JANUARY, 1936

Radio Engineering

VOL. XVI

NO. 1

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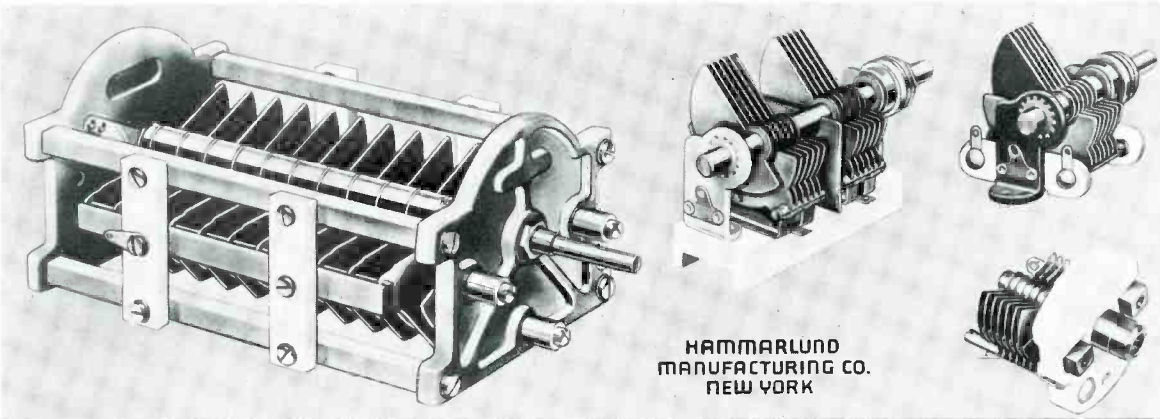

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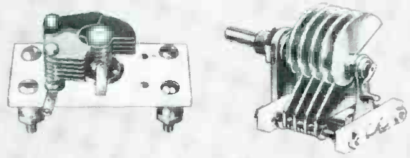

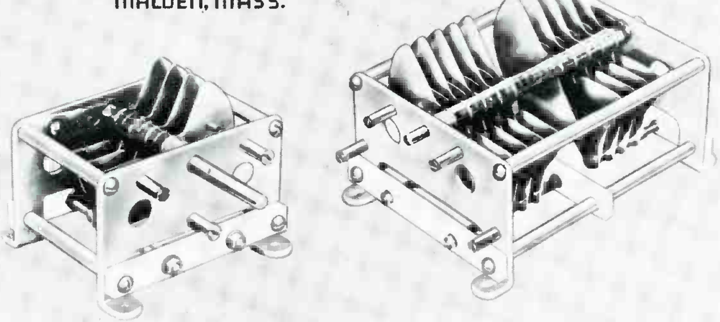

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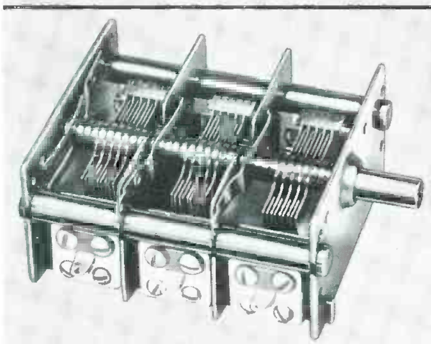

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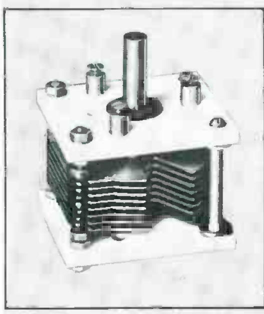

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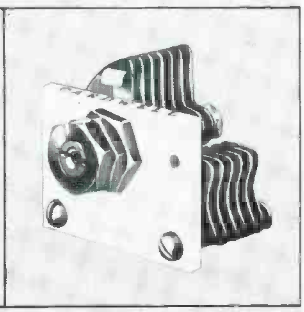

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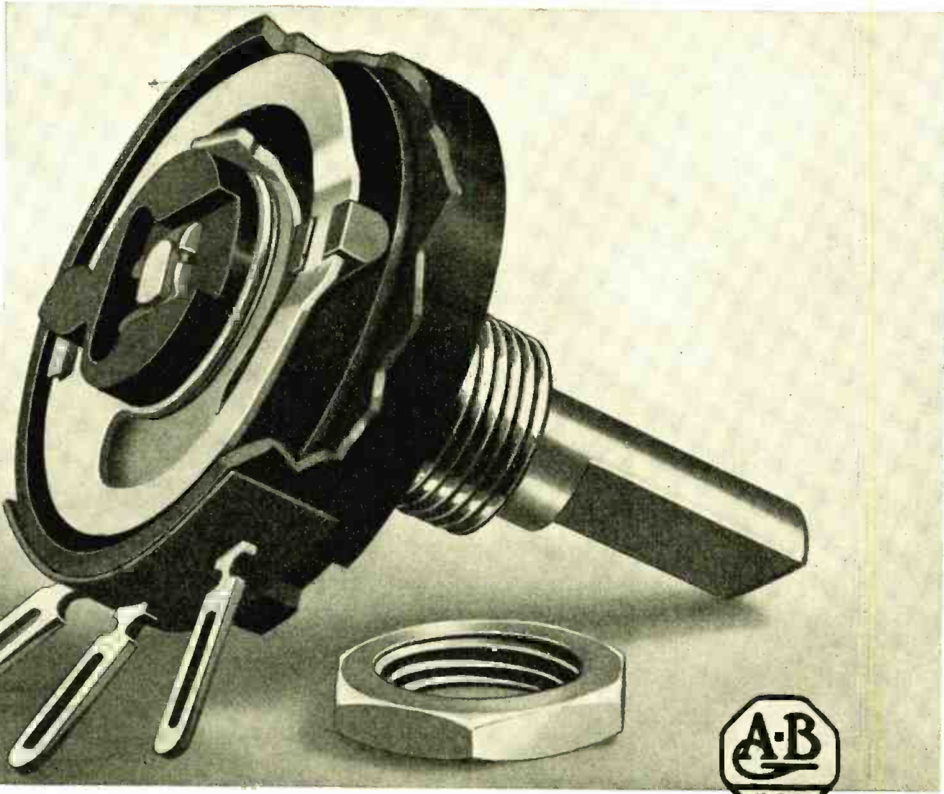

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SPECIAL EQUIPMENT FOR CHECKING TONAL FIDELITY OF RADIO RECEIVERS AT THE RCA LICENSE LABORATORY.

FEATURES

DEPARTMENTS

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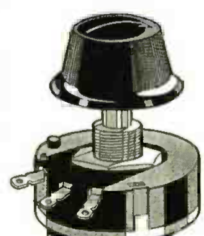

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EDITORIAL

MATERIALS PROGRESS

A MAJOR PART of the progress made in radio equipment design has been due to the remarkable strides in the development and application of raw materials.

The modern radio receiver is a good example of this: Though new functions have been added to circuits and mechanical improvements incorporated in the chassis, the basic designs are much the same as they were many years ago.

Major improvements have arisen through the development of better vacuum tubes, better coils and condensers, better transformers, and so on. These devices are better because new raw materials have been put to use, and because old, well-established raw materials have been improved upon through new methods of processing.

The physicist, the chemist and the metallurgist work toward a common objective; the constant improvement, and the development, of the raw materials that go into our industrial world. The manufacturer of unit parts and the fabricator of the completed products put these raw materials to new uses.

The design engineer is the go-between. It is he who must apply the materials to the products of his company. It is he who must be constantly on the lookout for the materials that will provide him with the greater efficiency he needs with which to improve the products.

At the same time there are many radio problems that are solved only by the development of new raw materials, or new methods of applying the materials available. There are things we do today that would be quite impossible were it not for one or more special raw materials that have been applied to designs. There are things that appear quite impossible today that we will do tomorrow when materials of appropriate characteristics are made available.

Our progress comes through a coordination of the work done in the radio field and the work done by the chemist, the physicist and the metallurgist. So long as the work in these diverse fields is put to use, radio design progress will continue at a fast rate.

• • •

NOISE ELIMINATION

IN AN EDITORIAL in the December 1935 issue of RADIO ENGINEERING, we expressed the opinion that the war against noise should be tackled not at the source but rather at the receiving end. We expressed the opinion that no great headway could be made in this respect until more was known of the character of noise and its relation to radio waves.

And now it may be disclosed that Mr. James Lamb, of the technical staff of QST magazine, has developed a simple, practical system of noise elimination predicated upon the findings of his studies into the character of noise impulses.

Mr. Lamb observed that static and man-made noise impulses have sharp peaks, are of high amplitude but are of very short duration. So short in duration that he has found that "punching holes of silence" in the signal at the points where the impulses would appear is permissible because the ear is unable to function with sufficient rapidity to note the interruptions.

The system itself is a supplementary delayed avc circuit working out of the first detector which is made to function as a quick-action silencing control. The circuit is adjusted to operate only on the noise peaks.

• • •

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But the question is, how much of a following have the amateurs? Judging by our own observations, it has become quite large.

• • •

CONTROLS

SOME RECEIVERS ARE getting out of control because they have too many controls.

There is a limit to what the average listener will handle on a set. He wants good reception with the least amount of bother. If he can't get it without thumbing a bunch of knobs, he'll take the poor reception and let it go at that. So, what good are the controls, anyway?

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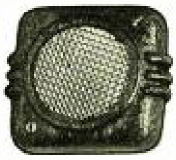

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RADIO ENGINEERING

FOR JANUARY, 1936

CRYSTAL FILTER DESIGN

PART I:—The Theoretical Considerations Involved. Subsequent Articles Will Deal with the Actual Design and Application of the Filters

By W. W. WALTZ

THE design of a crystal-filter network, whether it be low-pass, high-pass, or band-pass, resolves into two distinct steps. The first part of the process is that of obtaining an electrical network whose characteristics—with the exception, of course, of the various Q's—are similar to those of the network employing crystals; from that point certain of the electrical elements are converted into terms of crystal dimensions, resulting in the final design. It may be pertinent to mention, at this point, that difficulties will present themselves to the would-be designer who starts out with a crystal or crystals, ground to a given fundamental frequency. In general, the crystals available on the market are for oscillator use and, as we shall demonstrate later, these are not satisfactory for use in filters.

EQUIVALENCE BETWEEN CIRCUITS

One matter of great interest to the engineer concerned with the design of telephone transmission circuits, is the equivalence between circuits. This can be illustrated by a simple case which is, or should be, familiar to radio engineers; i. e., the equivalent circuit of a transformer. Fig. 1 shows the conventional circuit representation of a transformer; Fig. 2 is the equivalent-T network, the arms of which have the values, with respect to the constants of the actual transformer, as indicated on the figure. It is of interest to note, in connection with this point, that such an equivalence is only feasible mathematically, except in the case of a

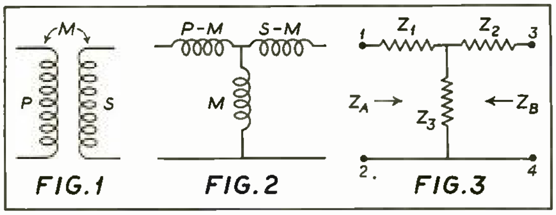


FIG. 1 FIG. 2 FIG. 3

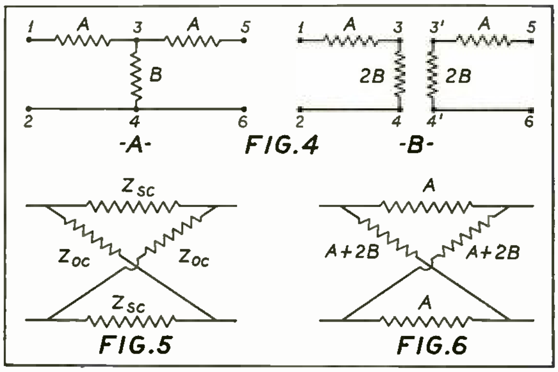


FIG. 4 FIG. 5 FIG. 6

1:1 transformer. For the unity ratio case, the equivalent-T network can be physically realized, but for any other ratio the physical structure would have to have one series arm of *negative inductance.* The proof of this is easily seen if one substitutes numerical values for P, S, and M of the figure.

It may be said, in general, that any four-terminal network can be replaced by an equivalent-T (or by an equivalent-π) structure. Table I shows the equivalents of a number of structures, the values of the various elements necessary for this equivalence being as indicated on the figures for the various circuits.[1]

OPEN- AND SHORT-CIRCUIT IMPEDANCES

The equivalence between any four-terminal networks is determined rigorously, as we shall demonstrate later, by the open-circuit and short-circuit impedances of the networks. The elements of any network can likewise be determined from these impedances; i. e., the open-circuit and short-circuit. Consider, for instance, the T network of Fig. 3. (Remember the previous statement to the effect that any four-terminal network can be represented by an equivalent-T). If the impedance of the network is measured at terminals 1-2, with 3-4 open, a

[1] For the proofs of these equivalences, and for a more detailed discussion, the reader is referred to the following: "Physical Theory of the Electric Wave Filter" by G. A. Campbell, Bell System Technical Journal. Vol. I, No. 2, November 1922. "Transmission Circuits for Telephonic Communication" by K. S. Johnson. D. Van Nostrand Co. 1927.

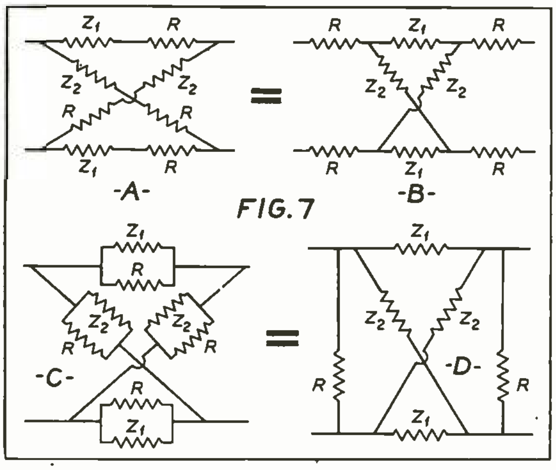


FIG. 7

certain value will be obtained which we will designate as Z_{oc-1}. The impedance measured at 3-4 with 1-2 open will be Z_{oc-2}. Now, applying a short-circuit across 3-4 and again measuring the impedance at 1-2 gives another value, Z_{sc-1}. Similarly, shorting 1-2 and measuring the impedance at 3-4 gives Z_{sc-2}. The impedance of any of the arms of the T network can then be found from the following equations:

$$Z_1 = Z_{oc-1} - \sqrt{Z_{oc-1}(Z_{oc-2} - Z_{sc-2})} \quad (1)$$

$$Z_2 = Z_{oc-2} - \sqrt{Z_{oc-1}(Z_{oc-2} - Z_{sc-2})} \quad (2)$$

$$Z_3 = \sqrt{Z_{oc-1}(Z_{oc-2} - Z_{sc-2})} \quad (3)$$

The impedances, Z_A and Z_B, variously termed the characteristic impedance, the iterative impedance, or the surge impedance, are given by:

$$Z_A = \frac{\sqrt{(Z_1 + Z_2)(Z_1 + Z_2 + 4Z_3)} + Z_1 - Z_2}{2} \quad (4)$$

$$Z_B = \frac{\sqrt{(Z_1 + Z_2)(Z_1 + Z_2 + 4Z_3)} - Z_1 + Z_2}{2} \quad (5)$$

These two impedances, Z_A and Z_B, are, in the case of a symmetrical structure, equal to the image impedance; the image impedance is defined by the relation:

$$Z_I = \sqrt{Z_{oc} Z_{sc}} \quad (6)$$

This brings us, logically enough, to a discussion of the so-called Bi-section Theorem.[2] With the principles outlined therein it is possible not only to obtain the equivalent of any four-terminal network, but also to derive a means whereby the inherent resistance of the coils of a structure—which, in a filter, results in decreasing the slope of the sides of the attenuation curve, and in an undesired loss throughout the pass region—can be eliminated from the calculation. As might be expected, this coil resistance adds attenuation which varies with frequency; getting the resistance outside of the filter structure has the effect of adding attenuation which does not vary with frequency.

LATTICE STRUCTURE

Fig. 4-A is a T-section, representing some kind of a filter, which we will convert to its equivalent lattice structure by means of Bartlett's principles. Of course, the process is reversible; i. e., we can as easily go from the lattice to the T or π section. The circuit of Fig. 4-B is the T-section divided into two inverted-L sections. Now, suppose we obtain—simply by inspection—the open-circuit impedance of the left half of the circuit of Fig. 4-B; obviously this will be A + 2B. The short-circuit impedance; i. e., with 3-4 shorted, as seen from 1-2 will be simply A. The lattice structure which we are seeking is, then, that of Fig. 5; it can be seen that the series (or line) elements of the lattice are equal to the short-circuit impedance of the T-network of Fig. 4-A, and the lattice (or shunt) branches are equal to the open-circuit impedance of the T-network. In an exactly similar manner, by finding the open- and short-circuit impedances, that is, any four-terminal network can be converted into its equivalent lattice structure. This will be found of real value in the design procedure.

EXTERNALIZING RESISTANCE

By a somewhat similar line of reasoning Mason[3] has interpreted the Bi-section Theorem to include the case where it is desirable to have the coil (or condenser) resistance out of the way. The cases shown by Mason are those indicated in Fig. 7. In this figure, A is the lattice network the coils of which have a series resistance, R. B of the same figure shows how this resistance is "removed" from the lattice and considered as an attenuator which is independent of frequency. Fig. 7-C is a lattice with resistance in shunt to its reactance elements, and 7-D is the lattice with the resistance again considered as essentially external.

QUARTZ CRYSTAL PLATES

We shall, at this point, turn aside from the consideration of equivalent networks to take up the subject of quartz crystal plates; this, however, is done only to enable us to correlate the two. As we mentioned in the first paragraph of this article, the problem of filter design involves the determination of the constants of the electrical circuit and then converting the results into the dimensions of a quartz plate. Obviously, we shall need to return to equivalent circuits after looking into some of the aspects of the crystal itself.

[2] A. C. Bartlett, Philosophical Magazine (London), Vol. IV, No. 24, November 1927. See also "The Theory of Electrical Artificial Lines and Filters" (same author). All of these data on equivalent circuits were derived from Bartlett's material.

[3] "Electrical Wave Filters Employing Quartz Crystals as Elements" by W. P. Mason, Bell System Technical Journal, Vol. XIII, No. 3, July 1934. See also, "Quartz Crystal Filters" by W. P. Mason, Bell Laboratories Record, Vol. XIII, No. 10, June 1935.

