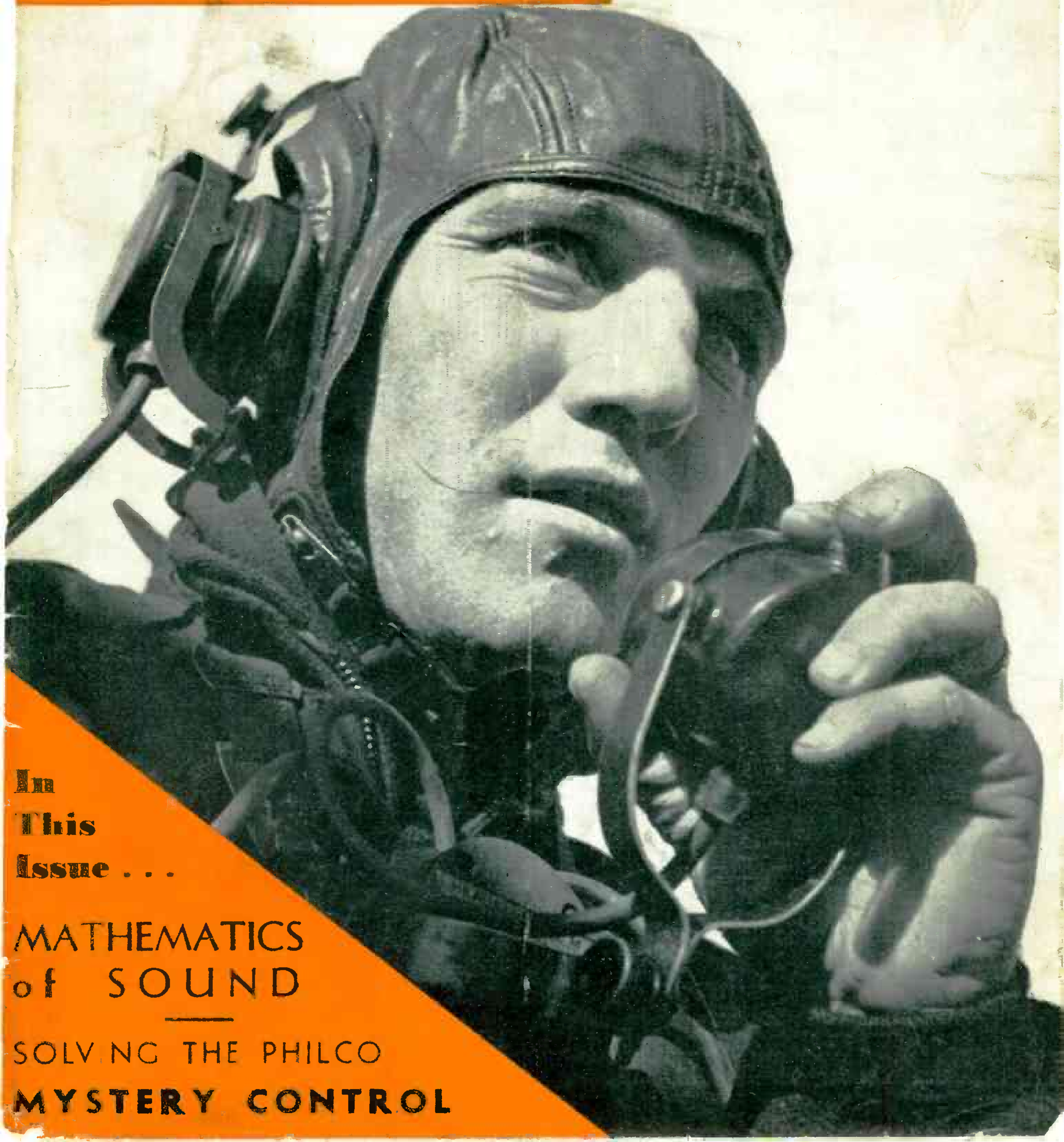
Radio
SERVICE DEALER

NOVEMBER
1943



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MATHEMATICS of SOUND

SOLVING THE PHILCO
MYSTERY CONTROL

1. Loud Speakers and Their Use
2. Superheterodyne First Detectors and Oscillators
3. Half-Wave and Voltage Doubler Power Supplies
4. Vibrators and Vibrator Power Supplies
5. Phono-Radio Service Data
6. Automatic Tuning
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VOL. 4, NO. 11

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"Navy Radioman at the Mike"

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SANFORD R. COWAN . . . . . **Editor & Publisher**

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132 West 43rd St., N. Y. 18, N. Y.
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Chicago, Illinois

RADIO SERVICE-DEALER, published monthly at 34 N. Crystal Street, East Stroudsburg, Pa., by the Cowan Publishing Corp. Executive and Editorial Offices at 132 W. 43rd Street, New York, 18, N. Y. Subscription rates—United States and Possessions, $2.00 for 1 year, $3.00 for 2 years; elsewhere $3.00 per year. Single copies 25c. Printed in U.S.A. Entered as Second Class Matter October 3, 1941, at the Post Office at East Stroudsburg, Pa., under the Act of March 3, 1879.

with the editor . . . . . .

TRIMMED AGAIN!

PAPER RESTRICTIONS force us again to trim the white margin closer to the black text. Paper savings so effected will be put right back into additional pages of text so that subscribers will benefit. Type matter in this and future issues may be smaller than that used heretofore so that more text will appear on less pages. We have also ordered a lighter weight stock. Future issues will be from 20% to 50% larger in number of pages, with no increase in total paper tonnage used.

Summarized, henceforth subscribers will get a lot more for their money!

★

THE CASE OF THE MISSING HALF-MILLION TUBES

THE ESTIMABLE WPB announced on or about October 12th that a half-million tubes being held by an export house were being offered for sale on open bid. On the heel of this announcement came word from a Reading, Penna. distributor that the tubes in question had been purchased by his organization. Thereupon we wrote the distributor urging that he exercise good judgment and spread the tubes equitably throughout the country. Within 24 hours he replied that "the Navy has padlocked the tubes, in spite of the WPB release." He also wrote, "This tube deal would make the best fiction story in history — no one would believe it."

Days have passed and nothing more has been heard about those tubes. Shades of *Sherlock Holmes* and *Ellery Queen* — what a mystery! We suggest that it be solved, and soon.

What say you, Mr. Barbey?

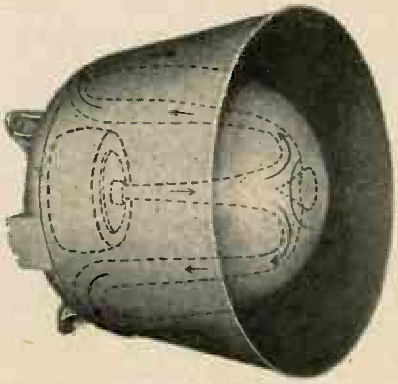
★

FIGURES DON'T LIE — SOMETIMES!

A GROUP OF gentlemen engaged in the commercial broadcasting business recently made a survey of conditions and reported that many thousands of radio receivers are becoming inoperative daily due to replacement tube and parts shortages. Then evidently someone realized that they'd "spilled the beans." If listening audiences were becoming smaller, obviously time rate charges must be lowered. To offset the potential threat to earning which the report engendered, a new tactic was employed: it was subsequently announced that "broadcast program listening is *up* from 16% to 60% because gasoline restrictions and rubber shortages now force the public to stay at home more. Consequently, radio programs have larger audiences than ever."

It is true that many homes had two or more radios and that not all the sets in homes have gone out of use. But from what our readers tell us many homes owning but a single radio now have not even that operating.

A Safe Bet for Steady Sales



Left—MARINE SPEAKER; approved by the U. S. Coast Guard, for all emergency loudspeaker systems on ships. Re-entrant type horn. Models up to 50 watts. May be used as both speaker and microphone.

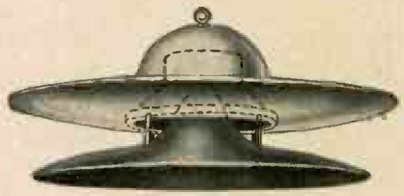
Right—RE-ENTRANT TRUMPET; available in 3½', 4½' and 6' sizes. Compact. Delivers highly concentrated sound with great efficiency over long distances.

Left—RADIAL HORN SPEAKER; a 3½' re-entrant type horn. Projects sound with even intensity over 360° area. Storm-proof. Made of RACON Acoustic Material to prevent resonant effects.

Right—AEROPLANE HORNS; super-powerful and efficient P.A. horns for extreme range projection. 9 and 4 unit Trumpets available.

Left—PAGING HORN; extremely efficient 2' trumpet speaker for use where highly concentrated sound is required to override high noise levels. Uses P.M. unit.

Right—RADIAL CONE SPEAKER; projects sound with even intensity over 360° area. Cone speaker driven. Will blend with ceiling architecture. RACON Acoustic Material prevents resonant effects.



SEND FOR CATALOG

RACON, pioneer and world's largest manufacturer of loudspeakers, horns and driving units, is working at capacity filling diversified orders — speakers for Army, Navy, Maritime Commission and industrial use. Now we are planning ahead.

Practically all industrial firms are users, or potential users of some type public-address, paging or sound distribution system. Statistics prove that a properly planned sound system installation is a good investment which in time generally pays for itself.

RACONS have always enjoyed a steady, high sales volume. We believe they always will, for our products are the finest that money can buy, or engineering skill produce. Receiver units supplied with either metal or plastic diaphragms. RACON products generally cost less than competitive brands because a lower power-rated and lower-priced RACON will outperform higher power-rated units of other make. In other words, don't let catalog list-prices fool you. Basic costs and rated outputs are the prime factors worth considering. That's why leading soundmen prefer and specify RACONS, they are dependable—a safe bet for steady sales and satisfied users.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

RACON ELECTRIC CO. 52 EAST 19th ST. NEW YORK, N. Y.

IN and AROUND the TRADE . . .

Being a condensed digest of some of the happenings in and around the radio trade as compiled by the Editors . . . .

Mitchell Bearish on Post War Buying but Bullish on Salesmen

To provide the volume of business necessary to avoid disastrous unemployment after the war, every man, woman and child must make purchases of goods and services totaling at least $1,000, Don G. Mitchell, vice-president in charge of sales of Sylvania Electric Products Inc., told a group of electrical industry executives in Chicago recently.

"Unless we want to have millions of people walking the streets looking for jobs when this war is over, every man, woman and child in this country will have to buy $1,000 worth of goods and services, if industry is to be able to provide the necessary jobs," Mr. Mitchell declared. "This will call for an annual output of 135 billion dollars worth of goods and services, compared to the total of only 98 billion dollars in the boom year of 1929.

"Furthermore, this problem will be complicated by the fact that rationing or other controls of some type will unquestionably be continued for a while after the war, in order to avoid runaway inflation when savings now in war bonds are released for spending. That means that the production man, who has been all-important for the past few years and who has done a magnificent job, will step down as directing genius of American industry and hand over his baton to the salesman."

Mr. Mitchell stated that the postwar development of the newer industries such as aviation and prefabricated housing would play an important part in maintaining this high level of expenditure. Of most promise, he said, is the electronics industry, which will find thousands of new jobs to do in manufacturing and transportation. At the same time, he scoffed at the exaggerated ideas that have grown up around this subject.

OPA Cracks Down; Collects 35 Gees.

The Benjamin T. Crump Co., Inc., wholesale radio distributor of Richmond, Va., has paid the U. S. Treasury $35,000 as a compromise settlement of a treble damage claim against it by the OPA for sales of radios to retailers at prices above legal ceilings, that agency's Enforcement Department announced today.

OPA stated that over-charges totaling about $23,000 had been made by the company on several thousand radios sold to retailers from August 1942 to May 1943.

This settlement disposed of one of the biggest cases handled by OPA involving violations of price ceilings on household goods.

Crosley VP Says What's To Come is $64 Question

Speaking in New York recently, Raymond C. Cosgrove, vice president and general manager, manufacturing division of the Crosley Corporation to Cincinnati, Ohio, said:

"Difficult as was the conversion from peace-time to war production for many manufacturers, the re-conversion to civilian production after the war will be much more difficult.

"In war production, the factors of time, value and quality are much more important than that of cost, while, in manufacturing in peace-time under highly competitive conditions, the element of cost is of major importance. This in itself involves an entire re-adjustment of methods and policies.

"In many plants, like our own, it will be impossible to get into production of civilian goods while filling the full schedule of war orders, for war product facilities must be made available before a start can be made on domestic production.

"Many problems must be faced and solved before post-war operations can be started. Some of these problems now under government control are:

"Who will get the first materials allotted for civilian use?

"What provision will be made for reconversion of companies filling large war orders?

"How much production will each company be allowed to make?

"What models will be permitted, and how many?

"Will there be Victory models?

"What prices can be established?

"What forms of distribution will be permitted?

"What controls are to be maintained and for how long?

"What preference ratings will there be for materials?

"These and many more questions must be answered and none of us knows all the answers yet."

SCA Jumps Gun with Theater Television

Perfected large screen television (up to 20 feet or more screen size) for motion picture theatres, homes, schools and churches, both in black-and-white and natural color, will be available commercially soon after hostilities cease as a result of basic patents issued by the Patent Office in Washington to Scophony Corporation of America, it was announced by Arthur Levey, President of SCA. The company is associated with Television Productions, Inc., a subsidiary of Paramount Pictures, and General Precision Equipment Corporation, which in turn is associated with Twentieth Century-Fox Film Corporation.

Mr. Levey revealed that SCA engineers are now working to make three-dimensional television a reality. Some leaders of the radio industry, says Mr. Levey, have expressed a belief that television broadcasting may develop on a subscriber basis as a means toward solving certain financial problems. If such method should be deemed desirable by the regulatory authorities, Scophony is prepared to provide it, since the company has already patented a "Secret Television" method whereby transmitted pictures which are scrambled at the source may be reproduced on television receiver screens of subscribers in full clarity. Such receivers would be provided with key patterns by means of which the received signals are unscrambled again so that only these subscriber receivers would be enabled to receive a clear and intelligible picture.

New WPB Order Leaves WERS Out In Cold; Helps Repairing Servicemen

Preference Rating Order P-133 was revised today by the War Production Board to make it the exclusive controlling order for obtaining maintenance, repair and operating supplies for radio communication and radio broadcasting.

For obtaining supplies, the rating of AA-5, without the "MRO" symbol is specifically assigned for the businesses of sound recording for commercial, educational and industrial purposes, and in the operation and maintenance of public address, intercommunication, plant sound and similar electronic systems, including systems for the controlled distribution of musical programs. Order P-133 previously had given an AA-2X rating for maintenance, repair and operating supplies for sound recording for commercial purposes.

Other changes in Order P-133 include a clarification of tube inventory restrictions. Use of ratings and allotment symbol to buy or repair a tube is prohibited unless a person has in stock less than one new and one rebuilt tube, or two rebuilt spare tubes per active socket. The previous order did not restrict the number of repaired tubes that could be stocked. However, no important change in the average radio station's stock is likely to result from this restriction.

Another added restriction bars use of the ratings to obtain supplies for the War Emergency Radio Service, the amateur operators' group under the Office of Civilian Defense.

Service repair shops doing maintenance and repair work for persons engaged in radio communication may use the rating and symbol of a customer to do such work, and the restrictions on use of ratings apply as to the customer.

