RADIO

NOVEMBER, 1944

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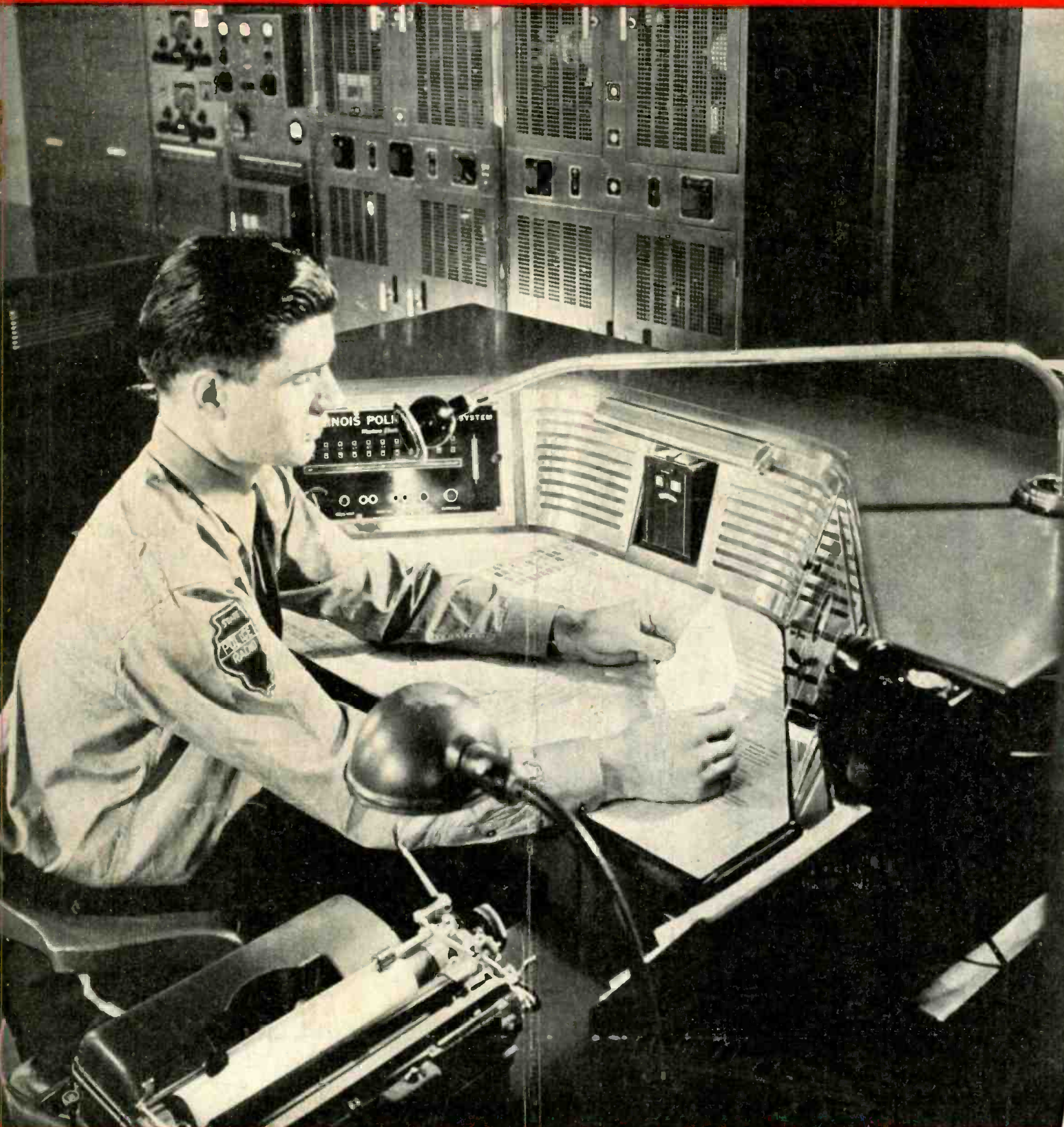


The Journal for Radio & Electronic Engineers

DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES AND EQUIPMENT FOR THE NEW ERA OF ELECTRONICS

Specify

C. T. C.

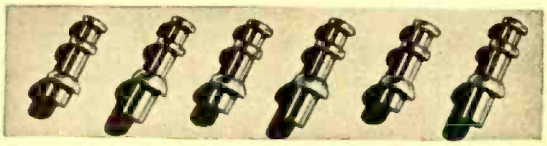
CRYSTALS

I-F TRANSFORMERS

TURRET TERMINAL LUGS

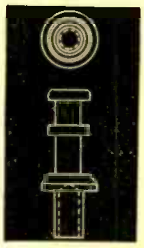
SPLIT LUGS

DOUBLE END TERMINAL LUGS

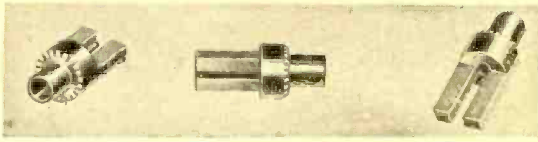


C. T. C. TURRET TERMINAL LUGS

Just swage these heavily silver plated Turret Terminal Lugs to the board and in a jiffy you have a good, firm turret terminal. Quick soldering, too. Sufficient metal is used in the Lugs to give them strength but not enough to draw heat thus increasing soldering time.

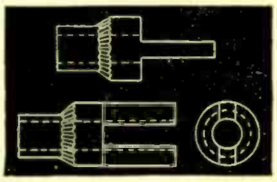


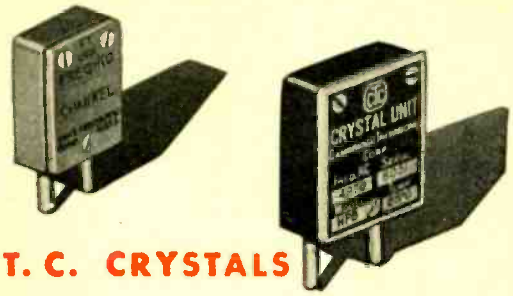
C. T. C. Turret Terminal Lugs are stocked to meet 1/32", 2/32", 3/32", 4/32", 6/32", and 8/32" board thicknesses.



C. T. C. SPLIT LUGS

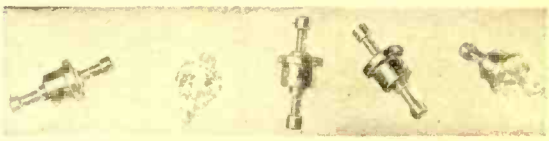
A .050 hole through the shaft permits wiring to these Split Lugs from either top or bottom without drilling or cutting. Just swage them to the board, then wire. Made of brass, heavily silver plated, C. T. C. Split Lugs are available in two sizes to fit 3/32" and 5/32" boards.





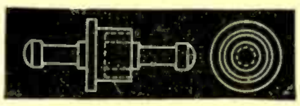
C. T. C. CRYSTALS

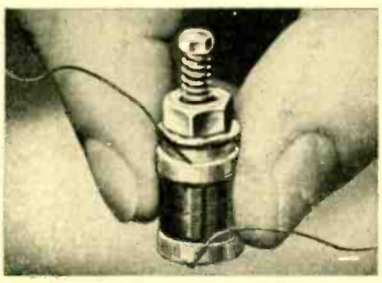
Accurate cutting of each slice — thanks to X-RAY ORIENTATION — insures constant frequency over a wide temperature range. Multiple mechanical lapping operations; dimensioning by edge lapping and finishing to final frequency by etching, are other important steps in the manufacture of C.T.C. Crystals that guarantee high activity and constant frequency throughout their entire life.



DOUBLE END TERMINAL LUGS

Use these Double End Terminal Lugs when you need terminal posts on both sides of the board. Like C.T.C. Turret Terminal and Split Lugs, C.T.C. Double End Lugs simply swage to the terminal board — provide twin terminal posts which may be wired from top and bottom. Heavily silver plated brass. Stocked to fit 3/32" terminal boards.





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John H. Potts . . . . *President*
Sanford R. Cowan . . . . *Sec'y-Treas.*
Charles H. Farrell . . . . *Adv. Manager*
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NOVEMBER 1944 Vol. 28, No. 11

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COVER

Operator at control desk of Illinois Police Radio Central Station. *(Courtesy Western Electric Co.)*

ARTICLES

MISCELLANEOUS

RADIO Magazine (title registered U. S. Pat. Off.) is published monthly at 34 N. Crystal Street, East Stroudsburg, Pa., by Radio Magazines, Inc. Executive and Editorial Offices at 342 Madison Avenue, New York 17, N. Y. Subscription rates—United States and Possessions, $3.00 for 1 year, $5.00 for 2 years; elsewhere $4.00 per year. Single copies 35c. Printed in U.S.A. Entered as Second Class Matter October 31, 1942, at the Post Office at East Stroudsburg, Pa., under the Act of March 3, 1879.

. . . How MYCALEX Solved a Tough Insulating Problem for HAZELTINE ELECTRONICS and the NAVY . . .

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September 15, 1944

Mycalex Corporation of America
30 Rockefeller Plaza
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Attention: Mr. Jerome Taishoff, President

Gentlemen:

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We put our problem in the hands of your company.

The cooperation which we received from your organization is to be very highly commended. The special material, which was developed after much experimentation and research on your part, has maintained a constant dielectric all through production.

We have delivered a quantity of these units to the Navy, and we wish to again thank you for the large part you played in making the delivery of these vital equipments possible.

Very truly yours,

J. E. Gray

J. E. GRAY
Co-ordinating Eng

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Transients

HIGH FIDELITY

★ Last month we published an article by O. B. Hanson entitled "Down to Earth on 'High Fidelity'" in which the author discussed various factors which affect better reproduction of broadcast programs. Mr. Hanson advocated more attention to a balanced system of reproduction and the limitation of the audio range to a maximum of 50 to 10,000 cycles for all types of broadcasting, including frequency modulation. He stressed the need for improved low-frequency reproduction, rather than for extending the range beyond 10,000 cycles at the possible sacrifice of other, and more important, considerations.

We feel that Mr. Hanson has made a sensible and realistic presentation of the situation, and that his article should be of value to all interested in the design and manufacture of high-grade receivers. At the same time we are definitely not in favor of ham-stringing designers who want to tackle the job of turning out a receiver to cover an audio range extending from, say, 30 to 16,000 cycles. There is plenty of room in the u-h-f spectrum for a frequency deviation band adequate for low-noise-level f-m transmission over this range. The war has proved to us that many ideas previously considered impractical can be worked out, and quickly.

Regarding the need for higher fidelity receivers, many have contended that the lack of widespread public acceptance of prewar so-called high-fidelity receivers proves that it isn't worth while to attempt to produce them. Fact is, those sets which were termed "high fidelity" were often not sufficiently better than other good receivers to impress the listener. Furthermore, the extended upper-frequency range, when present, was valueless on most programs on the standard broadcast band, where the four-or five-thousand cycle limit sliced it off at the transmitter.

Other things being equal, the public has never failed to accept radios which provide demonstrably better reception. The first models which furnished improved low-frequency reproduction, artificial and "boomy" as it was, were tremendously successful because the difference between these sets and their predecessors was immediately apparent.

At a meeting of the Institute of Radio Engineers several years ago, Dr. Fletcher of Bell Labs gave a memorable demonstration of sound reproduction in auditory perspective. His apparatus covered not only the frequency range from about 30 to 16,000 cycles, but also an exanded dynamic volume range. Never before or since has this writer heard such marvelously excellent reproduction. Then, that the audience might make comparisons, he introduced filters which limited the frequency range in progressive steps. While the difference in fidelity was detectable when the upper limit was reduced to 8,000 cycles, the quality of reproduction was still extraordinarily good. When the upper limit was restricted to 4,000 cycles, representing that of the average console receiver, the deficiencies of present-day receivers became immediately apparent.

Perhaps the greatest handicap to high fidelity reception is the limitation of the volume range, rather than the frequency range. Granting, for the moment, that a large proportion of the public is tone-deaf, most certainly they can hear and appreciate a closer approach to the true volume range than we are now getting. Regardless of frequency range, no broadcast of symphonic music can be considered high fidelity unless, when received, the contrast between the pianissimo and fortissimo passages appears to be similar to that which the listener hears at a "live" performance.

FLY RESIGNS

★ The announcement that James L. Fly has resigned as head of the FCC should be cause for deep regret among all who have the best interests of the radio industry at heart. Few men in public service have been subjected to such bitter attacks, yet even those who disagreed with him were bound to respect his sincerity and integrity. We believe the entire industry owes him a vote of thanks for the efficiency and fairness with which he has handled a most difficult job.

—*J. H. P.*

TECHNICANA

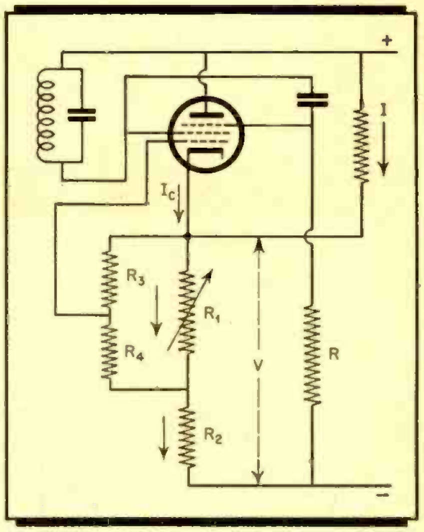


Figure 1

DYNAMIC RESISTANCE MEASUREMENT

The transitron as a negative resistance oscillator may be used to measure the dynamic resistance of a tuned circuit. It is of additional value as a screened oscillator for general purpose use.

The circuit is described in an article by Mr. F. P. Williams, appearing in the August, 1944, issue of *Wireless World.*

The basic transitron oscillator is shown in *Fig. 1,* in which the screen is

[*Continued on page 8*]

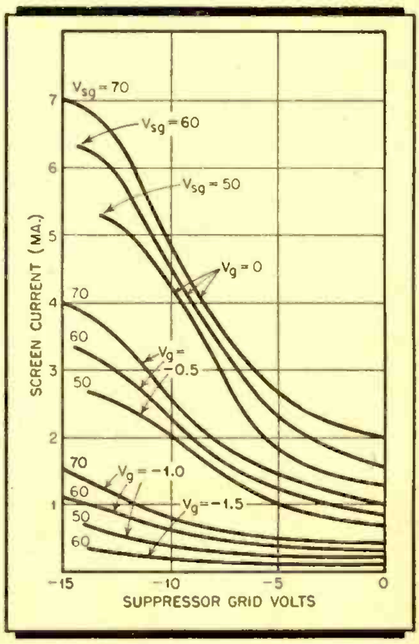
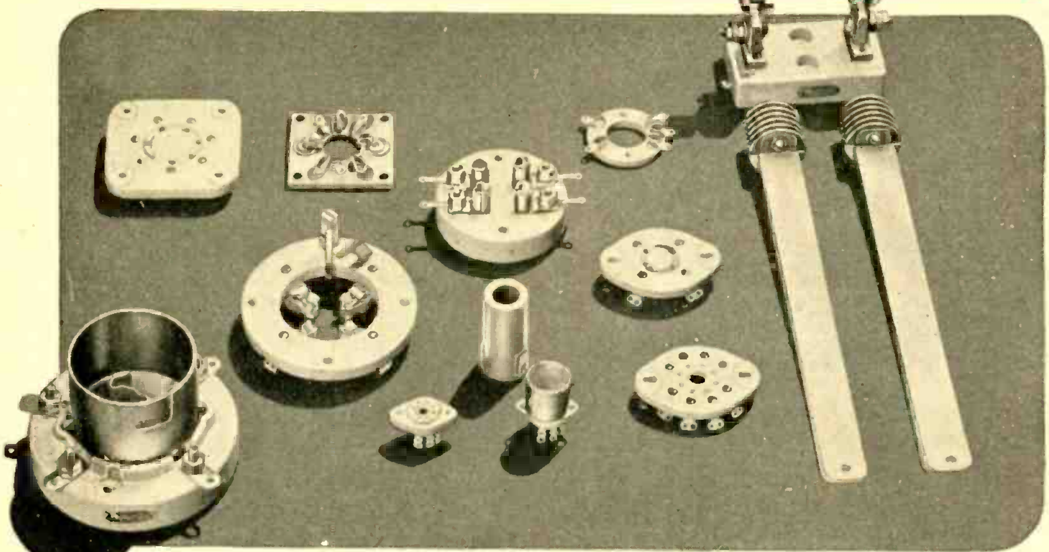


Figure 2

Sockets
FOR ALL TRANSMITTING TUBES



Fom the miniatures (such as the IT series or 9000 series) to the big ones (such as 204A, 833 or 889R) Johnson can usually supply the sockets. Most Johnson tube sockets have been designed in cooperation with the tube manufacturers and many of them were actually in production and ready for delivery before the tube was announced. This explains why the Johnson line is the most complete and why Johnson is the only manufacturer producing many of the types.

This confidence, cooperation and assistance on the part of the tube manufacturers explains too, why Johnson's mechanical and electrical design is superior. Both the Army and the Navy have recognized this superiority in Johnson wafer sockets for example, by specifying both the ceramic and the contacts used by Johnson.

Quantity production and economical manufacturing procedures make Johnson the best buy on the socket market—in fact the price is usually less than that of poorly designed imitations.

On that new socket requirement, investigate Johnson.

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[Continued from page 6]

held at a higher d-c. potential than the suppressor, but at the same alternating potential. Part of the electron current is collected by the screen. A decrease in the a-c screen potential decreases the suppressor voltage and increases the screen current. The retarding field effect produces a negative resistance, which may amount to a megohm.

Instead of using a battery bias, the author employs cathode resistors to bias the suppressor. The control grid bias is applied by the *R1, R3, R4* combination, in which *R1* is variable.

Fig. 2 indicates how a change of control grid bias varies the negative slope of the suppressor grid voltage-screen current characteristic. Several values of *Vg* and *Vsg* were employed, using the British type EF50 tube.

By varying *R1* the negative resistance is made to balance against the positive dynamic resistance, R_D, of the tuned circuit. Because the suppressor grid voltage is held fairly constant at about 10 volts, the operating point is made to stay on the nearly straight portions of the curves. This permits a substantially undistorted signal of approximately 2 volts, peak.

The practical circuit is shown in *Fig. 3.*

For measuring dynamic resistance the resistor R_1 is first calibrated in percent rotation against various resistances connected to T_1 and T_2. Measurements are made when oscillation just starts.

The unknown resistance may then be connected to T_1 and T_2 and the value taken from the calibration curve. For these measurements S_1 is open.

When used as a screened oscillator, the internal tank circuit is employed, S_1 being closed. The output is taken from the cathode follower, and is not more than two volts.

CLASS C AMPLIFICATION

The reasons for the efficiency of a class C R-F amplifier are generally

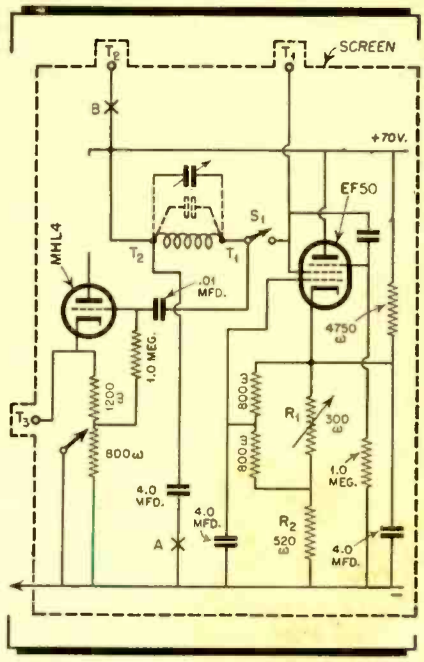

Figure 3

overlooked by the average radio engineer, and have received little attention in the texts, according to Mr. R. W. Hallows in an article entitled "Class C Amplifiers" appearing in the October, 1944, issue of *Wireless World*.

The author lists the following commonly recognized reasons for high efficiency in class C:

a. The tube operates during only a part of the positive half-cycle of grid voltage.

b. The whole of the grid-voltage, plate-current characteristic is employed.

c. Larger driving voltage swings are permitted.

An important factor in class C

COLONEL JOHN CASEY, Manager,
Chicago Municipal Airport . . .

Colonel Casey said, "The growing complexities of airport traffic make it ever more important that private planes and regular operating passenger aircraft be equipped with up-to-date, reliable two-way radio, if high standards of safety are to be maintained. One important factor is . . ."

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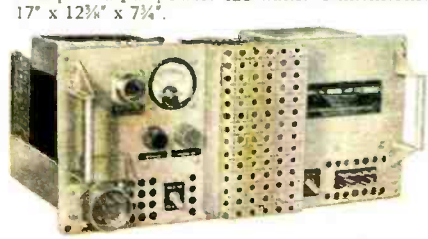

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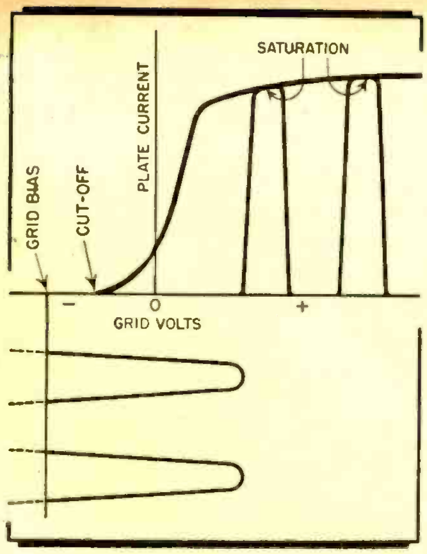

Figure 4

operation, however, is that less heat is required to be dissipated by the plate of the tube than in other types of amplifiers, since average electron velocities are less and anode current flows for only about 1/3 of the time.

The grid-voltage, plate-current curves are shown in *Fig. 4.* Negative grid bias should be at least twice cut-off. Since grid current flows during most of the plate current period, good drive is required. The plate efficiency is 60 to 80% as compared to 50 to 60% for class B operation and 25 to 35% for class A. Since a high degree of distortion is present, class C is only suitable for transmission of r-f power, rather than for reception.

Fig. 5 shows what happens to the plate voltage as the plate current varies due to variations at the grid. The plate voltage falls off with increased plate current in accordance with the drop across the plate load resistor. The phase shift between grid voltage and plate voltage is therefore 180 degrees. But the plate voltage swing may not exceed 120 degrees, and the minimum plate voltage may be as little as 10% of the plate supply voltage.

Maximum emission occurs when the plate voltage is small. Electron velocities are therefore small and less heat is developed at the plate.

MOVEMENT DETECTION

The detection of movements of persons or objects in a prohibited area, the protection of valuables, or the inspection of material as fabricated in continuous sheet form are suggested applications of the "Aniseikon."

This device consists of an optical system operating into two photocell circuits balanced to detect changes in illumination due to movements of the object in the area under surveillance. The Aniseikon is described by Dr.

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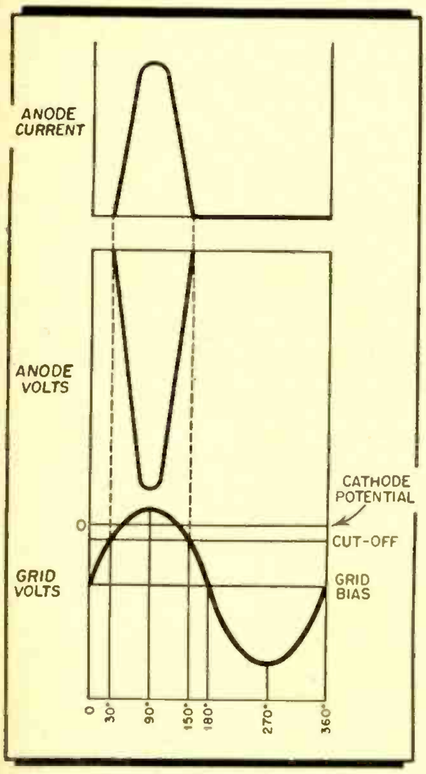

Figure 5

W. Sommer in an article under this title appearing in the October, 1944, issue of *Electronic Engineering*. The author points out that "Aniseikonia is a pathological condition in which the images which reach the consciousness through the two eyes are not of identical shape and size."

The two optical systems use different focal lengths so that the objects in the two photocells are unequal in size. If A is the cathode area in the photocell's and a is the area of the silhouetted image in the first photocell, then $A - a$ is the illuminated area in this cell. When r is defined as the ratio of the image areas in the two cells the illuminated area in the second cell will be $A - ra$. The indicating instrument measures the ratio $R1 = A - a / A - ra$. When this relation is disturbed, as by a movement into the supervised area, the new illumination ratio is $R2 = A - (a+b) / A - r(a+b)$ where b is the area of the new image corresponding to a. The pointer of the indicator is disturbed and can be made to control an external alarm.

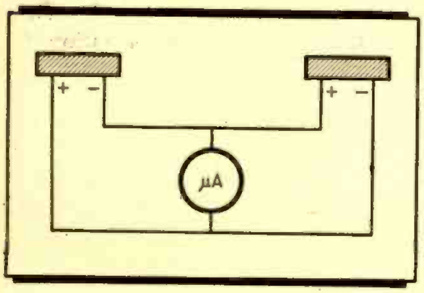

Figure 6

The system described is more effective than a device which depends on interception of a directed beam, since the intruder may avoid the beam. The Aniseikon will supervise an entire area depending upon the width of the lens angles.

Fig. 6 illustrates the balanced photocell circuit. The microammeter movement may be employed to operate an alarm either by an independent source of light beamed through an aperture uncovered by the pointer into an additional photocell, or by use of a relay such as the Weston type 705.

The above description applies to an Aniseikon suitable only for detection of alien objects appearing in the field under supervision. Movement of objects existing in the field can be detected by the introduction of gratings into the optical systems, these gratings to perform the function of the photoreceptors in the retina of the eye.

The patterns of the two gratings differ, so that the electrical balance of the photocells circuit will be upset by any slight movement of the object. In general, the image on one photocell should appear on a small grating element while the image on the second photocell is appearing on a larger element. A side of the smallest element should be approximately .03 millimeter in length for use with a photocell of 20 microamperes per lumen sensitivity.

Fig. 7 illustrates a type of grating which is considered foolproof. When the two gratings are used together the aniseikonia effect will result.

RESISTANCE-CAPACITANCE TUNING

A modified resistance-capacity oscillator circuit in which a wide frequency range can be covered with one con-

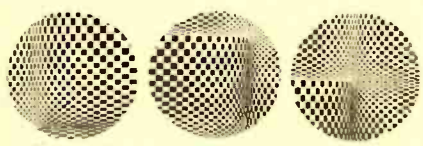

Figure 7

denser gang, and only one dial change is necessary to adjust frequency, is described by Mr. S. S. West in the August, 1944, issue of *Electronic Engineering*.

The circuit permits a 10 to 1 frequency range with one control, and with the use of decade resistances an extremely wide band of frequencies can be supplied at almost constant output.

The circuit of *Fig. 8* is a form of relaxation oscillator in that the frequency of oscillation is controlled by the *R5, C1* and *R6, C2* combinations, in which $R5 = R6$ and $C1 = C2$. The frequency is inversely proportional to either *R* or *C*, and can be varied by ganging either the *R*'s or the *C*'s, the latter being more convenient.

A random negative voltage at the *V1* grid produces an amplified voltage drop across *R1*, which is applied to the *V2* grid. This increases the plate current of *V2* and also the voltage drop across *R2* and *R3*. This drives the grid of *V1* still further negative to cut-off. The *RC* networks permit the charge on *C1* to leak away and the grid of *V2* goes negative. The process now reverses itself so that oscillations are produced.

