discarded or replaced. Begun during the year, the design of the 10-kilowatt amplifiers will shortly have been completed.

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IMPEDANCE MATCHING

(*Continued from page 9*)

impedance mis-matching, since the telephone line does not have a constant impedance, it may be considered as mismatching in the sense that the source and load impedances are not the image impedance of the line.

VIII NOMENCLATURE

There has grown up in the art a certain amount of nomenclature with respect to the equipment employed. We shall consider here the impedance rating of various devices.

The impedance of an electrically long transmission line refers to its characteristic impedance. If the line be distortionless, or nearly so due to loading over the frequency range desired, its impedance will be practically a pure resistance. For a telephone line this is about 600 ohms.

The impedance of a pair of secondary taps of an output transformer is the impedance of the load into which it feeds, as explained previously. Where there are several taps, the rating refers to one load connected at a time, although several loads can be connected simultaneously if their total reflected impedance is correct for the output tubes.

The impedance of an electrically short line refers to the terminating impedances, rather than to its characteristic impedance. Thus, a line connecting a source—such as a microphone—to the input transformer of an amplifier, would be rated as to the source impedance, since as was shown previously, the input transformer may be unloaded and hence present a high and variable impedance, but nevertheless, for best frequency response, requires a source impedance of a certain fixed value.

On the other hand, the impedance of the line connecting the output of the amplifier with the load is generally determined by the load impedance. Thus, if a 15-ohm loudspeaker load be connected to the output terminals of the amplifier, the connecting line would be called a 15-ohm line. The reflected internal output impedance of the power stage of the amplifier would usually be different from this value.

There are lines, however, that may be called, for instance, 500 ohms and yet may be terminated in impedances that are variable with frequency. It is difficult to determine in every case why they are so designated. Sometimes it is because the source normally operates into such a resistance, or the load from such a resistance source, but are used here in what may be termed an impedance mis-match relation because of poor design, economic justification and satisfactory results, or because certain special results are desired. In some cases the designation is due to the fact that the load or source has an impedance of 500 ohms at some particular frequency, usually 1,000 cycles. In most cases where these are the reasons for so designating the line, the system has been co-ordinated to work properly together, and the component parts are in a sense "tailor-made" for one another. Where an attenuation pad is interposed between such a source and load, the impedance of the line automatically becomes that of the image impedance of the pad.

IX CONCLUSION

From the foregoing the reader may have gained the impression that, in a sense, impedance matching is more often a question of impedance mismatching. However, as the author has endeavored to point out, if by impedance matching we mean the choice of impedances of the component parts so that they operate to give the desired results to a maximum degree, then matching can be on an equality basis or inequality basis, depending upon which are the optimum values. Transmission lines require equality matching; non-linear generators, inequality matching, etc., and the best way to define this process is by making the definition fit the actual facts, where these represent good practice. The attempt has been made, however to sort the different methods into various main groups, as indicated by the section headings, and if the result is that the reader is not more confused, but instead has a clearer picture of this subject, then this article will not have been in vain.

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OVER THE TAPE

G-E APPOINTMENTS

Charles E. Wilson, Executive Vice President, was elected President and Philip D. Reed, Assistant to the President, was elected Chairman of the Board of Directors of the General Electric Company at the meeting of the directors of the company in New York City, November 17. They will take over their new responsibilities January 1, succeeding Gerard Swope and Owen D. Young, who will become Honorary President and Honorary Chairman of the Board, respectively.

WASHER STOCK LIST

The Wrought Washer Mfg. Co. of Milwaukee, Wis., has announced the publication of a new stock list—No. 55-C. It is available to radio equipment manufacturers upon request.

WESTERN ELECTRIC DIVISION

To meet the unique requirements of broadcasting stations, airlines, the government services and other similar users of its communication equipment outside of the Bell System, the Western Electric Company announces the formation of a new branch to be known as the Specialty Products Division. This unit will be responsible for such by-products of telephone research as: hearing aids, aviation, marine and police radio; broadcasting equipment; sound systems; and equipment made to specification for the United States government. The new division, which will begin formal operation this month, will be located at the Kearny, N. J., works of the Western Electric Company and will be headed by F. R. Lack as manager.

TELEVISION PRICE LEVEL

In order to test out the price level of their large-screen television receivers, Models 180X, 181X, 182X and 183X, the Allen B. Du Mont Labs., Inc., Passaic, N. J., announce a special Christmas allowance on all retail sales of such sets made by authorized dealers during December, 1939. The test, points out the Du Mont management, is solely for the purpose of ascertaining to what extent lower prices can stimulate the television market.

RCA ADVANCES SOMMERER

Appointment of Harry L. Sommerer as Manager of Manufacturing for the plants of the RCA Manufacturing Company was announced by Robert Shannon, Executive Vice President. Mr. Sommerer, who was formerly assistant to the Executive Vice President, will have supervision of the company's manufacturing plants located at Camden and Harrison, N. J., Hollywood and Indianapolis. He has been associated with RCA Victor for thirty years.

(*Continued on page 30*)

A Frequency Monitor

By I. L. GLERUM
Chief Engineer
Edwin I. Guthman & Co., Inc.

THE inclusion of section 152.44 in the F.C.C. Regulations governing amateur stations has opened up large and new fields for gear suitable and sufficiently accurate to make the required frequency measurements.

Approved April 17th, 1939, and made effective the same date, the Federal Communications Commission removed relay broadcast stations from the experimental classification. This change allows greater usage of relay broadcast facilities as such transmitter can now be employed in commercial program work, where line facilities are not available or practicable.

In connection with the Rules and Regulations, Section 40.02 (b) states that the frequency monitor to be employed shall be designed in accordance with good engineering practice and shall have an accuracy sufficient to determine that the operating frequency is within one-half (½) of the allowable tolerance. Section 40.02 (c) states that the licensee of each relay broadcast station shall provide the necessary means for determining that the frequency of the station is within the allowable tolerance. Section (d) states that the frequency of such stations shall be checked at each time of beginning operation and as often thereafter as necessary to maintain the frequency within the allowed tolerance.

Relay broadcast stations are required to maintain the operating frequency within plus or minus the percentage of the operating assigned frequency as follows:

Class of Station	*Frequency Tolerance*
(a) 1,622 to 2,830 kc/s	0.04%
(b) 30,000 to 40,000 kc/s and above	10 watts or less 0.1% above 10 watts 0.05%

The frequency tolerance of stations in the high-frequency emergency municipal police classification of service is as follows:

Equipment Authorized

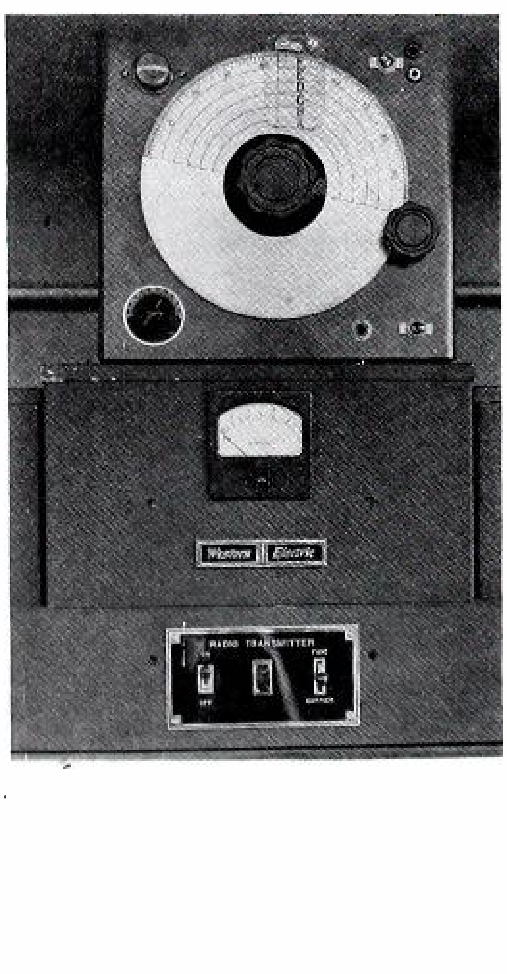
Class of Station	*Before:* 10-1-38	*After:* 10-1-38
Fixed and land stations above 30,000 kc/s	.05%	.02%
Portable and mobile stations above 30,000 kc/s	.05%	.03%

Although the monitor illustrated was originally designed to meet the amateur requirements, it has found application with slight changes for relay and police station work. In order to well maintain the accuracy specified, this instrument is designed so that the tolerance of the frequency monitor is better than one-half of the Commission's required specifications.

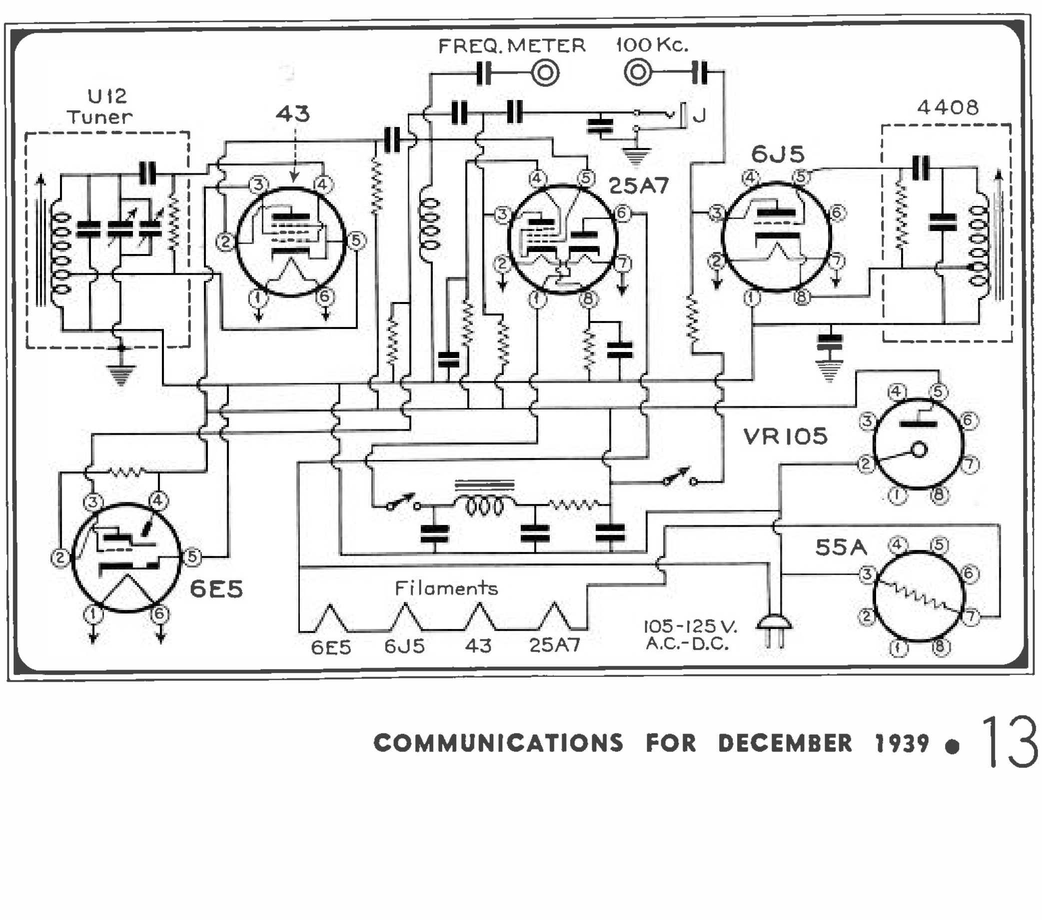
This monitor has been used at radio stations WCMI and WLAP of the Southern Network, for the measurements over relay broadcast stations WEGE, WEGD and WEGO which operate on frequencies of 31,000 kc/s; 35,620 kc/s; 37,020 kc/s; 39,250 kc/s. Also, the 50 watts WATA which operates on an intermediate relay broadcast frequency.

In Lexington, Kentucky, the Fayette County Police Patrol maintains a two-way high-frequency police station that operates on a frequency of 37,100 kc/s. This system is monitored by a remote receiver continuously. The frequency check on all of the County Patrol equipment is made daily at this remote receiver with its associated monitor. All relay broadcast transmitters are checked with the U-10A monitor prior to, and after each transmission whether it be in connection with equipment tests or regular commercial or sustaining program broadcasts. The monitor's calibration is checked at the time of each measurement against harmonics of radio station WHAS, operating on a frequency of 820 kc/s. In Lexington, WHAS has a measured field strength of 12.4 millivolts per meter which is highly satisfactory for the purpose. Also, the meter's calibration curve is regularly spotted against WWV transmissions. At WCMI, on the Southern-Mutual Network in Ashland, Ky., the monitor is also regularly checked against harmonics and beats of the

(*Continued on page 26*)



**Left: Frequency monitor mounted on a transmitter.
Below: Circuit diagram of the monitor.**



Frequency Modulation

Part II

By CHARLES H. YOCUM

EARLY experimenters tried to produce f-m systems, but failed largely because they did not expand the frequency swing, but tried to compress it. However, they did prove that an f-m system could not make use of conventional a-m modulation methods.

It would be well to review the basic requirements of a successful f-m system before attempting to understand its operation. Major Armstrong lists these requirements as follows:

(1) The frequency transmitted by an f-m system shall vary alternately above and below a fixed frequency which is the assigned carrier. These variations should be symmetrical with respect to the mid-frequency, pass through it, and return exactly to this carrier when modulation stops.

(2) In the transmitter, the frequency deviation of the f-m wave at any instant must be directly proportional to the modulating current resulting from the program. This deviation in frequency, however, must be independent of the frequency of this modulating current.

(3) In the f-m receiver the detecting device, corresponding to the second detector in an a-m receiver, must respond to changes in frequency only. Changes in amplitude of the incoming signal must be prevented from affecting the detecting device.

(4) The transmitter carrier shall be considered 100% modulated when its output is such that a properly designed receiver is modulated 100%, or very nearly so. A lower percentage modulation at the transmitter must produce a strictly proportionate and lesser modulation in the receiver.

(5) In the f-m receiver, the amplitude of the current produced by the detecting device, as the result of the receipt of a signal, must be strictly proportionate to the change in frequency at the transmitter, but independent of the rate of change of this frequency.

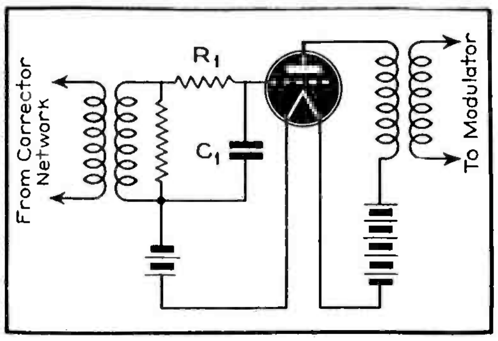


Fig. 6-b. The input from the microphone passes into a correction network in which the higher audio frequencies are amplified more than the lower ones.

Modulation means the continuous and reversible change of the r-f output of a transmitter from one set of conditions to another. In the earliest stations this change was accomplished by keying. If the operation of the key interrupts the signal, we have a crude form of amplitude modulation. If the key causes detuning, we have a crude equivalent to f-m transmission.

True frequency modulation is not developed in present day f-m transmitters. Actually phase modulation is produced, then converted to frequency modulation.

