NINTH YEAR OF SERVICE

RADIO ENGINEERING

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The JOURNAL of the RADIO INDUSTRY

RADIO ENGINEERING

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Alterations in Style Sheet

In order to conform more specifically to the standard usage of terms and the rules of abbreviation, Radio Engineering has made alterations in its style sheet.

In the case of technical terms that have been in use for many years, and have become commonplace, the original forms stand, since many of the expressions that still hold sway are colloquial and should not be deromanticized. The only divergence from this rule is in terms that have evolved into compound words, such as super-heterodyne, head-phone, wave-length, feed-back, and so on. Since these terms are of long standing, the hyphens have been dropped and you will find them in the printed page as, superheterodyne, headphone, wavelength, feedback.

We have, likewise, dropped the hyphen from such compound words as electrodynamic, photoelectric, loudspeaker, but have retained the hyphen in the case of long-wave, short-wave, direct-current, etc., when they are employed as adjectives.

All abbreviations have been altered and their use is dependent upon the status of the word. Thus: audio-frequency, which can be employed as a noun or as an adjective, retains the hyphen when used as an adjective and is abbreviated as a-f. On the other hand, kilowatt and kilocycle are abbreviated as kw. and kc., respectively.

All such abbreviations are in lower case letters, with the exception of the abbreviations of the names of organizations, etc., and in such cases where the abbreviation of a term is employed in the heading of an article.

Any criticisms of these alterations will be appreciated.—Editor.

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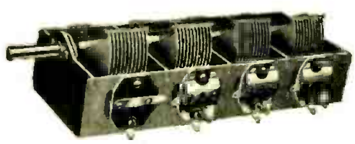
Representative radio firms call on Scovill to supply them with condensers that are made to their market requirements. Condensers that are made of high grade raw material, and in accordance with latest and most effective scientific developments. Condensers that contribute materially toward winning consumer preference for their finished products.



Instead of rubbing a magic lamp, however, they either telephone, telegraph or write—for a Scovill representative to call.

Every step in the manufacture of Scovill condensers and radio parts is under strict laboratory supervision

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EDITORIAL

April 1929

THE VACUUM TUBE

IT IS odd, to say the least, that the vacuum tube, which is the backbone and mainstay of radio, should prove such a fickle commodity. It is a moon on the tide of radio and so, often has its own way regarding the fate of a company or the progress of the industry.

It is odd, likewise, that the vacuum tube should be the most sorely disputed engineering development; odd, that is, if one views it through impartial eyes. It looks so damnably unimportant in itself; like a frail, young woman, but, like a frail, young woman, it can, and does, sway a lot of destinies.

Possibly the vacuum tube is catered to a bit too much for its own good and the good of its followers. Like a frail, young woman, it can get very high-minded and do a lot of very disconcerting things if it gets to know that it is a law unto itself.

At any rate, it is being "rushed" at the moment, mainly because of its appeal, and there is that little question to the fore, regarding production and the market, that wants answering.

We do not profess to know a great deal about frail, young women and their reactions to an overdose of attention, and so it may be that our simile is rather damp, but we have always assumed that most things can be understood moderately well if one just watches and listens.

So—we have been watching the rise of the radio industry, the rise of its stocks and the general increase in the size of the market. Each year the industry tacks up a new record of set sales that overshadows the previous year, and along with this remarkable increase in the sale of sets there has been a proportionate increase in the manufacture and sale of vacuum tubes.

Then, the frail, young vacuum tube turned A-C. and the sets turned likewise. All sorts of things happened in that renaissance period, including an entirely new merchandising structure of great possibilities, and a *frail*, young A-C. tube.

There was a great rush to buy these new radio sets that would operate right from the light socket in the home, and with each set went a batch of the frail, young tubes. Some of these tubes hardly lasted the trip home, and the few that did survive the trip developed galloping consumption and neatly expired in short order.

So, crowds of people bought new tubes and then bought some more new tubes until they were quite exasperated over the situation, and it certainly looked as though something was about to go beserk.

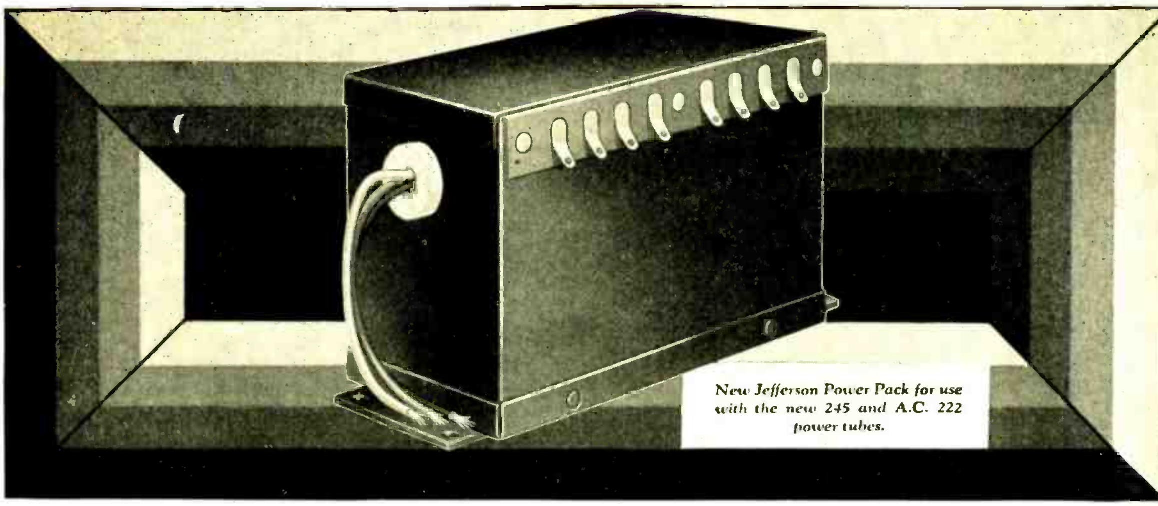
If we remember correctly, there was a great tube shortage around that time, and dealers were offering a premium for any tubes they could lay hands on. Merchandisers were having great sport—and so, we presume, were the design engineers in the tube laboratories.

This was all very hard on the character of the tube and it suddenly forgot to be high-minded and got down to the business of long life in a moderate and efficient sort of a way, without disconcerting everyone.

In the meantime, production on tubes was being increased to take care of the former situation and many new factors opened up plants to meet the very same condition. Now, everyone is at least doubling production and there are, probably, twice as many producing companies as there were at the time of the drought. The public is still holding out the bucket and the new tubes pour in at a tremendous clip, but the bucket no longer leaks dead tubes in the manner it did heretofore.

We can readily see that a great number of sets are going to be sold this year, but we are a bit hazy on the point of where all the tubes are going, particularly those that must, for economic reasons, remain high-priced.

M. L. MUHLEMAN, *Editor.*



New Jefferson Power Pack for use with the new 245 and A.C. 222 power tubes.

Transformers and Chokes *for* New Power Tubes

Specially Engineered by Jefferson

AGAIN Jefferson Engineers have anticipated the need of the Radio Industry. The transformer and choke problems which will be met in building sets around the newly developed power tubes have already been solved by Jefferson Engineers.

A new power transformer has been designed, perfected, and thoroughly tested for use with the new tubes No. 245 and No. A.C. 222 shield grid tube.

A wide choice of choke units are ready—heavy single duty chokes, double chokes of the conventional design—or staggered choke units consisting of one heavy and one light choke. The last is an especially economical method which minimizes hum and allows maximum voltage on the tubes without overloading the rectifier.

Special audio transformers have been developed with improved design to make use of all the possibilities of these new tubes.

Jefferson reputation, backed and maintained by Jefferson engineering is your guarantee of quality, service, and satisfaction on these new units. And the foresight of Jefferson Engineers together with the Jefferson production capacity are your insurance of prompt deliveries now and throughout the season.

Take advantage of this engineering work already done for you by writing us your problems. Complete electrical specifications and quotations will be supplied on request.

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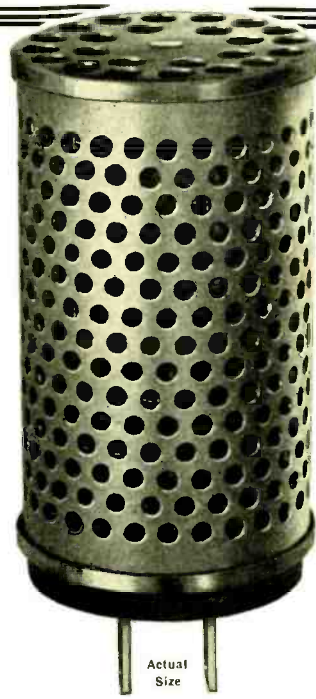
Announcing the LINE BALLAST CLAROSTAT

YOUR 1929 A-C sets are incomplete if they do not include automatic line-voltage control. And you run the danger of losing many potential sales, experiencing plenty of service troubles, and having your engineering judgment—yes, and even your merchandising sense—seriously questioned by dealer and public alike. All of which you cannot afford in a highly competitive market.

The LINE BALLAST CLAROSTAT is the answer to the automatic line-voltage control problem. Foolproof. Absolutely automatic. Compact. Inexpensive. Sturdily built. Sealed in stout metal casing to avoid tampering. Functions over wide limits, such as between 100 and 135 volts, with resultant secondary voltages varying less than plus or minus 5 per cent—well within the specifications of A-C tube manufacturers. Plugs into standard receptacle.


Actual Size

The LINE BALLAST CLAROSTAT is inexpensive. It is the best investment you can make in your new designs, yet it pays the biggest dividends. By doing away with tapped transformer primary, together with switching mechanism or terminals and the extra wiring, the LINE BALLAST CLAROSTAT goes far toward paying for itself. And on the basis of merchandising advantages, it pays for itself a hundredfold.

Don't fail to look into these merchandising advantages, quite as well as the engineering advantages. Remember, the LINE BALLAST CLAROSTAT makes it possible for you to sell sets in low-voltage areas, because of full volume and tone which it provides, and in high-voltage areas, because of no extra strain on the tubes to cause heavy replacements and keen dissatisfaction.

All of which means a better A-C set, more sales, more good will, and more dealer and consumer interest.

The Line Ballast Clarostat is intended only for those who are engaged in the design and manufacturing of A-C sets.

And while we are discussing Clarostats, don't forget the Hum-Dinger, which eliminates A-C tube hum; the Clarostat Strip Resistors, which provide accurate and reliable low-wattage resistance; and the Clarostats, which afford precisely adjustable resistance where there are variable values to be compensated for.

WRITE for technical bulletin on the LINE BALLAST CLAROSTAT. *Better still, send us a sample power transformer with an 85-volt primary, with complete specifications, and we shall submit to you the proper sample for your inspection and test.* Meanwhile, don't forget that there is a Clarostat for every radio purpose—variable, fixed and automatic resistance.

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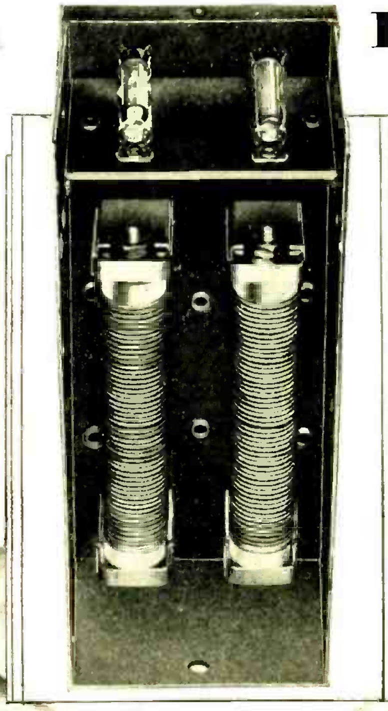
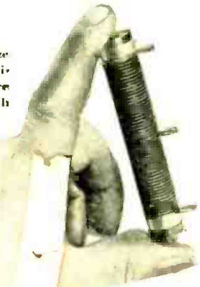
This New Elkon Rectifier Eliminates the Power Transformer in Dynamic Speakers





This shows the size of one of the rectifier units. Two are required on each speaker.

The rectifier units can be easily replaced when necessary as may be seen here.

AGAIN Elkon leads the field. The new Elkon D-29 Power Supply is the outstanding development of the year in rectifiers for dynamic speakers.

This remarkable rectifier operates directly from the AC power line eliminating the Power Transformer and reducing the cost of assembly.

Supplied complete, ready to install, or the rectifier units (two required on each speaker) can be sold separately.

Wonderfully efficient, quiet in operation. The units can be replaced when necessary as easily as a tube is changed in a socket.

If you have not already sent us a sample of your new speaker, do so at once. We will equip it with the new Elkon rectifier and return it to you promptly.

The Elkon D-29 Power Supply Installed on a Dynamic Speaker.

ELKON, Inc.

Division of P. R. Mallory & Co., Inc.

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New York City

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Please send us complete information on your new Elkon D-29 Power Supply for Dynamic Speakers.
Name ....
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To manufacturers with an eye to the service problem

"The standard line of Sangamo Fixed Condensers leaves the factory tested to maximum variation of 10%!"

Sangamo standards of precision carried into the manufacture of Fixed Condensers, have made it possible for manufacturers to eliminate much of the trouble ordinarily caused by the imperfect operation of condensers. The internal loss is low and insulation nearly infinite in Sangamo Condensers. They are accurate and they *stay* accurate.

The Sangamo Type "A" Condenser

Every sound characteristic is affected by the quality of the fixed condensers in a set. Sangamo builds accurate mica condensers, molded within an overall enclosure of genuine bakelite with only the terminals brought outside. Moisture, heat, shocks or jars will not alter their characteristics nor affect operation after the set leaves the factory.

Sangamo Type "A" Condenser—solidly molded in bakelite and immune to thermal or atmospheric changes.

The Sangamo "Illini" Condenser

This new condenser is of the same quality as the standard Sangamo Fixed Condenser—but is of a size and shape that more readily adapts itself to factory production. The greater convenience of connecting lugs which may be bent to any position without danger to the condenser can readily be appreciated.

The new Sangamo "Illini" Condenser—for manufacturers' use only.

All prices on request

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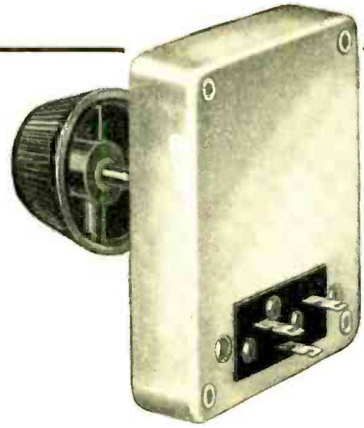
- ☐ (*For manufacturers*) Please send engineering data on your transformers and condensers.
- ☐ (*For dealers*) Please send data on Sangamo Condensers.
- ☐ (*For set builders*) Please send circulars describing your apparatus and latest audio hook-ups.

A *Remarkable* New 5-WATT VOLUME CONTROL and a *Superior* COVERED RESISTANCE



Complete assembly of the new ELECTRAD VOLUME CONTROL; showing neat compact design, predominance of metal for rapid heat dissipation; firmly riveted for strength. Size: 2 3/16" x 2 13/16" x ⅝" deep. One-hole panel mounting.

THE radio profession has waited for these two new Electrad achievements—but it has not waited in vain.

They are now available and will capably fill a need, long felt, but not until now effectively satisfied.

First: A volume control entirely different in principle, that easily dissipates a full five-watts without breaking down or varying in resistance. Laboratory tests, equal to more than 10 years' normal service, prove its extraordinary quality and long life.

The resistance element is a highly-developed graphite paint fused to an enameled metal base. The contact is pure silver, designed literally to float over any slight inequalities of surface. Result: A smooth, stepless flow of current which improves with use owing to a microscopic deposit of silver from the contact on the resistance element.

Can be made in any desired range of values for general requirements—uniform or tapered curve. Send us your specifications.

Second: A new standard in covered resistances. May be run at rated capacity without burnouts. Heavier than usual Nichrome resistance wire—hence cooler.

The contact bands and soldering lugs are Monel metal. Costs more—worth it. No unequal expansion—no broken connections.

Last, but not least—covered by an elastic insulating enamel, baked on at only 400 degrees F. Less chance for injury to resistance wire and contacts.

The bands, tube, wire and enamel expand and contract alike under load, insuring against breakage of wire at contact points and along the tube.

Can be made in practically any resistance values and wattage ratings desired. What are your needs?

High quality refractory tube. Oversize Nichrome resistance wire; Monel metal contacts and soldering lugs; elastic insulating enamel.

ELECTRAD, INC., Dept. RE-4, 175 Varick St., New York.

Send complete data on your new 5-Watt Volume Control and Covered Resistance—also sample for tests.

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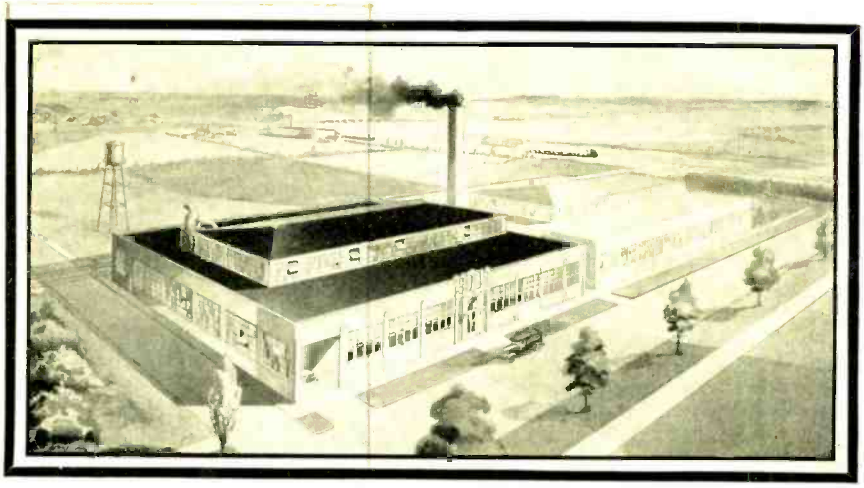

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A New Plant - housing an organization many of whom have been associated with Peter L. Jensen during most of his career.

A New Plant - complete under one roof equipped to produce and market with efficiency assuring the high standards of Jensen quality at the lowest prices in Jensen history.

Jensen has again kept a step ahead of the industry in dynamic speaker design! The 1929 Jensen Standard and Auditorium Dynamic Speaker Units are now in production. Samples of another model intended primarily for manufacturers are available for laboratory test. With Jensen as your source of supply you are assured of "on time" scheduled deliveries. The Jensen engineering and laboratory staffs are now located in Chicago. Their services are available to work in cooperation with your engineering department.

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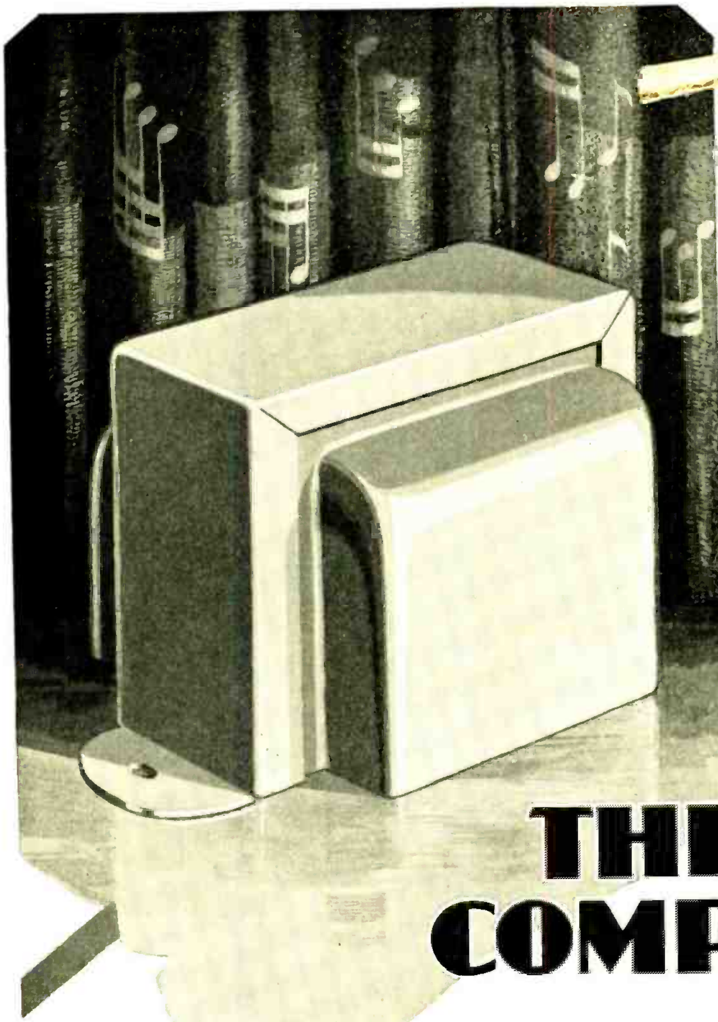
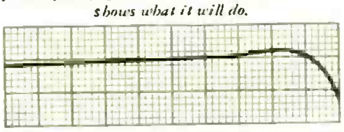


T. C. A is the preferred source of supply for many makers of the finest receiving sets. Primarily because the uniformly high standards of T. C. A. Transformers measure up to their exacting requirements. But they have found, too, that dependable deliveries are a big consideration — and withal, the cost is no more.

THE NEW COMPETITION

The illustration above pictures the cadmium plated exterior of the new T.C.A. Audio Transformer for 245 power tubes—the diagram below shows what it will do.



This curve speaks for itself. Study it and compare with the performance of any other transformer made to work with these new tubes.

RADIO sets are sold almost entirely on comparative performance; that means competitive demonstration.

Not only does the customer want performance, but the dealer must have it or lose the sale.

The audio end of the set is where the greatest difference comes in and the audio transformer is the key to tone-quality.

Ever alert to stay abreast of this fast moving industry. T. C. A. already offers authentic transformer design to meet the highly special needs of the new 245 tube.

T. C. A. engineers are ready to offer their assistance to set manufacturers who are confronted by the problem of meeting this new competition.

Watch for May announcement on T. C. A. development, which will interest every set manufacturer.

Audio Transformers for Intermediate or Push-Pull stages.. Output Transformers.. Chokes, single or double ... Power Transformers or Power Packs.. Input Transformers for Dynamic Speakers.

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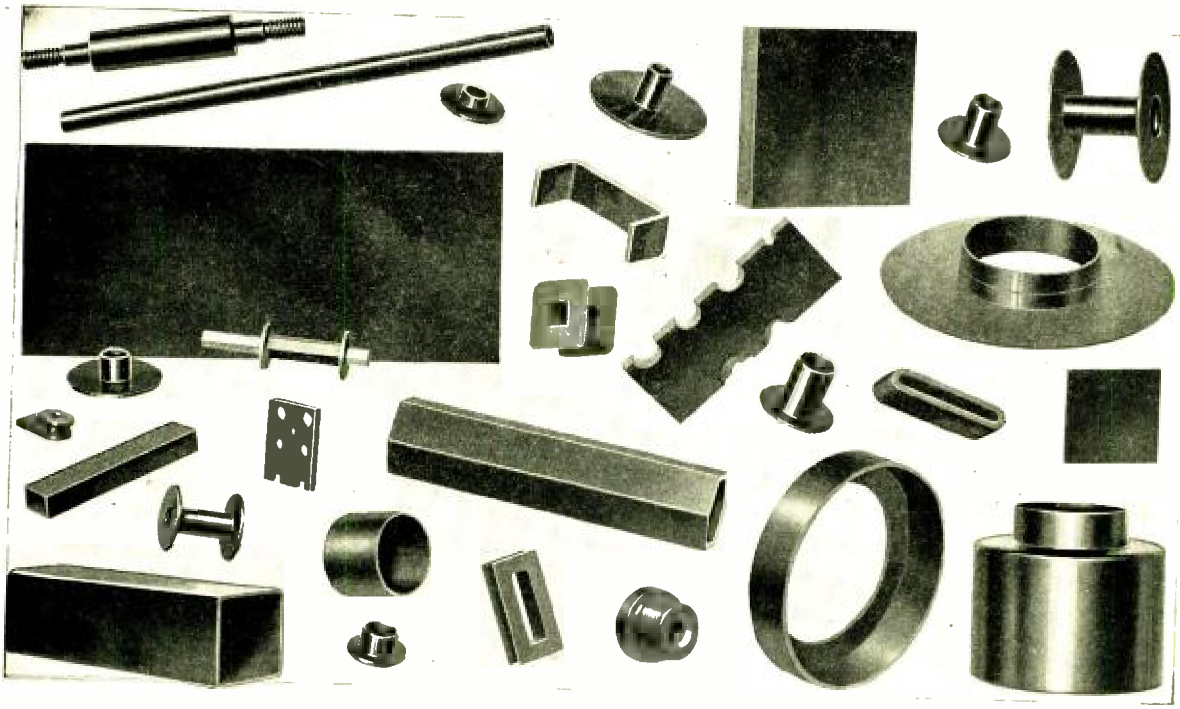


Analysis of Papers Employed in Radio Manufacturing

I. The Microscope as an Asset in the Radio Laboratory

By I. L. Gartland

This, the first of a series of articles dealing entirely with microscopic research, is intended to familiarize those unaccustomed to its use with enough information to be able to follow the thoughts to be portrayed in the ensuing experiments; for without a basic knowledge of at least the simplest rudiments, one is entirely at sea.

And for those experienced in its use the author suggests that, with the constant demand on us (in the research laboratory) to meet and contend with problems, we recognize the necessity of bringing into action all the available resources we can to control our product and standardize our materials. Short cuts of every kind are being tried out in order to enable us to accomplish this and yet very frequently we neglect some of the most accessable and helpful means.

The condenser manufacturer, for instance, knows that his product must have a certain potential capacity. He strives to the utmost, under trying conditions to control this,—his foil,—his wax,—and lastly his paper, are tested singly and in combination to maintain that standard expected not only of his own organization, but to those whom he sells.

Yet in all this endeavor for control, one of the most important instruments, either through lack of knowledge of them or neglect, is often disregarded. This is the microscope either in its simple, but preferably in its compound form. Experience has taught these things, and so it is with the desire to arouse this interest that these series of experiments with the Compound Microscope are presented.

The second and third articles of this series will cover in detail the fibre and chemical analysis of special papers. This information should be of material assistance to the research engineer who at the present does not employ such elaborate but worthwhile means of testing and analyzing condenser tissue, fish paper, etc.

The forthcoming articles will include some very interesting details on new fibre testing methods.

Principal Types of Lenses

THERE are six different types of lenses: (1) Convexo-concave (also called "Meniscus"); (2) Plano-convexo; (3) Double convexo; (4) Double concave; (5) Plano-concave; (6) Concave-convex. The mere names of these lenses are probably a sufficient description, but reference to Fig. 1 will illustrate their characteristics and before leaving the listing of basic types of lenses, prisms should be mentioned, since this is such an important "adjunct" of a lens in the development of modern objectives.

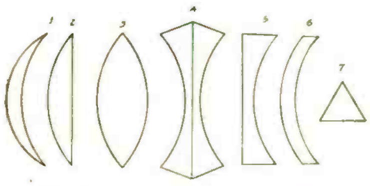


Fig. 1. The various forms of lenses employed in microscopes.

The whole system of building objectives is the intelligent use of one or more of the six varieties of lenses (together with prisms) to accomplish the kind of work for which a given objective is intended. Objectives are named from the extreme range at which they will focus—thus every objective falls somewhere between the 16 mm. objective and the 1.9 mm. oil immersion type. In the case of the "16 mm. objective," (Fig. 2) it is built up of a combination of plano concave (A), double convex (B) and so on through the four lenses. The Abbe Condensers (Fig. 3) of the aplanatic type, are a particularly happy illustration of this use of combinations of lenses, biconcave (A), plano concave (B), double convexo (C), convexo concave (D), plano concave (E) and double concave (F). In passing, it might also be mentioned that the bi-convex lens is composed of a number of prisms arranged about an axis.

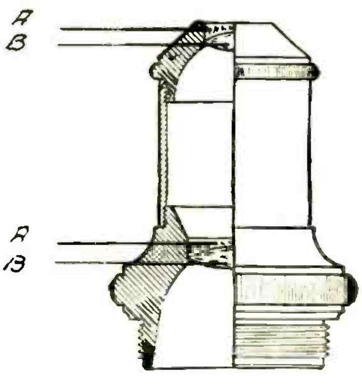
To understand the work of a microscope better, it will also be well to discuss refraction for a moment. Refraction is, in simple language, the phenomenon that occurs when a ray of light passes through any transparent medium—the medium "bends" the ray of light. This ability of lenses to bend light rays gives them their magnifying power.

There are two fundamental laws of refraction which we would well keep in mind—

First: When a ray of light passes from a denser to a rarer medium it is refracted (or bent) away from a line drawn perpendicular to the plane which divides the medium—and vice versa.

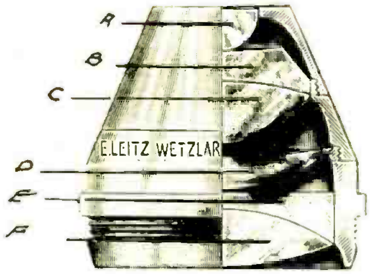
Second: The sines of the angles of incidence and refraction (that is to say, of the angles which the ray makes with the perpendicular immediately before and after it is refracted) bear a constant ratio to one another in a given substance. This ratio is known as the "index of refraction" for that substance.

An illustration which will present this in an interesting way is shown in Fig. 4. The light ray enters at A and leaves the glass at B. Following the light through, it will be seen that the light is shifted "laterally." This explains why a medium, in addition to the glass slides, must be used for high-



16 mm Objective

Fig. 2. A 16 mm. objective, built up of a combination of plano concave (A) and double convex (B) lenses.



Aplanatic Condenser, of N. A. 1.40.

Fig. 3. An Abbe Condenser of the aplanatic type, employing a combination of six lenses.

power objectives in microscopy. This additional medium (a drop of cedar oil is now almost invariably used) having the same index of refraction as the glass, prevents the light rays from diverging from the normal . . . gathers them, in other words, at the lowest point of the objective, which is exactly where we want them.

There is an index refraction known as the numerical aperture, which is the resolving power by which an objective shows distinctly separated two small elements in the structure of an object (Fig. 5), which are only a short distance apart. The higher the numerical aperture the greater the resolving power of the objective and the final detail that can be revealed. In brief, numerical aperture is the index of refraction of the medium in front of the objective, multiplied by the sine of half the aperture.

Convexo lenses are chiefly used in microscopy. The other forms are used to make certain modifications in the rays passing through these convexo lenses so as to exact their performance. It is difficult, however, to construct a convex lens so that all the rays of light that pass through it shall come to the same focus. The rays which traverse each peripheral or marginal portion are of shorter focus than those which pass through the central portion. This naturally distorts the image and is technically known as spherical aberration. Another aberration which, when light traverses a convexo lens and the different colors which compose it do not all come to the same focus, is known as chromatic or color distortion. The correction for this is the exclusion of the marginal rays and it has been found that in lenses whose penetration is greater than their "flatness of field" these color fringes are usually present. The correction of both these aberrations is entirely up to the optician, and when purchasing objectives, they should be taken into consideration.