Mica Hit, So Condenser Production Gets Axe

Because of a serious depletion in stockpiles of better qualities of mica, the War Production Board acted today to conserve supplies of this material. Users of high-quality mica are being notified that the Board will undertake to provide only sufficient quantities of these qualities to maintain consumption at the average rate maintained during the first nine months of 1943. This policy will become effective about December 1.

In view of the gravity of the situation, the Mica-Graphite Division, after

(Continued on page 29)

Mathematics of Sound Made Easy

by IRA KAMEN

Member, Institute of Radio Engineers

Since accurate and profitable sound installations depend greatly on the knowledge of a few mathematical formulae, the author gives them here in understandably simple form.

Introduction

L. HOGBEN in his widely read book, "Mathematics for the Millions," reports the apocryphal encounter of Diderot, the great Encyclopaedist of the French Revolution, with Euler, foremost mathematician of his time. Diderot had completely captivated the nobility of the Russian court with his brilliance and glibness so completely, that an envious Tsarista decided to embarrass him publicly. Diderot was confronted by Euler who proclaimed dramatically, that he had mathematical proof of the existence of God; "$\frac{a + b^n}{n} = X$, therefore God does exist," he pronounced. "What have you to say to that?"

Diderot was confused, frightened, absolutely unable to reply. He left the Russian court in a huff and returned immediately to France, because when faced with an algebraic equation, he was helpless. He could not proceed to think or argue successfully. Possibly the greatest stumbling - block to a clear understanding of many electronic engineering problems is this very fear of mathematics, and the consequent desire to avoid those questions with which that subject is concerned.

It is the purpose of this article to present the basics of *audio mathematics* in a simple form, divorced from the burden of Greek symbols and complicated formulas. Letter symbols will be shown only to permit their identification when found elsewhere.

The Decibel

Since the ear responds logarithmically, (see *"Basics of Sound," July* RADIO SERVICE-DEALER), the unit of audio measurement should be one which follows logarithmic ratios. This unit is known as the decibel and is abbreviated *db*. Familiarity with this unit and its application is essential to all who would undertake audio design. In this connection a brief review of logarithms will prove helpful.

Logarithms

It will be remembered that a logarithm is an exponent. Consider the following powers (or exponents) of 10.

$10^{-4} = 0.0001$
$10^{0} = 1.0000$
$10^{3} = 1000.0$

The exponent of 10 on the left side of the equation is called the logarithm to the base of 10 of the number on the right side of the equation. Thus —4 is the logarithm to the base 10 of 0.0001 and 3 is the logarithm to the base 10 of 1000. Another way to say this is that the logarithm (log for short) of 1000 to the base 10 is 3. The logarithm of any number to the base 10, then, is the power to which 10 must be raised to equal that number ($10^3 = 1000$).

Logarithmic tables have been established to permit ready determination of the logarithm of any given number or, given the logarithm, the determination of the number.

It is obvious that most numbers are not integral powers of 10. Thus 1666 is more than 10^3 and less than 10^4. As a result its log will be 3 plus a decimal. The whole number or integral part of the log is called its *characteristic* and the decimal part is known as the *mantissa*. The characteristic is equal to the number of digits to the left of the decimal point minus 1, or, in the case of decimal fractions, it is equal to the number of ciphers between the decimal point and the first significant number, including the significant number. Thus the characteristic of .0001 is —4 and the characteristic of .000196 is also —4; while the characteristic of 123 is 2 and 123.456 is also 2.

To find the exact log of 1666 refer to a common log table, and locate the intersection of the row that has 166 under the N column with the column headed 6 at top. See Fig. 1.

The *characteristic* of 1666 is 3

The *mantissa* of 1666 is .22167; therefore

The *log* of 1666 = 3.22167

One of the most important applications of logarithms is the translation of *power ratings* into *decibels*. Actually the decibel is a relative measure of two powers. It tells of the logarithmic ratio between them; and it will be appreciated since the ear responds to sources of sound energy logarithmically, that the logarithmic ratio of any two powers will indicate their relative value to the human ear.

In the system of common logarithms discussed above, the logarithm of the ratio of any two numbers is known as the *bel*. This unit proved too large for most calculations and in the same way that *1/1000 Farad*, the microfarad, has become the basic unit of capacity measurement, *1/10 bel*, the decibel, has become the basic unit for expressing the logarithmic ratio between any two powers.

The formula is:

$$DB = 10 \log_{10} \frac{P_2}{P_1}$$

$10 \log_{10}$ means ten times the loga-

N	0	1	2	3	4	5	6	7	8	9
165	22748	22775	22801	22827	22854	22880	22906	22932	22958	22985
166	22011	22037	22063	22089	22115	22141	22167	22194	22206	22246
167	22272	22298	22324	22350	22376	22401	22427	22453	22479	22505

Fig. 1. Extract of logarithm table

rithm to the base 10 (common logs are always figured to the base 10) of P_2 (the larger power in watts) divided by P_1 (the particular reference level used or the lower power).

For example, find the *db* rating of a 10-watt output amplifier, using a reference level of .006 watt

$$DB = 10 \log_{10} \frac{10}{.006}$$

$$= 10 \log_{10} 1666$$
$$= 10 \times 3.22167$$
$$= 32.2167 \text{ decibels at .006 watts reference level.}$$

Reference Levels

The decibel expresses the ratio between any two powers, but it must be remembered that the db is a relative not an absolute measure, and *must* therefore *be referred to some specific reference level*. Unfortunately, a number of different reference levels are in use by different organizations today. Broadcast engineers began to use a reference level of 12.5 *milli*watts (.0125 watt), based on peak power of speech in a telephone transmission line, while telephone and audio transmission line engineers have used 6 *milli*watts (.006 watt) as their reference level.

The latest of many attempts to standardize the decibel reference level is the adoption of 1 *milli*watt (.001 watt) reference level. This has been called the Volume Unit (V.U.) A volume level indicator, which reads in V.U. is manufactured for broadcast work since the V.U. is numerically equal to the number of decibels above a reference level of 1 milliwatt.

Several microphone manufacturers have employed a reference level of zero db = 1 volt. Thus a crystal microphone may have an output specification of —60 db (or 60 db *down*) under a pressure of one bar. (bar =1 dyne per square centimeter), across a load resistance of 100,000 ohms with 1 volt equal to zero *db*.

db Equivalents at Different Reference Levels

A group of typical problems will clarify the relationship between *db* and the reference level and will indicate the importance of specifying the reference level employed in any given analysis or design problem.

(a) Assume a power amplifier which has a rated output of 50 watts when driven by an input power of 2 watts. What is the gain of the amplifier in *db*?

(1) $db = 10 \log_{10} \frac{P_2}{P_1}$

(2) $= 10 \log_{10} \left(\frac{50}{2}\right)$

(3) $= 10 \log_{10} 25$

(Reference to a common log table will show that the log of 25 is 1.39794.)

(4) $= 10 \times 1.39794$

(5) $= 13.9$ or roughly 14 *db*.

(b) Using a reference level of 1 milliwatt, what is the power output of an amplifier rated at 32 *db* output?

(1) $db = 10 \log_{10} \frac{P_2}{P_1}$

(2) $32 = 10 \log_{10} \frac{P_2}{.001}$

(3) $3.2 = \log \frac{P_2}{.001}$

(4) or $\log \frac{P_2}{.001} = 3.20000$

We must now find that number whose logarithm is 3.2, which is the same as 3.20000. Reference to a common log table (*Fig. 2*) will show that *mantissa* 20,000 lies between the two adjacent *mantissas*, 19976 and 20003. The precise value can be determined by proportions, but for audio calculations it is accurate enough to use the *mantissa* 20003 which corresponds to 1585. The characteristic of 3.20000 is 3 and therefore the number corresponding to the logarithm 3.2 is 1585 and therefore

(5) $\frac{P_2}{.001} = 1585$

(6) $P_2 = 1.585$ watts

Note that 32 *db*, when using a reference level of .001 watt, is equal to only 1.5 watts whereas, when using a reference level of .006 watt, it is equal to 10 watts. This evidences the importance of specifying the reference level employed.

(c) Assume a 5-watt amplifier driving a speaker with an attenuator which causes an insertion loss of 6 *db*. How much power reaches the speaker?

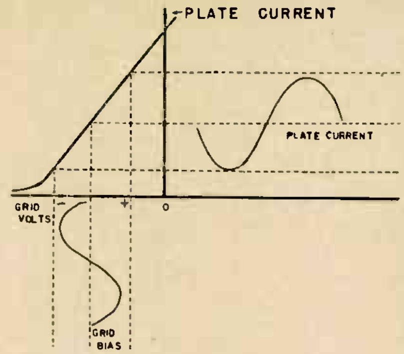


Fig. 3. Characteristic curve for Class A bias.

(1) $db = 10 \log_{10} \frac{P_2}{P_1}$

(2) $6 = 10 \log_{10} \frac{P_2}{P_1}$

(3) $0.6 = \log \frac{P_2}{P_1}$

Reference to a common log table will show that 6 is the *mantissa* of .3981 and since the *characteristic* is 0, the number corresponding to the log, 0.6 is 3.981 and therefore

(4) $3.981 = \frac{P_2}{P_1}$

and since there is a loss of power, the large power $P_2 = 5$, (the output of the amplifier), then

(5) $3.981 = 5/P_1$

(6) $P_1 = 1.25 +$ watts reach the speaker

Note that if there had been a gain of 6 *db* between the output of the amplifier and the speaker, equation

(5) would have read $3.981 = \frac{P_2}{5}$ or

$P_2 = 20$ watts reaching speaker.

Handy Things to Remember

There are a number of handy bits of mathematical information which

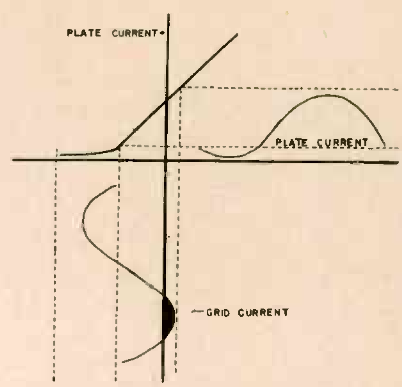


Fig. 4. Characteristic curve for Class B bias.

N	0	1	2	3	4	5	6	7	8	9
157	19590	19618	19645	19673	19700	19728	19756	19783	19811	19838
158	19866	19893	19921	19948	19976	20003	20030	20058	20085	20112
159	20140	20167	20194	20222	20249	20276	20303	20330	20358	20385

Fig. 2. Extract from common logarithm table

can prove of considerable value when committed to memory.

Remember that 3 *db* represents a power ratio of 2 to 1. For example, the difference between 10 watts and 5 watts is 3 *db* which represents only *one* noticeable change to the average ear. As further evidence, see the note appended to example *(c)* above, where it is shown, mathematically, that a gain of 6 *db* following an output of 5 watts results in 20 watts; two steps of 3 *db*, doubling the source power twice.

It has been proved time and again that most people cannot detect the difference between the output of a speaker driven at 20 watts and the output of the same speaker when driven at 10 watts. The obvious value in amplifiers of greater power is that they permit considerably greater coverage by dividing the power into a *number* of speakers. Thus a 20-watt amplifier driving two speakers can provide practically twice the sound distribution achieved as when it drives a single speaker.

An amplifier with a gain of 10 is equivalent to 10 *db*; an amplifier with a gain of 100 is equivalent to 20 *db*, a gain of 1000 is equivalent to 30 *db* and a gain of 10,000 or 10^4 is equivalent to 40 *db*. It should be remembered, that while an orchestra, playing at its loudest, creates 1,000,000 times the sound energy created when playing at its softest, it does not sound 1,000,000 times as loud but only *60 db louder*. In other words, to the average ear, this vast increase in power represents only 20 audible increases. The above are handy multiples when it is necessary quickly to approximate the *db* rating of amplifiers specified in gain.

It may often happen that the reader will find it necessary to translate decibels into watts when a logarithm table is unavailable. As a simple mathematical device for making such calculations, the following formula can often prove helpful:

$$W = 2^{(db/3)}\ (.006)$$

Thus to translate 30 db into watts:

$$W = 2^{(30/3)}\ (.006) \text{ or}$$
$$W = 2^{10}\ (.006)$$
$$= 1024\ (.006)$$
$$= 6.144 \text{ watts}$$

This procedure can, of course, prove rather cumbersome, and is not specifically recommended, but it can prove extremely useful in making accurate calculations when only paper and pencil are available.

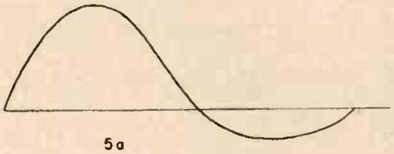
Classes of Audio Amplifiers

Amplifiers are classified in terms of their ability to amplify voltage or power. There are today four general classifications: Class A, AB, B and Class C.

The Class A amplifier is designed so that plate current flows during the complete cycle of the grid voltage. Plate current flow is a function of the grid bias potential, and in a Class A amplifier, the grid is biased at the center of the characteristic tube curve, *(Fig. 3)*.

The Class AB and A amplifier has been defined differently by various sources. It is usually sub-divided into two separate classes; AB_1 and AB_2.

Class AB_1 has a grid bias slightly higher than Class A, so that when signals of small amplitude actuate the grid, it behaves like a Class A amplifier. When the amplitude of the signal increases to a value which would normally drive the grid of a Class A amplifier positive, the Class AB amplifier bias increases due to the increased plate current and the resultant increase in current flow through the bias resistor. A larger signal can thus be handled by the AB_1 amplifier without driving the grid positive.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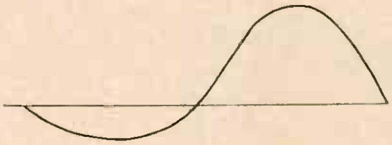
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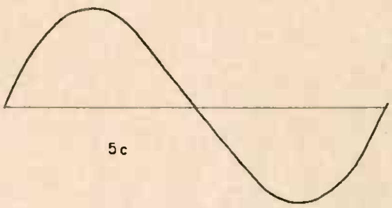
5c

Fig. 5a. Wave form of first tube in Class B push pull.

Fig. 5b. Wave form of second tube in Class B push pull.

Fig. 5c. Combined wave form of two tubes in Class B push pull (in the output transformer).

The grid bias of a Class AB_2 amplifier is greater than that in the AB_1 amplifier, but lower than that in Class B, and as a result this type of amplifier can handle a larger grid signal than Class A and AB_1, but a higher distortion level is present since grid current flows during a part of each cycle. This type of amplifier must be used in a push pull arrangement in audio work, to reduce the natural distortion.

In a Class B amplifier the grid bias is approximately equal to the cut off value (that value of grid bias at which plate current is practically zero), so that plate current is approximately or close to zero when no grid voltage is applied. As a result, plate current flows for only one half of each cycle when the exciting grid voltage is applied. This operation can be readily observed by reference to *Fig. 4*.

Note that the applied grid bias reduces the plate current practically to zero and consequently the first half of the signal wave merely drives the grid further negative, but produces little change in the plate current. On the second half of the cycle the grid is driven past zero and made less negative relative to the cathode, producing the half wave of plate current, corresponding to the second half of the exciting signal.