Late in 1931, Hans Roder, of General Electric, published a paper in which he developed the theory of three possible types of modulation. It was shown that the amplitude, or the phase, or the frequency of the emitted signal may be varied to convey intelligence. The mathematical derivation of his results is too lengthy for this discussion. Nevertheless, Roder's conclusions are the basis for present f-m designs and can be briefly summed up in the following statements.

Normal a-m transmission may be represented by a carrier of fixed frequency plus two side bands symmetrically located above and below the carrier frequency, in phase with the carrier. These side bands are proportional in amount to the amplitude of the applied program material.

In both phase and frequency modulation, however, an unlimited number of upper and lower side frequencies may be produced. With phase modulation, as long as the phase shift is kept less than 30°, the carrier and the first side frequencies predominate, while all the others are present in negligible amounts. Also, if this shift is kept small, the amplitudes of the important side frequencies are very nearly proportional to the impressed audio signal, and the percentage of energy in the undesired side frequencies of third and higher order is but a per cent or two of the total. (See Table 2.) In both phase and frequency modulation the carrier is 90° (or 270°) out of phase with the side frequencies at peak modulation. At peak modulation the side frequencies are in phase with each other.

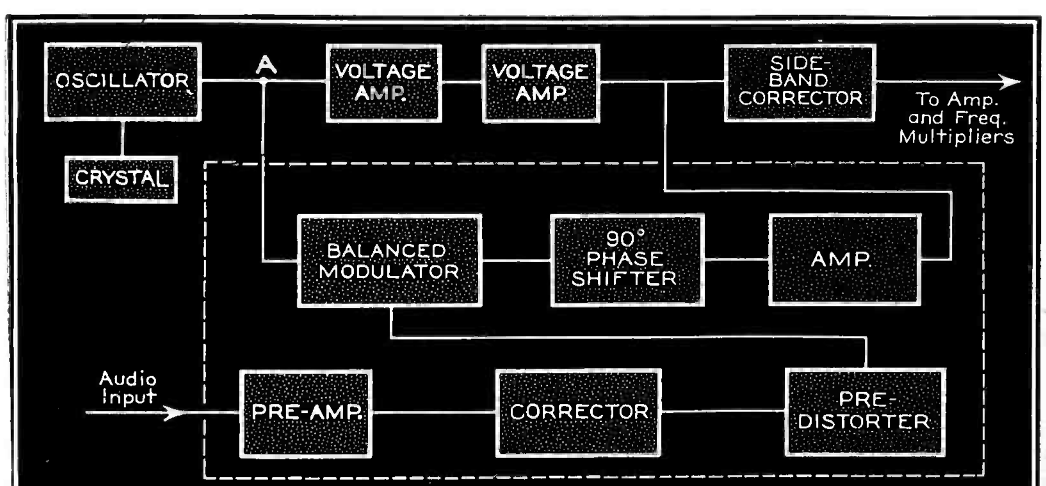
Frequency modulation is merely one type of phase modulation, in which the amount of phase shift is inversely pro-

Table II. Roder's calculations for frequency-modulated amplitude variations. Phase modulation (last column) should be restricted to less than 30° to avoid serious distortion. Note that in phase modulation the phase shift varies inversely as audio frequency; in true frequency modulation the frequency deviation varies directly as the audio frequency.

AUDIO SIGNAL FREQUENCY (Cycles per Sec.)	CARRIER AMPLITUDE	SIDE FREQUENCY AMPLITUDES								CORRESPONDING PHASE SHIFT.
		1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
10,000	100	2.5	-	-	-	-	-	-	-	2.9°
5000	100	5.0	-	-	-	-	-	-	-	5.7°
2500	99	9.9	-	-	-	-	-	-	-	11.5°
1000	93.8	24.2	3.1	-	-	-	-	-	-	28.6°
500	76.5	44	11.5	1.9	-	-	-	-	-	57.3°
250	22.4	57.7	35.3	12.9	3.4	-	-	-	-	114.6°
100	17.7	32.7	4.6	36.5	39.1	26.1	13.1	5.3	1.8	286°

Amplitudes are expressed as percent of unmodulated carrier.

Fig. 6-a. In the Armstrong system a conventional crystal-controlled oscillator produces a voltage, part of which passes through normal voltage amplifiers and the other part through the circuit enclosed in the dotted lines. This represents a practical f-m design.



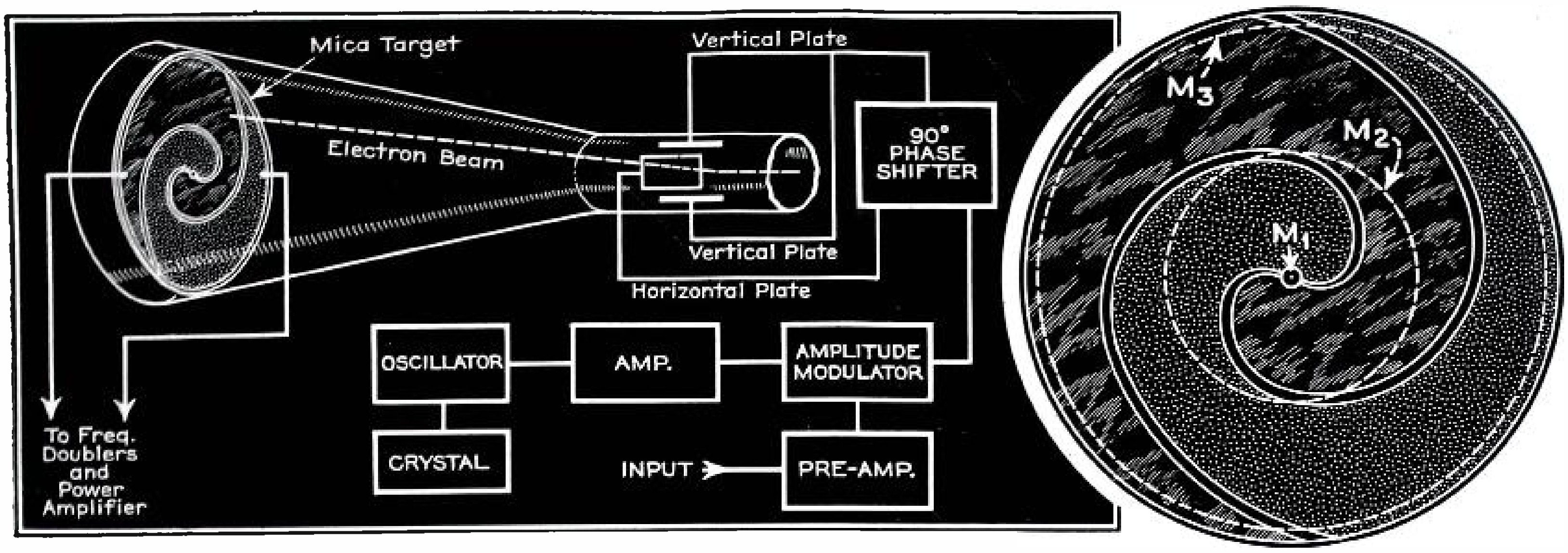


Fig. 8. In the system suggested by R. E. Shelby, a special cathode-ray tube is used to generate phase shifts in excess of 500°. A special target (shown at right) is used.

portional to the frequency of the audio signal presented to the modulating device.

It is well known that a phase shift of a wave may be developed if we beat or mix with this wave a second wave which is out of phase with it. The amount of phase shift resulting at any instant will be proportional to the phase difference between the two and their respective amplitudes. Therefore if we can set up a modulating device which will produce a carrier, then mix with it a second wave of like frequency (but whose phase relationship to the carrier depends on the amount of input energy and is inversely proportional to the audio frequency of that input) our problem will be solved.

Two modulators will be discussed. One is the Armstrong circuit used in most transmitters on the air today. The other has not been installed in any transmitter to date. It was described at the recent IRE convention in September by Mr. R. E. Shelby of the National Broadcasting Company, who developed it.

Let us consider the Armstrong system first. If we refer to Fig. 6-a, we note a conventional oscillator, crystal controlled, producing a voltage which is divided at point A, part passing through normal voltage amplifiers. This ultimately will be the carrier. The other branch of this circuit is enclosed in dotted lines and represents a practical f-m design.

The input from the microphone passes into a correction network in which the higher audio frequencies are amplified more than the lower frequencies. In any system the higher frequencies are attenuated most in tranmission. By use of the corrector we can overcome the attenuation and present a program to the listener in which both high and low notes are equally well reproduced. This is a common practice in a-m transmission as well as f-m. It is limited in a-m by the necessity of avoiding adjacent channel interference. There is no such danger in the f-m system.

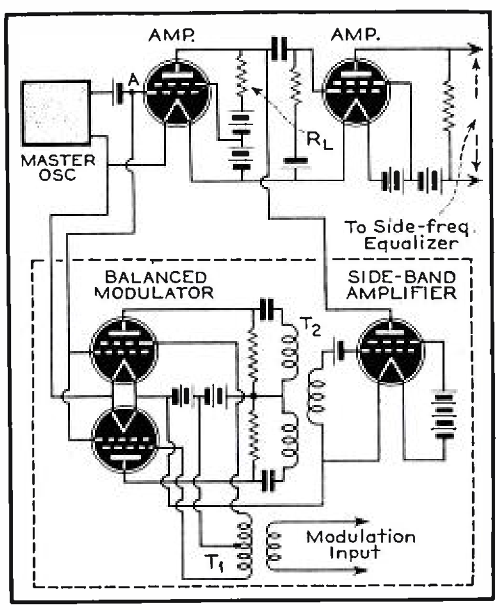


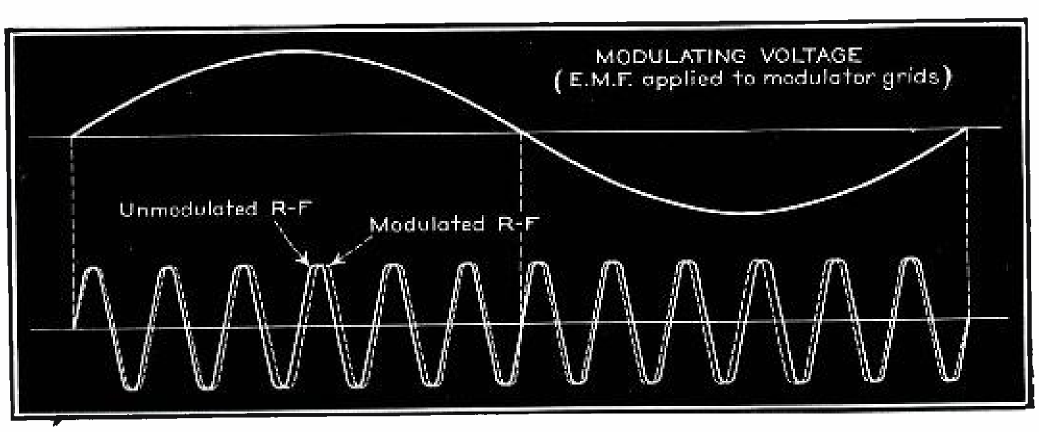
Fig. 7-b. The frequency-corrected microphone output is fed to a pair of balanced modulator tubes. The amplified output of these tubes as well as the amplified output of the oscillator appears across common load resistor R_L.

The corrector network contains a resistor R_1 and a capacity C_1. R_1 and C_1 are in series, and the voltage which drives the succeeding stage is that across C_1. The impedance of C_1 even at low audio frequencies is negligible compared to R_1. Consequently, the voltage presented to the succeeding stages is inversely proportionate to frequency. See Fig. 6-b.

This output is fed to a pair of balanced modulator tubes through a transformer T_1. The plate circuits of these modulator tubes are nonreactive for the crystal frequency. Thus, their plate currents are in phase with the control grid voltages. When their screen grids are energized, by a voltage from the input transformer, T_1, the output from the modulators is fed to the primary of T_2, which has a natural frequency well above that of the master oscillator. The side frequencies generated by this network are shifted 90°, amplified, and fed into a resistive load R_L. The amplified output of the oscillator also appears across R_L. (See Fig. 7-b.)

At any particular frequency, the amount of phase shift in the resultant voltage appearing across R_L is proportional to the amplitude and inversely as that frequency. At any particular amplitude or per cent modulation, the time necessary to change from the normal phase arrangement to some new arrangement, and back to normal again, will be inversely proportional to the actual input frequency. The inverse of this time is called the *time rate of change*. The wave diagrams in Fig. 7-a

Fig. 7-a. It can be noticed that when the modulating voltage reaches zero, there is no phase shift between the modulated and uumodulated r-f waves.



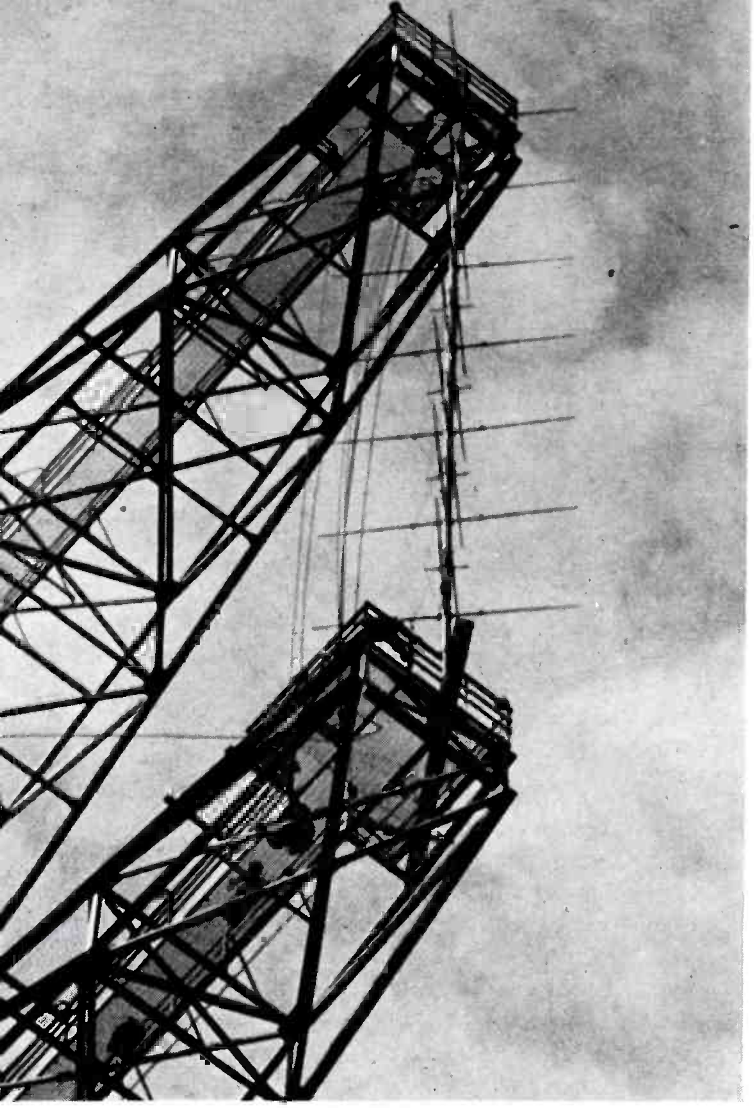


Fig. 9. Major Armstrong's Alpine, N. J., radiator is of special construction to transmit horizontally polarized energy.

will serve to make the progressive changes of the modulated energy more understandable.