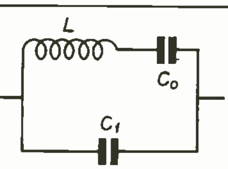


FIG. 8

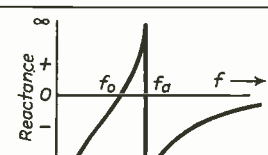


FIG. 9

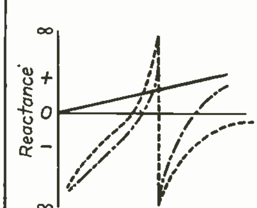


FIG. 10

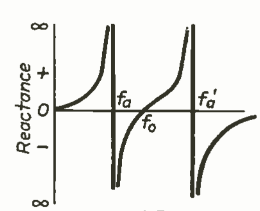


FIG. 11

No generalizations on the subject of quartz plates are needed here; this subject is pre-eminently that of the radio engineer, although it must be admitted that the reactionist engineering tendencies of that group functioned beautifully to give the telephone engineers the full credit for this—still unsuspected—epochal development.

The chief interest in crystals had, until the advent of crystal filters, been in obtaining a plate with a minimum temperature-frequency characteristic. True, the presence of spurious frequencies of vibration has always been more or less troublesome, but certain types of cuts had been found in which the effects of these so-called secondary spectra were at a minimum. Crystal plates for use in oscillators and transmitters had only to function at one frequency with a fair degree of "hop"; the tuned circuits of the oscillator or transmitter served to pick out this frequency and reasonably effectively to exclude all others.

Investigations[4] had shown the possibilities of zero temperature coefficient crystals for oscillator use. It was also found, by those working on crystal filters, that certain cuts were even more suitable for filter nets than were the zero temperature characteristic plates.[5] Where the plates for oscillators were orientated with respect to the so-called electrical, or X axis of the crystal,[6] those for filter circuits are orientated with respect to the mechanical, or Y axis. The filter crystals are essentially the more or less familiar perpendicular, or X-cut plates, differing only by reason of this orientation. A rotation of —18.5 degrees about the Y axis was found by Mason to be the most suitable in that it afforded the best compromise between the conflicting requirements.

CRYSTALS FOR FILTER USE

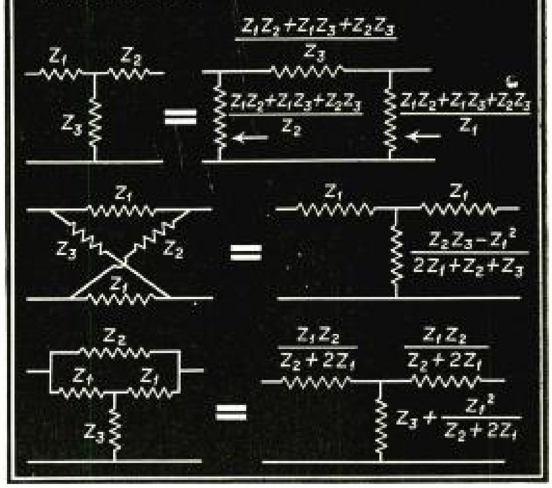
The crystals for filter use are cut with the major surfaces parallel to the optical axis, and with the thickness parallel to the electrical axis; this statement being qualified, of course, to the extent necessary to secure the —18.5 degree rotation described above. If such a plate has a length—dimension paralleling the Y axis—three or more times its width—dimension paralleling the optical axis—its electrical impedance can be represented by the circuit of Fig. 8, to a point well above the first natural frequency of the plate. This impedance is as shown by the curve of Fig. 9; as is evident, there is a resonant frequency and, slightly higher, an anti-resonant frequency.

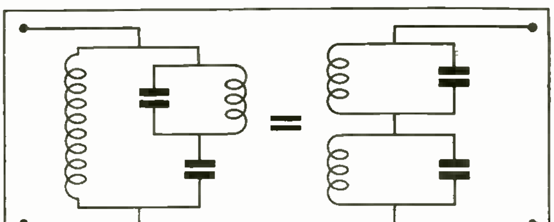
The separation between these two frequencies—f_0 and f_a in Fig. 9—is a function of the ratio of C_1 to C_0. For quartz this ratio cannot be less than 125; increasing the value of C_1 serves only to increase this ratio. For the crystal alone, the separation of the frequencies of resonance and anti-resonance is 0.4%. In the equivalent circuit of Fig. 8, the capacity C_1 includes such capacity as may be in shunt to the crystal; i. e., that due to the crystal holder electrodes, or the shunting capacity of a vacuum tube, etc. This capacity may, of course, be increased, but cannot be decreased below the point where the ratio, mentioned above, is less than 125. Since the capacity C_0 is purely hypothetical, it cannot be varied; this fact is what fixes the minimum value of 125 for the ratio between the two. However, since in crystals cut for filter use the length is the factor governing the resonant frequency, the location of f_0—and hence, of f_a—may be selected by properly proportioning the plate. The height of the reactance curve may be controlled by varying the ratio of crystal area to thickness; this, within limits, gives the designer a degree of control over the impedance—magnitude, that is.

[4] Notably of Lack, Willard and Fair of the Bell Telephone Laboratories. See their "Some Improvements in Quartz Crystal Circuit Elements," Bell System Technical Journal, Vol. XIII, No. 3, July 1934.
[5] W. P. Mason, *loc. cit.*
[6] Section 9, Radio Engineering Handbook, 2nd Ed. 1935.

TABLE I

The following circuits are equivalent when the various elements are related as indicated:





-A- **FIG. 12** -B-

CRYSTAL DIMENSIONS

For design purposes it will be convenient to know the values of the elements of the circuit of Fig. 8 in terms of the crystal dimensions, of which they are functions. Mason gives the following (with dimensions in centimeters):

$$C_1 = 0.402 \times 10^{-12} \frac{l_m l_o}{l_e} \qquad (7)$$

$$C_0 = 0.289 \times 10^{-14} \frac{l_m l_o}{l_e} \qquad (8)$$

$$L = 118.2 \frac{l_m l_e}{l_o} \qquad (9)$$

in which.

l_m = length parallel to the mechanical axis
l_e = length parallel to the electrical axis
l_o = length parallel to the optical axis.

Since a capacity in parallel with a crystal has the effect of decreasing the difference between the resonant and anti-resonant frequencies, it seems pertinent to examine the possibilities of increasing this difference. The general theory of the electric-wave filter shows that a

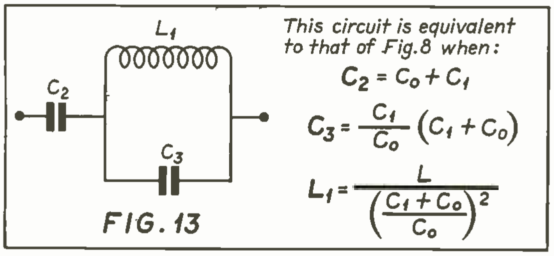


FIG. 13

pass-band exists where the resonant frequency of the series branch coincides with the anti-resonant frequency of the shunt branch—these remarks applying to the so-called ladder type of structure; i. e., the T or π network. For the lattice structure, the condition for a pass-band is that the reactance of the line (series) branch shall be opposite in sign to that of the lattice (shunt) branches.

Obviously, to design a filter employing only crystals would result inherently in a device which, at the most, could pass only a 0.8% bandwidth. Adding condensers would further restrict the width of the band.

EFFECT OF INDUCTANCE

However, placing an inductance in series with the crystal has the effect shown in Fig. 10; here the broken line curve is the characteristic of the crystal alone, the solid line curve is the reactance of the added inductance, and the dot-dash curve is the resultant. It is perfectly apparent that the separation of the frequencies of resonance and anti-resonance has been increased. If the inductance is in shunt to the crystal, the characteristic of Fig. 11 obtains; here it is seen that two anti-resonances are established with a resonant frequency at the original point (see f_0, Fig. 9); if this parallel inductance is varied, the upper anti-resonance is shifted without appreciably changing the lower.

Here we are presented with an approach to the problem of obtaining a wide response band with circuit elements that, of themselves, would result only in an extremely restricted response. In order that we may take full advantage of this, it is necessary that we again go into the subject of equivalent circuits. However, the problem is somewhat different than the ones discussed earlier; here we will need to be able to determine the actual circuit elements for a given impedance rather than the generalized impedance relations. The principles which we will use are those of G. A. Campbell, as expanded by Zobel and Foster.[7] The derivation of these principles is too involved to be taken up in the space available. Foster has expressed the problem most simply by stating, in effect, that any impedance may be realized by a parallel combination of n resonant circuits, or by a series combination of $n+1$ anti-resonant circuits, n being the number of frequencies at which the impedance has been specified.

The general equation, as given by Foster, is:

$$Z = -jH\frac{(\omega_1^2 - \omega^2)(\omega_3^2 - \omega^2)\ \ldots\ (\omega_{2n-1}^2 - \omega^2)}{\omega(\omega_2^2 - \omega^2)\ \ldots\ (\omega_{2n-2}^2 - \omega^2)} \qquad (10)$$

From this equation it is possible to prove the relations of Fig. 12; it should be noticed that A of this figure is the crystal equivalent circuit of Fig. 8 shunted by an inductance, since by this same means, the circuit of Fig. 8 can be shown to be exactly equivalent to that of Fig. 13. The expressions for the relationship in Fig. 12 are too long to be included here; we shall, however, have occasion to introduce them later in our discussion of the actual design procedure.

(*To be continued*)

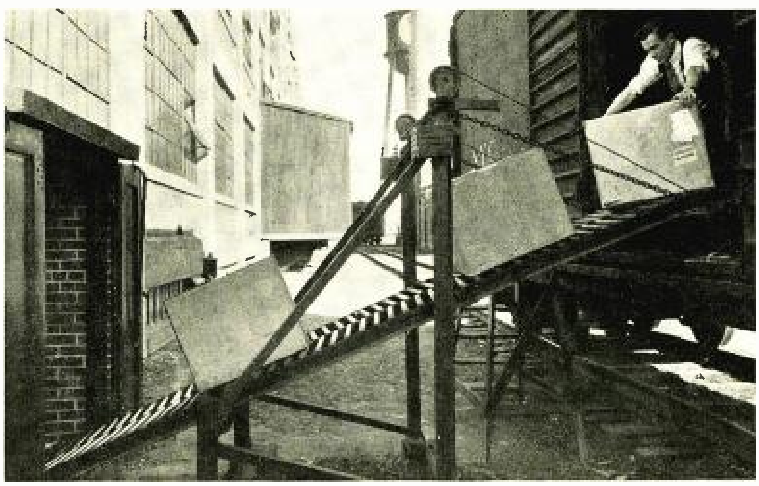
[7] G. A. Campbell, *loc. cit.* O. J. Zobel, "Theory and Design of Uniform and Composite Wave Filters," Bell System Technical Journal, Vol. II, No. 1, January 1923. R. M. Foster, "A Reactance Theorem," Bell System Technical Journal, Vol. III, No. 2, April 1924. For the fundamental discussion of this subject, the reader should refer to Campbell's "Cisoidal Oscillations," published in the Journal of the A. I. E. E., 1911, Vol. XXX, Part II, pages 873-909.

HERRINGBONE CONVEYORS SIMPLIFY UNLOADING

Gravity herringbone conveyors, replacing trucks and elevators, greatly simplified the unloading of raw materials from railroad cars to the basement warehouse of the Westinghouse Lamp Company, Trenton, N. J. The more efficient unloading was necessitated by double production as a result of absorbing another plant with corresponding increased input of raw material.

Three conveyors equally spaced along the side of the building make it possible to unload as many cars simultaneously. By the former trucking method, two cars at the most could be unloaded simultaneously, a condition partly the result of restricted platform area. Cars are still unloaded by hand trucks, especially for those materials too fragile to shoot down conveyors, so that, altogether, five cars may be unloaded at one time.

The Trenton Plant, a single, narrow building, receives the bulk of its raw materials and lamp parts from a lone track siding. In the past the use of hand trucks and elevators was slow and tedious, frequently holding up supplies at times of peak production. Congested truck traffic often tied up elevators that should have been delivering supplies to the production line on the top floor. Frequently, too, it was necessary to truck materials to the opposite end of the building from the elevator on which they were lowered to the basement.



Speaker Design

RECENT DEVELOPMENTS IN THE LOUDSPEAKER INDUSTRY

By J. Q. TIEDJE
Engineer
THE ROLA COMPANY

A discussion of some of the recent developments of the loudspeaker industry, with regard to their application to radio and public-address systems, would be of interest at this time.

Much publicity has been given to the recent introduction of the curved diaphragm as applied to loudspeakers. While it has been known for some time that curved cones have had certain features, it is only recently that production methods have advanced to the point where it has been economically possible to produce this type of diaphragm of suitable materials.

SUB-HARMONICS

There has been some publication of the fact that this type of diaphragm has greater overload characteristics because of the prevention of sub-harmonic tones in the middle and upper frequency range. These "sub-harmonics" are very familiar to those who have operated speakers on constant frequencies at fairly high input powers. It might be well at this time to review briefly the theory upon which this is based. For example, let us compare a section of the conventional straight-sided cone to a straight beam "A" (Fig. 1) and with the force generated by the voice coil represented by the force "F". For the first half-cycle of the audio voltage the force "F" will deflect the beam to the dotted position "B", and for the second half-cycle the beam will return to position "A." But due to inertia and certain other factors, upon application of the second cycle the beam will first be deflected to "C", and then return to "A" for the last portion of the second cycle. It can then be seen that for *two* complete cycles of the applied audio voltage, or force in this case, the beam has moved through *one* cycle, thus giving rise to sub-harmonic or *half* frequency motion.

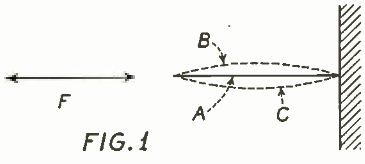


FIG. 1

Due to force F, the beam A is deflected to B, and on the second cycle to C.

Now let us assume the same force is applied to a curved beam "A", such as shown in Fig. 2. For the first half of the first cycle the beam is deflected to "B", and then to position "C" for the second half. But on the application of the second cycle, the beam again moves in the same direction to "B". This then produces the *same* number of cycles of motion as the applied force.

In actual practice, this theory is borne out only to a certain extent. The greater portion of the overload distortion is due to localized sections of the cone breaking up into small diaphragms, each capable of radiation with its own frequency response.

THE CURVED DIAPHRAGM

The use of curved diaphragms has allowed the engineer to reduce the amount of high-frequency response with a slight extension in range, although at the same time it has introduced a number of faults. It is fortunate that conical diaphragms, such as those used in loudspeakers, break up into various modes of vibration above the midrange and do not continue to act as pistons of constant mass throughout the entire range. If this were true, the response would fall off inversely as the frequency, and the loudspeaker would have only bass and midrange response. As it is, the cone breaks up into the various modes with consequent reduction in equivalent mass, and so gives rise to the high-frequency acoustic response.

The amount of this high-frequency response can be controlled only to a certain extent by the type of material used for the fabrication of the diaphragm, and by the size and shape of the diaphragm. The use of a curved instead of the straight sectioned cone has materially reduced this response. The amount of reduction is increased up to a certain point by a decrease in the radius of curvature (the shorter the radius—the more the apparent curvature). There are an infinite number of radii, combinations of two or more radii, or mathematical curves that can be used. It has worked out in practice that most types of response can be obtained with a single radii, with no need of using the more complicated shapes. This is especially valuable from an economical standpoint when it comes time to build production tools.

PROBLEMS INTRODUCED

Up to this time no specific mention has been made of the problems that have been introduced by the use of this type of diaphragm. It develops that for most units of this type, with a reduction of the above mentioned high-frequency response, a spurious response is being built up in the form of one or more peaks in the range that is very important to voice and music reproduction—i.e., 1000 to 2000 cycles. These peaks are very noticeable and give rise to a type of reproduction that was prevalent a number of years ago. The magnitude of this undesirable response increases with a decrease in radius of curvature. This fact forces the engineer to compromise between the conventional straight cone, having in some cases too many "highs," and one having a definite value of radius with its undesirable response characteristics.

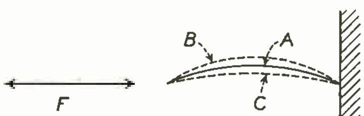


FIG. 2

The effect of the force F on a curved beam A, the result being the same number of cycles of motion as F.

The production engineer has also had new problems to face. The configuration of this curved-sided cone is such that slight deformations of the conical surfaces produce greater distortions of the round voice coil than that with the conventional straight-sided cone. It is also true that the curved cone has much

(*Continued on page* 14)

ADVANCED DESIGN OF

By MAURICE APSTEIN

Chief Engineer

MORLEN ELECTRIC COMPANY, INC.

The demands of true wide-range reproducing systems have dictated that in a real high-fidelity amplifier, a wide power range with low harmonic content is just as important as a flat frequency characteristic. The general acceptance of this fact has led the amplifier industry away from Class A amplification systems to the more efficient Class B and, more recently, Class AB types. The Class AB amplifier is peculiarly suited to wide-range reproduction due to the fact that at low output levels it operates as a Class A amplifier with consequently a very low percentage of harmonic content, at the same time affording a power swing far in excess of that obtainable with a Class A amplifier of comparable size and cost.

Certain requirements necessary for the proper operation of such an amplifier and, in particular, the necessity for driving the output power stage with an adequate amount of distortionless input power were discussed by the author in Radio Engineering for April, 1935. A continued study of the types of distortion peculiar to amplifiers which draw grid current has disclosed several problems, the solution of which should prove interesting to designers of this type of equipment.

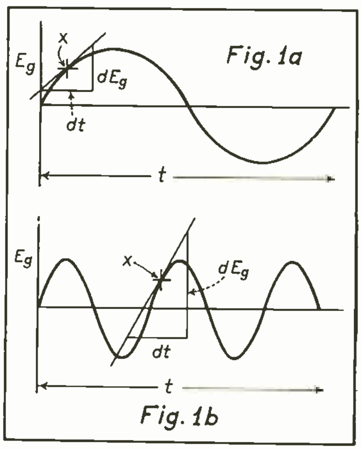
GRID CURRENT PROBLEMS

It has been pointed out (in the above-mentioned article) that the grid circuit of Class AB stages imposes very stringent operating conditions upon the driver stage, due to its variation in impedance. In addition, however, the flow of grid current introduces several additional and equally serious effects which must be considered if the full possibilities of the system are to be realized. The first of these effects is due to the sudden change of tube input impedance at the instant grid current starts to flow. This sudden change results in a surge through the grid circuit which almost invariably results in the setting up of a damped oscillation in the grid circuit. This oscillation is of course amplified by the output stage and appears in the output of the amplifier. Its frequency is determined by the values of inductance and stray capacity of the grid circuit and is practically independent of the frequency of the input signal.

Fig. 2a is an oscillograph picture of this form of distortion. It may be clearly seen that the break-up of waveform begins along the increasing *side* of the cycle rather than at the peak, and starts to die out as soon as the signal begins to fall back to zero.

