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Radio Engineerin

MAY, 1937

VOL. XVII NO. 5

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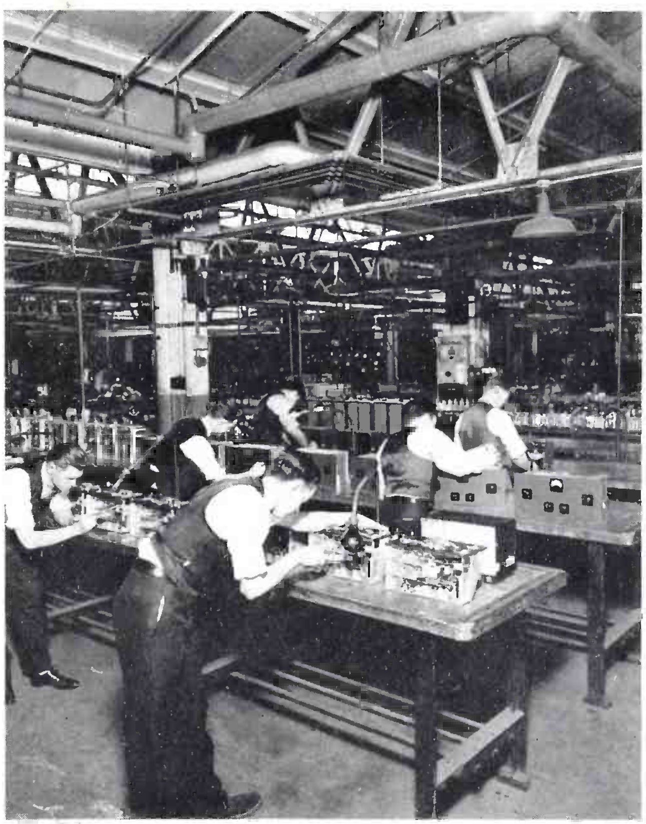

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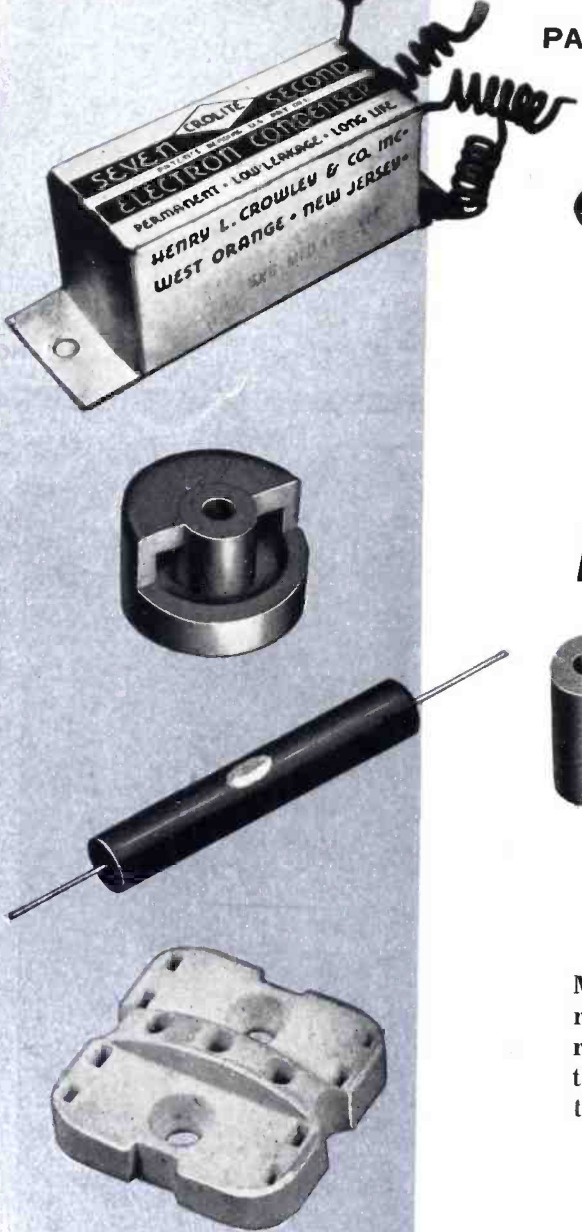

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CONTENTS FOR MAY

FEATURES

DEPARTMENTS

VOL. XVII — *Member Audit Bureau of Circulations* — NO. 5

COVER ILLUSTRATION

RADIO RECEIVING EQUIPMENT ON THE WAY THROUGH THE KEARNY PLANT OF THE WESTERN ELECTRIC COMPANY.

PUBLISHED MONTHLY by the

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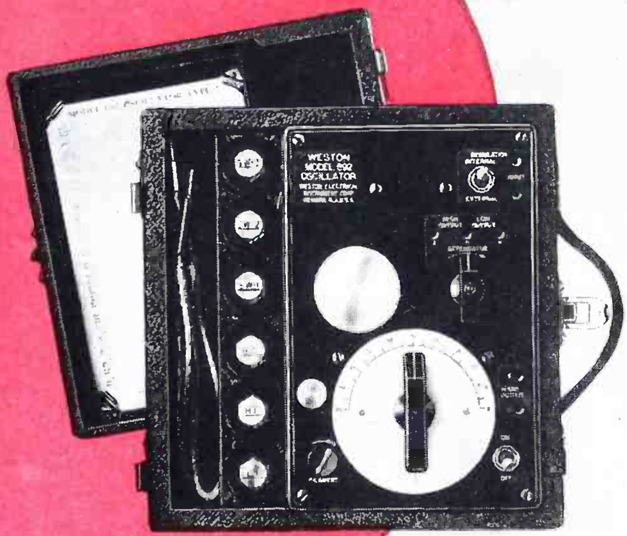

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Editorial

THIS MONTH

WE EXTEND CONGRATULATIONS to the Institute of Radio Engineers on the occasion of the twenty-fifth anniversary of that organization; and with the congratulations go our best wishes for the continuance of the impressive services which the Institute has rendered in the past.

For a long time we have been of the opinion that true high-fidelity radio reception would be attained only with the adoption of circuits which would closely approximate a rectangular response characteristic—in other words, the type of characteristic given by a band-pass filter. Evidently we are not alone in this opinion; several engineers with whom we have discussed the matter have agreed that filters, crystal or otherwise, must be the eventual solution. And, when television "arrives," the use of filters for r-f and i-f coupling may be the only answer to the problems of selectivity and gain.

It is with these thoughts in mind that we present our lead article. The subject of filters for high frequencies is covered in a manner which should at least indicate the general line of approach to this particular problem.

There have been any number of articles lately on the subject of inverse feedback. Relatively few of these have been of any value to engineers; most of them could be boiled down to this: "I built an amplifier and added a few extra resistances and condensers. I think that I have inverse feedback—although God only knows how, or how much. Anyway, it sounds swell." Consequently, we have resisted the urge to rush into print with the first material on feedback that came to our desk. (It will be recalled however, that RCA's first application note on this subject—the *first practical* data to be made available—appeared in RADIO ENGINEERING in September 1936.)

Now we follow-up with a feedback article which has such a beautiful balance between "it ought to" and "it does" that little if any thing more need be said on our part. It is of interest, though, to point out that our author, Mr. Martin, has shown for the first time just what the characteristics of the "apparent triode" (our term for it) look like as compared with those of the pentode.

There are many things that have been charged to the international unpleasantries of 1917-18, but not many persons realize that among other things the U. S. had to develope new sources of supply for papers suitable for use in condensers, as a direct result of the blow-up. In its entirety, the story would probably read like dozens of others involving industries that suddenly found their sources of supply shot to Hell—literally as well as figuratively. But the story of how it was done properly belongs in publications other than this; what concerns modern times is "what has been accomplished?" The article on condenser papers supplies the answer; it likewise indicates that condenser manufacturers seem to have the situation well in hand.

WIDOWS AND ORPHANS

IT WASN'T so long ago that everyone (almost) was shedding tears over the sad fate of these unfortunates who, to an amazing degree, were dependent upon meager incomes derived from investments that were either gilt-edged or wild-cat (according to the political complexion of the then current speaker or writer).

Our thought in the matter is that quite a few of these widows and orphans would remain as wives and children if only those working on circuits would remember the fundamental fact that a shock from hand to hand, or from hand to foot traverses just about all of the vital organs and nerve centers.

So little is known of electric shock that it just doesn't pay to take even the slightest chance; we know of two widely separate cases neither of which makes sense. In one, ninety volts very effectively killed a man. In the other, thirty-three hundred volts didn't do a thing but cause a fall—the fall broke a couple of bones, but from the standpoint of vital statistics the accident was a flop. The point is, though, the shocks in both cases were from hand to hand.

Everyone concerned with electrical work of any kind should be thoroughly familiar with the approved method of resuscitation, and should keep three rules invariably in mind: (1) Don't be alone while working on a circuit; (2) consider ALL circuits as "hot"; (3) keep one hand clear—in the pocket is a good place for it.

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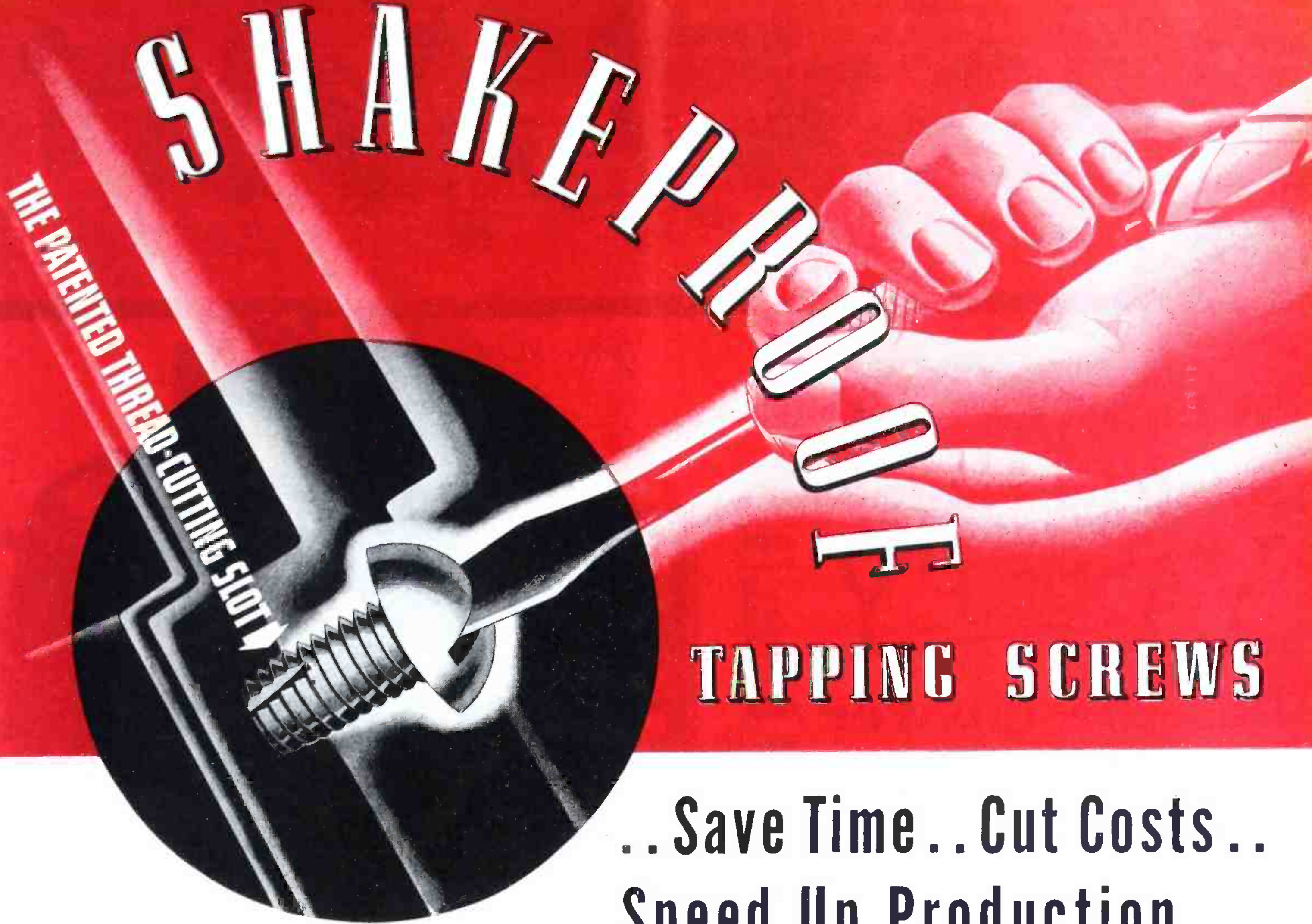

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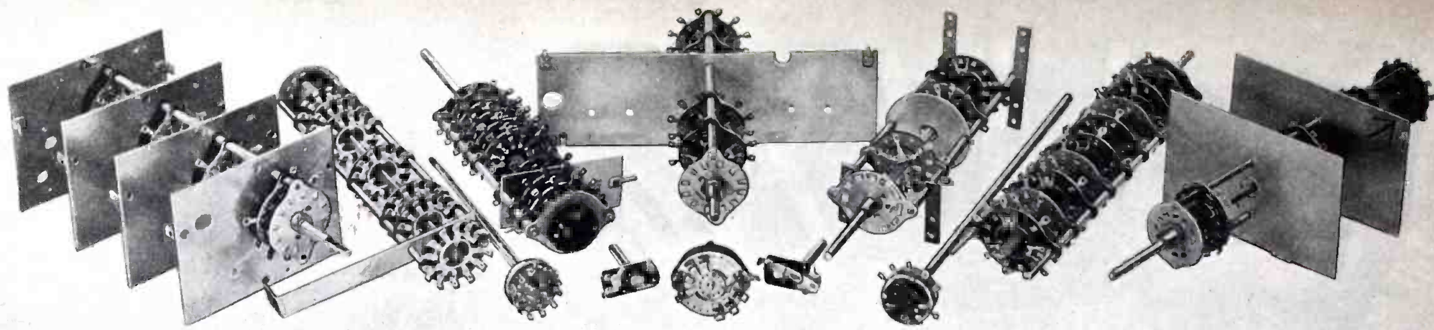

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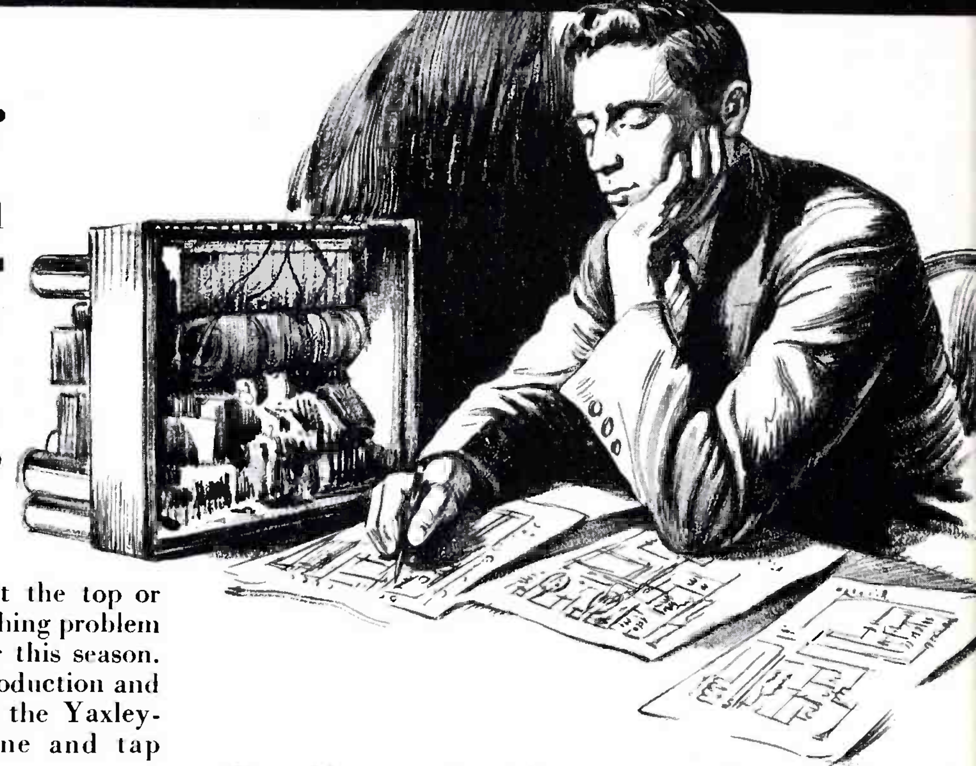

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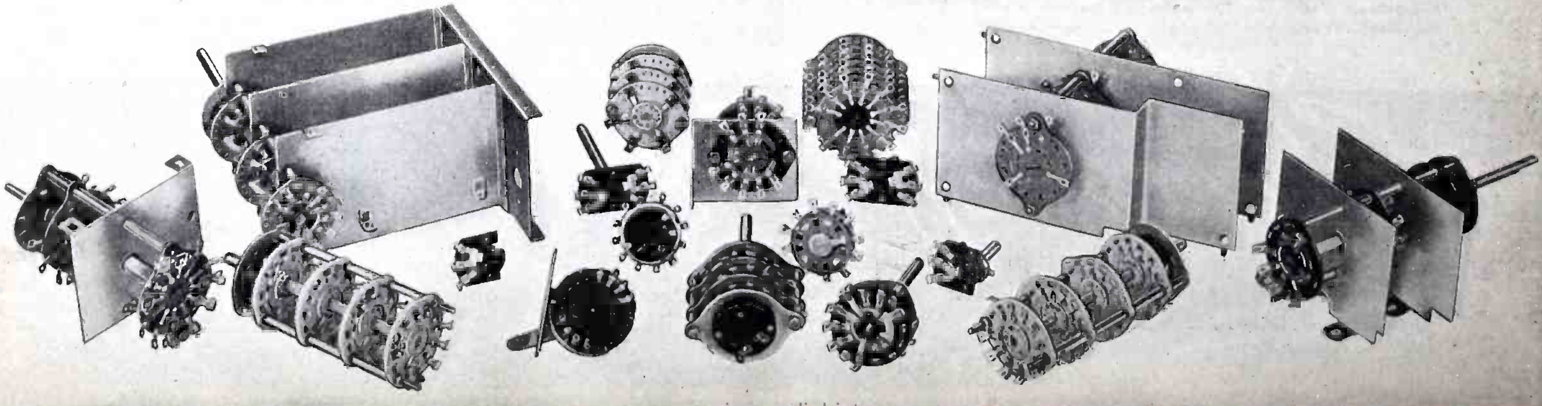


RADIO ENGINEERING

FOR MAY, 1937

25TH ANNIVERSARY—IRE

From the Institute's President and from Several of the Past Presidents Come These Messages to the Institute and to the Radio Industry at Large.

THE RELATIONS of such organizations as the IRE to the art of communication is analogous to that which communication itself bears to the world. The extraordinarily rapid evolution of radio would have been impossible without prompt dissemination of the creative work of each individual. Just as radio helps bind the world together and brings the results of human thought and experience promptly to the individual, so for 25 years the IRE, through its international character, its broad and unbiased leadership, its co-operation with other organizations, its special committees and its Proceedings, has served as a clearing house for radio and allied arts. It has become the outstanding agency in this country whereby the achievements of the individual or group are made available for the use of all.