In this method of modulation, if the maximum frequency swing of the modulator is large compared to the master oscillator frequency, the upper side frequency will be larger than the lower, due to the increased reactance of the primary of T_2. If a 15,000 cycle band of frequencies is to be transmitted, and a master oscillator of 75 kc is used, the upper side frequency will be almost twice the lower one. This would produce serious distortion in the receiver. This is corrected by an R-C network which is the side frequency equalizer. This correction is accomplished after the side frequencies are combined with the oscillator output at R_L. The energy level is low, and little or no amplitude distortion has yet occurred. After equalization, amplitude linearity is of no importance. Conventional frequency doublers and triplers, modified sufficiently to pass the requisite band width may be used to convert the phase-shifted fundamental frequency of 100 or 200 kc to 14 or 15 megacycles. Here the output is heterodyned against a second crystal, bringing the fundamental frequency down to 1 or 2 megacycles, but leaving the phase shifts and side frequencies unchanged. This frequency is increased to 40 or 50 megacycles, which is the proper carrier. In this process the original phase shift has been multiplied several thousand times, causing an apparent frequency shift or modulation of the carrier. The large number of frequency doublers is necessary to produce sufficient modulation in the receiver. Suppose a receiver were so built that it required 45° of phase shift to give 100% modulation, as a minimum. We are limited to a maximum phase shift of 30° in the transmitter. (See Table 2.) This phase shift will be inversely proportional to frequency. If we are to send an audio band of from 30 to 15,000 cycles per second, then 15,000 cycles would cause a shift of but 6/100's of one degree. Thus, in this assumed case, multiplication by about 1,000 would be required to correctly operate the receiver. Actually, to overcome losses with some safety margin, the original phase shift is increased about 3,000 times in commercial designs.

In the system suggested by R. E. Shelby regular amplitude modulation is produced, with or without high-frequency correction. This a-m energy is fed into a phase changing device, which divides the input into two equal parts, 90° out of phase with each other. These quadrature components are fed to a special cathode-ray tube which produces the necessary phase shift as follows: If two voltages, equal in amplitude, but 90° out of phase, are fed to the horizontal and vertical plates of a c-r tube the electron beam will scan a circular path on the screen. The diameter of the circular path is proportional to the amplitude of the voltage. In place of the conventional c-r screen a mica target is used on which a spiral conducting ribbon is deposited. The spiral is of a particular type, known as the Archimedian spiral. In Fig. 8 it may be seen that as the input amplitude changes, the diameter of the beam path also changes. Zero modulation is represented by the spot M_1, 50% by the circle M_2 and 100% by M_8. If the metal ribbon on the screen were in a pattern of straight lines, no phase shift would occur in the output current. But a glance at the diagram will show that by virtue of the spiral form of the conductor, phase shift does occur, and it becomes greater as the modulating voltage increases.

Phase shifts of upwards of 500 degrees are claimed for this device. Thus a considerable saving may be effected in the modulator unit. Fewer frequency doublers and triplers are required to reach the transmitting frequency than in the Armstrong system. But the amount of signal that must be fed to a cathode-ray tube is large. The difficulty of balancing the voltages fed to the horizontal and vertical plates of the cathode-ray tube is somewhat greater than that of balancing the modulator tubes. The output from the cathode-ray tube is far less than that from the balanced modulators, requiring added power amplifi-

(Continued on page 27)

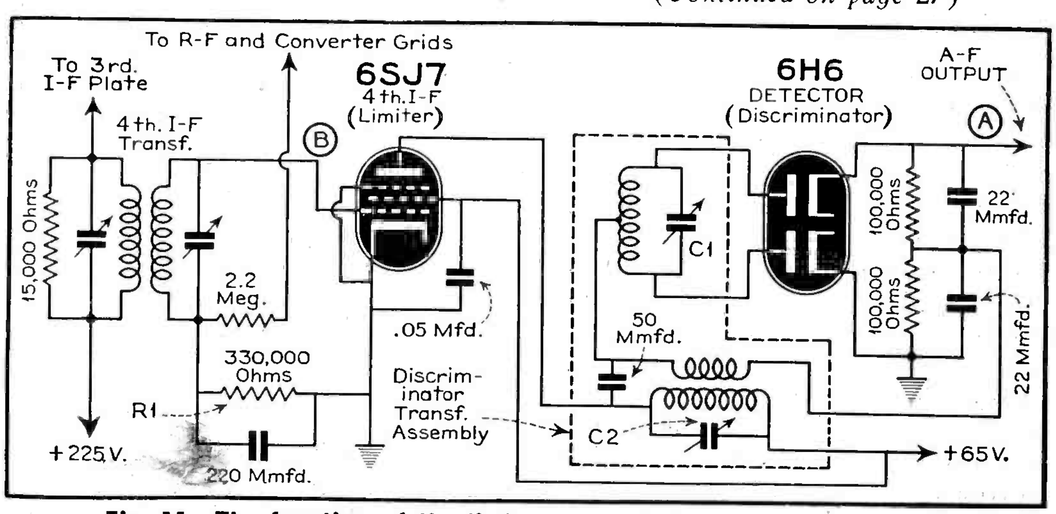
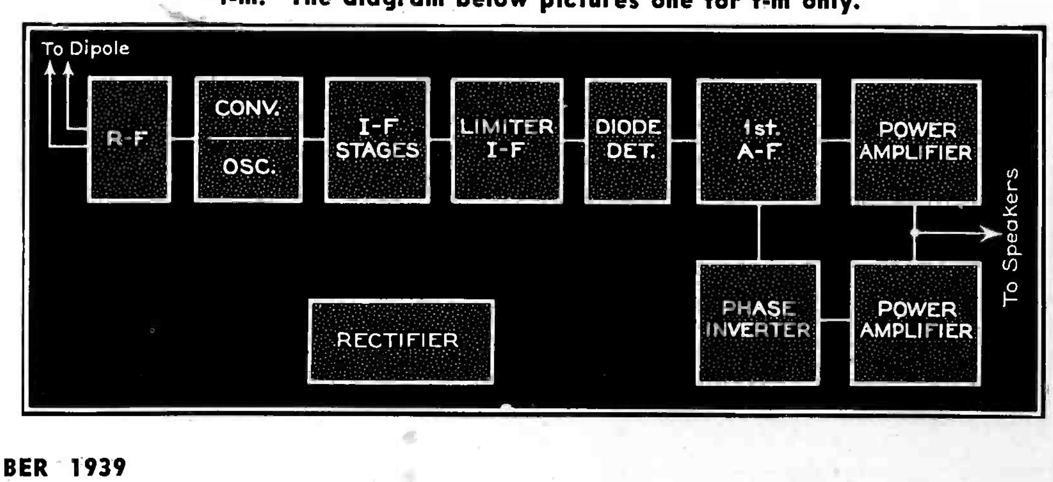


Fig. 11. The function of the limiter stage is to prevent changes in amplitude from reaching the discriminator.

Fig. 10. Two types of f-m receivers are already on the market. One is exclusively for f-m signals; the other is for both a-m and f-m. The diagram below pictures one for f-m only.



TELEVISION ENGINEERING

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TELEVISION ECONOMICS

Part XI

By
Dr. ALFRED N. GOLDSMITH
Consulting Industrial Engineer

J-13 Traffic Handling

ONE division of television broadcasting which requires close and unremitting attention, and which must be handled on an exact basis for most types of program syndication, is traffic control. This involves the assignment of programs throughout the day to specific stations, on a prearranged schedule, but with such flexibility as will permit almost instantaneous modification in the event that an emergency arises. Some idea of the complexity of the handling of traffic in present-day broadcasting can be gained by an inspection of the telegraph and teletypewriter rooms of any major network, as well as the huge wall charts showing the program on each station of the network for each program period throughout the day and night. The handling of network program traffic also involves continuous and close contact with the individual stations and the handling of a great amount of detail. Not only must the programs be routed to the stations, but station reports on the program quality as received and on any interruption or special incidents during the program must be secured, analyzed, and properly handled. All this constitutes a sizable item of expense.

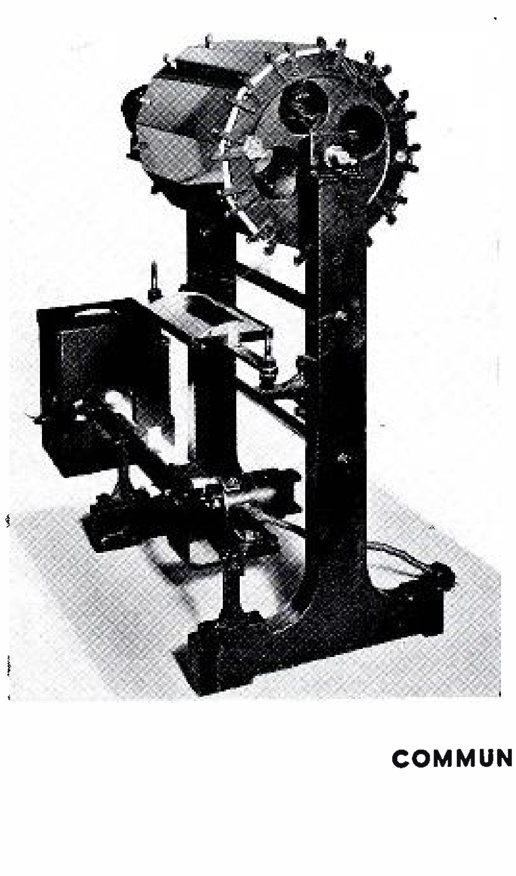
J-14 Commercial Activities

It is self-evident that an important element of cost in television broadcasting will be sales promotion and actual selling of time, and programs and artists. The purchase of stories is also involved. As before, the broadcaster will have relationships with the agency, the client, the author, the artists, and the studio personnel, all of which relations may have commercial, legal, patent or copyright aspects. In the case of determining title to television copyrights, the related problems may be expected to be even more vexatious than for sound broadcasting, at least judging from the experience of the motion-picture producers who have found that it may take months or even years to clear the copyright situation in a given country on a specific story. The complex relationships between the television and motion-picture industries will also doubtless require careful analysis and handling by a skilled commercial staff.

J-15 Public Relations

Another important aspect of broadcasting is its contacts with the public. This involves the cost of publicity addressed to newspapers, magazines, sponsors, agencies, and other interested groups. It includes the careful preparation of program schedules sufficiently in advance, and the release of information concerning them. It comprises further the handling of the bulky correspondence received by the broadcasting station from the audience and the answering of communications from interested persons whenever an answer seems required. The building of good will by the broadcasting station or network is in considerable measure dependent upon considerable expenditures along these directions. Broader problems of public relations are involved as well, inasmuch as broadcasting is of such major interest to the public that some legislators, whether animated by devotion to the public welfare or by no nobler motive than a craving for publicity and political advancement, are prone to propose sometimes astonishing or disconcerting "solutions" for what are imagined by them to be the current "problems" of broadcasting. In common with commercial activities having an educational and entertainment aspect, the legislative side of broadcasting tends to alternate between breathing spells and midwest cyclones. In one form or another, these difficulties, combined with the cost of furnishing elaborate data to governmental agencies at frequent intervals, constitute an economic factor not to be neglected.

Optical chassis of Scophony home television receiver.



J-16 Patent Costs

The development of television has been carried out over a period of years in a number of well-equipped laboratories manned by skilled personnel. As a result, many inventions have been made which, in turn, have become subject matter of issued patents or applications from which the owner hopes in due course to recoup research cost and

(*Continued on page* 21)

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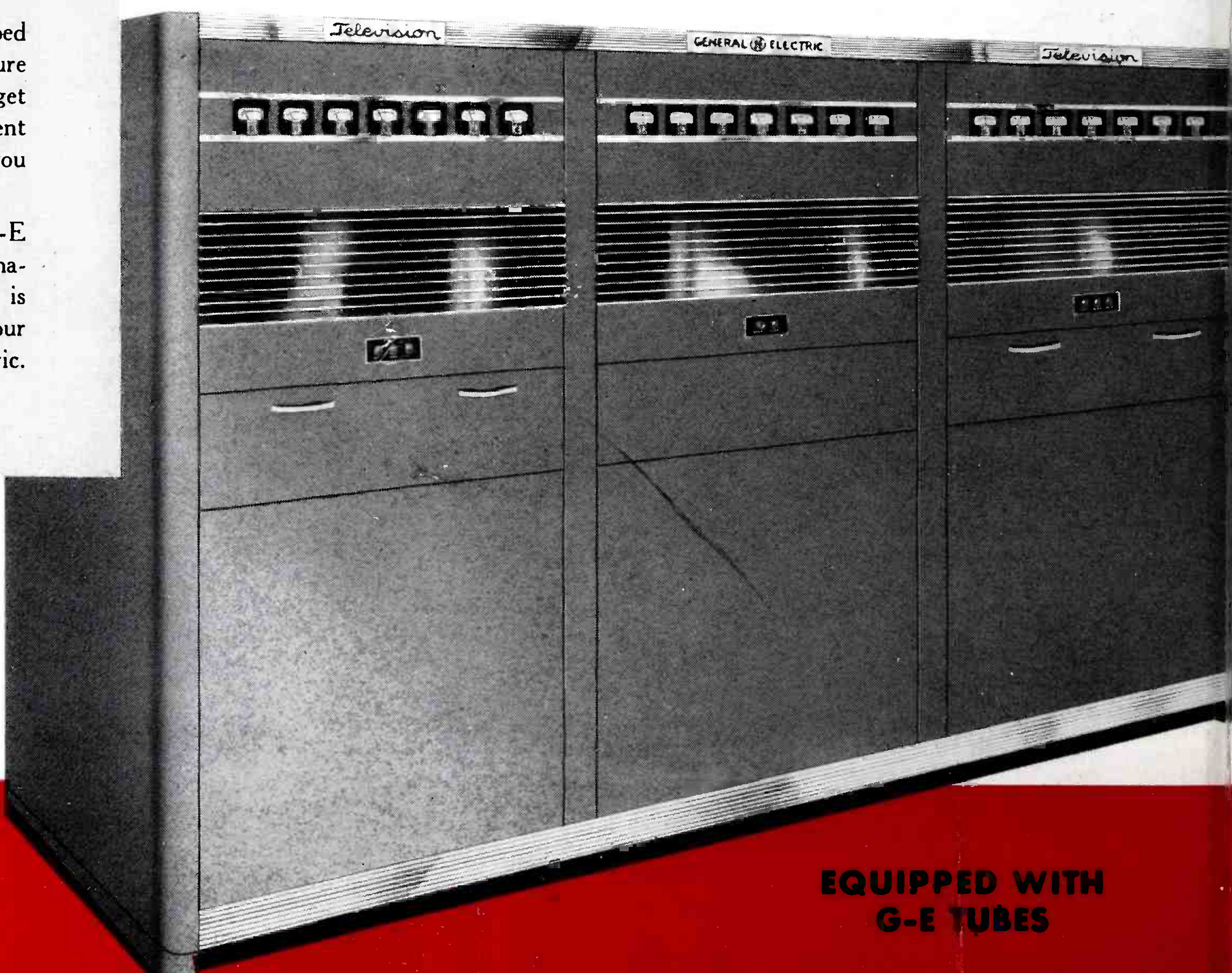

This is the new G-E 1-kw television picture transmitter. On the opposite page, the new G-E 1-kw frequency-modulation transmitter.