SHOCK EXCITATION

The amplitude of the damped oscillation is almost invariably determined by the frequency of the input signal, and seems to increase as the frequency of the input signal increases. The reason for this latter effect can be easily shown by a physical analysis of the transient conditions in the grid circuit. The amplitude of any damped oscillation is dependent upon the rapidity of the shock producing it, or in other words, the slope of the charging current with respect to time. As the frequency of the input signal is increased, the slope of the portion of the cycle at the point at which the grid goes positive also increases, making the change from zero grid current to grid current flow more rapid and therefore increasing the severity of shock excitation.



Showing effect of shock excitation: Fig. 1a, at low frequency; Fig. 1b, at high frequency.

This effect is clearly illustrated by Fig. 1a, which is a plot of grid voltage Eg against time for a relatively low-frequency signal which causes grid current to flow at the point (x). The slope of the tangent at the point (x) is dEg/dt, and as may be seen in Fig. 1b, this slope approaches the vertical as the frequency is increased and the time axis is kept constant. Thus, with an increase of frequency the shock excitation to the grid becomes progressively more pronounced and the type of distortion caused by it becomes more and more noticeable. Below some critical frequency, at which the shock is just sudden enough to start oscillation, the surge will produce negligible effect. This critical frequency usually falls in the neighborhood of 1,000 cycles, although it is naturally subject to wide variation with different components.

UNDAMPED OSCILLATION

A second type of distortion common in both Class AB and Class B amplifiers is an undamped oscillation which occurs at the crest of the input signal. This oscillation is usually due to the tendency of the output tubes to act as dynatron oscillators when the grid voltage reaches an instantaneous value comparable to that of the plate. Its form is shown in the oscillograph picture of Fig. 2b.

The frequency of oscillation is usually somewhere between 10 kc and 30 kc and is determined by the values of the leakage inductance and distributed capacity of the input transformer. While it sometimes can be successfully damped out by the use of small by-pass condensers from grid to ground of each output tube, very often the leakage inductance and distributed capacity of the input transformer are so high that the frequency occurs too close to the audio band for the small condensers to have an appreciable effect without impairing the response of the amplifier itself. Current practice is to maintain the leakage inductance and the distributed capacity of the input transformer at the absolute minimum values possible. This causes the frequency of oscillation to be of such high period that it falls in the region where the amplifier response is low enough to prevent oscillation, or at least allow the use of such small by-pass condensers that the response will not be effected. In addition, resistors are inserted in the grid circuit of each tube to both increase the by-passing effect of the condensers, and to prevent the grids from being driven far enough into the positive region to cause oscillation.

This, at best, is only a partial solution, since the possible variations in design of the transformer are both limited and expensive, and the series resistors prevent the tubes from delivering maximum possible output

THIRD TYPE OF DISTORTION

A third type of distortion, very similar in form to the above oscillation, occurs most commonly in amplifiers designed for good low-frequency response; an obvious requisite of a high-fidelity system. This oscillation usually occurs when the frequency of the input signal is below 100 cycles and also takes the form of a very high-frequency oscillation appearing at the crest of the input signal. It is due to the non-linearity of the characteristic curves of the core material and the tendency to assume a a negative slope in certain regions of its operation, providing a magnetic effect analogous to a negative resistance characteristic in an electrical circuit, the latter being one of the basic requirements for an oscillatory condition. Since most commercial amplifiers today have poor response below 100 cycles at maximum output, this effect is not generally noticed, but in those systems that do have good response between 40 and 100 cycles, *and which retain that response as maximum output,* a very definite "fuzziness" occurring on certain bass notes at high volume may be directly attributed to this type of transient.

It is significant to note after having catalogued and analyzed these various forms of waveform distortion, that they are all dependent for their existence upon some resonant characteristic of the input circuit of the power stage. The obvious solution would be to eliminate from the input circuit any inductive (i.e., resonating) components, which is exactly what was attempted and which proved to be eminently satisfactory. A non-inductive coupling network indicated the use of resistance coupling as the method possessing the best possibilities. However, it must be borne in mind that the coupling must be designed for power-transfer efficiency; a very unusual application of this form of network. Conventional constants for resistance-coupled amplification are designed for maximum voltage transfer and neglect factors involving power efficiency which make them useless in this case.

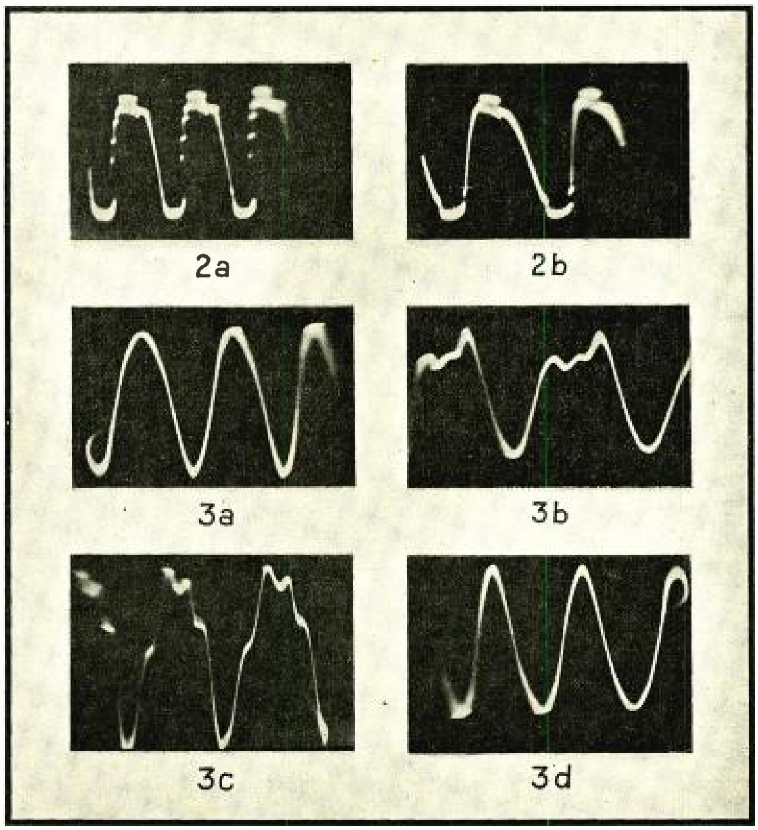


Fig. 3. A group of oscillographic photos showing waveforms obtained under various conditions of Class AB operation. Fig. 3d shows the 9000-cycle waveform obtained with the resistance-coupled method described in this article.

RESISTANCE COUPLING

The method of approach in the design of the amplifier illustrated was as follows: The use of resistance coupling necessitated that driving power be kept at a minimum; hence the output tubes should be of as high power sensitivity as possible, and still be capable of high power output.

These requisites are filled admirably by an output pentode such as the 6F6 metal tube in pentode connection. The compactness of the metal shell and the uniformity of construction and operation made possible by the new metal manufacturing technique allow four of these tubes to be used in the output stage without any of the usual electrical defects, and with remarkable compactness. With the advancements in control of frequency response, and the emphasis which has been placed upon reproduction of the higher audio frequencies, the rising frequency characteristic of the pentode, properly handled, proves to be beneficial rather than harmful; the latter being the heretofore generally accepted viewpoint. The rising characteristic may be used to compensate for many of the high-frequency losses encountered in audio amplification providing sufficient attention is paid to the low-frequency end to provide adequate bass and a consequently balanced reproduction.

THE DRIVER

In the driver two 6F6's as triodes, provide approximately four times as much power as is required to drive the output tubes to maximum. This excess power is an absolute necessity, not only as has been previously pointed out, but for the following additional reasons: The power-wasting characteristic of the resistance coupling network provides the very beneficial service of acting as a constant load upon the driver tubes *at all frequencies,* an effect practically impossible to obtain by loading the secondary of an interstage transformer with resistance. Since the power efficiency of commercial transformers of this type is a widely varying factor, the stabilizing effect of the resistance network is not as wasteful as it would seem at first glance. The optimum practical relations between stabilizing load and useful load are such that the coupling network absorbs somewhat more than half the power output of the drivers, with the grids of the power tubes providing an additional load which at full output absorbs an additional 25%. Thus the total swing of the driver tubes is about 75% of maximum; well within their linear characteristics, and yet the variation in driver load impedance is only one-third that which would normally obtain.

RESULTS OBTAINED

The four oscillograph pictures in Fig. 3 show a startling resume of the results which can be expected with the system described, compared to the results obtained with conventional transformer coupling. Fig. 3a illustrates the waveform at 400 cycles of three setups (two transformer and one resistance) taken at 35 watts output on the above amplifier. In all three the waveform coincides so closely that one picture suffices for illustration. Fig. 3b shows the waveform at 9000 cycles of one transformer at the same output level. Fig. 3c is a similar 9000-cycle exposure with a second transformer of another manufacture. Note that the breakup of waveform has different characteristics, probably due to a variation in design.

Both these transformers were designed for the specific application in which they were used and were of the highest grade obtainable on the open market, with frequency-response characteristics exceptionally flat between 30 and 12,000 cycles. It is significant to note that both transformers maintain good waveform at 400 cycles, at which frequency practically all commercial power output versus distortion ratings are made. The fact that standard signal generators and most harmonic analyzers operate with this frequency as a fundamental is an unfortunate coincidence. If these analyses were made at the critical frequency of the amplifier under test, the ratings would obviously be far different.

Fig. 3d shows the 9000-cycle waveform obtained at the same output with the resistance-coupled method described, the abbreviated circuit of which is shown in Fig. 4. No further explanation is necessary.

SUMMARY

By way of summary, the important conclusions to be drawn are the following:

1—Serious waveform distortion can and does occur in amplifiers which draw grid current, (all Class AB and Class B amplifiers) the percentage of distortion being a variable with respect to the frequency of the input signal.

2—By an unfortunate coincidence in the design of conventional test equipment, this type of distortion is usually least serious in the region of frequencies at which most amplifier and tube ratings are made.

3—The presence of this distortion is directly due to either the characteristics of the coupling transformer itself, regardless of its frequency response, or the mere presence of inductive reactance in the coupling circuit between driver and power stage, or both.

4—The use of a non-inductive coupling network not only eliminates the possibility of distortion due to the characteristics of the coupling transformer itself, but in addition provides a non-resonant coupling device which is not susceptible to transient or oscillatory conditions.

5—By proper design of the constants of the coupling network, it can be utilized to perform the very necessary function of stabilizing the load upon the driver tubes *equally well at all frequencies.*

6—Due to the limited power-handling capabilities of such a resistance network, high-gain, high power-sensitivity output tubes are recommended.

7—Performance from an amplifier designed with the proper application of the above principles adequately fulfills the requirements of a true high-fidelity system both as to power range and *low distortion percentage at all frequencies.*

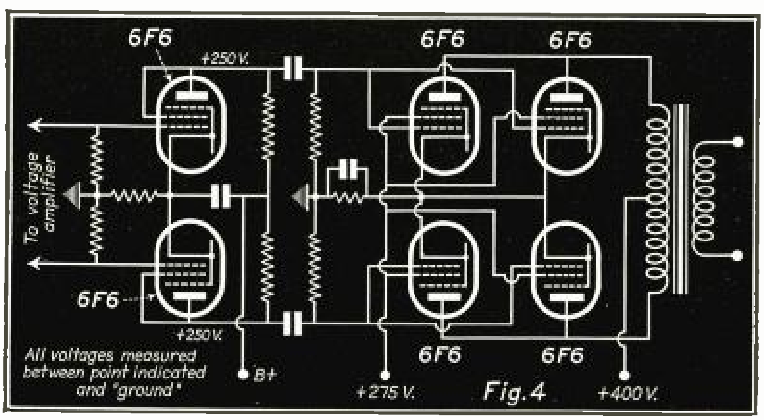


Fig. 4. The basic circuit of the resistance-coupled Class AB amplifier. The system is made possible through the use of metal-type output tubes having high power sensitivity.

SPEAKER DESIGN

(*Continued from page 11*)

less inherent rigidity. These facts necessitate new and improved methods of assembly and handling in order to produce a unit that will meet the rigid standards for acceptable performance set up by the industry.

This greater deformation has also made itself known upon application of high powers at low frequencies. There are always slight irregularities present in outer cone suspensions regardless of the type of suspension. Of course high input powers at low frequencies give rise to large amplitudes which, in turn, because of the above mentioned irregularities, cause voice-coil deformations and consequent off-center operation. All these problems must be taken account of in the development of new types of diaphragms.

RESPONSE CHARACTERISTICS

There have been endless discussions as to the type of response characteristics desired for the various applications of loudspeakers. It is pretty well established that it is necessary to partially compensate for the lack of high-frequency response in the conventional receivers, by the excess response of the loudspeaker. This excess response has had to be reduced for some applications, such as for use with the newer radio receivers having variable selectivity and consequently "flatter" high-frequency fidelity, and with the better types of public-address systems.

While it has not been possible to give definite quantitative data in an article of this length, it has been the object of the author to point out qualitatively the results that have been obtained and which may be expected with a curved diaphragm type of dynamic loudspeaker. There is no doubt that for certain types of applications more desirable response characteristics may be obtained from this type of unit. But the engineer is, as always, faced with the problems of balancing the results of a new and improved product against its increased economic cost.

A LOGARITHMIC CATHODE-RAY RESONANCE-CURVE INDICATOR

By SAMUEL BAGNO and MARTIN POSNER
RADIO INSTRUMENTS CO.

IN order to present a true picture of the selectivity of a radio receiver or any selective circuit, it is necessary to know how well a signal from a nearby station, whose field intensity may reach a fraction of a volt, may be eliminated and a distant station in an adjacent channel tuned in whose field intensity is in the order of microvolts.

Such a selectivity or resonance curve is plotted by determining what input voltage it is necesary to supply to the selective circuit in order to get a constant output throughout its range of response. The same results may be obtained by measuring the output for a constant input voltage.

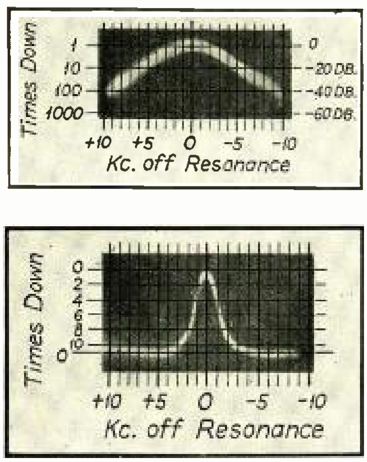


Fig. 1. Logarithmic curves obtained on screen of oscilloscope using the device described in the text.

This is the method used in obtaining a resonance curve in a cathode-ray band-response oscilloscope, where a constant r-f frequency, modulated over a desired frequency range in synchronism with a linear time base, is fed to the selective circuit under test and the output of this circuit, after rectification, is used to actuate the vertical deflectors.

LOGARITHMIC PLOTTING

The vertical deflectors give a deflection which is linear in volts. Thus if a one-millivolt signal will bring the height of the curve up to one centimeter, ten millivolts will show a curve ten centimeters in height. Now a curve ten centimeters high is just out of the range of the average cathode-ray tube screen (which is three inches in diameter), whereas at ten times down, or at a height of one centimeter, it is almost impossible to determine accurately the slope of the curve and its exact position.

In order to overcome these difficulties presented by a linear amplitude axis it has been customary, in plotting resonance curves, to plot the output on a logarithmic scale. An example of such a curve, projected on an oscilloscope screen by means of a new device to be described, is shown in Fig. 1. It can be seen from the curve that it is readily apparent what the selectivity is ten thousand times down, or at any given number of times down. Moreover, due to the inherent nature of the logarithmic curve, the percentage of accuracy to which the curve can be read is independent of the magnitude of the selectivity ratio at that point.

THE VACUUM-TUBE VOLTMETER

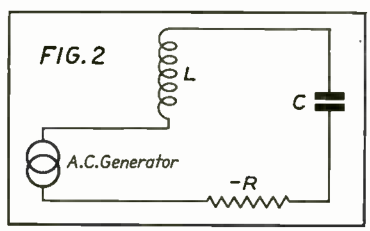
If a logarithmic amplitude axis could be provided for a cathode-ray band-response oscilloscope, then a resonance curve could be projected on the screen that would be linear in db and so could easily be read 10,000 times down. In order to accomplish this, it was necessary to devise a new type of vacuum-tube voltmeter whose output voltage would be directly proportional to the logarithm of the input voltage. Moreover. the instrument had to be able to respond to any signal from 10 microvolts to a tenth of a volt in a single range without overloading; that is, it had to be able to handle a 10,000-to-1 range of input voltages and keep well within the saturation characteristics of the tube. Such a translation device we found to exist in the guise of a super-regenerative detector.

SUPER-REGENERATOR USED

At this point it is advisable to describe the complete operation of the logarithmic unit as finally developed. Referring to Fig. 4, a frequency-modulated signal having a desired band sweep is fed to the selective circuit whose characteristics we wish to determine, and the output signal from this circuit is fed into the conversion grid of a 6A7 used as a mixer-oscillator. The output from the 6A7, whose amplitude now follows the shape of the resonance curve over the frequency-modulated cycle, is fed by impedance coupling to the input of a 20-meter super-regenerator. The resulting plate current change of this super-regenerative stage is converted into a voltage change by using the IR drop across a 10,000-ohm resistor in its plate circuit. This voltage is then fed through a low-pass filter (which has a cut-off slightly above 4,000 cycles and is used to take out the blocking frequency) to the grid of a voltage-amplifier tube, and the output of this voltage amplifier actuates the vertical deflectors of the cathode-ray tube.

OPERATION OF DEVICE

Now referring to Fig. 3, we can examine the operation of the super-regenerative detector in greater detail. A signal is fed into the grid of a tube so connected that in its steady state it would serve as an oscillator. When the input signal is of the same frequency as the frequency at which the tube tends to oscillate, the impulse fed to the grid of the tube is amplified and fed back to the input again. Here it is again amplified and again fed back.



Circuit illustrating a condition of negative resistance.

As a result, the impulse that was initially fed into the grid of the super-regenerator builds up exponentially until the voltage fed back to the grid from the plate is of such a magnitude as to saturate the tube. This saturated condition remains until an external impulse paralyzes the tube and thus prevents it from acting as an oscillator. Then this paralyzing impulse is removed from the tube and the cycle is permitted to recur. The length of time that it takes to saturate the tube depends on the strength of the input signal, and since the voltage in the tube builds up exponentially, the length of time required for the saturated condition is directly proportional to the logarithm of the input voltage.