Walter G. Cady

IN SO FAST MOVING an art as radio it is only on occasions such as this that we may take our eyes off the road ahead and look back over the territory through which we have travelled. It is difficult to realize that less than 25 years ago radio was a practical service only in its marine application. Today it is a vast industry with services that enrich the lives of millions.

The quarter-century of achievement which the Institute of Radio Engineers celebrates this year is, I feel, the radio industry's best assurance that future technical progress will not lag. The accomplishments of the past have been hard won, and there is little to encourage the belief that research will be any different in the years ahead. Yet I believe the most serious challenge of the future does not lie in radio's unconquered frontiers but in making the fullest use of the growing abundance of radio and electronic facilities.

H. H. Beverage,
PRESIDENT, I. R. E.

AS EACH SUCCESSIVE Annual Convention of the IRE marks another milestone in the growth of the great Radio Industry, those who, like myself, have pioneered from its earliest beginnings must pause to reflect upon the colossal strides which this once novel idea of "Wireless Signalling" has achieved in thirty-eight years. Search the annals of Science and Industry in vain to find a parallel, save in the Motion Picture Industry; and how relatively unimportant was the Cinema to direct or mould political and economic trends until radio, through its amplifier, gave to the film a loud voice, as it already had given to the Telephone Art a long-distance voice.

And in the past five years Radio has begun its march into varied industries, and in the vast field of Therapeutics, until it may not be too wild a hazard to suggest that in future years the electronic tube may become almost as widely employed as is the incandescent lamp today.

As the engineers of radio scan the near future they see most prominently displayed that cabalistic word, "Television." With that inherent instinct (hybrid of Science and Bureaucracy) to classify, define, and regulate, even if it be pre-natal and akin to birth-control, certain precocious engineers and officials have already felt an incumbent duty to stipulate exactly how and by whom Television shall be born, what shape and lines in its face, what style diapers and rompers the foundling shall wear.

As logically should the Canadian Medical Association have prescribed in advance the number and sex of the Dionne immigration. Or back in 1911 the Bell Engineers, abetted by the ICC, have stipulated that the telephone repeater of the future should be only of the "Shreve type," its form and characteristics strictly specified, and that no other device should be permitted to go on the lines in America.

Equally sapient are the hard and fast rules now already adopted by the RMA and more or less blandly suggested to FCC for official ukase. Let us hope that before that Body makes any definite ruling in this perilous direction it will be constrained to wait to see just what in the way of Television may actually be proved capable of *commercial* exploitation; lest they prenatally hamstring this promised infant! *Lee de Forest*

(*Continued on page* 36)

THE DESIGN OF FILTERS
AT HIGHER AND HIGHER FREQUENCIES

by C. E. Lane

Bell Telephone Laboratories, Inc.

SINCE THE INVENTION of electrical wave filters by Dr. G. A. Campbell, more and more exacting requirements in many directions have continually made necessary the use of new methods in filter design. The need for filters at higher and higher frequencies has been one of the reasons for some of the design problems encountered.

Until about five years ago most of the filters were used in wire communication systems and the maximum frequency locations of their transmission bands were below about thirty kilocycles. This frequency is approximately the upper limit of the open-wire carrier-telephone system which had then been in use for some time. For only a few purposes had filters at that time been designed for use at frequencies as high as one hundred and fifty or two hundred kilocycles. At radio frequencies, selectivity was generally obtained by the use of tuned circuits. This was a practical method since frequency space was relatively plentiful, since both sidebands arising from modulation were transmitted, and since the wanted bands were relatively narrow with reference to the mid-band frequency.

Today the situation is quite different. Filters with their sharp cut-offs and uniform transmission bands are now commonly used as high as two or three million cycles and sometimes as high as fifty or sixty million cycles. More and more filters at higher and higher frequencies will without doubt be needed to provide high quality and efficient high frequency carrier systems[1] utilizing cable, open wire, concentric conductor, and radio space. While filters are practically essential to single sideband transmission, they may also be required where both sidebands are transmitted to provide efficiency, high quality, and eliminate interference.

Since the problems in the design of filters for use at higher and higher frequencies arise from their need in carrier systems for transmission over wire or through space, the nature of carrier systems will be reviewed. In their normal frequency allocation the essential frequency components of signals, i.e., speech, music, etc., fall in a frequency band which may be defined by an upper and a lower frequency limit. In carrier systems this frequency band is relocated by modulation to some higher frequency for transmission. However, the frequency band width in cycles remains exactly the same after relocation as before. In this way, a large number of channels may be provided utilizing the same transmitting medium by locating the channels in different adjacent frequency ranges. If the medium is to be used efficiently the channels must be segregated from each other by the use of filters.

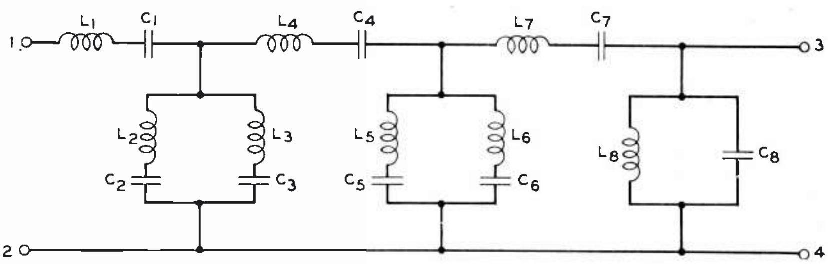


Fig. 1. Schematic of band-pass filter.

Primarily, the problem of providing filters for multi-channel systems is a band filter problem. If equally good band filters are to be provided for carrier systems they should have the same band width in cycles at any frequency allocation; they should have the same maximum loss in the band to transmitted frequencies; they should provide about the same minimum discrimination against unwanted frequencies; there should be no greater number of cycles required, as the frequency allocation of the filter is increased, for the loss to rise from the low loss in the band of the filter to the high loss required outside the band; and in the transmission band the distortion should for all filters not exceed some specified amount.

The above requirements are determined by three main objectives to be accomplished. First, the frequency range of the signals must be restricted by the elimination of all frequency components which otherwise would fall below or above the frequency range considered essential and cause interference between channels. Second, if single sideband transmission is to be used, the filters must eliminate either the upper or the

[1]The term carrier system is here used in its broadest sense to include all radio systems.

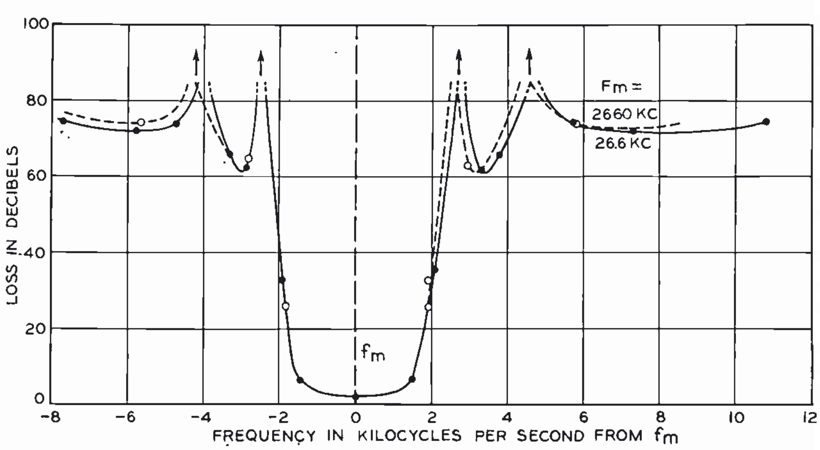


Fig. 2. Loss characteristics of filter shown in Fig. 1.

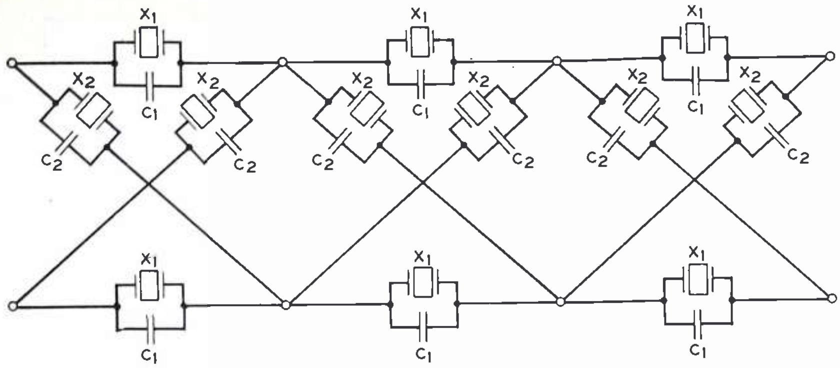


Fig. 3. Schematic of band-pass crystal filter.

lower sideband arising from modulation and permit free transmission of the opposite sideband. Regardless of the frequency range, to which the signal is shifted for transmission, the two sidebands are exactly the same number of cycles apart, i.e., twice the number of cycles of the lowest frequency to be transmitted in the original signal. A third condition that sometimes exists is that a number of the filters must work in parallel and, to prevent energy loss and distortion, any filter must offer a high shunting impedance in the transmitting ranges of all the other filters.

The above definition of what constitutes equally good filters for use at higher and higher frequencies is rather idealistic but convenient, for it provides a good basis for examining the nature of the problems encountered. Consider the usual method of designing such a band filter by connecting together a number of constant-k ladder filter sections which have like image impedances at the junction. This filter will consist of one or more sections having infinite attenuation at zero and infinite frequencies and other sections having very high losses at frequencies not far from the edges of the transmitting bands of the filter. When this procedure is followed, the following conclusions may be drawn relative to the elements of the filter:

(1) The same filter schematic may be used and, hence, the same number of elements regardless of the location of the filter.

(2) The higher the frequency allocation of the filter band, the more nearly the elements used in their construction should approximate pure reactances, that is, the Q of the inductances and capacitances would need to become better and better, increasing in direct proportion to the frequency of band location.

(3) The spread in the magnitude of the element values required for the filters for both the inductances and capacitances would increase as the square of the frequency of allocation of the band. By spread is meant the ratio of the largest to the smallest value of either inductance or capacitance called for in the filters.

(4) The largest inductance or capacitance value would remain essentially the same provided the filters were designed to operate at the same impedances.

(5) The smallest element values, therefore, would decrease as the square of the frequency increases.

(6) The precision expressed in percentage to which the elements must be adjusted and maintained would increase directly as the frequency.

The following is an example illustrative of the above statements: Fig. 1 is the schematic of one of the channel filters used in a standard open-wire carrier-telephone system. Another schematic might have been chosen for illustration, of course, but the same general statements made above would still apply. The mid-band frequency of the filter is 26.6 kilocycles and the inductances have Q's of 140. The element values of the filter are listed in Table I.

It will be noticed that the ratio of the largest to the smallest elements, either inductances or capacitances, is a little over one hundred to one. The loss characteristic of the filter in terms of kilocycles removed from the mid-band frequency, f_m, is given by the solid curve in Fig. 2.

Now on paper one can obtain essentially the same characteristic in cycles from mid-band frequency at one hundred times the frequency using the same identical schematic but with different element values, the small difference being shown by the dotted curve in Fig. 2. In doing this it is necessary to assume for the new filter a Q of 14000 for the inductances and much larger Q's for the capacitances in order to maintain the same loss in the band and the same sharpness of cut-off in cycles. The element values of such a 2660 kc filter are given in Table II.

The spread in the element values is now ten thousand times what it was before or a little over one million. The largest elements for both filters are practically the same. It would not be possible to construct such a filter at 2660 kc for reasons outlined below. About the limiting frequency for meet-

TABLE I

Inductance (Milli-henries)		Capacitance (Micro-microfarads)	
L_1	42.3	C_1	840
L_2	5.6	C_2	8700
L_3	4.1	C_3	6300
L_4	46.7	C_4	760
L_5	17.4	C_5	2490
L_6	14.3	C_6	2040
L_7	48.9	C_7	730
L_8	0.46	C_8	77400

TABLE II

Inductance (Milli-henries)		Capacitance (Micro-microfarads)	
L_1	43.7	C_1	0.081
L_2	4.5	C_2	0.79
L_3	4.5	C_3	0.79
L_4	48.4	C_4	0.074
L_5	15.9	C_5	0.224
L_6	15.9	C_6	0.224
L_7	50.5	C_7	0.070
L_8	0.000045	C_8	79700.

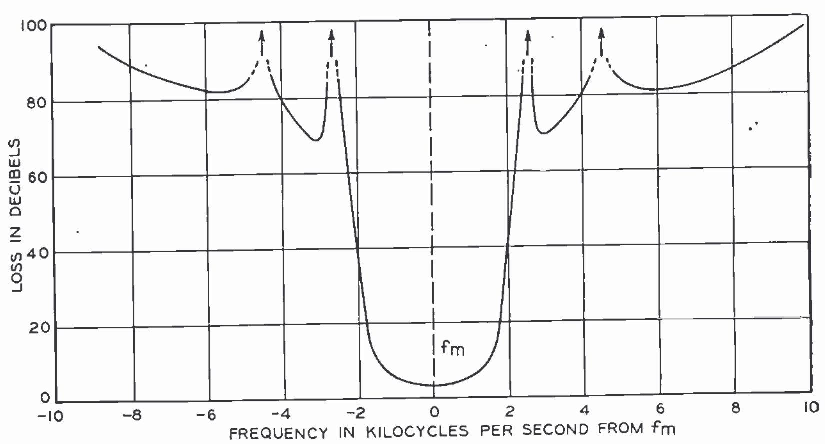


Fig. 4. Loss characteristic of filter shown in Fig. 3.

ing such filter requirements using coils and condensers would be 50 kilocycles using Q's of 280.

The difficulties that are encountered as effort is made to build equally good filters at higher and higher frequencies are many. Such filters can be realized only over a limited frequency range. However, the need for building such filters exists and any development which makes it more nearly possible to do this, may be said to be in the direction of economy. Sometimes the recognition of the limitations in producing equally good filters at higher frequencies frequently leads to the use in carrier systems of a second modulation step. Furthermore the use of a second step of modulation might be used also for reducing the number of different types of band filters required. When this is done a second set of band filters is required having more lenient requirements than the first set.

The difficulties arising in the design of equally good filters may be summarized as follows:

(1) The best Q obtainable at reasonable cost for the inductance coils is usually about 200 or 300 anywhere in the frequency range from 1000 cycles to 100,000,000 cycles. Furthermore at any frequency there is a limited range of magnitudes of inductances for which these best Q values can be realized. The higher the frequency the smaller the optimum value of inductance for obtaining a good Q and the narrower the spread of values for which the good Q is obtainable.

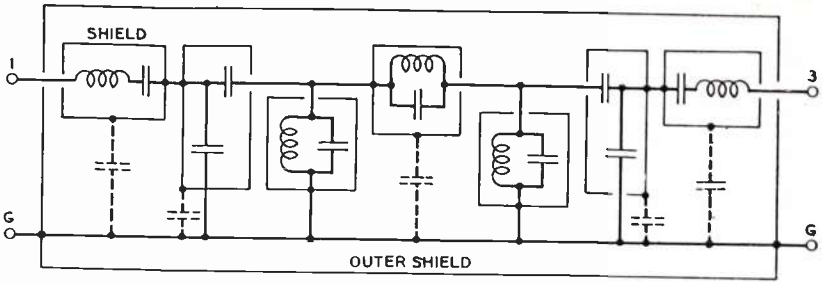


Fig. 5. Band-pass filter schematic before and after impedance transformation.

(2) The need for large values of inductance at high frequencies is another difficulty. Large inductance values vary rapidly in effective value with frequency as resonance with the distributed coil capacity is approached. Above resonance the inductances become capacitances.

(3) The very small values of inductance required are of the same magnitude as the inductances of the short lengths of wire used to connect the filter sections together.

(4) Large values of capacitances at high frequencies which have good Q's would be very expensive.

(5) The very small values of capacitances required are of the magnitude of the stray distributed capacitances within the filter and make it impossible to realize the lumped element structure called for in the theoretical design.

Recent developments have made available many means which now make it possible to design better filters for use at higher and higher frequencies. The use of quartz crystals as filters in the frequency range from thirty kilocycles to two or three million cycles has been a very outstanding step forward. These elements have Q's that are of the order of one hundred times those obtainable for inductances. Furthermore they are very stable with respect to temperature and aging effects. By their use filters can now be designed at two million cycles that are as good as, on the basis of the definition used above, filters previously designed at twenty or thirty kilocycles. Fig. 3 is the schematic of a crystal filter which could be realized with a mid-band frequency of 2660 kc. The loss characteristic is shown in Fig. 4. This compares favorably with the characteristic shown in Fig. 2[2].

There are two means that can be employed in the design of electrical filters at high frequencies that overcome some of the difficulties encountered because of the magnitude of the elements. First, filters which have been designed along conventional lines may be modified by introducing impedance transformation internal to the filter[3] and thereby obtain element values that are of more suitable magnitudes for construction. To get optimum magnitudes for the end elements of the filter it is well to design the system to call for a filter operating at the most suitable impedance level as internal impedance transformation does not modify these end elements very much. In impedance transformation internal to the filter results are obtained equivalent to the insertion of ideal transformers at desired points internal to the filter. This means that magnitudes of certain elements may be increased or decreased as desired within limits depending upon the filter. This in general results in a modification of the filter schematic. The narrower the band of a filter on a percentage basis the greater the impedance transformations that can be made. This is fortunate since the narrower the band of the filter as designed in the usual way the greater the original spread in the element values. Fig. 5 shows the schematics and element values of a recently designed filter both

(*Continued on page* 16)

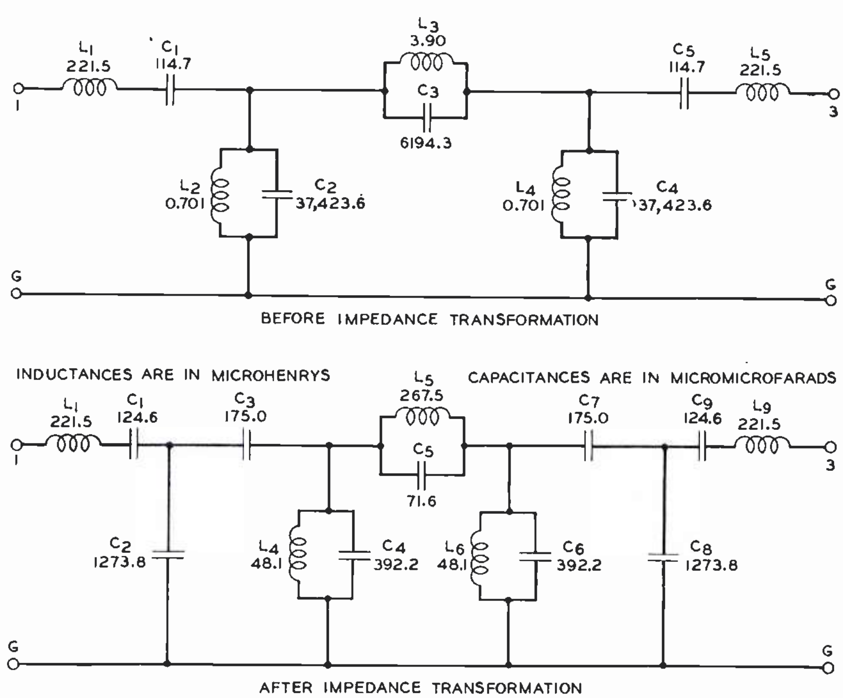


Fig. 6. Illustrates method of shielding high-frequency filters.

[2]For a discussion of crystal filters see W. P. Mason. Bell System Technical Journal, July 1934.
[3]See Patent 1681554 by E. L. Norton.