To preserve good wave form the degree of regeneration must be controlled. This is done by selecting resistor and capacitor values such that the potential at the grid of *V2* is always at a fixed-ratio to the plate potential of *V1*. In other words, the ratio *e2/e1* of *Fig. 9* must be constant. This condition is fulfilled if the CR product remains constant since it is shown that

$$e2/e1 = \frac{j\omega CR}{1 + 3j\omega CR - (\omega CR)^2}$$

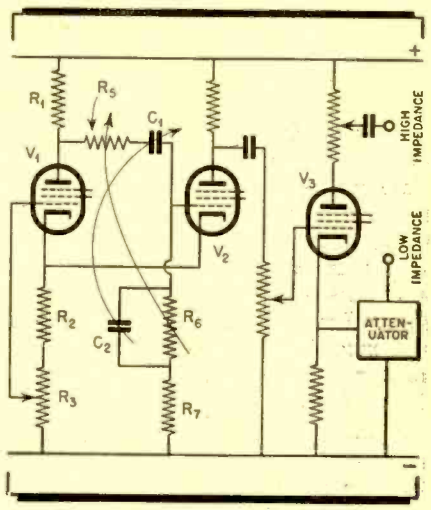

Figure 8

It is also shown that the series network *C1, R5* and the shunt network *C2, R6* produce equal and opposite phase shifts when the frequency is inversely proportional to *CR*. The net phase angle must be zero for oscillations to occur.

The impedance of the network *C2, R6* is

$$Z1 = \frac{X_c{}^2 R - jX_c R^2}{X_c{}^2 + R^2}$$

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[*Continued from page 10*]

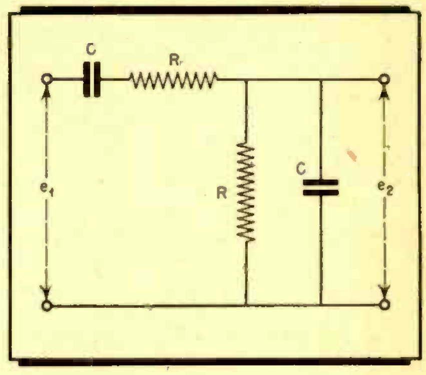


Figure 9

and the impedance of the series network is $Z2 = R - jX_c$, where the *R*'s and the *C*'s are equal. The phase angles are $\tan \phi_1 = -R/X_c$ and $\tan \phi_2 = X_c/R$, from which $f = 1/2\pi CR$.

The grid of *V1* is returned to the tap in *R3* for negative feedback control of oscillation conditions. *R3* is small compared to *R2*.

Resistor *R7* is employed to compensate for the effects of *R2* and should be one-half the value of *R1*.

V3 is used as an output buffer.

DYNATRONS

★ The dynatron as a negative resistance signal source has been replaced by the transitron oscillator in many applications where stable operation is desired.

A dynatron employing a pentode tube instead of the conventional screened tetrode is recommended because pentodes are now more readily obtainable. Mr. G. A. Hay, in an article "Pentodes as Dynatrons" points out that the pentode can be employed by connecting together the screen and suppressor. The article appears in the Sept., 1944, issue of *Wireless World.*

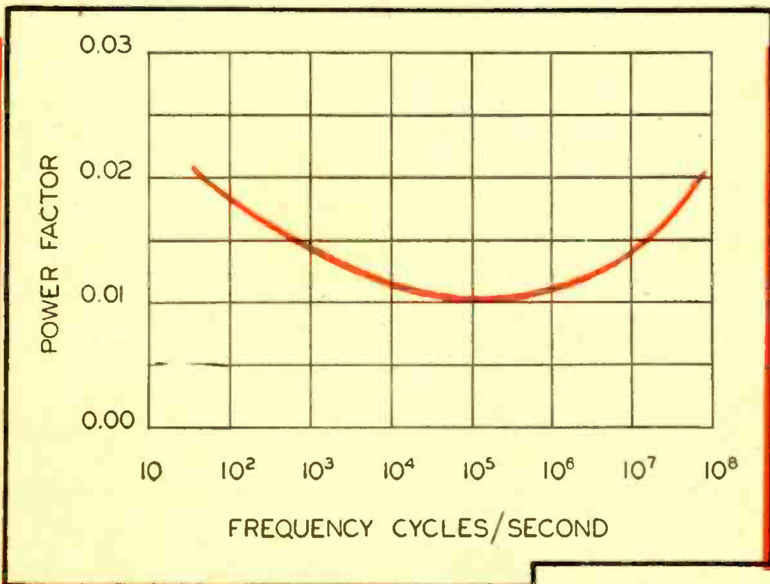
Mr. Hay's studies indicate that some pentodes give better negative resistance characteristics than others—low negative resistance and a long, straight, negative resistance curve. The most suitable tube examined was found to be the British Osram VMP4G.

A limitation to the very low negative resistance lies in the power rating of the screen. When secondary emission is very high the screen current will exceed the plate current, which may even be negative. The power rating of the screen depends upon its ability to dissipate heat.

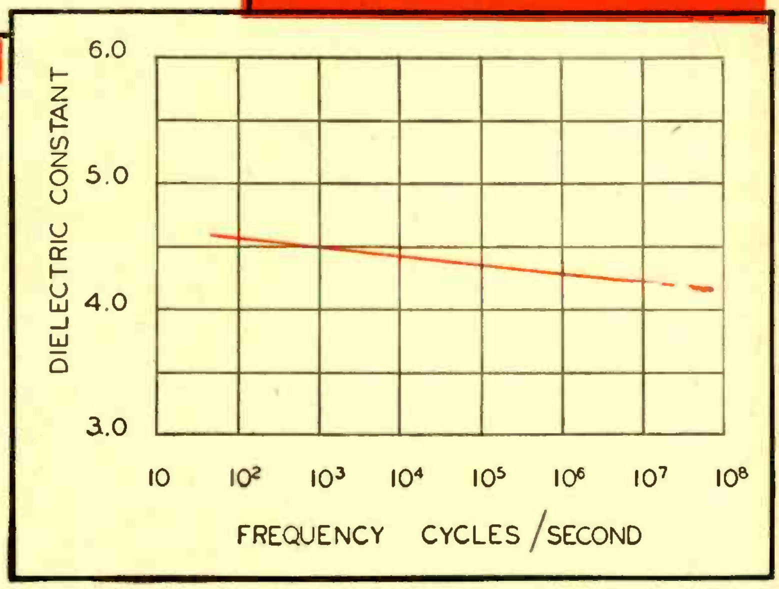
The author finds the negative conductance, $1/Rp$, to be directly propor-

[*Continued on page 14*]

How's this for POWER FACTOR and DIELECTRIC CONSTANT



In a Machinable, Easily Worked Material?



● *These data represent average values measured at normal laboratory conditions of temperature and humidity on specimens not previously conditioned.*

THESE curves show how closely Formica MF-66, glass mat base laminated phenolic insulating material, approaches ceramics and other high quality insulators at high frequencies. It can perform many of the functions for which these materials were once thought necessary.

At the same time it has the mechanical strength to withstand sharp blows and the vibration that is so often present where airborne, ship, and ground installations must be used. Dimensions are stable under changes in temperature and humidity. MF-66 resists the growth of fungi and may be used in the tropics.

It has the usual Formica characteristics of machinability and workability — speeding production and reducing labor costs.

This combination of qualities opens a wide field for the application of the material which as yet has scarcely been scratched.

Test samples are available on request.

FORMICA

THE FORMICA INSULATION COMPANY
4670 Spring Grove Avenue, Cincinnati 32, Ohio

TECHNICANA

[*Continued from page 12*]

tional to the cathode current and practically independent of the screen voltage, so long as the latter is sufficiently large as to attract nearly all secondary electrons away from the plate and the cathode current is held constant. This fact was used as a basis for comparing various tubes.

CORRECTION

The photograph of the Type B-100 Bolometer, shown on page 27 of the September, 1944, issue of RADIO, should have been credited to Tung-Sol Lamp Works, Inc., manufacturers of this tube, instead of Sylvania Electric Products, Inc. We regret this error.

TUBE PRODUCTION

The production of 9,100,000 miniature receiving tubes for the Army, Navy and Lend-Lease in the first quarter of 1945 will be necessary if present requirements are to be met, officials of the Radio and Radar Division, War Production Board. announced recently.

Current production of miniature radio receiving tubes, at approximately 2,600,000 tubes per month, indicates a serious shortage of this type of tube used extensively by both the Army and Navy, members of the Radio Receiver Vacuum Tube Industry Advisory Committee were told at a meeting here November 2. The total shortage was placed at 250,000 tubes per month, while monthly production of battery type miniature tubes was said to be 200,000 a month short of essential requirements, Radio and Radar officials reported.

Demands for these tubes have increased instead of fallen off, largely as a result of battle losses and the development of new electronic equipment for use in the war effort.

Representatives of WPB indicated that the reduction in tube requirements for Army electronic equipment after "V-E" Day would be only about 26 per cent, instead of about 50 per cent, as formerly predicted. In view of continuing Navy equipment requirements, the reduction in military tube demands after "V-E" Day is expected to be very slight.

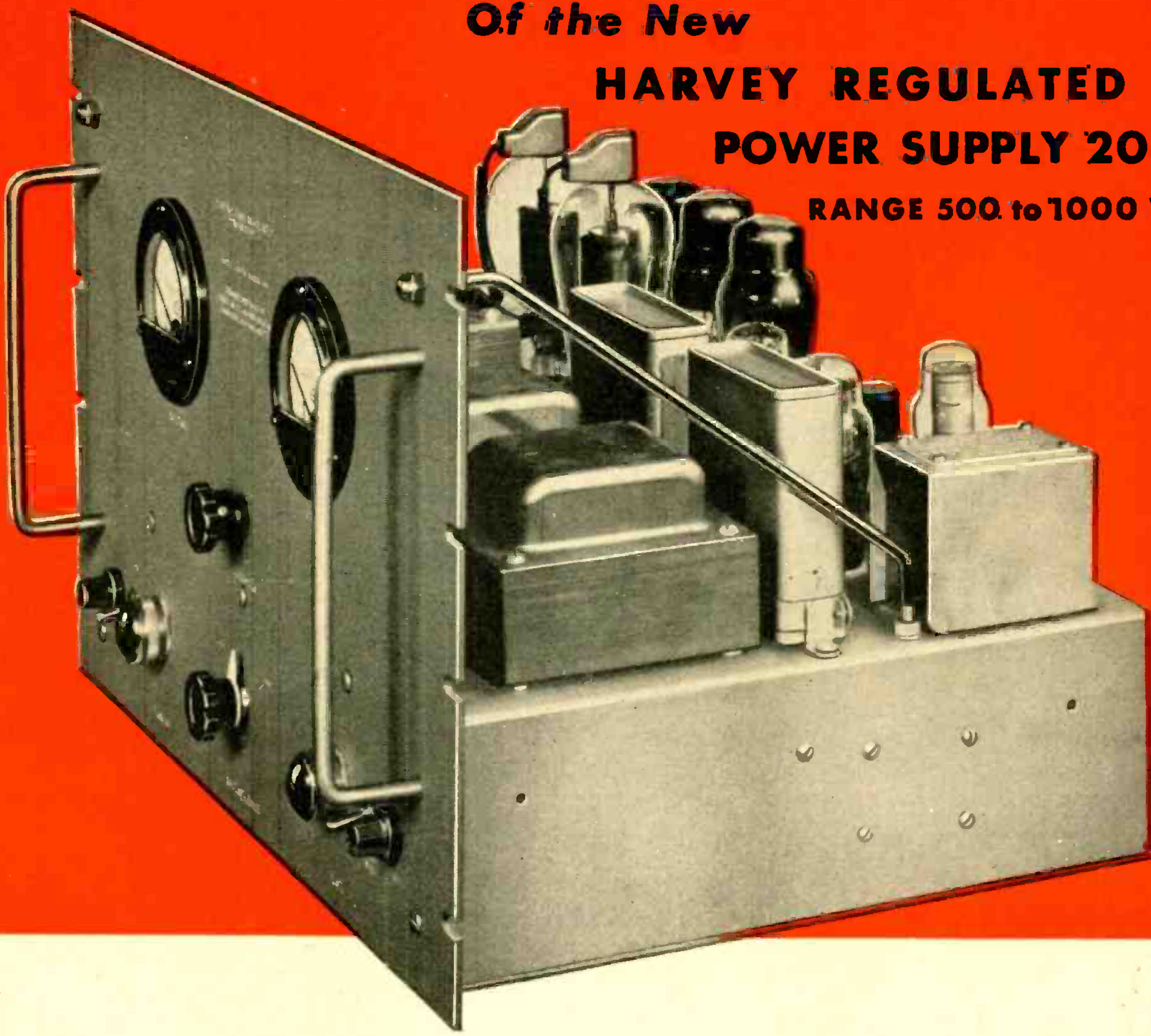
Army officials also pointed out that the Army was in short supply of five important types of miniature tubes at its depots where replacements are stored, and that current inventories showed far less than the normal supply.

Members of the committee endorsed a plan for the organization of a subcommittee to meet in Washington each month with officials of the Radio and Radar Division to study production and scheduling of orders for all receiving tubes to maintain a free and even flow of the necessary tubes to meet wartime demands. This

[*Continued on page 16*]

FIRST OFFICIAL PICTURE

Of the New
HARVEY REGULATED POWER SUPPLY 206 PA
RANGE 500 to 1000 VOLTS



Look It Over! You'll see the quality craftsmanship and compact construction of this new HARVEY 206 PA—its sound design, precision assembly and easy accessibility. Notice the gray, crackle-finish panel and the copper plated chassis.

The new Harvey 206 PA is equipped with spare fuses, a generous 6 ft. heavy duty Typex cord, two interlocks for safety, overload and time delay relays—everything to make it a thoroughly dependable, easy-to-operate source of laboratory D. C. power.

Although the picture gives you an indication of why the HARVEY 206 PA operates smoothly and efficiently, it can't show you how this precision instrument operates in two ranges—500 to 700 volts at ¼ of an ampere; 700 to 1000 volts at .2 of an ampere—with both ranges accurately regulated within one per cent. That's up to the instrument and us. We'd like nothing better than the chance to show you just what this important new development can do. Get in touch with

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HARVEY RADIO LABORATORIES, INC.
454 CONCORD AVENUE • CAMBRIDGE 38, MASSACHUSETTS

TECHNICANA

[Continued from page 14]

committee will be representative of the seven receiving tube manufacturing companies, and M. E. Lauer of WPB will be chairman. The first meeting is scheduled for November 17, 1944, it was announced.

When war demands for miniature receiving tubes are materially reduced, WPB will authorize their manufacture for civilian use, WPB officials said, emphasizing the belief that there is little hope for such action in the near future in view of new requirements and continued demands for established standard tubes used by the Army, Navy and for Lend-Lease.

The desirability of having a standard post-war AC/DC miniature tube complement was pointed out. In view of the fact that the 25 kinds of miniature tubes used in military equipment are not applicable for civilian sets, it was indicated that some engineering standards should be worked out for post-war civilian use.

RADIO ENGINEERS ELECT NEW OFFICERS

Dr. William L. Everitt of Washington, one of America's foremost authorities on radio and electronics, has been elected President of The Institute of Radio Engineers for the coming year, it was announced by the Board of Directors of that society. Dr. Everitt, who is Chief of the Operational Research Branch, Office of the Chief Signal Officer of the United States Army, succeeds Professor Hubert M. Turner of the Department of Electrical Engineering at Yale University, New Haven.

Dr. Everitt, who has been directing important research for the Army at Washington since 1942, was recently appointed professor and head of the Department of Electrical Engineering at the University of Illinois, Urbana. He was granted a leave of absence from that university to continue his army work but will assume his duties there on release from war service.

The election of Dr. Hendrik J. Van der Bijl of Johannesburg, Union of South Africa, as Vice President was announced simultaneously. Dr. Van der Bijl, Fellow of the Institute since 1928, is Chairman of the Electricity Supply Commission, the S. A. Iron and Steel Industrial Corporation, Ltd., and the Industrial Development Corporation of S. A., Ltd.; Chairman and Managing Director of African Metals Corporation, Ltd.; Director of the S. A. Board Barclays Bank; Director-General of War Supplies, and Chancellor of the University of Pretoria, all of Johannesburg, Union of South Africa.

The three Directors elected for three-year term, 1945-1947, were Stuart L. Bailey, Consulting Radio Engineer of Jansky and Bailey, Washington; Keith Henney, Editor of "Electronics" magazine, New York; and Dr. Benjamin E. Shackleford, Engineer-in-Charge of RCA Frequency Bureau, Radio Corporation of America, New York. All are Fellows of the Institute.

Measurement of Receiver Characteristics

A. C. MATTHEWS

A thorough analysis of methods and technique used in laboratory tests of broadcast receivers

PART I

During the development of a modern radio receiver it is necessary to make many qualitative measurements. The degree of accuracy of these measurements must be high if the results are to be of any value. Fortunately, these tests have been fairly well defined and standardized.[1] It remains then to interpret the definitions properly and avoid faulty technique in making the measurements. It is the intention of this article to discuss the necessary test procedures and to point out precautions to be taken during the measurements to insure consistently accurate results.

While the required measurements, as mentioned previously, have been established for some time it is not surprising to have two engineers working independently obtain quite different results, due to slightly different techniques in their measurements. Such a condition is not so unusual if the tests are made in different laboratories, since the accepted conditions of measurement are likely to vary slightly with different manufacturers. This is often due to the type of measuring equipment employed and is no reflection on the ability of the engineering departments. But when results are not comparable between groups in a particular engineering department, where the equipment is usually more or less standardized, it is evident that the technique of making the measurements is at fault. Some of the more common errors will be discussed in the hope that these differences may be minimized.

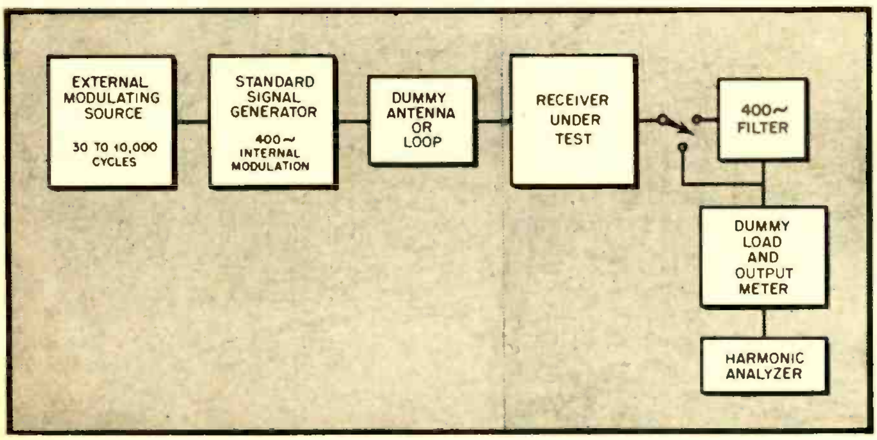

Fig. 1. Block diagram of setup for lab tests of receiver

Test Equipment

Fig. 1 shows a block diagram of the necessary equipment as set up for the measurement of receiver characteristics. In addition to the apparatus shown, the following should be readily available:

1. High resistance d-c voltmeter-ohmmeter
2. A-C voltmeter
3. Adequate milliammeters to cover a range of 0-150 ma.
4. Oscilloscope
5. Means for adjusting primary power source, whether line or battery
6. Complete set of "average" vacuum tubes
7. Complete set of "high-low" limit tubes
8. Necessary alignment tools
9. Data record book.

Signal Generator

A standard signal generator *(Fig. 2)* covering the desired frequency range should provide an output voltage of at least one volt to satisfy most requirements as a source of r-f signal voltage.

[1] Standards on Radio Receivers—Institute of Radio Engineers—1938.

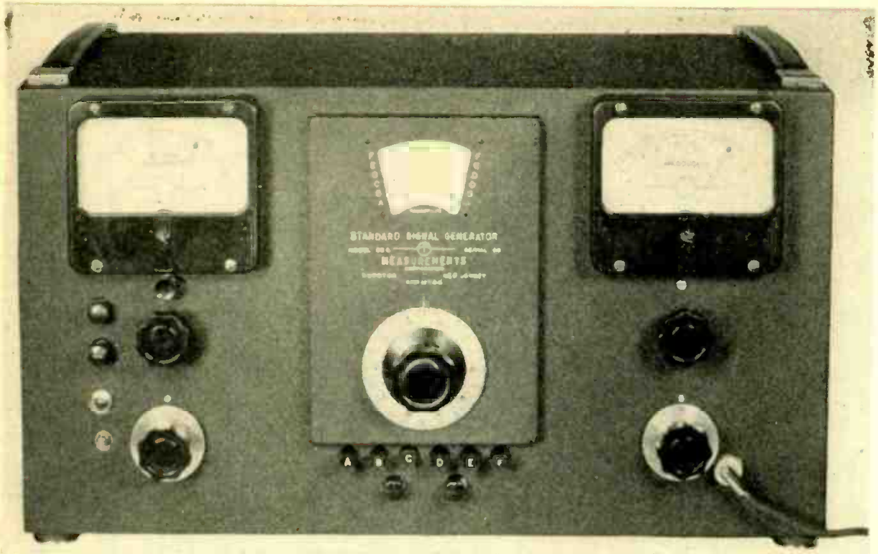

Fig. 2. Typical laboratory-type standard signal generator

(Courtesy Measurements Corp.)

This voltage must be capable of attenuation from its maximum down to approximately 0.5 microvolt without any appreciable shift in the carrier frequency. Adjustment of the carrier frequency to within 0.1 per cent or better of the required frequency is very desirable.

The audio frequency source for modulating the signal generator should be accurate as to frequency and low in harmonic content. A tolerance of 2 per cent is considered acceptable. With amplitude modulated signals the per cent modulation should be continuously variable from zero to 80 or preferably 100 per cent. In the case of frequency modulated signal generators, the deviation should be continuously adjustable from approximately zero to 0.5 per cent of the center carrier frequency.

The accuracy of the signal generator is obviously of utmost importance and should therefore be checked periodically. Errors introduced by stray leakage fields are usually negligible in a well designed generator, but this should not be taken for granted.

A simple check may be made by connecting an exploring coil, consisting of a few turns of wire, to the input terminals of a sensitive receiver and carefully moving it about the generator with the receiver tuned to the same frequency as the generator. The pickup should be negligible with the coil placed within six inches of any part of the instrument. Particularly check the areas around any indicating meters and also at the point where the output leads are fed through the case. It should be possible to connect the receiver input terminals to the generator output terminals, with the attenuator set for minimals, with the attenuator set for minimum output and shorted, without noticing any appreciable response to the signal. When measuring a receiver with a loop antenna it is possible to orient the loop with respect to the equipment to minimize stray pickup.

Next in importance is the calibration of the attenuator. This should be checked by first setting the output at a relatively high level, say one volt, and measuring with a diode voltmeter. The lower ranges are then checked against the higher ranges by means of a receiver in which the detector has been calibrated to act as a vacuum tube voltmeter over at least a 10-to-1 range. It should be noted that the output impedance of most generators varies between the high and low attenuator settings.

The unmodulated signal generator output of 1 volt is now coupled to the receiver through a dummy antenna, and the receiver sensitivity adjusted to a point where its detector calibration indicates the top of a 10-to-1 range. The signal generator output is then reduced to 0.1 volt which should decrease the detector voltage 10 times. The attenuator ratio error should not exceed 2 per cent. In this way the attenuator can be checked step by step for accuracy.

Another check of importance is to determine whether there is a null point near the zero setting of the attenuator. Such a condition will exist if leakage or stray fields are present which combine out of phase with the normal generator output. Usually this is due to a difference in carrier potential between the generator power supply cord and shield case. This can ordinarily be eliminated by an r-f line filter and/or locating the receiver under test away from the cord. Stray noise voltages of course must be avoided if good accuracy is to be obtained. This may necessitate the use of a double shielded room or booth to eliminate such effects, if they are troublesome.

Percentage Modulation

Percentage modulation can most

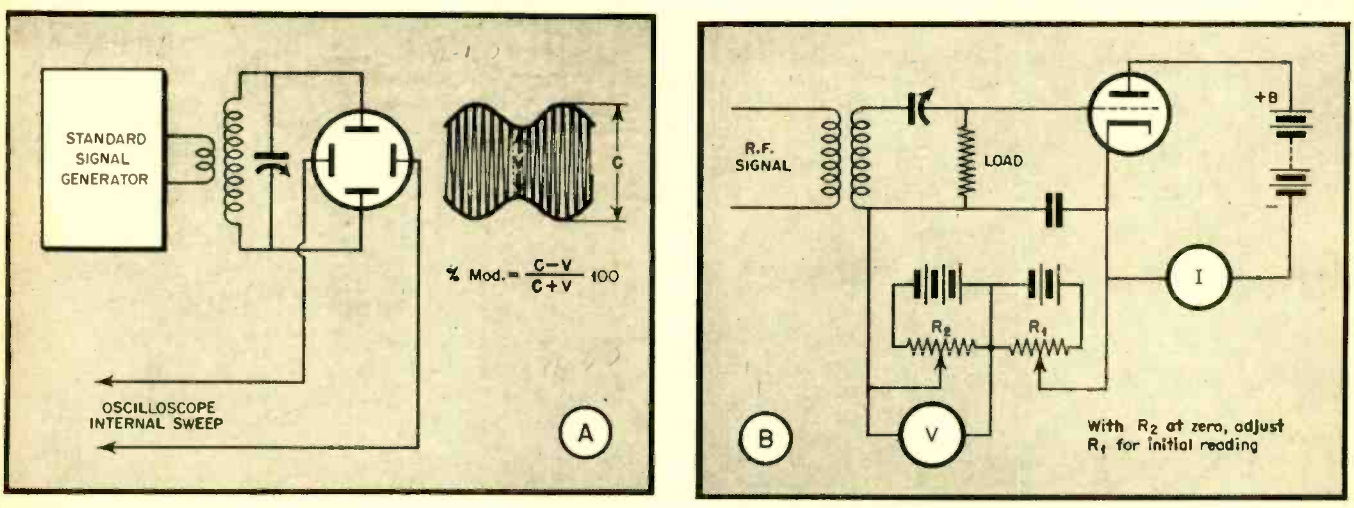

Fig. 3. Oscilloscope setup, (A), and v-t voltmeter schematic, (B), for checking modulation percentage

conveniently be checked by means of a cathode ray oscilloscope. The signal generator output is coupled through a resonant circuit as shown in *Fig. 3* to the vertical plates of the scope. After the tuned circuit is resonated to the signal generator frequency, thereby amplifying its output to a usable value, the modulation can be checked by carefully measuring the crest and valley of the modulated signal wave as shown by the 'scope. The modulation percentage is equal to the difference between the crest and valley divided by the sum of the same, times 100, as given in equation (1).

$$\% \text{ modulation} = \frac{c - v}{c + v} \times 100 \quad (1)$$

By using a cross-section type viewing screen on a 5 inch scope accuracies of better than 5 per cent can be obtained.

Another method of checking per cent modulation makes use of a vacuum tube peak voltmeter. By measuring the peak values of the modulated and unmodulated carrier the per cent modulation can be determined by

$$\% \text{ modulation} = \frac{(E_{mod} - E_{rf}) \times 100}{E_{rf}} \quad (2)$$

where E_{mod} and E_{rf} represent the peak values of the modulated and unmodulater carrier respectively. *Fig. 3b* shows a typical set up. With R_2 at zero, R_1 should be adjusted so that milliammeter *(I)* barely indicates current. The unmodulated carrier is then applied and the potentiometer R_2 is adjusted for zero current at the milliammeter. The d-c voltmeter (V) will now indicate the peak unmodulated value of the carrier. Modulation is then applied and R_2 again adjusted for zero current indication. The voltmeter then indicates the peak modulated carrier voltage. The per cent modulation can now be calculated from equation (2).

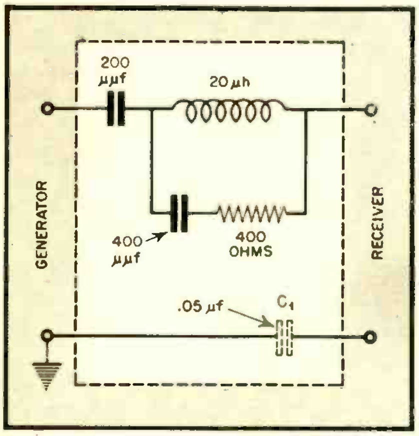

Fig. 5. Standard dummy antenna

Most amplitude modulated generators have some frequency modulation present, particularly at the high frequency end of the band. This is not usually troublesome unless a very selective receiver is being tested, in which case the selectivity curve will appear to be unsymmetrical due to the vector addition of the amplitude modulation with the frequency modulation on the opposite slopes or sides of the curve. In such cases it is advisable to make measurements with an unmodulated signal.