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TELEVISION ECONOMICS

(*Continued from page* 17)

a reasonable profit. Several substantial groups of such patents have been assembled and the manufacturer of television transmitting or receiving equipment will require competent advice to determine the nature and likely scope of patent licenses which he may require for the effective conduct of his business. Transmitting equipment purchased for broadcasting stations will presumably carry license charges in its first cost, as will the receivers purchased by the public. In addition to patent licenses, copyright privileges in the musical and story fields will be necessary, and these are sometimes rather complicated and difficult to define or secure. As a general rule, any major television broadcasting group will include divisions capable of handling normal routine along these directions.

K. PROGRAM SYNDICATION

The justification of program syndication in television, as heretofore in sound broadcasting, is the corresponding reduction in program cost per member of the audience. It is this factor which enables a fine quality of entertainment to be sent to the public even though production costs are high. Syndication has been found essential in one form or another in broadcasting and may constitute as vital a factor in the case of television, where unit program costs are higher than for present sound broadcasting.

The type of syndication to be used will determine in some measure the scope and quality of the television art. There are two fundamental types of syndication namely, those having simultaneity between the performance of the program and its reception (such as a studio pick-up or an outside-event pick-up), and second, those based on some form of permanent record (e.g., transcription programs for sound broadcasting). Each type of program has its advantages and disadvantages. It is believed by many that the element of simultaneity is extremely important to home audience, and that the listeners feel considerably more interest in and emotional response toward an event received by them at the moment of its occurrence. In support of this, the attractiveness of sporting-event broadcasts, political conventions and the like, and timely or topical events is cited. It is further urged that, if network facilitates are made available for such programs, it is economic and desirable to use them for all programs (a broad conclusion which is open to further and detailed analysis). The advocates of the recorded program point out that it also has major advantages including the possibility of repeated rehearsals until the desired effect is obtained in the record, the avoidance of errors or "flat" performances during the actual broadcast, the possibility of flexible editing and cutting (a factor particularly important in connection with picture-and-sound programs on film), the establishment of a program library, the flexible assembly of station groups for syndication, the avoidance of station interconnection costs, the transfer of the time of a program from the time of its occurrence to the time of maximum audience, and the possibility of presenting a program at the same local time in a number of different time zones. The analog to present-day studio performances sent over a network would be television studio performances transmitted to the audience by radio-relay or coaxial-cable systems. The analog to present-day transcription programs would be television programs on film. In addition, there is a type of syndication mentioned below which has not hitherto been used systematically in sound broadcasting but which may prove useful in the more costly television field, namely the use of the road-show company.

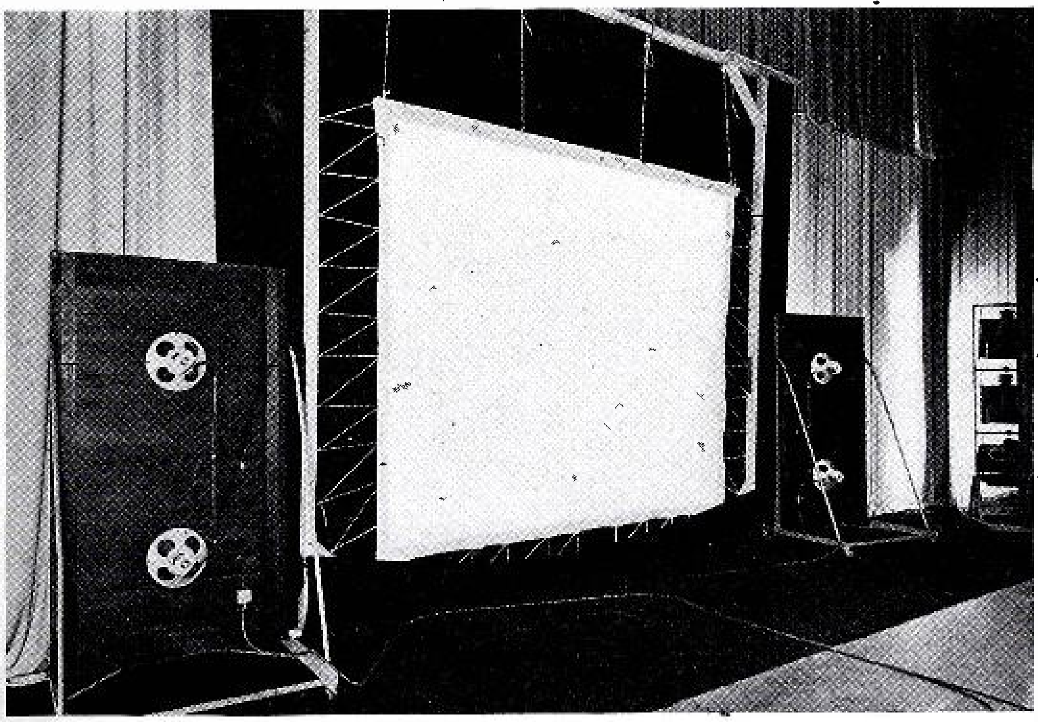
K-1 Road-Show Syndication

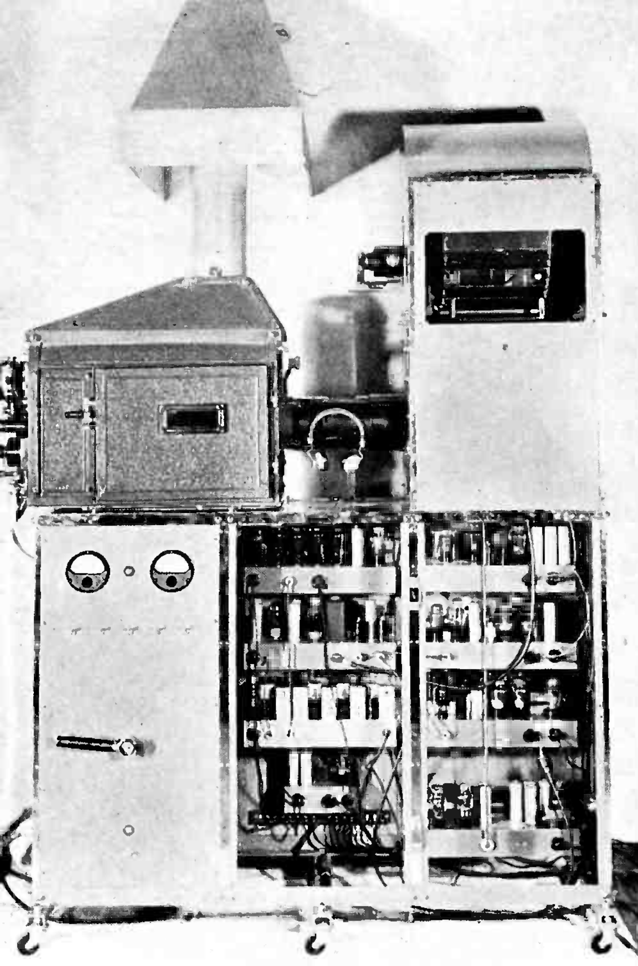
Essentially this involves sending a group of actors or other performers from studio to studio to give substantially the same program or series of programs from each station. Thus, a road-show company might present a series of dramatic, comic, or other sketches every night for a week, or on some other schedule, in each city to which they came. Assuming that the associated studio sets were not too complicated and that careful management were available, this plan might prove workable. Particularly suitable to the purpose would be dramatic or comic stock companies, vaudeville acts, and "little theater" groups. The road-show companies of the past were made up of actors who were, in the terminology of that field, "good troupers." These actors were quick to learn new parts accurately and with but few rehearsals. They could meet emergencies with astonishing resourcefulness. Depending upon the nature of their performances, they might remain in a given city anywhere from a day to a month, or even longer. Road-show syndication has one distinctive advantage over other syndication means, namely the fact that the performers, being physically present in the locality where the broadcasts will originate, are available for excellent related publicity. Thus, the road-show members may participate in local activities at times when they are not broadcasting and might even work with a tie-in at local theaters presenting material other than that which is broadcast. The economics of this form of syndication have not been sufficiently explored to draw definite conclusions but, from the entertainment viewpoint, such a plan has some advantages and appealing features.

K-2 Film Syndication

It is obviously possible, using means previously described, to transmit television-telephone programs from sound-motion-picture film, either in the 35- or 16-mm sizes. In addition to the general advantages of transcription programs mentioned above, the use of film syndication permits the accomplishment of two hitherto important results, namely

Showing screen and speakers for the Scophony system.





Projection equipment used in Scophony television system.

the "splicing of time" and the "joining of space." More concretely, any two scenes, no matter how far separated in time or space, can be spliced together as represented in a reel of film to produce any desired dramatic or artistic effect. This permits "flashbacks," elaborate changes of locale, and instantaneous changes in time, costuming and the like. It is of course obvious that film transmission and personal performances may be mixed in transmission if desired, by photographing some scenes using the same studio personnel and injecting these scenes at an appropriate portion of the programs. The accurate timing of programs is readily possible with film by suitable cutting. Further, a film program can be slightly speeded up or slowed down as required, provided non-synchronous constant-brightness film projectors are used. The addition of advertising material in film programs by prefacing, injecting, or appending such material is readily possible. The audition checking of acceptability of the performance, when on film, can not only be carried out at will but repeatedly, and with the assurance that the film broadcast will be an exact replica of the audition. Editing is similarly possible and relatively simple. Film also enables repeat performances to be carried out at any time, and takes care of such special needs as the evening broadcasting of news or sporting events which occurred in the preceding afternoon. When transoceanic high-speed plane traffic is widely available, European news films may be presented in America the next day, a most interesting and unique method of surmounting present limitations. Further, film records of performances enable the establishment of a valuable film library which can be used in new stations as these are established, thus bridging over the relatively unprofitable period before a major local audience is established. As previously mentioned, time-zone differences can readily be handled with film syndication.

From the economic viewpoint, safety film in substandard sizes is highly desirable since it will reduce both production costs (negative costs) and print costs. A computation of such film costs shows an astonishing saving in favor of the smaller-gauge films, and their use is to be encouraged insofar as permitted by the requirements of picture quality.

To the extent that film syndication is widely used, from the network viewpoint it involves a certain shifting in the center of interest. The present-day network is founded on inter-connection means and, while excellent sustaining programs are syndicated over the networks, the major portion of the sponsored programs are produced outside of the control of the networks. In other words, the networks do not appear as the major sponsored-program-producing agencies by serving the clients *directly* in this regard (though with the collaboration of the agencies). If the major emphasis in syndicated broadcasting were to be shifted to film program production and away from wire or radio networks, it might require a considerable change in attitude, activities, policy, and methods of the syndicating organization.

K-3 Radio Networks

The transfer of programs from one city to another may be accomplished by the use of radio-relay or booster stations. Early experiments in this direction indicated the practicability of operation within certain limitations using a single relay station between two cities separated by a distance of 90 miles. Experiments were carried out on frequencies of 44, 61, and 79 mc using a power of 100 watts in the relay station. It is, however, desirable to use considerably higher frequencies than these for the purpose, e.g., of the order of 150 mc or above and also to space the relay stations more closely. Micro-waves in the neighborhood of 500 mc or beyond have also been proposed.

It may be mentioned that even at such high frequencies as 250 or 500 mc, there are found differences of the order of 30-50% between the overland attenuation for a given distance in winter time and the correspondingly greater attenuation in summer time, over or through a path containing trees and vegetation.

Relay stations for high-grade service will probably be located at distances between 10 and 20 miles from each other and preferably on the highest, least shielded, and electrically most nearly quiet places. The requirements governing quality and reliability of operation will necessarily be stringent. Each station must relay the incoming signals with an absolute minimum of frequency or phase distortion. Unless the loss of quality at each relaying station is kept at an extremely low value, the aggregate or cumulative effect of the multiple relaying will cause a serious deterioration in picture quality. The higher the frequency used for the relay network, the more compact in general will be the equipment and the more effective the system, within limits. Highly directional transmission is more readily accomplished with antennas of economic size on the highest frequencies. Further, natural and man-made electrical disturbances decrease as the frequency is raised. This is an important factor, since the repeated introduction of noise into the signal at each relay station will necessarily be cumulatively injurious to the quality of the final output. For the same reason, tube and circuit noise within the stations must be closely controlled.

In view of the necessity for a relatively inaccessible location of many of these stations, far from centers of population, it is likely that the majority of these stations (if not all) should be automatically operated (that is, they should be unmanned stations). The equipment may be run from gasoline-engine-driven generators or storage batteries or wind-driven generators or a combination of the preceding. Such stations will however require periodic inspection; and some sort of transport or means of access to their locations, capable of use under any reasonable weather conditions, must be provided. If such stations are located on hilltops, for example, this may lead to an appreciable cost item. On the other hand, the hill-top locations avoid the need for the elevation of the antenna on a tall mast which might be required in valleys or plain locations. The decision as to inclusion or non-inclusion of a mast at the station is subject to careful balancing of increased station range and diminished number of stations versus erection and maintenance cost of the mast and elevated antenna.