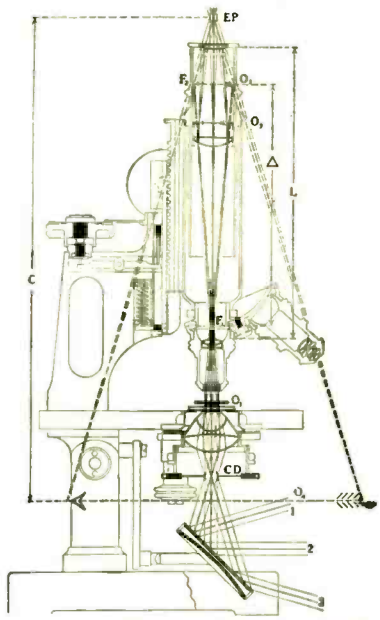
Principal Types of Objectives

There are two principal types, dry and immersion. In dry objectives, nothing intervenes between the object and the objective except, of course, air. In the immersion objective, however, some liquid medium, such as water or oil, must be placed on the cover glass over the object and make a contact between the cover glass and the objective. The most commonly used objective is the homogeneous oil immersion; the reason for this being, that with objectives of this type, the oil has the same refractive index as the front lens of the objective (cedar oil for example). There are also non-achromatic objectives in which the color distortion is not corrected and the image produced is usually bordered by a color fringe.

Chromatic objectives are those in which the color distortions are corrected.

Apochromatic objectives are those in which three spectral colors combine to one focus instead of two, as with the chromatic.

Aplantic objectives are those in which the spherical aberration is corrected.



(*Courtesy of Bausch & Lomb*)

Fig. 6. Mechanical illustration of a standard form of laboratory microscope.

There are, of course, a number of special objectives such as those with collar corrections, those with shields for paraboloid condensers used with the ultra-microscope, and so on.

Kinds of Oculars

Of the oculars or eye lenses, there are the ordinary Huygenian eyepiece, the compensating and the projecting oculars. Each one, the objective and the ocular magnifying independent, but combined, give us our ultimate visual magnification. It must always be remembered that the objective's function is to magnify the object and the ocular's function is to magnify again what the objective has already magnified.

Principal Mechanical Parts of a Microscope

By referring to Fig. 6 certain points of interest are illustrated.

F1—Upper focal plane of objective.
F2—Lower focal plane of eyepiece.
Δ—Optical tube length = distance between F1 and F2.
O1—Object.
O2—Real image in F2 transposed by the collective lens to
O3—Real image in eyepiece diaphragm.
O4—Virtual image formed at the projection distance C, 250 mm from EP.
EP—Eyepoint.
CD—Condenser diaphragm.
L—Mechanical tube length (160 mm).
1, 2, 3—Three pencils of parallel light coming from different points of a distant illuminant; for instance, a white cloud, which illuminates three different points of the object.

Best Sources of Light

While on the subject of light (a sadly neglected necessity) some suggestions may be of value. The very best source of light that could be used in microscopy, is the reflection from a white cloud. However, if artificial light is necessary, there are two or three very good makes of lamps on the market. The principle, however, is to use just sufficient light to illuminate evenly the object to be viewed, as an excess of light will not only distort the object, but will flood the objective so much that it is sometimes impossible even to view it. It is wise to use a filter on the iris diaphragm or at the front point of the lamp for eliminating the intense rays of the filament of the ordinary bulb. Usually a round blue glass accompanies all microscopes and should be used as much as possible.

Microscopic Accessories

There are some various accessories which are quite unfamiliar to the average chemist and which, sometimes, are of great assistance in short cutting and eliminating unnecessary work. For instance, the dissecting-scope. This is an excellent accessory for surface investigations of paper, fabrics, etc., and is also of great assistance in "teasing out" fibres preparatory to staining and mounting. The stage of the dissecting-scope is also excellent for mounting, as it is usually of glass, and Ferrant's medium or balsam is very readily removed.

A camera lucida is a very economical, but sometimes tedious method of

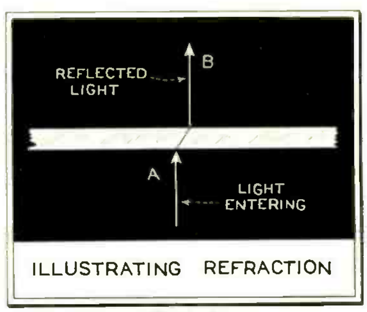
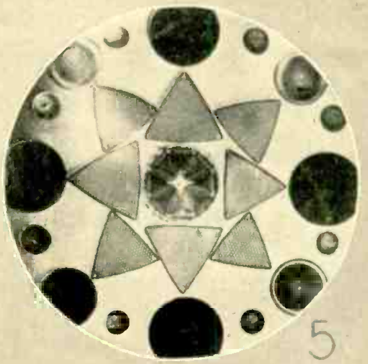


FIG. 4

Note that the light passing through the lense is shifted laterally.



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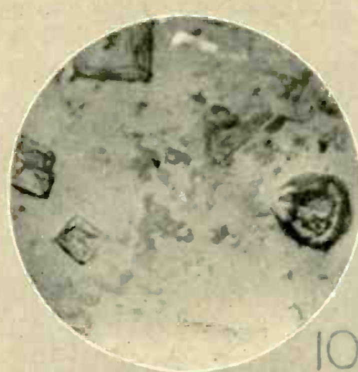

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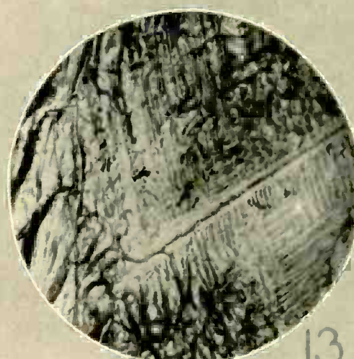

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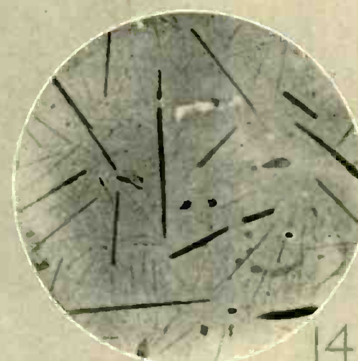

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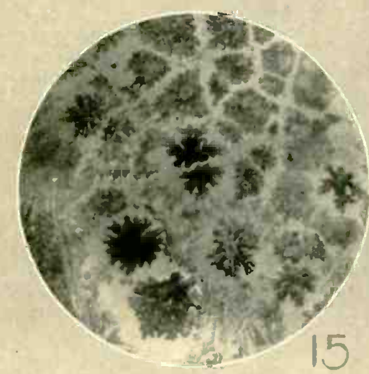

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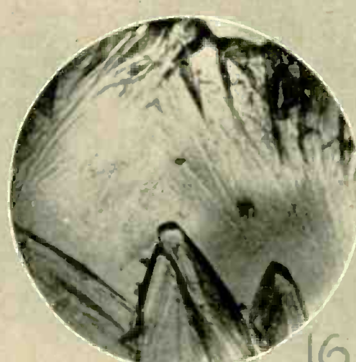

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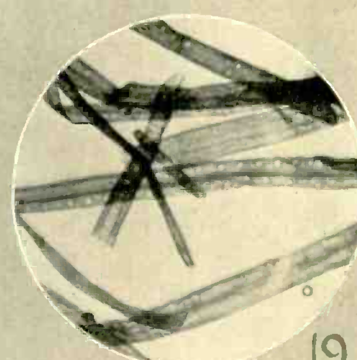

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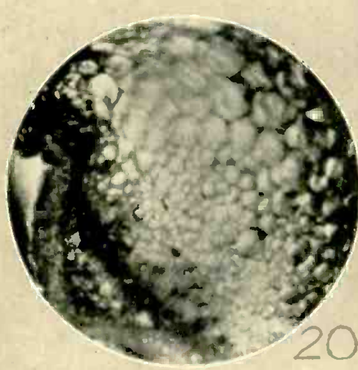

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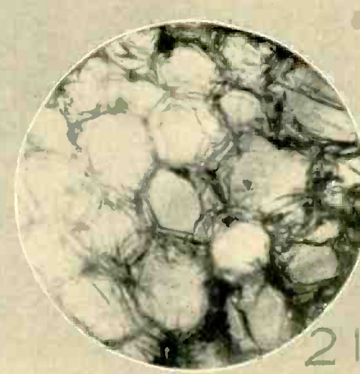
Illustrations

Fig. 5. An arrangement of diatoms.
Fig. 10. Sodium sulphate.
Fig. 11. Strychnine sulphate.
Fig. 12. Evaporated solution of sodium nitrate.
Fig. 13. Evaporated solution of ammonium sulphate.
Fig. 14. Potassium permanganate.
Fig. 15. Sodium carbonate, evaporated by gentle heating.
Fig. 16. Evaporated crystals of copper sulphate.
Fig. 19. Fibres of condenser tissue.
Fig. 20. Specimen stained with Eosine. Red filter used.
Fig. 21. Same cross-section as Fig. 20. using green filter.



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keeping records of slides. It consists of a prism which is silvered on one plane in the center of which is a small hole. The silvered section of this prism is on an angle so that it reflects through the medium of a mirror at the right, the pencil point ten inches below the eyepoint and through an optical illusion it combines with the visual transmission of the object, thus enabling the operator to outline on the paper below the mirror, the object which he sees through this small opening. This is also an excellent instrument for measuring objects.

Abbe condensers (Fig. 3) are quite frequently neglected and their relationship to the better definition of the object to be viewed often forgotten. Most microscopes having Abbe condensers are fitted so that it is possible to adjust these condensers and raise or lower them so that the cone of light on the object will be either increased or diminished. The iris diaphragm should be about 2/3 the diameter of the field when looking down the tube with the ocular removed. If this rule is followed, a great deal of unnecessary changing of lights, etc., will be avoided.

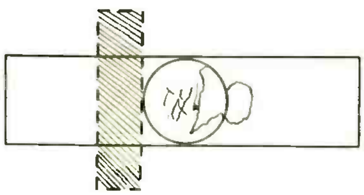


Fig. 7. Manner of staining specimens.

Permanent and Temporary Mounting

A very serious problem has been to distinguish between what should be permanently and what should be temporarily mounted. In the past the objection to permanent mounts was the waste of both cover glasses and slides and frequently specimens, which when only temporarily mounted, were spoiled. It has been found, however, that most anything that is worth while can be mounted in a permanent form and if, at a later date, the slide becomes useless, it can be cleaned with a solution which will save not only the slide but the cover glass. The formula for this is:

50 C.C.	H_2O
45 C.C.	C_2H_5OH
5 C.C.	NH_4OH

By using a staining dish and immersing the slides to be cleaned in this solution for about one week or ten days, the mounting medium is entirely removed and the slide and cover glass need only be washed with cold water.

There is still another method of mounting permanently and that is with shellac, or gold size and the use of a turn table. This is especially good for mounting permanent slides of microchemical compounds and the cell in which the mount is to be made can be regulated at the will of the microscopist.

Manipulation

Before passing on to the subject of the use of the microscope it might be well to mention a few things in regard to the general manipulation of the accessories of this instrument. When balsam oil drops on the stage it is advisable to remove it as quickly as possible and a little Xylol is excellent for this purpose. In using an oil immersion lense it should always be wiped immediately after the immersion has been performed with lense paper. No other oil but regular cedar oil manufactured for immersion purposes should be used.

In attaching a mechanical stage, in the laboratory it is frequently adjusted merely to the scope stage and let go at that, the result being that the stage will sometimes work more easily in one direction than in the other, or it will not work at all. This is overcome by placing a very thin piece of cardboard on the stage and then clamping down the mechanical stage; on removing the cardboard, a space is supplied wherein the stage easily works in both directions.

Quite often the use of the micrometer is necessary in measuring fibre length. Aside from its inconvenience, the simplest and most satisfactory form is the stage and ocular micrometer combination. Many chemists are opposed to this method because they cannot readily find the lines on the stage micrometer. If, in the use of this, a little ink is rubbed horizontally across the slides on both sides and let dry, it finds its way into the grooves of the etching and the lines become perceptible.

Standard Slides

To analyze properly and intelligently the microscopic structures of cellulose, silicious earth, metals, etc., a standard set of slides should be on hand. These may be purchased already prepared, as for example, the accompanying arrangement of diatoms, (Fig. 5) or the microscopist himself may make them. This is far to be preferred, for in the making of slides one becomes more accustomed to the character of the substances being prepared, familiarizing himself with the structure, etc. more so than if purchased slides were merely looked at.

A few suggestions might not be amiss if one intends to mount or stain their own permanent slides.

It is wise when the specimen is ready to be stained, to lay the cover glass over it and, taking a drop of reagent on a glass tube, place it on the outer edge of the cover glass. At the opposite edge carefully place a small piece of high grade filtering or blotting paper. It will then irrigate to the center and completely stain the object, as Fig. 7 will illustrate. This has saved a great deal of trouble and often avoided the entire loss of the specimen.

Chemical Microscopy

In his work (Elementary Chemical Microscopy) Professor Chamot writes: "The failure of the chemists to obtain from the microscope all that the instrument is capable of yielding is perhaps largely due, first to the fact that few of them are given an opportunity of becoming sufficiently familiar with that instrument and its accessories and second, they are not aware of the great variety of problems which are solvable through the microscope nor of the specific sort of problems for the investigation of which this is the instrument par excellence. Third, there has been a lack of elementary manuals covering the field and for this reason the microscope has been looked upon as an instrument peculiar to the biological laboratory."

Indeed this situation is true and only illustrates the author's thought in the opening paragraph of this article. It might be wondered at that chemical microscopy should have a place in the radio industry and yet when one considers the vast amount of various elements used in all branches of radio manufacture and research; to the chemist or engineer skilled in the use of the microscope he questions whether or not some opportunity has not passed by the researchers of this industry to use this instrument to great advantage. Since chemical microscopy is playing an important part in other industrial researches, and in a great many cases circumventing considerable detail work he will briefly outline the principals of this subject.

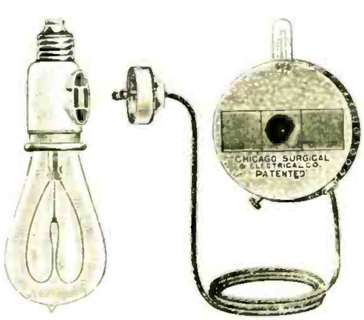


Fig. 8. An electric warmer, for evaporating or melting crystals.

The fundamentals of chemical microscopy are crystals and indeed the most interesting, but unfortunately our source of reference is very much limited. Emil Chamot has produced so far as can be found, one of the best up-to-date works on Chemical Microscopy and it is the intention of the author to try to interest you in this subject by presenting a few of the possibilities in this connection with the aid of his book.

Crystals are a most common result of chemical combinations and reactions under the microscope and are produced either by

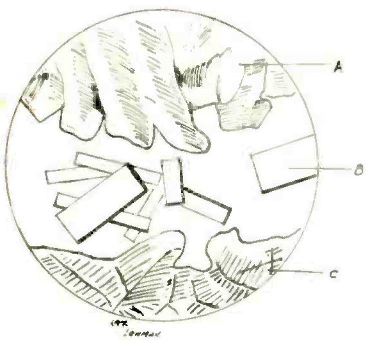


Fig. 17. Contact between silver and sodium nitrate. A is the silver nitrate; C, the sodium nitrate and B, the two in combination.

1. Evaporating a solution,
2. Cooling a melted solid,
3. Cooling vapor.

Thus, for example, sodium chloride crystals are formed by evaporating a salt solution; Sulphur crystals by melting and then cooling sulphur and iodine crystals by heating iodine and cooling the vapor. These methods are respectively called evaporation, fusion and sublimation and are carried out under the microscope through the medium of a warm stage (Fig. 8).

Kinds of Crystals

Of the crystals, there are six systems which are as follows:

1. Isometric 4. Orthohombic
2. Tetragonal 5. Monoclinic
3. Hexagonal 6. Triclinic

There is another division entering into the classification of crystals and this is based upon refraction. When a crystal is singly refractive, it is said to be isotropic and when rotated between Nicol prisms, (Fig. 9) there is no change. When a crystal is double refractive, it is said to be anisotropic and when rotated between prisms alternately becomes light and dark. Take for example sodium sulphate (Fig. 10). This is anisotropic monoclinic, whereas, sodium chloride is isometric isotropic. This may be also considered as an illustration of system 1.

Fig. 11 represents strychnine sulphate which is tetragonal-anisotropic.

Fig. 12 represents an evaporated solution of sodium nitrate which is also anisotropic and comes under the hexagonal system of crystals.

Fig. 13 shows an evaporated solution of ammonium sulphate which is anisotropic and orthohombic.

Fig. 14 is potassium permanganate coming under the same heading but will illustrate an acicular and needle-like aggregate.

Fig. 15 shows sodium carbonate, evaporated by gentle heating. The crystals here are under the heading of anisotropic-monoclinic. They will also illustrate what are called dendrites which are tree-like, moss-like, or fern-like masses.

Fig. 16 represents crystals of copper sulphate evaporated and comes under the heading of anisotropic triclinic.

This will give an example of the six principle systems previously mentioned. A simple method to follow, when solid substances, for example, are to be compared, is to place a small portion of one under the cover glass and heat it until it melts. A small portion of the second substance is then placed just outside the cover glass and this in turn melted so that it will flow under and join the first substance that has been melted. (Fig. 17) Incidentally, by so doing, the crystals of one substance may be noted independently of the other. When the two substances cool and recrystallize, the phenomena across the line of contact is indeed striking. The illustration (enlarged after Lehman) given as an example shows the contact between silver nitrate and sodium nitrate and are excellent examples of two substances to be compared. "A" shows the silver nitrate entirely separated and "C" shows the sodium nitrate, "B" the resultant double salts.

Briefly, therefore, we have outlined and illustrated the basic systems of crystals as the principals of Chemical Microscopy, a subject so absorbing, and interesting that it will be discussed in a later article.

Photomicrography

There are some things which present themselves in our daily laboratory procedure which impress us. These things are more or less imprinted on our minds and when occasion presents itself may be put into use through the recalling of such and such a circumstance.

The construction department, for instance, make it their business to record (by the use of the camera) certain developments in the progress of a building. This is done so that it may aid the engineering force in future work.

So by combining the camera with the microscope, we could record infallibly exact resultant developments. The mode of procedure is simple and patience the greatest asset. Fig. 18 will show the general layout of the camera, microscope and lamp suitable for ordinary work. The camera employed in taking the microphotographs (Fig. 19) was a Graflex 8 x 10, the microscope, a Seibert, with an objective No. 3 (American equivalent 1/8 inch). For illumination a gas filled 220 volt, 110-watt bulb and a bull's eye condenser were employed. This was done so that the light might not only be concentrated, but the color distortion caused by the filaments eliminated. The average time of exposure was 30 seconds. In Fig. 20, the cross-section, which was stained with "Eosine," a red filter was used, but in the chemicals (Figs. 10 to 16) filter No. "H" (Blue) was used. Note the lack of detail in construction and how the cell walls are so indistinct. This serves to illustrate what would happen if the sample of cellulose were stained with Herzberg stain and if a large percentage of cotton, linen or hemp were present and a red filter used.

Fig. 21 is another portion of the same cross section but a green filter was used. The difference is certainly apparent. This indicates why care should be taken in the choice of filters, as too much contrast should not be obtained, or the result will be a choking of shadows with the loss of detail, as in the instance of the cross section stained with Eosine (Fig. 20). For instance, it may be necessary to combine filters, based, of course, on their spectral wavelengths. Hence, in photographing violet, filters D and H with a dominant wavelength of 4,500 may be used; or for blue, filters C and H with a wavelength of 4,800, or for yellow, filters B and G with a wavelength of 5,500 and with red filter "F" with a wavelength of 6,250. By dividing filters into pairs, the spectrum is divided into approximately monochromatic portions and as a general rule, when contrast is required for blue use a red filter, for green, red and for red, green; for yellow, blue and for violet, yellow. It is impossible, however, to lay down any laws regarding the use of filters and the operator must use his own judgment after a visual inspection of what is to be photographed.

Spectral Transmission of Filters

The spectral transmission of the above mentioned filters is:

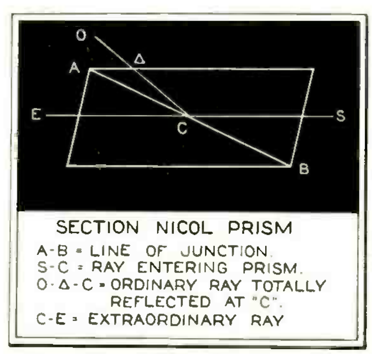


FIG. 9

Reflected light in a Nicol prism.

Name of Filter	Visual Color	Spectral Transmission
B	Green	from 5,800 to Red end
C	Blue Violet	from 4,000 to 5,100
D	Purple	from 3,800 to 4,600 or from 6,400 to Red end
H	Blue	from 4,200 to 5,400
G	Strong Yellow	from 5,100 to Red end
F	Red	from 6,100 to Red end

These filters can be obtained from the Eastman Kodak Co., Rochester, N. Y., and all the available information

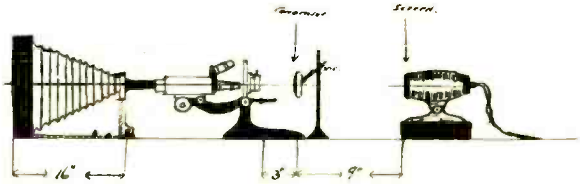


Fig. 18. General layout of camera, microscope and lamp suitable for ordinary photomicrography.

regarding the use of them is described in three or four booklets, which they publish and which, if it is intended to go into photomicrography extensively, should be consulted.

Another important consideration is the relation of the color of light to the resolving power; as aforesaid, the distance between two lines which can just be resolved by a microscope objective is equal to half the wavelength of the light by which it is observed, divided by the numerical aperture of the objective. The formula is:

$$\text{Distance} = \frac{1}{2}\frac{WL}{NA}$$

For instance, with a numerical aperture of 1.0 and an F filter (F filter pure red) we shall be able to see 80,000 lines to an inch, with B filter 95,000, etc., depending of course on enough light.

Time of Exposure

Another important factor is exposure. (The Eastman Kodak Co. booklet on Micrography gives invaluable data on this.) But for the purpose of this article we give one of their tables showing the effect of the numerical aperture in regard to the variation of exposure, and also the exposure factor:

Effect of N. A. (Numerical Aperture)

$$\text{Exposure varies as } \frac{1}{(N.A.)^2}$$

Focal Length	N. A.	Approximate Exposure Factor
4 in., 100 mm.	.08	40
3 in., 75 mm.	.09	30
2 in., 50 mm.	.15	10
1 in., 25 mm.	.25	4
2/3 in., 16 mm.	.35	2
1/2 in., 12 mm.	.45	1½
1/3 in., 8 mm.	.50	1
1/4 in., 6 mm.	.8	2/5
1/6 in., 4 mm.	.85	1/3
1/8 in., 3 mm.	.9	1/3
1/12 in., 2 mm.	1.3	(1.0 for photography)

Light for Microphotography

Light is one of the most important factors in this work, particularly as to its steadiness and for this reason the concentrated filament gas-filled bulb has displaced the arc light in many instances, as the bulb gives a steady wave of light, while the least draft of displacement of some part of the apparatus of the arc causes considerable fluctuations. Above all, a steady source of light is absolutely necessary.

In conclusion, it might be said that since the outstanding principals of the microscope have been covered as briefly as possible, the next article will demonstrate the solution of some outstanding problems in branches of the radio industry.

(To be continued)

Making The A-C. Heater Tube Noiseless

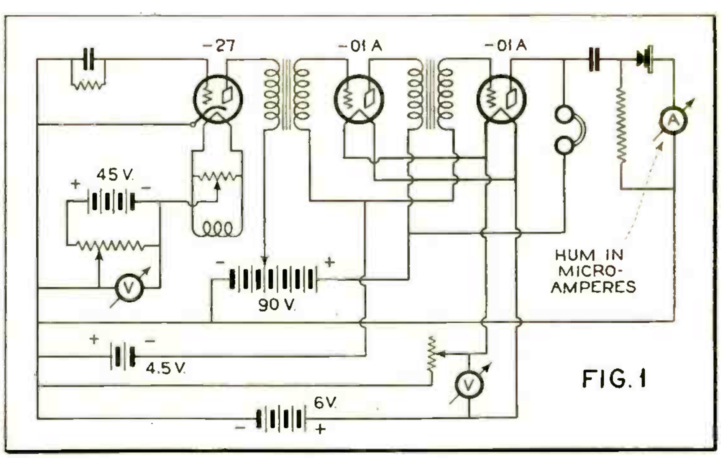
A Review of an Investigation of Hum and Noise Caused by Various Constructions of Indirectly-Heated Cathode Tubes

*By Allen B. DuMont**

DURING the past year there has been a gradual tendency on the part of set manufacturers to improve their audio system and loudspeaker equipment. This is particularly true with regard to the low frequencies. The result has been that the—27 type or a-c. heater tubes, which operated satisfactorily and without noticeable hum in the first socket-power sets made, now give appreciable hum, cause a high background noise and generally poor reception. In fact, critical radio enthusiasts have in many instances preferred to continue with battery-operated tubes, despite the admitted convenience, uniform performance and low operating cost of the a-c. tube set.

The Testing Circuit

With the foregoing facts in mind, and also mindful of certain other causes of noise in the a-c. set, such as motors, leaky transformers, poor voltage regulation and so on, an investigation was undertaken by our engineering department in order to determine what changes, if any, could be made in the heater-type tube to eliminate or at least reduce the a-c. hum and other tube noises. A test set, following the general scheme shown in Fig. 1, was assembled. The essential components of this test set are a two-stage amplifier, using the best grade transformers available in order to pass approximately the same degree of 60-cycle hum as would be realized in the best type of radio receivers on the market, together with the necessary batteries, voltmeters, headphones and a microammeter with crystal rectifier. The two-stage amplifier is operated from a direct-current source, that is, A, B and C batteries are used. This is to eliminate any possibility of hum outside of the a-c. heater tube being tested. The tested tube is connected up so that the voltage between heater and cathode sleeve can be varied.



The circuit employed for testing the hum factor of heater-type a-c tubes. Note that the amplifier is operated from a direct-current source, in order to preclude any hum outside of the heater tube under test.

* *Chief Engineer, DeForest Radio Co.*

As a means of obtaining definite values in order to plot curves showing the hum at various voltages, both aural and visual indicating means are employed in the output circuits. These are obtained by means of a pair of headphones connected between the B plus and the plate, in order to get a direct current to the plate itself. A condenser is placed as shown, together with a high-resistance, a crystal detector, and a microammeter. By this arrangement it is possible to get a direct reading on the meter of the hum and any extraneous noises that may be present in the tube under test. It is also possible to check with the pair of headphones, in order to be certain that the noise registered is primarily hum or crackling noise.

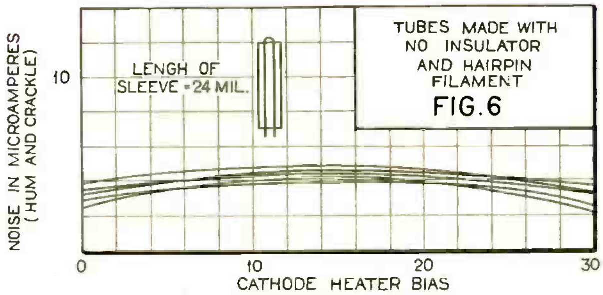
Findings

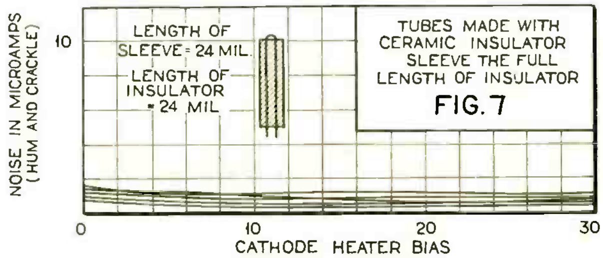
Various types of cathodes, representing all the various methods employed today, were made up. Curves were plotted, showing the values of hum and noise with different cathode heater biases. It will be seen in analyzing the curves that the best condition is shown in Fig. 7. This particular cathode, it will be noted, has the ceramic insulator the full length of the sleeve, and shows extremely low values of hum for all cathode heater biases. As a basis of comparison, a reading of 36 microamperes is obtained for the usual —26 or filament type a-c. tube.

The curves shown in Fig. 5 are for the type of cathodes previously employed by the majority of manufacturers. It will be seen that when using this type of cathode, very erratic results are obtained. In some cases the values of hum are very low and in other cases very high. It was also found that on some tubes of this type it was impossible to plot a curve because the values shifted about materially. The probable reason for this is that the exposed portion of the insulator accumulates a charge, followed by a discharge between this surface and the cathode sleeve. This action produces a crackling noise which is very annoying. It also appears that the insulator, if not completely shielded by the sleeve, allows an appreciable hum to be superimposed on the plate current. However, if the insulator is completely shielded, the hum can be reduced to approximately one-tenth that of the old-style —27 type tubes.

Based on these findings, together with our investigations into various insulating materials for the cathode insulator, we have evolved a new and improved type of a-c. heater or —27 type audion, which is now in production. This new tube promises to place the a-c. set in the same class, with regard to minimum hum, absence of crackling noises, and even quick heating time.

The curves on this page are practically self-explanatory. Note the degree of hum in microamperes registered in Figs. 2, 3 and 5 as against the hum factor indicated in Fig. 7. The improved operation illustrated by the curves in Fig. 7 is gained by employing a ceramic insulator and increasing the length of the sleeve to equal that of the insulator; a very simple alteration in design.





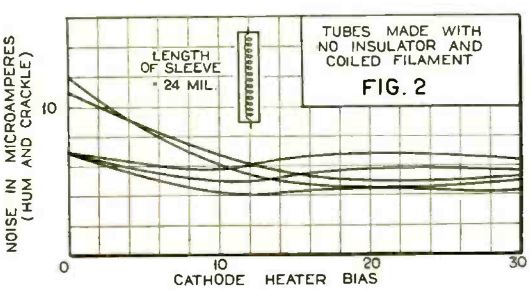
SOUND RECORDING AND REPRODUCTION

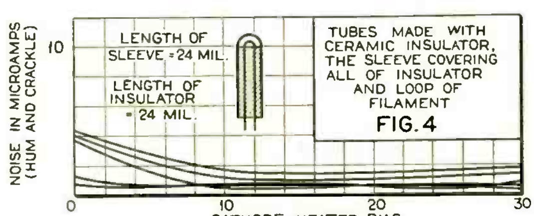
Rapid strides are being made in the recording of sound on film and the reproduction of sound under varying conditions, in and out of doors.

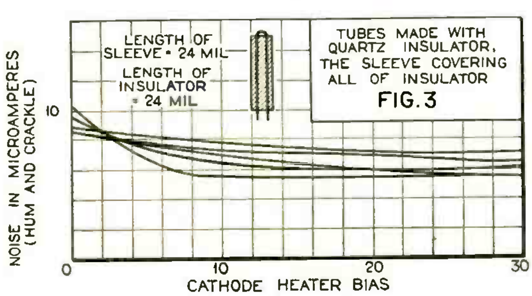
The technique of recording is tied in with numerous factors aside from the purely mechanical and electrical considerations; such as monitoring, retakes, etc.

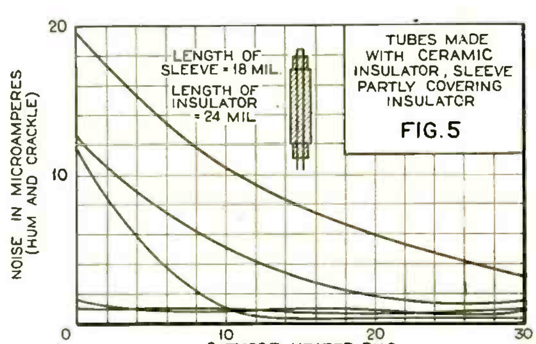
Automatic monitoring; an arrangement which practically eliminates the necessity of retakes, and a new recording arrangement minus the conventional light shutter, are but a few of the recent developments in this field.

