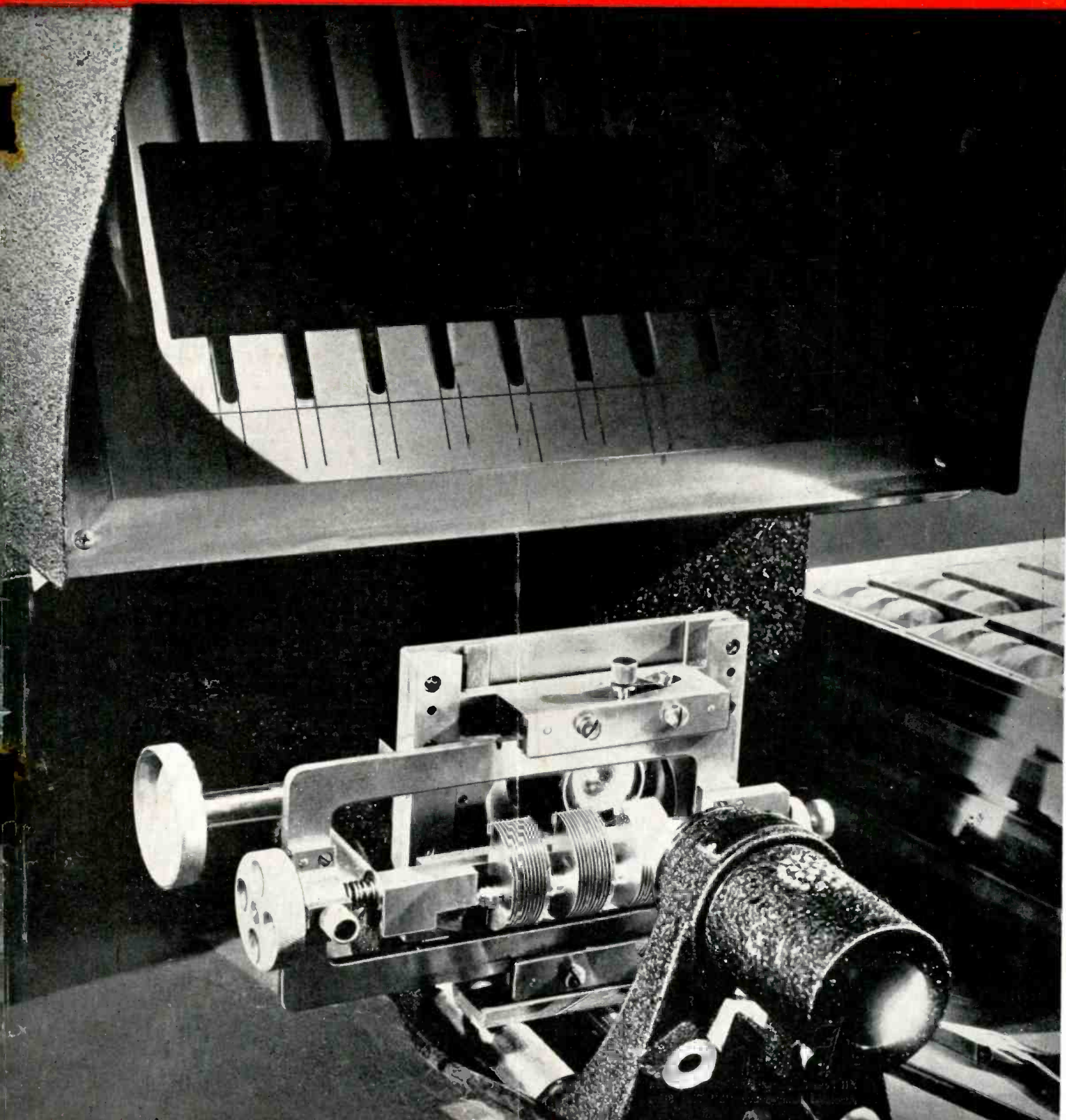
RADIO

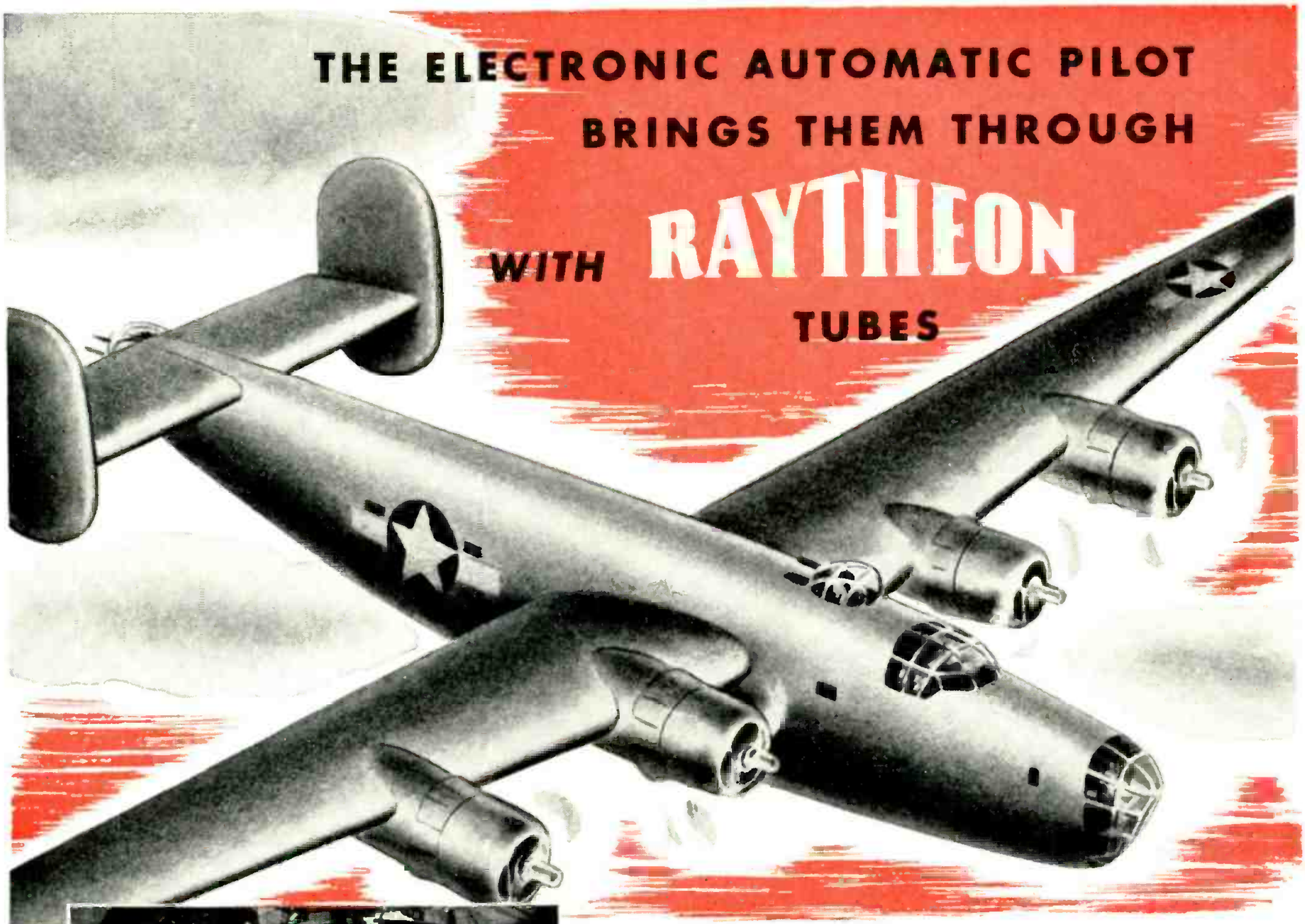
SEPTEMBER, 1944

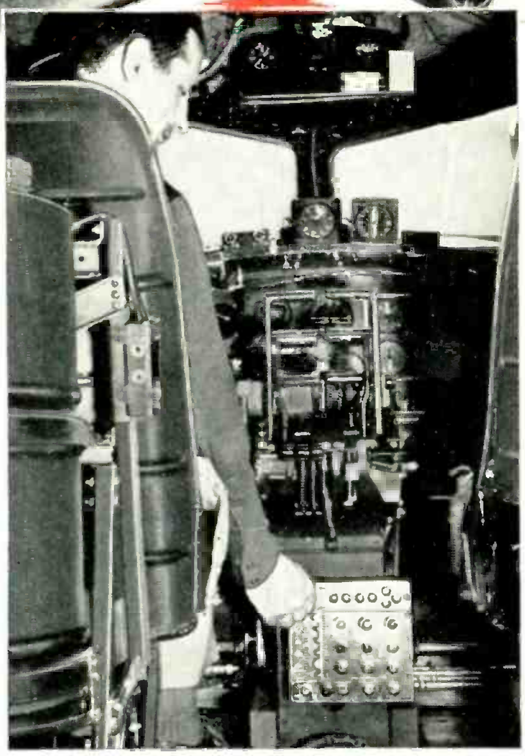
Including:
Optical Path Chart

Design • Production • Operation



The Journal for Radio & Electronic Engineers





THE ELECTRONIC AUTOMATIC PILOT, pioneered and developed by Minneapolis-Honeywell, is one of the most significant advances made in aircraft science. Developed to keep bombers on a straight course in their bombing run, the electronic automatic pilot promises safer and more efficient flight for airlines . . . and, because this device must operate with complete reliability at all times, Minneapolis-Honeywell uses thousands of RAYTHEON tubes.

The special wartime experiences of Raytheon Manufacturing Company in devising and producing advanced electronic tubes for the war effort, means that you will be able to offer your customers the best tubes for all applications. Because you have the best tubes, you will have better customer good-will, faster turnover and greater profits.

Raytheon Manufacturing Company

RADIO RECEIVING TUBE DIVISION

Newton, Massachusetts • Los Angeles • New York • Chicago • Atlanta

All Four Raytheon Divisions Have Been Awarded Army-Navy "E" Plus Stars

RAYTHEON

High Fidelity

RADIO AND ELECTRONIC TUBES

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


A GIFT OF
RESEARCH
TO THE
ELECTRICAL INDUSTRY!