While a single one-way relay system seems at first sight comparatively simple, there are nevertheless refinements which may be required and which will introduce additional costs. For example, if full dependence is to be placed on relay systems of this sort, it may be-

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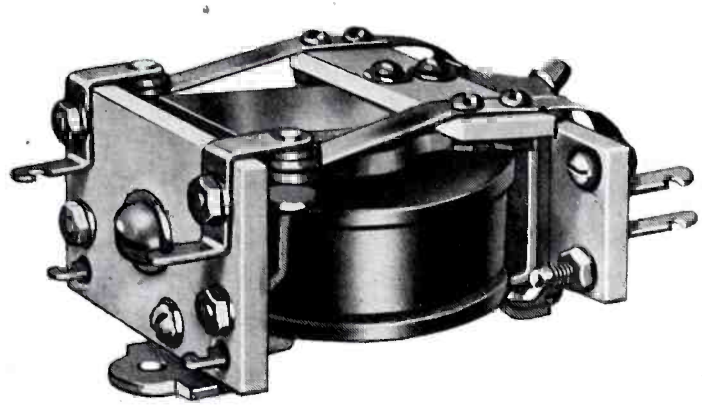
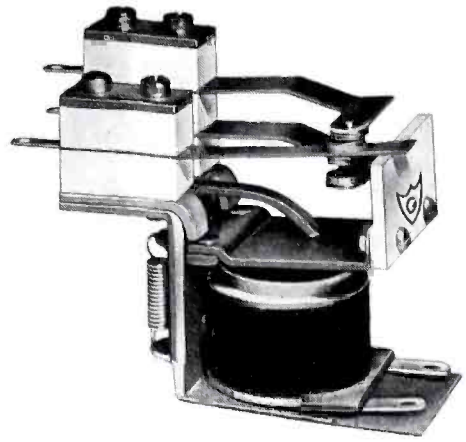
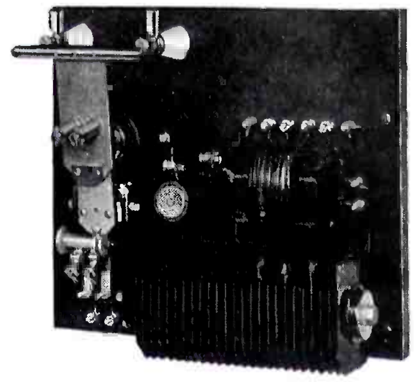
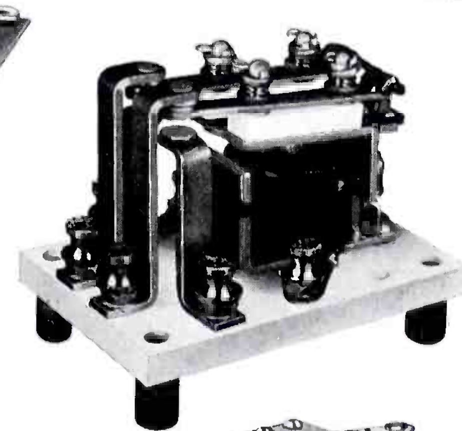
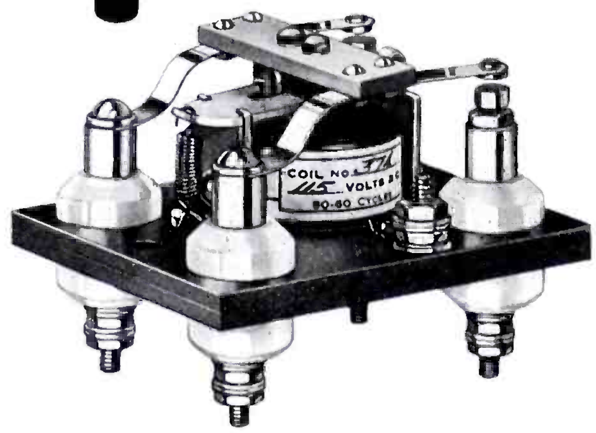




ALL THESE RELAYS USE ISOLANTITE

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ON the relays of the leading manufacturers of radio and electrical equipment, Isolantite* is liberally used because it meets the most exacting requirements of design engineers. Both electrically and mechanically, it offers definite advantages to the equipment manufacturer. Its extremely low power factor makes it an efficient insulator, particularly at high frequencies. Impervious to the effects of moisture and temperature, it also offers the excellent stability under all operating conditions required by delicately adjusted relays. Its high mechanical strength decreases the danger of breakage through shock and continued vibration to which many relays are subject. Moreover, Isolantite has the advantage of being readily adaptable to new shapes. Its manufacturing processes permit the economical production of special parts. Isolantite engineers will be glad to cooperate with you in working out the most economical design of parts that meet your requirements. This is part of the cooperative consulting service that Isolantite offers to the radio, television, and electrical industries. Through its long experience in the design of ceramic insulators, and its specialized knowledge of the industries it serves, Isolantite is enabled to meet present needs and anticipate future ones. Consult with Isolantite engineers on your insulator requirements.

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GREETINGS

TO our members, friends and well wishers we extend our sincerest wishes for a Very Merry Christmas and a Happy and Prosperous New Year.

OLDTIMER

A real old timer, a veteran wirelessman of over twenty-five years standing, "Doc" James Forsyth, well known to all operators of days gone by and many of those presently following the calling, is now the only wirelessman among over seven hundred former seagoers in Sailor's Snug Harbor, Staten Island, N. Y. "Doc" has been in there these past five or six years and is gradually losing his sight: he says he will be totally blind in less than a year. It can readily be realized that one, who, like "Doc," has traveled the world over, must feel terribly confined—unable to leave the premises unless accompanied by someone who takes it upon himself to take "Doc" for an automobile ride and even then unaware of where he goes. He misses the days of old but is reconciled to his future. How "Doc's" face lights up when he hears a familiar voice from outside. To witness his pleasure is sufficient recompense for a visit to Snug Harbor. His visitors number but one or two a year. There are many of us who knew "Doc" when he was sailing the seas. Why not take time out to pay him a visit. Now that the holiday season is with us a Chirstmas card will cheer him immeasurably. His roommate will read it to him. To get there take the Staten Island Ferry at South Ferry (the Battery) and when you alight at St. George, ask the bus inspector for the bus that passes Snug Harbor. The entire trip takes but forty minutes. Won't you visit him soon. You'll enjoy the trip and it will give "Doc" a new lease on life. "Doc" sends 73 to all his friends of old.

15th CRUISE

All Aboard! All Aboard! For our Fifteenth Anniversary Dinner-Cruise, celebrating the continued progress of our Association in furthering the ideals upon which it was founded back in 1925 by a handful of pioneer veteran wirelessmen. In New York a gala Dinner-Dance will be held at the Astor Hotel, scene of many earlier grand affairs. The date this year is Wednesday evening, February 21st, 1940. It is the eve of a holiday (Washington's Birthday) so a late curfew is in order.

A fine program of events for the evening, including several awards to worthy recipients, entertainment by outstanding talent. dancing to a fine orchestra and evening of general good fellowship—a minimum of speeches and a maximum of private "gabfests." Our annual Cruise affords a splendid opportunity to see your friends of yore, many of whom you have lost track of for years. Many friendships of long standing have been renewed at these affairs to the gratification of all concerned.

We are still anxiously awaiting details from our chapters regarding their plans for simultaneous celebrations and if they reach us before the first of the year with the plans we will include them in the January issue of COMMUNICATIONS. Please send them along, Chapter secretaries.

Tickets are available at $4.00 per person for the Cruise at the Astor and may be obtained by request to us at Radio City. Tables of ten may be reserved in advance and early reservation will assure a good location. Tickets must be purchased in advance. This is necessary as definite commitments must be made in advance and unless we know exactly how many will attend we cannot properly plan a successful Cruise. We will appreciate your wholehearted cooperation and look forward to seeing you at the Astor on the 21st.

SCHOLARSHIP

Excerpts from the broadcast over Mutual Broadcasting system network of the award of the Marconi Memorial Scholarship to Robert Barkey follow: Mr. Robert T. Pollock, President of the American Institute, said in part:

"Robert Barkey won this award in competition with a score of enterprising club members. His fine work, persistent study, and the fact that he has his own radio station in his home, make him well qualified to receive this award. The award is a scholarship for two years in the R. C. A. Institutes, where he will receive the finest instruction in this important field and work with the most complete and modern radio and television equipment.

"The American Institute is pleased and appreciative that the Veteran Wireless Operators Association has chosen to make this fine award to a member of our clubs.

"I now have the pleasure of presenting the President of the Veteran Wireless Operators Association, Mr. William J. McGonigle."

Mr. McGonigle:

"The Veteran Wireless Operators Association is an international fraternal organization of old-time wireless operators bonded together with these 'Aims and Purposes':

"To foster and extend an esprit de corps among wireless operators.

"To afford opportunity for social intercourse, and to promote a fraternal and comradely sentiment between and among its members.

"To recognize meritorious service rendered by wireless operators on land, at sea, or in the air, by the erection of memorials and by the bestowal of testimonials, medals, scholarships or other suitable awards.

"To acquaint the public with the work, traditions and ideals of wireless operators and to perform and encourage any other purely fraternal activity or activities adjudged helpful to the wireless profession.

"Following the death on July 20, 1937, of our illustrious honorary member, Gulielmo Marconi, founder of the wireless art, in order to keep alive his memory we named our several awards—Marconi Memorial Awards. Among those honored in the recent past are Dr. E. C. Woodruff, President of the American Radio Relay League, received the Marconi Memorial Medal of Service; David Sarnoff, former wireless operator, now President of RCA, received the Marconi Memorial Medal of Achievement; Lieut. Carl O. Petersen, radio member of both Byrd Antarctic Expeditions, received the Marconi Memorial Medal of Valor.

"In words more eloquent than mine—Dr. Lee de Forest, 'Father of Broadcasting' and Honorary President of our Association, greeted our recent dinner in these words: 'Far indeed have the lengthening years travelled since those days, and far indeed has that primitive art as we beginners knew it developed into the magnificent network of Radio Communications which today enlaces the globe. Justly proud are we Veterans to have intimately witnessed this incredible advance, to have had active, personal hand in this development, matchless in all the annals of scientific progress. Because we deeply felt, away back there in the early years of this century, that the seas on which we were embarking were as boundless as they were uncharted; that mystery and strange allure and great adventure beckoned us on.

"'The Annals of the Veteran Wireless Operators Association are glowing ones, bright-starred with names and deeds of heroic sacrifices. We have a record which as high heritage we can pass on to our successors with deep satisfaction and pride, confident that this fine tradition will be carried on.'

"It is in this spirit so well expressed by Dr. de Forest that we pay tribute today to a young man selected for his scholastic record to receive the First Annual Marconi Memorial Scholarship Award.

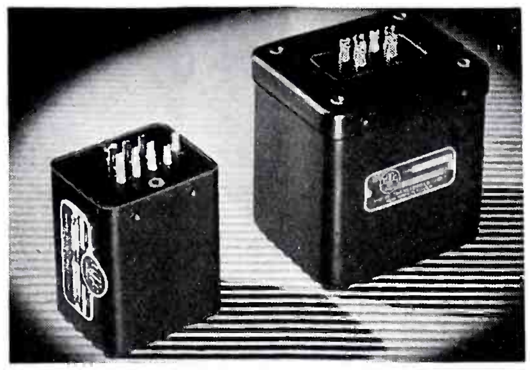
"It is my pleasure to introduce a Charter Member and Director of our Association, Secretary and Chief Engineer of the Bamberger Broadcasting Service and Radio Quality Group, Inc., himself a graduate of R. C. A. Institutes, and Chairman of our Marconi Memorial Scholarship Committee, Mr. J. R. Poppele."

Mr. Poppele:

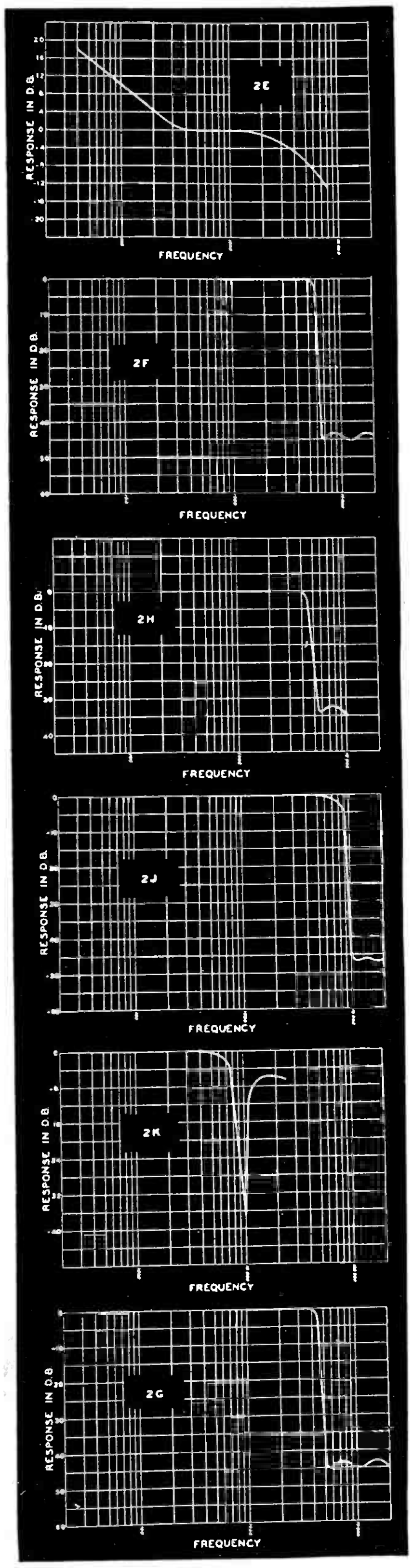
"Through the cooperation of Mr. Charles J. Pannill, President of R. C. A. Institutes, it has been arranged for our Association to yearly bestow upon a worthy young man of our selection the Marconi Memorial Scholarship in Radio and Electrical Communication. The Scholarship represents a value of approximately one thousand dollars and comprises matriculation fee, all text books and full tuition in the R. C. A.

(*Continued on page* 26)

FILTERS and EQUALIZERS



UTC produces special filters for many organizations. In addition to these special units, a number of standard items have been developed for specific requirements of the communications field. Some of these are described below.



PHONO and RADIO FILTERS

(500 ohm impedance)

2E PLAYBACK EQUALIZER

In hill and dale recordings, as well as some lateral recordings, the high frequencies are brought up when recording to effect a high ratio of signal level to surface noise. Simultaneously, the low frequencies are attenuated so that the high amplitude will not overrun the track. The 2E equalizer compensates for both of these effects in playback. H-3 case, Net **$25**

2F LOW PASS FILTER

In practically all high fidelity sound sources such as phono, sound on film, microphone and similar service, a substantial amount of scratch or other parasitic noise is encountered. Since this noise is in the upper range of the audio spectrum, a low pass filter will eliminate the greater portion of it. For highest fidelity, however, this filter should have little effect on frequencies below the cutoff point. The 2F filter is ideal in this respect and is recommended for all broadcast work. Frequency of cutoff is 6000 cycles. H-3 case, Net **$40**

2G LOW PASS FILTER

Same as above, but cutoff frequency is 4500 cycles. H-3 case, Net **$40**

2H SCRATCH FILTER

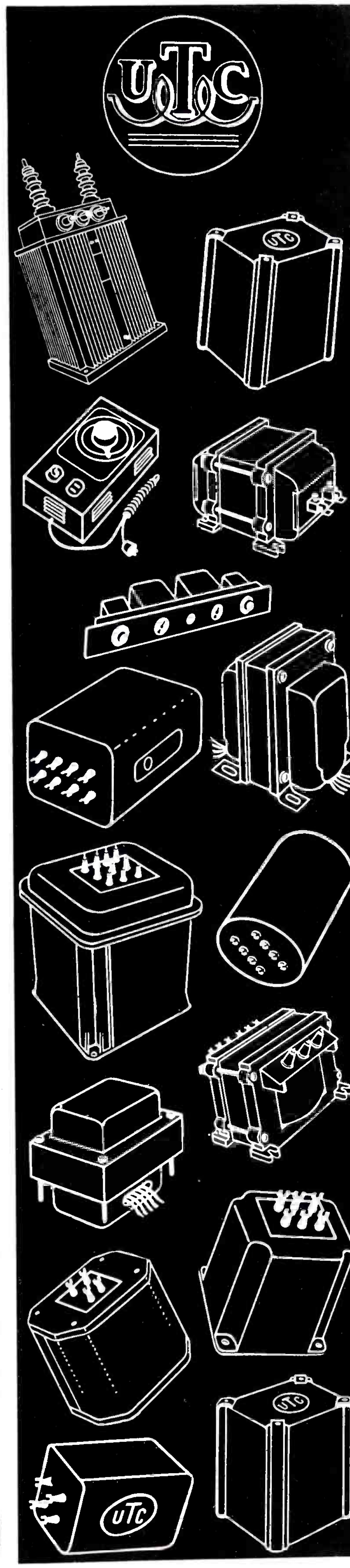
This low pass filter is similar in purpose to the 2G but has not as sharp cutoff characteristics; suitable for most commercial and home applications. H-1 case, Net **$15**

2J LOW PASS STATION FILTER

This filter has a 9000 cycle cutoff, attenuating all frequencies beyond this point to eliminate the possibility of the broadcast station overrunning its sidebands. H-3 case, Net **$40**

2K INTERSTATION BEAT FILTER

In high fidelity receivers some difficulty is encountered due to the 10KC beat frequency between the carriers of stations on adjacent channels. The 2K filter is designed to eliminate this one frequency without affecting the other high fidelity characteristics. H-1 case, Net **$13**



UNITED TRANSFORMER CORP.