The accuracy of the frequency calibration of the signal generator should be known, also its drift characteristics. In general, most generators are relatively stable after an initial warm-up period of 15 minutes. Since methods of frequency calibration are so well known it should not be necessary to go into detail on this subject. Periodic checking by the zero beat method against broadcast stations or the standard frequency transmission of WWV should be sufficient.

TABLE 1

NORMAL TESTS AND OPERATING CONDITIONS FOR RECEIVER MEASUREMENTS

Type Receiver	Line Power A-C, D-C or AC-DC	Battery Power Storage	Battery Power Dry Cell
Normal Power Input	117 volts	6.6 volts	1.35 volts
Power Input—Limits for Special Tests	106-128 v	5.8-7.8 v	1.1-1.6 v
Tubes	Use tubes having center characteristics for those parameters which affect performance. Check operation at power input limits with high and low characteristic tubes.		
Power Output	R.M.S. at 10% harmonic distortion across rated load.		
Normal Test Output	0.5 watt when power output exceeds 1 watt. 0.05 watt (50 milliwatt) when power output exceeds 0.1 watt but is less than 1 watt.		
Sensitivity[1] Normal	400 cycle 30% modulation		
Max. output	400 cycle 80% modulation		
Selectivity	400 cycle 30% modulation—Normal output.		
Fidelity	30-10,000 cycles 30% modulation—Normal output. Measure curve at center of r-f band unless, due to selectivity effects, the fidelity changes substantially over the tuning range, in which case fidelity should be measured at or near the ends of the r-f band.		
Image Response	400 cycles, 30% modulation.		

[1] *Sensitivity should also be checked at limit voltages of power input indicated.*

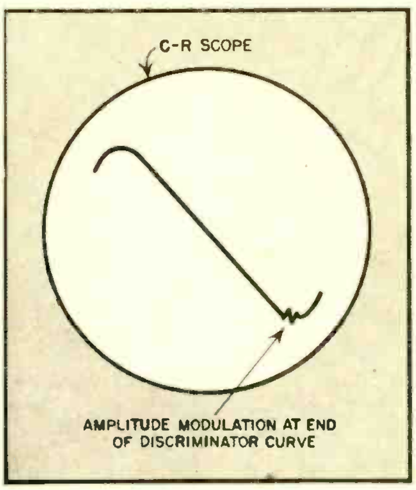

Fig. 4. Determining deviation frequency

Deviation Frequency Tests

The above discussion, with the exception of the part on modulation, applies both to frequency-and amplitude-modulated signal generators. With a frequency-modulated generator, instead of being interested in the variation of the carrier output as influenced by the audio frequency modulating voltage, we are interested in determining the accuracy with which the audio frequency modulating voltage deviates the carrier about its center frequency.

To be more specific, we are interested in checking the calibration of the frequency modulating properties of the generator. A simple method consists of using a cathode ray oscilloscope in conjunction with a f-m receiver and a separate amplitude modulated test oscillator. An f-m signal is tuned in on the receiver and the discriminator curve is observed on the oscilloscope.

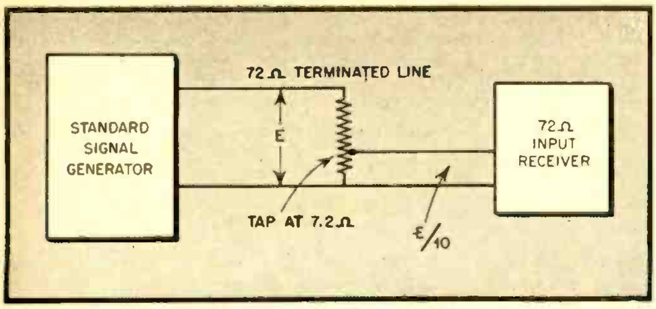

Fig. 6. Divider network for u-h-f tests

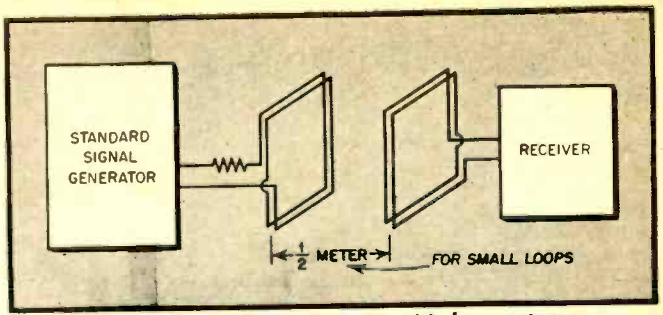

Fig. 7. Setup for testing set with loop antenna

Now, if a signal of the proper frequency from the test oscillator is fed into the receiver input, it will appear on the discriminator curve, as shown in *Fig. 4*. As the frequency of the test oscillator is varied the indication will shift up or down the curve on the oscilloscope. By adjusting the frequency of the test oscillator so it moves the indication from one end of the straight line portion of the discriminator curve to the other, and noting the frequency change required on the test oscillator, the deviation of the f-m signal generator will be determined. The change in frequency between the two end points will be equal to twice the deviation of the f-m generator. An accuracy of 10 per cent can be expected.

Artificial Antenna

In order to simulate actual operating conditions during the measurement of a receiver an artificial or dummy antenna must be employed. Such a device has been standardized by the IRE and RMA, and consists of two condensers, an inductor, and a resistor connected as shown in *Fig. 5*. The impedance characteristics vary from a capacitive reactance at low (broadcast) frequencies to nearly a pure resistance of 400 ohms above 10 megacycles. (It is permissible for simplicity to use a 400-ohm resistor in place of the standard dummy at frequencies above 3 megacycles.)

The dummy antenna should be constructed as a small independent unit to obviate coupling to other equipment. Connecting leads from the signal generator through the dummy antenna to the receiver should be shielded to reduce external fields. At broadcast and medium high frequencies the length of these leads is of minor importance as long as the voltage drop remains negligible. At frequencies higher than 20 to 30 megacycles it is common practice to use a half-wave dipole antenna system and, accordingly, receivers are usually designed wtih input systems to match a 72-ohm load. (Impedance at center of average half-wave dipole).

It is evident that our standard antenna no longer fulfills the requirements for this type of operation. Generators for ultra-high-frequency work are therefore often terminated with a resistor equal to the impedance of the transmission line which is supplied as part of the instrument. It is important that the terminating impedance of the line be known in order to correctly match and measure a receiver, since an improper termination would result in a variation of output over the frequency range due to reflections caused by a mis-matched load.

In some u-h-f generators a low resistance tap is provided on the terminated line output. This permits the connection of a low impedance receiver input without affecting the generator output voltage. The maximum voltage output is thereby reduced in proportion to the ratio of the resistance at the tap to the terminated line resistance, as shown in *Fig. 6*.

Receivers with loop antennas do not require a dummy antenna to simulate normal operation. The signal generator output voltage is induced in the receiver loop from a co-axial coil as shown in *Fig. 7*. For convenience of operation, this coil may be so designed that the receiver sensitivity can be obtained from the signal generator output voltage by dividing the output voltage by ten.[2, 3] The receiver loop is placed coaxially with respect to the signal generator radiating loop, the latter having its low potential face towards the former in order to minimize electrostatic coupling effects. The spacing between loops should exceed twice the largest diameter of either loop and both loops should preferably be at least twice this distance from any large metal object, such as a wall of a screen room.

Fig. 8. Typical v-t voltmeter
(Courtesy Measurements Corp.)

It is good practice to rotate the loop at the receiver before making any measurements, to check for reflections from nearby objects. If reflections are present, obviously they must be eliminated before any accurate measurements can be made. Proper orientation of the loops (keeping them spaced coaxially of course) will usually remedy the condition. When the largest dimension of the loop antenna is less than 1 foot the recommended spacing between loops is one-half meter.

There is some question as to the validity of this method of measurement by some engineers. However, since it is an accepted standard results are at least comparable.

Standard Output Load

Receiver output measurements are made with a standard dummy load connected in place of the regular speaker. The load, which should be resistive, must be capable of withstanding the full output of the receiver without any appreciable change in its resistance. Ordinarily a value of resistance for the dummy load is chosen which gives the greatest value of undistorted output for the specific operating conditions involved, although the recommended value published by the tube manufacturer is sometimes used. Measurements may be made with the load resistor shunted across the primary or secondary of the output transformer. Usually the load is connected across the primary with the secondary open-circuited. This does not take into account the efficiency of the output transformer but, since one receiver may be used with several different size speakers, the output transformer is usually considered as a separate component and tested accordingly.

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[2] Measurement of Loop Antenna Receivers—Swinyard—*Proc. I.R.E.*, July, 1941.
[3] Loop Antenna Design — Matthews — Radio, Feb. 1944.

Audio Frequency Filter

The majority of overall receiver measurements are made with an audio frequency modulation of 400 cycles. For this reason it is practicable to use a band-pass filter (tuned to 400 cycles) between the dummy load and the output-measuring instrument. Thus it is possible to make measurements in the presence of an appreciable amount of background noise.

Precautions should be taken in the design of the 400-cycle filter to prevent saturation of the magnetic circuit in the iron-core inductances. In other words, the power-handling capacity of the filter must be adequate to prevent the generation of harmonics at high output levels. The attenuation at 400 cycles must be known in order that a correction factor may be applied to the measurements. A switch should be provided to disconnect the filter from the circuit when not required.

Distortion Meter

Evaluation of receiver characteristics is not complete without measurement of the magnitude of audio distortion present under given operating conditions. An arbitrary value of 10 per cent has been chosen as the maximum amount permissible before it becomes objectionable. The meter should therefore be capable of indicating the magnitude of the audio distortion present over a range of 1 to 30 per cent with an accuracy of approximately 5 per cent.

Since most measurements are made with an audio frequency of 400 cycles, it is only necessary to provide one high-pass filter. The high-pass filter should provide excellent attenuation at the fundamental frequency being used, and pass all of the harmonics up to 5000 or 7500 cycles without appreciable discrimination between them. Distortion percentage is determined by measuring the r-m-s value of the output with and without the filter (fundamental plus harmonics and harmonics only).

High-pass filters for the measurement of distortion at 50, 100, 1000, 5000 and 7500 cycles are commercially available, if it is desired to investigate these frequencies.[4]

The distortion meter should obviously not affect the harmonic output of the receiver being measured, therefore it should have a sufficiently high impedance input in order not to modify the output load circuit. For adequate sensitivity, the device should preferably be of the square-law type. A suitable distortion-free amplifier and attenuator will usually be required in conjunction with the distortion meter to provide a wide range of operation. The various conditions of measurement will be discussed in detail later.

[4] General Radio Company—Type 732-P1 Range Extension Filter.

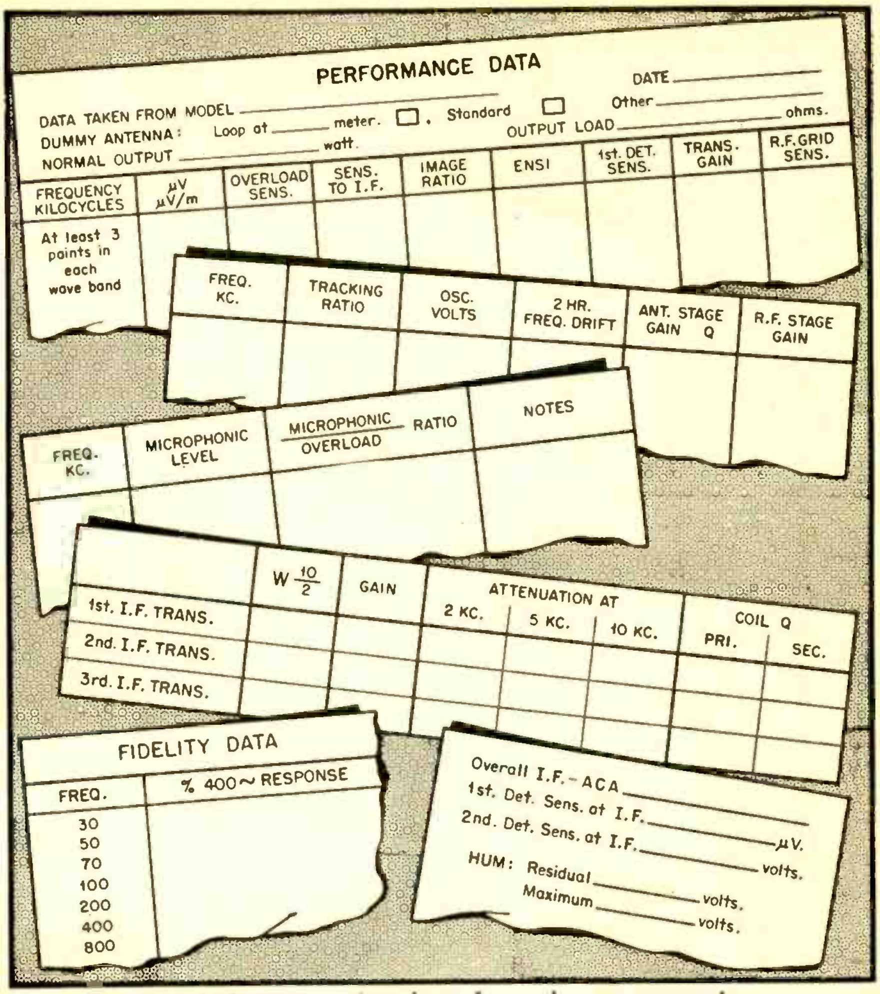


Fig. 9. Typical test data sheets for receiver measurements

Output Meter

Power output delivered to the output load may be measured with a vacuum tube voltmeter, thermocouple ammeter, copper-oxide voltmeter or wattmeter calibrated to read r-m-s values. The vacuum-tube voltmeter is probably the most satisfactory since it is versatile and convenient in its operation. *Fig. 8* shows a typical instrument which, incidentally, can be used for many other receiver measurements to be described later. Copper-oxide meters are also extensively employed, but they are limited in their usefulness because of temperature and frequency errors, the latter being the most objectionable. Whichever type of meter is employed, it is obvious that it should not affect the value of the output load resistance.

A-F Oscillator

Since the standard signal generator is ordinarily only provided with 400-cycle modulation it is necessary to supply a separate source of variable audio frequency voltage for the measurement of receiver fidelity. This is usually obtained from a beat-frequency or a resistance-capacity audio oscillator having a range of 30 to 10,000 cycles. Harmonic distortion should not be greater than 2 per cent, over a voltage range of 0.1 to 100 volts. Such a large voltage range is not necessary for modulating the signal generator, but will be very useful in determining audio amplifier characteristics. Unless the oscillator is known to be extremely stable the frequency calibration should be checked before making any fidelity measurements.

Cathode Ray Oscilloscope

The cathode ray oscilloscope is one of the most flexible instruments available to the radio engineer. It not only can be used to view the operation of separate sections or overall performance of the receiver, but it can be employed to check the accuracy of some of the other measuring equipment. The 'scope should be provided with an internal amplifier of known characteristics, a variable sweep voltage, and means for synchronizing the input voltage.

[*Continued on page 74*]

Magnetic Phonograph Pickups

ROY DALLY
Consulting Engineer, Electrovox Corporation

An analysis of the characteristics of magnetic pickups and their application in reproducing apparatus

THE magnetic pickup made possible the change from acoustic phonographs to the electrically amplified type, bringing with it improvements that had always been the dream of every phonograph engineer. Accurately controlled volume level, power output limited only by the amplifier used, greatly increased frequency range and controlled tonal effects were only a few of the advantages gained.

Early types of magnetic pickups were all very similar in design, operating at vertical pressures averaging about 6 oz. They were usually large and unwieldy, with great masses of weight attached for counterbalancing,—in general, a far cry from present-day designs operating at less than 1 oz. pressure. However, they paved the way for the modern phonograph, and still have advantages for specific applications where other types of pickups have proved inadequate.

Pickup Design

Fig. 1 illustrates the most conventional type of design. Both pole pieces and armature were machined or formed from soft iron or high permeability alloys. The armature, in an approximate shape of a cross, had section "A" machined or swaged to a cylindrical shape, about which were fitted rubber sleeves, to act as bearings, the pole pieces were so shaped as to retain and compress the rubber bearings when assembled to a back plate (not shown), which permitted the armature to reciprocate in an approximate lateral plane only, indicated by the double arrow.

The magnet was a permanent horseshoe type, tungsten in early designs, and cobalt alloys in later models.

A coil of wire surrounded the armature, being spaced to permit the arma-

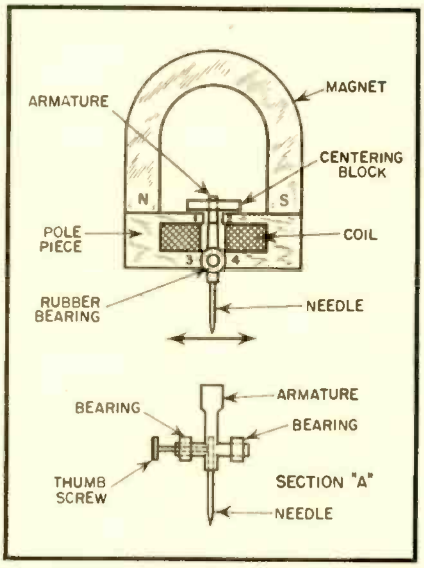


Fig. 1. Diagram of conventional type of magnetic pickup

ture to move, and held rigidly in the pole piece assembly. The impedance of the device was determined by the number of turns of wire used, high impedance pickups having as much as 10,000 turns of #44 EN wire, with a resulting impedance at 1000 cycles of about 50,000 ohms.

Air gaps existed on each side of the armature and the upper pole piece tips, which varied with different designs from .008″ to .018″ each. However, when once determined for a particular design, these were held very closely by means of assembly gages.

Since a decided magnetic attraction existed between the armature and the pole piece tips, some means was necessary to center the armature in the air gap by overcoming the attraction, but which would permit the armature to reciprocate between the tips when driven by the record groove. The material most commonly used for such a centering block was gum rubber and, later, a loaded rubber stock. The centering block was slotted to receive the free end of the armature, and was in turn clamped to the pole piece assembly in such a manner that it could be moved laterally, thus centering the armature in the air gap.

An equivalent fixed air gap existed between the lower part of the armature and the lower pole piece tips, through the rubber bearings. There was no metal-to-metal contact between the armature and the pole pieces.

In operation, the armature reciprocated between pole piece faces 1 and 2, varying alternately first one and then the other air gap. Thus, when the armature was nearer to 1, a greater number of lines of force appeared through the armature between 1 and 4, since the reluctance between the north and south poles of the magnet was smallest for that magnetic path. When the armature approached face 2, conditions were reversed, the lines of force through the armature were also reversed, being predominant between 2 and 3, and current was generated in the turns of wire due to the reversal of flux through the armature.

Now that we have a general picture of a simple magnetic pickup, let us consider certain design considerations necessary for desirable characteristics.

Design Considerations

Voltage output is dependent on flux density, saturation, the number of turns of wire in the coil, and velocity. By velocity is meant the speed at which the armature travels as it reciprocates in the air gap. Flux density is dependent on the magnet used and the reluctance of the air-metal circuit between the magnet poles. Only one precaution need be observed with respect to flux density, namely, that the armature must not be saturated at any time. Saturation would result in distortion, and would particularly affect the dynamic range and response of the pickup. Fortunately, this condition is rarely encountered, since the air gaps are usually sufficient to prevent it, but in attempting unusual designs, it is well to keep saturation in mind.

Increasing the number of turns of wire does not result in a proportionate increase in voltage, since the resistance of each turn increases as the turns become larger, but in any practical design, a worth while gain may be had.

Velocity, when considered from a pickup standpoint is not a variable to be tampered with indiscriminately. It may be changed in any one design by increasing the ratio of the distances between the bearing and needle point, and the bearing and upper air gap, so that for a given distance of travel of the needle point, the armature between the upper pole piece faces will travel a greater distance, but such practice invariably results in greater difficulties with armature resonance, to be discussed later. Good design practice calls for a ratio of about 1 to 1.

Voltage output is the simplest of the design problems to deal with, since adequate gain is available in any good amplifier, at little or no cost. Very worth while savings may be effected by using low cost materials in the pickup design, resulting in low flux density and less output, and letting the amplifier carry on from there.

Resonance

As is usual with all electro-mechanical devices covering a wide frequency range, we come to the important problem of mechanical resonance. This has been discussed at some length in previous articles[1, 2] in connection with tone arms and crystal cartridges. The resonance conditions encountered in a magnetic pickup, however, are much more severe than in a crystal cartridge, because of the fact that the armature must have low magnetic reluctance and for a given mass, such metals and alloys exceed by far the weight of aluminum and magnesium used in making chucks for cartridge. In order to obtain a frequency range beyond 5000 cycles without resonance peaks or cutoffs, a great deal of thought must be given the armature, striving for the lowest possible mass and greatest stiffness.

With a few exceptions there has been a notable reluctance to break away from the conventional design as shown in *Fig. 1,* and this design is definitely limited mechanically when one begins to think in terms of response to 10,000 cycles, and tracking pressures of less than 1 oz. The prime reason for lack of improved design may be traced directly to the insistence of magnetic pickup users that the voltage output be kept relatively high. 2.5 to 3.0 volts RMS at 1000 cycles was not unusual at tracking pressures of 6 oz. Gradual refinements over a period of years resulted in tracking pressure being reduced to about 2.5 oz., and approximately .5 volts output.

Vertical Inertia

In considering further reduction of pressure, the problem of vertical inertia, discussed in the article on tone arm design, becomes of prime importance. While it is simple enough to reduce the effective vertical pressure of the system by counterbalancing, either by spring or weight, such counterbalancing is no way decreases vertical inertia, quite to the contrary, weight counterbalancing increases it. Therefore, in order to avoid groove skipping, particularly in coin-operated phonographs, the total mass and weight of tone arm and pickup must be kept at a minimum. This in turn means a lighter, smaller magnet, as well as attention to every detail in order to save weight, and the inevitable result must be decreased voltage output. In addition, a pickup mechanism cannot be made to track at low pressures unless it has a suitably high compliance, which can be obtained only by small light moving parts, a minimum of damping and centering resistance, and a good bearing system. Therefore, every improvement in tracking, frequency range, and quality must be made at the expense of voltage output. If users of magnetic pickups would be content with approximately 0.1 volt output, very definite improvements could be made in magnetic pickup design.

A two-fold problem exists in centering and damping a magnetic pickup. Maintaining the armature in the magnetic center of the air gap, and yet permitting it to move freely when driven by the groove, is a condition requiring a tough, resilient system, unaffected by humidity and temperature changes, and showing little change of characterististics over long periods of time. In addition, the armature must be adequately damped to overcome resonant peaks and transient response. Unfortunately, the requirements of a good centering material and an efficient damping material are very much in opposition with each other. The very nature of damping material requires that it be soft and with a minimum of resilience. Obviously, such could not be used for centering.

Centering

Probably the simplest, most efficient, and least expensive means of centering is pure gum rubber. It may be applied mechanically in a number of ways, the only precaution being that it be used generously, and not in small blocks, which tend to age much more rapidly. But such centering is useless, from a damping standpoint, since rubber so used lacks that ability to a marked degree. Damping must then be applied separately, using a material having the desired qualities. Both centering and damping may be applied in compression or shear, however compression is preferable, since in shear,

[*Continued on page 60*]

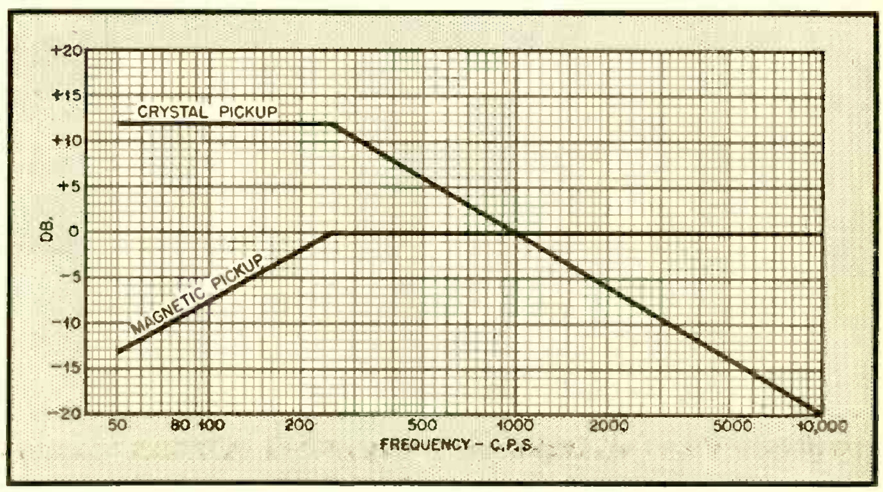


Fig. 2. Comparative theoretical response curves of crystal and magnetic pickups

[1] Tone Arm Design, *Dally,* RADIO, July, 1944.
[2] Crystal Phonograph Pickups, *Dally,* RADIO, September, 1944.

Pi-Networks as TANK CIRCUITS

W. H. ANDERSON
Trans-Canada Air Lines

Design data for using a pi-network to couple the final amplifier to the antenna

Many of the mechanical problems of coupling a final amplifier to an antenna may be sidestepped by the use of the familiar three element pi-network as the final tank. This is common practice particularly in commercial multi-frequency transmitters designed for quick band-change. However, there is a possibility that in designing and adjusting these, the factor of proper Q may be overlooked. Furthermore, the classical equations which involve a generator as a supply of energy cannot be said to apply directly to a vacuum tube amplifier, as in the former case Q is not a relevant factor.

Fig. 1 shows the conventional pi-network with R_1 as the input resistance and R_2 as the output resistance, presumably the resistance of an antenna or its feed system. *Fig. 2* is a rearrangement of *Fig. 1* to the more familiar tank circuit form. Obviously, for sake of direct application of tank circuit formulae, the parallel circuit XC_0 and R_2 will have to be replaced with an equivalent series circuit. This is accomplished in *Fig. 3*. It is now possible to derive equations for XC_1, XL_1 and XC_0 in terms of R_1 and R_2.