Recent Formica research assisted by new developments in the glass industry which produced glass mat and glass cloth fabrics, along with the perfection of new resins suitable for laminating, has made possible new Formica grades with many important electrical characteristics.
Formica grade MF-66 is a low loss insulator at high frequencies, which retains the high mechanical strength of other laminated grades, and can be machined for rapid production.
Grade FF-10 made with glass cloth base combines good insulating qualities with very high heat resistance, and is just what is needed for such applications as motor slot wedges.
Grade FF-41 made with glass cloth has been especially developed to resist surface tracking and arcing.
These valuable qualities are available in glass base Formica to a degree that was never offered before in laminated plastic materials. Perhaps they can solve some of your problems. Samples for testing on request.
"The Formica Story" is a moving picture in color showing the qualities of Formica, how it is made, how it is used. Available for meetings of engineers and business groups.
FORMICA
ARMY E NAVY
THE FORMICA INSULATION COMPANY
4670 Spring Grove Ave., Cinti. 32, Ohio

RADIO

Published by RADIO MAGAZINES, INC.

John H. Potts .... Editor
Sanford R. Cowan .... Publisher

Executive & Editorial Offices
342 MADISON AVENUE
NEW YORK 17, N. Y.
Telephone MUrray Hill 2-1346

John H. Potts .... *President*
Sanford R. Cowan .... *Sec'y-Treas.*
Charles H. Farrell .... *Adv. Manager*
Ann Limberg .... *Adv. Production*
Sylvia Bornkoff .... *Circl. Manager*

PACIFIC COAST REPRESENTATIVE
Loyd B. Chappell,
427 West 5th St., Los Angeles, Cal.

