Ninth Year of Service

RADIO ENGINEERING

Vol. IX SEPTEMBER 1929 No. 9

IN THIS ISSUE

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The Journal of the Radio Industry

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RADIO ENGINEERING

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Departments

Engineering Trends

By H. B. Richmond
President, R. M. A.

SCREEN-GRID sets! This is the outstanding selling point of this year's radio sets. Is it, however, a phenomenal advance in engineering? The question may be even broader. Is there any phenomenal advance? The answer is, no.

Although the screen-grid tube is many years old, it has just become popular. It has certain decided advantages. It is not, however, revolutionary and has not made obsolete other types of sets. Our progress in radio has been along the lines of logical development. There has been a demand for improvement. Devices and circuits have been developed to meet this demand. It has been very rare that almost over night an important development has appeared which has changed at once existing radio sets.

The engineering trends this year and next will follow the standard lines. They are, as they have been, for simplicity, selectivity, and fidelity. No longer is a set with many controls acceptable. Radio in the home is entertainment, and not an engineering puzzle.

With high-power broadcasting stations, with the increase in the number of stations, and the increased sensitivity of receivers, it has become essential that receivers be made very selective.

Fidelity of tone is now the most important point under consideration. It is not sufficient to receive a noise. True reproduction is the object sought. To obtain this, wider channels in the radio-frequency, the detector, and the audio-frequency parts of the sets are being developed. The detector and audio end have been well cared for. Engineering attention is now being directed toward the radio-frequency end. To obtain fidelity here, the increased use of band-pass filters is predicted.

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James A. Walker, *Secretary*
E. M. Bacon, *Advertising Manager*

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EDITORIAL

September, 1929

THE SEVENTH WONDER

THE Sixth Annual Radio World's Fair, in New York City, is to offer a pageant, representing an expenditure of $50,000. It is to be called the Radio Pageant of Progress and will reveal the past, present and probable future of this comparatively new child of science.

On first thought, the expenditure of such a large sum of money on a mere pageant seems out of proportion with common sense, but this panorama of Radio will bring to the mind of the tyro . . . the man on the street . . . an entirely new conception of what Radio is and what is in store for this generation and the generations to come. It may well impress upon the visitor to the Fair that Radio is indeed the modern Seventh Wonder of the World.

In this age, Seventh Wonders seem commonplace. The public has lost its simple, rustic mentality; the people are pitched to a new and fast moving order of things and have come to expect the unusual. But let it not be forgotten that the public still has imagination. . . . an imagination far more extensive because of the general increase in knowledge. It is this imagination and the sense of the romantic that has placed Aviation on its feet much before its time. And this same characteristic imagination and sense of the romantic will be appealed to by the Radio Pageant of Progress. And $50,000 will have been well spent.

It is a long measure of time from the first crackle of a "wireless" spark to the present silent transmitters; from the crude recorders of yesterday to the efficient broadcast receivers of today . . . but there is no measure within the realms of human conception capable of encompassing the complete panorama of present-day radio. Our space has been annihilated; the measure of time that it takes a radio wave to travel around the world is a measure that is understandable on paper only. The wonder, though, lies not in figures or technical facts but in the picture. Our Nation, once culturally separated and segregated, has, through the element of a vastly amplified voice, become unified. The broad expanses of the United States have, through the medium of Radio, been reduced to a village square. And tomorrow? Tomorrow the culture of the world will be included and we may expect that a greater understanding and appreciation will grow out of the linkage.

The wonders of Radio do not cease here. Hinged to the structure of this art are the Talking Motion Pictures which, given time, will contribute an immeasurable amount of perspective to our lives. With the coming of Television, Radio and the Talking Motion Pictures will be welded into a single unit, when, for the first time, space will be annihilated with both visual and aural transmissions.

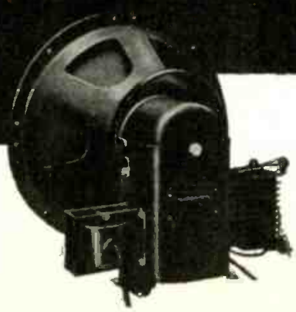
We have yet to experience the thrill of our bodies vibrating under the power of a "soft musical passage" rising above an orchestral background. But it will not be long before present experimental high-power sound-reproducing devices, permitting an entirely new freedom of musical expression, will be put to use in auditoriums and out-of-doors.

Of more interest, possibly, is radio control. The most modern automatic elevators are controlled by radio circuits, and with a remarkable precision. Radio control extends to Aviation, where radio beacons and course-shift indicators assist the pilot in keeping his course. Recently developed "radio altimeters," that indicate altitude from the surface of the earth rather than sea level, will, when refined, prevent many plane catastrophes. The piloting of planes by radio, from the ground, is another accomplishment that in time will find general use.

Radio has also entered the medical field. High-frequency currents, produced by vacuum tube oscillators, have been found to have curative effects and may yet prove to be the sole cure for one of the most dreaded diseases of mankind.

Radio *is* the Seventh Wonder of the Age, and greater things are yet to come of it.

M. L. MUHLEMAN, *Editor.*



Models 107, 109 and 201
12¼" high, 12" wide, 8¼" deep
10½" cone

The U. S. Patent Office has granted to the Magnavox Company exclusive use of the word "DYNAMIC" in connection with radio loud speakers.

Patents may be infringed, trademarks may be borrowed, but performance quality cannot be copied. The making of a dynamic speaker is an art that was started by Magnavox and carried on since 1911.

THE MAGNAVOX COMPANY

Factory and Pacific Sales: OAKLAND, CALIF.
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cell manufacturers a complete Engineering Service on production problems.

Send us particulars of your requirements. Prompt deliveries assured. Place your orders now.

Lepel High Frequency Laboratories, Inc.

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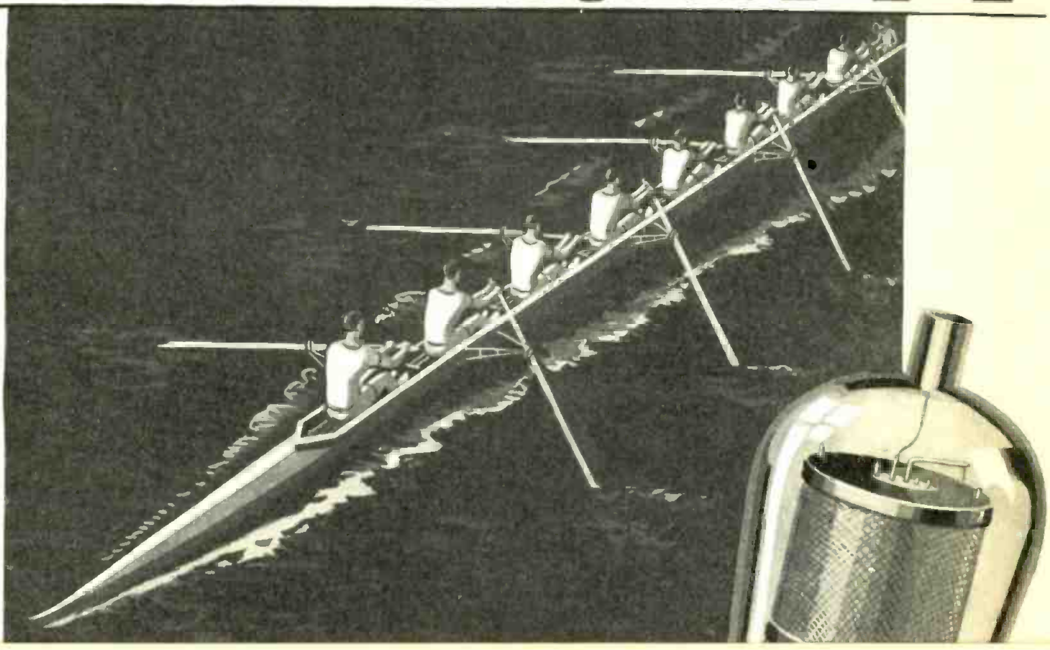
New York City

UNIFORMITY



THE BIG THREE OF RADIO

227

The most perfect detector made — that's why SPEED 227's cost more for us to make, but not for you to buy. Burn-out proof! Fast heating — 5 seconds flat (not by words—by test!)

224

New? Not to us. In production in 1928 when demand was only experimental. While others have been announcing, we have been improving. That's what foresight and tube-making experience were able to do.

245

Perfected and in production weeks ahead of others. Very rigidly constructed — extra bracing of the elements and special anchoring of filament in the SPEED 245 give added volume and finer tone quality.

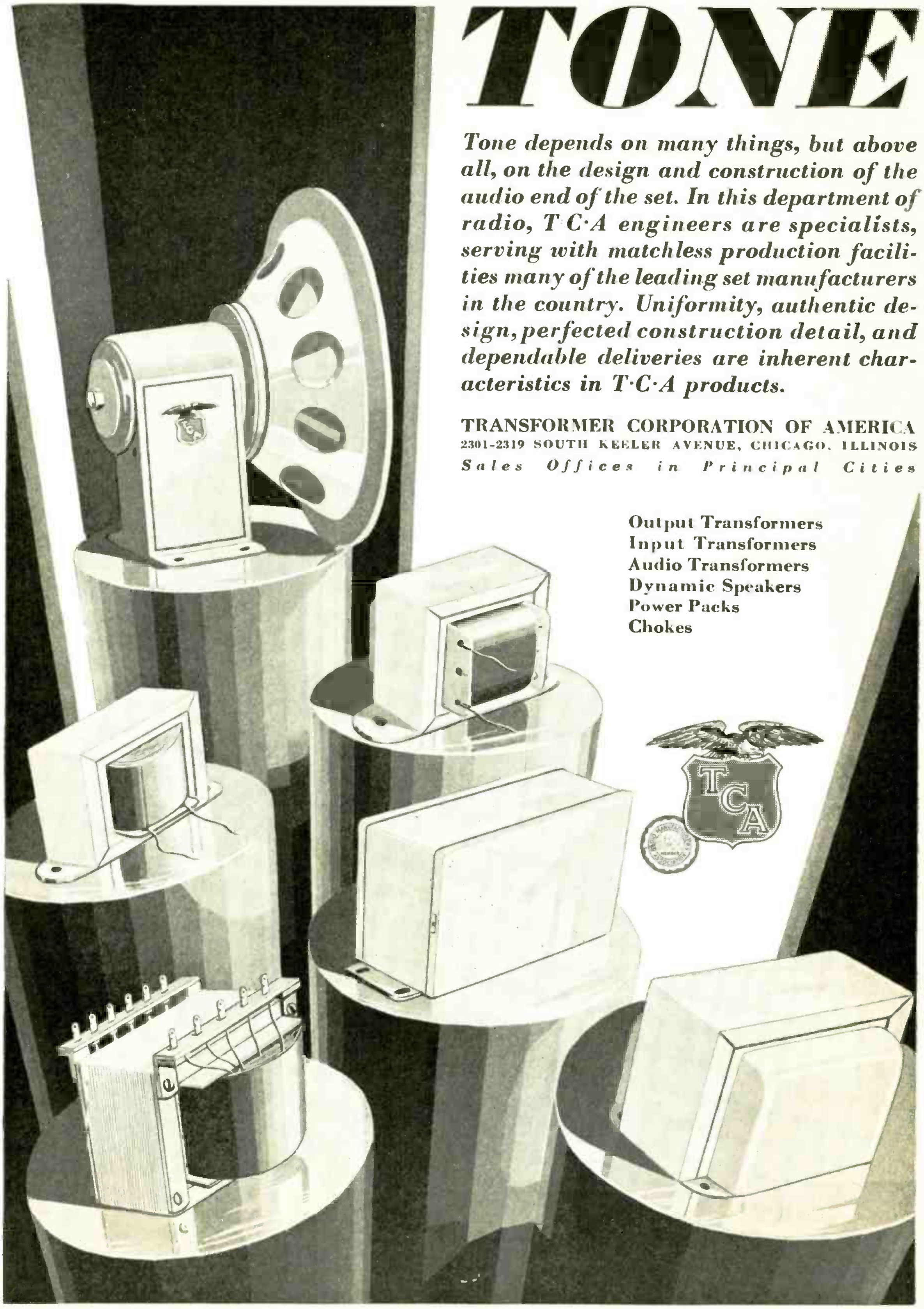
THE SPEED Tube line is, of course, complete*. But these are the "Big Three" now—the ones you're interested in particularly, because they're the ones your customers want. Carry the quality 227's, 224's, 245's,—SPEED—and your tube business is assured.

The SPEED proposition demands the consideration of every wide-awake jobber and dealer as a matter of good business. Work fast—write at once—franchises are going fast.

* The SPEED line also includes the 201A, 199, X140, WD11, WD12, 200AA, 112A, 171A, 171AC, 210A, 250, 226, 280, 281.

SPEED
CABLE RADIO TUBE CORPORATION
84-90 No. Ninth St., Brooklyn, N. Y.

MAKERS OF RADIO TUBES SINCE 1924


TONE
Tone depends on many things, but above all, on the design and construction of the audio end of the set. In this department of radio, T·C·A engineers are specialists, serving with matchless production facilities many of the leading set manufacturers in the country. Uniformity, authentic design, perfected construction detail, and dependable deliveries are inherent characteristics in T·C·A products.
TRANSFORMER CORPORATION OF AMERICA
2301-2319 SOUTH KEELER AVENUE, CHICAGO, ILLINOIS
Sales Offices in Principal Cities
Output Transformers
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Dynamic Speakers
Power Packs
Chokes
TCA

Who knows the
MERSHON CONDENSER
?

RADIO ENGINEERS know the Mershon Condenser; for years they have known this marvelous device which has smoothed the way in the radio field toward the definite end of condenser trouble. . . .

Acoustical engineers know the Mershon Condenser; know that it simplifies their problems and gives uniformly excellent results. . . .

Radio Manufacturers know the Mershon Condenser—they know it from the pocket-book angle, for the Mershon Condenser is most economical as well as most efficient. . . .

Radio Dealers know the Mershon Condenser. They know it without ever seeing it, for radio sets equipped with the Mershon never develop Condenser trouble. . . .

Wherever a smoothing condenser is necessary; wherever great capacity in small space, dependable service and economy are desirable; wherever you want a condenser free from trouble, self-healing in case of puncture, unaffected by atmospheric conditions . . .

Ask Us How The Mershon Condenser Can Help Your Particular Problem

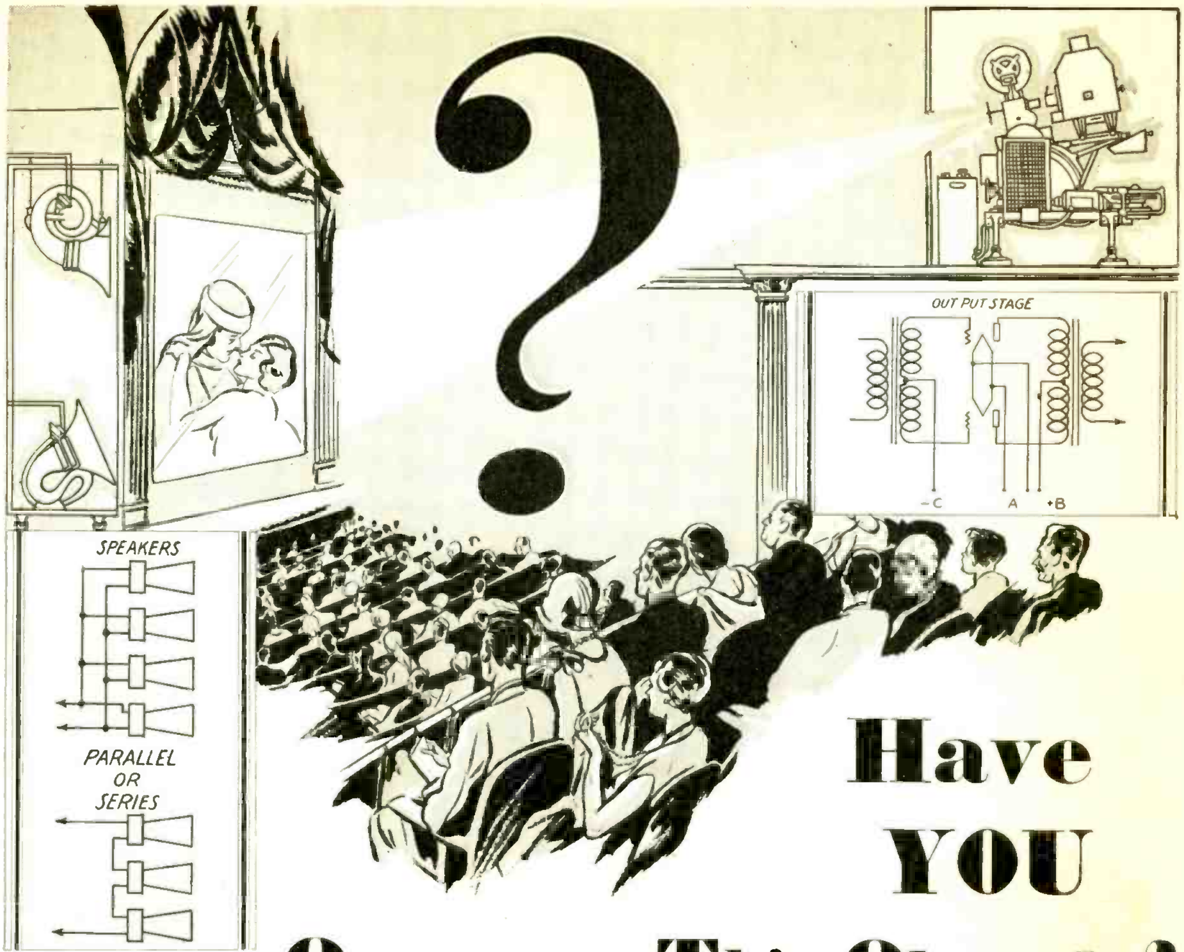
Department RE
THE AMRAD CORPORATION
Medford Hillside, Mass.

J. E. HAHN
President

POWEL CROSLEY, JR.
Chairman of the Board

National
Advertising

. . . . AND
10,000,000 consumers know about the Mershon Condenser. In the leading weekly magazines in America they are learning through a powerful national advertising campaign that a radio set equipped with the Mershon Condenser *will not develop condenser trouble!* They are learning to ASK FOR A RADIO that contains the Mershon Condenser.



Have YOU Overcome This Obstacle?

Between the amplifier and loud speaker lies the source of considerable difficulty in attaining perfect reproduction of sound and talking pictures.

Our engineers,—thoroughly experienced in such a highly specialized field, — have been particularly successful in eliminating this trouble.

If YOU have yet to overcome this obstacle, consult—

AMERTRAN

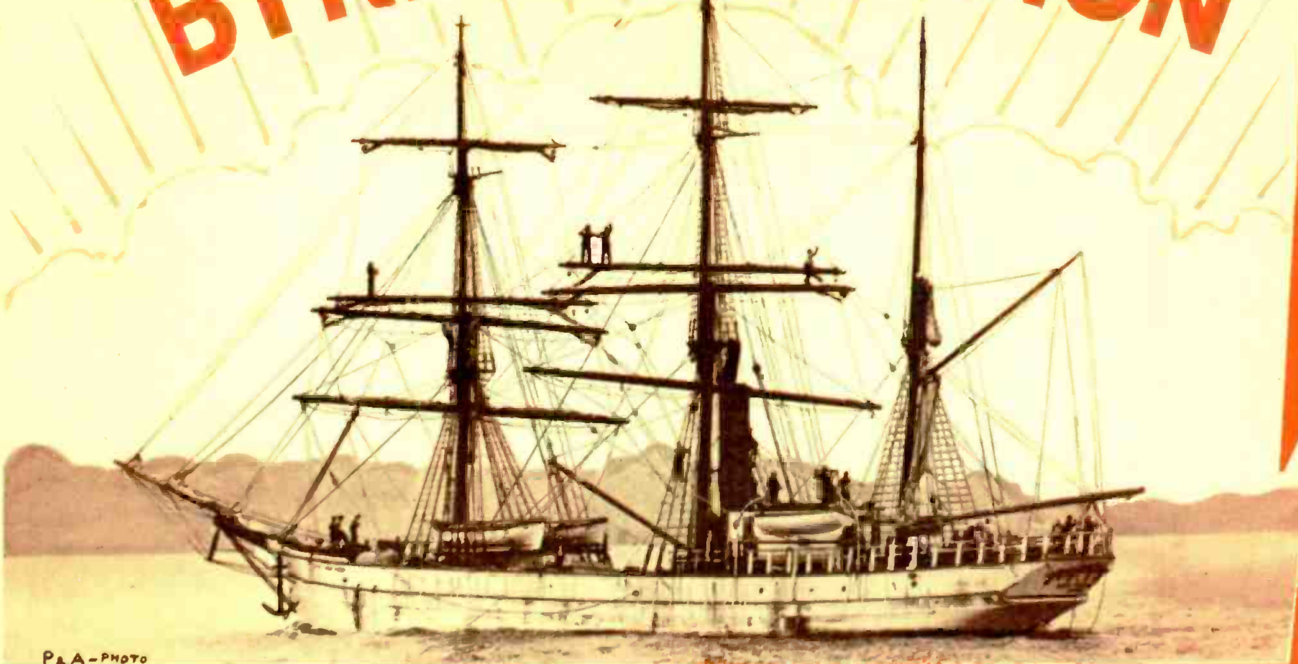
TRADE MARK REG. U.S. PAT. OFF.

AMERICAN TRANSFORMER COMPANY

Transformer builders for more than 28 Years

178 Emmet Street Newark, New Jersey

BYRD EXPEDITION



Transmitters and Receivers employ Sangamo Condensers

Away down among the ice barriers of the Antarctic . . . only the dependable operation of short wave transmitters and receivers keeps the Byrd Expedition in touch with the civilized world. Only the snappy kick of short wave equipment affords a plane in trouble the protection of the mother ship.

Not unusual then, the choice of Sangamo 5000-volt Fixed Condensers for the radio equipment. Tested at 5000 volts d.c. and 3500 a.c. and built to the world radio-known Sangamo standard, amateurs, commercial men and manufacturers have come to rely on Sangamo High Voltage Condensers.

Accurately rated, more than adequately tested and enclosed in an impervious Bakelite molding—these condensers offer the maximum protection in high voltage, high frequency circuits.

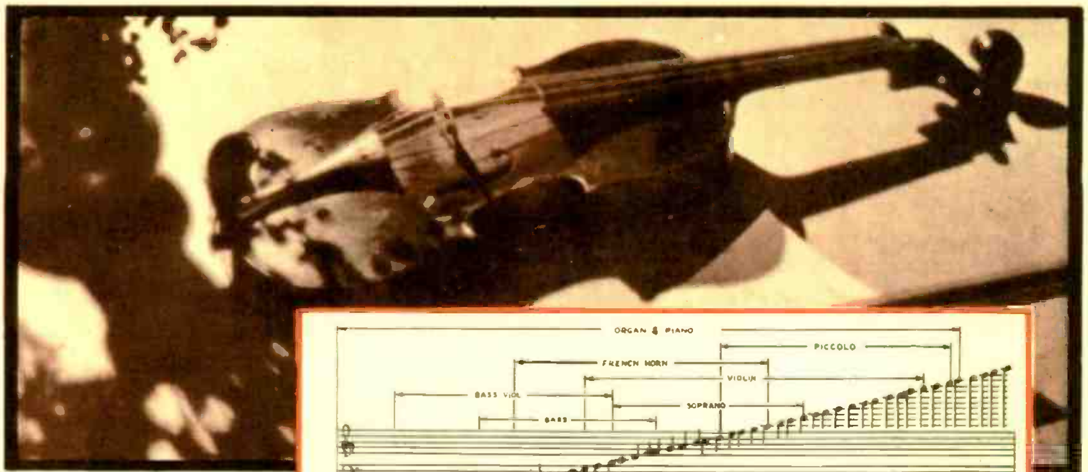
SANGAMO ELECTRIC CO.

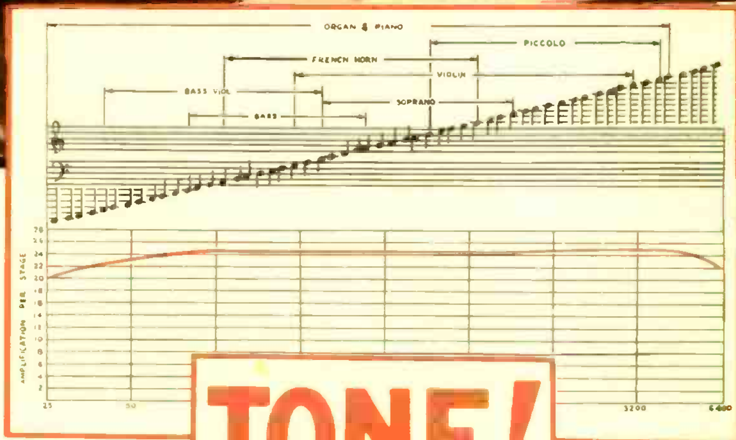
SPRINGFIELD, ILLINOIS, U. S. A.

Manufacturers of Precision Electrical Apparatus for 30 Years

SANGAMO

See reverse side





Curve of Sangamo Type "A" Transformer. Note the uniformity of amplification at all audible frequencies.

TONE!

Type A straight audio amplification.........list price, $10.00

Type B Push-pull Input Transformer for all tubes............ ....list price, $12.00

Type C-171 Push-pull Output, for 171 or 250 type power tubes with cone speaker.......$12.00

Type D-210, same as C except for 210 and 112 power tubes, $12.00

Type H-171, Push-pull Output for 171 or 250 power tubes for Dynamic Speaker.............. ....list price, $12.00

Type G-210, same as type H except for 210 and 112 tubes...... ....$12.00

Type F Plate Impedance for use as a choke to prevent oscillation and for impedance coupled amplifiers.........list price, $5.00

According to *musical* standards

It may be true that the search for straight line audio-amplification is an out-of-proportion effort to accomplish a small objective. It may be true that few average listeners can really tell the difference between just "good" transformers and the best transformers!

But we do know, however, that the true beauty of music arises in seemingly small perfections—many of them known by name to only the trained musician. And we know that the *average* ear also responds, perhaps unconsciously, and derives greater pleasure from music "as it should be."

Therefore, in designing and building Sangamo "A" Transformers even the smallest improvement was important. No possible betterment was disregarded. Cost was disregarded, for this transformer is built for the man who wants the best and knows that it costs more. The core metal alone costs as much as the total manufacturing cost of many transformers, but it permits a dense, compact field without saturation and is worth the money because it increases amplification in the lower registers.

So Sangamo has built this master transformer to *musical* standards for those who demand the best. For the set builder to add to his pride of craftsmanship and achievement, for the manufacturer who wants a "tone" advantage against competition.

The coupon below is for your convenience in securing complete data.

Pin this to your letterhead and mail

SANGAMO ELECTRIC CO., Springfield, Ill., U. S. A. Dept. 94

Sangamo Electric Co. of Canada, Ltd., 183 George St., Toronto.

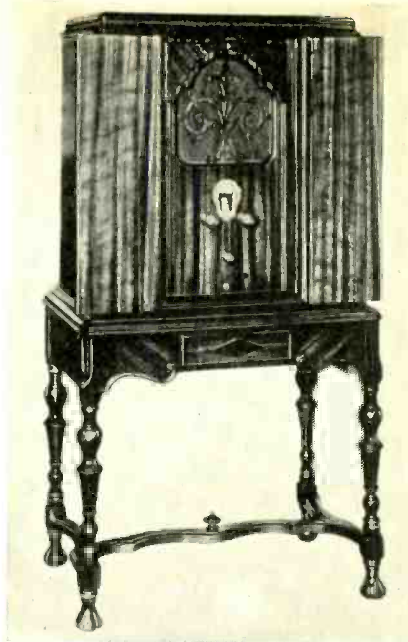
☐ *(For manufacturers)* I am interested in engineering data regarding your transformers and condensers, also the phonograph amplifier hook-up.

☐ *(For dealers)* Please send data on Sangamo Condensers.

☐ *(For set builders)* Please send booklet describing your apparatus and latest audio hook-ups. I enclose 10c to cover cost of mailing.

DURHAM Metallized RESISTORS and POWEROHMS are available for every practical resistance purpose in radio and television circuits, 500 to 200,000 ohms in power types; 1 to 100 Megohms in resistor types; ratings for all limited power requirements; standard, pigtail or special tips.

THE LEADERS STANDARDIZE ON DURHAM RESISTANCES



The FREED NR 95 Radio—a 9 tube neutrodyne in de luxe walnut veneered console with electro dynamic speaker.

Only the BEST is Good Enough for The FREED RADIO

IN the automobile field there are several makes of axles—but there is only one TIMKEN — the axle that is installed in the leading cars of the industry. In radio there are many makes of resistances—but only one DURHAM — the Resistors and Powerohms which are used by leading quality receivers in the industry. Freed Radio easily could cut the cost of their resistances by a small fraction, but their engineers, their dealers, their jobbers and their ultimate consumers get added value in finer reception because FREED RADIO RECEIVERS use Durhams. The presence of Durhams in a receiver is a guide to the quality of all other parts. Write for engineering data sheets, samples for testing and complete literature. Please state ratings in which you are interested.

DURHAM
METALLIZED
RESISTORS & POWEROHMS
INTERNATIONAL RESISTANCE CO.
2006 Chestnut Street, Philadelphia, Pa.

Vacuum Tube Products Co.

MERGED

Schultz Machine Co.

Schultz Machine Co., Inc.
Newark, N. J.

Vacuum Tube Products Company
Hoboken, N. J.

It was but logical and inevitable that these two organizations so closely akin in their manufacturing endeavors and policies should join for the common purpose of rendering better service to the radio and electrical industries with radio tube parts and filaments of the highest quality.

The advantages of this linking together of these organizations are easily apparent. In products of both companies in the past, precision workmanship and quality manufacture won the patronage of leading tube manufacturers. Now unified management and control, coordination of engineering efforts and skill, economies of manufacture and purchasing, and the consequent larger production are bound to bring great benefits to the radio and electrical industries and the ultimate consumer.

The Radio Products Corporation is confident that its radio tube parts such as shields, collars, getter cups and plates, its filaments, electrode leads, and its other products will win even a higher place in the estimation of the trade.

Radio Products Corporation

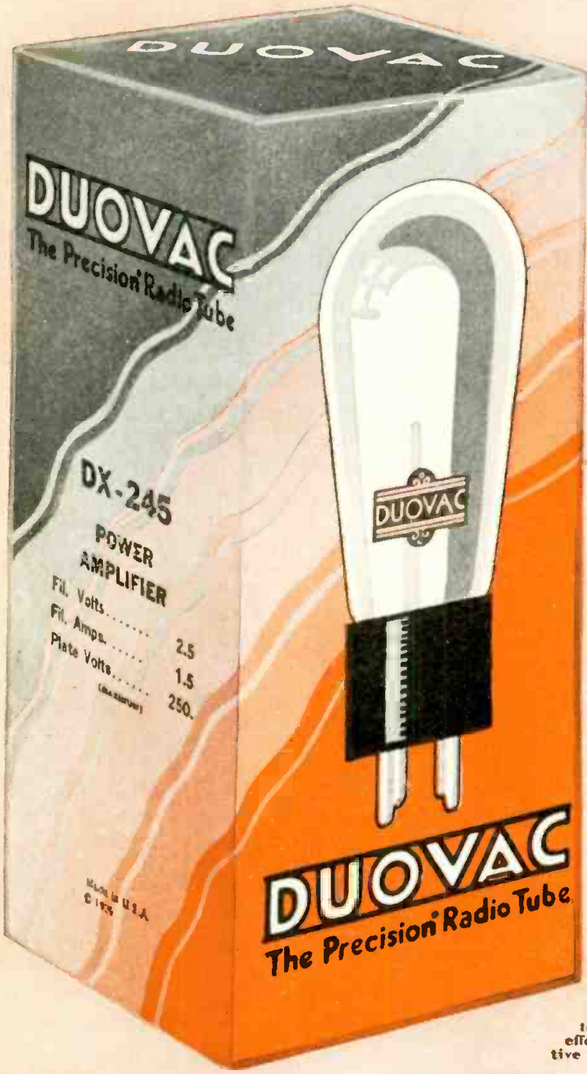
548 South 11th St.
Newark, N. J.

219 Bloomfield St.
Hoboken, N. J.

VISIT BOOTH 4 - SECTION GG - EXPOSITION FLOOR
Radio World's Fair, Madison Square Garden
September 23rd to 28th inclusive

Schultz Machine Co., Inc.

. . . designed much as other tubes



but—

the DUOVAC factory was designed as no other tube plant ever has been . . . to achieve uniformity in every operation to maintain uniformity in every DUOVAC, to let no tube be called a DUOVAC which is not uniform.

The DUOVAC PROCESS which makes DUOVAC uniformity possible will be advertised widely before set owners everywhere. The dealer who serves this enlightened clientele by featuring DUOVACS will not only be assuring his trade greater tube satisfaction . . .

He will also be reducing his service problems because of the uniformity of DUOVACS . . .

DUOVAC RADIO TUBE CORPORATION
360 Furman Street
Brooklyn, N. Y.

The DUOVAC package—(shown here in 2 colors) is actually printed in four colors, shaded from deep blue to deep red in a gorgeous rainbow effect, an ideal combination for effective window, counter or shelf display.

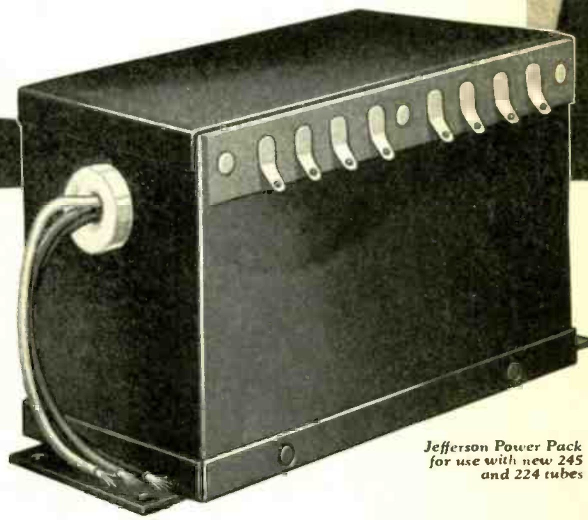
DUOVAC

The *Precision Radio Tube

*PRECISION—The quality of being precise, strictly accurate—identical. Standard Dictionary

At the R. M. A. Show in New York visit our display at booth 6, section B. B.

Jefferson Out in Front in New Power Tube Transformers



Jefferson Power Pack for use with new 245 and 224 tubes

ONE of the pioneers in the radio parts field, Jefferson has rendered valuable aid in solving audio and power transformer problems for numerous set manufacturers. With the coming of new power tube sets, Jefferson again stepped out in front in the development of highly efficient transformers, chokes and audios for use in these new sets.

Our large and complete engineering department, a modernly equipped laboratory and staff of sales engineers with a long experience in transformer design and construction, are available to assist you in working out your electrical problems.

And when you select Jefferson as your source of supply for audio, output, power transformers or chokes, you are assured prompt deliveries in peak and emergency periods as well as under normal demand conditions.

Besides all these advantages of superior service, in addition to Jefferson quality, our mass production schedule gives you the benefit of low prices. Be sure to get our quotations on your requirements.

JEFFERSON ELECTRIC COMPANY
1592 South Laflin Street Chicago, Illinois

A Wide Choice of Choke Units

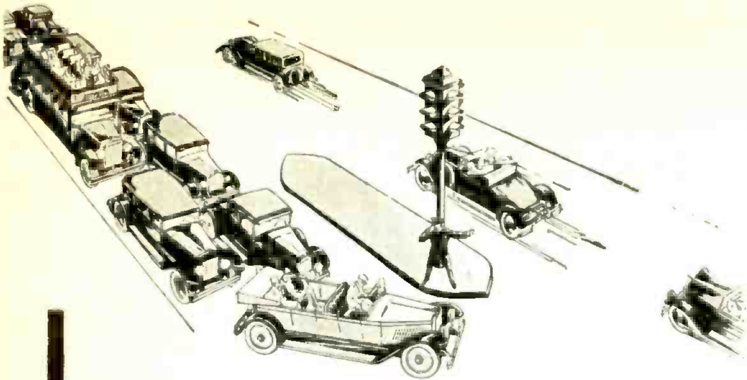
Economical and excellent results are obtainable in the wide choice of choke units available for use with the new Jefferson power tube transformers—especially the choke unit which makes use of one heavy duty choke and one small choke. This unit minimizes hum and permits maximum voltage on the power tubes without overloading the rectifier.

Likewise Jefferson Audio transformers have been improved to function most advantageously with the new power tubes.

JEFFERSON

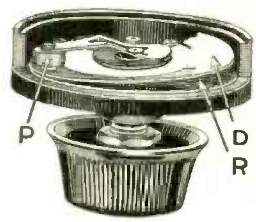
AUDIO and POWER TRANSFORMERS and CHOKES

(9482)



LIKE A CAR WITH A BALKED GAS LEVER IN HEAVY TRAFFIC

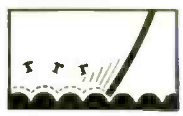
THIS shows the exclusive rocking disc construction of Centralab volume control. "R" is the resistance. Contact disc "D"



has only a rocking action on the resistance. Pressure arm "P" together with shaft and bushing is fully insulated.

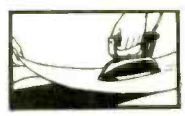
Your foot on the gas brings a jerky response . . . you're holding up traffic that's anxious to move.

Your variable resistance feeds the "gas" to your radio receiver . . . and there's all the difference in the world if it's a CENTRALAB.



This is the action of the usual wire wound control after it has been in use for some time . . . like dragging a stick over a cobblestone pavement.

Quiet, even flow of current without a crackle or a sputter . . . that's CENTRALAB performance. . . . a scientifically constructed precision control for the modern radio receiver.



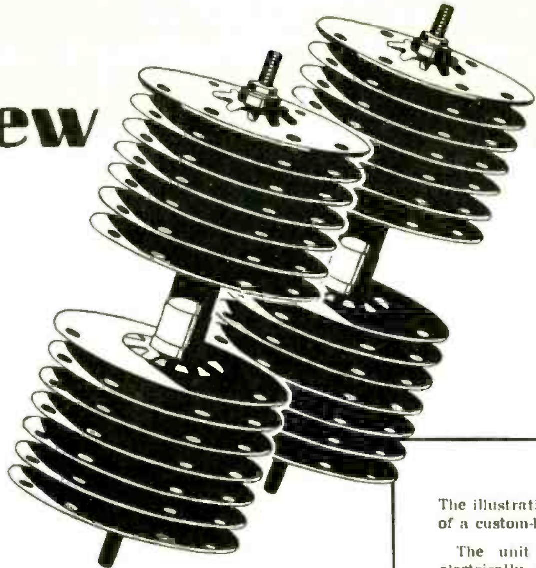
The tailor uses the same principle as Centralab. He does not want to ruin the garment by placing the iron on it so he places a cloth in between. Centralab controls can not ruin the resistance because the rocking disc is in between the pressure arm and the resistance.

Write for our Free Booklet "Volume and Voltage Controls—Their Uses."

