NINTH YEAR OF SERVICE

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RADIO ENGINEERING

Vol. IX | JANUARY 1929 | Number 1

IN THIS ISSUE

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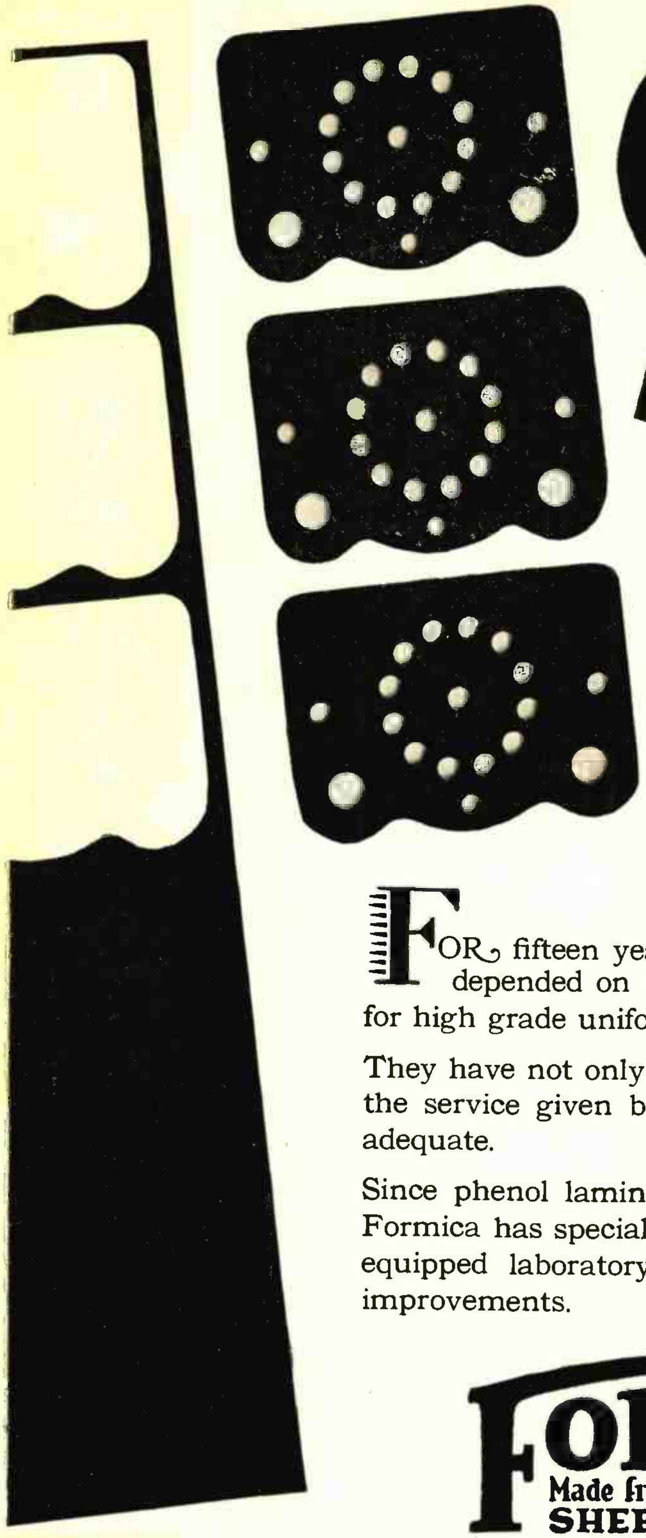

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The High Power Amplifying Tube

BY GEORGE LEWIS

Vice President, Arcturus Radio Co.

THE general tendency toward quality reception is justifiable and consistent. Endeavors in this direction have evolved the high power amplifying tube—the "fifty type"—and circuits and transformers that make most of it. Practically perfect reproduction can be secured with this tube with a large volume output. But the tube itself is in line for further development and improvement—a consideration that is rather general for A.C. tubes today. The majority of tubes designed for operation from alternating current are merely modifications of D.C. tubes that, while solving the major problems of A.C. operation in a fairly satisfactory way, do not make the most of the possibilities of humless reception and long life. Research has adequately demonstrated this. The majority of "A.C." tubes are merely D.C. tubes operated on alternating current.

Progress in A.C. tubes designed as far as high power tubes are concerned, will undoubtedly be directed toward the development of the cathode type. A close study of thermodynamics will probably evolve a new super-power tube during the coming year, a tube with practically unlimited life with an almost imperceptible decrease in mutual conductance and a similarly minute increase in plate resistance over an active period of several thousands of hours.

Much of this development work will undoubtedly be done in the laboratories of the independent tube manufacturers. In passing, it is interesting to note the "caste" that these manufacturers have achieved during the past year.

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EDITORIAL

January 1929

THE RADIO INDUSTRY

A NEW year is upon us. It is time for everyone to re-cast the old and start out with renewed stimulation. This usually calls for a general recapitulation in order that we may institute a more agreeable mental balance and gain a better sense of direction.

Industrial executives have put on their thinking caps and the air sizzles with new-born ideas. The radio industry has concluded a very satisfactory year and it is readily apparent that, with the new plans put into operation, the new year will be even more productive.

There is stimulation in the knowledge that the problem of A. C. operation is completely licked. The greatest obstacle to the sale of radio receivers has been once and for all abolished. It is pleasant to review the improvements made in the A. C. tubes, for it is no longer necessary to condemn them. Though the A. C. tube has not reached its final state of perfection, it has at least been lifted out of the state of imperfection and can be considered as being practically fool-proof. Consistency in the operation of A. C. sets is another matter that lends brilliance to the new-year perspective. No matter how one views the engineering phase, he finds that the fear of failure is but a shadow of the past.

The radio industry has been criticized more than once for being haphazard. There may be an element of truth in the accusation, for where is the industry that grew fully and completely without being haphazard at some period? Inconsistent or not, the remarkable point is that the radio industry has been able to cram so many new and radical engineering developments, production activities and merchandising plans into a single year and emerge in a position to record the whole as an indisputable achievement.

With good reason, the industry looks into this new year with greater confidence and more elaborate hopes. The executives are aware of the fact that for the first time in the history of radio the industry is looked upon as a stabilized force, that it has economic importance and has the confidence of the public.

Since the industry is no longer in the speculative stage, we expect to witness further stabilization in production and merchandising methods. Quantity production has been attempted and in many instances has proven highly successful. It took the automotive industry years to learn that cars could be sold during the winter months. The radio industry has learned in a very short space of time that radio sets can be readily sold during the summer months and in large quantities. The summer period of inactivity in production will eventually be filled in and it is reasonable to expect that the industry will never again experience complete production paralysis as it has in the past.

We believe that the industry is also aware of feminine buying influence and that manufacturers are giving more than the usual amount of thought to cabinet and console design. The use of style and design in practically all industries is on the increase and they have proven their worth.

The matter of style is even more important to the radio industry than to the automotive industry. There is a distinct movement in America towards beautifying the home. Woman is demanding style, color and harmony in home decoration and she is insisting that all objects of utility conform to her inherent taste. She is demanding as much in the radio set she buys.

We believe that set manufacturers are cognizant of this new stage in the development of the industry—the appearance stage—and will bend a great amount of their efforts in this direction. The engineering and manufacturing efficiency stages are no longer the industry's main worries. These stages have advanced rapidly within the past year and will come near to being completely rounded out during 1929.

M. L. MUHLEMAN, *Editor.*

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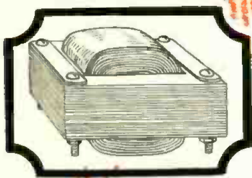
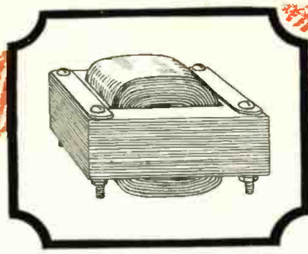
Send for this free booklet: "Do it with Durez." Contains complete information about Durez—physical and dielectric properties, color ranges, and scores of practical applications.

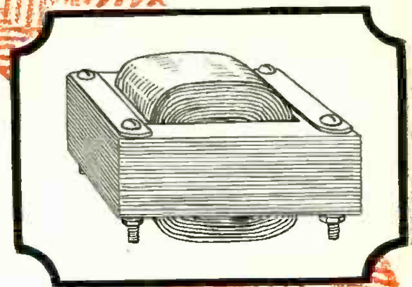
1925 *Volume of Business*





1926

1927



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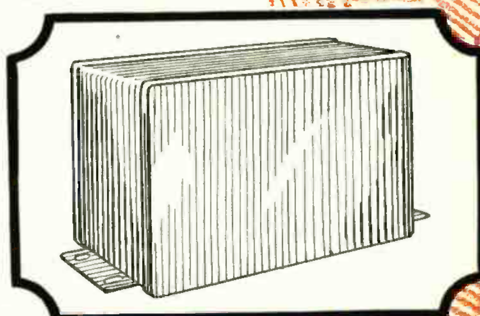
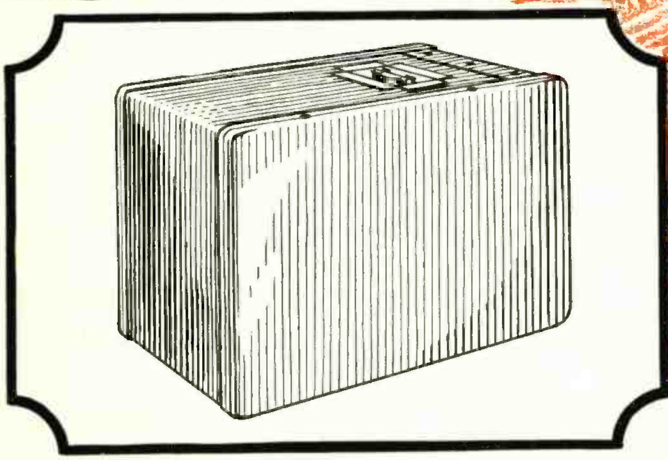
Wide reputation for efficiency and durability, due to refinements in construction and careful design, has resulted in a constantly increasing appreciation of T.C.A. Products. A new factory of seven times greater capacity is now under way to take care of the steadily mounting demand.

1928



1929 *Estimated Volume*



T.C.A. Products include a complete line of power, audio and neon transformers, chokes, power packs and filament transformers for A.C. conversion. They are being used as standard equipment by many of the country's largest builders of radio sets and accessories.

Sales offices in all principal cities. Send specifications to Chicago office. **Manufacturers expecting to change or improve design this year should submit specifications early.**

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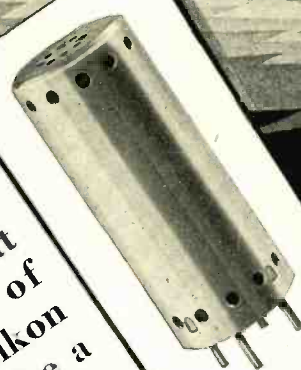

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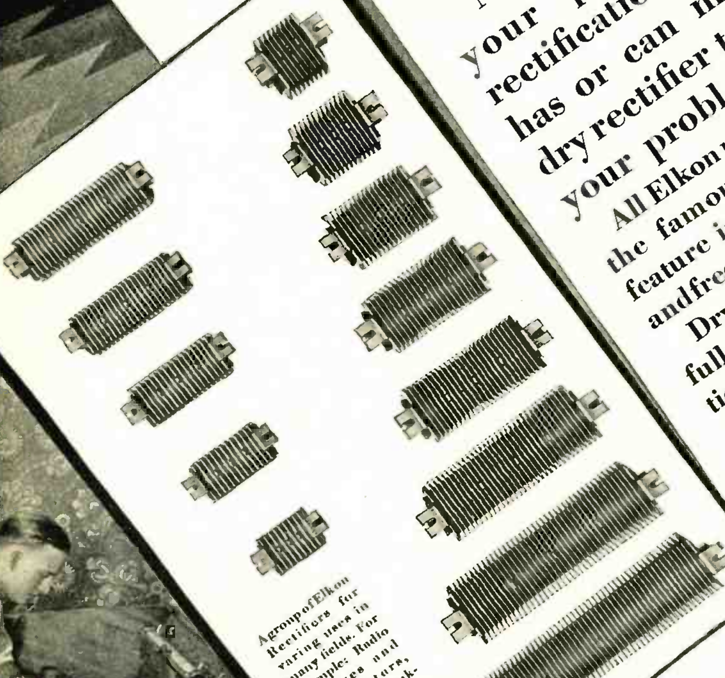
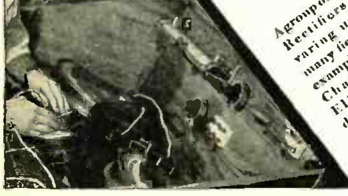


A group of Elkon Rectifiers for varing uses in many fields. For example: Radio Charges and Eliminators, dynamic speakers, Railway Signals, Telephone.



Of course the Wheatstone's Bridge plays its part in the Research Laboratory.

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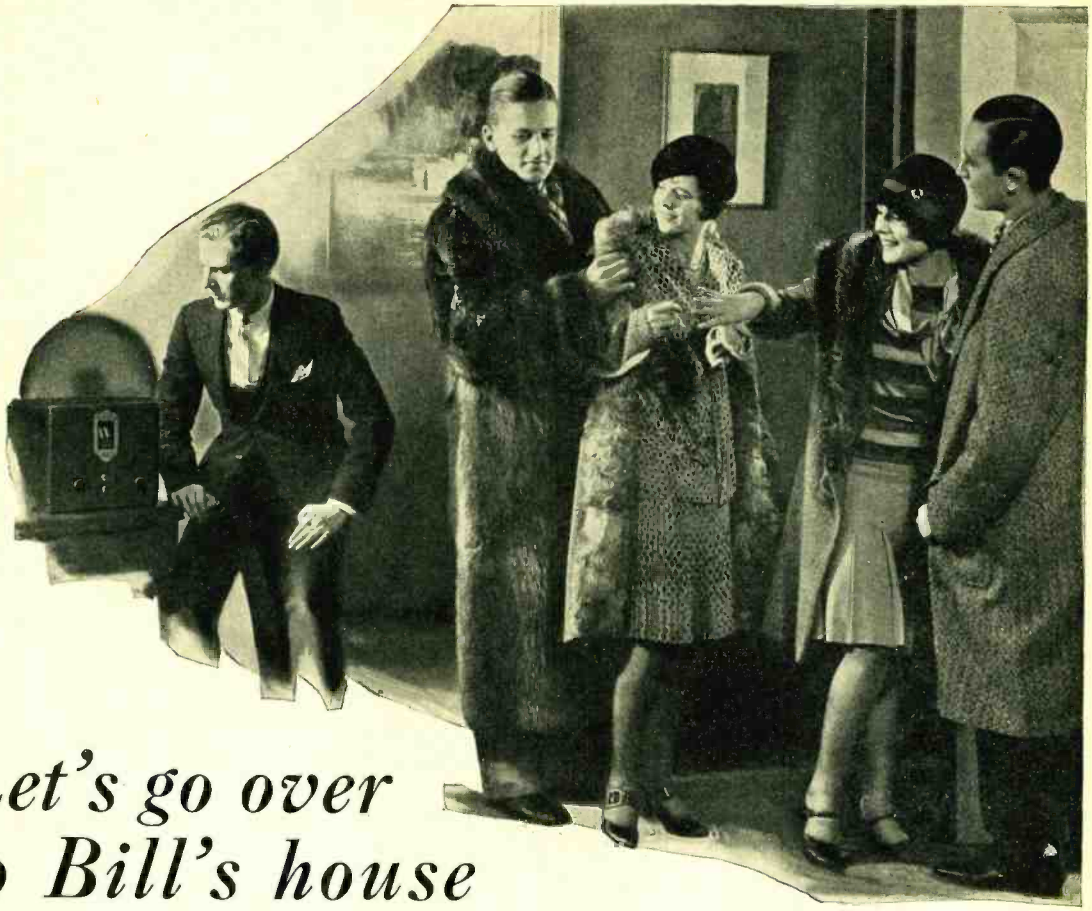

"Let's go over to Bill's house —his set hasn't 'adenoids' . . ."

It is mighty discouraging to realize that your set doesn't command the same enthusiasm and respect as that of one of your friends.

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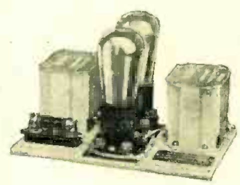

AmerTran Push-Pull Power Stage (illustrated above)—completely wired with input transformer and a choice of 4 output transformers depending on speaker and power tubes. Price, east of Rockies—less tubes—$36.00.

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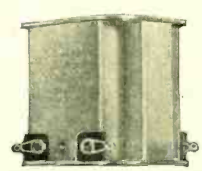

AmerTran DeLuxe Audio Transformer, (illustrated above,) Standard of Excellence, 1st Stage: Turn Ratio, 3: 2nd Stage: Turn Ratio, 4. Price, each $10.00.

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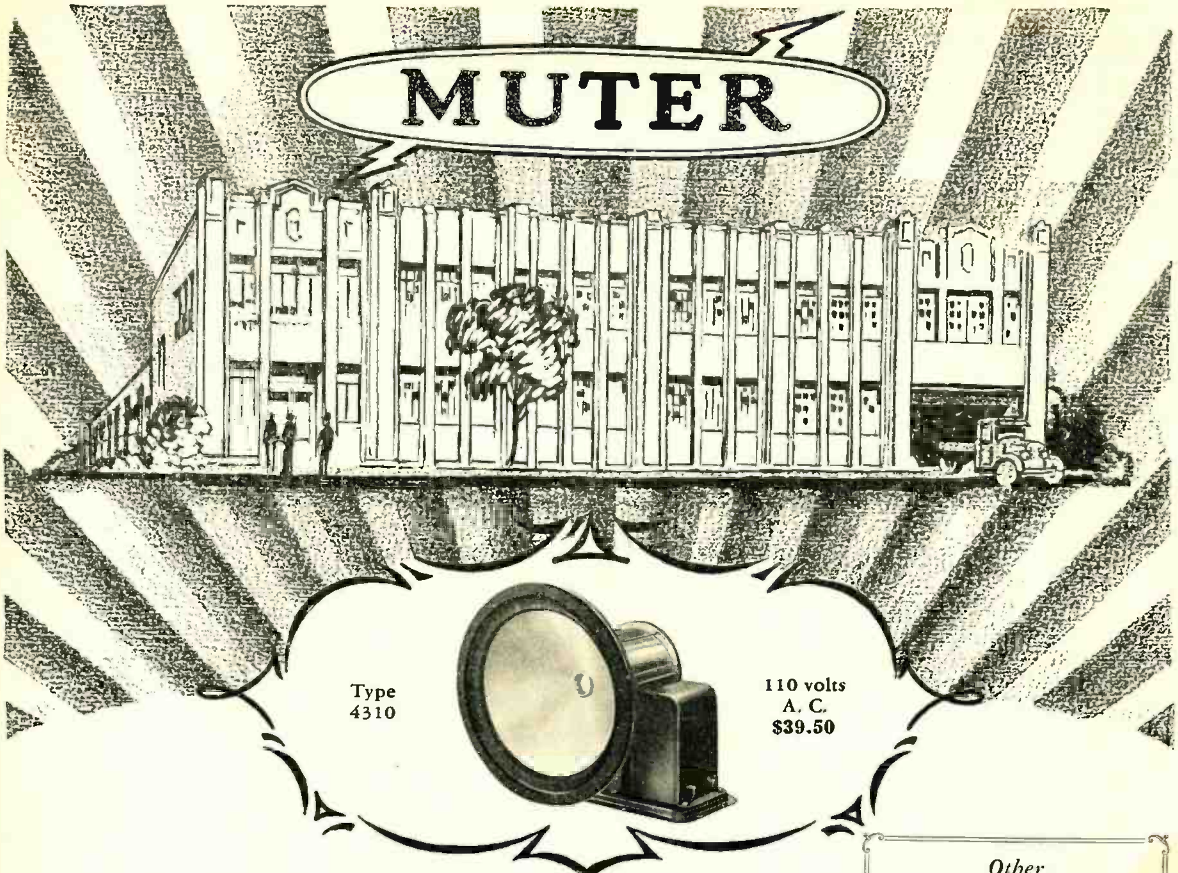

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Dependable Dynamic Speaker Unit

Power	Type	Price
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90 volts D. C.	4390	**33.00**
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Table Model in Solid Walnut Cabinet

Power	Type	Price
6 volts D. C.	4406	**$19.50**
90 volts D. C.	4490	**53.00**
110 volts A. C.	4410	**59.50**

Spinet Console Model of Solid Walnut

Power	Type	Price
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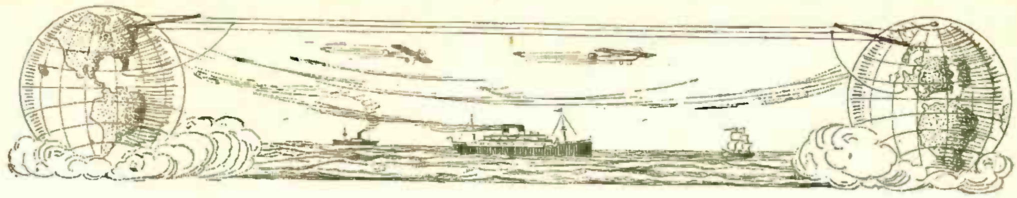


Characteristics of Electric Wave Filters

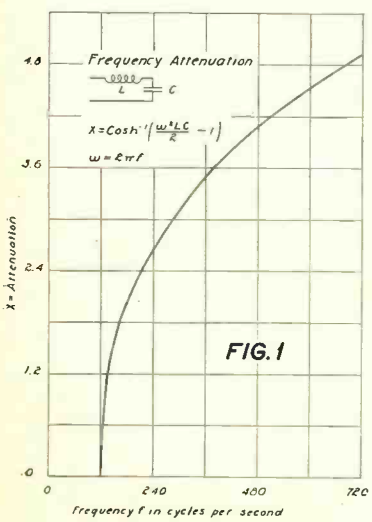
Dealing With the Design of Filters for Radio Power Supply

*By Clyde L. Farrar**

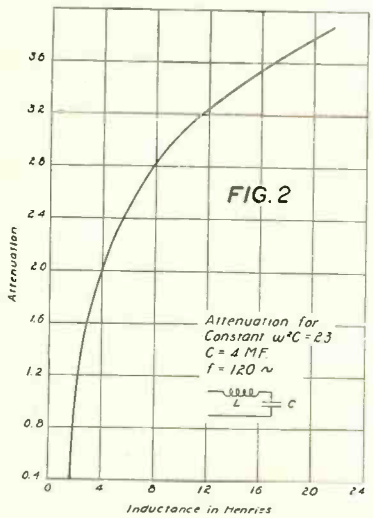
IT is the purpose of this paper to present a set of curves which show the operating characteristics of electric wave filters. The discussion will be limited to non-resistive, low-pass filters, because the effect of resistance is to increase the attenuation of the current waves through the filters. By proper design, the resistance can be made low enough to minimize this effect.

An electric wave filter is a device for separating current waves which have different frequencies. In its usual form, the wave filter transmits currents of all frequencies within one or more specified ranges and excludes currents of all frequencies outside of these ranges without absorbing the energy of the excluded frequencies. Electric wave filters are used extensively in conjunction with rectifiers to obtain direct current from alternating current for operating radio receiving sets. The following discussion is limited to filters that are used for this purpose.

**Asst. Professor of Electrical Engineering, University of Idaho.*



Curve showing attenuation of a filter at various frequencies.



Variation in attenuation for constant capacitance and variable inductance.

Frequency Structure

For the purpose of design, the pulsating output of a rectifier may be looked upon as having a constant direct current component upon which are superimposed an infinite number of alternating currents of different frequencies, but having a fundamental frequency equal to the number of pulsations per second in the filter output. For single rectification this fundamental frequency is equal to the frequency of the alternating current applied to the rectifier, while for double rectification the fundamental frequency is twice the applied frequency of the alternating current supply.

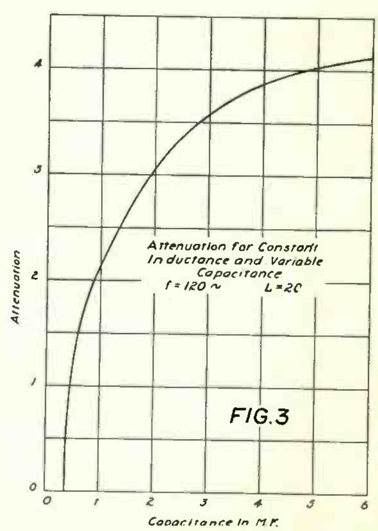
A non-resistive electric filter is a network of capacitances and inductances and a low-pass filter consists of shunted capacitances and series inductances. The function of the filter is to attenuate the alternating current components of the rectifier output and to pass the direct current component with a minimum attenuation. For this attenuation to take place, the cut-off frequency of the filter must be lower than the fundamental frequency of the rectifier.

In the design of a filter, it can be seen from an examination of Equation 1, that no attenuation of the alternating current will take place unless (W^2LC) is greater than 4.

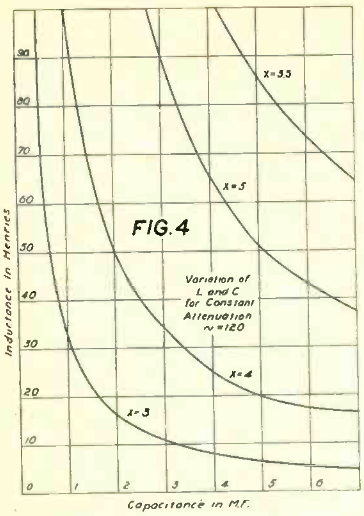
$$X = \text{Cosh}^{-1}\left(\frac{W^2LC}{2} - 1\right). \qquad (1)$$

W is equal to $2\pi f$, where f is the fundamental frequency of the rectified alternating current, L is the inductance in henries, and C the shunted capacitance in farads.

Fig. 1 is a curve showing the attenuation of a filter to various frequencies. This curve shows that for design purposes, only the fundamental wave need be considered since a filter which will properly attenuate the fundamental will attenuate all higher harmonics at a much greater rate. This curve does not represent an actual condition since the cut-off frequency of a filter applied to a double rectifier would be adjusted to give the desired attenuation at the fundamental frequency of the applied wave. For example, if it is desired to have an attenuation of 3.6 at 120 cycles, which would be the fundamen-



Curve of attenuation plotted against capacitance.



Curves showing the proper inductance and capacitance to give various values of attenuation.

tal frequency of the applied wave from a 60 cycle double rectifier, the cut-off frequency of the filter would be 51.5 cycles.

Variation in Attenuation

Fig. 2 is a curve showing the variation in attenuation for constant capacitance and variable inductance. From this curve it can be seen that the gain in attenuation is relatively small for all values of inductances above 22 henries. Since choke coils having an inductance greater than this are expensive to make if the resistance is to be kept to a minimum, it may be said that this is the upper limit of the inductance.

Fig. 3 is a curve of attenuation plotted against capacitance. For various reasons little gain is made by using values of capacitance greater than 5 or 6 M. F. This value takes into consideration only the filtering action. The condenser which terminates the filter must have a capacitance sufficient to supply the alternating current load of the radio set. This function of the terminating capacitance must be investigated along with the design of the filter.

Fig. 4 is a set of curves showing the proper inductance and capacitance to give various values of attenuation. In general, it is not economical to have an attenuation greater than 4 per filter section. These curves show the large increase in inductances and capacities necessary to obtain the high attenuation.