A very interesting article covering these new systems will appear in the May issue of RADIO ENGINEERING. —Editor.









Die Castings in the Modern Radio

A Short History of Metal Moulding and Detailed Data on Present-Day Die Casting as Applied to Modern Industry

By L. H. Pillion*

THE art of casting metals into previously prepared moulds has been known and practiced since prehistoric times. We find the casting of metals referred to in many passages of the Bible. The casting of the golden calf by Aaron is probably the most prominent and best remembered. His work is described in the following words (Exodus, Chapter XXXII): "And all the people brake off the golden earrings which were in their ears, and brought them unto Aaron. And he received them at their hand, and fashioned it with a graving tool, after he had made it a molten calf."

We also find that King Solomon's throne was adorned with two huge bronze lions and in many other instances there appear references to the casting of metals in Biblical times. The value of these statements in scientific research has been questioned, but there are many facts that point to their probability.

Although the Egyptians practiced the art of metal casting long before any other nation, the Greeks were undoubtedly the most skillful in this art during the ten centuries immediately preceding the beginning of the Christian Era. One of the seven wonders of the world is the bronze statue of the Sun God Helios in Rhodes, commonly known as The Colossus of Rhodes, made by a Greek named Chares, during the reign of Demetrius in the fourth century before Christ. This work occupied him for twelve years, and when finished stood 105 feet high, weighing 360 tons. It was destroyed by an earthquake in 224 B. C. Other Greek colossi such as the Apollo of Calamis, the Zeus and Hercules of Lysippus and Zeus at Olympia are amongst the most remarkable castings of any age. In 479 B. C. a bronze pillar was set up by the Greeks to commemorate their victories. It was about 20 feet high, cast in one piece, hollow, with the names of the states engraved on it.

* Vice-President, Doehler Die Casting Co.

The question as to the priority of certain metals or alloys in history has created an extensive discussion amongst archaelogists throughout the world. According to the accepted theory, the first three stages from barbarism to civilization are clearly defined by the relics of stone, bronze and iron. It is then assumed that bronze was used before iron.

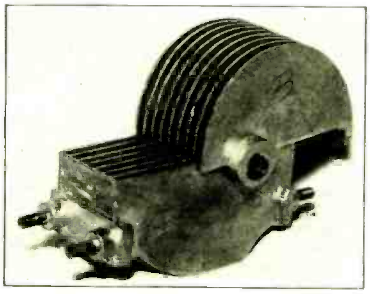


Fig. 9. A die cast variable condenser, made in two pieces, and with brass inserts.

From a purely metallurgical standpoint and without entering into an extended archaeological discussion, it would appear that amongst the useful metals, iron was probably known first and used for hammering into implements of war, since iron was to be found in its native state in the form of meteorites. Copper was probably known next since this element was also found to a large extent in its native form and required no smelting operation. Bronze (by which is meant copper-tin alloys) was probably next used since "tin-stone" was so abundant in Cornwall. Brass (by which is meant copper-zinc alloys) was probably the last to be used—many historical facts tending to prove this classification.

Early Furnaces and Moulds

The early Egyptian type of furnace was made by digging a hole in the ground and setting the crucible into it with a surrounding layer of fuel. A draught was created in the earlier types of furnaces by fanning with bamboo matting, although in the later types of furnaces a bellows appears to have been used which was worked by foot power, two men being required to operate each bellows. This furnace undoubtedly forms the basis of the pit furnace used so extensively in modern foundry practice.

The Greek furnace appears to have been built along the lines of the modern cupola furnace. This served as an annealing, forging and preheating, as well as a melting furnace.

During the Middle or Dark Ages, very little progress was made in furnace construction, but we find the reverberatory furnace in use to a large extent as early as the fifteenth century.

In tracing the evolution of the metal casting art, we find the composition of the moulds used at the various stages to be of more than passing interest. A whole series of moulds belonging to the first Dynasty of Egypt (about 2400 B. C.) has been unearthed. They show that the moulds were carved in thick pieces of clay, baked into pottery, and lined with a fine ashy clay. In the lake dwellings of Switzerland various moulds have been found which date from 1000 to 2000 B. C. Some are of rock, others of clay. Rock seemed to be preferred for the flatter objects, clay for the more complicated. Whether the first moulds were of stone or baked clay is uncertain, since stone and clay are more closely related to the pottery art, which is far older than recorded history and was known and practiced long before the metal casting art.

Both rock and clay moulds, or at least some of them, were constructed in halves or in even more parts, so that they could be preserved. Holes for plugs are to be seen which were

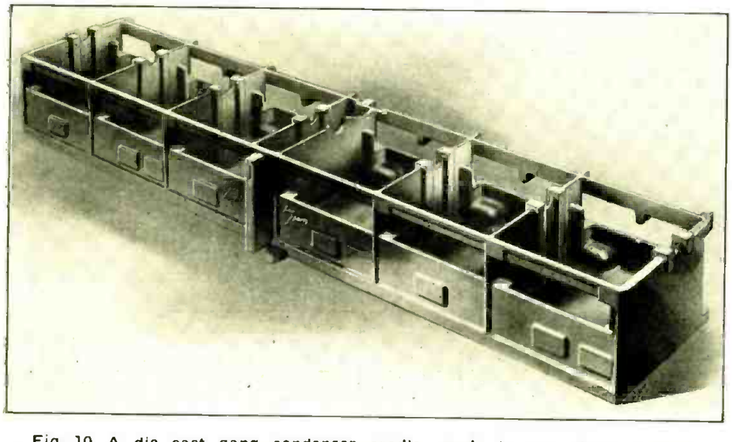


Fig. 10. A die cast gang condenser cradle, made in one piece; a good example of modern die casting.

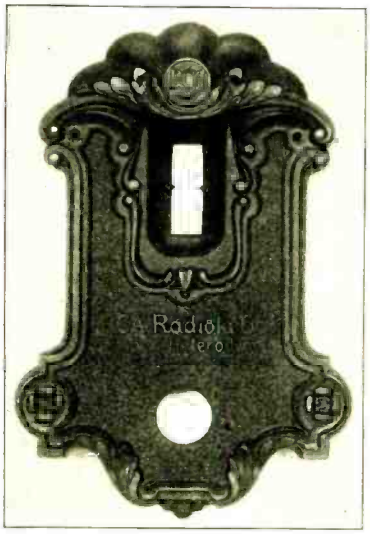


Fig. 11. Escutcheon for Radiola 60, cast from a metal alloy.

used in fitting the parts of the moulds together. Moulds found in ancient Troy likewise show the use of both stone and baked clay, some of them being constructed in symmetrical halves.

Moulding in sand commercially, began about 1708. At that time, Abraham Darby, in Wales, had been having considerable trouble in the casting of hollow iron vessels, when an apprentice by the name of John Thomas conceived the idea that by using sand instead of clay the air would be more easily released from the casting thus producing a better casting and avoid the destruction of many moulds. After considerable experimenting, most of which was carried on after their regular working hours, they were finally successful in perfecting the idea, and the present-day method of sand casting was thus originated.

In England a patent for sand moulding was allowed by the government in 1758, although it appears that Ramemer used sand for moulding and his furnaces as well as his other equipment were not unlike those in use in modern foundries.

The Metal Mould

The first appearance of the metal mould seems to have come with the advent of printing in 1454. The demand for cheap type led to improvements along this line, which resulted in the evolution of the modern linotype machine.

During the seventeenth and eighteenth centuries metal moulds began to be used for casting pewter tableware which was greatly in vogue during that period. During the nineteenth century metal moulds also came into use for the production of hollow lead toys, clock frames, etc., which were produced by the so called "slush" process.

The avalanche of motor propelled vehicles, which marked the beginning of the twentieth century, together with the evolution of many automatic vending, printing, and talking machines, created a demand for a simpler and cheaper method for producing accurate castings than the old-fashioned sand process. The metallic mould seemed to be the only solution to this problem and many years of labor and experiment were spent in an attempt to establish this process on a commercial basis.

In 1906, H. H. Doehler perfected and in 1907 patented his die casting process and placed so called die castings made from alloys of zinc, tin and lead on the market. These castings were smooth and accurate, requiring little or no machining. From this obscure beginning the process developed rapidly. Metal mixtures or alloys with a strict regard to metallurgical principles were gradually evolved. New and improved casting machines were devised, scientific casting methods were adopted; and the die casting industry has become one of the largest and most important branches of the non-ferrous metal trades.

Die Casting

The term "die casting," as used by engineers in this country, applies to metal castings made by forcing molten metal under pressure, into a metallic mould or die. The origin of the name is not known, having just simply grown up with the industry. The term "pressure casting" is synonymous with "die casting" and is undoubtedly more descriptive of the product. However, the name "die casting" has been almost universally adopted for this product in the United States.

By referring to the definition of "die casting," i. e., "metal castings made by forcing molten metal, under pressure, into a metallic mould or die," it is apparent that there are three vital factors entering into the successful operation of the die casting process. They are:

(1) A die casting machine capable of holding the molten metal under pressure.

(2) A metallic mould or die, properly designed and constructed, capable of receiving the molten metal under pressure.

(3) A suitable alloy that will produce a casting of specified physical properties when cast in that machine and die.

It is apparent from the foregoing that the successful die casting process does not consist of a die casting machine or of a die. It is also evident that no alloy can be said to be a "good die casting alloy" and produce uniformly good die castings, since the process is not dependent on the alloy alone for the production of good die castings. The best die casting machine built will not produce satisfactory castings from the best die casting alloy known, if the die has not been properly designed and constructed.

The manufacture of die castings requires an organization composed of men highly skilled and specialized in mechanics and metallurgy, and the quality of the product is dependent upon their ability to perfect and coordinate the three vital factors in the process, i. e., machine, die and metal.

The design of die casting dies is the first and most important step in the manufacture of a die casting. A die that is improperly designed cannot produce satisfactory castings and frequently a die so constructed cannot be corrected. There are many vital factors that must be considered by the die designer before deciding on the construction of any die. The following are some of the points to be considered.

The Gate

The location of the gate or metal inlet is of vital importance to the user of die castings. The gate location is decided upon not only from the standpoint of casting production, but from the user's viewpoint of the finished casting. The designer of a die is in a much better position to locate the gate properly if he is thoroughly familiar with the service application of the die cast part. In order to illustrate this point, reference is made to Figs. 1 and 2.

Venting of Dies

Since all die casting dies are made from steel, it is evident that methods must be provided for the exit of the air in the die cavity when it is displaced by the metal entering into the die. Failure to provide proper vents in the die will naturally result in unusually porous castings. Many

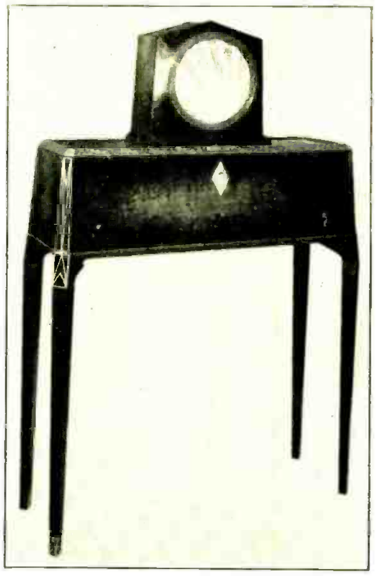


Fig. 12. The new Radiola 33 and 100-B speaker, both with die cast cases.

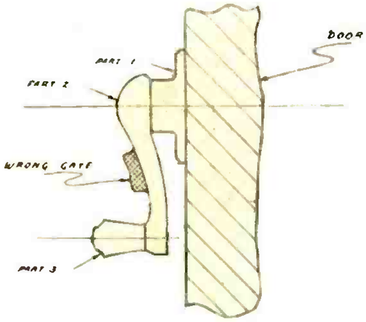


Fig. 1. Wrong gate location in a die.

methods of venting are employed in the design of die casting dies. The size, contour and section of the casting determine the method of venting that is most applicable. Here also the skill of the die designer is a vital factor in determining the final quality of the die casting.

Ejectors

Proper means must be provided in every die for rapidly ejecting the casting from the die, after the casting operation. This is usually accomplished by means of ejector pins. In the process of ejecting the casting, the ejector pins have a tendency to make a slight impression in the casting. On examining a die cast part "ejector pin marks" are frequently quite visible. It is the task of the die designer to place these ejector pins in such position on the casting so that they will eject the casting rapidly and without distorting the casting; at the same time the marks made by the ejector pins on the casting must not be objectionable from the user's standpoint.

The gate location shown in Fig. 1 would produce satisfactory casting from a purely casting standpoint. However, the gate must be removed and, in doing so economically, may spoil the contour of the casting at a point where it is visible in service.

If the gate location shown in Fig. 2 were used the gate could easily be removed and any disfiguration that might occur in the removal of the gate would not be objectionable, since the point is not visible in service. It is apparent that if the die had been designed with gate location shown in Fig. 1 the product would be spoiled at the first stage in the process and all castings made from that die subsequently would be of an inferior quality.

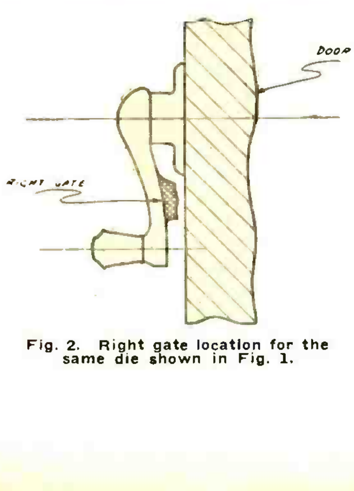


Fig. 2. Right gate location for the same die shown in Fig. 1.

It is evident from the foregoing that the proper design and construction of the die is one of the most vital factors in the successful die casting process. The construction of cheap dies invariably proves to be a false economy.

In designing parts for the die casting process, one fundamental difference between the die casting process and foundry practice should be kept in mind, viz., in foundry practice, a core of any conceivable shape can be molded in sand, and when the casting has been made around the core it can be destroyed and removed from the casting. In die casting practice, all-steel cores are used (which obviously cannot be destroyed after every casting) and means must be provided for removing such cores. Summarized, it resolves itself into the general rule—*avoid undercuts*. Although undercuts cannot generally be cast in the die casting process, the exceptions to this rule are numerous.

Important Considerations

The designer should bear in mind the following primary rules:

(1) Avoid undercuts.

(2) Avoid sharp corners. Fillets and webs not only add strength to the part, but also assist in producing a better casting.

(3) State limitations required on all vital dimensions. Do not allow for shrinkage.

(4) Apply inserts only where special qualities are required.

(5) Lettering can be cast either raised or depressed. Raised letters are less costly and more practical. Depressed panels with raised letters frequently answer the same purpose as depressed letters.

(6) Make use of the advantage of thinner walls which the die casting process offers.

(7) Bear in mind the possibility of combining several parts into one unit which is made possible by the die casting process.

(8) It is not economical nor practicable to die cast parts which can be produced by the sand casting process and can be used without machining, or surface finishing. Generally speaking, die castings cannot compete with simple stamping or simple screw-machine products.

(9) Before specifying the alloy to be used, consider qualities and adaptabilities, and give due consideration to limits and characteristics mentioned herein. The following general information will be found helpful by the designer: Sections of castings should be as uniform as possible. Large fillets and thin sections are most desirable within the limits stated below. These limits are necessarily general only, as dimensions affected by die parting or movable slides and cores require broader tolerances than otherwise. The general design of each piece must be considered individually.

Use of Inserts

The quality and usefulness of a die cast part are very frequently improved by the use of inserts.

The method of application is to place the insert into the die before casting and then cast the metal around the insert. Turning or pulling out of the insert is prevented by means of "undercuts" of various types as shown in the following illustrations. It will be apparent that inserts for use in die castings must be maintained to extremely accurate dimensions. If an "oversize" insert is placed into the die it will "score" and possibly ruin the die. If an "undersize" insert is used the insert will not completely fill the cavity of the die, provided for the insert, with the result that the molten metal which is under pressure will cast around the insert producing objectionable "fins" or "flashes" of metal which are sometimes difficult to remove.

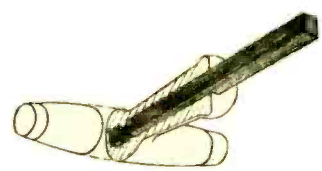


Fig. 3. Reinforcing steel shank cast in place; a typical insert.

As a general rule, inserts should not vary more than plus or minus .002" on any dimension in order to produce satisfactory results.

General Practical Limits

	Zinc alloys	Aluminum alloys	Tin or lead alloys
Minimum wall thickness	3/64 inch	3/64 inch	3/64 inch.
Variation from drawing dimensions	Plus or minus .002" per inch.	Plus or minus .0025" per inch.	Plus or minus .001" per inch.
Draft — cores	.005" per inch of length.	.015" per inch of length.	None if essential.
Draft — side walls	.005" to .010" per inch.	.015" per inch	.005" per inch.
Cast holes (min.)	.031"	.093"	.031"
Threads cast external (max.)	28 per inch	24 per inch	32 per inch.
Threads cast internal	Where cheaper than tapping.	Not cast	Where cheaper than tapping.

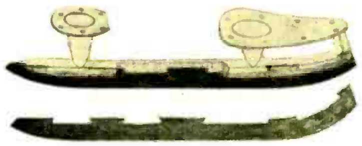


Fig. 4. Hardened steel runner in a skate cast in place.

The designing engineer should have a thorough knowledge of the possible application of inserts in die casting practice, since often the use of a die casting is only made possible by the use of an insert. The engineer, however, should bear in mind that the use of an insert tends to retard the die casting operation, thereby increasing the unit cost of the casting. It therefore follows that inserts should not be used in die castings unless a compensating advantage is gained thereby. Furthermore no attempt should be made to cast in such inserts as ordinary steel or brass pins or simple bushings which can be pressed into place after casting by a subsequent inexpensive operation. Inserts may be used in die castings to produce the following results:

(1) To provide greater strength at localized points in the casting. Fig. 3 illustrates this application of inserts.

(2) To provide greater hardness at localized points in the casting. Fig. 4 illustrates this application of inserts.

(3) To provide means of soldering or brazing on castings made from alloys which cannot be soldered or brazed such as aluminum and its alloys. Fig. 5 illustrates this application of inserts.

(4) To provide special electrical properties at localized points in the casting. Fig. 6 illustrates this application of inserts.

(5) To provide means of lubrication to inaccessible points in the casting from points readily accessible when assembled. Fig. 7 illustrates this application of inserts.

(6) To provide an alloy of better anti-friction qualities at localized points in the casting. Fig. 8 illustrates this application of inserts.

(7) To reduce cost of assembly. This use for inserts is demonstrated in the above illustrations of the application of inserts in die casting practice.

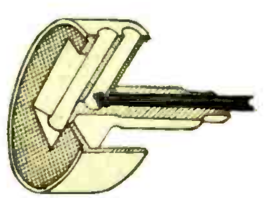


Fig. 5. Copper tube for soldering or brazing, cast in place.

Invariably the use of such inserts reduces the cost of assembly.

The Alloy

The mistake is frequently made in specifying a die casting without regard to the alloy to be used. All die castings are not alike, as neither are all sand castings alike, nor forgings alike. A sand casting made from brass bears no relation to one made from iron or monel metal. Similarly, a die casting made from aluminum has properties entirely different from a die casting made from tin or lead alloys.

It is well to bear in mind that die casting is essentially a method of casting that is applicable to a large variety of alloys. At frequent intervals enthusiastic proponents of some special alloy have proposed that alloy as a "cure-all" and panacea for all die casting ills. It is manifestly absurd to assume that any one zinc alloy or

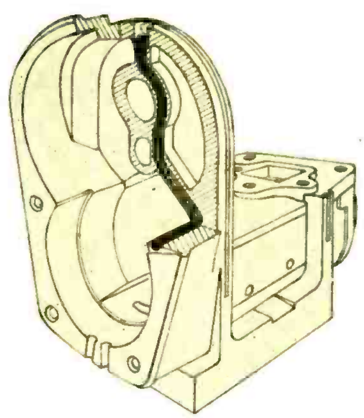


Fig. 7. Copper oil tube, for internal lubrication, cast in place.

aluminum alloy, or any other alloy will meet the service requirements of all die castings. It is equally absurd to propose one trade-marked alloy for all foundry practice.

The physical properties of two very well known trade-marked alloys that represent the results of over 20 years research will convey the strides that have been made in applied metallurgy in this field.

Zinc Base Alloy

Tensile strength, 35,000 to 40,000 pounds per square inch.

Elongation, 5 per cent. in 2 inches.

Hardness, 80 Brinell.

Melting-point, 750 degrees Fahrenheit.

Weight per cubic inch, 0.22 pounds.

Aluminum Base Alloy

Tensile strength, 21,000 to 25,000 pounds per square inch.

Elongation 2.5 to 5 per cent. in 2 inches.

Hardness, 40 to 60 Brinell.

Melting-point, 1150 degrees Fahrenheit.

Weight per cubic inch, .102 pounds.

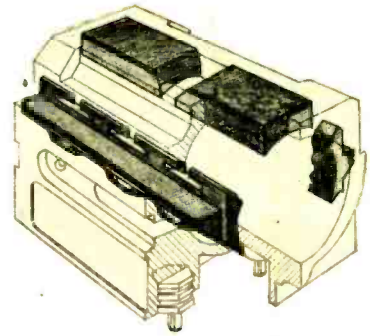


Fig. 6. Magnetic pole pieces, shown dark, cast into a frame.

Die Casting of Radio Parts

Die casting is among those of the relatively new processes that have had a decided influence in the design of radio parts. Due to their uniformity and low cost of production they have been used extensively in such internal parts as dial drums, variable condensers and condenser cradles and brackets, as shown in Figs. 9 and 10, but more recently for external parts and for decorative uses as in Escutcheon plates (see Fig. 11), knobs, cabinet feet and complete cabinets and loudspeaker housings, because of their clean definition, low finishing costs and the facility with which they can be worked into economical assembly.

With the development of new methods of finishing die castings as in the "Doler-Art" process, entirely new effects and refreshingly new styles of cabinet work are possible. No more typical example of the application of modern processes and materials to modern craftsmanship can be pointed to than in the Radiola 33 cabinet and the RCA 100-B speaker portrayed in Fig. 12.

By the use of die cast frames and corner posts with die cast upper and lower leg members, and the loud speaker housing, all finished in the "Doler-Art" process; only sheet metal panels and leg tubes are required to complete the assembly, creating a modernistic design with all the beauty of an old world cloissonné, to gratify the prevailing demand for style with utility.

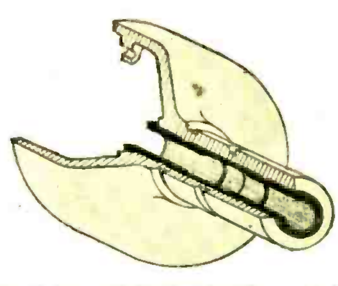


Fig. 8. An anti-friction bushing cast in place; another typical insert.

Light-Sensitive Cells

II. Characteristics of the Alkali Metal Cell

By John Patton Arnold

IN the foregoing article we have considered the methods of preparing light-sensitive cells of the alkali metal type. As this type of cell is deemed at present the most suitable for practical work, some of its most important characteristics will be discussed here.

We shall further limit the discussion mainly to the central anode form: that is, that structure which employs a centrally located anode surrounded by the light-sensitive cathode, usually deposited on the inner walls of a glass bulb, which is either exhausted to a high degree or into which gas at suitable pressure is introduced. This type of cell is the only one readily obtainable in a commercial form and, therefore, is almost exclusively employed for talking moving pictures, visual communication, etc. Its chief features, when properly designed, are instantaneous response and proportionality between the light that falls upon it and its electrical output. This current output, however, is very small, requiring considerable amplification by means of vacuum tubes to operate relays or other electrical apparatus, or when the generated signals are to be transmitted to a distance, as in the case of television.

The behavior of these cells may be studied under the influence of various conditions, such as of light (intensity, frequency, polarization, angle of incidence), voltage, temperature, electric and magnetic fields, pressure of the gaseous atmosphere, condition (rough or specular) of the light-sensitive surface, etc. Obviously, while of interest and of scientific importance, all of these matters can not be considered here, even briefly. Hence, only such facts that might be of value to engineers are presented; but, in addition and for the sake of completeness, references to the original literature are also included in order that the reader may turn to them for fuller information. It might be mentioned in passing that all of the papers quoted are considered of importance in the study of this subject.

To gain a thorough knowledge of the performance of any particular cell, certain relationships should be known. This information is usually plotted as curves showing—

(1) The current-voltage relationship which indicates the electrical conditions under which the cell should be operated;

(2) The current-intensity relationship which signifies the electrical response to light of various intensities; and,

(3) The current-frequency relationship (wavelength sensitivity) which designates the "color" of light to which the cell is most responsive.

From the first and second curves, one can draw most of the information he needs to use the cell to the best advantage. The third curve merely shows that different alkali metals and their hydrides differ from each other in responding to light of various wavelengths.

Current-Voltage Relations

A study of the current-voltage curves of Figs. 6 and 7 will reveal the fact that photoelectric emission begins at a definite positive voltage. This point, known as the "stopping potential," which varies with the wavelength of the exciting radiation, is the limit beyond which, with higher positive voltages, the ejection of electrons does not occur. But, when these potentials are reduced and the light-sensitive electrode becomes negative, in the case of the central anode, vacuum-type cell, the current rises rapidly to a saturation point. The saturation level for a particular wavelength of light may always be determined when an increase of voltage in a negative direction fails to materially increase the current through the cell.

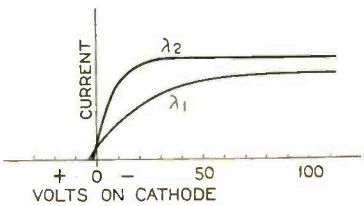


FIG. 6

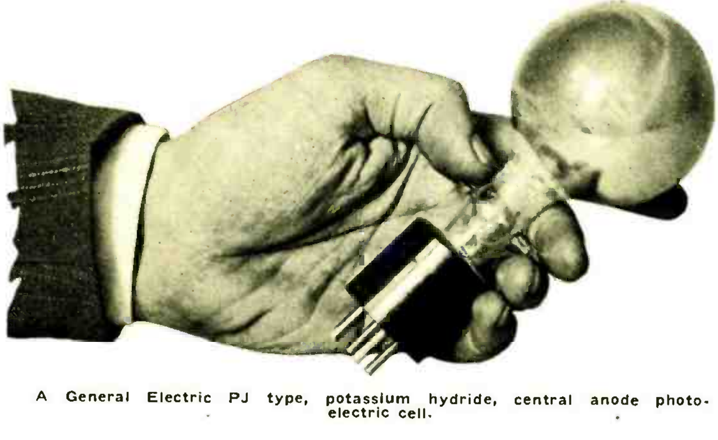
(Courtesy of Bell System Technical Journal)

Voltage-current curves for typical central anode vacuum cell, showing the response to light of short (1) and long (2) wavelengths.

When a gas is introduced in this type of cell, ionization by collision takes place. Thus, instead of saturation, the current-voltage curve continues to rise and tends to approach parallelism with the current axis, the current increasing with the voltage until the critical potential for the particular gas is reached and a glow discharge takes place in the cell.

In both the vacuum and the gas cells of the central cathode type, the curves are practically the same. In the vacuum cell of this type, it might be noted that saturation is reached when the applied field reaches zero. The current-voltage characteristic is probably the most important for practical work and the conditions for operation under certain applied voltages should always be given by the manufacturer for the particular cell. If not obtainable, this curve may be determined by placing the cell in series with a sensitive current meter and a battery and noting the deflections for various voltages. The cell, referring to an alkali metal cell of the gas type, should never be operated above the critical voltage, above which point the glow discharge takes place. Such a discharge may permanently ruin the cell or wreck delicate meters which are in the circuit with it. The use of a protective resistance in series with the cell will prevent damage by accidental applications of high voltage for a short time.

Therefore, a cell should always be used below the critical voltage. This point, it should be understood, is lower for higher light intensities. It may be suggested where high sensitivity is not demanded or where the photoelectric current is subsequently amplified, that



A General Electric PJ type, potassium hydride, central anode photoelectric cell.

lower voltages be used, since small variations in the source of potential will have only a negligible effect on the current output of the cell.

It is often found in many cells that there is a reverse photoelectric current for small positive potentials applied to the light-sensitive material. This is due to the fact that it is practically impossible to prevent some of the alkali metal from depositing on the anode itself.

Current-Intensity Relations

The number of electrons emitted per unit of time from a photoelectric surface is directly proportional to the intensity of the exciting radiation. This proportionality has been verified over ranges of illumination so weak that the human eye will not respond to intensities comparable with sunlight. Elster and Geitel[1] found strict proportionality to hold from 30,000 lux (1/3 the value of sunlight) down to 6×10^{-4} lux. In another paper[1-a] they reported an extension of this relation down to 3×10^{-9} erg per sq. cm. per second for blue light and 2×10^{-7} for orange light.

Although this law of proportion is strictly true, there are factors which may occur in practical cells which will nullify such results. Ives[2] mentions that the relationship will hold both in vacuum and gas cells "provided there are no free glass surfaces on which charges may accumulate. If the window is made too large it may become charged and cause an appreciable curvature of the illumination-current relationship."

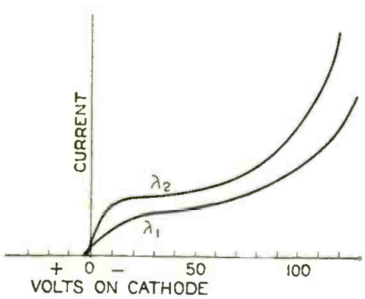


FIG. 7

(*Courtesy of Bell System Technical Journal*)

Voltage-current curves for typical central anode gas filled cell, showing response to the light short (1) and long (2) wavelength.

In addition to the collection of electrical charges on insulating surfaces, Allen[3] mentions the effect of the "space charge" within the cell and Hughes[4] the "alteration in the multiplying factor of ionization (of the gas) by collision under extreme conditions" which may produce abberations in the relationship. Careful design of cells will take these points into consideration.

[1] *Phys. Zeitschr., Vol. 14, p. 741*; 1913.
[2] *Bell Sys. Tech. Jour., Vol. 5, p. 324*; 1926.
[3] *"Photo-electricity," p. 128.*
[4] *Bull. Nat. Research, Coun., Vol. 2 (2), p. 107; Apr.*, 1921.

The current-intensity relationship of a typical cell is shown in Fig. 8.

Wavelength Sensitivity

The response of a photoelectric cell to light of any wavelength is determined by its specific sensitivity. (Specific sensitivity includes the factor of the different energies transmitted by different parts of the spectrum and is stated in terms of coulombs of electricity traversing the cell per erg of incident energy for a given impressed voltage across the cell terminals.)

The maximum sensitivity for the alkali metals and their hydrides, as determined by Seiler[5] is as follows:

	Li	Na	K	Rb	Cs
Metal	405	419	440	473	539
Hydride		427	456	481	540

(Wavelength maxima in micro-millimeters.)

It will be noted from this table that the sensitivity shifts toward the red end of the spectrum as the metal becomes more electro-positive. It also appears that the hydrides respond to the longer wavelengths than the corresponding metal. Allen[6] points out, however, that these results, which were obtained by measuring thirty cells of the Kunz type, are characteristic of the particular cells themselves rather than of the metals, since the normal and selective photoelectric effects were not differentiated in these experiments.

Fig. 9 shows the complete curves of these metals and their hydrides. The photoelectric emission begins at a certain definite wavelength, known as the *long wavelength limit*, beyond which point emission does not occur. From this point, however, the emission rises gradually to a maximum at some shorter wavelength.