SATURATION TIME

If now the blocking cycle is constant and independent of the input, the length of time during which the tube will remain saturated is equal to the time during which the tube is capable of acting as an amplifier less the time required for actual signal build-up within the super-regenerator itself. If we assume that the plate current follows the envelope of the signal in the super-regenerator stage, the portion of the plate current during the build-up period is always constant. This can be demonstrated in the following way: Let the input voltage to the super-regenerator be Em sin ωt, and the current through circuit i. The tube in its function as an amplifier feeds more energy into the tank circuit than the original energy of the input, and the amount fed back depends upon the input voltage. It can thus be described as a negative resistance (— R) which adds energy to the circuit instead of absorbing it as a positive resistance would do. The energy that it adds to the circuit depends on the voltage across the tank. This is shown schematically in Fig. 2. The current at any instant through the circuit in Fig. 2 is equal to:

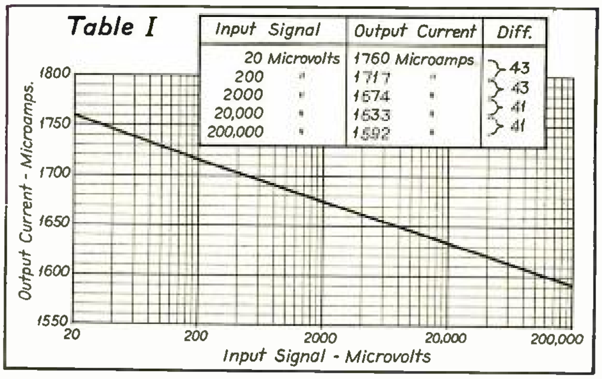


Table I

Input Signal	Output Current	Diff.
20 Microvolts	1760 Microamps	
200 "	1717 "	43
2000 "	1674 "	43
20,000 "	1633 "	41
200,000 "	1592 "	41

Complete input-voltage, plate-current characteristic for the voltmeter circuit.

$$E_m \sin \omega t = -Ri + L\frac{di}{dt} + \int \frac{idt}{C} \qquad (1)$$

The solution of which is

$$i = \frac{E_m}{Z} \sin (\omega t + \theta) + \frac{E}{Z} \sin \omega t e^{+\frac{R}{2L}t},$$

$$\text{where } \omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} \qquad (2)$$

From (2) it is evident that the envelope of the current during the build-up cycle, or the average current, is independent of the amplitude of the signal coming into the super-regenerator. This is shown graphically in Fig. 3. During saturation of the tube the plate current is constant and the length of time it lasts varies as the logarithm of the input voltage. Thus it becomes apparent that the average current is equal to a constant less the logarithm of the input voltage. This is especially true since during the decay cycle the tube is completely paralyzed and the average plate current during this portion of the cycle is always constant.

FREQUENCY OF RESONANCE

The frequency of resonance of the super-regenerator depends on the amount of negative resistance and the amount of positive resistance in the circuit. The formula is given as

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}.$$

Since the resistance varies, the resonance frequency likewise varies and by choosing the proper resistance-to-

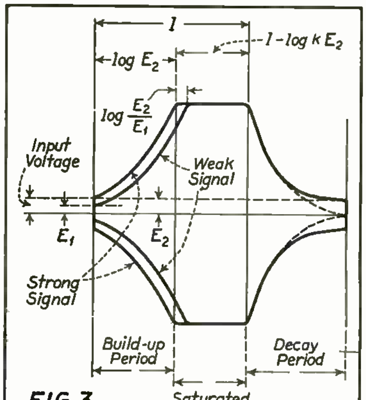


FIG.3

Illustrating the operation of the super-regenerative detector.

inductance ratio, the resonance frequency can be made to traverse the band, which may be 30- or 40-kc wide, required by the varying frequencies of the frequency-modulated input to the super-regenerator in such a way that the output over that range is substantially constant. This was accomplished by increasing the positive as well as the negative resistance of the super-regenerator, and at the same time increasing the input frequency during which the super-regeneration cycle occurs. The blocking cycle is made to occur at such a frequency as to cover a negligible distance on the cathode-ray tube screen. If the frequency-modu-

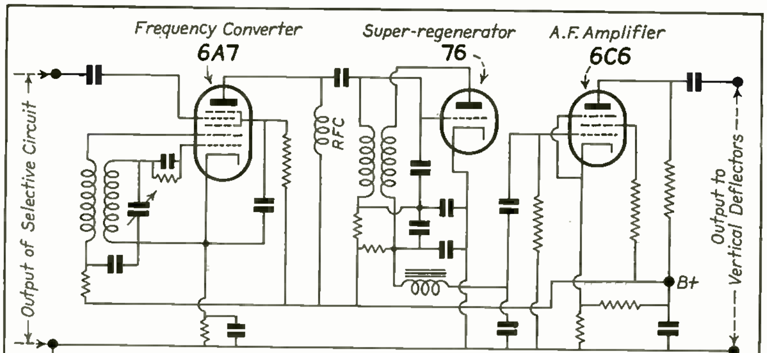


FIG.4

Circuit of the super-regenerative unit used in conjunction with the oscilloscope to obtain logarithmic curves.

lated cycle takes place in 1/60 of a second, and a three-inch cathode-ray tube is used, the blocking must be above 4000 cycles in order that the width of one cycle should be less than .05 inch. This condition is very easily obtained, since the limitations to a frequency higher than 4000 cycles are the build-up time required and the delay time, or the negative and positive resistance of the blocking cycle. If a 20-meter super-regenerator is used, the blocking frequency may be well above 15,000 cycles.

BLOCKING CIRCUIT WAVEFORM

The super-regenerative circuit used in the present instrument to give a logarithmic range was operated around 20 meters, and a frequency-conversion stage was used to convert the frequency fed from the selective circuit to 20 meters. For simplicity and ease of operation, the super-regenerative stage used was a modified Flewelling circuit. The waveform of the blocking circuit was made triangular by connecting the grid leak directly to B plus. By means of a capacity bridge. the tendency for the oscillation to block the tube periodically was increased considerably by producing the proper delay of the low-frequency plate current component. This delay substantially fixed the time required for the blocking cycle. Whereas this departed from the square-wave blocking circuit previously analyzed, the results were sufficiently close to permit that method of analysis to give a picture of its operation. The audio amplifier which followed the super-regenerative stage and fed the vertical deflectors of the cathode-ray tube was designed to eliminate any phase distortion at the lower frequencies so as to insure a true image of the amplified signal appearing on the screen.

SELECTIVITY RANGE

Due to the extreme sensitivity of the super-regenerator, it is possible to use this logarithmic vacuum-tube voltmeter with a radio receiver to cover a tremendous selectivity range and still keep within the saturation characteristics of the tubes employed by the receiver. The tube used in the present instrument will respond to a signal of about one microvolt, and requires a signal of well over a volt before it is thoroughly saturated. Table 1 gives a complete input-voltage, plate-current characteristic for the voltmeter circuit.

CHECKING I-F TRANSFORMERS

An instrument of this type can also be used to very good advantage in checking i-f transformers or a complete chain of i-f's for overall gain and selectivity. Since the sides of a resonance curve are essentially logarithmic, the slope of the characteristic curve shown on the cathode-ray tube is an excellent indication of the behavior of the selective system.

Another application is as a secondary standard for the calibration of signal generators, since the logarithmic curve and the extreme sensitivity of a voltmeter of this type make it possible to cover tremendous ranges of output. Numerous other applications will suggest themselves to engineers.

BRAZED SEALS FOR ALL-METAL TUBES

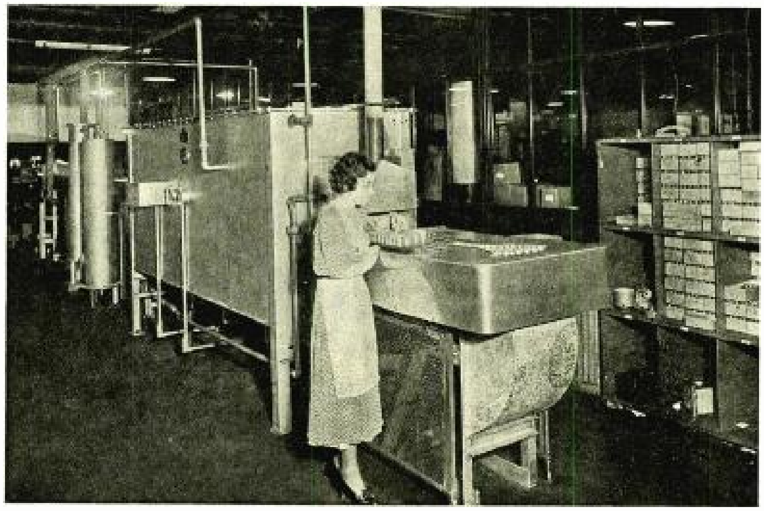
Completely automatic control of the temperature, time in the furnace, and furnace atmosphere during brazing and bright-annealing, thereby assuring uniformity of product and duplication of results, have been attained by the Radiotron Division of the RCA Manufacturing Co., Inc., Harrison, N. J., in the manufacture of the all-metal radio receiving tubes developed by the General Electric Company. In addition, pronounced savings in production and maintenance costs have been realized.

THE FURNACE

The production setup includes a General Electric mesh-belt conveyor-type electric furnace and combustion-type furnace-atmosphere controller, the latter supplying processed city gas to serve as the furnace atmosphere for only $1.75 a day. The combination is used in electric-furnace brazing the special-alloy eyelets of the all-metal tubes, in which are located the glass beads used to insulate the leading-in wires, to the "header," the annular part just above the base of the tube to which the envelope is later welded. The eyelets are first welded to the header. Next, a ring of copper wire is placed around each eyelet and then the header sub-assembly is placed on the mesh-belt conveyor of the electric furnace, coming out at the discharge and completely brazed and ready for the next step in the manufacturing process.

The 41-kilowatt furnace, with a capacity of 225 pounds gross an hour, is operated continuously, the belt traveling at 1-1/3 feet per minute. The heating chamber of the furnace is seven feet long and the cooling chamber eighteen feet long. The belt is eight inches wide, with a guard edge. Operation of the furnace is at about 2050° F. Both the belt and the ribbon-type resistors of the furnace are of long-life nickel-chromium alloy (Ni 80, Cr 20).

In those tubes having a lead through the top of the envelope, the additional eyelet used there is similarly both welded and brazed. In that case it is desired that the copper flow to a greater extent; hence the travel through the furnace is at one foot rather than 1-1/3 feet per minute.



Mesh-belt conveyor-type furnace. 41 kw, for copper-brazing and firing metal-tube parts. Belt 8 inches wide, door opening 6 inches high, heating chamber 7 feet long, cooling chamber 18 feet long.

The Electron Switch—

An Accessory for the Cathode-Ray Oscillograph

By ALLEN B. DUMONT
ALLEN B. DU MONT LABORATORIES

EVER since the cathode-ray oscillograph became useful in examining electrical phenomena, it had the disadvantage over the older electromechanical form of oscillographs of being capable of examining only one phenomena at a time, while as many as eight different phenomena may be examined simultaneously by some of the more elaborate forms of string oscillographs.

The electronic switch is designed to overcome this disadvantage. It enables the simultaneous observation of two separate phenomena by switching them alternately on the oscillograph. This switching is done so rapidly that the human eye fails to realize it and the two phenomena seem to be present at the same time. The rate at which the oscillograms change place must be at least thirty per second.

MECHANICAL VS. ELECTRICAL

On first thought it would seem that a mechanical vibrator could serve the purpose. In fact, mechanical vibrators have been used for such work in the past. There are, however, two serious disadvantages to these devices. One is that the frequency of vibration can't be varied within wide limits; the other is that there is a comparatively long time between the disappearance of one oscillogram and the appearance of the other. In the electronic switch the frequency of switching is adjustable so that the point on the oscillogram where the switching occurs may be made to fall always on the same part of the screen. The importance of this will be shown later. Care must be taken in the design of this switch to decrease the length of time between the appearance of oscillograms. This time should be made shorter than one ten-thousandth of a second.

THE MULTIVIBRATOR

The multivibrator was found to be the most practical device to accomplish the fast changeover of the two oscillograms. The operation of the multivibrator is well known by anyone skilled in the electronic art; therefore it will not be described.

Its function in this case is to overbias two amplifier tubes alternately. The input of each of these amplifiers is connected to one of the potentials under examination, while the outputs of both feed on to the cathode-ray oscillograph. Since only one amplifier is operative at a time—the other one being overbiased by the multivibrator—one of the oscillograms will appear amplified but free from the other. A short time after, the multivibrator quickly changes the bias and the other amplifier becomes operative. The faster this changeover, the clearer the oscillogram.

Although the multivibrator is practically the fastest available instrument in this respect, there is still a faint vertical line showing the point on the oscillogram where the changeover occurs. The presence of this vertical line does not disturb the observation as long as it remains standing on the side of the oscillogram. However, if the rate of switching is not synchronized with the signal, and consequently with the sweep oscillator, this line slides by from one end of the screen to the other, which is rather undesirable.

SYNCHRONIZING SWITCHING RATE

Synchronizing the rate of switching is done automatically in the electronic switch. Some of the output from the amplifiers is coupled to the multivibrator which has a tendency to pull in with one or the other signal. An adjustment of the rate of switching is provided on the front panel of the instrument which enables the operator to move the natural period of the multivibrator near enough to a quotient of the signal frequency so that it may pull into synchrony. This operation is very simple. All one has to do is to turn the knob until the line running across the screen stops. By turning the knob slightly to the right or left, it is possible to place this line almost anywhere on the screen. It is usually preferable to keep it on the side, off the oscillogram.

Front panel view of the electron switch for use with cathode-ray tubes.

APPLICATIONS

The number of applications of this instrument is many, and new ones are discovered daily. By way of an example, it may be well to mention the testing of audio amplifiers. Both the input and output of the amplifier are made to appear on the oscillograph and slight phase shifts or distortion can easily be detected by placing the two oscillograms on top of one another. This usually may be done throughout the audio range without changing the adjustment on the electronic switch.

Somewhat similar to this method is the testing of radio receivers. The audio frequency is modulated into the signal generator and the output of the receiver under test, together with the initial a-f, is put on the oscillograph through the electronic switch. Distortion in any part of the receiver becomes visible with this method. It is necessary, however, to have a good signal generator, properly modulated. For phase-shift tests on high-fidelity receivers this is a fast and accurate method.

In the laboratory the simultaneous observation of current and voltage in a circuit was found greatly facilitated with the electronic switch. It is also useful for supplying a timing wave on the cathode-ray oscillograph or for calibrating a-f oscillators by comparing them to a timing fork or other standard source of steady frequency, or for showing phase shifts of low-voltage electrolytic condensers, and for many other uses too numerous to describe.

All measurements and tests are comparisons in the final analysis and there is no better way to compare two oscillograms than by placing them right on top of each other.

Book Reviews

THE RADIO AMATEUR'S HANDBOOK, 1936 *Edition, by the A.R.R.L. Headquarters Staff.* 480 *pages (including a* 96*-page catalog section), with approximately* 500 *diagrams, charts and photographic illustrations.* 6½ *by* 9½ *inches, double-column format. Published by The American Radio Relay League, West Hartford, Conn., U.S.A. Price, paper binding,* $1.00 *postpaid in U.S.A. and possessions; elsewhere,* $1.15; *buckram binding,* $2.50 *in all countries.*

The present 1936 edition of the Radio Amateur's Handbook, published by The American Radio Relay League, is the completely revised and greatly enlarged successor to the previous series of 12 editions. In these nine years the Handbook has established itself the world over as the standard manual of amateur radio communication, and has been widely adopted as a practical reference by radio technicians and as a course book for radio study by many schools. The present edition actually constitutes an entirely new book, having a total of 21 chapters with an appendix of miscellaneous information and an exceptionally comprehensive topical index which makes quick reference easy.

An entirely new 30-page chapter on vacuum tubes contains comprehensive tabulated tube data, including 10½ pages of rating and characteristic tables for all types of metal and glass receiving tubes, as well as for transmitting and special-purpose tubes, supplemented by practical information on operating characteristics determinations and applications. The new receiver design chapter contains a wealth of circuit features described in concise, practical detail. Modern receiver construction is given a separate chapter, the how-to-make-it of a complete line of successful models from a simple two-tuber to a Single-Signal Superheterodyne with 12 of the new metal tubes.

In the chapter devoted to transmitter design, the theoretical and practical considerations involved in transmitter circuits are given sectionalized treatment, while in the chapter on transmitter construction the very latest circuit developments of proven merit are exemplified. Only modern transmitters are described, including multi-band models with coil switching. An enlarged chapter on keying methods is followed by a chapter on the principles of modulation and fundamentals of radiotelephony circuits, from microphones to controlled-carrier systems. The constructional chapter on radiotelephone transmitters gives design and operating details of successful types ranging from low to high power.

Ultra-high-frequency communication has two chapters devoted to it, telling how super-regenerative receivers work, and how to build them, describing superhets and the new super-infragenerator receiver. Construction of types with acorn, glass and metal tubes is included. The u.h.f. transmitter chapter is a practical treatment of proven circuits, from the simplest self-excited oscillator through linear oscillators, and oscillator-amplifiers.

Power supplies are treated in greater detail than ever, covering receiver-packs, voltage dividers, and supplies for grid-bias, as well as all the standard rectifier-filter equipment.

Antenna design is especially complete. Numerous charts facilitate the planning, from simple single-wire antennas to complex directional arrays; transmission-line design being given particular attention.

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A FUGUE IN CYCLES AND BELS, by John Mills, published by D. Van Nostrand Co., New York; 269 *pages, cloth covers. List price,* $3.00.

The author of this book is well known to most readers for such recent works as "Signals and Speech in Electrical Communications," "Within the Atom" and "The Realities of Modern Science." To the older generation, however, he will always be associated with the earlier work, "Radio Communication." While his best known works are of a strictly non-technical nature, albeit dealing with highly technical subjects, his original work was of a highly technical nature and appeared at a time when literature on radio subjects was anything but plentiful. Few, indeed, of the older men in the radio fraternity have not read and reread his original work.

The author states that this book is written for those who may wish to know what science is doing to music and what it can do for music. This book states the facts in non-technical language, emphasizing not how the wheels go 'round, but where they make take us. It is highly readable and interesting both for the material it contains and for the author's inimitable style.

This book is divided into five parts with eighteen chapters in all, dealing with such interesting material as: Electrical Ears, Amplifiers and Engineers, The Power of Music, Electrical Music, and Auditory Perspective. This treatise should have considerable appeal for the non-technical reader, who likes to take his dose of technical information with a coating of non-technical sugar. While there may be no royal road to an understanding of this subject, the author has at least eased the bumps and jolts along the way by the use of homely illustrations taken from every-day life, as well as by his point of attack. The author keeps the reader sufficiently removed from the details so that he can see the forest rather than the trees.

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MAKING A LIVING IN RADIO, by Zeh Bouck, published by McGraw-Hill Book Company, Inc., New York, N. Y. 222 *pages, cloth cover. Price* $2.00.

In writing "Making a Living in Radio," Zeh Bouck has not only blown the nose of the radio industry, but wiped it as well: that which is misleading has been labeled as such; that which is honest has been given due credit.

And it is of importance to you and to others connected with the multitudinous phases of radio, that the industry be held up before the prospective student and the ambitious disciple of radio with a washed and polished schnozzle.