The ratio of current at the output to the current at the input of a filter section can be expressed in exponential form

$$i_2 = i_1 e^{-x} \qquad (2)$$

where i_2 and i_1 are the currents at the output and input of the filter respectively. x is a factor determined by Equation 1.

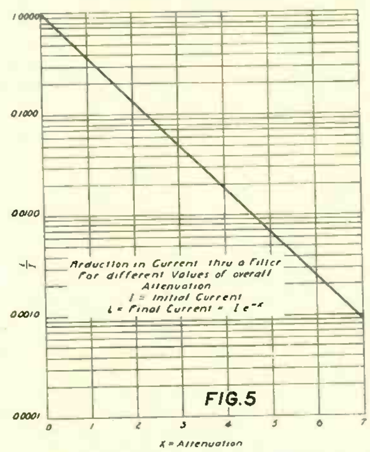
x in the usual case is a complex number but for the purpose of this paper, the absolute value of x is only desired.

Reflection From Load

Equation 2 is only true providing no reflection from the load occurs. This reflection will be zero providing the number of filter sections are infinite, or what is the same electrically, the load impedance be made equal to the surge impedance. The surge impedance of a filter of this type is equal to

$$Z_s = \left\{ \frac{L}{C} - \frac{W^2L^2}{4} \right\}^{\frac{1}{2}} \qquad (3)$$

Z_s = characteristic or surge impedance. W_1L_1 and C having the same significance as before. The load impedance Z_L must then be made equal to Z_s in order for the desired attenuation to be obtained. Since Z_s is a function of the frequency squared, it is easily seen why a filter is not always successful,



Ratio of A.C. amplitude in the output and input sides of the filter.

especially when applied to a radio set for high frequencies. Since in this case the last term becomes large. In this case propogation of the disturbance is from the opposite direction. That is, a filter must be designed to work not only from the input frequency (usually low frequency) but also from the load frequency.

Unless the output impedance is properly matched, the expression for the current at any point in the filter is equal to

$$i_m = \tfrac{1}{2} \left(I_o - \frac{E_o}{Z_s}\right) e^{-xm} + \tfrac{1}{2} \left(I_o + \frac{E_o}{Z_s}\right) e^{-xm} \qquad (4)$$

where the terms have the following meaning.

i_m = current at any desired filter section; I_o value of alternating current at the input; E_o value of alternating current voltage at the input; x is the attenuation constant per filter section; m the filter section under consideration; and Z_s the surge or characteristic impedance.

It can be shown that if the load impedance Z_L, is made equal to Z_s, Equation 4 reduces to

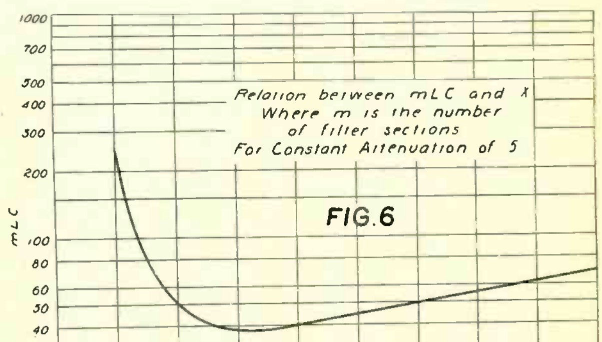
$$i_m = I_o e^{-xm} \qquad (5)$$

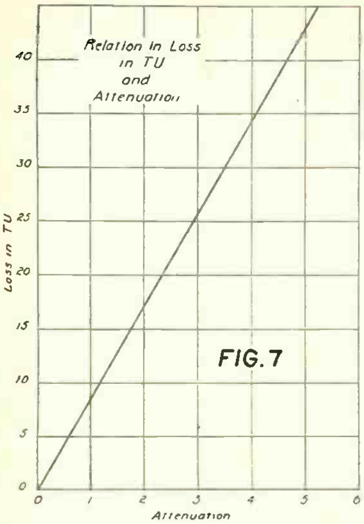
which is the same as Equation 2, except this is more general since it applies to a multi-section filter.

Fig. 5 is given to show the ratio of the alternating current amplitude in the output side of the filter to the alternating current amplitude in the input side of the filter. For example, an attenuation of 3 gives a current ratio equal to .05. That is, the alternating current in the output is equal to .05 of its value in the input circuit. Hence, if the reduction in amplitude of the alternating current is known, the attenuation of the filter may be found. If a loud speaker is serving as the load for the filter, the ratio of amplitudes of the alternating currents should be about .05, which corresponds to an attenuation of 3. If head phones are used as a load, the ratio of currents should be less than .008, which corresponds to an attenuation of 5. Except in rare cases, an attenuation greater than 5 is not needed.

As was mentioned before, it is not desirable to use a greater attenuation than 4 per section. In order to obtain

Curve showing the relation between the number of filter sections and the product of inductance, capacitance and number of sections.





Curve showing the relation between loss in TU and attenuation.

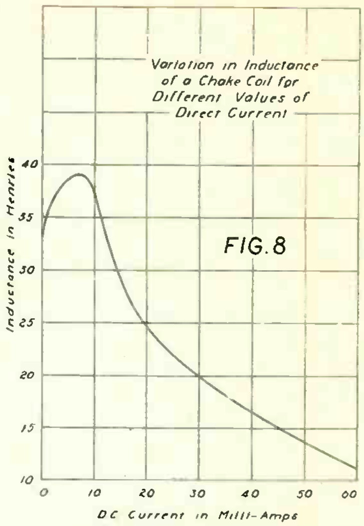
attenuation of 5, recourse is usually made to multi-section filters. An attenuation of 5 may be obtained by a two-section filter having an attenuation of 2.5 per section or by a 4 section filter of 1.25 per section. This relation may be written as, X = bm., where X is equal to the desired over-all attenuation, b the attenuation per section, and m the number of sections.

Fig. 6 is a curve showing the relation between the number of sections and the product of inductance, capacitance, and number of sections. The ordinate is a measure of the amount of material used in the filter. The most economical filter from the standpoint of material is a three-section filter, but a two-section filter would prove the cheaper, since fewer units would be used. As the over-all attenuation increases, the number of sections also increases.

In order that the attenuation units may be converted into loss in transmission units (TU), which are quite well established, Fig. 7 has been included. By the use of this curve, any of the previous curves may be converted into loss in TU instead of using attenuation units.

These curves have been given on the basis that the inductance was constant for all values of load current. However, the inductance of most iron core coils varies with the load current, especially when operated on the curved part of the saturation curve. Fig. 8 shows the variation in inductance of one of the common types of filter inductances. It can be seen from this curve that the inductance must be determined for the largest value of current to be used. In order to keep the inductance always operating on the straight part of the magnetization curve, an air gap should be included in the magnetic circuit.

In order that the voltage regulation may be reasonably good, the in-



Curve showing the variation in inductance of a common type of filter choke.

ductance should be kept to a rather low value. This will enable the resistance of the inductance to be kept to a minimum which will, of course, improve the voltage regulation. This should not be carried too far, since most rectifiers have a relatively high resistance which makes the over-all voltage regulation poor, regardless of the resistance of the inductances.

The Rating of Radio Receivers

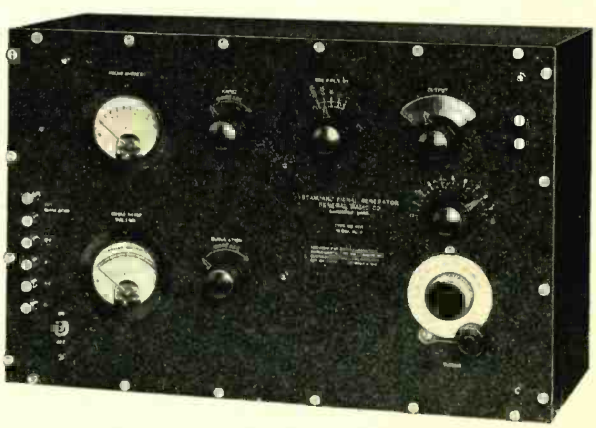
Description of a System for the Measurement of the Comparative Sensitivity of Receivers

*By G. C. Woods**

As the manufacture of radio equipment settles down to a stabilized industry, quantitative ratings are looked for with which to describe such equipment in a manner similar to that used for other electrical and mechanical apparatus. The inadequacy of such ratings as "coast-to-coast reception every night" becomes apparent as the Barnum era passes. At first the usual methods of rating electrical machinery in kilowatts or kilowatt hours do not seem applicable to such a device as a radio instrument. Actually, however, a radio receiver is a power converter, and its output is logically expressed in terms of power, but in milliwatts rather than in kilowatts. Obviously, a rating in terms of output power is a very incomplete description of a radio receiver, since it has no reference to the signal intensity in the antenna required to give the rated output. In order to describe the instrument completely (so far as sensitivity goes), a relation between input voltage and output power must be derived. This might be expressed as a ratio, but, in order to simplify the relation, a standard output has been agreed upon which permits a receiver to be rated in microvolts required to give standard

* *Engineering Dept., General Radio Co.*

Front view of the standard signal generator designed to conform with the strict requirements in the rating of radio receivers as outlined in this article.



signal, or, more simply, as possessing a sensitivity of so many microvolts, standard output being assumed.

The arbitrary figure of 50 milliwatts has been tentatively agreed upon as the standard output[1] and the microvolt becomes the unit of sensitivity on this basis.

Basis of Measurement

In order to measure the sensitivity of a receiver in microvolts, it is necessary to introduce into the receiver a signal sufficient to give the standard output, and to determine the strength of this signal in microvolts. The measurement of voltages of a few microvolts is not a matter of attaching a voltmeter of proper range, and reading the scale. The simplest method of determining voltages of this order is by putting a known current through a known resistance. It is essential that the voltage be impressed entirely at one point, i. e., the antenna and ground posts of the receiver. If there is any stray field from the voltage source, large errors will be introduced. Thus, there is required for these measurements a local signal generator so designed that a known minute radio-frequency voltage may be produced between two designated terminals and nowhere else. With such a device, over-all measurements, either of the entire radio-frequency amplifier or of the whole receiver, may be taken. The single unit should contain both the source of voltage and the means for adjusting and determining it, i. e., should consist of both a radio-frequency oscillator and a calibrated attenuator.

An instrument has been designed to meet these requirements. This outfit was developed to fulfill four conditions:

(1) A portable source equipped for use with external, unshielded batteries.

(2) A range of output voltages from one microvolt up, with sufficient shielding to prevent the induction by stray fields of voltages comparable with the output voltage in any adjacent tuned circuit.

(3) An accuracy well within the consistency of measurements with highly stable receivers.

(4) The whole outfit to be reproducible by ordinary skilled shop labor.

Description of Unit

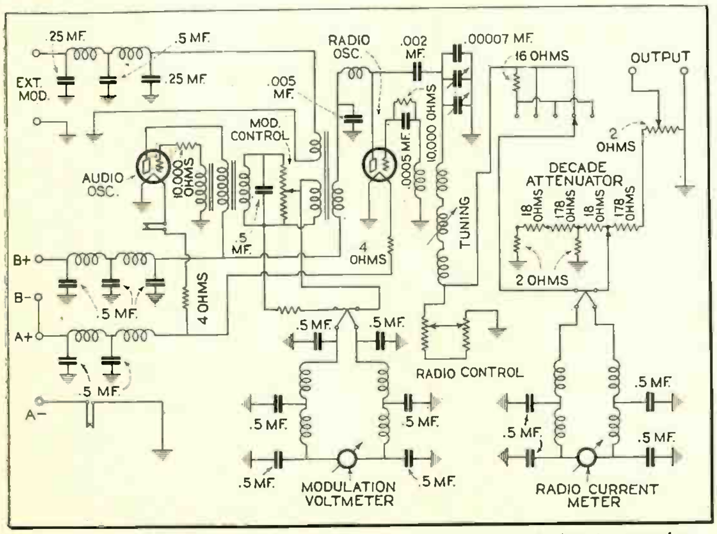
A diagram of the circuits employed is shown in Fig. 2. A single audio-oscillator tube is provided within the apparatus, for modulation at a fixed frequency of about 400 cycles. This is the frequency normally used for the most common measurements, sensitivity and selectivity. This oscillator comprises the tube shown at the left of the drawing, and the iron-core transformer tuned by a fixed condenser. This transformer feeds a modulation transformer through a resistance voltage divider marked "Modulation Control." The audio voltage is impressed by the modulation transformer (of one-to-one ratio) upon the plate circuit of the radio-oscillator tube, and is measured by a thermal voltmeter comprising a resistance, a 30-ohm thermocouple, and a panel-mounting direct-current galvanometer shown at the lower part of the figure. If fidelity measurements are to be made, an external audio oscillator is necessary, for which provision is made with a third winding on the modulation transformer. This third winding is connected through a low-pass filter to exposed "External Modulation" terminals on the main panel. This filter permits the use of an unshielded external audio oscillator, which may be positioned anywhere with respect to the signal generator and the receiver under test, and which may be connected to the signal generator through unshielded leads. The radio-oscillator tube has a "parallel-feed" plate circuit comprising the secondary of the modulation transformer and a radio-frequency choke coil in series with the positive plate-battery terminal and the plate. The tuned circuit of the radio oscillator consists of a "variometer" inductance which is connected by a metal belt to the variable tuning condenser, both being operated by a tuning dial on the front panel. The system maintains a nearly constant L/C ratio, and obviates the need of continual readjustment of the current as the tuning is changed. A small variable condenser is provided in shunt with the main condenser for fine tuning adjustments. The tuned circuit is closed through an attenuator which is by-passed to ground by a non-inductive variable resistance marked "Radio Control." This resistance thus furnishes a means for adjusting the modulated radio-frequency current flowing into the attenuator. The current which passes into the attenuator is measured on a 4-ohm thermocouple connected through a twin two-section filter into a panel-type direct-current galvanometer which is exposed on the front panel of the outfit. The output end of the attenuator terminates in a 2-ohm non-inductive slide-wire which is connected to the output terminals on the front panel. This slide-wire consists of a short piece of No. 36 manganin wire stretched over a copper return path with an insulation strip between them 0.01 inch thick.

Line Filters

It will be noted, first, that all battery lines, the external modulation lines, and the lines of the two direct-current meters pass through filters. Flters are, of course, absolutely necessary if external batteries and modulation sources are to be allowed. Also, the advantage of being able to expose the current-measuring instruments without covering their dials with metallic screens is obvious.

The resistance attenuator is built of small non-inductive units in which no wire larger than No. 36 manganin is employed. It will be noted that no single resistance unit is larger than 178 ohms. This permits the use of the reversed-loop form of winding, which experience has shown to be more reliable as a radio-frequency voltage-drop resistance at 1500 kilo-cycles than the so-called "bifilar" or parallel-strand winding. Capacity effects in the reversed-loop winding would be important, even with wire as small as No. 36 if high resistances were employed.

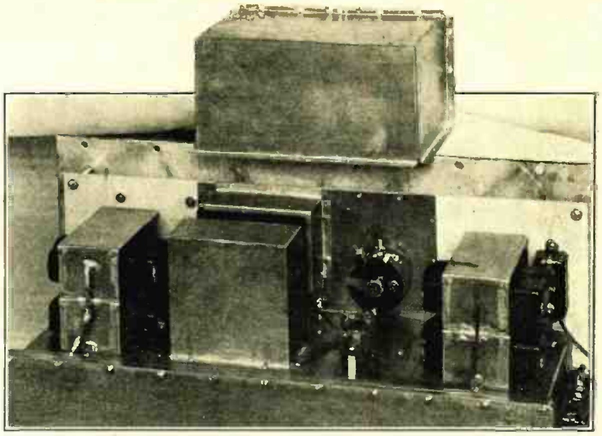
[1]*I. R. E., Preliminary Report of Committee on Standardization, May,* 1928.



The schematic diagram of the specially designed standard signal generator.

By using the slide-wire, then, we are enabled to employ a decade attenuator having only five steps. Using the values of resistance shown, the attenuation ratios at the various points on the attenuator from left to right on the diagram are respectively as follows: 10,000 to 1, 1,000 to 1, 100 to 1, 10 to 1, and 1 to 1. The slide-wire is provided with a calibrated scale of ten divisions. Thus, with the current through the "Radio Current" meter adjusted to a fixed value of 50 milliamperes, and the attenuator at the last point on the left on the panel a radio voltage of one microvolt is impressed between the output terminals with the slide-wire on its first scale division, and 10 microvolts with the slide-wire at maximum. The slide-wire scale is correspondingly multiplied in microvolts output at other points on the attenuator. The current may also be operated at twice the foregoing value without forcing the meter off scale, which provides a maximum output voltage of 200,000 microvolts.

Interior view of a portion of the standard signal generator. Note the substantial shielding employed.



Compensating Resistance

The sliding-contact switch shown above the decade attenuator in the diagram is simply a device for throwing a fixed resistance of approximately 16 ohms in series with the attenuator on alternate points, in order to keep the total resistance in the radio-frequency circuit constant and to prevent current variations as the attenuator is shifted. This compensating resistance is controlled by a separate switch mounted on the same shaft with the attenuator switch, because it and its associated leads must be carefully shielded from the right-hand or low-voltage portion of the attenuator. The shielding of this attenuator is a delicate and rather complicated matter, brought about by the fact that, for convenience, we elected to start with large radio-frequency currents. It may appear strange to the casual observer that we simply wind up a set of individually measured resistances, connect them together in an attenuation network, and assume that the attenuated voltage is equal to a value computed from the diagram. This procedure is justified, however, by the arrangement and shielding of the units. The features of the shielding system do not appear in the diagram. Its nature may be suggested by the fact that at the point of maximum attenuation, a current of 100 milliamperes may be in the attenuator switch arm, whereas a current of 10 micro-amperes and no more must flow into the slide-wire. This means that the net capacity between all conductors connected to the switch arm and all conductors connected to the last attenuator point (including the slide-wire) must be less than 0.5 micromicrofarad in order to reduce the capacity error to 2% at 200 meters.

The units of the attenuator itself are distributed through three brass boxes, one inside the other; the compensator resistance and switch are in a separate shield; and finally, the radio control rheostat and all leads carrying the main current from the oscillator are separately shielded from the slide-wire and the leads connected to the output terminals. In localizing a measured microvolt between two terminals, as is done here, it is also found that the question of ground currents from the attenuator points and elsewhere is very important. The proper locations for the various ground connections shown in the diagram were worked out only after some thought and a great deal of discouraging experience.

The Shielding

Regarding the general shielding of the outfit, little has been said because it is more or less conventional. The radio and audio-oscillator circuits are mounted in a heavy copper box with a removable lid. The fittings are rather massive because the lid could not be soldered on and forgotten, as is readily done with laboratory equipment. This main internal shield is attached to a metal subpanel, which is spaced by metal studs from the outside panel, also of metal. The outside panel is screwed tightly to a copper-lined cabinet and forms with it the outside shield. In some outfits of this sort it is better to insulate the internal assembly in its shield from the outer shield; this is determined, in general, by the location of the attenuator and associated equipment with respect to the radio-oscillator circuit, which determines the ground current paths. The various filters are each distributed, part inside the internal shield and part between the internal and external shield. All controls are brought through both shields to the front panel on insulating shafts. Metal shafts are undesirable because they frequently make rubbing contacts with one or both shields and produce unexpected and disturbing phenomena.

A word should be said as to the accuracy of the voltages supplied from the generator. Certain methods are available for checking the voltage ratios by comparison with an external voltage divider, and by comparison with known current ratios, also for checking the absolute values of voltage against other sources of a different nature. Thorough cross-checks and intercomparisons on this particular system indicate the following points: (1) The error in any ratio on the slide-wire or decade attenuator is not greater than 3% at any frequency below 1500 kilocycles; (2) The error in the absolute value of the voltage between the generator terminals is not greater than 4% at any frequency and is probably much less for voltages above 10 microvolts.

Operation

The accepted practice in measuring and rating receivers is to impress the known voltage from the generator in series with the local antenna circuit and the input terminals of the receiver. The output of the receiver is equipped with a resistance load appropriate to the power tube or tubes which terminate the audio amplifier. A "normal signal" is specified for all receivers, usually 50 milliwatts. All measurements are referred to the radio-frequency voltage, with a specified percentage modulation and a specified antenna, which will produce normal signal in the output load of the receiver. With an output load of 2000 ohms, for example, normal signal corresponds to about 10 volts, which is a reasonable loud-speaker voltage. A simple "output meter" is required for all such measurements It may be a vacuum-tube voltmeter or a thermal meter. Furthermore, sensitivity measurements are usually made with a modulation frequency of 400 cycles and 30% modulation. Suppose a receiver with specified antenna constants gives normal signal at 100 microvolts. This figure of 100 microvolts is a rational sensitivity rating for the receiver, because it means physically that if the receiver is fed from a 2-meter antenna having substantially the same effective inductance and capacity as that used in the measurement, a field strength of 50 microvolts per meter is required to provide entertainment.

Gas in Metal Parts of Vacuum Tubes

Relative to Gas-Forming Contaminations and Degassifying Treatments

*By J. H. Ramage**

WITH the recent rapid commercial development of the radio vacuum tube, the metallurgist, engaged in this field, has been confronted with many rather novel problems, difficult of commercially practical solution.

Not the least of these is the demand for gas-free metal parts. To meet the present requirements for satisfactory tube operation a vacuum of less than .0007 mm. of mercury pressure must be obtained and maintained during the life of the tube. Any slow evolution of gas from the metal parts will obviously raise the pressure to values in excess of this in a very short time. The metallurgical problem is to prevent such gas evolution.

Gas Evolution

It is the purpose of this article to discuss briefly some of the possible sources of gas evolution in metals, indicate measures taken to eliminate some of these sources, and illustrate, with a few examples, some of the troubles arising from this gas evolution.

In considering the sources of gas in metals, there are, first of all, the gases inherent in metals from the time of their reduction from ores. All the forms in which gas may be present from the time of solidification of the metal are not fully known to science at present. There is some gas entrapped in mechanical voids, such as blow holes and shrinkage cavities, in the body of the ingot as cast. There are also impurities in the metal such as oxides, nitrides, carbides and sulphides which are apt to be sources of gas later in conditions existing in the vacuum tube. These sources are readily proven and definite methods can be taken to obviate them. However, with these sources removed, there is still gas in the metals held in manners not fully understood, variously designated as dissolved, absorbed or adsorbed, and which, due to our lack of knowledge as to its origin, is much more difficult to deal with. Some of the possible explanations for the presence of this gas are (1) that it is actually dissolved in the metal as in another gas or liquid, that is, that there is a mixture in molecular proportions, (2) that it is present in the body of the metal at grain boundaries only, being held by mutual electrical attractions of atomic or molecular proportions, (3) that it is condensed on the surface of the metal, probably also an electrical phenomenon. That there is intergranular penetration of gases in hot metals is readily demonstrated by the etched microsections of nickel burned in sulphurous atmosphere or tungsten burned in an oxidizing atmosphere. Microphotographs Figs. 1 and 2 are illustrations of this phenomenon.

* Metallurgist, Westinghouse Lamp Company.

Fig. 3. Nickel supports (marked by arrows) pressed in the glass stem of a tube. There is an absence of gas bubbles, causing cracked stems. (Transmitted light; specimen immersed in monochlor benzol. Mag. 5.)

Fig. 1. A microphotograph of nickel that has been burned in a sulphurous atmosphere and which shows sulphur contamination along grain boundaries. Mag. 200.

Further Sources of Contamination

Besides the gas sources considered above in the metal as cast, there is possibility for further contamination in the hot and cold working processes necessary to reduce it to the finished tube parts required. The surface of course, can assume a layer of oxide, sulphide or carbide if the necessary impurities are present in the atmosphere in which the metal is worked. A film of lubricant used in cold drawing or rolling and left on the metal through subsequent processes may lead to contamination. This contamination may penetrate intergranularly into the body of the metal making its removal more difficult. Then there is also the possibility of the so-called adsorbed and absorbed gases described above in cold metals also.

We know of no process of removing the so-called dissolved, absorbed and adsorbed gases other than heating the metal in vacuum. After this treatment the metal cannot be exposed to the gases again or reabsorbtion will occur. It is therefore necessary to perform this heating operation during the evacuation of the tube. We have found, however, that certain pretreatments of the metal parts greatly accelerates this final degassifying operation. For instance, a heat treatment in hydrogen prior to mounting the parts in the tube has been found most efficient. Analyses of the gas content of nickel parts treated in this manner as compared with similar parts given the same treatment in vacuum are most interesting, considering the subsequent performance of the metals. In both cases the parts were exposed to air again for some time prior to analysis for gas. As compared to untreated metal, no reduction in hydrogen content was shown by the vacuum treatment, while the hydrogen treatment showed an increase in hydrogen to 4½ times the volume of that in the untreated metal. The vacuum treatment showed a reduction in oxygen of 10% and no reduction in nitrogen content. The

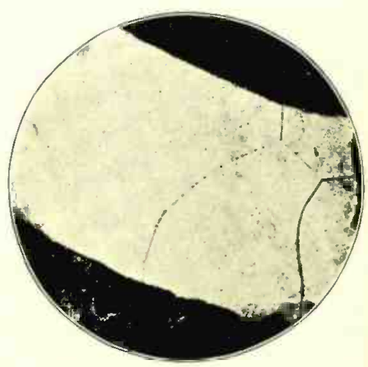


Fig. 2. The piece of tungsten here shown was burned in an oxidizing atmosphere and shows oxide contamination along the grain boundaries. Mag. 50.

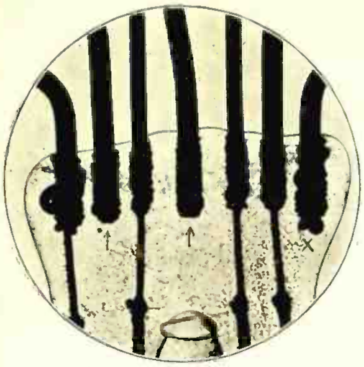


Fig. 4. The nickel supports marked by arrows show correct amount of gas. That one marked by an X was untreated before using and contains too much gas. (Transmitted light; specimen immersed in monochlor benzol. Mag. 5.)

hydrogen treatment showed a reduction in oxygen of 20% and in nitrogen of 15%. Neither treatment showed more than 7% reduction in total gas content. the vacuum treatment giving the best analysis. Yet in actual operation, the hydrogen treated matrial is much more readily degassified in the final tube making step and the resultant tubes are better. We do know also that hydrogen is more readily removed in this final step (heating in vacuum) than any of the other gases encountered.

The indications from these results are that the gases which subsequently cause trouble are held in the metals as chemical compounds such as carbides. oxides. nitrides and sulphides. There is always a large proportion of hydrogen in the residual gases left in the tubes which, in itself, is harmless. However, in the presence of the hot metal and aided by the possible decomposition of the contaminating compounds by ionic bombardment, gases such as water vapor, hydrogen sulphide, ammonia and hydrocarbons are formed which do not "clean up" but render the tube permanently gassy. It is therefore possible that the usefulness of this so-called degassifying process (heat treatment in hydrogen) is in removing a large part of these gas-forming contaminations at or near the surface of the metal. Following this line of reasoning, several other "degassifying" processes designed to remove certain contaminations have been devised for special cases with very promising results.