In photometric measurements, it is necessary to know the wavelength, or color, sensitivity of the particular cell used for the experiment, but in ordinary applications, such general information as the foregoing is usually sufficient for the purposes of the engineer.

It might be pointed out, by way of example and in explanation of these curves, that the potassium hydride cell has a maximum sensitivity in the blue-violet region of the spectrum as compared with the maximum sensitivity of the average eye in the yellow-green.

Temperature

Ives[7] states that the "photoelectric current decreases with decreasing temperature, the effect being greater for yellow than for blue light." The temperature range studied in these experiments was from +20 to —180 deg. C. The effect was particularly noticeable in the case of potassium. However, temperature changes within the normal working range (0 to 50 deg. C.)

[5] *Astrophys. Jour., Vol. 52, p. 129*; 1920.
[6] *Photo-electricity, p. 277.*
[7] *Jour. Opt. Soc. Am., Vol. 11, pp. 565–579*; 1925.

do not appreciably affect the sensitivity of practical cells. As a matter of precaution, it is not advisable to operate a potassium hydride cell at a temperature above 50 degrees, for part of the alkali metal may vaporize and settle in cooler portions of the bulb, thus changing the character of the useful light-sensitive surface.

Instantaneity of the Photoelectric Effect

It is well known that photoelectric emission is practically instantaneous.

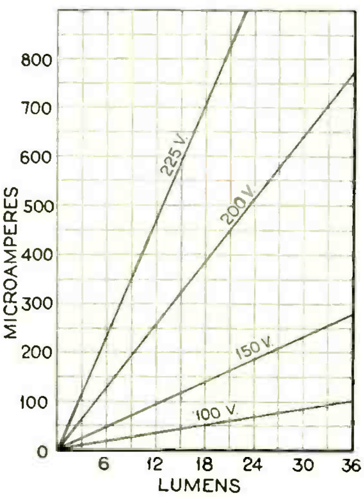


FIG. 8

(*Courtesy of G-M Laboratories, Inc.*)

Relationship between the light (expressed in lumens) and the current in a commercial potassium hydride cell.

Lawrence and Beams[8] have recently conducted experiments which confirm this within 3×10^{-9} sec., employing for these tests three-electrode cells with potassium and potassium hydride plates. The grid and plate of the cells were connected in series with a biasing battery across one of two condensers which in turn was connected in parallel with a spark gap. When the potential across the spark gap was nearly a maximum the field between the photocell plate and grid was such as to draw electrons to the grid and on to the collecting electrode. "A definite time after the discharge of the spark (equal to the wire path connecting the photocell to the spark gap divided by the velocity of light) the field reversed, thereby preventing electrons from leaving the plate. By varying the wire path this device permitted a study of the times of ejection of electrons by short flashes of light from the spark."

Fatigue

Diminishing photoelectric activity with time or under certain operating conditions has been observed in alkali metal cells. This phenomenon is commonly known as the "fatigue" of the Hallwachs effect. Allen,[9] who reviews the literature of this subject up to 1925,

[8] *Phys. Rev., Vol. 29, p. 903*; 1927.
[9] *Photo-electricity, Chap. 12.*

says that "it is now generally considered that the photoelectric activity of a pure metal is an intrinsic property of that metal, and that no fatigue would be observed with a clean metallic surface in a perfect vacuum." This applies to the alkali metals themselves; yet it remains a fact that a diminution of activity occurs in the practical cells which employ these metals.

Koller[10] recently studied the effect of oxygen on the photoelectric emission. The experiment consisted in admitting enough oxygen into a potassium cell to form an absorbed layer one atom deep. No change in sensitivity was observed, and not until fully 355 microns of oxygen were admitted was any effect apparent. The next 300 microns increased the sensitivity three-fold, but after this each 100 microns resulted in an immediate drop in sensitivity and the recovery with time was less and less complete. "The explanation of these phenomena lies in the absorption of oxygen by the potassium. Small quantities diffuse in so that no oxide is left on the surface. After the potassium is nearly saturated, the diffusion in is slowed down so that the effect on the surface can be observed. The gradual recovery takes place as the oxide diffuses in and a fresh potassium surface is formed. Eventually the potassium is all converted to oxide and the sensitivity is completely destroyed."

As Allen has stated, it is difficult to sum up the results of experiments which have been carried out under various conditions. The preparation of the alkali metal, the removal of occluded gases, and the nature and composition of the gaseous atmosphere, as well as the operating conditions, must be taken into consideration. It would seem probable, however, that variations in the gas pressure (since there is a critical pressure to which most commercial cells are individually adjusted) and the failure to remove occluded gases contribute largely to the photoelectric fatigue. That there may be other contributary causes is not to be denied, but the two mentioned are probably the most common.

What is the probable life of an alkali metal photoelectric cell? This is a question which is often raised and rarely answered with any degree of satisfaction. Were this point brought up in regard to a radio tube, an answer could be given with a fair amount of certainty; that its life will approximate the "average" figure determined by tests of thousands of tubes of this type, providing always that it is not abused in operation. It has been pointed out that photoelectric cells have not been standardized, and hence there are no figures of this kind available. Even if they were, they would mean very little, merely because it is not yet possible to duplicate cells as it is possible to duplicate radio tubes. But as one manufacturer puts it, "the purity of

[10] *Phys. Rev.*, *Vol.* 29, *p.* 209; 1927.

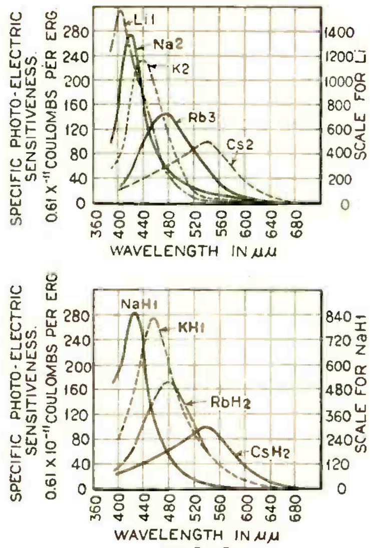


FIG. 9

(Courtesy G-M Laboratories, Inc.)
Color or wavelength sensitivity of the alkali metals and their hydrides.

the materials and the care of manufacture are determining factors of first importance." If this care has been exercised, the useful life of the cell is then largely governed by the maintenance of that delicate balance between the original treatment of the light-sensitive surface and the adjusted pressure of the gaseous atmosphere. The ability of the cell to hold its vacuum or to resist changes in its gas pressure becomes the chief factor unless one persists in using a gas cell as a glow-discharge tube (operating above the glow point) or in operating either the gas or vacuum type cells at high temperatures. They are much more rugged than the radio tube and their life is many times longer.

Rectifying Properties of Cells

Anderson[11] discusses the rectifying properties of cells as follows: "Every electric wave detector of the rectifying type is of use as a detector either (1) because of its rectifying properties or (2) because its current-potential curve is not linear. Inasmuch as the photoelectric cell possesses both of these properties it may be used in two ways, as Dunwoody has shown crystal detectors may be used. In case the rectifying property is made use of the efficiency depends upon the degree of rectification. As in the photoelectric cell the power of rectification is of a very high order, it should prove as efficient as any detector used."

He found that the rectifying power of a photoelectric cell, using potassium for a cathode, was of the ratio of 2000 to 1; that the form of the rectified cycle is the same for different pressures, electrodes and applied potentials, and that the amount of current for a given potential depends on the pressure of the gas, the electrode distance, and the intensity of light falling on the cell, but does not increase continuously with increasing intensity. Thus the high power of rectification and the high resistance of such cells indicate that they may be very efficient for the detection of electric waves.

[11] *Phys. Rev.*, *Vol.* 1, *p.* 222; 1913.

In the following articles, other data will be presented that may be useful in the practical application of cells and finally some information regarding light-sensitive devices that do not employ the alkali metals.

(To be continued)

Grid Bias Detector

THE recent introduction of several radio receivers using the C-327 tube as a detector with plate rectification, obtained through the use of a grid bias instead of the usual grid condenser and leak arrangement has again brought this system of detection to the fore.

Considerable experimental work has been done in the Cunningham laboratory to determine the relative efficiencies of the grid condenser and leak arrangement and the grid bias system under various operating conditions.

In using battery operated tubes such as the CX-301A, it has been common practice to use a negative grid bias of 4.5 volts at a plate voltage of 45 volts for plate rectification. With the C-327, however, maximum sensitivity is obtained by using a lower grid bias, on the order of two to three volts. However, even at this point of maximum sensitivity, the sensitivity of the tube for a given signal input, is less than is the case when using the grid condenser and leak method.

Reduces Overloading

With the grid bias method it is possible to apply a much higher signal voltage to the detector tube without danger of overloading so that very good results can be obtained with this system by using a sensitive radio-frequency amplifier capable of delivering a high signal voltage to the detector, thus making up for the lack of sensitivity in the detector.

If the grid bias voltage applied to the detector is small (the condition for maximum sensitivity), it will be noticed that when the volume control in the r-f. stages is turned low, the quality will be excellent. As the volume control is turned up gradually, the volume will increase until the detector begins to draw grid current when distortion will begin and there will be an actual decrease in volume with further advance of the volume control. This operating condition makes it necessary to use a grid bias of at least six volts in the average set.

The C-327, used as a grid bias detector, follows the "square law" much more closely than is the case when grid condenser and grid leak are employed, resulting in less distortion in the output of the detector tube, and therefore giving improved tone quality.

The Engineering Rise in Radio

By Donald McNicol

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

Part XI

CHAPTER 10

The Valve and the Audion

FEW outstanding inventions have been made which did not arrive in the wake of processes of evolution which, unerringly, if unknowingly, erected edifices of knowledge out of which invention might materialize. This was true of the Branly coherer, brought out in 1891. The evolution of the coherer has been traced through the work of Varley (1852), Hughes and Lodge (1879), Hertz' (1887), Lodge (1889), and then Branly. There is in this situation nothing which detracts from the importance of the ultimate, key invention. Rather, it usually is a tribute to the genius of the inventor that he was able to consolidate the various seemingly unrelated ideas and, combining them, produce a useful device not thought of by prior workers identified with its evolution.

The invention of the audion by Lee deForest, in America, was, quite naturally, preceded by odd observations and discoveries in several countries; easy enough to identify as to their importance after the invention of the audion, but which, previously, were not regarded as being of particular value.

Throughout the fifty years before Hertz, experimenters in laboratories, working with induction coils and condensers, had noted mysterious sparks in metallic systems in the neighborhood, all of which was understandable after Hertz, but not before. And so, very likely it was with effects noted by many investigators, years before Fleming and deForest (1904-1905).

The evolution of the audion may be traced by making note of published statements and announcements which, viewed retrospectively, were, in fact, discoveries which contributed toward an unforeseen, but useful development.

Professor Buff[1], of the University of Giessen, in 1853, published a paper dealing with the electrical properties of flame. He reached the conclusion that gaseous bodies, rendered conducting by strong heating, were capable of exciting other conductors, solid, as well as gaseous, electrically. In 1853, the incandescent electric lamp was twenty-six years distant in the future, so Buff had to employ glass tubes into which he inserted small strips of platinum, separated by an air space: the air within the tube being heated by the application of heat to the external surface of the glass. With this crude device, Buff was reported to have demonstrated that electric current from a primary battery could be maintained in a steady state through the path of the gas in the tube, whereas, with the tube cold, no indication of passing current could be observed, on a connected galvanometer. Here was a start of the science of electric conduction through gases.

[1] *National Telegraph Review, New York, July, 1853.*

The Edison Effect

In 1883, Thomas A. Edison was still at work on problems connected with the incandescent electric lamp, introduced by him four years previously. The discovery by Edison, of the "effect" which twenty-three years later was to constitute a principle of the Fleming valve and the deForest audion was clearly a by-product of an investigation into pecularities of the incandescent lamp. An observed difficulty was that the efficiency of the lamp for illumination purposes was reduced because the bulb in time became blackened due to a dark deposit on the inside surface of the glass.

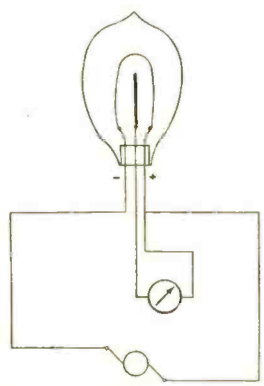


Fig. 14. Circuit for demonstrating the Edison Effect.

In the course of his puzzlement over this undesired effect Mr. Edison noted that frequently there was on the glass in the plane of the filament, a line which was not blackened. Further, and of the utmost importance, he noted that the leg of the filament which cast the shadow was always the one connected to the positive side of the circuit carrying current. It appeared as if the side of the filament connected to the negative lead were throwing off minute carbon particles which travelled past the positive leg, depositing themselves on the glass everywhere excepting directly in line with the positive leg.

Here, a wonderful discovery was just around the corner. But, that was five years before Hertz: twelve years before Röntgen, in Germany, discovered X-rays, and thirteen years before the electron was identified.

In studying the effect Mr. Edison had constructed lamp bulbs containing filaments, and in addition, small plates situated between the two legs of a filament. By connecting a galvanometer to the plate and to the positive side of the filament, the galvanometer indicated current flow across the gap within the bulb. (See Fig. 14).

Mr. Edison was able to extend the investigation to the point where he was aware that a stream of what he supposed to be carbon particles from the negative leg of the filament rendered the path across the gap conducting. In his patent application[2] covering the discovery, (patent 307,031) Mr. Edison incorporated a significant clause: "This current I have found to be proportional to the degree of incandescence of the conductor or candlepower of the lamp."

Many years after the discovery of the "effect," Mr. Edison in discussing the subject said: "As I was overworked at the time in connection with the introduction of my electric light system I did not have time to continue the experiment." It is just as well, of course, that the great genius returned to the problems of electric lighting, for, due to his concentration on that subject the general introduction of incandescent lamps proceeded satisfactorily. And, for that matter, a "valve" or "audion" available in 1883, would have been ten to fifteen years ahead of its time.

Elster and Geitel

Elster and Geitel[3], in Germany, in 1882 began an investigation of the ionization produced by incandescent metals, out of which came some additions to knowledge on this subject, but their researches into phenomena in evacuated bulbs were not carried out until about five years after Edison's discovery.

W. Hittorf[4], in Germany, in 1884, demonstrated that a small electromotive force could sustain an electric current between a hot carbon electrode and a cold electrode, in the highest vacuum obtainable at that time, pro-

[2] *The Edison Effect and its Modern Applications. By Clayton H. Sharp. New York*, 1921.

[3] *Elster and Geitel. Wied. Annalen, XVI*, 1882.

[4] *Wiedeman's Annalen, January*, 1884.

vided the hot electrode was connected to the negative pole of the battery.

Samples of Edison's bulbs, with filament, and mid-filament plates, with which the asymmetrical conductivity of current between the separated electrodes had been demonstrated, were given by him to William H. Preece, of the British telegraph system, in 1884. Mr. Preece, in that year reported the phenomena to the Royal Society. J. A. Fleming, in England, also experimented with an Edison bulb, in 1890: discussing the subject before the Royal Society, in the same year, and again in 1896.

In these citations we may see that the mystery bulb was bandied about the laboratories of the world as a curiosity; as a device which possessed unusual characteristics, but for which no one seemed able to discover a use.

The connection between the properties of the Edison bulb and the unknown became clear following Röntgen's announcements of 1895. The studies thereafter instituted led to the discovery that a hot electrode in a vacuum tube emits electrons. J. J. Thomson, in England, had discovered a new body having a mass but 1/1845 part of that of the hydrogen atom. This body was, by its discoverer, first called a corpuscle, later becoming known as an electron. Here was information of real importance. The mystery of Mr. Edison's blackened incandescent lamp bulbs was cleared up.

It was not until several years later that it occurred to anyone to investigate the possibilities of evacuated bulbs as detectors of electromagnetic waves. Engineers working on the problems of radio prior to 1904, had many things to think about other than trying to find some different sort of detector. But the vacuum tube was a product with a destiny. Its properties as a radio device could not long escape discovery.

The Fleming Oscillation Valve

Recalling his examination, fourteen years previously, of the Edison bulb, J. A. Fleming, in 1904, sensed the possibilities of the bulb as a detector of radio waves. In the latter year he introduced a detector of this type which became known as the Fleming valve, or two-electrode tube. (See Fig. 15.) An ordinary incandescent lamp bulb, with carbon filament had a metal plate included within the bulb; or, a metal cylinder placed around the filament, the plate or cylinder having an external terminal connection the same as the terminals of the filament.

The knowledge which accrued from the discoveries of Röntgen, J. J. Thomson, and others, in the two decades, 1883-1903, with reference to conduction through gases, rectification of alternating currents, and emission of electron streams from hot bodies in vacuoa, supplied the explanation of the action of the original Edison two-electrode bulbs and of those constructed by Fleming in 1904. That is: when the filament is rendered incandescent by current actuating it, the space between the filament and the neighboring metal plate, occupied by a highly rarefied gas, possesses unilateral (one-way) conductivity, and negative electricity (to use a simple term) passes from the filament to the plate, but not in the opposite direction.

Here, then, was a device which was a rectifier of alternating currents; thus far, similar in action to the electrolytic and crystal detectors described in a previous chapter. If a bulb so constructed has its filament supplied with current from a direct-current source, and another circuit is made up connecting the negative side of the filament and the metal plate, the circuit extended through an indicating instrument (galvanometer or telephone) and to an antenna system,

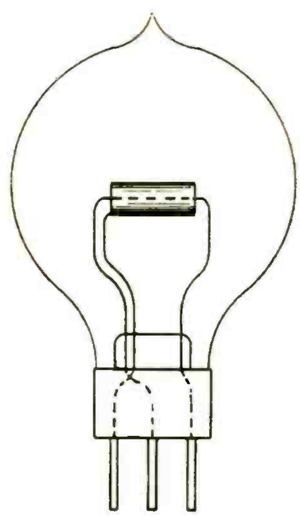


Fig. 15. The Fleming valve, or two-electrode tube. The filament conductor passes through a tubular plate element.

by coupling or otherwise, the oscillating current produced in the antenna by the intercepted waves will be rectified in the gap between filament and plate of the bulb and thus give signal indications in the translating device.

It is to be remembered that an electric current, considered as a flow of electrons, is from the negative to the positive electrode, while ordinarly it has been customary to regard current as flowing from the positive to the negative contacts of supply, through conducting circuits. The emission of electrons from the hot filament is a physical as distinguished from a chemical process, resulting from the thermal agitation acquired by electrons when the substance with which the particular electrons are associated is raised to a high temperature.

Fleming's patent (U. S. No. 803,684, of 1905) for the Diode, or two-electrode valve was basic, and throughout the life of the patent it held a key position in the field of the use of electron tubes as wave detectors. As a detector, the Fleming valve was little, if any, better than the electrolytic and crystal detectors, and as a two-electrode detector few of them were used compared to the vast number of crystal detectors employed in radio telegraph service. Actually, it was merely another kind of detector, another type of alternating-current rectifier.

The DeForest Audion

In the evolution of the electron tube the scene shifts back to America, where we find that deForest had, as early as the year 1900, made observations of conduction through gases, the significance of which was a subject for speculation during the following four or five years.

DeForest had the tube detector subject well in hand in 1904. His patent applications filed in November, 1904, and in January, February and April, 1905, disclosed tubes with two plates, or "wings." (See Fig. 16.) In later applications[5] he disclosed the well-known assembly of filament, plate and grid, as shown in Fig. 17.

The name "audion" was given to the device by C. D. Babcock, one of Dr. deForest's technical aids: "aud" being Latin and "ion" Greek, signifying "audible ions."

The first public announcement of the invention of the audion was given by deForest at the October 20, 1906, meeting of the American Institute of Electrical Engineers, New York, in his paper entitled "The Audion, a New Receiver for Wireless Telegraphy."

The discussion which followed the presentation of deForest's paper showed that the principle of operation of the device was far from clear. Fleming's explanation of the action of the Edison bulb, used as a detector of electromagnetic waves was that it performed as a simple rectifier. In describing the action of the audion deForest advanced the theory that there was a relay action having nothing to do with rectification.

A historically inclined student reviewing the mass of literature, trial evidence and technical discussions, bearing on the theory of operation of the audion, which continued for many years after the device appeared, can hardly avoid reaching the conclusion that Dr. deForest, in 1906 "builded better than he (or anyone else) knew."

After listening to the reading of deForest's paper of 1906, Dr. Pupin felt at a loss to account for the audion's action, asking: "Why does it operate?" and stating: "I have no explanation to offer * * * *. If Dr. deForest cannot explain it, I certainly cannot." In answer to a question as to whether the claimed relay action of the tube was due to ionization of the residual gas within the bulb or to electrons emitted from the electrodes, deForest replied: "I think it is due

[5] *U. S. Patent No 879,532, filed January* 29, 1907.

to the ionization of the residual gases; the gases still exist in the lamp, because the vacuum is only that which obtains in all incandescent lamps."

It is true that by 1906 considerable had been learned about the emission of electrons from hot bodies, but Dr. deForest may have had in mind that Röntgen rays are able to pass long distances through gases and as they pass through the gas ionize it, splitting up the molecules into positive and negative ions, as stated by J. J. Thomson, in 1903. From this reasoning deForest evidently concluded that Hertz rays reaching the audion acted in the same, or a similar manner.

In the literature of the art there was a general recognition of two distinct actions within the tube, depending upon whether the tube was highly exhausted or contained appreciable gas. In the former it was realized that a pure electron discharge occurred between heated filament and the cold plate, while in the latter ionization occurred due to collision between the emitted electrons and the ions resident in the contained gas. Years later (in 1915), Langmuir showed that the current in the plate circuit is limited for a given plate voltage by reason of a space charge within the bulb. He stated that the electrons flowing between the heated filament and the cold plate constitute a negative electric charge in space which repels the electrons escaping from the filament, causing some of them to return to the filament. Only a portion, therefore, of the electrons emitted from the filament reach the plate; the remainder being repelled by the electrons in space, return to their source. In the course of time it became the practice to use "soft" or gaseous tubes as detectors, and "hard" or highly exhausted tubes as amplifiers.

Small wonder that the audion of 1906 was not clearly understood. It was a new thing. Dudell's oscillograph had been introduced in 1898, but few engineers were familiar with its uses, or had apparatus of this type available for examining the characteristics of vacuum tubes, at this early date. Further, in 1906, there was no great demand for one more form of detector of electric waves.

In Fleming's use of the "valve" detector a single battery was employed—the battery supplying current to light the filament. A tap was made from the negative side of this battery, connected through the secondary of the antenna coupler, thence through the translating device and to the plate of the tube. DeForest, in 1906 applied separate batteries to maintain potentials at the terminals of the inclosed plates, and in 1907, as previously noted, perfected the assembly by replacing one of the inclosed plates by a "grid."

This improvement, after its function was fully understood, was destined to give impetus to extensions of radio telegraphy; make radio telephony practicable, and revolutionize long-distance, land-line telephony.

Tube Development in Europe

It was natural that Röntgen's announcements, in 1895, relating to mysterious, penetrating rays which, because their properties were not at first understood, were called "X" rays, should send the German savants off into new fields of exploration. At the time Fleming, in England, and deForest, in America, were laying the foundation of the great tube art, R. von Lieben and Eugen Reisz[6], in Austria, carried out experiments on a gas valve containing a form of ionizer based on the discovery of Wehnelt, in 1904, that strongly heated oxides of certain salts, particularly those of calcium and barium, emit electrons at low voltages.

Later forms of the Lieben-Reisz tubes[7] employed a content of mercury vapor. A rather high e.m.f. was required on the plate element and the tube itself was considerably larger than the audion. It was used by the German wireless telegraph organization, but had rather limited use elsewhere.

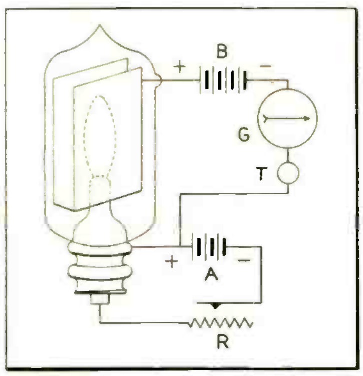


Fig. 16. The deForest audion of 1906, with filament and two-plates, but without grid element.

O. von Baeyer, in Verh. d. D. Phys. Ges. Vol. 7, p. 109, 1908, described a three-electrode tube in which the anode was a cylinder and the cathode a wire placed along its axis. The third electrode was in the form of a wire gauze cylinder, mounted between the cathode and anode.

The Tube a Detector

The Fleming valve and the first audions were simply detectors. They were new instrumentalities in about the same sense as Faraday's one-to-one ratio transformer of 1831 was new. What Callan, Page and Ruhmkorff did for the transformer (induction coil) deForest did for the vacuum tube receiver by inventing the local, "B" battery circuit, which at once made the device an amplifier. With a single audion an amplification of 500 per cent. was indicated, and with three audions connected in cascade an energy amplification of about 120 times that of the input was obtained, in tubes used prior to 1914.

The Regenerative Audion

Many reasons have been advanced to account for the fact that the audion throughout the first seven years of its existence was employed in radio telegraph signaling only to a limited extent. Principal among the reasons advanced were that "wireless" as a commercial utility was given a damaging set-back in those years as a result of various stock-jobbing schemes[8] based on earnings claims many years in advance of what was likely to be possible; that the majority of those employing radio receivers was made up of boys, working as amateur experimenters, to whom the high cost of the early audions acted as a check on sales; that the audion was little more sensitive than the best of the crystal detectors, which latter were quite inexpensive; that patent litigation prevented the use of the audion by companies operating many of the ship and shore stations in marine service.

The audion, however, had a great destiny awaiting it in the years ahead. Further discoveries made, beginning in 1912, brought to the tube a full measure of usefulness. It was discovered that the tube had regenerative properties not previously thought of, and that, properly connected with other circuit elements, it could produce electric oscillations on its own account, as well as translate those reaching it from distant radio transmitters. These discoveries were made prior to the Great War, and the pressing needs of extensive, and special communication facilities on land and sea, in the sky, and in subterranean operations throughout the conflict accelerated enormously the utilization of the tube for communication purposes.

The physicists in various countries, beginning with O. W. Richardson's application of the electron theory of metallic conduction to the electron emission from heated metals, in 1903[9], continued to investigate thermionic currents, and electron emission phenomena in evacuated tubes; notably, Wehnelt, 1904; Lilienfeld and Soddy, 1908; Fredenhagen, Langmuir, Pring and Parker, in 1912; Pohl, Pringsheim, Porter and Coolidge, in 1913, and Wiedemann and Hallwachs, in 1914[10]. But, the electricians, the engineers and others engaged in devising apparatus betterments and circuit improvements

[6] *Philosophical Magazine, X, p.* 80 (1905).

[7] *The Electrician, London, LXXII, p.* 726 (1914).

[8] *Success Magazine, New York, issues of June and July,* 1907, *contained a ten-page, illustrated article entitled "The Wireless Telegraph Bubble" by Frank Fayant, which contains an account of some of the early wireless telegraph company organizations.*

[9] *Phil. Trans.* 201, 516 (1903).

[10] *For references to the work and announcements of these thirteen investigators see Proc. Inst. Radio Engineers, September,* 1915, *pp.* 262–266.

for radio signaling, continued from 1905 until 1913 and later, to use the audion as a detector and as an amplifier only. Dr. deForest, following the events of 1912, 1913 and 1914, was subjected to no little criticism for having nursed the audion through its babyhood and adolescence without earlier discovering the full potentialities of the device. But it should be remembered that throughout those seven sterile years, hundreds of audions were in the hands of as many of the world's most advanced scientists, experimenters and engineers, and the audion itself was more of a listener than talker.

It will be recalled that there was a seven years hiatus between Hertz's announcement of 1888 and Marconi's achievement of 1895, and that following the young Italian's early demonstrations in England several eminent scientists voluntarily presented alibis which were quite plausible.

In the text-books published between 1907 and 1912, a typical explanation of the action of the audion was that:

> The audion is based on the fact that when a filament, plate and a grid are sealed in an evacuated glass bulb, a current can pass from the filament to the plate (while the filament is incandescent) but not from the plate to the filament. By connecting a local battery to the plate and filament a flow of electrons is set up which travels from the filament to the plate, and any change, or variation, in the local battery current will cause a like variation in the volume of electron flow, filament to plate. This phenomena is taken advantage of, in audion circuits, by connecting the receiving antenna to the grid of the bulb, to the end that the incoming electric waves, in response to the dot and dash elements of the telegraph code, alternately obstruct, and permit to flow, the streams of electrons in the plate circuit which contains the local battery and the translating telephone receiver. These variations in the strength of current in the telephone receiver actuate its diaphragm in accordance with the signal impulses reaching the antenna.

And in the simple audion detector hookups this is about what took place, but the audion connected up in another manner possessed properties which enabled it to do much more than this.

Up to 1912, the audion contained an undisclosed secret, an undiscovered phenomenon. Discoveries made in 1912-1913, disclosed that it was a generator of electric oscillations, and then followed quickly applications of the new principle which brought in their train the terms which in the intervening years have become familiar to all radio workers: regeneration, reaction, feed-back, tickler, oscillating audion, et cetera.

The time was ripe for such discoveries. Workers who were on the trail of the elusive secret were Lee deForest, E. H. Armstrong, C. V. Logwood, Irving Langmuir and Van Etten, in America; C. S. Franklin and H. J. Round, in England; A. Meissner and G. von Arco, in Germany, and S. von Strauss, in Austria.

A year before the discoveries of deForest, Armstrong and Logwood, in America, a French patent (No. 13,726, of 1911) had been issued to the Austrians Lieben, Reisz and Strauss, covering the use of three-electrode tubes for amplifying received radio signals. In a cascade arrangement the plate circuit of the first tube was connected through the primary of a transformer the secondary of which was connected to the grid of the second tube. Thus by amplification incoming signals were rendered louder than when a single tube was employed.

It was a logical conception to replace the telephone receiver in a single-tube receiver with an air-core transformer, the secondary coil of which could be connected to the input circuit of a second tube, but doing this without complete knowledge of the characteristics and properties of the tube, left much to be accomplished in the way of stability of circuit performance.

By the year 1912, land-line telephony had made considerable progress in the establishment of long distance service, but there was great need for a telephone repeater more suitable than any at that time in use. DeForest, in that year, studied the audion with a view to its employment as a telephone repeater, and in the course of this study noted the production of peculiar tones by the audion, which it was later learned were due to oscillating properties.

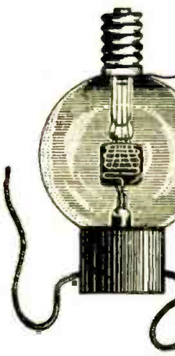


Fig. 17. Early type of audion, with filament, plate and grid.

DeForest stated that he discovered in August, 1912, that "if the input, or grid, circuit was inductively coupled with the output, or plate inductance, the audion became a generator of continuous alternating currents, originally made evident by a shrill tone in a telephone receiver."

The question as to who first discovered the oscillating properties of the audion, and the feed-back circuit principle, like the question of the invention of the telephone by Bell, or Gray, or Berliner, very soon became a matter for court determination—fated to remain undecided for many years.

Armstrong and the Feed-back Circuit

E. H. Armstrong, a student at Columbia University, New York, had an amateur wireless telegraph installation at his home, and in 1912, (he was then twenty-two years of age) while experimenting with receiver circuits, employing an audion detector, was impressed with the idea that the incoming radio-frequency oscillations might be passed into the plate circuit in which the telephone receiver was connected, and thus increase the volume of sound reproduced. He tuned the plate circuit to the radio frequency by means of capacity and inductance elements, and found that the amplified energy could then be "fed back" into the grid circuit, thus increasing the electric potential at the grid; in other words, producing regeneration, which increased the sensitiveness of the detector to incoming waves and gave a greater volume of sound in the translating telephone.