CHARACTERISTICS OF INVERSE-FEEDBACK CIRCUITS

by Louis Martin
RCA Mfg. Co., Inc.

TWO TYPES of inverse-feedback circuits are in general use. In one type, a portion of the voltage that appears in the output circuit of an amplifier is fed back to the input in the proper phase to reduce the overall gain of the amplifier. By deliberately reducing the gain of an amplifier in this manner, extraordinary improvements in performance can be obtained. Distortion due to a non-linear plate-circuit characteristic is reduced; variations in overall gain due to changes in line voltage are reduced; and output-voltage changes due to a variable load characteristic are reduced. In the second type of inverse-feedback circuit, the usual by-pass condenser across the self-bias resistor is removed. The alternating voltage developed across this resistor and the signal voltage are 180 degrees out of phase; hence, inverse-feedback action is obtained. This type of circuit reduces amplitude distortion and the effects of changes in line voltage; it does not reduce output-voltage changes due to a variable load characteristic. The second type of inverse-feedback circuit, however, has additional advantages of simplicity and low cost.

Both types of circuits have been analyzed mathematically. It is felt, however, that a method of visualizing and predicting feedback-amplifier performance by well-known methods is of value to the practical designer of amplifiers. The explanation will be divided into two sections: the first will discuss the type of feedback in which a portion of the output voltage is fed back to the input through a separate feedback circuit: the second section will discuss the type of feedback in which the voltage across an unby-passed cathode resistor produces feedback action.

Consider the simple single-stage feedback-amplifier circuit of Fig. 1. An input signal E_1 is amplified to a value E_o. A fraction of E_o is applied to the input in the proper phase to oppose E_1; this fraction is numerically equal to $R_1/(R_1 + R_2) = n$ when the reactance of C_f is negligible compared to $(R_1 + R_2)$. The net signal voltage actuating the tube is $(E_1 - nE_o)$; if the gain of the stage without inverse feedback is G, the output voltage is

$$E_o = G\,(E_1 - nE_o) \qquad (1)$$

The gain of the stage with feedback is

$$G_f = E_o / E_1 = \frac{G}{1 + nG} \qquad (2)$$

The input signal required for this output is

$$E_1 = \frac{E_o\,(1 + nG)}{G}$$

But $E_o/G = E_s$ is the signal voltage required for the output voltage E_o without feedback; therefore, a useful expression for the ratio of the input signals required for an output voltage E_o with and without inverse feedback is

$$\frac{E_1}{E_s} = 1 + nG \qquad (3)$$

Eq. (3) is the ratio of the change in gain due to inverse-feedback. In all these expressions, if the phase of the feedback voltage is reversed so that the input signal and the feedback voltage add arithmetically, the term $(1 + nG)$ becomes $(1 - nG)$. However, this change indicates regeneration, not inverse feedback.

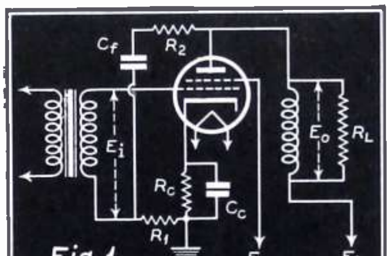


Fig. 1 Typical One-Stage Feedback Amplifier

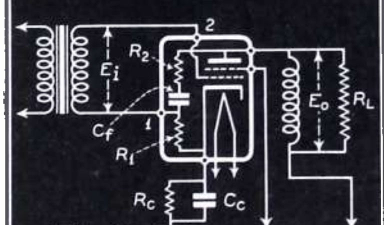


Fig. 2 -Equivalent Circuit of Fig. 1 with Inverse-Feedback Circuit Built in Hypothetical Tube-

Suppose that a hypothetical tube is built in which the inverse-feedback circuit is connected to the proper terminals inside the tube. Under these conditions, the only terminals available for external connections are those used in conventional circuits. Such a tube and its external circuit then appears as in Fig. 2. The performance of the amplifier can be determined by conventional methods, provided the characteristics of the hypothetical tube are known. The characteristics of a tube with inverse-feedback can be determined from the tube's characteristics without inverse-feedback for a given value of n.

The plate family of a 6L6 for 250 volts on the screen is shown by the dashed-line curves of Fig. 3. It is required to obtain a new family for a given value of n. Consider the conductive-feedback circuit shown in Fig. 3. To construct the —30-volt characteristic, for example, set E to —30 and adjust R_1 so that 10 percent of E_b is applied to the grid in series with E. When $E_b = 300$ volts, the total grid bias is zero; the point on the characteristic is represented at (a). When $E_b = 250$ volts, the total grid bias is —5 volts; the corresponding point on the new characteristic is (b). All the solid-line curves in Fig. 3, which are the plate characteristics of the hypothetical tube, were constructed by proceeding in this manner. In the actual circuit, C_f blocks out the d-c component of the output; the ordinate then represents relative values of alternating currents, the abscissa represents relative values of a-c voltages, and the solid-line curves represent relative values of signal voltage. The negative signs on the signal-voltage curves are not shown. The original dashed-line curves should be used for all d-c measurements.

These new data can be used to predict the performance of the tube, when $n = 0.1$, by familiar methods. Note that the new characteristics are not carried beyond the original zero-bias curve. Operation beyond the original zero-bias curve produces grid current, which may distort the wave form of the input signal. Inverse feedback does not reduce distortion generated in the input circuit connected to the grid of a tube.

The new curves do not indicate the

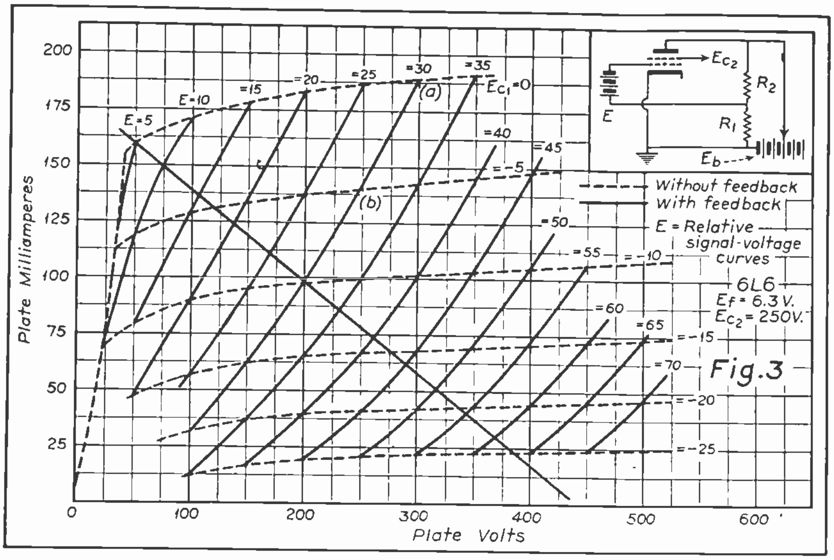


Fig.3

proper operating bias; they merely indicate the input signal necessary to produce output with 10 percent voltage feedback. The proper bias with inverse feedback is the same as the proper bias without feedback. Suppose that the tube is biased to —14 volts and that a 2500-ohm load (R_L) is used. Without feedback, a peak signal of 14 volts is required for full output. With 10 percent inverse feedback, a peak signal of $(40 - 5) = 35$ volts is required for full output (Fig. 3); the ratio of the sensitivities is $35/14 = 2.5$. Without feedback, total distortion is approximately 10 percent. If distortion calculations are made on the characteristics of the hypothetical tube by familiar methods, it will be found to be nearly $10/2.5 = 4$ percent. Thus, no new relations are necessary to calculate distortion when the plate family is redrawn to account for feedback. The calculated values indicated have been checked repeatedly by measurements.

The new curves indicate a much lower internal plate resistance for a tube with inverse feedback. The value of the new plate resistance is readily determined. Connect an alternating voltage e_p in place of the load R_L in Fig. 2 and short circuit terminals 1 and 2. The voltage impressed on the grid due to the feedback network is ne_p; the alternating plate current due to this grid voltage is $g_m ne_p$. This value of alternating plate current is added to the alternating plate current due to the plate cathode resistance of the tube to obtain the total alternating plate current due to e_p. Thus,

$$r_p' = \frac{e_p}{i_p} = \frac{e_p}{ng_m e_p + e_p/r_p} = \frac{r_p \dfrac{1}{ng_m}}{r_p + \dfrac{1}{ng_m}} \quad (4)$$

where r_p is the plate resistance of the tube without feedback, r_p' is the plate resistance of the tube with inverse-feedback, and i_p is the alternating plate current.

Eq. (4) shows that the internal plate resistance of a tube with inverse-feedback is equal to the plate resistance of the tube without feedback shunted by a fictitious resistance $1/ng_m$. For the 6L6, $n = 0.1$, $g_m = 6000$ micromhos, and $1/ng_m = 1660$ ohms.

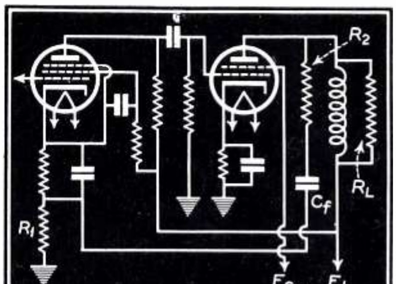


Fig.5
~Typical Two-Stage Inverse Feedback Amplifier~

The internal plate resistance of a tube shunts the plate load. Hence, the effects of a variable load characteristic are reduced when the load is shunted by a low resistance. With n equal to 10 percent in a single-stage 6L6 amplifier, the speaker is loaded to such an extent that hangover effects, which occur at the resonant frequency of the speaker, are greatly reduced.

The loading effect was demonstrated by an impulse test. A signal having a sharply peaked wave form was fed to the grid of a 6L6 amplifier; the voltage across the voice coil without inverse feedback is shown at (a) of Fig. 4. The output voltage with n equal to 16 per cent is shown at (b). From these oscillograms, it is seen that the effect of adding inverse feedback is to damp transient motions of the speaker. The oscillogram at (c) shows the voltage across the voice coil of the same amplifier when feedback is replaced by an acoustic resonator. Oscillogram (d) shows the output with the acoustic resonator and with n equal to 16 percent. It is seen that this value of n produced about the same beneficial effects as the acoustic resonator alone.

The low plate resistance of a tube used with this type of feedback circuit requires good filtering of the plate-supply voltage when single-stage amplifiers are cascaded. For push-pull stages, the plate-supply voltage should be well filtered to avoid high hum output due to possible unbalances in tubes and circuits.

An amplifier stage with inverse feedback is relatively insensitive to line-voltage changes because the circuit is self-regulating. Suppose the effect of changing the line voltage in an amplifier without feedback is to change the gain k percent; with feedback, the same line-voltage change produces a change in gain of $k/(1 + nG)$. This reduction in change in gain is substantial for large values of nG.

It is seen from the previous discussion that the addition of inverse feedback reduces gain, distortion, and the effects of varying line voltages by a factor of $(1 + nG)$. It is desirable, therefore, to make nG as high as possible. A minimum permissible value of sensitivity usually limits the highest value of nG that can be used in a single stage. However, by feeding back over two stages, it is possible to increase nG to very high values.

In feeding back over two stages, it is necessary to reverse the phase of the feedback voltage in order to maintain proper phase relations between signal and feedback voltages. Thus, Fig. 5 shows a means of feeding back over an even number of stages; the circuit of Fig. 1 indicates how feedback may be used over an odd number of stages. When the output stage has two tubes connected in push-pull, the circuit of Fig. 1 may be used for feedback over an even or odd number of stages, provided R_2 connects to the plate of the proper push-pull tube. The proper push-pull tube is easily determined by test.

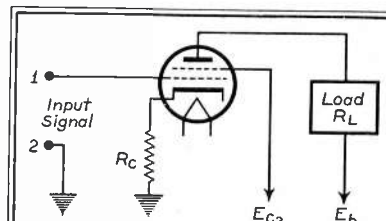


Fig.6
~Typical Circuit Illustrating Second Method of Obtaining Inverse-Feedback Action~

It should be noted that an input transformer is shown for the circuit of Fig. 1. When a resistance-coupled amplifier precedes the output stage and the circuit of Fig. 1 is used, the plate resistor of the previous tube, shunted by the plate resistance of the tube itself, and the grid resistor of the output tube (through which the feedback voltage is fed) form a voltage divider; the values of resistors which are employed in plate and grid circuits are usually such as to reduce considerably the value of n.

Feedback over a single stage with values of n from 10 to 20 percent is usually sufficient for most purposes. However, when the output tubes operate in the grid-current region, as in a Class AB_2 amplifier, the presence of the feedback resistor R_1 (Fig. 1) introduces grid-circuit distortion. Feedback over two stages is then desirable. Commercial Class AB_2 amplifiers using two-stage feedback for this reason have been built.

Troubles may be experienced with oscillation, even in single-stage feedback. Mathematical criteria for oscillation are known, but it is difficult for the practical engineer to determine whether a given amplifier design satisfies these criteria. He can, however, build the amplifier and observe its performance. The presence of oscillation can be detected by a cathode-ray tube or by measurements of electrode currents.

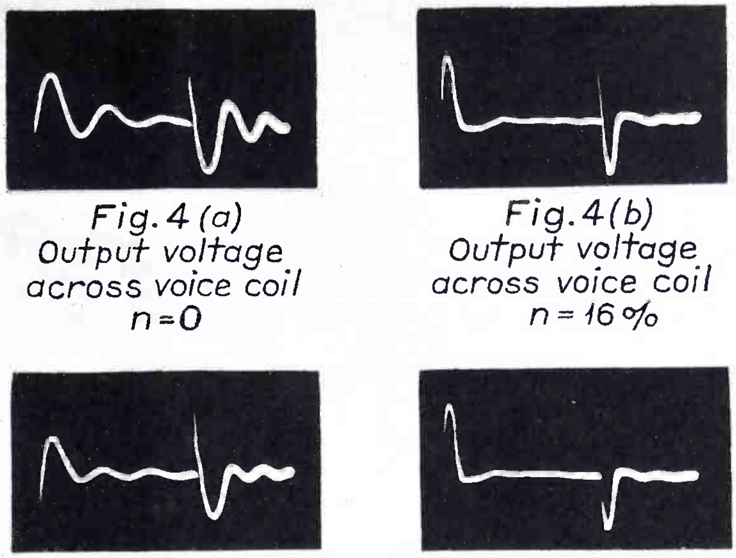


Fig. 4 (a) Output voltage across voice coil n=0

Fig. 4 (b) Output voltage across voice coil n = 16%

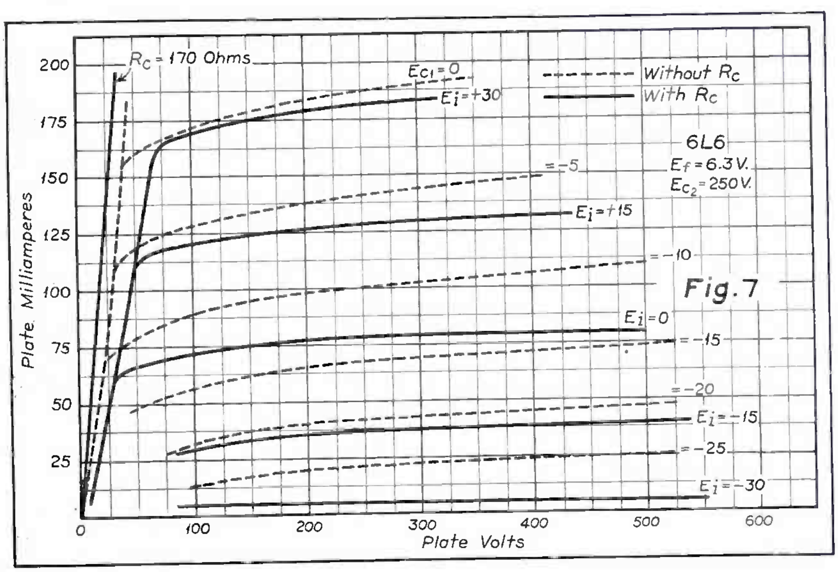
Fig. 4 (c) Output voltage across voice coil with acoustic resonator

Fig. 4 (d) Output voice coil with acoustic resonator and inverse feedback n = 16%

A circuit may oscillate when the feedback voltage is in phase with the signal voltage and the magnitude of nG is equal to or greater than unity. From a practical point of view, then, there should be no frequency at which nG is equal to or greater than unity and at which the feedback voltage completely reverses its proper phase. In a single-stage resistance-coupled amplifier, the phase of the output voltage may shift nearly ±90 degrees; the maximum phase shift over two stages is ±180 degrees. Because this maximum phase shift occurs at low or high frequencies when the gain is zero, the criteria for oscillation are not satisfied and the circuit is stable. However, should the feedback circuit introduce phase shift, a two-stage feedback amplifier may oscillate.

When a two-stage feedback amplifier oscillates, therefore, the gain of one or both stages at the frequency of oscillation should be made nearly zero in order to decrease the value of nG.

The feedback voltage may be taken from the primary or from the secondary of the output transformer. When taken from the secondary, the presence of feedback compensates for poor frequency response. When the voltage across the voice coil rises above or falls below a certain value, the regulating action of the circuit compensates for abnormal output voltages. But this connection is not a good one for stability. The leakage reactance of primary and secondary of the output transformer shift the phase of the voltage across the secondary at high or low frequencies, which tends to make the circuit oscillate. Thus, obtaining feedback from the secondary of the output transformer improves frequency response and increases the tendency toward oscillation.



When the feedback voltage is obtained from the primary of the output transformer, feedback tends to maintain a constant voltage across the primary; the voltage across the voice coil falls, due to leakage reactance in the output transformer. However, the primary connection does not introduce a phase shift in the feedback circuit; therefore, the feedback voltage should be obtained from the primary of the output transformer when good stability is necessary.

When feedback over three stages is desired, the possibility of oscillation is great, because each stage (resistance coupled) can introduce a possible phase shift of 90 degrees; the criteria for oscillation is then easily satisfied. Two expedients can be used to avoid oscillation when feedback over three or more stages is used. The frequency-response characteristic of one stage can be made very good over a wide frequency range. Thus, at frequencies where $nG = 1$, the phase shift introduced by the third stage is small, and the criteria for oscillation are difficult to satisfy. However, it may not be easy to adjust the output voltage at low and high frequencies to desired values at reasonable cost. In this case, it may be desirable to use one feedback circuit from the output of the third stage to the input of the second stage and to use a second feedback circuit from the output of the first stage to the input of the first stage.

The second type of inverse-feedback circuit is one in which a cathode-resistor by-pass condenser is not used. Under this condition of operation, the a-c component of the voltage across the cathode resistor is 180 degrees out of phase with the applied signal voltage. The elements of this type of circuit is shown in Fig. 6. Simple expressions for gain and distortion for this circuit can be obtained easily. Let E_i be the applied signal and E_o the output voltage with feedback. The grid-cathode voltage is then

$$E_g = E_i - \frac{R_c E_o}{R_c + R_L} = E_i - nE_o$$

where $n = R_c/(R_c + R_L)$. When E_g is multiplied by the gain of the amplifier without feedback (G), the value of the output voltage E_o is obtained. Thus,

$$E_o = (E_i - nE_o)G$$

and

$$\frac{E_o}{E_i} = \frac{G}{1 + nG},$$

the gain of the amplifier with feedback. The total output voltage (E_o) appears across R_c and R_L; the useful output voltage appears only across R_L. The percent loss in power output is then $R_c/(R_c + R_L) = n$. Because distortion and noise appearing in the output is applied to the input in reverse phase, distortion and noise with inverse feedback equals distortion and noise without feedback divided by $(1 + nG)$.