Recalling that in any parallel resonant circuit the terminal resistance equals $Q\ XC$

$$XC_1 = \frac{R_1}{Q} \qquad (1)$$

Also, since Q is defined as the net inductive reactance divided by the resistance,

$$Q = \frac{XL_1 - \dfrac{R_2^2\ XC_0}{R_2^2 + XC_0^2}}{\dfrac{R_2\ XC_0^2}{R_2^2 + XC_0^2}}$$

Simplifying,

$$\frac{Q\ R_2\ XC_0^2}{R_2^2 + XC_0^2} = XL_1 - \frac{R_2^2\ XC_0}{R_2^2 + XC_0^2} \qquad (2)$$

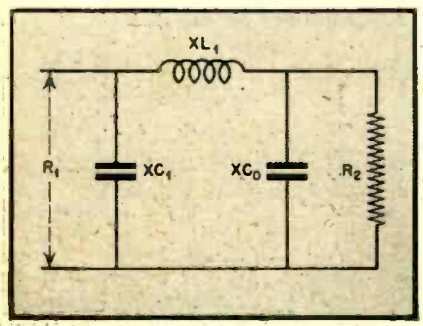


Fig. 1. Conventional pi-network

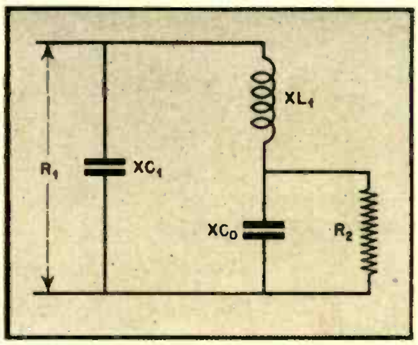


Fig. 2. Pi-network in tank circuit form

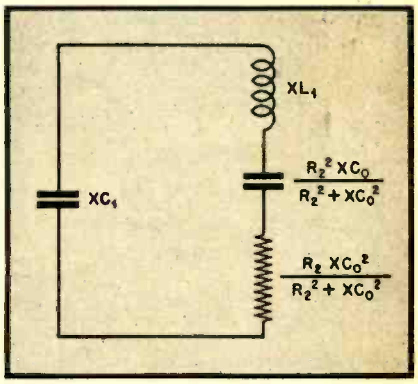


Fig. 3. Equivalent circuit of network

$$XL_1 = \frac{Q\ R_2\ XC_0^2 + R_2^2\ XC_0}{R_2^2 + C_0^2} \qquad (3)$$

In any parallel resonant circuit

$$R^2 = XL(XC - XL)$$

[Continued on page 62]

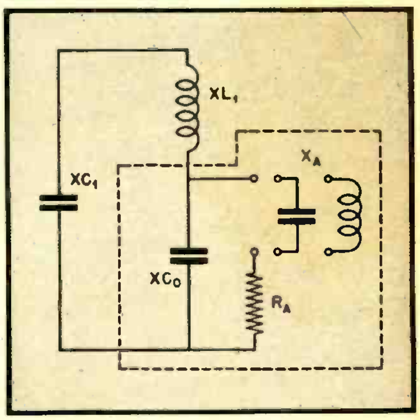
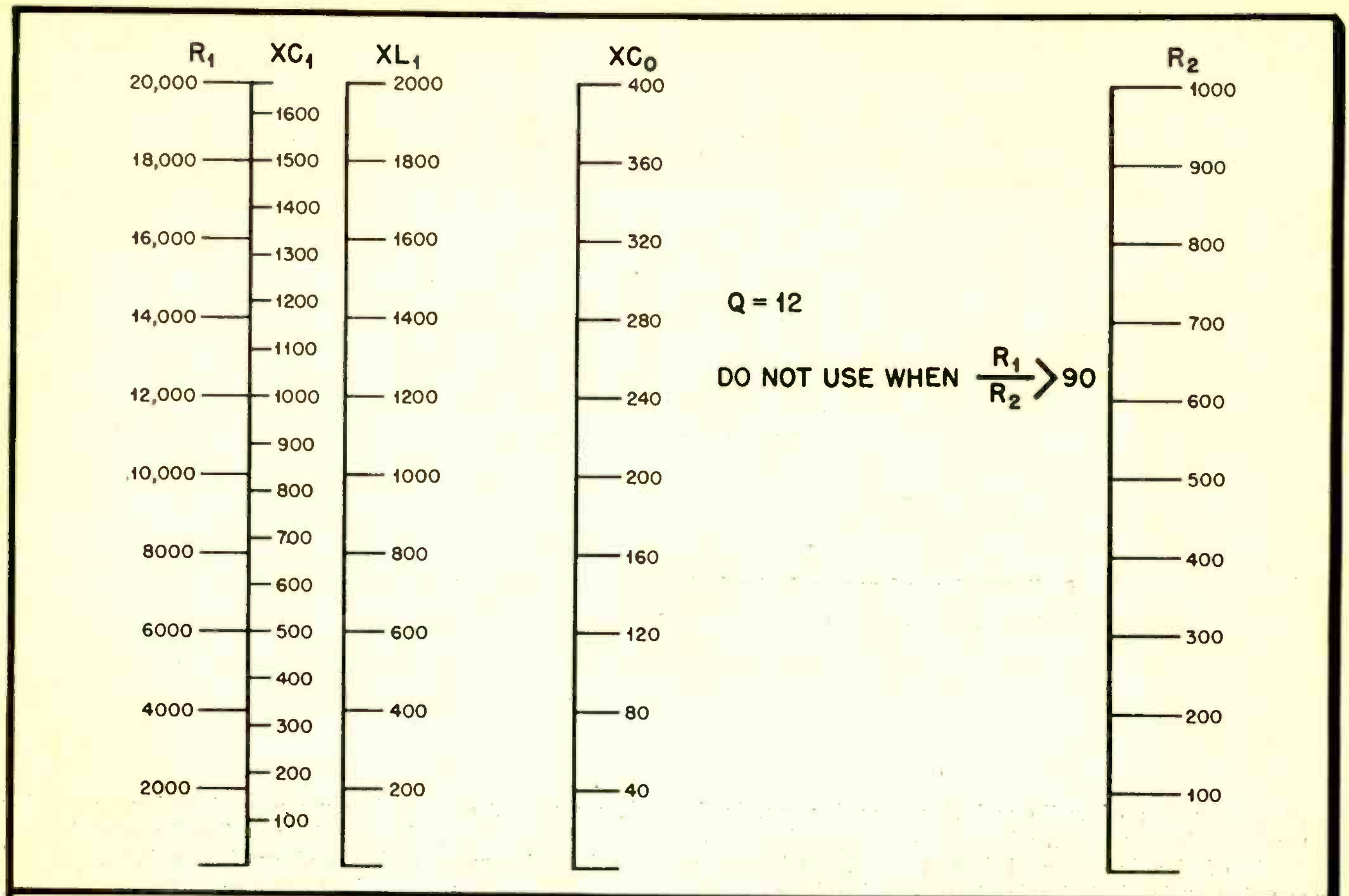
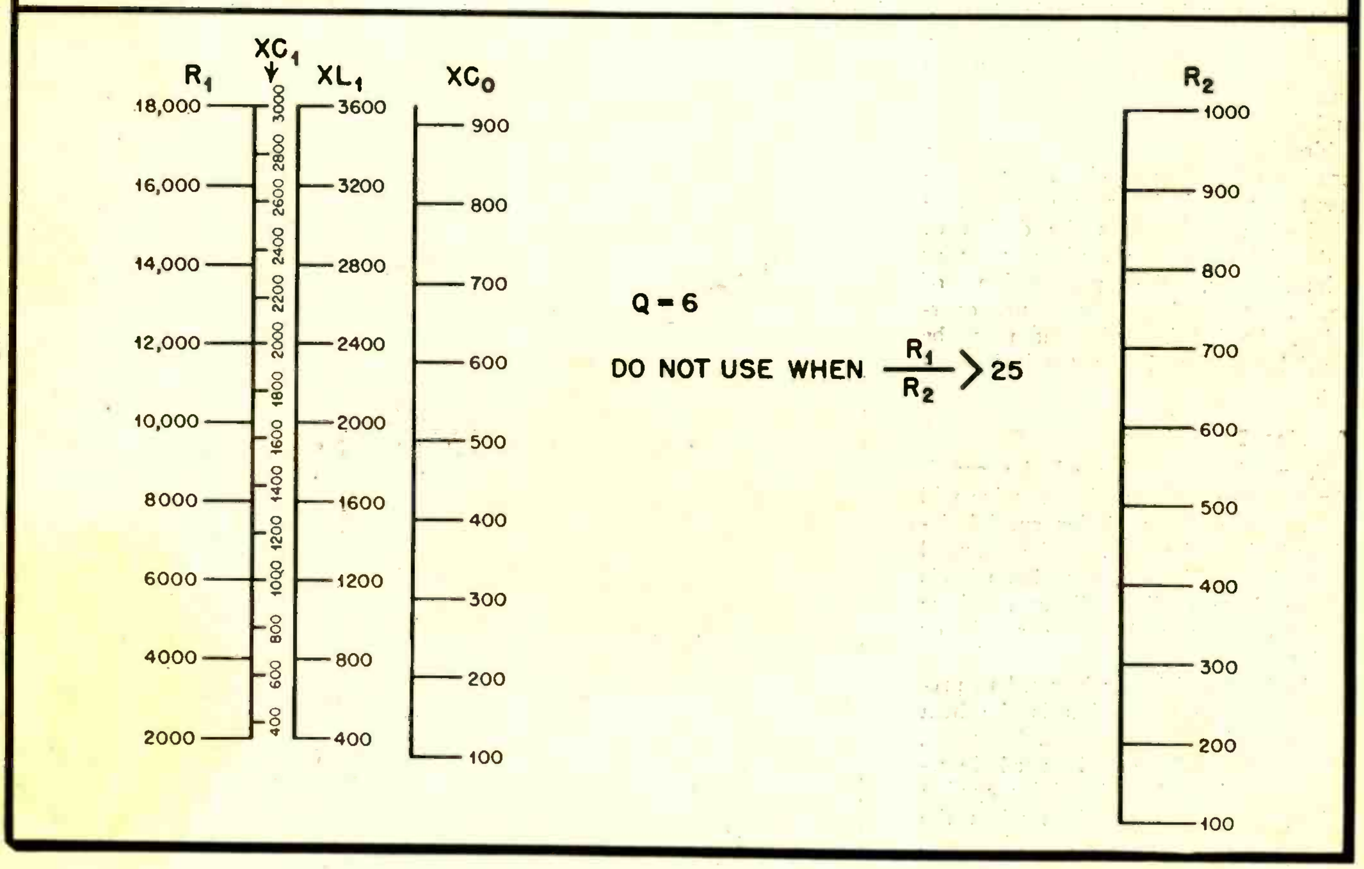


Fig. 4. Network feeding antenna





Figs. 6 (top) and 7. Alignment charts for determining values of pi-network elements

TROPICALIZATION

H. A. PARKER

A discussion of methods to follow and precautions to be observed in preparing radio and electronic equipment for tropical service

THE preparation of radio and electronic equipment for tropical service is of the fundamental importance today. "Tropical Service," however, is not confined to the geographical area of the tropics, but is extended to any area where moisture and fungus are to be found.

Tropicalization (the design and preparation of radio and electronic equipment for tropical service) is as specialized a problem as the design of industrial electronic equipment or as winterization, the preparation of equipment for low temperature operation. In brief, equipment must be specially designed for tropical service.

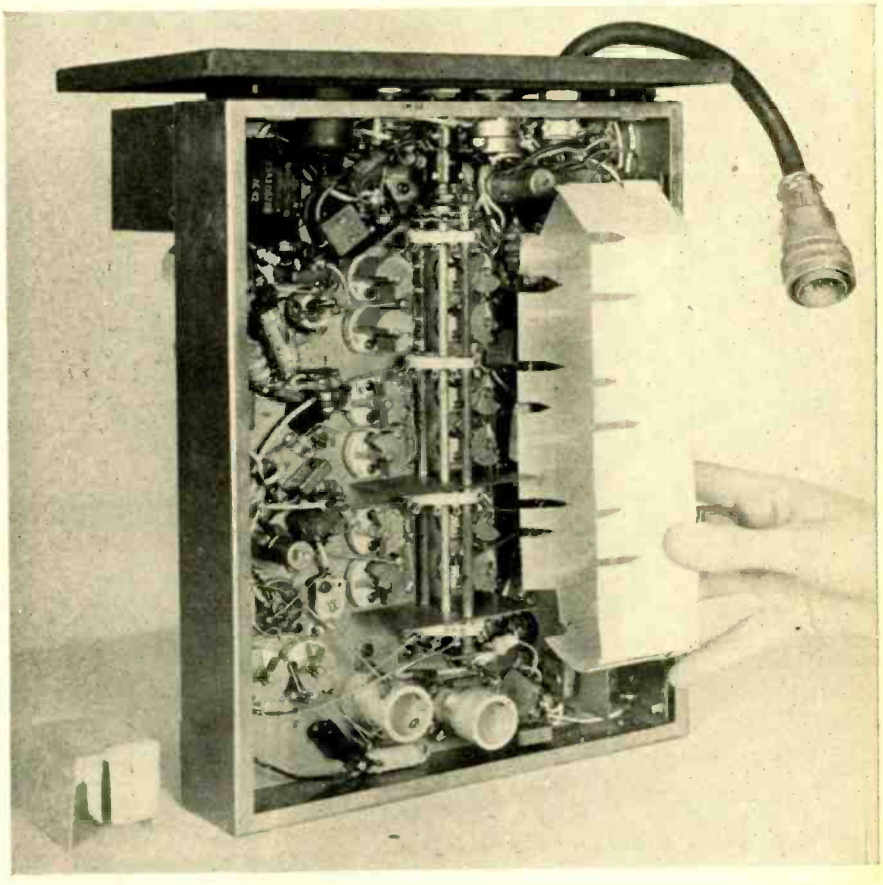
Service Conditions

A partial definition of the conditions to be met in tropical service will demonstrate the need for special design: This equipment must be operated intermittently in low, wet, damp lands where there is little direct sunshine and no cover, and where repair or maintenance parts are not available.

The heat which can be used to prevent moisture absorption is the heat generated in the equipment. However, since this equipment is used intermittently, there is a humidity cycling effect. During the periods when the apparatus is not operated, moisture is absorbed by certain parts of the equipment. At night or during other cool periods—where the change of temperature is sudden—the moisture absorption is further pronounced by dew point conditions. Condensation takes place on the non-absorbent surfaces, causing an increase in the moisture content of the equipment.

High humidity causes three destructive forces to go to work on electronic equipment; rot and swelling, corrosion, fungus. All are directly related to the moisture absorption problem.

It is impossible to completely expel



Method of masking equipment before tropicalizing treatment is applied
(Signal Corps photograph)

moisture from electronic equipments, under the conditions dictated by modern warfare. With the necessity for small light-weight, easily transportable, but highly efficient equipment, excellent places for forming moisture are furnished unless special care is taken.

The problem resolves itself into several associated problems:

1) Selection of materials and components which do not readily absorb moisture.

2) Selection of materials and components to minimize corrosion.

3) Selection of materials and components, not readily attacked by fungus.

4) Protective coatings of those parts subject to damage by moisture, corrosion, or fungus.

5) Proper design which takes cognizance of the problems.

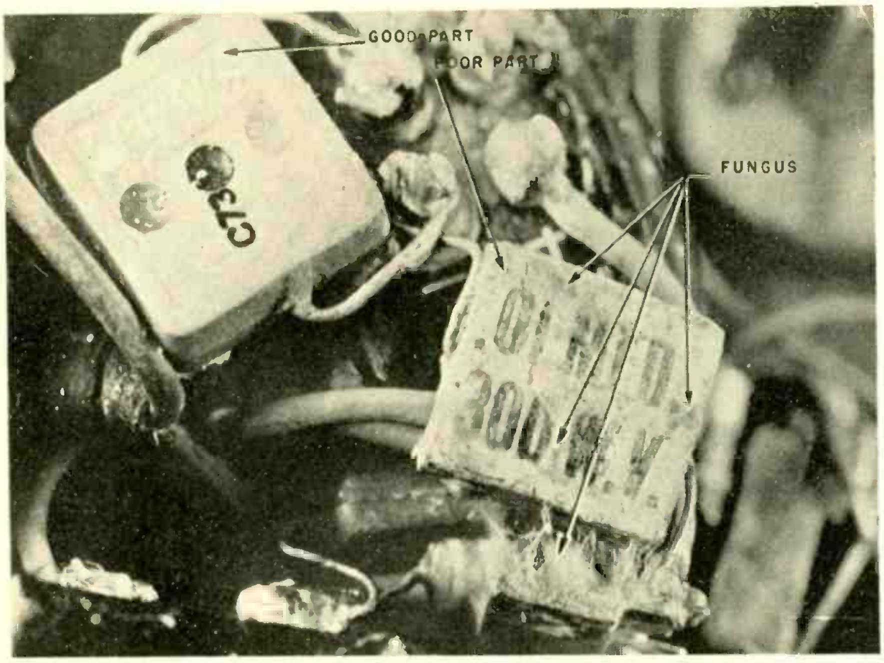
Since the problem is broad in nature, this discussion can present only the highlights. Reference, however, is made to the Signal Corps publication, "This is Serious!" which further describes the problems and attempts at solution.

The selection of material and components which do not readily absorb moisture can be the subject of much discussion. The guide post to materials is the index of water absorption, a recognized measurement. This measurement must be used with care, because in many cases milled and unprotected ends of material are not taken into consideration during the testing. Certain conclusions are, therefore, presented:

Phenolic insulation, such as terminal boards, supports, and the like should be molded, wherever possible and practical. If this is not practical, a non-organic base laminate is preferred to cotton or linen. Water absorption can be reduced by thorough varnish impregnation before or after terminals are placed into the terminal board. Special care should be taken to see that the fibre ends are sealed against moisture penetration. This can eliminate such effects as swelling, the lowering of the insulation resistance, the growth of fungus.

Fibre, cotton, linen, wood, and other cellulose derivatives have proved troublesome, due to swelling, rotting, lowering of insulating properties, fungus growth, moisture retention affecting nearby parts. Certain attempts have been made to keep moisture to a minimum. Essentially, each strand must be saturated with a moisture-resisting fungus-inhibiting impregnate after the material has been thoroughly dried. Certain surface treatments have also been attempted without too much success.

Ceramics are porous in an unglazed state. Certain treatments have been proven successful. Wherever possible, however, the solution to the problem is glazing the surface—thereby reducing the porous surfaces and crevices.



Effect of fungus growth on good and poor parts
(Signal Corps photograph)

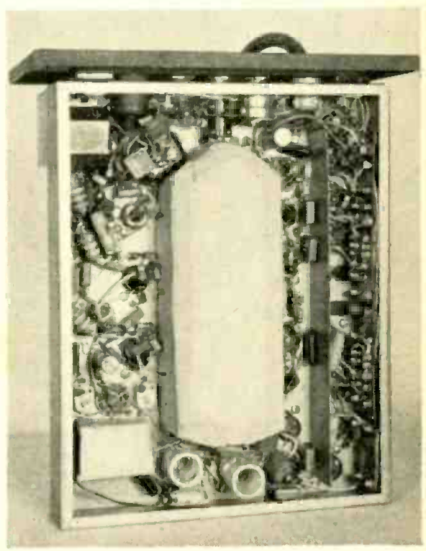
Selecting Components

The selection of components to resist the inclusion of moisture is a more difficult matter, since there are no readily obtainable guide posts. The government specifications on component parts do set up certain categories of components which are more resistant to humidity exposure and/or salt water immersion cycling. The latter, not a true indication of water absorption, is an indication of the part's ability to withstand the excesses of high humidity and salt atmosphere. No correlation exists between the time of true life and time at which failure occurs from salt water immersion cycling.

There is some relationship, however, between the porosity of the component's coating and its ability to withstand salt water immersion cycling. That this relationship does exist can be easily seen. Examine, e.g., resistors of the two categories of Navy Specification RE 13A 372J, Fixed Wire Wound Resistors, Power Type. Two categories are set up: More resistant to salt water immersion cycling, and less resistant to salt water immersion cycling. The former is defined within the specification as able to withstand nine alternate cycles of high temperature salt solution (saturated) followed by low temperature salt solution (saturated); the latter is defined as able to withstand two alternate cycles. To meet the conditions of the former, a hermetically sealed glass enclosure has been placed around the resistor; to meet the latter conditions, a superior vitreous finish has been applied. Still, under high humidity conditions, the latter type has opened since its coating is more porous.

This leads to one conclusion: all components should be hermetically sealed where possible. This is in conflict with our first statement that equipments must be small and compact. There rests the problem.

These conclusions apply:



Equipment masked for spraying
(Signal Corps photograph)

Resistors of the fixed composition variety should be insulated and coated with a mineral wax, preferably bearing a fungus-inhibiting material. But since such wax may melt under high temperature operation, care should be taken in this respect. Resistors of the power wire-wound type should be selected to be of maximum resistance to high humidity exposure and salt water immersion cycling consistent with the space allowed; the use of small diameter wires and exposed windings should be avoided. Precision resistors using small diameter wire should not be used; precision resistors, if used, should be of large diameter wire, thoroughly aged, and impregnated to withstand high humidity and thermal shock.

Capacitors

Capacitors of the fixed mica type, molded in phenolic, should be coated with mineral wax and fungicide; care must be taken to guard against high temperature operation for the wax will melt. Oil-filled capacitors should be hermetically sealed to withstand humidity excesses; paper wrappers are virtually useless under high humidity conditions.

Transformers and chokes should be hermetically sealed, preferably potted in a metal case; certain new impregnates show possibilities of meeting these requirements without the use of a metal case. R-f. coils should be thoroughly impregnated and wound on forms which are suitably moisture resistant, such as molded phenolic or glazed ceramic.

Wire should be selected to have a high initial insulation resistance, so that under prolonged humidity exposure the insulation resistance will still exceed ten megohms. Cotton, linen, and like coverings should have individual strands treated to withstand high humidity.

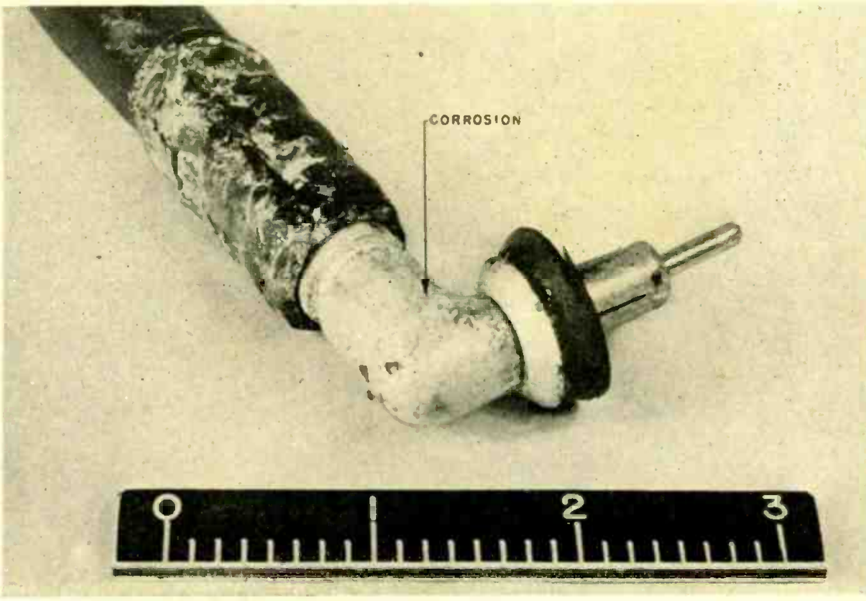
It is difficult to form any conclusions as a result of the above discussions. Water absorption of materials and components can be stopped if care in selection is applied. The best rule would be—when in doubt, eliminate the component or material, if an acceptable alternate is available.

Minimizing Corrosion

The rules for elimination of or minimizing corrosion are better established than any of the other rules in this discussion. Corrosion has been defined as an electrochemical destructive reaction between two dissimilar materials. Since two unlike surfaces and a conducting medium are necessary for most corrosion, perhaps the simplest method of preventing corrosion is the coating of each surface.

The corrosion resulting under the conditions of two unlike surfaces and a conducting medium is an electrochemical reaction depending on the ability of metallic salts to conduct electrical currents. These salts have been examined at quite some length.

Placing a metal in defined concentration in a solution and measuring



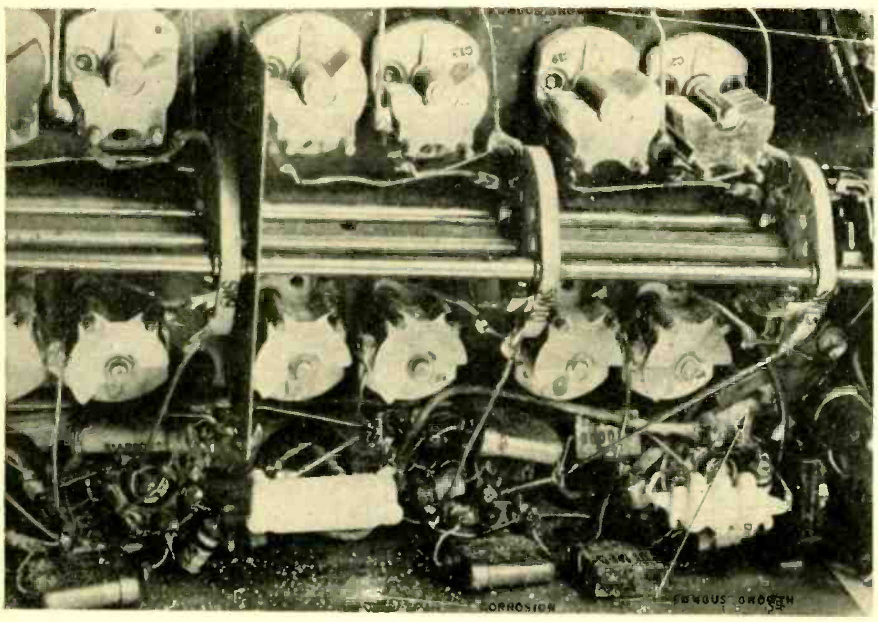
How corrosion affects connector
(Signal Corps photograph)

the electromotive potential produced against hydrogen has led to the establishment of the Electro-Potential Series. This series can be found in most handbooks.

Certain metals, readily dissolved, such as potassium, calcium, magnesium, and aluminum are extremely negative to hydrogen; certain others, such as the noble metals are moderately positive to hydrogen. It could, therefore, be seen that magnesium and silver in proximity and in solution would cause a high electric current flow. This flow of current would result in the destruction of the cathode, magnesium.

These rules apply, in general. Certain other factors complicate this problem: the formation of protective salts and the type of atmosphere.

Protective salts can be obtained in the manufacturing operation. In practice, it is common to treat aluminum with anodic processes to give a protective salt on the surface. This anodic treatment means the formation of a



Effects of corrosion and fungus growth
(Signal Corps photograph)

Typical Signal Corps communications equipment

(Signal Corps photograph)

sulphate, chromate, or a like salt on the surface. Other metals, similarly treated, will withstand corrosive atmospheres.

The atmosphere controls the type of conducting solution, the corrosion products, and the length of exposure. These conditions can best be determined by simulating the atmosphere to be encountered—or by a study of the solubility of expected salt products.

Effective treatment of unlike surfaces would be as follows: proper cleaning of the surface, priming, painting. Elimination of metallic inserts in an unlike metal. Study of types of atmospheres to be encountered and expected corrosion products.

The selection of materials and components, not readily attacked by fungus, is a little more difficult to define than any of the other problems already presented. Certain things we know, and these are few: fungus grows in a moist atmosphere, fungus attacks certain metals to form organic salts, fungus grows in confined atmospheres, fungus will attack rough surfaces.

Fungus Growth

The elimination of those materials and components which tend to absorb moisture has already been discussed. The importance previously has been that of the prevention of swelling, loss of insulation resistance and the like. Now the problem of moisture must be viewed from the point where moisture will cause fungus growth.

Bare metal surfaces, as ideal places for corrosion, assume new importance also when it is considered that the fungus and attendant organic salts cause a corrosion of the metal. This corrosion, like any other corrosion, will cause a deformation of the surface. This roughened surface is a good nesting place for the fungus, contributing to its growth.

Confined atmospheres are the most difficult problems to solve. Compact, light-weight equipments make necessary the very thing which contributes to the equipment's failure: confined atmospheres which are good clinging places for the fungus.

The points of concentration of fungus growth are readily illustrated to be the confined atmospheres: lacing of wire, switch contacts, meters, etc.

These points of growth can be best eliminated by proper design. Selection of materials and components, and the proper protective coatings (to be discussed) can aid in a limited way in the prevention of fungus growth—the rest is up to the equipment designer.

[*Continued on page 68*]

A Method of Measuring

AMPLIFICATION FACTOR and PLATE RESISTANCE

F. E. PLANER, Ph.D. (London)

A simple method of measuring these tube parameters under operating conditions

The radio engineer is frequently confronted with the problem of determining rapidly the approximate values of the amplification factor and anode impedance of a tube. While there exist, of course, accurate bridges which enable these quantities to be measured quickly and accurately, these may not always be available. The setting up of suitable bridges, or the measurement of the static tube characteristics, in particular in the case of multigrid tubes, where the operating conditions have to be established first, is often a somewhat lengthy process.

The following notes describe a simple method which allows the rapid determination of these two quantities without requiring any major changes in existing circuits.

Fig. 1 shows the equivalent circuit of a resistance coupled amplifying tube having an amplification factor μ and anode impedance R_p. R is the anode load across which the output voltage E_1 appears, and E_0, the generator voltage, is given by $-\mu Eg$, where Eg is the alternating voltage impressed upon the grid of the valve.

If now a condenser C is shunted across the load resistance as shown in *Fig. 2* the output voltage will fall to a new value E_2. Connecting this condenser across the anode load does not affect the operating conditions of the valve and both the anode and cathode potentials remain unaltered. If the frequency of the generator and the values of C and R are known, μ and R_p may be determined merely by measuring the a-c grid voltage Eg and the output voltages with and without the condenser connected across R.