Centralab

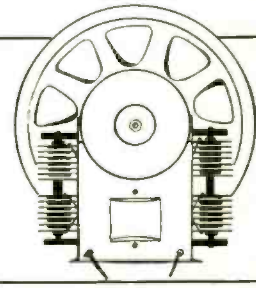
CENTRAL RADIO CRL LABORATORIES

20 KEEFE AVENUE, MILWAUKEE, WIS.



New High Voltage Rectifiers

Custom built!



The illustration shows an example of a custom-built Kuprox Rectifier.

The unit was designed both electrically and mechanically to meet existing specifications and is now faithfully doing this on this manufacturer's production.

KUPROX Rectifiers by the very nature of their construction may be readily manufactured in sizes and styles differing widely in both electrical and mechanical characteristics.

Currents from 50 to 200 Milliamperes—Voltages ranging from 60 to 110 DC, from commercial 115 AC supply without the use of a transformer—Wattages ranging from 7 to 15 watts.

This flexibility is such that in many cases the Rectifier may be designed to exactly meet individual requirements. Send us one of your Dynamic Speakers and let our Laboratory custom-build a Rectifier to suit.

Remember the Wire Shortage!

Set manufacturers, in some cases, are already embarrassed in their production due to the shortage in supply of small size wire.

A good part of this small size wire is needed for the field coils of Dynamic speakers operating from the plate supply.

By equipping the sets with AC Dynamics, a field coil of a few turns of heavy wire (which is easy to obtain) may be used.

We have many suggestions for saving wire in the construction of Console sets with Dynamic speakers. Submit your problems and let us assist you.

FREE! Our new Booklet "KUPROX Rectifiers for Dynamic Speaker Use," illustrating all the various KUPROX Units for such purpose and containing complete engineering data thereon, will be sent gratis to any speaker manufacturer, engineer, or designer writing us upon his firm's letterhead.

The Kodel Electric & Mfg. Co., *Cincinnati, O.*

KUPROX

DRY COPPER OXIDE RECTIFIER

IMPRESSIONS *and* EXPRESSIONS

By

AUSTIN C. LESCARBOURA

Those A B C Grades of Vacuum Tubes

THE practice of some vacuum tube manufacturers to market their normal rejects under different brand names, is to be deplored. The individual manufacturer indulging in such practice, quite as well as the industry at large, is the loser, and if this point were better appreciated, the practice would soon cease.

Of course no manufacturer enjoys the high shrinkage to which vacuum tube production is subject. The rejection of anywhere from 5 to 50 per cent of the tubes produced is at once cruel and costly. Indeed, more than any other factor, the high percentage of rejections in honest tube production makes for high production costs. Nevertheless, just as a farmer must separate the good apples from the bad, so must the honest vacuum tube manufacturer distinguish between good tubes and bad tubes. There is no middle ground.

We maintain—and this view is based on what we have seen in some tube plants—that unless the policy of the tube manufacturer is to turn out good tubes only, that manufacturer is not building for the future. In plants where the A B C system of grading is employed, the personnel is not very much concerned about turning out as many A grade tubes as possible. In other plants, where the tube is either good or it is discarded, the personnel is compelled to concentrate on good tubes. There is positively no salvage, as in the case of the plants selling B and C grades. We have come across instances where tube manufacturers ship out their entire production as A grade, and those returned as off-standard are again shipped out as B grade, while those returned as worthless are once more shipped out as C grade.

A most unfortunate state of affairs, this situation, but we firmly believe that it will cure itself in time.

We Want Quick-Heating Tubes, But—

THERE is no denying the fact that the long wait for the usual a-c. heater tubes to come up to full operating efficiency is a serious drawback in the popularity of the socket-power radio set. It is therefore logical for radio engineers and vacuum tube manufacturers to seek ways and means of reducing heating time. Nevertheless, we see some grave dangers ahead in some of the quick-heating designs that are now being promoted, and therefore sound this note of warning: Don't reduce the heating time if it is at the expense of other desirable characteristics!

For instance, in some quick-heating tubes, the hum is considerably increased, so much so, in fact, that certain tube manufacturers have been receiving many returns of their tubes from set manufacturers who simply cannot use them. Again, in other instances the quick-heating tubes have proved highly fragile in design, so that short-circuited elements have given considerable trouble in production as well as in shipment. In still other instances, tube life has been materially reduced by gaining quick-heating through an undersized heater wire.

Of course the public wants quick-heating tubes. But by all means be sure that your quick-heating design does not introduce increased hum, troublesome fragility, and greatly reduced life.

Let's Encourage Radio Accessories!

IS the radio set of today too complete? That may sound like illogical reasoning to the public, interested in having something that is complete and final; but to the radio manufacturer and merchandiser, bent on selling this year, next year and for many years to come, there is such a thing as doing things too well and too finished. If we examine present-day radio sets from the standpoint of the radio industry, it does seem that perhaps we are making them too complete and too final.

The average radio set contains everything necessary for satisfactory radio performance. Loudspeaker, power amplifier, power plant and radio receiver proper are housed in an attractive cabinet. There is nothing missing; indeed, there is no chance to add anything. But is the offering so complete? For instance, if we included a jack or a pair of binding posts for an external loudspeaker, wouldn't we be encouraging the use of a second loudspeaker in another part of the house, or out on the porch, or even out in the yard these warm days? Again, we might include a switch whereby the built-in loudspeaker or the extension loudspeaker could be operated at will.

Another thing: many families would like to use their splendid radio equipment for playing phonograph records. A jack for an external electric pickup would go well.

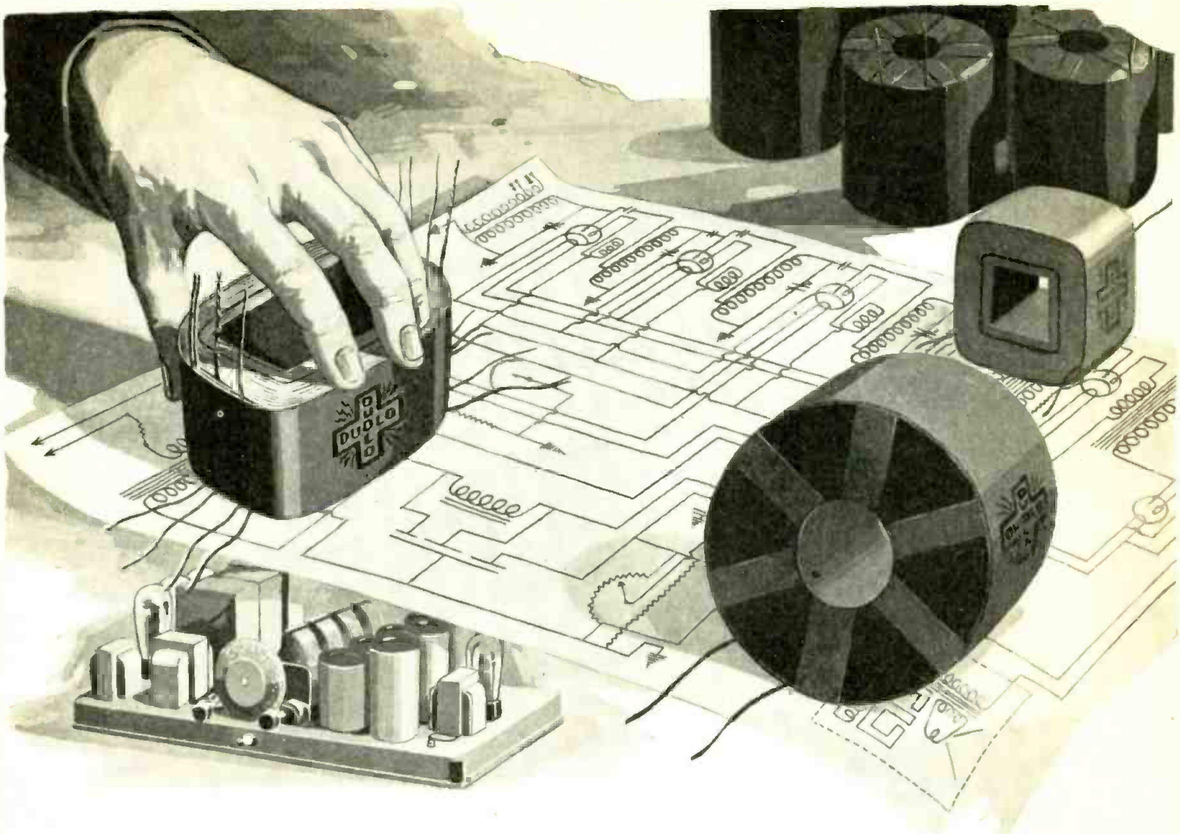
Why not include these features? True, the set manufacturer may not necessarily do the business in extra loudspeakers and electric pickups, but at least he is making his set that much more desirable to the buyer, while at the same time contributing to the sum total of radio trade. At any rate, it's a worthwhile thought.

And Now — — — Real Rural Radio

THIS fall will mark the opening of a large and important radio market, namely, the rural and farm market. In other words, the radio industry, having concentrated these past three years on the socket-power radio market, now turns to the requirements of a large and neglected market found in some six million rural homes beyond reach of the usual electric light system, together with some three million unwired homes in towns and cities. However, let us not take the latter too seriously as a radio market, since these unwired homes represent the poorer families and therefore the least promising prospects for radio sales.

We hasten to predict that if the rural and farm market is properly catered to, the radio industry is going to experience an excellent expansion. Previous attempts to open this market have more or less failed, because the storage battery set, such as served the city and town radio enthusiast at the time, was most troublesome to the rural family due to the recharging problem, while subsequent dry battery sets were far from practical due to the use of the —99 type tube.

There is a world of opportunity for every radio manufacturer, whether he be interested in sets, loudspeakers, power supplies or whatnot, to engage in supplying the demands of the farm and rural radio market. However, if it is simply with the idea of forcing on the rural buyer something not primarily designed to meet the conditions of the unwired home or at least the conditions encountered with the usual 32-volt farm lighting system, the entire matter better be forgotten.



Fitting the Coil into radio design

Coils are as important in a receiving set as the mainspring in your watch. In the last analysis, the rest of the set can't do much unless the coils are right..

Dudlo has achieved leadership in the coil world by the plain, old-fashioned policy of doing a real job.

The exceptional resources of Dudlo, both in production and in research engineering, make possible a complete and precise service . . . a service which does not stop in the laboratory, but is also available in the field to every radio manufacturer, wherever located.

See the Dudlo Exhibit, Section S, Booth No. 3,
New York Radio Show

DUDLO MANUFACTURING COMPANY, FORT WAYNE, INDIANA
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DUDLO

THE COIL'S THE THING IN RADIO

Notes on the Design of R-F. Band-Pass Filters

Mathematical Treatment of Band-Pass Filter Design in Reference to the Screen-Grid Tube

By Charles J. Hirsch, E.E.

THE recent and sustained interest in sets using some sort of radio-frequency band-pass filter makes desirable the derivation of some of the laws of these circuits in a convenient form. The lack of appreciable grid-plate capacity in the screen-grid tube makes actual design possible. It is hoped that the following equations will be of real use to the set designer.

The following equations are derived in terms of circuit constants, resonant frequency, and frequency away from resonance.

Nomenclature

L is the inductance of the tuning circuit.

C is the capacity of the tuning circuit.

R is the resistance in the tuning circuit.

Lm is the mutual inductance.

Cm is the mutual capacity.

Rp is the plate resistance of the tube.

μ is the amplification factor of the tube.

Gm is the mutual conductance of the tube, or μ/Rp.

k is the coefficient of coupling between circuits.

w_0 is the angular velocity at resonance, or $2\pi f_0$.

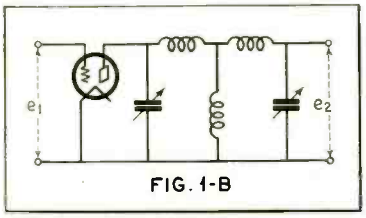
fo is the resonant frequency.

d is the difference in angular velocity between the resonant frequency and frequency away from resonance.

t is the difference in frequency between resonance and any other frequency away from resonance so that $d = 2\pi t$.

$J = \sqrt{-1}$

$\Delta\omega$ is the difference in angular velocity between the peaks of coupled circuits as determined from circuit constants but *neglecting the circuit resistance.*



Another form of band-pass filter.

I—Circuits Having One Tuning Element in Common

In this category we include circuits of the form shown in Fig. 1.

If both circuits are tuned to the same frequency, then the ratio of output to input voltage will be a maximum for the following two frequencies, *if the resistance is negligible:*

$$1 - f_1 = \frac{f_0}{\sqrt{1 - K}}$$

$$2 - f_2 = \frac{f_0}{\sqrt{1 + K}}$$

However, we are interested mostly in the difference between these two frequencies, so that

$$f_1 - f_2 = \frac{f_0}{\sqrt{1 - k}} - \frac{f_0}{\sqrt{1 + k}}$$

Since k is small, less than 2%, this can be simplified to:

$$f_1 - f_2 = kfo, \text{ or } \overline{\Delta\omega} = k\omega_0 \qquad (1)$$

In other words, if the circuit resistance is small, the band width is equal to the resonant frequency multiplied by the coefficient of coupling. If the coupling remains constant, then the band width increases directly with the frequency.

As an actual case, let us take a band width of 10 kc. at 550 kc. This requires a coefficient of coupling equal to 10/550 or 1.8%. If this coupling remains unchanged and the resistance is negligible the band width at 1500 kc. will be 27 kc. To maintain a band width of 10 kc. at 1500 kc. the coefficient of coupling should be changed to .66%.

If the coupling is of the form of Fig. 1-A, then means must be provided, if we desire constant band width, to alter it by changing the relative position of the coils. If it is of the form of Fig. 1-B then the inductance Lm must be decreased with frequency.

If the coupling is of the form of Fig. 1-C, that is capacitive, the coefficient of coupling is given by the relation

$$k = \frac{C}{C + Cm}$$

and the resonant frequency by

$$\omega_0^2 L \frac{C\,Cm}{C + Cm} = 1$$

or

$$\omega_0^2 L k Cm = 1$$

So that

$$k = \frac{1}{\omega_0^2 L Cm} \qquad (2)$$

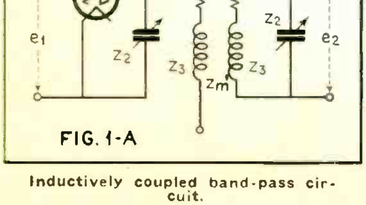
but

$$k = \frac{\overline{\Delta\omega}}{\omega_0} \qquad (1)$$

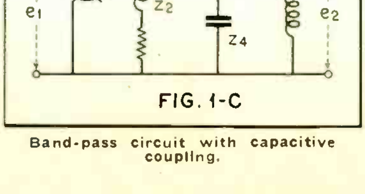
Therefore $$\overline{\Delta\omega} = \frac{1}{\omega_0 L Cm} \qquad (3)$$

In other words, the band width, for constant value of Cm decreases with frequency.

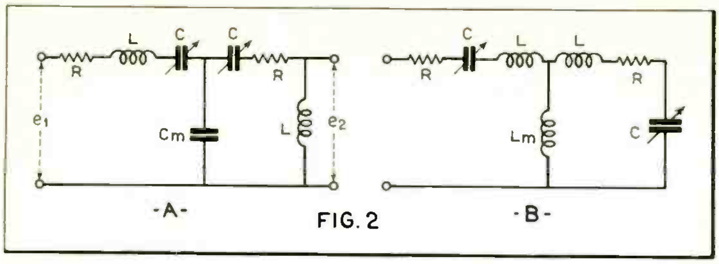
As an actual example let us take an inductance equal to 200 microhenries, a band width of 10 kc. and a fre-



Inductively coupled band-pass circuit.



Band-pass circuit with capacitive coupling.



Two generalized band-pass filter circuits. The inductances L, in Fig. 2-B should be indicated as L_1.

quency of 550 kc. The coupling capacity for this condition is Cm= .023 mf. If this capacity remains unchanged, the band width at 1500 kc. will be only 3.65 kc. To maintain a band width of 10 kc., the capacity Cm should be changed to .0084 mf. (If the resistance is negligible.)

Of course, the value of Cm must be included in all tuned circuits as it is an integral part of the tuning capacity.

It must be remembered that the above formulae apply only if the coil resistance is negligible. If this is not so the band width is materially altered. Actually, with commercial coils, this assumption is never warranted. To determine the effect of resistance, the equations determining the shape of the resonance curve were derived for circuits shown in Figs. 2-A and 2-B.

For 2-A, this equation is:

$$\frac{e_2}{e_1}=\frac{L/Cm}{R^2+\frac{1}{\omega^2 Cm^2}-4d^2L^2+J4RdL} \qquad (4)$$

It is seen that in this case the band width is given by the equation

$$2d=\frac{\sqrt{R^2+\frac{1}{\omega^2 Cm^2}}}{L}=\frac{\sqrt{R^2+\overline{\Delta\omega}^2L^2}}{L} \qquad (5)$$

We have already shown that as the frequency increases, $\Delta\omega$ decreases. However, since the value of coil resistance increases with frequency, we see that the band width remains more nearly constant. In this case the coil resistance helps us to maintain constant band width.

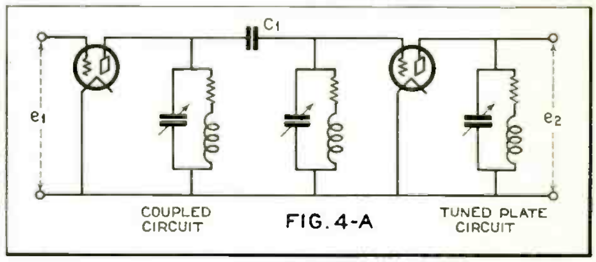
For the case of Fig. 2-B, this equation is

$$\frac{\omega^2 L L_m}{R^2+\omega^2L_m^2-4d^2[L_1+L_m]^2+J4Rd[L_1+L_m]} \qquad (6)$$

In this case the value of band width is very nearly given by the relation

$$2d=\frac{\sqrt{R^2+\omega^2L_m^2}}{L_1+L_m}=\frac{\sqrt{R^2+\overline{\Delta\omega}^2[L_1+L_m]^2}}{L_1+L_m} \qquad (7)$$

Since in the case of inductive coupling the value of $\Delta\omega$ increases with frequency, the coupling remaining constant, we see that $\Delta\omega$ and R both vary in the same direction and the effect of coil resistanc is to add to the variation in band width occuring between low and high radio frequencies.



A capacitive coupled band-pass filter circuit the resonance curve of which is shown in Fig. 4-B.

Since ordinary tuned circuits are broader at the high frequencies, a stage of capacity coupled tuned circuits will tend to offset this tendency. Of course R has to be small enough to make

Desired Band-Width=2d=

$$\frac{\sqrt{R^2+\overline{\Delta\omega}^2L^2}}{L} \qquad (5)$$

Cases of Fig. 2 With the Effect of Tube Constants

The equations for the various circuits were set up as required by Kirchoff's laws for meshes. Thus for Fig. 1-A the vector solution is given by

$$A=\frac{e_2}{e_1}=\frac{\mu Z_2{}^2 Z_m}{Z_1[Z_2+Z_3]^2+Z_2Z_3[Z_2+Z_3]-Z_m{}^2[Z_1+Z_2]}$$

It must be remembered that the Z's are vector quantities and that

$$Z_1=R_p;\ Z_2=\frac{-J}{\omega C};\ Z_3=R+J\omega L;\ Z_m=J\omega M$$

Substituting these values in the above vector equation, we get

$$\frac{e_2}{e_1}=\frac{\mu K\omega^3L^3}{\sqrt{[R^2\omega L+K^2\omega^3L^3-[4RR_p+2\omega^2L^2]dL]^2+[R_pR^2+[R_pK^2-R]\omega^2L^2-4R_pd^2L^2-2R\omega LdL]^2}} \qquad (8)$$

This equation allows us to compute the value of the amplification at resonance and for any frequency close to resonance.

For Fig. 1-C the vector solution is

$$\frac{e_2}{e_1}=\frac{\mu Z_4 Z_2{}^2}{Z_2Z_4[Z_2+Z_4]+Z_1Z_4{}^2-[Z_1+Z_2][Z_3+Z_3+Z_4]^2}$$

In terms of actual circuit constants this becomes

$$\frac{e_2}{e_1}=\frac{G_m\omega^2L^2\overline{\Delta\omega}L}{\sqrt{\left[4d^2L^2-[R^2+\overline{\Delta\omega}^2L^2]^2\right]^2+L^2\left[\frac{\Delta\omega\omega^2L^2}{R_p}-4Rd\right]^2}} \qquad (9)$$

II—Circuits Coupled as Shown in Figs. 3-A and 3-B

For 3-A, the band width is given by the relation

$$\overline{\Delta\omega}=\omega^3LC_1 \qquad (10)$$

The vector equation for the amplification is given by the relation

$$A=\frac{e_2}{e_1}=\frac{\mu Z_2^2}{Z_2[2Z_1+Z_2+Z_3]+Z_1Z_3}$$

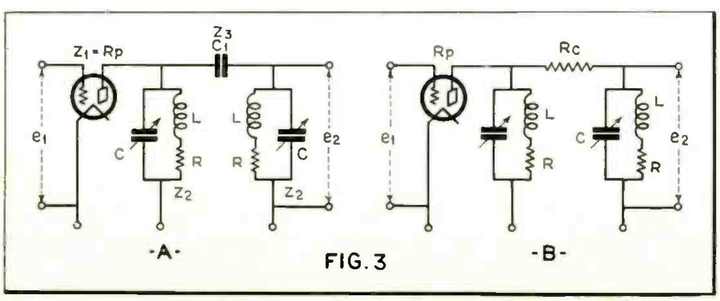
and the actual amplification is given by

$$\frac{\mu_o\omega_o{}^2L^2}{\sqrt{\left[2RR_p+\omega_o{}^2L^2+\frac{2RdL}{\omega_oC_1}+\frac{4R_pRdL}{\omega_o{}^3L^2C_1}\right]^2+\left[4R_pdL-\frac{R}{\omega_oC_1}-\frac{R_pR^2}{\omega_o{}^3L^2C_1}+\frac{4R_pd^2L^2}{\omega_o{}^3L^2C_1}\right]^2}} \qquad (11)$$

For the circuit of Fig. 3-B, the band width is given by the relation

$$\overline{\Delta f}=\frac{Rf_o}{R_cL} \qquad (12)$$

It must be noticed that in cases of Figs. 3-A and 3-B, the product LC determines, not resonance, but one of the cut-off frequencies. For this reason this type of circuit cannot be made to keep in step with straight tuned plate circuits as in the latter case LC determines the center of the resonance curve. If we use a circuit as shown in Fig. 4-A we will obtain a resonance curve as shown in 4-B.



Two representative band-pass filter circuits.

For convenience the equation giving the resonance curve of straight tuned plate circuits is also given here. This is

$$\frac{e_2}{e_1} = \frac{\mu \omega_o^2 L^2}{\sqrt{[RR_p + \omega_o^2 L^2]^2 + [2 R_p d L]^2}} \quad (13)$$

And the ratio of the amplification at resonance to the amplification at any angular velocity away from resonance by d is

$$R\left(\frac{f_o}{f_1}\right) = \sqrt{1 + \left[\frac{2 R_p d L}{RR_p + \omega_o^2 L^2}\right]^2} \quad (14)$$

Negligible terms were dropped in deriving the above equations. These would only clutter up the equations without adding appreciably to their accuracy.

If the reader decides to check the above relations, it might be well to show the derivation of the term d.

Let $d = \omega - \omega_o$

The reactance of a simple circuit is given by

$$\frac{[\omega^2 LC - 1]}{\omega C}$$

or

$$\frac{[\omega_o + d]^2 LC - 1}{\omega C}$$

Simplifying

$$\frac{\omega_o^2 LC + [2\omega_o + d] dLC - 1}{\omega C} = \frac{[2\omega_o + d] dLC}{\omega C}$$

So that we get 2d L.

Care was taken in the above equations to cancel the proper terms because resonance is not always indicated by the product of L and C.

It is hoped that these relations will prove of value to the designing engineer and that they will help to clear up some of the misinformation existing relative to tuned coupled circuits.

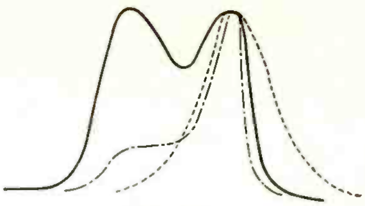


FIG. 4-B

Resonance curves of the circuit of Fig. 4-A. Solid line is the curve of the coupled circuit; dotted line, the tuned plate circuit and the dot-dash line the overall resonance.

New Ratings for the Screen-Grid Tube

Increase in Respective Grid Voltages Prevents Tube from Drawing Grid Current

*By Allen B. DuMont**

AFTER the introduction of the screen-grid vacuum tube, radio enthusiasts, dealers, manufacturers, and engineers made lavish claims for its amplification possibilities. Experience soon indicated that many of these claims were true. However, one disconcerting feature presented itself, and it was this that led our engineering staff to change the rating of the screen-grid audion, namely, that while it is possible to obtain very high amplification with the screen-grid tube, the last stages of tuned radio-frequency amplification have a tendency to draw grid current, which results in broad tuning and modulation of the carrier wave. That is to say, strong static will modulate the carrier wave of a weaker station, resulting in serious interference.

The high amplification of the screen-grid tube is brought about by the reduction of the grid-to-plate capacity in the tube to a very small part of the value in the former three-element tubes. It was this feature that made it possible and practical to design a tube which in itself has a high amplification factor. Of course it is possible to obtain a high amplification factor in the ordinary three-element tube, but it would be of little value since the circuit would oscillate with such a high gain.

The screen-grid tube, as originally conceived and as presented in practically all the a-c. screen-grid tubes today, has the following rating:

Filament	2.5 volts
Control Grid	—1.5 volts
Screen-grid	+75 volts
Plate	180 volts

When the investigation was undertaken to determine just what changes could be made in the way of improved performance, it was soon found that when operating at the foregoing rating, the grid commenced to draw current anywhere between ½ and 1 volt. The point at which this tube draws grid current is very similar to that at which a —27 or heater type a-c. tube starts to draw grid current. However, due to the much lower bias employed on the screen-grid tube, a much smaller voltage swing will start the grid current. For instance, a —27 type tube operating with 2.5 volts on the filament, —13.5 volts on the grid and 18 volts on the plate, would not start to draw grid current until the grid voltage had changed from —13.5 to —1 volt. The screen-grid tube, on the other hand, could only go from 1.5 to —1 volts when it would start to draw grid current. It is due to this fact that, while great amplification is obtained, the last stages of radio-frequency amplification are likely to draw grid current and broaden the tuning.

Advantages of New Rating

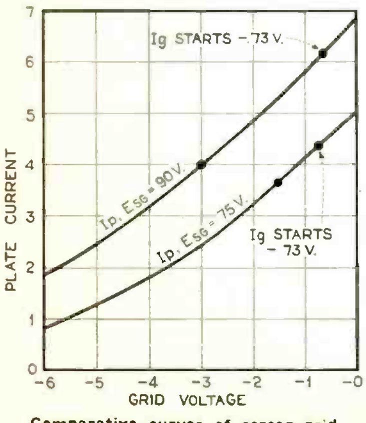
With these facts in mind the engineering staff undertook to change the rating so that the existing drawbacks would be corrected and, at the same time, the same characteristics would be approximately retained. We did this, and the new rating for the type 424 audion is as follows:

Filament	2.5 volts
Control grid	—3 volts
Screen-grid	+90 volts
Plate	180 volts

At the new voltages, the characteristics of this tube—the amplification constant, plate resistance, mutual conductance, plate current and control grid current—are essentially the same as at the old rating. The raising of the screen-grid voltage compensates for the additional control grid voltage. The advantage of the change is in the fact that an additional 1.5 volt grid swing is obtained. With the new rating, the grid voltage can change from —3 to —1, instead of from —1.5 to —1 volts before the tube draws grid current.

The results of the change are graphically illustrated in the accompanying curve which gives the old and the new characteristics, and which indicates the plate current as a function of the grid voltage, as well as the point on both curves at which grid current starts. It will be readily noted that at the new rating the tube can handle four times the voltage swing that was previously possible.

* *Chief Engineer, DeForest Radio Co.*



Comparative curves of screen-grid tube with old and new rating.

Vacuum Tube Design—and Production

The Quality Requirements of Vacuum Tubes For Use in Broadcast Receivers

By Dr. Paul G. Weiller

Part I

VACUUM tubes for use in broadcast receivers have been produced in large quantities during the past six years. Last year's production is being variously estimated at between 50 and 75 millions; the 1930 production is being predicted as around one hundred million. These are astounding figures for an industry so new—one that caters mostly to entertainment.

If we are honest with ourselves we must admit that the improvement in quality has not quite kept up with the phenomenal growth in the number of tubes produced.

In days gone by there were good and bad tubes. High mutual conductance and amplification factor were the hall marks of good tubes. Today we can produce tubes with any reasonable amplification constant or mutual conductance, if we want to break radically with old designs.

It may seem surprising that no one is willing to deviate considerably from past practice. We may also ask ourselves why there should be such seemingly great variations both in characteristics and in life between tubes of the same type made by the same manufacturer. To find the answer it is necessary to consider the history and development of the vacuum tube.

History of the Vacuum Tube

When Dr. Lee deForest began his work on three-element tubes the crystal detector was not generally known. No form of satisfactory detector was available, the Fleming two-element tube never having been very desirable.

The result of deForest's work was at first a gassy tube. Soon thereafter regeneration was discovered and provided a considerable degree of sensitivity which made long distance communication practical and reliable. Audio amplification followed shortly and further improved reception.

Radio telephony, however, still remained much of a dream. At this point the telephone interests took up the work. The result was a line of tubes for use in long distance telephony and as a by-product van der Bijl's classical work on vacuum tubes.

In 1922 when broadcasting began to gain impetus the tube situation stood as follows: The telephone tubes were expensive precision devices ill-adapted for use in broadcast receivers. Furthermore only a few of them were available.

These tubes were of the coated filament type. Tubes for radio use were being made in very moderate quantities only. They were of the tungsten filament variety, rather flimsy in construction and not uniform. Manufacturing processes were slow and not adapted for mass production.

The regenerative sets which at first dominated the field could be made to work with most any tube. A multiplicity of controls when skillfully handled could be made to compensate for much of the lack of uniformity of tubes.

Special audio tubes were not required as there were neither good transformers nor good loudspeakers available. There was, therefore, no need for special tubes.

In 1923 manufacturers were suddenly called upon to produce tubes by the hundred thousands. All their research facilities were taxed to develop production methods. Redesign could not be thought of. Radio was termed a passing fad and no one cared much for quality. The only worry appeared to be the considerable filament current consumption of the 201 type tube then marketed.

The following year brought relief with the 201-A and 199 types—the thoriated filament tubes. At the same time came another unexpected increase in the demand for tubes.

The production of thoriated filament tubes with the use of magnesium as getter, and the introduction of induction heating of the elements during exhaust, proved to be problems of great magnitude. All facilities were again taxed to their limit in producing the required quantities of tubes and in reducing shrinkage. Redesign again had to be left for a later date.

Structurally the 201-A tube was very similar to the old 201. With the advent of the neutrodyne the tuned radio-frequency principle gained a firm foothold and manufacturers produced the first receivers which could be called instruments for entertainment, with the use of some imagination.

The desire for good reproduction and power operation was a natural consequence which made necessary the development of output tubes, rectifiers and a-c. tubes. These new types followed each other at such short intervals, that engineers and manufacturers did not have sufficient time for radical redesign. For the sake of speed it was imperative to use as much as possible of the equipment and material on hand. Consequently the new design had to follow previous patterns very closely.

The Situation at Present

The vacuum tube situation as we know it at present is only a logical outcome of the recent past. We are still in the midst of a period of rapid, rather helter-skelter, development.

Recently one more factor has been added to those already retarding redesign of tubes. Our sets are designed for the tubes now available. Some of the new tubes at least must fit old sets as well as new ones. As a result we have a product which is too flimsy. Even jolts in transportation are apt to displace the elements and thereby change the characteristics of tubes. The small spacings between the elements, the thin wire, the fact that a change in spacing of one-thousandth of an inch will produce a noticeable change in characteristics, make the quantity production of tubes a difficult problem.

Large manufacturers make extensive use of forming dies and assembling fixtures. In spite of such efforts the final condition of the tube is still largely dependent on skill and the extreme care of the operator. Large variations are therefore unavoidable. In small tubes, as the 227, plate current variations of 100 per cent are considered permissible.

Tube Specifications

The purpose of tube specification is the fixing of limits for the tube characteristics. These limits must be narrow enough so as not to interfere too much with set design. They must be wide enough to allow for inevitable variations occurring in quantity production. At present the accepted limits are rather too wide from the viewpoint of the set designer but only barely wide enough for the tube manufacturer. If at any time it should prove desirable to build tubes to closer limits it will be necessary to make the tubes larger and sturdier mechanically.

When a new tube is designed the engineer must consider the special purposes for which the tube is to be used and the limitations of filament voltages practicable in broadcast receivers. After these are determined he must compromise with available manufacturing facilities. If possible he must use some parts used in other types. For instance, the plates of several tubes are identical or differ only by a few thousandths of an inch. Most grids are wound with the same size wire. The general process of mounting and exhausting should deviate as little as possible from past practice.

To make the genesis and meaning of tube specifications plain a lengthy dessertation on vacuum tube theory would be in order at this point. Unfortunately, sufficient space is not available and we must be satisfied with some general remarks.

The basic phenomenon of the vacuum tube is the emission of electrons by hot bodies. All substances emit electrons if their temperature is sufficiently high. Unfortunately most substances emit sufficient electrons only at a temperature near to their melting or vaporization point. Only a few highly refractory materials emit at temperatures sufficiently far from that of their structural disintegration. Pure tungsten melts considerably above 3.000 degrees centigrade. It is operated in tungsten filament tubes at 2600 degrees centigrade. Thoriated filaments are operated at 1600 degrees C. The melting point of nickel is approximately 1400; nickel filaments coated with barium-strontium oxides are operated at about 800. In this the oxides emit the electrons, the nickel filament only supplies the heat. The quantity of electrons emitted increases very rapidly with the temperature. It is, however, independent of the plate voltage.

A great deal of research has been done on the subject of emission without explaining all phenomena observed in an entirely satisfactory manner. Infinitesimal impurities, physical condition of the surface, degree of vacuum, etc., are all very hard to control or even measure under operating conditions and influence results to such an extent that it is difficult to follow the basic law.

Assumed that we have an emitting filament in a vacuum with a grid and a plate; their action is due principally to the electrostatic action of the field created by grid and plate as if the electrons were merely small particles with a definite negative charge. The fundamental law of such a system was studied by Clerk Maxwell long before the triode was known. According to the principles governing electrostatic fields then, assumed that we have an ample emission, the characteristics of the tube are determined purely by the geometric arrangement of its elements. Amplification constant and mutual conductance should depend only on spacing between grid and plate, grid and filament, spacing and thickness of grid wires, surface of the filament and so forth. It can be plainly seen that even according to theoretical considerations only the characteristics depend on a great number of factors. The designing of a tube for predetermined characteristics is, therefore, a rather intricate problem even on this account alone.

Governing Factors

There are a number of other factors which influence the operation of the tube but are not as yet completely amenable to mathematical treatment. There is, for instance, the contact potential between grid and filament which in some cases requires the use of a grid bias different from that expected. We also find that in many cases an increased filament temperature will cause an increase in plate current. This fact is not easily accounted for. Add to this the effect of the small amounts of gas usually present, the fact that the amount of emission will influence the characteristics slightly, and other quite obscure effects and you have a picture of the complexity of the problem.

Tube specifications and testing methods are, therefore, to be considered only as an indispensable means to keep the production of tubes within tolerably definite limits of uniformity. We will see that these limits have to be kept generously wide to make mass production of tubes practicable.

When we consider that a shifting of the grid by one-thousandth of an inch will produce a noticeable change in characteristics in the present models of closely spaced tubes and that grids are made of wires only five-thousandths of an inch thick; that these wires get white hot in the process of exhausting tubes—it becomes quite clear why tube specifications must allow for seemingly unreasonably wide variations of characteristics.

The Set Manufacturers' Problems

From the standpoint of the set manufacturer, tubes should be as nearly uniform as possible. It is a ticklish problem to design sets with a uniform amplification over the entire broadcast band as anybody familiar with the subject will admit. Wide variations in tube characteristics only add to the difficulty.

Due to the flimsy construction of our commercial tubes considerable variations are unavoidable. It is the object of specifications to confine these permissible variations within definite limits and also to furnish a measure of the general care with which the tube has been designed and manufactured. Accordingly, tests can be divided into quality tests and tests for electrical characteristics, the latter depending largely on the accuracy of the dimensions of the elements and their spacing.

These tests consist mostly in determining the static characteristics only. If the tube is properly designed it is not necessary to test dynamically as any variation of dynamic characteristics must necessarily be accompanied by a change of static characteristics.

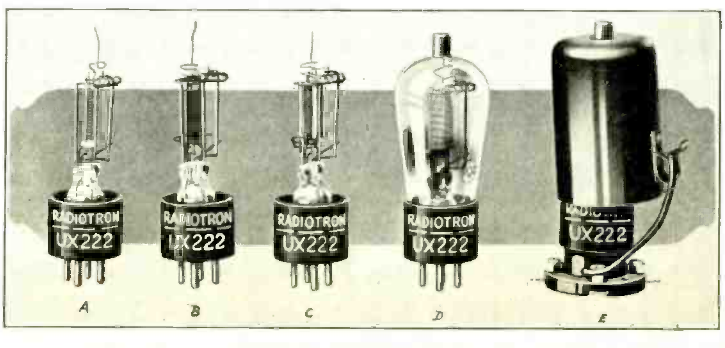
Experience with large manufacturers has shown that tubes passing properly drawn specifications for static tests will very seldom be rejected for defects due to dynamic characteristics. It is, therefore, perfectly proper to omit tests for dynamic characteristics from production test specifications. However, if it is desired to determine whether any given make of tube is properly designed it is necessary to check dynamic characteristics also.

Quality Tests

Emission: The emission current that can be drawn from a given filament depends entirely on its temperature. To draw all its emission at any given temperature from a filament it is necessary to apply sufficient voltage to overcome the space charge. Once this voltage is reached no increase in emission current is caused by a further increase in voltage. The current obtained is called the total emission of the filament.

For several reasons it would be impractical to measure the total emission of filaments for production purposes. We compromise by measuring under conditions which permit assuring ourselves that ample emission is available. For most tubes this is done by measuring the current with grid and plate tied together at 50 volts. It is obvious that to get proper readings the voltage must be read directly across the tube and not across the source of power whenever a lamp or other protective resistance is inserted in the power supply source.

To ask how much emission is necessary for proper operation of a tube is only a fair question. Some consideration of the function of the vacuum tube will give the answer.



The intricate construction of the UX-222, let alone all a-c. tubes, suggests the difficulties encountered in manufacture when automatic machines replace hand work.

If a tube being operated at normal plate voltage and grid bias is acted upon by a signal the grid voltage is alternately increased and reduced by subsequent half cycles. If the tube is used in an audio stage or as an output tube the instantaneous value of the grid voltage may well reach zero or at least near zero in normal operation. The filament must, therefore, have sufficient emission at operating voltage to give the full plate current at zero grid and normal plate voltage. If the emission is not considerably greater than the maximum plate current it will be found that the dynamic characteristics of the tube are somewhat abnormal. It is, therefore, necessary to have a surplus of emission. As the emission decreases during the life of the tube it is essential for a long life tube to have an additional surplus.