The characteristics of a hypothetical tube having an unbypassed cathode resistor inside the tube can be determined from the characteristics of the same tube without the cathode resistor for a given value of R_c. Consider the plate family of a 6L6, shown by the dashed-line curves of Fig. 7. The reciprocal of the slope of line R_c equals the value of the cathode resistor of interest; a value of $R_c = 170$ ohms was chosen. The solid-line curves represent the plate family with a 170-ohm resistor in series with the cathode.

The method of obtaining the solid-line curves is best described by explaining the construction of a single curve, the 15-volt curve for example. For any value of plate current, the bias developed across R_c is determined by the intersection of the plate-current line of interest and the line representing R_c. For example, 20 volts is developed across R_c for a plate current of 117.5 ma. If 15 volts is applied from grid to ground the net bias is —5 volts; the corresponding point on the family is at $E_{c1} = -5$, $I_b = 117.5$ ma. This point corresponds to a plate-cathode voltage of 45 volts; the actual plate-supply voltage is $45 + 20 = 65$ volts. Another point on the 15-volt curve is obtained by assuming 21 volts across R_c; this point is located on the —6-volt curve at a plate-current of 123.5 ma.; the plate-cathode voltage is 125 volts and the plate-supply voltage is $125 + 21 = 146$ volts. All the solid-line curves were obtained by proceeding in this manner.

The solid-line curves are different from the dashed-line curves in two respects: (1) the solid line curves are more horizontal than the dashed-line curves, which shows that the use of an unby-passed cathode resistor has the effect of increasing the internal plate resistance of a tube; (2) the solid-line curves are spaced more uniformly than the dashed-line curves, which indicates lower distortion. These new curves also shown that the gain of the stage is decreased and that the proper value of load $(R_L + R_c)$ does not change when the cathode-resistor by-pass condenser is removed. A load line drawn through the knee of the solid-line curve represents the value of R_L. The proper value of bias resistor is the same with and without feedback. These curves are used in the same manner described for Fig. 3.

The value of the equivalent internal plate resistance of the tube with R_c unby-passed can be determined from Fig. 6. Suppose that the load is replaced by a zero-impedance generator developing a voltage e_p. With R_c by-passed and terminals 1 and 2 short-circuited, the plate current $i_p = e_p/r_p$, where r_p is the internal resistance of the tube under these conditions. When the by-pass condenser is removed from R_c, the alternating plate current is reduced to $i_p' = e_p/(r_p' + R_c)$, where r_p' is the value of the internal resistance of the tube when R_c is unby-passed; the alternating voltage across R_c is $i_p' R_c$. The decrease in plate current due to grid action is $i_p' R_c g_m$, where g_m is the mutual conductance of the tube. When the decrease in plate current due to grid action is subtracted from the plate current with R_c by-passed, the following relation between r_p' and r_p is obtained.

$$\frac{e_p}{r_p} - i_p' R_c g_m = \frac{e_p}{r_p' + R_c}$$

and

$$r_p' = r_p (1 + R_c g_m) - R_c$$

The increase in plate resistance of the tube with this type of feedback means less damping of the speaker by the tube. Transients, especially those due to very rapid changes in applied signal, persist for longer periods of time and may be disagreeable to a listener. This circuit does not improve the frequency characteristic of an amplifier, because the value of n depends on the reflected impedance of the speaker. It does not stabilize the voltage across the voice coil, because the feedback voltage depends on the value of load reflected to the primary of the output transformer. However, the removal of the by-pass condenser will not cause the amplifier to oscillate; hence, cathode-resistor by-pass condensers can be removed from several stages with consequent improvement in stability and decrease in distortion. Because of the higher effective plate resistance of the tube, less filtering is required in the plate circuit for a given hum level.

Thanks are due to O. Schade and F. H. Shepard, Jr., for their suggestions and criticisms, and to C. Dodd for his measurements on transient response, shown in Fig. 4.

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FILTER DESIGN

(*Continued from page* 12)

before and after impedance transformation. Before impedance transformation the spread in element values is over three hundred to one. Afterwards it is about the square root of this value. This is quite representative of the improvement that can be obtained.

The development of improved methods of shielding filter elements has been a great help in the design of filters at high frequencies.[5] By proper shielding it is possible to concentrate the stray capacitances between the elements of the filter and between the elements and ground so that these capacitances are localized where they are called for in the filter schematic. This enables smaller capacitances to be used in the filters than otherwise possible. This shielding also eliminates mutual coupling between the inductances. Fig. 6 illustrates the manner in which this shielding is applied. The capacitances indicated by the dotted lines are those between the inner and outer shields. It will be noticed that these are localized where capacitances are required by the filter. This is the same filter as that referred to in Fig. 5.

[5]See Patent 1985042 by C. E. Lane.

DIELECTRIC PAPER

AND ITS APPLICATION TO CAPACITORS

by William M. Bailey

Chief Engineer, Industrial Capacitor Div., Cornell-Dubilier Corp.

CONDENSER TISSUE can be broken into two main subdivisions; namely, Linen and Kraft. The former, being white, is made from linen rag stock, while the latter is produced by breaking down chips of spruce, giving it a brown color. However, this article will treat the two kinds as one, with few exceptions.

In general, the following embryonic description holds for the production of paper from pulp. In the digesters, the rag or wood chips are broken down, usually by the action of sodium hydroxide, into tiny fibres as grown in nature. The pulp is "beaten" by rotating knives. In this process the fibres are cut, shredded, fibrillated or hydrated. The next step thoroughly washes it in as pure water as possible in order to remove all alkalies and make the paper chemically neutral. The pulp is then centrifuged to remove foreign particles.

It is now ready to start on its way through the paper-making machine, first being placed on fine wire screens where it is shaken to felt it down and remove the water. The felted pulp is then further dried by vacuum and pressed on couch rolls, finally going through the calender rolls, where it is squeezed to the thickness desired. After leaving the calender rolls it is wound as paper on 30" diameter jumbo rolls 26 to 88 inches wide; later to be split down into commercial widths for capacitor windings.

The structure of the paper (Fig. 1) is made up of approximately sixty-five percent fibrous material, about 30 percent air and 5 percent moisture. The micro-graph shows complete and partial fibres as well as fibrous filling.

The thickness to which the paper is calendered varies depending upon the capacitor design, but extremes of 0.00025" to 0.002" have been used. The most common sizes are 0.0003" to 0.0006".

It is obvious that with 0.0003" paper, the maximum thickness of a foreign particle cannot exceed this dimension. Now if these happen to be conducting particles, they will actually present a short circuit through the paper at these points. These defects, however, are reduced to a minimum by the excellent centrifuging processes, mentioned earlier, which have been developed and used by most of the suppliers making condenser tissue. This process eliminates by centrifugal separation most of the heavy particles which formerly contaminated the paper. Some of the particles are mineral in nature—others are carbonaceous or metallic, but being heavier than the pulp and water mixture, are for the most part rejected. With paper as thin as 0.0003" it is more difficult to eliminate these particles than it would be with 0.0005" paper where small particles may lie buried under the surface. The elimination of particles is so complete today that sometimes in testing a specimen no indication is found in a strip of 0.0004" paper 1 inch wide by 20 feet in length.

To overcome the above condition, which nevertheless does exist, multiple layers of paper must be used. This construction then of course builds an extra factor of safety into the capacitor, providing it with a voltage breakdown well above its rating. This reserve cannot be fully utilized except for comparatively high transient voltage peaks due to paper variations and deterioration; the latter is caused principally by the entrance of moisture during the life of the capacitor when not hermetically sealed. It is almost impossible to expect every area of paper to be 100 percent perfect; however, this is more nearly approached by the use of multiple sheets. The law of averages then actually works. For instance, if it were found that out of one hundred 0.1 mf sections tested at 2000 volts, two sections broke down, we would then expect each 10 mf section made in a similar way to break down at the same voltage as it virtually consists of one hundred 0.1 mf areas continuously connected. This is precisely what does happen.

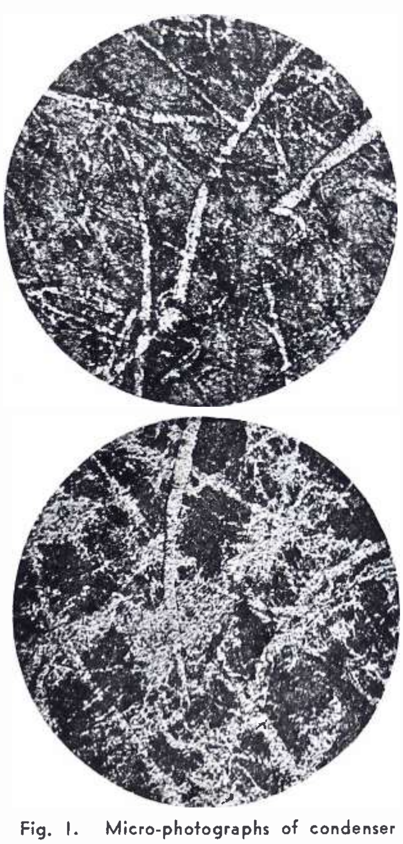


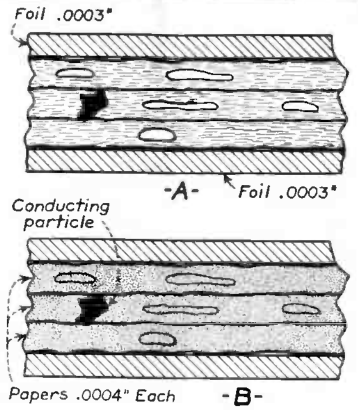
Fig. 1. Micro-photographs of condenser paper.

To avoid this high mortality, in shop practice, the 10 mf capacitor would be subdivided into five 2 mf sections connected in parallel, as well as having the test voltage and rating somewhat lowered. This of course greatly reduces the wastage of material. For the paper to properly perform its function in the ordinary type of capacitor, it must be thoroughly dried and vacuum impregnated with a wax or oil. Its purpose is then to act as a spacer and barrier which is more or less porous. The porosity, as we have noted before, is caused by the interlacing of all the cellulose fibres. When these interstices and fibrous tubes are completely impregnated, the base paper forms a barrier spacer which is considerably better in its voltage characteristic than would be found if it were possible to fill the space between the electrodes with wax or oil only. In the case of wax, the presence of the paper barrier also prevents the formation of long crystals. With either impregnation, the barrier is of great aid in preventing puncture by voltage, and provides a mechanical support and accurate spacer of the foils to be compressed or left in the round form as the type of capacitor dictates.

In this composite dielectric, it will be noted that the paper itself forms only a part thereof; but to further enlarge upon the importance of the paper barrier to voltage puncture, the following is pertinent: A 100-mil gap in oil will withstand a potential of 40,000 volts before breaking down. If this gap is reduced to only 10 mils of oil impregnated paper, puncture values of 60,000 volts or 50 percent higher can be obtained with only 10 percent of the original gap idstance. This represents a gain of 15 times over oil alone in voltage stress per mil. With 0.001″ or 0.002″ paper, this gain in voltage puncture is in the same order of magnitude. No attempt will be made here to describe the various types and windings of the paper capacitor except to mention the fact that aluminum or tin foil are almost universally used as electrodes in conjunction with the dielectric. The foil is only 0.00025″ or 0.0003″ thick, thereby representing a small percentage by volume in the total section.

High quality condensers can be made by using the greatest number of paper laminations per dielectric consistent with cost limitations. The following ruling may be used; total thickness of dielectric in inches divided by four equals paper thickness (the nearest standard thickness should be used). If the thickness of the paper from the above is found to be less than 0.0003″, then divide the total thickness of the dielectric by 0.0003″ to obtain the proper number of papers for the laminated dielectric. The total dielectric thickness used is rarely under 0.0008″ or 0.0009″, thus indicating the use of two 0.0004″ or three 0.0003″ papers.

It is difficult to state any definite operating voltage stress per mil for the paper dielectric, as this depends on the impregnating material as well as working conditions. Some of the variables found in practice are ambient temperature, transient peak potentials, humidity and duration of service. The working stress on well processed sections lies between the range of 200 to 400 volts dc per mil with wax impregnation and 600 to 1200 volts dc per mil with oil impregnation. As there is a wide variety of waxes and oils in use today, a proper choice must be made depending on the condition and allowable loading.



A - Enlarged cross section of paper foil unit not impregnated

B - Enlarged cross section of same unit impregnated Irregular shaped areas represent end section of tubular fibres.

Fig. 4

The paper must be of more than ordinary quality to withstand these stresses. In order to determine its many characteristics, tests are used for porosity, tensile strength, effect on heating, conducting particles, ash content, acidity or alkalinity, general appearance and mechanical considerations such as yield, thickness, size of roll, width, mandrel, etc. To discuss a few of these, the porosity, for instance, is usually checked by an Emil Greiner Porosity Tester, Fig. 2, in which a single sheet of paper is placed in position and clamped air-tight around its edge. Then by lowering the water reservoir to a predetermined level, an air suction is produced through the paper which acts as a porous diaphragm. The change in height of water in the glass column registers the amount of air passing through the paper. This column is graduated in cubic centimeters. The volume recorded in 15 seconds is taken as the quality factor. In general, the lower this figure, the higher is the grade. Paper 0.0003″ thick has an average figure of 3, whereas 0.0005″ paper runs about 1. The Kraft paper is usually slightly more porous than linen paper in this test. Tensile strength is checked by simply weighting a strip of paper at a definite rate until failure is reached and calculating against the cross sectional area involved.

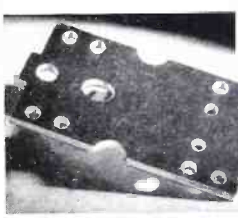
The effect of heating brings into play the strength of the paper during and after impregnation where relatively high temperatures are encountered. Kraft or linen paper should not be greatly weakened by a four-hour exposure at 210° F or 250° F, otherwise the mechanical strains set up by clamping and voltage stress may cause a rupture of the dielectric with consequent failure.

The conducting particle test is made by running the papers between two brass rolls, Fig. 3. A phone is connected in series with a resistor and 90-volt battery across the rolls; thus any conducting material buried in the paper, and sufficiently large to contact both rolls, causes a sharp click in the phones. One roll is 12 inches in circumference and the other 1 inch wide. Therefore twelve turns of the large roll equals one square foot of coverage.

(*Continued on page* 35)

Fig. 2 (left). The porosity test.
Fig. 3 (below). Conducting-particle test.

SOMEONE "PULLED A BOX"



It's a fire! A signal—an eye winks—a relayed signal—answering men spring out like jacks-in-boxes—coat-tails flying, before a gong dies—sirens scare a path through traffic—hose unbends—swells—there's water! . . . And only a moment ago, pale fingers "pulled a box" . . . The efficiency of water for fires depends upon the speed with which it can be rushed into action. Such speed requires perfect performance from a chain of electrical apparatus. SYNTHANE laminated bakelite contributes to the dependability of emergency fire-fighting equipment. SYNTHANE is used in fire-alarm telegraph systems, automatic controls for booster pumps and on motors, primarily because of its low moisture absorption, high dielectric strength and machineability. SYNTHANE laminated bakelite is a uniformly dense, solid material possessing a combination of desirable physical and electrical characteristics. It is tough, strong and light in weight; one of the most effective dielectric materials; chemically inert and corrosion resistant and easy to machine.

The uses for SYNTHANE are legion. Just as SYNTHANE is a material aid to fire-fighting, so its use may make a *material* difference in the reliability of your product. Write for "Synthane laminated bakelite for Mechanical Applications". (Please note on your request an indication of your requirements.) . . . SYNTHANE gives you MATERIAL SATISFACTION.

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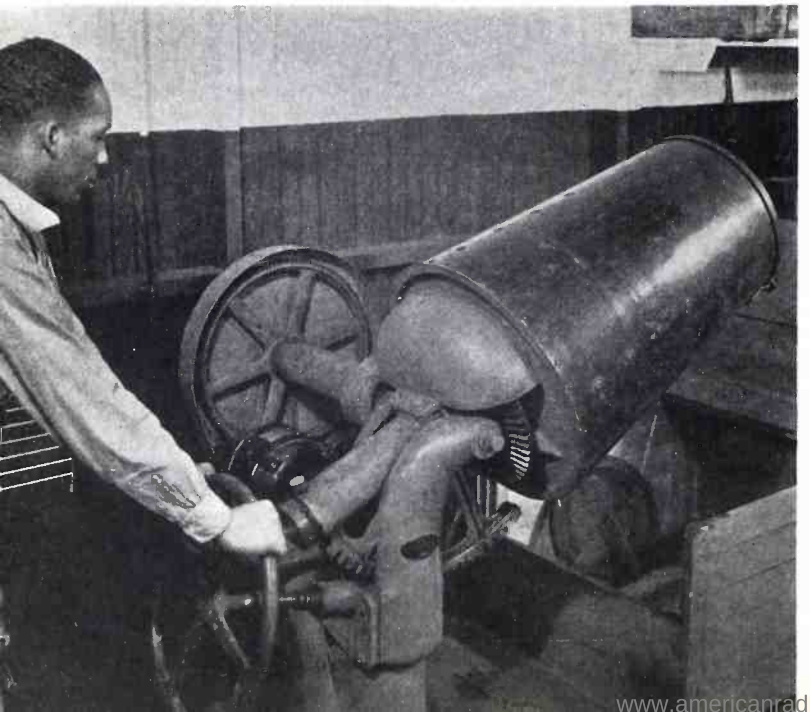
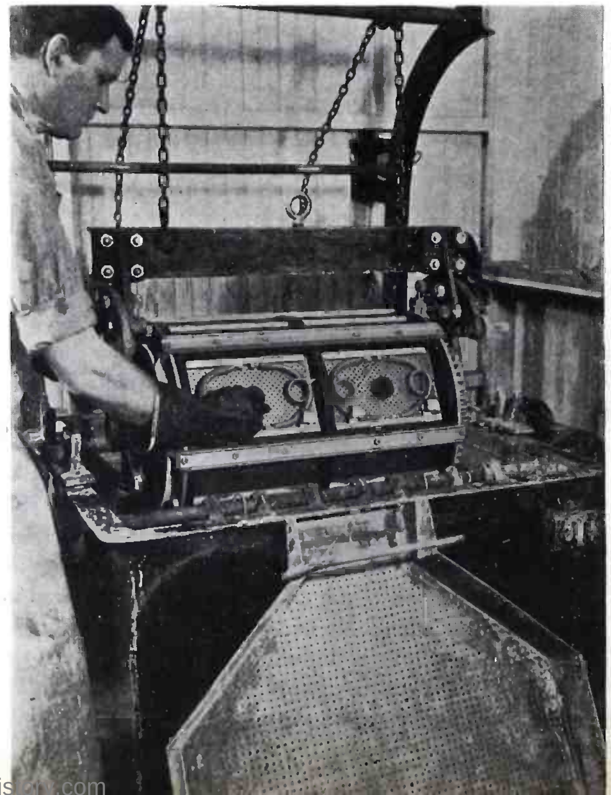
CONDENSER

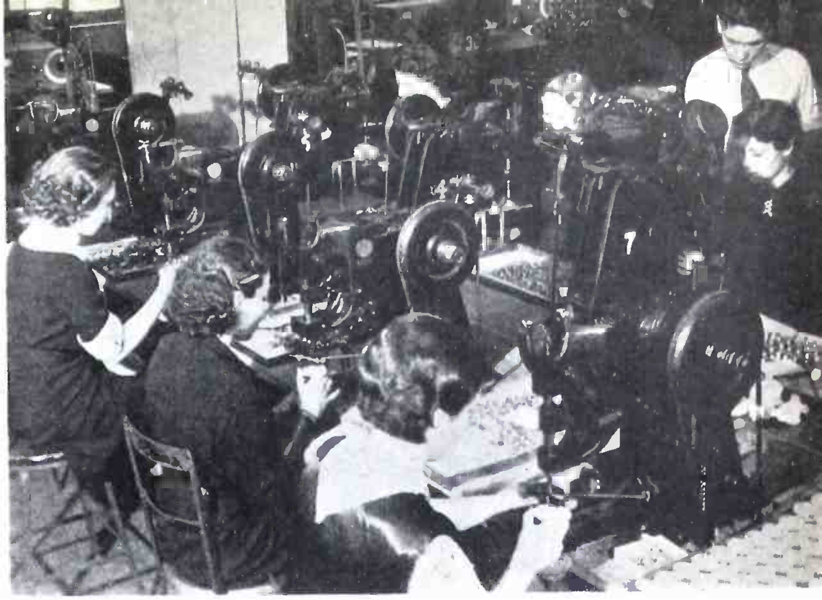
General view of condenser laboratories, showing chemical and electrical equipment. Large numbers of absorption tests are made on insulating materials.