OHIO-PENNA. REPRESENTATIVE
A. Hawley & H. Stuart
Bulkley Bldg., Cleveland, Ohio

GREAT BRITAIN REPRESENTATIVE
Radio Society of Great Britain,
New Ruskin House, Little Russell St.,
London, W.C. 1, England

SEPTEMBER 1944 Vol. 28, No. 9

CONTENTS

COVER

A commercial projector, often used for micro measurement of tools, gauges and parts, was adapted to the alignment of variable condenser plates by development of special holding and indexing fixtures. The operator bends the plates into correct plane as she watches the effect on the magnified image of the projector.—*Courtesy of 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.

Transients

FINANCING TELEVISION

★ The fact that all surveys indicate a tremendous public interest in television seems to have created a considerable degree of over-optimism regarding the commercial possibilities in this field immediately after the war. The general public appears to believe that, shortly after reconversion, it will be possible to drop into the nearest neighborhood store, get a television set installed, and sit back and enjoy a variety of fascinating programs. They expect picture definition comparable, at least, to home movies, complete coverage of important spot news events, good light opera, and a host of other features.

Presenting such programs, hour after hour, day after day, is an expensive proposition. And, until a wide distribution of receivers is obtained, it is unlikely that advertising sponsors will bear any great portion of the cost of underwriting these presentations unless costs are kept low. Thus the major portion of the expense must be borne, as now, by broadcasting stations. Alternatively, inferior programs must be presented. While, for a time, almost anything will be acceptable because of the novelty of television to the layman, unless the quality of the programs is constantly improved, the prospects for a healthy growth of home television do not appear bright.

Concurrently with the expansion of home television receiver sales, there is a possibility of chain theater presentations of television programs. In most cases, television will simply be an adjunct to standard movie programs and will be employed to cover important news and sports events. According to an article appearing in *Television,* televising of events of major importance would be limited to theaters because of the ability of exhibitors and audiences to pay more for television rights than any advertiser. If this policy is followed, and expanded to include high-grade Broadway shows, the difficulties of broadcast stations in maintaining interest in home television broadcasts are bound to increase. Theater television will be in direct competition with the marketing of home television receivers, and the incentive to invest in home television receivers will be greatly decreased.

It is important that the theater amusement industry should take up television because it can help to publicize the attractions of television as well as to provide much-needed revenue. But it is even more important that no single segment of the amusement field be permitted to monopolize the greatest attractions for television presentation. Broadcasters can control this situation, because special facilities would be necessary for exclusive transmissions.

If chain theater television presentations get into operation before there is wide distribution of television receivers, theaters would have little to gain in demanding exclusive presentations. The amount of business which they would lose through non-exclusive presentation would be negligible. But the effect on the potential market for home receivers would be bad. Even after a large number of receivers have been sold there will still be plenty of customers for theater presentations among those who cannot afford television sets.

Putting on television programs which will hold the interest of the public is, to our mind, the greatest problem which confronts this branch of the industry. Money to do the job right must come from somewhere, otherwise it is unlikely there will be any sustained expansion of home television.

RADIO-RADAR PROGRAM

★ When Germany surrenders, the military radio-radar program will be reduced 25-35% (more on Army and less on Navy contracts, depending on the type of product and its future necessity against Japan), the Industry Committee of the RMA has been informed at a meeting with high WPB officials. However, because the minimum military program for the balance of the year has been stepped up to about 16% above the July rate, it appears that even cessation of the European war will not reduce schedules much below the July rate of production. So there is no reason to believe there will be any appreciable slackening of work in the radio-electronic industry for some time to come.

—J. H. P.

TECHNICANA

ULTRASONIC WINDOWS

★ A suggestion for the design of windows for transmission of high frequency energy is outlined in an article appearing in the August, 1944, issue of *General Electric Review.* The article, entitled "Ultrasonics" is written by D. Cochran and R. W. Samsel of the G. E. Laboratory.

Two design factors are of importance. The thickness of the window must be an even number of quarter wavelengths for maximum transmission of energy. In addition, the ρC of the window material should match the ρC of the neighboring medium. The letter ρ represents the density of the material, and C the velocity of propagation in the material.

Theoretical transmission curves for slabs of varying thicknesses are shown in *Fig. 1.* The subscripts *1*, as in

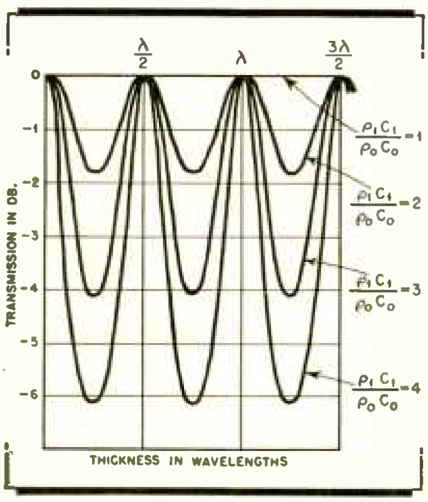


Figure 1

$\rho_1 C_1$ are for the window material. The subscripts *0* apply to the neighboring medium from which the energy is transmitted through the window.

When the ρC's match, all energy is transmitted, regardless of thickness.

When the ρC's differ, some energy is reflected if the thickness is not correct. When the thickness is an even number of quarter wavelengths the energy reflected from the rear surface cancels the energy reflected from the

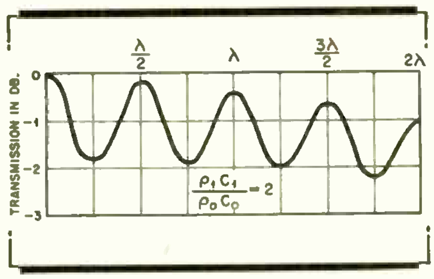


Figure 2

front surface, and reinforces the energy transmitted through the front surface.

In practice, however, there is some absorption loss in the slab, so that transmission will be more like that shown in *Fig. 2,* where there is a theoretical loss of ½ db per wavelength.