These considerations permit an intelligent estimation of the emission required for a good tube. Generally speaking, the filament should give easily an emission of five times the normal plate current to operate properly. In addition there should be sufficient surplus, so that the operation of the tube will not be impaired when the emission drops through use. This requirement is not fulfilled in all types of tubes. The ¼-ampere, 171-A, for instance, is rated at 20 ma. plate current. It should, therefore, have over 100 ma. emission. With the small filament surface of this tube it is hardly feasible to have that much emission and many tubes shipped as first class tubes do not reach more than 75 ma.

Gas: The gas test consists mostly in measuring the grid current at normal bias and plate voltage. Gas-free tubes show no grid current unless leakage is present. For small tubes (226, 227) the permissible gas current limit is 3 microamperes; for large tubes, 10 microamperes.

A gassy tube is noisy and is apt to suffer a premature death by rapidly decreasing emission.

At this point it should be mentioned that a tube may come to testing apparently free from gas, but the metal parts may still hold undue quantities of gas which is released gradually during the life of the tube. Such a tube, while passing the test, would become gassy very soon. The only way to avoid trouble on this account is to subject tubes to a rather severe seasoning schedule before they are tested. Such a schedule, while improving properly exhausted tubes, will hopelessly ruin tubes which are not properly exhausted.

Cold Leakage: The leakage test is made under the same conditions as the gas test, except for the filament which is not lighted. If any grid current over one microampere is present the tube should be rejected. Leakage is mostly due to decomposition of the glass bead or the press (stem) by improper handling of fires. It may also be due to a deposit of magnesium. The leakage test is omitted by most manufacturers.

Life Test: The three former tests are designed for production purposes. They will detect most of the ordinary defects which adversely affect life. Normally the percentage of early failures in the field of tubes which pass these should be below 5 per cent.

To assure ourselves that there are no undetected defects among tubes being shipped, a certain number of tubes are taken daily from production and subjected to a "life test." The tubes are placed on a specially constructed rack and are kept operating continuously at normal voltages. At proper intervals the tubes are taken off and tested. The number of tubes which failed before one thousand hours is noted for each lot. A purchaser of large quantities of tubes should also undertake life tests from time to time.

The results of life tests have to be taken with a grain of salt. Life test conditions cannot be made identical with conditions of operation in the field. They are, therefore, to be considered only as comparative, and have to be repeated very often to yield definite results.

Tests for Electrical Characteristics

Plate Current: Plate current is measured at normal grid, plate and filament voltages. It is substituted as a production test for dynamic tests. Any change in spacing of the elements which would affect amplification constant or mutual conductance will also affect the plate current.

It is very difficult to mount the current types of tubes accurately enough to obtain any high degree of uniformity. Warping of the metal parts when they are heated during exhaust adds to this difficulty. The permissible range of variation of plate current is from 100 per cent for small tubes, such as the 227, to only about 60 per cent for larger types. On the face, these ranges appear to be unduly wide. Nevertheless under the present state of the art it would be hardly possible to narrow these limits without unduly increasing manufacturing cost. Before such narrowing of limits can be thought of, mounting by automatic machines must become an accomplished fact. This will hardly be practical with the customary mechanical design of our tubes.

To permit automatic mounting the general shape, spacing and methods of support of the elements will have to be radically changed.

As to the importance to the buyer of correct plate current, it is difficult to generalize. Some sets are very sensitive to it and will barely tolerate the permitted variation without squealing or showing other signs of disorder; other sets are not materially affected. Properly designed sets will not be unduly affected by permitted variations. Most of them, however, will not operate properly if the tubes used are far out of limits.

At this point it is well to mention a rather frequent defect in tubes of some manufacturers—that is, the protruding of the filament from the grid. Whenever that is the case the electron current from the exposed parts of the filament is not subject to grid control and acts somewhat like a high resistance between filament and plate, in parallel with the tube, which, of course, increases the plate current and simulates a high mutual conductance. If, then, the grid is changed to offset this effect a tube of entirely abnormal characteristics results in spite of a correct plate current.

It must be remembered that the customary tests yield data which can be properly interpreted only if the tubes are correctly constructed.

Filament Current: The filament current itself has no direct bearing on the proper operation of the tube. However, with numerous other factors, it determines the temperature of the filament. As the emission depends on the temperature it indirectly affects the life of the tube considerably. It also accounts for some variations in plate current caused by variations in emission.

Unfortunately, what has been said about plate current is more true of filament current. Only if the filament is of correct dimensions is it sufficient to measure filament current as a check. There are tubes on the market which give proper filament current readings, the filaments of which are operating at improper temperature. Such tubes are apt to have a short life. Once the proper specifications for the filament are determined it is possible to keep filament conditions quite uniform in coated filament tubes. With the heater type tubes this is quite difficult. Dimensions of the holes in the insulator, tightness or looseness of the nickel sleeve, amount of coating, and other factors, have a considerable influence on the filament current and on the temperature of the emitting surface. Variations of 10 per cent above and below specified current are frequent.

Because of the variations of line voltage the effect of abnormal and subnormal voltage must also be considered, for all tubes to be used in a-c. sets. Besides the variations in average line voltages from location to location, which are quite extensive, we have to contend with variations of as much as 20 volts in the same location at different times of the day and night.

The tube must, therefore, be designed to function properly considerably below and above the specified filament voltages and current.

This discussion of tube quality covers the points of major importance. One can infer from the aforesaid that specifications for vacuum tubes are a necessary guide to their design and purchase but they must be intelligently used and interpreted.

(To be continued)

Research, Engineering Development and Production Testing

Three Interlocking Factors Steadily Growing In Importance In Meeting the Increasing Severity of Competition in the Radio Industry

By Austin C. Lescarboura, Associate Editor

Mem. A. I. E. E., Mem. I. R. E.

SUCCESSFUL radio manufacturing depends on something more than the actual production itself. In the first place, it must rest on a sound foundation of original research, which provides the constantly renewed life blood of any growing science or art. In the second place, it calls for engineering development, which takes known facts as well as the latest findings of research, and works them into satisfactory products. In the third place, it depends on a constant check-up of production, to the end that flaws may be discovered and corrected before they reach the market, thus preventing the tarnishing of an otherwise good name.

Heretofore, these factors have been considered the concern of the leaders of our industry. The smaller manufacturers may have exercised production testing to a considerable degree and may even have engaged in some engineering development. Original research, however, has been left to the largest organizations, not only because of the heavy cost involved, but perhaps for the misconception that only the leaders of any industry are privileged to point out the way of progress. Today and in the future, however, these factors become the basis of all successful radio enterprises, small as well as large, with the ever-increasing severity of competition. Hence the following dissertation on research, engineering development and production testing.

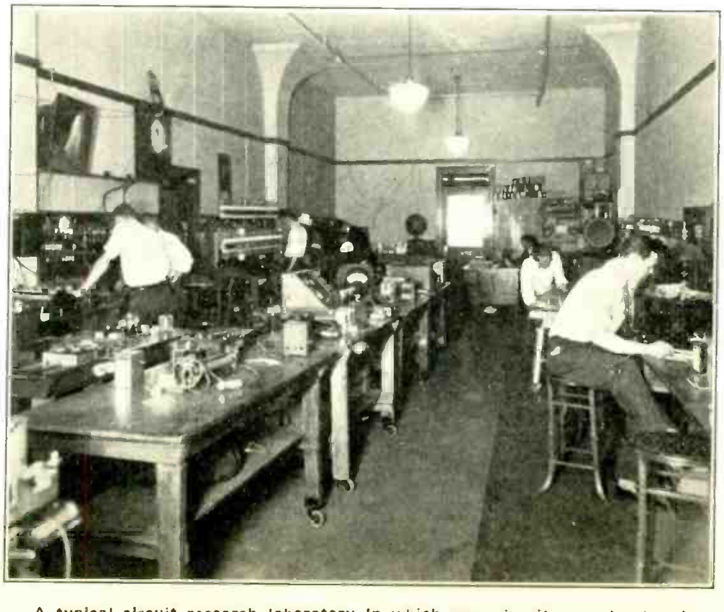
The Purpose of Radio Research

During the past year, research has suddenly come into its own in the radio industry. Prior to that time, only the largest companies were engaged in original research, and the smaller companies were either ready to take out patent licenses under any new and important inventions or developments worked out by the leaders, or simply to help themselves to whatever inventions or developments they pleased with little regard for patent rights. In fact, the past history of the radio industry is by no means savory in this respect, for in no other calling has there been such flagrant treatment of patent rights.

It is a much mooted question whether the radio industry has suddenly reformed its evil ways and decided to respect patent rights, or whether it has come to appreciate the necessity of original research and engineering development, thereby acknowledging the rights of those who blaze the way and offering to pay a tribute so as to encourage the pioneering efforts. Personally, we believe the latter to be the case. We believe that the radio industry recognizes the importance of group research and engineering development, as a sound basis for standardized practice and sound mass production. Accordingly, the industry has accepted the license terms of the leaders to the end that there might be a definite co-ordination of major technical features and practices.

Now radio research as it is practiced today has to do with a wide variety of subjects. Obviously, the main theme is the discovery of new radio principles. In many laboratories radio men are constantly at work on all manner of radio circuits, endeavoring to find some better way of effecting radio-frequency amplification, detection, audio-frequency amplification, transmission, and so on. Important studies are being made with new forms of wave propagation. This is slow work indeed, for the research workers are often given full freedom of action, with no particular subject to work on. In this respect the General Electric Research Laboratory is unique, in that many of its workers do more or less as they please. These workers have their own preconceived ideas, perhaps, of what they are after or what fields they would like to exploit, but they are not harnessed with definite problems to solve. The story is told about Dr. Irving Langmuir and how he was found one day playing with a beaker of water, a medicine dropper, and some oil. This savant was dropping oil on the water and watching the formation of the oil film. When interrupted and asked what he was studying, Dr. Langmuir replied that he was entranced by the thought of oil molecules rolling about on the surface of the water. The oil film was just one molecule thick. This simple experiment suggested the thoriated tungsten filament for vacuum tubes, which soon became a most important contribution to the radio art.

Radio research, however, does not stop with principles and main issues. It also has to do with details and with specific problems. Thus there are research workers specializing in various



A typical circuit research laboratory in which new circuits are developed, together with the details such as choke coils, condensers, transformers and so on.

fields, such as vacuum tubes, loudspeakers, microphones, transmitters, materials, and so on. In the vacuum tube field, we have research workers constantly developing new types of tubes. These workers delve into every available piece of literature on thermionic valves, searching for new ideas. They study every phase of pure science as applied to vacuum tubes. They examine every detail of vacuum tube design and construction, testing no end of new materials with a view to improved performance. In many of the tube research laboratories, the workers are equipped with miniature tube production facilities, so that the idea of this morning becomes the sample tube of this afternoon, ready for test. Skilled glass-workers and mechanics work side by side with the research men, so that thoughts can be rapidly converted into tangible results.

In a certain research laboratory devoted to gaseous tubes and rectifiers, men are constantly studying gaseous conductors. Literature is secured from all parts of the world, so that no discovery or invention is being overlooked. New designs are constantly being worked out and made up in the form of models. Gases of every conceivable nature are on hand, so that the workers may try out any gas or combination. Glassworkers fashion the various designs in glass. Mechanics turn out the metal parts. Huge test racks contain hundreds and even thousands of sample tubes undergoing tests, while even the production samples from the associated plants are studied to ascertain their qualities and imperfection. It is interesting to note that the research laboratory in question brought into existence a vast radio business which persisted for several years until the advances made in filament rectifiers made it preferable for the organization to engage in the production of filament tubes. Nevertheless, the organization was in a position to combat all competition, fair and unfair, which attempted to take away the business which it had created and developed; and today, even though the organization is more interested in filament type tubes, the research and development on gaseous tubes continues and may yet lead to very important things.

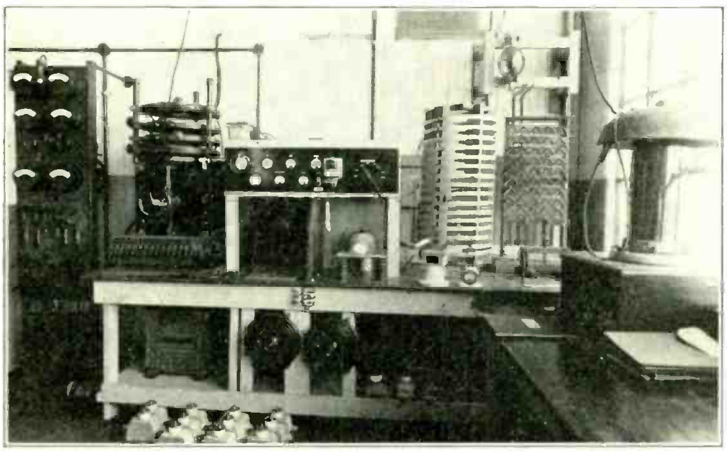
Detail Research

Radio research extends even to minute details. Thus we have research workers on vacuum tube filaments, seamless nickel sleeving, lacquers, impregnating waxes, condenser papers, insulating materials, bakelite, and so on. In fact, the many purveyors of raw materials and components to the radio industry have of late engaged in considerable research on their own account, to the end that they might be better prepared to serve their customers.

New and highly efficient alloy filaments have recently been introduced for the base of oxide-coated filaments, as the result of research by the metallurgists of wire-drawing companies. In fact, with these new alloy filaments it is possible to make the -01-A type tube so efficient that it will provide normal emission on 3 to 3.5 volts, and will last several thousand hours.

Just now there is a real demand for seamless nickel tubing for the heater type a-c. tubes. Here again, detail research is in order, and certain organizations are engaged in producing seamless tubing in laboratory lots until a satisfactory commercial production system can be worked out.

Even such simple materials as lacquers are being subjected to considerable original research. It is interesting to note that all lacquers cannot be employed for radio parts, due to their chemical or electrical characteristics. Thus special lacquers have been worked out with certain electrical properties, others with certain moisture-proof qualities, still others with certain chemical properties, so as to resist the action of hot impregnating compounds, and so on. We know of an instance in which the success of a certain intricate radio assembly, sealed in impregnating compound, depended on finding a lacquer that would resist the chemical action of the compound. Finally a lacquer company, after long research, did develop a satisfactory formula for this purpose.



A corner of a condenser research laboratory maintained by a leading condenser manufacturer.

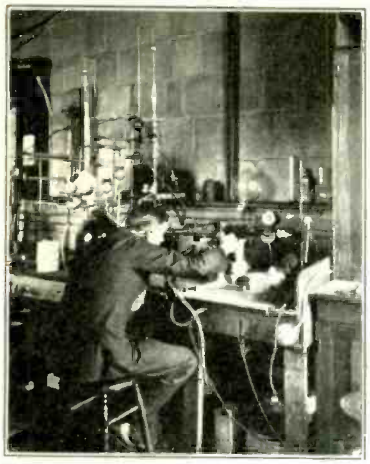
Impregnating waxes are a fit subject for original research, particularly in meeting the requirements of the radio industry. Here again the purveyors maintain their own laboratory facilities and do much of the work which would otherwise fall on the shoulders of the radio industry. Much of the transformer failures of a few years ago could be traced to the corrosive action of impregnating compounds on fine wire of the secondary winding. Impregnating compounds also have had to be developed with paper condenser requirements in mind, and here a world of research has gone into the development of satisfactory compounds.

Condenser papers have called for much research, not only on the part of paper manufacturers, but also on the part of the more enterprising condenser manufacturers who must be sure of the materials entering into their products. In fact, successful paper condensers, capable of operating year after year on voltages of the order of 200 to 1000 volts and even over, are a monument to original research in all phases of the condenser technique. One condenser manufacturer in particular has maintained a large research laboratory for years, testing and trying no end of materials and designs. This same manufacturer developed an accelerated life test on condensers several years ago, whereby the service life of a condenser, perhaps running into thousands and even tens of thousands of hours, might be determined in several hundred hours or less. This accelerated life test technique has proved indispensable in developing the highly satisfactory condensers of today. The same manufacturer tests every lot of paper, impregnating compound, tinfoil and other materials bought, so as to insure satisfactory materials quite as well as production skill in the making of condensers.

And so we might go on and on in telling of the various research activities on the part of those who make the raw materials and components for the radio industry. In fact, the industry is exceptionally fortunate that so large a portion of the research is being handled by purveyors, for not only the expense but the highly specialized efforts involved, might well prove beyond the scope of the average radio manufacturer if he were called upon to handle detail research.

When Is a Company Too Small for Research?

All of which may, by now, be caus-



An authority on gaseous rectifiers studying the glowing tube in order to determine, by means of the spectrum, the chemicals present.

ing the reader to say: "Well, what has that got to do with me. Let the big fellows worry about research. It's no small man's game!" In other words, when is a company too small to engage in original research?

It is our belief, based on long contact with the radio industry from the largest organizations to the very smallest, that no company worthy of remaining in business is too small to engage in original research. After all, original research and engineering development may be conducted on any scale befitting the size of the organization. No one expects a small set manufacturer to maintain a laboratory staff as impressive as that of the leading organization, yet nevertheless one does expect some sort of research and engineering activity. Furthermore, there is an erroneous idea that research and engineering staffs are an added expense. This is also a false conception, for the reason that any research and engineering investment should pay handsome returns by way of new ideas, better products, increased prestige, and greater sales and profits.

Some manufacturers today are of the opinion that by taking out a license under the leading group patents, they are contributing ample to original research and engineering development. Such manufacturers seem to feel that only the largest laboratory staff can possibly carry on research and engineering development, and that a small company has no place in this game. Such deductions are quite faulty. In fact, while it may be an excellent thing to be licensed under the group patents and thereby gain patent protection, standardized practice, and much engineering aid, the fact remains that brains are by no means monopolized, nor is luck limited to any one group, so that the smallest organization has ample opportunity to work out ideas of its own. In fact, during the past few months some mighty important original work on radio circuits has been carried out by one of the moderate sized organizations, and when this work becomes known, it may prove highly startling to the industry.

No matter how small or how large, any radio organization that indulges in original research is bound to find a brand new source of dividends. In fact, what our industry needs more than anything else today is more original research. There is too much the attitude of letting George do all the work, and while George is doing most of it, George is getting kind of lax because of lack of competition in research. Let's have more research! The industry needs it, especially if we are to keep up our volume of radio business in the future; for, just as the automobile industry avoids saturation by coming out with new and improved cars year after year, so must we introduce no end of improvements in order that radio sets will become obsolete in a reasonable length of time.

Where Engineering Development Begins

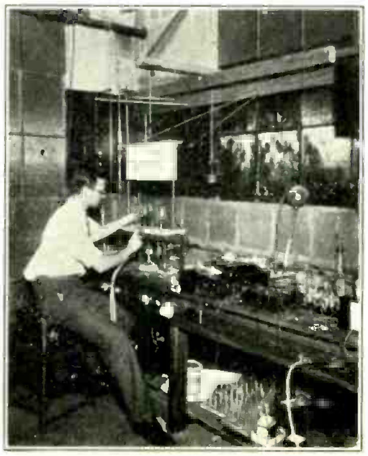
And then there is engineering development, which is relatively common practice in the industry today. In fact, while many smaller organizations may hesitate to indulge in original research, they do not hesitate to maintain an engineering department. This phase begins where research ends, namely, once definite principles are established, it is for engineering development to work out a satisfactory and marketable product, thus bridging the gap between the science and the art.

Notable progress has been scored in engineering development during the past few years, not only in the number of organizations maintaining an engineering staff, not only in the worthwhile salaries paid to capable engineers, but also in the results obtained. Time was when a radio engineer was offered about a third the wages of an ordinary electrician, yet was expected to carry about a couple of degrees, work fourteen hours a day, help out in the production end when necessary, and prove to be an Edison or Westinghouse. Today, a good engineer receives a worthy salary, is given ample facilities, is given a place on the executive staff of the organization, and is expected to produce just a fair amount of work over a reasonable period of time. In fact, the stock of the radio engineer has been rising steadily. We have noted of late that radio engineers in some organizations are treated with utmost respect and consideration, often outranking the production and sales personnel. And yet we agree with this situation, for the success of any organization rests entirely on the soundness of its products. Unless the engineering is correct, the production and the sales efforts are seriously handicapped. The Ford automobile is an example of the part played by engineering; the design is correct, and therefore mass production can be engaged in with absolute assurance of a ready market, while the merchandising is almost reduced to a routine matter of order taking. It seems to us that many organizations in which trouble is experienced in merchandising the line, involving vast sums of money for advertising, sales promotion and high-pressure selling methods, might well look into their engineering end for a possible cause of all the trouble.

Engineering development is indispensable, no matter whether the set manufacturer be licensed or not. Irrespective of the fundamentals at the disposal of the manufacturer, it is still necessary to work out the details, and that is where engineering development comes in. Even in the production of simple components, engineering development is necessary. Simple things such as rheostats, switches, transformers, vacuum tubes and so on call for no end of engineering development, if the manufacturer is to secure his share of the market. There is entirely to much confidence placed in standardized practice, and "let well enough alone."

In the case of vacuum tubes, for instance, there is comparatively little engineering development taking place among the majority of manufacturers. The greater part of the work is left to the leaders of the industry, and the smaller fellows are satisfied to trail along. This is the wrong attitude, for there is more than ample work for everyone concerned, particularly by way of turning out *quality* rather than quantity. There has never been an over-production of really good tubes, but there is always an over-production of poor tubes.

A relatively newcomer into the vacuum tube industry has from the beginning expended a very considerable proportion of his budget on re-



In the average tube research laboratory, a skilled glassworker is always at hand so that ideas may be translated into practical terms without delay.

search and engineering development. As a consequence, this newcomer has scored one innovation after the other by way of refinements in existing types and now, having established a complete line of standard tubes, this same manufacturer is about to introduce entirely new types for which there has long existed a latent demand. As a consequence, this newcomer, in the short space of one year, has taken his place among the topnotchers of the tube industry. Surely the money expended for research and development is relatively small compared with the gain in sales and public acceptance.

Is Engineering Geared to Production?

The one problem in research and engineering development is that of practical value. A good research worker, unfortunately, is generally pretty far removed from the world of affairs, and therefore gives little or no thought to commercial requirements and production possibilities. It is at this point that the engineering staff comes in and is supposed to think in production and marketing terms, while studying and applying the research findings. Only too often, however, the engineering staff also fails to think in these practical terms, so that the manufacturer becomes impatient.

We know of one organization with a splendid research staff headed by an outstanding engineer in his particular line. All kinds of remarkable developments come out of the research laboratory and are turned over to the production staff. Yet very little comes through the production end, and when it does, it is generally all wrong. The reason is, first of all, that the research and engineering staff is inexperienced in production matters, and has no conception of what can and cannot be made at a price; and secondly, that the production staff takes very little interest in the research and engineering activities. Obviously, these various functions must be geared together if the manufacturer is to realize the utmost return from his research and engineering efforts. The ideal arrangement, of course, is to have a man at the head of the research and engineering who actually knows production. We are familiar with one case where the chief engineer not only directs a research and follows up with engineering development, but actually directs the production even to the extent of designing special machinery to make the products which he as invented or refined. Such a man, of course, is mighty rare, and the next best thing is to have a group of men working in close harmony on research, development and production.

The Question of Production Testing

Once the product is in production, the engineering staff is interested in just one more phase, and that is production testing which has to do with the goodness of the product and the possibilities of further refinement. In many instances the production testing extends out into the field, under typical service conditions.

Perhaps the smaller radio manufacturer does not pay sufficient attention to production testing, and therefore loses out on one of the most valuable engineering activities. More things can be learned about a product under actual service conditions than in any other way. Thus we have in mind the policy of several large set manufacturers, who make up sample sets and send them to various parts of the country—in large cities near broadcasting stations, to test selectivity; out in rural sections, to test selectivity and sensitivity combined; out in the sparsely settled sections for a supreme test of sensitivity; along the seaboard to study the effect of extreme dampness, and so on. Such manufacturers generally do not score any mistakes with their offerings, as compared with those who rush into production without prior tests.

From these life racks the tube manufacturer can learn just what he can expect of the tubes in actual use. This is the production testing feature of engineering.

And then there is the careful study of returned and damaged goods. We know of many radio manufacturers who examine each tube failure with keen interest, in order to determine the cause; or the radio set, to learn why it has failed to give satisfactory results; or again the power amplifier, to find out why condensers or resistors break down. Much valuable engineering guidance can be obtained by a study of returned goods.

No matter how careful the production may be, production testing is essential in protecting a good name. Quite aside from the routine testing in the factory itself, it is good practice to take a representative product out of a given volume, day in and day out, and make a thorough test. We might point out the splendid work of the Radio Corporation of America, in this respect. With several plants manufacturing sets and loudspeakers and vacuum tubes, it is essential that some check be maintained on the uniformity of quality. Hence a certain percentage of each factory production is sent to the technical and test laboratory for a complete check-up. The product is examined in a purely superficial way, followed by very thorough radio tests. In the case of tubes, these are examined and tested, and then subjected to a life test so as to determine just what can be expected in normal use. Only through such elaborate production testing can this organization be sure of a uniform quality from its scattered manufacturing divisions.

Make Engineering the Foundation of Your Business!

In conclusion, let us pay more attention to the engineering side of our business, no matter whether it be large or small, new or old. We owe it to the radio industry, to the radio public, and to ourselves to carry on our share of research and engineering development and production testing to the end of making the best possible products.

Above all, let us encourage the training of good radio engineers. The small salaries heretofore paid so-called radio engineers have done more harm than good for no man is going to spend many years of his life mastering the principles of engineering only to earn a weekly stipend that cannot be compared with that of the electrician. But on the other hand, let us not overlook the value of the practically trained radio man. In many engineering staffs today the practical man is found working side by side with graduate engineers, and this combination of the purely practical with the engineering type mind, seems to produce excellent results.

Comparison of Formulas for Calculation of Inductance of Coils and Spirals

IN an article entitled "A comparison of the formulas for the calculation of the inductance of coils and spirals wound with wire of large cross section," by F. W. Grover, appearing in the Bureau of Standards Journal of Research for July, 1929, two methods have been used for the calculation of the inductance of coils of wire having a relatively large cross section. Of these, the summation method gives the inductance of the coil as the sum of the self-inductances of the turns and the mutual inductances of all the pairs of turns. The Rosa method calculates the inductance of the equivalent current sheet as a first approximation to the inductance of the coil, and obtains the correction which must be applied by calculating (a) the differences between the self-inductance of the turns of wire and of the current sheet, and (b) the differences of the mutual inductances of pairs of turns of wire and of the corresponding turns of the current sheet. It is here shown that, contrary to previous opinions, the two methods give identical results, when terms of the same degree are retained in the series expression.

Electromagnetic Phonograph Pickups

Further Notes on the Design of Electromagnetic Pickups

*By George B. Crouse**

PART II

THE value of this load impedance will be shown in the following to be a fuction of the electrical impedance of the circuits into which the device is working, of the characteristics of the magnetic system of the pickup, and of the geometry of the magnetic airgaps of the device.

Turning back to Figs. 1 and 2, the electric potential is generated in the coil 16 due to changing flux in the armature 9, occasioned by the motion of the upper end of the armature in the upper air gaps.

When the armature stands in the mid position, no flux from the permanent magnet will flow through it, and for a small displacement δ from the mean position, the flux ϕ through the armature will be

$$\phi = SK_1 \delta \qquad (1)$$

where S = the magneto-motive force applied to the system by the permanent magnet. K_1 is a constant of proportionality determined by the geometry of the air gaps as will be pointed out in more detail later.

The rate of change of flux through the armature will be:

$$\frac{d\phi}{dt} = SK_1 \frac{d\delta}{dt} \qquad (2)$$

Since the voltage generated in a coil is proportional to the rate of change of flux therethrough, the voltage E_ε generated in the coil 16 will be:

$$E_\varepsilon = K_1 \; SK_2 \; T \; \frac{d\delta}{dt} \qquad (3)$$

Where K_2 is a physical constant of the units employed and T is the number of turns in the coil.

But $\frac{d\delta}{dt}$ is the velocity of the end of the armature in the air gap, and in forming the electrical analogs, we saw that velocity was equivalent to current, and we, therefore, replace $\frac{d\delta}{dt}$ with the symbol I_m, or mechanical current, and rewrite Equation 3 as—

$$E_\varepsilon = K_1 \; K_2 \; ST \; I_m \qquad (4)$$

An expression connecting electrical current and mechanical voltage (force) E_m may be derived by considering that electrical current flowing through the coil will cause a force to be exerted on the armature tending to displace it from its mid-position, and this force, using the symbol of the analog, will be given by:

$$E_m = K_3 \; K_4 \; ST \; I_\varepsilon \qquad (5)$$

Where K_4 is a constant (depending on the units employed) relating the flux through the armature with the force exerted thereon in the field of the upper gap, and K_3 is the constant of proportionality between the flux flowing in the armature and the ampere-turns of the coil determined by the reluctances of the circuit.

Now, the impedance of the electrical system in terms of the voltage and current in the system is:

$$Z_\varepsilon = \frac{E_\varepsilon}{I_\varepsilon} \qquad (6)$$

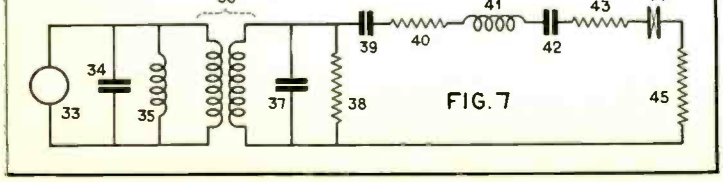
and therefore from Equation 4 and Equation 5, we may write:

$$Z_\varepsilon = K_1 \; K_2 \; K_3 \; K_4 \; S^2 \; T^2 \; \frac{I_m}{E_m} \qquad (7)$$

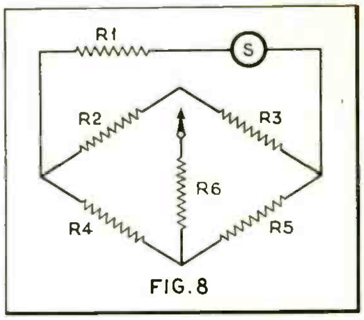
By analogy, $\frac{I_m}{E_m} = \frac{1}{Z_m}$ where Z_m is the mechanical impedance, or in other words, the quantity 45 of Fig. 7, and given by:

$$Z_m = \frac{K_1 \; K_2 \; K_3 \; K_4 \; S^2T^2}{Z_\varepsilon} \qquad (8)$$

* Consulting Engineer, Hardwick-Hindle, Inc., and Radiart Laboratories, Inc.



Equivalent circuit diagram of magnetic pickup shown in Figs. 1 and 2, in Part I of this article.



Generalized electrical structure of magnetic pickup system.

Since it was previously shown that in practice, Z_m should be made as large as practical, it is important to examine the factors of this equation in detail.

The quantities K_2 and K_4 are physical constants whose numerical values depend upon the units chosen, and are not connected with the design of the system.

The constant K_1 may be evaluated from the following considerations. Examining the magnetic system, it will be seen that it is a circuit in which the reluctances are arranged in the form of the Wheatstone bridge, so well known in electrical circuits, as shown in Fig. 8.

In this figure, the internal reluctance of the permanent magnet is represented by R_1. The magneto-motive force is generated in this branch as shown at S. The two upper gaps are represented by reluctances R_2 and R_3, and the two lower gaps as R_4 and R_5. The armature forms the bridge arm reluctance R_6, which is permanently connected in fixed relation to the lower gap reluctances, and in variable relation to the upper.

Values of R_2 and R_3 depend upon the areas and inversely, upon the lengths of the upper gaps, and, therefore, upon the displacement of the armature. K_1 is, therefore, calculated by the usual equations for Wheatstone bridge circuits, as the flux flowing in R_6 for unit magnet strength when the armature is displaced a unit distance from the center.

In a similar manner, the constant K_3 is determined as the flux flowing in the armature when one unit of magneto-motive force is generated in the coil with the armature in the mid-position.

The structure of the device should be such as to make the constant K_1 as large as possible and this is accomplished by making the length of the air gap as short as practicable. In practice, a compromise must be struck between the gain in sensitivity due to reducing the air gaps, and the loss in sensitivity due to the necessary stiffening of the rubber blocks to prevent instability of the armature.

Considered alone, it would appear that the constant K_4 should also be made as large as possible by reducing the reluctances of the air gaps, but this quantity is connected in a very complex manner with the possible number of turns. The coil, considered as the winding of a generator, has internal impedance, and works into an electrical circuit having a finite impedance, and therefore for maximum voltage output, there must exist a best relation of the internal and external impedances. The internal impedance is determined not only by the number of turns on the coil, but also by the characteristics of the magnetic circuit through the coil. The factors which increase K_4 also increase this magnetic effect, and therefore, the internal reactance of the coil, with the result that with a given load impedance, the number of turns must be decreased and an experimentally determined compromise must be struck between the two factors.

The greater the magneto-motive force available, the greater the sensitivity, and the size and strength of the magnet are limited only by considerations of cost and weight, with the added

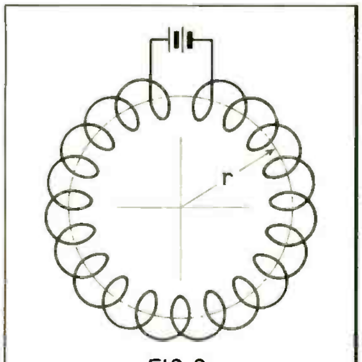


FIG. 9

Explanatory diagram, illustrating flux path in a toroidal coil.

limitation that the material of the armature must not become saturated; as was shown previously, the size of this member cannot be increased without decreasing sensitivity and increasing record wear.

The design of the magnetic system will be taken up in more detail in a later article, together with the design of the tone arm.

The effective life of an electromagnetic pickup will be no greater than the life of the permanent magnet, which supplies the magneto-motive-force for its operation. It is, therefore, of great importance to the designer to be able to predict the behavior of the permanent magnet, which it is proposed to use in any particular design. Unfortunately, there is no adequate theoretical basis on which to base the design of a permanent magnet for any given application and recourse must be had to purely empirical data, expressed if possible in convenient mathematical form. It will be attempted, in the following, to give a brief summary of the empirical data available, and the method of applying it to the design of a specific magnetic system.

Related Electrical Quantities

In magnetic phenomena, there are recognized three measurable quantities expressable in definite definable units, which are closely analogous to three quantities in electrical phenomena. In magnetism, we have a magnetic potential, or force, usually designated as magneto-motive-force, which corresponds to the potential or voltage in electricity. The amount of magnetism passing through a given area, known as flux, is equivalent to electric current. Further, in any magnetic circuit, there is a quantity which connects the amount of flux flowing in the circuit with the magneto-motive-force. This quantity is known as reluctance and corresponds with resistance in an electric circuit.

In an unvarying magnetic system, these three quantities are related by a law identical with Ohm's law in electricity, that is, reluctance times flux equals magneto-motive-force.

While we have so far stressed the analogy between magnetic and electric circuits, we cannot push this likeness too far. There is one important respect in which the two systems differ. In an electrical circuit, the maintenance of current by electro-motive-force requires the expenditure of energy, whereas, the maintenance of magnetic flux by magneto-motive-force in an unvarying system, does not require energy. In other words, an electric battery, from which current is being drawn, will inevitably be exhausted sooner or later, unless the energy generating elements within it are replenished. A source of magneto-motive-force, on the other hand, will pass flux through its associated magnetic circuit indefinitely, without being replenished. If this were not so, it would be impossible to secure a permanent magnet.

Turning now to a more detailed discussion of the three magnetic quantities, defined above, it is well known that magnetic flux flows around a conductor carrying electric current, and that the amount of flux, if the conductor is located in air or in a vacuum, is directly proportional to the amount of current flowing in the conductor. Since electric current is an easily measurable quantity, it is convenient to measure electro-motive-force in terms of current flowing in a wire. A unit of electro-motive-force is, therefore, defined as the amount generated by one ampere of current flowing through a closed electric circuit comprising a single turn of wire. The force is directed along the axis of the turn.

A unit of reluctance is defined as that of a column of air of unit length and area. It is a curious fact that for practical purposes, the reluctance of unit length and area of most substances as also unity, the only exceptions being metallic elements—iron, nickel, and cobalt, and their alloys, and a few re-

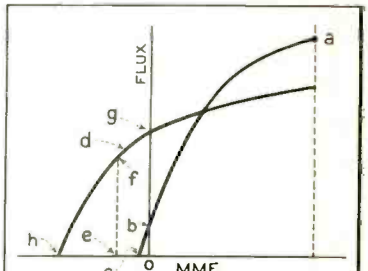


FIG. 10

Flux quantity plotted against magneto-motive-force.

markable substances known as the Heussler alloys, which are of only scientific importance. In the case of the magnetic alloys, the reluctance of the unit cube is very much less than unity.

With the above two definitions in mind, it is apparent that the unit flux will be the amount of flux flowing through an area of one square centimeter under the driving force of one unit of magneto-motive-force.

Another very important quantity in magnetic calculations is the flux density, which is the amount of flux flowing across a given area divided by the area.

We are now in position to consider the actual phenomena occurring in a given magnetic circuit. Consider, first, a toroidal coil of wire as shown in Fig. 9, having a mean radius of *r* centimeters, and assume further, that a single turn has an area of *A* sq. cm. Let there be a total of *T* turns of wire in the toroid and suppose that a current of *I* amps. flows through the wire. Such a system will generate a closed ring of flux through the turns. The reluctance of the flux path is evidently $2\pi r/A$ and the magneto-motive-force will be equal to I T. The flux density will be equal to $I\ T/2\pi r$.

In this system, it is important to note that flux is maintained only so long as the current flows through the wire, disappears within a minute fraction of a second after the current ceases and reappears in the opposite direction when the current is reversed.

We now introduce a soft iron core or ring of toroidal shape and cross sectional area A in place of the air core of the original experiment, and notice a number of changes in the resulting phenomena. In the first place, the amount of flux flowing in the ring is enormously increased. The amount of this increase is measured by the quantity u called the permeability so that the new reluctance will be equal to $2\pi r/A$, and the flux density will be equal to I $T/2\pi r$. The permeability unfortunately is not a constant for a given sample of iron but varies in an unpredictable manner with the flux density existing in the iron and must, therefore, be determined experimentally for any given grade of magnetic material.

A further difference between the magnetic system of one with an iron core and one with an air core is that in the former case, when current ceases to flow in the surrounding coil, it will be found that some flux continues to flow in the iron. In other words, the flow of flux through the iron has created within the material a magneto-motive-force due probably to some configuration of the molecules of the material, which continues to exist after the external magneto-motive-force is removed. It is this phenomena which makes the permanent magnet possible.

Representative Curves

Putting the above statements in graphic form, we may lay out a chart of rectangular coordinance as shown in Fig. 10, in which the abscissa represent magneto-motive-force and the ordinates represent the resulting flux in our toroidal iron ring. If the original M. M. F. (magneto-motive-force) and resulting flux lie at the point *a* in the diagram, the remaining flux at zero M. M. F. will be at some point *b*, and if the M. M. F. were gradually reduced from its maximum value to zero, the flux would follow a curve as shown. It will be apparent that in order to reduce the flux to zero, it will be necessary to apply an M. M. F. in a direction opposite to the original, and of a value such that the curve will be continued to zero flux value as shown at *c*.