Special instruments and especially trained operators are used to gauge the thickness of mica sheets (right). The tumbling barrel (below, left) insures that all burrs are removed from the edges of the condenser plates, after which the plates and other metal parts are thoroughly cleaned and degreased. Then all metal parts receive a plating of cadmium in the tank shown (below, right).

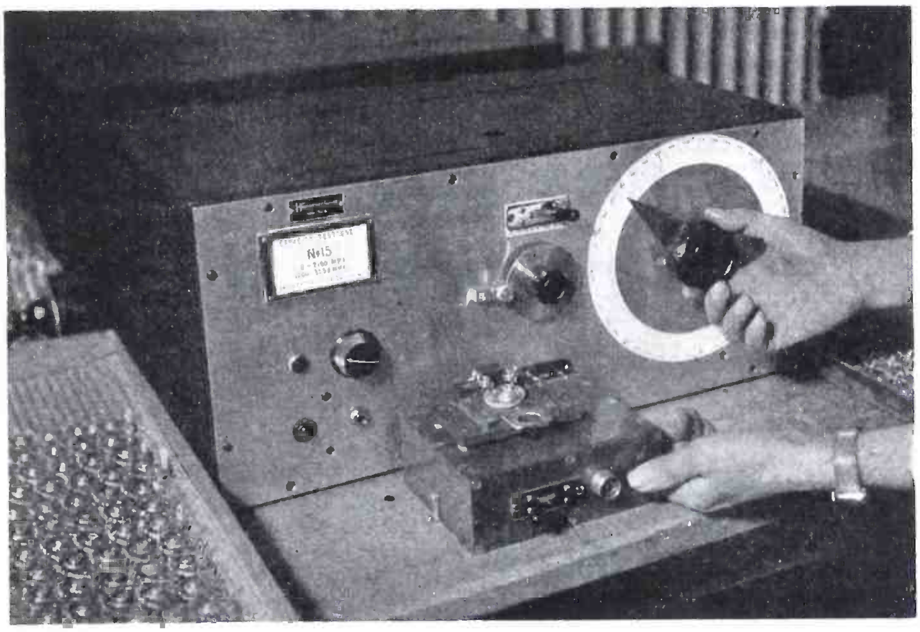




MANUFACTURE

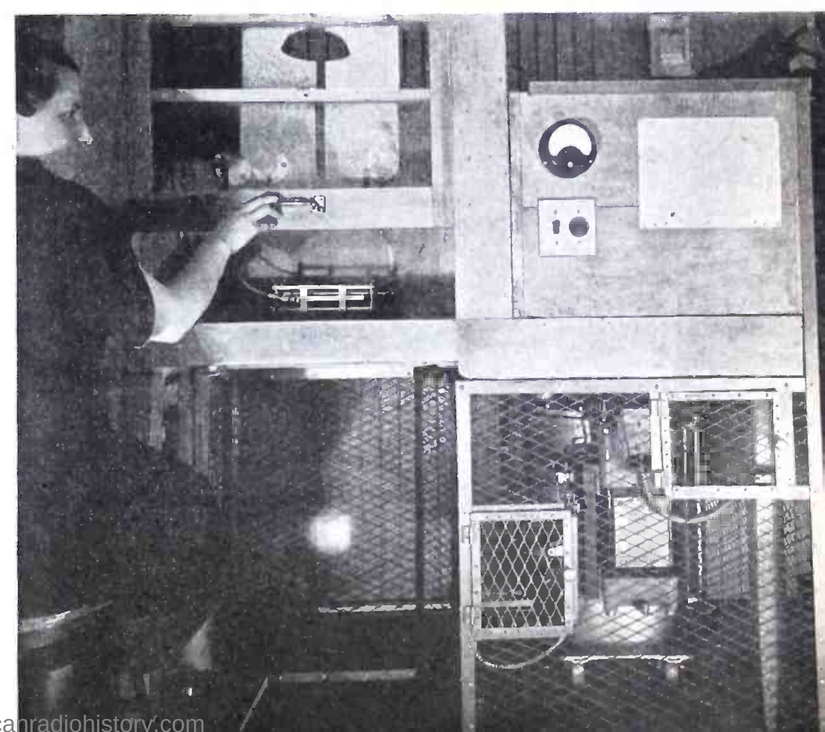


Extreme care must be taken to seat the eyelets in the Isolantite bases of trimmer condensers. These machines both insert and stake the eyelets.



Trimmer condensers are checked on a specially-designed oscillator (left) which enables the operator to test trimmers over the range from 0 to 3050 mmfd. Plates for variable condensers are hand assembled in jigs (below, left) and soldered while being held rigidly in place. All receiving and transmitting condensers receive a breakdown test in the equipment shown (below, right). Voltages up to 30,000 are available.

(Photos made in the plant of the Hammarlund Mfg. Co., Inc.)



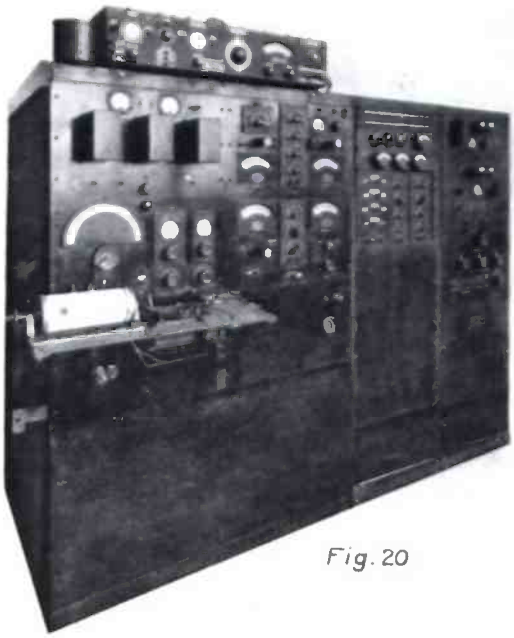


Fig. 20

With this, the third article of the series, we conclude a comprehensive resume of current practice in loudspeaker measurements. It is interesting to note the comment to the effect that a listening test is the final criterion of performance; yet, the laboratory measurements are an essential prerequisite.

EQUIPMENT AND METHODS USED IN ROUTINE MEASUREMENTS OF LOUDSPEAKER RESPONSE

by S. V. Perry *

THE EQUIPMENT described last month is used for close-up measurements of response of loudspeaker units of the type usually employed in present-day radio receivers and phonographs and similar reproducing equipment. For large reproducers and for overall measurements on complete radio receivers in cabinets an entirely different set-up is employed.

Fig. 20 shows the arrangement of the equipment at the operating position. It utilizes a beat-frequency oscillator having about five watts output from push-pull Class A type 250 tubes. The frequency scale, as normally used, fits commercial 30 to 10000 cycle logarithmic paper. For high-fidelity development work, a special scale approximately logarithmic from 20 to 20000 cycles is available by throwing a single switch. Semi-automatic curve drawing equipment is provided as shown in the photograph. By means of switches provided on the control board, the output of the oscillator may either be connected to cables feeding directly into the sound room for measurements of loudspeaker response or may be connected as a source of modulation for the signal generator.

The signal generator normally used covers the broadcast band. For short-wave work a portable RCA Victor type TMV-18 is used. The output is fed through a shielded cable to a dummy antenna at the receiver position in the sound room.

The microphone amplifier is compensated for the free

*RCA Manufacturing Co., Camden, N. J.

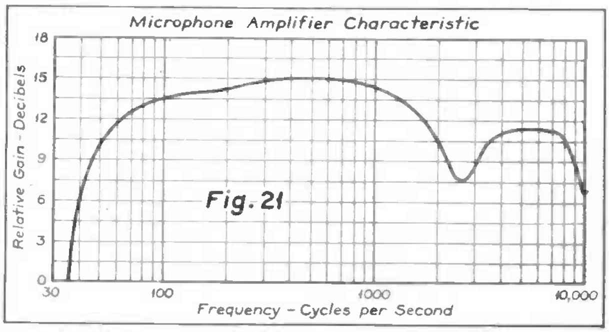


Fig. 21

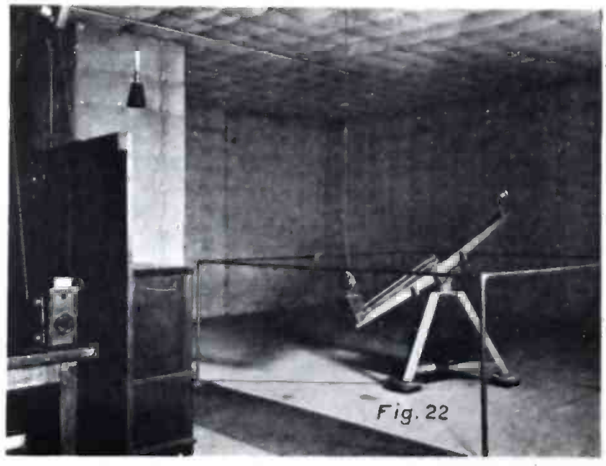


Fig. 22

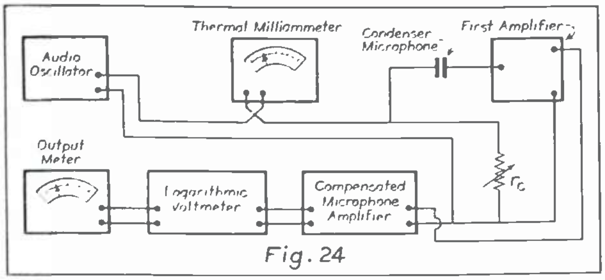


Fig. 24

wave characteristic of the microphone, averaged over the path of the microphone motion. The amplifier characteristic is as given in Fig. 21. A high-pass filter cutting off at about 35 cycles is incorporated in this amplifier to eliminate the effects of vibrations from certain rotating machinery in the building.

The output meter is a logarithmic voltmeter covering the 40-db range from 2 volts to 20 millivolts and not deviating very seriously from a true logarithmic curve for 10 db on either side of this range. The scale of ordinates is continuously adjustable and ordinarily a scale of about 4 db per inch is used.

The panel at the extreme right of Fig. 20 is a Western Electric type 6010-B direct audio oscillator of good frequency stability. It is used for frequency calibration and certain high-frequency development work where its 50 kc range is useful.

For the measurement of overall acoustic fidelity of complete radio receivers and for similar acoustic measurements on large reproducers, the close-up arrangement of microphone is not satisfactory. This is because the sound field close to a large reproducer differs considerably from the average sound field at some distance away, so that close-up curves usually give misleading results. In order to get useful data in these cases it is necessary to make measurements at a considerable distance. This necessitates the incorporation in the equipment of some suitable method of eliminating the effects of reflections from the curves in order that they may be of maximum usefulness. The method used in this equipment is to move the microphone over a certain path in space and to average out the output variations around this path by electrical means in the output meter circuit.

The microphone arrangement is shown in Fig. 22, looking approximately in the direction in which the receiver faces during the test. It is a condenser type and is mounted in a shielding screen directly over the first amplifier stage which in turn is connected to the remaining stages through the cable shown. The microphone orbit is a circle about six feet in diameter having its center about 54 inches from the floor, and about ten feet from the receiver. The axis of rotation is tipped at an angle of about 30 degrees from the vertical toward the receiver. Two eccentric cranks and connecting rods operate to keep the microphone facing in the same direction as it rotates around its axis. It may be shown that this arrangement of microphone orbit will considerably reduce the effects of all room reflections except those from the floor directly in front of the receiver. These remaining reflections undoubtedly produce some irregularities in the curves in the region below two thousand or three thousand cycles, but have not caused any errors in our interpretation of these curves to the best of our knowledge.

The sound room in which this microphone is located is 40 x 32 x 11 feet high, using double walls of Gypsum block, padded inside with Balsam wool. The floor is floated on several inches of sawdust to reduce mechanical vibration. The receiver under test is faced in a direction parallel to the longest side and about fifteen feet from one end of the room. A typical receiver set up for test is shown in Fig. 23. Directly behind it, at a distance of two inches from the back of the receiver, is located a back wall panel of wood, six feet square by one inch thick. The purpose of this back wall is to complete the acoustic system of the receiver, since most receivers are normally used with their back surfaces parallel to, and spaced about two inches from a wall and since the performance of most receivers under this condition is considerably different from their performance when placed at much greater distances from the wall.

The loudspeaker shown suspended from the ceiling is a "standard" for checking the equipment. The meter is a remote frequency indicator direct reading in frequency from 30 to 10000 cycles, with an approximately logarithmic scale. Selsyn motor control of the oscillator frequency is provided at this point.

The operating procedure used with this equipment is as follows:

(a) The receiver is set up two inches from the back wall with the specified supply voltage applied, antenna and ground leads connected and voltmeter leads connected to the voice coil.

(b) The control switches are set to produce the circuit shown in Fig. 24, with the polarizing voltage removed from the microphone. The output of the oscillator is adjusted to one milliampere at 400 cycles, and the calibrating resistor adjusted to a value given by the equation

$$r_c = \frac{p\,m}{i}$$

in which

p is the desired reference pressure.
m is the microphone constant in volts per bar.
i is the current in amperes.

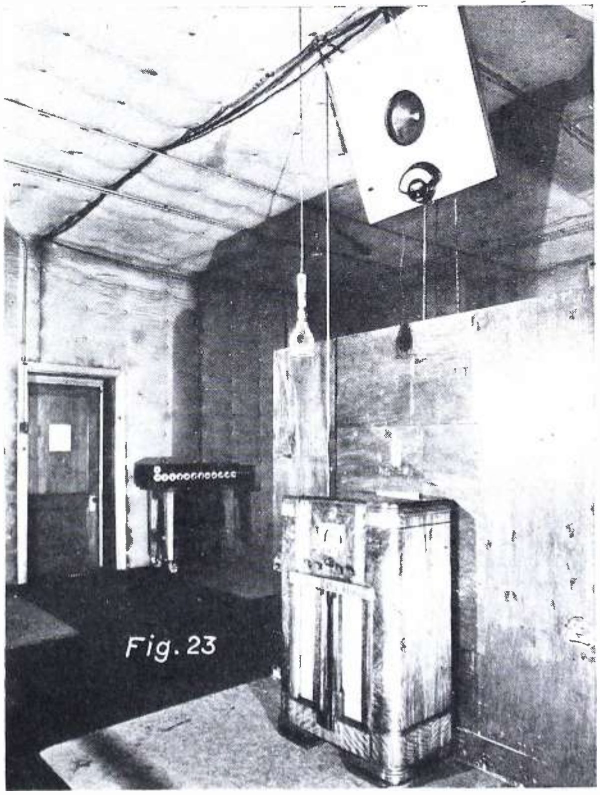


Fig. 23

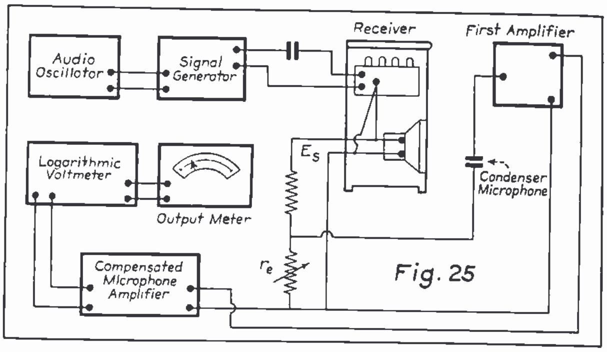


Fig. 25

For ordinary work

p = 2 bars

m = 1.2×10^{-3} volts at 400 cycles

whence r = 2.4 ohms.

With this adjustment the gain of the microphone amplifier and the level control of the logarithmic voltmeter are adjusted so that the reference pressure mark comes at the desired position on the page (usually near the center).

(c) The output of the oscillator is now switched over to the signal generator and the modulation depth adjusted to 30 percent and the carrier level to 10000 microvolts. The voltmeter leads from the voice coil are connected to the calibrating resistor through another fixed resistor of such value that the total resistance in this circuit is one thousand ohms. This produces the circuit shown in Fig. 25. By means of its own tuning control the receiver is now tuned to produce maximum output at 400 cycles. The modulation frequency is now changed to some high frequency above the point where the fidelity curve starts to cut off, and the carrier frequency is shifted to such a position that minimum response is produced. The entire procedure for tuning for minimum high-frequency response is somewhat complicated and cannot be described in detail here.

(d) The next operation is to adjust the volume control of the receiver to produce the desired output level. By experimental test with a receiver having a good avc system and a calibrated volume control, we first determined a sound level known to us as "normal room volume," which represents about the average volume normally used for listening purposes in the average home. Laboratory measurements on this same receiver indicated this level to be about 1.5 bars sound pressure averaged over the region from 400 to 2000 cycles. With normal present-day loudspeakers this requires from 0.1 to 0.3 volt-amperes in the voice coil. If the receiver to be tested is of completely unknown acoustic characteristics, it may be necessary to make a trial curve in order to determine the correct volume control adjustment.

The voltage on the voice coil is measured by means of the circuit of Fig. 25. In operation (b) this voltage measuring circuit was accurately calibrated at 2.4 millivolts, 400 cycles. Hence, if now the calibrating resistor is adjusted to some new value r_e so that the output meter deflection is the same as it was in operation (b), the voltage on this resistor will again be 2.4 millivolts and the voltage on the voice coil will be $\frac{1000}{r_e} \times 2.4$ millivolts, or more generally the voltage on the voice coil will be

$$E_s = \frac{r_c}{r_e} \text{ volts}$$

in which r_c is the value of the calibrating resistor during operation (b) and r_e is the value of the calibrating resistor during operation (d). The procedure of adjusting the receiver volume control to produce the correct sound level is very necessary on the majority of present-day receivers, in which the audio system is so designed that the shape of the electrical and acoustic fidelity characteristics is dependent on the volume control adjustment. In receivers which do not have this design feature this procedure is not as necessary, but it is our practice for the sake of standardization and to facilitate comparisons to make all measurements at approximately the same sound level, unless special circumstances warrant deviation from this procedure.

(e) The switches are now adjusted to produce the circuit of Fig. 26; the potentiometer which now appears across the voice coil is adjusted by trial to such value that the curve will not go off the page, and the electric fidelity curve is drawn.