This is not to say that "Making a Living in Radio" is a book only for the man or woman who wishes to enter some phase of the business; it should be of equal value and interest to the service man, the engineer, the announcer, the commercial operator and the writer, for there are lessons to be learned from the text by the industry's own children—particularly those children who have eyes on some other branch of the business or who are ambitious to better themselves in their chosen niches.

The first chapter deals with cold facts —unemployment in the radio industry, what opportunities exist or may exist in the future, where such opportunities may arise, etc.

Subsequent chapters deal with the radio service man, the business of servicing, the radio operator, the engineer, horizons and the engineer, broadcasting, radio writing and industrial radio work.

An appendix includes a fine bibliography, together with the reviews of books chosen by the author as helpful in the various branches of the profession. There is also a list of addresses to which application can be made for radio operating positions, and of companies specializing in transcribed programs.

HIGH-GAIN AMPLIFIERS

Approaching the Audio Gain Limit with Commercial Electronic Devices

By HUBERT L. SHORTT
Chief Engineer
WHOLESALE RADIO SERVICE CO., INC.

Modern low-level input devices, such as the excellent crystal and velocity microphones now used everywhere, have in the past few years revolutionized the requirements of public-address and similar amplifiers, and driven designers of such amplifiers closer and closer to the theoretical limit of audio gain.

Gain requirements have increased steadily from the 60 db required a few years ago for high-level carbon microphones, to the 120 db necessary in commercial public-address work today. This doubling of a logarithmic exponent means little or nothing to the user of the apparatus, but has presented endless headaches to the engineer.

GAIN REQUIREMENTS

It is necessary to translate the decibel ratings just given into more commonplace electrical terms if the problems involved are to be examined in detail. In the final analysis an amplifier is a voltage-amplifying device, and the problems it presents to the designer are of a voltage character. Taking for granted that the tubes are capable of producing the necessary output voltage at the required output impedance, the essential requisite of any public-address amplifier is enough voltage gain to provide the rated power output from modern low-level input sources. Assuming the amplifier is to deliver 30 watts power to a 500-ohm line, which is a sufficiently common requirement, the output voltage that must be developed will be approximately 123 volts. At 120 db gain the input voltage will be 123 microvolts, and the amplification ratio, or mu, in the order of a million to one, a voltage gain almost undreamed of in the old days.

The input voltage involved is so small that it cannot be measured directly by any instruments available in ordinary laboratories but must be obtained indirectly by calculating a ratio.

HUM PROBLEMS

Although many problems are involved in dealing with voltages of that order, obviously the first major question to present itself will be that of hum pickup. Even in the case of a midget radio the power transformer and power chokes will often give rise to eddy voltages, between certain extremities of the chassis, that are stronger than the voltage output of a modern public-address microphone. Yet the power coils involved are much smaller than those used in the average amplifier. In the amplifier the transformer and chokes carry a-c at something like one thousand billion times the power of the microphone line. It is impossible to space those two circuits any great distance from each other, since commercial requirements limit the size of the entire amplifier to something less than twelve inches square.

The problems of avoiding hum pickup in such equipment are enormous. Potential differences are often encountered across relatively short distances of the chassis, or in amazingly short ground loops, that give rise to loudspeaker hum strong enough to drown out the microphone sound. The complete suppression of such phenomena is the first headache encountered in the design of modern amplifiers, and presents a problem of the first order, involving exhaustive experiment in shielding, grounds, and the placement of power coils.

TUBE CATHODE HUM

Despite the difficulties just outlined, present-day commercial amplifiers have been advanced to the point where their gain is not limited by any factor in their own construction, but by hum level introduced by the cathodes of the tubes. The amplifier engineer can do no more. The next step is up to the tube maker. The writer has assembled enormous quantities of data upon the cathode hum level of present-day tubes, which may be made public in the near future. It should be noted, however, that the hum level of tubes of all makes is constantly changing, indicating that manufacturers pay little attention to this point. It would be most helpful, not only to the designer but to the user of modern amplifiers, if manufacturers would rate their tubes according to hum level as well as other factors. This would assure a more constant product, and enable users as well as makers of amplifiers to choose tubes that will not cause them trouble.

Another difficulty introduced by tubes, which limits audio gain, is the microphonic level, created by loose elements. This factor also should be rated by the makers of tubes. Contrary to what may be thought, metal tubes have as yet not been found superior to glass tubes in this respect.

GENERAL REQUIREMENTS

Before going further it may be well to enumerate all of the more important requirements of a modern p-a amplifier, in addition to those of 120 db gain, low hum level, and low noise level.

(a) Twenty-five to thirty-five watts power output represents the average demand made upon public-address equipment today.

(b) The harmonic content at that output into a 500-ohm line must be limited to 6 or 7 percent.

(c) The frequency response must be in keeping with that of the input devices, which in the past few years have improved amazingly.

(d) Trick circuits cannot be used, since the equipment may have to be serviced in the field.

(e) The possibility of field servicing also requires accessibility of all parts and reasonably standardized construction.

(f) Tubes should be of types that are available everywhere throughout the world.

(g) Components capable of standing abuse, not of the radio receiver variety, since the equipment may be used commercially, where a breakdown will be a serious and expensive matter. It will often be exposed to rough handling in transportation year after year, and compelled to operate from power lines of deplorable regulation.

SUBSIDIARY REQUIREMENTS

Less important characteristics, which are still in urgent commercial demand, are:

(h) Direct-current output adequate to the field coil needs of loudspeakers used with the amplifier. This presents a point of economy important to the user, since the cost of the speakers in a p-a system often exceeds by several times the cost of the amplifier.

(i) An input mixer capable of blending sound voltages from two or more sources, permitting the use of more than one microphone or of a phonograph as a background to microphone speech. (This requirement must be met in the face of the hum pickup problems described previously).

(j) A tone control, useful not only for monitoring quality, but often indispensable for opposing feedback when a high-level sound output is used with a modern low-level microphone.

The writer considers that these requirements fully cover what may at the present time be termed a good commercial high-gain, public-address amplifier. They are met in the circuit diagrammed in Fig. 1, which offers examples of concrete and practical solutions to the problems set forth above.

THE CIRCUIT

High-mu triodes are used as preamplifiers ahead of the two-channel mixer circuit, which is built around a 53. This arrangement effects a sharp increase in signal voltage before the mixer controls are reached. Without such preamplification noiseless mixing would be difficult to obtain, and any wear or deterioration of the mixer potentiometers would introduce serious noise. With the preamplification arrangement used, however, the mixers operate at a sufficiently low level to provide trouble-free results over long periods of time.

The mixer feeds into a second 53, which excites the 59 driver. The more common practice would be to use the mixer output to excite the 59 directly, and employ a higher gain preamplifier. The use of an additional driver stage, however, is more than justified by the lower harmonic content achieved.

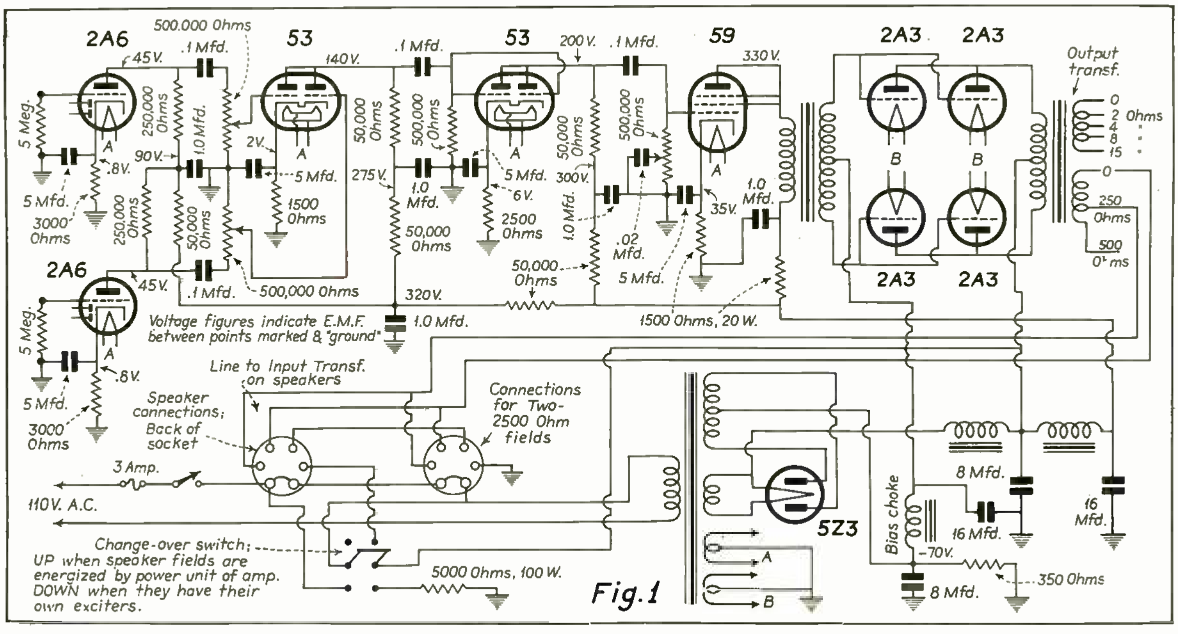
Similar considerations of sound quality dictated the choice of a 59 as driver, in place of two 56's often used for that purpose, the latter being incapable of providing the full power output necessary when the grids of the final stage swing positive. At the same time the use of the 59 affords a lower source impedance—a factor very vital in Class AB operation.

Several advantages are realized through the use of four 2A3's in push-pull parallel. The output stage composed of these tubes is in no way strained at maximum volume, and contributes extremely little harmonic distortion. Two tubes only could be used, with higher plate and bias voltages, but the small cost of the additional 2A3's is more than compensated for by the longer tube life, realized through the use of conservative plate voltage. Lower plate voltage furthermore reduces the possibility of condenser breakdown or other high-potential troubles.

POWER SUPPLY CIRCUIT

A striking feature of this circuit lies in the use of a speaker field supply which is in no way part of the amplifier filter system, in consequence of which the performance of the amplifier remains entirely independent of the number or type of speakers used. A simple switch, seen at the lower left of the drawing, permits the substitution of a-c speakers, the power circuit being closed in that event by means of the 5,000-ohm, 100-watt resistor shown just to the right of the switch.

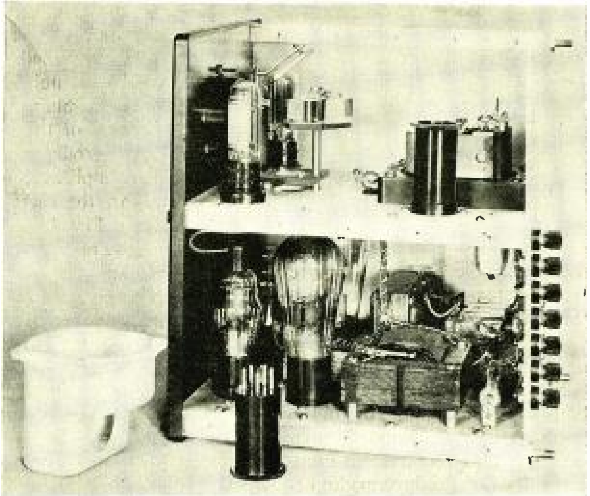
The bias of the power tubes is supplied through a separate filter. This arrangement affords operating characteristics that closely approach the results obtained with fixed bias without necessity for a separate rectifier. Moreover, the separate filter keeps the grid bias source impedance approximately 500 ohms, a result never attained when separate rectifiers are used, and compensates for a great part of the variation ordinarily encountered when the grids swing positive. Theoretically, of course, a separate bias supply is steadier, but in practice, since it requires a 2,500-ohm bleeder, the variations in voltage encountered are almost as great as those found in the circuit here diagrammed.



Design details of the amplifier. It has a peak output of 38 watts, gain of 124 db, hum level 42 db below sound output. Frequency-response variation between 40 and 10,000 cycles is 2 db.

AUTOMATIC POTENTIOMETER

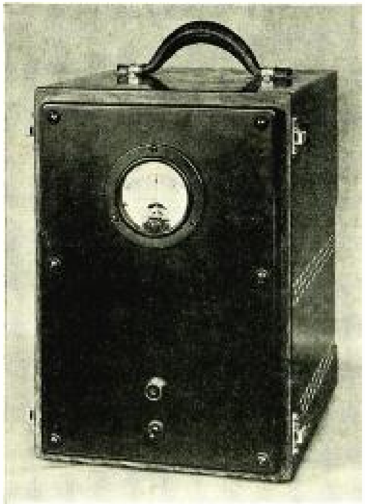
Operates at High Speed



Interior view of the automatic potentiometer, showing the photo tubes on the upper deck and the rectifier and control tubes on the lower deck.

RAPID OPERATION OBTAINED BY USING PHOTO TUBES IN BRIDGE CIRCUIT

An automatic potentiometer in which the balancing circuit is continuously and rapidly adjusted by photoelectric control has been developed by engineers of the Weston Electrical Instrument Corporation. The instrument provides a highly sensitive means for indicating or recording voltage or current at ranges as low as 2 millivolts or 5 microamperes full scale, or even lower if required. Temperature, pH values, or other physical quantities convertible to electrical terms may be indicated, recorded or controlled with a speed and precision hitherto unattainable in dealing with the minute electrical input encountered in many such applications.



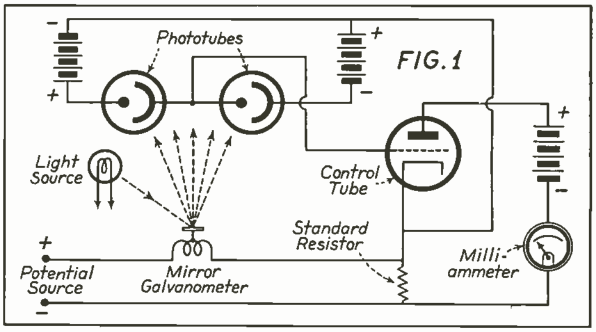
The automatic high-speed potentiometer in its carrying case.

PHOTO TUBES IN BRIDGE CIRCUIT

The instrument furnishes an indicating current capable of operating a number of meters, recorders, control relays, etc. which can be placed at any distance from the potentiometer proper.

The instrument contains no moving parts with the exception of the galvanometer itself, which has no control torque and is free of zero drift. Deflection of this mirror galvanometer causes a beam of light to differentially illuminate a pair of photo tubes. These photo tubes (See Fig. 1) are in a bridge circuit connected to the grid and cathode of a vacuum tube, so arranged that the changing light differential between the photo tubes results in a change of grid voltage. This change in grid voltage, in turn, electronically readjusts the indicating current to balance the circuit across the standard resistor. The circuit will hold itself in balance constantly, and immediately readjust itself for any change of input value. Balance involving a full scale change in indicator deflection takes place in a fraction of a second.

This system of balancing is independent of elements other than the value of the standard resistor and the meter giving the final readings. Changes in supply voltage, vacuum tube characteristics, photo-cell efficiency, light source intensity, etc., lie outside the critical circuit. Thus, the instrument can be used on the regular power supply, and need not be checked against a standard cell. The standard resistor is arranged for plug-in connection, so that the range of the instrument can be changed at will.



The diagram of the automatic high-speed potentiometer using two photo tubes in a bridge circuit.

RMA NEWS

RMA BOARD AND SET DIRECTORS TO MEET

INDUSTRY PROMOTION plans for 1936 will be considered by the RMA Board of Directors at a meeting scheduled by President Leslie F. Muter for January 29 at the Stevens Hotel in Chicago. This will be the first meeting in 1936 of the RMA governing board and on the same date Chairman Arthur T. Murray of the Set Division will hold a meeting of the set directors. Several important policies, in view of new developments in the industry, require the attention both of the set group and the Association's governing board. Several cooperative measures with the National Association of Broadcasters and other affiliated organizations are being promoted, including the plan for a Radio Foundation to make industry awards for outstanding achievements in 1936. At a meeting December 11 at the Commodore Hotel in New York City, the RMA directors made progress on several projects proposed for the new year and these will be developed further by the RMA board at the January 29 meeting in Chicago. More definite data on receiving set ownership in detail and by States, of interest to broadcasters and advertisers as well as the radio manufacturing and distributing interests, is one of the constructive projects under consideration. The cooperation of the RMA in developing such data has been requested by the National Association of Broadcasters, the American Association of Advertising Agencies and the American National Advertisers.

OCTOBER EXPORT INCREASE

SUBSTANTIAL INCREASE in American radio exports which began last August continued through October, according to the last report, for October, 1935, of the U. S. Bureau of Foreign and Domestic Commerce. They approached the $3,000,000 mark for the month, compared with $2,143,756 in September, and were ahead of the $2,378,592 exports in October, 1934. Export interest in American radio is also indicated by an unusual number of foreign inquiries received at RMA headquarters. The new RMA trade directories, detailing the companies, personnel and products of Association members, have been widely circulated abroad and detailed information is given from RMA headquarters to the numerous foreign correspondents.

During October, 1935, the total value of radio exports was $2,714,113, according to the last report of the U. S. Bureau of Foreign and Domestic Commerce. The October exports included 63,552 receiving sets, valued at $1,659,892, compared with exports of 57,678 sets valued at $1,454,593 in October, 1934.

Tube exports during October, 1935, numbered 667,185, valued at $307,320, compared with exports in October, 1934, of 648,326 tubes, valued at $291,953.

Receiving set components valued at $504,103 were exported in October, 1935, compared with $437,442 in October, 1934.

Loudspeakers exported during October, 1935, numbered 27,751, valued at $51,882, compared with 20,640 speakers valued at $50,062 in October, 1934.

Other radio accessories valued at $38,057 were exported in October, 1935, against $51,556 in October, 1934, and the values of exports of transmitting apparatus, respectively, were $152,859 against $92,986.

That the total 1935 exports will equal or surpass 1934 exports is indicated by the available figures on exports for the ten months ending October, 1935, as compiled by RMA. These were $20,300,059 for the first ten months of 1935 against $19,762,462 during the similar period last year.

During the ten months' period receiving set exports totaled 460,080 valued at $11,966,410, compared with exports of 474,070 sets valued at $11,787,071 during the ten months ending October, 1934.

Tube exports during the ten months ending October, 1934, were 5,450,252 tubes valued at $2,368,585, compared with 5,615,470 tubes valued at $2,738,245 during the period ending October, 1934.

Exports of component parts during the ten months ending October, 1935, were $3,804,334, compared with $3,634,760 during the first ten months of 1934.

Loudspeaker exports during the ten months ending October, 1935, were 164,762 valued at $383,122, against 111,817 speakers valued at $293,126 during the comparative period of 1934.

Exports of other radio parts during the ten months of 1935 were $411,397 against $411,069 in the similar period of 1934, while exports of transmitting apparatus during the comparative periods were $1,366,211 and $898,191.