Mechanically Trapped Gases

There are several difficulties encountered due to gas evolution from metals other than vacuum troubles which have a bearing on radio tube manufacture in special cases rather than in a general way. The matter of mechanically trapped gases is illustrated rather forcibly in trouble encountered in large power tubes having a portion of the outer vacuum-tight container made of metal. In these tubes, the anode is of copper and serves also as part of the outer envelope. In operation, the heat developed in this portion can melt the copper unless weather cooling is resorted to. Trapped gas contained in blow holes cannot be discovered in the cold drawn tubes but will cause blisters as the metal gets hot during the tube operation which result in defective cooling at these areas and subsequently fusion holes and tube failures. A vacuum treatment prior to use followed by close inspection is resorted to as a means of detecting such defective anodes.

The so-called hydrogen "degassifying" treatment in a modified form is resorted to also in preparing nickel for insertion in glass. In the case in question. the metal cannot be completely degassified as, owing to its coefficient of expansion as compared to glass, it cracks the glass when no gas is evolved during the insertion. On the other hand. if too much gas is evolved, the nickel pieces. used for supports inside the tubes. become loose and fall out. An optimum gas condition of the metal has been found which causes a slight gas evolution during insertion resulting in an unstrained but at the same time secure seal between the glass and the nickel. This is not, of course, vacuum-tight but in this case a vacuum-tight seal is unnecessary. The microphotos. Figs. 3, 4, 5, and 6, illustrate the case in question.

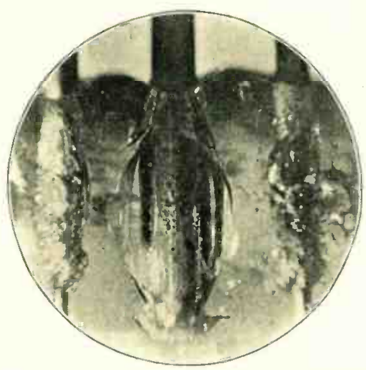


Fig. 5. Same as Fig. 3. Note the cracks in the glass stem due to the too complete union between the glass and nickel. (Transmitted and reflected light; specimen in air. Mag. 11.)

Gas Bubbles

The presence of gas bubbles in excess on the seal wire is, of course, another illustration of the evils of gas evolution. Fig. 7 illustrates good and poor seal.

We know of no one process to which the finished metal parts can be subjected which will act as a cure-all for these gas troubles. Preventative measures will have been indicated in the foregoing discussion of the causes of the trouble. To sum up. care must be exercised in kind of metal selected, in its preparation as to freedom from mechanical voids and gas forming impurities. Further care must be exercised during the cold working processes necessary in reducing it to wire or strip, especially during the necessary annealing steps, both as to the nature of the atmosphere in which it is annealed and the freedom of the surface from dirt of any kind *before* annealing.

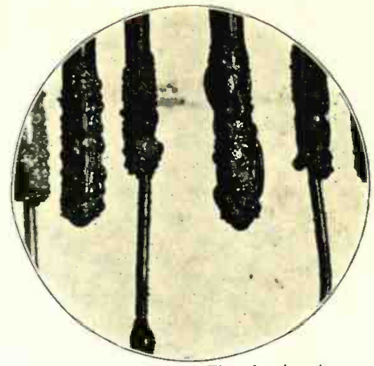


Fig. 6. Same as Fig. 4, showing that there was the correct amount of gas, as cracks in glass are absent, there being only a partial union between the glass and nickel. (Transmitted and reflected light. specimen immersed in monochlor benzol. Mag. 9.)

Then the hydrogen anneal referred to will render the common metals used susceptible to very complete degassification at the final evacuation of the tube if they have not been very bady contaminated up to this point. This, of course, does not apply to the so-called irreducible oxide forming metals such as chromium, tantalum, thorium, zirconium, etc. All these precautions may still be defeated by dirt introduced in assembling the parts, especially by excessive oxide formed at welding operations. Absolute cleanliness of the parts as mounted and ready for exhaust is practically a surety of a hard tube after the exhaust operation if this operation is carried out properly.

Fig. 7. The continuous row of bubbles on the left seal wire caused a leak in this stem. The right seal wire was satisfactory. (Transmitted and reflected light; specimen immersed in monochlor benzol. Mag. 9.)

New Musical Effects Produced by Electrical Means

New Freedom of Musical Expression Gained Through the Use of High Power Sound Reproducing Devices

By Edward W. Kellogg*

MR. KELLOGG convinces us that the art of musical expression is to be enriched by means of electrical reproduction.

That a purely commercialized device will hitch itself to the purely aesthetic and remain as a contribution to the art of all sound expression appears far fetched. The fact remains, however, that with the aid of super-power reproducing devices, quality and volume can be controlled independently and an entirely new form of musical expression obtained.

That point of development has been reached where we can "make the heavens resound to a whisper." We shall yet experience the thrill of our bodies vibrating under the power of "a soft musical passage" rising above the orchestral background —Editor.

ONE of the most striking recent developments in the art of sound reproduction is that of loud speakers capable of delivering large volume of sound. The gain from this increase in loudness is not simply that the ears are relieved of strained attention to catch what is said or played, but a change of quality as judged by ear occurs as the loudness is altered, even when the actual sound wave shapes are kept the same.[1] For this reason,, reproduced speech and music will not sound natural unless the reproduction is at approximately the same loudness as the original.

The advent of the Radiola No. 104 brought radio music into the home with a volume about equal to that of a piano in the room. Electrical reproduction was then applied to phonographs, and the Brunswick "Panatrope" and Victor "Electrola" far exceeded the machines depending on direct or mechanical reproduction, in point of sound power.

Auditorium Speakers

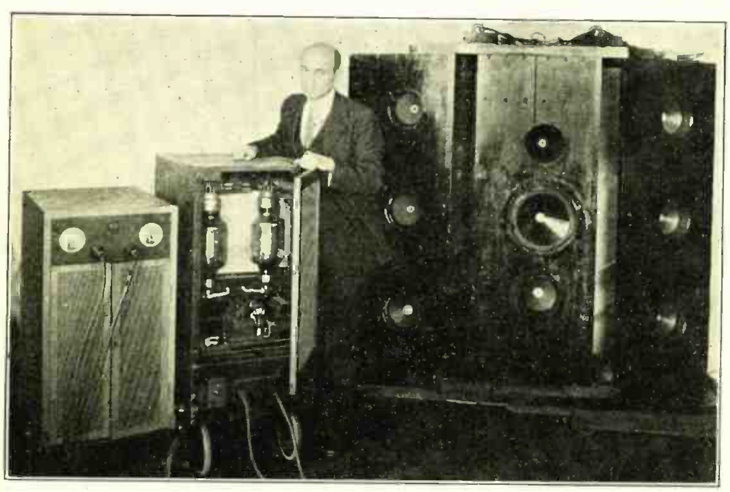
More recently there have been evolved loud speakers of much higher power for use in auditoriums or out-of-doors. In these devices no pains are spared to secure faithfulness or high quality, and amplifiers of ample capacity are employed to avoid distortion. Speakers of this class have for the most part been of two types, one employing a large horn, perhaps 12 to 20 feet long, with a bell opening of the order of 8 feet by 8 feet, while the other type employs a number of cone type speaker units. As an example of the cone type auditorium speaker a model built about two years ago under the writer's direction may be briefly described. It employed nine coil-driven cones such as used in the Radiola No. 104. the units being arranged in three racks, of three cones each. The power stage of the amplifier consisted of a pair of UX-851 tubes, each drawing .3 ampere plate current at 2000 volts. The amplifier could supply about 150 times the power without distortion which the UX-210 tube can supply to its cone in the Radiola No. 104 or the Panatrope. This equipment was used in a number of public gatherings at which orchestras or bands were present. It could, with pleasing effect, be run at a setting at which it was definitely louder than a ten to fifteen-piece dance orchestra, or comparable with a military band.

Violin at Band Volume

In the course of these demonstrations one characteristic of the music, produced by means of the high power speaker, impressed itself on those of us who were present. It is as easy to get a powerful sound from a single voice or instrument as from a large number of voices or from a whole orchestra. In fact we can with a given equipment put out considerably more sound power when reproducing a single voice or instrument than when reproducing the highly complex sounds of a large chorus or orchestra. Phonograph records are usually so cut that a vocal or instrumental solo is practically as loud as a band recording. What this means with the household phonograph is that the solo numbers are reproduced with somewhere near their original volume, but that the orchestra and band numbers, while loud enough to be enjoyed, are faint imitations of the originals. The high power auditorium speaker can practically duplicate the orchestra, chorus, or band, but it can do something which has not been possible before—sing a tenor or soprano solo, or play a violin at band volume.

New Musical Expression

Such reproduction is of course not exactly "natural," but the function of a musical device, such as the loud speaker, is not necessarily limited to imitation (although it must be capable of imitation) but to afford pleasure to the listener. And one of the elements which brings a thrill to the listener is the flood of sound that shakes his whole body, that in some passages seems even deafening. The



Mr. Edward W. Kellogg, and the high-power amplifier and bank of dynamic speakers employed in the interesting experiments discussed in this article.

[1] "Auditory Masking of One Pure Tone by Another," R. L. Wegel & C. E. Lane, Phys. Rev., Vol. 23, P. 266, 1924.
"Physical Measurements of Audition," H. F. Fletcher, Bell System Tech. Jour., Oct. 1923, P. 145. Jour. Franklin Inst., Sept. 1923.
"High Quality Transmission and Reproduction of Speech and Music," W. H. Martin and H. Fletcher, A. I. E. E., Vol. XLIII, 1924, P. 385.

* Research Laboratory, General Electric Co.

ability to reach such sound levels extends the range of musical expression, and carries an impression of power. Why else do we build giant organs, organize choruses of hundreds of voices, bands of fifty pieces, and orchestras of a hundred or more instruments?

It will be argued that the large orchestra is necessary to afford the desired variety of instruments and to give proper balance. But if there are several instruments of each kind, this explanation can hardly stand. Still less do such reasons apply to the two hundred voice chorus. A quartet, or for some compositions a sextet, can carry all the parts, afford the full range of voice qualities, and can be controlled and blended more perfectly than a larger number of voices. There is, of course, a psychological factor in favor of the large orchestra or chorus, but the primary purpose is to produce a great volume of sound.

Altered Sound Quality

The multiplication of sound sources results inevitably in a change of sound quality, the wave shape from the multiple source being more complex. With the best of tuning, two different instruments playing the same note will produce more or less rapid beats. With a large number of instruments playing the same note, each will beat with all the others, and the result is rapid and rather irregular fluctuations in intensity during the playing of each note. Whether the net effect is pleasing to the ear is perhaps a matter of taste. Those who prefer the complex tones would probably describe them as "richer." Those who like the simpler tones would speak of them as "mellow" or "smooth" and find, relatively, a certain harshness in the complex tones.

Heretofore we have had no choice but to accept the complex wave and the tonal qualities which it carries, whenever we have wanted great sound volume. The two factors have gone hand in hand. With the new tool at our disposal, the high power sound reproducing device, we can control volume and tone quality independently, and can have the smooth and mellow tones of the small group or single instrument at any volume. There is thus a new freedom given to musical expression. The quality resulting from blowing or bowing strongly can be reproduced softly as desired, or the quality of an instrument played softly may fill the auditorium. Still more important is the advantage to be gained in the rendering of vocal selections. Every voice changes in quality according as the person sings loudly or softly, and the change is certainly in the direction of an impairment in quality as the loudness approaches the point where strain and effort are present. The forced voice gives no pleasure and is likely to result in permanent injury. We seek the world over for the rare combination of great power, pleasing voice quality, and sufficient musical appreciation and training to use the voice with artistic effect. But there are thousands of singers who have all of the requirements except power, and whose voices may even surpass those of their more celebrated brothers or sisters in richness and fineness. These voices are now made available in the theatre and auditorium as well as in the parlor. All singers may use their voices at more natural levels, and the smooth round tones of the soft or subdued voice may be heard with ease in all parts of the house.

Amplifying a Whisper

Certain difficulties are encountered in the attempt to magnify the voices of singers actually present on the stage, and the full advantage of electrical sound production cannot perhaps be realized under these conditions. But where music is recorded and then reproduced the new factors will become of great importance. Already the alteration of sound levels possible with electrical phonograph recording and reproduction has been utilized to produce records of a type that has been quite popular, namely, the "whispering" tenor solo. The microphone is placed very close to the singer, who speaks and sings in a voice little above a whisper. On the higher notes the voice becomes nearly a falsetto. The reproduction is many times louder than the original, and the effect is of a voice of very unusual quality. Those who listen probably do not often realize the discrepancy in loudness, and might not like it so well if they did. We have so long been seeking naturalness in reproduction that unnaturalness is thought of as a fault, even though it may have been brought about for a purpose and with pleasing effect.

Although a large orchestra is looked upon as the finest that can be provided in musical entertainment, it may be predicted that where recorded music is used, the aim in general will not be to give the best possible imitation of the large orchestra (although this can be done with remarkable success when desired), but to render in whatever volume is wanted the simpler music of a small orchestra, with single instruments instead of groups of instruments carrying melodies. Balance is not dependent on the use of the proper number of instruments of each kind, but can be controlled by the positions of the players relative to the microphone.

The Orchestra of the Future

Let us venture another prediction, farther probably from early fulfillment. The orchestra of the future will make extensive use of electrical sound producing devices. One of the most important applications will be to accentuate the tones of certain instruments in order that a single instrument may carry a melody, or to give the effects of accompanied solos without subduing the entire remainder of the orchestra. Again new tone qualities are obtainable by electrical means. For example, let us suppose that an electrical sound pick-up is located within the instrument whose tones are to be magnified. The character of the tones will vary with location and also with the design of the electrical pick-up or microphone. Instruments which are not at present loud enough to be useful, except in the softer passages of the composition, will be made useful for the loud passages as well. With such electrical assistance as has been suggested, the orchestra of the future will be able to produce many effects not now possible.

ONE TEN-THOUSANDTH OF AN INCH IS IMPORTANT IN "TALKIE" MAKING

THE first sound picture or talking movie designed especially for purposes of military instruction was completed recently and shown before a representative group of military and naval officials. The film was made at the Infantry School at Fort Benning, Georgia. It is a result largely of the Western Electric Company's experimental work and production methods.

One of the "most difficult of all production tasks," to quote the company's statement, was placed before the Hawthorne organization of the Western Electric Company by the enthusiastic public reception of the talking pictures.

More than $500,000 worth of the most modern machine equipment had to be bought, and especially adapted to this project. A heavy production schedule was set up. The tool room was geared up to capacity for turning out the required tools. A storeroom covering 6,500 square feet of floor space was built in record time for the storage of material, process parts and apparatus.

Accuracy and precision were the basic features in the planning. One ten-thousandth part of an inch was a familiar item. The finest work was necessary in the manufacturing processes entailed in making the new condenser type transmitter (the microphone used in recording for the talking pictures). One small disc, a part of the transmitter, must be ground until its surface is exactly flat—microscopically flat. To test this flatness a quartz disc is used. By placing this disc on top of the other disc, a patchwork of light rays broken into spectrum rays is seen. If this patchwork of light rays does not have a certain design then there is something out about the flatness of the manufactured disc.

Dust-proof rooms are used for transmitter assembly. Dust, any speck of it, in this instrument, would be fatal. Glass cabinets, with all the moisture exhausted, contain the parts which are assembled in the cabinet. The workmen place their wrists through rubber sleeves fixed to the cabinet in order to assemble the parts.

Executives Service Bulletin

The Engineering Rise in Radio

By Donald McNicol

Fellow A.I.E.E., Fellow I.R.E., Past-President, Institute of Radio Engineers

PART VIII

THE very thorough investigations carried out by Pickard brought to light all that it seemed possible to learn about the action of crystals as wave detectors. Tracing backward from effect to cause, it was early noted that the current actuating the telephone receiver associated with a crystal detector, was of the nature of a rectified current. That is, the alternating current produced in the antenna by passing electric waves was, after passing through the crystal detector, changed into a uni-directional current, made up of the succeeding pulses of one sign.

Pickard ascertained that it was necessary to have a large area contact on one side of the crystal, and that the direction of rectification was always the same for the same crystal. In some of the early crystals experimented with by Pickard, the thermo-electric current (generated when the assembly was made up as a thermo-couple) were in the same direction as the rectified current. This is an effect which would lead an investigator to conclude that thermo-electric action was a factor of the detecting properties of the crystal. Pickard, however, extended his inquiry over a wide range of crystals, and in the case of impure silicon discovered that the thermo-electric current was in the opposite direction to the rectified current.

With the rectifier principle established, Pickard suggested that the name "solid rectifiers" be given to detectors of the mineral type, to distinguish them from electrolytic and gaseous rectifiers, or valves. Of the mineral group, in addition to the carborundum type, four other solid rectifiers developed by Pickard came into general use. These were the silicon, zinc oxide (perikon), molybdenite, and pyron (iron sulphide), of which the perikon proved the most efficient.

As used in service the construction of these detectors was quite simple. Disregarding workmanship and fine appearance, a solid rectifier detector made up at a cost of fifty cents worked as well as one costing ten dollars. The silicon type had a small section of the mineral fixed in a metal cap, constituting one terminal, the other terminal being a fine metal point, adjustable as to pressure on the crystal. The carborundum detector had a block of the substance fixed between two metal plates. The galena detector was the same as the silicon arrangement, except that the fine metal point was maintained in lighter contact with the crystal. The improved form of perikon detector provided contact between zincite and copper pyrites or bornite.

To account for the action of crystals as rectifiers, no aid seemed to be forthcoming from theories of electric action in conductors, nor from any of the exceptional "effects" observed by scientists over a long period of years.

JOHN V. L. HOGAN

By applying the modern electron theory in an analysis of crystal action, Pickard, in 1909, advanced the theory of electron shift at the point of contact. As a perfect contact of small area is one of the requisite conditions for the manifestation of the rectifying property, it appeared evident that the current flow in the rectifying conductor must be extremely constricted in the immediate neighborhood of the small contact. Such extreme constriction of current path in material where the conduction is not metallic may lead to electron impoverishment of either the positive or negative electrons, depending upon whether it serves to present maximum conductivity for currents entering the crystal through the contact of small area, or for those presenting maximum conductivity in the reverse direction. The effect being to make the passage of either "in" or "out" currents difficult, the conductor and contact of small area then acting as a rectifier.

The crystal detector throughout its approximately ten years of use served two very desirable ends. It was employed as a detector in thousands of small and large radio installations set up for commercial working on land and in ship stations, tiding over the years during which the audion was being perfected: especially the six years 1906-1912 before the full potentialities of the audion were discovered.

Also, the crystal, being an inexpensive device, enabled a host of amateur experimenters in America and other countries to set up small stations, primarily for amusement purposes, but out of which came much of suggestion for improvement in details, and much experimental data of immediate use to scientists engaged in solving the larger problems of radio transmission.

Amateur experimentation under operating conditions, largely sponsored by the American Radio Relay League has, almost from the beginning of the art, continued to contribute knowledge of real value to the advancement of radio signaling. In later years the amateur's contributions in knowledge of short wave radio telegraph operation has been of particular merit, from which the larger radio undertakings, both governmental and private, have profited materially.

"Beat" Currents and the Heterodyne Principle

Although the audion detector, the development of which is traced in a later chapter, was introduced in 1906, six or seven years were to elapse before the amplifying properties of the tube were discovered. Throughout the years when the electrolytic, magnetic and crystal detectors were employed, and during the six or seven years while the audion was employed as a simple detector, it was realized by those identified with radio telegraph undertakings that there was need for a method of augmenting the radio-frequency energy reaching the detector, by means of a local e.m.f., which latter could be maintained at any desired value and in a stable condition.

This would be in accord with wire telegraph practice where a sensitive relay is caused, through its armature contacts, to operate a reading sounder, the relay armature and sounder being in circuit with a local battery.

Many attempts were made to devise microphonic relays which would be actuated by the minute rectified currents of the crystal detector, but for the needs of rapid, continuous telegraph service none of these contrivances was found to be practicable.

With the requirement clearly in mind, Fessenden, in 1902, conceived the idea of the Heterodyne,[23] by means of which "beat" currents are employed. The principle back of the idea is that if two radio-frequency currents of slightly different frequencies are impressed upon a circuit, they will successively assist and oppose, being in and out of phase progressively.

The result of the interference is that a third value is produced which is known as a beat current. As the interfering current is produced by a local generator it can be given a frequency which will insure that the beat current will occur at audio frequency, and the latter passed through a rectifying detector will produce the signal indication in the translating device.

The name "Heterodyne" is coined from the Greek words "heteros" and "dynamis," signifying "other" and "force," to imply that the received signal in the telephone is produced by energy of the received waves plus that from a local source of e.m.f. Obviously the pitch of the tone in the telephone may be varied by varying the frequency of the locally applied e.m.f. Thus if a current of 50,000 cycles per second is impressed on a circuit on which a current of 59,500 cycles per second already is impressed, the resulting, or "beat" current will have a frequency of 500 cycles per second.

The heterodyne method of reception introduced no new instrumentality. The interfering local e.m.f. could be applied by coupling the output of a high-frequency alternator, or alternating-current arc, to the receiving antenna.

In 1905, Fessenden applied for additional patents[24] covering the heterodyne, and in the years following many ingenious applications of the system were worked out by F. K. Vreeland, J. V. L. Hogan, E. D. Forbes, H. E. Hallborg, A. F. Van Dyck, Louis Cohen and G. W. Lee, all of whom were at that time associated with Fessenden interests.

The heterodyne principle although conceived by Fessenden as early as 1902, remained a laboratory device of engaging possibilities until it was given a thorough tryout in competition with the "tikker"[25] system of receiving continuous waves, in 1910. Tests for which facilities were provided by the U. S. Navy were carried out in that year: first, between the Fessenden station at Brant Rock, Mass., and stations on board the fast cruisers Salem and Birmingham, and later from the Navy's station at Arlington, Virginia, to stations on ships.

Tests showed that heterodyne reception was possible up to a distance of 3,000 miles, and that heterodyne signals were on the average five times as loud as signals from the same source and over the same distance when the electrolytic or crystal detector was employed simply as a rectifying detector without applying the locally generated interference (heterodyne) oscillations to the antenna circuit.

The invention held possibilities of vast importance which were destined to reach fruition following the discovery in 1912-1913, that the audion can be utilized to produce electric oscillations. With the little audion bulb available to produce the interfering oscillations, replacing the machine alternator and cumbersome arc generator, important improvements were soon made in the design of radio receivers. The "external" heterodyne (coupled to the receiving antenna) could be replaced by an "internal" or self-heterodyne circuit; an oscillating audion performing the desired function. And out of it all was evolved the super-heterodyne radio receiver, popular for broadcast radio-phone reception in 1926.

CHAPTER 8

The Propagation of Electric Waves

IN a previous chapter it was related that Mr. Marconi brought to the United States, in 1899, an operating outfit with which an attempt was made to report the progress of the international yacht race between the *Shamrock* and the *Columbia*. After the conclusion of the race, Marconi carried out a series of trials of wireless telegraphy between two American war-ships, at the request of the United States naval authorities, signals being exchanged up to a distance of thirty-six miles. On the return journey to England, Marconi fitted the steamer on which he sailed with an outfit of his equipment, and about forty miles from the English coast signals were received on shipboard from a land station.

Upon his return to England, Marconi had arrived at the conclusion that the time had come for an attempt to communicate across the Atlantic, England to America. It may be imagined that this project was somewhat of an inventor's dream, when it is recalled that prior to 1901 the longest distance covered was in the neighborhood of 150 miles; and that, at sea.

In Chapter 4, of this work, is incorporated a brief statement of the theory of electric wave propagation prevalent in the year 1900. In general, the understanding was fairly accurate, even if at that time no great distances had been covered. There was, of course, later, a host of problems which grew out of the attempts to bridge distances which involved surmounting the curvature of the earth.

There is to be noted here an outstanding difference between the problems of "wire" and "wireless" signaling. In telegraphy and telephony by wire the betterments have resulted, in large part, from improvements made in the media extending between the terminal instruments—the line and the cable. In radio signaling, the inventor, in order to produce systems which will be improvements upon present systems, has only the field of the terminal equipment in which to work. The medium connecting transmitting and receiving installations is not subject to treatment of a sort that would affect the grade of transmission through it of radio signals.

Mr. Marconi's success in transmitting test signals across the Atlantic ocean, from a station at Poldhu, Cornwall, to a station at St. Johns, Newfoundland, on December 12, 1901, immediately precipitated a considerable amount of diverse opinion and conjecture as to how the transmitted energy could possibly indicate its presence at a point 1800 miles from its source. In France, one official advanced the notion that the submarine telegraph cables which follow the same general direction as the Poldhu-St. Johns line, acted as a guide to the radio waves. Blondel assumed that the layers of ether at the surface of the ground have a maximum electrical density, comparable to a sort of electric mist, extending to a height about that of the usual antenna. The same conditions obtaining at each end, the receiving antenna, he assumed, would be more

[23] *U. S. Pat., No. 706,740 (1902).*

[24] *U. S. Patent Nos. 1,050,441 and 1,050,728, granted in 1913. See also U. S. Patent No. 1,141,717, Lee and Hogan (1915).*

[25] *The "tikker" or ticker, due to V. Poulsen, was developed by him as a receiver for use where continuous wave arc transmission was employed. It consisted of a mechanical vibrator, connected in the secondary circuit of the antenna coupler, which included a telephone receiver and a condenser in parallel. As the vibrator rapidly opened and closed the condenser circuit the denser was charged and discharged correspondingly, the charging current being that due to the antenna oscillations. Thus groups of audible signals reached the telephone identical with the telegraph dot and dash signals transmitted from the distant station.*

Goldschmidt, also, invented an interrupter of this type called a "tone wheel" for use as a receiver of undamped waves such as those transmitted by the alternator of his invention. A metal wheel with alternate insulating and conducting segments, rotating under a conducting brush, was connected to the antenna, the brush being in series with a telephone receiver. The wheel was rotated at a speed such that for each alternation in the antenna due to incoming oscillations, one conducting tooth passed under the brush. In this manner the high-frequency oscillations were "cut up" into audible groups corresponding with the transmitted telegraph signals.

Dr. L. W. Austin designed a rotary type of ticker comprising a rotatable grooved wheel in the groove of which one end of a fine steel wire rested. When the wheel was rotated by means of a motor the chattering contact thus formed between wheel and wire served to render audible incoming oscillations in a receiving antenna connected thereto. A similar rotary ticker was independently devised by C. V. Logwood.

influenced when entirely immersed in this hypothetical mist, than when it was extended to greater heights.

Others clung faithfully to the idea that the theory of propagation of light rays should afford an explanation of the behavior of Hertz waves. Some held that the waves were propagated by diffraction, increasing as the waves became longer. But, there was the stern reality that in crossing the Atlantic the waves had to surmount an obstacle more than 186 miles high, the curvature of the earth.

Various Theories

Emile Guarini, in France, and Professor La Grange, in Belgium, distinguished between the progress over the surface of the earth, or through it, of the electric and magnetic components of the electric wave. Guarini[1] referred to experiments of his which convinced him that "an electric field can traverse obstacles only with loss of energy (deviations and absorptions), while a magnetic field traverses the earth's crust without serious difficulty and with moderate loss."

The amount of "bending" of electric waves around the earth's surface in traveling from England to Canada may be understood when it is stated that a ray of light starting from England in a horizontal direction would pass over the nearest point of land in Canada at a height of one thousand miles, approximately.

At operating distances in excess of a thousand miles a new series of transmission phenomena was presented. In 1902, Marconi, during a voyage across the Atlantic, observed an effect of daylight on the strength of signals. Signals from the English station were readable at night to a distnce of 1,600 miles, while in daylight they were not received beyond a distance of 800 miles.