(f) The circuit of Fig. 25 is now re-established, the voice coil voltage measuring line is opened and polarizing voltage is applied to the microphone. The sound pressure curve or overall acoustic fidelity characteristic is now drawn, usually requiring about 6 minutes time. During this time the microphone is rotated at about 25 rpm and the output meter is heavily damped with a capacity shunt of 8000 mfd across 1000 ohms to prevent excessive swinging due to room reflections as the microphone rotates around the orbit. Typical overall electric and acoustic fidelity characteristics on a modern console receiver are shown in Fig. 27.

(g) Overall electric and acoustic fidelity characteris-

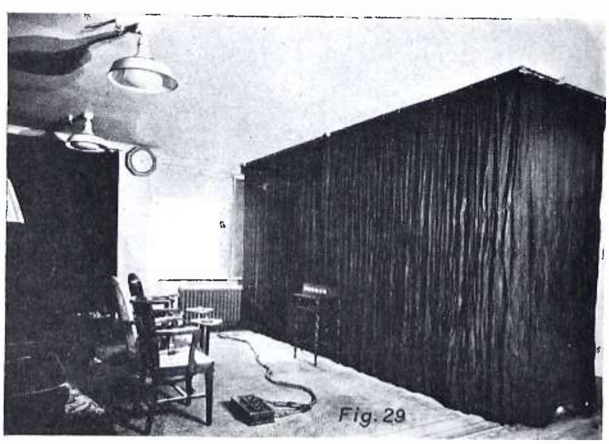


Fig. 29

Overall Electric and Acoustic Fidelity Characteristics of a Radio Receiver

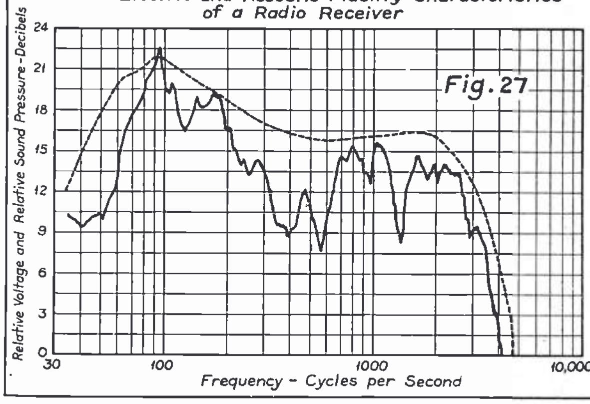


Fig. 27

tics on phonographs are drawn by the same apparatus and method, except that the oscillator and signal generator are replaced by a phonograph record. Frequency alignment between the record and the paper is obtained by driving both the turntable and the recording drum by synchronous motors from the same power line. Distinctive signal tones are cut on the record every octave and are easily heard and may be marked on the curve by the operator while the curve is being drawn. The record is cut with the highest frequencies on the outside, so the recording drum is driven backwards from the usual direction. RCA Victor Record No. 84505-B is used for setting levels at 400 cycles and RCA Victor Record No. 84522-A is used for drawing the frequency characteristics. This latter record has been especially cut for this purpose using the same frequency characteristic as was used in the production of commercial records at the time it was made. These records as well as a number of other technical purpose records are available to laboratories requiring them. Typical overall electric and acoustic fidelity curves of a phonograph are shown in Fig. 28.

By the methods and equipment already described, graphical records can be made of the acoustic performance of loudspeaker units and of complete radio receivers. These graphical records are extremely useful during the development work on a new loudspeaker or receiver, since they show accurately the direction and the magnitude of the results produced by any particular change which may be made in the design. However, we do not recommend that the shapes of these curves be used as the sole indices of performance of the devices to which they pertain. The final test of any loudspeaker or acoustic reproducing system is the listening test, which is always made by the ultimate user, whether or not it is made by the development engineer. For this reason we do not attempt to determine the relative excellence of two acoustic systems solely from the shapes of their response curves. The interpretation of the shape of the curves is made only as the result of experience gained in listening to a very large number of receivers, on each of which the response curves were available. Whenever an important development project is nearing completion, and whenever an important comparison is to be made between two acoustic reproducing systems, the final test is always a listening test.

For this purpose a listening room is available, as shown in Fig. 29. This room is about 17 feet from back to front, about 25 feet wide and 9 feet high, enclosing a volume of about 3800 cubic feet. The major portion of the floor is carpeted, hanging drapes cover parts of the walls and the furniture consists of an assortment of hard chairs as well as overstuffed chairs and davenport. The

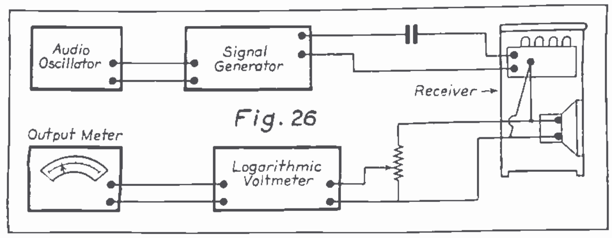


Fig. 26

acoustic conditions in this room are probably well within the range of variation found in living rooms. The receivers which are being compared are hidden from view by the curtains shown in the photograph and identification is made by means of lighted numbers operated synchronously with the switching system. For less important tests, the curtains are not used, and the set-up is then as shown in Fig. 30.

While important final tests and demonstrations are always made in the demonstration room, the experience gained over a period of years in predicting the performance of acoustic reproducing systems from the shapes of their response characteristics has resulted in greatly cutting down the time spent in the listening room. About five years ago when the overall response measuring set-up was first put into operation, the development work on a radio receiver consisted chiefly of making a change in the laboratory and then holding a listening test at which from 5 to 50 people would express their opinion regarding the improvement produced. This process would be continued until the desired performance was obtained, or the allotted development time had elapsed. Now the desired response is obtained purely by laboratory measurements and a final listening test and demonstration is held as a confirmation of these measurements. The improvement in efficiency is obvious, and the results speak for themselves for it is in the last four or five years since this equipment has been in use, and since equipment similar to it has been in use in other laboratories in the radio industry, that the major improvements in overall acoustic fidelity of radio receivers have been made.

The two sound measuring equipments which have been described in these articles are used in the development of radio receivers and of loudspeakers for use in them. For general research work, for development of theatre and auditorium and other reproducers, for microphone development, and for certain production testing, other sound measuring set-ups are available. Each of these differ in some details from those described, but in the fundamental principles of their operation they are all the same.

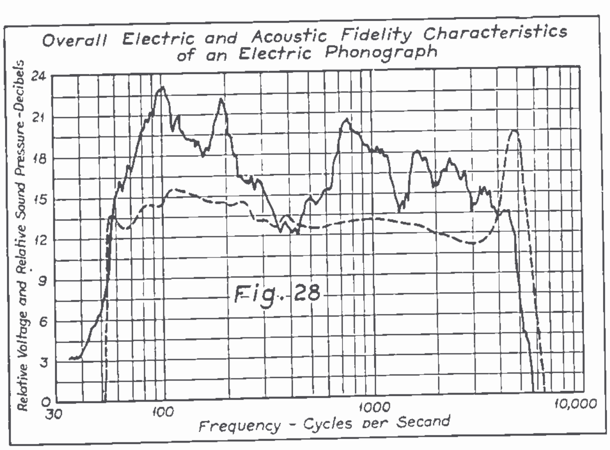


Fig. 28

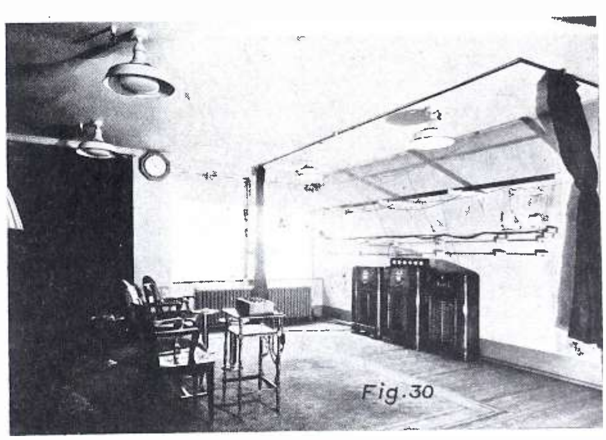


Fig. 30

SIMPLIFIED DIELECTRIC LOSS MEASUREMENTS

by A. W. Barber

Consulting Engineer

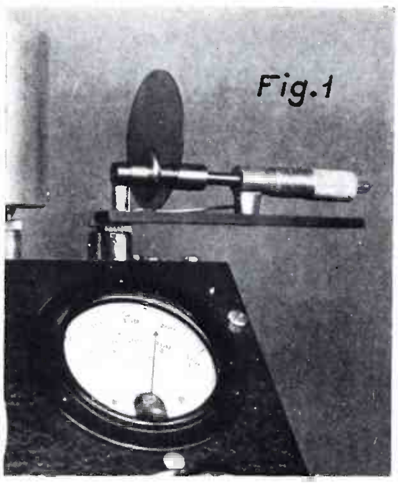


Fig. 1

THE CHOICE of suitable electrodes is one of the most important problems encountered in the accurate measurement of dielectric constant and losses. Means for rapidly changing samples is desirable if the accuracy of measurement is not impaired. Foil electrodes have been widely used, but they require time and care in their application and in other ways are not ideal. The following description deals with a simplified electrode arrangement suitable for rapid and accurate measurement of dielectric constant and losses of solid materials.

Briefly, the device to be described consists of a pair of circular plane electrodes with accurately ground parallel surfaces. One electrode is fixed and the other is movably mounted on a calibrated micrometer thread. Solid dielectrics up to one-half inch in thickness may be measured with the device.

Investigators seem to agree that the most satisfactory method of measuring dielectric loss at radio frequencies is by measuring the effect of a capacity formed through a dielectric sample on the losses of a parallel tuned circuit. At least one standards report recommends voltage rather than current measurements at frequencies of 5 megacycles or over. The measurement of dielectric losses to an absolute accuracy of a few percent would appear to be satisfactory when it is remembered that the object usually is to compare materials having widely different losses, and that samples of the same material often show considerable variation. With these things in mind, a Q meter was chosen for this investigation. This meter, by means of a vacuum-tube voltmeter across a circuit and a known current through a known resistance in series with the circuit measures Q, by measuring the gain in the circuit, to a rated absolute accuracy of ± 5 percent. Observational errors were found to be of the order of 1 or 2 percent when making comparative measurements of Q above 100. Fig. 1 shows a mica sample loss measurement being made.

Electrodes suitable for dielectric measurements must be so arranged that if the capacity between their surfaces in air is C the capacity becomes kC when material having a dielectric constant k is interposed between them. In order to accomplish this, the capacity C between the surfaces of the electrodes must be accurately known and air must,

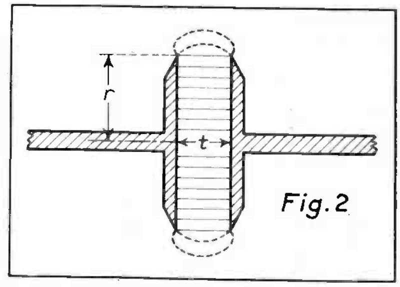


Fig. 2

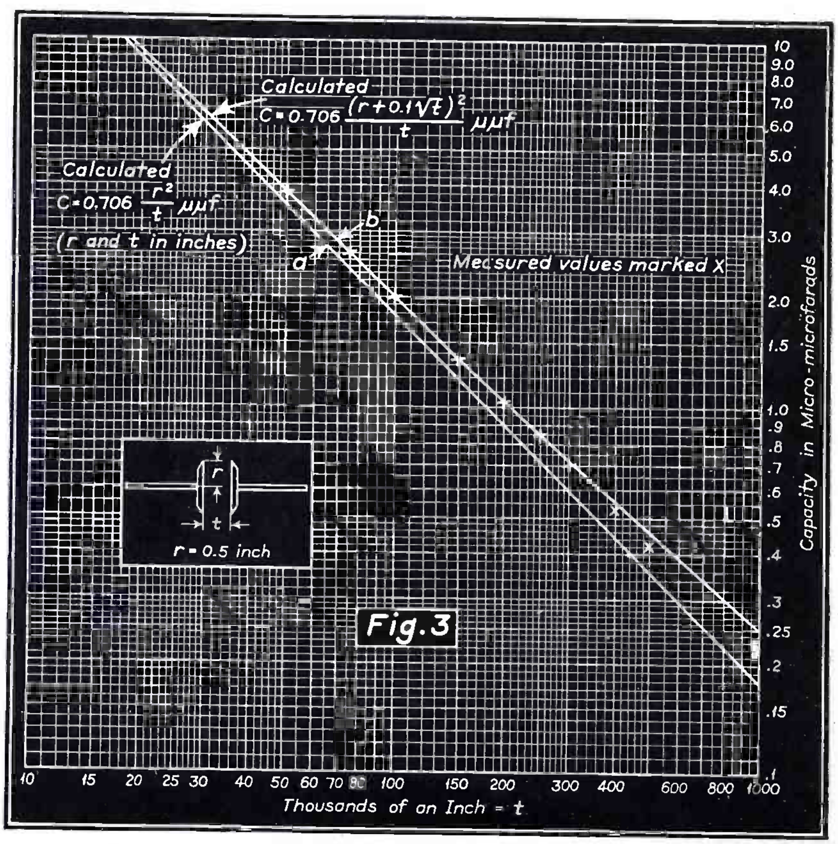
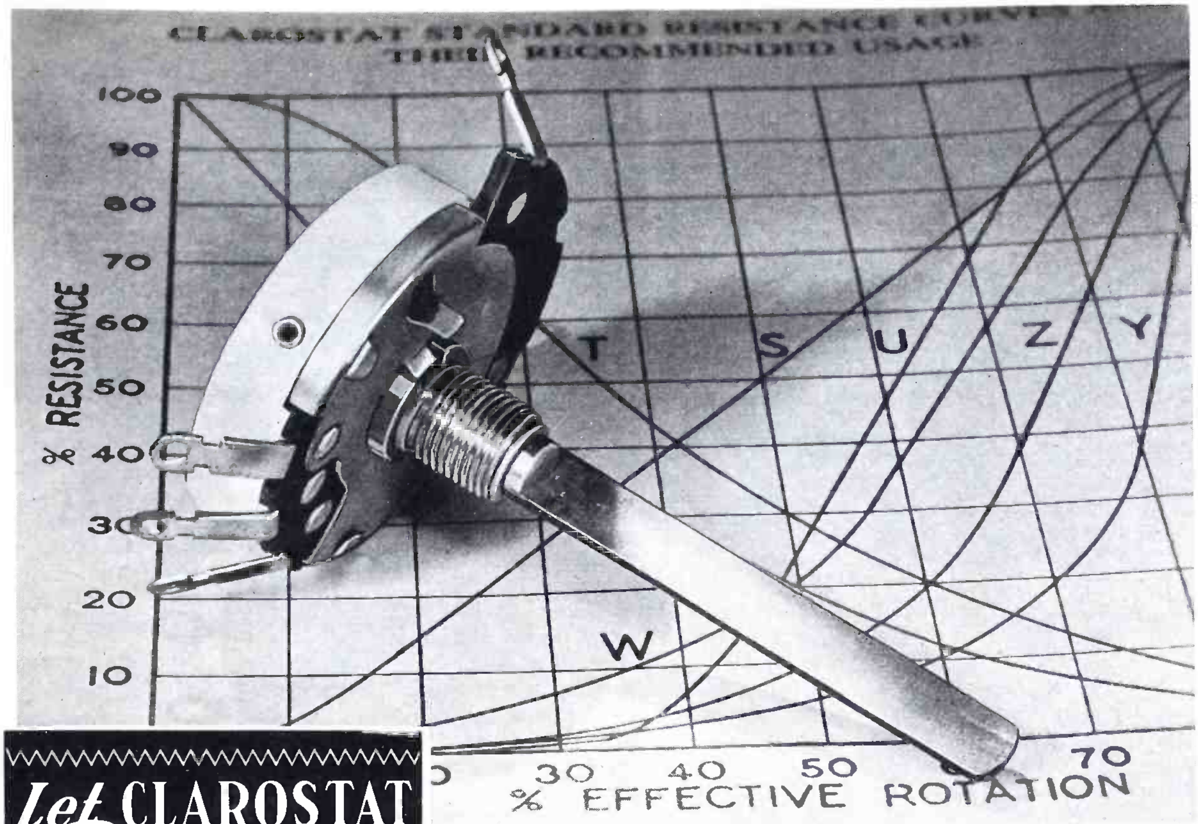


Fig. 3



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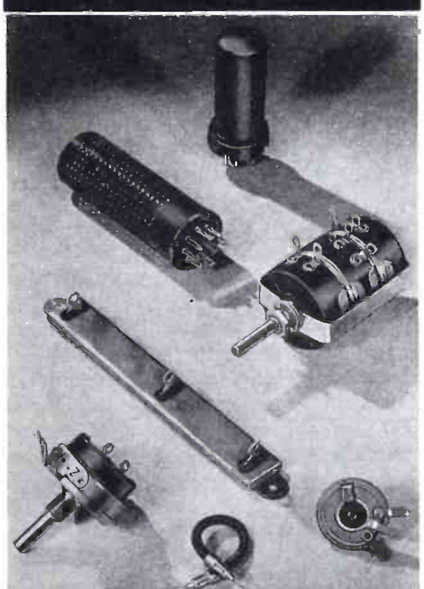

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Fig.4

as far as possible, be excluded from between the electrodes and the dielectric sample.

Neglecting edge or fringe effects the capacity between two circular plane electrodes parallel to each other in air and separated by a distance t is,

$C = 0.0885 \quad A/t$ micro-microfarads

where A is the area of one electrode in square centimeters and t is in centimeters. Since the electrodes are circular their capacity in terms of radius r of either is,

$C = 0.278 \quad r^2/t$ micro-microfarads

where r and t are expressed in centimeters or,

$C = 0.706 \quad r^2/t$ micro-microfarads

where r and t are expressed in inches.

The capacity expressed above is the capacity due to the parallel flux lines between the electrodes as shown by the solid lines in Fig. 2. There is in addition an edge or fringe field as shown by the dotted lines. This fringe field has been reduced in the present case by beveling the edges of the electrodes, as shown, but it is still necessary to evaluate it for accurate results. For instance, the 1-inch diameter electrodes used here had a 10 percent added capacity due to the fringe field at a separation of 0.1 inch.

Curve "a" of Fig. 3 shows the calculated capacity between the 1-inch diameter electrodes, due to the parallel flux in micro-microfarads, plotted against electrode separation in thousandths of an inch as determined by the above formula. It was found that the added capacity due to the fringe field was a function of the separation between the electrodes and could be accurately accounted for by an apparent increase in the radius of the electrodes equal to $0.1\sqrt{t}$. Thus the total capacity between the electrodes was expressable as,

$C = 0.706 \quad (r + 0.1\sqrt{t})^2/t$ micro-microfarads

where r and t are expressed in inches. Curve "b" of Fig. 3 is a plot of this corrected capacity against electrode separation t. The result was checked by careful measurement and the measured points marked "x" were found to agree with the calculated values to within 1 percent for electrode separations less than 0.3 inch. The micrometer scale on the movable electrode permits accurate and rapid setting of the electrodes to any desired separation.