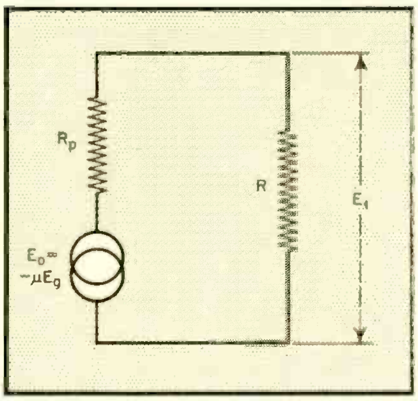


Fig. 1. Equivalent circuit of resistance-coupled amplifying tube

The anode impedance R_p may then be found, as follows:

In *Fig. 1*, E_1 is given by

$$E_1 = \frac{E_0R}{R_P + R}$$

Similarly,

$$E_2 = \frac{E_0Z}{R_P + Z}$$

where Z is the impedance of C and R in parallel. Substituting for Z it will be found that the absolute value of E_2 is given by the expression

$$E_2 = \frac{E_0R}{\sqrt{(R_P+R)^2 + \omega^2C^2R^2P^2}}$$

Dividing E_2 by E_1, and solving for R_p finally gives for the anode impedance:

$$R_P = 1 \Bigg/ \left(\frac{\omega C}{\sqrt{\left(\frac{E_1}{E_2}\right)^2 - 1}} - \frac{1}{R} \right)$$

where $\omega = 2\pi \times$ frequency in c.p.s.

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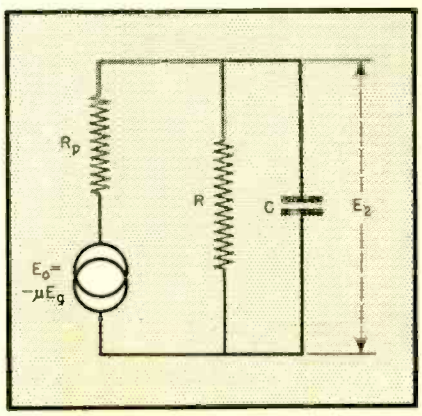


Fig. 2. Equivalent circuit with shunt condenser added

RADIO DESIGN WORKSHEET

NO. 31

DETECTION OF F-M SIGNALS; CONDITIONS FOR CONSTANT BAND WIDTH; EMPIRICAL FORMULAE; SERIES RESONANT FREQUENCY

DETECTION OF FREQUENCY MODULATED SIGNALS

The nature of a frequency modulated signal has been discussed in previous Radio Design Worksheets.[1, 2] Broken down to simple operations, this is accomplished by converting the variations in frequency to corresponding variations in amplitude and their detection in the ordinary manner, usually with diodes. Perhaps the simplest method of converting frequency variations to amplitude variations is by detuning the tuned circuit immediately preceding the detector.

This method is seldom used in spite of its simplicity because of the following severe limitations: It results in an amplitude wave in which the amplitude variations are not directly proportional to the frequency variations, thus introducing non-linear distortion due to the curvature of the resonance curve over wide frequency swings. This can be corrected by reducing the Q of the tuned circuit so that a larger linear section of the resonance curve may be used, but this reduces efficiency of conversion.

Better efficiency can be had by employing a higher Q circuit if narrow band frequency modulation is employed. This in turn reduces the signal-to-noise ratio potentialities of frequency modulation, which is one of its principal advantages.[2] This is illustrated by the curves of *Fig. 1*, obviously more efficiency can be obtained if it is possible to operate at resonance of a high Q tuned circuit.

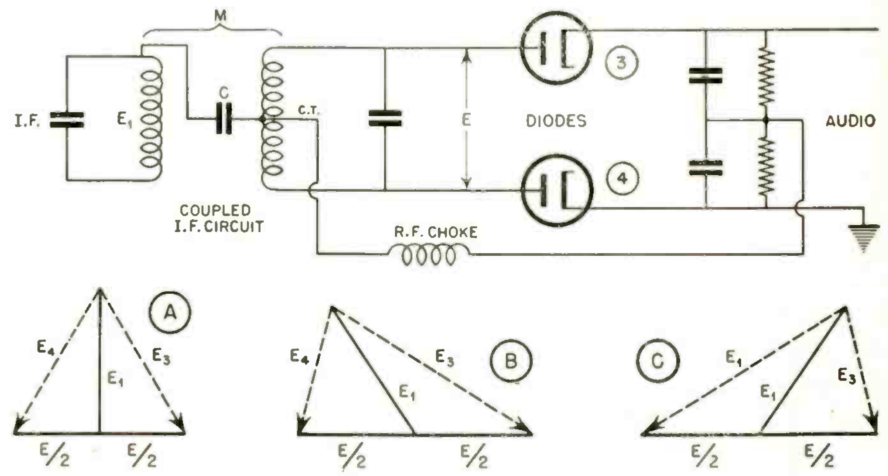


Figure 2

Fig. 2 illustrates one of the best known types of practical discriminators. Here the primary of the intermediate frequency transformer is coupled to the center tap of the secondary by capacitor C_1. The primary and secondary of the transformer are coupled inductively at something less than critical coupling. Thus the primary voltage is added vectorially to one-half the secondary voltage applied to the diodes. Since the primary and secondary voltages are in phase quadrature, the vector diagram for the resonance condition *(Fig. 2A)* is similar to that of the Scott connection discussed in Radio Design Worksheet, No. 24.[3] As a result of this vector addition, E_3 is applied to diode *3* and E_4 is applied to diode *4*. The diodes are connected differentially so that the audio voltages in the diode output circuit subtract. *Figs. 2A* and *2B* illustrate the vector diagrams for the condition when the carrier swings below and above resonance.

It will be noted that the quadrature relation between primary and secondary voltages no longer holds, so that the voltages applied to the diodes are no longer equal in magnitude as they were at resonance.

From the above it can be seen that the audio output will vary in magnitude in accordance with the frequency swings of the frequency-modulated signal. Thus the frequency variations are

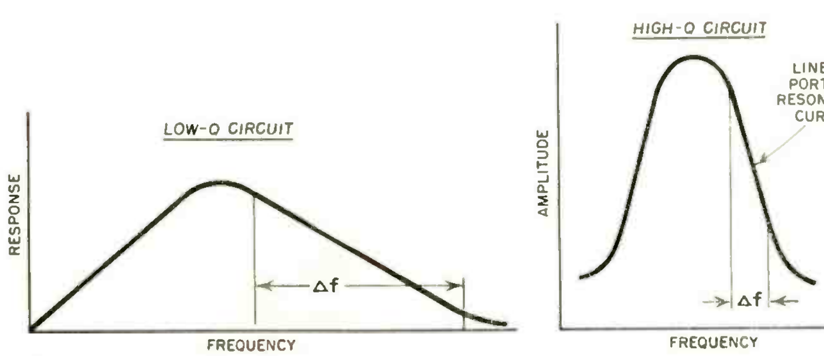


Figure 1

converted to amplitude variations in an efficient manner. Linearity of the relation between frequency variation and amplitude variation is of course as important in this case as it was in the simple detuned circuit converter. This is obtained by circuit adjustment and i-f transformer coupling adjustment as well as by proper choice of intermediate frequency. The method of accomplishing this will be shown in a forthcoming design worksheet.

There are in addition to the circuit shown a number of other ingenious discriminator circuits, some of which have been described in the literature. Future design worksheets will discuss the operation of these circuits and compare their operational characteristics with the basic circuit shown herein.

[1] Radio, May 1944, page 25.
[2] Radio, June 1944, page 36.
[3] Radio, April 1944, page 36.

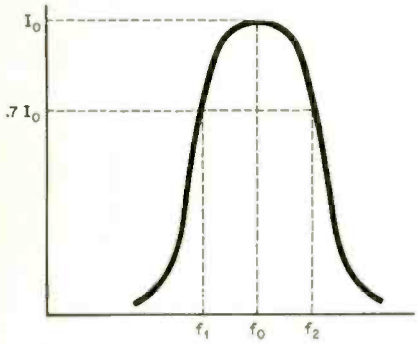


Figure 3

CONDITIONS FOR CONSTANT BANDWIDTH OF TUNED CIRCUIT

The bandwidth of a tuned circuit is frequently defined as the frequency difference between points of 0.7 maximum response or 3 db loss

$$\text{Let: } \Delta f = f_2 - f_1$$

The shape of the curve of *Fig 3* is largely determined by $R/2f_0L$. The quantity $R/2f_0L$ is usually referred to as the decrement of the tuned circuit which may be derived as follows:

$$2\pi f_2L - \tfrac{1}{2}\pi f_2C = R$$
$$2\pi f_1L - \tfrac{1}{2}\pi f_1C = R$$

Multiplying by $2\pi f_2C$ and $2\pi f_1C$ respectively:

$$4\pi^2f_2^2LC - 1 = 2\pi f_2CR, \text{ or}$$
$$C(4\pi^2f_2^2L - 2\pi f_2R) = 1$$
$$4\pi^2f_1^2LC - 1 = 2\pi f_1CR, \text{ or}$$
$$C(4\pi^2f_1^2L - 2\pi f_1R) = 1$$

Whence:

$$4\pi^2f_1^2Lf2\pi f_1R = 4\pi^2f_2^2L - 2\pi f_2R$$
$$R(2\pi f_2 + 2\pi f_1) = 2L(2\pi^2f_2^2 - 2\pi^2f_1^2)$$
$$\frac{R}{2L} = \frac{\pi(f_2^2 - f_1^2)}{(f_2 - f_1)} = \pi(f_2 - f_1)$$
$$\frac{R}{2f_0L} = \frac{\pi(f_2 - f_1)}{f_0}$$

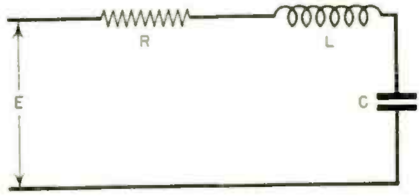


Figure 4

Therefore:

$$\text{Decrement} = \frac{R}{2f_0L} = \frac{\pi\Delta f}{f_0} = \pi R\sqrt{C/L}$$
$$\frac{R}{2L} = \pi\Delta f, \text{ and } \Delta f = \frac{fR}{2\pi fL} = \frac{f}{Q}$$

EMPIRICAL FORMULAE

In Radio Design Worksheet No. 23[4], some of the more or less common methods of relating data to curves and of evaluating the formulae to best represent the data was shown. It is sometimes desirable to use the differential calculus to determine slope; maxima, and minima from the formulae. This can be simply illustrated by *Fig. 5*. In this case, $y = x$

$$\delta/\delta x\ (y = x) = 1$$

That is, the slope of the curve is unity. Whence the curve may be drawn if one point is known. Thus, if $x = 1$, then $y = 1$ and $\delta/\delta x\ (y = x) = 1$ defines the curve. when $\delta/\delta x\ [f(x)]$

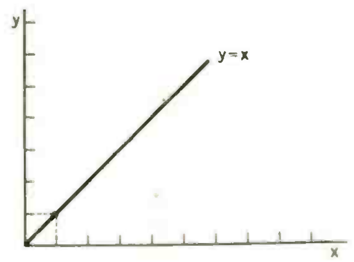


Figure 5

$= 0$, the curve will be a maximum or a minimum, since the slope would be zero (i.e., the curve at that point would be parellel to the x axis). In the case of $y=x$ the maximum is infinity.

In *Fig. 6* this is illustrated somewhat better. Here the equation is:

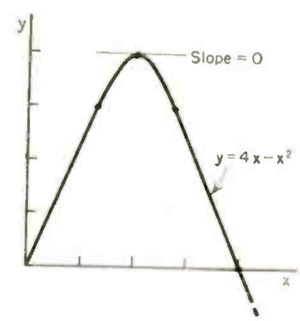


Figure 6

$$y = 4x - x^2$$
$$\delta/\delta x\ (y = f(x)) = 4 - 2x$$
$$\text{If: } \delta/\delta x\ y = 0$$
$$\text{Then: } 4 - 2x = 0$$
$$2x = 4$$
$$x = \frac{4}{2} = 2$$

Since $\delta/\delta x\ y = 4 - 2x$ we can determine the slope for any value of x by substitution.

x	y	$\delta/\delta x = 4 - 2x$
0	0	4
1	3	2
2	4	0
3	3	—2
4	0	—4
5	—5	—6
6	—12	—8

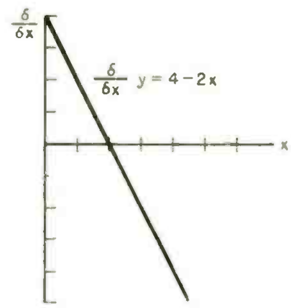


Figure 7

It is usually a simple matter to determine whether $\delta/\delta x = 0$ is a maximum or a minimum. It is not evident from inspection, it can be accomplished by computing y for values of x slightly greater and slightly less than the value of x at $\delta/\delta x = 0$.

[4] Radio, March 1944.

C. R. Nelson

SERIES RESONANT FREQUENCY

The standard formula for resonant frequency (Thomson's Approximation), must be used with caution when low-Q circuits are under analysis;

$$f = \frac{1}{2\pi\sqrt{LC}}$$

is strictly true only when multiplied by the factor

$$k = \sqrt{1 - \frac{R^2C}{4L}}$$

when square wave excitation is employed, so that the true series resonant frequency $= kf$, as originally demonstrated by Thomson.

The correction factor is required when the term $R^2C/4L$ is sensibly different from one, under the conditions of the analysis.

R. G. Middleton, Engineer,

This Month

Edmund A. Laport

LAPORT AND KNOX RECEIVES NEW POST

Edmund A. Laport, widely-known for his installations of broadcasting transmitters both here and abroad, has been appointed staff engineer for international communications systems and special apparatus at Camden, N. J., it was announced by Dr. C. B. Jolliffe, chief engineer of the RCA Victor Division, Radio Corporation of America. At the same time announcement was made of the appointment of James B. Knox to succeed Mr. Laport as chief engineer for engineering products at RCA's Canadian subsidiary, RCA Victor, Ltd.

In his new position, Mr. Laport will be responsible for the company's engineering in connection with international communications systems and engineering products for sale in the international field.

WESTINGHOUSE ACQUIRES HAZELTINE LICENSE

The acquisition of a Hazeltine license for home receiver manufacture was announced recently by Mr. Walter Evans, Vice President in charge of the Radio Division of the Westinghouse Electric and Manufacturing Company.

"This action, in addition to other licensing agreements signed by Westinghouse," Mr. Evans asserted, "is another step taken in our preparations for production of home receivers after present restrictions are lifted. The Hazeltine engineering and research organization now becomes available to us for consultation and other services."

Organization within the Westinghouse Receiver Division for manufacture and distribution is progressing rapidly, Mr. Evans made known, with plans now completed for having ready a comprehensive line of home receivers and phonograph combinations for its distributors and dealers as soon as possible after the "go ahead" signal comes from the government.

A war plant of Westinghouse in Sunbury, Pa., will be reconverted for manufacture of home sets. Headquarters of the new division will also be located there.

HALLICRAFTERS POSTWAR POLICIES

The initial outline of the general postwar policies of the Hallicrafters Company, Chicago, was presented last week to more than 50 company sales representatives and heads of the firm's export departments by William J. Halligan, president.

The company planning was discussed at a meeting held in the Stevens Hotel, Chicago, prior to the opening of the Electronic Parts and Equipment Industry Conference on Oct. 19.

James B. Knox

Major points in the policies to be followed by the company include:

1. The continued exclusive manufacture of high frequency communications equipment.
2. Use of the same type of distributors as has always handled Hallicrafters products.
3. Particular sales emphasis on the amateur radio market.

Indications in the Halligan outline of company policies were that for the immediate postwar period, at least, the company has no plans for home radio receivers bearing the Hallicrafters name.

The firm's proposed emphasis on the postwar amateur radio market is already the theme of much of the Hallicrafters advertising. Halligan reiterated that "all of our attention and the best of our efforts will continue to be focused on the amateur —the ham, the fellow who actually helped us develop Hallicrafters equipment to the high pitch of perfection it enjoys today."

TUBE PRODUCTION

Combined military and civilian requirements for radio receiving tubes after Germany's defeat will be about 60 to 70 per cent above present maximum production rates, Government officials told the Radio Receiver Vacuum Tube Industry Advisory Committee recently, the War Production Board reported. The total production in August was about 10,000,000 tubes.

Committee members said their ability to meet these requirements will be almost wholly dependent upon an increase of manpower in the industry. Cutbacks occurring in other industries should substantially increase the supply of labor available for radio tube production, they said.

Military requirements for receiving tubes now average approximately 10,000,000 tubes a month. The end of the European war will reduce military requirements slightly, but not until one year after Germany's defeat is a 45 per cent cut in such requirements expected, WPB officials said.

Because of the nature of the work and the assurance of continuous employment after the war, large numbers of women are expected to be attracted to this field when cutbacks in other industries occur, WPB officials said.

At present, approximately 13 per cent of total radio receiver tube production is available to civilians for replacement purposes only. Tube production came under WPB control in May, 1942.

G-E RADIO SURVEY

Nine out of every ten General Electric stockholders and radio dealers who replied to a recent post-war radio survey conducted by the company would like to buy an FM (frequency modulation) radio receiver.

This interest in FM radio reception was indicated in replies to a questionnaire returned by 16,635 stockholders and 1,538 radio dealers.

Almost half of those who replied were undecided as to when they would buy their new radios, which was interpreted by H. A. Crossland, Manager of Sales, Receiver Division, as an indication that many post-war receiver customers are awaiting the appearance of FM stations in their localities before they make a selection. As soon as receivers become available, 26.9 per cent of those answering stated that they will buy a new set.

The replies to the questionnaire also showed that 80 per cent knew about FM and that one out of every 10 had already bought an FM receiver.

Another phase of the survey disclosed that about 15 per cent of all the radios owned by those making replies were out

[*Continued on page 38*]

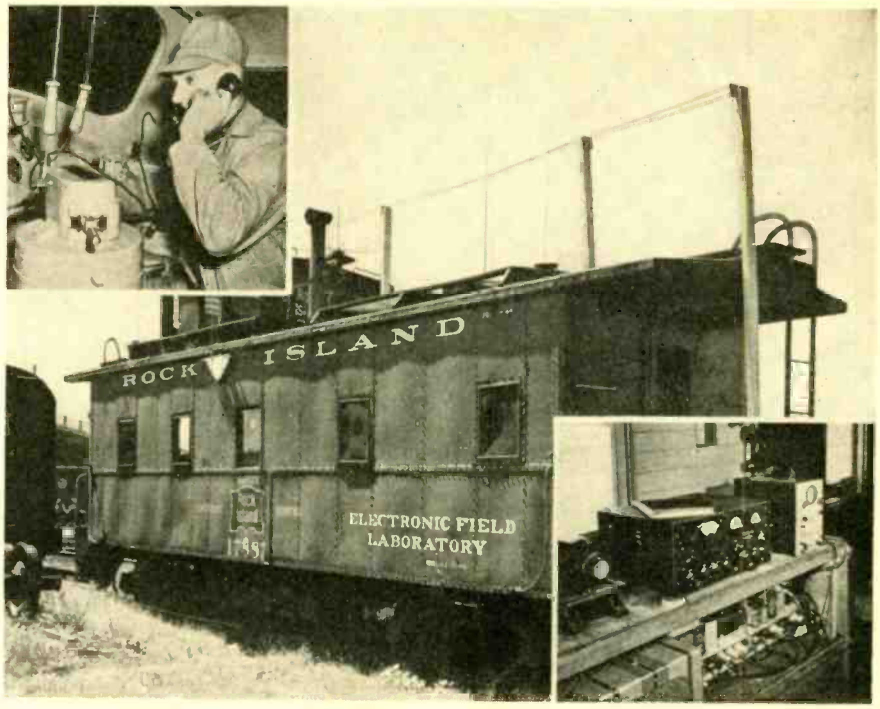
This Month

[Continued from page 37]

of order because of war shortages on parts and tubes. Twenty per cent stated that they have one set currently out of order, while 10 per cent showed that they had two or more sets idle for lack of service.

The replies also revealed a distinct change in trend in the selection of models. They pointed out that 38.9 per cent now owned table sets while 13.5 per cent said they had floor radio-phonograph combinations. However, in giving their preferences as to post-war sets, the table sets were listed first by only 22.2 per cent, while the floor radio-phonograph combination claimed the choice of 33.8 of the respondents.

Almost 85 per cent of those replying stated that they plan to buy a portable radio after the war. The popularity of this type of receiver was seen in the responses of 2,268 stockholders who stated that they use a portable 75 per cent of the time indoors.



Rock Island Railway's Electronic Field Laboratory with insets showing Hallicrafters Model S-36 receiver which is used to maintain communication with engine

POSTWAR TELEVISION CHANNEL ALLOCATION

For some time engineers at Emerson Radio have felt that, from a technical point of view, there are three important phases of television presentation when carrier frequency is considered. They have to do with the width of band required. Present 525-line television pictures require a band width of 6 megacycles for combined sight and sound. To transmit this, a carrier frequency of at least 40 megacycles must be used. Since other conditions of transmission make it desirable to use the lowest possible carrier frequency, the present 525-line system is operating in the region of 50-90 megacycles.

We believe that a 525-line picture will give excellent general-purpose performance. Its relative simplicity and present high state of development make possible a setting up of definite post-war television plans. While it may not be justified to consume an entire series of allocations from 50-200 for this present system, we believe nevertheless, that a substantial portion of this band should be allocated for 525-line general-purpose television.

Two other classes of television presentation should also be considered and provision made for their future allocation. First, it has been determined that an 1800 to 2000-line picture is the maximum definition under any and all conditions. Such a picture requires a greatly expanded band. The carrier frequency should, therefore, be above 200 megacycles. We suggest that suitable plans for allocation be made for such a high definition system in the region of 500-1000 megacycles. At present, the art has not progressed to a point where high power transmission is possible at these frequencies. There are many other highly technical problems, the solution for which is not at all apparent. Such a system, if indeed possible, may require a minimum of two years of development work in the post-war period before it could be made available to the public. Equipment cost will naturally be much higher than the now practical general-purpose 525-line system.

The second television presentation requiring consideration and planning is full-color video. To date, there has been demonstrated no full-color system capable of high definition and unlimited motion of the subject. Undoubtedly, such systems can and will be developed. It is quite generally agreed that color television requires a wider band than a similar black and white system with the same definition. A general-purpose color television system could operate in the 500-1000 megacycle band of the high definition black and white system indicated above. However, a high definition color television system will require a band of even greater width and it will, therefore, be necessary to consider high definition color allocations perhaps in the region of 3000-10,000 megacycles. The art, in this band, is even less developed than in the 1000 megacycle region. It follows, therefore, that both general-purpose and high definition color television will require considerably more time for development and receivers will cost correspondingly more.

To summarize, engineers of Emerson Radio feel that the following television allocation program is the most logical and equitable solution:

1. Recognize that there are three fundamental classes of television: (a) general purpose—black and white 525-line; (b) high definition—black and white 1800-2000 line; and/or general purpose color television; (c) high definition color television.

2. Provision should be made for allocation of a reasonable but not excessive number of bands in the 50-200 megacycle region for general purpose television, the development and promotion of which can start as soon as the war program permits of the release of engineering and manufacturing facilities.

3. Provision should also be made for allocations to be used by high definition black and white and general purpose color television in the 500-1000 megacycle region.

4. Additionally, it is to be remembered and considered that there may ultimately be a system of high definition color television which will operate in some even higher frequency region.

High definition black and white television and color television will not obsolete general-purpose black and white television. A market will exist for all types of equipment and the sponsors will benefit accordingly. When the high definition television band is ultimately standardized it probably will be possible to coordinate it with an acceptable general purpose color television system. In this manner both can operate in the same frequency band and on their respective receivers. Thus a station can broadcast in color while receivers can receive the program either in color or black and white, depending on the design of the receiver.

This is a logical solution to the television allocation problem and the answer to the many conflicting and often prejudiced statements which have appeared recently.

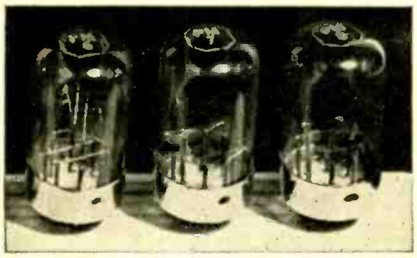
SYLVANIA NEWS

ELECTRONIC EQUIPMENT EDITION

NOVEMBER — *Published in the Interests of Better Sight and Sound* — 1944

PM Lamps Offer Easy Way of Measuring RF Power Output

The group of Power Measurement Lamps introduced by Sylvania a little over a year ago have fully demonstrated their merits as a simple, accurate means of measuring the high-frequency power output of radio equipment.



3 of the 6 Sylvania PM Lamps

The present series consist of 6 lamps, with which power outputs ranging from 0.05 to 25 watts can be measured directly, with the aid of ordinary meters. Accuracy of the measurements is within 5%, without any special calibration of the lamps.

Full information on the principle of operation of these lamps, and on their ratings and characteristics, is available from Sylvania.

DID YOU KNOW...

That fluorescent lights are now helping with the job of guiding Pan American Clippers to port? They illuminate seadrome landing strips which were developed by Sylvania in cooperation with Pan American.

* * *

That 7½-watt ruby lamps have been developed by Sylvania for use in Army photographic printing equipment? Smaller than most lamps of its type, the 7½-watt size is easily ɩnstalled in portable printers.

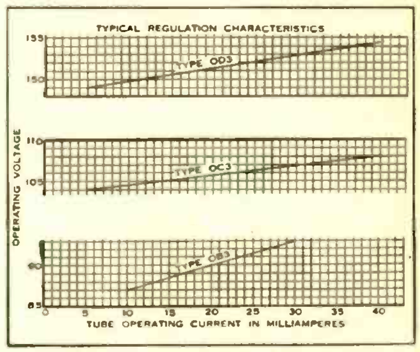
* * *

Th. ..he Army Medical Corps' new ten-car hospital train is fluorescent lighted throughout? Patients in the tropics will be more comfortable under these lights, which radiate little heat.

Regulator Tube Maintains Voltage within Narrow Limits

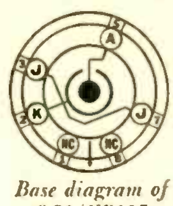
Maximum Regulation of Type OC3/VR105 Is 4 Volts over Operating Current Range

A voltage regulator tube, for applications where practically constant voltages must be delivered to a load, was recently placed on the market by Sylvania. Like previous tubes in the Sylvania line of voltage regulators, the new tube, designated as Type OC3/VR105, is of the gas filled, cold cathode type. It's outstanding difference from earlier types lies in its lower voltage regulation. With a design center operating voltage of 105, the OC3/VR105 has a maximum regulation of 4 volts over the operating current range from 5 milliamperes minimum to 40 milliamperes maximum. Characteristics of the new tube are compared with those of the OB3/VR90 and OD3/VR150 in the accompanying curves.



Comparative regulation characteristics of Sylvania voltage regulator tubes.

It should be noted that individual tubes may not deliver identical voltages to the load. However, the voltage will be within the specified operating limits of 105-112 volts, and the regulation 4 volts or less for any tube.



Base diagram of OC3/VR105

The tube is mounted in an ST-12 bulb with a standard small 6-pin octal base.

A current-limiting resistor should always be used in series with the OC3/VR105, to keep the operating current through the tube down to 40 milliamperes if the load should be disconnected.

28D7 USEFUL AS VOLTAGE BOOSTER

With 28-volt operation of radio equipment attracting increasing interest in its current aircraft applications, and in its commercial potentialities, the Sylvania Type 28D7 is finding new fields of usefulness.

The 28D7 is a Lock-In output tube specifically developed for operation direct from a 28-volt source. The 28D7 can be used as a convenient voltage booster. This feature is particularly important where the 28-volt supply may drop too low to operate tubes having a critical minimum voltage.

For voltage boosting, the 28D7 is coupled as an oscillator to a load coil of the required characteristics, and the output rectified by a diode. Output voltages up to 500 to 600 volts can be obtained in this way.