A theory of this phenomenon, prevalent at the time and for some years thereafter, was that daytime transmission was less effective as a result of ionization of the air in the immediate neighborhood of the sending antenna, caused by the rays of ultraviolet light from the sun.

Small wonder that when Marconi sent signals across 1,800 miles of space, in 1901, there should be speculation as to the mechanism of transmission of the waves. No doubt the energy departed from the sending antenna and existed for a fraction of a second in a medium extending continuously between sending station and receiving station. There was the question as to the nature of the medium, but the action of the sending antenna by means of which the distance effect was produced seemed to be consistent with the understanding that electromagnetic waves were produced and radiated.

[1] *Scientific American, New York, May 9, 1903, p. 22864.*

Mr. Marconi's 1897 demonstrations so astonished the physicists that several of these openly discussed the possibility that an entirely new electrical phenomenon was involved. Reference was made in Chapter 2, to Richard Kerr's query in 1898, as to whether or not Marconi was, perhaps unknowingly, using a new system of electric waves, differing from those discovered by Hertz, and it may well be realized that following the first successful trans-Atlantic demonstration, in 1901, the question should be asked: are the very long distances covered consistent with the properties of pure Maxwellian or Hertzian waves?

The idea of a "bound ether" occurred to Dr. Lodge to account for wave propagation around the surface of the earth, the thought being that the ether present in the earth and its atmosphere was in some fashion bound or locked as an inherent element of the whole. Thus, the progress of electric waves over the surface of the earth between points widely separated might be conceived as being possible because the waves adhered to the bound ether path, instead of travelling off in a straight line into the free ether of space.

Mr. Tesla, as late as the year 1912,[2] held to the view that in a radiating system employing spark-gap and earth connection, in addition to an elevated antenna, transmission takes place through space; conduction effects being excluded. But, when an arrangement whereby the spark-gap is replaced by an energy-storing inductance, one side connected to earth, the other to an elevated antenna, the distant receiver will be energized by currents conducted through the earth while an equivalent electric displacement occurs in the atmosphere.

Tesla's notion was that "the distant receiver is operated simply by currents conducted along the earth as through a wire, energy radiated playing no part." Loss of signal energy as distance is overcome was explained as being due to evaporation of moisture from that side of the earth at the time turned toward the sun, the conducting particles carrying off more or less of the electric charge imparted to the earth at the transmitting station. Inasmuch as evaporation is considerably greater during day hours Mr. Tesla's novel theory at least advanced an explanation which might seem to account for the longer ranges of operation possible at night than in the day time.

Nor was it likely in the wide search for other theories which might contain some degree of plausibility, or perhaps prove to be the "lucky shot in the dark," that the possibility of a part being played by the earth's natural magnetism, should be overlooked.

Although eight years later E. V. Appleton,[3] in England, and H. W. Nichols and J. C. Schelleng,[4] in America, were to designate the relation of the earth's magnetic field to wave propagation under certain conditions, in 1917; J. S. Clemens,[5] in America, advanced the theory that in order to transmit signals over the earth's surface without conducting wires it should be necessary only to "excite" the magnetic lines already in the air. It was Clemens' notion that the high voltage applied to a radio antenna acted to excite the natural magnetism, resulting in the creation of magnetic waves which travelled outward, following the curvature of the earth by virtue of the fact that in the region of the earth magnetic lines are present.

[2] *Electrical Review and Western Electrician, Chicago. July 6, 1912, page 34.*

The electromagnetic theory of light having been postulated by Maxwell, and the existence of electromagnetic waves, artificially produced, having been demonstrated by Hertz, most of the terminology and nomenclature associated with light rays quite naturally attached to the radiation mechanism of wireless signaling. Indeed, no explanation of the early success in space signaling had a reasonable foundation except that which could be stated in the terms employed by Hertz; reflection, refraction, polarization, and interference, which terms are common to the light-wave theory. But, light waves travel in straight lines unless reflected or refracted, and there are but a few substances which either the direct rays or refracted rays can penetrate. The phenomenon of light and dark hours on the surface of the earth had long since disclosed the main properties of light waves from the sun. Hertz waves were known to be highly penetrative, and Marconi's transocean demonstration indicated that they reached points so far distant from their source that (except for certain sun-effect losses) no "dark hour" period existed.

Kennelly-Heaviside Layer

The first to advance a logical explanation of the mechanism of Hertz wave transmission over distances which involved the curvature of the earth, was Dr. A. E. Kennelly, of Harvard University. In an article published in the *Electrical World and Engineer*, New York, March 15, 1902, (three months after Marconi's first trans-Atlantic demonstration) Dr. Kennelly stated:

> "There is well-known evidence that the waves of wireless telegraphy, propagated through the ether and atmosphere over the surface of the ocean are reflected by an electrically-conducting surface. On waves that are transmitted but a few miles the upper conducting strata of the atmosphere may have but little influence. On waves that are transmitted to distances that are large by comparison with fifty miles, it seems likely that the waves may also find an upper reflecting surface in the conducting rarefied strata of the

[3] *Proc. Phys. Soc. London, Part 2, p. 22D, February, 1925.*

[4] *Propagation of Electric Waves Over the Earth. Nichols and Schelleng. Bell System Journal, April, 1925.*

[5] *The Electrical Experimenter, New York, March, 1917, p. 814.*

air. It seems reasonable to infer that electromagnetic disturbances emitted from a wireless sending antenna spread horizontally outward and also upward, until the conducting strata of the atmosphere are encountered, after which the waves will move horizontally outward in a fifty-mile layer between the electrically-reflecting surface of the ocean beneath, and an electrically-reflecting surface, or successive series of surfaces, in the rarefied air above.

If this reasoning is correct, the curvature of the earth plays no significant part in the phenomena, and beyond a radius of, say, 100 miles form the transmitter, the waves are propagated with uniform attenuation cylindrically, as though in two-dimensional space. The problem of long-distance wireless wave transmission would then be reduced to the relatively simple condition of propagation in a plane, beyond a certain radius from the transmitting station. Outside this radius the voluminal energy of the waves would diminish in simple proportion to the distance, neglecting absorption losses at the upper and lower reflecting surfaces, so that at twice the distance the energy per square meter of wave front would be halved. In the absence of such an upper reflecting surface, the attenuation would be considerably greater."

Based on measurements made by Professor J. J. Thomson, Dr. Kennelly believed it would be safe to infer that at an elevation of about fifty miles above the earth's surface, a rarefaction of the atmosphere exists which, at ordinary temperatures, accompanies a conductivity to low-frequency alternating currents about twenty times as great as that of ocean water.

The probability of a reflecting layer in the upper atmosphere occurred also to Oliver Heaviside, very likely independently, in June, 1902. At that time, writing an article on Telegraphy, for the Encyclopedia Britannica (published, December 19, 1902) Heaviside said:

"Sea water, though transparent to light, has quite enough conductivity to make it behave as a conductor for Hertzian waves, and the same is true in a more imperfect manner of the earth. Hence the waves accommodate themselves to the surface of the sea in the same way as waves follow wires. The irregularities make confusion, no doubt, but the main waves are pulled round by the curvature of the earth, and do not jump off. There is another consideration. There may possibly be a sufficiently conducting layer in the upper air. If so, the waves will, so to speak, catch on to it more or less. Then the guidance will be by the sea on one side and the upper layer on the other. But obstructions, on land especially, may not be conducting enough to make waves go around them fairly. The waves will go partly through them."

Although the first public suggestion of the importance of taking into consideration the probability of an upper conducting layer was made by Dr. Kennelly, the fact that Heaviside's announcement followed so closely, and his studies of the reflection of electromagnetic waves were so extensive, it soon become customary to refer to the condition as the Kennelly-Heaviside layer.

There is no need to commiserate with the scientists of 1902, because they were not able to develop a conclusive theory of radio transmission, while we keep in mind that as late as 1925–1926, the Kennelly-Haviside layer was in some quarters still on probation.[6] Two years after the Kennelly-Heaviside announcements, J. A. Fleming, of the Marconi organization, in his paper of 1904, read at the St. Louis Electrical Congress, asked the question: "How is it that the bending of the electric radiation takes place? If it is due to a simple diffraction, then it is proportionately to the wave length vastly greater than anything of the kind we find in connection with the ether waves which produce luminous sensations. It may be suggested that we have here one of the facts which indicate that the radiation sent off from an earthed antenna is not identical in every way with that sent out from an insulated Hertz oscillator."

Here was a task for the giants: a problem for the best of intellects. Intelligible signals had been transmitted between points on the earth's surface, eighteen hundred miles apart, without the use of conducting wires. How account for this through reasoning applied to explain the behavior of light waves, or of sound waves in air?

Attempts to determine whether diffraction could occur to a sufficient extent to account for the observed facts were supposed by some thinkers to involve the ratio of wave length to the earth's diameter. The optical analogies discussed by Fleming, and others, did not seem to lead in the direction of understanding. Naturally, many of the brightest minds in the world were engaged in attempts to unravel the mystery. Contributions to the subject, of greater or less value, were made by E. Lecher, W. V. Rybczynski and A. Sommerfeld, in Germany; H. Poincare and H. Abraham in France; J. Nicholson, W. H. Eccles, MacDonald, Love and Watson, in England.

The researches of these physicists extended through the years from 1901 to 1919. Sommerfeld, in 1909, (*Annalen d Phys.*, Vol. 28) assumed that part of the radiation is a surface or cylindrical wave which follows the contour of the earth, analogous to the transmission of electric waves over wire lines, the waves being rapidly damped in a downward direction, and subject to damping in the direction of propagation. Sommerfeld's idea was that the surface wave following the contour of the earth was not diffracted: or at least, diffraction was not essential to its progress over long distances.

Inquiry into the phenomena of wave propagation over long distances is little aided by consideration of the electrical action which takes place at, and in the immediate neighborhood of, the transmitting antenna, but an understanding of complete cycle of events from transmittted wave to received wave is of value in setting up the problem, the solution of which is desired.

[6] *Propagation of Electric Waves Over the Earth. H. W. Nichols and J. C. Schelleng. Bell System Technical Journal, April,* 1925.

The Mechanism of Radiation

The electrical engineering concepts and the terminology which grew up based upon the association of electrostatic and electromagnetic effects in and around conducting wires, for educational purposes served well to build the entire art of electrical engineering, and although the electron theory, which reaches more deeply into elemental causes, is now the only useful theory of electricity we have, it is very likely that for many years to come studies of and applications of electric circuits will continue to be subject to interpretations couched in the terminology long established.

The theory of radio transmission stated in the Blondel-Ferrie paper, of 1900, (Chapter 4) was an epitome which in few words set forth the consensus of the foremost thinkers of that time. The terms there used explain that in the transmitting antenna the lines of electric force are in meridional planes, connecting perpendicularly with the earth; the magnetic lines of force being in circles having the antenna as a common axis. Thus the electrostatic and magnetic components of electric waves were set forth in an understandable manner.

The relative significance of these components in telephone circuits had, eleven years previously, been investigated by J. J. Carty, in America, in connection with "cross talk" phenomena. In a paper read before the New York Electric Club, in 1889, Carty showed conclusively that the disturbing current induced in neighboring wires is due to electrostatic induction: the electromagnetic effect being a consideration only when the wires are in very close proximity. A reason for this is that in telephone lines the current is relatively small. In the case of electric power lines the electromagnetic field may be the greater factor.

The very fact that when the existence of electric waves was first-proven high-frequency currents were employed to produce them was, no doubt, responsible for the notion which prevailed for a considerable length of time that electric waves were purely a high-frequency phenomenon. The writings of Maxwell and Heaviside were freighted with suggestion that an alternating e.m.f. alone was the essential. Obviously, experimental investigation alone was not likely to afford the discovery that radiation takes place at low frequencies: it was a subject for the mathematician, and in the course of time the mathematicians gave the answer, notably John R. Carson, in America.

The effect of any alternating current in a conductor is to create in the space surrounding it electromagnetic and electrostatic fields, linked together. With an alternating e.m.f. applied to the conductor these fields are in a continuous state of change. They re-

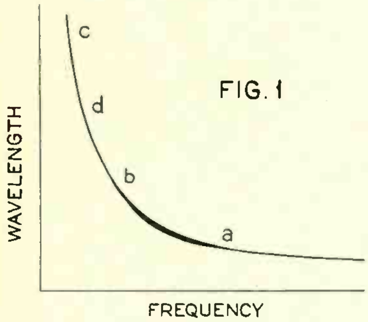
(*Continued on page* 32)

At the Knee of the Curve

An Interesting Recital on the Vagaries of Radio and How the Engineer Has Evolved Suitable Compromises and Employed Some of the Elements to His Advantage

*By J. E. Smith**

SOUNDS like the title of a romantic novel, doesn't it: something like "At The Cross-Roads," or, "Behind the Turnstile." Well, as a matter of fact, there *is* quite a bit of romance connected with the knees of the curves, as we shall hear about, but it is not the sentimental kind of romance that we usually have in mind. It is the romance that is connected with the development and discovery of matters scientific—the fruits of the life work of those connected with such discoveries and developments.



A curve indicating the relation between wavelength and frequency.

There is romance in work, as well as in love. We philosophize further; in keeping with the popular meaning of the word, we might perhaps suggest that part of the romance is found in one's love for his work.

We had not meant to philosophize; but actually it is getting us quite a way into the subject of our article. For the love one has for his work is in direct proportion to the interest he finds in it. And to go one step farther, the magnitude of that interest varies inversely with the sameness of the work.

If the work never varies, interest in it is soon lost, and the monotony of it all may command as much, if not more, attention, as the work itself. Think of having to do problems in Ohm's law all day long; a simple multiplication or a division. The only variation in the problem is in the actual numbers used in the calculations. But it is always I = E/R or E = IR. Amperes equal volts divided by ohms, or volts equal amperes multiplied by ohms. The first one or two calculations are interesting, but after that it is the same thing over and over again.

But suppose there is some disturbing factor that makes these calculations hold true only under certain conditions! Well, then we have found something that breaks the monotony—that revives our old interest in Ohm's law, not because of Dr. Ohm's law itself, but because of this new disturbing factor which we have encountered; it is another law acting upon the old one. In fact, the old one was not an exact law, nor a universal law, to tell the truth. It was only a particular case or a particular application of a more universal law.

And so, it is because of such things that the radio engineer's life is filled with interest for his work or, if we wish to consider the matter from another angle—with agony, on account of the countless complications which arise in his daily work, to cause him grief and worry. And all this is due to the "knee of the curve."

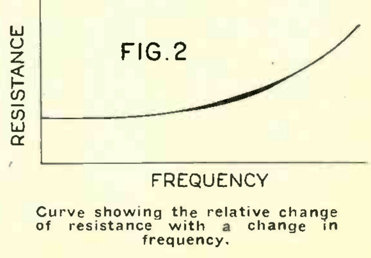
Relativity

What do we mean by the "knee of the curve?" Let us look at Fig. 1. This shows a curve, known as a hyperbola, which shows the relation existing between the wavelength and the frequency of the radio waves to which we tune every day, or of the currents which are flowing in the circuits of our radio receivers. This curve can be calculated from the simple formula, wavelength in meters equals 300,000 divided by frequency in kilocycles per second.

The knee of the curve is where it bends abruptly. This part is more heavily inked than the remainder of the curve. But why all the worry about the knee of this curve? Well, just this; higher up on the curve than the knee, the wavelength increases more rapidly than the frequency, and lower down on the curve than the knee, the reverse is the case. So as we move along the curve from the point *a* to the point *b*, or in the other direction if we please, first we have one of the two changing more rapidly than the other, and then later on we find that the opposite is true. And the trouble with it all is that the broadcasting range of frequency and wavelength lies *right at the knee of the curve*. In other words, the radio engineer can expect all kinds of complications in his work, and he usually finds them. Wavelengths which are longer and shorter than those of the broadcasting range are assigned to other classes of radio communication, such as naval and commercial radio, airplane radio, etc. The broadcaster, and designers of sets to receive broadcasting, are confined to that unpleasant portion of the curve known as the "knee."

Distressing Variations

Away up on the curve, as at *c* (Fig. 1) where the curve is practically a straight line we have the very long waves and *audio frequencies*. When the curvature begins to be appreciable we enter the region of *radio frequencies*, as at *d*. And of course, later on as the frequency gets higher and higher, we come to the ultra-high frequencies, or the ultra-short wavelengths. On either side of the knee we have what can be considered, for practical purposes straight lines, and we can more or less definitely state that one thing or another happens; at the middle or knee of the curve, however, we cannot always be so sure. Let us see how this works out in the case of some things with which we are familiar. Let us consider first, how the resistance of coils varies with frequency. We all know that at very low frequencies the resistance of coils is very low, and does not vary appreciably with frequency. But let us increase the frequency considerably; let us get closer to what we call the radio frequencies. We find then that a serious phenomenon occurs which makes the resistance of the coil no longer constant, but rather, this resistance increases steadily as the frequency increases, slowly at first, but at an ever-increasing rate as the frequency increases. When we get to the radio frequencies, we find that the resistance begins to rise at a very much more rapid rate, and we find ourselves "at the knee of the curve." This is shown in Fig. 2, where the knee of the curve has been heavily inked.



Curve showing the relative change of resistance with a change in frequency.

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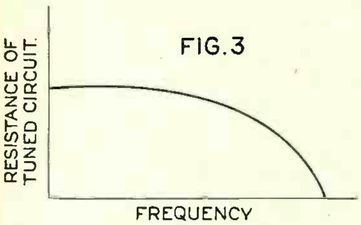
The Skin Effect

The reason for this increase of resistance with frequency is known as the "skin-effect." As the frequency becomes higher and higher, the tendency of the current to confine itself to merely the "skin" or outer surface of the wire becomes more and more marked. And when the wire is made into a coil only that portion of the "skin" is used which is on the outside



Another typical case of the "bends," where the resistance of a tuned circuit changes with a change in frequency.

of the coil. Consequently, as the frequency increases, less and less of the wire is used to conduct the current; consequently the wire acts as if it were smaller in diameter than it really is, and as if its resistance has been increased considerably. Unfortunately, again, the "knee of the curve," where the resistance begins to increase rapidly, occurs in the broadcasting frequencies. Below these frequencies the resistance is almost constant.

Distributed Capacity

What has been said of resistance, of course, applies as well to the effect of coil capacity on the resistance of the coil. It is well known that distributed capacity has the effect of making the coil act as if its resistance were higher than it actually is, in addition to making it act as if its inductance were greater than it actually is. This gives us the terms "apparent" inductance and "apparent" resistance, referring to the inductance and resistance which the coil "appears" to have.

Both the apparent resistance and the apparent inductance of a coil increase as the frequency increases, and once again, unfortunately, this increase begins to become very marked at the frequencies used for broadcasting. In Fig. 2, if we would change the word resistance to the word apparent resistance or apparent inductance, we should have then a picture of how these quantities vary with frequency, the knee of the curve being at the heavily inked portion.

Mutual Inductance and Regeneration

So we can go on and on, and show how this knee of the curve troubles the radio engineer. The apparent mutual inductance between two coupled coils, or the "coupling" as we generally call it, changes with frequency, due to the capacity between the two coils. This increase of mutual inductance, or coupling, beings to become serious right in the broadcasting range of frequencies; we are, for the umpteenth time at the "knee" of the curve.

Next, we can go into the matter of regeneration; this is an important phenomenon, as you all know, whether we find it in the ordinary grid suppressor circuit or in the bridge circuits, few of which are accurately balanced.

At low frequencies there is not much regeneration, as in audio-frequency circuits. There is some, it is true, but not enough to cause us to lose a lot of sleep over it. As the frequency increases, however, the regeneration increases more and more rapidly, until when we get into the radio frequencies, we find it a very serious factor in the design of radio receivers.

It is on this account that bridge circuits are more difficult to balance at frequencies higher than about 1,000,000 cycles per second (300 meters). When these circuits are slightly unbalanced, they generally oscillate first below 300 meters, on this account. It seems that the knee of the curve occurs at about 300 meters, or 1,000,000 cycles per second—right in the broadcasting range, once again.

If we measure the amount of regeneration we have in the circuit by the amount that the apparent resistance of the tuned circuits is decreased by this regeneration, then we can picture the effect as we have done in Fig. 3. If the regeneration becomes too strong, the apparent resistance of the tuned circuit may become zero, in which case the receiver oscillates. This is a powerful cause for worry for the radio engineer, and is due to the fact that the downward bend of the curve occurs in the broadcasting range of frequencies.

Feed-back

On the other hand, we will find an opposite state of affairs in the grid suppressor circuit. In this circuit, as you know, a resistance is placed in series with the grid in order to suppress oscillations. On this account, no stage of the receiver is *by itself* regenerative for the negative resistance introduced into the tuned circuits due to regeneration is never great enough to neutralize the high resistance in series with the grid. From a rather complicated combination of effects, it is found that there really is introduced into the tuned circuits quite a lot of *positive* resistance, by the *individual* stages. This resistance increases steadily with frequency, and as we have found in other cases before, the knee of the curve occurs at about 300 meters.

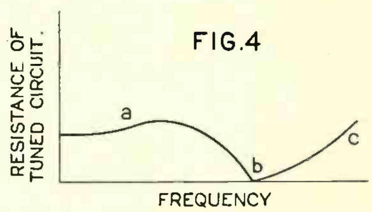
On the other hand, when we connect several of these stages in cascade, as we do in radio receivers, the feed-back from one stage to another is additive or cumulative, the feed-back from the third stage reinforcing that of the second stage, and so on. This is an "over-all" feed-back, not the simple feed-back of an individual stage, as from the plate circuit to the grid circuit.

This over-all feed-back, increases with frequency, just like all the other things we have considered. And so we have an extremely complicated and peculiar result. Look at Fig. 4 and we shall try to explain what is going on in the tuned circuit of the grid suppressor circuit. At very low frequencies we have little or no regeneration, so the resistance of the tuned circuit is the true resistance of the coil and condenser.

Next, as the frequency increases we find the "skin-effect" adding to the resistance of the coil and condenser, and the apparent resistance rises slightly, as at *a*, Fig. 4. The regeneration has not yet become serious.

Positive and Negative

However, as the frequency increases further we have introduced into the tuned circuit the positive resistance of the individual stages, and the negative resistance due to the over-all feed-back. The latter increases at first more rapidly than the former, so the net effect is that of a considerable reduction of resistance in the tuned circuit, which, if the over-all feed-back is strong enough, may actually lead to oscillations, as at *b*, Fig. 4, where the apparent resistance has become zero.



A particularly charming curve, which gets that way due to the influence of positive and negative resistance.

This point, where the tuned circuit resistance is least, always occurs in the broadcasting range of frequencies.

On increasing the frequency still further, we find that the positive resistance of the individual stage increases much more rapidly than the negative resistance due to the over-all feed-back, so that at the higher frequencies, or shorter wavelengths, we find the resistance becoming rather great, as at *c*, Fig. 4.

This explains why, when these circuits oscillate, they do so near the middle of the dial and why so many of them are so broad at short wavelengths. Of course, it is possible to remedy these difficulties when they are clearly understood. For instance, a little more over-all feed-back would cure the high resistance at the higher frequencies, and a little more grid suppression would stop the oscillations at the middle of the dial.

At any rate, look at all the kinks and bends of this curve! And they all fall in the broadcasting range of frequencies. Here are plenty of "knees."

Characteristic Curve of Vacuum Tube

In concluding this article, it is hardly necessary to call to your attention the "knee" with which you are all mostly familiar. (By the way, please remember that all these "knees" are inhuman—or rather un-human.) This most familiar knee is the knee of the characteristic curve of the electron tube. What a blessing that this curve has a knee. Without this knee there would be no detectors. We would have only amplifiers; but what good would amplifiers be if we have no detector to feed into them. The point is that the detector is a detector because it has a knee, or rather, because its curve has a knee. If we are using the good old "plate circuit rectifier," it is a rectifier because we operate it at the knee or bend of the plate current, grid voltage curve. Or, if we are using a grid leak-grid condenser detector, then we are operating the tube at the knee of the grid voltage, grid current curve. On the one side of the knee the current changes more rapidly with the voltage than on the other side of the knee. Consequently we have a *net* increase or a *net* decrease of plate current, depending upon which type of detector we are using. It is this *net change of current* that is the signal output of the detector.

THE ENGINEERING RISE IN RADIO

(*Continued from page* 29)

verse, expand and contract according to the variations in the direction of, and the intensity of the current. When the frequency is high (say, above 10,000 cycles per second) a considerable part of the energy is radiated into space in the form of electromagnetic waves, having the same frequency as the actuating current.

It will be understood that at very low frequencies the energy radiated is inconsiderable, and that when the frequency employed is of a high order radiation takes place which travels outward long distances.

It would be in error to suppose that the theory that electromagnetic waves are transmitted as detached waves through space, the hypothetical ether serving as the medium of transfer, was arrived at in a manner so convincing that all students of the subject have been in agreement with its postulation. From Newton's time (1686) until the present, the wave theory of light has been subject to periodical analysis and attack. And as the wave theory of light and the wave theory of radio have been associated in some degree of harmony since Hertz's time (1887), the rise of radio has been accelerated or retarded from time to time as those engaged in the work have had to devote time to running down new theories at variance with those of the accepted order.

Newton regarded it as beyond reason to conceive of waves or vibrations in any fluid being propogated outward without a continuous and immediate bending such as would quickly terminate their outward progress. In quite recent times Dr. Einstein, of Germany, has thrown discredit on the wave theory of light; which is either aid or confusion for those engaged in applying the electromagnetic wave theory in radio signaling—depending upon what the future has in store in the way of further disclosures of truth.

An American student, of amateur experience, in 1916, wrote and published a book[7] on the subject of radio transmission, in which he took the ground that transmission is purely electrostatic, the air acting as one side of the communication circuit; the surface of the earth, the other. His notion was that the air is a fair conductor for high-frequency currents and that the energy sent off by a transmitting antenna is conveyed to the receiving antenna with the air serving as the medium—ether playing no part in the transfer. With such a theory prevailing the deductions of Maxwell and the demonstrations of Hertz would fall, but a reason would stand out accounting for the faithfulness with which radio waves follow the curvature of the earth; adhering to a path in which air is present.

The early writers on radio felt that they were clear on the points that within a distance of about one-half wave length from a straight wire vertical antenna there exist no complete electric waves: for, within this distance some of the lines of force still remain attached to the conductor: That a free Hertzian oscillator emits free waves which are propagated outward and travel through space as do light waves: and that a grounded oscillator gives off grounded waves—half waves whose electrostatic lines instead of being self-closed, terminate on the earth. Poincaré, in France, and Vreeland, in America, in 1904, and others, concluded from the latter consideration that the waves follow the conducting surface of the earth and sea over which they slide.

Writing in the Electrical World, New York, of September 26, 1908, Dr. J. E. Ives, enlarging on the work of Zenneck and Hack, in Germany, discussed the mechanism of electric wave production and of detachment from an antenna, dealing entirely in terms of the electrostatic flux. In the article no mention is made of the magnetic component. Ives pointed out that when an antenna is initially charged the electric flux surrounding the antenna slides down to earth, and an attempt is made to account for the subsequent detachment of the flux from the antenna by the electric forces resident in the flux; that is, in the tension along the flux lines and in the distension perpendicular thereto.