Class B amplifiers are more efficient than Class A, AB_1 or AB_2, but push pull is also required when using this arrangement for audio work. In a Class B push pull amplifier, the two tubes each amplify one half of the input signal and operate alternately, the separate waves of the plate current being combined in the output transformer as shown in Figures 5a, 5b and 5c.

In general, Class A amplifiers have the lowest harmonic distortion, and are the least efficient and therefore the largest and heaviest amplifiers for any given output.

Amplifiers operated in Class AB provide greater output than those operated in Class A, are lighter and smaller than Class A amplifiers and have greater harmonic distortion than amplifiers operated in Class A.

Class B operation provides maximum output, and permits the smallest and lightest of amplifiers for any given output. Load matching of a Class B amplifier is quite critical, however, and Class B operation results in high harmonic content. Class B amplifiers are the most economical to operate since power consumption drops when the signal diminishes or ceases. (It will be remembered that Class B amplifiers are biased for plate current cut-off when no signal is applied.) In Class A amplifiers, of course, current flows at all times. It is characteristic of Class B amplifiers that operation at low level results in a high level of distortion. In this connection, it is interesting to note that automobile amplifiers are normally designed in Class B because they must be operated at high level to overcome the considerable noise in the car. It is also a primary consideration in auto radio design that the radio unit be kept small, and Class B operation makes this possible.

Class C amplifiers are biased beyond cut-off. This type amplifier has no value in audio work. « « « «

[*This is one in the series of articles on Sound by Messrs. Kamen and Harman. Another installment will appear in an early future issue.—The Editors.*]

Solving the Philco MYSTERY CONTROL

by Willard Moody

Even with shortages, the repair of receivers featuring the Mystery Control is profitable.

★ There is nothing mysterious about the fundamental operating principle of Philco "Mystery Control" sets, and yet many a serviceman has found a mystery on his hands when one of them was to be repaired.

Several Philco receiver models employed the same basic mechanism. These sets are tuned automatically to any one of 8 separate stations, and the volume control adjusted, both by remote control.

The complete diagram of the control portion of a typical receiver of this kind is shown in *Fig. 1*. The circuit diagram for the remote control unit is shown in *Fig. 2*. Many service men do not have this information available and it should be quite helpful.

Within 15 seconds the receiver—previously turned "on" manually—tunes-in stations selected by dialing at the remote control box. Volume is controlled by further dialing, the degree being determined by the length of time that the electric motor is permitted to operate. A little practice is required to use the control efficiently, inasmuch as the momentum of the motor tends to alter the volume, up or down as the case may be, beyond the desired setting.

Control Box

The control box contains a battery-type oscillator, and a great deal of routine service trouble is due to "B" battery failure. The battery can readily be checked by (1) substituting a new one; (2) connecting across it a load resistance equivalent to the plate load of the tube and measuring the voltage, with a 1,000 ohms /voltmeter, or better; (3) by checking the voltage while the oscillator tube is energized. Under load, the voltage should be 80% of the open-circuit value.

The dial is connected to a *pulsing mechanism* which times the return of the dial so that a connection is made at regular intervals. When the dial is rotated, the 30-type oscillator tube has its filament lighted and the tube operates. When the dial spins around in returning to the starting position, the oscillator "B"-battery negative-return circuit to the filament is keyed, or pulsed, with a make and break action. Thus the output of the portable generator is modulated. When the dial assumes the "at rest" position, the filament of the tube in the portable generator is disconnected and there is no radiation and no battery power consumption.

Receiver

In the bottom of the receiver cabinet, there is a large coil or loop, tuned to the frequency of the oscillator in the control box. A trimmer located inside a cylindrical cardboard box in one corner of the loop permits adjustment of the tuned circuit to resonance with the control-box oscillator. This adjustment is important, for if the circuits are slightly out-of-tune, the sensitivity control on the chassis will need to be advanced farther than necessary, which makes the receiver more susceptible to the influence of static or noise impulses on automatic tuning operation.

This loop, identified at the lower-left in *Fig. 1*, picks up the signal radiated by the control box. The pulses are then amplified by the types 78 and 6J7G tubes. The 6ZY5G duo-diode serves as an a.v.c.

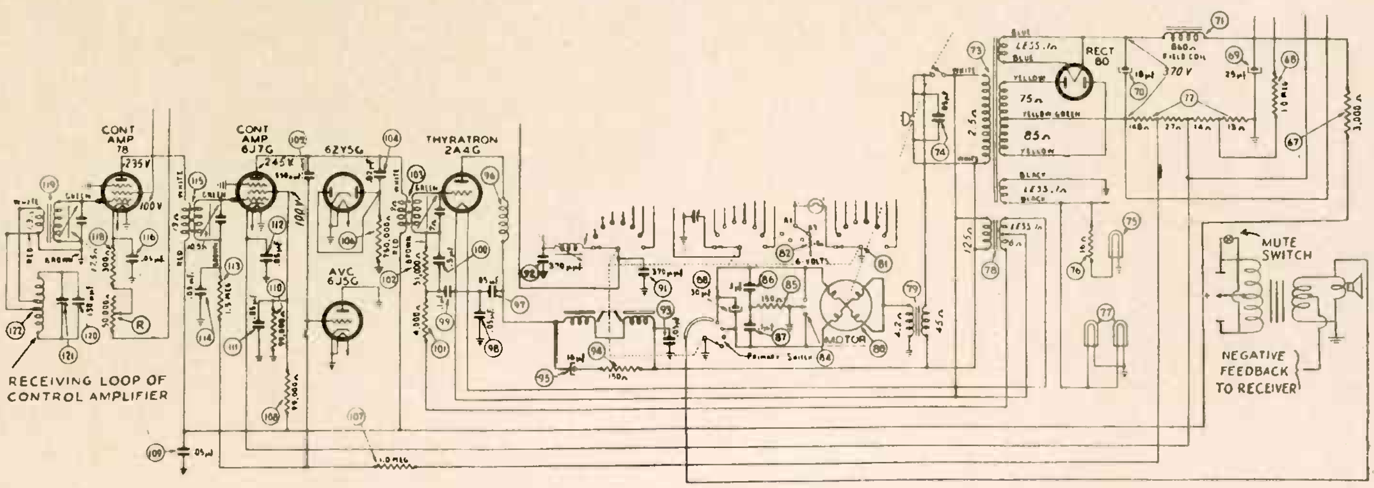

Figure 1. Complete diagram of the control portion using the Philco Mystery control.

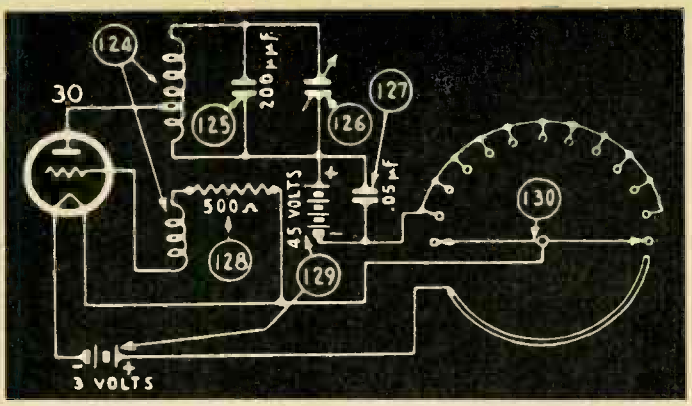

Figure 2. A simple battery-operated oscillator is the heart of Control system.

tube to maintain an even input to the 2A4G thyratron, as does the 6J5G. A wide range of signal levels can thus be handled. One diode section serves as a limiter to damp strong signal peaks which could cause the thyratron to conduct over too long a period.

The argon gas in the thyratron gives the triode structure special characteristics. The grid permits current flow in this rectifier tube only when the bias is correct. The 2A4G bias is taken from the secondary of the filament winding on the transformer while the plate supply is taken directly from the a.c. power line. Since the plate and grid voltages are out of phase no current flows between plate and cathode until the signal from the control amplifiers is high enough to overcome the bias and ignite or "fire" the tube. Once the gas in the tube has broken down and ionized, the tube has the characteristic of continuing to conduct regardless of any further change in the voltage between its grid and cathode. The plate-cathode current flows through the holding relay and energizes it and permits operation of the *stepping relay*.

Stepper and Selector

The stepper assembly contains the holding and stepping relays. When the thyratron conducts, the holding relay closes and the stepping relay actuates a ratchet just so many times as the pulses occur in the control box. The stepper relay operates one of two ratchets—the primary ratchet which is connected to the primary switch. This switch, in turn, controls the volume control motor and short-circuits the voice coil to ground in the starting and station selecting positions. A muting switch connects the plates of the output tubes together during station selection. Since the set is operative during changes in volume, it is necessary to mute it, which is the job of the secondary ratchet as it returns to home position and moves to the station dialed on the control box dial.

Below the chassis is placed the station selecting mechanism driven by the stepper mechanism. Three groups of contacts are operated by the stepper (see *Fig. 1*). One group changes the oscillator coil connections, another shifts the connections to the antenna padding condensers, and the third changes the connections to the dial lamps on the panel which indicate the station selected.

Motor drive is used for the volume and on-off switch. The motor is equipped with a clutch that works automatically, releasing and dropping back as soon as the volume control is released by the stepper primary switch. This prevents blasting when adjusting volume and stops the gear train immediately when the end stop is released on the control box. (The gear train drives the volume control.) In addition, there's a further protection against damage in that a clutch is used in the volume control itself, preventing the jamming of the mechanical system if the control lever should happen to be held down when the set is turned off.

The primary switch is a s.p.d.t. unit used to connect the correct winding in the volume control motor to increase or to cut down on volume. In parallel with this switch is a s.p.d.t. switch controlled by the manual volume control, and mounted directly below the receiver's dial bezel.

Normally, the range of the control box is such that effective results are obtained when the receiver is considered the center of a circle having a radius of 25 ft., sensitivity being controllable by a 50,000-ohm variable resistance, *117* in *Fig. 1*, in the cathode circuit of the control amplifier. Operating the control so that it does not assume a position representing more than half its full-scale rotation will limit the response of the radio set to stray impulses and guarantee best operating conditions. If absorption of the signal from the control box, due to steel or other metal located near the receiver abstracting power, the sensitivity control may need to be advanced. In some cases, those same metal objects are responsible for shielding of the receiver from static or noise impulses, so that advancing the sensitivity control does not detract from performance.

These receivers have control box oscillators which send out signals from 350 to 400 kc., approx. If two such sets are used in the same home, the manufacturer recommends that a 20-kc. separation between oscillator control frequencies be used, to prevent interference between separate units. If the separation is 10 kc. the sets will not interfere with one another provided the remote control of one set is kept at least 10 feet away from the other receiver. Using a 20-kc. frequency separation, the selectivity is such that no interference will be experienced even if the control box of one set is placed on top of the other.

In setting up the pushbuttons, the procedure is similar to that of an ordinary system, except that the control box dial is used instead of the pushbuttons on the face of the radio panel.

Service Problems

In addition to the service troubles in this receiver, which are common to any set, a few others may be mentioned.

Realignment is generally required if the sets have been in service for some time, although it is surprising how long they can go before getting out of hand. The control box should be checked first, before attempting to service the relatively complex mechanism of the receiver proper. A poor oscillator tube, for example, will result in only a weak signal being sent out, causing inferior control action which should not be blamed on the thyratron or some other relatively unlikely cause for service.

The bakelite wheel on the volume control may chip and break off, causing the volume control to jam. This is quite common and a new wheel must be obtained from the parts dis-

(*Continued on page 20*)

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TECHNICAL SERVICE PORTFOLIO

SECTION XXXIII

SERVICING POWER SUPPLIES

The servicing of power supplies has become complicated because of the shortage of replacement parts. This section deals with many trade short cuts which should help solve this difficulty.

★ Although there are relatively few components in the power supply system of the average radio receiver, it is a fact that more breakdowns occur in this section than in any other portion of the set. These troubles usually are rather easy to identify and, when an adequate supply of exact replacement parts is available, the repair job is generally simple. But under present conditions, it is often impossible to secure just the right replacement part, particularly insofar as power transformers and condenser blocks are concerned. In some cases it may be necessary to make radical changes in the circuit design to get the set working again. And we are going to encounter more and more jobs where someone else has tried—and failed—to find a satisfactory replacement part. We have to make certain that our replacements not only restore original performance, or a reasonably accurate facsimile thereof, but also that this performance will be maintained over an appreciable period of time. There can be no alibi for the power transformer replacement which fails to stand up; the smell of a burned-out transformer is unmistakable, even to the customer. Therefore, in this article we are going to consider the more important factors involved in the selection of suitable replacement parts and in circuit modifications, when required.

Half-Wave Circuit

Let us first consider the simple half-wave circuit of *Fig. 1.* No power transformer is required which, in these days, is quite a blessing. But, because the rectifier functions on only one-half the wave, the filter condensers have to be twice as large in capacity as would be required with a full-wave rectifying system to produce the same degree of freedom from hum. We mention this because we feel there are many cases where a circuit of this type may be substituted for a full-wave type, using a power transformer, in the event that no replacement power transformer is obtainable.

In this circuit, using half-wave rectifier tubes such as the 25Z5, the plates of each section may be connected in parallel, likewise the cathodes, in order to increase the power-handling capacity. This may be necessary when substituting this type of circuit for a full-wave type in a receiver having heavy power tube current drain. When an electrodynamic speaker with a shunt field is employed in the receiver, the field winding is usually placed across the output of one section of the rectifier and the other section is used for ordinary B-supply purposes.

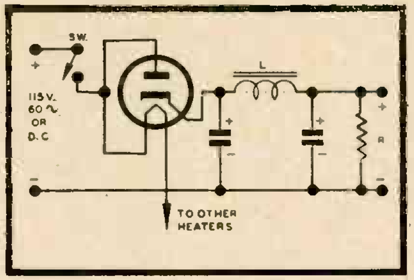

Figure 1.

A commonly seen filter-rectifier circuit used in AC-DC receivers.

Reducing Hum

Because the rectified current must pass through the choke *L*, there will be a decrease in the voltage across *R* if a choke with a higher d.c. resistance than was originally used is substituted. Or, using the same choke, if we need a heavier current drain to adapt this power supply to some other receiver, we are going to find that the output voltage across *R* will likewise decrease due to this cause. A heavier current drain will also necessitate an increase in the amount of filter capacity to keep the hum level down to its original value. It is good to keep in mind that the most economical filter circuit, insofar as its effectiveness in reducing hum is concerned, is obtained when both filter condensers in the circuit shown have the same capacity. In the case of a two-section filter, the second and third condensers should have approximately the same capacity . . . in such circuits increasing the capacity of the first condenser has less effect in reducing the hum than increasing the output capacity section.

In *Fig. 2* is shown a typical voltage-doubler circuit, except a power transformer has been used to couple the circuit to the power line. When the power transformer is not used, the line supply is connected directly to the points where the transformer secondary now connects.

Let us analyze this circuit so that some of those to be described later are more understandable. On one, half-cycle current passes through *T1*, charging the condenser *C1* in the polarity shown. On the reverse half-cycle, *T1* no longer conducts, but the polarity is right for *T2* and therefore current passes through it, charging *C2*. Because these capacities, *C1* and *C2*, are large in value when the current drain is low, the

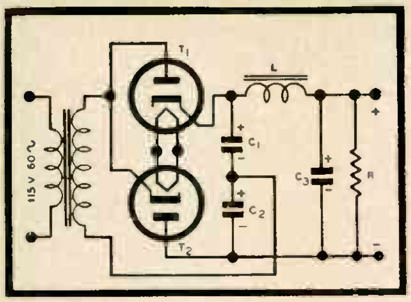

Figure 2.