"Car 54 go to 8th and Main—Signal 17 and doesn't the transmitter sound swell since I put in those Sylvania tubes? That is all."

SYLVANIA ELECTRIC PRODUCTS INC.
Radio Division · Emporium, Pa.

MAKERS OF FLUORESCENT LAMPS, FIXTURES, ACCESSORIES, INCANDESCENT LAMPS, RADIO TUBES, CATHODE RAY TUBES, ELECTRONIC DEVICES

The Terminology of ELECTROMAGNETIC THEORY

Because recent developments in the field of microwave radiation and generation have greatly widened the engineer's interest in electromagnetic theory, the following alphabetical list of terms, ideas, and theorems is presented. It is not so much intended that the discussions be rigorous definitions as that they shall give interesting ideas and serve as an introduction to the concepts.

Nepers-N—The neper, like the decibel, is a ratio unit which measures the gain or loss of a signal in terms of a logarithmic scale. Also, like the decibel, it is primarily useful to us because certain physical apparatus responds logarithmically. For example, the losses in a transmission line are that way. In each unit length of the line, the loss is not a fixed amount as it would have to be if linear variables were to be an adequate measure of its operation, but instead the loss is a certain percentage of the amount entering that unit length. Strictly, this is exactly the type of phenomenon that gives rise to Naperian logarithms to the base ϵ. While decibels are based on logarithms to the base 10, the neper uses logarithms to the base ϵ. This would seem to make the neper the more logical unit for many calculations but, since the difference between the neper and the decibel is only a numerical constant, its advantage is really trivial.

If two quantities W_1 and W_2 are said to differ by N nepers then

$$N = \tfrac{1}{2} \log_\epsilon (W_1/W_2).$$

To convert nepers to decibels, multiply by 8.686. To convert decibels to nepers, multiply by 0.1151.

Newton—Just as the dyne is the unit of force in the centimeter-gram-second system of units, so the newton is the unit of force in the meter-kilogram-second system. *A newton is that force which can just accelerate one kilogram of mass at the rate of one meter per second per second.*

In either of these metric systems the distinction between force and mass is much more clear than it is in the English units of mechanical engineering where we use the pound to measure both the quantity of a commodity that can be purchased for a given price (i.e., mass) and the tension or compression that a mechanical member must withstand (i.e., force).

Fortunately, the electrical engineer and the physicist have almost universally avoided using English units. In expressions such as $F = BIL$, which gives the force on a conductor of length L carrying a current I through a field B, units are arranged so that F comes out either in dynes or newtons. In the MKS or Giorgi system of units, F is in newtons if B is in webers per square meter, I in amperes, and L in meters.

A watt of power is equivalent to one newton of force acting through a distance of one meter each second. One newton is equivalent to 10^5 dynes and is of a convenient size for practical measurements. Roughly, a newton is about equal to 0.22 lbs. of force while a dyne is the equivalent of only about .35 ounces.

Oersted-H—Oersteds are used in the gaussian system of units as a measure of the magnetic field, H. *One oersted of magnetic induction exists at the center of a long solenoid when $H = 4\pi NI/10$ is equal to unity. I is measured in amperes and N is the number of turns per cm wound on the solenoid.*

In the MKS or Giorgi system of units, the quantity corresponding to the oersted has no special name and H is measured in terms of amperes per meter. The reasoning is that if a current flows in a device such as a coaxial line, the H field is entirely restricted to the space between the conductors and for that device depends only upon the current densities in the inner and outer conductors. These current densities may be measured in terms of amperes per meter of conducting surface. Thus, if the outer conductor has an inside diameter of 3 cm and carries a current of 10 amperes, it has a current density of $10/(.03\pi)$ amperes per meter because the 10 ampere current is effectively spread over a conducting surface whose width is equal to the inner circumference of the outer conductor.

The unit of H in the Giorgi system is best defined in terms of the field between two infinite, but parallel, plane current sheets carrying charge in opposite directions. The field there in Giorgi units is just equal to the current density and is expressed in the same units. It is reasonable to use these units because the induction field for such a pair of infinite plane conductors is completely independent of everything else such as the spacing between the plates and the nature of the medium. The oersted is a much smaller unit than the ampere per meter.

Permeability-μ— If currents flow in conductors located in a certain region, the magnetic field at a point in that neighborhood can be measured in terms of the magnetic field, H, or in terms of the magnetic induction, B. *The ratio, B/H, may be defined as permeability and is usually represented by μ.* Since H depends only upon the currents and not at all upon the medium, while B is generally larger than H by an amount dependent upon the medium and its condition, it follows that μ is a quantity which describes the medium.

Iron materials may have very large permeabilities; some other materials such as pure nickel and certain alloys also cause B to be much larger than H; most other materials have a permeability approximately equal to that of free space.

It is very important to understand that permeability is not a constant of a material. With a certain iron, for example, it is not safe to say that the permeability is 2500 gauss per oersted. If a B-H curve is drawn for such a piece of iron the familiar hysteresis curve showing saturation of B for large values of H is obtained.

Thus although, for small values of H, μ may be 2500, for larger H values it drops off and eventually may become very small.

The permeability of a given material may also be affected by grain orientation or by cold working of the iron.

Permeability in Free Space-μ_o— There are two numerical constants in the Giorgi system of units which must be re-

[*Continued on page 50*]

. . . "Among their Latest Triumphs is an inter-communicating telephone for interior use in buildings, which furnishes in itself, by pressing buttons, complete exchange connections, with all parts of the building, and releases the same automatically and comprises the only successful system of its kind of the present age."

The glowing phrases above, written not long after the turn of the century, describe a Connecticut Telephone and Electric "First" which doubtless caused grandpa to wonder, "What won't they think of next!"

The things our engineers are thinking up today in cooperation with U. S. Army engineers are full of interest and promise, but they can't be talked about now. You can count on better communications...in fact, you can confidently expect war-born improvements in all branches of electrical and electronic science.

If your product-development plans involve a problem of electrical or electronic engineering and manufacturing, perhaps we can be of assistance. We also invite preliminary inquiries connected with inter-communicating and signalling systems for postwar buildings now in the design stage.

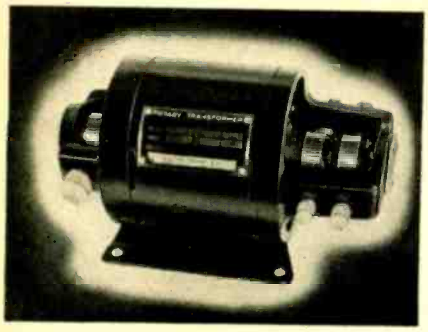
CONNECTICUT TELEPHONE & ELECTRIC DIVISION

GREAT AMERICAN INDUSTRIES, INC.

MERIDEN, CONNECTICUT

TELEPHONIC SYSTEMS • SIGNALLING EQUIPMENT • ELECTRONIC DEVICES • ELECTRICAL EQUIPMENT • HOSPITAL AND SCHOOL COMMUNICATIONS AND SIGNALLING SYSTEMS • IGNITION SYSTEMS

New Products



MULTI-OUTPUT DYNAMOTOR

The heavy drain on storage batteries by the use of several electric motor-generators in mobile equipment has been reduced by the development of the Multi-Output Dynamotor produced by the Carter Motor Company, 1608 Milwaukee Avenue, Chicago.

"Wherever a transmitter and receiver have been used—especially in police and aviation radio work—there has always been the condition of excessive battery drain," said Robert W. Carter, Managing Director of the firm. "We have developed a new type of multi-output dynamotor which will deliver as many as three separate outputs simultaneously from the same unit. We have found that the Multi-Output Dynamotor answers the requirement for different power supplies from the same unit, and hence the same space. It is possible, for instance, to use 6.3 volts A.C., as well as "B" power for the receiver and also have the high-voltage for the transmitter available at the flick of a switch—all from the same generator," he claimed.

A complete brochure on this advanced unit is being prepared and will be made available to all radio engineers requesting it.

TUBE INTERCHANGEABILITY CHART

With the tube situation becoming rapidly worse, and some types becoming unobtainable, Lafayette Radio Corporation, 901 West Jackson Blvd., Chicago, announces that there is an excellent substitution tube chart on pages 2 and 3 of their current free catalog No. 94.

While there are many more complete charts on the market, it is felt that the Lafayette chart will more than fill the bill for the serviceman whose customers have the usual radios. Of course, there are many tubes for which there is no substitute; but on the whole, the most often found types are described together with suitable connections which will enable the use of some of the less scarce tubes now on the market, or available without high priorities.

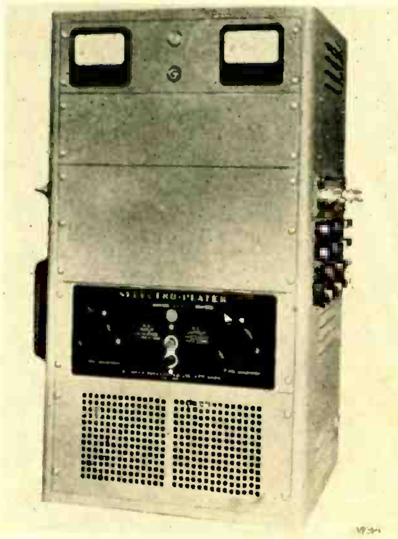
MULTI-RECTIFIER

Research and development laboratories which have heretofore faced diverse and difficult problems with regard to d-c power supplies have a distinct asset in the newly developed Multi-Rectifier by the Green Electric Laboratories, 130 Cedar Street, New York 6, N .Y.

This new multi-rectifier incorporates six selenium rectifier sections which may be interconnected by external links to provide four ranges of d-c power:

0-8 volts, maximum capacity 100 amperes
0-16 volts, maximum capacity 50 amperes
0-24 volts, maximum capacity 35 amperes
0-48 volts, maximum capacity 18 amperes

Thus it is possible for the two panel-mounted voltage control switches to provide a range of control in 49 steps, from zero to maximum, on any range. The built-in voltmeter and ammeter indicate the d-c output voltage and current at all times, and red line calibrations indicate the maximum current limitation on each range.



RADIO AND ELECTRONIC BOOK GUIDE

Under the stimulus of World War II the science of radio and electronics has rapidly developed over widely divergent fields, and its literature has mushroomed in the last few years. As a guide to this literature, to permit rapid selection of books by title, author, publisher, subject, or application, Allied Radio Corp., Chicago, has released for free distribution a booklet containing a wide selection of publications on radio, electronics, and related subjects.

Listings cover simplest fundamentals to advanced practices for beginner, student, radio amateur, instructor, technician, service and maintenance man, and engineer.

The listings are divided into two major parts: (1) A classified directory by subject (Aeronautics, Electricity, Engineering, Basic Training, etc.); (2) A listing under publisher, by author and title, with a brief summary of contents, size, number of pages, price, etc.

To obtain this booklet without charge, write to Allied Radio Corp., 833 West Jackson Boulevard, Chicago 7, Illinois.

NEW DYNAMIC MIKE

Universal Microphone Co., Inglewood, Cal., has brought out its first new model since 1940 with the presentation to the trade of the new D-20 series.

The new Universal dynamic microphone has a response of 50 to 8,000 cycles. Ultra-streamlined in appearance, the D-20 will be modeled in brushed satin chrome finish case with Universal's new "micro adjust" swivel. Dust proof hood and twenty-five feet of cord will be included in the attractively packed unit.

D-20 will be manufactured in four impedances, according to James L. Fouch, president.

Universal will also resume production on some of its microphone models including the KD and 15MM, both of which are dynamics; 200 series, a dynamic handi-mike model; and X-1 and XX, both carbons.

Distribution will be through the usual trade channels of Universal's factory representatives and the parts jobbers, according to Cecil L. Sly, vice-president and sales manager.

VACUUM TUBE VOLTMETER

A new development offered by the Reiner Electronics Company, Inc., is their Model 450 Vacuum Tube Volt-Ohm-Milliameter. This new instrument incorporates many features which simplify operation and save time in production testing. Of particular importance is the wide frequency range a-c Voltmeter which measures from 50 cps. to 50 megacycles; also the six d-c voltage ranges, with input capacitance of less than 2 $\mu\mu f$ and input resistance of 11 megohms on all ranges; d-c current ranges from 50 microamperes to 1 ampere in six ranges.

Features of Model 450 Voltmeter in detail are: Wide Frequency range a-c Voltmeter; one linear scale for all voltage and current scales; freedom from the effects of temperature and humidity; single zero adjust for all a-c and d-c ranges. Measures 100 ohms to 1,000 megohms without

[Continued on page 44]

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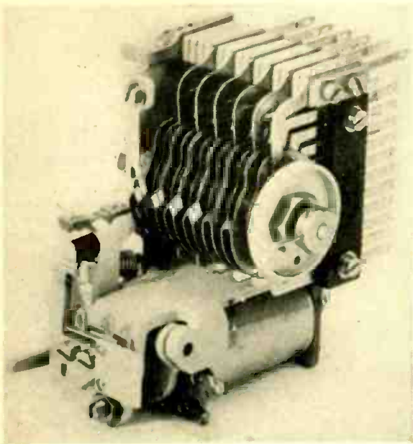
[*Continued from page 42*]

battery. The battery is used only for measurements below 100 ohms. Voltage regulated supply provides stable operation.

Ohmmeter Ranges—.1 ohm to 1,000 megohms. Center scale resistance: 10, 10^1, 10^2, 10^3, 10^4, 10^5, 10^7 ohms. Center scale accuracy, 2%. Three low ranges battery operated. Three high resistance ranges internally powered.

Further information or descriptive bulletin may be had on request to Reiner Electronics Company, Inc., 152 West 25th St., New York 1, N. Y.



AUTOMATIC SELECTOR

Smaller, lighter electrical equipment is made possible by a compact FTR 800 automatic selector now being manufactured by Federal Telephone and Radio Corporation, Newark, N. J., associate of International Telephone and Telegraph Corporation. Occupying approximately half the space required by other selectors of a comparable range, this high-speed, multi-contact switch is adaptable for use as an automatic or remote control device for railroad, radio, airport and many industrial applications.

This unit will make connection between a number of given circuits and a similar number of other circuits, each pre-selected from a group; control and perform various operations among a group of circuits by making consecutive individual connections; act as a timing device or switch when it is used in connection with time-pulsing apparatus. It may also be used in telegraph or electronic equipment, remote control and signaling systems, testing and radio control.

SYLVANIA BULLETIN

Nine types of electronic tubes for specialized applications are described in a new 24-page bulletin published by Sylvania Electric Products, Inc.

Products described include strobotrons for the study of reciprocating and rotating motion; Pirani and thermocouple tubes for measuring vacuum; voltage regulator tubes; facsimile tubes; germicidal tubes; black light and near ultraviolet lamps. Technical sections of the bulletin give specifications, basic circuit diagrams and suggested applications for products and accessories. Fluorescent lamp characteristics are given in tabular form and curves.

Copies of Bulletin 202 are available on request to Sylvania Electric Products, Inc., Special Products Division, 60 Boston St., Salem, Mass.

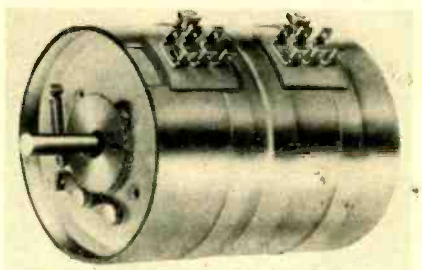
NEW ALIGNING TOOL

A new tool for precision alignment of padding condensers in radio receivers and transmitters is announced by General Cement Mfg. Co. of Rockford, Illinois. The new TL-207 alignment tool is constructed of two basic parts molded from Durez Plastic. A scientifically designed barrel with small knurled head accommodates a spring controlled plunger with a larger control knob. The barrel is hexagonal shaped in its working end to accommodate the condenser adjustment lock nut. The plunger has a metal insert in its lower end resembling a screw driver tip. The spring prevents plunger tip from protruding beyond the hexagonal end of the tubular barrel.

Minute adjustment is made by the plunger when it pushed forward to mate itself into the cloven pin end of the condenser adjusting screw. Movement of the barrel quickly loosens or tightens the hexagonal locking nut which collars the condenser adjusting pin. Movements of magnitude and direction are indicated by the arrow engraved on the control knob end.

NEW ATTENUATOR

The Daven Company of 191 Central Avenue, Newark, New Jersey, announces a newly improved model for Dual-Unit Attenuators. Engineers at Daven have incorporated into the improved Dual-Unit, all the developments and advances of



former Daven standard single unit attenuators, plus many new essential features.

The dual-unit construction finds most important application in balanced "H" Attenuators, as well as in special multi-circuit controls of the Potentiometer, "T," Ladder, "L," and Rheostat types. Comprised of two units, one mounted behind the other, the respective shafts of each meet in a lap joint within a long snug bushing, providing quick and easy separation of the units. This is done by simply loosening a knurled nut and releasing a snap-on fitting, without dismounting the front unit from the instrument panel.

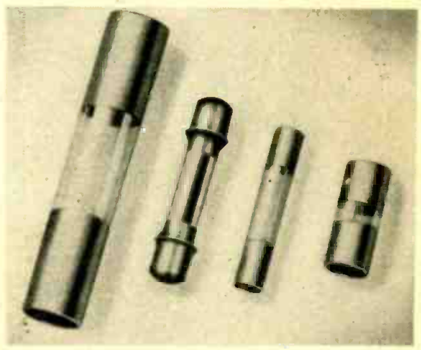
The new model is electrically the same as previous models. In addition it has fungus and mildew resisting varnish on all bakelite parts and resistive windings. Contact and switch blades are of tarnish resistant, improved silver alloy. Other metals are optional. The means of coupling front and rear attenuator shafts is simple, positive, durable and foolproof.

METAL PLATING ON GLASS

The unusual adhesion obtained by Electro Plastic Processes in plating on plastic materials has been further adapted for application to glass and ceramics. Laboratory and field tests indicate greatly improved hermetic sealing. Tests on pyrex glass have been conducted by heating the solder sealed piece to 350° F. and immersing it immediately into dry ice, indicating the adaptability of the new process for all temperature ranges. Adhesion obtained is much better than that of other commonly used methods.

Any normal soldering method is satisfactory—hot iron, oven soldering or electronic, and no special solders are required.

The process is adaptable to the her-



metic sealing of such electrical components as resistors, condensers, small relays, transformers, instruments, etc. Either glass or ceramic cases can be plated with a metallic band for soldering to metallic end caps or insulators plated for solder sealing to metallic containers.

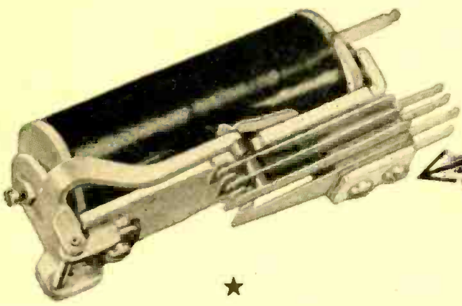
Details may be had by addressing Electro Plastic Processes, 2035 West Charleston Street, Chicago 47, Illinois.

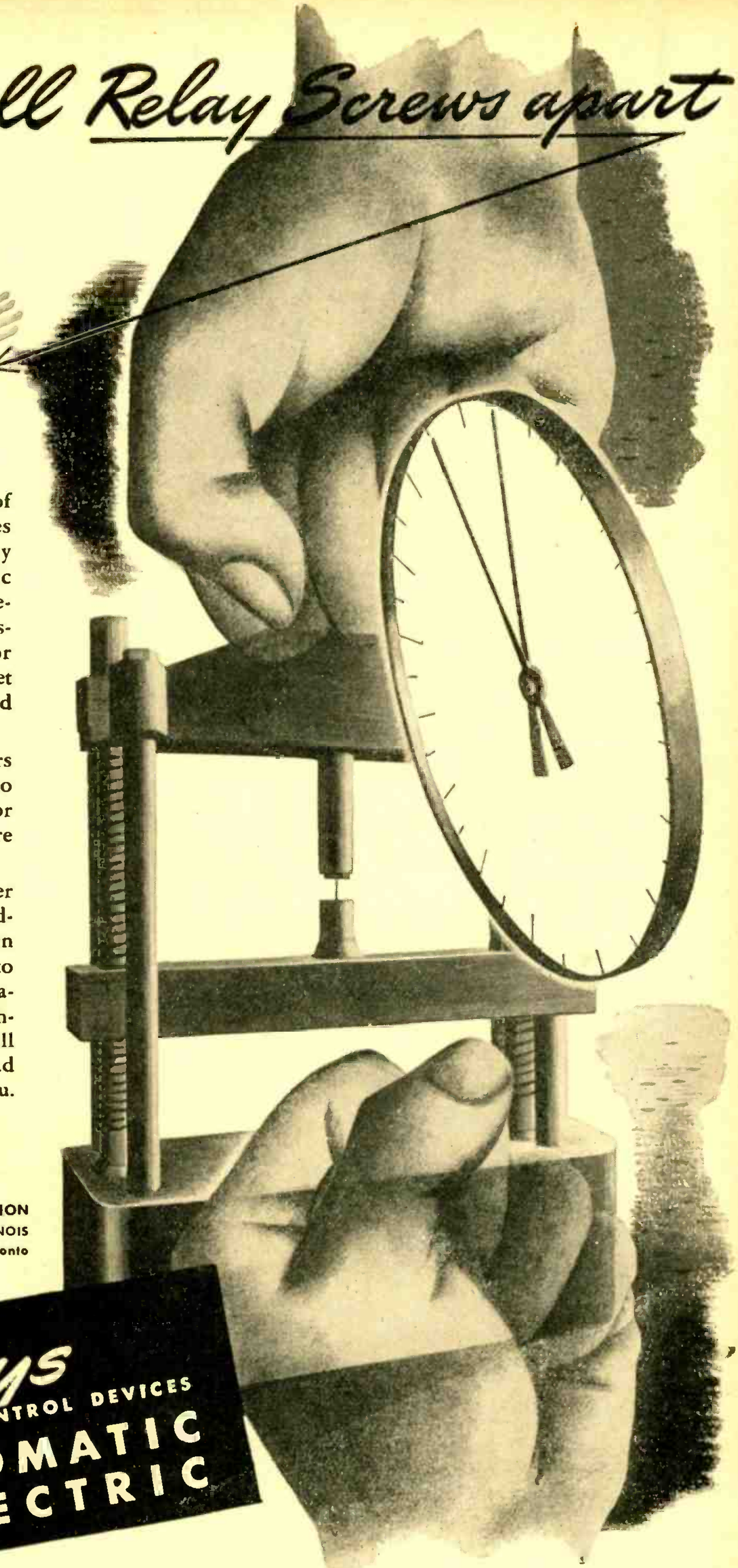
MIDGET RELAY

A new, light weight, midget relay, product of Guardian Electric Manufacturing Company, is said to be engineered for applications where weight and space are at a premium. Weighs only 1.2 oz., and measures 1 9/32" x 1 5/32" x 29/32", single pole, single throw.

For further information, write Guardian Electric Manufacturing Company, Dept. M-R, 1605 West Walnut Street, Chicago 12, Illinois. Ask for bulletin 295.

Why we pull Relay Screws apart





Vibration, humidity and extremes of temperature can be bitter enemies of relay dependability. That is why the contact springs on Automatic Electric relays are clamped by special screws, which exert the necessary pressure without breaking or stretching. Such screws must meet the exacting tensile tests prescribed by our designers.

These tests, and scores of others like them, are vital contributions to the long life and dependability for which Automatic Electric relays are famed.

When you need relays or other electrical control devices, take advantage of our unique fund of design data and experience. First step is to write for the Automatic Electric catalog. Then, if you need sound technical advice on your problem, call in our field engineer. He will be glad to put his knowledge to work for you.

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"AFTER TURNING HIMSELF INSIDE OUT FOR TWO MONTHS TRYING TO GET SOME COILS, THE BOSS JUST LEARNED THAT ALL HE HAD TO DO WAS CALL ALBION . . ."

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membered. One is the dielectric constant in free space and the other the permeability. The permeability is especially important to remember because it is approximately the same in free space and in all media except magnetic materials. In Giorgi units $\mu_o = 4\pi \times 10^{-7}$ henry per meter; in the gaussian system $\mu_o = 1$.

The simpler value obtained in Gaussian units is a great advantage of that system but not always one that outweighs the use of powers of 10 and c which must be used in changing to practical units. *By definition $\mu_o = B_o/H_o$ where H_o and B_o are respectively the values of the magnetic induction B and the magnetic field H at a point in free space.*

With rationalized Giorgi units it is interesting to notice that expressions for wave velocity and impedance in free space are expressed very simply in terms of μ_o and ϵ_o. Starting with Maxwell's equations we may derive wave equations for E and H as

$$\nabla^2 E - \epsilon\mu \frac{\delta^2 E}{\delta t^2} = 0$$

$$\nabla^2 H - \epsilon\mu \frac{\delta^2 H}{\delta t^2} = 0$$

For a plane wave traveling along the z-axis of a cartesian coordinate system we may arrange to have the E vector point along the x-axis and the H vector along the y-axis. In that case we have only E_x and H_y for which to solve these differential equations. Furthermore, we may anticipate that our solutions for E_x and H_y will be of the form of a sinusoidal traveling wave. If we assume such a form and use an arbitrary constant for the velocity we may substitute the tentative solutions back in the differential equations and not only show that they are indeed solutions but also that the wave velocity is given by $1/\sqrt{\epsilon\mu}$. In free space, therefore, $1/\sqrt{\epsilon_o\mu_o} = c = 3 \times 10^8$ meters per second. Also having found E and H for a plane wave we can form the quotient as the impedance and show that the impedance of free space is given by $E_o/H_o = \sqrt{\mu_o/\epsilon_o} =$ 376.6 ohms.

Phase Velocity-V— *The wave or phase velocity of a traveling wave is just what the name implies. It is the velocity with which a point of given phase moves in a traveling wave containing a single frequency.*

The most important consideration in understanding the distinction between phase and group velocity has to do with the flow of energy. Energy always moves in accordance with the group velocity of the wave and never at a speed dictated by the phase velocity. The phase velocity is essentially a phenomenon of a steady state in which the wave has no beginning nor end, other than in the source or load.

When the source is first energized and the beginning of the wave train travels to the load, the situation is such that we must consider that beginning as traveling with the group velocity because its frequency is not single valued even though the source oscillates at only one frequency. Only if the wave extends indefinitely in both directions can it be exactly measured, even in principle, and thus be said to have only a single frequency component.

Another way of saying the same thing is that the beginning of the wave is the equivalent of a 100% modulation and modulation by definition travels with group velocity.

When a wave motion is traveling in a steady state, however, phase velocity is a very real concept and subject to measurement and calculation. If, for example, a length of wave guide is imagined to be perfectly matched to a source and load and to have a unity swr, we can at least imagine measuring the phase velocity by using a very agile probe which will move along the guide in coincidence with a point of maximum electric field. Since such a probe would be moving with a velocity equal to that of a phase point (the point of maximum E), it must be moving with a speed equal to the phase velocity.

Phase velocity is numerically different from group velocity only when the phase velocity changes with frequency. Under certain conditions the phase velocity of a wave may be greater than the velocity of light. This does not contradict the principles of special relativity because energy is not transported at that velocity.

Point Impedance— The concept of impedance, like that of many other physically measurable quantities, is one which has more or less grown with time. The term was first used to allow us to write an alternating current analogy of Ohm's law as applied to a direct current through a resistance. Gradually the term impedance has been applied to more complex situations until now its meaning is not always clear except in the context with which it is used. Especially since it has proven convenient to define certain impedances in terms of electric and magnetic fields in a wave guide as well as in terms of the currents and voltages that are involved, it is usual to refer to several sorts of impedance which, although closely related in meaning, still indicate somewhat different measuring techniques.

There is not complete agreement on the exact terminology used but at least characteristic impedance, input impedance, intrinsic impedance, surface impedance, equivalent impedance, and point impedance may be found in various books on the subject and serve a useful purpose, at least so far as their names are self-explanatory.

Of them all, point impedance is the easiest to define. *It is the ratio of the maximum E to the maximum H field that is observed at a given point in a wave guide or transmission line due to the energy flow under consideration.* The point impedance of a given point in a wave guide system will in general depend upon the geometry of the whole system but its measurement may be made by considering the situation of the single point alone.