Engineering advance is predicated upon mathematical deductions and experimental determinations which, circulating through the literature of the subject attract the attention of engineers and artisans in direct touch with practical operation. This might seem to be a condition carrying the suggestion that it would be well to have all literature on a given technical subject pass through the hands of a reviewing and correlating Board to the end that every paper and book might be consistent in its statements with prior publications, or explain the reasons for the inconsistency. Undoubtedly, if such coordination were practicable, much time would be saved by students who, otherwise, have no choice but to attempt out of their own resources to reconcile discrepancies of statement, or to conclude that stated theories, even if generally accepted, are to be regarded as ever subject to modification.

To return to the subject of wave components. Obviously, with an alternating e.m.f. applied to a transmitting antenna, the electrostatic field is constantly varying, and when electrostatic induction is varying a magnetic field is produced. The reverse, also, is true: when magnetic induction varies an electrostatic field is produced. The surging to and fro of the electric charge in the antenna entails, therefore, a magnetic field, which makes up part of the detached energy. As the energy in wave form detaches, the magnetic component is preponderant; and, as stated by Lowenstein[8], at a distance of one-sixth of the wave length, the magnetic intensity is forty per cent greater than the electric intensity. Further, at a distance of one-half wave length the preponderance of magnetic over electric intensity is only five per cent, and at a distance of one wave length the two values are equal.

(*To be continued*)

[7] *Revolutionary Theories in Wireless. F. E. Summers, Memphis, Mo.*, 1920.

[8] *The Mechanism of Radiation and Propogation in Radio Communication. Fritz Lowenstein. Proc. Inst. Radio Engineers, New York, June*, 1916. (*presented December* 1, 1915).

Sound Projector Systems for Motion-Picture Theatres†

A Description of the General Equipment Employed With Sound and Talking Motion Pictures

By Edward O. Scriven*

IN theaters at which motion pictures accompanied by synchronized speech or music are presented, the records come in two forms. Some are composition discs similar to ordinary phonograph records, while others are standard motion-picture film bearing at one side a track of alternate light and dark bands, of varying density. In either case there must be apparatus synchronized with each projector to derive from the records an electric current in which all the variations in pitch and loudness are accurately represented. There must in addition be apparatus to amplify the current, to effect its conversion into sound and so to direct the sound into the theater auditorium as to create the illusion that it emanates from, rather than merely accompanies, the picture. When a theater is being prepared for presenting sound pictures, the film projectors in use are ordinarily retained but each is fitted with a new motor and driving mechanism; It is provided with a turntable and electric pick-up for disc records, and with analogous equipment for film records, or both.

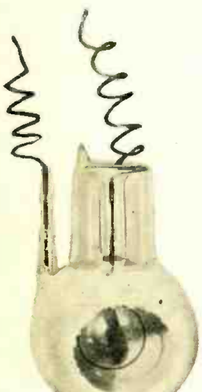


Fig. 2. This is the type of photoelectric cell which is employed for the reproduction of music from sound films.

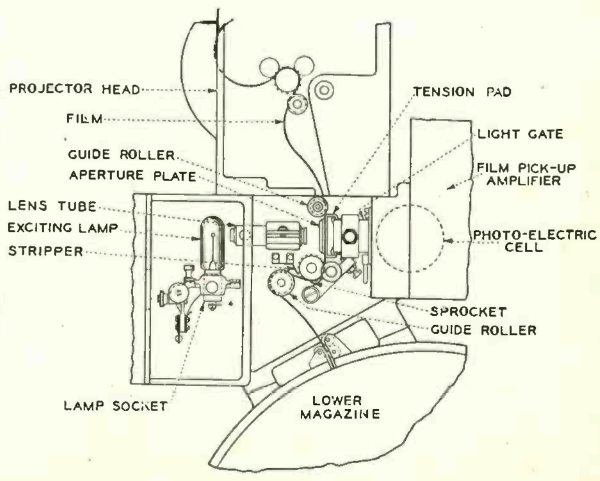
Electric Pick-up

The pick-up used for disc records is in some ways similar to the reproducer of an ordinary acoustic phonograph, with a needle holder connected to a clamped diaphragm of highly tempered spring steel. To the diaphragm there is fastened an armature made of a special high-permeability alloy, so arranged that as the diaphragm and the armature vibrate, the flux in the air-gap of a permanent magnet varies correspondingly; in appropriately placed coils currents are induced which are the electric representation of the wave groove which moves past the needle. Although this instrument delivers energy at a comparatively low level, it has a very uniform response over a wide range of frequencies. That result has been secured largely by preventing distortion which would arise from resonance in any part of the system; the members have been designed with natural periods beyond the range of frequencies to be transmitted, and the magnet chamber back of the diaphragm is filled with a heavy oil to damp free vibration. The films used with the disc records, called synchronized films, differ from ordinary films only in that one frame at the beginning of each is marked to give the starting point.

Film Records

With the optical or film records, the sounds are represented by parallel bands, alternately light and dark. Intensity or loudness is represented by differences in density of the record, and pitch by the closeness of the bands. For reproduction from these another apparatus group is required, and it too is connected to the projector. A narrow light beam of high

Fig. 1. The arrangement of the projector apparatus for reproducing from sound films. The light from the exciting lamp is brought to a focus on the film as a line 0.001 by 0.080 inch, thus covering the record with an allowance of 0.010 inch for variation of position.



† Courtesy of Bell Laboratories Record.
*Apparatus Development Department, Bell Telephone Laboratories.

intensity passes through the film record and falls upon a photoelectric cell to produce a current corresponding to that from the original recording transmitter. There is fastened to the projector an "exciting" lamp and a system of lenses for focusing its light upon an aperture 0.0015 inch by 3/16 inch; by other lenses the image of the aperture is then brought to focus upon the film record as a line 0.001 inch by 0.080 inch. Since the track on the film is 0.100 inch wide, there is an allowance of 0.010 inch on each side for variation in its position. The position and focus of the lens tube are fixed, but the exciting lamp is mounted on a movable carriage so that new lamps as installed may be brought properly into focus. (See Fig. 1.)

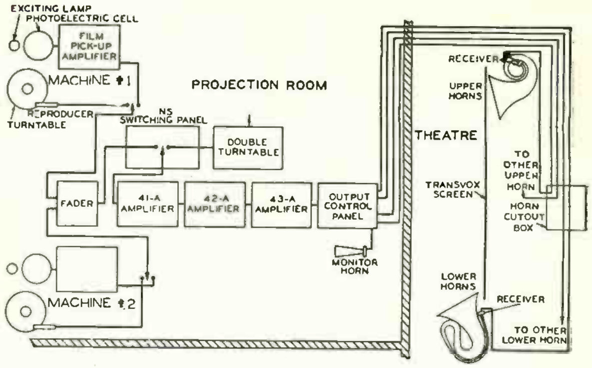


Fig. 6. A typical theatre layout for the presentation of sound pictures.

P. E. Cell and Amplifier

A photoelectric cell of the type used is shown in Fig. 2, and the circuit in Fig. 3. When polarized by a proper voltage, the cell passes a current proportional, within limiting values, to the intensity of the light falling upon it. The polarizing voltage is supplied to the cell through such a high resistance that in operation there is obtained from the cell a voltage across the resistance proportional to the incident light. The voltage bears, therefore, at any time an inverse relation to the density of that part of the sound track when between the exciting lamp and the cell.

The photoelectric cell circuit is inherently one of high impedance. In such a circuit local interference is readily picked up, and since the energy level is low, the current so acquired may be appreciable in comparison with the sound currents themselves. In addition the shunting effect of the capacity between the conductors is noticeable, particularly at the higher frequencies. Hence a vacuum tube amplifier, which serves both to increase the energy and to make that energy available across a low impedance circuit, is closely associated with the cell upon the projector itself. The amplifier is shown in Fig. 4. Cell and amplifier are enclosed in a heavy metal box made fast to the frame of the projector, and the frame is carefully grounded. As a further precaution, the amplifier is supported within the enclosing box by a rather elaborate flexible suspension, lest vibration of the vacuum tubes introduce noise components into the current. The amplifier brings up the energy level to about that obtained from the magnet coils of the reproducer for disc records.

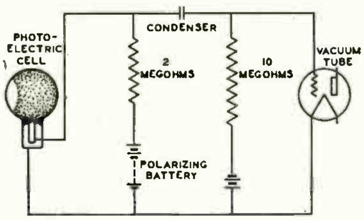


Fig. 3. The circuit employed between the photoelectric cell and the adjacent amplifier.

Mechanical Filter

It is evident from the relative location of apparatus, shown in Fig. 1, that it is not feasible to print the film with the pictures directly opposite corresponding parts of the sound record. Furthermore the pictures move intermittently before the projection lens, while the sound record must of course move uniformly in front of of the photoelectric cell. Picture and sound record are therefore separated longitudinally by 14½ inches, and a certain amount of slack is allowed between the sprocket carrying the film in front of the projection lens and that carrying it before the photoelectric cell. To prevent vibration of the projector or variations in the supply voltage or load from varying the speed of the latter sprocket, it is connected to the other moving parts of the system by a mechanical filter which absorbs any abrupt changes in speed. The driving motor is held electrically at the correct speed, but at will the automatic control can be disconnected and the speed regulated manually by the operator.

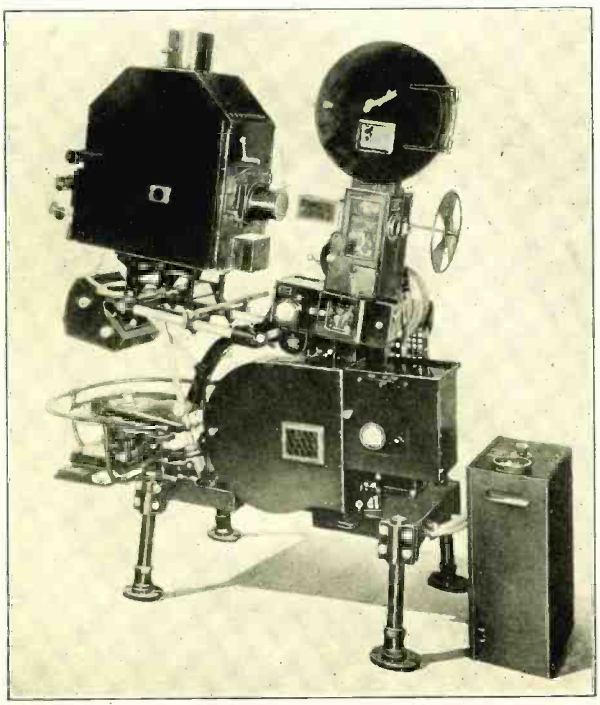


Fig. 5. A Western Electric projector for sound pictures, on which is used a Simplex head. A Powers or Motiograph head may also be employed.

The Fader

As with ordinary motion-pictures, two projectors must be used alternately to present a continuous program. At the end of a record, the music or speech coming from one machine must be blended imperceptibly into that from the other just as the picture from one reel is faded into that from the next. At the end of each sound film or disc the music overlaps that at the beginning of the next; to make the transition there is a device called a fader, a double potentiometer. As the starting projector goes into operation, the fader knob is turned and the current delivered to the amplifiers is changed quickly until it comes entirely from the new record. Ordinarily the fader is installed with auxiliary dials and handles, so that the operator can control it from any position around the projectors. In its lower range, used in changing between projectors, the steps are rather large, whereas in the upper range the volume changes in scarcely perceptible steps. The fader thereby fills another use; it makes possible any volume of sound desired, within reasonable limits, by choice of the proper step in the upper range, and thereby permits equalizing the level of sound obtained from different records. There is provided as well a switch for changing from film to disc records, and the reverse, and a key for connecting a spare projector in place of either of the regular machines.

The Power Amplifier

After passing through the fader, the sound currents go to the main ampli-

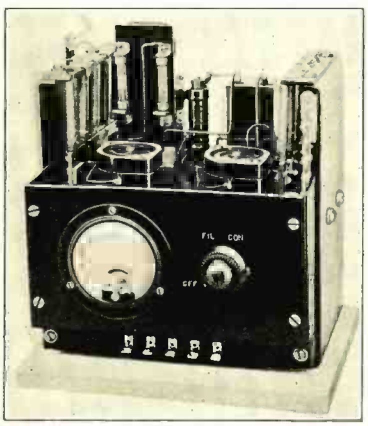


Fig. 4. The amplifier to which the photoelectric cell is connected, showing the suspension for absorbing vibrations. The tubes are not in place.

fier, where their energy is raised to a level adequate for the loud speakers of the particular theatre. This combination of apparatus is capable of multiplying the energy 100,000,000 times, and is so designed that all frequencies in the range from 40 to 10,000 cycles are amplified about equally. A potentiometer is provided on the amplifier but after it has once been adjusted at the time of installation it is ordinarily not changed; necessary adjustments in energy level are made on the fader instead. The amplifier* is built in three units, of which the first consists of three low-power tubes connected in tandem, resistance coupled, with the filaments heated by a twelve-volt battery. In the second unit there are two medium-power tubes with a

* *Described by H. A. Dahl in the Bell Laboratories Record for May,* 1928.

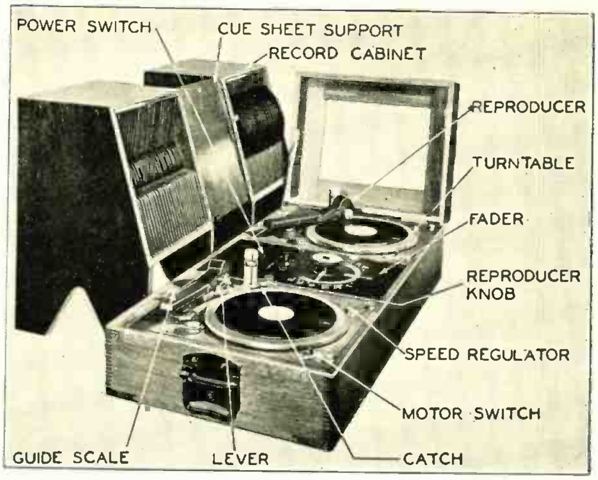


Fig. 8. The cabinet for the reproduction of sound from disc records that are not synchronized with the pictures.

push-pull connection, whose filaments are heated by low-voltage alternating current. Two similar tubes in this unit act as a full-wave rectifier, and supply rectified alternating current for the plate circuits of the amplifier tubes in the first and second units. The third unit has a single stage of high-power push-pull amplifier tubes and push-pull amplifier tubes; like the second, it operates entirely on alternating current. The three units can be arranged to meet any conditions. In small theaters only the first two are required, and in larger houses the high-power unit, the third, is used as well. For unusual conditions two or more of the high-power units may be operated in parallel from the output of the second unit to give a greater volume of sound.

Control Panel

Following the amplifier there is an output control panel consisting of an autotransformer having a large number of taps which are multiplied to a number of dial switches. To the switches are connected the loud-speaking receivers, so that the impedance of the amplifier output can be matched to the desired number of horns. Thereby there is secured the most efficient use of the power available, and adjustment of the relative volumes of the individual horns is made possible at any time.

A theater installation ordinarily contains four horns. They are mounted behind a transvocent screen, on which the pictures are shown, so that the sound may seem to come directly from the picture. Two horns are mounted at the line of the stage and pointed upward toward the balconies and two are mounted at the upper edge of the screen, or above it, and directed downward.

One or more Western Electric No. 555 receivers* are used with each of the horns. Since these show extremely high efficiency, converting into sound energy thirty per cent of the electrical energy supplied them, they reduce to a minimum the output required from the amplifier. A horn is ordinarily fitted with one receiver, but for outdoor use or other special requirements it may be fitted with two, four or nine by a throat such as that shown in Fig. 7. The maximum electrical input to a horn for continuous safe operation is approximately five watts per receiver. To disperse the sound-waves over a large angle, more horns are needed than for a comparatively small angle. This directive characteristic of the horns is important, since it is responsible for the illusion that the sound comes directly from the mouth of the horn, that is, from the screen. When the horn is replaced by a loud speaker of otherwise identical characteristics which radiates is sound over a very wide angle, the sound seems to come from a point some distance behind the screen, so that the illusion of coming from the picture is destroyed.

* *Described by A. L. Thuras in the Bell Laboratories Record for March,* 1928.

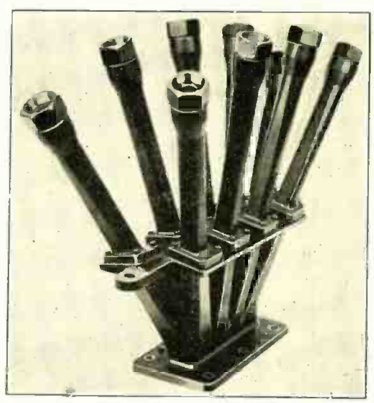


Fig. 7. The throat by which a horn can be fitted with nine receivers, for outdoor use.

The "Round the World Four"

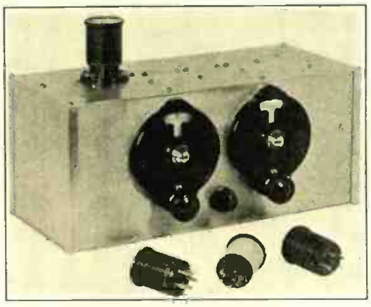
WERE short wave television to arrive today, it would most certainly be handicapped by the lack of a satisfactory receiver.

With thousands of short wave regenerative receivers in daily use, this statement may seem at first to be inaccurate and incorrect. It is well borne out by a single startling fact—that this type of set, once the most popular of all broadcast receivers, is now not only almost extinct for broadcast reception, but is actually barred by more intelligent municipalities, and in England totally tabooed by the Post Office Department. This is because regenerative tuners ruin programs for nearby receivers. (A single dry battery operated receiving tube when oscillating has been heard thousands of miles on short wave—think, then, of the chaos that would accompany general use of short wave regenerative receivers).

Modulated and Unmodulated Reception

For amateur code (C. W.) reception such a set is quite sensitive enough to bring in stations half-way 'round the world; but not so for broadcasting (modulated C. W.) reception. The distance at which a C. W. heterodyne note from a transmitter can be heard may be 1,000 miles while the program service area will extend for only 25 miles, or 1/40 this distance. It is apparent that the great sensitivity of the short wave regenerator for code is almost entirely lost for broadcast program reception, and that for voice or modulated reception (not code) a much more sensitive set is needed and a non-radiating set is essential to avoid interfering with other acts. Further, the average regenerative detector set as used by amateurs is additionally poor for voice reception, since for such work regeneration control (and detector regeneration is today a necessity on short-waves) must be smooth and gradual. This calls for a new technique in receiver design (particularly the addition of an R.F. amplifying and blocking tube) for such characteristics are generally lacking in ordinary short-wave receivers which, always oscillating for C. W. code reception, do not make good regeneration control a prime necessity.

The "Round the World Four" receiver has been designed expressly for listening in on far-away short-wave broadcasts and for non-radiating code reception. Its tickler control is so smooth and sweet that one can sneak right up on a station, pushing regeneration right up to the ragged edge—and seldom get the usual dismal oscillation "plop" blotting out the critically sensitive regenerative region just below oscillation. Instead the "Round the World Four" slides into oscillation without any "stickiness" or loss of that tremendous sensitivity associated with critical regeneration just below oscillation, and that sensitivity is available with all its tremendous amplification to pu "punch" into a modulated signal that may not even be audible on the usual short-wave tuner.



Front view of the receiver. The case is aluminum.

Much of this results from the ideal conformation and design of the new S-M plug-in coil forms. The 222 screen-grid R.F. amplifier materially boosts signal strength, and eliminates re-radiation and all "holes" or "dead spots" at which ordinary sets often fail to oscillate. The set is almost independent of the type of antenna used. A quite considerable gain in sensitivity, all had through the carefully executed application of R.F. amplification to the set, pushes its sensitivity up to the point where English and other foreign amateurs are received fairly regularly in Chicago.

Operation

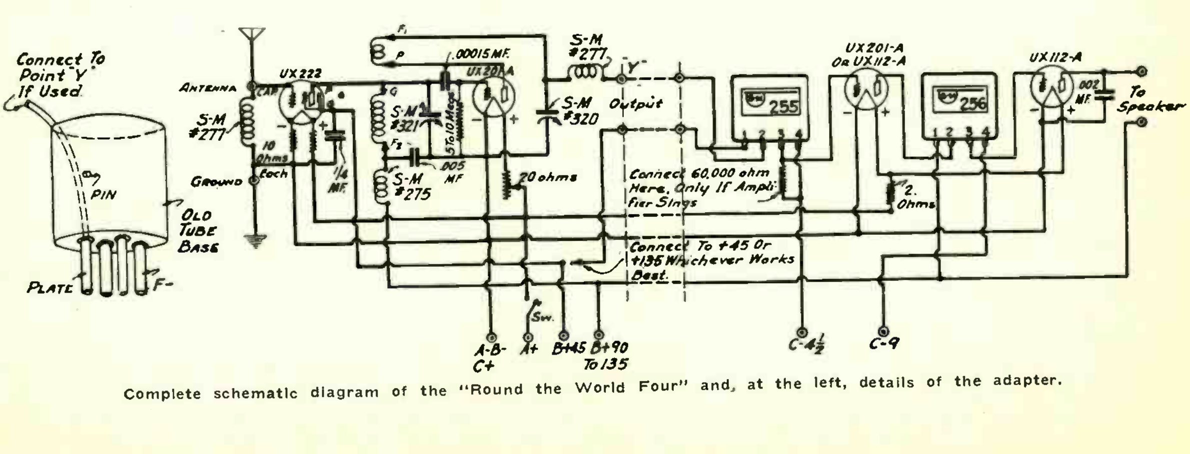
The antenna may consist of a single properly insulated wire, strung up either indoors or outdoors, and from 20 to 100 feet long, depending upon results obtained.

Insert 131-V coil (with greatest number of enamelled wire turns) in socket on top of cabinet and turn rheostat knob so that arrow points straight up. Examine tuning curve and note that Station KDKA on 64 meters should be found at about 20 to 25 on the left dial. Turn right dial up from zero until a dull "plunk" is heard in speaker and then rotate left dial about its setting until a sharp squeal is heard. Continue to adjust left dial, with right dial turned up above point at which plunk is heard, until a continuous sharp squeal, indicating a broacast station, is heard. Adjust left dial to obtain lowest pitch of squeal, and turn right dial down until squeal just disappears and program is heard. The adjustment of both dials for best signal will be found critical, and to facilitate tuning, the dial reduction ratios may be increased by turning to the right the small nickel buttons just above the tuning dial knobs, which will cause the indicator dials to revolve very slowly for a given knob movement. Volume may be reduced by turning down the right dial. To tune in other stations, adjust dials as above, plugging in proper coil for station wavelength desired and varying left dial about setting at which desired wavelength should be heard as indicated by chart. The chart is only approximate, and as stations are heard, an accurate set of tuning curves should be made by correcting the original curves.

Remember that to find a station, the right dial must be turned above the "plunk" point so that the station squeal may be easily found, and left dial rotated, with proper coil in place, to final squeal. Once a squeal is found, the right dial should be retarded, bearing in mind that broadcast programs will be loudest when it is just below the point where the squeal disappears, whereas code will be the loudest when the right dial is just above the point where the squeal disappears. The small knob, once set, should not be used in tuning, and need only be used to turn the set on and off and to adjust detector tube filament voltage at start of operation.

Wiring

All wiring is clearly depicted in the schematic diagram. All "A" and "B" circuit wiring is done with the S-M flexible insulated hook-up wire. It is best to put in all flexible "A" and "B" circuit wiring at first, cutting and fitting each wire to proper size. All grid and plate leads must

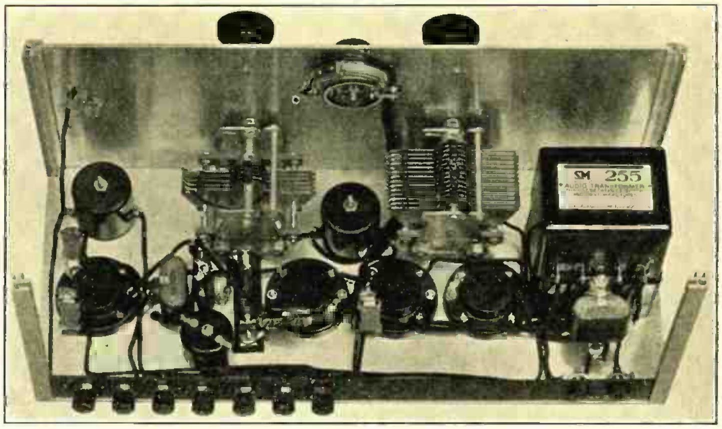


Complete schematic diagram of the "Round the World Four" and, at the left, details of the adapter.

be put in using straight lengths of bus-bar, bent at angles where necessary and covered with spaghetti. It is important that all grid and plate leads be short and direct, and that they be kept at least half an inch away from each other and from other wiring. The wire leads of the 60,000 ohm resistor, which is connected from post 3 to 4 of the No. 256 transformer, are soldered directly to these posts, and stiff enough to support it away from the metal cases. A four-inch length of insulated hook-up wire with the phosphor-bronze clip soldered to one end, and the other to the "Antenna" end of the left No. 277 R. F. choke, serves to make contact with the top cap of the 222 screen-grid R. F. amplifier tube. The 5-megohm grid leak is held in its clips. All wiring should be very carefully checked for possible error which might cause tube burn-outs or damage in first tests.

LIST OF PARTS REQUIRED

1—S-M 321 .00014 mfd. tuning condenser.
1—S-M 320-R .00035 mfd. tickler condenser.
1—S-M 131-T, 131-W, 131-V, and 131-W coils.
1—S-M 512 5-prong socket.
2—S-M 277 R. F. chokes.
1—S-M 275 R. F. choke.
1—S-M hook-up wire (25 feet).
1—S-M 734 aluminum shielding cabinet with terminal strip.
1—S-M 255 first stage A. F. transformer.
1—S-M 256 second stage A. F. transformer.
3—S-M 511 tube sockets.
1—Yaxley 20-ohm midget rheostat.
1—Yaxley rheostat switch attachment.
2—Yaxley insulated tip-jacks.
1—Naald 481KS spring socket for detector.
1—Polymet .00015 mfd. condenser.
1—Polymet .002 mfd. condenser.
1—Polymet .005 mfd. condenser.
1—Polymet grid leak mount.
1—Polymet 5-megohm grid leak.
1—Durham 60,000-ohm resistor.
1—Sprague ¼ mfd. midget condenser.
2—Carter M-10, 10-ohm resistors.
1—Carter H-2, 2-ohm resistor.
8—Binding posts consisting of 8/32 screws, nut and insulated top.
2—National type-B vernier dials.
1—Set hardware.



Interior view of the "Round the World Four". Note the neat layout of the parts. Regeneration is controlled by the large variable condenser.

For those who wish to build the "Round the World Four" as an Adapter to their present radio set, it is only necessary to use a discarded UX tube base plugged into the detector socket, and the plate terminal of the detector socket connected through the tube base to point "Y" of the circuit, thus eliminating the audio end of the "Round the World Four" receiver.

For those who wish to wind their own coils, the following data is available.

All secondaries start (top) at "G," and (bottom) at "F2", and have turns spaced over full length of winding form. All ticklers are wound in the slot at bottom of form in same direction so secondaries, start at "F I" and end at "P".