A voltage doubler circuit in which the transformer serves to isolate the circuit from the house lines, so that the B minus may be grounded if desired. The transformer may be eliminated if no ground is used and the line voltage then being applied where the transformer secondary is indicated in this diagram.

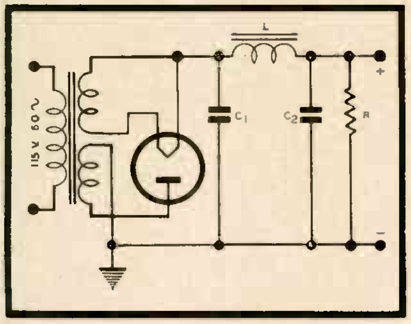

Figure 3.

For AC receivers this half-wave circuit is often the one which is used.

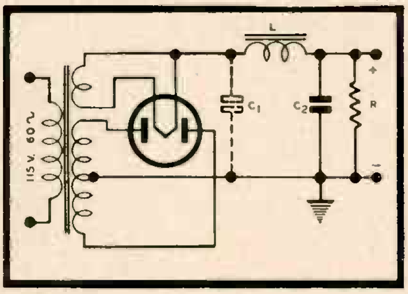

Figure 4.

A conventional full-wave rectifier and filter circuit for AC receivers.

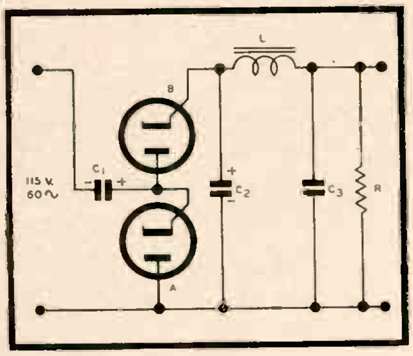

Figure 5.

The B minus is grounded through the power supply line. This will give a greater hum reduction and stability.

voltage to which each was originally charged is held, and because the polarities of the voltages are as shown across each condenser, these voltages add. Hence, the initial rectified voltage is doubled.

When the current drain is increased, it is necessary to likewise increase the capacity values in voltage doubler circuits. Otherwise the voltage output of the doubler circuit will be reduced.

The standard half-wave transformer coupled circuit is shown in *Fig. 3*. The similarity to *Fig. 1* is obvious, at least, insofar as the filter circuits are concerned. Consequently, it is apparent that failure of the transformer need not put the apparatus permanently out of commission if no replacement power transformer is obtainable, provided we substitute one of the power supply circuits shown in either *Figs. 1* or *2*. If the circuit of *Fig. 1* is employed, it will be necessary to take into account that the output voltages are probably going to be considerably lower than those obtained when the power transformer circuit was employed. Often the resulting decrease in the power output of the set may be greatly improved by replacing the output tube or tubes with types such as the 25L6, which are designed for utmost power output at relatively low voltages. Further, the gain of the set may be augmented by making certain that the screen supply voltage is taken off at the maximum B voltage point, not at a 100-volt tap on a 250-volt divider, as is sometimes done, and which of course results in a screen voltage much lower than 100 when the 250-volt point is reduced in voltage. Of course, if a series dropping resistor is employed to provide the screen voltage, as is the general custom in the more modern sets, no change is necessary when the power supply voltage is reduced.

Full-Wave Circuit

The full-wave transformer-operated power supply circuit shown in *Fig. 4* is unquestionably the most widely employed arrangement found in modern receivers. We show this circuit for comparison purposes with *Fig. 3*. Note that it is a simple matter to convert *Fig. 4* into *Fig. 3*, insofar as the rectifier is concerned. We need only to employ but one-half the secondary winding. It follows that a power transformer with one-half its secondary open need not necessarily be junked; it may fit in as a replacement for the half-wave circuit of *Fig. 3*, provided the voltage and current ratings are suitable. Or, we may alter the full-wave circuit of *Fig. 4* and operate it half-wave, in the event that one section of the secondary opens. We will have to increase the filter capacity to overcome the increase in hum which otherwise results; we'll need to parallel the plates of the rectifier tube to bring the current capacity up to its full-wave capacity. And we may expect some reduction in output voltage. But we can restore operation which will be at least acceptable without replacing the transformer.

Reducing the Hum

Where the substitution is necessary of a power transformer with higher secondary voltages than those used in the transformer to be replaced, this voltage may best be reduced by connecting a resistor in series with the high voltage secondary center tap, and ground. Since all the B-supply current will then pass through this resistor, it should have a reasonably high wattage rating, depending upon the current in the circuit and its resistance value. The voltage may likewise be reduced by placing the resistor in series with the filter input and the rectifier output. In some receivers, where a two-section filter is employed, by simply removing the input condenser to the first section of the filter will bring down the voltage without the need for a series resistor. However, it may be necessary to add this capacity to the output filter capacity section to bring the hum level down. In addition, sometimes it will also be found

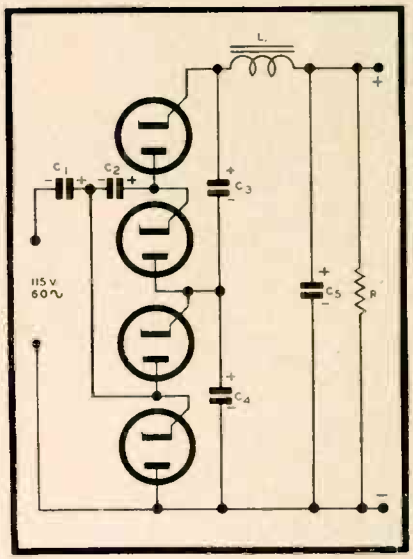

Figure 6.

This quadrupler circuit produces four times the voltage obtainable from the usual half-wave circuit.

necessary to increase the capacity in the intermediate section of the filter circuit.

Replacing Transformers

In replacing power transformers, care should be taken that only units which are electrically equivalent are substituted, unless appropriate circuit modifications, as described above, are made. We need to know the current ratings of each secondary winding and to make certain they are not exceeded. This is particularly true of the high voltage secondary winding, which is really the governing factor. When the current ratings are unknown, a rough approximation may be arrived at by making certain that the core dimensions or cross section of the substitute are at least equivalent to those used in the original transformer. As stated, this is of course only a very rough method of estimating the requirement since there are many other factors involved. It is surprising how often transformers which are manifestly inadequate in size to handle the power load, are substituted unwittingly with disastrous results.

Doubler Circuits

In multi-tube receivers where no power transformer replacement can be obtained which will handle the entire load, it is sometimes possible to utilize voltage-doubler circuit operating directly from the line and through its own small filter, to supply plate and screen voltages for all tubes except the output power tubes. This relieves the power transformer of a portion of its load and may enable the substitution of a smaller replacement power transformer without the risk of overloading and consequent rapid failure. When using such doubler circuits, if the current drain is relatively small, it will be found feasible to substitute resistors of the order of 1,000 to 5,000 ohms for the filter choke and thus make the power supply sufficiently compact for incorporation in the usual congested chassis. While the doubler circuit of *Fig. 2* shows 2 tubes and transformer, it should be remembered that only a single tube is required provided it has two cathodes and two plates, brought out separately to base pins. Also, as mentioned previously, no transformer is required unless it is desired to ground the d.c. output or to step the voltage up more than can be accomplished by connecting the doubler circuit directly to the power line. When the load is light, this latter should not be necessary, since it is usually possible to get out well

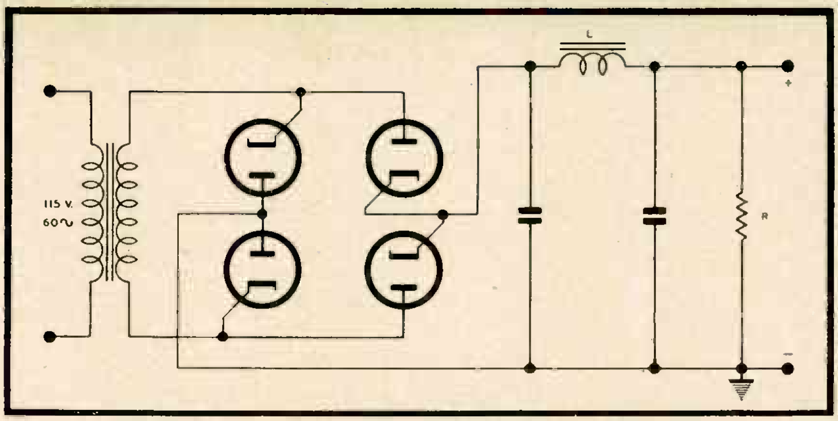

Figure 7.

To obtain full-wave rectification without the use of a center-tapped transformer the bridge circuit shown in the diagram above may be used.

over 225 volts for operation of voltage amplifier and similar small tubes.

Another type of voltage doubler, not quite so economical to make as that shown in the circuit of *Fig. 2*, is represented in the schematic of *Fig. 5*. In the former circuit, note that the two condensers are in series, each being charged to one-half the total voltage. But in the circuit of *Fig. 5*, the total voltage appears across both *C1* and *C2*, therefore capacitors for this circuit need to have twice the voltage rating of those employed in the circuit of *Fig. 2*. Just how this circuit works is as follows: On one-half the cycle tube *(a)* conducts current, charging condenser *C1* to the peak value of the a.c. voltage. Since tubes *(a)* and *(b)* are in series, condenser *C2* receives the same charge. On the next half-cycle, the polarity of the alternating voltage is reversed and the rectifier tubes no longer are conducting. However, the voltage to which each condenser was charged on the previous half-cycle remains, so the actual voltage difference across each condenser is equal to the voltage which it attained during the positive half-cycle plus the peak negative voltage reached over the other half-cycle. Thus the voltage is doubled. An advantage over the circuit of *Fig. 2* is that in this arrangement the negative output terminal is at ground potential.

Redoubling Voltage Output

The remarkable thing about the circuit of *Fig. 5* is that it is possible to take the output of the voltage doubling circuit and go ahead and redouble, just as we do in bridge, but with more uniform success. In *Fig. 6*, for example, we have a perfectly good voltage quadrupler, which can produce an output voltage of over 440 from a 110-volt a.c. source, without the use of any transformer. The advantages of such a circuit in forming an emergency voltage supply in the event a high voltage power transformer is unobtainable are obvious. Although this circuit requires fairly high values of capacitance when the current drain is large, it is eco-

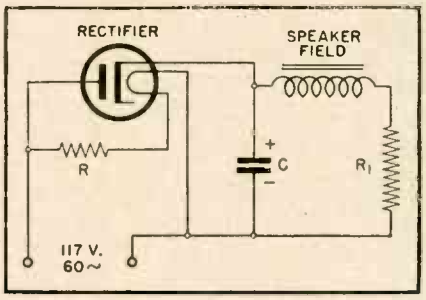

Figure 8.

Using a filament resistor to limit voltage on a 25Z5 rectifier. With a 117Z6 tube this may be eliminated.

nomical when used as a power supply for voltage amplifiers, in both r-f and a-f circuits, because then relatively low capacity condensers may be successfully used.

When a power transformer is at hand with a half-wave winding, and if we are long on tubes and short on filter condensers, it is possible

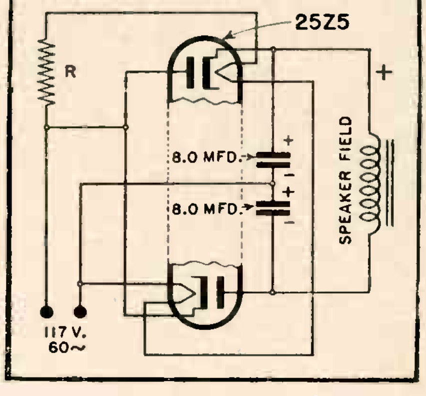

Figure 9.

A suitable voltage doubler for use with high-resistance speaker field.

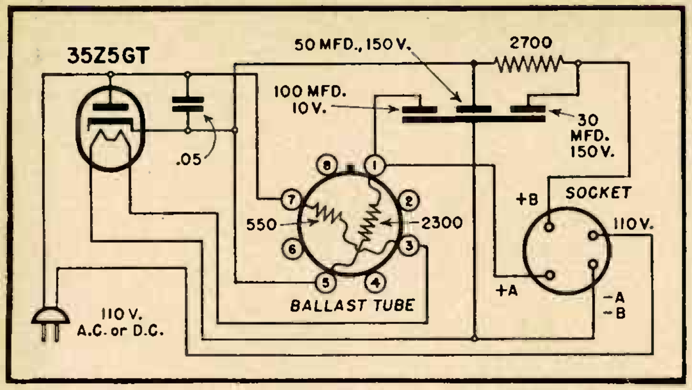

Figure 10.
Diagram of an RCA "Electrifier" developed for farm battery receivers and other radios of similar type.

to use the bridge circuit for full-wave rectification, as shown in *Fig. 7*. Here we get the same voltage output at d.c. as would result if we had 2 transformer windings of the same voltage, or a single winding, center-tapped, of double the voltage, to feed a full-wave rectifier tube of the conventional type. A useful adaptation of this arrangement is to use a conventional full-wave transformer to feed this bridge rectifier circuit. If, for instance, we have a power transformer with a high-voltage secondary of 175 volts each side of its center tap, we may ignore the center tap and connect the full 350-volt secondary across the bridge rectifier circuit. The output voltage will then be the same as would be had if a secondary of 350 volts each side of center tap were employed in conjunction with a conventional full-wave rectifier circuit.

Speaker Fields

Right now it is very hard to get replacement speakers of the permanent magnet dynamic type. One way out is to substitute an electro-dynamic type with a special field supply to avoid overloading the power supply in the receiver itself. One simple method for low-voltage, high current fields is to use the circuit shown in *Fig. 8*. Here a simple half-wave rectifier, operating directly from the a.c. line, provides the energy required for field excitation. The resistance *R* should be about 275 ohms if a 25Z5, or other 25-volt rectifier is employed. If you can get your hands on a 117Z6, which requires no series line voltage dropping resistor, then *R* may of course be omitted. The capacitor *C1* may be an 8-mf electrolytic. The series resistor *R1* may often be omitted if the speaker field has a resistance in excess of 750 ohms. For lower resistance fields *R1* should be sufficient to build the circuit resistance up to this value in order to avoid overloading the rectifier tube.

For speaker fields using high-resistance coils, of the order of 3000 ohms or more, the voltage doubler circuit of *Fig. 9* will serve. Capacities of the value shown are generally more than adequate; often it is possible to use somewhat lower values, particularly when the speaker field resistance is in excess of 5000 ohms.

Substitute for Batteries

Batteries for operating portable receivers are becoming more and more scarce. When either an a.c. or d.c. line source is available, the electrifier circuit shown in *Fig. 10* may be adaptable. This is the type CV-42 Electrifier, introduced by RCA Victor as a power supply for the models 25BK, 25BT-2 and 25BT-3 receivers of their make. While the value of resistance shown in the diagram apply only to the current drain required by receivers of these models, other sets having the same voltage and current requirements may likewise be energized by this simple power supply.