The above theory was substantiated by the authors in experiments using the slab of polystyrene in water, with measurements at 750 kilocycles.

ELECTRON BEAM DEFLECTION

★ An analysis of the dynamics of transversely deflected electron beams which promises to be of some interest to designers of cathode ray tubes, and may be of value in describing the effects of an electric field which exists in a resonant cavity, appears under the title "Deflected Electron Beams," by J. H. Owen Harries, in the June, 1944, issue of *Wireless Engineer.* The author limits his discussion to transverse deflections but suggests that the problem of describing velocity modulation is related because in the latter case the modulating field lies in the same line as the beam.

Mr. Harries first develops the equation for the path of an electron beam directed between two plates of infinite length and width. An alternating voltage is applied to the plates. The differential equations for the path of an electron are

$$\frac{d^2y}{dy^2} = \frac{eE}{dm}, \text{ and } \frac{d^2x}{dt^2} = 0$$

in which x is the axis of the beam, y the transverse deflection, d the distance between plates, c the charge on an electron, m the mass of the electron, and $E = Ee^{j\omega t}$, the deflecting voltage.

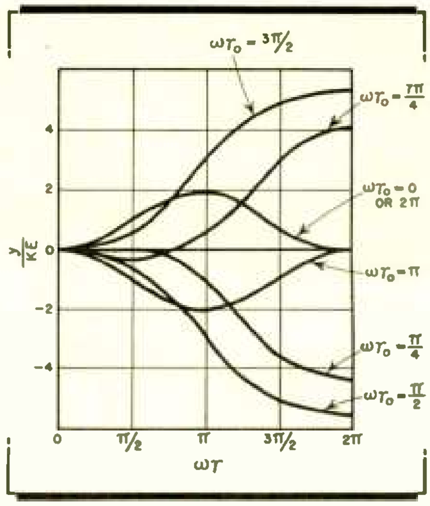


Figure 3

The path of the beam becomes

$$y = \frac{eE}{\omega dm}\left[\cos \omega t_0 - \omega\tau \sin \omega t_0 - \cos(\omega t + \omega\tau)\right]$$

in which t_0 is the time the electron enters the field and τ is the transit time so that $\tau = t - t_0$.

The path of the beam depends upon the entrance angle ωt_0, as shown in *Fig. 3.*

The horizontal axis of the graph is given in terms of $\omega\tau$, which is proportional to the actual distance x, since $x = v_x t$, and v_x is constant. The vertical axis is given in terms of y/KE, where $k = c/\omega^2\, dm$.

The impedance, Z_d, to the transverse electron current is determined to be such that

$$1/Zd = \frac{I_0 e}{d^2\omega^3 m}\left[\omega\tau \sin \omega\tau + \cos \omega\tau - 1 + j(\omega\tau \cos \omega\tau - \sin \omega\tau)\right]$$

in which I_0 is the longitudinal beam current. This equivalent impedance is complex and varies in sign with the transit time, as illustrated in *Fig. 4.* The part in brackets in the above equa-

[*Continued on page 8*]

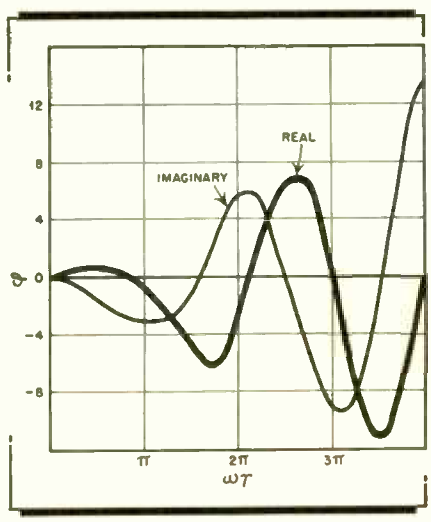
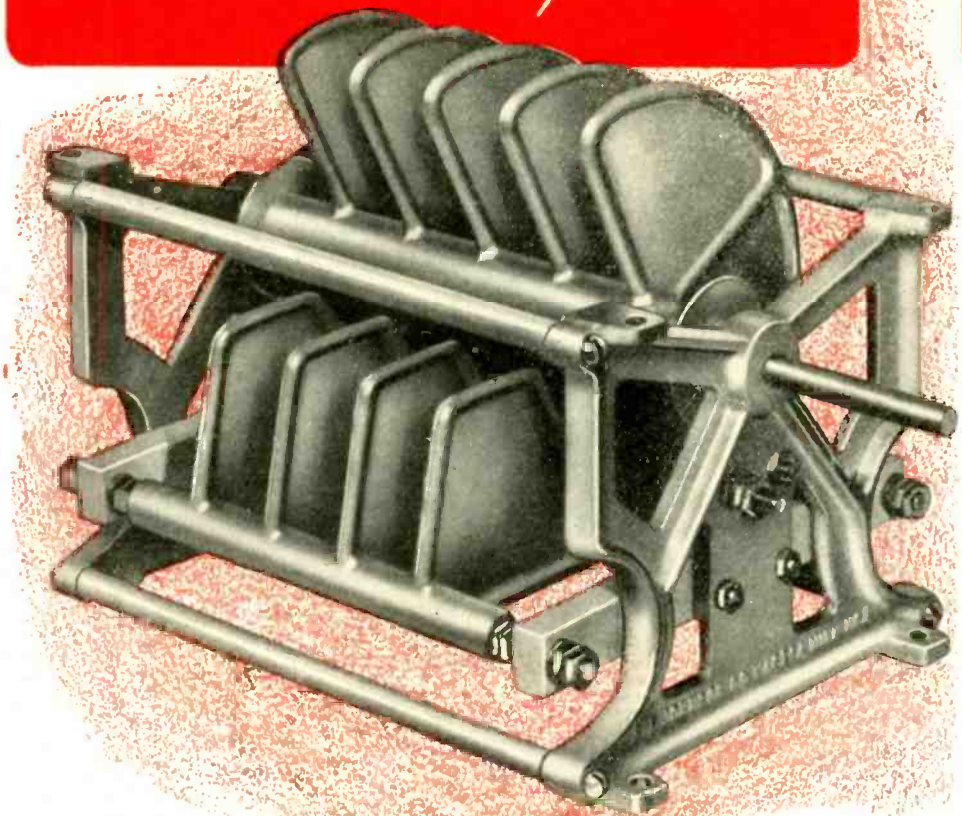