When the impedance of free space is said to be 376 ohms, there can be no question of the measurement of current or voltage. What is meant is that the point impedance of any point in free space is 376 ohms. The E vector at any such point is in proper units 376 times larger than the H vector.

On the other hand, when the task is one of matching two wave guides of different size by the use of some sort of coupling section, it is certainly not enough merely to arrange to match point impedances. Rather it is a matter of smoothly transferring the electric field from one wave guide to the other over the whole area of cross section. This is accomplished when the currents and voltages generated in the walls of the guide are matched. Such an impedance based on current and voltage is frequently referred to as an equivalent impedance. For practical reasons of measurement it is normally estimated or calculated from measured values of point impedance.

Poisson's Equation— *The differential equation which may be conveniently written in the form*

$$\Delta^2 V + 4\pi\rho = 0$$

is one of especially wide application and hence well known in the fields of hydrodynamics, astronomy, and aerodynamics, as well as in the study of electromagnetic theory. Its most important use in the electrical case is occasioned by its ability to describe the electric potential arising from electric charge, no matter how that charge is distributed throughout the neighborhood of the space in which we are interested. It is only necessary that the position of all the charge be known and specified by an equation involving ρ (the charge density) and the coordinates of a coordinate system.

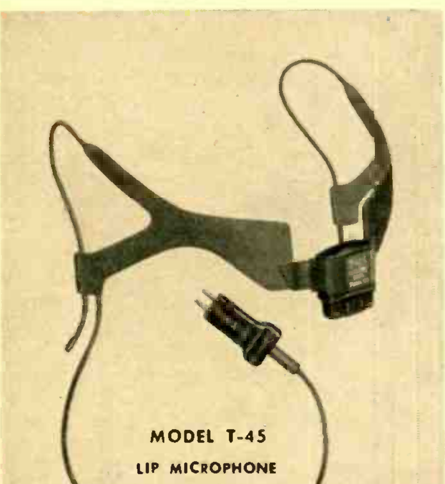
When such an expression is available, it is only necessary to solve it for ρ, substitute for ρ in Poisson's equation, and solve the differential equation for V subject to whatever boundary conditions are in force. The resulting expression for V will give the potential as a function of the coordinates and, upon substituting numbers corresponding to the coordinates of any point, a numerical value of V is obtained which is the potential of that point.

Polarization, Dielectric-p — A conductor differs from a dielectric inasmuch as it contains free electrons as well as positive and negative charges that are bound together. These free charges are able to move about through the conductor, and when they do so under the influence of a voltage, they constitute the flow of an electric current. A dielectric, on the other hand, contains only bound charges which are not free to move away from each other, although there is some elasticity in their binding which allows their relative positions to be somewhat distorted under the influence of an electric field. *The distortion in the positional relations of groups of bound charges in a dielectric is referred to as polarization.*

[*Continued on page 52*]

History of Communications. Number Nine of a Series

MILITARY COMMUNICATIONS BY TELEPHONE



During the Spanish-American War the telephone as a means of electronic voice communication met with favor and played a vital part in military action for the first time. Replacing men and horses, a telephone message could cross and recross enemy territory by wire without delay and cost of life.

Today, telephones in the office and home life of the average American have been an instrumental force in our higher standard of living.

Universal, manufacturing microphones and other voice communication components for the allied forces, will again after Victory is ours, stock dealers' shelves with the Universal components you have been waiting for. Until then — *Buy War Bonds.*

Model T-45, illustrated at left, is the new Lip Microphone being manufactured by Universal for the U. S. Army Signal Corps. Shortly, these microphones will be available to priority users through local Radio Jobbers.

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[*Continued from page 50*]

If there are equal quantities of positive and negative charge oriented at random in every small volume of a dielectric then, because the atomic charge unit is so very small, the net charge density of the dielectric is zero and no external field or potential is occasioned by the presence of the bound charge.

If, however, an external field is applied to the dielectric, polarization takes place and the bound charges are no longer oriented at random. Instead, the pairs or groups of bound charges tend to line up so as to allow the positive bound charges to move with the applied field and the negative bound charges against it. If, in such a situation, a small flat cavity is cut into the dielectric and the field measured in that cavity, it will be found to be greater than the applied field because positive bound charges, in trying to move with the field, will distort their bounds so as to pile up against the up field side of the cavity, and negative charges will do the same on the down field side. The charge appearing on the walls of the cavity in this manner is called polarization charge and is the reason why the dielectric field D is larger than the electric field E. The relation between the two in Gausian units is

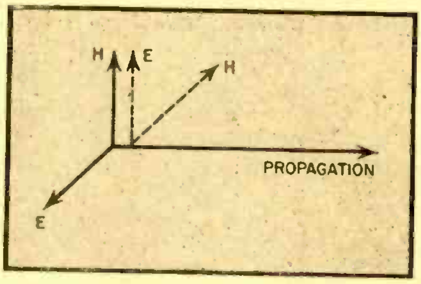
$$D = E + 4\pi p$$

where p is the polarization of the dielectric.

Polarization, Wave— The polarization of electromagnetic waves is a phenomenon which is well known in the study of optics as well as of radio waves. The direction of propagation of electromagnetic energy, the electric field vector, and the magnetic field vector are generally all perpendicular to each other. But as may be seen in the accompanying sketch, this still makes it quite possible for the E and H vectors together to be rotated to either of the positions shown or to any position in between. *When the mutually perpendicular E and H vectors are governed in this rotation by some simple law the electromagnetic beam is polarized.*

When the rotational orientation is random, or when E and H fields exist simultaneously with various angular orientations, the beam is said to be unpolarized. The simplest type of polarization is called plane polarization. In this case the rule is simply that the E vector shall always point in a certain direction and the H vector shall indicate a direction 90 degrees away.

For example, if we are considering a horizontal radio beam traveling from east to west and the E vector points only upward or downward as the H vector is respectively directed northward or southward, we have a plane polarized beam which is said to have vertical E polarization. Similarly a horizontally plane polarized beam is one in which the E vector is always horizontal. Circularly polarized beams are ones in which the E and H vectors at a given point in space rotate together with a constant amplitude. Elliptically polarized beams are those in which the E and H vectors rotate and change their magnitude so as to trace out an ellipse.



Rotation of E and H Vectors

Ground wave signals received from a vertical transmitting antenna are generally plane polarized and are best detected by a vertical receiving antenna. Frequently, under such conditions, the signal strength may even be zero for a horizontal antenna. The sky wave which is reflected from the ionosphere will, on the other hand, be generally elliptically or circularly polarized. In certain cases the sky wave may even be nearly plane polarized in the horizontal direction.

With microwaves where no sky wave is ever encountered the polarization is more completely under the control of the designer. The merits of vertical versus horizontal polarization for all applications have not been entirely settled as yet.

Poynting's Theorem— *In Gaussian units, Poynting's theorem may be written mathematically as*

$$\text{div}\left[\frac{c}{4\pi}(E^{*}H)\right] + \frac{\delta}{\delta t}\left[\frac{1}{8\pi}(\varepsilon E^2 + \mu H^2)\right] = -E \cdot u$$

Its meaning is, in general, the same as the principle of the conservation of energy. Electrical energy like energy in any other form is indestructible. The theorem says specifically that in any small space during any very short length of time, the net energy carried out of that space per unit time plus the amount of energy stored in the space per unit of time must be equal to the net rate of production of electromagnetic energy within the space.

In the first term of the equation which states the theorem, $(c/4\pi)$ $(E^{*}H)$ is the familiar expression for Poynting's vector which describes the flow of energy in the small space in which we are interested as well as in the neighborhood of that space. Wherever E and H have components perpendicular to each other, Poynting's vector is perpendicular to both and indicates by its magnitude the amount of energy flowing in the direction in which it points. Taking the divergence of Poynting's vector makes the first term of Poynting's theorem tell the excess of the outward flow of energy over that which enters the volume. If more energy is entering the space than is leaving the term becomes negative.

It is well known that it takes energy to build up electric or magnetic fields. To charge a condenser, voltage and current must be applied to the condenser. Likewise an electromagnet obtains its magnetic properties only after a current has flown long enough to overcome the inductive effect which at first causes a voltage drop to also be present. The amount of energy necessary to build up these fields is respectively given by $(1/8\pi)$ (εE^2) and $(1/8\pi)$ (μH^2). The partial time derivative of the sum of these tells the rate at which energy is being stored in the space.

The right member of the equation which states Poynting's theorem gives the energy produced in the volume. Here u is the current density (statamperes per cm^2) flowing in the space under consideration. If, for example, the space contains no batteries but only resistance material of resistivity σ (statohms per unit cube) then by Ohm's law $u = \sigma E$ and the right member of the equation becomes $-\sigma E^2$, representing a negative amount of power generated or a positive dissipation into heat.

On the other hand, if a battery is present, the electric field there is opposite in direction to that appearing across a resistance, since it is the cause rather than the result of the motion of the charge. Thus the force on a charge in a battery is $-E$ and the rate of working of the force on unit charge is $-E$ times the velocity of the charge. To change this rate of doing work on a single charge to the rate at which work is done by the battery per unit volume of space, we multiply by the charge per unit volume. Since the charge per unit volume times the charge velocity is just u, this again gives $-E \cdot u$, with the minus sign combining with the inherent negative value of the field of the battery to cause the whole expression to invariably come out as a positive quantity when electrical energy is being manufactured by a source.

Poynting's Vector-S— As radio waves travel through space they can carry energy with them. Poynting's vector is a quantity which may be calculated for every point in the wave at every instant of time. Its value at a certain point and time gives the direction of the energy flow and the rate of that flow.

It is a vector whose magnitude is the product of E and H and whose direction is that of a right hand screw placed and rotated as if to turn E into H.

If H is in oersteds and E in electrostatic volts per cm, Poynting's vector is $(C/4\pi)$ $(E \times H)$ ergs per square cm per sec; if H is in amperes per meter, and E in volts per meter, Poynting's vector is $E \times H$ watts per square meter.

A certain amount of arbitrariness is inherent in the interpretation of Poynting's vector as a flow vector. For example, if an electric charge is isolated and placed at the center of a small permanent bar magnet, the radial electric field is at right angles to the well known magnetic field distribution and Poynting's vector calls for

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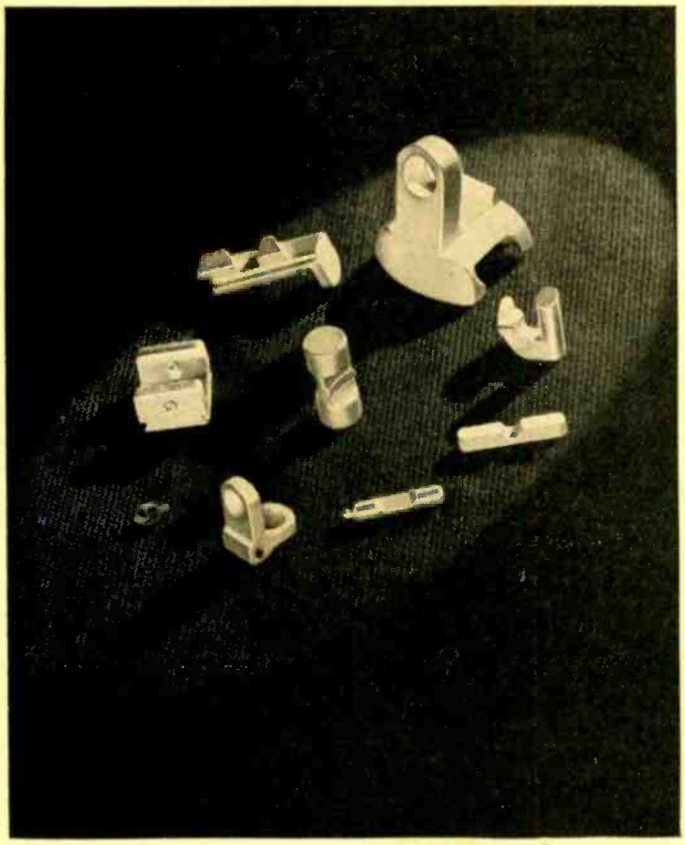
WADSWORTH SKILLS



. . . built up through half a century of leadership in the exacting Watch Case Industry will be available soon to many manufacturers who will require large quantities of small precision parts for their postwar assemblies.

Work of this character is now being supplied to many leading companies which normally produce radio equipment, refrigerators, automotive parts, precision instruments.

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Wadsworth workers' feeling for precision and their ability to get work out on time will ease postwar headaches for many producers.

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[*Continued from page 52*]

a continual circulation of energy around the magnet.

This situation, although certainly possible, does not particularly appeal to our reason. On the other hand, the energy flow interpretation of S is very helpful in many places and is not known to ever lead to contradictions. It is therefore worthy of use.

Propagation Constant-γ — The wave length of a traveling wave is a simple concept and, as long as there is negligible attenuation in the wave, it is easy to measure. But when the wave is damped rapidly, it becomes more difficult to talk of wave length and frequency. Indeed, if by a wave of a certain length we mean one which is like a sine curve that makes a complete oscillation in that distance, we will find that sine waves of many wave lengths must be added up to get a sum equal to the damped wave we have in mind. This is the same as saying that a damped wave contains many wave lengths. For this reason and because the form in which the propagation constant is written allows a very simple expression to portray a wave with or without damping, it is common to omit direct reference to wave length in symbolizing traveling waves.

In writing a mathematical expression to represent a traveling wave we need, in general, to provide for three things. We wish to indicate that the wave position will progress along its line of action with time; we want to show that at any given value of time the wave disturbance will extend with oscillating values along its line of travel; and we want to show the effect of damping by indicating a lessening of strength with greater distance along the path of travel. These three properties are shown by three factors of the expression. The variation with time factor is taken care of by $\sin \omega t$ or $e^{-i\omega t}$. If the propagation direction is called the x axis of a coordinate system, the oscillation with x and the damping may be respectively expressed by $\sin (2\pi x/\lambda)$ or e^{-ibx} and e^{-ax}. Choosing the exponential form of writing the sinusoidal variation with x, these last two factors may be combined and written as $e^{-(a+ib)x}$. If now we choose to replace the complex number $a + ib$ with a single symbol γ, then that symbol is the propagation constant. *The propagation constant is, in general, a complex number whose real part measures the damping of a wave and whose imaginary part describes the wave length that wave would have without damping.*

Q of a Resonant Cavity—*A convenient definition for the Q of a resonant cavity is*

$$Q = 2\pi \frac{\text{Energy stored}}{\text{Energy loss per cycle}}$$

This definition indicates that Q is an inverse loss factor just as when it is applied to wired resonant circuits. The usual definition which is given as $Q = (\omega L)/R$, is not used with cavities because the meaning of L for a cavity is rather indeterminate and at best only a derived property of no direct interest. For either the cavity or the wired tank circuit, Q is a factor of merit which is large in proportion to how small the losses of energy from the cavity can be made.

Shape and size determine the frequency of a resonant cavity. The resistance of the walls, with due reference to the skin effect, influences the Q. In general, therefore, the cavity of the greatest volume and with the most surface area is the one of highest Q. This is because the greater area will generally allow the current flowing through any one part of the wall to be smaller and yet cause the same total energy storage in the cavity. Since the power used up by the need of overcoming resistance is given by i^2r this can be quite important. By the same token, reëntrant cavities which by their nature call for high current densities at corners or bends, are to be avoided if a high Q is desired.

Silver and copper are the best materials for the construction of cavities since they keep the losses to a minimum. Since the skin depth for microwave frequencies is very small indeed, silver plating of any material makes it satisfactory for the construction of high Q cavities. Soldered joints must be watched with great care and should preferably be plated after assembly. In certain cases it is possible to make designs which allow the soldered joints to come at points where there is no current flow.

In actual practice there is very little choice in the Q's which are possible in cylindrical, spherical, and rectangular cavities, although the first type is most used for practical reasons. The higher modes of the cavity usually give the best Q because they allow for larger dimensions. The extent to which one can go in this direction, however, is generally limited by the practical necessity of limiting operation to a single mode.

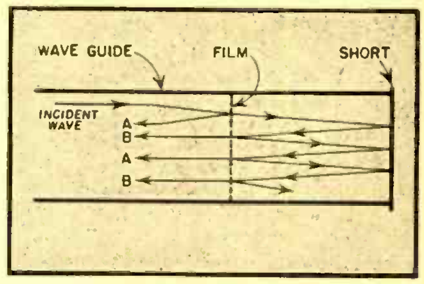
Quarter Wave Attenuator—Microwave wattmeters are usually built in accord with thermodynamic principles. Either a medium such as water is circulated through the instrument so as to directly absorb the energy, or a device such as a thermocouple is heated by a portion of the energy flowing into the meter.

In any event, the amount of radio-frequency power present is usually measured in terms of temperatures or temperature differences. Because of this it is not convenient to have extended ranges of measurement and it is usually considered better to use calibrated attenuators.

When very high powers are to be measured the energy is first run through an attenuator which is known to remove a certain high percentage of the power and then a measurement on the remainder makes it possible to calculate the actual power. Likewise, when a very weak signal of known strength is desired in order to calibrate a receiver, it is usually convenient to measure a power of medium magnitude and then use an attenuator to reduce that power by a known fraction.

For these applications it is therefore clear that ideally we want an attenuator to be a device which, when inserted in a transmission line, absorbs power without introducing reflections. The simplest, although somewhat idealized, form of such a device is one which is known as a quarter-wave attenuator. *It consists of two energy absorbing grids or other structures placed in the transmission line. These are separated by an odd number of quarter wave lengths and are not only designed so as to absorb energy but also fixed so that reflected energy from the second grid just cancels that which is reflected from the first.* To accomplish this it is only necessary that a certain numerical relation exist between the impedance of the two grids and the impedance of the wave guide transmission line. This causes the two reflections to be equal in magnitude and, since one has twice traveled the quarter wave section, they are out of phase and completely cancel each other. In this form the attenuator works only for waves traveling along the guide in one direction. By the addition of a third grid it is possible to remove this restriction.

Quarter Wave Termination—It is frequently desirable to terminate a wave guide transmission line so as to absorb all the energy traveling through it without reflection. To do so is to accomplish the same thing as is done in circuit theory when a line is terminated with its characteristic impedance. The wave guide or transmission line then acts as if it were infinite in length.



Effects of Shorted Termination — Quarter Wave Line

One way of accomplishing this is by the use of the so-called quarter wave termination. When it is used *an energy absorbing grid or film is stretched across the wave guide at a distance of ¼ wave length from the shorted end and arranged so that the reflection from it is just canceled by the multiple reflections from the shorted end.* When this is arranged properly we say that the impedance of the grid is matched so as to give a perfectly absorbing termination.

Referring to the sketch, we can see qualitatively how the scheme works. Suppose a wave of strength unity is incident upon the film. A certain fraction of it will be absorbed, another part reflected, and a third part transmitted. The trans-

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TERMINOLOGY

[*Continued from page 54*]

mitted portion after reflection from the shorted end of the guide will again be incident upon the film although this time from the opposite side. As is indicated in the diagram, this will again cause absorption, transmission, and reflection, and moreover from the reflected wave the whole thing will repeat not just the three times as shown but an indefinitely large number of times. Each time the waves involved become weaker because of the absorption.

If the impedance of the film is properly arranged, the waves marked A and B will completely cancel each other so as to give the perfect termination we desire. This is possible because the quarter wave section causes those marked A to be out of phase with those marked B, and because the film can be adjusted to transmit a prearranged amount more than it reflects so that the first reflection need not outweigh the net effect of the latter transmissions but only balance them out.

Quarter Wave Transformer—In much the same way that an output matching transformer may be used to couple the plate of a vacuum tube and the voice coil of a loud speaker, so may devices be used at microwave frequencies to couple a high impedance source and a low impedance load. By analogy such devices are called transformers even though they bear no physical resemblance whatever to the sort of transformer which has an iron core and primary and secondary windings of wire. Nevertheless, the fundamental functions of these transmission line devices is the same as that of the more familiar sort of transformer. In either case a large current at a small voltage is made into a smaller current at a larger voltage or vice versa.

An important case of a transmission line transformer is the quarter wave transformer which, however, is limited to use in matching two dissimilar impedances that have no imaginary components. Said in another way, a quarter wave transformer is useful for matching a source to a load of different impedance, provided the load is capable of presenting a unity standing wave ratio and the source is capable of delivering maximum power into a matched load which does present a unity standing wave ratio.

A quarter wave transformer is a length of lossless transmission line which is an odd number of quarter wave lengths long and which has a characteristic impedance that is a geometrical mean between the real impedance of the source and the real impedance of the load.

The simplest method of giving a qualitative explanation of such a transformer is the one involving traveling waves. A traveling wave from the source is normally transmitted in part and reflected in part as it encounters the different impedance of the transformer. As the portion which is transmitted reaches the still different impedance of the load, it is again reflected in part. The wave from the second reflection, however, travels the length of the quarter wave transformer twice and hence is just a half wave behind the wave from the first reflection. If the impedances are correctly arranged, these two reflections are equal and because they are out of phase they entirely cancel each other and only a continuous flow of energy from the source to the load remains.

Standing Wave—*When two equal sinusoidal traveling waves move through a medium in opposite directions the medium is said to be supporting a standing wave.*

As the waves move past each other, the disturbance felt at each point in the medium is the algebraic sum of the disturbances that would be felt because of the presence of each wave alone. This sum may be anything from zero to twice the amplitude of one of the waves. It turns out, however, that certain points spaced a half wavelength apart along the propagation direction are always disturbed by zero amount. Excitation of those points by one wave is always just canceled by that of the other.

Such points are called nodes. Midway between these nodal points are other places which are subject to very violent oscillations because there the two waves continually cooperate in disturbing the medium. These points of maximum activity are called loops.

Standing waves are usually obtained by

[*Continued on page 58*]

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TERMINOLOGY

[*Continued from page 56*]

reflecting a wave back on itself. Under such conditions, at least, a perfect standing wave is a practical impossibility. In a really pure standing wave the nodes would be absolutely stationary and no energy could flow past them along the wave.

In practice, some flow is always necessary to overcome friction and other types of dissipative loss. Standing waves are therefore usually accompanied by at least a very small traveling wave which moves away from the source.

Standing Wave Ratio-SWR—To understand *SWR* measurements it is necessary to understand the cause of standing waves and the way in which traveling sinusoidal waves, which are moving in the same direction with the same velocity, may be added. The nature of standing waves is discussed under the heading *Standing Waves*.

Briefly, a standing wave is obtained when a medium supports two waves which are equal but traveling in opposite directions. However, if the waves are not equal, the larger of the two may be thought of as being made up of two waves, one equal in magnitude to the opposing wave and the other of such size as to take up the remainder of the amplitude.

A medium supporting two opposing traveling waves may generally be equally well said to be supporting a standing wave plus a traveling wave. With only a traveling wave present, a time average of the magnitude will be the same anywhere in the medium since all parts of the wave travel by every point: with a pure standing wave nodal points in the medium can be found at which no amplitude ever exists, and loop points can be found where the oscillation is a maximum. Since *SWR may be defined as the ratio of the maximum to the minimum wave strengths to be found along the propagation of a wave,* it follows that a pure standing wave corresponds to infinite *SWR* while a single traveling wave indicates unity *SWR*.

SWR measurements are particularly useful in wave guides, where dissipative losses of energy may well be less important than reactive losses.

Reactive losses are really just a reflection of energy back along the guide toward the source. Hence, a large *SWR* marks the presence of a standing wave and reflection due to reactive mismatching in the waveguide. An *SWR* measurement, if made near the source, will show the net reflections from the overall system. It will not show losses due to radiation or dissipation.

Velocity of Light-C— *The velocity of light in free space is usually taken as* 3×10^{10} *cm per sec.*

This is equivalent to 3×10^{8} meters per second, or 186,000 miles per second. Although *C* is usually referred to as the velocity of light, it is actually the velocity with which all electromagnetic radiation travels in free space quite independent of frequency.

Echo sounding devices using electromagnetic waves can, for example, determine range by multiplying one-half the transmission time by *C*.

In accordance with the theory of special relativity (not to be confused with general relativity, which is a rather complicated subject), neither matter nor energy can travel faster than this. Special relativity has had ample experimental verification by many people.

Naively, phase velocities in wave guides may seem to be an exception. They do often involve velocities greater than *C*. Close examination, however, shows that no energy moves with the phase velocity. Group velocity is the velocity of the energy motion and that is always less than *C*.

In fact, in any medium or under the restraint of any boundary condition, electromagnetic energy is always slower than in free space.

[*To be continued*]

ASTATIC APPOINTMENTS

Mr. Ray T. Schottenberg, Mr. William J. Doyle and Mr. Allen J. Stark will direct sales for The Asiatic Corporation of Conneaut and Youngstown, Ohio, during the ensuing year, according to an announcement just made by Mr. Floyd H. Woodworth, head of the corporation.

Mr. Schottenberg, long known to the trade, will continue as Sales Manager of the Jobber and Public Address Parts Division. Mr. Doyle will be in charge of sales to radio set manufacturers, and Mr. Stark will direct sales in the Radio Cable Connector Division.

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PICKUPS

[*Continued from page 25*]

a portion of the material is necessarily carried with the armature, and thus adds to the mass and weight of the moving system. This in spite of the fact that damping in shear is more effective.

Much research has been done in attempting to obtain better damping materials. Many compositions have been tried, some borrowed from other industries, and a few satisfactory compromises have been found. It is possible to both center and damp with one material, but such material never has both properties to a satisfactory degree, and failure can result if precautions are not taken from a mechanical standpoint. In addition, materials having good damping qualities are invariably subject to severe changes in characteristics with changes of temperature. Increased temperature results in decreased damping efficiency, and resonant peaks appear in the pickup response.

It is to be hoped that among the many new materials being produced today, a more suitable damping medium will be found, particularly with respect to temperature effects.

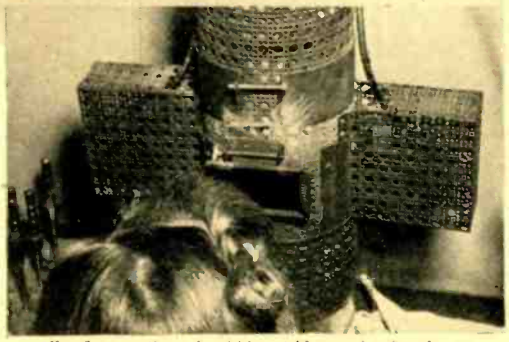
Bearings

There is little to be said about bearing systems. Rubber has been used in the majority of designs, being simple, effective, and inexpensive. Knife-edge bearings have been used successfully, and result in long operating life, but have the disadvantages of added cost, mechanical noise, and aggravation of resonance problems. A combination of rubber and knife edge has also been used, but with little success. If a rubber bearing system is to be utilized, precautions should be taken to see that pure gum stock or its equivalent is used, and that the walls of the tubing or sheet be as thin as practical. Excessive wall thickness will result in loose play of the armature at the bearings, becoming more pronounced in effect as the frequency increases, low efficiency and distortion can only result.

The magnetic pickup differs from a crystal device in that the voltage output is proportional to velocity. Reference to *Fig. 2* illustrates the comparison between theoretically perfect crystal and magnetic pickups. A perfect magnetic pickup would reproduce the magnetic recording head characteristic, since both are proportional to velocity. The loss of bass response below

[*Continued on page 66*]

welding with a paint brush?



Alloy flows easily and weld is quickly completed under arc.

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is the focusing of all branches of science upon the development and improvement of electron vacuum tubes.

To solve a difficult welding problem, Eimac laboratory technicians compounded a welding alloy that could be applied with a paint brush. The alloy flows easily under an arc to complete the weld, yet subsequent heating to temperatures as high as 2900 degrees Centigrade will not destroy the weld.

Such is but an example of the application of the Science of metallurgy in the "science behind the science of electronics." The extent to which Eimac Engineers went to solve this relatively small problem reveals two important facts:—(1.) The thoroughness of Eimac Engineering, and (2.) The completeness of their engineering facilities. The leadership which Eimac tubes enjoy throughout the world in all phases of electronics is attributable to the soundness of this engineering.