Often, in replacing power transformers, it is found that the only type of transformer available of equivalent rating to the one to be replaced is larger in size and just can't be fitted in without removing something else. In some cases, the "something else" may be one of the filter chokes, increasing the filter capacities to make up for the hum increase due to the removal of the choke. This, of course, can not always be successfully done; it is often possible, though, when two-section filters are employed. An aid to better filtering is to make certain that the power for the output tubes is not taken off after both sections of the filter; this amount of filtration is seldom necessary for output tube plate supply, because there is no amplification after this point and therefore a relatively high hum level may be tolerated. Also, the high signal level in the output circuit tends to mask hum.

Resistance Filter

In many modern receivers no filter chokes whatsoever are employed, yet good hum filtration is secured. The typical circuit of *Fig. 11*, for example, is used successfully in one commercial amplifier. Note that there is very little filtration for the output tubes; just the 16-mf condenser for the plates and for the screens, only the 2000-ohm series resistor and the 8-mf condenser are added. This partly is because in push-pull output stages, hum tends to become balanced out when the tubes are accurately matched. If a single output tube were employed, more filtration would be necessary, which could be accomplished by a higher value of series resistance in the screen circuit and by increasing the capacitance in the plate supply circuit, or by taking both the plate and screen supply voltages from the point where the screen supply connection is now shown.

Note that amplifying stages where the signal level is low require more filtration than stages where the

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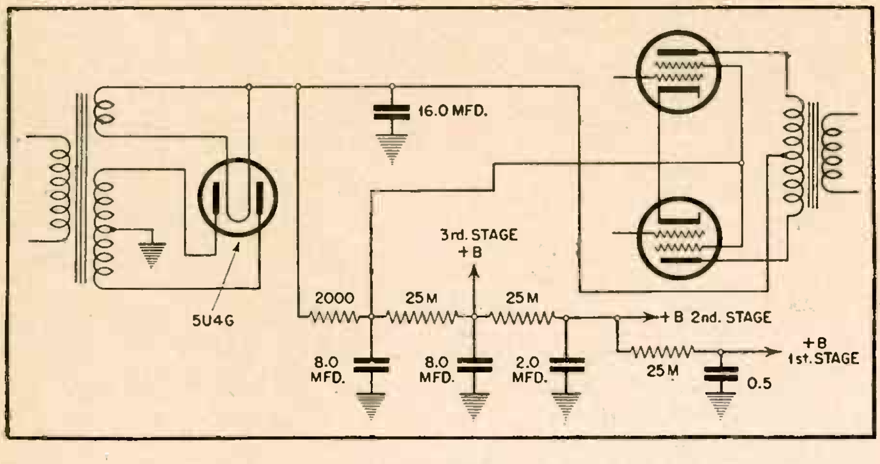
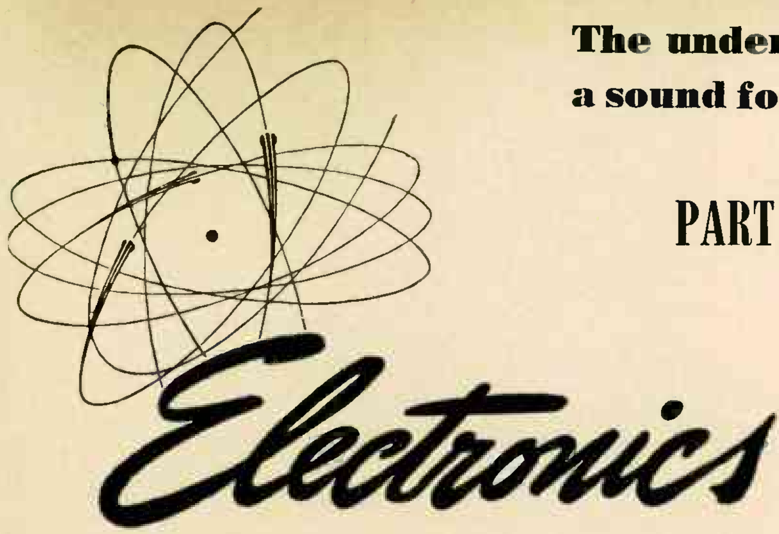


Figure 11.
Great savings in space and weight may be effected when chokes are replaced with resistors in the filter part of power supply.



The understanding of this new field is a sound foundation for television work.

PART 3.—"ELECTRON OPTICS"

by

PAUL R. HEYL, Ph.D

★ In the earlier lectures of this series we saw that an electron may behave in different ways under varying experimental conditions. At times it may act like an electrically charged particle, and at other times like a little bunch of waves. While we do not yet understand the actual structure which gives rise to these wave and particle aspects, this has not prevented us from applying what we know about the behavior of electrons in important ways.

The charged particle aspect of electrons has been evident since their discovery, and in all their earlier applications it was this aspect which was of importance. The wave aspect, as we have seen, came later. It was suggested by De Broglie on theoretical grounds in 1924, and was experimentally verified by Davisson and Germer in 1927 and by G. P. Thomson in 1928. These discoveries gave an impetus to further theoretical and experimental study, and by 1932 the new field of electron optics had become clearly defined. In its practical development this subject has produced the important inventions of television and the electron microscope.

The new field was so named because of certain analogies in the behavior of rays of light and moving electrons. This resemblance does not arise entirely from the wave aspect of the electron. As we shall see, the particle aspect plays at least an equally important part. In fact, in many phenomena the behavior of electrons is better described in terms of the old corpuscular theory of light than by the modern wave theory, but at least superficially there are certain similarities in behavior.

A beam of electrons, as we have seen, is deflected on passing through an electrostatic or a magnetic field in a manner suggesting the deflection of a ray of light passing from one medium to another. Such a beam can also be reflected from an electron mirror, or concentrated to a focus by an electron lens. The theory of magnetic electro-optical devices is much more complicated than that of the electrostatic forms, and the problems involved in their design are correspondingly more difficult. Because of their greater simplicity we shall discuss first the electrostatic forms.

We owe to Faraday the concept of lines of force in an electric field, lines which indicate by their direction the direction of the resultant force on a charged particle, and by their closeness the intensity of the field strength. An additional useful concept is that of equipotential surfaces, which are everywhere normal to the lines of force. These lines and surfaces are suggestive of the meridians and parallels in geography, and afford a complete description of the electric field. Theoretically, the pattern of lines and surfaces resulting from any given system of charged electrodes is capable of calculation, but except in a few simple cases the mathematical solution is quite difficult. However, it is always possible in any case, no matter how complicated, to determine the shape of the equipotential surfaces experimentally, and when this is done the determination of th lines of force is simple matter.

The apparatus for this purpose is called an electrolytic tank(1). An enlarged model of the electrode system is immersed in a weak electrolytic bath, and to these electrodes are applied potentials which are proportional to the actual potentials in the working system. The lines of current flow in the electrolyte then correspond to the lines of force in the electrostatic field. By means of an exploring probe points of equal potential in the liquid can be located, between which no current flows. This probe is kept at a given potential, and is connected to a sensitive galvanometer. Suppose the probe is at a potential of 50 volts. When it is at a point in the liquid where the potential is greater or less than 50 volts the galvanometer will show a current; but where the potential of the liquid is equal to that of the probe the galvanometer reading will be zero. In this way we can trace out in the liquid an equipotential surface of 50 volts.

Since in practice most electrode arrangements are symmetrical with respect to a certain plane, we may arrange the electrode model so that this plane coincides with the liquid surface, and, in fact, dispense entirely with the non-submerged half of the model. The probe is then adjusted so that it just touches the liquid surface. In addition, the probe may be connected to a pantograph by means of which its motion will trace out a corresponding line on a sheet of paper. When a sufficient number of equipotential lines has been plotted it is a simple matter to draw lines of force intersecting these equipotentials normally, and thus obtain a complete graph of the field in its plane of symmetry.

The next step is to determine the trajectory of an electron moving in this field. Here again, in most practical cases, mathematical difficulties are serious and graphical methods of solution must be employed. Automatic apparatus has been devised for this purpose(2). Only in a few cases is a mathematical solution practicable. Instances of such cases are those where the lines of force are straight lines, either parallel or radial. In the first case the theory of balistics applies, and in the second celestial mechanics.

There is an important point to bear in mind in considering the trajectory of an electron in a field of force, and

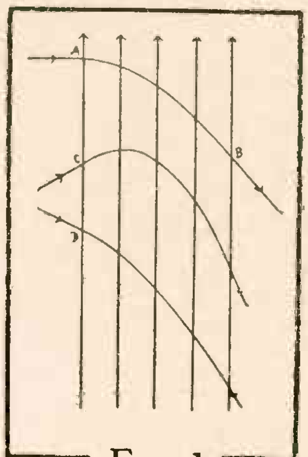


FIG. 1

* *Numbers in parentheses indicate references*

this is that in practice an electron will but seldom be found moving along a line of force. Suppose that there is a field of straight lines, and that an electron is placed in this field with no initial velocity. It will start to move along the line of force on which it happens to be located, and will travel with an accelerated velocity. As long as the line of force remains straight the electron will follow it; but suppose it becomes curved at a certain point. The electron on reaching this point will be urged by its inertia along the tangent to the curve, while the field force will try to make it follow the curve itself. In consequence, the electron will follow a resultant path between the curved line of force and its tangent. For the determination of this resultant graphical methods are usually necessary.

It will be interesting to consider one case of a trajectory which can be mathematically handled, that of an electron moving with uniform velocity, which enters a field of straight parallel lines of force. An approximation to such a field is found between two parallel plane electrodes at different potentials. Such a field is represented in *Fig. 1*. The lines of force are directed vertically upward, and a negative electron enters the field at *A* with a constant velocity v in a horizontal direction. The field will exert a downward acceleration on the electron equal to eF/m, where e is the electronic charge, m the electronic mass and F the strength of the field. Taking *A* as the origin of coördinates, and measuring x horizontally to the right and y vertically downward, we will have for the distances traveled in time t,

$$x = vt$$

$$y = \frac{1}{2}\frac{eF}{m}t^2$$

Eliminating t, we obtain

$$y = \frac{1}{2}\frac{eF}{m}\frac{x^2}{v^2}$$

which is the equation of a parabola with its vertex at the origin *A*. During the time that the electron remains in the field it will follow a parabolic path *AB*, and when it leaves the field it will continue along the tangent to the parabola at *B*.

If the electron enters the field with a velocity sloping upward as at *C*, or downward as at *D*, its path in the field will still be a parabola, but it will not begin at the vertex.

Here we have an instance of what was mentioned earlier, that the similarity in behavior of light rays and moving electrons is rather superficial. In ordinary optics a light ray is never deflected when it passes normally from one medium to another, as the electron does at point *A*. There is, however, a perfect parallel between the three cases illustrated in *Fig. 1* and the path of a projectile from a gun in the earth's gravitational field.

We shall now consider a simple case of an electron mirror. In *Fig. 2*, *P* is a negatively charged plate. The lines of force near such a plate and not too close to the edges are straight lines perpendicular to the plate. Suppose that a negative electron is traveling toward the plate at any angle with a velocity *EA*. The plate will repel the electron with a horizontal force *EC*. This force may be resolved into two components, *EB* in the line of motion of the electron and *ED* perpendicular to this line. *EB* will retard the electron and *ED* will deflect it. The electron will follow a curved path, the retarding force continually diminishing, and will eventually reach a point *F*, where for the moment it will be moving parallel to *P*. At this point the retarding force will be zero and the deflecting force a maximum. The electron will then follow the curved path *FG*. Along this path an accelerating force *GH* will make its appearance and continually increase. There will be no sharp angle of reflection, nor will the paths of incidence and reflection be straight lines except at a distance from the plate, yet there is a distant resemblance to the reflection of light at a plane mirror.

Suppose now that instead of a plane electrode we have one which is concave, as in *Fig. 3*. Near the axis of the mirror the equipotentials and lines of force will be as indicated in the figure. Two electrons approaching the mirror in parallel directions, as at *A* and *B*, will follow curved paths converging toward a focus. This focus will not always be as sharp as is the case with light rays. For this there are several reasons(3). One is that as the electrons converge their mutual repulsion comes into play, and this sets a limit to the current density that can be crowded into a focal spot of any given area. For low current densities, where the electrons do not follow each other too closely, they may cross each other's path without mutual deflection, like traffic at an unlighted intersection; but where the traffic is heavier the electrons must turn out to get by, and more space is needed for the crossover. Fortunately, the elbow room required is never so great as to interfere seriously with practical applications of electron focussing.

In the construction of electron mirrors it is not necessary to have an actual charged plane or concave surface. If by any other spatial arrangement of electrodes we can produce the same pattern of lines of force, reflection will occur. By the use of tubular electrodes "transparent" mirrors have been constructed, where the reflection takes place in empty space.

We shall now consider a simple case of an electron lens. *Fig. 4* represents in cross section two tubular electrodes separated by a small air gap. One of these tubes is at a potential of 100 volts and the other is at zero potential. The shape of the equipotentials is shown for steps of ten volts. The whole arrangement is symmetrical about the axis *AB*. Electrons diverging from *A* will be brought to a focus on the other side of the lens, the same limit of current density at the focus applying here as in the case of the concave mirror.

It will be seen that in such a lens the left and right halves operate differently. The left half has a convergent effect and the right half divergent. In all practical cases, however, the convergent effect predominates. The optical analogue is a combination of a convex and a concave lens, where the convex lens predominates.

We shall now discuss the corresponding magnetic forms of apparatus used in electron optics, and it will be well first to consider the difference in the behavior of electrons in electric and magnetic fields.

An electric field will always have some effect upon an electron, whether the latter is at rest or in motion, but a magnetic field will not always take notice of an electron. If an electron is at rest in a magnetic field it will remain at rest; and if it is in motion along a line of magnetic force its mo-

[*Continued on page 18*]

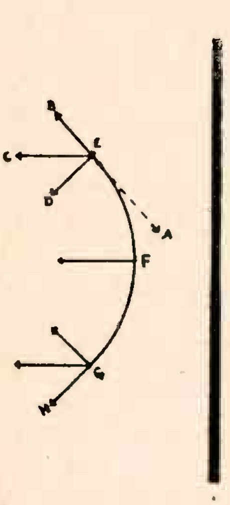


Fig. 2

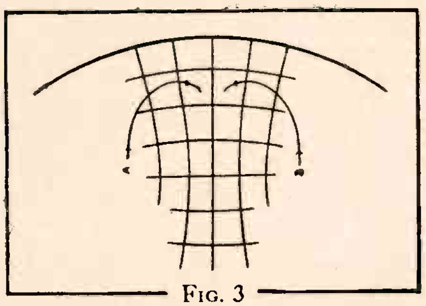


Fig. 3

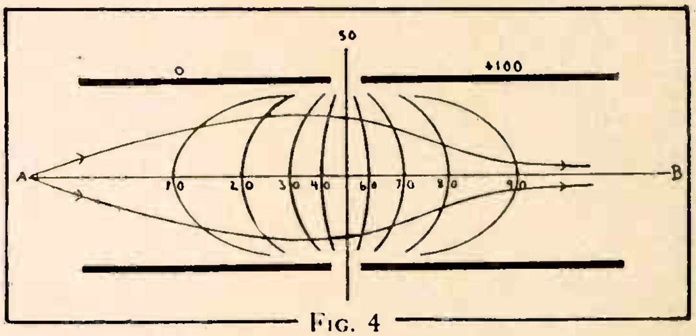


Fig. 4

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WANTED—Automatic key Mac oscillator; also used Echophone receiver. Have complete set of Coyne reference books, also N.R.I. course for sale or trade. Cpl. Harry W. Carlile, Hq. 92nd Signal Bn., Radio Detachment, Camp Maxey, Texas.