ONE-FOURTH INCREASE IN 1936 SALES SUPPORTED BY NOVEMBER EXCISE TAX

THE OFFICIAL November report of excise tax collections, released December 20, indicates further that 1936 sales of the radio industry will show an increase of about 25 percent over 1935. This preliminary estimate is supported by other information and statistics available in the industry.

During November, the U. S. Revenue Bureau reports, the 5 percent radio and phonograph excise tax collections were $571,479.61, an increase of 23.5 percent over the collections of $462,638.47 during November 1934. This data does not include excise taxes on automobile radio which are not separately reported but are included among automobile accessories taxable at 2 percent. During November, 1935, the excise tax collections on mechanical refrigerators were $309,108.68 against $147,376.52 in November of last year.

The radio excise tax collections for the eleven months ending November, 1935, according to tabulations of RMA, totaled $3,706,420.65, an increase of 25.5 percent over the similar excise tax collections of $2,952,737.48 for the similar eleven months' period of 1934. The radio tax collections for eleven months of 1935, with the December returns yet to come, were already larger than the total 1934 radio taxes of $3,520,855.47.

RMA WILL DESIGN APPARATUS TO TEST AUTOMOBILE IGNITION

IN FURTHER cooperation with the automotive industry in the promotion of automobile radio, the RMA Board of Directors has arranged to develop apparatus to test radio interference of automobile motors. Substantial funds to employ special engineering talent, develop and design such interference testing apparatus was voted by the RMA Board of Directors at its meeting in New York City on December 11, on recommendation of Chairman Baker of the RMA Engineering Committee.

For several years the Society of Automotive Engineers and the RMA engineering staffs have been working closely together in developing automobile radio. The interference problem has been one of the most important and will increase with the future development of facsimile and television. The joint committee of SAE and RMA at a meeting last month in New York decided that lack of apparatus to make exact tests of automobile motor interference was a serious deficiency in the studies and work of both automotive and radio engineers. The responsibility of designing apparatus, to be manufactured in the radio industry, to test motor ignition interference was regarded as that of the radio industry, and the RMA Board of Directors has proceeded to provide for proper testing equipment.

Another automobile radio problem which has had the attention of the RMA Engineering Committee concerns the frequencies of many sets covering wavelengths to 1600 kc. A few police allocations are immediately beneath the 1600-kc limit and many standard designs of automobile receivers extend to this band. The RMA Committee on Broadcast Receivers has advised the Association's Board of Directors that it is not commercially feasible to entirely prevent the possibility, under certain circumstances, of reception of police signals on automobile receivers designed for reception of the broadcast band. However, the engineering committee and the Board of Directors both are opposed to the building of automobile receivers for sale to the general public which are specifically designed to receive police frequencies. Little or no difficulty thus far has developed however from the extension of standard receivers to the 1600-kc frequency and no serious opposition from police authorities to such extension has been encountered, probably because of the very small amount of police broadcasting on the frequencies just below 1600 kc.

RMA ENGINEERS ACTIVE ON MANY PROBLEMS

IMPORTANT ENGINEERING developments are requiring unusual activity of RMA engineering committees, under the direction of Dr. W. R. G. Baker of Bridgeport, Conn., general chairman, and Virgil M. Graham of Emporium, Pa., chairman of the Standards Section. The heavy work and responsibility of the RMA engineering staff

(*Continued on page 25*)

NEWS OF THE INDUSTRY

OUTLOOK FOR 1936

By Gerard Swope
President, General Electric Company

The volume of electrical manufacturing business in 1935 was approximately 30 percent greater than in 1934, which was about the same increase as was shown for 1934 over 1933.

Consumption of electricity in the United States was the greatest in the history of the country, being about 7 percent more than in 1934 and 3 percent more than in 1929, the previous peak year. As I said last year, this has been due largely to increased use of electrical appliances in the home.

Orders for capital goods in the electrical manufacturing industry have not increased to any great extent, because of the difficult position of the public utilities and transportation companies throughout the United States. Practically the only increase in the production of capital goods has been brought about by the modernization of industrial plants.

Successive increases in the use of electricity must eventually mean an increase in the generating capacity of public utilities, which will bring an increase in orders for capital goods to the electrical manufacturing industry.

For the year 1936 we look forward to a continued improvement in business.

"CALLITE CONTACT POINTS"

Callite Products Company, 540 Thirty-ninth Street, Union City, New Jersey, have just issued a new catalog entitled "Callite Contact Points".

The major purpose of this 24-page, well-illustrated catalog is to provide contact buyers with a practical, ready-reference handbook for every-day use. It has been divided into two sections; one section being informative in nature, while the second section contains considerable tabular data.

New equipment, improved methods in manufacture, and an increased line of 9 different styles of tungsten contacts in over 500 standard stock types are three advances of interest to buyers of electrical contacts.

AMERICAN CONDENSER OPENS FACTORY

The American Condenser Corporation have opened a factory at 2508 South Michigan Avenue, Chicago, Illinois, for the manufacture of electrolytic and paper condensers. Mr. Irving Menschik, long associated with the radio industry, has been placed in charge of the manufacturing.

NEW HASKINS CATALOG

R. G. Haskins Company, 4636 West Fulton St., Chicago, has just published a new general catalog No. 44, covering their line of flexible shaft equipment.

In addition to complete specifications for the machines, this 40-page booklet treats of the many applications of this type of equipment in the various industries and contains a large number of illustrations.

RADIO AND P-A FOR TEXAS EXPOSITION

The most complete and versatile radio and public-address system ever devised will serve the Texas Centennial Exposition, which opens in Dallas, June 6.

Construction on the elaborate system will be started Jan. 1, it was announced by O. H. Carlisle, Southwestern Division Manager for the Gulf Refining Co., who purchased sponsorship and will build studios and the system at a cost of $120,000.

Included will be a centrally located radio building, portable transmitter, twenty loud-speaker units on half a dozen separate public-address systems, and a public-address truck, to be used for special events in areas outside the Exposition.

Focal point for programs and operations will be a beautifully appointed radio building. Centrally located on the grounds, the building will house the master control room and two complete studios with individual control rooms for each.

KENNEDY RETAINED BY RCA

Following the regular meeting of the Board of Directors of the Radio Corporation of America, Mr. David Sarnoff, President of the Corporation, announced that the services of Mr. Joseph P. Kennedy, former Chairman of the Securities and Exchange Commission, have been retained by the Corporation for the special purpose of making a study of the problems relating to its capital structure.

Mr. Kennedy is undertaking this study immediately, and will advise the Board as soon as it is completed.

NEW GRUNOW OFFICIALS

Wm. C. Grunow, head of General Household Utilities Company, manufacturers of Grunow Radios and Refrigerators, has announced the appointment of Howard J. Shartle as General Sales Manager and Otto H. Bowman as Assistant Sales Manager.

Mr. Shartle, long known for his successes in the electrical appliance field began his career as a stenographer with the Victor Talking Machine Company and upon leaving that organization to become President and General Manager of the Cleveland Talking Machine Company had risen through various factory and executive assignments to charge of all domestic and export phonograph record sales.

Otto H. Bowman, the new Grunow Assistant Sales Manager has been associated with Mr. Grunow since 1919 and has headed the well-known Janney-Bowman Company of Detroit. He established the Grunow organization's first 23 distributorships and is highly regarded by electrical appliance wholesalers and retail merchants throughout all 48 states.

"PLASKON" COMPANY

Toledo Synthetic Products, Inc., makers of Plaskon, colorful urea molding material, announces a change in name effective January 1. 1936.

The new name of the company is Plaskon Company, Inc.

"THE ELECTRONIC PARADE"

The Electronic Laboratories, Inc., Indianapolis, Indiana, have recently issued a very interesting and useful booklet entitled "The Electronic Parade". Among other things is a cross index reference of Electronic vibrators, replacement guide, and a 32-volt vibrator replacement guide and cross index. Circuit diagrams and descriptions are included for a converter, and vibrator tester. Various other charts and circuit diagrams are also included.

I. R. E. FORMS NEW SECTION

The eighteenth section of the Institute of Radio Engineers was authorized by the Board of Directors at its December meeting. This section will be known as The Emporium Section with headquarters at Emporium, Pennsylvania. The organization meeting was held on December 12, 1935 with E. Finley Carter, Sylvania Division Engineer of Hygrade Sylvania Corporation, acting as Temporary Chairman.

Officers elected for the year were R. R. Hoffman, Chairman, Herbert A. Ehlore, Vice Chairman, Lloyd E. West, Secretary, Virgil M. Graham, who has recently been elected to membership on the I. R. E. Board of Directors, was appointed Chairman of the Meetings and Papers Committee for the Emporium section.

Harold P. Westman, I. R. E. National Secretary, who made a special trip to Emporium to attend the initial meeting, spoke briefly on the history of the Institute and the responsibilities of a section. George C. Connors of New York City and Charles E. Marshall of Chicago spoke on "The Work of a Field Engineer." These two papers were discussed by Walter R. Jones of Emporium.

Although the newest, The Emporium Section is far from being the smallest. About forty new applications for membership have been received since the organization. These will bring the total membership of the section up to seventy or more.

The fact that this is the first section in seven years to secure sanction from the Board of Directors for organization is a compliment to the engineering activity in the Emporium District.

NEW ADDRESS FOR KAHLE

Kahle Engineering Company has moved from 300 Manhattan Avenue, Union City, New Jersey, to 941 De Motte Street, N. Bergen, New Jersey.

NEW STRUTHERS DUNN CATALOG

An interesting and colorful catalog consisting of twenty-eight pages and cover has just been issued by Struthers Dunn Inc., 139 North Juniper St., Philadelphia, Pa.

It deals with relays, timing devices, thermostats, pots and ladles, resistors, thermal links, insulators, etc.

A copy will be sent free to anyone writing Struthers Dunn Inc., and mentioning this magazine.

HAMMARLUND CATALOG "36"

The Hammarlund Manufacturing Company, Incorporated, 424-438 West 33rd Street, New York City, now have available their new Catalog "36". This 12-page catalog covers condensers, coil forms, sockets, transformers, chokes, shields and other products for ultra-short-wave, short-wave, and broadcast receiving and transmitting use. The numerous items are illustrated, technical descriptions, charts, diagrams, curves, etc., being included.

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MAHONEY ADDRESSES C. R. E. C.

Mr. Charles Mahoney, head of the metallurgical department of The Ken-Rad Corporation, Owensboro, Ky., tube manufacturers, addressed the Chicago Radio Engineers Club recently on the subject of "Radio Tubes and Metallurgical Problems." Mr. Mahoney brought out several interesting points not generally known in the industry. The speaker made particular reference to research and development work on metal tubes.

The Chicago Radio Engineers Club is an organization composed of the leading radio and tube engineers in the Chicago area. Their meetings which are held semimonthly, frequently develop technical discussions that are of special interest to this specialized group.

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QUINBY JOINS WESTERN ELECTRIC

Edwin Jay Quinby has joined the public relations department of the Western Electric Company in an editorial capacity. He is located at the Company's headquarters, 195 Broadway, New York.

Mr. Quinby was formerly a member of the publicity and advertising department of RCA-Victor, where he founded and edited that Company's sales publication, "Broadcast News." Previously, he was associated with Bell Telephone Laboratories as an engineer.

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CENTRALAB PURCHASES PERFEX CO.

According to information received from Mr. H. E. Osmun, Vice-President of Centralab, Milwaukee, Wis., manufacturers of volume controls, sound projection controls and fixed resistors, this firm has purchased the Perfex Controls Co., of Milwaukee, Wis., line of wave-change switches and other radio products.

While Centralab have been working on their own switch developments, this move seemed the quickest and most logical way of entering this business, so closely allied, in these days of short-wave radio to their own business.

The Perfex Switches enjoyed considerable acceptance and were approved and used by leading radio manufacturers, it is said. These switches under the Centralab banner will be included in the line and will be advertised along with Centralab's other products.

A number of the sales personnel and engineering staff of the Perfex organization will be retained by Centralab.

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AGENCY WANTED

The agency for U. S. manufactured radio parts, especially volume controls, fixed condensers and resistors, is wanted. Address Elma 10, Rue Theophraste Renaudot Paris 15 (France).

"THE PEDDLERS"

"The Peddlers", an organization of radio parts salesmen, has changed its name to "The Representatives of Radio Parts Manufacturers".

The following officers were elected at a recent meeting: J. B. Price, President; Earl Dietrich, Vice-President; David Sonkin, Secretary and Treasurer. The Membership Committee is composed of D. R. Brittan, 27 Park Place, New York, N. Y., Martin Camber, c/o Micamold Radio Corp., 1087 Flushing Ave., Brooklyn, N. Y., and H. C. Gawler, c/o Raytheon Production Corp., 30 E. 42nd St., New York, N. Y.

The Membership Committee invites all representatives of radio parts manufacturers to communicate with reference to their joining the organization.

It is the hope of the organization to become national in scope, and that local chapters will eventually be organized in various leading centers.

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IMPORTERS AND EXPORTERS

E. Biggins & Co., Ltd., 2/4 Idol Lane, Eastcheap, London, E. C. 3, have decided to increase their export department, for the general purpose of buying, as largely as possible from abroad, new products for sale in the United Kingdom. They prefer products not previously exploited in a serious manner in the United Kingdom. It is stated that some of the most important firms in the Electrical, Radio, Motor, Engineering, Refrigerator and allied industries are numbered among their customers.

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BELL SCIENTIST HONORED

On October 23 Dr. Edward C. Wente of the Bell Telephone Laboratories received the first award of the Progress Medal of the Society of Motion Picture Engineers. The award was made to Dr. Wente for his fundamental contributions and outstanding inventions in motion-picture technology.

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RMA NEWS

(Continued from page 23)

is indicated by the fact that during the last four months there have been eleven meetings, with thirteen standards proposals considered by the General Standards Committee, ten of which were adopted. Revision of the RMA handbook of standards has begun and will be carried to completion as rapidly as possible. This is the first general revision of RMA standards in several years and will be a complete revision of industry standards and deletion of obsolete standards.

The standardization of component parts is another new activity of the Association engineering work. Also there is the general radio interference work, being developed through the American Standards Association. This is immediately under the supervision, however, of RMA through a sectional committee of ASA. Dr. Baker is chairman, L. C. F. Horle, vice chairman, and Virgil M. Graham, secretary of the sectional committee.

In the work on radio interference, however, the joint coordination committee of RMA, Edison Electric Institute and the National Electrical Manufacturers Association, their committee on public relations has been considering publication and distribution of another pamphlet on interference. The RMA Board of Directors regards a pamphlet for public distribution as inadvisable and ineffective but has asked the engineers to consider development of an interference handbook which would be of service and instructive to radio service men.

MORE NEWSPAPERS SUBSCRIBE FOR RMA SHORT-WAVE PROGRAMS

A CONSIDERABLE number of newspapers, both in Canada and in the United States, have been added to those receiving the weekly RMA short-wave programs. The newspaper requests for the short-wave program service have come to RMA by long-distance telephone as well as telegraph and mail. Seventeen of the leading French and English language publications of Canada are among the new subscribers to the short-wave program service; the mailing list of those receiving this service now includes over 800 of the principal newspapers of the United States and Canada. Recent special features of the short-wave programs were the Christmas and New Year's broadcasts planned by many large and also small foreign countries, with interesting features of holiday observances in many foreign lands. The RMA short-wave program bulletins are afforded without charge to the newspapers, now being an established news feature in view of the wide use by the public of the new short-wave receiving sets. The programs constitute one of the leading services and promotion activities developed during the past year by the RMA.

ST. LOUIS AUTO RADIO BILL DIES IN COMMITTEE

ANNOUNCEMENT OF the death in committee of the proposed St. Louis ordinance to prohibit automobile radio has been made by municipal authorities. The bill was opposed by local and national radio and automotive interests, including the RMA. After the public hearing and many protests against the proposed ordinance it was referred to a committee of the St. Louis Board of Aldermen. It is stated officially that the bill will die in committee and that no further action is contemplated.

STEAMSHIP RATE INCREASES OPPOSED

ANNUAL RECEIPT at this time by radio companies from steamship conferences of 1936 shipping contracts has brought forth rate increases which are being generally opposed by the radio industry. In some cases the proposed shipping contracts have been returned unsigned and other RMA members are being asked to join in refusal to accept the proposed marine rate increases. These are especially burdensome in shipments to Latin America. The RMA Export Committee and its members are co-operating in exchange of information and action against acceptance of the proposed 1936 shipping rates when they provide for substantial increases.

TRADE COMMISSION'S NEGOTIATIONS CONTINUE

NEGOTIATIONS BETWEEN the Federal Trade Commission at Washington and the RMA in connection with the proposed trade practice agreement for set manufacturers will continue into 1936. The Trade Commission cases were studied by the RMA Board of Directors at its meeting December 11 in New York City. It was found necessary and desirable to have a legal examination made by counsel, delaying procedure with the Trade Commission for several weeks.

NEW PRODUCTS

NEW 4-POSITION AMPLIFIER

The Webster Company, 3829 West Lake St., Chicago, announce a new four-position, 17-watt amplifier. This is a product of Webster-Chicago engineers. The manufacturer states that this new unit is suitable for four crystal microphones or three crystal microphones and one phono. input. It is of the high-gain type and requires no pre-amplifier. The output impedance is tapped from 2 to 500 ohms. In line with other products they have developed from time to time, The Webster Company have made this a completely enclosed, self-contained unit, resulting in efficient operation based on sound engineering. This unit is suitable for multiple microphone and public-address installations.

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CONTROLLED RECTIFIERS

Ward Leonard Electric Company, Mount Vernon, New York, announces the development of Controlled Rectifiers to supply a d-c output from a commercially constant, single-phase, 110-volt a-c line. The output voltage regulation is plus or minus 2% from approximately one-tenth to full load. On all sizes that cover a range from 30 watts to 250 watts, the efficiency is better than 50% and the power factor better than 65%, it is said.

These Controlled Rectifiers are described in Bulletin No. 8601, obtainable on request.

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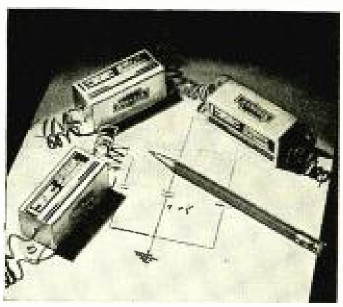
SPRAGUE "TINY-MIKE" ANNOUNCED

An unusually small dry electrolytic condenser of full capacity and 450-v working voltage has just been perfected and placed upon the market by Sprague Products Company, North Adams, Massachusetts. The condenser is called the Sprague "Tiny-Mike," Type TM.

Basing their size comparisons upon their own standard types, the makers of "Tiny-Mike" assert that this little fellow actually fits into one-half the space occupied by standard condensers of equal capacity. This makes an exceptionally compact unit—although one that is large enough and so constructed as not to overheat. Like other Sprague Condensers, the TM units are guaranteed unconditionally when used on any voltage up to their rated capacity, it is stated.