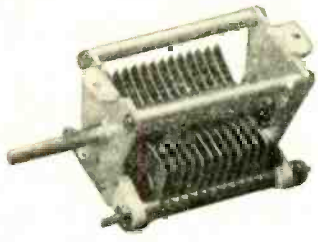
Figure 4

New Development

Decreased Spacing
Shorter Length
Lower Minimum
Less Inductance



Types C and D for peak voltages of 3500 to 13,000



Types E and F for peak voltages of 2000 to 4500

Type H for peak voltages of 1500 to 3000

Type N neutralizing condensers in 5 sizes

Again Johnson scores a first with newly designed thick plates which allow much higher voltages, particularly at high frequencies.

It has long been known that plates with rounded edges have higher breakdown voltages in variable condensers, but it remained for Johnson Engineers to work out ratios of plate thickness, design, voltage, and spacing for maximum advantage.

Greatly decreased length (as much as one-third in some cases) results in lower minimum capacity and lower inductance due to shorter frame rods and other metal parts, which is extremely important at high frequencies.

Corona is noticeably less with the new type plates and corona shields have been added where stator bars enter insulators, resulting in still further improved performance.

Despite these many improvements, in most cases prices are lower because of the saving in material.

Now available in Types A and B, both fixed and variable, this new plate shape and construction will be incorporated in other types as quickly as possible. Write Johnson today for more information and for recommendations on YOUR variable condenser application.

New Catalog 968K now ready.

JOHNSON

a famous name in Radio

E. F. JOHNSON COMPANY • WASECA • MINNESOTA

TECHNICANA

[*Continued from page 6*]

tion is φ_0. The real and imaginary parts of φ_0 are plotted separately against the transit time.

Fig. 4 illustrates the equivalent electrical circuit for the theoretical case of infinite planes, but this analysis does not correspond to any actual case.

The author states that there can be no generalized expression, for there is an infinite number of electrode shapes and boundry conditions.

A more practical case than that of the infinite planes is that in which the deflection field varies periodically along the x-axis so that it is always zero at the ends of the deflecting plates. This type of field would completely eliminate end effects. It is pointed out, additionally, that in a resonant cavity at very high frequencies the vector field along the path of the beam approaches a sine function. If the cavity is circular disc-shaped the variation across a diameter is a Bessel function of zero order, which is approximately a cosine function.

In a sine-shaped deflecting field the differential equation for transverse motion is

$$\frac{d^2y}{dt^2} = \frac{eE}{dm} \cos \omega\tau \sin \frac{\pi\tau}{\tau_0}$$

where τ_0 is the time required to transverse one-half period of the field variation. The component $\sin \frac{\pi\tau}{\tau_0}$ equals 0 when $\tau = 0$ and when $\tau = \tau_0$ and thus defines the sine-shaped field.

The solution of the equation is only useful for specific values of τ_0. The deflection coefficient of the solution is plotted in *Fig. 5* against transit angle $\omega\tau_0$ for one value of $\frac{\tau}{\tau_0}$, which is the the distance travelled along the x-axis

[*Continued on page 12*]

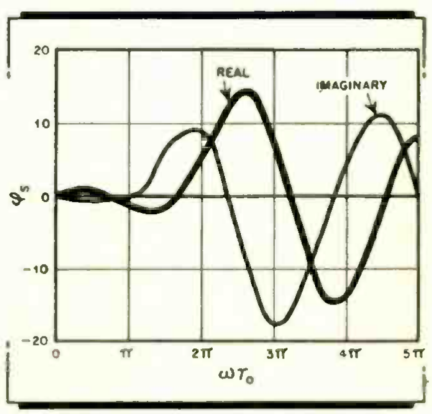


Figure 5


Federal
Low Frequency Transmitters Used
Inside the
FEDERAL TELEPHONE & RADIO
FTR

Arctic Circle

To maintain unfailing communication between airports and from field to plane inside the Arctic Circle, requires the use of low frequency transmitters that will operate reliably far from service facilities.

Federal, pioneer in both low and high frequency radio communication, provides the solution with its 10 KW low frequency transmitter, consisting of an exciter, rectifier, RF transmitter and antenna tuning equipment, housed as separate units. Compact, light in weight, they may be transported in a cargo plane without dismantling.

Through blinding storms and almost perpetual night, pilots in the Far North stake their lives on the dependability of these Federal radio transmitters.

Your transmitting equipment may never be called upon to meet such rigorous demands. But, whatever your requirements are in low or high frequency transmission, Federal, with its technical experience and leadership in radio communication, is prepared to solve your problem.

Intelin High Frequency Power and Coaxial Cables manufactured by Federal, meet every construction and performance requirement of the most exacting specifications.

Federal Telephone and Radio Corporation

AN IT&T ASSOCIATE

Newark 1, N. J.

TECHNICANA

[*Continued from page 8*]

in terms of half-sine periods of field variation.

The solution of the case of a sine-shaped field reveals that any desired phase relationship may be made to exist between the beam displacement and the displacing field, at any point on the path of the beam. This is true because the phase angle is itself a function of the transit angle $\omega\tau$ and ω can be varied at will. The value of τ depends upon the accelerating voltage used to establish the horizontal electron beam velocity.

Fig. 6 shows beam profiles found in a sine-shaped field for various instantaneous times in the deflecting field time cycle. The instantaneous deflecting field varies as a sine function along the x-axis, as shown. The beam profile is shown directly beneath its instantaneous deflecting field. The upper graphs are given for an entrance angle $\omega\tau_0 = 3.8\pi$, and accelerating voltage of 41,000 volts. The lower graphs are given for $\omega\tau_0 = 7.9\pi$, and accelerating voltage of 9,600 V. In both cases $\frac{\tau}{\tau_0} = \frac{1}{2}$.