Armstrong's records indicate that he made the discovery of the feed-back principle in the summer of 1912; show that he had a sketch of his circuit arrangement witnessed on January 31, 1913, and filed an application for a patent on October 29, 1913.

DeForest's records indicate that he discovered the regeneration principle on August 6, 1912; that on August 29, 1912, demonstrations of its operation were made, and that on April 17, 1913, he had oscillating audion circuits in actual operation. Application for patent was filed by DeForest and Logwood, covering this invention, on March 12, 1914.

Unquestionably, Round and Franklin, in England, and Meissner[11], in Germany, were, at about the same time, close to the truth.

The reader of history has a right to require that elements of romance, if any exist, be incorporated in the story. In the story of radio the arrival of the young Italian, Marconi, on the far-flung, advance line of scientific progress, (in England) in 1896, must be recognized as a departure from prescription and procedure which does not often result for the adventurer in anything but disappointment and chagrin. The spectacle of the twenty-three-year-old youth cavorting over Salisbury Plain, freighted with batteries, metal plates, Leyden jars and an induction coil, with which he demonstrated to the learned that the range of Hertz waves was not that within laboratory walls, but rather, a matter of miles, contains scientific romance of a sort that is refreshing.

In the evolution of radio, E. H. Armstrong's contribution to progress bordered on the romantic to the extent that a tinkering amateur, independently, suspected the existence of, trailed to its lair, and discovered a principle of electric action which contributed in large measure to the vast radio industry as it exists at the present time.

Armstrong was but fifteen years of age when he took up amateur radio telegraphy, in 1905. He continued to

[11] *The Electrician, London, Vol. 73, p. 702 (1914).*

tinker with the gear available at that time and later. In 1908 he came into possession of a great prize—a Fleming oscillation valve, and two or three years later procured a deForest audion. Thenceforward he made rapid progress, some of the results being those previously described.

Thousands of youths throughout the world were tinkering with "wireless" in the years before and after 1912. Fathers on innumerable occasions listened to the weird reports of sanguine sons relative to "hookups" of their contrivance by means of which it was easy to hear far distant stations "with the fones on the table," while with any other known receiver it was necessary to clamp the telephone receiver close to the ear and listen "hard."

Occasional "freak" reception undoubtedly played a part in many of these experiences, but the reasons for freak phenomena were not to be understood clearly until years later when the intensive study directed upon the subject by engineers engaged in investigating variations in broadcast performance, uncovered the truth.

Armstrong was one of these sanguine youths. Although he was at the time taking a college course in electrical engineering, he was, so far as radio was concerned, an attic laboratorian. His experience in 1912, in obtaining loud signals, by means of audion circuits of his own devising, prompted him to tell his father about it with the hope that money would be forthcoming to pay for patent proceedings. Possibly his father had talked with other fathers in his circle, and had been impressed with a peculiar similarity in the tales he had heard, with that of reports presented to the others. The result was that one legitimate source of assistance was closed.

Young Armstrong then approached an uncle, but either his persuasive powers were not well developed, or the uncle had on his mind matters which to him appeared to be of greater importance than a boy's wireless schemes.

Here, an invention went begging, which was to produce hundreds of millions of dollars for manufacturers, commercial communication companies; and shop-keepers, who in 1912, had little idea that they would ever be engaged in selling radio receivers.

This was romance of the only sort that science can know, but to young Armstrong it is likely that at the time his only notion was that he was the central figure of a tragedy.

A Little Suspected Source of Distortion

The Effect on Reproduction of Loose Laminations in the Output Transformer or Impedance

By W. F. Sutherland

DISTORTION is frequently caused in the receiving set by the most unsuspected causes. The writer recently had occasion to try out a new output transformer with a balanced armature loudspeaker unit associated with an 8 ft. exponential horn and was puzzled for a time to account for a peculiar rasping or rattling which occurred only at extremely large outputs and only in the vicinity of certain well-defined frequencies. Suspicion naturally centered in the loudspeaker unit as the symptoms had every indication of being caused either by the overloading of the unit or by false resonances introduced by the clamping of the diaphragm edges. The unit was pulled down, checked over and adjusted, reassembled and placed on the horn again, with no improvement.

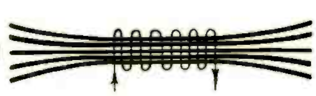
It was then noticed that the output transformer itself was functioning, although in a somewhat weak fashion, as a loudspeaker unit, music being quite audible from it at a distance of two or three feet, and the same distortion being quite evident in its sound output.

This gave a clue to the problem and on dismantling the transformer it was found that the laminations were quite loose, being easily compressed to a measurable degree with the fingers. The laminations were wedged tightly where they passed through the windings, where exposed they were taped up tightly and the assembly restored to the case. The improvement was remarkable. Filling the transformer case with molten parafin would probably also have stopped the chatter of the laminations.

Theory Presented

Now for the theory of this trouble. Fig. 1 shows a coil of wire surrounding a laminated core. A current flowing through the coil magnetizes the core, each lamination having a north pole at one end and a south pole at the other. Since all these individual poles are alike at either end and since like poles repel each other, the laminations are forced apart at each end. If current flowing through the coil be of audio frequency then this spreading apart of the laminations occurs every time the current reaches a maximum in one direction or the other: thus a vibration is set up of double frequency and if the inertia and elasticity of a lamination be of the proper value a mechanical resonance will be set up, amplifying the magnitude of the vibration at certain frequencies.

It may seem strange that this mechanical vibration should find its way into the audio-frequency output in the form of distortion but this is also easily explained since every time a lamination moves, the reluctance or resistance of the iron core to the flow of magnetism changes. The amount of magnetism changes, in consequence, and since a change in flux creates an electromotive force in a coil through which it passes, the audio-frequency windings have impressed on them a voltage exactly corresponding to the movement of the laminations. Thus, the distortion appears in the loudspeaker.



The laminations of an audio transformer are influenced by the current flowing in the primary winding and excessive vibration of the laminations in turn impresses a voltage in the winding corresponding to the movement.

Effect Pronounced in Push-Pull Circuit

This distortion will not be of any great magnitude since only a comparatively small distortion voltage is available for the modulation of the transformed distortionless voltage from the set. The effect may also be apparent at high outputs. It also is far more noticeable in push-pull output transformers than in the ordinary output transformer operating on a single tube, for in the latter the direct current component of the plate current, gives a steady flux, which tends to keep the laminations spread apart and so adds to their mechanical stiffness. In push-pull transformers the direct current has no effect in magnetizing the core.

The output transformer is the only one in which this effect is at all apparent since in other stages the energy level is not high enough to produce enough force.

Any transformer with sufficient excitation may produce sound through a molecular vibration of the iron mass as a whole. This vibration is not objectionable, does not introduce distortion and is usually very small in amount.

The Problems of Radio Servicing

I. An Outline of a Servicing Procedure to be Undertaken Preparatory to the Actual Testing of a Receiver

By John F. Rider, Associate Editor

CONSIDERING the status of the radio service field, and recognizing the interest evidenced therein by all large publications and manufacturers, it is needless to mention or to discuss the need for the radio serviceman—he serves a very beneficial purpose. Of greater interest is his work; what he should do and how he should do it. Hence, without further preliminaries, we might just as well delve right into the work at hand.

The visiting serviceman is our subject. Strange as it may seem to many who are interested in this work, much can be said from the desk, via a typewriter, about what the serviceman should do out in the field. To those who feel skeptical, let us say that this discussion is not analogous to the Sunday sermon about the problems of the working man, by an individual who has never labored. We have been out in the field and have had the occasion to make extensive observations.

We have had the pleasure of calling numerous servicemen to repair defective receivers in order to study their working methods and have found plenty to speak about. We realize fully that many visiting radio-tricians operate along the proper lines, but we also know that many do not.

SINCE the termination of his series of articles on "The Mathematics of Radio," Mr. Rider has been investigating the problems of servicing and the matter of its relation to the radio industry. His studies of this phase of the radio field have brought to light some very interesting conditions which, up to the present, have been overlooked.

The present article serves as an introduction to the general subject of servicing, and though it contains many valuable pointers in connection with the technique of servicing; such as the general use of "ailment charts," and a standard questionaire, it is presented mainly as a groundwork for the future material.

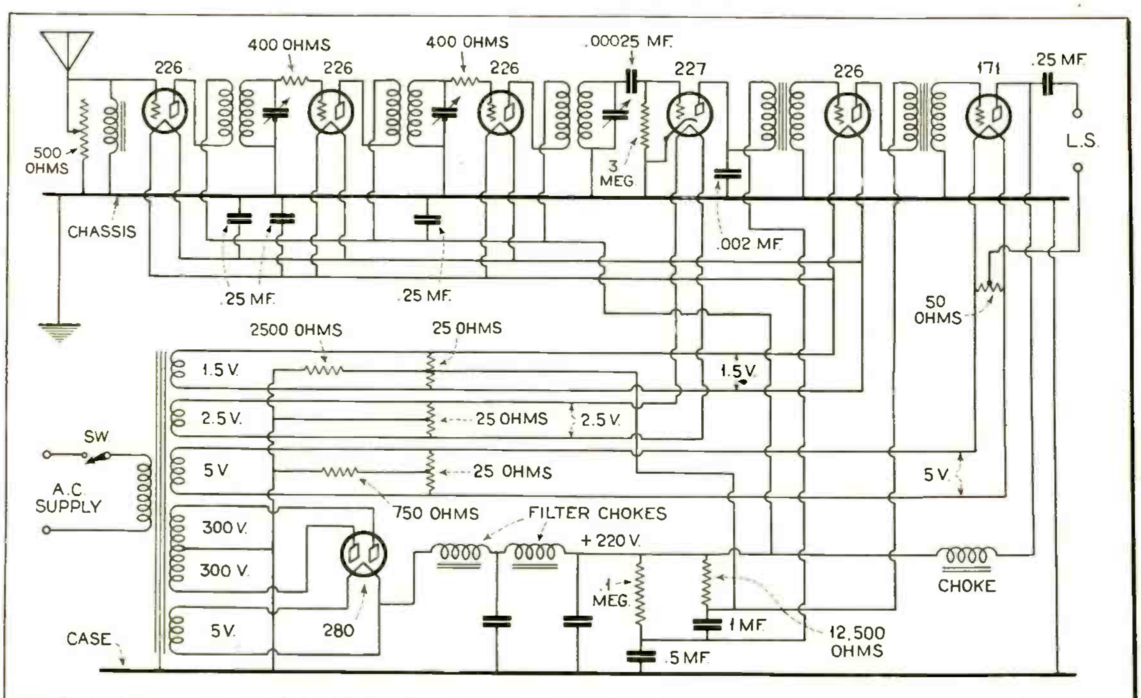
Mr. Rider's articles will deal with new testing methods and equipment, servicing procedure in its many phases; including data on the servicing of p-a. systems and theatre equipment, and a wealth of data on manufactured receivers.

Mr. Rider intends to cooperate with servicemen to the best of his ability and any suggestions from readers, regarding individual problems will be gratefully received.—Editor.

Process of Elimination

The process of elimination when applied to a defective radio receiver is the most rapid method of isolating a fault, particularly when the serviceman is familiar with the receiver at hand. However, this method of diagnosis requires a little more work than is entailed by recognition of the symptoms and subsequent search. The search for the possible source of trouble can frequently be expedited by the radio receiver owner. The average radio serviceman who calls upon a set owner makes a stock query, which actually has little significance. "What seems to be the trouble?" is the usual introductory comment. On first thought the question may appear logical, but upon second thought, it is just the contrary, because the reply is seldom informative. It is quite unlikely that the receiver owner can tell the visiting serviceman, the source of trouble, or even the trouble, other than to say that the receiver does not perform in a satisfactory manner. In sum and substance the method of attack is wrong.

Then again many visiting servicemen do not ask this query, but ask to be shown the receiver and they immediately start their diagnosis. This



Complete schematic diagram of the Atwater-Kent No. 37 receiver. Note that the antenna circuit is untuned.

method of procedure is extremely faulty, and the reasons are self-evident. We do not mean to disparage the operating methods of others. Our purpose is to set forth a process of operation which has been found to be successful and conducive to more profitable operation, which we know to be superior to the two examples mentioned and which makes use of the radio knowledge possessed by the receiver owner, no matter how sparse it may be. It is true that this information is not always available, that is to say, all of it is not available, but quite a good deal is at hand at all times, no matter when the serviceman makes his call.

Value of Cross-Examination

It is our belief that a short cross-examination of the receiver owner by the visiting serviceman is in order immediately upon entry. If the man of the household is absent, the lady may be questioned. Her replies will be hazy, it is true, but informative to a certain degree, and any information is valuable. Such a cross-examination should supply the serviceman with certain information, data which he cannot secure by observation of receiver performance—data which will lead to more rapid and therefore more profitable analysis of the receiver and more rapid isolation of the trouble.

Many factors associated with the operating life of the receiver; the batteries, the tubes, the accessories and the performance prior to the trouble or defect, are of great importance in the analysis of the trouble. Such data expedites the diagnosis. Therefore, the first step is to ascertain this information. A few such questions are:

1. How old is the receiver?

2. How long has it been in use?

3. How old are the tubes—the batteries—the accessories?

4. Did you make any internal wiring changes—any battery changes—any tube changes—where?

5. Was the receiver subjected to any physical jars or shocks?

6. Was the receiver moved from one locality to another?

7. Was the receiver in operation when the failure occurred?

8. What control or controls were being manipulated at the moment of failure?

9. Were any changes made upon the accessories—the eliminator?

10. Is the aerial in good condition?

11. Did you make any mechanical changes upon the receiver or the accessories?

In short, the customer must tell all he knows about the receiver, because such information is vital. It is astonishing to note the amount of time saved by such an examination. Time and again, the information thus secured points directly to the source of trouble. Rapid diagnosis and analysis is profitable to every one concerned. It means rapid repair and a satisfied customer. Besides, rapid repair means profit to the serviceman because he spends the minimum amount of time on each job. The serviceman sells time and knowledge. These two items constitute his entire stock.

With few exceptions, receiver failures are attributable to faults common to a myriad receivers. The introduction of the a-c. electric receiver increases the number of possible sources of trouble, but not by a large figure. The period of operation is a limiting factor in the possible sources of trouble. For example, mechanical failures are seldom encountered a short period after the installation of a new receiver, but a defective tube or a defective battery or a broken connection, jarred loose during local transit, will impair the operation of a new receiver. Hence the first query.

The answers to the second and third questions governs the possible increase in the number of probable sources of trouble. The older the set the more numerous the sources of trouble. This information supplemented by the present performance of the faulty receiver guides one to the tubes or the batteries in the installation. Mechanical failures are more likely in a receiver operated over a period of a year than in a new receiver. Old tubes or run-down batteries will cause poor receiver performance. Low electronic emission of filament type rectifiers and defective gaseous rectifiers will cause insufficient plate and grid voltages. Continual overloading of a loudspeaker will alter the physical alignment of the parts within the speaker.

The answer to the fourth question will show possible incorrect wiring changes. Many receiver owners who have made such changes and found them disasterous are loathe to provide this information and will only speak about it, when questioned. The change may be simple, yet an hour may pass before the serviceman, who has not queried the receiver owner, discovers the alteration in wiring. The answer to the query "where" will save much time. Many receiver owners are tinkerers and like to make what they believe will be improvements. Incorrect placement of a fixed condenser and the set tunes broadly. An incorrectly placed resistance and the filament voltage is low with unsatisfactory receiver performance. Many are apt to purchase accessories which, while secured in good faith, are not suited to the receiver. All this information must be at hand.

The average owner thinks nothing of a shock applied to a receiver during transit, particularly if the receiver performs well after the period of transit and then goes dead during operation. Yet many imperfect connections are jarred loose during transit and a contact broken during the reproduction of a loud signal, when the speaker causes a slight vibration of the receiver cabinet. Such cases are frequent when the speaker is within the cabinet. Then again internal plug connections are frequently "opened" during transit. Such imperfect contacts cause "crackling" disturbances and as far as the fan is concerned, the new locality is very poor, because "static" is prevalent—his reception was perfect in the old locality—before the connection was impaired and the contact rendered imperfect.

The answer to the seventh question is usually valuable, particularly when the trouble is noisy operation, or when the set ceased operation suddenly. Once again the period of operation is important and the answers to two or more queries are interlocking. Mechanical failure is more likely in an old set and if noise developed during the manipulation of a variable resistance, and the receiver is months or perhaps a year old, it is very likely that the contact between the various elements of that certain control resistance, is imperfect, or oxidization has reached the stage where it insulates one member from the other and the set goes dead. The trouble is easily remedied, yet the receiver is useless, and as far as receiver operation is concerned, this minor trouble is equal to any major trouble. Association of the answer to questions seven and eight will usually point to such troubles. In many cases manipulation of B-eliminator resistances will cause major troubles, particularly when the eliminator is old. Very often the trouble is not in the unit itself, but in some other part of the installation associated with that unit.

Practical Chart System

We have something else to say about the serviceman's visit. While the function of the serviceman is to repair a receiver and restore it to its original high electrical efficiency, repeat business is a basis for success. To secure this business it is necessary to show that the work is carried out in a systematic manner. Repeat calls for the capable serviceman are few and far between, but each call made, can be arranged to produce more customers by means of a silent, yet effective form of advertising. It is difficult to estimate the number of repeat calls for service upon one particular receiver owned by one man. The controlling factor in this instance is the receiver owner. If he is a tinkerer, repeat calls are numerous. If he knows enough to leave well-enough alone, the calls are infrequent. But no matter what the arrangement, detailed knowledge of the past record of the receiver, its ailments, its components, its previous operating life, and other such data, is of vital importance to the man who makes the call. It is not always possible to send the same individual if the servicing organization employs many men, or to see the master of the household when the call is made. Detailed cross-examination on each occasion is aggravating to the customer, yet the knowledge must be secured. . . . Why not apply an ailment chart system?

A permanent record made at the time of service, after the original cross-examination will be of aid to whoever calls to service the radio receiver. The original chart can be fastened inside the receiver cabinet, with thumb tacks. A copy of this chart should be kept in the serviceman's file, for reference purpose.

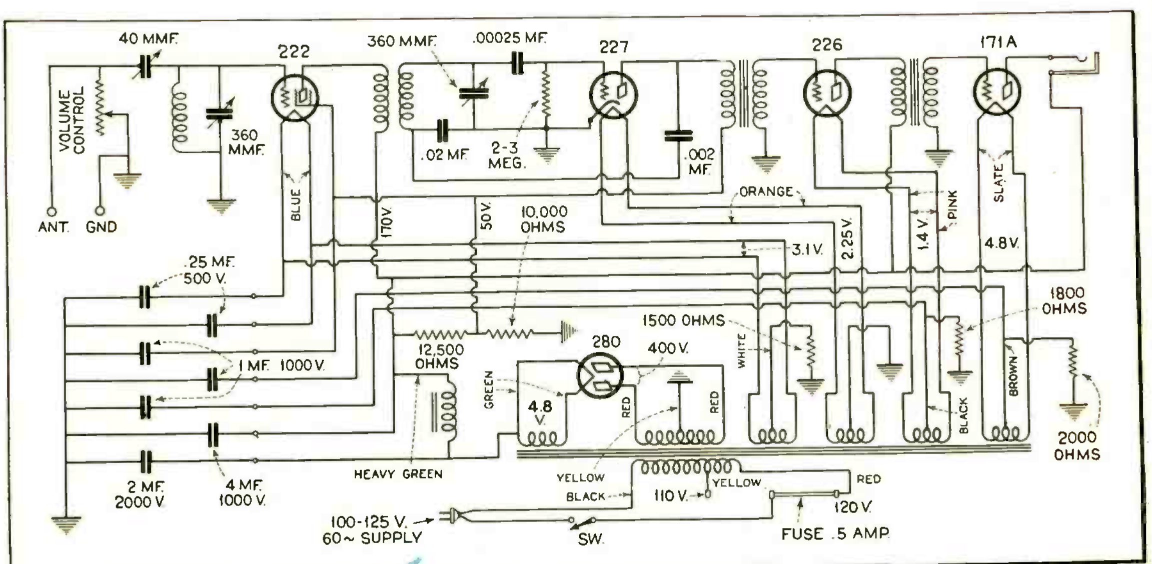
In this connection the reader should not believe that he is aiding the cause of his competitor in the event that his customer moves into a new locality and a new organization is called upon to service. What is true with his competitor is true with himself, if all servicemen make such records, hence all benefit and improve the status of the cause. A permanent record of material gleaned after a cross-examination and the analysis of the receiver will benefit everyone concerned. It is a record good for years of service and it facilitates diagnosis and service at a later date. Like the original cross-examination, it helps point to the trouble. If the records show that the tubes are a year old, and the present receiver provides little amplification, one immediately suspects the tubes. If the record shows that the last repair was the replacement of a certain audio-frequency transformer because the original unit "blew," and the present receiver is dead, one immediately suspects that stage of audio-frequency amplification and examines the continuity. If the records do not point to the ailment, they at least facilitate the complete analysis by providing information otherwise unavailable, unless the master of the house, who purchased and cared for the receiver, is at home.

The data contained on this chart should include the date of installation. If such a chart is not available at the first service call, the serviceman should ascertain the date of installation and make his permanent records. A full record of tube performance and electrical conditions is necessary. Peculiarities of receiver performance, local conditions, past symptoms and repairs are also of aid and should be recorded. The making of such a chart and application to a serviced receiver shows conscientious, capable servicing. It shows that the work is carried out in a systematic manner and the final result is the creation of public confidence. The chart is a continual reminder of good servicing. In the event of future trouble the receiver owner has a simple means of locating the name, address and telephone number of the serviceman. This information is accessible when he desires to give the name to his friends. * * * A silent, yet effective salesman.

Knowledge of Circuits and Operating Conditions

It is needless to continue examples of the beneficial effects of cross-examinations and charts. What has been said should suffice for the present. Let us turn back the progress of time and consider the case of the original call for the radio serviceman. We know, and definitely so, that in few instances do service stations ask queries about the problem at the home of the receiver owner when the original call for the serviceman is made. In this connection we do not wish a hasty conclusion by the reader. The queries in this case, do not refer to those mentioned before. Here our interest is the wiring diagram of the faulty receiver, or the power unit, if such be the case. Assuming that a call is received and an appointment made, what information is available to the serviceman? To declare a receiver repaired, he must know the correct operating conditions as set forth by the manufacturer. He likewise must know, wherever possible, the electrical constants of the various units within the receiver. This information is available on the wiring diagram of the receiver. Unless tabulated, the serviceman is at a loss when he attempts to analyze the radio set. Without questioning—without asking about the type of installation involved, he seeks an unknown quantity. Hence the suggestion that inquiry be made regarding the type of equipment involved and that the correct wiring diagrams be carried by the visiting serviceman. Now it is very likely that these wiring diagrams are not easily obtained. In that case, every effort must be made to secure them.

The significance of the wiring diagram cannot be fully appreciated unless one is confronted with the problem of servicing a radio receiver and the internal connections are not known. In this connection we know that many regret failure to clip out the wiring diagrams shown in many radio publications. We also know that many claim wiring diagrams unnecessary. With this we cannot agree, and the development of the a-c. receiver wherein the B-eliminator is an inherent part and binding post connections with voltage designation are



Schematic diagram of the Freshman Q15 receiver, using a stage of screen-grid radio-frequency amplification. Note that the filament of the screen-grid tube is supplied with "raw" alternating current.

not available, aggravates this condition.

Rated and Specified Tube Voltages

Many are prone to believe that the voltages applied to the filaments of the various vacuum tubes in a commercial receiver are the rated voltages quoted in all vacuum tube tables. This idea is erroneous and proves that voltage specifications and wiring diagrams are available. As concrete examples, we submit the following voltage specifications which show the correct voltage indications to be expected when a Weston or a Jewell set analyzer is applied to a receiver. Note that the filament voltages are below the tube manufacturers' ratings. Note that the filament voltage applied to the 226-type of tube, rated at 1.5 volts, is appreciably less than 1.5 volts. But if this information is not known, how can the serviceman be certain that the 1.35 volts applied to the filament of a tube rated at 1.5 volts is correct and predetermined in the design of the receiver? The same applies to the plate and grid voltages. How can one tell what the correct voltage readings should be unless the values are known? One would be justified in believing that the 1.35 filament voltage was insufficient, when the tube is rated at 1.5 volts, yet the former potential is correct. Examine the figures submitted and you will find that the correct voltage specifications are necessary and should be in the possession of every radio repair man. Note the correct voltage specification for 227 tubes as detectors.

Measurements made with a Jewel set tester, with tube in socket show the following correct values on Kolster Models No. K21, 23 and 24 with a line voltage of 116 volts: 226 tube=1.4 volts on filament; rated voltage 1.5. 227 tube=2.0 volts on filament, rated voltage 2.25.

Kolster Models 6F, J, K, R and 6L tube in tester socket: 226 tube=1.35 volts on filament, rated voltage 1.5. 227 tube=2.0 volts on filament, rated voltage 2.25.

As another illustration, the 171 tube in the above five receivers is supplied with a filament potential of 5 volts and a plate potential of 178 volts, but the correct grid bias is 36 volts, rather than the normal rated grid bias of 40.5 volts.

Then again, we have the Zenith models tested with the Weston set tester. The following voltages are correct with the tube in the tester socket for the model 34P, with a line voltage of 116: 227 tube=1.9 volts on the filament: rated filament voltage 2.25 volts. 210 tube=6.9 volts on the filament; rated filament voltage 7.5 volts. 281 tube=6.5 volts on the filament; rated filament voltage 7.5 volts.

The need for such voltage specifications is clearly evident. The most capable individual would imagine that 6.9 volts on the filament of a 210 tube, rated at 7.5 volts by the tube manufacturer, would indicate insufficient filament voltage. Yet the low value is correct and indicates correct operating conditions. At the present time we are collecting such data because we are certain that it will prove beneficial to the service phase of the radio industry.

Differences in Circuit Wiring

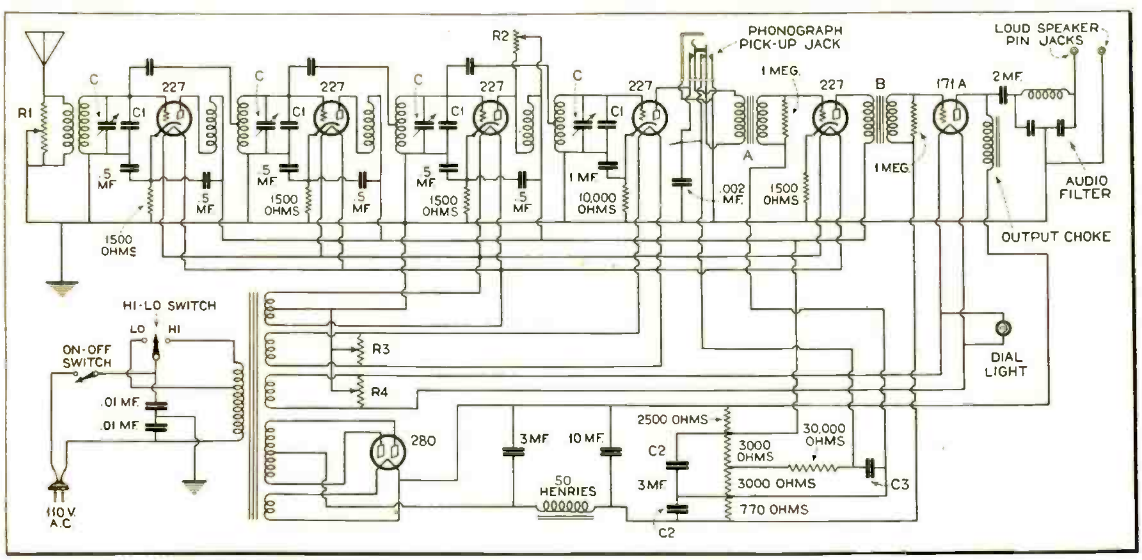
With respect to the need for wiring diagrams, may we refer to the three shown here; that of the Freshman Q15, the Atwater-Kent 37 and the Stromberg-Carlson 635-636 a-c. receivers. Without a diagram for reference, how can the serviceman know that the grid bias arrangements differ?

Compare the detector circuits in the Stromberg-Carlson and the Atwater-Kent receivers. If one were to test between the cathode and the B minus, the former would show a negative voltage applied to the grid of the detector tube, whereas the latter would show zero voltage, because the cathode is connected to the B minus terminal. Examine the source of grid potential applied to the 171 output tube in these receivers. In one case the grid bias is secured from the B-eliminator, in the other by means of voltage drop across a resistance in the grid-filament circuit. In one case the total eliminator drain flows through a resistance and the voltage drop is applied to the 171 tube. In the other case, the plate current of the 171 tube only is caused to flow through a resistance. But no matter what the arrangement it is evident that a wiring diagram is necessary in order to correctly analyze the receiver. If repairs are necessary, the problem is even more acute. How can one determine the correct electrical constant if the unit is damaged? It is naturally impossible and replacement is likewise impossible.

It is unsafe to judge wiring systems of defective receivers by tracing circuits. One is not certain if the arrangement present, is correct or incorrect and a wiring diagram is imperative. For example, the filter circuit of the Freshman and the A-K receivers; one utilizes a choke input and the other a condenser input. The need for the wiring diagram is very evident.

There are many other cases which prove equally as well the advantage of having at hand the circuit of the receiver being serviced. Do not forget that every set has its own circuit peculiarities.

He who believes that he can operate successfully without a wiring diagram is harboring a false premise of superior intellect.



Schematic diagram of the Stromberg-Carlson 635 and 636 receiver. Note the phonograph pick-up jack, and the audio filter in the output circuit.

The Screen-Grid Vacuum Tube

A Semi-Technical Article Covering Both the Theory and the Practical Applications of the Screen-Grid Tube, Including Its Use as a Space-Charge-Grid Amplifier

*By J. E. Smith**

THE screen-grid vacuum tube, first offered to the public late in 1927, is one of the major contributions which science has made to the radio industry. This tube, also called the "Shield Grid" and "Shield Plate" tube, is new only in the sense that its development to the stage of a practical device suitable for production in large quantities is comparatively recent.

Until a few months ago the three-electrode vacuum tube working into a carefully designed amplifier circuit, such as the neutrodyne, seemed to be the ideal for radio-frequency amplification. The screen-grid tube has, however, opened up an entirely new realm of possibilities for not only does it give much greater amplification per stage than the best of the three-electrode tubes but also the screen-grid does away with the necessity for neutralizing by virtue of the fact that it reduces the tube internal grid-plate capacity to a minimum value.

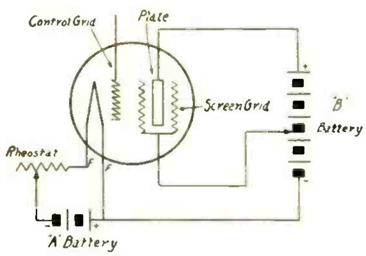


Fig. 3. General circuit connections for the screen-grid tube.

The fundamental principles of the screen-grid tube were discovered and investigated several years ago by Schottky, a German scientist. Two American research workers are, however, responsible for the tube in its present form. Messrs. Hull and Williams of the General Electric Company Research Laboratories, continued the research begun by Schottky, improved the screening and produced a tube which enabled them to achieve almost to the theoretical limits of amplification. This particular tube though, was a laboratory device not suited to economical manufacture. Further work finally led to a production model which retained a surprisingly large proportion of the excellent characteristics of the earlier tube.

* *President, National Radio Institute.*

MR. SMITH'S article on the screen-grid tube will be of particular interest to Set-Builders and Servicemen. The screen-grid tube is coming into general use and it is, therefore, important that everyone connected with the professional end of the field have the complete technical information.