It is important that the surfaces of the electrodes and the dielectric samples be accurately plane and parallel especially in the measurement of thin, high dielectric constant samples. The error introduced by a given air space between the electrodes and the sample is a function of the thickness of the sample and its dielectric constant, becoming greater as the sample decreases in thickness and increases in dielectric constant. The error appears as an error in determining kC and hence affects directly the determination of k and $Q = 1/RkC\omega$. If the air space has an average thickness d the apparent capacity through the sample will be low by a factor $t/t + kd$.

Fig. 4 shows the electrode set-up as developed in this investigation and Fig. 5 shows a piece of ¼-inch material included between the electrodes. The electrodes consist of brass plates 1/16 inch thick for stiffness turned to an accurate diameter of 1 inch. The edge is beveled at an angle of 30 degrees to the front surface and is carried to a fine edge.

A simple measurement technique consists in measuring the Q of a standard circuit with the above described micrometer condenser in parallel, with and without the dielectric sample under test included between the plates. If ΔC is the change in capacity which takes place when the dielectric sample is placed between the electrodes, C is the capacity between the electrodes in air at a separation equal to the sample thickness, C_1 is the total capacity required to resonate the standard circuit, Q_1 is the standard circuit Q without the sample in the circuit and Q_2 is the net circuit Q with the sample between the electrodes, the Q of the sample is,

$$Q_x = (\Delta C + C)\, Q_1 Q_2 / C_1 (Q_1 - Q_2)$$
$$= 1/R\,k\,C\,\omega$$

and the dielectric constant of the sample is,

$$k = \Delta C + C/C$$

Fig.6				
Sample Material A		Thickness 0.125"		
ΔC = 6.0 Mmfd.		C = 1.36 Mmfd.		K = 5.4
FREQUENCY	C_1	Q_1	Q_2	Q_x
0.5 Megacycles	395 Mmfd.	190	156	16.30
1.0 "	92 "	225	105	15.80
2.0 "	121 "	215	117.5	15.75
4.0 "	300 "	186	145	16.13
5.0 "	193 "	202	136	15.90
7.0 "	96 "	218	107	16.15
9.0 "	57 "	219	79	16.00
12.0 "	64 "	220	86	16.25

Average Q_x equal to 16.00
Average deviation equals 1.08 %
Maximum positive deviation equals 1.9 %
" negative " " 1.6 %

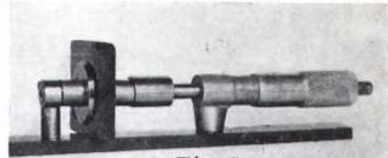


Fig.5

Since the electrodes are equipped with a micrometer scale any air space between them and the sample may be evaluated by taking the difference between the reading on the electrode scale and the average thickness of the sample as determined by measurement with a pair of standard micrometers. While samples should be as accurately plane as possible, it has been found that air spaces of one or two thousandths of an inch may be encountered. The effect of the air space may be corrected for by applying the equations below,

$$\text{true } k = \frac{\text{apparent } k}{1 - \dfrac{\Delta C\,d}{C\,t}}$$

$$\text{and true } Q_x = \text{apparent } Q_x \left(1 - \frac{\Delta C\,d}{C\,t}\right)$$

For example, a sample 0.1 inch thick having a k = 5, will show an error in measured k and Q_x of 4 percent due to an air space of one thousandth of an inch.

A check on the present electrode method was made by comparing measurements made with it to measurements made with carefully applied foil electrodes. A piece of material of a thickness of 0.066 of an inch and dielectric constant 6 checked to within 1 percent by the two methods after the above correction was applied for a one-thousandth inch air space. The measurement was made with the micrometer electrodes in a small fraction of the time required to prepare and measure with foil electrodes.

Fig. 6 shows a typical set of measurements made with the system which has been described. While the absolute accuracy of the measurements depends on the calibration of the Q meter the average and maximum deviations from average Q_x values are a measure of the accuracy of the observations and of the agreement between the various frequency ranges of the Q meter and the micrometer electrode arrangement. The average error of observation was about 1 percent and the maximum error was less than ± 2 percent.

The author wishes to express his appreciation to the engineers of the Boonton Radio Corporation for their suggestions and co-operation in this investigation.

NEWS OF THE INDUSTRY

MECK APPOINTED PRESIDENT OF ELECTRONIC DESIGN CORPORATION

The board of directors of this newly formed entry into the radio-electric field has just announced the appointment of John S. Meck as President and General Sales Manager. Factory and general offices are located at 164 North May Street, Chicago, Illinois, where their Vocagraph Sound Equipment line is now in production. Plans call for manufacturing and merchandising through regular jobber channels of a complete array of sound amplifiers and accessory equipment.

— RE —

JOHNSTON JOINS ARCTURUS SALES DIVISION

Wm. J. Johnston has recently joined the equipment sales division of the Arcturus Radio Tube Co., Newark, N. J. With headquarters at the company's branch office located at 1301 South Michigan Ave., in Chicago, Mr. Johnston will contact radio receiver and equipment manufacturers in the middle west.

— RE —

NEW CATALOG ON GRAPHIC METERS

The Esterline-Angus Company, Indianapolis, has just issued a new 88 page catalog describing its complete line of graphic instruments. The book illustrates seven types of instrument cases, twenty-one different chart drives and twenty-four kinds of meter elements. The publication is designated as Catalog 337.

— RE —

HYGRADE SYLVANIA MOVES LAMP SALES HEADQUARTERS

Lamp Sales Executive Headquarters of Hygrade Sylvania Corporation will be located in Boston, Mass., shortly after May 1. The company has leased office space on the thirteenth floor of the new wing of the 10 Postoffice Square Building, where the district lamp and tube offices of the corporation have been located for some time.

— RE —

HOLYOKE TO SUPPLY RUBBER-COVERED WIRE

The Holyoke Company's newest addition, at Holyoke, Mass., a 10,000 square foot building equipped with over $50,000 worth of newly developed rubber-covering machinery, enables this old-established wire supplier to fill any radio or electrical device manufacturer's requirements.

Heretofore, Holyoke specialized in high quality, patented gutta-percha covered hookup wires, cord sets and harnesses. Now both rubber and gutta-percha type wires are available in all standard sizes or to specification.

CALLITE CATALOG

A catalog containing complete information on fluorescent materials has been issued by the Callite Products Company, Union City, N. J. In addition to describing in detail all of the many phenomena, charts and tables on Cal-Lux materials are included.

— RE —

C-D COLOR CODE CHARTS

A convenient chart, of vest pocket, size, illustrating the standard RMA mica capacity color code, has been made available by the Cornell-Dubilier Corporation. The extreme compactness of the modern mica capacitor has necessitated the substitution of a color code for the usual numeral capacity identification. This chart, therefore, will be found of exceptional value by the engineer, serviceman, and amateur. The chart is being distributed through Cornell-Dubilier jobbers.

— RE —

MAJESTIC MOVES

N. L. Cohen, president of the Majestic Radio & Television Corporation, has announced that the entire plant and general offices of the organization is now located in a new building at 50th and Rockwell Streets in the heart of the Kenwood manufacturing district, in Chicago.

— RE —

PHEOLL CATALOG

The 1937 catalog of the Pheoll Manufacturing Company, makers of screws, bolts and nuts, is ready for distribution. Copies may be obtained by writing to the company at 5700 Roosevelt Road, Chicago, Ill.

— RE —

INDUSTRIAL ADVERTISERS CONVENTION

Wm. E. McFee (Chief Copywriter, American Rolling Mill Co., Middletown, Ohio), President of National Industrial Advertisers Association, Inc., announces the selection of the Edgewater Beach Hotel, Chicago, as the meeting place for the 1937 Conference of the National Industrial Advertisers Association, to take place on September 23, 24 and 25.

— RE —

RAILWAY EXPRESS BULLETIN

Of interest to all concerned with COD shipments is a bulletin available from the Railway Express Agency, 230 Park Avenue, New York, N. Y. The pamphlet describes in detail the services offered by Railway Express in connection with COD shipments.

CLAROSTAT EXPANDS PRODUCTION SPACE

Due to the considerable and steadily rising volume of its jobber business, The Clarostat Mfg. Company, Inc., announces a 25 per cent increase in its production space. Much new machinery and other equipment has been installed, together with the hiring of additional factory personnel, in order to meet the expanding volume of trade with prompt deliveries. The Clarostat plant is located in the company's own building at 285 North 6th St., in Brooklyn, N. Y.

— RE —

ADDITIONAL FACTORY FOR SOLAR

Otto Paschkes, president of Solar Manufacturing Corporation, 599 Broadway, New York City, has announced that the corporation has leased an additional factory at the foot of West 23rd Street, Bayonne, New Jersey.

The Solar departments for making electrolytic condensers will be moved to the Bayonne addition immediately. General offices and other production departments will continue at 599 Broadway, New York City. This expansion program has been made necessary because of greatly increased business offered the company for the coming season.

The new Solar factory adds approximately 75,000 feet of floor space to the Solar plant capacity. It comprises several modern brick factory buildings favorably situated on several acres of ground. A modern power plant for the generation of steam and electricity provides economical power supply for both present requirements and future expansion.

— RE —

CUNNINGHAM RETIRES

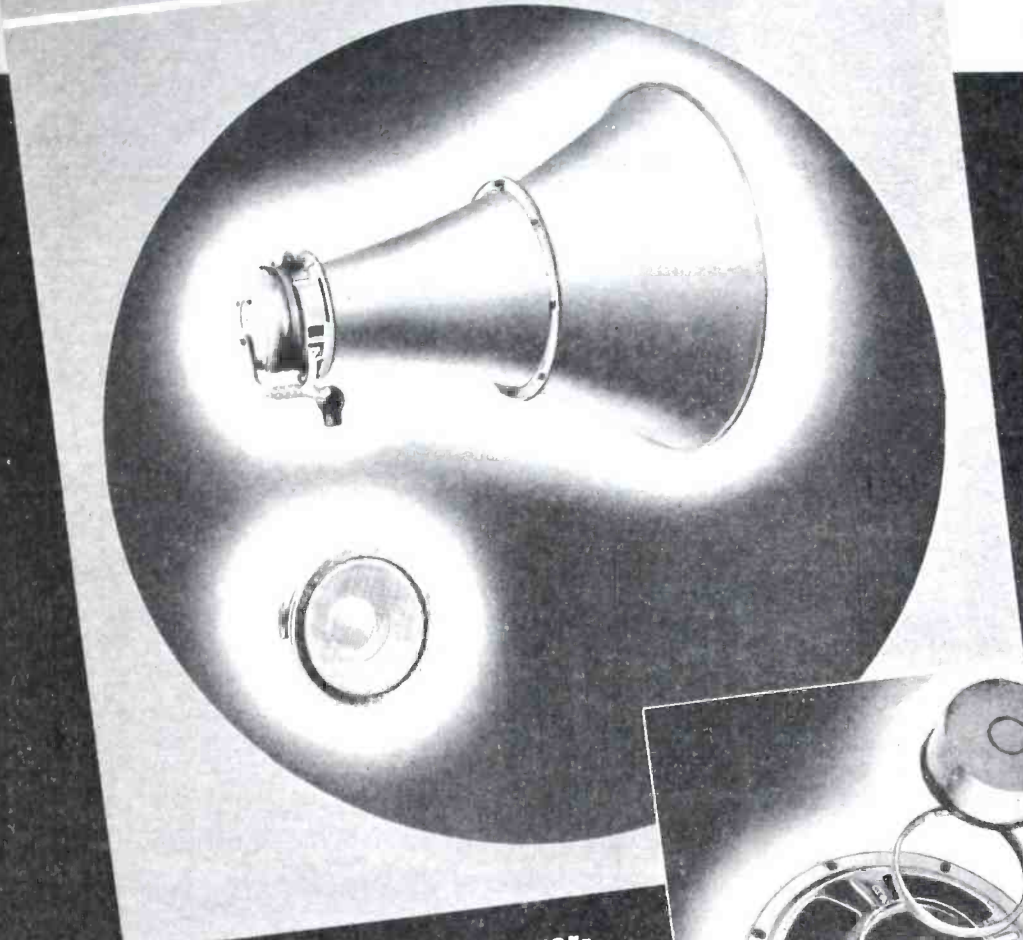
David Sarnoff, President of the Radio Corporation of America, today announced the resignation of E. T. Cunningham as President of its subsidiary, the RCA Manufacturing Company, Inc. Mr. Cunningham continues as a member of the RCA Manufacturing Company Board of Directors, and has been retained as counsel on production, sales and trade relations.

In December, 1930, Mr. Cunningham sold his radio tube company, E. T. Cunningham Company, to Radio Corporation of America. That year RCA had also begun its own manufacture of the radio apparatus which it had formerly purchased from others. At that time RCA acquired factories in Camden and Harrison, New Jersey; Boston, Indianapolis, and Hollywood, California.

In 1931, Mr. Sarnoff appointed Mr. Cunningham to coordinate and to integrate the varied sales and manufacturing activities of RCA in the fields of radio tubes and receivers, Victor phonograph records, Photophone equipment, radio transmitters and miscellaneous radio products.

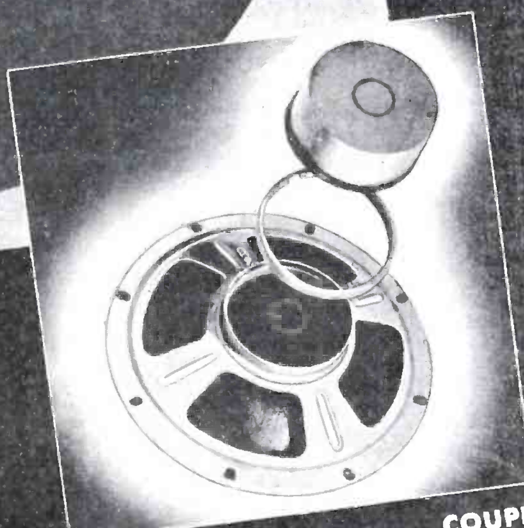
Today these activities of the RCA are consolidated in the RCA Manufacturing Company, Inc., with factories in Camden and Harrison, New Jersey; Indianapolis, Hollywood, California; and in eight foreign countries.

RECOGNITION—the REWARD FOR ACCOMPLISHMENT



CINAUDAGRAPH CORPORATION, with its extensive background of engineering experience and modern manufacturing facilities, has earned leadership recognition for the industry. This is because its line of speakers is outstanding in performance, quality of materials and workmanship. CINAUDAGRAPH Speakers are styled and built to meet today's requirements — they are sold on a competitive price basis.

MODEL SUA—A powerful exponential unit with 3½" voice coil—the ultimate in air column sound projectors.



COUPLING RING UNIT ASSEMBLY Assures Permanent Voice Coil Alignment and Simplifies Cone Replacement.

May we send you a copy of Catalog No. 237? It's yours for the asking!

CINAUDAGRAPH CORPORATION

Speaker Division • Stamford, Conn.

A complete line of Magic Magnet Speakers ranging in size from 5 to 18 in.

NEW PRODUCTS

CENTRALAB SWITCH

A new switch, available in three types, has been introduced by Centralab, 900 E. Keefe Avenue, Milwaukee, Wis. These switches compact in size, have been designed primarily as step-type tone controls, although other uses such as phonograph switch, sensitivity control, wave-band selector, etc., will be obvious. Further details may be obtained from the manufacturer.

— RE —

IMPROVED RECORD PLAYERS ANNOUNCED BY RCA VICTOR

As a successor to the R-93 model, which established a unique record of continuously mounting sales since its introduction, RCA Victor introduces another record-player, model R-93-A. In appearance the new instrument resembles a chest or cigar humidor. The Camden engineers have made a number of improvements in the R-93-A; these include a more efficient motor insuring more constant speed of the turn-table; an improved pick-up arm, which gives an even better tonal range; quieter operation and marked improvement in the bass response through the use of bass compensation.

To replace another popular record-player, Model R-93-2, RCA Victor introduces the latest in deluxe record players, Model R-94. This instrument is housed in a handsome hinged cabinet of choice walnut veneers, beautifully finished. Its mechanism is completely new and a vast improvement over its predecessor. Both 10" and 12" records may be played with the lid closed. Automatic starting of the turntable and bass compensation are two of its features.

— RE —

MILLIAMPERE RATINGS FOR CIRCUIT BREAKER

Due to the use of a fully-magnetic nonthermal mechanism which, it is said, can be accurately calibrated for a given overload tripping point, a circuit breaker is now available in ratings as low as 50 milliamperes. Known as the Re-Cirk-It, it is a combination tumbler switch and circuit breaker. And despite its ratings in milliamperes, this device is sturdily constructed to withstand the roughest service.

Re-Cirk-It is available in either instantaneous-trip or time-delay action. The former trips when the load reaches 125 percent of rated current. The time-delay action type is available in one of four time-delay curves, tripping after a time lag of from a few seconds up to 400 seconds on 125 percent overload, depending on the curve selected. On higher overloads the tripping time is reduced, until at 700 percent overload the tripping is virtually instantaneous.

The low amperage ratings available with this device make it applicable to numerous delicate circuits, particularly the protection of X-ray tubes, radio equipment, electronic devices and so on. The switch may be thrown to the "ON" position immediately following tripping, provided the overload condition no longer exists. Re-Cirk-It is manufactured by Heinemann Electric Co., Trenton, N. J.

— RE —

ERIE INSULATED RESISTORS

The Erie Resistor Corporation, Erie, Pa., announces a new line of insulated resistors in ¼ and ½ watt sizes.

The units are known as "ceramic-sealed" insulated resistors inasmuch as they are completely covered with a pre-formed ceramic case and sealed at the ends with a high-dielectric ceramic cement which bonds itself to the insulating case, the tinned-copper terminal wires and to the brass cap covering the end of the solid molded carbon resistance pin.

ACTUAL SIZE

Both the ¼ and ½ watt insulated "ceramic-sealed" resistors are obtainable in all resistance values from a few ohms to several megohms. ¼ watt unit measures approximately ¼" x ½". The ½ watt size measures ¼" x ¾". Both sizes have 2" tinned-copper terminal wires.

— RE —

CUPRON

Cupron is one of the oldest resistance materials known to the engineering profession. Because of its unvarying resistance over all temperature ranges, it was originally christened "Constantan" and covered many fields of service before the advent of the more durable Nickel-Chromium alloys. Today, under its present name of Cupron, its use is limited to certain low temperature applications for which it has become the accepted standard.

The outstanding electrical characteristics of this alloy are said to be a moderately high resistivity, a practically nil temperature coefficient of resistance, and a high thermo-electric effect against copper or iron. Applications which have evolved from these properties include radio rheostats and low temperature resistance units, motor starters, measuring instruments that require negligible temperature coefficient, voltmeters, shunts, etc. By selection, temperature coefficients ranging between 0.000015 to 0.00004 can be supplied by Wilbur B. Driver Company of Newark, N. J., who produce Cupron among many other alloys for critical applications.

DU MONT TYPE 164 THREE INCH OSCILLOGRAPH

This instrument although designed especially for the service engineer to be used in conjunction with any standard frequency modulator and oscillator or with any of the new designs of frequency modulated oscillators will serve the many purposes of a really efficient portable oscillograph as well.

The 164 employs a Du Mont Type 34-XH three inch cathode-ray tube; has separately controlled horizontal and vertical high-gain amplifiers, flat from 30—30000 cycles per second, internal or external positive synchronization; high- and low-voltage power supplies, assuring a brilliant pattern and no interaction of controls.

Provisions for applying signals direct to the deflection plates have been made at the rear of the unit. All controls including horizontal and vertical positioning controls are on the front panel. The unit has an amplified sweep with a frequency range which allows observation of a single wave from 15—30000 cycles per second. Complete information may be obtained from the manufacturer, Allen B. Du Mont Laboratories, Inc., Upper Montclair, New Jersey.