"Tiny-Mike" condenser is fully described in the Sprague 1936 Catalog which will be sent upon request to the manufacturer.

LEPEL 5-KVA CONVERTER

The Lepel 5-kva converter, Model C-4, is shown in the accompanying illustration. This converter is of the tungsten quenched-gap type, having a variable-frequency primary-exciter circuit which is tuned and coupled to a low-loss tank circuit. The standard units are designed to operate from a 220-volt 60-cycle single-phase line. Units to operate from odd frequency and voltage supply lines can be furnished.

The output frequency range is from 160 kc to 500 kc. It is tunable from 2.5 microhenrys to 20 microhenrys. The high-frequency current at 316 kc through 6 microhenrys is 140 amperes.

The high-frequency power output is entirely controlled by means of a 10-step reactance input control, ranging from 1300 to 4000 watts input. The line-current supply is switched on and off by means of a remote-control magnetic switch built into the unit, which in turn may be controlled with a small pilot switch or a foot switch.

Mica blocking condensers in each leg of the power transformer and proper balancing of the high-frequency circuits results with zero high-frequency potential against ground in the center of the load inductance. This feature makes the unit safe and eliminates radio interference, it is said.

For complete information write the Lepel High Frequency Laboratories, Inc., 39 West 60th Street, New York City, for Bulletin No. 401.

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NEW JENSEN P. M. SPEAKERS

The Jensen Radio Manufacturing Company has just released a complete new line of permanent magnet electro-dynamic speakers in 6, 8, 10 and 12-inch sizes.

These new speakers open entirely new fields of application for electro-dynamic speakers, it is said, because they are more highly efficient and more compact physically than previous designs and at the same time substantially lower in cost. Thus, battery-type radio receivers for automobile or home may now be equipped with electro-dynamic speakers fully equal in ability to the energized type used in a-c receivers. For public-address, announcing, and other general applications several models are offered, all particularly suited for the purpose.

The prinicpal feature of these new speakers is the use of a newly discovered alloy used in the magnetic structure, which is greatly superior to the material available previously.

A complete descriptive folder of these speakers is available upon request to the manufacturer.

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NEW SYLVANIA 6X5

In consideration of the interest being shown in automobile radio receivers, using metal tubes, the engineering department of Hygrade Sylvania Corporation has developed a metal-tube rectifier suitable for auto-radio service. The new tube is announced as 6X5, and is similar in characteristics and applications to the popular glass-tube rectifier, type 84.

The 6X5 is enclosed in a metal shell of the same size as the improved Sylvania 5Z4 and the 6F6. Although this new type was designed especially for use in automobile receivers it may also be utilized for compact a-c operated receivers where the rectified current drain does not exceed the maximum output current rating of the tube. With the introduction of the new rectifier tube the Sylvania metal tube group now consists of eleven types.

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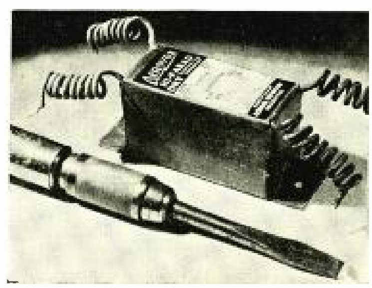
MULTIPLE-SECTION MIDGET ELECTROLYTICS

Extreme compactness and utility are combined in double- and triple-section midget electrolytic condensers recently made available by Aerovox Corporation, Brooklyn, N. Y. Such units provide entirely separate and distinct sections in a single cardboard container, with individual positive and negative flexible leads for each section. The double-section units are available in 250 and 525 volt peak ratings, in combinations of 4-4 to 8-16 mfd. A single 8-8-8 mfd triple-section unit is offered. Heavy cardboard cases, thorough impregnation, positive sealing and handy mounting flanges characterize these units.

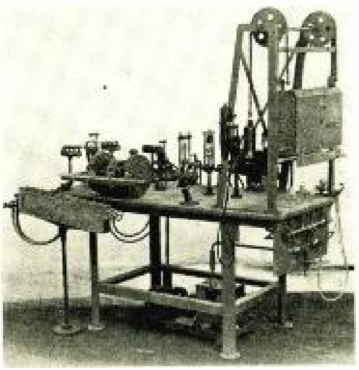


EISLER ELECTRONICS LABORATORY UNIT

The construction of the various types of electronic tubes, radio tubes, luminous tubes and incandescent lamps, involves innumerable operations from cutting glass tubing to spot welding, glass working, exhausting and basing.

The machinery and equipment generally available for these operations is quite bulky and occupies considerable floor space as well as involving the investment of considerable sums of money.

The electronics laboratory unit shown in the accompanying illustration has been designed by Charles Eisler of the Eisler Engineering Co. of 760 So. 13th St., Newark, N. J., to meet the demand of schools, colleges, research and experimental laboratories for a compact and inexpensive plant



which can easily be set up and occupy little space in the laboratory.

Students of electronics as well as research engineers can now construct standard or special tubes to their own ideas and designs in the laboratory with this fully equipped plant.

This unit operates with the same precision as larger production machines in making lamps and tubes. The equipment is conveniently mounted on a table for performing the following operations:

(1) Cutting various kinds of glass.
(2) Flaring many sizes of tubing.
(3) Making different types of stems.
(4) Sealing-in bulbs of all shapes.
(5) Electric spot welding.
(6) Annealing stems and bulbs.
(7) Exhausting.
(8) Basing and capping bulbs and tubes.
(9) Soldering.
(10 Testing vacuum.
(11) Special glass working.

Bulletin 58 containing further information concerning this laboratory unit may be had by writing the above company.

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ALNICO—A NEW, POWERFUL MAGNET

Research in the field of permanent magnet alloys has resulted in a new alloy, Alnico, so much more powerful than those commonly used hitherto as to open entirely new fields of application for permanent magnets, it has been announced by the General Electric Company. Small motors, and various control devices hitherto operated by electromagnets can now use permanent magnet fields, at a considerable saving in cost and greater simplicity of construction; and Alnico already has been applied by General Electric in a variety of applications, including blow-outs for relays, holding-in magnets of large switches, in latching and special timing relays, and in different control devices. Alnico magnets will lift about 60 times their own weight, when designed for that purpose, it is said.

The new alloy is usually a cast material and is finished to shape by grinding. Alnico generally should be cast in quantities for commercial applications, and is not available in standard bars for individual fabrication. The Simonds Saw and Steel Company of Lockport, N. Y., has been licensed by the General Electric Company to manufacture and sell magnets of the new alloy.

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NEW CONNECTORS

Bank Inter-Air Products, 4526 49th St., Woodside, N. Y., has introduced four new types of connectors as shown. This is in addition to their almost complete line of plugs, jacks, posts, etc. One type supersedes the old fashioned solderless telephone tips and is far superior in detail. It has no metal part exposed to contact with fingers. These are solderless, shock-proof and are now made to take heavier wires.

The four new types permit easy connection to the wire after which the metal part is screwed into the handle. Quick, efficient assembly is thereby assured.

All types come in several beautiful colors; namely, red, black, blue, purple, green, yellow and white.

New bulletin 35F describes the complete line of over 100 other types.

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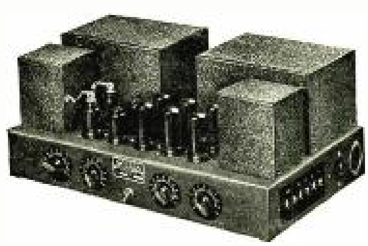
NEW METAL-TUBE AMPLIFIERS

Morlen Electric Company, Inc., 100 Fifth Ave., New York, N. Y., announces the first of a complete line of amplifiers with metal tubes in all stages, including the output. In addition to the basic advantages of the all-metal tubes, the new line uses the exclusive Morlen "Power-Driver" circuit. This new development, applied to



metal tubes, gives maximum power output over the widest frequency range of any known system, it is said. Such performance is a proven requirement for high-fidelity reproduction.

The new MC38 amplifier now available uses two 6F5 and two 6C5 triodes in the voltage amplifier, two 6F6 triodes as "Power-Drivers" and four 6F6 output tubes. The amplifier will deliver 38 watts a-f normal and 45 watts in continuous heavy-duty speech service. The amplifier includes a two-position input mixer with universal impedance, main gain control, tone control, a-c switch, a-c convenience outlet and dual output of 500 ohms and 15 ohms tapped at 8 and 4. An input coupler is also available for adapting low-impedance microphones, such as velocity and dynamic types, to the input.

The MC38 can be used in practically every class of p-a service.

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CARBONIZED RESISTORS

Morrill Carbonized Resistors during the past three years have found a wide acceptance in the electronic industry owing to their quality and reliability, it is stated.

Crystalline carbon is fused into the surface of a porcelain body in an electric vacuum furnace. Resistance values higher than 1500 are secured by turning off part of the carbon, thus leaving a spiral ribbon of conducting material. Suitable terminals are provided and the unit is coated with lacquer to exclude moisture.

These resistors can be furnished in the 3-watt size with a tolerance of plus or minus 1 percent—from 100 ohms to 10 megs.

For further information write to Morrill and Morrill, 30 Church Street, New York City, for Catalog 341D.

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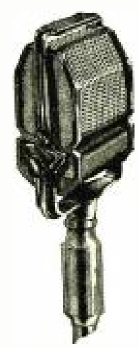
"PLUS-A-STAGE" VELOCITY MICROPHONE

High fidelity at high output (-40 db) is the *raison d'ôtre* of the new plus-a-stage Amperite Velocity Microphone, made by the Amperite Corporation, 561 Broadway, N. Y. C. Feeding the velocity directly into the grid of the compact one-stage pre-amplifier eliminates the input transformer with its inherent noise and inductive hum. A gradual rising characteristic (7,000 to 11,000 cps) results in a brilliancy of re-



production never before obtained in velocity microphones, it is said. Its signal-to-noise level is unusually high—ideal for recording and remote. Operating directly into the grid of the tube, the microphone does not get boomy on close talking—ideal for crooners who insist on hugging the microphone.

The 6J7 metal tube used can be operated from batteries or a-c. Either a compact a-c power supply or floor stand with self-contained batteries can be supplied. The cylindrically shaped one-stage pre-amplifier forms the bottom of the microphone.

RADIO ENGINEERING BUYER'S GUIDE

A continuous, indexed recording of the reliable sources of supply of

Materials—Component Parts

ALLOYS, RESISTANCE
AMERICAN ELECTRO METAL CORP., Lewiston, Maine
CALLITE PRODUCTS CO., 542 39th St., Union City, N. J.
Cleveland Wire Cloth & Mfg. Co.
Consolidated Wire Corp.
Driver Company, Wilbur B.
Driver-Harris Company
Fansteel Metallurgical Labs.
Hoskins Mfg. Co.
Jelliffe Company, C. O.
Prentiss & Company, Geo. W.

ARRESTORS, LIGHTNING
Birnbach Radio Corp.
Knox Porcelain Co.
Johnson, E. F., Co.

BASES, VACUUM TUBE
AMERICAN LAVA CORP., Chattanooga, Tenn.
American Phenolic Corp.
American Record Corp.
ISOLANTITE, INC., 233 Broadway, N. Y. C.
Kurz-Kasch Co.
RCA MFG. COMPANY, INC., Camden, N. J.
Westinghouse Lamp Co.

BINDING POSTS
BANKS INTER-AIR PRODS., Woodside, N. Y.
Eby, H. H., & Co.

BRASS—COPPER
AMERICAN BRASS CO., THE, Waterbury, Conn.
ANACONDA COPPER CO., 25 Broadway, N. Y. C.
Baltimore Brass Co.
Bristol Brass Corp.
Copper & Brass Research Ass'n
Ryerson & Son, Inc.
Scoville Mfg. Co.
WATERBURY BRASS GOODS BR., Waterbury, Conn.

CABINETS—WOOD
Adler Mfg. Co.
Alden Corp.
EXCEL WOODCRAFT CORP., THE, Columbus Rd. at Leonard St., Cleveland, Ohio
Peerless Cabinet Co.
Superior Cabinet Corp.

CATHODES (See Tubing, Seamless Cathode)

CATHODE RAY—TUBES
DUMONT LABORATORIES, ALLEN B., 542 Valley Rd., Upper Montclair, N. J.
General Electric Co.
HYGRADE-SYLVANIA CORP., Clifton, N. J.
RCA MANUFACTURING CO., INC., Camden, N. J.
WESTERN ELEC. CO., 195 Broadway, N. Y. C.
Westinghouse Elec. & Mfg. Co.

CATHODE RAY—OSCILLOGRAPHS
DUMONT LABORATORIES, ALLEN B., 542 Valley Rd., Upper Montclair, N. J.
General Electric Co.
RCA MANUFACTURING CO., INC., Camden, N. J.
RADIO INSTRUMENTS CO., 22 Wooster St., N. Y. C.
WESTERN ELEC. CO., 195 Broadway, N. Y. C.
Westinghouse Elec. & Mfg. Co.

CERAMICS
AMERICAN LAVA CORP., Chattanooga, Tenn.
Amerian Phenolic Corp.
Colonial Insulator Co.
Crowley & Co., Henry L.
Dielectric Products Co.
ISOLANTITE, INC., 233 Broadway, N. Y. C.
Mycalex Corp. of Amer.
STUPAKOFF LABORATORIES, INC., 6627 Hamilton Ave., Pittsburgh, Pa.

CHOKES
ACME ELECTRIC & MFG. CO., 1440 Hamilton Ave., Cleveland, Ohio
ALLOY TRANSFORMER CO., 135 Liberty St. N. Y. C.
AMERICAN TRANSFORMER CO., 175 Emmet St., Newark, N. J.
General Transformer Co.
HAMMARLUND MFG. CO., 424 W. 33rd St., N. Y. C.
KENYON TRANSFORMER CO., INC., 840 Barry St., N. Y. C.
UNITED TRANSFORMER CORP., 72-74 Spring St., N. Y. C.

COIL MACHINERY
UNIVERSAL WINDING CO., Elmwood Ave., Providence, R. I.

COILS—POWER
ANACONDA COPPER CO., Waukegan, Wisc.
ACME WIRE COMPANY, 1255 Dixwell Avenue, New Haven, Conn.
American Enameled Magnet Wire Co.
Belden Manufacturing Co.
Coils, Incorporated
Electrical Winding Company
GENERAL ELECTRIC COMPANY, Schenectady, N. Y.
Roebling's Sons, John
Westinghouse Elec. & Mfg. Co.

COILS—RADIO RECEIVER
ALADDIN RADIO INDUSTRIES, INC., 466 W. Superior St., Chicago, Ill.
Alden Manufacturing Co.
Automatic Winding Co.
Coils, Inc.
ELECTRICAL WINDING CORP., 22-26 Wooster St., N. Y. C.
General Mfg. Co.
GUTHMAN & CO., INC., Edwin I., 1306 W. Van Buren St., Chicago, Ill.
HAMMARLUND MFG. CO., 424 W. 33rd St., N. Y. C.
Meissner Mfg. Co.
National Company
Sickles Company

COILS—SPEAKER
ACME ELECTRIC & MFG. CO., 1440 Hamilton Ave., Cleveland, Ohio
ALLOY TRANSFORMER CO., 135 Liberty St., N. Y. C.
AMERICAN TRANSFORMER CO., 175 Emmet St., Newark, N. J.
ANACONDA WIRE & CABLE CO., Muskegon, Mich.
Chicago Transformer Corp.
Dongan Electric Mfg. Co.
GENERAL TRANSFORMER CORP., 500 S. Throop St., Chicago, Ill.
Halldorson Company
JEFFERSON ELECTRIC COMPANY, Bellwood, Ill.
KENYON TRANSFORMER CORP., 840 Barry St., N. Y. C.
RCA MANUFACTURING CO., INC., Camden, N. J.
STANDARD TRANSFORMER CORP., 854 Blackhawk Street, Chicago, Ill.
Thordarson Elec. Mfg. Co.
UNITED TRANSFORMER CORP., 72-78 Spring St., N. Y. C.

CONDENSERS, FIXED PAPER
ACME WIRE COMPANY, 1255 Dixwell Ave., New Haven, Conn.
AEROVOX CORP., 90 Washington St., Brooklyn, N. Y.
CORNELL-DUBILIER CORP., 4388 Bronx Blvd., N. Y. C.
CURTIS CONDS. CORP., 3088 W. 106th St., Cleve., O.
ELECTRONIC LABORATORIES, INC., Indianapolis, Ind.
Flechtheim & Co., A. M.
Girard-Hopkins, Inc.
Magnavox Co., Ltd.
MALLORY & CO., P. R., Indianapolis, Indiana
Micamold Radio Corp.
Polymet Mfg. Co., Inc.
SOLAR MFG. CORP., 599-601 Broadway, N. Y. C.
Sprague Specialties Co.
TOBE-DEUTSCHMANN CORP., Canton, Mass.

CONDENSERS, FIXED ELECTROLYTIC
AEROVOX CORP., 90 Washington St., Brooklyn, N. Y.
Condenser Corp. of America
CORNELL-DUBILIER CORP., 4388 Bronx Blvd., N. Y. C.
CURTIS CONDENSER CORP., 3088 W. 106th St., Cleveland, Ohio
Magnavox Co., Ltd.
MALLORY & CO., P. R., Indianapolis, Indiana
Micamold Radio Corp.
Polymet Mfg. Co., Inc.
SOLAR MFG. CORP., 599-601 Broadway, N. Y. C.
Sprague Specialties Co.

CONDENSERS, ADJUSTABLE
DeJur-Amsco Corp.
HAMMARLUND MFG. CO., 424 W. 33rd St., N. Y. C.
Meissner Mfg. Co.
SOLAR MFG. CORP., 599-601 Broadway, N. Y. C.
TOBE-DEUTSCHMANN CORP., Canton, Mass.

CONDENSERS, VARIABLE
CARDWELL MFG. CO., ALLEN B., 81 Prospect St., Brooklyn, N. Y.
DeJur-Amsco Corp.
General Instrument Co.
GENERAL RADIO CO., 30 State St., Cambridge, Mass.
HAMMARLUND MFG. CO., 424 W. 33rd St., N. Y. C.
OAK MFG. CO., 711 W. Lake Street, Chicago, Ill.
Precise Mfg. Co.
Radio Condenser Co.
Reliance Die & Stamping Co.
Scoville Mfg. Co.

CONTACTS, METAL
Baker & Co., Inc.
CALLITE PRODUCTS DIV., 542 39th St., Union City, N. J.
General Plate Co.
General Tungsten Mfg. Co.
MALLORY & CO., P. R., Indianapolis, Indiana
Wilson Co., H. A.

CORES, RESISTANCE COIL
AMERICAN LAVA CORP., Chattanooga, Tenn.
Colonial Insulator Co.
ISOLANTITE, INC., 233 Broadway, N. Y. C.
Steward Mfg. Co.