Mr. Smith has presented the subject in complete form which makes it valuable as a reference work. Nothing has been left to the imagination.—Editor.

Before explaining the properties of this tube it should be pointed out that all tubes having two grids are not, necessarily, screen-grid tubes. For many years there have been vacuum tubes having more than one grid. Especially in Europe there have been sets and circuits designed and built around double grid tubes. These tubes are vastly different in their action and construction from the screen-grid type for in the usual double grid tube, such as has found wide application abroad, both grids have been used as control grids. Fig. 1 shows the general arrangement of the parts in a screen-grid tube. Instead of the usual three, there are four electrodes, the filament, the control grid, screen-grid, and the plate. It should be noted that "control grid" is a name which has been adopted in place of grid. This has been required by the fact that there are now two grids: (1) the control grid which has the same action as the grid of an ordinary three-electrode tube, and (2) the screen-grid, a new electrode which gives certain remarkable properties to the tube.

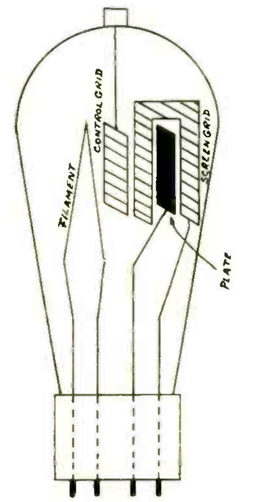


Fig. 1. Illustrating the general makeup of the screen-grid tube.

While the general external appearance is similar to that of an ordinary tube it will be found upon closer examination that the internal arrangement is quite different. The four prongs which extend through the base are used for connection into a circuit in the usual way except that the "grid" prong must be connected to the screen-grid circuit wire. A fifth connection, that of the control grid is brought out, through the glass top, to a small cap. (See Fig. 2-d.) By referring to Fig. 2 a general idea may be obtained of the construction of the screen-grid tube. The filament is a coarse spiral and forms the central element (Fig. 2-a). Surrounding the filament and spaced from it by a few thousandths of an inch is the control grid which is made up of a fine spiral mesh (Fig. 2-b). The plate is an open ended cylinder of thin sheet metal placed outside of the

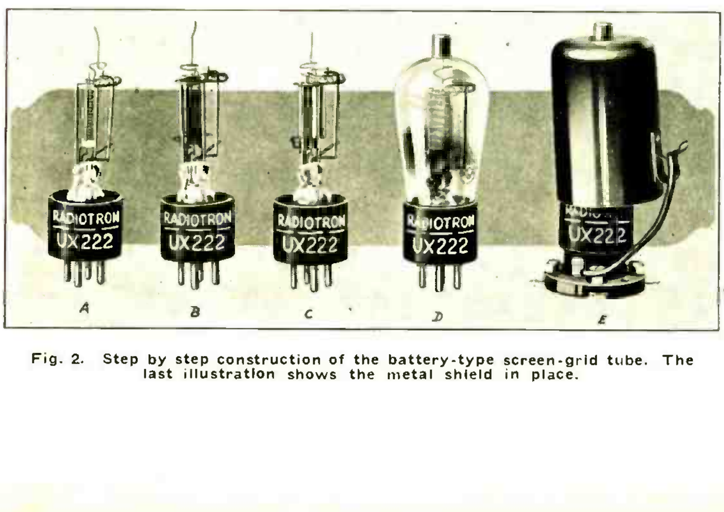


Fig. 2. Step by step construction of the battery-type screen-grid tube. The last illustration shows the metal shield in place.

control grid (Fig. 2-c). The screen-grid is in three sections, the first is a fine spiral mesh between the control grid and plate, the second a spiral mesh surrounding the plate, while the third is a flat metal disc which connects the upper portions of the two mesh sections. Fig. 2-d shows the outer spiral mesh and the metal disc

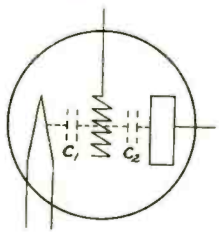


Fig. 4. Diagram of inter-electrode capacities in the three-element tube.

portions of the screen-grid but the inner mesh is hidden by the plate.

The object of the screen-grid is to electrically shield the control grid from the plate. To accomplish this and obtain the necessary degree of shielding requires the most accurate and careful mechanical construction of the electrodes located in the small space within the tube.

"A" and "B" Batteries

The screen-grid vacuum tube requires for its operation a filament or "A" battery and a plate or "B" battery. As in the three electrode tube the "A" battery is used to heat the filament to incandescence, while the "B" battery furnishes the energy which increases the effect of the radio waves. In addition, the screen-grid must be kept at a voltage higher than the filament. This is most conveniently done by tapping the plate battery at a point which will give from ¼ to ⅓ the full plate voltage. A diagram of the screen-grid vacuum tube with the necessary battery connections is shown in Fig. 3.

Comparison With Three-Electrode Tube

Before proceeding further it should be thoroughly understood that the ac-

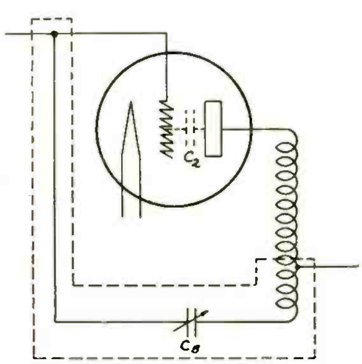


Fig. 5. Neutralizing circuit for three-element tube. C_B is the balancing capacity.

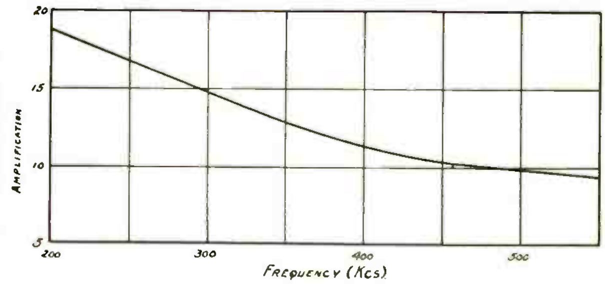


Fig. 8. Amplification curve of standard three-electrode tube of the 201-A type. Compare this with the curves of Figs. 9 and 10.

tion of the filament, plate and control grid are exactly the same as for similar electrodes in the older tubes. The filament emits the electrons which act as the current carriers of the plate current between plate and filament, and the control grid is the device which regulates the amount of plate current which flows between the plate and filament.

Interelectrode Capacity of the Three Electrode Vacuum Tube

In Fig. 4 is shown a diagram of a three-electrode tube illustrating the capacities which exist between the va-

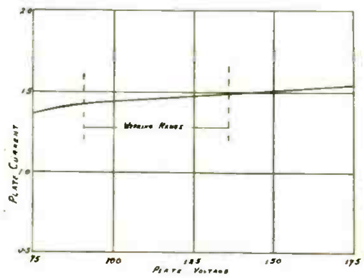


Fig. 7. Plate voltage, plate current curve of screen-grid tube.

rious elements. Of particular importance is the condenser C2 resulting from the capacity between the grid and the plate. This capacity in the average three-element tube has a value of from ten to fifteen micromicrofarads.

In the early days of vacuum tube amplification at radio frequencies this small capacity was of no importance because the frequencies in use were in the low range. With the advent of broadcasting on frequencies in excess of seven hundred kilocycles and, later, with the discovery that frequencies higher than three thousand kilocycles were worth-while for long distance communication, the problem of grid-plate capacity became one of utmost importance.

It will be recalled that the reactance of a condenser to the passage of alternating current depends on the frequency of the current. At low frequencies the reactance is very high and a small capacity such as exists between the grid and plate of a vacuum tube of the three-element type will pass a negligible amount of current. As the frequency is increased, however, the reactance of a condenser becomes smaller and consequently larger and larger currents are passed. When using ordinary tubes as radio-frequency amplifiers it is found that the reactance of C2 at frequencies higher than about seven hundred kilocycles becomes so low that sufficient energy is passed from the plate circuit through the grid-plate capacity (C2) to the grid circuit to cause instability or oscillation. Reduced signal, poor quality and howling are some of the bad effects which result from this feedback condition. Balancing or neutralizing schemes are necessary to counteract the feedback which is so detrimental to radio-frequency amplifying circuits. A balancing circuit, shown in Fig. 5, introduces a small condenser in the circuit. This condenser is connected at one side to the grid and on the other side to a point on the plate coil which is below the effective ground tap. The condenser, when properly adjusted, carries a current equal to but opposite in phase from that which passes through C2. Hence the two currents "neutralize" or "balance out" and oscillation and instability are prevented. It should be noted, however, that balancing does not prevent the feedback.

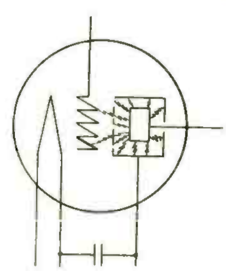


Fig. 6. Illustrating the function of the screen-grid.

Defects of Balanced Circuits

At best, balancing is merely a "way out." It does not do away with the cause of the trouble yet requires more complicated circuits. At the very high frequencies (above 3000 kc.), it is nearly impossible to obtain a balance no matter how carefully the circuits are laid out and adjusted. Furthermore, whenever a tube is changed it is frequently necessary to rebalance because the grid-plate capacity of the replacement tube is not the same as that of the tube which has been removed.

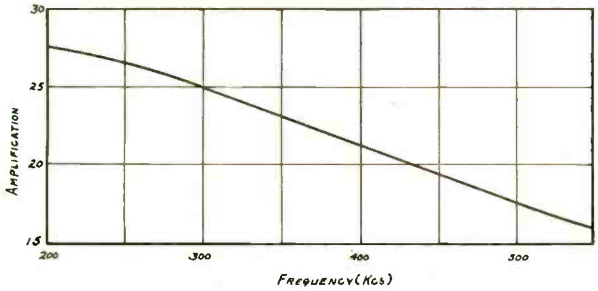


Fig. 9. Amplification curve of a "high-mu" tube, of the 240-type. Compare this with the curves of Figs. 8 and 10.

Grid-Plate Capacity of the Screen-Grid Tube

In the screen-grid tube the grid-plate capacity has been almost entirely eliminated and has a value of only 0.1 micromicrofarad, or one one-hundredth of the capacity present in the three-electrode tube. This low grid-plate capacity has been achieved by inserting a screen or "shield" between the control grid and plate. In Fig. 6 the screen-grid tube is shown in diagrammatic form. The screen-grid is shown completely surrounding the plate and the lines of electric force which, in the three electrode tube run from plate to grid, are now intercepted by the shield. The screen-grid is kept at "ground" potential by means of a large capacity C which is connected on one side to the screen-grid and on the other to the filament. Hence, only a few of the lines of electric force pass through the screen to the control grid with the result that the capacity is very small.

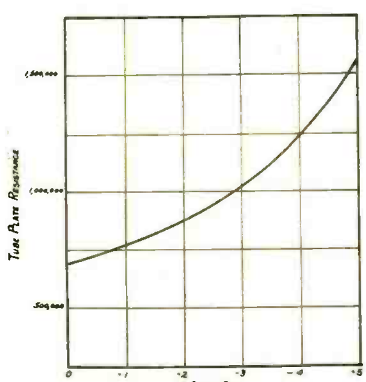


Fig. 11. Graph of plate resistance of screen-grid tube, plotted against control-grid bias. Compare this with Fig. 12.

Since the control grid-plate capacity is almost negligible it follows that changes in the plate circuit will have no appreciable effect on the control grid circuit for there is no path for the feedback. Consequently there is no instability or oscillation to hamper the radio-frequency amplifier performance.

The practical elimination of the control grid-plate capacity does away with the necessity for balances and the intricate circuits associated therewith. Also, radio-frequency amplification may be obtained with the screen-grid tube at frequencies as high as 100,000 kilocycles.

Characteristic Curve

Another interesting feature of screen-grid tube performance may be discovered by examination of a characteristic curve. In Fig. 7 the plate current is plotted against plate volts with a fixed control grid and screen-grid bias. Between the limits of 90 and 145 volts on the plate, which is the limit of operating voltage, there is a change in plate current of only 0.1 milliampere. In the ordinary three-electrode tube a similar change of plate voltage would cause a current variation of nearly 9 milliamperes. The practical value of small current variation due to voltage changes on the plate is readily seen when modern radio circuit power supply systems are considered. The majority of the new broadcast receivers as well as many older types make use of plate or "B" current supplied through rectifiers or filters from house lighting power. Such a power supply is subject to changes in voltage which, of course, affect the plate voltage. The screen-grid tube remains unaffected by small voltage changes and is unlikely to reflect, except in limited degree, fairly large variations in the plate supply.

Radio-Frequency Amplification

One of the major improvements to be found in the performance of the screen-grid tube is the exceptional sensitivity resulting from its high amplification factor. Fig. 8 shows the amplification to be expected from an ordinary three-electrode tube at various frequencies; Fig. 9 is a graph of the amplification obtained with a so-called "high-mu" tube while Fig. 10 shows the extraordinary amplification possible with the screen-grid tube. Laboratory amplifiers have been built which used several special screen-grid tubes. These amplifiers proved so sensitive that the effect of electrons striking the plate of the first tube has been heard as a roaring noise in the loud-speaker connected to the output stage.

The high amplification comes about as follows: Due to the absence of control grid-plate capacity of appreciable value, the plate resistance of the commercial screen-grid tube is extremely high. From Fig. 11 it will be found that the d-c. plate resistance may vary from 850,000 ohms to 1,600,000 ohms under usual conditions, as compared with 9,000 to 10,000 ohms (Fig. 12) in a three-electrode tube. By reason of its very high value, which may be considered as infinitely large, the screen-grid tube alternating current plate resistance may be neglected as a factor in determining the amplification. Hence, the amount of voltage amplification obtainable depends on the amount of resistance which can be placed in the external plate circuit of the tube times the mutual conductance of the tube itself. The mutual conductance has a constant value for any one grid potential, therefore the amplification of the screen-grid tube is in proportion to the amount of resistance in the external plate circuit. Fig. 13 shows graphically how the amplification factor increases with the plate circuit resistance.

It is, then, highly important that a kind of plate circuit be selected which

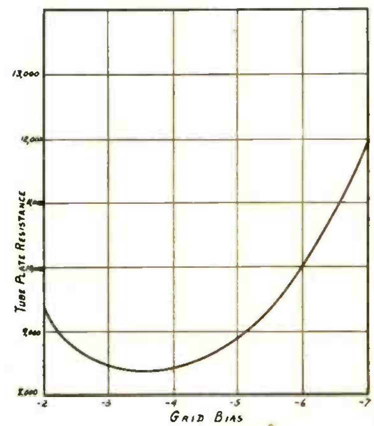


Fig. 12. Plate resistance curve of a three-electrode tube. Note the low value as compared to Fig. 11.

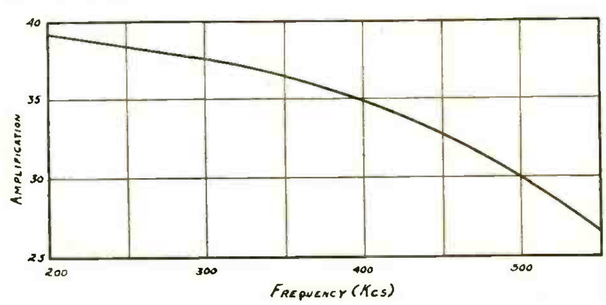


Fig. 10. The amplification curve of a screen-grid tube. It will be noted that this curve is superior to the curves shown in Figs. 8 and 9.

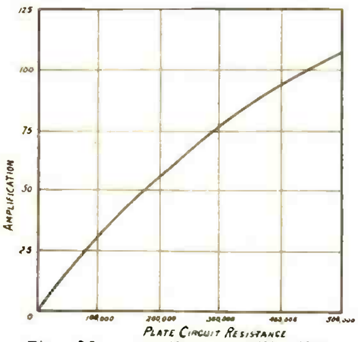


Fig. 13. Another amplification curve of the screen-grid tube. Note the direct increase in amplification with increase in plate circuit resistance.

will have the required extremely high resistance. A tuned plate circuit having a large inductance and small capacity fulfils the condition. In Fig. 14 is a diagram of a tuned plate circuit in combination with a screen-grid tube. Fig. 15 shows the resistances which may be obtained at various frequencies from carefully designed resonant impedances of the type used in the tuned plate circuit in Fig. 14.

In theory the nearer the external plate resistance matches the tube internal plate resistance the better the circuit and tube function together. This condition holds for the three-electrode tube where the highest amplification from stage to stage is obtained when the tube and circuit resistances are equal. In screen-grid tube circuits this rule must be modified. It is, of course, necessary to couple each stage of amplification to the following tube. By doing so the resistance of the plate circuit is decreased, by an amount depending on the tightness of the coupling. If the coupling is made in a manner which permits of high plate resistance (above 200,000 ohms) it will be found that the grid of the following tube will get but little excitation and consequently the overall efficiency of the amplifier will decrease, though one stage may be operating at a very high rating.

The Space-Charge Grid

A further use of this adaptable tube requires a different connection from that specified in the preceding description. Fig. 16 shows the tube hooked up as a "space-charge grid" amplifier. In this case the inner grid is given a positive potential, while the outer or screen-grid performs the functions of the control grid.

It will be remembered that a heated filament emits electrons if, as in the case of an electric light bulb, there is nothing to prevent. the electrons from being attracted back to the filament at the same rate as they are emitted. In the three-electrode vacuum tube the plate is given a positive charge and some of the electrons (negatively charged) which are emitted by the filament are attracted to the plate. For a given plate voltage a certain number of electrons are attracted to the plate while the rest rejoin the filament. As the plate voltage is increased more electrons are attracted to the plate. The reason that all of the electrons emitted by the filament do not go to the plate is that the "space-charge" between the two elements limits the electron flow. The space-charge is the repelling effect of the electrons upon themselves and since the electron cloud is most dense near the filament so the space-charge is highest in that location.

Now, if an electrode be introduced very close to the filament and a positive potential placed upon it, this electrode will exert a great attraction upon the electrons in the cloud around the filament and cause a material reduction in the space-charge. The inner grid of the new tube, when hooked up as in Fig. 16, serves just this purpose. Its positive potential neutralizes the space-charge and imparts a tremendous velocity to the electrons leaving the filament. Because of the grid structure only a few of the electrons are actually intercepted by the inner grid. The great majority pass through the space between the openings to come under

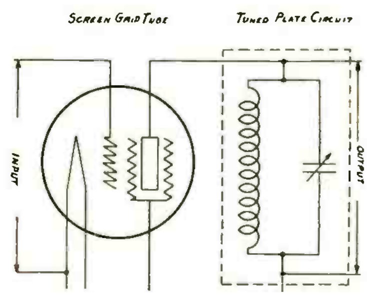


Fig. 14. Diagram of the elements of the tuned plate circuit in combination with the screen-grid tube.

the controlling influence of the outer grid which is now acting as the control grid. If the control grid happens to be positively charged, the electrons which have come through the inner grid are further accelerated and proceed to the positively charged plate. Should the outer (control) grid be negatively charged the electrons would, of course, be repelled and would not reach the plate. The practical results of the space-charge grid connection may be summed up as:

(a) That the plate current for a given plate voltage is much increased.

(b) That the mutual conductance of the tube is increased.

The grid-plate capacity has reappeared with this type of hook-up, however, making the tube of no use as a radio-frequency amplifier. It is in the audio-frequency circuits that the space-charge grid finds its field of usefulness and a very high amplification per stage can be obtained at the audio frequencies. It will be improbable that more than one stage of space-charge audio amplification, followed by an output tube, will ever be necessary for ordinary purposes.

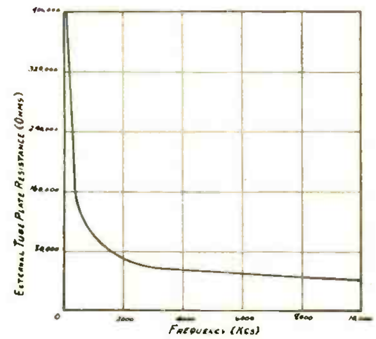


Fig. 15. Graph of the maximum resistance obtainable using the tuned plate circuit with the screen-grid tube.

Practical Application of the Screen-Grid Tube

Having discussed the means by which the screen-grid tubes accomplish their extraordinary performance, it remains to show the methods and circuits required for utilizing the tube in practice. First of all comes the necessity for the thorough shielding of all external circuits. The manufacturer in making the screen-grid tube has done an excellent job in eliminating the capacity between the control grid and plate. His work will be nullified, however, if circuit capacities are permitted to act in the same manner as the old grid-plate capacity. Without proper external shielding the operation of the screen-grid tube is impaired. In Fig. 17 the capacities which may exist in the external circuits are depicted. Since they couple plate and control grid circuits together, it can be understood that feedback is again possible and that balancing or neutralizing methods will be required once more. Thus, one of the prime factors in the excellence of the screen-grid tube will have been lost through careless assembly or wiring.

The screen-grid tube is a very fine and sensitive device. It is not pretended that this tube can be used in a "haywire" hookup with any degree of success. The circuits to which the tube is connected must be carefully laid out and shielded from one another and from the tube in order that the full possibilities of this new tube may be realized. In Fig. 18 a single tube

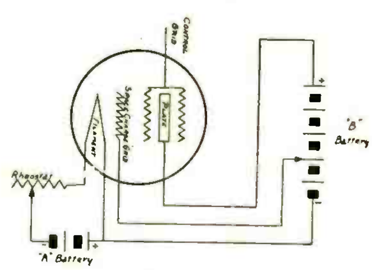


Fig. 16. Circuit connections for the screen-grid tube used as a space-charge amplifier.

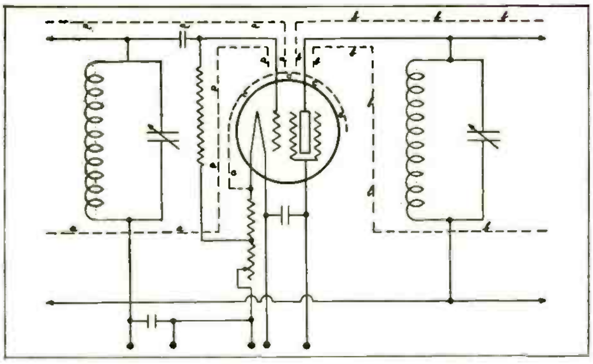


Fig. 18 Sketch of the shielding required for the most efficient operation of the screen-grid tube. The tube, particularly, should be shielded.

is shown connected to the external circuits necessary for a single stage of radio-frequency amplification. The dotted lines represent the shielding which should be used for the effective action of the amplifying unit. In Fig. 18, a-a-a-a is the shielding around the control grid circuit. Notice that it completely surrounds the tuning coil and condenser of the input circuit and effectively confines all of the radio-frequency field within the limits of the shield. An extension of the shielding in the form of a small metal tube may lead to a point close to the control grid terminal so that only a fraction of an inch of unshielded connecting wire will be exposed. The plate circuit shield, represented by b-b-b, is as thorough as that of the grid shielding. Once more all of the elements of the radio-frequency circuit are confined within the shield which extends to within a short distance of the plate terminal at the tube socket. The shielding shown as c-c-c is a metal jacket fitting closely over the glass bulb of the tube, but having a hole with an insulated bushing at the top through which connection is made to the control grid.[1] The shielding for the plate and control grid circuits is in the form of a metal box or compartment for each circuit. In addition, it is desirable to have a separate small special compartment for the tube itself. The general layout of the compartments may be along similar lines to that shown in Fig. 19.

Shielding is also helped by keeping the control grid and plate wires as far apart as possible. This has been made relatively easy by the construction of the tube which brings the control grid out of the top and the plate out of the bottom of the tube assembly. A further aid is to make the control grid and plate connecting leads as short as possible in order that the capacity may be decreased and the coupling losses to the shield reduced. If these cautionary shielding measures are carried out a long step towards satisfactory screen-grid tube operation will have been taken.

It is important that the screen-grid be kept at "filament" potential with respect to radio-frequency currents. From the foregoing explanation of the action of the screen-grid it will have been seen that the duty of the screen is to intercept the electrostatic lines of force between the plate and the control grid. If, however, the screen-grid is at a higher radio-frequency potential than the filament a charge will be induced on the control grid and feedback will take place. The resistance of the

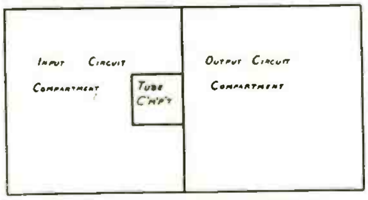


Fig. 19. The box layout which insures proper shielding. This, or a similar arrangement, should be followed.

"B" battery, especially when low, or the choking action of long or small wires may be the means for keeping the screen-grid at a high radio-frequency potential with respect to the filament. To avoid this condition a large capacity condenser, about 0.5 microfarad, is connected between the screen-grid and the filament. To assure that this condenser will act efficiently in by-passing the stray radio-frequency energy, the location should be as close to the tube socket as possible, with short leads to the socket terminals. By so doing the radio-frequency energy chooses the low impedance path represented by the condenser. Thus, long wires or battery circuits in which there may be considerable potential drop at high frequencies are avoided and the screen-grid is thoroughly grounded.

Selectivity

The trend of radio receiver design is always along the lines of increasing sensitivity, better selectivity and improved quality. The advent of the screen-grid tube solves beyond question the problem of sensitivity. With amplifications of from 20 to 40 per stage easily obtainable at the broadcast frequencies, one or two stages of screen-grid amplification will satisfy the desires of the most rabid of broadcast listeners as far as distance is concerned. The increased sensitivity has resulted in no loss of quality and, as a matter of fact, the quality will usually be improved because of the elimination of feedback and the absence of regenerative circuits.

In the matter of selectivity, however, the application of the screen-grid tube does have certain limitations. It has been quite the custom to rate the sensitivity of a radio receiver in terms of the number of tubes employed in the radio-frequency amplifying stages. It is quite as correct and fully as important to regard the selectivity of a receiver as another function determined by the number of tuned radio-frequency stages. In other words, several stages of radio-frequency amplification are desirable not only for the sake of sensitivity but also for the necessary selectivity.

Under the present conditions of broadcast reception the general custom has been to demand a selectivity such as will be produced by two well designed tuned radio-frequency stages (three tuned circuits) or one radio-frequency stage (two tuned circuits) with a regenerative detector.

The screen-grid tube, when employed in place of a three-electrode tube in a radio-frequency amplifier, will have the following effect on selectivity:

(a) With the same number of stages the *effective* selectivity will be reduced because of the large gain in sensitivity.

(b) With fewer stages the selectivity will be reduced because of the fewer tuning circuits.

From the foregoing explanation it will be seen that special attention must be paid to the tuning circuits in order that the necessary selectivity be obtained. Coils of ample dimensions, good quality condensers and other parts, and the elimination of stray couplings, which increase resistance, are some of the requirements demanded of the screen-grid circuits.

(To be continued)

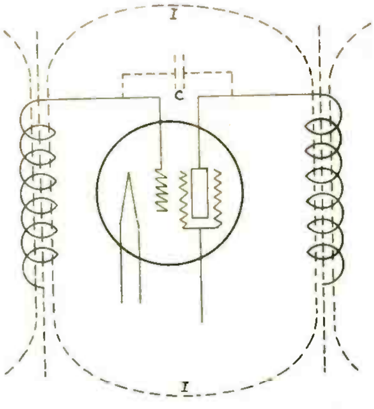


Fig. 17. Capacitive and inductive coupling is detrimental to the operation of the screen-grid tube. Shielding should be used.

[1] *The usual metal jacket should not be used with an A.C. screen-grid tube. Ventilation is required.*

The Hammarlund-Roberts A-C "Hi-Q 29"

By Joseph Riley

SINCE the appearance of the screen-grid tube on the market there have been several more or less successful attempts to employ it in a receiver. One of the outstanding sets in which this tube was successfully used was the Hi-Q 29, which was described in the September, 1928, issue of RADIO ENGINEERING.

This receiver was entirely d-c. operated, but since the a-c. screen-grid tube has been introduced, slight changes were made in the Hi-Q 29 for its incorporation. It has been found that this set is now more sensitive because the mutual conductance of the new 2.25-volt screen-grid a-c. tube is 1000. Also the hum is negligible because of the indirect heating of the cathode.

Let us briefly review the theory of this receiver. The circuit employs two screen-grid tubes operating at maximum efficiency, followed by a detector and two-stage transformer-coupled audio-frequency amplifier. The special "tuned-grid, tuned plate" circuits are responsible for the excellent sensitivity and selectivity of the set. These two stages are band-pass filters, as both the grid and plate coils of each stage are tuned to exact resonance by separate variable condensers. This type of circuit makes it possible to use a greater proportion of the possible amplifying properties of the screen-grid tube than if any other circuit were employed.

Operating Principles

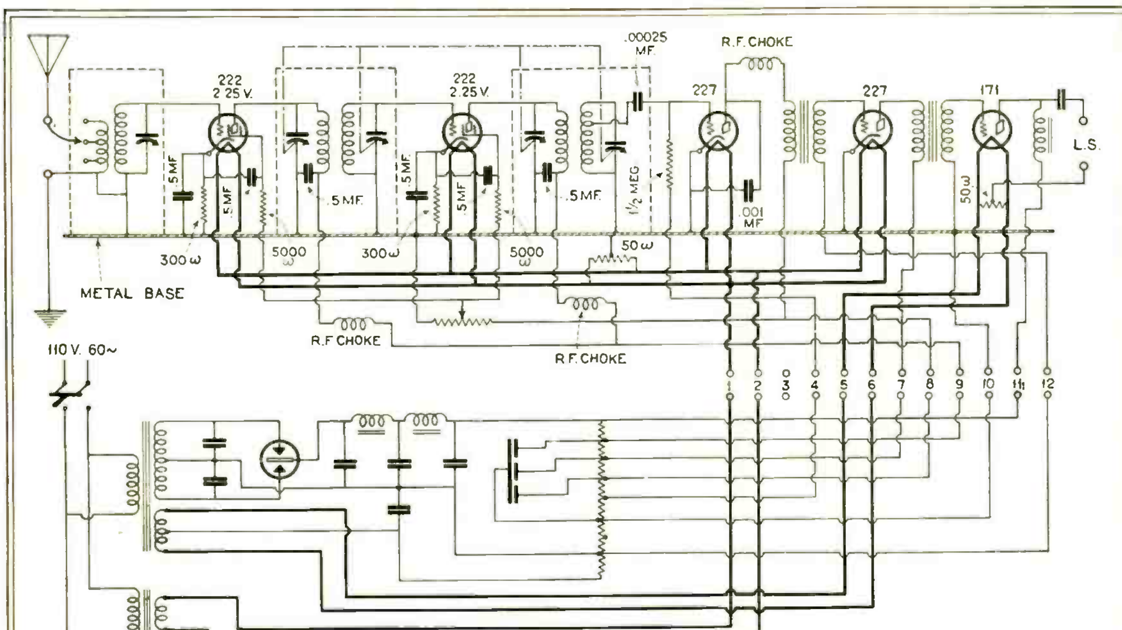
The remarkable performance of this receiver can best be understood by consideration of the principles involved in its design. The interstage r-f. transformers are quite unique, in that they consist of two exactly similar coils. One constitutes the primary of the transformer and is connected in the plate circuit of the preceding tube, the other coil acts as the secondary and is connected to the grid of the following tube. Each coil is tuned to resonance with the desired signal by means of a .00035 mf. variable condenser. Due to the rather unusual mounting arrangement the mutual inductance of coupling between primary and secondary is very small. However, this does not mean that the energy transfer from primary to secondary is inefficient. On the contrary, when two tuned circuits are coupled to each other, the maximum secondary voltage is obtained when the relation $(2\pi f)^2M^2 = R_1R_2$ is satisfied, where f = frequency to which both circuits are tuned, M = mutual inductance in henrys, and R_1 and R_2 are the effective radio-frequency resistance of the primary and secondary respectively. In the case of the coils used in the receiver under discussion the maximum secondary voltage is obtained with a coupling coefficient of the order of one per cent. The physical arrangement of the coils, as shown in the photograph of the completed receiver, was chosen because it seemed the simplest way to secure such loose coupling while still keeping the coils close to each other, thus conserving space.