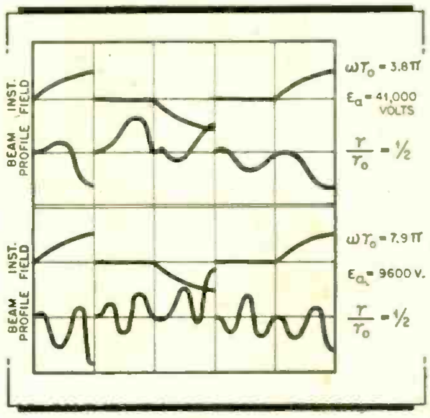


Figure 6

The graphs show how the beam "snakes" its way through the field. The exit angle will vary with the entrance time angle, but the maximum value of the exit angle is a measure of the sensitivity of the tube.

The power used to deflect a beam is determined by the author to be a function of the variable $\frac{\tau}{\tau_0}$ in addition to the other variables of the system. The expression for power is never negative for beams deflected by a transverse electric field.

[*Continued on page 15*]

ALLEN H. GARDNER, *President*
Colonial Radio Corp. . . .

"The public knows only part of the splendid job electronic engineers have done during the war, and of the marvelous accomplishments that have been made in radio communications, because of the extremely secret nature of most of the developments. One of the results which can be mentioned now is the . . .

"TREMENDOUS INCREASE IN NEW USES FOR MODERN, VERSATILE VIBRATOR POWER SUPPLIES"

Yes, Mr. Gardner, many fields, after the war, will find E-L Vibrator Power Supplies the key to a host of new improvements in their products and services. The transit industry, radio, aviation, railroad, marine, electrical and electronic are just a few of the fields in which E-L equipment will do many important jobs . . . The most significant new E-L development is the perfection of an electrical current division circuit between vibrator contacts. This has made possible an enormous increase in output capacity, to as much as 1500 watts at present!

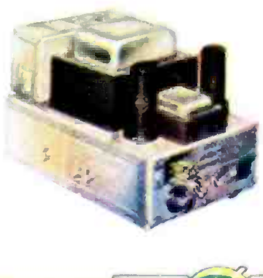
For the transit field, Electronic Laboratories offer four patented current conversion systems for fluorescent lighting in all types of vehicles. These systems will operate any type or size fluorescent lamp, either hot or cold cathode, as well as any number of lamps.

E-L is ready now to bring you the benefits of its tremendous wartime experience for two-way radio in planes, trains, transcontinental busses, boats and other fields . . . Multiple input and output units are available. Vibrator Power Supplies may be designed to supply any needed wave form. They are efficient and long-lived and economy is assured with the minimum of maintenance. E-L design engineering service will design a Vibrator Power Supply to meet specific requirements in size, weight and voltage.

E-L STANDARD POWER SUPPLY MODEL 619

This is a typical unit for mobile or portable applications with such equipment as 5 or 10 meter shortwave rigs. Model 619 allows you to operate from regular 115 volt AC power line and then switch easily to a 6 volt DC battery. Characteristics: Input voltage, 115 volts 60 cycle AC and 6 volts DC; Output voltage, 6.3 volts AC at 100 ma. and 300 volts DC at 100 ma.; Output power, 55 watts maximum.

Dimensions: 9¼ x 5¾ x 6 inches. Weight: 14½ pounds



Write for further information of this and other power supply models with different inputs and outputs for a wide range of uses.

Electronic LABORATORIES INC.
INDIANAPOLIS

VIBRATOR POWER SUPPLIES FOR LIGHTING, COMMUNICATIONS, AND ELECTRIC MOTOR OPERATION • ELECTRIC, ELECTRONIC AND OTHER EQUIPMENT

THERE'S GOLD HERE!

another new letter contest

$200.00 in prizes every month

$100.00 first prize, $50.00 second prize, $25.00 third prize, $15.00 fourth prize, $10.00 fifth prize, plus $1.00 for every letter received.

Here we go again. Another great Hallicrafters letter contest for service men. Wherever you are, whenever you see this announcement, drop us a line. Write and tell us your first hand experience with *all* types of radio communications built by Hallicrafters, including the famous SCR-299.

There is gold here! Write today to get your share. Tell us your story in your own way. You can't lose and you *can* win as high as $100.00.

Rules for the Contest

Hallicrafters will give $200.00 for the best letters received during each of the six months of September, October, November, December, 1944, January, and February, 1945. (Deadline: Your letter must be received by midnight, the last day of each month.)

For every serious letter received, Hallicrafters will send $1.00 so even if you do not win a big prize your time will not be in vain. Your letter will become the property of Hallicrafters and they will have the right to reproduce it in a Hallicrafters advertisement. Write as many letters as you wish. V-mail letters will do.

Open to servicemen around the world. Wherever you are, whenever you see this ad, drop us a line. Monthly winners will be notified immediately upon judging.

There's gold here at the end of the rainbow in Hallicrafters great letter contest—and there's a great and exciting future ahead for short wave enthusiasts. In peace time Hallicrafters will continue to build "the radio man's radio" and that means the best that can be made. There will be a set for you in our postwar line.

BUY A WAR BOND TODAY!

hallicrafters RADIO

THE HALLICRAFTERS COMPANY, MANUFACTURERS OF RADIO AND ELECTRONIC EQUIPMENT, CHICAGO 16, U.S.A.

[*Continued from page 12*]

It is found that the power to deflect a beam can be approximately 1% of the power in the beam, so that a tube used for transverse deflection can have a high input impedance, even at extremely high frequencies, and the tube should be expected to give high power amplification efficiency.

Deflection sensitivity can be increased by employing a long field-free space beyond the deflecting plates. This space is termed the "throw" of the beam.

Further analysis proves the fact that cathode ray tube sensitivity depends upon the "throw" and the maximum exit angle from the deflection plates. The exit angle in turn varies with the accelerating voltage, distance between plates. deflecting voltage, and frequency.