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WANTED—High-grade meter, sensitivity 2,000-20,000 ohms per volt; full scale deflection with from 50-500 microamps, thru moving coil. Calibration unimportant. Needed by 3rd class radio technician in Navy. J. B. Boult, Sault Ste. Marie, Mich. Box 365).

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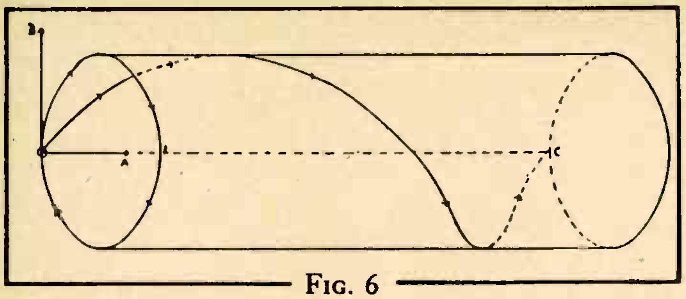

Fig. 6

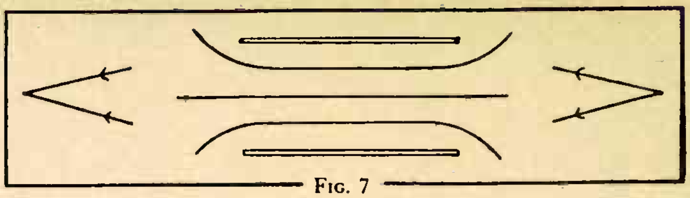

Fig. 7

tion will be unchanged. If, however, an electron moves at an angle to the lines of magnetic force it will be deflected. In this connection there is an interesting analogy to the relation between a citizen and the government. As long as the citizen keeps his actions within the lines laid down by the law, the government will take no notice of him; but let him attempt to cut across the lines of the law, and the government will deflect him in a direction in which he had not intended going.

Referring again to *Fig. 1*, suppose the lines of force to be those of a uniform magnetic field. An electron entering this field normally at A with a constant velocity will be deflected—not into a parabola in the plane of the paper, but into a circle in a plane perpendicular to the lines of force. If the field is a small one the electron may get out and proceed along a tangent to this circle; but if the field is extensive the electron may be permanently captured and kept revolving in a circle. The radius of this circle will be less if the strength of the field is greater, and will be greater if the electron moves more rapidly, according to the following formula:

$$R = \frac{mv}{eH}$$

where R is the radius of the circle, e and m the electronic charge and mass, H the strength of the field and v the velocity of the electron.

In electron optics, magnetic fields are extensively used in the construction of magnetic lenses. When high speed electrons are to be dealt with, as is often necessary, a magnetic field has a practical advantage over an electric field, for it may be difficult to obtain an electric field intense enough to give these rapidly moving electrons the desired deflection without danger of a spark discharge between the two electrodes; but the intensity of a magnetic field can be increased almost indefinitely.

The discovery of magnetic lenses was accidental. After the discovery of electrons much experimental work was done on the "cathode rays," as they were then called. These experiments often involved the measurement of the deflection of a beam of electrons by an electric field. For this purpose a sharply defined spot was needed on the fluorescent screen at the end of the cathode ray tube, and focussing of the divergent beam of electrons emitted by the cathode was necessary. The first attempts in this direction made use of diaphragms with small apertures to cut down the beam to a nearly parallel bundle. In 1899 E. Wiechert(4) tried another method. He enclosed the cathode ray tube in a solenoid through which a current was passed. At that time there was no theoretical basis as a suggestion for this idea. It may have been merely a "hunch" on the part of Wiechert, but it worked. By properly adjusting the current strength a sharply defined spot could be obtained on the screen.

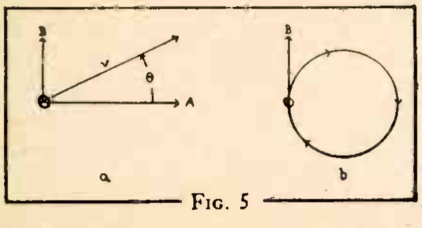

Fig. 5

And then the accident happened. On one occasion when the spot was out of focus it was found, while groping for the adjustment, that at a certain current strength in the coil an enlarged image of the cathode appeared on the screen. This discovery was at once turned to advantage, for it enabled the operator to see whether the cathode was in good condition, emitting electrons from its whole surface. Such a tube with its "concentration coil" was the original ancestor of the electron microscope.

The theory of this image formation did not become clear until the publication of a paper by H. Busch in 1926(5), in which he showed that any axially symmetrical magnetic field could form an image of the source of electrons. The general theory of this action involves some rather difficult mathematics, but we can discuss the simplest case—that of a uniform magnetic field long enough to contain the source of electrons and the image formed.

Referring to *Fig. 5 a*, suppose that there is an electron moving with a velocity v in a uniform magnetic field whose lines of force are parallel to OA. We may resolve this velocity into two components, OA parallel to the field and OB perpendicular to it. The component OA will be unaffected by the field, but the component OB will be bent into a circle, shown in an end-on view in *b*. The radius of this circle will depend on v and on the strength of the field H, but the time taken for the electron to make a complete revolution will be independent of v, of θ and of the radius of the circle, and will be a function only of H, e and m, given by the formula:

$$t = \frac{2\pi}{H}\frac{m}{e}$$

The resultant of this circular motion and the translational component OA will be a helix, shown in *Fig. 6*, drawn on the surface of an imaginary cylinder whose axis is parallel to the magnetic lines of force. An electron starting from O will follow this helix, and after making one complete revolution will arrive at a corresponding point C at the other end of the cylinder.

Suppose now that there is a divergent beam of electrons emitted from the point O (*Fig. 5 a*). Even if all these electrons have the same velocity v, they will have different values of θ, and consequently different values of the translational component $OA = v$, cos θ and of the perpendicular component $OB = v \sin \theta$; and if the electrons have different values of v these components will differ still more widely. But since the time of revolution is independent of v and θ, all the electrons will reach the line OC at the same instant of time, but not all at the same point, as their translational components are different. However, for a beam of electrons of so small an angle that cos θ will differ inappreciably from unity, all the OA components will be practically the same, and all the electrons will reach the same point on OC at the same time. In other words, a narrow beam of electrons diverging from O will be brought spirally to a focus at a common point.

Apparently this may be expected to happen only if the magnetic field is long enough to exert a constant effect upon the electron from start to finish; but Busch showed that even if the origin of the electrons lies outside of a short solenoid the beam will still be brought to a focus on the other side, as in *Fig. 7*. In this figure only the initial and final parts of the electron paths are shown; the intermediate portions will not be simple helices, as the electrons have to pass through the nonuniform fields around the ends of the solenoid. Experiment confirms Busch's mathematical analysis, and the use of short fields in magnetic lenses is common practice.

Both magnetic and electrostatic lenses are subject to the same limitation of maximum current density in the focal area, and in addition, both classes of lenses are affected by errors similar to those that are found in glass lenses —sperical aberration, lack of flatness of field, etc. Much ingenuity has been expended on the correction of these

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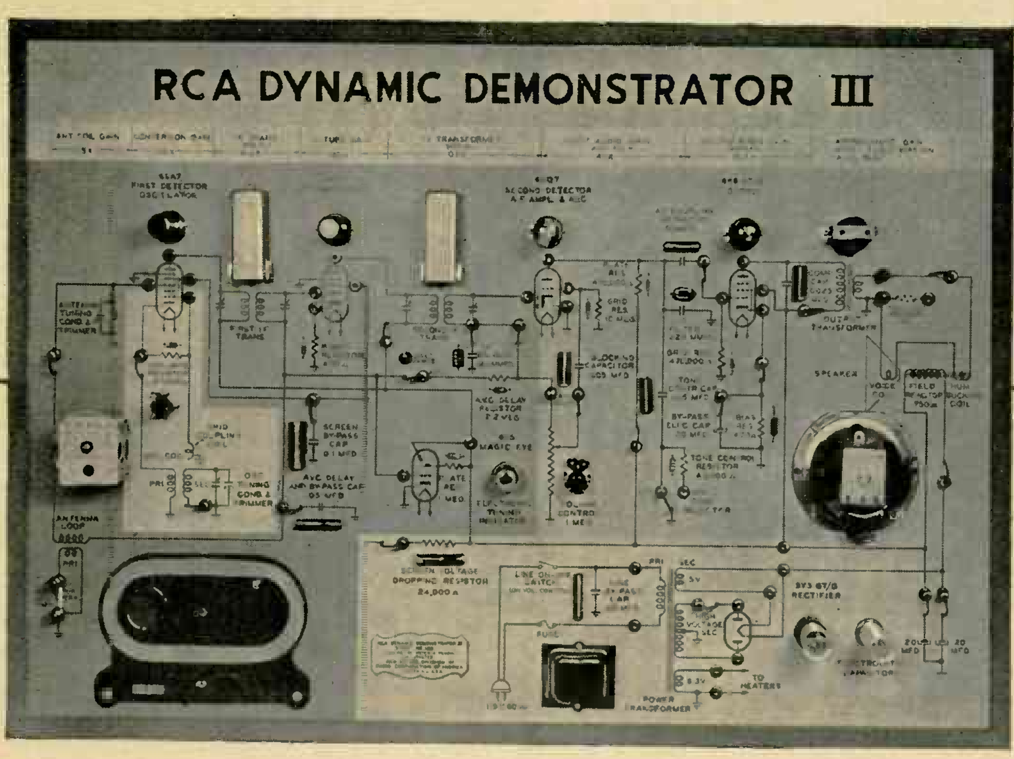

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Solving Mystery

(*Continued from page 10*)

tributor. Another fault is binding of the selector switch gears. Frequently this is due to nothing more than need for new lubricant. With the chassis out of the cabinet and turned upside down, you can get at the selector switch. The collar can be loosened, if necessary, so that there is not too much pressure and not a great deal of friction, if the dialing mechanism seems slow to respond and sticks. The contacts can be cleaned with carbon tetrachloride. In taking the chassis out of the cabinet you must first take the dial panel off, and then remove the screws which hold the front of the radio to the front of the cabinet.

The most common trouble encountered seems to be the shifting of stations automatically when noise impulses are picked up. This is particularly apt to occur if the receiver is used in a location where there are overhead power lines, trolley wires or heavy electrical machinery. In fact, if the writer received a notice of erratic operation and visited a customer's home in the suburban sections of New York, etc., his first step would be to ascertain whether or not an overhead power line was near the home. If a line was visible it was reasonably certain that its electrical interference was the cause of trouble. In some cases, reducing the sensitivity by adjustment of the knob on the rear of the chassis was sufficient to cut down on the response to random pulses; in others, it was necessary to use a line filter and doublet-type antenna to improve the operation of the set (including reduction of noise).

The shifting of stations due to noise pulses would occur, of course, only when the receiver was set for pushbutton tuning.

Although it is probable that not as many of these sets were sold as were the smaller and less complicated ones, they nevertheless did enjoy a wide distribution and there are many of them in customers' homes today which are not working or working poorly simply because the serviceman did not have the technical data on them. Working on these receivers is valuable experience for the electronic age to come, for these sets represent a practical application of electronic principles, far ahead of their time. The same principles used in this receiver can be employed in industry and in the home in the future, and will be so employed.

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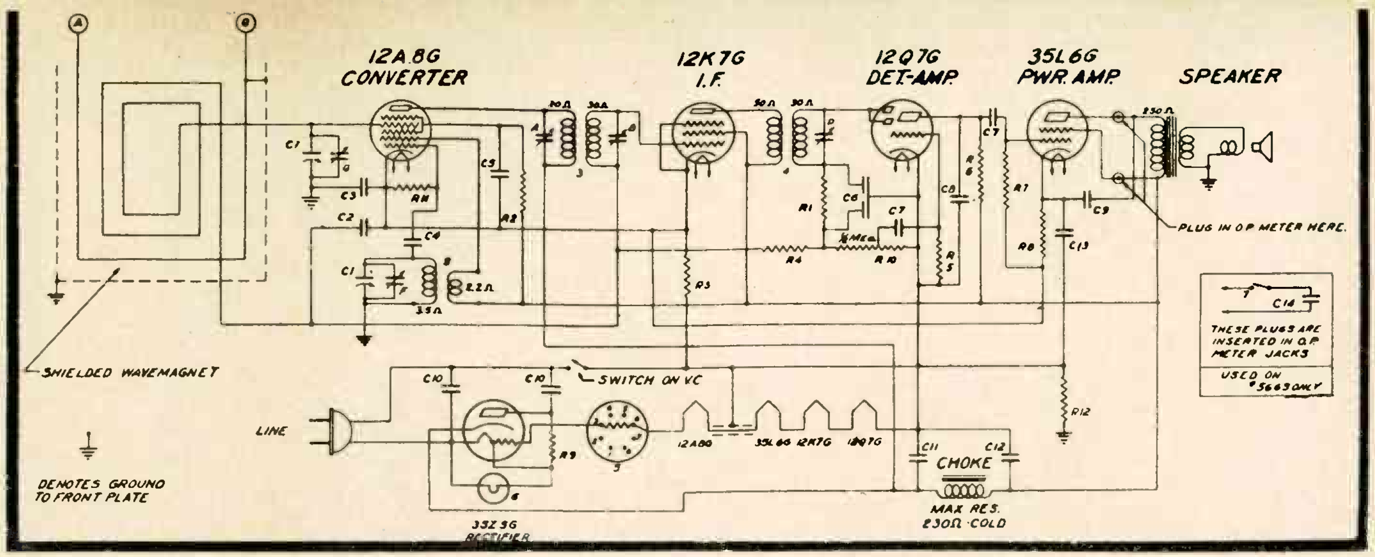

ZENITH SHOP NOTES

Zenith Models 6D470, -411, -413, -414, -425, -426, -427, -446 and -455. Bakelite Chassis Nos. 5659, 5660, 6553 and 5664.

See cut above

★ When one of these receiver models remains "dead", look for a leaky or shorted diode load bypass condenser. The remedy is to replace the mica dielectric in the dual 100 mmf. diode load bypass condenser assembly. This component is C6 in the complete receiver diagram reproduced here.

Distortion and double-talk may be caused by a carbonized wire-wound 150-ohm 35L6 cathode bias resistor (Part No. 63-638) and 27-ohm rectifier protecting resistor (Part No. 63-1017). Even though both resistors check OK, they should be replaced.

Weak reception may be caused by low-Q i-f transformer. Check carefully for broken strands of the litz wire in the i-f coil leads. Sandpaper the ends and resolder them at their terminals. Remember that even a single broken strand may appreciably reduce the efficiency of the litz cable.

If jarring the set results in noisy operation, the trouble may be due to i-f leads touching each other or the coil shield, or, the trouble may be caused by a poorly grounded i-f coil shield can. In either case, remove the shield can and dress the coil leads, then resolder the shield can in place to assure a positive ground.

Off-calibration and mistracking between converter and oscillator circuits, are additional faults which may be encountered in these receiver models, and may be caused by a change in capacity of the 100-mmf. oscillator grid coupling condenser. The solution here is to remove the leads to condenser C4; adjust its capacity to be 90- to 100-mmf., then resolder the leads and align the receiver.