It has been found by experiment that the shape of this curve depends upon the quality and character of the iron. For instance, steel having a moderately high carbon content properly tempered will retain a great deal more of its flux than soft iron and will require a much higher external reverse M. M. F. to reduce its magnetism to zero. Its characteristics will be represented more nearly by curve *d* in the diagram. It will, however, never pass as much flux under high magnetizing forces as the soft iron, because its permeability is much lower and consequently reluctance much higher.

A permanent magnet in the form of a closed iron ring would be of no practical value in any application since the flux is all confined within the ring. In any magnetic device, there must always be an air gap. We have seen that in the air gap, no magneto-motive-force can be selfsustaining, and it has been further shown that just as an electric current flowing through a resistance generates an effective counter electro-motive-force, so magnetic flux flowing through a reluctance generates a counter magneto-motive-force. Therefore, considering curve *d*, suppose that we introduce an air gap into the toroidal ring such that a counter M. M. F. of value indicated at *e* is generated. In this case, the flux in the ring will have a value as indicated at *f*, and we have a complete permanent magnet system, with an air gap in which we may place an armature or a coil, or some other device for utilizing the flux therein.

It has been further found that up to certain values of counter M. M. F. in any given sample of magnetic material, the internal M. M. F. is not destroyed and when the external counter force is removed, the flux returns to its original value as *g* in the diagram. Beyond a certain critical value, the internal M. M. F. is destroyed and the steel rapidly loses its magnetism. This critical counter M. M. F. bears a rather loose relation to the total M. M. F. required to completely remove the magnetism from the sample, and, therefore, the distance *zero* to *a* is a measure of the permanence and the merit of a steel intended for permanent magnets. This quantity has been named the *coercive* force.

Nature of Steels

Originally permanent magnets were made of tempered high carbon steel. As the art of building electrical meters became more refined, the demand grew for a permanent magnet which should have greater coercive force and constancy than that obtainable from unalloyed steel. It was found that certain alloys of iron and tungsten and iron and chromium had these desirable properties and tungsten magnet steel is today used almost exclusively in high grade electrical indicator instruments for both portable and switchboard work, and shows no signs of being replaced by any of the more recently discovered alloys.

Quite recently it was found that alloys of iron and cobalt could be made which gave higher coercive forces than tungsten alloys. The comparison of these two steels is indicated approximately in Fig. 11.

It is important in the intelligent application of these alloys to understand thoroughly the difference in their properties. For instance, tungsten steel cannot be subjected to a greater counter M. M. F. than that indicated by the point *i*, whereas cobalt steel may be subjected to a counter M. M. F. several times as great as indicated by *j*. Put in other terms, for a given length of cobalt magnet, we may employ air gaps of much higher reluctance than may be employed in the case of tungsten. However, with a correctly designed air gap, the tungsten magnet will pass more flux because of its lower internal reluctance. It must be pointed out and strongly emphasized that in a properly designed magnet circuit, tungsten magnet is just as permanent as the other, and will make available a greater quantity of flux. It must be further noted that if size is not a consideration, a longer tungsten magnet will do all and more than the cobalt magnet will do.

As a result of much experimental data, an empirical equation has been obtained by means of which the permanence of a given magnet may be predicted. Let A_g equal the area of the air gap, and L_g = the length of the gap. Let A_1 = the area of the magnet, and L_1 = its length. Then for tungsten steel:

$$\frac{A_g}{L_g} \times \frac{L_1}{A_1} > 70$$

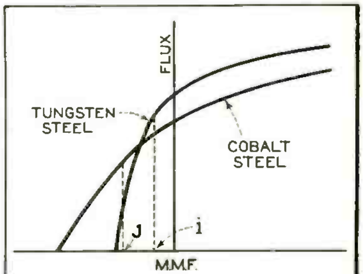


FIG. 11

Comparative coercive forces of cobalt and tungsten steels.

Since the dimensional quantities are all ratios, it does not make any difference whether English or Metric lengths and areas are used.

For cobalt steel, containing 15% of cobalt, the numeric on the right hand side of the above expression, may be reduced to 35.

New Moving System

Cobalt steel has come into general use in electro-magnetic pickups because of the large air gaps, which it has been previously necessary to employ, and because the necessary size and weight of the tungsten magnet under these conditions was prohibitive. In a more recent type of pickup, however, an improved form of moving system is employed, which makes possible the use of shorter air gaps, and consequently the tungsten with its higher flux density may be advantageously used.

In the design of magnetic systems employing permanent magnets, it is customary to disregard the reluctances introduced by the soft iron pole shoes since these are generally small in relation to the flux in the gap. Precautions must be taken in the design, however, to prevent undue leakage between the poles of the magnet since such leakage provides a path whereby flux is uselessly shunted around the working gap. The effect of such leakage is to increase the quantity A_g, in the above expression for stability.

(To be continued)

The Engineering Rise in Radio

By Donald McNicol

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

Part XVI

THE situation a year or so prior to the 1912 radio conference, with reference to inductively coupled tuners, was that while several types of tuner had been employed not much was known (or at least had been published) in regard to the interaction of the currents in one of the windings on the other.

The German engineers had been using a form of coupler which became known as the "Doughnut" tuner, and which was later employed at Marconi stations, and by 1909 or 1910 also was widely used by amateur radio experimenters. It consisted of a hollow cylinder of insulating material on which was wound a single layer of No. 22 copper wire. A sliding contact mounted on a rectangular metal rod made it possible to have in circuit any given number of turns of the coil. A coil wound on a cylinder six inches in diameter had a wavelength up to 1500 meters. The secondary, or doughnut, winding mounted within the cylinder on which the primary was placed was wound with No. 28 wire and had fixed to it a shaft extending out through the primary cylinder so that the coupling relations of primary and secondary might be varied. To facilitate close tuning the secondary winding was tapped every few turns, the taps connected to contacts over which a switch arm could be moved. (See Fig. 28)

Tuners of this type, known as loose-couplers, and as vario-couplers, together with their associated variable condensers were employed in the best of the radio receiving sets in the period 1908-1913. Indeed a receiving set consisted of one of these tuners, one or more variable condensers, a detector and a pair of head telephones.

One of the most intelligent attacks made on the subject of the theory of the inductive coupler was that carried on in 1910-1911 by J. O. Mauborgne, at that time instructor at the army signal school, Fort Leavenworth, Kansas. Mauborgne found that with the usual design of inductive coupler the secondary coil moved beyond the point of maximum coupling in either direction, making two positions of the secondary coil with respect to the primary where the coefficient of coupling had the same value. The maximum coefficient of coupling obtained when the turns of the primary coil, regardless of the number of turns, were so placed that they were exactly over the center of the secondary coil. By computation and experiment Mauborgne showed that varying the coupling of the two coils varied the wavelength, and that regardless of what degree of coupling was used the receiver was tuned to two wavelengths at the same time. Out of these studies came a considerable amount of useful information relating to "close" coupling, "loose" and "very loose" coupling. It was clear that for long waves increasing the number of turns of the primary in circuit increased the wavelength of the tuner; likewise, increasing the coupling increased the wavelength, and for long waves the full secondary inductance and large amounts of primary should be used, with close coupling. For short waves small amounts of primary and secondary inductances and very loose coupling gave the best receiving results.

Building on these investigations Lieut. Mauborgne a year or two later, with the assistance of Prof. G. W. Pierce, and E. R. Cram, published an excellent work on the uses of the wavemeter in wireless telegraphy, which was of immediate value to experimenters.

Remembering that the reason for employing wavelength regulating elements in a radio receiver is so that the receiver may be adjusted to make the most of the energy picked up by its receiving antenna, radiated from a transmitting station whose signals it is desired to receive, it is important that exact information may be had with reference to the transmitted wave.

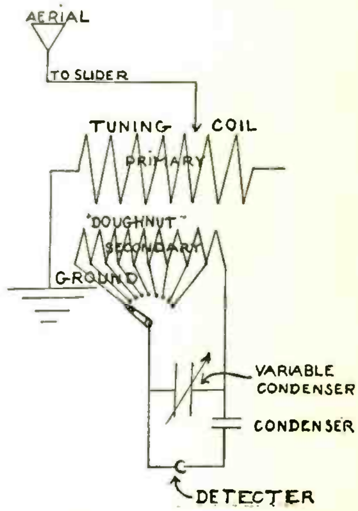


Fig. 29. Wiring arrangement of a radio receiving circuit employing a "doughnut" tuner. The translating telephones were connected in shunt with the detector.

It was understood in 1909, and before, that in a transmitter using close coupling in the closed and open oscillatory circuits, even though resonance obtained, the station sent out two waves, one greater and the other less than the wavelength or frequency to which both circuits were individually tuned, but as late as 1910 there was still doubt as to the wavelength emitted by a uniform straight rod oscillator in free space with a spark-gap at the center of its length; that is, the natural wavelength of a single-wire antenna freed from encumbrances or artificial loads and connected to earth.

On this point there still remained two schools of thought. Abraham, in France, for instance, maintained that

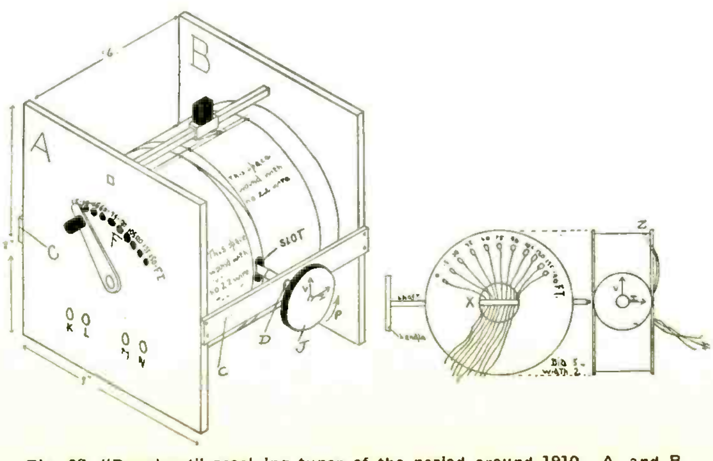


Fig. 28. "Doughnut" receiving tuner of the period around 1910. A, and B, are the retaining ends; F, the secondary contact switch; D, adjusting shaft, and J, a handle by means of which the coupling is varied between primary and secondary.

the wavelength of a free double oscillator was a little over (a few per cent.) twice its length as a rod; so that a rod, say, 10 meters long, with a small spark gap in the middle, would emit a fundamental wave whose length would be a few centimeters more than 20 meters. The other school, which may be identified by the views of MacDonald, in England, maintained that the wavelength was a little over two and one-half times the length of the rod, so that the 10 meter free double oscillator would give a fundamental wavelength about 25 meters long. Prof. J. E. Ives, in America, in 1910 carried out a series of experiments which tended to corroborate the views of Abraham.

It is well to keep in mind the character of the change which has taken

Fig. 31. A typical plug-in type Honeycomb tuning coil.

place in radio from the period prior to 1920, when in the amateur field at least, there were approximately as many transmitters as receivers in use; and the time since that year during which the number of receivers has increased so that there are perhaps hundreds of thousands of receivers to each individual tansmitter in operation.

Returning to the subject of the evolution of the radio receiver it may be recorded that in 1913, the design of vario-couplers took on new form, as illustrated in Fig. 30, by the type of coupler introduced perhaps first by P. Mertz, in America. This coupler was the forerunner of the highly efficient vario-couplers and variometers employed in the radio broadcast receivers introduced to meet the wide demand created by the inauguration of broadcasting in 1921. This coupler, and modifications of it, were used in commercial radio telegraph operation, and by hundreds of amateur experimenters from the time of its introduction in 1913, and continued as a favored device even in competition with the efficient "honeycomb" coils (see Fig. 31) brought out in the war years, and perhaps first developed by Morton W. Sterns, in America.

Inasmuch as following the events of 1912 the audion became the only considered detector element for use in

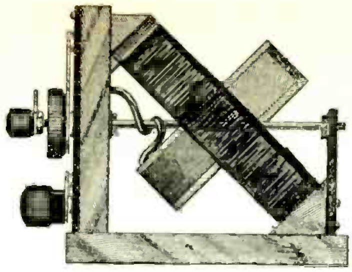


Fig. 30. Rotary receiving tuner, or vario-coupler, of 1913. Both primary and secondary coils are tapped. The inside, secondary, coil is rotated by the knurled knob on the shaft.

radio receivers it is of interest to look at the circuit arrangements employed in association with the tube as time progressed.

In receiving circuits employing the two-electrode "valve" detector, due to Fleming, the valve occupied a place in the circuit the same as that given to the crystal detector in receivers using a crystal, as indicated in the circuit of Fig. 32.

The circuit employed with the deForest audion of 1906 (comprising two plates and a filament, as shown in Fig. 33) was made up in a somewhat different manner. Here a "B" battery was used, in addition to the battery used to supply current to heat the filament, and the translating telephones were connected in the plate circuit. It may be noted that the two plates were connected together, a wire from the plates passing to the secondary circuit of the antenna coupler.

The first valve circuit and the first audion circuit making up radio receiving sets were little, if any, more effective in detecting intercepted electric waves than were the electrolytic and crystal detectors. In 1907, however, deForest replaced one of the "plates" in the tube with a "grid" which at once brought to the audion all of the wonderful potentialities later developed.

And, although it was not until five or six years later that the advantage of tuning the plate circuit of the audion was discovered, the receivers, in which the audion was used as a detector, employed from 1907 until 1913, consisted of unimportant variations of the arrangement illustrated in Fig. 34.

Improvements made in the design of inductive couplers following 1912 were, in an important measure, due to analyses carried out by G. W. O. Howe, in England and F. A. Kolster, in America. The question of distributed capacity in the coil windings, which had been considered in earlier years, was re-examined by these engineers in a thorough fashion, a result of which was that in time the coupling units employed were considerably improved in efficiency.

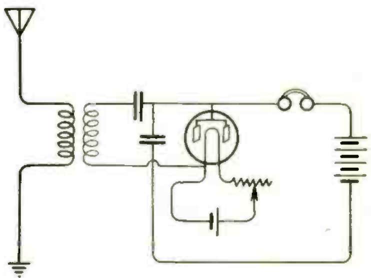


Fig. 33. Typical audion receiving circuit of 1906.

Marconi Receiving Sets of 1913

Standard receiving sets manufactured by and issued for service by the Marconi Wireless Telegraph Company of America, in the year 1913, may be regarded as reflecting the best practice of that time. It may be recorded, however, that at that time the Arm-

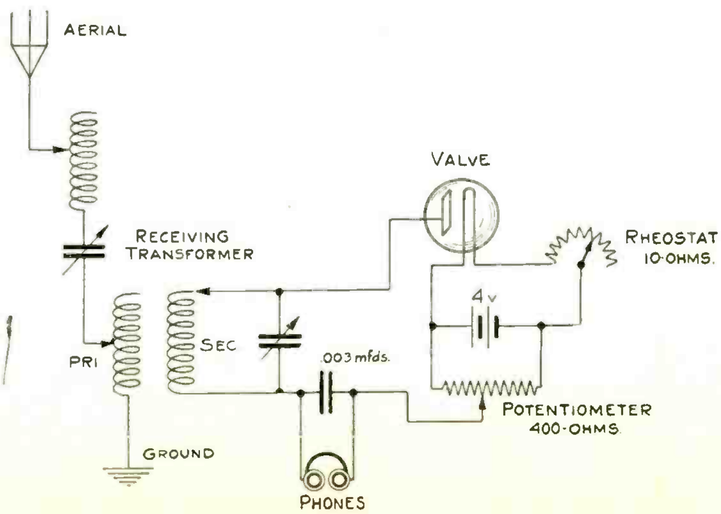


Fig. 32. Receiving circuit employing the Fleming valve detector.

strong regenerative receiving circuit and the deForest ultra-audion circuit were just emerging from their chrysalises at Yonkers and High Bridge, and also, the patent situation was such that the Marconi Company was not at liberty to use the audion in service.

The Marconi receiver of 1913 was of the two-circuit inductively coupled type comprising inductive coupler with primary and secondary, primary variable condenser, secondary variable condenser, coupling controller, detector stopping condenser, a carborundum detector and a cerusite crystal detector. Either crystal could be used as desired. The circuit is shown in Fig. 35.

The inductive coupler consisted of a fixed primary and a movable secondary mounted on a rod and controlled in its motion by a flexible metal band passing over a number of pulleys, by which means the coupling could be varied over a wide range simply by turning a small knob. Both primary and secondary tuner windings were divided into four sections connected to the controlling switches in such a way that "dead ends" were avoided. These sets were designed for operation on wavelengths up to 7000 meters.

Perhaps the most highly developed receiving arrangement used by the British Marconi Company employing the magnetic detector, widely used in ship service in the days before the more modern tube circuits became available to Marconi interests, was the set known as the multiple tuner.

In the illustration of Fig. 37 showing the multiple tuner it may be noted that there are three distinct circuits; the antenna circuit, the intermediate, and the detector circuits. Each circuit was tuned to the desired incoming wavelength. The antenna circuit had an adjustable inductance A, an inductive winding B, and a variable condenser C, all in series to ground. The coil B, induced oscillations in D and in E, resonance being obtained by means of the variable condenser F. The detector circuit from coil G, included in series an adjustable condenser and the primary winding of the magnetic detector, into the secondary of which the translating telephones were connected.

Receivers of 1913 Employing Audions

By the year 1913 deForest had developed receiving circuits which made it possible to employ several stages of amplification, thus greatly increasing the sound of received signals in the translating telephone. Audion sets were on the market in which the audion served simply as a detector, and sets were constructed embodying a detector and two stages of amplification, an audion being employed in each stage.

The Grid "Leak"

The early audions in their physical makeup were essentially of incandescent lamp construction. They were manufactured by the glass blower and the lamp maker. In the tubes produced prior to 1912 it was customary to use a "B" battery potential of not more than 50 volts, as it was found that voltages much higher than this caused excessive ionization. The air exhauston obtained was about the same as in commercial incandescent lamps. It was not until 1912 or 1913, after the audion's additional properties were discovered, that there was immediate need for the application of higher voltage to the plate circuit.

In the early audion receiver circuits in some instances a stopping condenser was inserted in series with the wire leading to the grid of the tube. With the low-vacuum tubes available there were sufficient ions in the tube ordinarily to prevent accumulation on the insulated grid of a troublesome negative charge, which if permitted to build up would soon obstruct the flow of current from plate to filament; that is, the current from the "B" battery.

The condition here under consideration may be understood when it is stated that when an incoming wave by way of the receiving antenna reaches the grid of the tube the positive component of the wave passes freely from grid to filament, while the negative component tends simply to pile up a charge on the grid. When a small condenser is inserted in series with the grid, then, upon the termination of a group of incoming oscillations, the charge accumulated on the negative, or grid side of the condenser has no outlet other than by way of the grid itself.

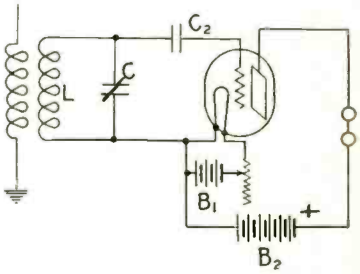


Fig. 34. Circuit employing the three-electrode audion—patent issued to deForest, February 18, 1908.

In 1913, or earlier, deForest corrected this difficulty by connecting a high-resistance leak circuit around the stopping condenser, of the order of one megohm, in this manner providing a way of escape for the negative charges which otherwise would accumulate on the grid element of the tube.

The provision of an outlet circuit around the grid condenser by way of which the grid could rid itself of the negative charges imparted to it, effected a material improvement in the operation of radio receiving circuits in which tubes were employed.

The deForest audion detector and three-stage amplifier receivers described in December, 1913[1], were accompanied by the deForest ultra-audion arrangement[2], in which the grid leak resistance appeared. In this circuit arrangement, shown in Fig. 38, there was no regeneration control, the tube oscillating over a rather broad band of wavelengths. Tuning was accomplished by varying the turns of antenna inductance and by adjusting the variable condenser. The system was somewhat critical as to filament current and this had to be just right for good results.

Regenerative Circuits

Improvement in the design and construction of vario-couplers had fortunately kept pace with the expanding sphere of the audion, so that when the regenerative, feed-back circuit came into use, there were at hand efficient vario-couplers and also a modification of the coupler called a variometer. The latter comprised two short cylin-

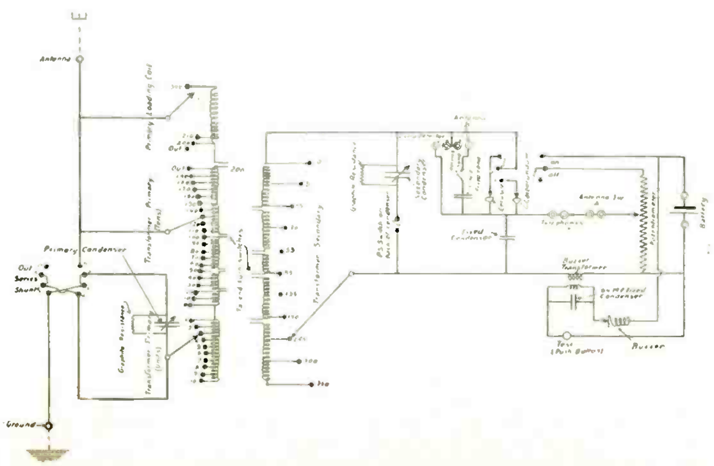


Fig. 35. Schematic diagram of the Marconi Receiver of 1913.

[1] *Proc. Inst. Radio Engineers, March,* 1914.

[2] *Electrical World and Engineer, New York, February* 20, 1915.

drical coils with the inner and smaller diameter coil pivotally mounted within the larger stationary coil. The inner coil was connected in series with the outer one and could be rotated about its axle through 180 degrees. Properly connected as to direction of the respective windings, in one position with opposing magnetic fields the inductance was at zero value, while by altering the position relation of the coils the inductance was increased as required in tuning.

Progress in Europe

The discovery of the oscillating property of the audion and of the significance of tuning the plate circuit opened the way for the design of radio receiving circuits far surpassing in usefulness any circuit arrangement previously employed.

In addition to the steps immediately taken in America and England to apply these discoveries to practice, the physicists and engineers on the continent also made creditable progress. In Germany, Dr. A. Meissner, in March 1913, devised a tube oscillating circuit, and previous to this, Siegmund Strauss, in Austria, applied for a patent on December 11, 1912, to cover a design of a tube oscillating circuit. In France a number of engineers soon were in the forefront of the advance toward the day of more sensitive and more selective radio receivers. Among these latter were Lucin Levy, M. C. A. La Tour, H. Abraham, M. Goulton, Captain Metz, and Lieutenants Brillouin, Gueritot and Manescau.

It was unavoidable that from this point onward there was a deal of duplication of effort and of achievement. Many of the advances made in one

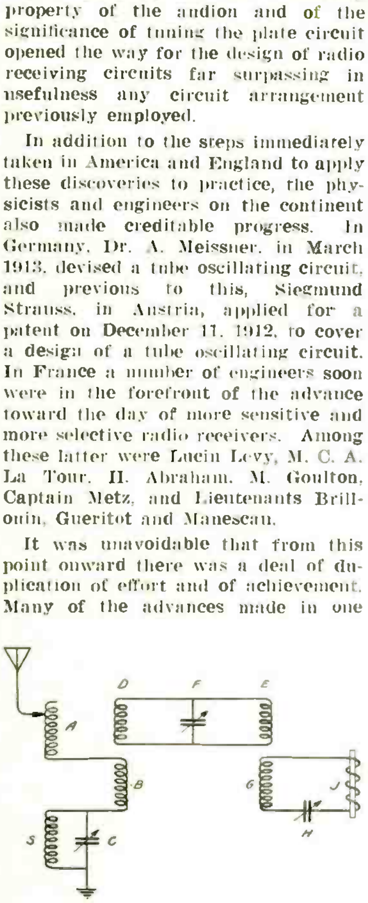


Fig. 37. Circuit diagram of the Marconi multiple tuner.

country were almost simultaneously duplicated in other countries. The evolution of the multi-tube radio receiver, however, may very well be traced by noting the successive steps taken in America from the time of the discovery of the regenerative principle.

Single Circuit Regenerative Receiver

In this receiver a single adjustable antenna inductance is employed for antenna tuning. A typical circuit is shown in Fig. 39. Regeneration is accomplished by connecting a variometer in the plate circuit, thus producing an amplification of the loudness of the signals heard in the telephone. A single circuit regenerative receiver also is provided by connecting a "tickler" or "feed-back" coil from the plate of the tube, as illustrated in the two-circuit receiver, instead of using a variometer in the plate circuit.

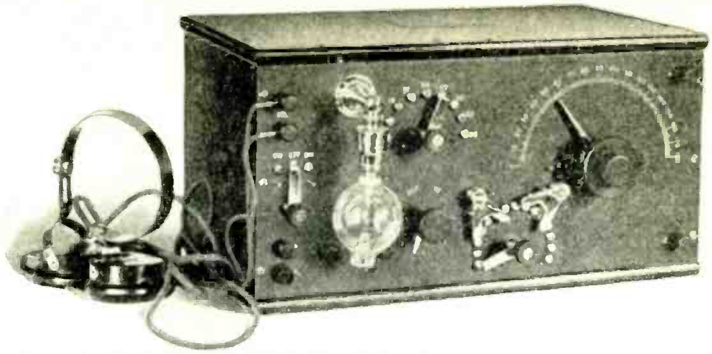


Fig. 36. Radio receiver of the year 1913, comprising an audion detector and contained tuning element with "dead end" switches.

Two-Circuit Regenerative Receiver

In the two-circuit receivers, circuits of which are shown in Fig. 40, it may be noted that the antenna has a direct circuit to ground through the primary of a vario-coupler and a variable condenser, while the secondary coil of the coupler has associated with it a variable condenser by means of which the secondary may be tuned to the incoming wavelength as set up in the tuned antenna circuit. Regeneration is accomplished by mounting a third (tickler) coil close enough to the primary and secondary coils of the vario-coupler to be in inductive relation therewith. The "honeycomb" coil admirably answered the requirements for primary, secondary and tickler, as three of these units, each properly wound for its purpose could be conveniently mounted in a compact rack. Also, instead of using a tickler coil to produce regeneration of signal strength two variometers could be employed, one in the plate circuit and one in the grid circuit, with practically as good results.

Several of the regenerative circuits at first placed in service embodied no provision for avoiding re-radiation outward into space by way of the receiving antenna acting as a sending antenna. The presence in a receiving circuit of an audion which under certain circuit conditions would generate oscillations was not a serious matter until receiving antennas multiplied by the hundred thousands for the purpose of picking up broadcast matter. With several receiving antennas mounted on a single roof, or in an ordinary sized back lot, electric waves radiated from one or more of these antennas was sure to affect the other antennas, causing interference which could not very well be tuned out by persons attempting to tune their sets to a particular broadcast transmission. The need quickly developed for non-radiating receiving sets, but as hundreds of thousands of the offending sets had been installed by purchasers, naturally a considerable length of time was to elapse before replacements were made.

These "radiating" receivers caused mysterious "howls" in neighboring receiving sets, and when the cause of the disturbances became known a campaign of education was launched which to some extent mitigated the evil. It was discovered that care had to be exercised in the adjustment of the feed-back coupling. If this were too "close" the least disturbance in the plate circuit caused the grid, by its control action, to maintain the changed conditions, setting up undesirable oscillations which had an outlet by way of the receiving antenna. It was learned that for receiving purposes it was necessary only that the detector tube circuits be adjusted so that the oscillating state was not quite reached. By loosening the tickler adjustment and by maintaining the filament current at a strength just sufficient to insure good reception, the tendency for sets of this type to radiate was reduced.

The Heterodyne and the Audion

In Chapter 7 the principle of "beat" currents and the heterodyne is described, as originally conceived by Fessenden in the application of high-frequency machine generators to radio reception. In 1908, Fessenden employed ingenious receivers which operated on the heterodyne principle. If the frequency of the incoming signal wave is 500,000 cycles per second and there is impressed on the circuit current from a local source at a frequency of, say, 501,000 cycles per second, then the amplitude of the resulting current will rise to maximum and fall to minimum successively 1000 times per second. This current rectified by a crystal or tube detector produces in the telephone receiver an audible tone at a frequency of 1000 per second. This is what is called heterodyne or beat reception.

With the audion available as an "internal" heterodyne to take the place of the previously employed "external" heterodyne, quite naturally the entire question as to the principle of the Fes-

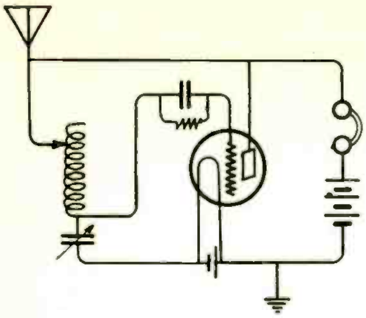


Fig. 38. The Ultra-audion circuit of 1913.

senden invention was brought into the open when the audion in 1913 found employment as a producer of oscillations.

What was almost an orgy of invention immediately followed, precipitated perhaps by J. V. L. Hogan's technical paper on tests with heterodyne reception, presented before the Institute of Radio Engineers, New York, in July, 1913.

Late in 1913 patent applications were filed by Round and Franklin, in England, and by Meissner and Arco in Germany. The inventions of deForest, Logwood and Armstrong, in America, have been referred to elsewhere herein. Forthwith, also, a prolonged debate began bearing on the degree of amplification of received antenna current accomplished by the heterodyne method.

Following Hogan's paper of 1913, Dr. Austin, in a Bureau of Standards Bulletin of April 1, 1914, stated "the reports indicate that the heterodyne is somewhat more sensitive than the slipping contact, but that the difference is not very great." Dr. Louis Cohen[3] held that heterodyne amplification could be increased indefinitely by increasing the local current (using an ideal detector of unlimited current-carrying capacity), while Dr. B. Liebowitz[3] undertook to show mathematically that "the true heterodyne amplification" is four. E. H. Armstrong[4] stated that the results with the tube auto-heterodyne appeared to support the views advanced by Liebowitz, while G. W. O. Howe[5], in England, showed by several different methods of considering detector and heterodyne action as compared with "chopper" detection of received energy, that if the detector gives an audibility current proportional to the received current, the maximum amplification of audio power is 2.43, not increasing indefinitely with increase of locally applied current.

The whole matter of the heterodyne principle is important as an illustration of how the radio receiver art in practice continued in advance of generally accepted theory throughout several years following 1913. Armstrong's research[4] brought to the surface much that aided in clearing up the misunderstanding when he found, by separation of the various effects, that there existed three distinct types of amplification. The first or *equal heterodyne* type occurring when the local oscillating current is equal to the signaling current. The second or *optimum heterodyne* type occurring when the local current is increased to the critical value for maximum response in the indicator. The third or *regenerative* type resulting from the amplifying action of the tube and its associated circuits: the roughly approximate numerical values of the three types being five, twenty and fifty.

The contributions to the subject made by Armstrong, Liebowitz, Austin, and others, were closely examined in England, out of which study came further light shed by G. W. O. Howe and E. V. Appleton[6]. The latter in a technical paper on the subject showed that the amplitude of the combination tone produced in a radio receiver telephone reaches an optimum value for a

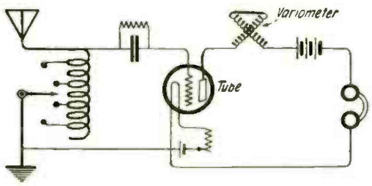


Fig. 39. Schematic diagram of early single-circuit regenerative receiver.

certain value of the local oscillation amplitude, distinguishing between anode rectification and grid condenser action. Also that the magnitude of the combination tone is directly proportional to the strength of the signal oscillation when optimum heterodyne current is applied locally, while the ratio of the optimum value of the combination tone to that appearing with equal heterodyne is inversely proportional to the strength of the received signal.

It is to be remembered, of course, that Hogan's tests of 1910, and those which followed, were made with electrolytic and crystal detectors. With detectors of the contact type, giving an audibility current proportional to the square of the received current, the amplification might greatly exceed four. In Hogan's report of the *Salem* tests he stated that the greatest amplification factor measured was twelve times, the average throughout the tests being five.

In a regenerative receiver circuit arranged for rectification and amplification of the incoming oscillations one audion may serve as detector and as generator of oscillations. This is known as autodyne reception. With the antenna circuit tuned to the frequency of the incoming waves, and the tube circuit adjusted to produce locally oscillations of a slightly different frequency, beats of audible frequency will actuate the telephone receiver connected in the receiving circuits.

With the oscillating audion available for the production of the locally generated "interference" currents necessary for heterodyne reception, little time was lost in applying the principle to receiving sets using audions. J. V. L. Hogan, in May 1915, supplementing by discussion Armstrong's paper of March, that year, showed circuits of a receiving system employing an audion as detector and an audion as generator of the heterodyne frequency. In 1915, L. W. Austin employed beat reception with audions, at the Darien, Canal Zone station of the U. S. Navy.

In the meantime the war in Europe had begun and several years were to elapse before it would be possible to learn much about the progress in radio made by the engineers of the nations engaged in the struggle. After the entry of the United States into the war all effort was directed toward inventing and producing agencies by means of which the war could be terminated as quickly as possible, with victory for the Allies. In connection with American participation in the operations there was formed a Division of Research and Inspection of the U. S. Signal Corps, and into this group came several of the bright minds of radio, including E. H. Armstrong, W. A. MacDonald, J. H. Pressley, H. W. Houck, Harold M. Lewis and W. H. Priess. The research headquarters were in Paris, France.

It is of more than passing interest that the communication requirements of the cooperating armies should find in conference, or engaged in a single undertaking: H. J. Round and J. B. Bolitho, from England, Marius C. A. Latour and Lucien Levy, of France, and Armstrong and his associates from the United States.

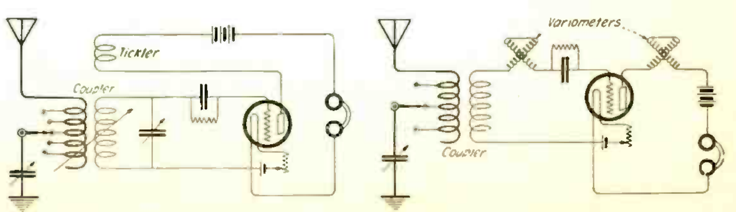


Fig. 40. Two diagrams of early two-circuit regenerative receivers.

[3] *Proc. Inst. Radio Engineers, July*, 1915.
[4] *Proc. Inst. Radio Engineers, October*, 1917.
[5] *Proc. Inst. Radio Engineers, October*, 1918.
[6] *Proc. Inst. Radio Engineers, November*, 1923.

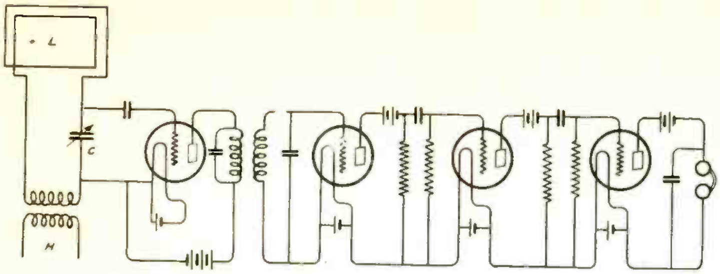


Fig. 41. General circuit of early Superheterodyne receiver.

The French, under Latour, produced a six-stage, four-tube amplifier known as the L-3 type. The British, under Round, produced a seven-tube amplifier known as No. 55. For the uses of the A. E. F., the Americans adopted the L-3 receiver of the French, as it was the only amplifier available, but still greater amplification was desired, and here again we find the genius of Armstrong measuring up to the needs.

Armstrong's four or five years experience with regeneration, oscillating audions and the heterodyne, gave him a fund of just the right sort of information necessary to successfully attack the problem. He has related[7] that with this experience in mind the idea occurred to him to solve the problem presented by selecting some frequency which could be handled by the tubes available at that time, building an effective amplifier for that frequency, and then transforming the incoming frequency to this readily amplifiable value by some converting means which had no low limit: preferably the heterodyne and rectification. This was in June, 1918.

The Superheterodyne Radio Receiver

Although the production of ultra-audible frequencies by heterodyning was pioneered by Levy, in France, Round, in England and Meissner, in Germany; in America the immediate outcome of Armstrong's deliberations was the development of a receiver system which came to be known as the superheterodyne. The early circuit arrangement is illustrated in Fig. 41 wherein both rectifications are accomplished by three-electrode tubes of the audion type. Although any form of stage coupling may be used, resistance coupled amplification is shown.

In this arrangement the tuned circuit LC is adjusted to some frequency between 50,000 and 100,000 cycles, and if desired may be regenerative by any form of reactive coupling. If the frequency to be received is 5,000,000 cycles this may be stepped down to 500,000 cycles, re-amplified and detected. An advantage of this method of amplification is that the tendency to oscillate due to the reaction between the output of the amplifier and the input is eliminated as the frequencies are widely different.

Armstrong designed an eight-tube receiver consisting of a rectifier tube, a separate heterodyne oscillator, three intermediate-frequency amplifiers, a second detector and two audio-frequency stages. The intermediate stages were coupled by tuned air-core transformers designed to have a frequency of about 100,000 cycles, with adjustment for regeneration control. Amplification of voltage as noted at the input of the second detector (the amplifier being just below the oscillating point) was approximately equal to a radio-frequency amplification of 500. The first sets were somewhat critical in adjustment and considerable skill was required in operating them. At this stage of development the armistice ended the work of the Americans in France, and which was resumed in America by Armstrong some months later.

After the close of the war it was learned that the German radio engineers had made important progress in developing radio receivers of improvded sensitivity and selectivity. Walter Schottky, in Germany, in March, 1918, in designing an improved system of radio reception for war service needs, followed a path of logical reasoning which took him over ground similar to that covered by Armstrong and his American and British associates in France.

To obtain the desired improvement Schottky's first notion was to undertake to provide special amplifying tubes having large electronic currents and low internal resistance, but later he reached the conclusion that as the amplification of very short waves involves a large consumption of energy in the amplifier tubes, there is advantage in converting short waves into longer waves at the point of pickup, amplifying the latter only, thus avoiding loss of received energy and still dealing with inaudible frequencies. As recorded by Schottky[8], in March, 1918, "This is accomplished by heterodyning another frequency differing by about 10 per cent. so that the beat wave again becomes high-frequency, but longer."

In the fall of 1919 Armstrong undertook to determine the results obtainable by pushing the heterodyne method of reception to the limit of its possibilities, by constructing a resistance coupled intermediate-frequency amplifier employing five tubes of high amplification factor. The voltage amplification of the five stages was probably between 5,000 and 10,000-fold. A complete set with two-tube frequency converter, five-tube amplifier, detector and one stage of audio amplification gave excellent receiving results.

The long distance possibilities of the superheterodyne receiver were demonstrated in December, 1920, when Paul F. Godley, representing the American Radio Relay League at a temporary receiving station on the west coast of Scotland received signals from a number of amateur transmitting stations in America. The receiver used by Godley comprised a regenerative tube rectifier, a separate oscillator, four stages of resistance-coupled, intermediate-frequency amplification, a second rectifier and two stages or audio amplification.