Write: BROADCAST DIV. ★ 150 VARICK ST. ★ NEW YORK, N. Y.

EXPORT DIVISION: 100 VARICK STREET NEW YORK, N. Y. CABLES: "ARLAB"

VWOA NEWS

(*Continued from page* 24)

Institutes two-year General Course in Radio and Television.

"It was, of course, the desire of our Association to have this award made to one in every way fitted to fully utilize the opportunity afforded in this fine technical training. To this end, we conferred with officials of The American Institute of the City of New York, who, by virtue of years of experience in fostering science clubs in high schools throughout the country, have been of inestimable assistance. They developed a series of comprehensive tests to determine each contestant's aptitude for radio engineering work, his general intelligence and the suitability and adequacy of his present training. The immense task of grading these tests, averaging the scores and ultimately naming the winner was efficiently carried out by educational experts from the staff of The American Institute.

"At the conclusion of many weeks of work, the results of the tests were reported to the Veteran Wireless Operators Association. We have since made further investigation of the first ranking aspirant. We were gratified to find that, in addition to an excellent scholastic record, he is the possessor of a fine character and personality. I am indeed happy to have even a small part in starting this young man toward the goal which he has set for himself.

"His progress during the two years of schooling and thereafter will be followed by our Association and the optimism and hopeful interest of our membership is nearly as great as the eagerness of this sterling young man. Mr. Robert Barkey, will you please come forward?

"Mr. Barkey, on behalf of the Veteran Operators Association, it gives me genuine pleasure to present to you this Marconi Memorial Scholarship. We congratulate you on your well-won success and predict for you a happy and useful career in your chosen work. We are not unmindful of the responsibility which this award carries, but we are confident that you are more than equal to the assignment. It is our fervent prayer that you may make of your life the finest possible living memorial to Marconi the father of this great art, in whose name this award is made."

Robert Barkey:

"Thank you very much, Mr. Poppele, I am very grateful to you and the Veteran Wireless Operators for this valuable scholarship. I also wish to thank The American Institute of the City of New York for helping me in my radio activities, and Mr. Charles Hellman, sponsor of my radio club at Stuyvesant, for his personal interest. I hope I will be able to work hard while at R. C. A. Institutes and learn a great deal about radio and television in the next two years. Then I hope for a job in radio engineering. Thank you."

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FREQUENCY MONITOR

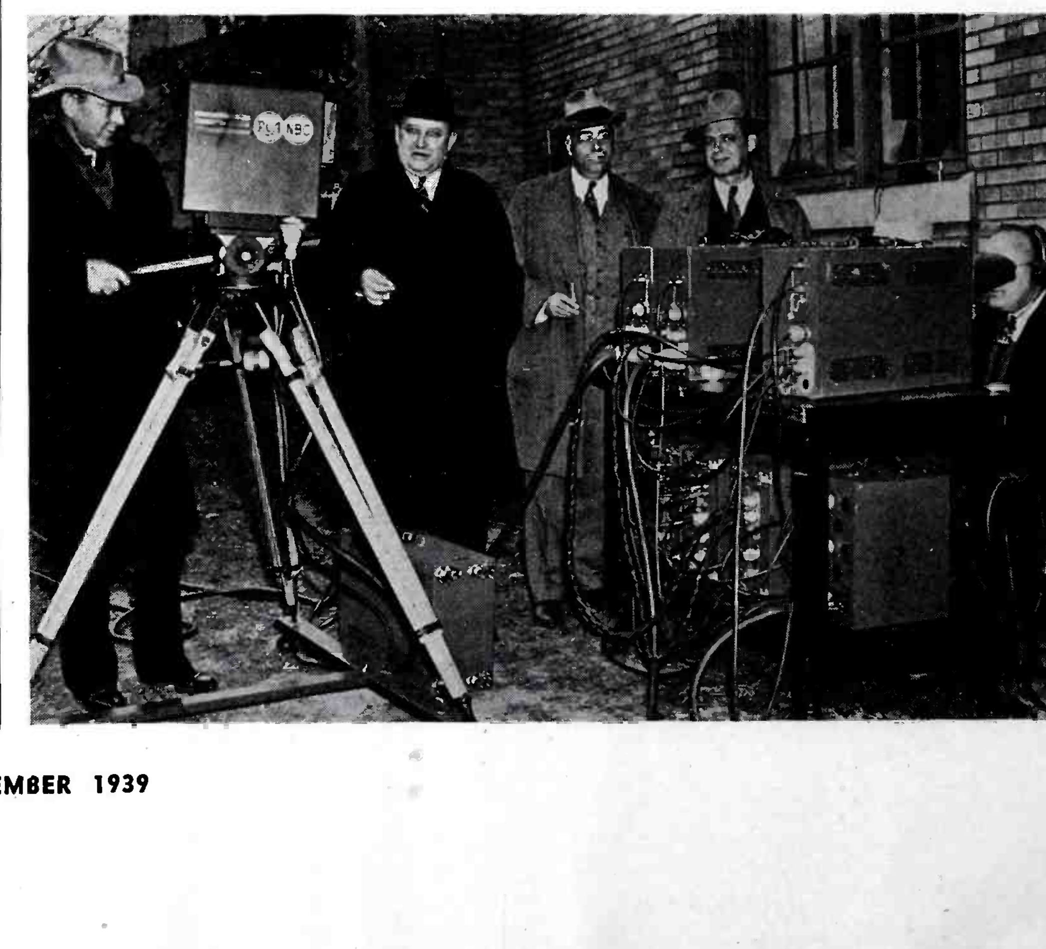
(*Continued from page* 13)

broadcast station's frequency. Here, also, measurements are made at the receiving station location in the transmitter building.

The accompanying circuit gives the fundamental design features of the U-10A monitor. With slight coil changes, it can be designed to cover any specified frequency by using either a 0-100 or 0-330 degree dial. Fundamentally, this instrument is designed for stability and ease of operation. As can be seen by the circuit, precautions are made to prevent frequency drift due to line variation. In addition to having voltage regulation, the filter condenser is abnormally large so that the tube draws current from this reservoir through a rapid line fluctuation, while the voltage regulator, of course, stabilizes the voltage through slower line variations.

The coil is wound on a ceramic coil form with permeability tuning, for accurate low-frequency setting. A small variable trimmer is included for zero setting at the high-frequency end of the dial. Each instrument is provided with

FCC members see new RCA television field equipment. Left to right: James Lawrence Fly, Thad. H. Brown, Norman S. Case, T. A. M. Craven. This portable equipment, developed by RCA engineers, is assembled in carrying cases weighing from 35 to 72 pounds.



a calibration chart and it is only necessary to make re-adjustment of the iron core, if abnormally used or if for some reason the operator has found it necessary to change the frequency range for some other application.

In most instances, there is a powerful broadcast station near enough to the scene of operation to permit inserting a headphone into the phone jack, using the amplifier tube in the monitor as a detector and zero beating the oscillator against a station for zero setting. In some remote locations, however, it may be necessary to heterodyne a receiver to accomplish the same result.

A 6E5 electron-ray tube is included in this instrument to permit checking frequency deviation during transmitter operation. The transmitter is coupled to the instrument and the eye at zero beat remains open. Any deviation in frequency causes an audio component, and closes the eye. Although this doesn't indicate the amount of deviation in cycles, it does tell the operator that the frequency has shifted. The amount can then be determined by readjustment of the large dial. For the convenience of the operation a 100-kc oscillator is included for spotting purposes.

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FREQUENCY MODULATION

(*Continued from page* 16)

cation. Each circuit has disadvantages but certainly each is extremely ingenious. Hence, further simplification would seem to be inevitable.

The balance of the transmitter is of conventional design, except that in the 50 kw types certain problems had to be solved which were peculiar to the production of such power at 40 megacycles. These were not due to f-m, but were simply u-h-f considerations. The radiator is of special construction, built to transmit horizontally polarized energy. See Fig. 9.

An f-m transmitter has a wide frequency range. Reasonable care in design and construction results in a system capable of handling frequencies from 30 to 15,000 cycles with ease. Consequently, program material must be carefully presented to the f-m transmitter since distortion which would be of little importance in other transmitters might be quite objectionable with an f-m system.

Present recordings and wire services are flat to about half the above audio range. This is not objectionable if the transmitter likewise cuts off at about 7 or 8 kc. In f-m stations, however, only the best recordings may be used and many wire services are unsatisfactory because the higher audio frequencies are lost. Wire lines flat to 15 kc can be built, but are very costly. It again becomes apparent that the change from a-m to f-m cannot come overnight. Not only must we change the transmitter, but the microphones, pre-amplifiers, disc recordings and pickups must also be of the finest type if full benefit is to be desired from f-m.

In this connection credit should be given to the Yankee Network. At their Boston studios they are operating a 250-watt, 136-mc transmitter. This is the first such relay to be used for fixed service. This u-h-f transmitter covers an airline distance of 41 miles to the main transmitter at Paxton, Mass., where the program is rebroadcast from a 2-kw transmitter. Soon, however, it will be rebroadcast by a 50-kw transmitter now under construction.

Two types of f-m receivers are on the market. One is for f-m only, one is for both f-m and a-m.* Fig. 10 shows the block diagram of a typical f-m receiver. One or more stages of r-f of conventional design are generally used. The oscillator and mixer circuits are not at all different from those used in a-m receivers. However, the i-f transformers are similar to television types. They are really band-pass filters capable of passing a band width of 200 or even 300 kc. One mark of an f-m receiver is the resistance loading always present in these inter-stage transformers. Several problems are solved by this arrangement. These resistors broaden the pass width of the coupling. Also in these circuits, composed of L, C, and R, the rapidly changing frequencies passing through the network may cause the generation of a number of harmonics. These must be dissipated lest they cause frequency or amplitude distortion. Loading resistors, of proper value, serve to absorb and dissipate these unwanted effects.

A radical departure in the f-m receiver is the use of a current limiter stage. This limiter follows the i-f amplifiers and is extremely important to the correct operation of the f-m receiver. The function of the limiter is to prevent changes in amplitude from reaching the discriminator. Such changes would appear in the speaker as noticeable distortion. A typical limiter starts to limit with an r-f input of about 3 volts peak, levels off at 5 volts and is reasonably flat to 100 volts or more. This tube is operated as a grid cathode rectifier, and the negative voltage developed across the resistor in the grid circuit from coil to ground may be used for a-v-c. This voltage may likewise be used for manual gain control by applying part of it to the r-f amplifier grids. If a magic

*Circuit diagrams of commercial frequency-modulation receivers will be found in the following articles: "F-M Receivers", p. 518, Nov., 1939, *Service;* "Receiver Trends for 1940", by Henry Howard, p. 476, Oct., 1939, *Service;* Frequency Modulation Receiver", p. 388, Aug., 1939, *Service;* "Frequency Modulation", by J. Snivas, p. 340 (circuit on front cover), July, 1939, *Service.* Also of interest is "A Receiver for Frequency Modulation", by J. R. Day, p. 32, June, 1939, *Electronics.*—Editor.

eye is to be used as a tuning indicator, it may be located at this point. Note that both the screen and plate voltages of a limiter tube are equal and less than normal to secure sharp cut-off with zero bias.

The device corresponding to the second detector in an a-m receiver is known as the frequency discriminator. This circuit must be so designed that it transforms the frequency swing of the transmitted wave into variations in amplitude in the audio system of the receiver. Depending upon the set, between 20 and 80 volts will be developed when the transmitter frequency swings 75 kc above or below the carrier. From this point to the loudspeaker the audio system may have any or all of the features associated with present models.

The most sensitive adjustment required in the servicing of the f-m receiver is that of the discriminator network. Condenser C_1 in the primary of the transformer linking the limiter to the discriminator, insures that the receiver is correctly tuned to the exact carrier. If this adjustment is poorly made, the output will be distorted because the wave form fed to the audio system will accentuate the plus frequency changes, limiting the others, or vice versa. Condenser C_2 in the secondary of the same transformer insures proportional voltage output for various amounts of frequency swing.

These two condensers should be adjusted by feeding into the first i-f stage a signal from a service oscillator of the exact i-f of the set. The oscillator should produce as flat an output as possible, over the working range. Connect a v-t voltmeter between Point A and ground (Fig. 11). Now vary the frequency fed to the i-f by swinging the oscillator over a band at least 200 kc wide, 100 kc each side of the i-f. The voltage between Point A and ground should be zero at the exact carrier frequency and should be equal in amount, although of opposite electrical sign when the frequency is set equal amounts above or below the i-f. Not more than 3 db variation should occur, over the range +100 kc to —100 kc.

The limiter may be checked by connecting a milliammeter in the limiter plate circuit, meanwhile varying the input voltage supplied by the signal generator. A v-t voltmeter between Point B and ground should indicate an input voltage from 1 or 2 volts to about 100. The limiting action should correspond to that described above.

Observe caution in aligning the i-f transformers. It is theoretically possible to widen the pass band of the i-f's by double peaking them. Nevertheless, the need for absolute linearity of phase shift throughout a band 100 or 200 kc in width suggests that a single peak will introduce less possibility of distortion. This may best be checked by putting a milliammeter in the limiter grid circuit in series with the grid resistor. An oscillator should be connected to the last i-f stage. This stage should be so adjusted that it passes the entire band width with a change in reading of the milliammeter of not more than 1 ma. The same adjustment should then be made for the next i-f and so on, until the mixer tube is reached.

Faults, normally not objectionable will frequently appear in an f-m receiver. Ripple in the power supply, particularly to the plates of the tubes, must be avoided. Microphonics, due to insufficiently rigid mechanical support of coils and condensers, may cause frequency modulation in the receiver itself. Distortion at times may be due to insufficient d-c bias between heater and cathode in the r-f stages. In some cases, it may be necessary to filter the r-f heater leads at the sockets to remove r-f.

In those sets which are adapted to both f-m and a-m reception, it will be found that two general designs are available. In each case a conventional second detector is used for the a-m programs and a limiter-discriminator for the f-m. Either one of these is chosen by means of a switch. In order to prevent broad tuning on the a-m position, some designers use two sets of i-f transformers with their outputs ganged with the above switch. An alternate method involves the use of but one set of i-f transformers with a 10 or 20-kc filter connected in series with the No. 1 grid of the second detector. If this filter is efficient, good results may be obtained on both types of programs.

Bibliography

Proc. IRE., Dec., 1931, Roder, Ampl., Phase, Freq. Mod.; Proc. IRE, May, 1936, Armstrong, FM.; G. E. Review, May, June, July, 1939; Electronics, June, 1939; Service, July, 1939; Service, Aug., 1939; Service, Oct., 1939; Q. S. T., Aug., 1939; Fortune, Oct., 1939.

TELEVISION ECONOMICS

(*Continued from page* 22)

come necessary to provide alternative relay paths in districts where interruptions of service due to weather conditions or the like may occur. Such alternative relay paths should preferably be placed into operation automatically if the original circuit is opened or becomes inoperative. Further, reversibility of relay systems is a requirement in many instances and, while this can be accomplished by several practical means, yet it constitutes an additional element of cost.