	Secondary		*Tickler*	
Coil number	Wire size	No. of turns	Wire size	No. of turns
131-T...	No. 22	6½	No. 34	5½
131-U...	Plain	13½	Double	5½
131-V...	Enamel	25½	Cotton	9½
131-W...	No. 24 double cotton covered	49½	Covered	15¾

The Screen-Grid Find-All Four

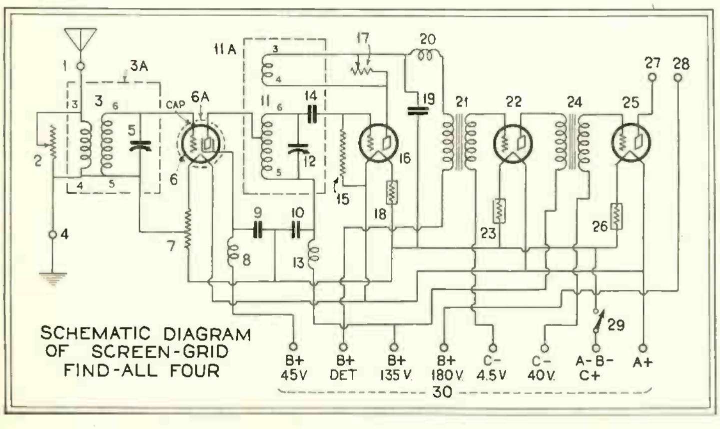
By H. G. Cisin, M.E.

FROM the standpoint of simplicity of construction and efficiency of operation, the ideal radio receiver would require only one tube and would be capable of bringing in distant broadcasting with loud speaker volume. It would have nearly perfect tone quality and still have sufficient selectivity.

The screen-grid tube has brought us a step closer to this ideal. By applying this tube correctly, it is now possible to make a four tube set do the work of a six or a seven tube one.

The screen-grid tube was introduced to the radio public about a year ago. The tube manufacturers were aware of the possibilities of the new tube, but apparently were in a position to furnish fans with accurate data and circuit constants which would permit set builders to use the tube properly and thus take advantage of its potentialities.

Shortly after the introduction of the screen-grid tube, numerous circuits were devised, which utilized the new tube with varying degrees of efficiency. Practically all of these circuits were experimental in nature. The screen-grid tube was tried out as an R. F. amplifier, as a detector, and as an audio amplifier. It was used as a straight screen-grid amplifier and as a space charge amplifier. Most of the circuits called for more than one screen-grid tube. In general, results were mediocre. Very often tuning was found to be extremely broad and in most cases the detector was overloaded as soon as any attempt was made to use the screen-grid tubes at anything like their normal efficiency.



Regeneration is controlled by a variable resistance in this circuit. The control grid of the screen-grid tube is automatically biased, by means of the filament resistor 7.

Simplified Design

The writer designed and constructed a large number of sets, using screen-grid tubes in every conceivable part of the radio circuit. He also experimented with the tube in numerous types of circuits, such as regenerative, non-regenerative, tuned radio frequency, superheterodyne, etc. After considerable research and experimentation, he found it possible to attain remarkable results, using only *one* screen-grid tube in a circuit, provided this tube was used in the proper place, and also provided that the tube and certain other portions of the circuit were correctly shielded, that the screen-grid tube stage was coupled in the right manner to the succeeding stage and that correct voltages were used.

This brought about the development of the Screen-Grid Find-All Four, utilizing a screen-grid tube in the R. F. stage. The remainder of the circuit consists of a regenerative detector and two stages of audio frequency amplification. In this circuit, the screen-grid tube is used so effectively that it enables this little four tube tuned R. F. set to bring in stations hard to get with a standard seven tube superheterodyne. On local broadcasting, the volume is extraordinary. Even stations 1000 miles distant are brought in very often, with the volume of locals. Thus, the Screen-Grid Find-All Four approaches the ideal set forth in the beginning of this article. It uses less tubes and less apparatus, but gives more volume and greater sensitivity. It has less wiring and is easier to assemble than the ordinary tuned radio frequency receiver. Furthermore, it uses standard parts throughout.

The Screen-Grid Find-All Four is a receiver of unusual merit capable of bringing in stations from coast-to-coast and because of its unique performance it should become one of the outstanding receivers of the 1929 radio season. In addition to the advantages mentioned above, this receiver has beautiful tone quality and can be built for approximately $50.

Details of Receiver

The radio frequency stage of the Screen-Grid Find-All Four is tuned by a .0005 mfd. Hammarlund condenser. A similar condenser tunes the detector. The antenna coupler is a standard Aero coil. Coupling between the screen-grid tube and the regenerative detector is accomplished by means of an Aero coil designed for the 222-type tube. An Aero 3-circuit tuner may be substituted in place of the screen-grid coil, but in either case, the secondary must be tapped, in accordance with directions to be given later.

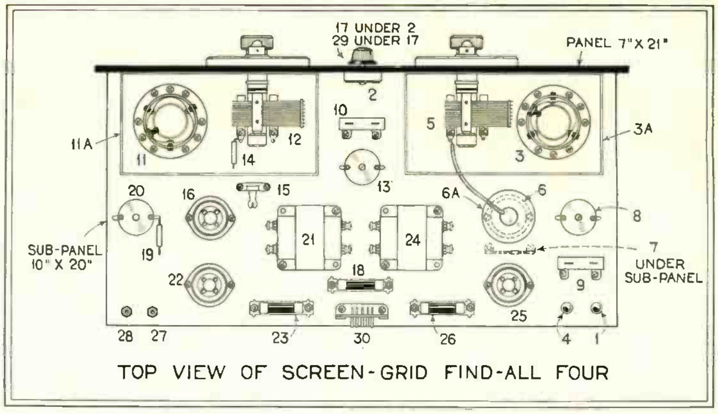
Each Aero coil, together with its tuning condenser, is shielded by means of a Silver-Marshall aluminum shield. The screen-grid tube is shielded separately by means of a Carter tube shield. The connection from the stator of condenser (5) to the cap (control grid) of the screen-grid tube is also shielded. This connection should be made as short and direct as possible and should be isolated from other wiring. In some instances, it may also be found desirable to shield the lead from the plate of the screen-grid tube to the tapped Aero coil (11).

Due to the internal shielding by the screen (outer) grid, no neutralization of plate to grid capacity is necessary. The operation of the receiver is characterized by extreme stability.

A Yaxley 75-ohm rheostat across the primary of the antenna coupler acts as a volume control. This may be supplemented, if desired, by an Electrad Tonatrol, connected across the secondary of the first stage Thordarson audio transformer. Regeneration is controlled by means of a Royalty type "p" rheostat, connected in shunt across the tickler coil: It is desirable to have the point of maximum regeneration occur when the rheostat is adjusted so that almost all the resistance is in use. This may be accomplished by adjusting the detector plate voltage to the necessary value. Since the tickler coil is rotable, this provides an additional method of controlling regeneration.

A Durham metallized resistor grid leak is used with a .00025 mfd. Polymet grid condenser. The circuit design calls for three Silver-Marshall radio frequency chokes, located as shown at (8), (13), and (20). Polymet fixed condensers are used to by-pass these chokes.

The audio portion of the circuit utilizes two Thordarson R-300 transformers. Those who have tried out these transformers, do not have to be told of the splendid tone quality resulting from their use. Four Eby sockets are required, and the Amplion loud speaker is connected by means of the new Yaxley insulated tip jacks. Amperites are used to regulate the filament current to the detector and the two audio tubes. Eby binding posts are used for aerial and ground and a Yaxley cable connector provides a convenient connection between "B" and "C" supply and the receiver. Since the screen-grid tube filament requires only 3.3 volts while the other tubes used are 5-volt tubes, it is necessary to reduce the filament voltage on the screen-grid tube by means of a Carter tapped resistor. The control grid bias is obtained by the use of the voltage drop in this resistor. Filament current is turned "on" or "off" by means of a Carter battery switch.



Detailed constructional layout for the receiver described. Note that the R.F. and detector circuits are enclosed in aluminum shields.

The B- and C-Power Unit

The Screen-Grid Find-All Four works perfectly in connection with a properly designed "B" and "C" eliminator. An "A" eliminator may also be used, if this is available.

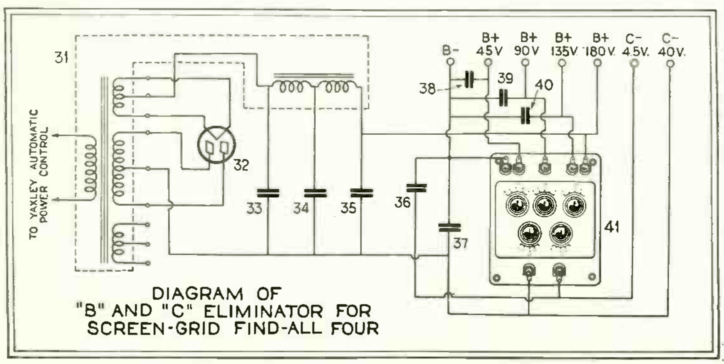
The "B" and "C" eliminator designed for the Screen-Grid Find-All Four uses a Thordarson R-280 power compact. A Polymet block condenser and three small Polymet condensers provide the necessary filters. In order that variable "B" and "C" voltages may be readily obtainable, an Electrad Truvolt Divider is used. This permits the voltages to be varied at will, by simply turning the convenient knobs. A Gold Seal full-wave rectifier is used. A Yaxley full automatic power control adds greatly to the utility of the complete outfit, especially where a storage battery is used in connection with a trickle charger, for the "A" supply. Seven Eby binding posts provide connection terminals for the Yaxley cable. These posts may be mounted on a binding post strip of hard rubber or they may be mounted directly on the wood base.

LIST OF PARTS REQUIRED

1—Aero Universal Antenna Coupler, type U-96 (3).
1—Aero Universal Coil for 222 tube, type U-2, with rotable primary used as tickler *or* 1—Aero 3-circuit tuner, type U-55, with fixed tickler unused and with rotable primary used as tickler (11).
2—.0005 mfd. Hammarlund "Mid-Line" Variable Condensers (5, 12).
4—Eby Sockets, new style, UX type (6, 16, 22, 25).
1—Electrad Royalty Resistance, type "F" (17).
1—Electrad Tonatrol type "S" (optional) across secondary of 1st audio transformer.
1—2 meg. Durham Metallized Resistor Grid Leak, with Durham vertical single mounting (15).
1—.00025 mfd. Polymet bakelite fixed mica condenser (14).
2—Thordarson Transformers, type R-300 (21, 24).
3—Amperites, No. 1-A, with M't'gs (18, 23, 26).
3—Silver-Marshall R. F. Chokes, type 276 (8, 13, 20).
2—½ mfd. Polymer "Hi Volt" filter Condensers, type C-903 (9, 10).
1—.001 mfd. Polymet bakelite mica Condenser (19).
1—Carter JU-10-25 tapped Resistor (7).
1—Carter "Imp" Battery Switch (29).
1—Carter Tube Shield, No. 322; Connector Cap, No. 342; with Shielded Wire, No. 352; Adaptor Ring, No. 332 (6 A).
2—Eby Engraved Binding Posts (1, 4).
2—Silver-Marshall Shields, type 631-A (3, A, 11 A).
1—Yaxley 75-ohm Junior Rheostat (2).
2—Yaxley Insulated Tip Jacks, No. 422 (27, 28).
1—Yaxley 12-Conductor Cable, No. 627, complete with Plug & M't'g Plate (30).
1—Can Kester Radio Solder (Rosin Core), By the Chicago Solder Co.
1—Roll Corwico Braidite, stranded core Hook-up wire.
1—Hard Rubber Panel, with "Sunburst" finish, 7"x21"x3/16".
1—"Radion" or "Ace" Hard Rubber sub-panel, 10"x20"x3/16".
2—Brackets, 1" high.
1—Gold Seal Screen-Grid Tube, type GSX222 (6).
2—Gold Seal Tubes, GSX 201-A (16, 22).
1—Gold Seal Power Tube, type GSX 171-A (25).
2—Vernier Dials.

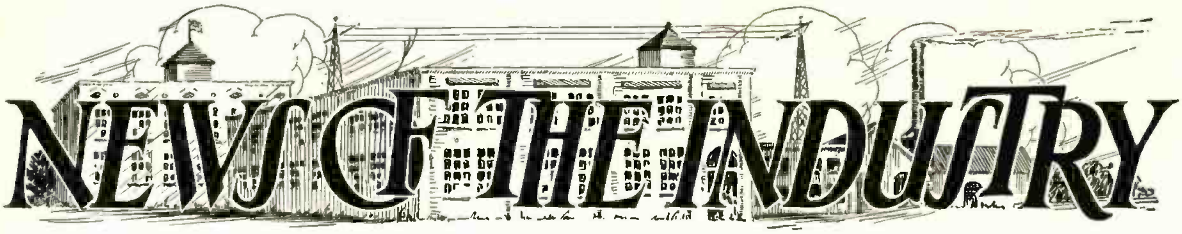
LIST OF PARTS REQUIRED FOR THE B- AND C-POWER UNIT

1—Thordarson R-280 Power Compact (31).
1—Polymet Block Condenser, type F.1000 (33-2 mfds.) (34-2 mfds.) (35-8 mfds.) (36-1 mfd.) (37-1 mfd.)
1—Electrad Truvolt Divider (41).
1—Eby Socket, new style UX type (32).
7—Eby Engraved Binding Posts.
3—1 mfd. Polymet "Hi Volt" "B" Filter Condensers, type C-924 (38, 39, 40).
1—Gold Seal Full-Wave Rectifier Tube, type GSX 280 (32).
1—Roll Corwico Braidite, stranded core Hook-up Wire.
1—Yaxley Full Automatic Power Control, No. 440
1—Wood Base.



The B and C power unit, which employs a 80-type full-wave rectifier. Note the compact, variable voltage divider.

NOTE: Numbers in parentheses after each part, refer to corresponding numbers used to mark parts on diagrams. Constructional prints, reprints of this article and additional information regarding the Screen-Grid Find-All Four and Eliminator, may be obtained from the Allied Engineering Institute, Suite 429, 30 Church Street, New York, N. Y.



YEAR'S BUSINESS TO EXCEED $512,000,000

Total radio sales for the year will exceed $512,000,000.

This is revealed by an analysis of the radio statistics for the third quarter of 1928, released by the Department of Commerce. These are compiled in cooperation with the Radio Division of the National Electrical Manufacturers' Association.

Figures compiled for the third quarter represent returns from 6,766 radio dealers, or 21.4 per cent of the 31,573 queried, and show a total business of $20,508.666. This is an increase of 3.6 per cent over replies received for the July 1 quarter. It follows that 100 per cent of the dealers did a total business of $95,834,887 during the quarter.

An estimate of the relative value of each quarter has been prepared by the McGraw-Hill Publishing Company. It shows that the months of July, August and September equal 18.5 per cent of the total radio sales made each year. Since the October 1 figures are the first to contain total sales, the quarterly business of $95,834,887, on the basis of 18.5 per cent, results in total year's sales of $512,621,010, establishing a new record. Furthermore, the full force of the season's increasing sales is not adequately reflected in the summer months of June, July and August and a greater momentum of increase in the last quarter is expected to swell the total somewhat above that indicated.

SURVEY OF RADIO DEALERS' STOCKS

That 6,766 radio dealers in the United States did $20,508,666 worth of business, or approximately $3,030 apiece, during the third quarter of this year, appears to be indicated by a study just made of replies to questionnaires sent out by the Electrical Equipment Division of the Department of Commerce.

This survey of stocks in the hands of radio dealers, and of the volume of business done by them during the three-month period, is made at the end of each quarter by the Commerce Department, with the cooperation of the Radio Division of the National Electrical Manufacturers' Association, to provide the radio industry in the United States with these statistics.

The 6,766 dealers to reply to the Commerce Department's queries on this occasion represented 21.4 per cent of the 31,573 queried, or an increase of 3.6 per cent in those answering as compared with the preceding quarter when 5,737 out of 32,216 canvassed, or 17.8 per cent, replied.

According to these returned questionnaires, these 6,766 dealers sold 23,599 battery sets, and almost 100,000 A.C. sets during the months of July, August and September. Of battery sets in the hands of these 6,766 dealers on October 1 there were 32,224, and of A.C. (electric) sets, 58,262, as compared with 28,311 and 24,566, respectively, in the possession of 5,737 dealers on July 1.

On October 1, these returned questionnaires also show, there were on hand with these dealers 53,180 loud speakers of the magnetic type and 14,085 of the dynamic type, as compared with 39,675, and 2,483, respectively, in the hands of 5,737 dealers on July 1.

The number of tubes (receiving) of the A.C. type in dealers' hands October 1, was 295,448, or more than double the 122,722 on hand July 1. Other questions replied to pertained to batteries, socket power units, and rectifying tubes on hand.

R. C. A. BOARD OF DIRECTORS

The board of directors of the Radio Corporation of America, at its annual meeting, made the following promotions: Vice-president and General Manager David Sarnoff to be executive vice-president; Joseph L. Ray to be vice-president and general sales manager; Dr. Alfred N. Goldsmith to be vice-president and chief broadcast engineer, and Colonel Manton Davis to be vice-president and general attorney.

In the RCA Photophone Company Elmer E. Bucher was promoted to be executive vice-president.

The RCA board also took action to create a separate subsidiary company for its communications business, the plan being to transfer to such company all its communications assets.

RADIO AND MUSIC GROUPS AGREE ON SHOW PLANS

Preliminary plans for the annual conventions and trade shows of the radio and music industries, both meeting in Chicago June 3 next, have been agreed upon by heads of the respective industries, represented by the Radio Manufacturers' Association, the Music Industries Chamber of Commerce, the National Association of Music Merchants, and allied music trade organizations. The concurrent radio and music industry attractions undoubtedly will draw the largest industrial assemblage of the United States to Chicago next June, the Radio Manufacturers' Association meeting at the Stevens Hotel and the Music Industry at the Drake. Measures of mutual advantage in coordinating the industrial meetings, banquets and shows, avoiding conflicts, were outlined at a conference here recently between officials of both industries.

A joint open meeting of the two industries is planned on Tuesday morning, June 4, at the Drake Hotel, the RMA accepting the invitation from the music trades to join in this meeting. Other branches of the radio industry will be invited to participate.

Separate banquets of the two industries will be held, the annual banquet of the RMA being scheduled for Wednesday evening, June 5, and that of the National Association of Music Merchants on Thursday evening, June 6. Participation by the music trades in the all-star broadcast program of the RMA banquet planned also was arranged.

WALTER A. SCHILLING NOW PUBLIC RELATIONS COUNSELLOR

Walter A. Schilling, for the past six years managing editor of *The Radio Dealer* and a nationally known figure in the radio industry, has announced his resignation in order to establish his own offices at 10 East 39th Street, New York, where he will serve as public relations counsellor to a number of leading organizations in radio, electrical and other industrial fields.

On technical work, Mr. Schilling has announced his intention of collaborating with Austin C. Lescarboura.

F. R. T. A. ANNUAL CONVENTION

The next annual convention of the Federated Radio Trade Association will be held in Buffalo, N. Y., February 18-19, 1929. These dates are for a two day convention only and the former three day convention which was scheduled is no longer in effect. At this convention the F. R. T. A. plans on having at least 500 registrants of the most prominent radio tradesmen in the United States. An invitation has been extended to Canada and according to recent advices there will be a large number of Canadian tradesmen in attendance.

The Statler Hotel in Buffalo has been engaged for the convention. This will be the first Federated Convention at which time there will be individual sectional meetings of the various divisions of the radio trade. The association will provide for nearly a day and a half of individual meetings to the devotion of individual problems.

The Manufacturers Representatives Section is composed of over 50 of the leading manufacturers representatives, who will further complete their plans for their organization and will meet to discuss their joint problems. The section is headed by George Riebeth of the French Battery Company.

The Radio Retailers' Association, a national organization of radio dealers headed by Jullan Sampson of St. Louis, Mo., will further complete their organization and will place committees in operation to increase the value of the association to the radio dealers. Prominent radio retailers will address their separate meeting on radio selling and merchandising. Information will be given the visiting dealers as to how they may better conduct their enterprises to make it more profitable. Prominent retailers from coast to coast have signified their intentions of being at this meeting and will do everything possible to increase the prestige of the retailer and to further organize this association.

The Radio Wholesalers' Association with Peter Sampson, of the Sampson Electric Company, as president will hold its own individual meetings at which time several prominent members of the radio industry will address the meeting on wholesaler problems. Committee reports will be made showing the activities of the association during the past year. Recommendations will be made concerning merchandising of radio apparatus.

Special consideration will be given to the committees on the following subjects:

1. Dealer Deferred Payment Plan. This committee, headed by James Aitken of the Aitken Radio Corp., Toledo, Ohio, has made an exhaustive study of finance plans now in operation for dealer sales. They will have a complete report and finance plan ready for adoption by members of the association.

2. Report of Insurance Plan Committee. Mr. Levy, of the Sampson Electric Co., Chicago, chairman of this committee, is now working on arrangements with insurance organizations to provide a suitable connection for members of the Radio Wholesalers' Association to secure better insurance. This committee report will be met with considerable enthusiasm on the part of the members.

3. Report of Credit and Collection Committee will be given with a view in mind to provide credit and collection service for members of the association. At the present time this important subject is being investigated very thoroughly by a committee composed of credit managers of various firm members of the board of directors.

Other business will be given considerable thought and many policies determined upon.

The meeting of the Federated Radio Trade Association, composed of all four groups, will be addressed by President Harold J. Wrape, who will review the activities of the organization since the past convention and will present the plans for the further operation of the association. Elmer C. Metzger, president of the Buffalo Radio Trade Association, will welcome the guests to Buffalo. There are several important speakers scheduled to address the meeting, among them being Herbert H. Frost, president, Radio Manufacturers' Association; Wm. Hedges, president, National Association of Broadcasters; Judge Van Allen, legal counsellor of the Radio Manufacturers' Association, and Hon. Frank D. Scott of Washington, D. C.

The convention will terminate with the election of the board of directors, who will govern the activities of this trade organizaiton for the coming year. New officers will also be chosen to direct the sectional activities and guide the course of these branches.

President Harold J. Wrape is very optimistic concerning the coming convention and expresses himself by saying that it will be the greatest the Federated has ever held. The Rochester Radio Trade Association and the Buffalo Radio Trade Association have combined to form a welcoming committee and with the joint convention committee they will surely provide a suitable background for the activities of the group.

MARTIN COHN WITH BOTTLAND CORP.

Martin Cohn, formerly chief engineer and production manager of the Mayolian Corp., New York, is now connected with the Bottland Manufacturing Corporation, 370 Gerard Ave., New York City, as president and chief engineer.

NEW FEDERAL WHOLESALERS

Two new Federal Ortho-sonic radio wholesalers have just been announced by the Federal Radio Corporation of Buffalo, N. Y., and Bridgeburg, Ont. They are the Swank Hardware Co., Johnstown, Pa., and the Standard Drug Co. of Elizabeth City, North Carolina.

POLYMET INCREASES CAPITALIZATION

Stockholders of the Polymet Manufacturing Company have authorized an increase in the company's no par value capital stock from 30,000 to 60,000 shares. Of this increase, 15,000 shares are to be issued to stockholders to whom rights will be given to subscribe in the ratio of one share of new stock for each two shares of the old stock held, at $20 a share.

N. C. Greene, vice-president in charge of sales, told stockholders that the company during August, September and October, the first three months of its current fiscal year, returned earnings of about $3 a share on the old capitalization and that the outlook for continued satisfactory earnings is indicated by the volume of orders on hand. The rate on the new stock will be $1.50 a share, the same as that paid on the old shares.

RAYTHEON ANNOUNCES SALES PERSONNEL

In keeping with the expanded merchandising efforts of the Raytheon Manufacturing Company, which has now entered the production and distribution of a line of improved filament and A.C. heater tubes, an enlarged sales personnel is announced at this time by Fred D. Williams, vice-president in charge of sales.

The sales representatives of the Raytheon organization cover the entire country, and are as follows:

Paul C. Smalley, 126 Liberty St., New York; Harry O'Connell, Raytheon Mfg. Co., Cambridge; John J. Downey, Hotel Lorraine, Philadelphia; Granville H. Kratsch, 2085 Cornell Road, Cleveland; W. N. Nevins and L. G. Darling, 411 Georgia Savings Bank Bldg., Atlanta; Harry Merrithew, 713 South Ervay St., Dallas; M. J. Friel, 171 Second St., San Francisco; H. Cal. Caldwell and William H. Nolan, 2007 Stout St., Denver. Export sales are handled by Ad. Auriema, Inc., 116 Broad St., New York.

SYNTHANE CORP. FORMED

The Synthane Corporation, incorporated in September, 1928, under the laws of Delaware, is completing the building of its plant at Oaks, near Philadelphia, Pa., and expects to commence production of Laminated Bakelite products in the early Spring.

R. R. Titus, formerly vice-president and general manager of the Diamond State Fibre Company and the Celoron Company of Bridgeport, Pa., heads the corporation as president, with J. B. Rittenhouse as vice-president and George J. Lincoln, secretary and treasurer.

KELLOGG APPOINTS NEW DISTRIBUTORS

Appointment of the following distributors for the line of Kellogg A-C receivers was announced recently at the Chicago office of the Kellogg Switchboard and Supply Company.

Motor Power Equipment Company, Ford road and River boulevard, Saint Paul, Minnesota, entire states of Minnesota, North Dakota, South Dakota, and Montana; York Auto Supply Company, 309 West Market Street, York, Pennsylvania, south central Pennsylvania; S. A. Blewett, Santa Fe building number two, Dallas, Texas, entire State of Texas, except the western section; Ed. S. Hughes Company, Abilene, Texas, western Texas; Henkle and Joyce Hardware Company, Lincoln, Nebraska, all of Nebraska, eastern Wyoming and northeastern Colorado; Stewart Sales Company, 114 East Ohio Street, Indianapolis, Indiana, southern and central Indiana; M. A. Hartley Company, Staunton, Virginia, western Virginia, Williamsport Auto Parts Company, 249 Third Street, Williamsport, Pennsylvania, north central Pennsylvania; Harvey Motor, Incorporated, 1201 Sixth Avenue, Huntington, West Virginia, entire State of West Virginia, exception of north central section and for eastern section of Kentucky and southeastern Ohio; Corlaer Radio Corporation, 155 Lafayette Street, Schenectady, New York, northeastern and east central New York State; Pittsburgh, Pennsylvania; western Pennsylvania; Rupert Electric Company, Rupert, Idaho, central and southern Idaho; United States Radio Corporation, 328 Dwight Street, Springfield, Massachusetts, western Massachusetts.

Newly appointed in charge of central station sales for the Kellogg Switchboard and Supply Company is Mr. R. W. Mounteer, former special representative of the Radio Sales Division of the same company. Mr. Mounteer will devote his time to promoting the sale of the popular line of Kellogg A-C receivers among public utilities throughout the country.

RADIO AND ASSOCIATED STOCK QUOTATIONS

Company	Nov. 2	Dec. 3	Jan. 3	Company	Nov. 2	Dec. 3	Jan.
Acoustic Products	20¾	24	18½	Kellogg	17¾	19¼	17¾
All-Am. Mohawk	39¾	40	35½	Kodel "A"	20	24¾	17
American Bosch	34⅝	41⅝	42	Kolster	83	91¼	75½
Bruns - Balke Collen				Magnavox	15½	15	11½
(Com.)	52½	54¼	52⅜	Polymet	....	52	....
CeCo Mfg.	....	68	60½	Radio (Com.)	228½	407	394¾
Crosley "A"	63	87½	117	Raytheon	53½	69	59
Davega	38¼	38⅜	36	Sangamo	34	35	37¼
De Forest	21	22¾	25½	Sonatron	127	157½	....
Dubilier	5	10	9	Sparks-Withington	160	170	180
Erla	24⅛	22	14⅜	Stromberg Carlson	26	30	31
Fansteel	15⅞	15⅛	12½	Stewart-Warner	105⅛	116¼	123⅝
Formica	24¾	24	30	Utah	59½	56	46
Freed-Eisemann	4¾	5⅛	5	Tower	3½	9	8¾
Freshman	12⅜	13⅞	11⅞	Union Carbide (Com.)	191	199¾	206⅞
General Elec. (Com.)	167	197	245¼	Victor (Com.)	121⅜	138½	152¼
Gold Seal	10	19⅛	25	Westinghouse	113⅝	135	143
Grigsby-Grunow (new)	111	143	148⅞	Weston (Com.)	22¾	23½	22⅞
Hazeltine	21⅛	50	48	Zenith (new)	193	n. 57	54

NEW CHICAGO-JEFFERSON CATALOGUE

The Chicago-Jefferson Fuse & Electric Company, of 1500 South Laflin Street, Chicago, Illinois, has just published its new catalog No. 33R-1, which illustrates and describes their entire line of radio transformers, accessories and fuses for the coming season.