— RE —

SHOCK-RESISTANT PLASTIC DEVELOPED

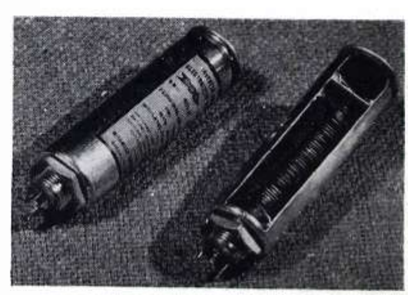
A phenolic molding material which is claimed to have five times greater impact strength than standard molding materials has just been announced by General Plastics, Inc., North Tonawanda, N. Y. Known as as Durez 1590, the material has an impact strength of 0.7 (ASTM) and should find many industrial applications where greater resistance to shock is desired, along with the other well-known properties of molded plastics. It molds and pre-forms easily, has a relatively low bulk factor and in molded form has a somewhat rippled surface, which can be minimized by ribbing or engraving in the mold on decorative pieces.

— RE —

WET ELECTROLYTIC CONDENSER

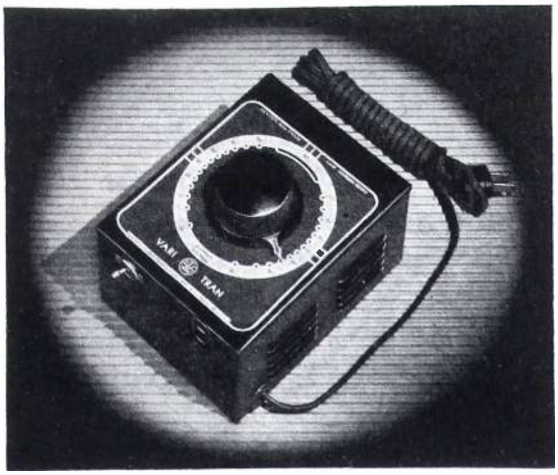
Micamold Products Corp. announce a wet electrolytic condenser which incorporates a new design of the anode structure that closely approaches the theoretically perfect unit, in that the current has the shortest average path from the can to all points on the anode surface.

More capacity for a given working voltage can, it is claimed, be put into standard size cans (very high capacity electrolytics are demanded by the new circuits). The condensers are made in cans of standard dimensions and fit the standard holes in radio chassis. Each condenser is equipped with a self-locking nut.



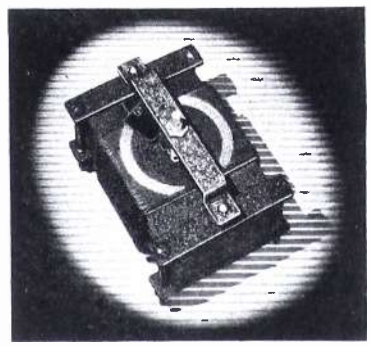
New VARI TRAN UNITS
PATENT PENDING

FOR CONTINUOUSLY VARIABLE VOLTAGE CONTROL



The UTC VARITRAN is an ideal voltage control unit of the type employing a sliding contact riding over the transformer turns. Using a newly developed method of construction the UTC VARITRAN has been made very compact, simple, rugged and inexpensive.

The V-1 unit illustrated has stepless voltage control from 0 to 130 volts and is designed to control the voltage to any load which draws a maximum of 5 amps. at 115 volts.



MODEL V-1—VARITRAN 570 watts, maximum rating, 115 volts 50 60 cycles input. Output 0 to 130 volts, complete with cord, plug and switch as illustrated **$10**

MODEL V-2—Same rating as VA-1 but uncased with terminal strip for rack mounting, etc. **$9**

OTHER VARITRAN MODELS

The standard Varitran is available in ratings of 250, 500, 850, 1250, 2000 watts.

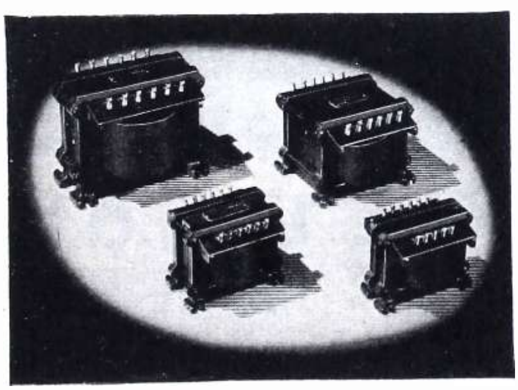
UTC also manufactures an **Automatic** type of VARITRAN control designed to correct automatically line voltage varying plus or minus 25% to plus or minus 2%. These units are ideal for broadcast and laboratory service. Designs are available in ratings of .5, 1, 2, 5, 7.5, 10, 15, 25 KVA. Other sizes on request.

VARIPOWER AUTOFORMERS

The UTC Varipower autoformer is a universal voltage control device suitable for every purpose where a step type voltage control is satisfactory. These autoformers are being put to new uses daily, some of the commercial uses being:

- Adjustment of voltages for testing refrigerators, radio sets, neon signs, insulation strength, etc.
- Measuring power consumption and other operating characteristics of electrical appliances where input voltage must be controlled.
- Control of soldering iron temperatures, temperature control of heating pots and electric furnaces.
- Dimmer control for theatre lighting.
- Stand-in and light adjusting control for photographic purposes.
- Motor speed control.
- Welding current control for spot welders.

VA-1—150 watt output rating, net ... 3.60
VA-2—250 watt output rating, net ... 4.50
VA-3—500 watt output rating, net ... 6.00
VA-4—1000 watt output rating, net ... 9.00
VA-5—2000 watt output rating, net ... 12.00



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

DIELECTRIC PAPER AND ITS APPLICATION TO CAPACITORS

(*Continued from page* 18)

Over a long period an average of two conducting particles are found per square foot in 0.0003" paper and one in 0.0005" paper. The percentage of ash is checked to determine the presence of any filler other than the base cellulose stock. A maximum limit of 0.5 percent is set, as an excess tends to prevent properly uniform impregnation, and hence to weaken the paper from a dielectric standpoint.

Acidity or alkalinity is checked by a standard method of titration with a weak standard solution of potassium hydroxide or sulphuric acid using an indicator dye or the Ph electrometric method. A newer and more accurate test of the total quantity of soluble salts is indicated by the difference in resistance of boiled distilled water and the water in which a given weight of paper has been digested. This resistance method can be used in checking the final wash water at the mill, as the residual soluble salts originate from this water. The purity of this water determines the proper mill site.

The compactness and average thickness are large factors in determining the area coverage of paper per unit weight.

The accompanying table lists the normal yield in square inches per pound to be expected from dry paper.

At least six desirable characteristics are improved by impregnation—capacity, resistance and breakdown voltage are increased; the power factor, size, and moisture are reduced. The optimum result is obtained by the use of the correct wax or oil, paper and impregnating cycle.

As we have observed, the dielectric in paper capacitors before impregnation is a composite consisting of cellulose fibres, air and water; see Fig. 4A showing unfilled voids between electrodes. The dielectric constant of cellulose alone is roughly 5.5, but as one-third of the balance is air, which has a dielectric constant of 1, the resultant overall factor is only 2 to 2.5 for a dry section before impregnating.

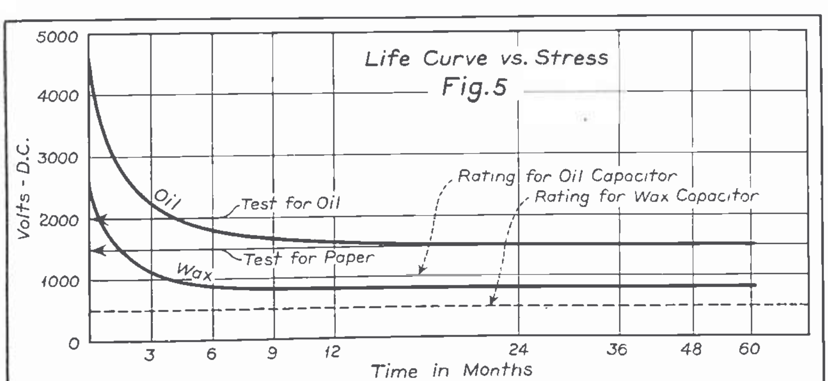
Obviously, no dependable capacity readings can be taken of an undried section as the water content having the very high dielectric constant of 80 controls the result. This is more especially true when it is considered that the water content varies in accordance with the humidity.

If the air voids of Fig. 4A are filled with an impregnant having a dielectric constant or K equal to that of the cellulose, namely 5.5, this then becomes the new dielectric constant for the combination, see Fig. 4B. Where this K is uniform throughout the dielectric no undue voltage strains are set up as is the case when a difference exists between two dielectrics. This gain reflects a definite increase in capacity which varies directly as K. Any reduction in dielectric thickness due to the increase in voltage stress per mil with some impregnants provides a large saving in space as the size varies as the square of the dielectric thickness.

The resistivity gain is largely due to the exclusion of moisture by the impregnating cycle. The medium used being of very high resistance, does not create a serious situation as a shunt path, except at high temperatures.

Power factor is a measure of power loss in a capacitor when used on alternating current. When this is of concern, linen paper in conjunction with a low-loss oil proved the present-day solution producing power factors of 0.08 to 0.25 percent in range.

Another property, namely dielectric absorption, on rare occasions becomes important to certain circuits. This characteristic is peculiar to dielectrics; it is noticed by the failure of the dielectric to return immediately the stored energy in a charge back to the electrodes. This lag of time can be seen by the unsymmetrical wave form on an oscillograph; or on direct current, after discharging an already charged condenser it will be noted that a second, third, fourth, etc., discharge can be ob-



Life Curve vs. Stress
Fig.5

tained, each decaying if the time interval is the same. If the time interval is increased to several hours a considerable discharge can be found on a well insulated, high-capacity unit. Here again, linen paper with mineral oil impregnation is superior in repressing this effect to most other combinations of fibrous dielectrics.

In checking paper the general procedure is to spot check rolls from each case in a shipment. When any trouble is encountered, the material is further tested to complete the investigation and average the results. These inspection checks have been gleaned from experience as well as accelerated life tests. A typical summation of such data appears in Fig. 5. Here it will be noted that down to a certain point, the life lengthens as the voltage is decreased. In this curve, the oil and wax units are the same in every respect except for the impregnating mediums. The former surpasses the latter in quality due largely to its mobility in the section preventing the formation of voids.

Although today a capacitor is one of the most efficient electrical devices in common use, research continues to attempt to reduce size, weight, cost and power factor. As most of the suitable pulp fibres such as jute, hemp, etc., have been tried already it appears that most promise is held in new impregnants rather than in the discovery of a new species of paper pulp.

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IRE

(*Continued from page* 9)

THE MATERIAL GROWTH of the radio industry has been so great that the part played by the engineer has frequently been forgotten. But it should be remembered that radio manufacturers have nothing to sell but various materials worked into a finished form as the result of engineering brains and effort. One might almost say that the manufacturer literally sells engineering thought.

Few members of the public realize the startling development of radio engineering during the past twenty-five years. Engineering in the "wireless" field started as a hope and a guess. During the next decades it became a determined effort to know the facts and to apply them wisely. And today it is nothing less than a science, exact in many respects and useful in practically every application.

Tesla once startled even imaginative people by saying that the day would come when a man, desiring to speak with his friend, would suitably tune his radio transmitter and call his friend. From the center of the desert or the wastes of the ocean or the vastness of the air would come the answer. But if no answer came, the caller would know that his friend was dead! While we have not achieved this ultimate goal, we are so close to it as a result of the application of radio telephony that even a dull person would refuse to be astonished by the prediction. Indeed, were it economically feasible, this accomplishment might be practically realized.

The radio industry, having profitably utilized engineering skill, should recognize that fact, foster engineering research and development, and draw the engineer ever more closely into the fabric of commercial exploitation and public use.

Alfred N. Goldsmith

THERE IS NO INCIDENT of my 47 years professional career that affords me more complete satisfaction than that I was responsible for the organization of The Society of Wireless Telegraph Engineers, and later was able to co-operate in the creation and fostering of our Institute itself.

Our Institute has made a memorable record in the rapidity of its growth in membership, in geographical extension and in its influence upon the development of radio. From my perspective, however, it appears to me that the most notable of its achievements has been to place the development of radio upon an absolutely sound scientific and engineering basis.

Fellow members, please accept my congratulations and best wishes.

John Stone Stone

RADIO IS THE shining symbol and conspicuous example of modern progress. In its 25 years of happy growth the Institute of Radio Engineers has become the undisputed medium of co-operation of those men who devote their lives to insuring the continued progress of radio and of mankind through radio. As the techniques and discoveries of radio attain usefulness in ever widening fields, an even happier future opens for radio engineers.

J. H. Dellinger

(*Continued on page* 38)

IRE

(*Continued from page* 36)

BECAUSE OF ITS SEEMINGLY unending applications radio has no parallel among the other industries—ship radio, air-transport applications, commercial telegraphy and telephony, picture transmission, geodetic exploration, communication between mobile vehicles, and broadcasting. In all but the latter it is possible to anticipate what the betterments are likely to be. Broadcasting has not yet found its wholly useful application. It is so new and so vast in possibilities that thus far evidently it has been practicable only to experiment with suggested services. Its product is a hodge-podge of the ridiculous and the sublime, its main promise being in its versatility. In a more orderly age broadcasting may find a more orderly employment.

Donald McNicol

THE BEGINNING of the second quarter century of the Institute of Radio Engineers finds its members, as in the past, leading contributors to the advancement of radio science and technology. In the field with which I am most familiar, that of transoceanic telephone radio service, the entire development has occurred within the life of the Institute. Current advances in the art give promise of great improvement in the scope and usefulness of this practical application of radio telephony. These advances include the use of single sideband in short-wave transmission and the development of an extremely sharp directive antenna receiving system which reduces noise, selective fading and signal distortion.

Ralph Bown

PROGRAM INTEREST must be depended upon to popularize Television and until such time as the action in a Television reproduction will take the mind of the observer away from the shortcomings of the present-day Television pictures, continued interest in this new field will not be possible. In any event, radio broadcasting should hold its own as the listening to reproduction of sound does not require complete attention and special room conditions.

Ray H. Manson

CONVENTION PAPERS

"The Origin and Development of Radio Telephony," by Lloyd Espenschied, Bell Telephone Laboratories, Inc.

"Transoceanic Radio Telephone Developments," by Ralph Bown, Bell Telephone Laboratories, Inc.

"Ground Systems as a Factor in Antenna Efficiency," by G. H. Brown, R. F. Lewis and J. Epstein, RCA Manufacturing Co., Inc.

"Simple Method for Observing Current Amplitude and Phase Relations in Antenna Arrays," by J. F. Morrison, Bell Telephone Laboratories, Inc.

"Ultra-High-Frequency Relay Broadcasting," by W. A. R. Brown and G. O. Milne, National Broadcasting Co.

"The Ultra-Short-Wave Beacon and Its Field of Application," by Walter Hahnemann, C. Lorenz, A. G., Berlin.

"A Multiple Unit Steerable Antenna for Short Wave Reception," by H. T. Friis and C. B. Feldman, Bell Telephone Laboratories, Inc.

"Time Division Multiplex in Radio Telegraphic Practice," by J. L. Callahan, R. E. Mathes and A. Kahn, RCA Communications, Inc.

"Automobile Receiver Design," by F. D. Schnoor and J. D. Smith, RCA Manufacturing Co., Inc.

"Radio Methods for the Investigation of Upper Air Phenomena with Unmanned Balloons," by H. Diamond, W. S. Hinman Jr., and F. W. Dunmore, National Bureau of Standards.

"Characteristics of the Ionosphere and Their Application to Radio Transmission," by T. R. Gilliland, S. S. Kirby, N. Smith and S. E. Reymer, National Bureau of Standards.

"An Automatic Sound Pressure Recorder," by W. S. Bachman, General Electric Co.

"A Basis for Vacuum Tube Design" by M. A. Acheson, Hygrade Sylvania Corp.

"The Development Problems and Operating Characteristics of a New Ultra-High-Frequency Triode," by W. G. Wagener, RCA Manufacturing Co., Inc.

"Study of Changes in Contact Potential," by E. A. Lederer, D. H. Walmsley and E. G. Widell, RCA Manufacturing Co., Inc.

"An Oscillograph for Television Development," by A. C. Stocker, RCA Manufacturing Co., Inc.

"Relation Between Radio Transmission Path and Magnetic Storm Effects," by G. W. Kenrick, University of Puerto Rico, A. M. Braaten, and J. General, RCA Communications, Inc.

"A New Antenna Kit Design," by W. L. Carlson and V. D. Landon, RCA Manufacturing Co., Inc.

"Concentric Narrow Band Elimination Filter," by L. M. Leeds, General Electric Co.

"Higher Program Level Without Circuit Overloading," by O. M. Hovgaard, Bell Telephone Laboratories, Inc.

"A Wide-Range Beat-Frequency Oscillator," by J. W. Brumbauch, RCA Manufacturing Co., Inc.

"Measurement of Condenser Characteristics at Low Frequencies," by W. D. Buckingham, Western Union Telegraph Co.

"A New Method of Measurement of Ultra-High-Frequency Impedance," by S. W. Seeley and W. S. Barden, RCA License Laboratory.

"Development of a Projection 'Kinescope,'" by V. K. Zworykin and W. H. Painter, RCA Manufacturing Co., Inc.

"High Current Electron Gun for Projection 'Kinescopes,'" by R. R. Law, RCA Manufacturing Co., Inc.

"A Circuit for Studying 'Kinescope' Resolution," by C. E. Burnett, RCA Manufacturing Co., Inc.

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You wouldn't send this lad on your sales errands....

. . . yet you are producing just as harmful an impression if your transmitter is putting out a poor signal . . . a signal which doesn't have a sales chance of being listened to alongside distortionless transmitters.

No matter how modern your transmitter, you cannot expect it to operate month after month with the same degree of fidelity as it did when originally installed and adjusted. Serious and unavoidable distortion may be introduced in *any* broadcast transmitter through changes in tube or circuit characteristics.

With the G-R Type 732-A Distortion & Noise Meter the total distortion can be checked in *10 seconds.* It's so simple that many stations using this instrument log the distortion regularly with other operating data.

This meter not only gives you a constant check on transmitter distortion but also on noise and hum throughout the entire system from audio line to antenna. Measurements can be made rapidly and accurately to isolate residual noise level, excessive hum, noisy tranmitter tubes, unbalanced rectifiers, noise in a-f amplifiers and studio or pick-up lines.

As a companion instrument the Type 733-A Oscillator is designed for use as a constant-frequency 400-cycle tone. Both the Type 732-A and Type 733-A instruments are completely self-contained, self-operated, relay-rack mounted, a-c operated and are furnished complete with tubes and all necessary accessories for immediate operation.

Type 732-A Distortion and Noise Meter **$220.00**

Type 733-A Oscillator **$62.00**

Write for Bulletin 136-K for complete data

GENERAL RADIO CO.
CAMBRIDGE, MASS.

MEET F.C.C. REQUIREMENTS

• Federal Communications Commission Rule 139, paragraph A, requires that no broadcast transmitter have more than a total of 10% combined audio harmonic when operated at a modulation level of at least 85 per cent. Systematic use of the Type 732-A Distortion and Noise Meter will tell you immediately whether or not this rule of the Commission is being complied with in your station.