High hum level may be due to the usual causes—leaky filter or coupling condensers.

Distortion and high pitched tweets and hiss, may at first prove to be baffling, but should be recognized as symptoms of probably an open r-f bypass condenser. This is the 500-mmf. unit, C8 (Part No. 22-822), and should be replaced.

If cracking and buzzing noises disrupt reception, look for a leaky filter condenser. Change this component (Part No. 22-835) even though it tests OK.

A high-level line hum ordinarily can be attributed to the a.c. line being coupled into the 1st-audio grid circuit. The remedy is to shield the brown lead between diode load by-pass condenser and the B— end of the volume control. Connect shield to B—.

Zenith Model 5G407, 5G441, and 5G461, Chassis #5537

See cut below

★ This is an a.c.-d.c. and 6V. receiver, with resistive filtering instead of the more common inductive or choke coupling, and in some instances a high hum level on a.c. may be encountered. This is due to insufficient filtering, and is readily corrected by adding the condenser, C-13, shown enclosed by dotted lines in the illustration. An electrolytic condenser of 20 to 40 mf., 25v., may be used, connected from A+ to ground.

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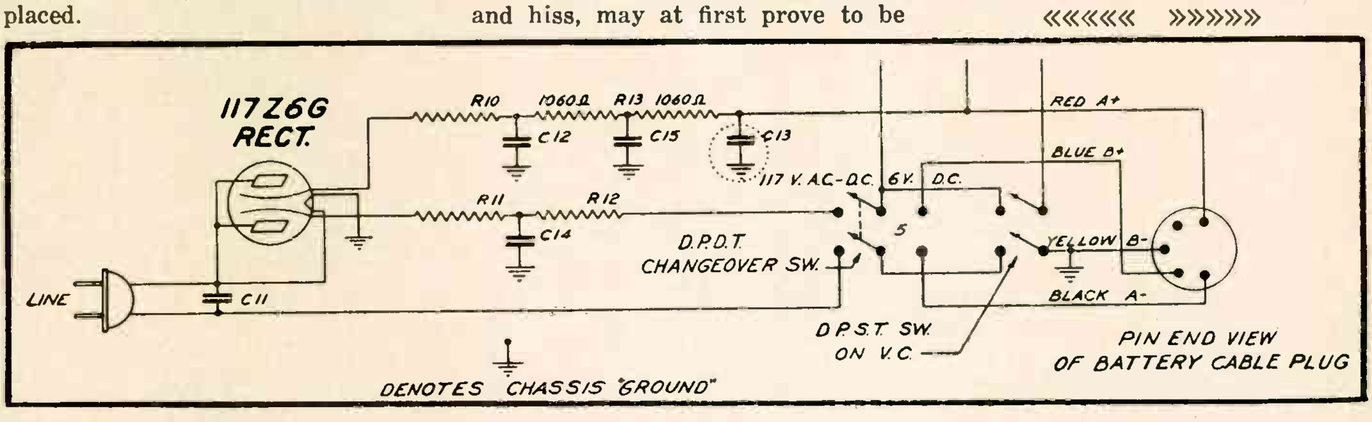

Service Portfolio

(*Continued from page 14*)

signal level is high, or where there is relatively little amplification following. Thus, the maximum filtration in the circuit of *Fig. 11* is for the first amplifying stage where we know any remaining hum is going to be amplified by succeeding stages along with the relatively weak signal. As we progress from stage to stage, the need for such complete filtration becomes less, so fewer filtering stages are required. In this way, it becomes possible to make an effective power supply filter circuit without the use of any chokes.

Substitution of resistors for chokes in some power supplies may cause motor-boating. This may usually be overcome by increasing the filter capacity, reducing the value of resistance used, or both.

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"MICRO TOPICS"

Every two weeks the staff of Universal Microphone Co., Inglewood, Cal., publishes a newsy house organ called "Micro Topics." The latest issue shows that employees have recently purchased nearly $11,000 worth of War Bonds and over $1,750 worth of War Stamps.

Electron Optics

(*Continued from page 18*)

errors, but only a beginning has been made. As Klemperer says: "The electron optical researches of the next few years wil have to pass through a laborious phase similar to that which occurred with glass optics. The way of progress will lie in the direction of analysing lens errors and of designing lens systems as free as possible from all those errors which are found most disturbing in practice."

Here we have an illustration of what was said in our last lecture—that the practical development of electronics is nearing a point where all the easy things will have been done, and that beyond this point future progress will be made chiefly by those who have a good knowledge of fundamental theory and a sufficient familiarity with the mathematical tools which these fundamental principles require for their development. Difficult as this theory is, the practical applications which it has already created have fully justified the attention that has been given to it, and there are undoubtedly many more such applications remaining to be discovered. We shall now discuss some of the important applications that have already been made.

The most prominent of these is the electron microscope. You may have seen pictures of this instrument — a large piece of apparatus, taller and heavier than its operator, and there comes at once to mind a comparison with the ordinary microscope, which can be carried about in a satchel, and which can be obtained for a fraction of the cost of the electron microscope. The question naturally arises, what advantage has the electron microscope to offer to offset these inconveniences of size and expense? Is the electron microscope merely an overgrown scientific curiosity?

By no means. The great advantage of the electron microscope is that it possesses a resolving power at least fifty times as great as that of the best light microscope. By resolving power we do not mean magnifying power. As the magnifying power of an ordinary microscope is increased there comes a point where, with a further increase in magnifying power, there is no finer detail perceptible. This limit is set, not by the construction of the microscope, but by the wave length of the light used. If we were making a mosaic picture in stained glass containing a life size representation of a human face, and had available as working material only pieces of glass an inch square, we would find it necessary, in order to obtain good detail in the picture, to break up these glass units into much smaller pieces.

And so it is with an image formed by light waves. The average length of a wave of visible light is about half a thousandth of a millimeter, and it is this which sets a limit to the fineness of detail obtainable. However, in the ultra violet region of the spectrum there are waves of about half this size. The image produced by these waves can be recorded photographically, and the ultra violet microscope possesses a resolving power about double that of an ordinary microscope.

Now X-rays are known to be waves of still shorter length, some of them less than one thousandth that of visible light, and these rays will also affect a photographic plate. The question naturally arises whether a microscope could not be constructed to use these rays and give a much higher resolving power. Unfortunately, no one has as yet been able to construct a lens which will focus these rays, nor to indicate theoretically how this could be done.

Here comes in the practical application of the wave aspect of the electron. Under ordinary conditions, the wave length connected with the electron may be even smaller than that of X-rays and, as we have just seen, it is possible to focus these electronic waves and produce images of their source. Moreover, such an image can either be photographed or made directly visible to the eye by means of a fluorescent screen. These two possibilities of lens construction and image recording make the electron microscope practicable.

When an electron behaves like a little bunch of waves, experiments such as those of G. P. Thomson tell us that their wave length varies inversely as the velocity with which the electron is moving. The wave length λ is given by the formula

$$\lambda = \frac{h}{mv}$$

where v is the velocity of the electron, m its mass and h is Planck's constant of action, which is equal to 6.59×10^{-27} erg seconds. When electrons have such velocities as commonly occur in practice, their wave length may be very small. For instance, electrons which have been accelerated by a 60 KV field will have a wave length of the order of one hundred thousandth of that of yellow light. Theoretically, this would give a resolving power many times greater than can be obtained with light, but the existing errors of the best electron lenses that have as yet been constructed (especially spherical aberration) make it impracticable to obtain more than about fifty times the resolving power of a light microscope. This, however, is a great advance; but when we learn how to correct these errors as perfectly as we have learned how to correct glass lenses, there will be an extensive region of discovery open to us.

The electron microscope in its structure follows closely the pattern of the ordinary light microscope. In the latter, the object is illuminated by transmitted light; in the electron microscope, by transmitted electrons. The object is usually of such small dimensions (of bacterial size) as to be sufficiently transparent to the electrons. The mounting of the object, however, requires special attention. The electrons will not penetrate an ordinary glass slide, and the usual practice is to mount the object on an extremely thin cellulose film, about a millionth of a centimeter thick, made by spreading a very small drop of a solution of cellulose on water and allowing the solvent to evaporate. This thin film is supported on a fine wire mesh screen. The objects to be examined are suspended in water and a small drop of the suspension placed on the film.

The electron shadow picture of the object is then passed through electron lenses, of either the electrostatic or the magnetic type, analogous in arrangement and function to the objective and the eyes piece of an ordinary microscope. The image is formed either on a fluorescent screen or on a photographic plate, which takes the place of the retina of the eye. The whole arrangement operates in a vacuum of about 10^{-5} mm of mercury.

The electron microscope has recently been applied in metallurgy for the examination of the microscopic structure of an etched surface of metal, which may itself act as the cathode. This field is quite new and in an elementary stage of development.

It may now be seen that the electron microscope depends for its action on two rather abstruse and as yet imperfectly understood points in electron theory—the wave and particle aspects of the electron. The focussing of the electrons and the formation of the image depend upon the charged particle aspect, and the great increase in resolving power is due to the wave aspect.

Another important application of electron optics is found in television. In current practice, an image of the object to be transmitted is projected optically on a flat surface consisting of a mosaic of tiny photo-electric cells, called an iconoscope(6). This mosaic is made by spattering one surface of a sheet of mica with microscopic particles of silver, and covering the other face with a thin sheet of metal. This arrangement is then equivalent to a capacitor with one electrode continuous and the other discontinuous. When an optical image is projected on the silver coated surface the metallic particles emit negative electrons and become positively charged to an extent proportional to the intensity of the light and shade at the different points of the image. This mosaic of charged particles is now scanned by a beam of negative electrons brought to a sharp focus. As each positively charged particle of silver is reached by the scanning beam it absorbs enough negative electrons to neutralize its charge, and a small pulse of current flows out of the mosaic capacitor. As the whole picture is scanned, there will be a rapid succession of pulses of current of varying strength, proportional to the light and shade at the different points of the picture. This series of pulses is transmitted via radio to the receiving station.

At the receiving station there is another scanning beam of electrons which sweeps over a fluorescent screen. The oscillations of this beam must be perfectly synchronous with those of the tranmitting beam. This is accomplished by radio control over a separate channel from that which transmits the picture. The picture is reproduced on the receiving screen by varying the current intensity in the receiving beam. This is produced by grid control, the received pulsating picture voltage being applied to the grid.

As may readily be seen, perfection of detail in the transmitted picture depends on the sharpness of focus of the transmitting and receiving beams. The size of the silver particles in the mosaic of the transmitter can at present be made much smaller than the focal spot of the electron beam. A high degree of perfection in the electron lens is therefore required. In addition, attention must be given to the constancy of the accelerating voltage applied to the electrons in the receiving and transmitting beams. A change in this voltage will alter the speed of the electrons, and this will produce a corresponding change in their wave length, or, to use an optical analogy, their "color." And just as in a glass lens we may have chromatic aberration, so in an electron lens different wave lengths will be differently refracted, and the focal length will change. What is needed is an achromatic electron lens, but this problem has not yet been satisfactorily solved.

The corresponding problem in glass optics was one which offered much difficulty in earlier days. Newton himself, after much study and experiment, gave up the problem of constructing an achromatic lens as impossible, and sidestepped the difficulty by using a concave mirror instead of a convex lens when he constructed the first reflecting telescope. The first achromatic lens was not produced until thirty years after Newton's death. A similar resort to electron mirrors is not likely to afford a perfect solution of the present problem.

By referring to *Fig. 3* it will be seen that the reflection of an electron is really deflection, or continued refraction, which will depend to a certain extent on the speed of the electron. A certain amount of chromatic aberration is therefore to be expected with an electron mirror — another case of a breakdown in analogy between ordinary and electron optics.

The field of electron optics, as we have seen, though but recently developed has made surprising advances; yet what has been accomplished is but a small fraction of what this new field will open up to us when it is developed and perfected to the same extent as ordinary optics. In this connection there is a historical parallel of interest.

Prior to the invention of the telescope, considerable information about the heavenly bodies had been accumulated, but this knowledge was confined to their positions and motions. The ancients knew how to predict eclipses, but to them stars and planets were merely points of light. They knew how these points moved, but of their ultimate nature they knew nothing. The telescope showed us the spots on the sun, the mountains on the moon, the canals on Mars, the rings of Saturn and the numerous satellites of the planets. In addition, the invention of the spectroscope has enabled us to do what the French philosopher Comte had declared to be utterly and forever impossible—to determine the chemical composition of the stars.

In our present knowledge of molecules, atoms and electrons we stand today much where astronomy stood before the invention of the telescope. We know a good deal about the motions and behavior of these bodies, but as to their ultimate structure we have yet much to learn. Bohr's "solar system atom" has had its day and ceased to be; Schrödinger's wave atom must eventually be replaced by a better guess; and of the ultimate nature of electrons we know almost nothing. Yet we stand today but a comparatively short step from an increase in our knowledge that will doubtless far exceed that brought about by the telescope.

The diameter of a molecule is of the order of 10^{-8} cm. The smallest detail visible in an ordinary microscope is about 2×10^{-5} cm, 2000 times the diameter of a molecule, and as we have seen, there is no hope of increasing the resolving power of this instrument. The electron microscope, imperfect as are its lenses, can detect detail as small as 4×10^{-7} cm, fifty times smaller than can be seen in an ordinary microscope and only forty times as large as a molecule!

And there is plenty of room for improvement. The waves used in the electron microscope are a hundred thousand times smaller than those used in the ordinary microscope, and theoretically, with equally perfect lenses, this should enable us to obtain a resolving power at least ten thousand times greater; but the best that we can do is fifty times, and we need only two thousand to see a molecule!

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[*Continued on page 31*]

DU MONT APPLIES FOR WASHINGTON TELEVISION LICENSE

Allen B. Du Mont Laboratories, Inc., with offices, laboratories and plants in Passaic, N. J., has just filed with the Federal Communications Commission a request for the reinstatement of the application of a commercial television station, to employ Du Mont-built equipment, for Washington, D. C. The station will operate on Channel 1 or 50,000 to 56,000 kilocycles.

Already the Du Mont organization is operating a New York television station, W2XWV, at 515 Madison Avenue, on a scheduled program basis. Each Sunday evening, from 8:30 until almost 10:00, this station is on the air with a program of genuine entertainment and enlightenment. In addition and more recently, W2XWV on Wednesday evenings is on the air with strictly experimental programs aimed at developing the sponsored program or telecast advertising technique for future commercialized television. Leading advertisers, advertising agencies and broadcasters interested in post-war telecasting, are taking part in these experimental activities.

★

MAGNETIC WIRE RECORDER

A new device being built by the G-E Company. One model, a nine-pound recording field unit is operated by batteries. The other model, a combination unit, has built-in recording, playback, and instantaneous erasure features.

Sixty-six minutes of continuous speech and sound can be recorded magnetically on 11,500 feet of hair-like steel wire on a spool no larger than the ordinary doughnut in the recorder. The sound and speech can be "wiped" off the wire magnetically without any wearout. 100,000 reproductions have failed to alter the quality of the wire.