A copy of this catalog may be had by addressing the above company.

WILLIAM J. BARKLEY JOINS DE FOREST ORGANIZATION

William J. Barkley, one of the best known pioneers in the radio industry, has joined the DeForest Radio Company, of Jersey City, N. J., in the capacity of Assistant to the President, according to the announcement of James W. Garside, President of that company.

"Mr. Barkley has been actively engaged in radio developments since 1912," states Mr. Garside, "when he became associated with the Wireless Specialty Apparatus Company. In 1914 he was elected president of the Wireless Specialty Apparatus Company, and continued in that capacity until 1918, when a combination was formed between the United Fruit Company, which controlled the Wireless Specialty Apparatus Company, and the General Electric Company. Mr. Barkley was retained in a consulting capacity after his resignation. Subsequently, he engaged in the production of mica condensers, followed by his entry into the field of manufacturers' representative, handling various electrical products in the New England territory."

SPLITDORF APPOINTS SPRAGUE ELECTRICAL

An appointment and the buying out of another company by the appointee, give Splitdorf Radio Corporation two distributing points in Connecticut and thorough coverage of the State for its products. Hal P. Shearer, general sales manager of Splitdorf has just made public the appointment of the Sprague Electric Co., of Waterbury, Conn., as Splitdorf distributors. At the same time the latter outfit announced the purchase of the Park City Electric Company at Bridgeport, possession of this business having been taken on November 10.

The head of the Sprague business is W. G. Sprague, a well known figure in Connecticut electrical circles. The company travels seven men and cover all of the State except the following counties: Tolland, Windham, and New London. Sprague Electrical has had considerable experience in the quality radio field, having represented Stromberg, Carlson and Steward-Warner.

FIELD TESTS ON TROPICAL RADIO EQUIPMENT

Final field tests of the special low-wave portable radio apparatus to go with the All-American Mohawk Malaysian Expedition to Borneo next month were witnessed this week by a group including newspapermen, radio engineers and officials of the company sponsoring the expedition.

Under the direction of William J. Schnell, director of foreign research at the All-American Mohawk Corporation laboratories, the special short-wave transmitter and receiving outfit were set up in the forest preserve near Chicago and subjected to rigid tests. All the apparatus, which is battery operated and specially adapted for service in a tropical climate functioned perfectly, Schnell reported.

A portable hand-driven field generator will be included in the radio equipment of the expedition, he said. This will be used after the party reaches the headwaters of the Barito river in Dutch Borneo and push on into the unexplored regions beyond. An attempt will be made to maintain constant radio communication with the expedition's proposed base and headquarters at Bandjermasin, capital of the colonial Dutch government. To pick up long distance broadcasts and time signals from the radio station at Manilla, P. I., a standard Lyric receiver will be used.

The expedition, according to Theodore Seelmann, Chicago mariner and amateur explorer, will investigate tropical and especially equatorial radio problems as well as matters of interest to geographic bodies.

RAYTHEON ANNOUNCES LINE OF FOTO CELLS

For television and other applications calling for photo-electric or light-sensitive cells, the Raytheon Manufacturing Company of Cambridge, Mass., now announces a comprehensive line of Raytheon Foto Cells. These cells are made in the hard-vacuum and the gas-filled types, as well as in bulb and tubular shapes.

Two types of the new Raytheon spherical and tubular photo-cells. The spherical type shown will fit a standard vacuum tube socket and is particularly adaptable to television work.

The hard-vacuum Raytheon Foto Cell has the characteristics of instantaneous response—no lag; response directly proportional to illumination; maximum photo-active surface; permanent characteristics; no leakage or "dark current." The gas-filled Raytheon Foto Cell has the characteristics of super-sensitivity; instantaneous response—no lag; response directly proportional to illumination; no damaging effect from ionization; low operating voltage; no leakage or "dark current."

The Raytheon Foto Cells are available in two spherical bulb types and three tubular types, to meet a wide variety of uses in television, daylight recording, photometer, fire alarm system, laboratory, experimental and other applications.

DE FOREST AUDION LINE

Five DeForest Audions have been added to the DeForest line during the past month, which, in addition to the 426, 427, 471-A and 480, complete the line of standard types. The additional tubes are:

DeForest 401-A: A general utility tube for radio-frequency, audio-frquency, and detector functions. Provided with new filament of the oxide-coated kind, capable of high emission at the usual 5-volt rating, and ample emission on the filament voltages as low as 3.5. Mica spacer to insure positive characteristics and complete elimination of microphonic noises.

DeForest 410: A power amplifier for socket-sets and amplifiers. Highly evacuated, with active getter constantly present to insure a hard tube for high plate voltages and quiet operation. Special filament for maximum emission and long life. Oxide-coated filament.

DeForest 412-A: Detector, amplifier and power amplifier. Highly evacuated with active getter to maintain high vacuum. Oxide-coated filament. Mica spacer.

DeForest 450: Super-power amplifier. Highly evacuated with active getter always present. Special ribbon filament with oxide coating for high emission and long life. Mica spacer.

DeForest 481: Half-wave, heavy-duty rectifier of 110-milliampere, 425-volt output. Special DeForest ribbon type filament, with heavy oxide coating. High vacuum maintained throughout life.

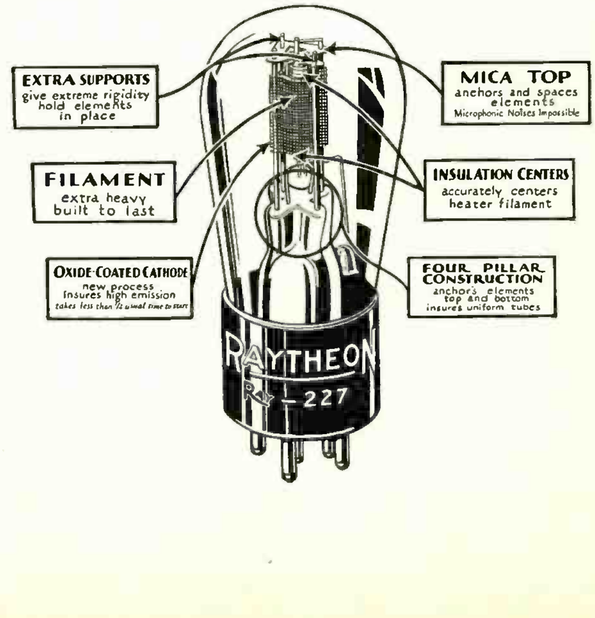
RAYTHEON ANNOUNCES NEW LINE OF TUBES

Although the Raytheon name has been closely identified with gaseous rectifiers which made the popular B-eliminator possible, the Raytheon Manufacturing Company, of Cambridge, Mass., now announces a new line of improved vacuum tubes for the usual A.C. broadcast receiver.

Four tubes are announced at this time as the forerunners of what promises to be a complete line of standard A.C. and battery type tubes, as well as power tubes and rectifiers. Special types to meet new radio requirements are under development. The present types offered at this time are the Ray X-226, Ray 227, Ray X-171-A, and Ray X-280.

The outstanding feature of Raytheon vacuum tubes is the unique four-post construction, which reinforces the tube elements in all directions instead of in a single straight line as with the usual design. The elements are carefully positioned and welded during assembly, and remain permanently fixed irrespective of shipping and rough handling. The characteristics are precisely set during production and remain precisely the same. In addition, special filaments made in the Raytheon laboratory, are employed. Improved pumping and flashing methods, as well as accurate seal-off, insure a higher and more permanent vacuum for noiseless operation.

Illustration of the new Raytheon heater type vacuum tube. Note the rigid construction. The heater element differs in design from the usual form.



NEW ARCTURUS '71-TYPE HEATER TUBE

It is claimed that the solution to the life problem of the "71" type medium power tube has been found in the design of a heater tube having the same amplifying characteristics as the filament tube. The average life of a well designed heater tube is well in excess of two thousand hours, according to reports issued by the laboratory of the Arcturus Radio Company where thousands of heater tubes have been subjected to intermittent life tests and where a heater '71 tube, known as the Arcturus 071H, has been developed.

New Arcturus '71-type heater tube.

The emission characteristics of the heater tube remain constant throughout the life of the filament, due to the relatively large cathode area. There is no decline in efficiency necessitating re-activation, as is characteristic of many filament type tubes.

The 071H has an amplification constant of 3, a mutual conductance of 1500, plate resistance of 2000 ohms and operates from a five volt direct current or A.C. source. It is merely substituted for the '71 tube without making any changes in wiring or voltage.

In addition to the life factor, the humless operation of the heater type tube is an added recommendation for the 071H in A.C. receivers and other sets in which the power tube is heated from a transformer.

For the Convenience of our many friends in Engineering and Production Departments, Radio Schools, Radio Clubs, etc., who are sending us Group Subscriptions.

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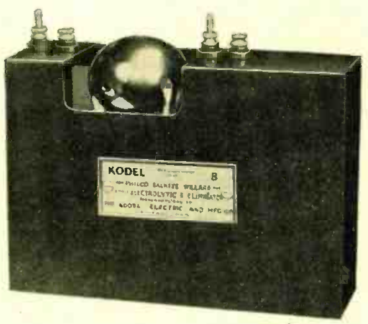
KODEL DRY "B" REPLACEMENT UNIT

The Kodel Dry "B" Replacement Unit for replacing the acid or liquid jars in Philco, Balkite, Willard, Exide and other wet "B" Eliminators and Combination Power Units has just been announced. This, naturally, eliminates further attention or watering and the unit is easily attached in a few minutes without the need of tools and requires only four simple connections.



Kodel dry "B" replacement unit.

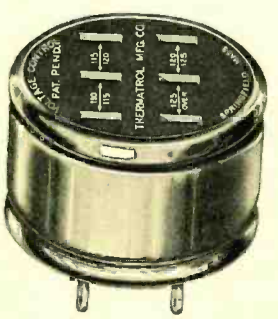
The Kodel Dry "B" Replacement Unit is metal-encased and is so small and compact as to be mounted on the inside of the eliminator case. Naturally, this eliminates further watering and the usual attention required in the operation of electrolytic rectifiers and maintains the same performance, without loss of power or the distortion or hum of the original rectifier.

Other than the tube, this unit contains nothing that can wear out and will last as long as the eliminator itself. Manufactured in one standard size for eliminators and combination eliminators, with maximum output not exceeding 150 volts. List Price, without tube—$6.00.

"THERM-A-TROL" VOLTAGE CONTROL

The Therm-a-trol Mfg. Co., of Springfield, Mass., has put on the market a new voltage control for electric sets.

This new voltage control combines compactness with attractive appearance being finished in polished brass and black bakelite. Due to the utilization of one set of contacts for two different voltages, compactness is made possible, diameter of the



The "Therm-a-Trol" voltage control.

face carrying the connections being only 2 inches. It has also a very short body extending only a minimum distance from the wall, eliminating chance of accidental disconnection by movable objects such as carpet cleaners, etc. Heavy contact pins are used which hold it firmly in the receptacle.

There are no moving parts and no adjustments are necessary so that voltage cannot be accidentally changed after adjustment. The prongs are offset obviating interference with other plugs in double or triple receptacles. The construction is rugged, high grade bakelite and sheet mica protecting all the current carrying parts, thus, insuring permanency of service with nothing to wear out.

An important feature is the multiple voltage outlets providing for the proper voltage regulation whatever the line voltage may be. The price complete ready to install is only $1.75.

BENWOOD-LINZE TYPE "A" RECTIFYING REPLACEMENT UNIT

The Benwood-Linze Company, of 19th and Washington Ave., St. Louis, Mo., have introduced a new dry rectifier replacement unit. This unit replaces the electrolytic rectifiers in trickle chargers, "A" power devices, etc., having a low transformer secondary voltage approximating 9.5 volts under load.

This full-wave rectifying unit has a charging rate from ½ to 1 ampere depending upon the transformer secondary and line voltages and the condition of the "A" battery.

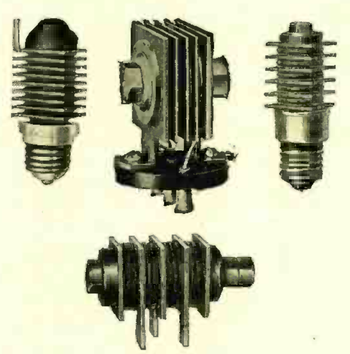
The list price is $4.50.

BENWOOD-LINZE C-110 RECTIFYING ELEMENT

The Benwood-Linze Company are also manufacturing a small element for charging devices to replace 2½ ampere rectifying bulbs requiring a connector for a Fahnestock clip at the top of the unit. It cannot be used in devices having a double connector in the base of the socket.

The list price is $4.00.

The type C-120 rectifying element is designed exclusively for charging devices



A group of new Benwood-Linze dry-type, half- and full-wave rectifiers.

equipped with standard screw base with double connector in the base of the socket thus eliminating the connector at the top of the unit. Both the C-110 and C-120 are half-wave rectifiers.

The list price of the C-120 unit is $4.00.

A new type of full-wave rectifier element, for use in connection with "A" battery chargers and "A" power units has also been announced. The general type is illustrated in the accompanying photo. The B-12 type will give a slightly higher charging rate than the B-16 with the same secondary voltage, whereas the B-16 is better adapted to stand overloads due to sudden increase in line voltages. The B-16 can also be used in devices where the D. C. back drain voltage is from 8 to 10 volts.

When properly used and not subjected to abuse or overload for a considerable period, it is claimed that these type B units should operate the minimum of 1 000 hours at the rate of 2½ amperes rectifier output; 3,000 hours when used at low rate charge of less than one ampere rectifier output and 1,500 hours when used at combined high and low rate charge, where the rectifier output varies from ½ to 2½ amperes.

NEW ZIERICK CABLE SLITTER

The F. R. Zierick Machine Works, of 8 Howard St., New York City, have introduced a new type cable slitter. This cable slitter is used for cutting the outer braid on double cable wires.

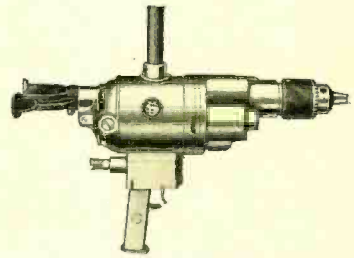
The machine is operated by foot pedal. The cable is inserted, the foot pedal pressed down and the cable removed.

The machine is rapid in action and very easy to operate. Very little pressure is required on the foot pedal.

NEW ¾" HEAVY DUTY DRILL

In response to demands for a powerful, low-speed, ¾-inch heavy duty drill for continuous, heavy duty service, The United States Electrical Tool Company, Cincinnati, now has quantities in the hands of jobbers and supply houses.

A universal motor, operating on alternating or direct current of sixty cycles or less, pulls this drill at 350 revolutions per minute, *load speed*. In all other respects, it is typical of U. S. Drills. SKF ball bearings. Chrome nickel steel gears, hardened,



New U. S. Tool Co. heavy duty drill.

running in grease. Double silk insulated, enameled, armature wire. One-piece, aluminum body frame and commutator head. Quick make, quick break, two-pole trigger switch. Three-jaw screw back chuck for straight shank drill bits, etc.

This new model weighs only 27 pounds, and sells at $78.

GENERAL RADIO MUTUAL CONDUCTANCE METER

Of the three fundamental dynamic constants of the three element vacuum tube, (plate impedance, amplification factor, and mutual conductance) the mutual conductance gives the most positive indication of the tube behavior, since it involves the ratio of the other two constants. While the mutual conductance is not a complete indication of the comparative merit of tubes of differing types, it is a positive indication among tubes of the same type. If a tube fails to meet the standard specifications of its type, either through faulty filament emission or an incorrect spacing of the elements, the mutual conductance will always be lowered. Since the mutual conductance is very easily measured, this constant is the one most suited for use as an acceptance standard for purchasers, and for use in factory, store or laboratory for rapid checking of tubes against a standard value. This device should not be confused with the G. R. Type 361-B vacuum tube bridge which is a laboratory instrument designed to give accurate measurement of all three constants.

The Type 443 Mutual Conductance Meter is a null-point bridge instrument excited by a self-contained microphone hummer and battery. A standard UX type of socket is provided as well as a socket for the five-prong separate heater tubes. All tube batteries are external. Any desired plate voltage may be applied to the tube as well as any desired grid biasing voltage. The instrument is equipped with a voltmeter for indicating the voltage across the filament. By the use of one or the other of the rheostats mounted on the panel it is possible to adjust the filament voltage to the correct value for any standard tube. A pair of telephones is used as a null indicator. If the bridge is operated in a noisy environment an external stage of amplification will be found desirable.

Values of mutual conductance having a precision of 1% to 2% are quickly made by the manipulation of a single dial to give silence in the phones. This dial is calibrated to read mutual conductance directly in micro-mhos fom 0 to 2500 micro-mhos. The dial spacing is not uniform but is so graduated as to maintain an approximately equal precision of reading over the entire scale.

this way a number of points may be obtained, which, when plotted on cross-section paper will result in a tuning curve.

When calibrating the short-wave coils those who know how, may pick out the harmonics of stations operating in the broadcast range and so obtain a number of calibration points. Otherwise it is necessary to identify short-wave stations on a receiver and follow the same procedure as stated above.

Manufacturers Engineers . . . !

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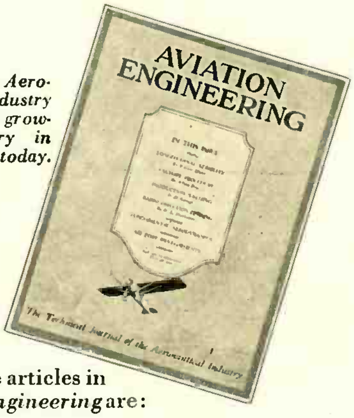

Some of the articles in *Aviation Engineering* are:

- Applications of Radio in the Aviation Field.
- Fundamental Aerodynamics (in installments).
- Welded Joints for Aircraft (Findings of the Bureau of Standards).
- Airplane Propeller Thrust.
- Aeronautic Standards (S. A. E.).
- Roller Bearings in Aircraft.
- Dynamometer Engine Tests.
- A Radio Altimeter—(by E. F. W. Alexanderson).

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Raytheon

LONG LIFE RADIO TUBES

"The Healthy Tubes"

This anatomical drawing shows why these tubes are HEALTHY!

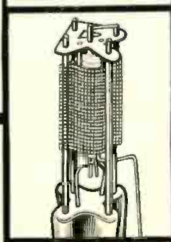
THE unique inner-construction of Raytheon means life-extension for radio tubes. For it accomplishes, among other advantages, the vital requirement of *permanent alignment* of the three tube-elements — filament, grid and plate.

Only a slight deviation in the relative positions of the elements will give rise to microphonic noises, affect reception, and shorten the life of a tube very materially.

Raytheon 4-pillar construction, cross-anchored top and bottom, positively maintains the elements in fixed relation. The result—greatly lengthened life, the elimination of microphonic noises, and healthy, consistent tube performance.

RAYTHEON MANUFACTURING CO.
Cambridge, Mass.

4-Pillar Construction



A Raytheon **Cross-Anchored Top and Bottom** *Exclusive Feature*

NEW ARCTURUS LOW VOLTAGE A.C. TUBES

The Arcturus Radio Company announces the addition to their line of heater tubes of the 126H type for use in the conventional amplifying circuits employing the "26" type of tube.

The electrical characteristics of the new tube are described as follows:

Filament voltage...... 1.5 volts
Filament current...... 1.05 amperes
Amplification constant. 8.1
Mutual conductance.... 890
Plate resistance........ 9,200 ohms

This tube can be plugged into the standard four prong socket wired in the conventional manner for A.C. operation. No circuit changes are required to take advantage of the improved characteristics of these heater tubes.

The Arcturus laboratory has also passed for production the 126 tube having the same characteristics as the 126H but employing an emitting filament. This tube is claimed to have a life in excess of the usual 26 rating and is being manufactured temporarily to meet the requirements of the enthusiast who does not care to assume the added expense of the heater type tube.

The 126H is a companion tube to the popular Arcturus 127, seven second heating, detector.

FLECHTHEIM "SUPERIOR VOLT. METERS"

Adding to their popular and well-known line of "Superior Condensers," A. M. Flechtheim & Co., Inc., of 136 Liberty St., New York City, have brought out a high grade line of high resistance voltmeters suitable for testing "B" batteries and "B" eliminators.

The Flechtheim Type C-J-600 Voltmeter.

The meters are furnished in finely nickeled cases and are equipped with polarity colored flexable cords and tips, making a very excellent and useful outfit.

There are several types—0-300 for D.C. and another with a scale reading of 0-500 D.C. An entirely new type of instrument is the type CV-600, for A.C. and D.C., reading to 600 volts. (List price, $12.50.) This meter should prove a boon to service men and custom-set builders.

A copy of the Flechtheim catalog will be gladly sent on request by the Flechtheim Company. Address all requests to them.

NEW JENSEN AUDITORIUM DYNAMIC SPEAKER

Peter L. Jensen of the Jensen Radio Manufacturing Co., of Chicago, Ill., and Oakland, Cal., has announced the new Jensen Auditorium Speaker employing the dynamic principle as a means of reproduction. In this newest development by Mr. Jensen are incorporated a number of improvements in design and construction.

In the model intended for operation with 110 volt A.C. there is a distinct departure over previous design in that a full-wave rectifying tube is used in place of a mechanical rectifier. The sensitivity of the new Jensen Auditorium Speaker has also been materially increased, yet at the same time it is capable of handling far greater volume than possible heretofore. The speaker responds faithfully to the output of an amplifying system employing only one type 171 tube or, on the other hand, will handle the full output of the most powerful type of amplifier employing type 250 tubes in push-pull.

The power required for field excitation of the three new units is approximately 18 watts. The new Jensen Auditorium Speaker units which have been designed and are in production at the present time, with delivery being made to the trade, are as follows: DA 4, for 110 volt D.C. operation; DA 5, for 220 volt D.C. operation; DAAC, for 110 volt A.C. operation. List prices of the units vary from $55 to $70.

VALLEY B POWER UNIT

The Valley B Power Unit, Model 828 is designed for all radio receiving sets up to ten tube sets.

It is finished in a handsome Berkshire green. The name plate is of brush brass, black background, with a dash of red.

The new Valley B-Power Unit. The maximum voltage is 180. There are two C bias taps, 9 and 40 volts. The detector B voltage is variable.

This unit employs the Raytheon rectifying tube because of its long life and proven performance.

The essential elements are the oversize transformer, special designed chokes and high voltage condenser.

Convenient terminals are provided for the negative, detector, intermediate, amplifier and power voltages. The Allen-Bradley high resistance control is in the detector circuit and may be adjusted to meet the requirements of every set.

This unit has two "C" battery taps: A 9-volt tap for use with the 112-A power tube, and a 40-volt tap for the 171 power tube.

All terminals, voltage taps, and controls are mounted under the cover of the unit. It is designed to give 135 to 180 volts of continuous power. Retails at $35.00. Manufactured by Valley Electric Company, 4221 Forest Park Blvd., St. Louis, Mo.

CENTRAL SCIENTIFIC VACUUM PUMP

The Central Scientific Company, 460 E. Ohio St., Chicago, Ill., is now offering a very efficient, rapid and dependable vacuum pump to the radio tube manufacturers. This pump is known as the Cenco Megavac Pump.

The Cenco Megavac Pump has a free air capacity of 57 liters per minute at the operating speed of 600 R.P.M. It does not require a preliminary or backing pump and will produce a vacuum of .001 mm or 1 micron of mercury in a 6 liter container in 2¼ minutes. The manufacturers guarantee it to produce a vacuum of .001 mm, but the records of the laboratory, in which all pumps are tested, show that the average vacuum produced by all the pumps made up to the present time is .0005 mm or 0.5 micron.

The Cenco "Megavac" Pump.

The Cenco Megavac Pump can be obtained in single units with direct motor drive for hand station exhausting or in sets of three units with direct motor drive for use with automatic exhausting machines.

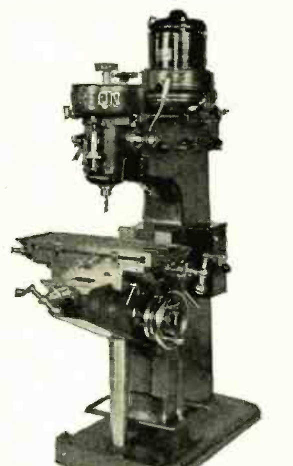
NO. 8-D VERTICAL MILLING & ROUTING MACHINE

The No. 8-D Vertical Milling & Routing Machine recently announced by the Geo. Gorton Machine Co., Racine, Wis., is the latest addition to their line of Die-sinking & Engraving Machines.

The machine is specially adapted for handling economically, electrical die and tool work, and similar milling and routing in brass, steel and cast iron. It is designed to run small cutters at high speeds, for the class of work now commonly performed on large plain milling machines with high speed attachments.

A feature of this machine is the sliding head. This unit carries the spindle and drive complete. With head close to column, the gap between spindle and column is 15". With head fully extended, gap is 30", making the area covered by table movement 15" x 22"; all at one setting of work. The machine will also swing a plate 60" diameter x 4" thick, or a cylinder 22" diameter x 15" high. Maximum—spindle nose to table 15", minimum 0". Height overall 68", weight 1600 lbs. Although built primarily for precision work, this is a rugged tool, and will operate a half inch diameter high speed steel cutter to the limit.

Direct drive with rubber V belt from ¾ H.P. standard ball bearing vertical motor. Ten spindle speeds (475 to 3000 R.P.M.) are obtainable without back gears or changing pulleys. Higher speeds up to 6000 are available for brass routing and use with diamond tools. For brass routing this machine is equipped with foot treadle, chip blower integral with motor, and a forming attachment for cutting curved surfaces.



Gorton milling and routing machine.

A spindle pulley brake facilitates cutter changes. It is possible to stop machine at any speed and change cutters, all in ten seconds, without jar or chatter.

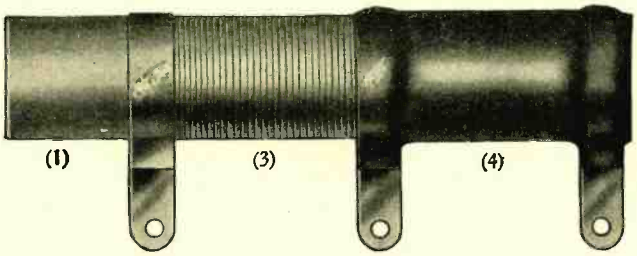
All feed screws are covered and ways are shielded. Rotating parts are dynamically balanced. Large diameter graduated dials permit accurate adjustment of all feed screws to fractions of a thousandth.