It will be recalled that it was in December, 1920, also that radiophone broadcast transmission had been developed to a degree of practicability warranting regular schedule operation such as in that month established by KDKA at Pittsburgh. A red letter month, December 1920, in the history of radiophone broadcasting.

The development of the superheterodyne receiver for broadcast reception purposes was continued by Armstrong assisted, in 1922, by H. W. Houck. For public use it was desirable to lessen the number of controls, and a step in this direction was taken by designing an intermediate-frequency amplifier for a given frequency and for a band 5,000 cycles above and below that and which would tune sharply on

[7] *Proc. Inst. Radio Engineers, March, 1924. Also see Proc. Inst. Radio Engineers, December, 1919.*

[8] *German patent D. R. P. 368937, June 18, 1918.*

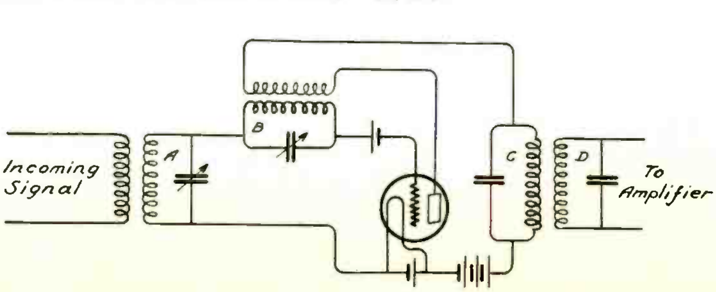


Fig. 42. Circuit arrangement of second-harmonic superheterodyne.

either side of the desired band; the operating adjustment simply accomplishing the change of incoming frequency down to the band of the amplifier.

A receiver was constructed in the spring of 1922, consisting of one (non-tuned transformer) radio-frequency stage, a rectifier tube, oscillator tube (used as a separate heterodyne), three-stage iron-core transformer-coupled, intermediate-frequency amplifier for a band of 20,000 to 30,000 cycles, a second detector tube and two stages of audio-frequency amplification.

To prevent the intermediate-frequency amplifier from oscillating, each stage was separately shielded. The use of a radio-frequency stage ahead of the first detector eliminated the reaction between the loop circuit and the oscillator circuit.

The cost of a receiver of this type was rather high, at a time when most persons who owned receivers had made them from purchased parts, or were accustomed to crystal-type receivers which could be purchased for twenty dollars or less. With the 6-volt tubes available in 1922, the "A" battery current for the superheterodyne receiver was ten amperes. The arrival, later, of the low current dry-cell tubes made possible a considerable reduction in the cost and maintenance expense of receivers.

Attempts were made to reduce the number of tubes required without lowering the sensitiveness of the receiver, by arranging so that a single tube would serve a double purpose, but there was little success in this until Houck[9] proposed to connect two tuned circuits to the oscillator, a simple circuit tuned to the frequency of the incoming signal and a regenerative circuit adjusted to oscillate at such a frequency that the second harmonic of this frequency beating with the incoming frequency produced the desired intermediate frequency.

The connections for this arrangement are shown in Fig. 42 where A is tuned to the incoming signal; B, is tuned to one-half of the incoming frequency plus or minus one-half the intermediate frequency, while C and D are tuned to the intermediate frequency. As pointed out by Armstrong, by reason of a symmetrical action of the tube, there were created in the circuits a variety of harmonics.[10] The second harmonic combining to produce beats with the incoming signals of the desired intermediate frequency, the tube rectifying these to produce the desired frequency; and, by way of C and D, the resulting frequency is applied to the amplifier circuit. Owing to A and B being tuned to frequencies differing by about 100 per cent, a change in the tuning of one had no appreciable effect upon the tuning of the other. By these means the problems of the oscillator and of reradition were solved.

A further step was to have the radio-frequency amplifier also amplify the intermediate frequency, thus reducing the number of tubes required. The signals then were amplified at radio frequency by the first tube and applied to the grid of the second harmonic oscillator by means of an untuned radio-frequency transformer. The combined signal and heterodyne currents then were rectified by the second tube, producing a current of the intermediate frequency; passed to the grid of the first tube, amplified there, and passed to the second stage of the intermediate amplifier.

At this stage of development the superheterodyne receiver passed into the laboratories of the large manufacturers associated with the Radio Corporation of America, where it had various refinements added which made of it an efficient six-tube receiver.

(To be continued)

[9] *Proc. Inst. Radio Engineers, March,* 1924, *p.* 545.

[10] *For the information of student readers it may be stated that in an oscillatory circuit with distributed capacity and inductance the system will oscillate at harmonics of the fundamental frequency. An alternating current with symmetrical half-waves has odd harmonics, such as first (the fundamental), third, fifth, seventh, and so on. When the two half-waves of a cycle are not symmetrical the harmonics will be both odd and even; first, second, third, fourth, etc. The second harmonic has twice the frequency of the fundamental; the third harmonic, three times that of the fundamental.*

Book Review

RADIO TELEGRAPHY & TELEPHONY—*By Rudolph L. Duncan, director, Radio Institute of America, and Chas. E. Drew, Electrical Division, Radio Institute of America.* 950 *pages.* 6x9 *inches. Stiff buckram covers. Profusely illustrated. Published by John Wiley & Sons, Inc., New York City. Price* $7.50.

Occasionally in the procession of books across this desk there comes a book which is a pleasure to describe. In fact, as in the case of Messrs. Duncan and Drew's work, we really have to get enthusiastic. It is a great piece of work.

These gentlemen say in their opening paragraph, "In order to acquire a sound knowledge of radio operation the student must thoroughly understand the principles of magnetism and electricity. On many occasions students have been heard to exclaim, 'I want to learn radio, not electricity.' That is impossible because radio phenomena are electrical phenomena." And they prove to the world that such is absolutely the case and what it is all about.

To go through each of the twenty-six chapters and describe them adequately would take up entirely too much space, so just a very few of the high spots can be considered.

First, an excellent exposition on magnetism is presented. This all-important fundamental is described so well that in various later chapters, when the various magnetic principles are reviewed to clear up a particular point under discussion, they seem superfluous; but to the student this is not so, for constant iteration drives a point home harder than all sorts of back references.

The principles of generators and alternators are described, as soon as the reader is considered well versed in magnetic theory. All types of rotation machines are explained with excellent diagrams.

Then are described the functions, theory, and care of storage batteries and their charging circuits. In this day of alternating-current vacuum tubes all this may seem out of place, but the authors have not forgotten the fact that in radio at sea the storage battery plays an important role. All types of batteries are considered and for which purpose they are best suited.

The theory of alternating currents is given in a concise form. This is a subject about which tomes have been written, but the authors have managed to condense into a relatively few pages—about eighty—sufficient information for the student to get a good idea of how this type of current functions and why.

The chapter headed "Vacuum tubes" is worth the price of the entire book. The electron theory is reviewed and amplified and each step in the development of the theory of the tubes is most clearly explained. Different types of tubes are described with their theory of operation and characteristic curves and how these are found. The very latest developments in a-c. tubes are described and it might be mentioned here that in the Appendix is a very complete tube chart showing the average characteristics of all types of tubes.

Then is taken up the theory of radio waves, their propagation and how they are detected and amplified. Receiving circuits from the lowly crystal to the latest multi-tuber are described, both as to character and theory. And progressing logically—there is then a chapter on telephone receivers and loudspeakers of all types.

But after all this, we have told about just half the book. There follow chapters describing antenna, resonance, rectifier devices, all types of broadcast and commercial transmitters and receivers, direction finders and compasses and an Appendix wherein is gathered a host of useful information so arranged that it is easily available.

There are plenty of mathematics throughout—it is well explained: there are scores of curves—they, too, have their excellent explanations and reason for being—in fact here is a book that we do not doubt will soon become an authority ranking with Morecroft, Van der Bijl and others of that ilk!

As we said before, space is limited and all we can say is—if you want to *learn* about radio, if you want to *review* almost anything about radio, if you want a radio *reference book*—buy this one. We are willing to wager you will find the money well invested.

TROUBLE SHOOTER'S MANUAL—*By John F. Rider.* 234 *pages. Illustrated.* 8½ x 11¼ *inches. Flexible buckram covers. The Radio Treatise Co., New York City. Price,* $3.50.

The average Serviceman who is out in the field repairing sets and locating troubles of various sorts is up against a hard proposition. He should know the circuit principles of every make receiver and have a good idea of the principles of operation of the various accessories used in connection with a set.

For a man to remember such a mass of detail is well nigh an impossibility and for this reason Mr. Rider has prepared this book. In the first hundred odd pages he deals with the manifold things that can go wrong with a set or the attendant equipment. Circuit diagrams of the various apparatus are given, so that troubles may be "shot" with a minimum of time and work. The section dealing with the possible troubles arising in vacuum tubes is exceptionally good and the author rightly deals with this subject at great length. Over a hundred pages in the rear of the book are devoted to the circuit diagrams of different makes of receivers—past and present.

Broadcast Difficulties

Findings by Bureau of Standards in Study of Short Period Fading in Broadcast Band

*By J. E. Smith**

FADING, static, and the absorptive effect of steel buildings and similar structures may be characterized as the three master stumbling-blocks to radio progress. Of these handicaps, the fading or fluctuation of signals perhaps imposes the greatest penalty on the forward-march of broadcasting. The phenomenon of music or speech being punctuated by periods of silence varying from a few seconds to several minutes is not only disconcerting to broadcast listeners but it remains an enigma to scientists. Crashing static may occasionally drive the listener to distraction but the breaking of the continuity of a program is such an exasperating experience as to drive him into a frenzy over the vagaries of radio waves.

Short Period Fading

An investigation, which has been in progress at the Bureau of Standards for one and one-half years, is inquiring into the whys and wherefores of the waxing and waning of radio signals. These studies, unlike similar inquiries into the phenomenon of fading, are being confined to the broadcast band of wavelengths and, therefore, the results are of potential interest to the estimated 50,000,000 broadcast listeners. The investigation is limited to short-period fading—fluctuations varying in duration from a few seconds to several minutes—and the observations are made at a field laboratory at Kensington, Maryland. This location was selected because of its freedom from telephone and electric-power transmission lines, thus insuring an absence of man-made interference that might confuse the studies and confound the results. Situated in an abandoned field, with young pines and other undergrowth struggling for existence, this open-air laboratory is nothing more than a shack to shelter the observing radio instruments and an antenna system to intercept the broadcast signals. Amid these environs, T. Parkinson of the Radio Laboratory of the Bureau of Standards trained his fading recorder, manually operated, on two broadcasting stations, for the most part—*WBAL* of Baltimore, and *WJZ* of Boundbrook, N. J.

Result of Investigations

Following studies of 18 months' duration, the investigation has not been completed but it has progressed sufficiently to warrant conclusions that are significant. Some of these results are in agreement with those of previous investigations while other conclusions are at variance with accepted theories or at least they isolate the several factors entering into the causes of fading. For instance, we note that a periodic fluctuation of signals is present even when the ground wave is absent.. Furthermore, in addition to the usually attributed causes of fading this investigation points to the existence of a number of indirect or atmospheric rays with varying paths and with rotating planes of polarization, which result in variations in intensity of the music or speech being received. Of the 50 records embracing the broadcast band between 1,480 and 660 kilocycles and over distances from 150 to 1,500 kilometers, there were numerous instances of interference between the indirect ray or the wave traveling through the sky and the ground wave. Up to a half hour after sunset the weak wave reflected from the upper atmosphere appeared to be normally polarized and, therefore, produced intensity changes in the coil antenna at a maximum position, possibly though a combination of interference effects and varying absorption. Seven-fold are the conclusions of the Bureau of Standards as to the results of this searching inquiry into the causes of waxing and waning of music and speech in our receiving sets:

(1) Appreciable fluctuation of signals is attributed to the changing intensity of the indirect or sky-skirting wave before it reaches the receiving antenna, and this conclusion is further supported by the observation that similar intensity variations occur at the same time in loop antennas at maximum and minimum positions as well as in combination loop and overhead antenna—barrage pick-up system—and with the coil at a minimum; (2) there is evidence of fading as the result of interference between ground and indirect waves, as shown in observations of reception from broadcasting stations in close enough proximity to produce a ground wave at the receiving point, and the intensity of signals at night is frequently less than those during the day due to the constant pressence of the ground wave; (3) signal phase displacements of less than 180 degrees between like records made at the same time on coil types of antenna in varying positions are explained by direction shifts; (4) there is an absence of proof of fluctuating signals caused by the changing heights of the ionized layer of atmosphere, although there is evidence of reflection of the indirect wave from a rising layer, inasmuch as the signal intensity in the coil antenna at a minimum position starts at zero in daylight and increases gradually during sunset; (5) considerable fading is caused by rotation of plane of polarization of radiation reflected from the upper atmosphere, especially during sunset, an explanation demanded by the 180-degree-out-of-phase relationship between records made at the same time with loop antennas in maximum and minimum positions; (6) the fading records show reflections arriving by multiple paths, indicating a periodic type of fading superposed on the main intensity variations and yet 180 degrees out of phase on simultaneous records with loop antennas in maximum and minimum positions, and this observation throws a question-mark around the calculation of the effective height of the ionized layer by means of the sine of the angle of incidence; and (7) the rapid fluctuation of signals previously observed by the Bureau of Standards during the sunset hour was noted as a common phenomenon in the reception of signals from the two broadcasting stations included in these studies.

Change of Phase Relationship

Signals from the near-by broadcasting station—for example, *WBAL* of Baltimore—showed intensity changes as much as 180 degrees out of phase on two records. This observation is applicable to fading of a few seconds duration as well as that lasting for one or two minutes. The same effect was noted by E. V. Appleton and J. A. Ratcliffe, English physicists, in simultaneous records made with a vertical single-wire antenna and with the ground wave suppressed in a single-turn coil of wire, in a maximum position. These experimenters, however, attributed the recorded differences to interference between indirect or atmospheric wave and ground wave, which was effective in the vertical antenna and eliminated from the loop. This, however, does not explain the anomaly in the Bureau of Standards fading studies, since with the ground wave effective in both antennas there is a lack of synchronism in the intensity changes of the two records.

"A possible explanation of this anomaly," suggests Mr. Parkinson of the Bureau of Standards, "may be reached by the process of elimination. Making the usual assumption that the indirect ray remains in the plane of the great circle connecting transmitter and receiver, the combined effect of ground and downcoming rays should be to cause similar changes in both

* *President, National Radio Institute.*

vertical single-wire and coil antennas. The only exception would be when the atmospheric ray arrived with zero angle of incidence, in which case only the ground ray should be effective in the vertical antenna and the intensity should remain at the daylight level, while in the coil antenna the combined effect of the two rays should continue to produce fading changes. This explanation does not fit the data; it is a change of phase relationship between the two records, not a cessation of fading in one, that is to be accounted for. Rotation of the plane of polarization of the incident ray also should produce like effects in the two receiving systems; therefore, by itself, this offers no solution.

"The answer presumably is associated, directly or indirectly, with the nearness of transmitting and receiving stations. For the distances concerned, 13 to 53 kilometers, it is perfectly possible to have direction shifts of the incident ray as great as 90 degrees, due to irregularities in the refracting or reflecting upper atmosphere. This could account for changes on the vertical antenna not occurring on the coil antenna, but not for the considerable time lag between similar changes produced in the two receiving systems. If, however, there should be a lateral direction shift combined with a rotation of the plane of polarization for the downcoming ray, we should expect just such differences in the pairs of records as appear. Suppose, for purposes of illustration, that the reflected ray is arriving with constant intensity and normally polarized. If, now, the lateral angle of arrival shifts until it becomes 90 degrees, the signal intensity in the vertical antenna will remain constant while that in the coil antenna will decrease to a minimum; in fact, to zero, if there should be no ground wave present.

Change of Phase Difference

"If, next, the plane of polarization rotates, the vertical component of the electric field will decrease until, with the electric field horizontal, the ray ceases to produce a current in the vertical antenna. Simultaneously, the component of the magnetic field in the vertical plane will have increased from zero to a maximum, thereby producing maximum current in the coil antenna for the given angle of incidence. Thus we have similar fading characteristics 180 degrees out of phase in the two antennas. If the direction of arrival of the incident ray gradually returns to the plane of the maximum coil antenna and the rotation of the plane of polarization continues, whether at regular or irregular speed, the phase difference between the two records will gradually decrease until it disappears. With the direction shifts more or less erratic we should have just the sort of changing phase relations shown on these two records; and if rotation ceases, we should again find the two records running in phase. The question whether the direction shifts necessary to this explanation actually exist requires proof. Bearings on these stations were taken at night by means of a coil antenna and revealed apparent direction shifts which were considerable. An actual test, however, can only be made with an antenna of the Adcock type (an English direction-finding system) if true directions of arrival of the reflected ray are to be found. Such a test awaits the construction of further apparatus."

Equipment Employed in Tests

The equipment employed in subjecting fading to a systematic study included at least four different arrangements of antenna systems, namely, a vertical single-wire, 15 meters high, with a 2-meter horizontal lead-in wire; a vertical coil or loop antenna having its turns of wire in a great circle plane common to transmitting and receiving points; a vertical coil antenna perpendicular to the great circle plane; and a so-called barrage antenna which is a hybrid arrangement of an indoor coil or loop antenna and an overhead aerial. The latter pick-up system consisted of a single-wire antenna so connected to the loop in the maximum position as to introduce an out-of-phase current and thereby neutralize the effect of the radio wave traveling along the ground as well as that of the vertical component of the wave skirting the upper atmosphere. The coil antennas were balanced by a center-tap arrangement, thus avoiding the undesirable "antenna effect" to any appreciable degree. The several antennas were operated at spaced intervals of from three to five meters apart.

Superheterodyne Receiver Used

The receiving sets were of the super heterodyne circuit. This double-detection system was selected for the following advantageous reasons: Beyond the first detector the frequency is constant and, therefore, the amplification is uniform irrespective of the frequency of the received signal; for any given frequency the amplification of the signal before reaching the intermediate-frequency amplifier remains constant so that a calibration showing relative sensitivities of this portion of the circuit-system to the different frequencies can be used to correct any measurements made at the output of the receiver; the fixed intermediate or beat-frequency to, say, 40 kilocycles, which for practical purposes is now the carrier, can readily be isolated from modulation effects by use of a transformer tuned to this frequency and coupled to a rectifier and indicating device; one calibration of the amplification control serves for all input frequencies, since this control affects only the amplifier and following stages, where the same beat frequency is always involved; and a calibrating unit is required only periodically for checking purposes and, therefore, one such unit may be used for several receiving sets. Thus, the size of the fading recorder is reduced to portable dimensions.

The Recorder

A conventional superheterodyne receiver is slightly modified to meet the requirements for a fading recorder. A two-electrode tube rectifier, an intermediate-frequency transformer, and a recording galvanometer constitute the additional units. These may be placed within the receiving set cabinet or may resolve into an individual piece of apparatus. The rewiring of the receiver merely involves opening up the plate-circuit of the second detector or of the last intermediate-frequency amplifier to insert lead wires to the primary winding of the extra transformer. Instead of the two-electrode tube rectifier it is feasible to use the three-electrode type, with the plate current balanced out of the indicating device. The latter arrangement makes necessary the additional units of a B battery, a balancing battery and resistances. In either arrangement, voltmeters or ammeters are necessary to keep tab on A and B batteries, in which case current supplies must be constant. A variable resistance or potential-divider, shunted across the primary winding of the first intermediate-frequency transformer, may be used as a filament control, but the adjustment of the filament current from a tube by a separate rheostat is not sufficiently stable for the delicate recording of fading.

Operation of Recorder

The fading of radio signals is converted into graphical records by the so-called Shaw manual recorder, which is driven by motors and they are automatically synchronized every second. This permits of a comparison of two records by superposition. The potentiometer method of indication is sometimes referred to as the slide-back principle. By use of an opposing current through this indicating device the deflection is reduced to an arbitrary zero at the center of the scale. If the deflection suggests that the signal has increased, the potentiometer is readjusted so as to neutralize the increased positive charge on the detector-grid by an equal negative potential. This brings the galvanometer-deflection back to its central position. If the signal fades, the negative potential on the grid is likewise reduced by the opposite potentiometer adjustment and again the pointer on the indicating instrument returns to its central location. By a manual control linked to a recording pen, writing on a moving tape, the waxing and waning of radio signals are reduced to graphic charts.

The Problems of Radio Servicing

VI. Trouble Shooting in Audio Amplifiers

By John F. Rider, Associate Editor

SHOOTING trouble in an audio amplifier is not as tedious as making an analysis of the amplifier . . . we take for granted that the trouble shooter is certain that the faults causing the defective operation are in the amplifier and the associated equipment.

The basic troubles in audio amplifier systems may be classified under two headings.

1. Operating voltages.
2. Circuit continuity.

The a-c. amplifier adds another possible trouble . . . rather, another condition which will cause trouble; coupling between stages or coupling between various parts of the system, which includes the a-c. power supply. To this must be added circuit balance in connection with the filament system. The latter is, of course, limited to a-c. circuits.

In connection with the first classification mentioned above, it is necessary that the repair man or the man who is diagnosing the receiver know the correct operating voltages, otherwise he cannot tell conditions of excessive or insufficient operating potential. This information is usually available. We must assume that whoever attempts the service work knows the correct operating potentials. In this connection, the average power amplifier, external of the commercial radio receiver installation, is designed for operation at the rated potentials. We make special reference to this fact because many radio receivers are designed for operation at potentials less than the manufacturer's rating. We hope that this point is clear. By operating potentials we mean tube operating potentials.

A-C. Systems

In view of the fact that a-c.-operated systems involve a greater number of possible troubles, we will devote more time to such systems; as a matter of fact, will concern ourselves with a-c. systems, since all defects other than those directly allied with the a-c. supply are representative of defects in battery-operated amplifiers.

Before starting upon the actual trouble shooting, we wish to make mention of one specific requirement. In order that the work proceed without hindrance due to doubt, it is necessary that a headset, known to be perfect, be at hand. This unit is to be employed in place of the convential speaker when the actual condition of the speaker at hand is unknown. The winding in the headset may be protected in the conventional manner, by means of a choke and a condenser. If the speaker at hand is known to be perfect, it is unnecessary to make use of the headset, but why delay operations because a means of noting signal output is not available. In this connection an indicating system is not as satisfactory because of the possibility of hum in the output.

As an example of a commercial installation we shall discuss the audio amplifier in the Stewart-Warner model 801A, Series B receiver, shown in Fig. 1. An analysis of the system shows that the amplifier consists of two stages and three tubes, a conventional stage and one stage of push-pull with an output transformer. Judging from the voltage indications, the first stage tube is a 226 and the output stage tubes are 171s or the equivalent. (It is best to analyize each wiring diagram before service work is attempted.) According to the wiring diagram, the filament supply for the audio tubes is independent of the supply for the radio-frequency tubes, a separate transformer winding being employed for the 226 tube in the audio amplifier. A separate winding supplies the 5 volts required for the filaments of the output tubes. All grid returns in the audio system connect to B- and ground. All C-bias voltages are secured by means of a drop across a resistance connected into the plate-filament circuit. All audio-frequency transformer cores and cases are grounded.

Reasons for Distortion

Let us assume that the radio-frequency and detector systems are perfect. The audio amplifier however, is defective. The amplifier output signal is fair but distorted . . . What now?

The fact that the signal output is fair is reasonable evidence that circuit continuity is normal.

We must consider several items. First are the tubes. Since the signal output is fair with respect to intensity, it is safe to assume that the tubes are in good condition. This conclusion is not definite, but in order to proceed it is necessary to assume certain conditions. This method of progress saves time in the long run. Second, is the condition of the speaker. Once again we shall assume that the speaker is perfect. . . . the trouble is the audio amplifier.

According to the possible reasons for distortion and normal intensity in an audio amplifier, we must consider a definite number of items, viz.:

(1) Tube overloading.
(2) Incorrect grid bias (insufficient).
(3) Excessive hum in the system.
(4) Excessive regeneration.
(5) Defect in speaker.
(6) Incorrect B-battery voltage (excessive).

A previous conclusion eliminates (5). To determine the truth of (1) we reduce the signal being fed to the amplifier and find that the distortion is still present, hence the trouble cannot be tube overloading. The amount of hum audible in the output is negligible, hence item (3) is eliminated. The remaining items are allied with operating voltages and since a test for operating voltages when carried out with a set tester will show circuit continuity, the correct test is self-evident, namely operating voltages.

The set tester is applied to the first audio tube, the 226, and plate, grid and filament voltages are found correct. These determinations do not mean that circuit continuity through the audio frequency transformer in that stage is correct, other than that the circuit is continuous. However, since the voltage measurements show values identical with or close to the values known to be the correct figures it is safe to proceed to the other tubes in the system. The set tester is now applied to the second tube in the amplifier, one of the push-pull stage tubes. The plate voltage is found to be higher than normal. The filament voltage is normal. The plate current is excessive and the grid bias is less than normal. It is evident that the trouble, whatever it may be, is in the push-pull stage. Let us analyze the conditions found in this stage.

Excessive plate potential cannot be due to increased output from the B unit, since the plate potential applied to the 226 in the audio system is normal. A decrease in voltage drop across the filter choke is likewise impossible since the drop across this choke would display an effect upon the plate voltage supplied to the 226 tube. The increase in plate current is attributable to the high plate voltage and to the low grid bias. The latter item is of importance.

According to the wiring diagram, the grid bias applied to the tubes in the push-pull stage is the voltage drop across the grid bias resistance, due to the *total* current flow (plate current) of the two output tubes. Apparently the amount of current required to produce the necessary grid bias voltage is not secured despite the fact that the plate voltage applied to the tube tested is excessive and the plate current in that stage is excessive. The logical conclusion is that the remaining push-pull tube is inoperative. With this tube in the circuit, the total plate current flow through this resistance would be greater, and because of the additional current drain, the plate voltage applied to the plate of the tube tested would approach normalcy. The next logical test is the other push-pull tube.

The set analyzer is applied. The filament voltage is normal. Plate voltage and plate current readings are absent. The condition bears out the deduction previously made in connection with the other output tube. Let us determine the cause for lack of plate voltage and plate current. The possible reasons are three in number:

(1) Open winding in output transformer.

(2) Defective tube.

(3) Poor contact or no contact between receiver tube socket and tube or tube insert.

(1A) An opening in the plate voltage feeder cable is impossible since the same cable supplies plate voltage from the B-power unit to the other output tube. Hence an open is possible in only one-half of the output transformer winding, the half connected to the plate of the tube being tested.

(2A) A defective tube may cause lack of plate current, but it should not limit the application of plate potential. This fact points towards the possible trouble mentioned in the last half of the preceding paragraph.

(3A) Poor contact between the tester insert and the receiver tube socket is possible and must be determined by means of a voltage test between the socket plate prong and the maximum B+ terminal.

To check (1A) the open in one-half of the transformer primary a battery voltmeter continuity tester is applied. The tester consists of a 22.5- or 45-volt battery block in series with a voltmeter, with satisfactory voltage range, as shown in Fig. 2. The tester is connected across the tube plate terminal on the socket and the B+ cable feeding the output transformer primary. The meter indicates zero or an open in that half of the transformer winding. The winding is shorted by means of a piece of wire and the tube inserted into the tester socket and the tester insert is plugged into the receiver tube socket. Plate voltage is observed and plate current flows through the system indicating that the tube is satisfactory.

As is evident from the above, the set analyzer as a unit will not indicate all conditions. It will, by aiding in the isolation of the trouble into a certain part of the receiver or indicating that the trouble is in one part of a tube circuit, help diagnosis, but absolute location of the trouble is beyond the device. In addition to the set analyzer, every man interested in servicing should have a continuity tester of the type shown which may be employed to indicate an open, a short, a partial short or satisfactory continuity. If the set analyzer is designed for continuity testing, all the better, but the continuity tester should be an inherent part of every service kit.

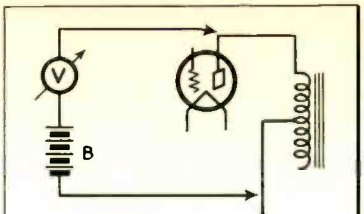


FIG. 2

Voltmeter and B battery connected in series and used as a continuity tester.

The set analyzer is of little utility when the trouble is of such nature that it concerns one resistance in parallel with the other, since a voltage test across one of the resistances will show potential even if the second resistance is open. We refer to the filament shunt resistance connected across the tube filament. A voltage test across the filament will show potential when the shunt resistance is open and the aural trouble is hum in the receiver amplifier.

Suppose that the trouble is excessive hum. If the signal output is normal, which condition is very possible, it stands to reason that circuit continuity must be satisfactory. This, of course, does not mean that all by-pass condensers are correctly connected, since an open by-pass condenser across a C-bias resistance will not interfere with the amount of amplification available in the system, but it will cause a bad hum. If, however, the output signal is weak, it is necessary to trace the items allied with low signal intensity. In all probability the reason for the low signal output is the reason for the hum. The reverse may be true, but we are interested in which came first, the chicken or the egg.

It is possible, however, to segregate the reasons for hum with the various degrees of amplifying power available in the system. For example, the design of the a-c. tube makes necessary certain filament, grid and plate voltages in order that the hum in the tube output circuit be minimum. Hence the first requirement in the quest for hum troubles is operating voltage.

Operating Voltages

It is needless to stress the methods of determining the correct operating voltages, since explicit directions accompany each testing unit sold on the market and the man who constructs his own set analyzer is undoubtedly familiar with the application of the device.

The determination of operating voltages will expedite the location of the trouble, since continuity is involved in the test, just as the open transformer primary showed up in the voltage test previously described. Here we find the difference between hum when the signal is normal and when the signal is weak. If the weak signal is due to an open circuit, the open will be isolated when the voltage test is made. This is why the possible reasons for hum, as mentioned in Part V devoted to "Troubles in Audio Amplifiers" are minimized, since an open grid circuit will make normal signal intensity impossible, yet will cause hum in many installations.

On the other hand, the application of incorrect operating voltages is possible with continuity through all circuits. If the hum is due to this condition it is necessary to determine the reason for the incorrect operating voltage. The possible reasons for incorrect operating voltages have been mentioned in a preceding chapter.

Supplementing this is lack of balance in the filament circuit. This condition cannot be determined by means of the set analyzer and an examination of the filament circuit is necessary. If the filament resistances are adjustable, the task is much simpler. . . adjustment or manipulation naturally follows. If the adjustment is of little aid, it is necessary to examine continuity of these filament shunt resistances or to seek perfect continuity between the transformer center tap and the remainder of the filament circuit.

In this connection we must again mention that accurate adjustment of the filament shunt resistance is necessary when 226s are employed. Accurate adjustment is not necessary with the 226, but operation is improved if the adjustment is accurate. Hence the second important item is filament circuit balance.

Filament Circuit Balance

Trouble shooting for hum is unfortunately more complex than we would like it to be. We make mention of the possibility of a large a-c. component in the plate voltage. This involves the design of the eliminator and the rectifying tube. The same is true of the filament voltage, if the source of filament potential is an A-eliminator. Hence in the quest of the possible reasons for hum, it is necessary to consider the operating life of the rectifying system in the B-unit and the rectifying system in the A-unit. If both of these devices have been in operation for a long period, specific attention must be paid to the possibility of worn out rectifiers. In this connection an indication will be available in the form of reduced operating potentials. A reversed line plug will frequently cause hum in a-c. installations.

Coupling between the power unit and the remainder of the receiver need not be considered in a commercial receiver, particularly if the receiver has been in operation for a period and the results have been satisfactory and physical changes have not been made. However, such trouble may develop if the ground is lacking on a core or case of one of the units in the installation. This is quite frequent and we make the third major possible reason.

Lack of Correct Grounding of Units in the Installation

With respect to coupling between the a-c. power circuit, inclusive of the filament wiring and the remainder of the receiver, particularly the audio amplifier, it is necessary to give detailed consideration to this item, when the receiver proper and the power system are assembled at home or when changes have been made in physical location.

When hunting trouble in ground circuits to locate an open ground or lack of ground and an incorrect location of a ground, it is necessary to disconnect the regular ground and trace continuity after studying the wiring diagram by disconnecting some of the grounded circuits. For example a ground in the secondary of the first audio stage of the Stewart-Warner 801 receiver shown in Fig. 1 would not be evident as long as the grid return terminated in the B — and ground. It would therefore be necessary to seek a ground in this transformer and a possible short by disconnecting the regular ground through the grid return and then test for the ground by means of the continuity tester.

A gradual increase in hum indicates the gradual failure of a unit which might cause the hum and the units within this category are

(1) The tubes in the amplifier.
(2) The rectifier in the A-eliminator
(3) The rectifier in the B-eliminator
(4) The filter condensers in the A-eliminator.

A sudden increase in hum means a sudden failure of a part. It is not characteristic of tubes to fail suddenly unless the failure of the tube is due to application of excessive potential at that moment. Such failures invariably mean injuries to the tube and discontinuation of function. Furthermore, the failure of certain units will not only cause hum, but will stop operation of the amplifier. The latter includes puncture of the grid bias resistance by-pass condensers and shorting of the grid bias resistance. Such a condition will cause lack of grid bias and if in the output stage, the amplifier will appear "dead."

When the advent of hum is sudden look for

(1) Open grounds to the set and the cores and cases
(2) Open filament shunt resistances
(3) Open filament transformer center taps
(4) Short circuits of filament shunt resistances
(5) Open by-pass condensers
(6) Open grid circuits
(7) Grounded grid circuits

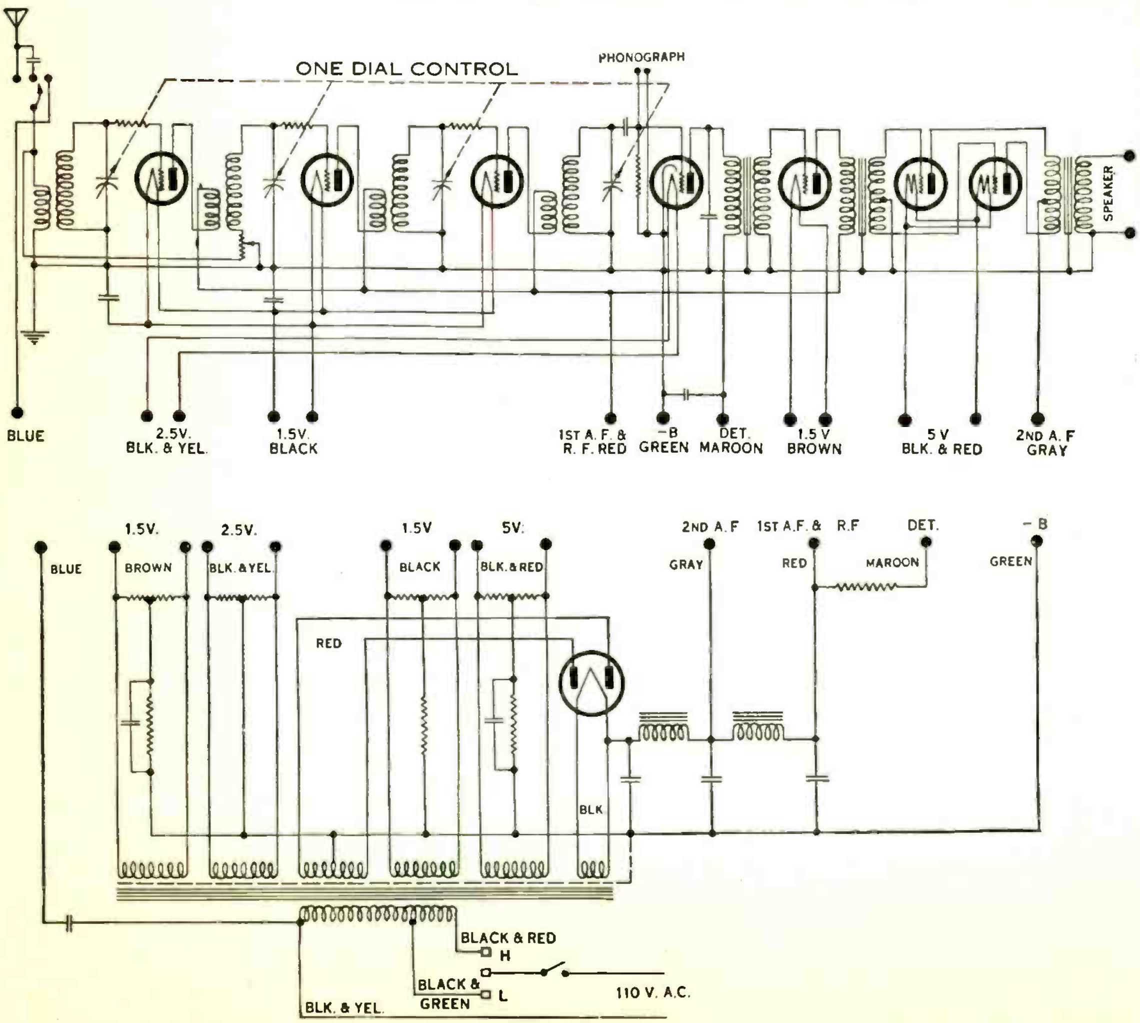
in the amplifier and

(1) Lack of ground
(2) Open filter condensers
(3) Open by-pass condensers

in the associated eliminators.

As is evident, the search for hum troubles is more difficult than for a defect in circuit continuity. The same is true of noise troubles. Once again operating voltages have very little to do with the possible troubles.

Noise is usually accompanied by normal signal intensity, hence circuit continuity may be considered perfect. With the exception of noise due to in-



Schematic diagram of the Stewart-Warner Model 801-A, Series B, a-c. receiver.

duction from external sources and noise passed to the receiver from the A- and B-eliminators noise may be classified under two headings

(1) Poor contacts or all kinds

(2) Defective windings or resistances caused by passage of excessive current flow.

A visual examination is necessary in the first case and replacement is necessary in the second. Replacement is recommended because it is much faster than a test of the device to determine the exact location of the defect in the unit. With respect to isolation of the fault, the method of procedure applies to the hum trouble and to noise trouble. The most rapid and effective method of isolating the fault to at least a part of the amplifier, is to remove one tube at a time, thus removing a stage at a time. It is, of course, necessary to start with the tube furthest from the output stage.

If the hum is present when all but the output tubes have been removed it is safe to assume that the hum does not originate in the stages preceding the output stage. It is possible that the trouble is due to an open filament shunt resistance, but this consideration applies only when all the tubes in the amplifier are fed from the same transformer winding. This is seldom the case.

It is possible that the hum is to be found in all stages, hence is present when all but the output tubes are removed. In that case, the hum is undoubtedly due to an excessive a-c. component in the plate voltage. It is, however, necessary to add the possibility of some condition in the output stage such as a defect in the grid bias system. Also excessive hum in the filament voltage supply if an A-eliminator is employed and induction between the filament circuit and the remainder of the amplifier, if the filament supply is a-c.

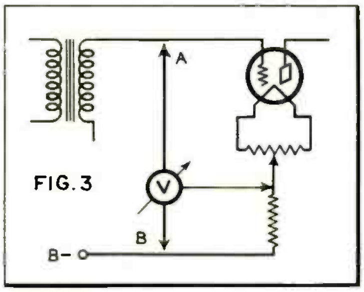
If the hum disappears when one of the intermediate audio amplifying tubes is removed, the origin of the hum is in that stage or in some part of the amplifier preceding that stage and check up of the possible reasons mentioned, is in order.