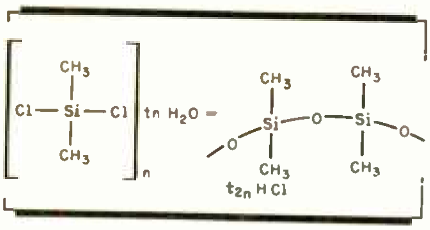
SURFACE TREATMENT OF INSULATORS

★ A new type of water-repellent compound* used to increase the surface resistance of electrical insulating materials, such as steatites and ceramics, is discussed by Dr. Francis J. Norton in the August, 1944, issue of the *General Electric Review.*

This compound is a member of the family of silicones in which silicon replaces carbon as the chain-forming element in organic chemical compounds.

For the particular problem of surface protection of ceramics a mixture of methyl-chloro-silanes is applied in the form of vapor to the surface to be treated. The vapor reacts with moisture on the surface and a thin film of insulating material remains.

This is illustrated as follows, where



n molecules of methyl-chloro-silane react with water to form hydrochoric acid and the silicone insulating material.

The vapor application is best done after the parts to be treated have been pre-conditioned at 50 to 90% relative humidity so that a film of water about 100 molecules thick remains on the surface.

* Trade Name—"Dri-Film."

[*Continued on page 16*]

TECHNICANA

[*Continued from page 15*]

An example of the results obtained is shown in *Table I.* The parts had been pre-cooled at —10°C. and placed in a chamber at 100% R. H. at 25°C. so that dew-point conditions prevailed.

TABLE I

Ceramic Sample	*Resistance (Megohms)*
Unglazed	1.4
Unglazed, waxed	230
Unglazed, methyl-chloro-silane treated	>200,000
Glazed, no other treatment....	42

The figures in *Table II* were obtained in a chamber at 100% R. H. at 25°C., without precooling.

TABLE II

Ceramic Sample	*Resistance (Megohms)*
Unglazed, untreated	3.590
Unglazed, waxed	29,500
Unglazed, methyl-chloro-silane	>200,000
Glazed, no other treatment....	1,550

Consistently superior insulation is indicated by measurements made after prolonged exposure (170 days) at 90% R.H. at 85°F. The average resistance of dri-film-treated pieces dropped to 4 x 10^{10} ohms in comparison to 2 x 10^{8} ohms for untreated ceramics and 10^{8} ohms for wax-treated parts.

Coils showed slight improvement in Q-factor when compared to untreated coils, particularly at high frequencies (4.5 megacycles) and under dew-point conditions.

Most of the tests were made under dew-point conditions and it is not claimed that the silicone treatment will offer any improvement when perfectly dry conditions prevail.

A disadvantage of the process is the formation of hydrochloric acid, which may be injurious to a careless operator. It also outlaws the use of ordinary metal parts attached to the ceramics.

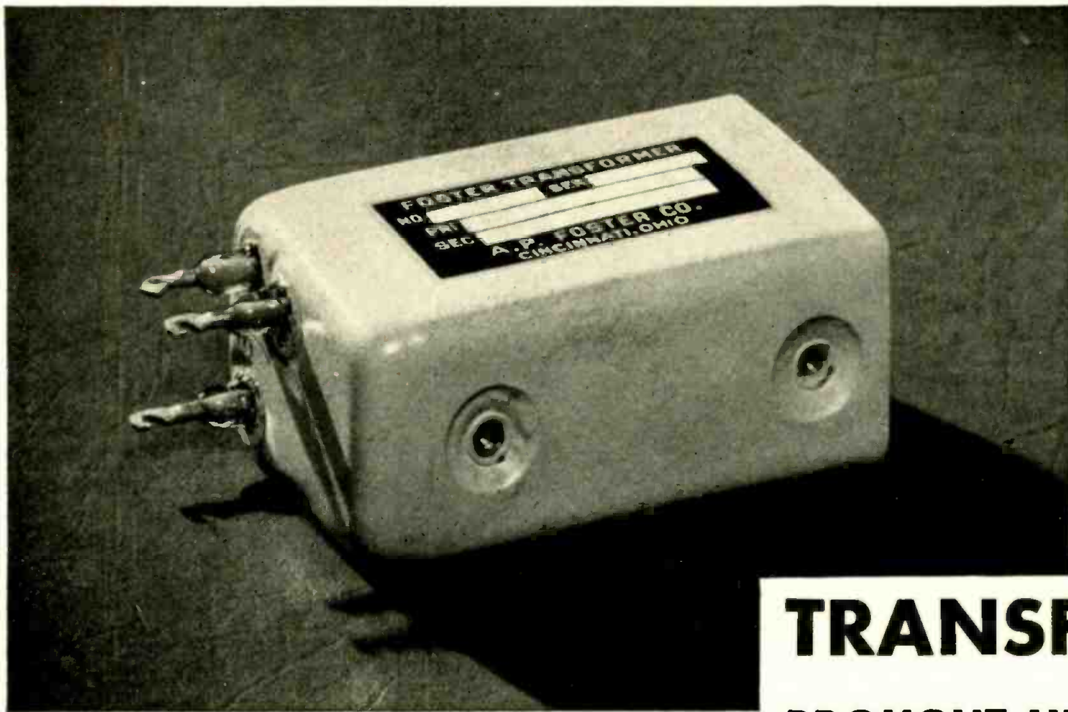
NEW MEGATRON

★ The Army and Navy have approved the release of further information on the General Electric Company's disk-seal electronic tube, widely known among radio engineers in the military services as the "lighthouse" tube. The new tube, developed by engineers of the G-E Electronics Laboratory, provides the basis for a multitude of new public services in the FM radio.