Spindle is completely enclosed, ball bearing, running in oil. It is machined from a solid bar of chrome manganese alloy steel hardened and ground inside and out, with splined drive. Spindle is mounted in a high carbon steel sleeve, hardened and ground inside and out, and sliding in a hardened, ground steel bushing. The service arrangements provide for quick replacement of these two parts, so that regardless of age, the spindle assembly will always retain its' original accuracy.

NEW

L. M. C. Silver Welded Resistors

(Patents pending)



1.—Bare Refractory Tube

2.—Copper Terminals with welded connections shown

3.—L.M.C. Special Resistance Wire

4.—L.M.C. Special Heavy Enamel

From the metallurgical laboratories of Lautz again comes a meritorious contribution to the radio production field.

The new silver welded L.M.C. resistor makes a *permanent, solid* contact — practically does away with terminal joint trouble — has a much lower operating temperature coefficient — and absolutely establishes and maintains an average increased working life of over 100%. They cost no more than the average resistor.

Sample inquiries and specifications invited from manufacturers

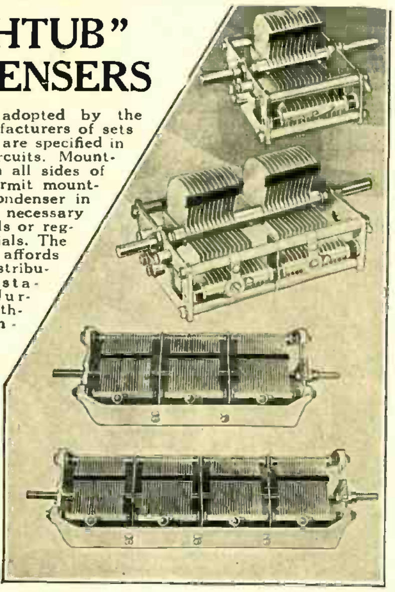
LAUTZ MANUFACTURING COMPANY, INC.

Electrical Alloy Products—Controlling Devices

245 N. J. R. R. Ave. Newark, N. J.

DeJur-Amsco

"BATHTUB" CONDENSERS



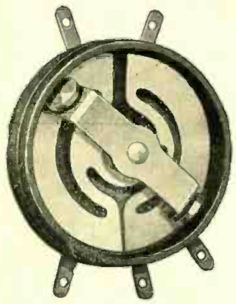
Have been adopted by the largest manufacturers of sets and kits and are specified in all leading circuits. Mounting holes on all sides of the frame permit mounting of the condenser in any position necessary for drum dials or regular panel dials. The tuning curve affords a uniform distribution of all stations. De Jur-Amsco "Bathtub" Condensers are available in double, triple and quadruple combinations in all capacities scientifically calibrated and perfectly matched.

Write for Catalog

DeJur-Amsco Corporation

Broome and Lafayette Sts., New York City

Individual—Independent Speaker Volume Control



Constant Input Resistance

List Price— $3.00

The Centralab Constant Impedance Volume Control is the only unit that allows a number of speakers operated from the same amplifier to be controlled individually without affecting the other speakers in the circuit. It is a dual resistance unit with one resistance shunting the speaker for volume control and the other resistance in series with the line.

Adjusting the knob varies both resistances so that while one short circuits the speaker to control volume, the other resistance is added to the line maintaining a constant impedance. Easy to install, smooth and efficient in operation. Send for interesting booklet of picture and wiring diagrams, "Voltage and Volume Controls—Their Use."

Centralab

22 Keefe Avenue, Milwaukee, Wisconsin

A New EBY Idea

Moulded Tip Jacks

No Insulating Washers—No Nuts

Here's something worth designing around—a pair of tip jacks moulded as inserts in a brown bakelite strip—available engraved "Speaker" or "Phonograph". No insulating washers—no nuts—improved appearance — positive contact — worth-while economies in assembly. Samples and quotations on request.

The H. H. EBY Mfg. Co., Inc.

4710 Stenton Ave. Philadelphia

A Promise for 1929

During 1928 Hardwick, Field, Inc. built the best resistors brains and materials could produce.

If money can buy a better resistor in 1929, Hardwick, Field, Inc. promise to produce it.

That is why so many leading manufacturers are buying the Har-Field Resistor in ever-increasing quantities. They recognize in its unusual dependability, a constant endeavor to build the perfect resistor.

Some of the more prominent concerns now using Har-Field Resistors are listed below:

- Western Union Telegraph Company
- Jensen Radio Mfg. Co.
- Splitdorf Electric Co.
- Colonial Radio Corp.
- Samson Electric Co.
- Philadelphia Storage Battery Company
- Stromberg-Carlson Tel. Manufacturing Company
- Kolster Radio Corporation
- American Transformer Co.
- Fansteel Products Co.
- Zenith Radio Corporation
- Crosley Radio Corporation

Tell us about the resistor you want. If we can't supply you from our standard range of sizes, we shall be glad to make up samples for you with prices.

Write to

HARDWICK, FIELD, INC.

Sales Office: 122 Greenwich Street, New York City.

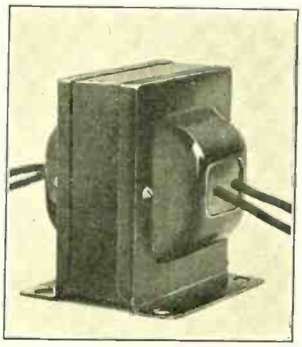
HAR-FIELD WIRE-WOUND RESISTORS

Factory: 215 Emmet Street, Newark, N. J.

COILS

Radio and General Use

TRANSFORMERS

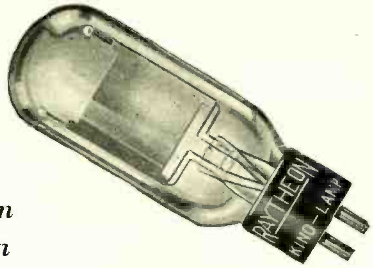


Radio Light and Power

Let Us Quote On Your Requirements

GARDNER ELECTRIC MANUFACTURING CO.
EMERYVILLE, CALIFORNIA

Raytheon Kino-Lamp



for Television Reception

This lamp is made in numerous types and styles, which provide suitable light sources and light-sensitive relays for all systems.

List Price, $7.50

Raytheon Foto-Cell

for Television Sending

This is an extra-sensitive broadcasting tube, supplied in either *hard vacuum* or *gas-filled* types, and in two sizes of each.

Information and prices on application

Raytheon BH
LONG LIFE RECTIFYING TUBE

for "B" Power Eliminators

Over a hundred different makes of "B" Eliminators require this tube, and take no other. There are millions of them in daily, satisfaction-giving use.

List Price, $4.50

Write for further information on any of this equipment

RAYTHEON MFG. COMPANY
CAMBRIDGE, MASS.

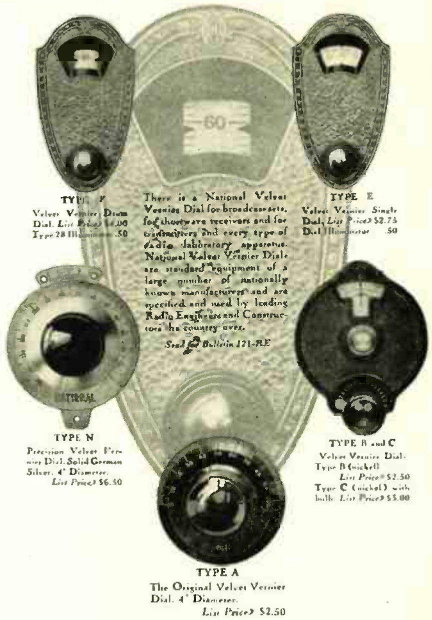
ARMOR
Radio Tubes

Manufacturers of a full line of radio tubes, including the new A.C. types, 226 and 227.

Armor tubes are fully guaranteed

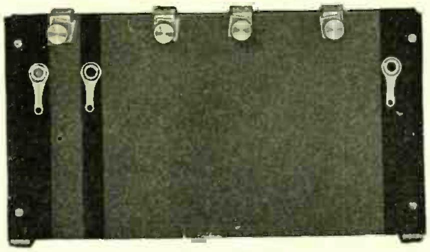
Armstrong
Electric & Mfg. Co., Inc.
187–193 Sylvan Avenue
Newark, New Jersey

For Every Radio Use



NATIONAL
VELVET VERNIER DIALS
NATIONAL CO. INC., W. A. READY, PRESIDENT MALDEN, MASS.

General Radio Type 446 VOLTAGE DIVIDER



Price—$2.75

The Type 446 Voltage Divider has been especially designed for use as an output potentiometer device for 300-volt rectifying systems. It is wound in two sections, one of 15,000 ohms for the plate supply and a 1500-ohm section for obtaining the bias voltage for a power tube. It is equipped with four adjustable sliders, suitably engraved, by means of which any combination of voltage may be obtained from the plate-supply unit. This unit will dissipate 60 watts. If intended for use with a 500-volt rectifying system two voltage dividers should be connected in series.

GENERAL RADIO CO.

Bulletin No. 931 on Request

30 State St. Cambridge, Mass.
274 Brannan St. San Francisco, Calif.

HOTEL MAJESTIC

CENTRAL PARK WEST
72nd STREET

Situated in New York's finest residential district, facing beautiful Central Park. Only 5 minutes from the smart shops, theatres, railroad terminals.

Service and Cuisine of Traditional Fame

The Majestic has always been the residence of many distinguished visitors to this continent.

Room & Bath - $3^{50} per day and up

Special weekly, monthly, seasonal and yearly rates.

ALHAMBRA

CONE SPEAKER PAPER

ALHAMBRA PAPER gives ABSOLUTELY UNIFORM RESONANCE. It has no resonance point of its own. Just as the cone speaker is supreme in radio reproduction, so also is ALHAMBRA supreme in imparting the utmost in tone quality.

The small clock and interior cabinet cone do not equal in soft, natural tone the separate cone made of ALHAMBRA which is used by high class makers.

Cone speaker manufacturers are invited to communicate with us concerning their requirements for the coming season. ALHAMBRA is furnished in sheets suitable for cone speakers of 13 inches to 36 inches diameter—special sizes to order. Prompt shipment guaranteed.

The SEYMOUR CO., 323 W. 16th St., New York City

PHOTO-ELECTRIC CELLS
THE BURT CELL

Without Fatigue—Highly Sensitive
Absolutely Reproducible—Instantaneous in Response

The BURT-CELL is made by a new method and should not be confused with any other photo-electric cell. By a special process of electrolysis, the photo-electric metal is introduced into a highly evacuated bulb directly through the glass wall of the bulb, giving photo-electric material of absolute purity. The superiority of the BURT-CELL is due to these features, making possible results never before obtainable. Described in Bulletin No. 271.

We also manufacture the STABILIZED OSCILLOSCOPE—the only VISUAL OSCILLOGRAPH having a linear time axis and no inertia—giving an accurate picture of high frequency wave forms.

Write for Bulletin 282.

DR. ROBERT C. BURT
Manufacturing and Consulting Physicist
327 S. Michigan Ave., Pasadena, Calif.

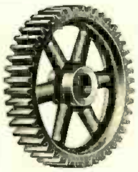
CORE LAMINATIONS

for Audio & Power Transformers — Chokes

A large variety of standard shapes carried in stock. Special designs stamped to your order.

Our BOOKLET on LAMINATIONS (sent on request) gives specifications of Stock Standard Shapes, and contains much data of value to the designer—and buyer.

Lamination Stamping Company
764 Windsor Street, Hartford, Conn.



GEARS ALL KINDS — SMALL

The most accurate made and prices reasonable. We carry a complete line of gears in stock for immediate shipment. Can also quote on special gears of all kinds. Send us your inquiries.

Write for Catalogue 200

CHICAGO STOCK GEAR WORKS
105 South Jefferson Street, Chicago

"SWEDMAG"

COLD-FINISHED MAGNETIC IRON

99.80% Pure

Made from Swedish Magnetic Ore for Radio Pole-pieces, Cores, etc., Electrical Instruments, Solenoids, Switches, Laminations, etc. Write for descriptive literature.

DAVID REID, Jr., Co., Inc., 85-89 Adams St., Brooklyn, N. Y.

8 Great Features Tell You Why 6000 RADIO-TRICIANS Are Offering These 4 New Hi-Q RECEIVERS

1. 10 K.C. Selectivity
2. Absolute Flat-Top Square Cut-off Tuning
3. Screen-Grid Tubes
4. Stage-Shielded Steel Chassis
5. Concealed Wiring
6. Simplified Operation
7. Natural Reproduction
8. Coast-to-Coast Reception

Custom-built to Any Pocketbook!

NO man can use the title "RADIO-TRICIAN" unless he can qualify as a radio expert. So when we tell you that 6000 authorized "RADIO-TRICIANS" throughout the country are building the new Hi-Q 29 Receivers you must agree that these receivers MUST have outstanding qualities.

The biggest advance of the year in radio design is the "Band Pass Filter"—a system which effects absolute FLAT TOP *square cut-off* TUNING with positive 10 K. C. selectivity. This is the big feature of Master Hi-Q 29 Receivers. No other set in the world has it to our knowledge. It eliminates "cross talk" even in crowded areas which have many powerful stations and gives a Super-sensitivity and Super-selectivity which assures coast-to-coast reception. Further than this, it produces a quality of tone which we have never heard equalled in any receiver!

There are FOUR Hi-Q Receivers for 1929—the Junior Hi-Q 29 at $54.35; the Junior A.C. Hi-Q 29 at $101.50; the Master Hi-Q 29 at $99.50 and the Master A.C. HiQ 29 at $151.50—four wonderful receivers which meet practically every range of pocket-book. All these instruments are the joint creation of America's ten leading parts manufacturers. All are stage-shielded, built on steel chassis from the finest parts available in the industry.

If You Want Real Radio Value, Write for our New 80-Page Book

The new 80-page Construction Manual is the biggest and most complete book of its kind ever published. Tells how to build all 4 new Hi-Q Receivers. Photos and diagrams illustrate every detail. Covers power amplifiers, tube and battery combinations, antennae, installation, short-wave adapters, house wiring and a wealth of other data on custom-built radio. Price 25c.

HAMMARLUND-ROBERTS, 1182-G Broadway, New York

Hammarlund Roberts Custom-Built Radio

Associate Manufacturers

Acme Wire Co. (Parvolt)
International Resistance Co. (Durham Resistors)
Radial Co. (Amperite)
Sangamo Electric Co.
Thordarson Elec. Mfg. Co.
Hammarlund Mfg. Co.
Yaxley Mfg. Co.
Benjamin Elec. Mfg. Co.
Arcturus Radio Co.
Electrad, Inc. (Truvolt)
Westinghouse Micarta

RESISTOVOLT

Voltage Controller
Automatic—Air-Cooled

Automatically checks all line voltage in excess of 110 volts, protecting your tubes from slow burn-out or line surges. Protects tubes and set wiring in case of short circuit by acting as a fuse. Banishes line noises caused by the use of electric appliances, switches, etc., in the home. This new DeLuxe model is completely Air-Cooled regardless of overload. All metal, entirely automatic, unconditionally guaranteed. **$1.75**

Consumes no current.

ANTENNAVOLT

Combination Resistovolt and Socket Antenna

The advantages of a light socket antenna have long been known but were obtainable only through great inconvenience. ANTENNAVOLT gives sharper tuning, less static, greater volume, completely enhanced reception—all the benefits of a light socket antenna without tying up the socket for set current *PLUS* giving RESISTOVOLT VOLTAGE CONTROLLING PROTECTION! **$2.25**

Consumes no current.

Complete Television Kits

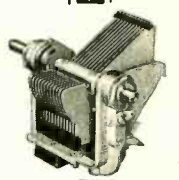
Model B-1	— Without amplifier or Television Tube..	$37.50
Model 45	— Same as B-1 with improved motor....	45.00
Model 52	— Same as 45 with four-stage amplifier...	52.00
Model 65	— Same as 52 with Television Tube......	65.00
Model A-1	— Model 65 completely built up on metal stand	$100.00

Also All Parts tubes, motors, discs, amplifier, etc. Write for catalog.

Your dealer can supply, if not remit cost to manufacturers:

INSULINE CORP. OF AMERICA
78-80 Cortlandt St. New York City, N. Y.

YEARS Ahead!



Radio condensers come and go—but the Hammarlund "Midline" *keeps ahead.*

Built with watch-like precision and embodying every feature demanded of a modern tuning instrument, the Hammarlund "Midline" Condenser has won world-wide renown.

Your choice of a manufacturers' model, "Battleship" multiple, or the standard model in all capacities—single, dual, triple and quadruple, at interesting prices.

HAMMARLUND MFG. CO., 424-438 W. 33rd St., New York

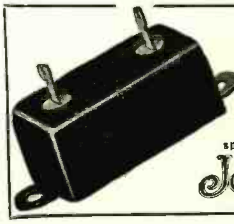
Let us Cooperate With You

For Better Radio Hammarlund PRECISION PRODUCTS

WIRE

STRAND—Antennae (plain or enameled)—Double Galvanized.
WIRE—Antennae (plain or enameled). Connecting and Ground (Rubber covered, braided or plain).
BUS BAR—Litzendraht-Loop.
MAGNET (Cotton or Silk).

John A. Roebling's Sons Co., Trenton, N. J.



CONDENSER SPECIALISTS

We make one thing and one thing only—wax impregnated paper condensers in medium and large capacities. We make no set hardware, no eliminators, no transformers, no parts, no sets. Our entire concentrated effort is on one product alone. Such specialization assures highest quality, economical production and dependable service. Millions of Fast Condensers now in use in leading sets and eliminators. Send us your specifications.

JOHN E. FAST & CO. 3982 Barry Ave., Dept. R.E. Chicago, U.S.A.

February Design Issue

The February issue of Radio Engineering will deal with design trends for 1929-30.

Advertising Forms Close January 28th

Buyers Directory of Equipment and Apparatus

Readers interested in products not listed in these columns are invited to tell us of their wants, and we will inform the proper manufacturers. Address Readers' Information Bureau.

Addresses of companies listed below, can be found in their advertisements—see index on page 62.

ADAPTERS:
Carter Radio Co.

ALUMINUM:
Aluminum Co. of America

ALUMINUM FOIL:
Aluminum Co. of America
Reynolds Metals Co., Inc.

AMMETERS:
General Radio Co.
Jewell Elec. Inst. Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Instrument Corp.

ANTENNAE, LAMP SOCKET:
Dubilier Condenser Mfg. Co.

ARRESTERS, LIGHTNING:
Jewell Elec. Inst. Co.
Muter, Leslie F. Co.
Westinghouse Elec. & Mfg. Co.

BASES, VACUUM TUBE:
Formica Insulation Co.
National Vulcanized Fibre Co.

BINDING POSTS:
Eby, H. H. Co
General Radio Co.

BRACKETS, ANGLE:
Scovill Mfg. Co.

BRASS:
Copper and Brass Research Assn.
Scovill Mfg. Co.

BROADCAST STATION EQUIP'T:
Cardwell, Allen D., Mfg. Co.
General Radio Co.
Radio Engineering Laboratories

BUTTS:
Scovill Mfg. Co.

CABINETS, METAL:
Aluminum Co. of America.
Copper and Brass Research Assn.
Radio Engineering Laboratories

CELLS, PHOTOELECTRIC:
Burt, Robert C.
Raytheon Mfg. Co.

CERIUM:
Independent Labs.

CHARGERS:
Benwood-Linze Co.
Elkon Co.

CHASSES
Aluminum Co. of America.
Copper and Brass Research Assn.
United Scientific Laboratories, Inc.

CHOKES, AUDIO FREQUENCY:
American Transformer Co.
General Radio Co.
Silver-Marshall, Inc.
Thordarson Elec. Mfg. Co.

CHOKES, RADIO FREQUENCY:
Cardwell, Allen D., Mfg. Co.
General Radio Co.
Radio Engineering Laboratories
Silver-Marshall, Inc.

CHOKES, B ELIMINATOR:
American Transformer Co.
Dongan Elec. Mfg. Co.
General Radio Co.
Silver-Marshall, Inc.

CLAMPS, GROUND:
Muter, Leslie F., Co.
Scovill Mfg. Co.

CLIPS, SPRING:
Scovill Mfg. Co.

COIL FORMS:
General Radio Co.
Silver-Marshall, Inc.

COILS, CHOKE:
Dudlo Mfg. Co.
Westinghouse Elec. & Mfg. Co.

COILS, IMPEDANCE:
Dudlo Mfg. Co.

COILS, INDUCTANCE:
Aero Products Corp.
Cardwell, Allen D., Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co.
Radio Engineering Laboratories
Silver-Marshall, Inc.

COILS, MAGNET:
Dudlo Mfg. Co.

COILS, RETARD:
Hammarlund Mfg. Co.

COILS, SHORT WAVE:
Aero Products Corp.
General Radio Co.
Hammarlund Mfg. Co.
Radio Engineering Laboratories
Silver-Marshall, Inc.

COILS, TRANSFORMER:
Dudlo Mfg. Co.

CONDENSER PARTS:
Aluminum Co. of America
Scovill Mfg. Co.

CONDENSERS, BY-PASS:
Aerovox Wireless Corpn.
Allen-Bradley Co.
Brown & Caine, Inc.
Carter Radio Co.
Condenser Corp. of America.
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E. & Co.
Muter, Leslie Co., Inc.
Polymet Mfg. Co.
Sangamo Elec. Co.

CONDENSERS, FILTER:
Aerovox Wireless Corpn.
Allen-Bradley Co.
Brown & Caine, Inc.
Carter Radio Co.
Condenser Corp. of America.
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E. & Co.
Muter, Leslie Co., Inc.
Polymet Mfg. Co.
Radio Engineering Laboratories.
Sangamo Elec. Co.

CONDENSERS, FIXED:
Aerovox Wireless Corpn.
Allen-Bradley Co.
Brown & Caine, Inc.
Carter Radio Co.
Condenser Corp. of America.
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E., & Co.
Muter, Leslie Co., Inc.
Polymet Mfg. Co.
Radio Engineering Laboratories
Sangamo Elec. Co.

CONDENSERS, MIDGET:
Cardwell, Allen D. Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co.
Scovill Mfg. Co.
Silver-Marshall, Inc.
United Scientific Laboratories

CONDENSERS, MULTIPLE:
Cardwell, Allen D. Mfg. Co.
Hammarlund Mfg. Co.
Scovill Mfg. Co.
United Scientific Laboratories.

CONDENSERS, NEUTRALIZING:
Muter, Leslie F., Co.

CONDENSERS, VARIABLE TRANSMITTING:
Cardwell, Allen D. Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co
Radio Engineering Laboratories

CONDENSERS, VARIABLE:
Cardwell, Allen D. Mfg. Co.
DeJur-Amsco Co.
General Radio Co.
Hammarlund Mfg. Co.
Radio Engineering Laboratories.
Scovill Mfg. Co.
Silver-Marshall, Inc.
United Scientific Laborstories

CONNECTORS:
Carter Radio Co.
Scovill Mfg. Co.

CONTROLS, ILLUMINATED:
Hammarlund Mfg. Co.
Silver-Marshall, Inc.

CONTROLS, VOLUME:
Carter Radio Co.
Central Radio Laboratories
Clarostat Co.

CONVERTERS:
Cardwell, Allen D., Co.
Electric Specialty Co.

CONVERTERS, ROTARY:
Electric Specialty Co.

COPPER:
Copper & Brass Research Assn.
Scovill Mfg. Co.

CURRENT CONTROLS, AUTOMATIC:
Radiall Co.

DIALS:
Hammarlund Mfg. Co.
Scovill Mfg. Co.
Silver-Marshall, Inc.
United Scientific Laboratories

DIALS, DRUM:
Hammarlund Mfg. Co.
Silver-Marshall, Inc.
United Scientific Laboratories

DYNAMOTORS:
Electric Specialty Co.

ESCUTCHEONS:
Scovill Mfg. Co.

EXPORT:
Ad. Auriema, Inc.

FILAMENTS:
Cohn, Sigmund.
Gilby Wire Co.

FILAMENT, OXIDE COATED:
Independent Laboratories, Inc.

FILAMENT CONTROLS, AUTOMATIC:
Radiall Co.

FOIL:
Aluminum Co. of America
Reynolds Metals Co., Inc.

GALVANOMETERS:
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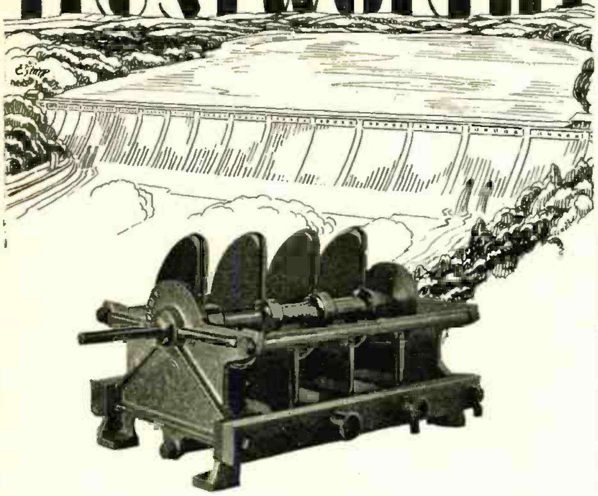

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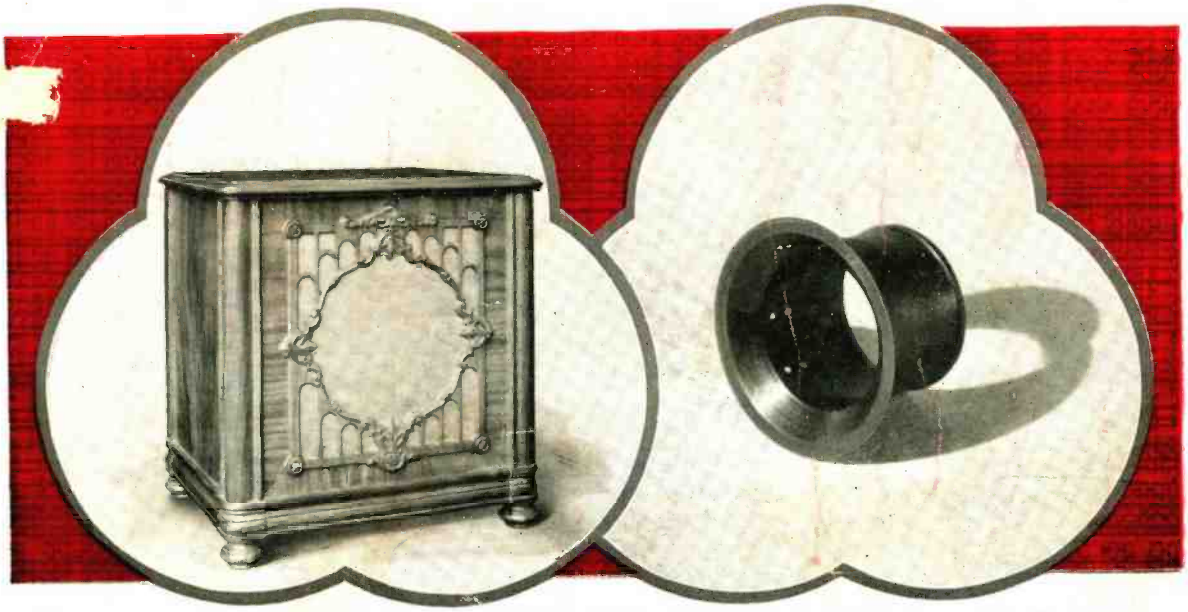

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