The same method of progression is applicable when searching for the causes for noise. Remove one tube at a time. . . . then examine the various elements in the respective circuits.

Low Volume and Poor Amplification

Suppose that the trouble is low volume. . . poor amplification. According to the list of possible reasons for this condition, we have many items to consider. But the problem is not as difficult as it appears upon the surface because one test, say the operating voltage test, will clear up or eliminate many of the items mentioned in the list of possible troubles. For example, if the filament voltage is normal, it eliminates all the items connected with the filament voltage. If the plate voltage is very low, it eliminates all factors not associated with plate voltage. In connection with voltage measurements, we suggest that when making grid bias voltage tests, the unit in the grid circuit be included. In other words, the grid be the negative terminal for the voltmeter and the positive terminal be the cathode or the filament center tap, as the case may be. This method of measurement will show continuity through the unit in the grid circuit. This test should supplement the regular grid voltage test, the latter showing the correct voltage in the circuit. This is illustrated in Fig. 3. Test A is across the entire circuit and test B across the unit producing the voltage drop. This circuit shows a resistance between the filament center tap and the B minus.

The application of the set analyzer to determine operating voltages and respective values of plate current will afford an idea of the condition of the vacuum tubes in the system, since a deactivated tube will have no or very



Manner of making grid voltage test.

little effect upon the plate voltage measurement, but the plate current consumption will be less than normal. The other significant data available with the plate current measurement have been enumerated and the reader is referred to that chapter on voltages.

We can, therefore, decide that the first test is that for operating voltages. Now, in connection with the voltage test, it is necessary to remember that a deactivated tube when used in a system, such as the first stage in the Stewart-Warner receiver shown in Fig. 1, will show normal or slightly higher than normal plate potential, less than normal plate current and less than normal grid bias, since the grid bias is a function of the magnitude of plate current. This condition must be differentiated from a condition resulting in a similar effect, when the plate voltage is less than normal or when the grid bias resistance is less than normal.

With but one exception, the operating voltage test accompanied by the plate current test will show the location of the defect, at least as far as a part of the complete circuit is concerned. The only exception is a short across the primary or plate coupling unit or a short across the secondary or grid coupling unit. Short circuits will permit d-c. voltage observations. Hence after all voltage tests have been made, and after tube tests show satisfactory condition, tests for short circuits in the units mentioned are necessary. However, the method of measurement shown above, where the grid bias voltage is measured between the grid and the cathode or filament center tap will show normal continuity through the secondary of an audio transformer, a grid choke or the grid leak, by reduced grid voltage due to the current consumption of the meter used. The reduced voltage indication does not mean that the grid voltage is likewise reduced because of the coupling unit in the grid circuit. The voltage drop is due to the current flow in the circuit when the meter is connected into the circuit. The normal circuit arrangement when the meter is omitted and and the grid bias is applied means lack of current, hence lack of voltage drop (d-c.) across the grid.

In the plate circuit we check the measured value against the rated value. We refer to the plate voltage at the tube element. Transformers are more apt to burn out than short and a "blown" primary winding will show an open in the plate circuit. To check a punctured by-pass condenser across the plate winding it is necessary to check the voltage drop across the plate coupling unit, with the condenser "in" and "out".

Dead Amplifiers

"Dead" amplifiers are due to numerous reasons and a rapid test is the removal and replacement of the tubes. Starting with the tube or tubes in the output stage a click should be heard in the speaker if the operating potentials are applied and circuit continuity is normal in the output stage. If the click is lacking, the fault may be located in the output stage in the form of an open, or the plate potential circuit is open. It is understood of course that the filament circuit is normal and that the tubes are lighted. If the click is heard, the tube constituting the amplifying stage nearest the output stage is removed and replaced. If the click is audible, we progress to the subsequent tube moving backwards. If, however, the click is not audible, investigation of the operating potentials is in order. The same is true of the continuity of the coupling unit between this tube and the output stage.

An open primary or plate circuit will cause a "dead" amplifier. A deactivated tube will cause a similar condition. Poor contact between the tube and the socket will cause a similar condition. The status of an amplifier may be determined by tapping the detector tube or the first audio stage tube with the finger nail or a light solid object. If the amplifier is normal a ringing sound will be heard.

For accurate work, operating voltage tests must be made, but if the set analyzer is not available, the above method of progress supplemented by a continuity tester will permit diagnosis.

(To be continued)

Radio and the Talking Motion Picture Field

The Opening of a New and Profitable Field for the Radio Technician

*By F. A. Jewell**

IT is an ill wind that does not blow some good to someone, as today one of Radio's offsprings, "The Sound and Talking Picture," is gathering so much momentum that it looks as if it might even dwarf its parent in magnitude from a commercial point of view.

We all know that it was through the developments of Radio, such as the microphone, the vacuum-tube amplifier and loudspeaker, that talking and sound pictures are commercially possible. This is evident because Edison failed at this very thing over twenty-five years ago. The reason was that he had only the unperfected, tinny-sounding phonograph for the reproduction of sound, which the public refused to accept as a medium of entertainment. Therefore, synchronized sound pictures lay dormant until electrical amplification and reproduction had advanced to a plane where they would reproduce sound and speech with a degree of fidelity that was acceptable.

Radio and sound pictures are so closely allied that it is hard to find the line that will distinguish one from the other, as practically all the fundamental principles of Radio are applied to this new form of entertainment.

A New Field Opened

Naturally this opens up a field for the Radio Technician and Serviceman and gives him the opportunity to utilize the knowledge that he acquired in Radio at a compensation which is much greater than the same work would command in the radio field. The reason for this is that this new art sprang up practically over night and nothing like a sufficient number of trained men could be found to fill the positions that were thrown open.

To substantiate this, here are a few approximate figures that may be interesting. First, we will take the approximate number of theatres in the United States and Canada, which is 20,000, that employed about 50,000 operators for the projection of motion pictures before the addition of sound. This will give us the basis for forming some conclusions as to the possibilities in this field.

It is estimated that less than 5% of these men are familiar with electrical acoustics and when a theatre is wired for sound, the number of operators has to be doubled, as it requires two men to a shift to operate sound pictures.

Before going on with this resume of the possibilities for the Radio Technician and Serviceman, it might be well to note here that it is not uncommon to pay as much as five hundred dollars to make an installation of the sound apparatus in a theatre booth; and to be frank about it, not much more engineering skill is needed than is required to install a high-grade radio receiver.

*General Manager, Projectionist Sound Institute.

Also, salaries of $5,000 to $10,000 yearly are ordinary for high-grade sound engineers, who maintain and service sound apparatus for chain theatres. Numbers of positions of this character are open now, and it is hard to find a sufficient number of men who are qualified to fill these positions.

But to go on with the figures, less than one-half of the theatres in this country are now equipped with sound apparatus and in less than two years, this new industry has absorbed nearly twenty thousand men as sound projectionists from some other field and in less than two more years from now, twenty thousand to thirty thousand more men will have to be found. These positions pay good salaries and are more of an engineer's job than that of just an ordinary workman.

The importance of highly-trained men to fill these positions is very apparent when you stop to consider the responsibility of keeping a show going under all circumstances, as the man in the booth holds it in his power either to make or break a theatre.

Take, for instance, a Saturday night, when the theatre is packed to the roof and the audience is held in a grip of intense interest, listening fervently to every word of the star in the big scene of the picture. Suppose a grid circuit in the main amplifier were to open or any one of a hundred other things develop, that are common with amplifiers and its associated apparatus. You know the answer. This goes to show the necessity of highly-trained men and the most logical men to fill these positions are those who have had experience in the radio field; as practically all the knowledge and experience acquired in radio is adaptable to sound-picture work.

Of course, additional knowledge and experience will have to be acquired, but it is much easier to acquire this additional knowledge and experience than it is to train a man from the ground up.

Servicing Theatres

Another point of advantage to the Radio Technician, who is operating a business which is servicing radios, is that he can take over the servicing of his local theatres, thereby making more money for himself and at the same time enabling the theatre to make a considerable saving, as the theatres would not have to keep a high-salaried engineer on their payroll at all times for emergencies.

Service work of this kind is capable of bringing in a substantial revenue. The author knows of an incident where the Serviceman received $125 for less than five hours work repairing an amplifier that was damaged in a thunder storm by a surge of lightning that came in on the a-c. lines, blowing the primary of the a-c. transformer. There is also a number of similar cases and if a few theatres can be taken over by the technician, he will find that he will have plenty to do, as this new art is a long way from being fool-proof. Besides, new improvements are being made almost daily and as these come out, advantage can be taken of them, eliminating the necessity of junking the equipment by its becoming obsolete, which is a costly procedure when you consider that sound equipment costs from $5,000 to $25,000 per installation.

When you stop to think about the magnitude of this new art which is an offspring of Radio, and its possibilities, it becomes staggering to the imagination, but the one thing of which you can be sure, is that the opportunity has presented itself and it is up to the individual himself, to take advantage of it.

RADIO SALES FOR SECOND QUARTER

RADIO sales totaling $91,000,000 were indicated for the months of April, May and June, 1929, according to figures compiled for the Radio Division of the National Electrical Manufacturers Association and released by the Department of Commerce.

In the July 1 tabulation of stocks in hand of radio dealers, from which this total was estimated, the Department queried 38,766 radio dealers, receiving replies from 6,031, or 15.6 per cent, whose business for the second quarter was $14,172,740. This compares with sales of $25,539,235, representing a 19.4 per cent return for the preceding quarter.

Estimates of total radio sales for the so-called radio year from June 30, 1928 to June 30, 1929, place the figure at approximately $510,000,000. The average total volume of business for each dealer during this radio year was $14,528. More than 3,108,000 sets—both a-c. and battery—were sold during the same period. Only 13 per cent of this total were battery operated sets.

ALL SET FOR THE RADIO WORLD'S FAIR

NOT less than 550,000 people are expected to attend this year's Sixth Annual Radio World's Fair in New York City and the Eighth Annual Chicago Radio Show. An augmented national interest in radio, which brought an industry attendance in excess of 31,000 to the June Trade Show, is responsible for the prediction that all attendance records will be broken.

When the doors of Madison Square Garden swing open on the Radio World's Fair on Monday afternoon, September 23, spectators will be privileged to inspect an exhibit of radio receivers, apparatus and equipment without parallel anywhere in the world. In dollars and cents its value will exceed a million dollars. But that million dollars of radio this year represents far more than a million dollars on last year's basis. For it will be quite apparent to the visitors that the radio manufacturers of the country are offering the biggest dollars worth of merchandise in history.

With the federal government, large and small employers, all announcing a full dinner pail and plenty of money to spend, it looks as though a good radio season is a fact and not mere speculation.

Trade Show hours, during which the public is not admitted, provide jobbers, dealers and manufacturers, an opportunity to inspect lines of merchandise and transact business unhurried and unhampered. The volume of business booked at the New York and Chicago Shows runs into the millions, and the amount has grown steadily since the inception of the shows in the early days of radio.

Exact trade show hours as announced by U. J. Herrmann, Director General, and G. Clayton Irwin, Jr., General Manager, are 11.00 A.M. to 1.00 P.M. each day, beginning Tuesday, September 24. No trade show hours are set for Monday, but the doors open to all at two o'clock.

Dealers will save time and avoid the annoyance of securing admittance credentials during the trade show hours by securing them in advance by writing Mr. Irwin, 1904 Times Building, New York City. Simply make the request on your business stationery, and the necessary credentials will be forthcoming.

For the first time in the history of the New York and Chicago shows there will be a parts and raw materials display of such size and importance that the show visitor cannot help being impressed with the quality of the materials and parts which enter into set construction.

More than fifty such manufacturers are among the exhibitors. They have planned displays comparable to those of the manufacturers who make the sets into which their products become a part. The Parts and Raw Materials Directory to be issued by the Radio World's Fair will provide executives, radio engineers, and purchasing agents a means of quick access to these exhibiting essential manufacturers.

In order to facilitate the movement of radio show crowds at Madison Square Garden, an entirely new entrance on the 49th Street side has been constructed. A hundred thousand dollars has also been spent by the Garden Management for an entirely new ventilating system which its makers say will keep the air in perfect condition.

The vast amphitheatre will be decorated in Goldenrod and a beautiful shade of green. Lighting effects throughout will be especially pleasing on account of the hundreds of new hand-made shades which the Radio Show Management will install.

The quality of the broadcast programs which will be put on the air over stations associated with the various networks of the National Broadcasting Company and the Columbia Broadcasting System, as well as independent New York City stations, will command the interested attention of radio fans everywhere.

From the Crystal Studio, which each year has to be made larger to accommodate the ever-increasing personnel of broadcasting orchestras, will be produced nationally known broadcast programs, as well as special features.

Adjacent to the studio will be found the "Radio Pageant of Progress," which depicts radio from its inception, brings it on up to the present and carries it forward into the future. It is being completed at this writing under the direction of George Clark, Show Manager of the Radio Corporation of America, which provided funds for Mr. Clark to make the "Radio Pageant of Progress" a credit to the industry.

No possible source has been neglected in the search for early and authentic apparatus. With the assistance which other companies have given the Radio Corporation of America, it is quite evident that this year's Radio World's Fair will house one of the most inspiring exhibits it has been the privilege of any industry to offer. The Pageant represents an expenditure of $50,000.00.

The interest which the radio industry has in its little sister, Miss Television, suggested the advisability of a display to reveal the progress that had been made during the year. Accordingly Television will be a part of the feature attractions of both the New York and Chicago shows.

The Television exhibit will be provided by the Radio Corporation of America, and is said to show decided improvements over television of a year ago. During the course of the public lectures on Television, the audience will be told that they can see for themselves that Television is not "just around the corner"—that much work must be done before it is ready to step out of the laboratory.

Prior to the show, search is being conducted for the Most Beautiful Radio Artist in America. The search has the cooperation of the National Association of Broadcasters. When found, the radio beauty will be brought to the Radio World's Fair as the guest of the management.

DILLON ASST. GEN. MANAGER OF AMRAD

Harry J. Dillon, formerly Production Manager of the Amrad Corporation, Medford Hillside, Mass. has been appointed Assistant General Manager of the Corporation.

HARRY J. DILLON

INCA MANUFACTURING CO.

George A. Jacobs, founder and former president of the Dudlo Manufacturing Company, and his associates have organized the Inca Manufacturing Corporation at Fort Wayne, Indiana, to manufacture copper wire products for the electric, radio, automotive and kindred industries. Offices have already been established and construction of a mammoth plant is well under way on the eleven-acre factory site purchased. It is expected to have the plant in operation with actual production within the next few weeks.

Officers of the Inca Manufacturing Corporation are: George A. Jacobs, president; Wendell C. Glass, vice-president; George W. W. Spindler, secretary-treasurer and S. A. Jacobs, in charge of sales.

The home office of the Inca Manufacturing Corporation and the plant, now under construction, is located at Fort Wayne. It is planned to establish later another large factory unit at Los Angeles, California.

The first unit of the factory, nearing completion at the present time, covers an area 200 by 300 feet and will afford immediate employment for 500 workers. The company will manufacture all the copper wire products and specialties essential for the needs of the progressive development of the automotive, electrical and radio industries, specializing in magnet wire and windings for electrical purposes.

FRTA SPONSERS NATIONAL RADIO WEEK

The Federated Radio Trade Association has officially set aside September 28th to be known as National Radio Week. This date coincides with the Radio World's Fair in New York City and it is felt that through cooperation with all associations scattered throughout the country that increased business may result and Radio given an added impetus for the coming fall.

ADDITIONAL FINANCING FOR HYVAC

Smidth & Efinger, New York, will offer shortly 38,000 shares of no par common stock of the Hyvac Radio Tube Co., Inc., Newark, N. J., it was reported. The outstanding capitalization upon completion of the proposed financing will consist solely of 125,000 common shares.

The Hyvac company recently moved into its newly acquired plant at 85 Shipman Street, Newark. The company is headed by George D. Duff as president; Gustav Binder, vice-president and treasurer, and J. Franklin Dorsey, secretary.

"SPEED" PRODUCTION UP

Announcement has been made from the headquarters of the Cable Radio Tube Corporation at 84-90 N. Ninth St., Brooklyn, that new equipment and new plant capacity will soon give Cable daily production of 25,000 tubes; 15,000 will be types for electric sets and 10,000 will be battery types.

In addition to the main factory a plant has been acquired to produce parts and tools needed for the manufacture of highest quality tubes.

Altogether 47,000 square feet of space are now devoted to the manufacture of Speed tubes.

GILBY EXPANDS

Investigation of the activity at 150 Riverside Avenue, Newark, N. J., disclosed the interesting fact that the Gilby Wire Company is constructing additional factory space to the tune of 30,000 sq. ft. thereby increasing its producting power 100%.

The new buildings will be ready soon and will be the last word in modern wire drawing efficiency. A vast amount of new machinery will be necessary to put the new plant in operation, in order to meet the volume of increased business.

A line of new materials have been added to their resistance wire products, namely: carbonized nickel, rolled selvedged mesh, and seamless nickel tubing, to serve the radio trade.

The engineering department has been enlarged with additional personnel in order to co-operate with the demands of new developments in the industry.

DILCO IN TUBE FIELD

The Dilco Radio Corporation of Harrison, N. J. announce that they will introduce to the trade at the Radio World's Fair in Madison Square Garden, a complete line of precision built vacuum tubes. The name Dilco is one well known in the electrical industry, and radio dealers handling electrical supplies will immediately recognize it as the same as the Dilco incandescent lamps for automobiles.

Dilco is housed in a new factory at Second and Jersey streets, Harrison, N. J. Every tool and machine in the plant is brand new. The accepted principles of mass production, with the raw materials moving along a straight line from machine to machine and worker to worker until complete are rigidly observed in the Dilco factory. The capacity of the Dilco plant will be 20,000 tubes a day. Operations are now running at the rate of slightly more than 4,000 tubes a day with peak production schedules for the month of October.

The officers of the Dilco Radio Corporation are: M. F. Desmond, president; G. M. Desmond, vice-president; W. J. Desmond, secretary-treasurer acting as general manager; L. G. Flynt, director of sales and advertising; Benjamin L. Frotton, Works manager; Chas. M. Mandra, plant engineer.

NEW TEMPLE PLANT

The Temple Corporation has just signed contracts for the construction of a huge new plant in the clearing industrial district of Chicago, that will provide sufficient space to permit the manufacture of 250,000 radio receivers per year.

Construction of the new plant, which will be a model of architectural skill both in exterior beauty and interior efficiency, will start at once. The plant and its administration building will be built of stone and reenforced concrete and will cost more than $500,000.

The new Temple factory will provide over 300,000 square feet of "all daylight" floor space, and sufficient ground also will be provided for further expansion at a later date.

This is the fifth plant that the Temple Corporation has been forced to provide in 30 months due to the urgent demand for increased production.

The new plant will be the first permanent home of the Temple Corporation and will be ready for occupancy on or about December 1st of this year, according to Alfred Marhcev, president and general manager.

All offices, as well as research laboratories, will be located in the administration building, which will be a two-story structure with a tower in the center, built on the order of a Temple. A giant beacon that will cast its friendly glow over the nearby municipal airport will be placed on top of the tower. The tower itself will be faced by graceful colonnades and will rise three stories above the administration buildings.

GULBRANSEN IN PRODUCTION

The Gulbransen Company of Chicago whose advent into the radio industry was recently made known, has now started operations on a definite production schedule calling for 1,000 sets a day by Oct. 1, according to an announcement by John S. Gorman, vice president of the company.

Two models of screen-grid sets, one a highboy cabinet, the other a lowboy or console cabinet, both of which have the radio-phonograph switch feature, are now being produced.

RECAPITALIZATION OF ACOUSTIC PRODUCTS

At a stockholders' meeting of the Acoustic Products Company, which owns the Sonora Phonograph Company, Inc., held on Wednesday, August 21, holders of a large majority of common stock and of considerably over 75 per cent of preferred stock approved the plan of recapitalization. Under this plan the holders of preferred stock are to exchange their stock for common stock on the basis of 8 shares of common for each of preferred, with an additional 2 shares of common in consideration of waiver of dividend arrears on each share of preferred, making in effect a 10 for 1 exchange.

To provide for this exchange and for working capital, the stockholders approved an increase of authorized common stock to 1,500,000 shares.

It is expected that stockholders will soon be offered the right to subscribe to 300,000 shares of the common stock, thus increased.

SYLVANIA OPENS SCREEN-GRID PLANT

Sylvania plant No. 3, now in full production exclusively on screen-grid tubes, is a further tribute to the extension enterprise of the Sylvania Products Company.

Three months ago the newest addition to the Production Department was merely a factory building at Lock Haven, Pennsylvania. Today it is a vital factor of Sylvania's manufacturing facilities, producing ten thousand screen-grid tubes a day.

The new plant—factory No. 3—is two stories high and has nearly twenty thousand square feet to the floor, high ceilings, sturdy construction, splendid lighting, and the very newest of test and production equipment.

Sidings connecting with two railroads are on the premises and trucking facilities are ideal, since the building is directly on the finest highway system of Pennsylvania.

MARVIN MOBILIZES ENGINEERING STAFF

The recent merger of six prominent independent vacuum tube manufacturers into a single organization known as the Marvin Radio Tube Corporation, with main plants at Irvington, N. J., and Chicago, Ill., not only represents a concentration of production facilities but a notable mobilization of engineering talent, as well.

The Chief Engineer of the Marvin Radio Tube Corporation is Eugene Bruyning, a recognized authority on vacuum tube design, production and application. Mr. Bruyning is a graduate of the Delft Polytechnique Institute (E. E.), and of Leyden University (B. S.), in Holland. In 1919-20 he served the Royal Dutch Shell Company as engineer. In 1921-24 he was tube engineer for the Brytone Radio Laboratory. In 1924-26 he was engineer for the Herald Electric Company. From 1926 till 1928 he was Professor in Charge of Radio, New York University, and a member of the Popular Science Institute of Standards. Today, Mr. Bruyning is Chief Engineer of the Marvin organization, and heads the research and test laboratory which guides the Marvin technique and checks up on the tube.

John J. Higgins, a Marvin engineer, started in the incandescent lamp field in 1907 and perfected the rotary oil pump now employed wherever lamps or radio tubes are manufactured. Mr. Higgins went to Westinghouse for the further development of lamp equipment, and during the last five years with that organization he served as Chairman of the Engineering Equipment Committee. This background provides Mr. Higgins with an intimate knowledge of every lamp and tube laboratory and factory in this country.

Previous to coming with Marvin, Mr. Higgins was with the Arcturus Radio Corporation, in charge of tube construction, manufacturing processes and equipment.

Mr. Higgins brings with him to the company over 100 patents on radio tube and incandescent lamp construction and equipment. He is personally responsible for the New Marvin MY-224 or a-c. screen-grid tube, which has several outstanding advantages over the usual 224 type.

Still another Marvin engineer is H. T. Wakefield, who started with the General Electric Company and left to go with the Independent Lamp & Wire Co. of Weehawken, N. J. General Electric later purchased this plant and made Mr. Wakefield factory manager. Later, Mr. Wakefield left to enter the radio tube business for himself, as owner of the Wakefield Mfg. Co., and Sunlight Lamp Company, where he instituted many improved production methods, especially in the designing of automatic machinery to produce radio tubes.

Raymond Pitchell, another Marvin engineer, started at an early age with the Westinghouse Lamp Co. He became a partner in the American Glass Bulb Co., which later sold to the General Electric Co. He started in the radio tube business in 1925, and is responsible for the development of the Marvin MY-227.

William F. Tait, of the Marvin engineering forces, was employed by the General Electric and Westinghouse lamp companies for over 13 years. He resigned from Westinghouse to engage in the manufacture of incandescent lamps, and after five years of successful experience he transferred his activities to radio tubes.

C. R. Hollinger, Marvin engineer, served as an engineer for the Independent Lamp & Wire Co. Later, he went with Westinghouse as assistant to Charles Elsler, Chief Engineer in the designing of tube equipment. Mr. Hollinger has been most successful in designing automatic tube equipment for both domestic and export uses.

COLORED PIPES IN TRIAD FACTORY

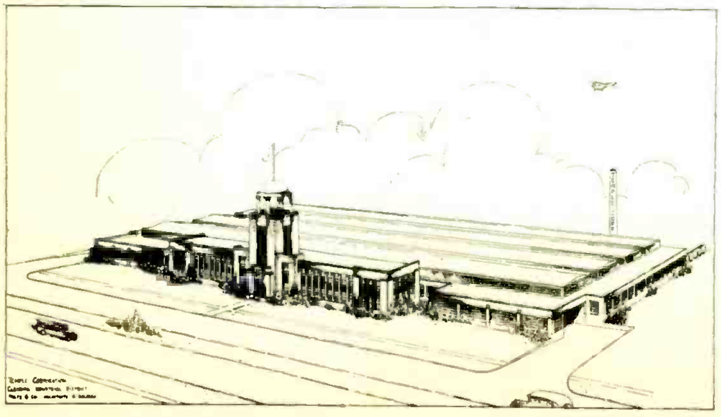
The coding in colors of pipes and conduits in the Triad Tube factory at Pawtucket, R. I., has reduced the time hunting trouble to a minimum. With the maze of piping used in a modern tube factory, the added cost of installation to paint the pipes and electrical conduits has more than paid for itself.

In the Triad factory there are pipes throughout the building which carry water, compressed air, gas and vacuum lines to the various machines. Various voltages are used throughout the plant for lighting and for use on motors, welders, and bombarding machines.

Air compressors, gas pumps, water supply and vacuum pumps are located in the power house with the special generating equipment for the entire factory.

Vacuum lines are painted blue, gas pipes are red, water lines are green and the compressed air lines are yellow throughout the plant. All pipes are slung from the ceiling, which is painted white, and connection is made to the machines through the floor above.

Lighting conduits are painted gray while the conduit which feeds the low voltage welding machines on the assembly tables can be picked out by the red couplings and junction boxes. The 220-volt supply to the bombarding machines is painted black.



Architect's drawing of the new Temple plant, in Chicago.

NEW NATIONAL-HARRIS PLANT

Advance of the radio industry in Newark has caused a marked expansion of the National-Harris Wire Company. That concern, to meet heavy demands by radio receiving set manufacturers for wire, nickel ribbon and nickel tubing, has taken over additional buildings of the former Heller Brothers File Works at Verona and Mt. Prospect avenues, the major buildings of which the wire company acquired a year ago.

Joseph W. O'Loughlin, treasurer of the firm, in announcing the expansion of its plant, also announced that his company had purchased the Connecticut Wire Company of Waterbury, Conn., and had begun moving that establishment's equipment in its entirety to Newark.

The National-Harris Wire Company two years ago purchased and amalgamated three wire plants, the National Alloyed Metals Company of Providence, R. I.; the Murray-Harris Wire Company and the Harris Alloys, Inc., of Newark. Besides Mr. O'Loughlin, the company's officers are Francis R., Francis A., Frederick T. and Albert E. Harris, president, first and second vice-presidents and secretary, respectively.

New additional plants of the National-Harris Wire Co., In Newark, N. J.

WIRE EXHIBIT OF EXCEPTIONAL INTEREST

While radio fans are fairly familiar with the mechanics of the set itself, there are many construction steps back of the modern receiver that have never been unfolded for them.

The Dudlo Company will stage a carefully planned exhibit at the Radio World's Fair that will lift the veil on some of the most delicate and interesting processes in the entire electrical field.

Each step in the drawing of a hair-like copper wire will be shown so the visitor can see the successive passage of the raw copper bar through a full set of steel and diamond dies.

Insulation of many types will be on display and their individual characteristics and application illustrated and displayed.

Coils, large and small, for every purpose will be on hand, many of them cut open so the methods of winding and layer insulation will be shown.

The educational character of the exhibit was decided upon after conferring with several leading set manufacturers who felt the public would be glad of an opportunity to see the intricacies back of the finished radio with which all are so familiar.

The completeness of the display can be sensed from the fact that well over a hundred different items will be shown.

TEN-FOLD INCREASE IN METALLIZED FILAMENT SINCE 1927

During 1927, approximately 700,000 feet, or 133 miles, of metallized resistance filament was employed by licensees of the International Resistance Company, in the United States and Europe, according to the statement of Francis R. Ehle, its President. This quantity of metallized filament was quite aside from the amount used by the company itself in the production of its own Durham resistors.

"During 1929," states Mr. Ehle, "we anticipate an actual sale to our licensees in the United States, England and Germany, of some 2,500,000 feet, or about 470 miles, of metallized filament. Our own Durham metallized resistor requirements will call for something like 1,000,000 feet of filament, or sufficient to make up some 5,000,000 resistors.

DUBILIER ANNOUNCES NEW DISTRIBUTOR PROPOSITION

An original credit system for distributors has just been evolved by the Dubilier Condenser Corporation of New York City. This system regulates credit on a graduated scale according to sales volume attained for the year. The following schedule shows how this credit system will be regulated.

Attained Sales Volume	*Rate of Credit*
$ 750.00 or more	2½ %
$1500.00 or more	5 %
$3000.00 or more	7½ %
$7500.00 or more	10 %

The attained sales volume, upon which the credit is applied, will be derived from the Dubilier record of payment received from an organization, for goods sold through that organization. The company's interpretation of this rule will govern, and any organization having several concerns which ought legitimately to be grouped for a single figure of attained sales volume, should advise of this fact, in order that the several concerns may be considered as a unit.

The credit as applied here will be for merchandise and not for cash; it will be credited on the books and will be available to cover payment for additional quantities of regular products at regular prices ordered during the ensuing fiscal year. The Dubilier Condenser Corporation believes that this system will be more satisfactory and fair to the distributor, than applying a hard and fast rule for large and small accounts alike.

LUKKO CO. OPEN NEW OFFICES

The Lukko Company, Chicago distributors for the Colin B. Kennedy Corporation, will open their main office and show room at 900-910 West Jackson Blvd., Chicago, Ill. The north side branch will be maintained at 5024 Irving Park Blvd.

TUBE PARTS COMPANIES MERGE

Announcement was made on September 10th of the merger of the Schultz Machine Company of Newark and the Vacuum Tube Products Company of Hoboken. The companies will operate in the future as the Radio Products Corporation, of Newark and Hoboken. Frank Schultz has been elected president; D. R. Donovan, vice-president; L. L. Stager, secretary; J. J. Glassberg, treasurer; and W. H. MacDonald, sales manager.

Both companies in the past were well-known manufacturers of radio tube parts and on their books are represented the leading tube manufacturers of the country. The linking up of these two quality manufacturers will permit a greater scope of operations, according to Mr. Schultz.

The Radio Products Corporation will manufacture precision built radio tube parts such as shields, collars, getter cups and plates; filaments, electrode leads, and aming other products French burners and high testing vacuum gauges. The production of the combined units is estimated by Mr. Schultp as being in excess of 2,000,000 radio tubes a day.

Among tre well-known tube manufacturers who use the products of this company are: Arcturus Radio Tube Co., Cable Radio Tube Corp., Champion Radio Works, DeForest Radio Co., Gold Seal Electrical Co., Grigsby-Grunow Co., Hy-Grade Lamp Co., Ken-Rad Corp., Marvin Radio Tube Corp., Matchless Electric Co., Northern Mfg. Co., Perryman Elec. Co., Sonatron Tube Co., Sylvania Products Co. and Triad Mfg. Co.

NEW BOOKLET ON PUMPS

High Vacuum Engineering is the title of a new 24 page booklet on the practice of high vacuum engineering as applied to the manufacture of radio tubes, photoelectric cells, and all similar products requiring a high degree of exhaustion. It has been compiled for the use of plant engineers by the manufacturers of Cenco-Hybac and Megavac high vacuum pumps. This booklet will be mailed free on request addressed to the General Scientific Co., 460 E. Ohio St., Chicago, Ill.

PAMPHLET ON SUPER-TONATROL

Electrad, Inc., manufacturers of the Super-Tonatrol, a new type variable high resistance, have put out a very interesting technical pamphlet covering the uses to which the device may be applied.

The pamphlet includes schematic diagrams indicating the positions in the circuit taken by the Super-Tonatrol when used as a volume control, bias control for screen-grid tubes, plate voltage control, as a volume control for an electric phonograph, and as a fader.

A copy of the pamphlet may be obtained, free, by addressing Electrad, Inc., 175 Varick St., New York City.

NEW MERCHANDISING AND OTHER SERVICES ORDERED BY RMA LEADERS

SEVERAL new services to radio manufacturers and expansion of other services to RMA members and the industry generally, and also the radio public, have been ordered by the Board of Directors of the Radio Manufacturers Association. Meeting August 8th at the Clifton Hotel, Niagara Falls, Ontario, and outlining the Association's expanded program for its new fiscal year, the RMA Board provided for new and comprehensive merchandising service, and enlargement of its engineering traffic, legislative information, patent and other services.

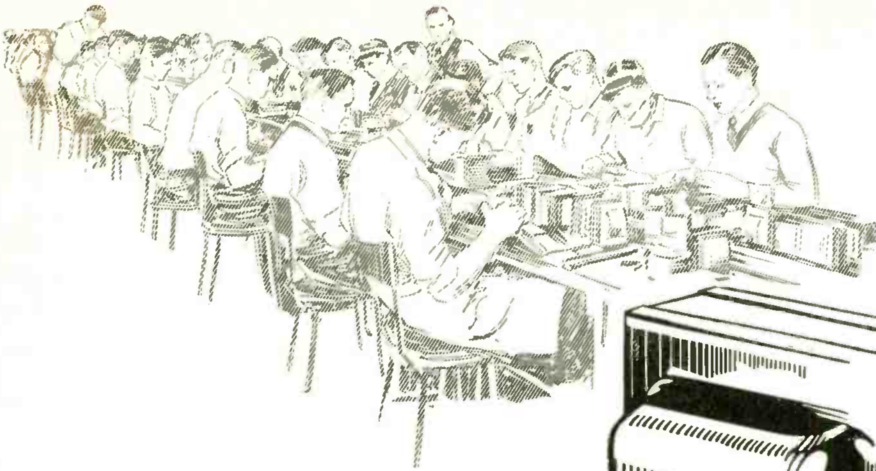
Mr. H. B. Richmond of Cambridge, Mass., President of the RMA, presided at the Niagara Falls meeting, which was attended by all but four Directors who are in Europe or on the Pacific Coast. Several other radio industry figures also were present.

The Merchandising Department, in charge of Major H. H. Frost of New York, Chairman of the RMA Merchandising Committee, and Mr. William Alley, Merchandising Manager, was authorized by the Board of Directors to launch at once the new merchandising service for manufacturers, and approved an extensive program recommended by the Committee. Efforts will be made immediately to guard against any possible prospect of overproduction of radio products, particularly during the next few months. Strictly within the limitations and in observance of the law, the Merchandising Department will recommend to manufacturers that their production schedules be carefully checked against the present and prospective future orders, to guard against undue expansion.

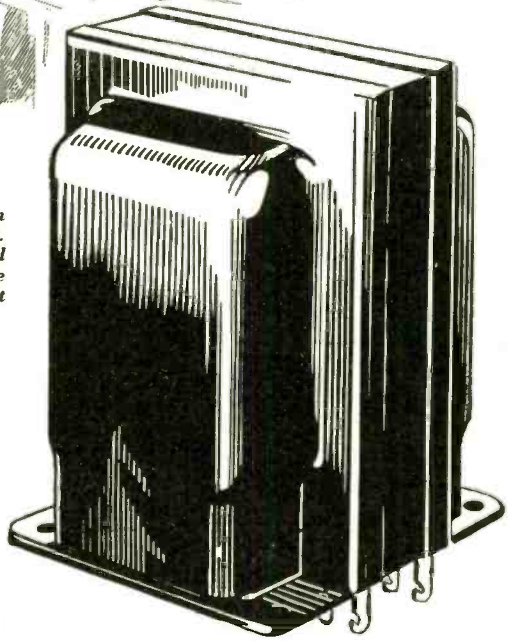
The RMA Engineering service, under the direction of Mr. Walter E. Holland, new Director of Engineering, also will be extended as reorganized.

For the radio public and in support of broadcasting also, the Board of Directors decided to undertake to present another series of special RMA programs next fall, to be contributed by various manufacturers, and broadcast on national chains. This enterprise will be in charge of Mr. B. G. Erskine of Emporium, Pa., Chairman of the RMA Broadcasting Committee. It follows the successful series of nearly a score of RMA programs presented last spring.

Mr. C. C. Colby of Canton, Mass., Chairman of the Association's Legislative Committee, reported complete organization in the east and substantial progress in other sections of the country in the establishment of the new legislative information service. Local radio leaders are being appointed to



One of the belt assembly benches in the power transformer department. Over four hundred employees find occupation in this department alone which occupies thirty thousand feet of factory space



Transformers

Every step in the engineering and manufacture of Thordarson transformers is carried out entirely within the Thordarson organization. The resulting excellence of product maintains a demand which absorbs a production more than double that of last year—and still is but partially satisfied.

THORDARSON

Transformer Specialists Since 1895

THORDARSON ELECTRIC MANUFACTURING CO.
Huron, Kingsbury and Larabee Streets, Chicago, Ill.

cooperate with the RMA in local and state radio legislative affairs, to protect all radio interests against harmful legislation. Mr. Frank D. Scott, Legislative Counsel of the Association, made a report regarding new radio legislation pending in Washington and the prospects of continuation for another year of the Federal Radio Commission.

The RMA voted unanimously to give full and active cooperation to the Government in the Department of the Interior enterprise to place more radio products in schools and other educational institutions. In response to a general invitation to all radio interests to cooperate with the Advisory Committee on Education by Radio, appointed by Secretary Wilbur of the Interior Department, the Board of Directors voted to offer the resources and services of the RMA to Secretary Wilbur. This tender will be made soon by a special committee consisting of Bond Geddes, Executive Vice-President, and Mr. Frank D. Scott. To make radio a greater educational agency, the Advisory Committee, with which the RMA will cooperate, includes Chairman Robinson of the Federal Radio Commission, President Aylesworth of the National Broadcasting Company, President Paley of the Columbia Broadcasting System, and many prominent educators.

Recent successes of the annual RMA convention, trade show and banquet were reported by Jess B. Hawley of Chicago, Chairman of the Show Committee, Henry B. Forster of Chicago, Chairman of the Convention and Banquet Committee, and Mr. G. Clayton Irwin, Jr., Show Manager.

The two RMA sponsored shows—the Radio World's Fair, at Madison Square Garden, to be held during the week of September 23d at New York, and the Chicago Coliseum Show in October—were reported to be completely sold out. In consideration of the place and date for the next convention and trade show, Chairman Hawley, Mr. Irwin and Executive Vice-President Geddes were directed to inspect the facilities at Atlantic City. Other invitations for the convention and trade show have come from New York, Kansas City, St. Louis and Detroit, as well as Chicago. A decision will not be reached for some time.

Director George H. Kiley of New York presented his resignation because of a new personal connection, and the Board elected Mr. Leslie F. Muter of Chicago as his successor. Mr. Kiley also was compelled to resign as Chairman of the Foreign Trades Committee and was succeeded by Mr. H. H. Pollock of New York. Mr. Muter was elected Chairman of the Credit Committee to succeed Donald MacGregor of Chicago who resigned.