Such relay systems, particularly on the micro-waves, are capable when correctly used of carrying an astonishing amount of traffic. Thus a number of the television signals and their corresponding telephone signals, as well as facsimile, telegraph, teletypewriter and "order-wire" connections of various sorts can be carried simultaneously by multiplexing a relay system of this type. The radio-relay network also lends itself conveniently to a certain amount of rural television broadcasting along the network by establishing automatic television broadcasting stations using the frequencies assigned for transmission to the public for that purpose at the relay stations and then connecting them into the network. That is, automatic broadcasting stations can be established along a radio-relay system and connected thereto; and such broadcasting stations can function to send programs to the public non-directionally, if desired, at the same time as the program is sent along the radio-relay network highly directionally and on far higher frequencies. Systems of this sort are definitely competitive with coaxial-cable networks and will doubtless be subject to intensive development and trial. They open up expanded possibilities of broadcasting and communication.

(*To be continued*)

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OVER THE TAPE

(*Continued from page* 12)

CHARLES E. SEMPLE, JR., DIES

Mr. Charles E. Semple, Jr., died suddenly on November 27. The loss of Mr. Semple, who was Vice-President and General Manager of the Astatic Microphone Laboratory, Inc., of Youngstown, Ohio, is deeply regretted.

ALLIED APPOINTMENT

Mr. A. D. Davis, President and General Manager of the Allied Radio Corporation, Chicago, Illinois, announces the appointment of J. W. Rubin as Manager of Advertising. Mr. Rubin comes up from the ranks, having started as a clerk in Allied's shipping room.

PORCELAIN PRODUCTS CATALOG

Announcement of a new line of switch and bus insulators is made by Porcelain Products, Inc., in a catalog just published. These new insulators are assembled with an improved asphaltic compound, known as "Permalastic" compound. Complete data is given on all standard N. E. M. A. and several specially designed switch and bus insulators. A line of conductor clamps, adapters and spacers is also shown. Porcelain Products, Inc., Parkersburg, W. Va.

WESTINGHOUSE APPOINTMENT

Announcement is made by Walter Evans, Manager of the Radio Division of Westinghouse Electric & Manufacturing Company that F. P. Nelson will be in active charge of programming and promotion of sales for the company's International Stations WBOS, Boston, and WPIT, Pittsburgh. International short-wave broadcast service has been maintained continuously on a non-commercial experimental basis since 1923 when the Westinghouse Company pioneered in short wave broadcasting to foreign countries with the establishment of station 8XS.

ERIE RESISTOR APPOINTMENT

Mr. G. R. Fryling, President of the Erie Resistor Corporation, announces the appointment of C. H. Alvord as Manager of their factory at Erie, Pa. Mr. Alvord is well known in the radio and electrical industry, having been connected with many well known companies supplying components to these fields.

CARLTON LAMP APPOINTMENT

Thomas Spina, formerly with National Union Radio Corporation, has been elected Treasurer of the Carlton Lamp Corporation of Union City, New Jersey. Mr. Spina is one of the pioneers in the radio tube and lamp bulb industries and assisted in the development of the nitrogen gas-filled incandescent lamp.

PRESTO BULLETIN

Presto Recording Corporation, 242 W. 55th St., New York City, have recently issued a bulletin covering their line of recording turntables, amplifiers, equalizers, discs, radio tuners, microphone mixers and other recording accessories. Copies may be secured from the above organization.

CORNELL-DUBILIER BULLETINS

Two bulletins have been made available by the Cornell-Dubilier Electric Corp., South Plainfield, N. J. One bulletin, designated as 1939-1940 Catalog No. 162, covers replacement motor starting capacitors. The second publication, Catalog No. 168A, covers "Test Mike" and "Service Mike," new instruments for a-c motor starting capacitor service tests.

WESTERN ELECTRIC BULLETIN

Western Electric Company, 195 Broadway, New York City, have recently issued a booklet devoted to their Absolute Altimeter—a radio terrain clearance indicator for aircraft. Rather complete data is given. Write to the above organization.

REPRINTS

The article "Designing Die Pressed Steatite Ceramics," by W. L. Scoville, which appeared in the October, 1939, issue of COMMUNICATIONS, is now available in reprint form. Those interested in securing copies should write to the American Lava Corp., Chattanooga, Tenn.

DUKE'S COLLEGE OF ENGINEERING

In accordance with a resolution adopted by the Board of Trustees of Duke University, the Division of Engineering, which was administered as part of Trinity College, was reorganized into the College of Engineering of Duke University. W. H. Hall, Professor of Civil Engineering and Chairman of the Division of Engineering, has been appointed Dean of Engineering.

AEROVOX BULLETINS

Aerovox Corporation, New Bedford, Mass., have recently issued an industrial condenser manual as well as their 1939-40 Catalog covering condensers, resistors and test equipment. Both bulletins may be secured from the above organization.

JOHNSON BULLETIN

The E. F. Johnson Co., Waseca, Minn., have recently issued a bulletin on their line of radio transmitting equipment. This bulletin covers variable condensers, inductors, antenna systems, antenna wire, insulators, plugs, jacks, etc. Write for Catalog No. 966.

STAR PORCELAIN BULLETIN

The Star Porcelain Co., 81 Muirhead Ave., Trenton, N. J., announces the publication of a 12-page booklet, "Survey of Technical Characteristics of Molded Ceramic Products." It takes up in detail the physical properties and applications of their specific ceramic formulas, namely, Commercial White, Nu-Blac, Thermolain, Vitrolain and Lavolain together with novelty porcelain and insulating beads.

SPEAK-O-PHONE REPRESENTATIVES

The Speak-O-Phone Recording and Equipment Company, manufacturer of instantaneous recording equipment and instantaneous recorders, has appointed the following as sales representatives in their respective territories: Paul Cornell, 3292 Cedarbrook Road, Cleveland Heights, Ohio.; Mel Foster, 601 Cedar Lake Road, Minneapolis, Minn.; Henry Segel, 235 Pine Street, Gardner, Mass.; Royal Stemm, 21 E. Van Buren Street, Chicago, Ill.; Royal Smith, 912 Commerce St., Dallas, Tex.; Byron Moore, 191 Starin Ave., Buffalo, N. Y., and Don Wallace, 4214 Country Club Drive, Long Beach, Cal.

THE MARKET PLACE

PHONO MOTOR

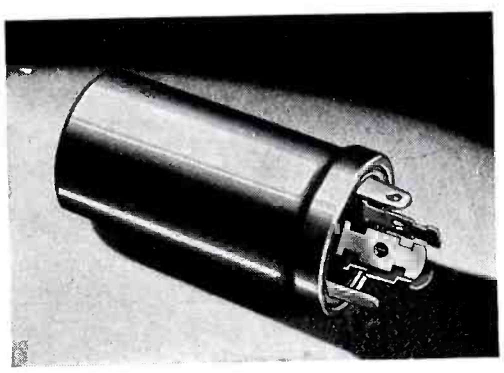
The General Industries Co., Elyria, Ohio, have recently announced a 78 rpm, gear drive, governor-controlled phonograph motor for heavy duty work. The motor is identified as Model RG and is furnished complete with mounting plate, 10 or 12" weighted turntable. Operates on 110-volt 60-cycle a-c. Complete data may be secured from the manufacturer.

BRUSH CRYSTAL MIKE

The Brush Development Co., 331 Perkins Ave., Cleveland, Ohio, have introduced their Model US crystal mike which is designed to meet the demand for a sensitive microphone with a high output, it is said. The output level is —44 db for close speaking. The US is housed in a moulded plastic case. Additional information may be obtained directly from Brush.

PRONG-BASE ELECTROLYTICS

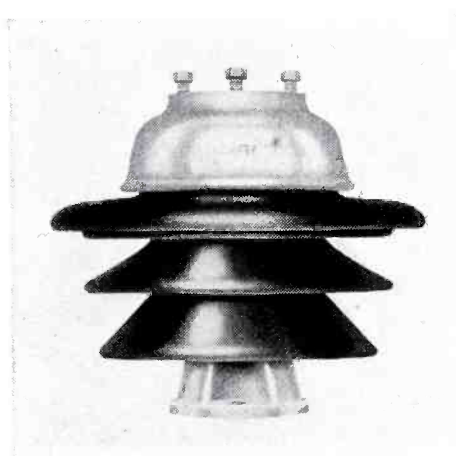
Prong-base midget can electrolytics are announced by Aerovox Corporation, New Bedford, Mass. Compact, economical, sim-



ply mounted, these dry electrolytics are for compact assemblies and replacements. Mounting prongs slip into an elliptic fibre supporting washer (insulated can) or metal washer (grounded can) riveted or eyeletted on chassis, and bent over. Terminal lugs slip through hole in washer, for soldered connections.

SWITCH AND BUS INSULATORS

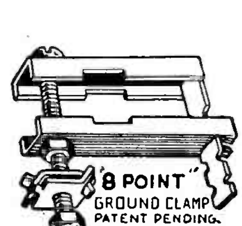
A new line of switch and bus insulators is announced by Porcelain Products, Inc., Parkersburg, W. Va. These insulators are assembled with a new asphaltic compound known as "Permalastic," which is said to be permanently elastic and to have a high softening point, as well as high elasticity at low temperatures. The line covers all standard N.E.M.A. units, as well as several special units. All units are available



with either radio-interference treated or standard glaze.

GROUND CLAMP

A newly developed "8 point" ground clamp has been announced by the Accessories Mfg. Co., 4612 N. Clark St., Chicago, Ill. The ground clamp provides a connection with 8 solid points of contact.



It is made to fit any size rod from ⅜" to 1-1/16" or any size pipe from ¼" to ¾" Literature is available from the manufacturer.

TYPE 50 VARIAC

The newest addition to the line of General Radio Variacs is the Type 50, available in a 115-volt model at 5 kva and in a

230-volt model at 7 kva. These are continuously variable auto-transformers intended for industrial applications and are designed to give reliable, continuous service. Particular applications include line voltage correction, voltage control in rectifier systems, speed control on electric motors, stage lighting control, and the control of heating in electric furnaces. General Radio Co., 30 State St., Cambridge, Mass.

VELOCITY MICROPHONE

The Carrier 300-V velocity microphone is said to incorporate all latest advance-

ments in microphone engineering and technique, including static and magnetic shielding, stand or suspension mounting, live rubber shock insulation, sturdy construction and corrosion proof interior assembly. It comes complete with 20 feet of shielded rubber covered cable and is available in two models—200 ohms impedance and 500 ohms impedance. Complete technical data will be sent to those interested simply by addressing the Carrier Microphone Company, 15 East 26th St., New York, N. Y.

CONSOLIDATED CONDENSERS

A new method of sealing both dry-electrolytic and by-pass units is now employed on all Consolidated condensers, according to a recent announcement made by Consolidated Wire & Associated Corps., 522 So. Peoria St., Chicago, Ill. All consoli-

dated condensers are now end sealed with a specially developed material which the manufacturer states offers great resistance to moisture and assures long life. The condenser illustrated is an inverted type, lock nut mounting, dry-electrolytic in drawn metal container.

WHEN YOU CHANGE YOUR ADDRESS

Be sure to notify the Subscription Department of COMMUNICATIONS at 19 E. Forty-seventh St., New York City, giving the old as well as the new address, and do this at least four weeks in advance. The Post Office Department does not forward magazines unless you pay additional postage, and we cannot duplicate copies mailed to the old address. We ask your cooperation.

MINIATURE TUBES

RCA Radiotron Division, RCA Manufacturing Co., Inc., Harrison, N. J., have recently announced to equipment manufacturers a new series of 1.4-volt miniature

tubes as follows: RCA-1R5 pentagrid converter, RCA-1S4 power amplifier pentode, RCA-1S5 diode-pentode, RCA-1T4 super-control r-f amplifier pentode. These new tubes provide a complete complement for the design of compact, light-weight, portable equipment. They are small in size (only about 2" in length by ¾" in diameter) and highly efficient in operation with 45-volt B supply. The high operating efficiency of these new types has been attained by a new design which provides compactness without decreasing the size of essential electrode parts. Compactness has been achieved by replacing the conventional base with a new glass "button 7-pin" base sealed to the glass envelope and by mounting the electrodes directly on the glass button.

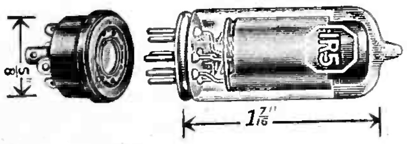
RECORDER

Duplex Recording Devices Co., 514 W. 36th Street, New York City, have recently announced the development of a profes-

sional recorder. This unit, shown in the accompanying illustration, is of the two-speed gear-driven 16-inch type. The operation of the turntable at either 33 1/3 or 78 rpm is accomplished by a single-control coupled to a syncro-mesh clutch arrangement that is said to be timed to engage and disengage the gears and motor at the same instant. The cutting mechanism travels transversely on two rigid bars across the turntable. The angle of the cutting stylus is adjustable. An added feature is a flexible shaft that can be adapted to drive any 16 mm hand crank camera.

MOLDED SOCKET

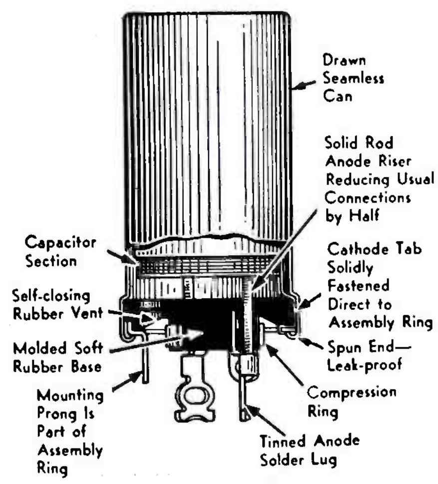
Designed to fit the new all-glass tubes announced by RCA at the Rochester I. R. E. Meeting. Socket is of molded high-dielectric black bakelite with seven



contacts arranged in a ⅜" diameter circle. Mounts in a plain ⅝" diameter clearance hole, and is held in place with a spring steel retainer ring. Floating contacts won't break seal between glass and .040" tube prongs. Center sleeve shields contacts from each other, and has a hole in lower end for grounding. Overall diameter of socket is no greater than that of the tube. Adapters for these tubes for use with tube testers and analyzers are also available. American Phenolic Corp., 1250 W. Van Buren St., Chicago, Ill.

ELECTROLYTIC CAPACITORS

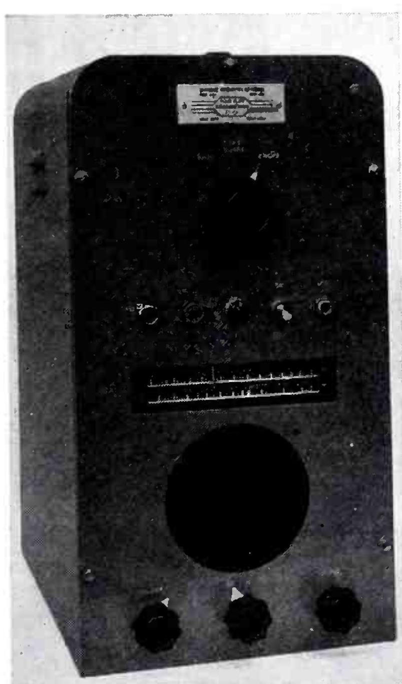
Solar Manufacturing Corp., Bayonne, N. J., has just announced a dry electrolytic capacitor, type DY, incorporating new features of construction. The base is a



novel soft rubber molding through which all terminals are brought and sealed under compression in a manner similar to that used in wet electrolytic practice. Low contact resistance, improved r-f characteristics, thorough sealing, freedom from the cause of intermittents, and the advantages of the wet electrolytic type of vent are claimed as features. A special engineering data sheet is available.