Due to the inherent characteristics of loosely coupled tuned circuits each of these doubly tuned r-f. transformers really constitutes a band-pass filter.

While one of these double-tuned r-f. transformers provides an unusual degree of selectivity, the use of two such stages in cascade results in a vast improvement.

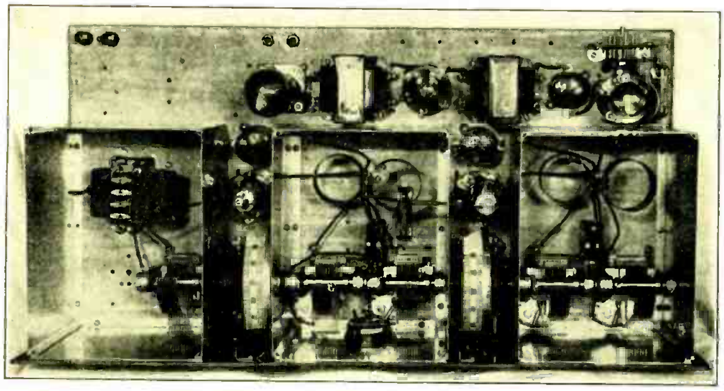
Rectangular Resonance Curve

The width and flatness of a resonance curve has an important bearing on the quality of the received speech and music. This is due to the fact that a broadcast station does not transmit on a single frequency, but rather on a band of frequencies. The width of the side bands varies somewhat depending on the transmitter adjustments and also on the type of program being broadcast. They are, however, generally conceded to be about five kilocycles wide for high-quality transmission. It is therefore apparent that the receiver should be capable of amplifying a band of frequencies substantially uniformly if the program is to be received faithfully. Hence



CIRCUIT DIAGRAM OF
HAMMARLUND-ROBERTS "HI-Q 29" RECEIVER
(MASTER A.C. MODEL) USING 2.25 V. A.C. TUBES.

This model employs heater-type tubes with 2.5 volt (rated) filaments; two screen-grid tubes, two 227s, and a 171 with five volt filament. The radio-frequency amplifier is a form of band-selector circuit.



Interior view of the "Master A.C. Model," Hi-Q 29. Note that the screen-grid tubes are between the shields, not inside of them. This arrangement provides sufficient shielding, and ventilation besides.

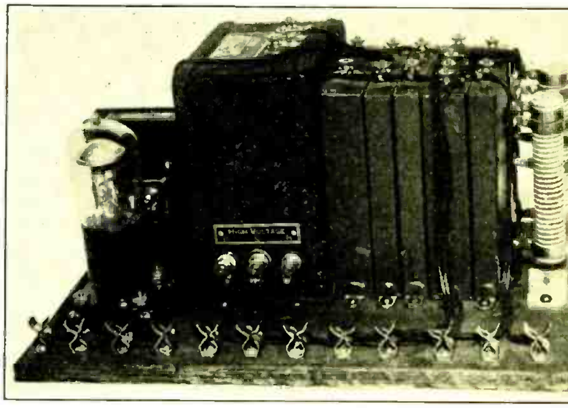
the desirability of the wide flat top on the overall response curve of a high-grade receiver. When the top of the response curve is sharp instead of flat all the frequencies in the band are not amplified equally. Consequently certain of these frequencies reach the detector much stronger than others with the result that even the most perfect a-f amplifier and loud speaker will be unable to reproduce the program with its original quality. This is the type of distortion referred to previously as "side band cutting," and usually results in the loss or weakening of the high audio frequencies making the output from the loudspeaker dull and muffled.

The two double tuned r-f transformers used necessitates the use of four variable condensers—one to tune each of the four coils. Since all four of the tuned circuits are identical these four variable condensers are rotated by a common shaft actuated by a new model drum dial having a smooth positive drive without backlash. The tuned input circuit to the grid of the first screen-grid tube, often referred to as the antenna coupler, is of the conventional type having a tapped primary making it adaptable to different length antennas. The variable condenser tuning this antenna coupler is on a separate shaft and has a separate drum dial, thus enabling this circuit to be tuned to exact resonance with the received signal, regardless of the type of antenna used.

The Volume Control

The volume control is quite out of the ordinary and is made possible only by the characteristics of the screen-grid tubes. It consists of a 100,000 ohm potentiometer, connected across the 45-volt "B" supply. The center tap of this potentiometer provides a variable voltage which is impressed on the screen-grids of the two r-f amplifier tubes. The amplification obtainable from these tubes varied within wide limits as the voltage on the screen-grids is changed, being at maximum around 45 volts and dropping rapidly as the screen-grid potential is reduced. This provided a very smooth control of volume within wide limits without affecting quality or tuning in the slightest degree.

While the screen-grid tubes have a very low value of capacity between plate and grid, thus almost entirely obviating the tendency of feedback through the tubes themselves, causing self-oscillation, this advantage is nullified if feedback occurs in other parts of the receiver. Taking this into consideration every effort has been made to isolate all circuits in which coupling might result in instability. The negative bias for the grids of the r-f tubes is secured by the drop across individual resistors in series with the cathodes. Since the screen-grids of both these tubes are biased by the 100,000 ohm potentiometer, a 5000 ohm isolating resistor is inserted in the lead to each of the screen-grids, which are in turn by-passed by means of separate one-half mf. by-pass condensers. The plate circuits of these tubes are likewise isolated by individual filters consisting of separate radio-frequency choke coils and by-pass condensers. In addition to the above mentioned precautions the entire r-f end of the receiver is thoroughly shielded. Each stage is entirely enclosed in a snug fitting aluminum box which is securely fastened to the metal chassis. The screen-grid tubes are so located that the leads to the control grids are as short as possible and farthest away from the plate leads which are also very short. By placing these tubes between the cans, as shown in the photograph, the can sides are used also as tube shields effectively preventing coupling between the tube elements and other parts of the circuit. This arrangement provides the minimum coupling between output and input circuits, which is extremely important.



A view of the Hi-Q 29 Power Unit. This includes the power transformer, the filament heating transformer, the condenser bank and the resistor units or voltage divider. Note that the full-wave rectifier tube is of the gaseous conduction type.

LIST OF PARTS REQUIRED

5—Hammarlund No. ML-17 .00034 mf. Midline Condensers.
1—Hammarlund No. "Hi-Q 29" Coil Set.
2—Hammarlund N. SDW Knob-Control Drum Dials (Walnut).
3—Hammarlund No. RFC-85 Radio-Frequency Chokes.
6—Benjamin Cle-Ra-Tone Sockets, No. 9040.
1—Sangamo .00025 mf. Fixed Mica Condenser.
1—Sangamo .001 mf. Fixed Mica Condenser.
1—Electrad Royalty B; 100,000 ohms.
1—Carter No. 11-S "Hi-Pot" Potentiometer with switch, 100,000 ohms.
2—Thordarson No. R-300 Audio Transformers.
1—Thordarson No. R-196 Choke Coil.
1—Thordarson No. R-171 Power Compact.
1—Thordarson No. T-2504 Filament Transformer, 3 volt.
6—Parvolt .5 mf. Series 200 By-Pass Condensers.
1—Parvolt 4 mf. Series 200 By-Pass Condenser.
1—Parvolt 3 mf. By-Pass Block.
1—Parvolt 1 mf. Series 200 Filter Condenser.
1—Parvolt 2 mf. Series 200 Filter Condenser.
1—Parvolt 4 mf. Series 200 Filter Condenser.
1—Parvolt 2 mf. Series 400 Filter Condenser.
1—Durham Metallized Resistor, 1½ megohms.
2—Durham Metallized Resistors, ¼ megohm.
1—Yaxley No. 612 Cable Connector and Cable.
1—Yaxley No. 660 Cable Connector and Cable.
1—Pr. Yaxley No. 422 Insulated Phone Tip Jacks.
1—Electrad "Truvolt" "Hi-Q 29" Type Resistor.
1—Electrad "Truvolt" 100 ohms.
2—Eby Engraved Binding Posts.
1—"Hi-Q 29" Master Foundation Unit (containing drilled and engraved Westinghouse Micarta panel, three complete aluminum shields, drilled steel chassis, shafts, binding post strips, Fahnestock clips, fixed resistance units, resistor mounts, brackets, clips, wire screws, nuts, washers, and all special hardware required to complete receiver) Hammarlund Manufacturing Co., Inc.

The Portable Screen-Grid Find-All Four

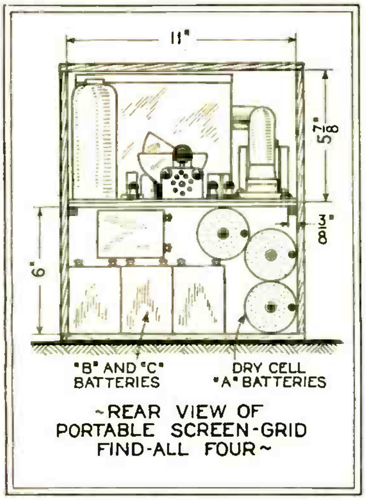
By H. G. Cisin, In. E.

FIRST of all, the set builder will want to know something about the capabilities of the Portable Screen-Grid Find-All Four. This set brings in local stations on the loop with suprisingly good volume. Even though high-ratio audio transformers are used, the tone quality is excellent. All local stations can be separated readily, even in congested broadcast districts. Naturally the use of the loop adds to the selectivity of the receiver. It is possible to increase the distance range of this set still further, by connecting an aerial and ground to a single turn loop, which is closely coupled to the loop ordinarily used for reception.

The loop takes the place of an antenna coupler. In its technical features, the circuit is the same as that of the original Find-All Four receiver. There is a stage of radio frequency using a screen-grid tube, a regenerative detector and two transformer coupled audio stages.

Only one Silver-Marshall shield is used in this set. A Carter shield is required for the screen-grid tube. Single dial tuning is attained by "ganging" together the two Hammarlund "Mid-Line" condensers. A small equalizing condenser is shunted across the loop. An Aero three-circuit tuner is used to couple the r-f. stage to the detector.

The constructor will find the portable Screen-Grid Find-All Four easy to assemble and still easier to wire. The sub-panel method of construction is followed, with most of the wiring performed beneath the sub-panel. Corwico Braidite has been found



Constructional and layout drawing, indicating the position of the "A", "B" and "C" batteries.

most suitable and convenient for work of this sort.

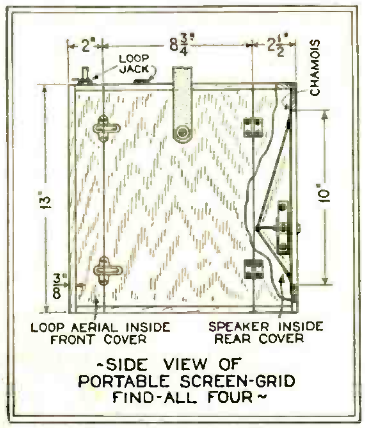
All parts of the Portable Find-All Four, including the set itself, the necessary dry batteries, the loop and the cone speaker are housed in a wooden box 11¾" wide, by 13" high, by 13⅛" deep. The receiver itself occupies the upper part of the box space, while there is plenty of room in the lower portion for the necessary "A," "B" and "C" batteries. The set requires three 1½-volt dry cells in series for the filament supply. The screen-grid tube draws .132 amp., the 120 tube draws .125 amp., while each 199 tube draws only .06 amp. The total "A" current required is .377 amp. Six 22½-volt small size dry cells are used as the "B" battery. An additional 22½-volt cell serves as the "C" battery.

The loop is wound within the front cover. The cover swings open on loose-joint hinges. These permit the cover to be removed and placed on top of the set when the loop is to be used. When in use, the loop rotates upon a small brass rod, which fits into small jacks in the top of the box and in the cover. The loudspeaker is constructed within the rear cover. This also, is on loose-joint hinges and may be rotated away from the set or removed and placed at a distance from the set. when in use. A thin-type direct driven electromagnetic speaker unit is used. The driving pin is fastened to the cone, with its apex towards the box and off-center, as shown in the illustration.

If the Screen-Grid Find-All Portable is to be used as a permanent automobile receiver, the "A" supply may be obtained from the car's storage battery. 201-A Gold Seal tubes should be used instead of the 199's and a 112-A instead of the 120. To increase the volume the chassis of the car may be used as a ground or counterpoise and an aerial may be used on the top or just blow it. Binding posts are provided for these two connections, although the receiver operates exceedingly well on the loop alone.

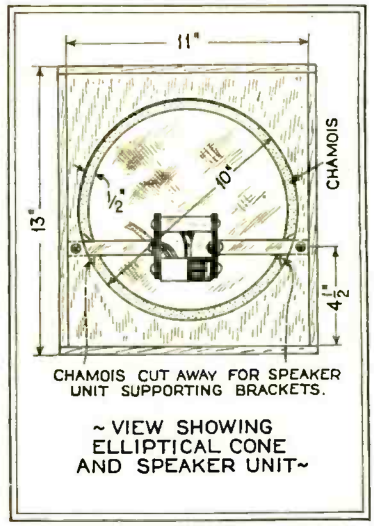
LIST OF PARTS REQUIRED

1—Aero Universal 3-Circuit Tuner, type U-55, with fixed tickler unused and with rotable primary used as tickler; or Aero Universal Coil type U-7 (16).
2—.0005 mf. Hammarlund "Mid-Line" Variable Condensers (7, 10).
4—Eby Sockets, UX type (9, 20, 26, 29).
1—Electrad "Royalty" Resistance, type "F" (21).
1—2 meg. Durham Metallized Resistor Grid Leak with Durham Vertical Single Mounting (19).
1—.00025 mf. Polymet Bakelite Fixed Mica Grid Condenser (18).
2—Thordarson Transformers, 3½ to 1 ratio, type R-150 (25.28); or a 6 to 1 ratio, type R-151 may be used at (28) for greater distance.
2—Amperites, No. 4V-199, with M't'gs (22, 27).
1—Amperite, No. 120, with M't'g (30).
1—Silver-Marshall Shield, type 631-A (17).



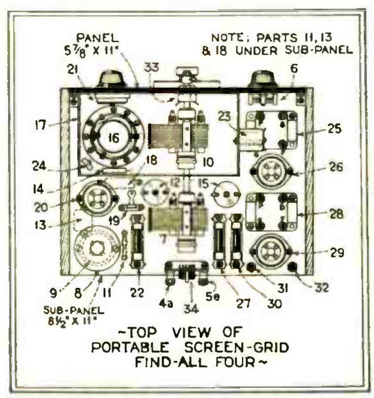
Working drawing of the carrying case for the portable set.

3—Silver-Marshall R. F. Chokes, type 276 (12, 15, 23).
1—Silver-Marshall Midget Condenser, type 340 (6).
2—.01 mf. Polymet Bakelite Fixed Mica Condensers (13, 14).
1—.0005 mf. Polymet Bakelite Fixed Mica Condenser (24).
1—Carter JU-5-15 Tapped Resistor (11).
1—Carter Tube Shield, No. 322; Connector Cap No. 342; with Shielded Wire No. 352; Adaptor Ring No. 332 (8).
1—Carter "Imp" Battery Switch (33).
2—Carter Tip Jacks (31, 32).
2—Carter Open-Circuit Short Jacks for Loop Sockets.
6—Eby Engraved Binding Posts (1, 2, 4, 54-a, 5-a).
1—Roll Corwico Braidite, Stranded Core Hook-up Wire.
1—Spool No. .22 double cotton covered Corwico Magnet Wire for Loop (3).



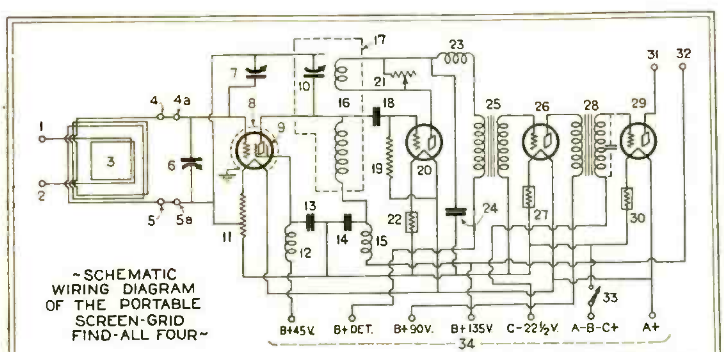
Illustrating method o. mounting the cone and speaker unit in the cover of the case.

1—7-Conductor Cable with M't'g Plate (34).
1—Can Kester Radio Solder (Rosin Core), by the Chicago Solder Co.
1—Composition Panel, 6" x 11" x 3/16".
1—Sub-Panel, 8¾" x 10¾" x 3/16".
1—Gold Seal Screen-Grid Tube, type GSX222 (9).
2—Gold Seal Tubes, type GSX199 (20, 26).
1—Gold Seal Power Tube, type GSX120 (29).
1—Vernier Dial.
1—Ensco Loud Speaker Unit.
1—Sheet of Burtex or Alhambra Paper, 12" x 12" for Loud Speaker Cone.



General layout of the parts composing the portable receiver.

3—1½-volt dry cells ("A" Battery).
7—22½-volt "B" Batteries (Compact, portable type); or 6 45-volt Batteries of Compact type with one 22½-volt Battery.
4—Brass Loose-Joint Hinges.
2—Brass Clasps.
1—Leather Strap for Handle.
Wood for Carry Case—White Wood:
2 pieces, 11¾" x 8¾" x ⅜" (top and bottom).
2 pieces, 12¼" x 8⅜" x ⅜" (sides).
1 piece, 6" x 11" x ⅜" (front cover of battery compartment).
Front Cover, containing Loop:
1 piece, 11¾" x 13" x ⅜" (front).
2 pieces, 11¾" x 1⅝" x ⅜", with 11"
2 pieces, 11¾" x 1⅝" x ⅜" (top and bottom).
2 pieces, 12¼" x 1⅝" x ⅜" (sides).
Back Cover, containing Speaker:
1 piece, 11¾" x 13" x ⅜", with 11" dia. hold for Cone of Speaker.
2 pieces, 11¾" x 2⅛" x ⅜" (top, bottom).
2 pieces, 12¼" x 2⅛" x ⅜" (sides).



The use of a screen-grid tube as tre radio-frequency amplifier makes it possible to use a small loop aerial and till obtain excellent results.

NEWS OF THE INDUSTRY

RMA TRADE SHOW PLANS

MANY new and novel features and entertainment events for the record-breaking gathering of the radio industry at Chicago in June during the Fifth Annual RMA Convention and Trade Show, were planned at the early spring meeting of the RMA Board of Directors at Hot Springs, March 7–8.

Also the RMA Board made plans for better distribution and advertising of radio products and for development of broadcasting, including wider use of the air for educational purposes in the public schools.

The Hot Springs meeting of the RMA Board developed into a general meeting of industry leaders, including representatives of distributors' organizations, the music industries, and broadcasting companies. Major H. H. Frost, of New York, President of the RMA, presided and nearly all of the RMA Directors attended. Two special RMA cars from New York and one from Chicago carried the radio clan. Officers and directors of the Federated Radio Trade Association, the Radio Wholesalers' Association, and many others identified with the radio industry attended the Hot Springs gathering, enjoying some golf, riding and other social festivities between business sessions.

A record-breaking attendance of radio distributors at Chicago June 3rd was predicted by industry leaders. The bulk of the 30,000 square feet of display space for the trade show, over-flowing into the three hotels engaged exclusively by the RMA for the trade show week, the Stevens, Congress and Blackstone Hotels, has been sold, according to a report made by Mr. G. Clayton Irwin, Jr., manager for the RMA of the trade show.

The national music industry, holding its Convention and Trade Show during the same week with the RMA events, also will have a record turn-out and display, according to a statement to the RMA Board by Mr. Delbert L. Loomis, Executive Secretary of the National Association of Music Merchants. Half-fare railroad rates for members attending the RMA Convention have been applied for.

All-Star Broadcast Program

For the annual RMA Banquet June 5th, an all-star broadcast program will be given. Through the courtesy of the National Broadcasting Company a nation-wide hook-up will carry the banquet events. Several novel entertainment features for the radio visitors to Chicago in June also were planned.

Development of radio as an educational agency and wider sales of radio products, was discussed by the RMA Board with Mr. Sam Pickard, former Federal Radio Commissioner and now Vice-president of the Columbia Broadcasting System. Special educational broadcast programs, beginning next fall, are planned by the Columbia System.

The special RMA weekly broadcast programs, begun February 6th, will be continued well into May, according to a report by Mr. B. G. Erskine, of Emporium, Pa., Chairman of the RMA Broadcasting Committee. Next fall further RMA institutional broadcasting is planned.

Development of better merchandising and "truth in advertising" practices in the sales of radio products also was discussed by the RMA Board.

Radio legislation, that recently passed by Congress and that planned in the future, also was discussed by the RMA Board. Mr. Frank D. Scott, legislative counsel in Washington for the RMA, reported that it was doubtful if new radio legislation would be attempted during the coming extra session of Congress. Because of the increase in radio legislation in several states, the RMA Board ordered its Legislative Committee, headed by Mr. C. C. Colby, of Boston, Mass., and Mr. Scott, to set up machinery for proper protection by the RMA of radio interests in state legislation.

Distribution of Products

Joint plans to improve distribution of radio products and develop closer working arrangements between jobbers and dealers were made by the RMA Directors with representatives of the national distributing organizations. Among these present at the Hot Springs meeting were Mr. Harold J. Wrape, of St. Louis, representing President Michael Ert of the Federated Radio Trade Association; J. M. Blackman, of New York, Vice-president of the Federated; Pete Sampson, of Chicago, President of the Radio Wholesalers' Association; Harry Alter, Tom White and Leslie F. Muter, of Chicago; Charles Gomprecht, of Philadelphia, and E. E. Healy, Elmer Metzger, Howard Funk and Edward Young, of Buffalo.

Expansion of Services

Expansion of RMA services to its members, made possible by increased financial and membership support, was ordered by the RMA Board of Directors.

F. L. BELL
Exec. Secretary-Treasurer, Mid-west Radio Trade Association.

Special service to members and other units of the industry in the merchandising of radio products will be given. A new merchandising Bureau at the New York headquarters of the RMA was ordered established, and an outstanding merchandising manager engaged. Comprehensive merchandising surveys, suggestions and counsel will be planned and given to RMA members gratis.

The RMA Traffic Bureau at Chicago, according to a report to the Board of Directors by Captain William Sparks, Chairman of the RMA Traffic Bureau, has secured proper ratings resulting in savings recently to parts manufacturers, and other savings in freight charges of members also have been made, and additional transportation reductions are being pressed. To serve RMA members more advantageously, an eastern division of the Traffic Committee has been formed with Mr. W. Hilderbrand, of Orange, N. J., as Eastern Chairman.

Further service in developing radio export trade also was ordered by the RMA Board. George H. Kiley, Chairman of the Foreign Trade Committee, reported that supplements to the comprehensive radio export guide, recently distributed free to the RMA members, had been prepared and would be sent out soon.

Mr. H. B. Richmond, of Cambridge, Mass., Director of the RMA Engineering Division, submitted a final draft of the revised issue of the RMA Interference Manual, "Better Radio Reception." An initial printing of at least 50,000 copies for distribution through radio sales channels will be made at once. The first edition of "Better Radio Reception" went into over 100,000 homes, and there is a large demand already for the revised edition. A large demand also was reported for the new edition of the RMA Industry Standards, a second print having been run off.

Credit and Collection

Increase of credit and collection service to RMA members was reported to the RMA Board by Mr. Theodore Sheldon, Chairman of the Credit Committee. Members are becoming better informed of the service afforded by the Credit Committee, and this service is being constantly developed and expanded.

The RMA patent interchange plan, submitted to the RMA membership at their meeting in Chicago last June, will be presented vigorously immediately, the RMA Board was told by Mr. LeRoi J. William, of Cambridge, Mass., Chairman of the RMA Patent Committee. A strong committee has been appointed by Chairman Williams and detailed information regarding the patent interchange or "pooling" plan, will be distributed soon.

New Indirect Services

Among the new indirect services ordered for members is in connection with radio legislation in many states affecting sales of radio products and the interests of members, as well as those of jobbers and dealers. In addition to the national service of the RMA in connection with national legislation at Washington, where Mr. Frank D. Scott is legislative counsel, the Board of Directors took steps to deal directly and efficiently with radio legislation presented in all states. The Legislative Committee, headed by Mr. C. C. Colby, of Boston, Chairman, in conjunction with Mr. Scott and also Judge John W. Van Allen, legal counsel for the RMA, will secure complete information regarding legislation in the various states, and take proper steps to protect radio interests.

M.R.T.A. OPENS CHICAGO OFFICES

The Midwest Radio Trade Association announces the official opening of their executive offices at 32 W. Randolph Street, Chicago, Ill., and the employment of a full-time executive secretary-treasurer. This important step was taken by the Board of Directors at their meeting on Friday, March 8th.

Mr. F. L. Bell, of Chicago, has been chosen as executive secretary-treasurer of the Association and will be in charge of the office. Mr. Bell is a graduate engineer from Texas A. & M. and is well qualified to handle the position because of his past position in sales and executive work together with his background of engineering training.

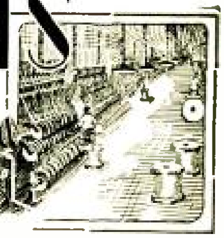
The Association has started an active campaign for new members and are immediately inaugurating several plans for the benefit of its members. Notably among these plans is the examination and registry of service men which Mr. Bell, with the cooperation of Mr. E. A. Briggs of Chicago Radio Institute, plans on putting into effect immediately for the Chicago and metropolitan area.

Mr. H. E. Richardson, President of the Association is very optimistic concerning the future of the group and looks forward to 1929 as being a banner year for the Association.

R.C.A. COMMUNICATIONS, INC.

Announcement has been made of the election of officers and directors of R.C.A. Communications, Inc., a new subsidiary,

NEW DEVELOPMENTS OF THE MONTH



WRIGHT-DE COSTER DYNAMIC REPRODUCERS

Wright-DeCoster, Inc., of St. Paul, Minn., are in production on their new dynamic reproducer.

The field coil of this dynamic speaker contains nearly fifteen pounds of wire, which, in combination with an extremely

Wright-De Coster dynamic speaker chassis.

low reluctance magnetic path provides a high degree of efficiency. Notwithstanding the fact that only nine watts are necessary for field excitation, and the air gap is somewhat larger than standard practice, there is sufficient sensitivity to produce an output, on a single 171-type power tube which is usually possible only with a 210-type tube.

The unit will stand exceptionally high powers, having been used successfully on amplifiers supplying as high as 45 watts of speech energy. Due to special construction of the voice coil, there is little possibility of voltage breakdown between layers.

There is usually no equalizer or cut-off filter necessary except on an amplifier in which there is a prevalence of harmonics of very bad wavelength distortion.

Prices on the speakers range from $52 to $100, with and without cabinets and in both 6-volt d-c. and 110-volt a-c. types.

WRIGHT-DE COSTER TONE MODULATOR

Wright DeCoster, Inc., of St. Paul, Minn., have also introduced a new Tone Modulator which is employed for increasing or decreasing the high and middle registers of the musical scale. This can be done at the will of the operator and without disturbing the lower middle and bass tones.

Wright-De Coster Tone Modulator.

The Tone Modulator is designed to be connected between the phonograph pick-up and the input of the audio amplifier. It readily lends itself for use in connection with sound equipment in theatres.

The Tone Modulator is priced at $7.50.

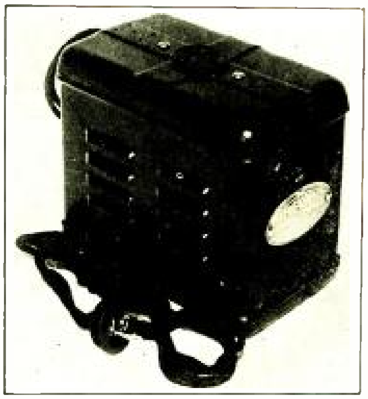
THE INSULINE CORP. "FILTERVOLT"

With the advent of power operated radio receivers for both a-c and d-c supply increased complaint of noise originating in the supply lines became universally evident. For the past few years prominent engineers have been at work on the seemingly elementary problem of devising means for filtering out these variations and disturbances from the supply.

The Insuline Corporation of America in the FILTERVOLT place upon the market a device representing the combined research of highly trained mechanical and electrical engineers.

When first attacking the problem the cure quite obviously lay in the "Electric Wave Filter." The device which makes possible multiplex telegraphy and telephony through its faculty of passing or rejecting chosen bands of frequencies.

The first filter section employs a special case of cambeti filter in a "low-pass" connector arranged for the filteration of an a-c line. The application of certain well known formula determines the frequency above which the current is alternated (diminished) either greatly or completely. We wish to pass the 60 cycle line current with no loss but we must so proportion the filter constants as to completely eliminate frequencies not of that order, short period crackles and snaps caused by switches opening or closing and high pitched whines from various electrical apparatus extending



Insuline "Filtervolt."

in frequency from a few hundred cycles up to a figure well outside the audibility range.

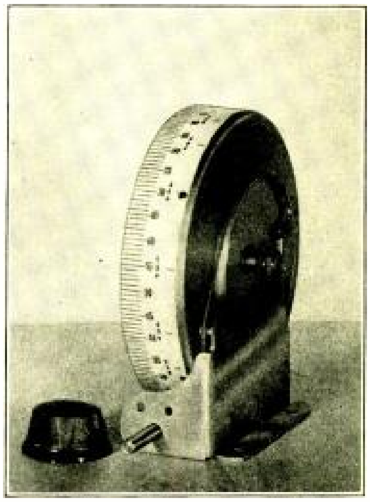
In a second section is used a slightly different arrangement consisting theoretically of resistance and reactance elements as opposed to the inductance and capacitance elements.

The resistance elements in the second section are wound from a special alloy and by virtue of a peculiar temperature, resistance coefficient not only aid in the suppression of short period line variations but also in the voltage regulation of the power supply.

The manufacturer of the Filtervolt guarantees it without hesitancy for use under the most extreme conditions in either alternating or direct current circuits and where motor generator sets are used for conversion of d-c into a-c. The method of connection is simplicity itself. The Filtervolt is connected between the set and the socket or receptacle. Its ground is used for the radio set by means of short length of insulated wire. No other connection is necessary and no changes are involved.

PRECISE DRUM DIAL

Precise Products, Inc., of 254 Mill Street, Rochester, N. Y., have announced to the trade their new No. 2058 Illuminated Drum Dial of center drive construction. The driving unit of this dial is claimed to be positive, without any backlash or slippage. A number of idle pulleys guide the flexible bronze cable for winding on the drum and hub which is fastened to the driving shaft by means of two set screws.



New Precise Drum Dial.

There is a screw takeup on the side of the disc for applying the tension of the bronze cable as well as two screws in the main hub of the dial for fastening the dial rigid to the condenser shaft.

The arrangement of the bracket is such that it may be used for sub-base or panel mounting.

Bands will be furnished with either 0-100 graduations with approximate kilocycle readings or with kilocycle readings from 1,500 to 550.

The entire dial and bracket are made of heavy steel, nickle plated. The dial measures 5½ in. in diameter.