RMA BOARD BREVITIES

Next month the RMA Patent Committee, headed by Mr. Le Roi J. Williams of Cambridge, Mass., will undertake an intensive campaign in furtherance of the RMA patent interchange plan. Expressions and action of the entire Association membership in connection with the so-called "patent pool" will be sought. A questionnaire has been sent to all Association members following a series of pamphlets outlining the patent interchange plan which, it is hoped, will reduce litigation and make radio patents more available, in the interests of the public as well as of the industry to RMA members.

Next month new railroad rates to the Pacific Coast, estimated to save approximately $200 on each car of radio products shipped, will become effective, according to a report from the RMA Traffic Department, headed by Chairman B. J. Grigsby of the Traffic Committee, and Mr. W. J. M. Lahl, Traffic Manager. A supplement to the present classification rates on shipments to the West Coast will be published by the carriers, it is stated, effecting substantial savings to RMA members. The traffic services of the Association are to be enlarged, and the Traffic Department now has under investigation several other items in connection with railroad rates in which reductions are being sought with considerable hope of success.

The new RMA Interference Manuals, designed to assist the public in solving its static troubles, are selling like the proverbial "hot cakes." To date over 180,000 copies of the new edition have been sold, according to Executive Secretary M. F. Flanagan. Many large and also smaller manufacturers are ordering large quantities of the Manuals to ship with each receiving set and to jobbers and dealers. The sales and publicity work in connection with the new Manual, prepared by the RMA Engineering Division in cooperation with NELA and other associated organizations, is in the immediate charge of Mr. William Alley, Merchandising Manager.

Several radio publishing friends attended the Niagara Falls meeting. Among those most happily present were Mr. M. Clements of Radio Retailing, Glad Henderson of the Talking Machine Journal, Lee Robinson of the Talking Machine World, and Curtiss Wessell of the Talking Machine and Radio Weekly. Mr. Orrin E. Dunlap, Radio Editor of the New York Times, who was spending his vacation at his old home in Buffalo, also dropped in on the RMA proceedings.

Why the RMA Board meeting at Niagara Falls was held on Canadian soil, at the Clifton Hotel, is a mystery still to be solved. Judge John W. Van Allen, General Counsel of the RMA, made the reception, golf and other arrangements. Hospitality, except from the U. S. Customs Guards upon returning, was unbounded.

Another new service to RMA members which will be organized soon by Mr. E. A. Nicholas of New York, Committee Chairman in charge, will be a study of the cost of distribution of radio products. Distribution costs of all varieties of radio products and in all localities will be secured and analyzed to assist members in further economies.

The next meeting of the RMA Board of Directors will be held September 25 at New York, during the week of the Radio World's Fair at Madison Square Garden. A special committee to represent the RMA and greet official guests at the Show will be named by President Richmond, and the Association will participate actively in other ways in the public show.

ROGER M. WISE JOINS SYLVANIA

Roger M. Wise for seven years chief engineer of E. T. Cunningham, Inc., now occupies a similar position with Sylvania Products Company. This became effective August 1st. This announcement has been made by George L. Richell, Sylvania's vice-president in charge of engineering.

Mr. Wise is one of the foremost of radio engineers and his experience embraces fifteen years of intimate contact with every phase of radio activity.

He was born at Fort Wayne, Indiana, and received his academic technical education at the University of California where he won his degree as electrical engineer. To a significant beginning in his profession, he added brilliant achievement in the years of the World War, distinguishing himself as Chief Radio Electrician in the Naval Air Service.

His work in this capacity was performed at all the major air stations in addition to the Bureau of Standards at Washington. Seven years ago he joined E. T. Cunningham, Inc., and later became chief engineer.

Mr. Wise already has taken up his residence at Emporium with his wife and young son. His joining with the executive staff of the Sylvania organization was heralded with great satisfaction by the engineering department—and is in keeping with the rapid general expansion of the company. The production department is just moving into two new factories which will enable them to produce the tubes required by the sales department for its program of sales three times as large as those of 1928.

DR. O. E. BROWN JOINS TEMPLE

Dr. O. E. Brown, eminent mathematician on the faculty of Northwestern University for the last five years, who has just received his Doctor of Philosophy degree at the University of Chicago, has joined the research staff of the Temple Corporation.

His duties will consist of a mathematical analysis of circuits and research work from a purely technical angle to determine ideal circuits and their constancy, in which work he will be assisted by J. Swallow and a group of practical radio engineers.

L. C. F. HORLE RETURNS TO CONSULTING WORK

Mr. Lawrence C. F. Horle, who for the last four years has, as vice-president of the company, directed the engineering work of the Federal Telephone Mfg. Corp., announces his retirement from the activities of that company and his return to his consulting practice at his earlier headquarters in New York City.

It will be remembered that prior to his connection with the Federal Company, Mr. Horle was active in many phases of radio research in a consulting capacity and in that work was responsible for much of the early work of the Bureau of Standards in comparative radio field strength measurement and radio receiver performance measurement as well as for the design and construction of several of the nation's earliest broadcasting stations.

His work in the radio field dates back over twenty years and is particularly interesting in connection with his work on vacuum tube circuit and apparatus development as carried on while a member of the Faculty at Stevens Tech, jointly with Prof. L. A. Hazeltine in the period between 1912 and 1916.

During the war Mr. Horle served as Expert Radio Aide, Navy Dept., in charge of the Radio Development Laboratory at the Navy Yard, Washington, from which work he joined the DeForest Tel. and Tel. Co. as chief engineer.

He will be glad to hear from any of his many friends in the radio industry at his offices at the Hudson Terminal Building, New York City.

CROSSLEY JOINS HOWARD

Mr. Alfred Crossley, one of the leading radio engineers of the country, is now Chief Engineer of the Howard Radio Company of Chicago. Mr. Crossley has been continuously identified with radio for the past twenty years. In the early days he was with the United States Navy, operating both ship and shore stations. Later he associated himself with the United Fruit Company and with the DuPont Company as Radio Engineer. Following these activities he became Research Assistant at the University of North Dakota under Dr. A. Hoyt Taylor. At the outbreak of the war, he became a commissioned officer in the Navy, his duties being confined to research work on special receiving apparatus. During this period he installed the distant control radio center, Naval Operating Base at Hampton Roads, Va. Upon completion of this work he was placed in charge of the installation and development of all submarine radio equipment. He was subsequently promoted to a position in the Radio Division, Bureau of Engineering, Navy Department, in charge of all Naval Radio research activities. Following the war he became expert Radio Aide in the Navy Department continuing research activities. He remained at this post several years, during which time he was responsible for many radio developments including crystal control receiving and transmitting and special amplifying systems. To him goes the credit for the development of the present standard of frequency now used in this country. Mr. Crossley has a great many patents issued and approximately twenty important patent applications in the Patent Office. He has contributed numerous technical papers to the art on subjects dealing with his various inventions and systems.

DR. SENAUKE JOINS DUOVAC

Perhaps one of the greatest radio authorities in the country has just entered the radio manufacturing field. He is Dr. Alexander Senauke who occupies the Chair of Radio Communication at New York University where he is Professor of Electrical Engineering. Dr. Senauke has for years made an intensive study of radio and is now placing his impressive radio background at the disposal of the Duovac Radio Tube Corp. by whom he has been retained as Consulting Engineer. In his researches he has developed various improvements which tend to standardize the production of vacuum tubes.

ALLEN AND STEVENS JOIN LYNCH CO.

Mr. Stratfrod B. Allen, formerly with the engineering department of Tobe Deutschmann Corp., is now connected with Arthur H. Lynch, Inc. and is in complete charge of their new factory at Malden, Mass.

Mr. A. E. Stevens, who has long been connected with the radio field, has been appointed sales manager of the Lynch organization. Mr. Stevens is located in the New York offices, in the General Motors Building, Broadway and 57th St.

NEW GREBE DISTRIBUTORS

Brothwell H. Baker, sales manager of A. H. Grebe & Co., Inc., of Richmond Hill, N. Y., has announced the appointment of Stewart-Downey, Inc., 700 Beacon Street, Boston, Mass., as distributors of Grebe products in the Boston territory which consists of Massachusetts, Vermont and the western half of New Hampshire.

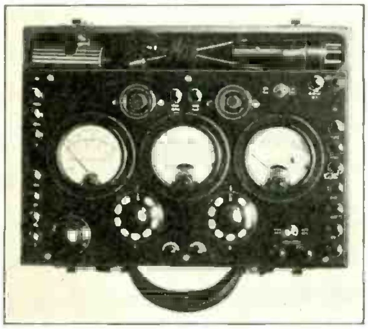
Stewart-Downey, Inc., is a newcomer to the ranks of radio distributors but it enters the field with a wealth of personal experience in back of it. John Stewart and Joseph A. Downey organized the Radio Department of The Boston Post in 1923 and have been in charge of this department ever since. Under their guidance, The Boston Post has become one of the outstanding radio newspapers of the country and is generally recognized as the "New England Voice of Authority" in the radio industry.

NEW DEVELOPMENTS OF THE MONTH

WESTON NO. 547 RADIO SET TESTER

The Weston Electrical Instrument Corp., of Newark, N. J., have introduced a new type radio set tester for servicing both a-c. and d-c. receivers.

Model 547 is contained in a handsome, rugged bakelite case provided with a carrying handle and a compartment for housing the set accessories and a few small tools. It has a removable, snap-on cover—the overall size is 12¾ x 9 x 3¾ inches and the weight is approximately 10 pounds. The panel on which the instruments and switches are mounted is of moulded bakelite as well as instrument cases, switches, binding posts, test sockets and tester plug.



The Weston 547 Radio Set Tester.

The instrument equipment consists of three 3¼" diameter Western models—an eight range d-c. Model 301 for 750/250/100/50/10/5 volts, 100/5 milliamperes—a double range d-c. Model 301 for 100/20 milliamperes and a five range a-c. Model 476 for 750/150/16/8/4 volts.

All ranges with the exception of the 750/150 a-c. voltage ranges are made available by means of three rotary switches at the Tester Plug which is permanently attached to the set by flexible cable. All voltage and the 100/20 milliampere ranges are also brought out to binding posts for use in making external tests using the flexible leads provided with the set.

Two sockets are provided on the panel, a UX and a UY. The tester plug has four prongs and an adapter is provided to change it to a five-prong plug.

All voltage and the 100/20 milliampere ranges are brought out to binding posts—the d-c. voltage and current ranges are brought to binding posts at the right and the a-c. ranges to binding posts at the left. Two binding posts and a 4½-volt C battery are provided for use in making continuity tests with either a high or low resistance voltmeter (1,000 or 100 ohms per volt). The resistance is changed by means of a toggle switch.

The net price to the dealer is $93.75, f.o.b., Newark, N. J.

CORNELL "CUB" CONDENSERS

The Cornell "Cub" is supplied in capacities ranging from .0001 to .006 mf. and the advantages gained by the use of this unit are as follows:

The Cornell "Cub" is self-mounting and can be used to advantage with the carbon type grid leak or any of the pig-tail leaks. It can be merely wrapped around the grid leak wires and both units soldered in the same operation. The use of the "Cub" condenser usually saves two or three labor operations.

It is the first paper condenser of its type that is wound non-inductively.

It will stand a d-c. flash of 1500 volts.

The Cornell "Cub's" dielectric thickness consists of three .0005" thick pure linen paper.

Its terminal contacts are rigidly fastened to a vacuum dried and impregnated mandrel. Consequently, there is no possible change of loose ends and noisy contacts.

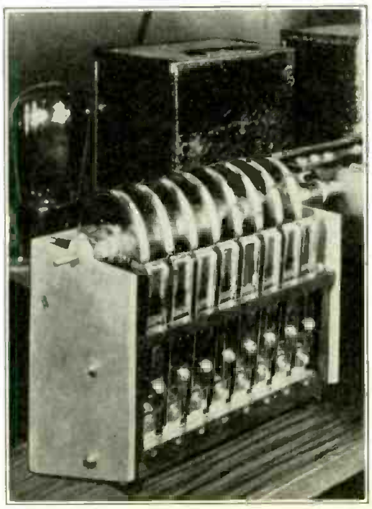
The capacities are held very accurately to their specified percentages.

THE CARTER ELECTRIC AUTOMATIC RADIO RECEIVER CONTROL

The Carter Electric Automatic Radio Receiver Control is made up of only four major parts. First contact is with the Selector. This is made up of a number of little station tabs which are also ingenious push buttons. The station call letters are scribed on these transparent celluloid tabs which fit into metal frames and are illuminated from the rear. A slight pressure on these tabs or push buttons sets the tuner in operation, tuning it to the station desired. In the illustration, this Selector is shown as inbuilt into the front panel of the radio receiver. Here a unit containing 8 tabs are used. Any number may be employed, limited only by the space available. This same Selector unit appears in the Remote Control which is treated in a later paragraph.

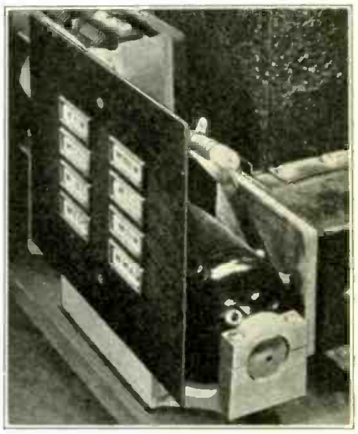
The next unit of the Automatic Tuner to be considered is the Finder. Here is the heart of the device. It is made up of a number of slotted drums with a like number of "fingers" or contact segments. This assemly is attached to one side of the condenser gang of the receiver. It "finds" your station for you, after you have made the selection by pressing the button on the Selector.

When a given station is selected by pressing its button on the Selector, the corresponding contact segment moves forward forming a wiping contact with the surface of the drum. This automatically starts a tiny electric motor, which rotates the condenser gang of the receiver. This motion continues until the contact segment reaches the slot in the drum with which it operates. On reaching this slot, the circuit is broken, instantly stopping the motor and the motion of the condenser gang. Action stops the instant the contact is broken, thus setting the dial exactly at the spot to which the station has been tuned sharply by hand.



The station selector mechanism of the new Carter remote tuning control system.

A most remarkable characteristic of the action of the Carter Automatic Tuner is that the receiver is tuned from station to station, in either direction of the dial. It may be set so that only one or two degrees on the dial are covered between any two stations. The condenser does not return to a neutral position at each operation, as is the case with most other electric tuning devices.



Showing the tab push-buttons and the driving motor of the Carter tuning system.

The power for the Carter Automatic Electric Tuner is supplied by a tiny motor which takes its current from the regular receiver supply. It interferes in no way with the efficient operation of the receiver.

The next and last unit of the automatic Tuner is the Relay Switch. This unit is required for the Tuner only when one or more Remote Controls are used. It permits of the receiver being turned on and off from any of the remote controls used.

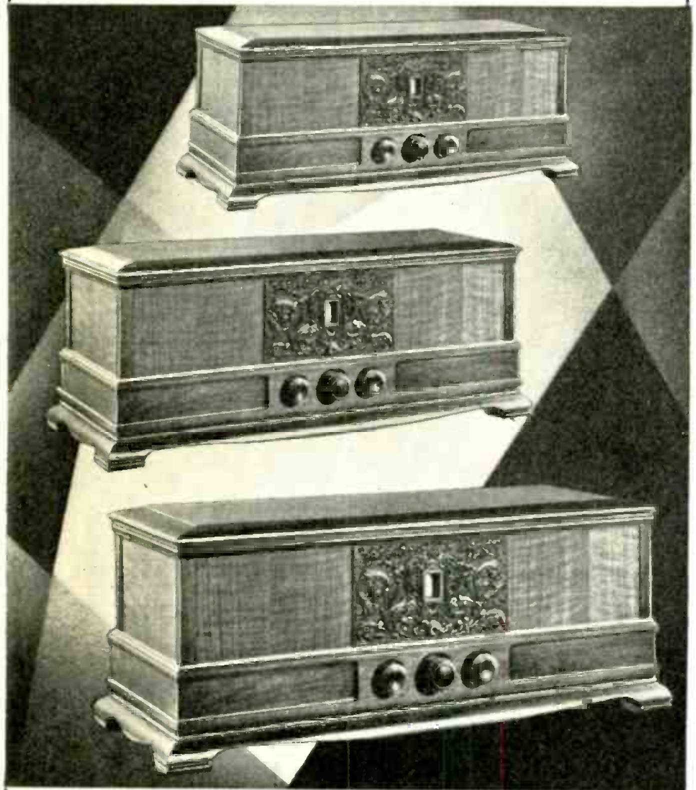
With this Carter Automatic Electric Tuner, any number of Remote Control Boxes may be employed to control the receiver from any advantageous point. The receiver may be in the living room and Remote Controls stationed in other rooms, such as the dining room, bedroom or kitchen. These controls may be installed in semi-portable fashion with exposed cable running to the set, or they may be permanently installed with concealed wiring, as with the electric lighting or telephone system. The Remote Control consists of a complete Selector Unit mounted in a metal box, on which is located the combination off-and-on switch and Volume Control. Simply press the small button in the center of the volume control knob and the set is turned on. Another pressure of the button shuts off the set and vice versa. Any number of Remote Controls may be connected in parallel with the "home" unit that is built into the set.

DUBILIER INTERFERENCE ELIMINATOR DEVICES

The Dubilier Condenser Corporation of New York City, announces the introduction of two new interference prevention devices known as the Disturbo-Ducon and the Interference Device No. 2, respectively.

Dubilier Disturbo-Ducon is a filter network of inductance and capacity to be employed in series with the radio receiver and the power supply. In this position it eliminates all power-line disturbances enter-

These could be made of DUREZ . . .



Radio Cabinet. Using Durez, any color could be used. Radio escutcheon plates, dials or knobs could be molded and assembled just as with other materials—*without waste in cutting, designing, or surfacing.* Elaborate scroll work would be part of the molding operation. They will be strong, tough. No expensive tooling, burnishing or polishing necessary. *Some of the many uses for Durez in the radio industry.*

then they would be

Light
Non-brittle
Acid and Alkaline resistant
Heat and Moisture resistant
Perfectly insulated
BEAUTIFUL ★
Durable—strong
Uniform in any quantity
Complete without tooling or polishing
Made in one operation
Economical

DUREZ
The perfect molding compound

★ Beautiful

BEAUTY won't make a worthless product successful. Attractiveness cannot take the place of durability, efficiency, or economy of production. But when beauty is added to all these, as it is in a Durez-made product, you have a worth-while combination —an *unbeatable* combination!

Durez is a molding compound. A beautiful molding compound. It has color in abundance. Reds, Greens, Blues, Browns. Many others. But not only straight colors. You can easily produce blended, mottled, or striated effects. And no matter what color you use, Durez brings remarkable freshness and smartness to your product.

Beauty is by no means the only Durez feature. Durez is strong, hard as flint. It is non-brittle. It is acid resistant, heat resistant, moisture resistant. Corrosion is never a problem. And further: Durez is quickly, easily, and economically molded. One operation, and the job is complete. No patching or additions. It is finished. Polishing, burnishing, painting are unnecessary.

Is your product losing out because it isn't "modern" enough? . . . Your competitor's product may be no whit better, but perhaps it *looks* better. Why shouldn't your product be beautiful? Does your present material give it beauty *economically?* If not, consider Durez. Durez *can* give beauty—with all the other necessary qualities in addition.

We'll go into details on these matters if you'll write to us. Durez can help you, and we'll welcome a chance to show you how. General Plastics, Inc., 95 Walck Road, North Tonawanda, N. Y. Also New York, Chicago, San Francisco.

•

Write for this free booklet—"Do It With Durez." Contains complete information about Durez —physical and dielectric properties, color ranges, and scores of possible applications.

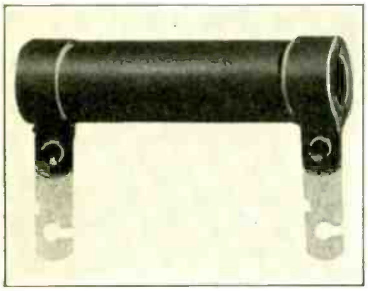
ing the receiver by way of the power line, as well as interference picked up by the power line, acting as a miniature aerial. The Disturbo-Ducon is also employed at the source of the disturbance when the appliance or machine is sufficiently powerful to radiate or broadcast its own operation. The device is connected in the same manner, in this instance, as it is in the case of the radio set, namely, in the power line.

Interference Device No. 2 does not incorporate inductance in its network, since it is a condenser assembly especially suited for interference elimination in commercial work, such as oil burners, elevators, a-c. and d-c. motors, electric sign flashers, etc. It is especially applicable to moderate power circuits since any number of interference causes may be connected in parallel on the same line and treated with just a single Interference Device across the common line. Users may therefore start with just one Interference Device and add to it in parallel until they achieve the exact value necessary for their purpose, thus providing the happy medium for the power user who requires a larger than average filter yet does not require a typical industrial filter of considerable proportions.

ELECTRAD LAYER-WOUND HIGH RESISTANCE

This addition to the well known Electrad line of radio resistances and voltage controls is recommended particularly for use as a plate resistor, multipliers for voltmeters and general laboratory work.

The finest grade of Nichrome resistance wire is wound in generously insulated layers around a selected refractory tube.



Electrad Layer-Wound Resistance.

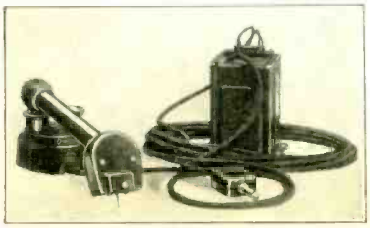
The entire unit is covered with a heavy coating of moisture-proof enamel of unusual elasticity, baked on at only 400 degrees to prevent loosened connections and fractured wire. Contact bands and soldering lugs are of Monel Metal. The lugs are solder-dipped for easy soldering. All parts expand equally under load.

The overall length of the unit is 2 inches, with a maximum outside diameter of ⅝ inches. It is made with resistance ratings from 10,000 to 250,000 ohms and priced from $1.50 to $5.00.

NEW STROMBERG-CARLSON PICKUP

A new magnetic pickup outfit, known as the No. 3-A has been designed by the Stromberg-Carlson Telephone Mfg. Co., for its new line of screen-grid receivers and other sets using power detection and requiring that the pickup circuit work directly into the grid of the amplifying tube.

This outfit differs from previous models in that the pickup unit or head is of the low impedance flexible armature type. As no scratch filter is incorporated in the outfit, the volume control is mounted in the base of the pickup arm to provide compactness. Due to the fact that the voltage generated by the low impedance pickup unit is very low, a step-up transformer is provided to raise the voltages to a value suitable for operating the audio amplifier. This transformer is placed close to the receiver chassis to avoid capacity effects in the long cord connecting it to the phonograph. Being inclosed in a finely finished brown enamel case, the transformer can be left loose on the table, back of the receiver. If desired, however, it may be fastened in a concealed position to the bottom of the table or cabinet on which the receiver is mounted.



Stromberg-Carlson electric pickup for power detector circuits.

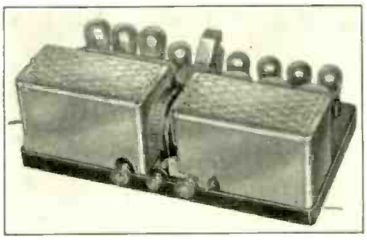
Flexible armature operation is provided in the No. 3-A pickup by having the armature shorter and lighter in weight and by using a more flexible cushion. This great flexibility as compared with the larger armatures on high impedance pickup heads reduces wear on phonograph records, increasing the life of the record in some cases by as much as thirty times.

A new design of counter-balancing spring is provided in the swivel joint of the pickup arm with a view of providing the correct weight on the needle point as well as to insure against any rattling in the joint when the pickup is operating on a record. This No. 3-A pickup is designed only for operation with full-tone needles.

LAFAYETTE SCREEN-GRID DUO-SYMPHONIC RECEIVER

In considering the inherent and commercial quality of any given piece of radio merchandise, it is pertinent to the entire subject to realize that practically all of the worthwhile manufacturers of radio receivers in the entire industry are licensed under the same patents, are using the same general circuits and design and the final product therefore, is merely these fundamentals with slight adaptations that may be built into it by the individual manufacturer according to his ingenuity and general knowledge of the art.

With the exception of the Superheterodyne, practically all other radio receivers employ the same general tuned radio-frequency circuit or, as previously stated, some adaptation of that fundamental circuit. In the Lafayette Receiver a tuned radio-frequency circuit is employed, utilizing both the Hazeltine neutralization system and the Beer's double primary method of neutralization. The reason for this seeming complication is this: The Beer circuit has all of the desirable characteristics: sensitivity, selectivity and volume on the high side and middle of the waveband. On the low side of the waveband, however, it is lacking seriously in selectivity and likewise in sensitivity. The Hazeltine neutrodyne circuit on the other hand, performs best from the standpoint of sensitivity,



Front view of the Lafayette screen-grid receiver chassis.

selectivity and volume on the low side of the waveband. Therefore, a combination of these principals gives practically a flat operating characteristic over the entire waveband which is the desirable factor.

The power pack is liberally designed to withstand without damage any a-c. line voltage from 90 to 135 volts and also to withstand voltage surges occasioned by removing tubes or disconnecting the speaker when the set is turned on. Also the power pack transformer is designed so that in case of trouble, it can actually be removed and a new one replaced by any individual who can handle a pair of pliers, and the design is such that it would be impossible to hook the new transformer into the power pack incorrectly.

Selectivity in this year's receiver is unusually good. The very maximum it is possible to attain is a clean separation of stations that are 10 kilocycles apart and it is possible to do this over practically the entire waveband with the new set provided only that the set is installed a rea-

Rear view of the Lafayette receiver chassis.

sonable distance from high powered local broadcasting stations.

Tubes employed in the circuit are nine in number. Five UX 226s, one UX 224, two UX 245s and one UX 280 rectifying tube. The chassis dimensions are 20¼" long by 11½" deep by 7¼" high. The weight is 34 lbs. and the set is manufactured for use with a dynamic speaker only.

I. C. A. ELECTROSTATIC ARRESTER

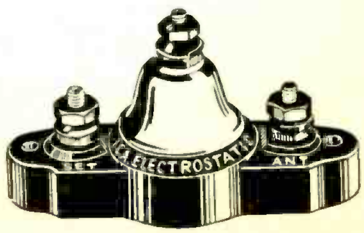
The I. C. A. Electrostatic Arrester incorporates and combines several well-known, time-tried principles. It employs the usual high resistance leak from aerial to ground. This leak is of special resistance material, offering very high resistance to weak radio currents, but low resistance to powerful static or lightning discharges. Hence, the high potential currents due to lightning, pass easily to the ground, whereas the radio currents, being of low potential, pass into the set.

A static shield, which is a distinctive feature of this arrester, is placed over the ground terminal and is so shaped that it shields the set connection from the electrostatic field set up across the aerial and ground connections by the high frequency atmospheric electricity. Excessive static is thus by-passed to the ground and this prevents direct sparking between the aerial and set terminals. The shield also serves the purpose of adding a minute electrostatic capacity across the high resistance element of the arrester. This is very advantageous, since the static is thus noticeably reduced, resulting in more quiet operation of the receiver.

A choke coil and condenser are also incorporated in the arrester, being connected between the aerial and the set terminals. The constants of the coil and the condenser have such values that they permit the radio currents to pass into the set unobstructed, yet they offer a very high impedance to static discharges of high frequency forcing them to take the path of least resistance to the ground. This circuit is capable of filtering out certain troublesome frequencies of static electricity picked up by the aerial. Furthermore, the additional loading effect makes the aerial system more efficient, thus resulting in increased sensitivity and volume.

The insulating property of the condenser protects the set from short-circuits due to accidental contact of the aerial with electric light or power lines. In the event that the condenser should fail, the choke coil in the arrester provides a secondary protection, since it is wound with fine wire, which will burn out before any harm can be done to the set. This arrester, therefore, affords double fuse protection.

The I.C.A. Electrostatic Arrester is well-designed mechanically, being rugged and weatherproof. It has a highly glazed porcelain base fitted with two mounting screw holes, which render it extremely easy to install. A $100.00 free insurance bond is given with each arrester.



The I.C.A. Electrostatic Arrester.

Speaking about Line Ballasts---

EVERY radio engineer, merchandiser and service man knows the whys and wherefores of line ballasts at this late date. It is generally admitted that line voltages vary, and therefore run over or under the specified 110 volts. It is also acknowledged that if the voltages applied to tubes exceed the 5 per cent plus or minus specified by manufacturers, there is ample trouble in sight. In brief, *under-voltage* means poor radio results, loss of sales and barren territories. *Over-voltage* means brilliant performance but likewise brilliant tubes which must burn out in short order.

Yet there are other phases of the line ballast situation which concern you more specifically. And so we have the following messages to deliver at this time. Please read the one addressed to you. Thanks for your attention.

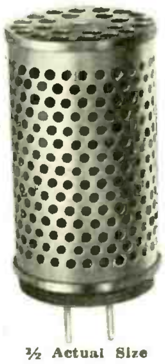
MR. RADIO MANUFACTURER: Better type radio sets are rapidly being equipped with line ballasts. This feature insures absolute freedom from line voltage variations and fluctuations. It makes for sales in many localities where low line voltage curtails radio results. It makes for fewer service calls and tube replacements in high-voltage areas. The public is rapidly becoming acquainted with the line ballast and the necessity of this feature in most localities. It is only a question of time when the radio buyer will look for the line ballast feature in your set. Don't wait for your competitors to force you to include this standard feature in your assembly. Do it now and get the benefit that goes with Leadership! Lead — don't follow!

MR. RADIO ENGINEER: Alibis are bad things to fall back on. Your engineering skill is judged by just one standard: the ultimate public acceptance of your products. Therefore, don't take a chance on line voltage. When you include the line ballast in your assembly, you are removing the last *variable* in the socket-power radio set. At least provide a socket for the line ballast cartridge, and be sure that your descriptive literature tells of the necessity of inserting this device in place before using the set.

MR. SERVICE MAN: More and more you are going to come across socket-power radio sets employing the line ballast, or at least provided with a socket for this device. And when you find a line ballast socket, always be sure to insert the proper cartridge. Remember, such a set has a low-voltage primary for the power transformer, and if no cartridge is used, the applied voltage will be excessive. NEVER short out the cartridge. To do so is to apply a serious overload on the tubes, which are certain to burn out in short order. And if you have exceptional trouble with line voltage variations or fluctuations, write your radio manufacturers so they may know that a line ballast is essential in your territory.

AND TO MR. EVERYBODY: When you have arrived at the inevitable conclusion that a line ballast is part and parcel of a satisfactory socket-power radio set or power amplifier, be sure to select a device that is properly designed and matched to your power transformer, that is sturdy mechanically and electrically, and that possesses ample life. These requirements and others are immediately available when you specify

Line Ballast CLAROSTAT



½ Actual Size

An automatic line voltage control matched to a specific transformer primary, and maintaining a constant voltage on that primary despite a line voltage variation up to 30 per cent. Ruggedly constructed with resistance wire supported on notched mica pieces held by brass angle framework. Turns cannot sag, short-circuit or break. The wire is non-oxidizing and has no plating or coating to peel or crack. The assembly is protected by heavy metal perforated casing, riveted to base. Available in double prong base for standard electric outlet or two-hole radio socket. Standard equipment in all sets now employing automatic line voltage control.

WRITE for details regarding the general problem of line voltage regulation and the LINE BALLAST CLAROSTAT in particular. If you are a manufacturer of radio sets or power amplifiers, we shall be pleased to make up sample ballasts matched to your power transformers. And there are other CLAROSTAT aids to better radio, which we shall tell you about on request.

CLAROSTAT MANUFACTURING COMPANY, INC.

Mem. R.M.A.

Specialists in Radio Aids

282 North Sixth Street, :: Brooklyn, N. Y.

Remember-there's a CLAROSTAT for Every Purpose

New Universal Condenser Microphone.

UNIVERSAL CONDENSER MICROPHONE

The Universal Microphone Co., 219 North Market St., Inglewood, Calif., have introduced a new model condenser microphone having a number of unusual features. Referring to the illustration, the single stage amplifier is housed in the casing to which the microphone proper is attached. This amplifier employs a single 224 screen-grid tube, arrangements being made to light the filament from a six-volt storage battery. The microphone case also includes an impedance matching transformer, in the output circuit of the amplifier.

A potential of 200 volts is maintained on the condenser.

All electrical connections are made through the special detachable 25-foot cable shown.

The price of the Universal condenser microphone, without swivel, is $250 with floor stand, $340.

NEW TRAV-LER PORTABLE RECEIVERS

Deliveries of the new model Trav-Ler Portable Radio Receivers to the distributing and dealer trade were started the last week of July from the factory of the Trav-Ler Mfg. Co., St. Louis, Mo.

The new line is comprised of three models ranging in prices from $65.00 to $100.00. The circuit in these new sets is a distinct and radical departure from that which has been employed heretofore in receivers of the portable type. Following the latest and advanced proved principles Trav-Ler engineers have perfected a highly efficient shielded circuit employing a screen-grid tube in all three models and power tubes in the last audio stages of the two larger sized ones. All of the new sets are being made for operation with either batteries or 110 volt a-c. or d-c. The power packs and batteries are quickly and easily interchangeable so that the owner of one of the new Trav-Lers may use the set regardless of the location or power supply by adapting the set either for a-c. or d-c. or where neither of these are available use batteries instead.

The interchangeability of the power supply is also pointed out by Harold J. Wrape, president of the company, as being of a distinct sales advantage to the dealer. He can supply not only a receiver to meet any current requirement but in turn need carry only a minimum stock of models yet can take care of his customers by having the two styles of power packs and batteries and equipping the models in accord with the buyers' demand.

The new models have only four tubes, one less than in the previous chassis. The screen-grid tube is used in the radio-frequency circuit, a type 199 tube as a detector and in the first audio stage. The type 120 tube is used in the last audio stage. With the greater amplifying ability characteristic of the screen-grid tube the signal delivered by the new circuit is far greater than in the previous models. The range of the new sets, both during the day and at night-time, is also much greater than heretofore.

A built-in loop is used with all three models with binding posts for antenna and ground also provided. A jack to plug-in head phones is also in the panel.

The Standard is the smallest of the new models and lists at $65.00. It is intended chiefly as a battery operated set but can be equipped with either of the power packs. When operated with batteries no power tube is used in the last audio stage. The case is covered in black Mocotan with the panel in black, green and gold crackle finish. When closed the Standard model measures 12¾ inches wide, 9 inches deep and 11 inches high. Opened with the loop in place the height is 24 inches. The weight complete with batteries and tubes is 27 pounds.

The De Luxe model, which is a larger set, lists at $75.00. It is intended for use with a power tube in the last stage and for a-c. or d-c. operation. Space is also provided for the required battery equipment when used in this way. The speaker chamber is considerably larger than on the Standard model to handle the greater volume delivered by the more powerful audio system. The case is also covered with black Mocoran with the panel in the green and gold crackle finish. This model when closed measures 14¼ inches wide, 9 inches deep and 13 5/16 inches high. With the loop in place the overall height is 28 9/16 inches. Equipped with the power pack and tubes or batteries the total weight is only 30 pounds.

The Aristocrat which lists at $100.00 is the largest of the three models, the size of the case being increased to accommodate a 7-inch cone speaker of a new type which has been especially developed for use in this portable receiver. The case is also more finely finished, being covered with genuine heavy Mocotan in a rich autumn brown shade. The panel is finished in a black, gold and green crackle finish which harmonizes exceptionally well with the covering of the case itself. When closed the case measures 15⅞ inches wide, 9 inches deep and 15¾ inches high. With the loop in place the height overall is increased to 28¾ inches. The weight complete with either of the two power packs is 39 pounds which is increased by 5 pounds when batteries are installed.

The new Trav-Ler prices are for the set complete with the speaker but do not include power packs, batteries or tubes. The Trav-Ler a-c. Power Pack lists at $35.00 while the d-c. unit is $30.00. Prices west of the Rockies are slightly higher with all list prices being f.o.b. factory St. Louis, Mo., or from either of the company's Chicago or New York City warehouses.

NEW METHOD OF REMOVING WOOD DUST FROM AIR

Removing fine wood dust that floats through the air from the woodworking plant is a problem that is bothering many concerns. This dust settles on products stored and in process of manufacture in other parts of the factory and makes costly cleaning necessary.

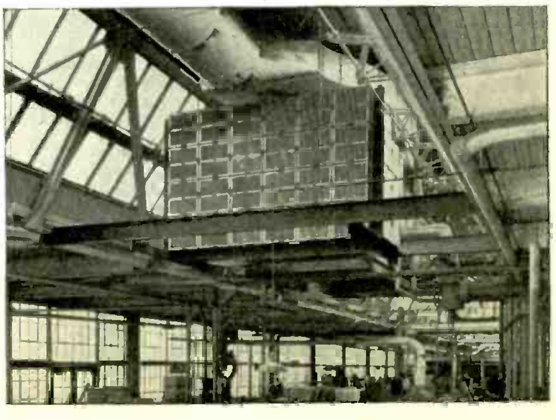
In the Rochester Plant of Stromberg-Carlson this difficulty has been remedied by drawing the warm air through air filters located near the ceiling by means of the ventilating system.

A 35-panel filter is located in 3 different parts of the plant. Each panel is rated at 500 CFM.

This ventilating system is so designed that it re-circulates warm clean air through ducts to various parts of the building in winter. In warm weather, air is taken from the outside of building and filtered from dust and dirt.

By supplying clean air in this factory, costly cleaning bills are eliminated and the efficiency of workmen is increased.

The filters referred to, which are manufactured by the Staynew Filter Corporation, Rochester, are made of felt mounted on rustproof wire cloth held in steel frames. Thus far it has been necessary to clean these filters about every two months. The time required for cleaning each panel with a vacuum cleaner is but a few seconds, as this work can be done without removing the filters from the panels.



Staynew panel air filters installed in the new Rochester plant of the Stromberg-Carlson Telephone Mfg. Co.

RADIO SET ANALYZER WITH TUBE MERCHANDISING CASE

A new 4-instrument set analyzer with a tube merchandising case is announced by the Jewell Electrical Instrument Company, 1650 Walnut Street, Chicago, Illinois.

The new kit has two compartments size 4¼ x 11¼ x 5⅛ inches and a drawer size 11¼ x 10⅜ x 2¼ inches, for the purpose of carrying tools and replacement tubes.

In this case, Jewell has made it easy for servicemen to make an additional profit from servicing through the sale of replacement tubes. The convenient method provided for carrying tubes is also a big time saver.

New Jewell 408 Radio Set Analyzer.

The Pattern 408, as the new analyzer is called, contains the same four Jewell instruments and all test equipment provided in the Jewell Pattern 409. It gives plate voltage, plate current, filament, and grid voltage readings simultaneously and makes every other desirable test.

STEVENS SUPER-DYNAMIC SPEAKER

A "super-dynamic" speaker has just been announced by the Stevens Manufacturing Corporation, Newark, N. J. This dynamic is designed for outdoor, auditorium and theatre use, and is especially suited for the "talkies."