MARINE RADIOTELEPHONE

The Series 126 Marine radiotelephone equipment is shown in the accompanying illustration. This equipment, available from the Kaar Engineering Co., 619 Emerson St., Palo Alto, California, is built in a special narrow cabinet measuring 8" wide by 15" high by 11" deep to facilitate placement in small boats.



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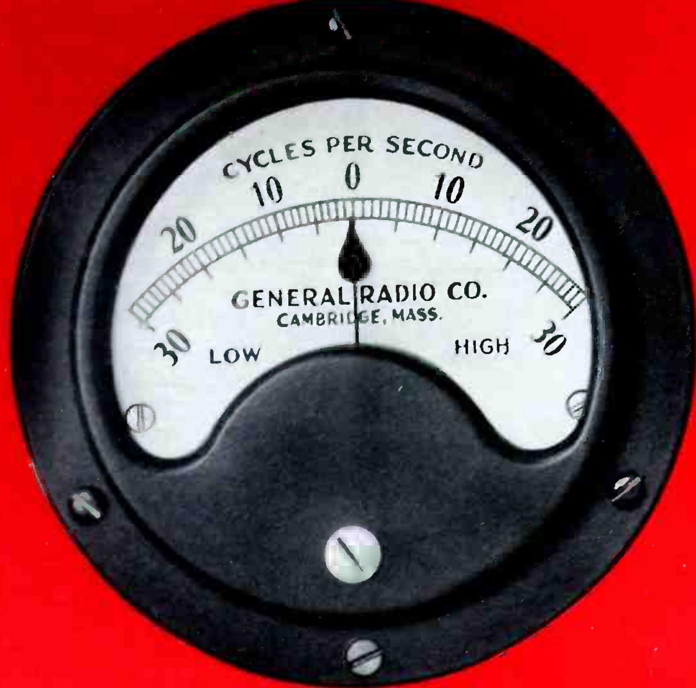
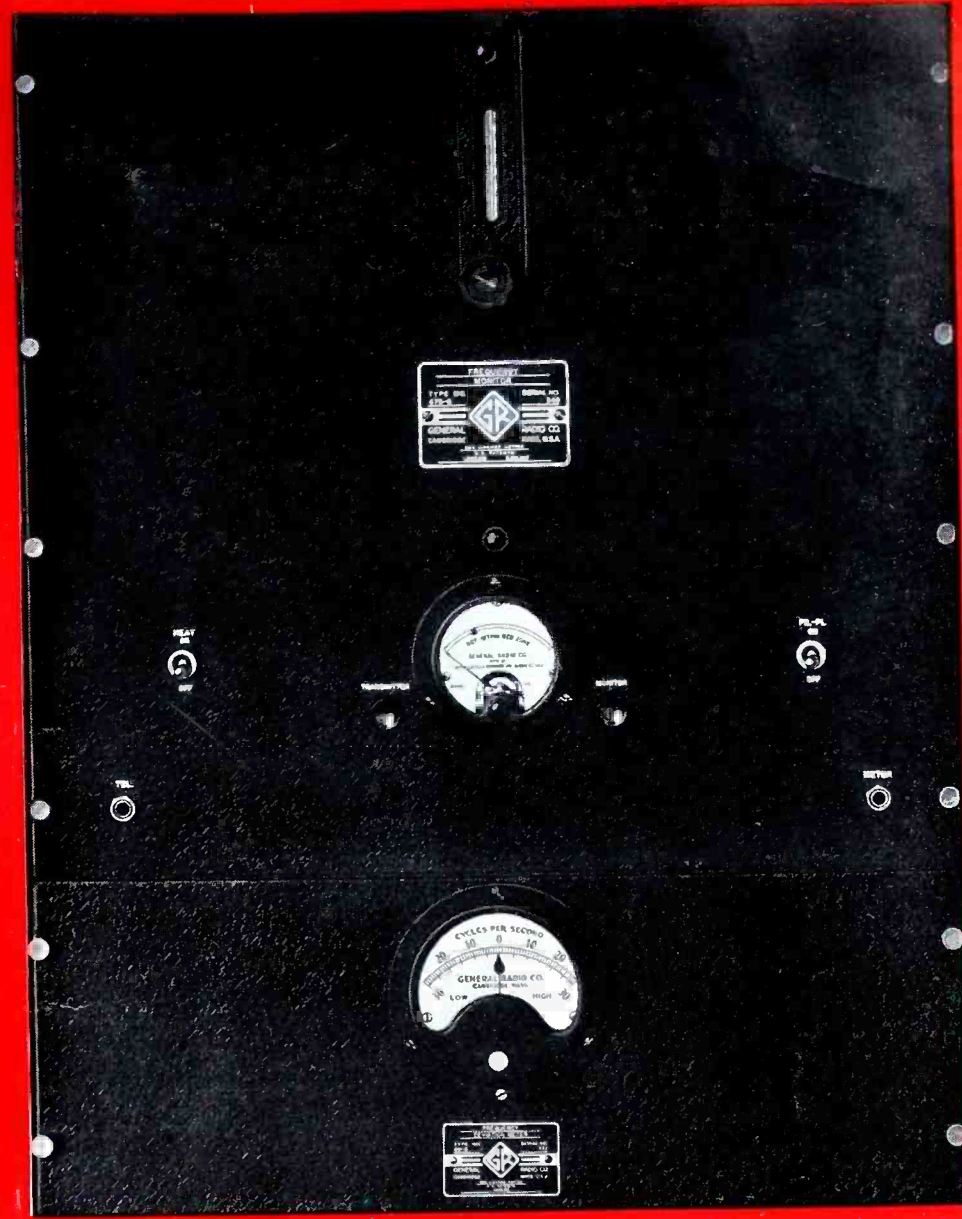


BROADCAST FREQUENCY MONITORING TO ± 20 CYCLES



TO ENABLE BROADCASTING STATIONS to comply with Rule 3.59 of the Federal Communications Commission, allowing maximum transmitter frequency deviation of only ± 20 cycles for new transmitters or new stations after January 1, 1940, General Radio announces an improved Broadcast Frequency Monitor.

A number of new electrical and mechanical features are incorporated in the new monitor, which bears FCC Approval No. 1452.

ELECTRICAL IMPROVEMENTS

1—New high-stability crystal-oscillator circuit.
2—Crystal amplifier to isolate oscillator.
3—Input amplifier to isolate transmitter.
4—Diode voltmeter.
5—New temperature-control system.
6—Improved frequency-deviation meter circuit.
7—Simplified operation.
8—New inside layout for simplified replacements.

The Deviation Meter scale now reads plus-minus 30 cycles and is direct reading to one cycle. The monitor has been so simplified in construction that the only controls on the panels are Heat and Filament-Plate OFF-ON switches.

NEW PANEL CONSTRUCTION

Through use of dress panels for both instruments, it is now possible to secure a frequency monitor to match any desired panel finish, at small extra cost. Four standard panel finishes are carried in stock. A plain aluminum panel is also available for finishing by the customer and subsequent engraving and assembly by G-R at the cost of the stock panels. Following prices are for G-R black crackle finish:

Type 475-C Frequency Monitor	$330.00
Type 681-B Frequency Deviation Meter	145.00
Type 376-L Quartz Plate	85.00

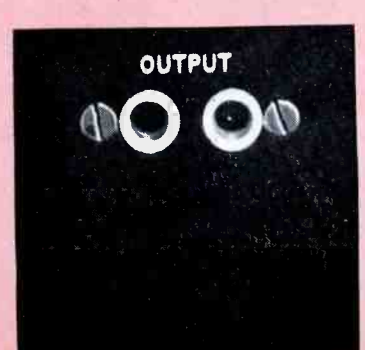
Special panel finish (other than standard G-R black crackle) available from stock in Western Electric gray, RCA gray, RCA flat black and plain aluminum for finish in any color (see above) . . . $5.00 per panel or $10.00 for complete monitor.

Deliveries start early in January, 1940.

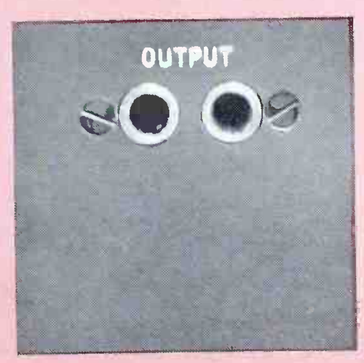
Write for Bulletin 518 for Complete Information

G-R STANDARD BLACK CRACKLE

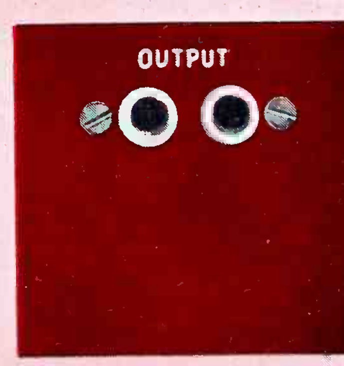
WESTERN ELECTRIC GRAY



RCA FLAT BLACK



RCA GRAY



ANY COLOR DESIRED

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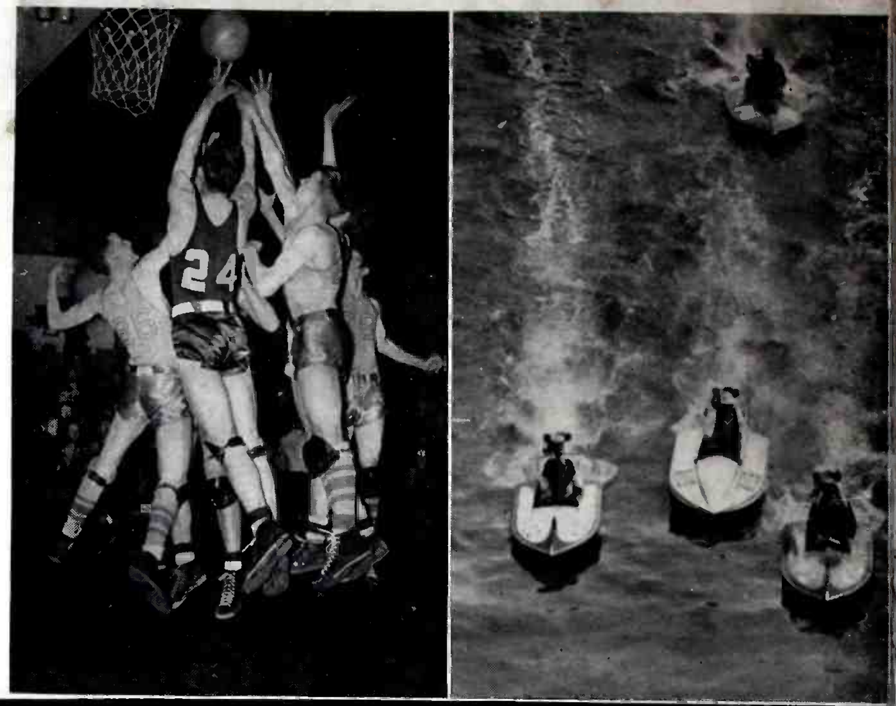

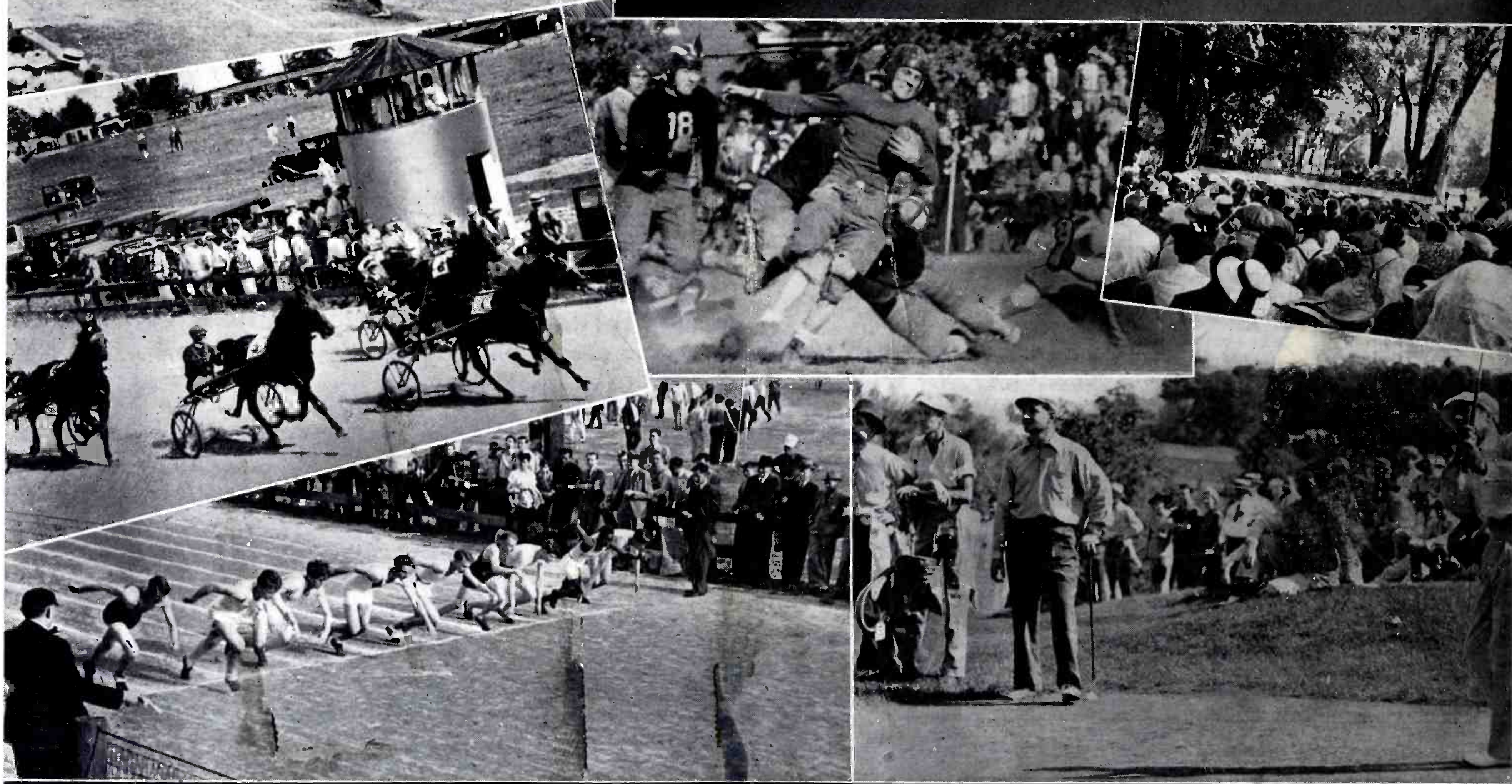

GATES RADIO & SUPPLY CO. MANUFACTURING ENGINEERS QUINCY, ILL., U.S.A.