NEW GENERAL AMPLIFIERS

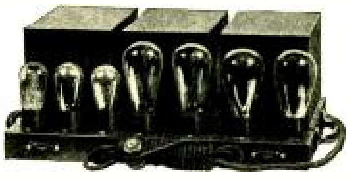
The General Amplifier Company, 27 Commercial Avenue, Cambridge, Mass., has introduced three new power amplifiers: Models GA 10, GA 20 and GA 30.

The GA 10 is a two-stage amplifier employing one 227-type tube, one 250 and a 281. It will deliver approximately 4 watts of undistorted energy to the speaker.

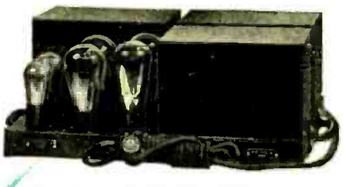
The GA 10 amplifier lists for $88.

The GA 20 is a three-stage amplifier employing two 250s, two 226s, two 281s and a 227. It will deliver approximately 14 watts to the speaker.

The GA 20 lists at $225.



New General Model GA20 Power Amplifier.



New General Model GA30 Power Amplifier.

The GA 30 is a three-stage amplifier employing two 250s, two 281s and two 227s. It will deliver approximately 12 watts to the speaker.

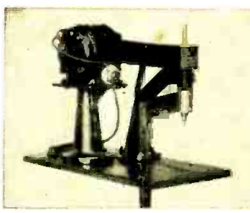
The price of the GA 30 is $175.

All three amplifiers are designed for use with either a magnetic or a dynamic speaker. No output devices are required. Each amplifier employs filters in the plate and grid circuits of the tubes, thus isolating the signal voltage from the plate supply.

The General Amplifier Company is in a position to manufacture amplifiers to meet special requirements.

VIM BENCH TOOL

The Vim Electric Tool Co., 149 Broadway, New York City, are now manufacturing a new form of electric bench tool which has wide adaptability. The model shown is known as Type "C." It can be mounted on a bench in fifteen minutes.



The Vim Type "C" Bench Tool.

This machine is particularly recommended for female help; no effort is required to operate the machine, which is controlled by a foot pedal. It will drive wood and metal screws up to No. 10/32 at 1,000 r.p.m. bit speed.

NEW TUBE TESTER GIVES DIRECT READING

An a-c. tube checker that gives direct readings is announced by the Jewell Electrical Instrument Company, of 1650 Walnut Street, Chicago. The Pattern 210, as it is called, tests all tubes including rectifier tubes. It operates from a-c. service lines, a high resistance rheostat being furnished to compensate for line variations between 100 and 130 volts.

This new tube tester is furnished in a compact leather case. The rectangular panel carries an a-c. voltmeter, a direct-current instrument, and a transformer that supplies filament energy of 1.1, 1.5. 2.5, 3,5, and 7.5 volts through a selector switch. Both four- and five-prong sockets are provided.

The scale on the d-c. instrument is divided into 100 arbitrary units. Values on all standard tubes in accordance with this scale are included in the instructions furnished with the tester. For rectifier tubes, a push-button is pressed and the instrument indicates the rectified current on a 100 milliampere scale. Double-wave tubes, such as the 280, which could not be tested heretofore on commercial tube testing apparatus, are taken care of by an additional push-button switch which causes the rectified current of the second plate to register on the 100 milliampere scale.

In operation the correct filament voltage is set on the selector switch. the tube inserted in the socket and the adjusting rheostat turned until the voltmeter registers normal condition. Then the potentiometer in the lower right hand corner is adjusted so that the d-c. instrument registers zero. The grid test button is then pressed and the net change in plate current is read directly from the instrument, eliminating the reading of two values and the subtraction of one from the other.

New Jewell Direct-Reading Tube Tester.

DUBILIER D-C INTERFERENCE DEVICES

The marked success which has attended the use of Dubilier a-c interference devices has caused the engineering staff of the Dubilier Condenser Corporation of New York City, to introduce d-c interference devices. The new d-c models are made in two types, one with 4 mfd. by-pass condensers, and the other with 2 mfd. by-pass condensers, both intended for a 400-volt d-c working voltage. There are three leads for the necessary connections across the line or power equipment, with the center lead to ground. The d-c interference devices differ from the a-c types in the matter of introducing resistance in the filter network, which depends on the amount of inductance in the load circuit. The ordinary pair of condensers will not always perform to the best advantage in d-c circuits, hence special d-c interference devices have had to be developed.

THE J-M-P SUBMARINER

The J-M-P Manufacturing Co., Inc., of Milwaukee, Wis., have introduced to the trade a new model of the original "Submariner" short wave adapter. The new model is designed for both a-c. and d-c. receivers and has interchangeable coils. Coils for this adapter are available to tune between 10 and 340 meters. The instrument, as shown, has a slow-motion dial and is completely shielded.

TALKING MOVIES FOR THE HOME

The DeVry Corporation, of Chicago, announce the Cine-Tone unit for immediate delivery. It consists of a regular 16 mm. motion picture projector, geared to a turn table. with tone arm and electric pick-up. The pick-up may be connected directly to any standard radio set, or used in conjunction with the special DeVry power amplifier, sold separately. The gear shafting forces absolute synchronization between the action on the screen and the sound on the record.

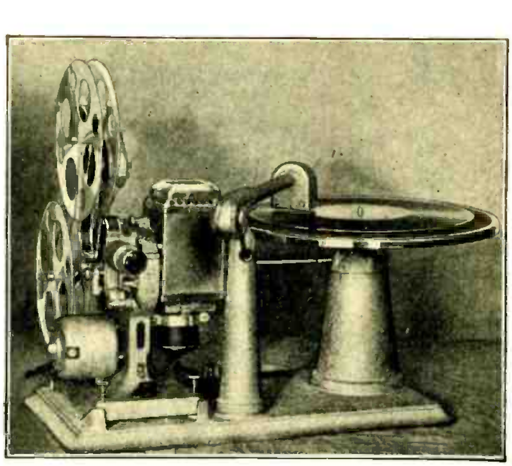
At one stroke a great library of popular electrically produced phonograph records such as the Victor, Columbia and Brunswick become wedded to motion picture illustration—and no expensive installations are required. The Cine-Tone is a compact light weight all metal unit that can be set on a small stand.

The present combination unit will cost less than the usual home projector alone—somewhere in the neighborhood of $250 with carrying case, and films or records may be run separately if desired.

The new combination films and records—all in the popular 16 mm. home size—will be issued each month so that there will be a constant supply of fresh and novel entertainment, and they will cost no more than the separate films and records do now.

Above: The J-M-P Submariner, a short-wave adapter.

Right: The DeVry Cine-Tone talking motion picture outfit for the home. The phonograph turntable is geared to the projector.

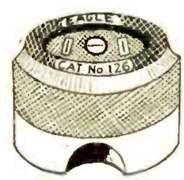


NEW ELECTRO-MOTIVE CONDENSER AND A RESISTOR

The Electro-Motive Engineering Corporation, who for years have been very active in the resistance field of radio, are introducing to the trade a bakelite moulded condenser, and a variable resistor for volume control, and for all power work.

The new bakelite moulded condenser is so constructed that it can be mounted in ways that permit of great flexibility. The mechanical construction of this condenser is such that it can be eye-letted or soldered into the set. The dielectric is of the finest grade of mica; the plates are of tin-foil and the element is thoroughly impregnated. These condensers are made in capacities from .00004 to .02 mf.

The new variable resistor, which will be introduced very shortly, will be greatly welcomed by the trade, because of its marked improvements. It can be used for controlling the volume of a set, and produces a gradual range from almost a whisper to a roar.



The Eagle Single Convenience Outlet.

EAGLE SINGLE CONVENIENCE OUTLET

The Eagle Electric Manufacturing Co., 59 Hall Street, Brooklyn, N. Y., have introduced a new type single convenience outlet which provides an easy way of handling outside wiring.

The patented metal finding ring makes it a simple matter to locate the slots quickly.

The outlet is made of porcelain, with contact binding screws.

OIL

IT SEEMS THAT OUR CONDENSERS WHICH ARE IMPREGNATED DIRECTLY IN OIL ARE BEING CONFUSED WITH OTHER SO CALLED "OIL" PROCESSES.

THE LIFE OF OUR OIL IMPREGNATED CONDENSER IS SO SUPERIOR AS TO BE ABOVE COMPARISON WITH OTHER TYPES AND IN JUSTIFICATION OF OUR PRODUCT WE FEEL THIS ANNOUNCEMENT IS NECESSARY.

ACRACON

CONDENSER CORPORATION OF AMERICA

259–271 CORNELISON AVE. JERSEY CITY, N. J.

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.

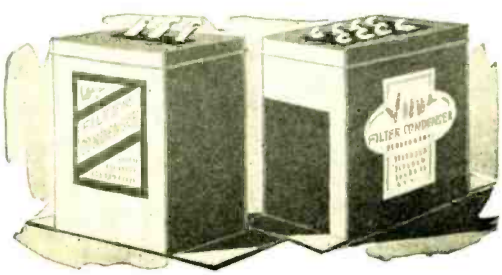
CONDENSER TISSUES

NO Radio set is any better than its weakest link, and the weakest link is very often a filter Condenser. No Condenser is any better than the thin strips of Insulating Tissue which separate the layers of metal foil. A pinhole or a speck of metal in the Condenser Tissue means a breakdown of the Condenser, with the entire set put out of commission.

DEXSTAR Condenser Paper is regarded by Radio experts as being the highest grade Insulating Tissue ever made—the freest from defects, the most uniform in quality, the most lasting under exacting and unusual requirements. DEXSTAR Condenser Tissue is the specialized product of a paper mill which has excelled in Tissue Paper production for three generations.

RADIO designers and builders should have the assurance that Condensers which they use are made with DEXSTAR Condenser Tissues. It is insurance against many radio troubles. The leading Condenser manufacturers are now using DEXSTAR Condenser Tissues exclusively.

C. H. DEXTER & SONS, INC.
Makers of Highest Grade Thin Papers
WINDSOR LOCKS, CONN.



ROLA

ROLA offers a high-quality, high performance electro-dynamic unit to the manufacturing trade. This unit combines high efficiency and high safety factors with compactness and simplicity.

The field coil is wound to meet any voltage current ratio, and for use with any power-pack circuit. Mounting of the unit is simplified by welded construction, permitting bolting direct to baffle board.

YOUR ASSURANCE
of Reliable Speaker *Performance*

DURING 1929 Rola brings new achievements in the art of fine sound recreation. A distinct engineering triumph of interest to manufacturers of console sets is the manner in which Rola loudspeakers combine brilliant performance with reliability and freedom from maintenance troubles.

In the design and manufacture of its new 1929 "J" line models, The Rola Company has incorporated still higher safety factors—reducing to a minimum service demands upon the dealer and manufacturer. These new Rola reproducers are unusually compact and of beautiful mechanical simplicity. A new and exclusive Rola feature is the removable centre-pole nose piece to enable easy elimination of any magnetic particles which might enter the air-gap.

During the coming season many of the leading radio sets and electric phonographs will be Rola equipped. Rola reproducers are also used in talking picture installations and public address systems.

© © ©

Inquiries for details, blueprints and prices from responsible manufacturers are solicited.

The ROLA COMPANY

CLEVELAND, OHIO
2570 E. Superior Avenue

OAKLAND, CALIF.
Forty-Fifth and Hollis Sts.

MANUFACTuring

Rectangular switchboard instrument

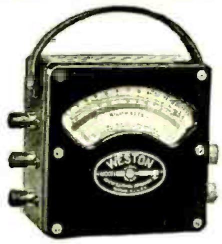
In modern practice the emphasis is on FACT

THE word *manufacture* originally meant *made-by-hand*. In those days rule-of-thumb methods sufficed. Today, in this mass production age, the very speed of operation would result in uncontrollable losses but for the balance wheel of *fact*.

Take, for example, the selection and use of materials, or the fabrication and assembly of parts by quantity production methods—a grain of dross in one, or a hair's breadth from the true gauge in the other, and in a few hours the coefficient of speed would turn an increment of error into an avalanche of waste.

That's why research laboratories, expert analysts and business machines are cheap at any price. That's why executives in charge of factories where the use of electric power is a factor choose Weston measuring instruments to safeguard their electrical equipment and insure its continuous and efficient operation.

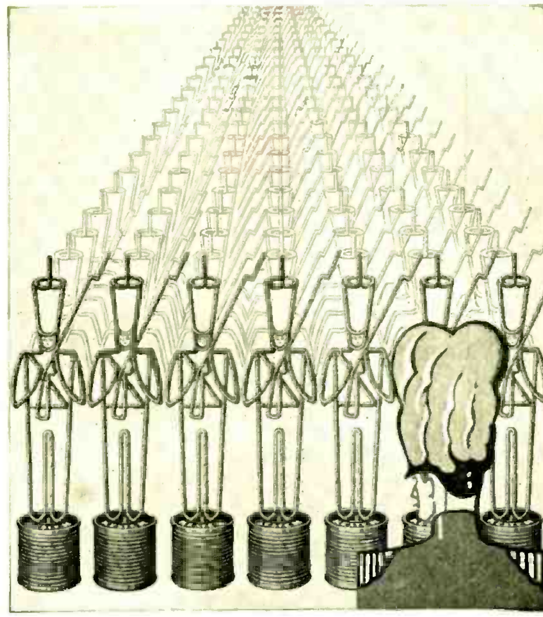
That's why electrical manufacturers of quality apparatus furnish "Westons" as an integral part of their products. Weston electrical instruments always give the biggest return on the investment. For more than forty years they have been the conceded standards the world over in the art of electrical measurement.



"Junior" Portable A.C. Instrument

WESTON ELECTRICAL INSTRUMENT CORP.
612 Frelinghuysen Ave. Newark, N. J.

Weston
PIONEERS SINCE 1888
INSTRUMENTS



At your command ~ the KESTER *corps of* FLUX CORE SOLDERS

ARE you still trying to defend—and advance—your profits and reputation with the individually weak and raw recruits of separate solder and flux? Is there a lack of liaison in your defense and attack? Are you trying to hold—and strengthen—your position with cavalry when artillery is needed?

Now at your command is this great army—sworn foes of the high production costs that raid your profits! Defenders of your quality and reputation! Modern strategy, recognizing the inability of solder and flux as individuals to combat high production costs, now offers you an alliance of these two units in more efficient form—KESTER CORED SOLDERS now waging successful campaigns for many manufacturers.

At your call for help KESTER shock troops will concentrate on your weakest salient. Order your signal corps to establish communication with KESTER headquarters, we will immediately hold a council of war, make tests, select the troops best suited for your campaign and dispatch a small detachment for your approval—no obligations to you.

Manufacturers are invited to submit their soldering problems to P. C. Ripley, chief of our engineering staff. We maintain a laboratory to solve just such individual needs. Mail coupon for further information and Mr. Ripley's book, "Facts on Soldering."

Established 1899
CHICAGO SOLDER COMPANY
4224 Wrightwood Avenue CHICAGO

KESTER SOLDER
Self-Fluxing

CHICAGO SOLDER CO. Date..........
4224 Wrightwood Ave., Chicago.

Please mail us further information about KESTER Flux-Core Solders for manufacturing uses: also Mr. Ripley's book, "Facts on Soldering."

Individual..........
Firm..........
Address..........
Products Manufactured..........

Four Representative

Raytheon

LONG LIFE RADIO TUBES

that prove the value of 4-pillar Construction

The proof of the tube is in its service. The tubes shown below are four of the most used Raytheons.

They have demonstrated very convincingly that the exclusive Raytheon 4-pillar construction gives longer life to the tube, at the same time doing away with microphonic noises and providing clear, vivid reception.

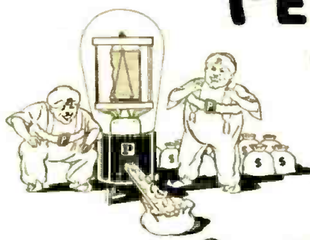
This is because the three elements—filament, grid and plate—are permanently anchored in their correct relative positions, so that the original characteristics of Raytheon tubes are indefinitely retained.

RAYTHEON MFG. COMPANY

Cambridge, Mass.

THERE IS MORE PROFIT IN

PERRYMAN TUBES



Because

The Patented Perryman Bridge

. . . holds the filament, plate and grid in permanent parallel alignment at top and bottom at the point of greatest efficiency. You can't shake them apart.

The Spring

. . . allows for uniform expansion and contraction of the filament, due to temperature changes.

1. They give a greater number of hours of satisfactory service.
2. They always produce a clear tone—bringing out the best in reception.
3. They eliminate many "trouble calls."
4. They guarantee satisfaction to your customers assuring you repeat business.

Perryman Electric Company, Inc.
33 West 60th Street New York, N. Y.
Laboratories and Plant, North Bergen, N. J.

PERRYMAN RADIO TUBES
A Complete Line of Standard Equipment for every Radio Purpose

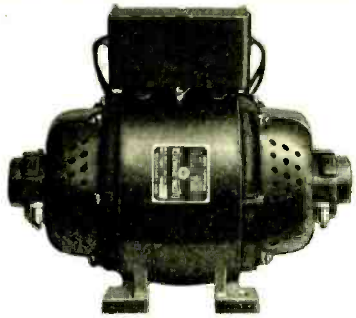
ARMOR

G U A R A N T E E D

RADIO TUBES

All Standard Types

ARMSTRONG
ELECTRIC CO.
187-193 Sylvan Ave.
NEWARK, N. J.



Dynamotor with Filter for Radio Receivers

MACHINES for OPERATING 60-CYCLE A. C. RADIO RECEIVERS, LOUD SPEAKERS and PHONOGRAPHS from DIRECT CURRENT LIGHTING SOCKETS WITHOUT OBJECTIONABLE NOISES OF ANY KIND

The dynamotors and motor generators are suitable for radio receivers and for combination instruments containing phonographs and receivers. Filters are usually required. The dynamotors and motor generators with filters give as good or better results than are obtained from ordinary 60-cycle lighting sockets. They are furnished completely assembled and connected and are very easily installed.

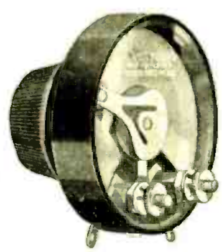
These machines are furnished with wool-packed bearings which require very little attention, and are very quiet running.

ELECTRIC SPECIALTY COMPANY

TRADE **"ESCO"** MARK

411 South Street **Stamford, Conn.**

"Details Make Perfection but Perfection is *No* Detail"



Centralab Modulator

A typical example of CRL superiority of design, Rocking Disc Contact, Constant Resistance, Durable Construction, Perfect Theoretical and Mechanical Design. Made in any resistance and any style for use as Volume Control in critical and non-critical circuits.

List Price $2.00

Centralab resistances are details that make for perfect reception.

Every time you tune in your radio set you must adjust the voltage and volume controls and then reset them for every different station or condition of reception. This important phase of operation of your radio set must not be neglected.

Centralab Voltage and Volume Controls have been giving satisfaction to the entire radio industry virtually since the beginning of radio. In them are embodied the improvements in theory and design developed by our engineering staff during these years of progress. They are undoubtedly the finest Variable Resistances that can be had today. It costs no more to equip your set with Centralab Resistances than with others and you are insuring perpetual freedom from the common irritation of noisy, faulty, volume and voltage controls.

CENTRAL RADIO LABORATORIES

22 Keefe Avenue, Milwaukee, Wisconsin

Centralab

AEROVOX

BUILT BETTER CONDENSERS AND RESISTORS

Takes the Hum Out of Any Dynamic

In spite of the many methods utilized to eliminate the hum in A. C. dynamic speakers, many of the best dynamics still have a hum which is sufficiently pronounced to be objectionable, especially during lulls in the program while waiting for announcements, when the volume control is turned up to full volume.

You will be surprised at the completeness with which an Aerovox 1500 mfd. "A" condenser, connected across the field coil or across the rectifier output, will eliminate the hum and increase the sensitivity of the speaker.

Complete details and comparative data showing the results of using these condensers in eliminating hum will be furnished on request.

Send for Complete Catalog

Complete specifications of all Aerovox units, including insulation specifications of condensers, current-carrying capacities of resistors and all physical dimensions, electrical characteristics and list prices of condensers and resistors are contained in a complete 20-page illustrated catalog which will be sent gladly on request.

The Research Worker

is a free monthly publication dealing with design factors in the use of condensers and resistors. Your name will be placed on the mailing list free of charge, on request.

AEROVOX WIRELESS CORP.

76 Washington Street, Brooklyn, N. Y.

PRODUCTS THAT ENDURE

EL-MENCO

Molded Bakelite Condensers

"Minimize Condenser Griefs"

THE **EL-MENCO** MOLDED BAKELITE CONDENSER comprises all of the very best and latest features in Condenser design and construction.

The One Hole mount facilitates assembly—The Hot Tinned Brass Lugs assure better soldering—The Solid Bakelite Outer Shell permits it being mounted directly to a metal panel, eliminating insulation—The high-grade clear India Mica used as a dielectric makes blow-outs negligible.

The High Standard of Manufacture and the rigid factory test assure users of **El-Menco** Condensers uniformity and longevity.

The same engineering skill and manufacturing ability that have secured the success of **El-Menco** Resistors are behind the **El-Menco** Condensers.

El-Menco Condensers will be made in the following capacities:

.00005 Mfd.	.0003 Mfd.	.0025 Mfd.
.0001 "	.001 "	.003 "
.00015 "	.0015 "	.005 "
.00025 "	.002 "	.006 "

Should any sizes other than above be required, they will gladly be furnished upon request and prices quoted.

Electro-Motive Engineering Corp.
127–133 W. 17th St., New York

Our NEW Catalog is Now Ready

A REGULAR encyclopedia of wire-wound resistor knowledge, this—new sizes, new mountings, special units, bracket specifications and drawings.

In fact, complete engineering data with simplified charts for working out your own requirements are within its covers.

Every electrical and radio manufacturer should have Catalog No. 429. Send for it today.

HARDWICK, HINDLE INC.

Sales Dept.
122 Greenwich Street
New York City

Factory
215 Emmet Street
Newark, N. J.

RESISTORS

Building a Transmitter or Receiver?

BE SURE YOU'RE RIGHT
THEN GO AHEAD!

Start with

CARDWELL CONDENSERS

AND YOU WON'T BE WRONG

Transmitting - - Receiving
Variable - Fixed

SEND FOR LITERATURE

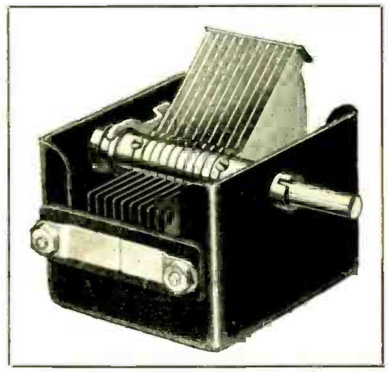
The Allen D. Cardwell Mfg. Corp.
81 Prospect St. Brooklyn, N. Y.

If your dealer does not stock, order direct

TRADE MARK
UNITED SCIEN. LAB
INC.

NEW TYPE B.T.
ARMORED CONDENSER

A Compact Precision Tuning Instrument



THE United Scientific Laboratories have produced this new Armored type B.T Condenser, to meet the growing demand for precision combined with rigidity. No set manufacturer whose specifications and requirements demand ultra precision, electrical and mechanical perfection, and compactness, can overlook this high grade instrument.

Note These Exclusive Features

1.—Rigid frame made of heavy drawn steel.
2.—Rotors and stators are precision spaced and soldered.
3.—Accuracy and calibration in ganging is assured by wide spacing between plates.
4.—Permanent and perfect alignment of rotors is assured because the removable shaft is independent of bearings.
5.—Circuit adjustments are facilitated by the gradual curve on the minimum capacity adjuster.
6.—Adjustable smooth acting end thrust and tension fork.
7.—The compactness of this condenser makes it the most convenient tuning unit made for individual shielding work.

These new type B. T. Armored Condensers are made in single, two gang, three gang, and four gang units of .00035 mfd. capacity and lower.

Samples now ready for delivery. Write for prices and full information. Watch for further details.

United Scientific Laboratories, Inc.
117 Fourth Avenue New York City

BRANCH OFFICES

St. Louis, Chicago, Boston, Minneapolis, Cincinnati, Los Angeles, Philadelphia, San Francisco

RADIO MANUFACTURERS ASSOCIATION RMA MEMBER

Canadian Offices: London, Ontario

Buyers Directory of Materials 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 80.

ADAPTERS:
Carter Radio Co.
Insuline Corp. of Amer.
Lynch, Arthur H., Inc.

ALUMINUM:
Aluminum Co. of America

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

AMMETERS:
General Electric Co.
General Radio Co.
Jewell Elec. Inst. Co.
Weston Elec. Instrument Corp.

AMPLIFIERS, POWER:
General Amplifier Co.
General Radio Co.
National Co., Inc.

ANTENNAE, LAMP SOCKET:
Dubilier Condenser Mfg. Co.

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

BASES, VACUUM TUBE:
Formica Insulation Co.
General Electric Co.
General Plastics Co.
National Vulcanized Fibre Co.
Synthane Corp.

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

BRACKETS, ANGLE:
Insuline Corp. of Amer.
Scovill Mfg. Co.

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

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

BULBS, PANEL:
Palatine Industrial Co., Inc.

BUTTS:
Scovill Mfg. Co.

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

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

CERIUM:
Cohn, Sigmund.

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.
Silver-Marshall, Inc.

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

CLAMPS, GROUND:
Insuline Corp. of Amer.
Scovill Mfg. Co.

CLIPS, SPRING:
Scovill Mfg. Co.

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

COILS, CHOKE:
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Dudlo Mfg. Co.

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Aero Products Corp.
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General Radio Co.
Hammarlund Mfg. Co.
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Dudlo Mfg. Co.
Valley Appliances, Inc.

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Scovill Mfg. Co.

CONDENSERS, BY-PASS:
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Allen-Bradley Co.
Carter Radio Co.
Condenser Corp. of America.
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E. & Co.
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Wireless Specialty Apparatus Co.

CONDENSERS, FILTER:
Acme Wire Co.
Aerovox Wireless Corpn.
Allen-Bradley Co.
Carter Radio Co.
Condenser Corp. of America.
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E. & Co.
Sangamo Elec. Co.
Wireless Specialty Apparatus Co.

CONDENSERS, FIXED:
Acme Wire Co.
Aerovox Wireless Corpn.
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Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Fast, John E., & Co.
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Hammarlund Mfg. Co.
National Co., Inc.
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United Scientific Laboratories

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Hammarlund Mfg. Co.
National Co., Inc.
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Silver-Marshall, Inc.
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Scovill Mfg Co.

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Insuline Corp. of Amer.

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Hammarlund Mfg. Co.
Silver-Marshall, Inc.

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Central Radio Laboratories
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HEADPHONES:
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HINGES:
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General Radio Co.
Silver-Marshall, Inc.

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Jewell Elec. Inst. Co.

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General Electric Co.
National Vulcanized Fibre Co.
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LUGS:
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Weston Elec. Instr. Co.

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OSCILLOSCOPE:
Burt, Dr. Rob't C.

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(See Cells)

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PLATINUM:
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General Radio Co.

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Kodel Radio Corp.

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Jefferson Elec. Mfg. Co.
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Silver-Marshall, Inc.
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National Co., Inc.
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Thordarson Electric Mfg. Co.

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General Radio Co.
Kodel Radio Corp.
Lynch, Arthur H., Inc.
National Co., Inc.
Thordarson Electric Mfg. Co.

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Insuline Corp. of Amer.
Radiall Co.

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Leach Relay Co.

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Carter Radio Co.
Central Radio Laboratories.
DeJur-Amsco Co.
Electro-Motive Co
Hardwick, Hindle Inc.
International Resistance Co.
Lautz Mfg. Co.
Lynch, Arthur H., Inc.

RESISTANCES, VARIABLE:
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American Mechanical Labs.
Carter Radio Co.
Central Radio Laboratories.
Electro-Motive Co.
Hardwick, Hindle Inc.
International Resistance Co.
Lynch, Arthur H., Inc.

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General Radio Co.
United Scientific Laboratories.

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Copper and Brass Research Assn.

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Lynch, Arthur H., Inc.
Silver-Marshall, Inc.

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Rola Co., The

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Jensen Radio Mfg. Co.
Rola Co., The

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Insuline Corp. of Amer.
Lynch, Arthur H., Inc.

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Jewell Electrical Inst. Co.

TESTERS, TUBE:
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Jewell Elec. Inst. Co.

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General Radio Co.
Jewell Elec. Inst. Co.
Weston Elec. Instrument Corp.

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Jefferson Elec. Mfg. Co.
National Co., Inc.
Sangamo Elec. Co.
Silver-Marshall, Inc.
Thordarson Electric Mfg. Co.
Transformer Co. of America.

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Jefferson Elec. Mfg. Co.
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Thordarson Electric Mfg. Co.
Transformer Corp. of America.

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Jefferson Elec. Mfg. Co.
Sangamo Elec. Co.
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Thordarson Electric Mfg. Co.
Transformer Corp. of America.

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General Radio Co.
Jefferson Elec. Mfg. Co.
National Co., Inc.
Silver-Marshall, Inc.
Thordarson Electric Mfg. Co.
Transformer Co. of America.

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Gold Seal Elec. Co., Inc.
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Ceco Mfg. Co.
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Cornish Wire Co.

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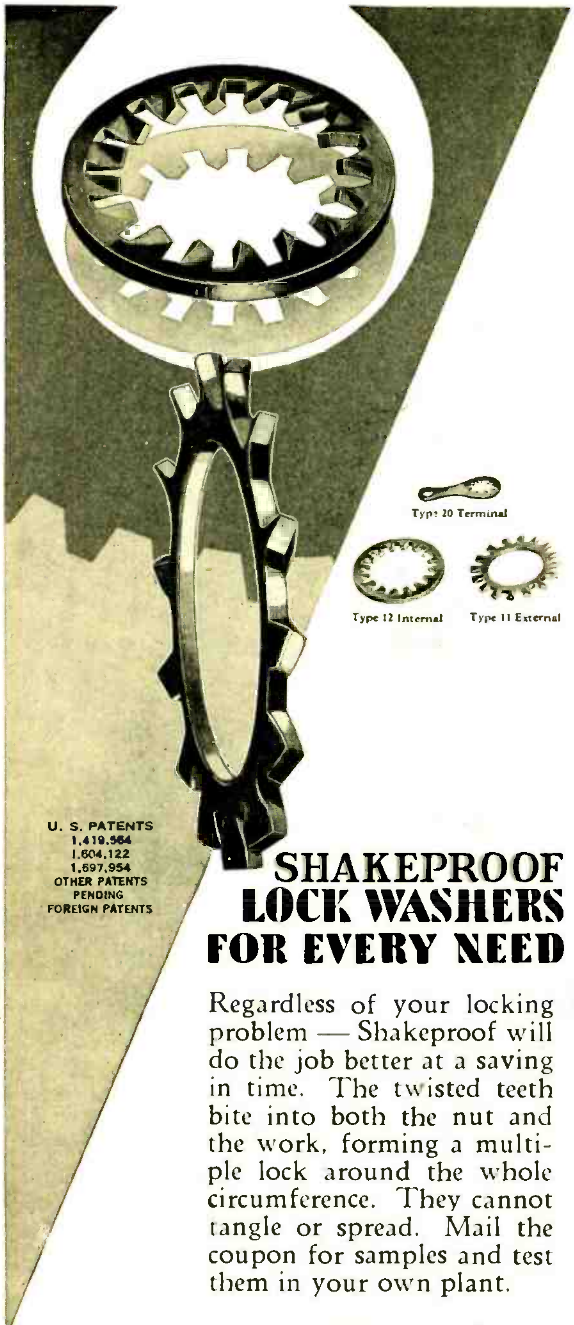

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