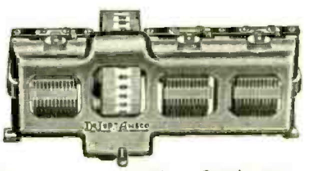
The Stevens super-dynamic speaker is capable of handling an input of 14 watts.

with an exceptionally smooth frequency response curve from 40 to 6000 cycles. The entire assembly is mounted on an extra-heavy chassis, including the transformer, choke and condenser, for operation on 110-volt, 60-cycle a-c. supply. The speaker employs a 14-inch cone of the cubical parabola type made of the well-known Burtex material. The supporting member is integral with the cone, making them practically one.

The special features of this super-dynamic speaker are several, beginning with a low-impedance voice coil of large diameter and few turns. This coil is supported at the center by a member attached to the pole piece. This flexing member is in turn integral with the diaphragm. The field coil is designed to provide a very high flux density, since there are 3,500 ampere turns around the center pole. The field excitation also presents a new development, with its 281 type rectifier tube applying 300 volts at 100 milliamperes to the field coil. Great care has been taken in the development of the voice coil transformer, the impedance of which is accurately matched to the input of the power tube and the output to the voice coil. Special attention has been paid to the materials used for the pot magnet and pole pieces. Also, the method of mounting insures correct balance and drive. With 120,000 lines per square inch of magnetic flux, this speaker is one of the most powerful dynamic speakers of today.

DEJUR-AMSCO MULTIPLE CONDENSERS

The DeJure-Amsco Corporation, Broome & Lafayette Streets, New York City, announce a new line of Multiple Condensers



DeJur-Amsco Multiple Condensers.

of the "Bath-tub" type with dial assembly completely matched and balanced. These condensers can be had in 1 to 4 gang units with or without dial and 2 to 8 gang units with dial.

NEW LYNCH RESISTORS

Arthur H. Lynch, Inc., General Motors Building, Broadway at 57th St., New York City, have introduced two new type resistors, known as the Lynch Standohm and the Lynch Dynohmic.

The Standohm resistor, illustrated herewith, is of the metalized filament type with molded end caps tapered for insertion in a standard cartridge type mounting. Tinned wire leads are molded into the caps and serve as the connections when a cartridge type mounting is not used.

Each Standohm resistor is supplied with an insulated base so that the resistor can be mounted on a metal surface if desired.

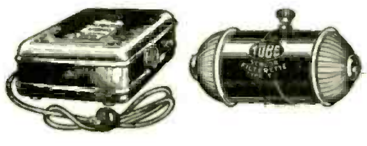
The Standohm resistors are made in 1- and 2-watt types, the prices being 90 cents and $1.00 respectively.

The Lynch Dynohmic resistor is a pigtail type unit, similar to the Standohm, but without the insulating base. The Dynohmic resistors are made in numerous sizes, to meet all purposes and come in .01-, 1- and 2-watt types. The Dynohmic resistors are also supplied without pigtail connections. Prices on request.

The new Lynch Standohm and Dynohmic resistors.

NEW TOBE FILTERETTES

The Tobe Deutschmann Corp., Canton, Mass., have introduced two new types of Filterettes for special purposes. The Senior Filterette, Type T. O., illustrated herewith, is designed for application to



Two new Tobe special purpose Filterettes.

household apparatus creating a more tense type of interference than that which may be suppressed by the Filterette Junior. The filter is designed to be connected in the attachment cord of the interference-creating apparatus and is provided with screw terminals to facilitate such connection. The maximum potential is 110 volts a-c. or d-c.; the maximum load, 500 watts and the maximum current, 5 amperes. The list price is $7.50.

The Tobe Diathermy Filterette, Type 1 H. F. O., is designed for use in conjunction with Tobe "Hi Frequency Screen" for eliminating radio interference created by diathermy apparatus. The maximum potential is 110 volts a-c.; maximum load, 600 watts and maximum current, 6 amperes. The list price is $20.

SUPER AKRA-OHM RESISTORS

The primary thought in the design of the new Super Akra-ohm Resistors (wire wound) has been commercial acceptability. However, to accomplish this there has been no sacrifice in accuracy; but rather by virtue of this commercial design, and special winding process an unusual degree of precision has been made possible.

A feature of particular interest in the Super Akra-ohm Resistors is that their are constructed in pies, each pie wound in the opposite direction thereby producing a non-inductive unit. Also the 8-32 terminal permits a quick laboratory set-up and ease of employment in commercial ap-

The Super Akra-Ohm Resistor.

paratus and factory testing circuits. The Super Akra-ohm Resistors can also be used in grid leak or cartridge fuse clips.

In order to insure a perfect resistor the Super Akra-ohm is wound by a special process (patent pending) that enables the reinsulation of every foot of wire used. At the same time, this process provides a water-proofing effect and prevents mechanical strains which tend to stretch the wire after the resistor is in service thereby changing the resistance.

They further receive a final coat of waterproof material selected and applied in accordance wtih rigid specifications in order to protect them against moisture and unfavorable atmospheric conditions. They are heat treated and thoroughly aged before leaving the factory.

The Super Akra-ohm Resistors (non-inductive wire wound type) are designed to dissipate one watt, and in some cases the dissipation can be considerably larger without permanent damage or change in accuracy, though a temporary change of the resistance value would be noted on account of high temperature.

NEW RACON DYNAMIC UNIT

A powerful, but compact dynamic speaker unit of unique construction has been placed on the market by the Racon Electric Company, 18 Washington Place, New York City. The unit is called the New Racon "Baby Giant" and incorporates a number of important improvements in its design.

One of the features of the "Baby Giant" is the new type diaphragm, made of metal and cloth. This is of such extreme lightness that it has practically no inertia. In fact, a jewelers scale is necessary to weigh it. The voice coil is wound with aluminum wire to keep the entire unit light. It has an impedance of 10 ohms. Flexible leads are used between the voice coil and the binding posts.

The diaphragm is dome-shaped, utilizing the principle of the "arch," which is the strongest form of construction known. An improved method of suspension is used in this diaphragm. The outer portion, which is clamped at several points, is made of chemically treated cloth. With this new type of suspension, extreme movements of the diaphragm are possible, without danger of cracking. The diaphragm rides up and down with a piston-like motion and hence it is impossible for it to get out of adjustment. A brass screen prevents dust and other foreign particles from falling onto the diaphragm. The case of the unit is made of a special magnetic steel, combining high flux density with light weight.

The new Racon unit weighs only 11½ pounds, being one of the lightest and most powerful dynamic units on the market. It will handle an undistorted output of 30 watts without rattling and even at enormous volume, the tone quality is clear and brilliant. The response range is wide, passing all the desired bass notes but also passing the higher frequencies, so that speech is clear and distinct. The unit is made for 110 volt a-c. operation and also for use with a 6-volt battery. It has a field consumption of one ampere.

New Racon Dynamic Unit.

The "Baby Giant" derives its name from the fact that it combines compactness with great power. It is 5½ inches high by 4½ inches in diameter. These are overall dimensions. The body of the unit is only 4 inches in diameter.

The new Racon unit is suitable for home radio use, for public address systems, for talking motion pictures, and is adaptable for theatre or outdoor use. The list price of the unit is $50.

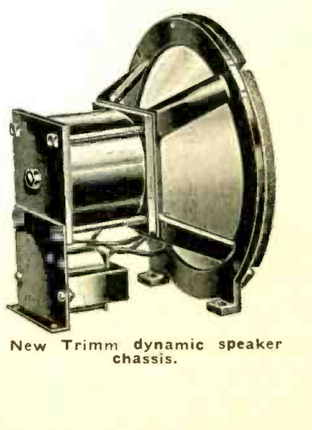
NEW TRIMM DYNAMIC CHASSIS

The Trimm Radio Manufacturing Company, Chicago, Illinois, has developed a dynamic chassis that combines wide range with true tone fidelity and furnishes extreme volume with mellowness. Blasting and distortion are entirely eliminated.

The Chassis is obtainable in two models—Model D100 and DV102.

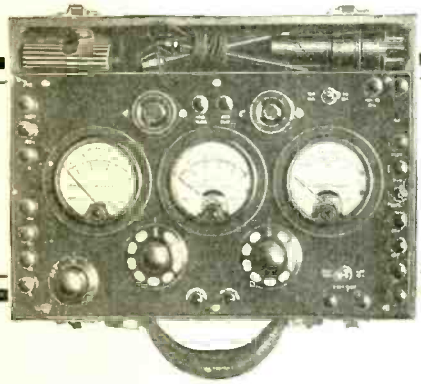
D100 operates from a chassis of the alternating-current type where the output energy is supplied by the conventional type of power amplifier tubes in push-pull, this energy being fed through an output transformer which matches the voice coil; and where the power pack supplies direct current for energizing the field coil.

DV102, illustrated, is provided with an output transformer which matches the conventional type of power amplifier tubes and the voice coil.



New Trimm dynamic speaker chassis.

The New Model 547 Radio Set Tester



—saves time
—simplifies testing
—increases sales

Service men remember the time when radio set testing required hours of time and satchels full of equipment. The model 537 reduced radio set testing to its utmost simplicity and made radio servicing a profitable business instead of a necessary evil.

NOW—Model 547—for A.C. and D.C. Receivers meets the service testing requirements of radio's latest developments, even taking into account the number of new tubes, sets and circuits. Handsome in appearance, it is light, but rugged, convenient and complete.

Provided with three instruments, carrying case, removable cover, panels and fittings of sturdy bakelite.

A.C. Voltmeter—750/150/16/8/4 volts. Only one selector switch is necessary.
D.C. Voltmeter—high range increased to 750 volts. Other ranges—250/100/50/10/5 volts.
D.C. Milliammeter—double range 100/20 M.A. provides for lower readings with better scale characteristics.

Tests—On A.C. sets the heater voltage and plate current can be read throughout the test while the D.C. voltmeter may be indicating plate bias or cathode voltage.

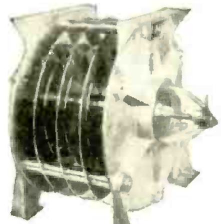
Self-contained, double-sensitivity continuity test provided. This can also be used for measuring resistance as well as testing for open circuits. Grid test can be made on A.C. or D.C. screen-grid tubes —also the '27 tubes when used as a detector—without the use of adapters. Two sockets on the panel —UY tube adapters eliminated.

Weston
PIONEERS SINCE 1888
INSTRUMENTS

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

POWER AND DEPENDABILITY FOR BROADCASTING

THE prestige attained by Cardwell Condensers is due to their fundamentally correct design. They have always been held to first principles, not dressed up to meet popular fancy, not cheapened to meet competition on the bargain counter. Though universally imitated as nearly as may be, Cardwell design affords a measure of efficiency and performance that continues to be the yardstick by which the desirability of other condensers is measured. Variable and Fixed (Air Dielectric) Condensers in powers to 50 KW. Write for literature



Special Fixed Transmitting Condenser, Type 2202 (several capacities, 140 mmf. to 1400 mmf.). Working voltage 30000 volts.

CARDWELL CONDENSERS

THE ALLEN D. CARDWELL MFG. CORPORATION
81 PROSPECT STREET + + BROOKLYN, N.Y.

"THE STANDARD OF COMPARISON"

G. & H. VOLTAGE CONTROL

Gardner & Hepburn, Inc., 2100 Washington Ave., Philadelphia, Pa. have introduced a new line ballast, known as the Continental Voltage Control No. 2. This control is in effect, an automatic rheostat, working on the positive temperature co-

Gardner & Hepburn Voltage Control.

efficient of a special iron alloy wire. This voltage control, which is air cooled, maintains a constant line voltage and prevents damage to vacuum tubes due to line surges, etc. The price of the deviec is $1.50.

ROLLER-SMITH PYROMETER

The Roller-Smith Company, 233 Broadway, New York City, announces the new Type FD Pyrometer.

The FD Pyrometer outfit consists of a pyrometer, 4-inches in diameter, a thermocouple and leads. The specific application of the device is the indication of the temperature of molten type metal as used with various kinds of type casting machines.

As compared with glass tube thermometers there are many points of superiority. A few are as follows:

1. Readings can be taken from any position and from considerable distances.
2. There is no breakage and the FD Pyrometer is strong, sturdy and, with reasonable care, will give good results over long periods.
3. Not damaged by abnormal temperatures.
4. The range is from zero to 1200° F.

The list price of $50.00, complete, is subject to liberal discounts.

NEW BELDEN AERIAL KIT

To solve the problem of radio owners who use an outside ground, the Belden Manufacturing Company, 2300 S. Western Avenue, Chicago, Illinois, has provided an Aerial Kit with two Window Lead-in Strips of insulated flat tinned copper. In addition to these strips the new Kit includes 75 feet Belden Bare Copper 7 x 22 Aerial Wire, 35 feet rubber covered Lead-in and Ground Wire, 1 Standard Type Lightning Arrester, 1 Belden Ground Clamp, two 3-inch Glass Insulators, 2 Nail-on Knobs, 2 galvanized screw eyes, 2 wood screws, and 1 instruction sheet.

New Belden Aerial Kit.

AUTOMATIC TIME CLOCK REGULATES RADIO SET

An attractive innovation has just appeared on the radio market in the form of an automatic clock that turns on and off the radio set. This clock may be attached to any radio set and the set tuned to the favorite station. At the hour of the favorite program, the clock will turn on the set regardless of where the owner may be. There is no danger of the station going off the air and the owner forgetting to turn off the set, for the clock does the job at the appointed time.

Another indispensable use of the clock is in the case of centralized radio installations, such as hotels, hospitals, schools, etc., where a number of receivers, automatically adjusted, carry a number of programs to the guests, patients or students. Installations of this type are entirely automatic, the wave channels being permanently selected. When working in conjunction with a clock of this type, the human element is entirely eliminated and the installation requires no attention month in and month out.

The new radio clock is extremely simple, working on an entirely new principle. The bottom part is the clock proper which, incidentally, is built in such a manner that the face protrudes through the panel, while the upper part of the clock, which is the time adjustment, is secreted behind the panel. This upper part has a small dial divided into twenty-four hours, with two movable hands. One is adjusted to start the set by turning it to the desired hour, A. M. or P. M., while the other arm reverses the process and stops the set.

Several manufacturers make use of a clock of this nature in their regular console model, according to Geo. E. Palmer, General Sales Manager of the Dubilier Condenser Corp., New York, manufacturers of the new radio clock. Its widespread appeal makes it certain that more and more of a demand will be evinced in a model of this sort at a reasonable price.

BRACH ARRES-TENNA

The L. S. Brach Mfg. Corp., are introducing a new product which is the result of an experience that dates back twenty-three years in the manufacture of electrical protective devices. This new product is called the Arres-Tenna and it is the first means of fully protecting electric radio sets against lightning which may enter either through the outdoor antenna or through 110 volt service wiring.

The introduction of electric sets has brought an additional hazard to radio because of the direct connection of 110 volt lighting circuits to the delicate wiring which is part of the power packs of radio sets and which is unusually sensitive to lighting induction. These facts have been fully verified by the number of radio sets brought to the Brach Company for repairs as a result of having offered a $100.00 free insurance guarantee with each Storm King Lightning Arrester which is designed to give protection against lightning induction entering through an outdoor antenna. As these sets have been coming in so frequently the Brach Company have found it necessary to make an Arrester that not only offers a "double protection for a double danger" but offers at the same time a light-socket aerial as the instrument is built between the lighting circuit and the aerial.

This combination further serves to improve reception by reason of increasing the capacity of the aerial circuit, acting as a filter and also providing a convenient outlet to the radio set attachment plug.

The instrument lists at $2.50 and carries a $100.00 free insurance guarantee.

NEW OXFORD DYNAMIC SPEAKER

Mr. Frank Reichmann, Vice-President and Chief Engineer of the Oxford Radio Corporation announces an additon to their regular line of Dynamic Speakers of the Auditorium Series which speakers have an overall height of 12¼ inches and a diaphragm measuring 11¾ inches. With these models, the Oxford line now includes standard speakers with 8-inch, 10-inch and 11¾-inch diaphragms.

This Auditorium Series is designed especially for Theatre work and for use in DeLuxe, high-priced sets where a speaker of exceptionally large size is desired. The one-piece cloth diaphragm which is metallized by a special process found only in Oxford Speakers is puncture proof with a controlled edge giving superior quality at all frequencies.

THE NEW DE FOREST 410 AUDION

The DeForest Radio Company of Jersey City, N. J., announces at this time a new DeForest 410 Audion especially designed for use as an oscillator or as a radio-frequency power amplifier in transmitting practice. It is also available as a power amplifier in audio systems.

The difference between the new DeForest 410 audion and the usual -10 type tube is immediately apparent. Creolite plate supports and mica spacers at the top afford

The deForest 410 Audion, especially designed for use as oscillator or radio-frequency power amplifier.

protection against voltage breakdowns common to the regular -10 type tubes when employed for high-frequency work. The use of an oxide-coated filament means greatly increased life as well as an operating temperature less than one-third that of the usual thoriated-tungsten filament. "Creeping" is entirely overcome, as it is virtually impossible to heat the carbonized plate which has nearly twice the area usually employed in the usual -10 type tube. In fact, the new 410 audion is capable of dissipating as high as 25 watts of energy.

The characteristics of the new DeForest audion are as follows:

Filament Voltage..........	7.5 Volts
Filament Current....... ..	1.25 Amperes
Normal Plate Voltage......	425 Volts
Normal Plate Current......	80 Milliamperes

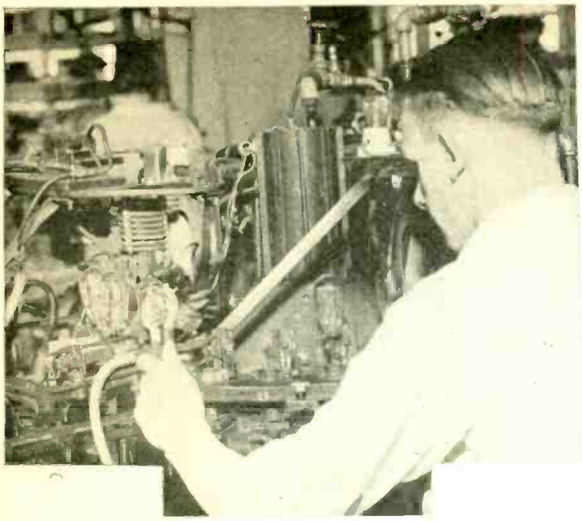
DE FOREST D-C SCREEN-GRID AUDION

The DeForest "422 d-c." screen-grid audion employs a special oxide-coated filament in place of the usual thoriated-tungsten filament. The new filament is three times the diameter of the usual filament, and operates at one-third the usual temperature, with more than ample emission together with a life well in excess of a thousand hours. Due to the bulk and the rigidity of the filament, the usual microphonic trouble is entirely avoided in the new audion.

The new deForest "422 D.C" screen-grid tube, which has a heavy oxide-coated filament.

Another distinctive feature is the mechanical construction of exceptional rigidity, so as to insure permanent positioning of the elements and positively to eliminate any chance of displacement during shipment or handling. In this way the standard characteristics built into the stem are positively maintained throughout the life of the audion. The characteristics are as follows:

Filament Voltage..............	3.3 Volts
Filament Current..............	.132 Ampere
Plate Voltage....................	135 Volts
Control Grid Voltage..........	—1.5 Volts
Screen-grid Voltage...........	+45 Volts



It's the Vacuum
that gives their remarkable
Performance and Life!

TO the uninitiated "vacuum" means nothing—but to the engineer—in radio tubes—it means everything. And no process of manufacture in making De Forest Audions is more zealously watched, checked and supervised than the exhausting and bombarding.

To assure the greatest degree of vacuum possible the cycle of exhausting operation is so regulated that every De Forest Audion is pumped to one Micron of vacuum. During this cycle, each Audion has been subjected to four positions of bombardment to drive out of the metal elements all gases and water vapor that otherwise would cause gaseous and soft tubes and rapid deterioration.

This exacting phase of tube production typifies the conscience—the care—the close tolerances with which De Forest Audions are made in all the other phases of their manufacture. It is why De Forest Audions have continuously established the world's standard for 23 years.

All tubes—no matter what their brand name—are made by license arrangement under De Forest-owned patents—but only De Forest Audions bear the name of the inventor.

DE FOREST RADIO CO., JERSEY CITY, N. J.

de Forest
AUDIONS

The *Never-Ending* Quest...

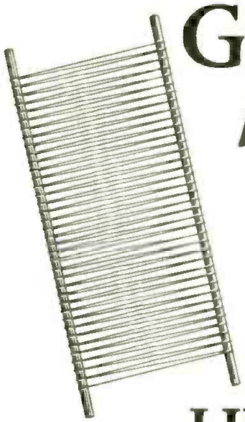
Among radio engineers and radio set manufacturers Arcturus *Blue* A-C Tubes have gained an enviable reputation. Their quick action, freedom from hum, immunity to line surge, and long life have made Arcturus the standard tube for test and experimental purposes.

But Arcturus engineers are constantly striving to improve Arcturus' performance. New designs, new materials, new manufacturing methods are continually being tried out to make Arcturus Tubes give better results in every A-C set.

Arcturus' present standing with radio listeners and radio engineers is due to this pioneering spirit...this never-ending quest for higher quality.

ARCTURUS RADIO TUBE COMPANY, Newark, N. J.

ARCTURUS
BLUE A-C LONG-LIFE TUBES



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Fansteel metals are made under laboratory control, which means that they adhere rigidly to high standards of purity and close tolerances of dimension. The Fansteel laboratory gladly aids manufacturers in the improvement of their products and processes.

Send for a copy of Fansteel's new book, "Rare Metals," which explains the unusual characteristics of little-known metals and alloys, and suggests many profitable uses.

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NORTH CHICAGO, ILLINOIS

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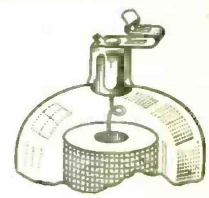

See Page 69

M.&W.Co. 1876

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Our Consulting and Advisory Service based upon Specialized Experience in this field will help you.

Whether it be Cabinets, Name Plates, Chassis, Shields, Coils, Paper Cones, Condensers, Resistors, or other parts, some of the materials listed will interest you.

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- Colored Resistor Enamel
- Coil Enamel
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Your inquiry is invited.

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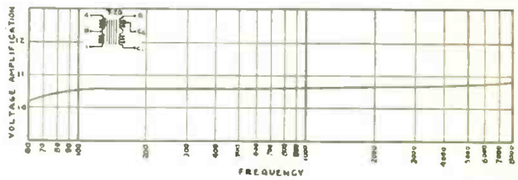
Type "T" Transformers

A Curve from 60 to 10,000 Cycles is Run on Every One of These Before It is Shipped



We can announce at this time that we have increased the production of our extremely high quality hand wound transformers and retards to a point which enables us to carry a stock for immediate shipment. The list includes the T-20, T-36, T-40, T-41, and T-42 Transformers, and the T-48, T-49, T-50, T-51, and T-52 Retards.

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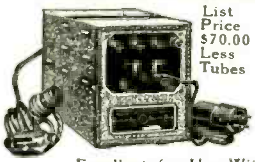

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This Unit uses a UX281 Tube for Rectifying and UX210 Tube as Amplifier.

Excellent for Use With Dynamic Speakers

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Addresses of companies listed below, can be found in their advertisement—see index on page 96.

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LACQUERS:
Maas & Waldstein Co.
Zapon Co., The

LACQUER, WOOD:
Maas & Waldstein Co.
Zapon Co., The

LACQUER, METAL:
Maas & Waldstein Co.
Zapon Co., The

LACQUER, ENAMEL:
Maas & Waldstein Co.
Zapon Co., The

LAMINATIONS:
Lamination Stamping Co.
Willor Mfg. Co.

LAMPS, MINIATURE:
National Carbon Co., Inc.

LAMPS, PANEL:
National Carbon Co., Inc.

LAMPS, SOUND RECORDING:
G. M. Laboratories, Inc.

LEAD-INS:
Electrad, Inc.

LOCK WASHERS:
Shakeproof Lock Washer Co.

LUGS:
Scovill Mfg. Co.
Shakeproof Lock Washer Co.

MACHINERY, TUBE:
Arrow Mfg. & Machine Co., Inc.
Engineering Co., The
Central Scientific Labs.
Eisler Eng. Co.
Lepel High Frequency Labs.
Manhattan Electric Bargain House, Inc.
Radio Products Corp.

MACHINES, SPECIAL
Willor Mfg. Corp.

MAGNESIUM:
Aluminum Co. of America.

MAGNETS:
Thomas & Skinner Co.

METALS, RARE:
Fansteel Products Co., Inc.
American Electro Metal Corp.

MERCURY SWITCHES:
(See Switches)

METERS:
General Electric Co.
Jewell Elec. Inst. Co.
Weston Elec. Instr. Co.

MICROPHONES:
Amplion Co. of America
Electro-Acoustic Prod. Co.
Jenkins & Adair, Inc.
Universal Microphone Co.

MOLDING MATERIALS
Bakelite Corp.
Formica Insulation Co.
General Electric Co.
General Plastics Co.
National Vulcanized Fibre Co.
Synthane Corp.

MOTORS:
Electric Specialty Co.

MOTOR-GENERATORS:
Electric Specialty Co.

MOUNTINGS, RESISTANCE:
DeJur-Amsco Co.
Electrad, Inc.
Lynch, Arthur H., Inc.
Polymet Mfg. Corp.

NAMEPLATES:
Crowe Nameplate & Mfg. Co.
Scovill Mfg. Co.

NUTS:
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OHMMETERS:
General Radio Co.
Weston Elec. Instru. Co.

OSCILLOGRAPH:
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General Radio Co.

OSCILLOSCOPE:
Robert C. Burt Scientific Labs

PACKING PADS CABINET:
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Scovill Mfg. Co.

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(See Motors)

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(See Cells)

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PLUGS:
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DeJur-Amsco Co.
Electrad, Inc.
General Radio Co.
Polymet Mfg. Corp.
United Scientific Laboratories

POWER UNITS, A-:
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Jefferson Electric Co.
Kodel Radio Corp.

POWER UNITS, B-:
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General Radio Co.
Jefferson Electric Co.
National Co., Inc.
Thordarson Electric Mfg. Co.
Webster Co.

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General Radio Co.
Jefferson Electric Co.
Kodel Radio Corp.
National Co., Inc.
Thordarson Electric Mfg. Co

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American Transformer Co.
Dongan Elec. Mfg. Co.
General Radio Co.
Jefferson Electric Co.
Kodel Radio Corp.
Lynch, Arthur H., Inc.
National Co., Inc.
Nelson, I. R., Co.
Polymet Mfg. Corp.
Powrad, Inc.
Thordarson Electric Mfg. Co.
Transformer Co. of Amer.

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Scovill Mfg. Co.

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Samson Elec. Co.

PUMPS, HIGH VACUUM:
Arrow Mfg. & Machine Co., Inc.

PUNCHINGS:
Aluminum Co. of America
Scovill Mfg. Co.

RECEPTACLES, WALL:
Carter Radio Co.

RECTIFIERS, DRY:
Elkon, Inc.
Kodel Elec. & Mfg. Co.

REGULATORS, VOLTAGE:
Central Radio Laboratories
Clarostat Co.
DeJur-Amsco Co.
Polymet Mfg. Corp.
Radiall Co.
Ward Leonard Elec. Co.

RELAYS:
Cardwell, Allen D., Mfg. Co.
Leach Relay Co.

REPRODUCERS, TALKING MOTION PICTURES:
R. C. Burt Scientific Labs.

RESISTANCES, FIXED:
Aerovox Wireless Corp.
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Central Radio Laboratories
DeJur-Amsco Co.
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Electro-Motive Co.
Frost, Herbert H.
Hardwick, Hindle Inc.
International Resistance Co.
Lynch, Arthur H., Inc.
C. E. Mountford
Polymet Mfg. Corp.
Ward Leonard Elec. Co.

RESISTANCES, VARIABLE:
Allen-Bradley Co.
Central Radio Laboratories
Electrad, Inc.
Electro-Motive Co.
Frost, Herbert H.
Hardwick, Hindle, Inc.
International Resistance Co.
Lynch, Arthur H., Inc.
C. E. Mountford
Polymet Mfg. Corp.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

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Allen-Bradley Co.
Central Radio Laboratories
DeJur-Amsco Co.
Electrad, Inc.
Electro-Motive Co.
Frost, Herbert H.
General Radio Co.
Polymet Mfg. Corp.
United Scientific Laboratories

SCREW MACHINE PRODUCTS:
Aluminum Co. of America
National Vulcanized Fibre Co.
Scovill Mfg. Co.
Standard Pressed Steel Co.
Synthane Corp.

SEALING COMPOUNDS:
Candy & Co.
Mitchell Rand Mfg. Co.

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Hammarlund Mfg. Co., Inc.

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Radio Products Corp.

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Hammarlund Mfg. Co., Inc.
Lynch, Arthur H., Inc.

SOCKETS, TUBE:
Frost, Herbert H.
General Radio Co.
Lynch, Arthur H., Inc.

SOLDER:
Chicago Solder Co.

SOUND CHAMBERS:
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Jensen Radio Mfg. Co.
Miles Mfg. Corp.
Oxford Radio Corp.
Rola Co., The

SOUND RECORDING LAMPS
(See Lamps)

SPAGHETTI:
(See Wire, Spaghetti).

SPEAKERS:
Amplion Corp. of Amer.
Electro-Acoustic Prod. Co.
Best Mfg. Co.
Jensen Radio Mfg. Co.
Magnavox Co.
Miles Mfg. Corp.
Oxford Radio Corp.
Potter Co., The
Rola Co., The
Transformer Co. of Amer.
Wright-DeCoster, Inc.

STAMPINGS, METAL:
Aluminum Co. of America
Radio Products Corp.
Scovill Mfg. Co.

STEEL, MAGNETIC:
See *(Iron Magnetic.)*

SUBPANELS:
Formica Ins. Co.
General Radio Co.
National Vulcanized Fibre Co.

SWITCHES:
Electrad, Inc.
Insuline Corp. of Amer.

SWITCHES, MERCURY:
G. M. Laboratories, Inc.

TABLES, STEEL WORK:
Standard Pressed Steel Co.

TANTALUM:
Fansteel Products Co., Inc.

TAPES, FRICTION:
Mitchell Rand Mfg. Co.

TAPPERS
Eastern Tube and Tool Co.

TELEVISION PARTS:
Allen-Bradley Co.
Clarostat Co., Inc.
Lynch, Arthur H., Inc.
Shallcross Mfg. Co.

TESTERS, B-ELIMINATOR:
General Radio Co.
Jewell Electrical Inst. Co.

TESTERS, TUBE:
General Radio Co.
Jewell Elec. Inst. Co.

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

TESTING KITS:
Jewell Elec. Inst. Co.

TESTING LABORATORIES:
Electrical Testing Labs.

TIN COATED METAL:
Baltimore Brass Co.

TOOL STANDS:
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TOOLS:
Eastern Tube and Tool Co.
Willor Mfg. Corp.

TRANSFORMERS, AUDIO:
Dongan Elec. Mfg. Co.
Ferranti, Ltd.
General Radio Co.
Jefferson Electric Co.
National Co., Inc.
Samson Elec. Co.
Sangamo Elec. Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America
Webster Co.

TRANSFORMERS, B-POWER UNIT:
Dongan Elec. Mfg. Co.
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General Radio Co.
Jefferson Electric Co.
National Co., Inc.
Nelson, I. R., Co.
Samson Elec. Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America
Webster Co.

TRANSFORMERS, BROADCAST STATION:
Samson Electric Co.

TRANSFORMERS, FILAMENT HEATING:
Dongan Elec. Mfg. Co.
General Radio Co.
Jefferson Electric Co.
Nelson, I. R., Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America

TRANSFORMERS, OUTPUT:
Dongan Elec. Mfg. Co.
Ferranti, Ltd.
General Radio Co.
Jefferson Electric Co.
Nelson, I. R., Co.
Samson Elec. Co.
Sangamo Elec. Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America

TRANSFORMERS, POWER:
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General Radio Co.
Jefferson Electric Co.
National Co., Inc.
Nelson, I. R., Co.
Polymet Mfg. Co.
Samson Elec. Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America
Webster Co.

TRANSFORMERS, R. F., TUNED:
Cardwell, Allen D. Mfg. Co.
Hammarlund Mfg. Co., Inc.

TRANSFORMERS, STEP-DOWN:
Amplion Corp. of Amer.

TUBE MACHINERY:
See (Machinery, Tube.)

TUBES, A.C.:
Allan Mfg. Co.
Arcturus Radio Co.
Armstrong Elec. Co.
Cable Radio Tube Co.
De Forest Radio Co.
Duovac Radio Tube Co.
Gibraltar Radio Supply Co.
Hyvac Radio Tube Co.
National Carbon Co., Inc.
Perryman Electric Co.
Sylvania Products Co.
Televocal Corp.
Triad Mfg. Co.

TUBES, RECTIFIER:
Allan Mfg. Co.
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Duovac Radio Tube Co.
Gibraltar Radio Supply Co.
Hyvac Radio Tube Co.
National Carbon Co., Inc.
Perryman Electric Co.
Sylvania Products Co.
Televocal Corp.
Triad Mfg. Co.

TUBES, SCREEN GRID:
Allan Mfg. Co.
Arcturus Radio Co.
Armstrong Elec. Co.
Cable Radio Tube Co.
De Forest Radio Co.
Duovac Radio Tube Co.
Gibraltar Radio Supply Co.
Hyvac Radio Tube Co.
National Carbon Co., Inc.
Perryman Electric Co.
Sylvania Products Co.
Televocal Corp.
Triad Mfg. Co.

TUBES, TELEVISION
See *(Cells, Photoelectric.)*

TUBES, VACUUM:
Allan Mfg. Co.
Arcturus Radio Co.
Armstrong Elec. Co.
Cable Radio Tube Co.
De Forest Radio Co.
Duovac Radio Tube Co.
Gibraltar Radio Supply Co.
Hyvac Radio Tube Co.
National Carbon Co., Inc.
Perryman Electric Co.
Sylvania Products Co.
Televocal Corp.
Triad Mfg. Co.

TUBING, VARNISHED:
Mitchell Rand Mfg. Co.

UNITS, SPEAKER:
Amplion Corp.
Best Mfg. Co.
Jensen Radio Mfg. Co.
Rola Co.
Temple, Inc.
Transformer Corp. of America
Wright DeCoster, Inc.

VARNISH:
Maas & Waldstein Co.
Mitchell Rand Mfg. Co.
Zapon Co., The.

VOLTAGE REGULATORS:
(See Regulators)

VOLTMETERS, A. C.:
General Electric Co.
General Radio Co.
Jewell Elec. Inst. Co.
Weston Elec. Instrument Corp.

VOLTMETERS, D. C.:
General Electric Co.
General Radio Co.
Jewell Elec. Inst. Co.
Weston Elec. Instrument Corp.

WASHERS:
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Scovill Mfg. Co.
Shakeproof Lock Washer Co.
Synthane Corp.

WAXES, IMPREGNATING:
Candy and Co.
Mitchell Rand Mfg. Co.

WAXES, INSULATING:
Candy and Co.
Mitchell Rand Mfg. Co.

WAXES, SEALING:
Candy and Co.
Mitchell Rand Mfg. Co.

WIRE, ANTENNA:
Acme Wire Co.
Dudlo Mfg. Corp.
National Vulcanized Fibre Co.
Roebling, J. A., Sons, Co.
Rome Wire Co.

WIRE BALLAST:
National-Harris Wire Co.

WIRE, BARE COPPER:
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Roebling, J. A., Sons, Co.
Rome Wire Co.

WIRE, COTTON COVERED:
Acme Wire Co.
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.
Rome Wire Co.

WIRE, ENAMELED COPPER:
Acme Wire Co.
Dudlo Mfg. Corp.
Polymet Mfg. Corp.
Roebling, J. A., Sons Co.
Rome Wire Co.

WIRE, FILAMENT:
American Electro Metal Corp.
Callite Products Co., Inc.
Fansteel Products Co., Inc.
Gilby Wire Co.
National-Harris Wire Co.
Radio Products Corp.
Vacuum Tube Products Co.

WIRE, HOOK-UP:
Acme Wire Co.
Dudlo Mfg. Co.
Roebling, J. A., Sons, Co.
Rome Wire Co.

WIRE, LITZENDRAHT:
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.
Rome Wire Co.

WIRE, MOLYBDENUM:
American Electro Metal Corp.
Callite Products Co., Inc.
Fansteel Products Co., Inc.
Palatine Industrial Co., Inc.

WIRE, PIGTAIL:
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.
Rome Wire Co.

WIRE, RESISTANCE
Gilby Wire Co.
National-Harris Wire Co.

WIRE, SILK COVERED:
Acme Wire Co.
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.
Rome Wire Co.

WIRE, SPAGHETTI:
Acme Wire Co.
Mitchell Rand Mfg. Co.
Rome Wire Co.

WIRE, TINNED COPPER:
Dudlo Mfg. Corp.
Roebling, J. A., Sons, Co.
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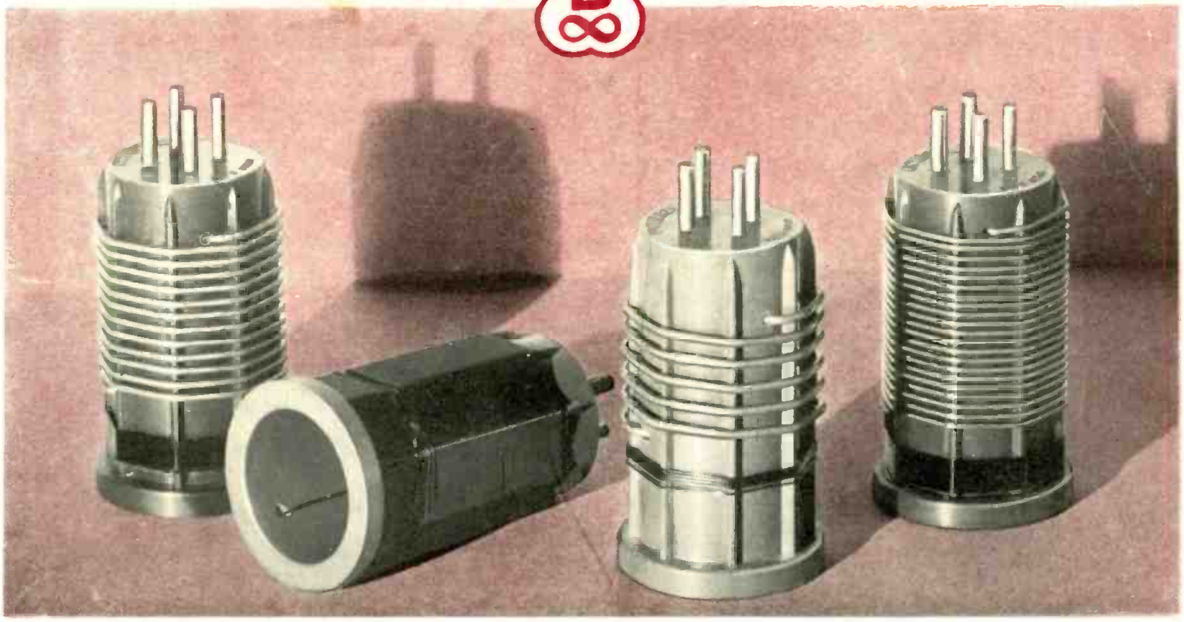

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