CORES, TRANSFORMER
THOMAS & SKINNER STEEL PRODS. CO., 1100-1120 E. 23rd St., Indianapolis, Indiana

CRYSTALS, QUARTZ and ROCHELLE SALT
BLILEY ELECTRIC CO., 237 Union Station Bldg., Erie, Pa.
Boonton Research Labs.
Premier Crystal Laboratories
RCA MANUFACTURING CO., INC., Camden, N. J.
BRUSH DEVELOPMENT CO., E. 40th St. & Perkins Ave., Cleveland, Ohio
SCIENTIFIC RADIO SERVICE, University Pk., Hyattsville, Md.

DIALS, ESCUTCHEONS
Crowe Nameplate Co.
KAY PRODUCTS OF AMER., INC., 560 DeKalb Ave., Brooklyn, N. Y.
Magnavox Company, The

DIAPHRAGMS, SPEAKER
Hawley Products Co.
Masland Mfg. Corp.
UNITED PRESSED PRODUCTS CO., 407 S. Aberdeen St., Chicago, Ill.

ELECTRODES, NEON
EISLER ELECTRIC CORP., Union City, N. J.
EISLER ENGINEERING CO., INC., 747 So. 13th St., Newark, N. J.
SWEDISH IRON & STEEL CORP., 17 Battery Pl., N. Y. C.

EYELETS
Platt Bros. & Co.
STUPAKOFF LABS., INC., 6627 Hamilton Ave., Pgh., Pa.
United Shoe Mach. Co.
WATERBURY BRASS GOODS BR., Waterbury, Conn.

FIBRE, PHENOL and VULCANIZED
Bakelite Corp.
Brandywine Fibre Products Co.
Continental-Diamond Fibre Co.
Formica Insulation Co.
Franklin Fibre-Lamitex Corp.
General Electric Co.
Mica Insulator Co.
National Vulcanized Fibre Co.
Resinox Corporation
SYNTHANE CORPORATION, Oaks, Penna.
Westinghouse Elec. & Mfg. Co.
Wilmington Fibre Co.

FLEXIBLE SHAFTING
Fischer Spring Company, Chas.
White Dental Mfg. Co., S. S.

FUSES
LITTELFUSE LABS., 4238 Lincoln Ave., Chicago, Ill.

GENERATORS
Carter Motor Company
Columbia Elec. Mfg. Co.
ELECTRONIC LABORATORIES, INC., 122 W. New York St., Indianapolis, Ind.
MALLORY & CO., P. R., Indianapolis, Indiana
ONAN & SONS, D. W., Minneapolis, Minn.
PIONEER GENE-MOTOR CORP., 466 W. Superior St., Chicago, Ill.

GETTERS (See Nickel Tube Parts)

GRAPHITE
ACHESON COLLOIDS CORP., Port Huron, Mich.

HORNS
BUD RADIO, INC., 1923 E. 55th St., Cleveland, Ohio
FOX SOUND EQUIP. CORP., 3120 Monroe St., Toledo, Ohio
HOPE MFG. CO., 401 Broadway, N. Y. C.
MACY ENGINEERING CO., 1452 39th St., Bklyn, N. Y.
RACON ELEC. MFG. CO., 52 E. 19th St., N. Y. C.
Toledo Sound Equip. Labs.
WRIGHT-DECOSTER, INC., 2253 University Ave., St. Paul, Minn.

INSTRUMENTS (See Meters or Cathode Ray)

INSULATION, BEADS
AMERICAN LAVA CORP., Chattanooga, Tenn.
ISOLANTITE, INC., 233 Broadway, N. Y. C.
Steward Mfg. Co.
STUPAKOFF LABORATORIES, INC., 6627 Hamilton Ave., Pitts, Pa.

INSULATION, CERAMICS (See Ceramics)

INSULATION COMPOUNDS
Candy & Co., Inc.
Dolph Co., John C.
Glenn & Co., J. J.
Mica Insulator Co.
Roebling's Sons Co., John A.
STUPAKOFF LABS., INC., 6627 Hamilton Ave., Pgh., Pa.
ZOPHAR MILLS, INC., Court, Lorraine and Creamer St., Brooklyn, N. Y.

INSULATION, LAMINATED BAKELITE
Franklin Fibre-Lamitex Corp.
SYNTHANE CORPORATION, Oaks, Penna.

INSULATION, MOLDED
American Insulator Corp.
AMERICAN LAVA CORP., Chattanooga, Tenn.
American Phenolic Corp.
American Record Corp.
Chicago Molded Prods. Corp.
Formica Insulation Co.
General Electric Co.
Kurz-Kasch Co.
Macallen Co.
STUPAKOFF LABS., INC., 6627 Hamilton Ave., Pgh., Pa.
Watertown Mfg. Co.
Westinghouse Elec. & Mfg. Co.

INSULATION, FABRIC TUBING
BENTLEY HARRIS MFG. CO., Conshohocken, Pa.
BRAND & CO., WM., 276 Fourth Ave., N. Y. C.
Glenn & Co., J. J.
Mica Insulator Co.

IRON, SWEDISH (Tube Parts)
SWEDISH IRON & STEEL CORP., 17 Battery Pl., N. Y. C.

LACQUER, PAINT, VARNISH
ACME WIRE COMPANY, 1255 Dixwell Ave., New Haven, Conn.
Dolph & Co., John C.
Irvington Varnish Co.
Maas & Waldstein
ZAPON COMPANY, 60 E. 42nd St., N. Y. C.
ZOPHAR MILLS, Court, Lorraine and Creamer Sts., Brooklyn, N. Y.

LAMPS, GLOW
LITTELFUSE LABS., 4238 Lincoln Ave., Chicago, Ill.

LUGS
CINCH MFG. CORP., 2335 W. Van Buren St., Chicago, Ill.
Thompson-Bremer Corp.
WATERBURY BRASS GOODS BR., Waterbury, Conn.

ZIERICK MACHINE WORKS, 68 E. 131 St., N. Y. C.

MAGNETS
THOMAS & SKINNER STEEL PRODS. CO., 1100-1120 E. 23rd St., Indianapolis, Indiana.

MELTING POTS
Dunn, Inc., Struther
STA-WARM ELECTRIC CO., Ravenna, Ohio
Trent Co., Harold E.

METERS; TESTING INSTRUMENTS
Apparatus Design Co.
Boonton Radio Corp.
BURTON-ROGERS CO., 755 Boylston St., Boston, Mass.
CLOUGH-BRENGLE CO., 1134 W. Auston Ave., Chicago, Ill.
Dumont Laboratories, Allen B.
FERRIS INSTR. CORP., Boonton, N. J.
General Electric Co.
GENERAL RADIO COMPANY, 30 State St., Cambridge A, Mass.
HICKOK ELEC. INSTRU. CO., Cleveland, Ohio
JACKSON ELEC. INSTRU. CO., Dayton, Ohio
RCA MFG. CO., INC., Camden, N. J.
RADIO CITY PRODUCTS CO., 28 W. B'way, N. Y. C.
RADIO INSTRUMENTS CO., 22 Wooster St., N. Y. C.
RADIO PRODUCTS CO., 145 Sunrise Pl., Dayton, Ohio
Rawson Elec. Instru. Co.
READRITE METER WORKS, Bluffton, Ohio
Shallcross Mfg. Co.
SUPREME INSTRUMENT CORP., Greenwood, Miss.
TRIPLETT ELEC. INSTRU. CO., Bluffton, Ohio
TRIUMPH MFG. CO., 4017 W. Lake St., Chicago, Ill.
WESTERN ELECTRIC CO., 195 Broadway, N. Y. C.
WESTON ELEC. INSTRU. CORP., 614 Freylinghuysen Ave., Newark, N. J.
Westinghouse Elec. & Mfg. Co.

MICA
BRAND & CO., WM., 276 Fourth Ave., N. Y. C.
Continental-Diamond Fibre Co.
Ford Radio Mica Co., Inc.
Macellen Co.
Mica Insulator Co.
New England Mica Co.

MICROPHONES
AMERICAN MICROPHONE CO., Los Angeles, Calif.
AMPERITE CORP., 561 Broadway, N. Y. C.
ASTATIC MICROPHONE LAB., INC., 830 Market St., Youngstown, Ohio
Beacon Microphone Co.
BRUNO LABORATORIES, 20 West 22nd St., N. Y. C.
BRUSH DEVELOPMENT CO., Cleveland, Ohio
Carrier Microphone Co.
ELECTRO-VOICE MFG. CO., INC., South Bend, Indiana
RADIO RECEPTOR CO., INC., 106 7th Ave., N. Y. C.
RCA MFG. COMPANY, INC., Camden, N. J.
SHURE BROS. CO., 215 W. Huron St., Chicago, Ill.
SOUND SYSTEMS, INC., 1311 Terminal Bldg., Cleveland, Ohio
Turner Company
UNIVERSAL MICROPHONE CO., LTD., Inglewood, Calif.
WESTERN ELECTRIC CO., 195 Broadway, N. Y. C.

MOLYBDENUM
AMERICAN ELECTRO METAL CORP., Lewiston, Maine
CALLITE PRODUCTS DIV., 542 39th St., Union City, N. J.
ELECTRO-METALS, INC., 1880 E. 40 St., Cleveland, O.
Fansteel Metallurgical Labs.

MONEL METAL
International Nickel Corp.

NICKEL, TUBE PARTS (Also see Svea Metal)
(plates, grids, wire cloth, cathodes, getters, hooks, heaters, base-pins, welds)
AMERICAN BRASS CO., Waterbury, Conn.
AMERICAN ELECTRO METAL CORP., Lewiston, Maine
CALLITE PRODUCTS DIV., 542 39th St., Union City, N. J.
Cleveland Wire Cloth & Mfg. Co.
Driver Co., Wilbur B.
Driver-Harris Co.
General Plate Co.
GOAT RADIO TUBE PARTS, INC., 314 Dean St., Brooklyn, N. Y.
King Laboratories, Inc.
Newark Wire Cloth Company
Pequot Wire Cloth Company
Prentiss & Company, Geo. W.
SUMMERILL TUBING COMPANY, Bridgeport, Penna.
Superior Tube Company

PAPER, for CONDENSERS
Dexter & Sons Co., Inc., C. H.
Schweitzer, Inc., Peter J.
Strype, Fred. C.

PAPER TUBES
Chicago Paper Tube Co.
Cross Paper Products Co.
Paper Tube Company, The
Paramount Paper Tube Co.

PHOSPHOR BRONZE
Phosphor Bronze Smelting Co.
Riverside Metal Company
Scoville Mfg. Company
Seymour Mfg. Company
Waterbury Rolling Mills, Inc.

PHOTOELECTRIC CELLS
Burt, R. C., Co.
Continental Electric Co.
Eby, H. H., Mfg. Co.
General Electric Co.
G-M Laboratories
RCA MANUFACTURING CO., INC., Camden, N. J.
Westinghouse Elec. & Mfg. Co.
WESTON ELECTRICAL INSTRUMENTS CORP., 612 Frelinghuysen Ave., Newark, N. J.

PICKUPS, TRANSCRIPTION
ASTATIC MICROPHONE LAB., INC., 830 Market St., Youngstown, Ohio
AUDAK COMPANY, THE, 500 Fifth Ave., N. Y. C.
BRUSH DEVELOP. CO., Perkins Ave., Cleve., Ohio
PROCTOR & CO., B. A., 17 W. 60th St., N. Y. C.
RCA MFG. COMPANY, INC., Camden, N. J.

PLASTICS (See Insulation, Molded)

PLUGS
Alden Mfg. Co.
American Phenolic Corp.
Cannon Elec. Development Co.
CINCH MFG. CORP., 2335 W. Van Buren St., Chicago, Ill.
Eby Mfg. Co., H. H.
Jones, Howard B.
MALLORY & CO., INC., P. R., Indianapolis, Indiana
REMLER CO. LTD., 2101 Bryant St., San Francisco, Cal.

POINTS, CONTACT
Baker & Company
CALLITE PRODUCTS DIV., 542 39th St., Union City, N. J.
Fansteel Metallurgical Corp.

RECTIFIERS
B-L Electric Mfg. Co.
GENERAL ELCTRIC CO., Bridgeport, Conn.
MALLORY & CO., INC., P. R., Indianapolis, Indiana
UNITED TRANSFORMER CORP., 72-74 Spring St., N. Y. C.
Westinghouse Elec. & Mfg. Co.

RELAYS
ALLEN-BRADLEY CO., 126 W. Greenfield Ave., Milwaukee, Wisc.
Automatic Electric Co.
Dunn, Inc., Struthers
ELECTRONIC LABORATORIES, INC., Indianapolis, Ind.
GENERAL ELECTRIC COMPANY, Schenectady, N. Y.
Kurman Elec. Co.
Mercoid Corporation
WARD-LEONARD ELEC. CO., 33 South St., Mt. Vernon, N. Y.
WESTON ELEC. INSTRU. CORP., 612 Frelinghuysen Ave., Newark, N. J.

RESISTORS, CARBON-COMPOSITION
AEROVOX CORP., 90 Washington St., Brooklyn, N. Y.
ALLEN-BRADLEY CO., 126 W. Greenfield Ave. Milwaukee, Wisc.
CENTRALAB, 900 E. Keefe Ave., Milwaukee, Wisc.
Chicago Tel. Supply Co.
CLAROSTAT MFG. CO., INC., 287 N. 6th St., Brooklyn, N. Y.
CONTINENTAL CARBON, INC., 13902 Lorain Ave., Cleveland, Ohio.
ELECTRAD, INC., 175 Varick St., N. Y. C.
ERIE RESISTOR CORP., Erie, Penn.
Globar Corp.
INTERNATIONAL RESISTANCE CO., 2100 Arch St., Phila., Pa.
MALLORY & CO., INC., P. R., Indianapolis, Indiana
Micamold Radio Corp.
Ohio Carbon Co.
OHMITE MFG. CO., 4835 Flournoy St., Chicago, Ill.
Speer Resistor Corp.
Stackpole Carbon Co.
SOLAR MFG. CO., 599-601 Broadway, N. Y. C.
Tech Laboratories
WARD LEONARD ELEC. CO., 33 South St., Mt. Vernon, N. Y.
White Dental Mfg. Co., S. S.
Wirt Company, The

RESISTORS, WIRE WOUND
AEROVOX CORP., 90 Washington St., Brooklyn, N. Y.
Atlas Resistor Co.
CLAROSTAT MFG. CO., INC., 287 N. 6th St., Brooklyn, N. Y.
Daven Company
ELECTRAD, INC., 175 Varick St., N. Y. C.
Hardwick Hindle, Inc.
INTERNATIONAL RESISTANCE CO., 2100 Arch St., Phila., Pa.
MALLORY & CO., INC., P. R., Indianapolis, Indiana
MUTER CO., THE, 1255 S. Michigan Ave., Chicago, Ill.
OHMITE MFG. COMPANY, 4835 Flournoy St., Chicago, Ill.
PRECISION RESISTOR CORP., 334 Badger Ave., Newark, N. J.
Shallcross Mfg. Co.
WARD LEONARD ELEC. CO., 33 South St., Mt. Vernon, N. Y.

SCREWS, SELF LOCKING
Parker-Kalon Corp.
SHAKEPROOF LOCK WASHER CO., 2501 N. Keeler Ave., Chicago, Ill.

STEEL
Allegheny Steel Co.
AMERICAN ROLLING MILL CO., Middletown, Ohio
American Steel & Wire Co.
Republic Steel Corp.
Ryerson & Son, Inc.

SOCKETS
Alden Mfg. Co.
American Phenolic Corp.
CINCH MFG. CORP., 2335 W. Van Buren St., Chicago, Ill.
Continental-Diamond Fibre Co.
Eby Mfg. Co., H. H.
FRANKLIN MFG. CORP., ALBERT W., 137 Varick St., N. Y. C.

SOLDER
Dunton Co., M. W.
GARDINER METAL CO., 4820 S. Campbell Ave., Chicago, Ill.
Kester Solder Company
RUBY CHEMICALS CO., 56 McDowal St., Columbus, Ohio.

SOLDERING IRONS
ELECTRIC SOLDER. IRON CO., 342 W. 14th St., N. Y.
INSULINE CORP. OF AMER., 25 Park Pl., N. Y. C.
STA-WARM ELECTRIC CO., 508 N. Chestnut St., Ravenna, Ohio

SPEAKERS and SPEAKER UNITS
Best Mfg. Co.
Boudette & Co.
FOX SOUND EQUIP. CORP., 3120 Monroe St., Toledo, Ohio.
Jensen Radio Mfg. Co.
Magnavox Co., Ltd.
OPERADIO MFG. CO., 13th and Indiana Sts., St. Charles, Ill.
OXFORD RADIO CORP., 350 W. Huron St., Chicago.
RCA MFG. COMPANY, INC., Camden, N. J.
RACON ELEC. CO., INC., 52 E. 19th St., N. Y. C.
Rola Company, The
UTAH RADIO PRODUCTS CO., 820 Orleans St., Chicago, Ill.
Victory Speakers, Inc.
WESTERN ELECTRIC CO., 195 Broadway, N. Y. C.
WRIGHT-DE COSTER, INC., 2253 University St., St. Paul, Minn.

SVEA METAL
SWEDISH IRON & STEEL CORP., 17 Battery Pl., N. Y. C.

TAPE, VARNISHED FABRIC
ACME WIRE CO., 1255 Dixwell Ave., New Haven, Conn.
BRAND CO., WILLIAM, 276 Fourth Ave., N. Y. C.

TRANSFORMERS (Also see Chokes)
ACME ELEC. & MFG. CO., THE, 1440 Hamilton Ave., Cleveland, Ohio
ALLOY TRANSFORMER CO., 135 Liberty St., N. Y. C.
AMERICAN TRANS. CO., 175 Emmet St., Newark, N. J.
Chicago Transformer Co.
Dongan Electric Mfg. Co.
GENERAL TRANS. CORP., 5025 S. Throop St., Chi., Ill.
HALLDORSON COMPANY, THE, 4500 Ravenswood Ave., Chicago, Ill.
JEFFERSON ELECTRIC CO., Bellwood, Illinois
KENYON TRANS. CO., INC., 840 Barry St., N. Y. C.
RCA MFG. COMPANY, INC., Camden, N. J.
STANDARD TRANS. CORP., 866 Blackhawk St., Chi., Ill.
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Belden Mfg. Co.
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LENZ ELECTRIC MFG. CO., 1751-1757 N. Western Ave., Chicago, Ill.
Rockbestos Products Corp.
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American Enameled Magnet Wire Co.
American Steel & Wire Co.
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General Cable Corp.
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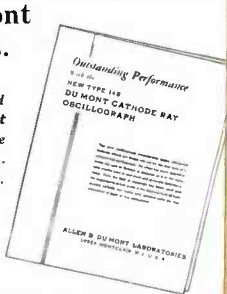

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