★

ERCO DEVELOPS RESONANCE METER

Resonance Meter type MW-60, has been developed by Erco Radio Laboratories, Inc., Hempstead, N. Y. This sensitive indicator provides convenient, accurate means of determining resonance in oscillators and transmitters; standing wave ratios, transmission lines, antenna systems, tank circuits, coupling devices, and modulation indication.

Ruggedly constructed, it is ideal for resonance measurement of transmitting equipment in the field and laboratory, such as: absolute altimeters, blind landing markers, glide path markers, airport traffic control, weather teletype, and broadcast relay circuits.

★

METAL-CASED MICA CAPACITOR ALTERNATES

Ultra-small oil-impregnated oil-filled capacitors for use in assemblies where both space and weight are at absolute minimum, are now announced by Aerovox Corporation, New Bedford, Mass. Originally designed as metal-cased alternates for mica capacitors, these Type 38 oil tubulars are now being used for newly-designed equipment.

Metal case is capped by double-rubber-bakelite terminal insulator assembly, and units are available with both terminals insulated or with one terminal grounded to the case. Pigtail terminals. Normally supplied without outer sleeve but can be had with insulating jacket adding 1/16" to dia. and length. Sizes: 1 and 1 3/16" long, 5/16 and 7/16" dia. Castor (Hyvol) or mineral oil impregnant and fill. Ratings: 300 to 800 v., d.c.w.; capacities from .001- to .01-mf.

G. E. UPS KAAR & NEVIN

Messrs. I. J. Kaar and G. W. Nevin have been appointed managers of the Receiver and Tube divisions, respectively, of General Electric's Electronics Department, it has been announced by Dr. W. R. G. Baker, vice president in charge of the department. The Receiver division is located at the company's Bridgeport, Conn., works, while the headquarters of the Tube division are located in Schenectady, with manufacturing plants in four cities.

★

HIGH SENSITIVITY IRON CORES

For applications calling for Iron Cores having high unit resistivity, the Electronic Components Division of the Stackpole Carbon Company, St. Marys, Penna., offers a special core material showing resistance of practically infinity. This is recommended for applications where a resistance of 150 megohms or greater is required, and where voltages do not exceed the breakdown value.

This high resistivity material reduces leakage currents and their resultant noise troubles. Possibilities of voltage breakdown between coils and cores are also reduced.' In applications using cup cores, the high resistivity core material avoids the necessity for heavy insulation on lead wires.

★

NEW TWO-TERMINAL CAPACITOR

Already a highly popular type of oil capacitor, because of its handy inverted screw mounting and compact dimensions, the Aerovox Type 10 is now further improved by the new double-terminal feature. Heretofore this capacitor has had a single insulated terminal and grounded can.

The new double-terminal lugs are insulated from the "floating" can and no insulating washer is required. These capacitors, available on high priorities only, are oil filled, rated up to 4.0 mfd. at 600 v.d.c. and to .5 mfd. at 1500 v.d.c.

★

POST WAR PLANS

Jack Geartner, Assistant Sales Manager of Emerson Radio & Phonograph Corp. has just completed a tour of several thousand miles, contacting distributors and dealers in key centers in connection with post-war research and planning.

"It is highly significant," stated Mr. Geartner, "that table model radios are nowhere to be found, yet in some areas console sets are still in stock by many dealers, despite the abnormal shortage of receivers that has prevailed for many months."

Very noticeable, too, according to Mr. Geartner, was the great optimism of the trade who anticipate a remarkable post-war business on radio. Distributing organizations, by and large, have been kept fairly intact, prepared for "R" day—the day when civilian Radios are again available.

SUN RADIO CHANGES NAME

The Sun Radio Co., of 212 Fulton Street, New York City 7, has modernized its name and will henceforth be known as the Sun Radio & Electronics Co.

★

ELECTRONIC CONTROL

Thordarson Electric Mfg. Co., of Chicago, offers "Flashtron", an electronic unit to afford improved performance in many types of automatic control setups. Flashtron is not in itself a control system, but may be considered a sort of "buffer" control element operating between the primary sensitive element and the power operating control element. It requires negligible power for actuation.

Using no relays in its makeup, Flashtron is silent in operation, hence especially advantageous where noise-free applications are required. Full particulars may be had by writing to Thordarson.

★

NEW INDICATOR LAMP

G-E announces a small molded plastic indicator lamp with a lock-on cap which cannot be shaken loose and will not "freeze" to the base. As many as five circuits can be identified on one panel by the use of five different color caps—amber, red, green, white and blue. The lamp is supplied ready for mounting.

Applications include radio transmitters, and any other equipment or control device where a glow lamp is needed to show that the device or circuit is on or off.

★

PHILCO DIVIDEND

The Board of Directors of Philco Corp. declared a dividend of twenty cents (20c) per share of common stock payable September 13, 1943, to stockholders of record August 28, 1943. Previous dividend payments this year were fifteen cents (15c) per share on March 12th and twenty cents (20c) per share on June 12th.

In and Around The Trade

(Continued from page 5)

consultation with Radio and Radar Division, decided that in the future, probably beginning December 1, the Mica-Graphite Division will undertake to provide only sufficient mica, of the presently accepted condenser qualities, to maintain consumption at what has been the average rate of consumption for the first nine months this year. Such quantity of mica of presently accepted condenser quality (good stained and better) will be released to each capacitor manufacturer or his supplier as will allow him to maintain his average monthly consumption for the first nine months of 1943.

The limitation of mica allocation is to apply only to block of good stained quality or better and film of second quality or better. On lower qualities of block and film, there will be no restriction on allocation. The capacitor manufacturers will have their choice of restricting their production to the number of condensers they can make from their allocations of the usually accepted capacitor qualities of mica, or using lower qualities of mica to expand their production. This policy should encourage a greatly increased use of lower qualities of mica for capacitors.

Emerson Develops Hot Raider Receiver

Now, with both hands and arms free to do their jobs, American Raider troops and paratroopers are equipped with "Raider" radio receivers over which they get their orders for action. The remarkable little development, produced by Emerson Radio and Phonograph Corporation, is another of the long list of Axis troubles being turned out in ever increasing volume by that company.

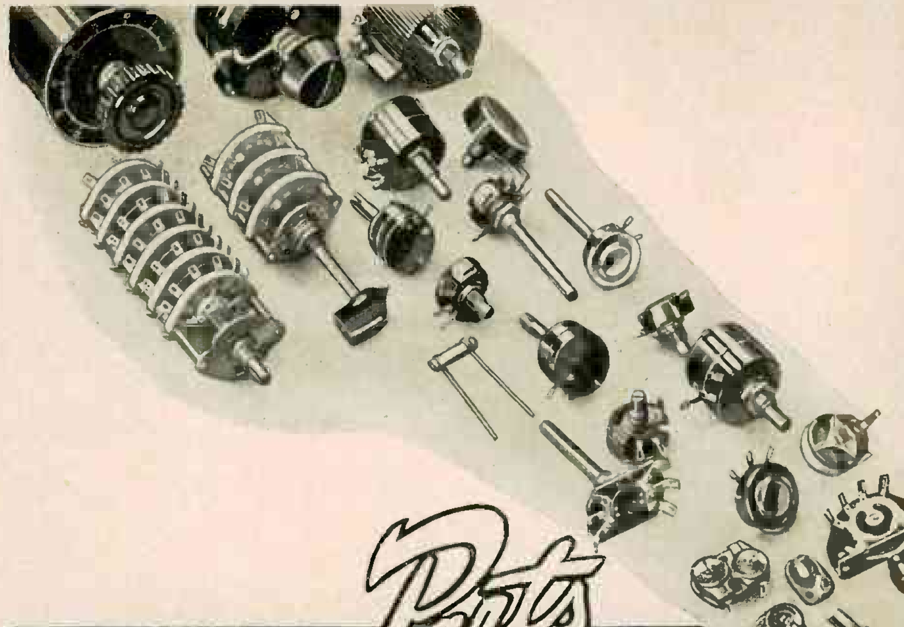
The receiver and battery of the "Raider" are contained in a small kit, the straps of which are slung over the shoulders and the set carried on the marine's chest. The earphones are built into a fabric cap and fitted into the metal helmet. The helmet acts as the antenna.

Unlike most receiving equipment [illegible]d by our armed forces, this compact Emerson product is virtually invisible and is an added safeguard to its operator in that it does not distinguish him from his regular marine companions. Furthermore, its construction makes it proof against harm to the equipment that is usual in immersion, storm, shock, heat, cold—to which the raider must submit himself and his equipment.

Ghirardi Sells Out To Farrar & Rinehart After 12 Long Years

After twelve highly successful years in the Radio book publishing business Alfred A. Ghirardi, internationally known author of some of the most highly regarded and widely used texts on radio theory, maintenance and repair, announces the purchase of his Radio & Technical Publishing Company by Farrar & Rinehart, Inc., Publishers, of 232 Madison Avenue, New York City, whose subsidiary the new Radio & Technical Division of Murray Hill Books, Inc. will continue to publish the present "Ghirardi" radio books as well as new ones that he will now have time to write.

This merger is the outcome of careful study and the realization that the new setup can render a service in the radio-electronic publication field that neither company alone could offer. Relieved from the exactions and many production and administrative details of running an ever-expanding publishing business, Mr. Ghirardi will now be able to devote all of his time and energies to the writing of new books for the radio-electronic field, which lack of time has hitherto prohibited. He will also continue in close touch with the editorial phase of the business in his new post as Editorial Consultant in the field of Electronics for Farrar & Rinehart, who plan to greatly expand their business in the radio-electronic book field.



Moving Soon?

Notify RADIO SERVICE-DEALER'S circulation department at 132 West 43rd Street, New York, 18, N. Y. of your new address 2 or 3 weeks before you move. The Post Office Department does not forward magazines sent to a wrong address unless you pay additional postage. We cannot duplicate copies mailed to your old address. Thank You!

BUY WAR BONDS— THEN BUY MORE BONDS

RADIO RECEIVER KIT

A 5-tube kit which permits progressive study of basic receiver subjects such as rectification, filtering, detection, r-f, i-f and a-f amplifications has been developed by Allied Radio Corp. of 833 W. Jackson Blvd., Chicago, Ill. The kit consists of all necessary parts, wire, hardware, solder, tubes, and speaker for the construction of a 5-tube a.c.-d.c. superhet receiver of advanced up-to-the-minute design.

SAFETY DOOR INTERLOCK SWITCH

Designed by G-E as an emergency device to interrupt control circuits where access doors are opened when the power is on. It has a carrying capacity of 10 amp., 110 or 220 volts a.c. or d.c. and an emergency opening capacity of a.c. 7½ amp., 110 or 220 volts; d.c. on low inductive circuits, 5 amp., 125 volts; 2½ amp., 250 volts.

Application covers a wide range where doors, windows or covers must be interlocked for the protection of the equipment and safety of the personnel.

Doing Favors Pays Dividends

by Stephen Porter Lathrope

★ There doesn't seem to be any connection between a dealer in radios and the collection of gas and electric bills, but J. W. Schroeder, owner of the Helshro Furniture and Appliance Store, located at 435 N. Broad Street, New Orleans, La., has made the collection of utility bills his business with beneficial results.

The Helshro store is located in one of the outlying neighborhoods of New Orleans, somewhat removed from the offices of the Public Service. In order to be of service to the people, and prospective customers living in his section, Mr. Schroeder made arrangements with the local utility whereby he would be allowed to collect gas and electric bill payments due. Just how well received was the novel idea may be gleaned from this fact: frequently as much as $2000 is collected in a single day, with dozens of families made happy by the free service obtained.

As might be expected, the people who receive favors from Mr. Schroeder show their appreciation in a tangible manner. They favor the Helshro store whenever in need of any commodity it handles.

Perceiving that "you get when you give," Mr. Schroeder has gone one step further. He applied for and obtained an American Express Money-Order agency franchise. Now he not only sells money-orders, but he also cashes them, and gets to know more intimately his clientele.

When interviewed recently, Mr. Schroeder admitted that Helshro's store had, at the time, exactly 703 radio repair jobs in the shop. Re[illegible] sales were breaking records too[illegible] though stocks of many items are [illegible] a dangerously low point. Summarized, it would seem that both the gas and electric bill collecting—and the money-order sales agency stunts were cooperative, appreciated, and worthwhile.

«««« »»»»

WANTED FOR CASH!

Photographs of radio and electrical appliance retailing establishments wanted. Interior and outside views—also musical instrument and record departments acceptable. Photos must be suitable for reproduction in RADIO SERVICE-DEALER. Submit glossy prints to News Editor, Cowan Pub. Corp., 132 W. 43 St., N. Y. 18, N. Y.

Electron Optics

[*Continued from page 25*]

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HOWARD W. BENNETT NOW MANAGER

Howard W. Bennett has been made manager of the Specialty Division of the G-E Company's Electronics De-

partment. He will be responsible for the engineering, manufacturing, and sales operations of that division.

★

ANOTHER STAR

The War Dept. has notified the Solar Mfg. Corp. that it has been awarded an additional star for continuance of an excellent production record since the "E" flag was awarded. The Solar Co. has also been recognized as a pioneer in the use of blind employees.

Servicing Becomes Diversified

THERE WAS A TIME when the average service shop specialized only in the repair of radios, while electrical appliance shops handled repairs of that character primarily. Now with the shortage of technically trained men (or women) the barriers are down and everybody is trying to service anything electrical that is brought in. A new era opens—and we plan to be right in the thick of things. So be sure to read the next and subsequent issues!

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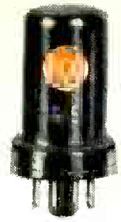
Why Is an RCA Electron Tube



Like Sherlock Holmes?

THINGS that were beyond the ken of ordinary mortals were "elementary" to the man in the fore-and-aft cap.

And why was this?

Simply because Holmes could analyze more deeply, see more thoroughly into the core of things, be more observant of little things than anyone else.

A modern Sherlock Holmes is the RCA Electron Tube employed in an electronic device to check tungsten wire leads for radio tubes.

With this difference: Sherlock master-minded *after* the crime. The electron tube in this device is the Magic Brain that detects microscopic flaws in wire leads *before* they can cause harm!

For with the aid of this device, powered with an RCA electron tube, a tiny flaw in a wire can be discovered instantly—and the faulty wire rejected before it finds its way into a completed tube assembly resulting in a leaky tube.

This is electronics in action *now*—at RCA.

Tomorrow many of you Distributors and Servicemen may be selling, installing, and servicing electronic equipment. The "electronic future" now developing should find you in an enviable position to cash in on your experience and familiarity with radio tubes, circuits, and parts. RCA, too, will be playing a leading part in tomorrow's electronic era—***because the Magic Brain of all electronic equipment is a tube—and the fountain-head of modern tube development is RCA!*** *RCA Victor Division,* RADIO CORPORATION OF AMERICA, *Camden, N. J.*

TUNE IN "WHAT'S NEW?"—*RCA's great new show, Saturday nights, 7 to 8, E.W.T., Blue Network.*

To detect flaws in wire leads for RCA tubes, wires are tested by placing them in the magnetic circuit of one of two radio-frequency electronic oscillators. These oscillators are coupled to produce a beat frequency which is dependent on the relative frequencies of the two oscillators. Since a faulty and a perfect wire produce different beat frequencies, as shown by an output meter, an observer watching the meter can instantly detect and reject the faulty piece.

ASK ABOUT. . .
RCA INDUSTRIAL MUSIC SERVICE

RADIO CORPORATION OF AMERICA