Performance of any electronic equipment is a direct reflection of the performance of its vacuum tubes. Hence it is advisable for users and prospective users of electronics to look first to the vacuum tube requirements. Because Eimac makes electron vacuum tubes exclusively their advice to you is unbiased and can be of great value. A note outlining your problem will bring such assistance without cost or obligation.

SPECTROGRAPH...*Analysis determines exact characteristics of metals to be joined.*

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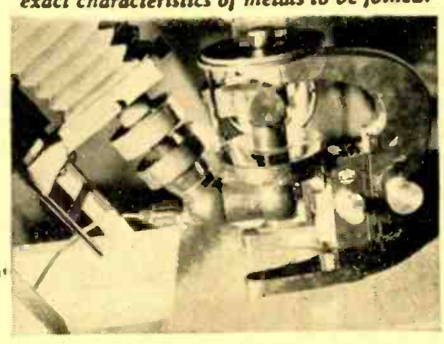

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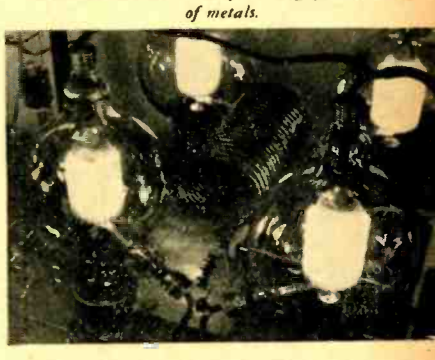

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PI-NETWORKS

[*Continued from page 27*]

Dividing through by R and substituting,

$$R = Q(XC - XL)$$

Applying this to *Fig. 3*,

$$\frac{R_2 XC_o^2}{R_2^2 + XC_o^2} = Q\left[\frac{R_1}{Q} - \left(XL_1 - \frac{R_2^2\, XC_o}{R_2^2 + XC_o^2}\right)\right]$$

From (3),

$$\frac{R_2 XC_o^2}{R_2^2 + XC_o^2} = Q\left(\frac{R_1}{Q} - \frac{QR_2 XC_o^2}{R_2^2 + XC_o^2}\right)$$

or

$$\frac{R_2 XC_o^2 + Q^2 R_2 XC_o^2}{R_2^2 + XC_o^2} = R_1$$

$$R_2 XC_o^2 + Q^2 R_2 XC_o^2 = R_1 R_2^2 + R_1 XC_o^2$$

$$XC_o^2 (R_2 + Q^2 R_2 - R_1) = R_1 R_2^2$$

$$XC_o^2 = \sqrt{\frac{R_1 R_2^2}{R_2(Q^2+1) - R_1}} \quad \ldots\ldots (4)$$

From (4),

$$\frac{R_2 XC_o^2}{R_2^2 + XC_o^2} = \frac{R_1}{(Q^2+1)}$$

$$\text{and} \quad \frac{R_2^2\, XC_o}{R_2^2 + XC_o^2} = \frac{R_1 R_2}{XC_o(Q^2+1)}$$

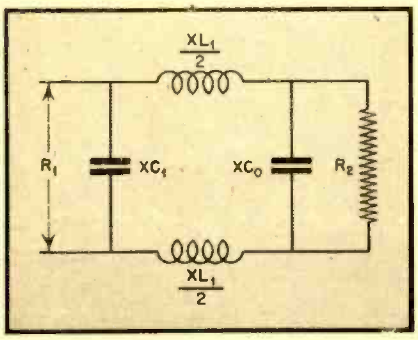

Figure 5

Then returning to (3)

$$XL_1 = \frac{QR_1}{(Q^2+1)} + \frac{R_1 R_2}{(Q^2+1)\, XC_o}$$

$$= \frac{R_1}{(Q^2+1)} \frac{(Q + R_2)}{XC_o} \quad \ldots (5)$$

If Q is large,

$$XL_1 = XC_1\left(1 + \frac{R_2}{Q\, XC_o}\right)$$

Referring to (4), as the denominator must at all times be real, $(Q^2 + 1)\ R_2$ must be greater than R_1, or in other words R_1/R_2 must be less than $Q^2 + 1$. Consequently, for very high ratios of transformation, the single-ended circuit with its higher Q will be somewhat more desirable.

Formulae (1), (4) and (5) hold only for R_2 being purely resistive; however, for loads that are reactive a good indication of circuit behavior may be had by noting whether normal loading (i.e., normal R_1 or input resistance) occurs with the specified value of XC_1. This follows naturally from the relation $R_1 = QXC_1$.

Fig. 4 shows the pi-network feeding antenna at other than a resistive point and X_A being inductive or capacitive depending on the antenna length. The portion inside the dotted line represents in itself a parallel resonant circuit. The reactive resultant of such a circuit may be expressed as

$$\frac{R_A^2 + X_A(XC_o + X_A)}{R_A^2 + (XC_o + X_A)^2} \quad \ldots\ldots\ldots\ldots (6)$$

should the antenna be operating at or near a half-wave point and swinging in the wind, X_A would be changing from a very large inductive reactance to a very large capacitive reactance and vice versa. This would result in profound changes in the value of (6) and thus the amplifier tuning would be very unstable. However this difficulty is not experienced at the quarter-wave points due to the fact that, while X_A may be changing in sign, its values are small and would have negligible effect on (6). Accordingly, antennae which are integral multiples of one-half wave-

[*Continued on page 64*]

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For the television audience — a simpler, less expensive receiver, more compact and efficient, and requiring fewer tubes.

This great forward stride is the logical outcome of Federal's long list of achievements in the field and the contribution of Federal's engineers to the development of the "Micro-ray" more than a decade ago . . . the forerunner of modern television technique.

And as a result . . . Federal has been selected by the Columbia Broadcasting System for the construction of its new television transmitter atop the Chrysler Tower in New York.

Federal's modern television technique will also be reflected in an equally advanced Federal television receiver for the home . . . producing the finest picture quality.

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PI-NETWORKS

[Continued from page 62]

length should be avoided with this type of coupler.

In push-pull circuits XL_1 is usually split into two parts to provide equal plate loading as shown in *Fig. 5.*

It is readily proved that to provide proper "flywheel effect" the optimum value of Q in single ended circuits is 12, and in push-pull circuits is 6, and *Figs. 6* and *7* are monographs of equations (1), (4) and (5) assuming these values of Q.

Knowing the input and output resistances, the impedances for the various elements may be found and then converted into actual values of inductance and capacity for the frequency used.

UNIVERSAL APPOINTS HALL

A. J. (Jack) Hall has been appointed production and research engineer for the Universal Microphone Co., Inglewood, Cal., according to announcement from James L. Fouch, president of the organization. He will devote his time and attention to current activities, as well as to postwar planning and reconversion.

He joins the Inglewood company after several years of service with the Kellogg Switchboard and Supply Co., Chicago, as engineer in charge of design, research and development laboratories.

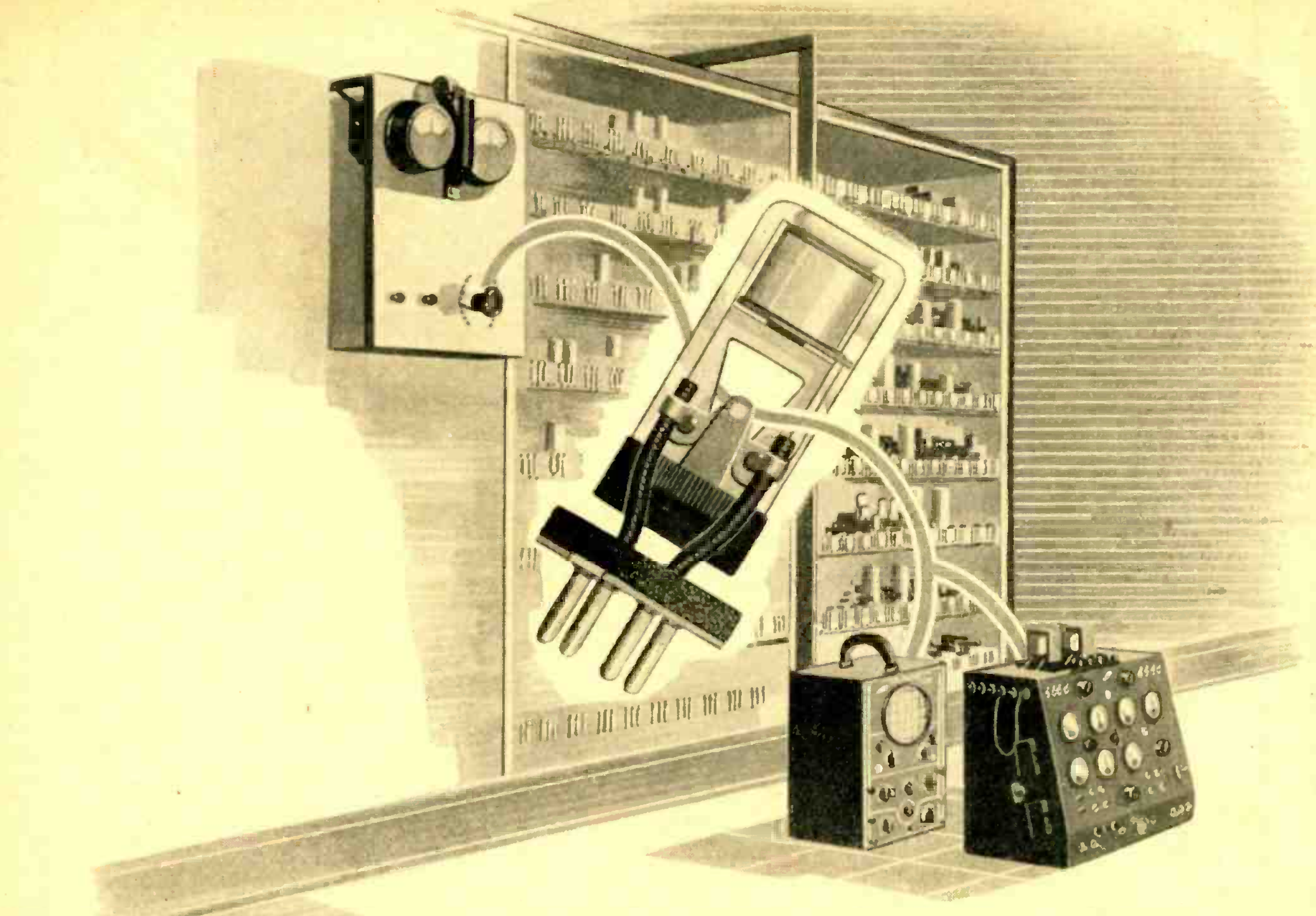
Previously he had been planning engineer with Western Electric Co., Chicago, over a long period of time, as well as production manager for the Leich Electric Co. in the same city.

SKELLETT JOINS N.U.

Dr. A. M. Skellett, formerly of Bell Telephone Laboratories, has been appointed Chief Engineer in Charge of Research for National Union Radio Corporation, radio-electronic tube manufacturer, according to an announcement made by S. W. Muldowny, President.

Widely known in scientific circles, Dr. Skellett has made many contributions to the advancement of electronics during his years of service with Bell Telephone Laboratories. As a writer he has published twenty-five scientific papers in Proceedings of the National Academy of Science, Proceedings of the Institute of Radio Engineers, Physical Review, Science, Review of Scientific Instruments, Journal of Applied Physics, Journal of the Society of Motion Picture Engineers, and Nature, the oldest scientific journal known to scientists throughout the world, which is published in England.

As an inventor, Dr. Skellett has been issued thirty patents, has twenty-five currently in process, principally on electronic devices, ten of which are in the secret category. World-wide recognition came to him in the field of astronomy as a result of his perfection of the coronavisor and adaptation of television technique to astronomy which made possible the study of the sun's corona without recourse to costly expeditions at times of solar eclipse.



PICKUPS

[Continued from page 60]

250 cycles is due to the constant amplitude recording characteristic of commercial home type records, made necessary to avoid break through between adjacent groove walls.

Unfortunately, the magnetic pickup cannot be compensated so readily as the crystal, as illustrated in the article[2] on crystal pickups. . . . Similar adequate networks would require the use of large iron-cored inductances and large capacitors, whose cost and space requirements would be prohibitive. It is much simpler to make the necessary compensations in the amplifier circuits, wherein suitable bass compensation may be had with little cost.

Moving Coil Types

Moving coil, or dynamic types of pickups have been designed, with varying success. They differ essentially from the armature type in that a coil of wire is movably suspended in an air gap and, when driven by the record groove, cuts lines of force existing through it, with a resultant generation of current proportional to velocity. The inherent drawback is reduction of weight in the moving system, which compels the use of very few turns of wire, as few as one turn being used. Since such a device would have very low impedance, it must be coupled through a suitable transformer for maximum efficiency. The transformer, in turn, is expensive and tends to aggravate hum pickup problems since it must be located closely to the pickup, to avoid excessive losses.

A distinct advantage, however, is that there is no centering problem because, by use of proper materials, there exists no magnetic attraction between the moving system and the pole piece assembly.

Successful moving coil systems have been expensive, delicately made, and suitable for use under exacting conditions, where they give a splendid account of themselves. It is not at all impossible, however, that the design may be applied to routine phonograph requirements with success.

The magnetic pickup has been neglected to a large degree since the general acceptance of the crystal types. However, it has demonstrated its dependability under adverse operating conditions where crystals are inadequate, and is by no means obsolete. General acceptance of low voltage outputs could result in some startling improvements that might well place it at the head of desired pickup types.

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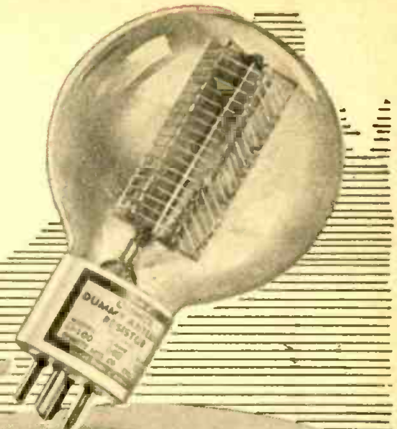
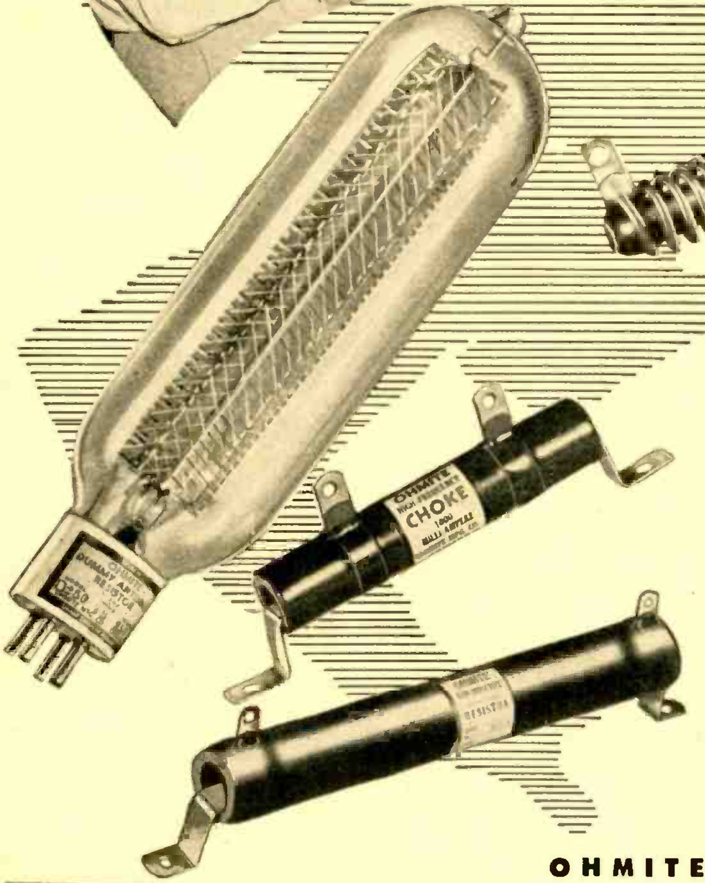
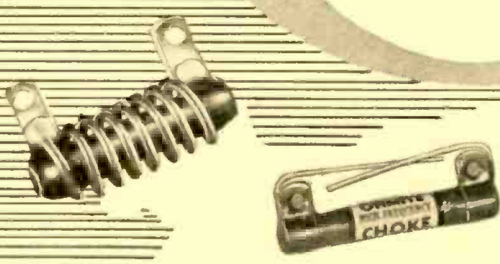


Ohmite Dummy Antenna Used in Testing Critical Transmitting Equipment

Here's what *COLLINS RADIO CO.*, well-known transmitter manufacturer, says: *"Within its power range . . . the most convenient to use, the most stable and the most accurate Dummy Antenna we have encountered . . . Used successfully for testing and measuring power output . . . Gives long life without detectable deterioration."*





Proved by use before war came . . . Ohmite R.F. Units today are performing vital functions in the production and operation of vital war equipment. An interesting example is the use of Ohmite hermetically-sealed, glass-enclosed gas-filled dummy antenna resistors by Collins Radio Company, and other well-known manufacturers for testing and measuring power output.

Other Ohmite Units doing specialized jobs in radio frequency applications are Vitreous Enameled Non-Inductive Power-Size Resistors, Parasitic Suppressor and R.F. Plate Chokes.

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TUBE TESTING

[*Continued from page 32*]

If a decade condenser box is available or a beat frequency oscillator, either C or f may be varied until E_2 is exactly 3 db below E_1, or $E_1 : E_2 = 1.0 : 0.707$. The above expression then simplifies to

$$R_P = 1/(\omega C - 1/R)$$

Once R_p has been determined μ may be found from the expression for E_1. Disregarding the negative sign which merely indicates the phase relationship, we have

$$E_1 = \mu Eg = \frac{E_o R}{R_P + R}, \text{ or}$$

$$\mu = E_o/Eg(R_P/R+1)$$

It is evident that the value of C must not be comparable with that of the stray capacitance of the circuit, and the frequency should be chosen accordingly. Either 60 c.p.s. or 1000 c.p.s. will in general be found quite suitable for the measurement.

The method may be extended to inductive anode loads, but the resulting expressions will then become more complex. One application of the above principle would consist in the provision of suitable, push-button operated condensers in electronic devices, enabling rapid checks on valve characteristics to be made.

NEW VIBRATION MOUNT

Rexon, a radically new type of vibration mount, characterized by extreme simplicity in design and application, and by virtual indestructibility in use, has just been announced by Hamilton Kent Manufacturing Company, a unit of U. S. Stoneware, Akron, O.

Determination of the proper type of Rexon mount and its actual installation requires neither engineering skill or alteration of equipment. Only two standard types of Rexon mountings are required to effectively isolate all kinds of vibration. All that an engineer need know is the total weight, the weight distribution of the machine to be insulated, and whether the direction of the vibration is vertical or horizontal. Loading is not critical—a tolerance of plus or minus 10% in computing machine weight or weight distribution is permissible.

Rexon utilizes the vibration dampening properties of rubber in shear, but with no possibility of overloading the shear elements. This unique property stems from the use of a special "X" type design of the rubber element which acts in shear at the points of the "X" under normal loading, but in compression when the load exceeds the rated capacity of the mount. Rexon mounts cannot be damaged by temporary or permanent overload. No rubber-to-metal bonds, either mechanical or chemical are used.

TROPICALIZATION

[*Continued from page 31*]

The statement might well be made: elimination of moisture and corrosion by the proper selection and treatment of individual materials and components and the elimination of confined spaces will do most to eliminate fungus. Additional help can be given by protective coatings.

Certain protective coatings have been approved by the Signal Corps in connection with this subject. Basically, these compounds represent a fungus-inhibitor such as phenyl mercurial or chlorinated phenol in solution. Certain carriers such as phenolic varnish, vinyl varnish, or the like have been employed.

This coating material is intended to inhibit the growth of fungus by its application in sprayed or brushed form. It is to be expected, however, that this material cannot be applied to all components since moving contacts and their respective contacting surfaces may be damaged by the compounds. Masking of certain parts will, therefore, be necessary.

It is also intended that this treatment should be renewed periodically since its effectiveness is of relatively short duration in terms of the total life of the equipment.

Circuit Design

Since each of the four above points have left reasonable doubt as to the complete preparation of the equipment for tropical service, certain additional ideas can be brought forth for the radio designer's use.

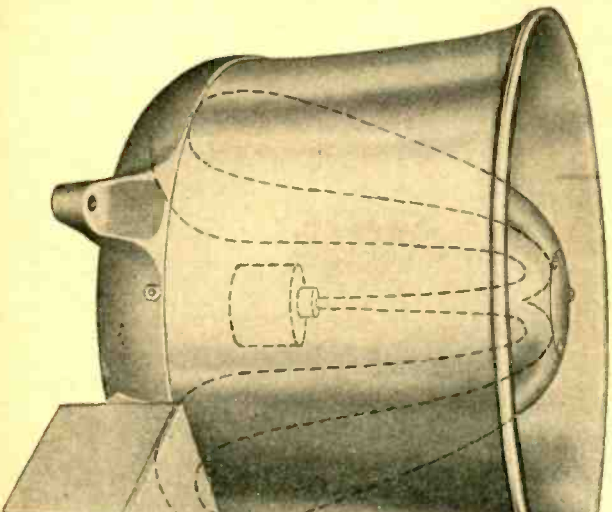
Critical, high-gain circuits perform well in a laboratory setup but do not perform satisfactorily in the field. The use of high resistance grid leaks in high gain amplifiers is one of the best examples of this: a five-megohm resistor 1/2-watt in the laboratory will measure and behave like a five-megohm resistor within the stated manufacturer's tolerance. Under high humidity conditions with moisture forming a slightly conductive path across the resistor's exterior, the resistor will be more like a three-megohm resistor.

Again high-Q coils in r.f. circuits will have a high Q only as long as no conducting film shunts the coil. Then the Q will drop considerably.

This type of reasoning would outlaw some of our highly developed circuits of today, if it were carried to its utmost. But the less critical the circuit, the fewer the parts, the more careful choice in the selection of parts and materials—the longer the equipment will last.

RACONS Invaded Normandy*

Official U. S. Coast Guard Photo



*This official U. S. Coast Guard Photo shows RACONS on the deck of a transport approaching the Normandy beach-head. A landing barge approaches the transport.

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An Automatic Radio Direction Finder—

[*Continued on page 72*]

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UNIVERSAL NOTE

Cecil L. Sly, vice president of the Universal Microphone Co., Inglewood, Cal., represented his company at the October Electronics Parts Conference in Chicago.

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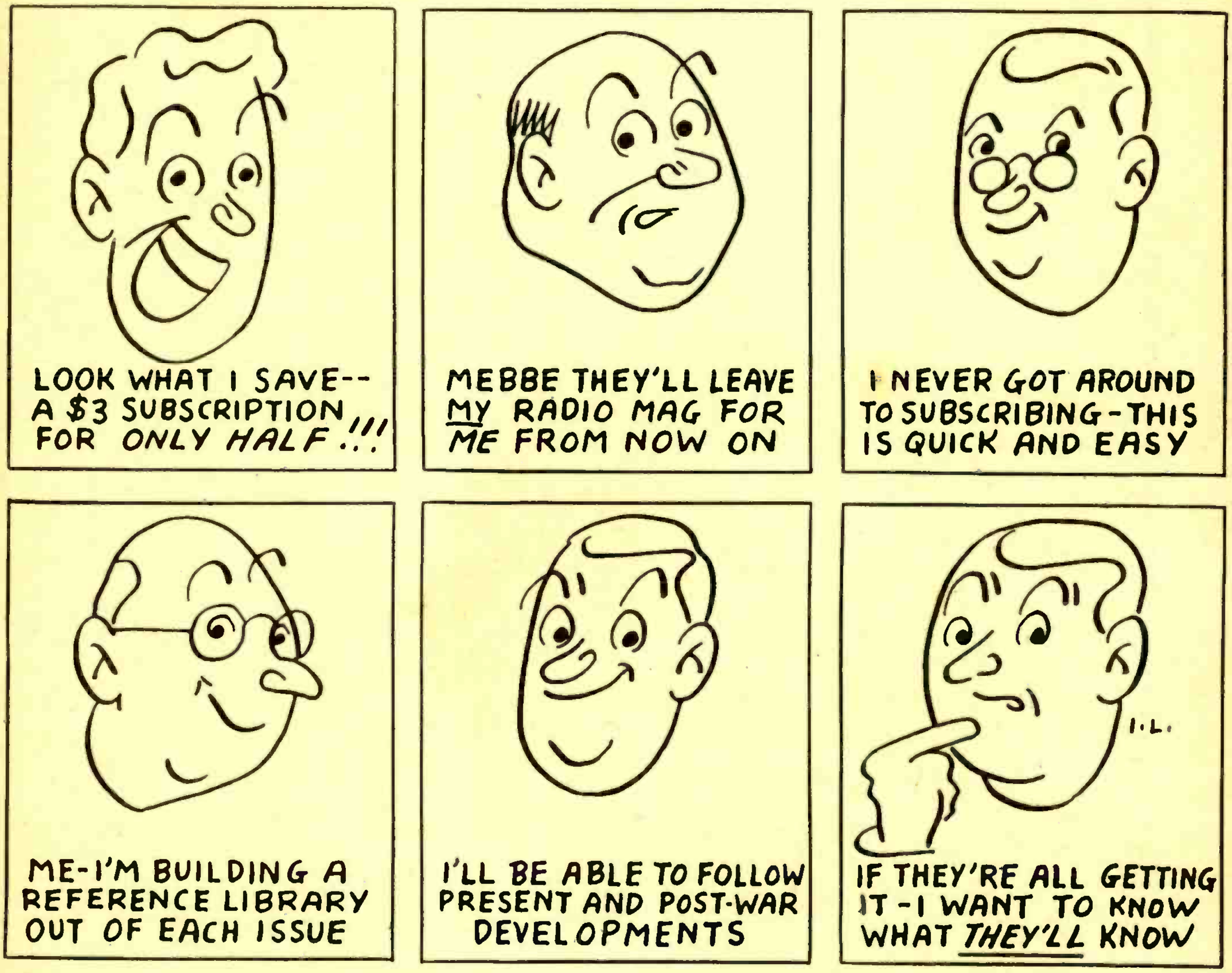

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MEASUREMENTS

[*Continued from page 23*]

Practically all oscilloscopes are now supplied with these features, so it is only necessary to select an instrument which has a frequency characteristic capable of handling the highest frequency to be encountered. If the voltage to be studied is of sufficient magnitude to "drive" the plates of the oscilloscope without the use of its internal amplifier, the frequency range will be satisfactory for practically all purposes.

Tests Required

Fig. 9 shows sections of typical test data sheets used during the development of a radio receiver. Many of these tests may seem to be unwarranted, because the information can be calculated from other data, but by making all of the tests it is possible to obtain a double check on some characteristics. For instance, knowing the second detector sensitivity, the i-f gain per stage, and the translation gain of a superheterodyne, it should be possible to calculate the first detector sensitivity.

To the uninitiated it might be surprising that the first detector sensitivity often does not check with the calculated value obtained by multiplying the individual stage gains together. If the measurements have been correctly made, and the calculated and measured sensitivities do not agree, the difference can usually be found to be due to overall degeneration or regeneration. These two effects can become very troublesome during production so it is to the designers advantage to know their magnitude and origin.

A discussion of these points will be given later as each measurement is described, particularly as to how the test apparatus should be arranged. At the same time, sample curves will be given to show the effects of certain discrepancies in measurement technique.

Normal Operating Conditions

As mentioned previously, in order that receiver characteristics may be more readily interpreted and compared, it is important that measurements be made under so-called Normal Test or Operating Conditions. *Table 1* has been arranged to show these conditions in a convenient, usable form. Note that certain tests should be made at high and low power line or battery supply voltages. This is necessary to determine whether extremes in power supply voltage will cause unstable operation such as blocking, oscillation, oscillaltor stoppage, microphonics, etc., to mention a few. Also note that both high and low transconductance tubes should be employed for the same reasons.

These checks, while time-consuming, will often prevent trouble and complanits after the receiver is in the customer's hands, where such operating conditions are likely to be met.

[*To be continued*]

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