The new tube eliminates the conventional type of grid, anode and cathode. Instead of components being fitted around one another as in the past, they are now constructed in simple, parallel planes or layers, with glass and metal fused together in rigid, inseparable units that are strong and capable of withstanding severe jolts. This design permits an extremely compact over-

[*Continued on page 18*]

RE-DESIGNED "TO ORDER"



TRANSFORMER

BROUGHT UP TO PAR BY

FOSTER

Some weeks ago a manufacturer brought this unit, as then being supplied to him, to Foster Engineers for examination. Performance of the original model of this transformer had failed to meet a certain high standard of minimum inductance and maximum resistance. Foster re-designed it, met the exacting specifications, somewhat reduced its over-all dimensions, yet kept the new Foster model interchangeable with the old—no costly changes were required in the product of which this transformer is a part.

It is another example of Foster skill and experience in designing and building transformers for specific requirements that will be of great value in the post-war world of electronic equipment. Our experience covers close tolerance vibrator transformers, output transformers, microphone transformers, saturable reactors, power transformers, audio filters and reactors . . . designed and custom-built to the most exacting individual requirements.

SPECIALISTS IN BUILDING TRANSFORMERS SINCE 1938

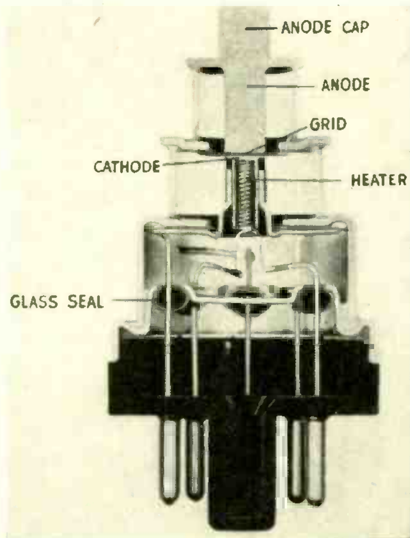
A. P. FOSTER COMPANY

TRANSFORMER ENGINEERS & MANUFACTURERS

719 WYOMING AVENUE, LOCKLAND 15, OHIO

TECHNICANA

[*Continued from page 16*]



all tube structure, while providing high frequency and high power output. It gives uniform co-planar electrode design, very low plate-to-cathode interelectrode capacitance, and very high permanence of characteristics.

(The military services will not allow release of specific information on the increase nor details on circuits or apparatus in which the tubes are used.)

MILLER EFFECT

★ The grid-plate capacitance of a tube, reflected to the input produces what is known as the "Miller Effect." This is particularly important in triodes, and at radio frequencies, and is responsible for some rather marked characteristics of the circuit.

C. J. Mitchell of the Northampton Polytechnic Institute analyzes this effect in a somewhat new way in an article entitled "Miller Effect Simplified" appearing in the June, 1944 of *Electronic Engineering.*

The interelectrode capacitances of a triode are shown in *Fig. 7.* In the diagram C_{gp} is the grid-plate capacitance, C_{gc} is the grid-cathode capacitance, V_g is the input voltage, and V_p is the output voltage. C_{cp}, plate-cathode capacitance, has been absorbed in the load

[*Continued on page 20*]

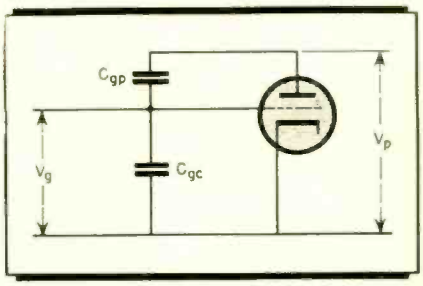


Figure 7

WHAT FREQUENCY RANGE

DO WE NEED FOR HIGH FIDELITY REPRODUCTION?

"Frequency Range and Power Considerations in Music Reproduction" is the title of number three JENSEN Monograph, now ready for mailing. With the approach of FM, Television, High Quality Recording and other advances in the audio electric art, calling for new and increased emphasis on the requirements of High Fidelity Sound Reproducing equipment, this subject is both timely and pertinent.

Do you know the maximum, useful audio frequency ranges under actual listening conditions? Do you know how frequency range is limited even if perfect transmission, reception and reproduction were possible? Or how much change in high frequency cut-off is required to be just noticeable to the listener?

All of these questions, and many more, are answered in this latest JENSEN Monograph. Based on an extensive examination of authoritative work in this field, treatment of the subject is such that it will be found valuable by professionals, the trade, educators and the public.

If you are interested in sound reproduction, you need this up-to-the-minute information. Get your copy today from your JENSEN distributor or dealer, or send 25c to:

Series So Far Issued

No. 1. Loud Speaker Frequency-Response Measurements.

No. 2. Impedance Matching and Power Distribution.

No. 3. Frequency Range in Music Reproduction.

Watch for the next issue!

Free to men in the Armed Services and to Colleges, Technical Schools and Libraries.

Jensen

JENSEN RADIO MANUFACTURING COMPANY
6615 South Laramie Avenue
Chicago 38, Illinois

Send me ☐ Loud Speaker Frequency-Response Measurements
☐ Impedance Matching and Power Distribution
☐ Frequency Range in Music Reproduction
(Check one, two or three. Send 25c for each book ordered.)

NAME ______________________

ADDRESS ______________________

CITY ______________ ZONE ____ STATE ______

TECHNICANA

[Continued from page 18]

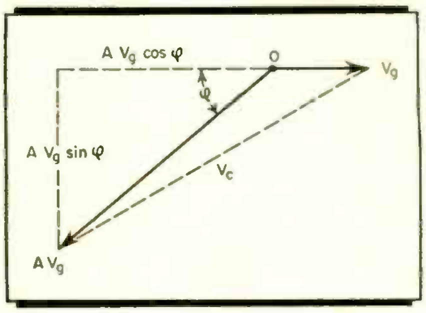


Figure 9

and does not appear in this discussion. It is assumed that *Ccp* is in parallel with the load, since the high voltage line is shunted to ground in the power supply, and is therefore at ground potential for r-f.

Vp will be 180° out of phase with *Vg* for a resistive load, so that the circuit is represented by two ac. generators as in *Fig. 8*. In this figure *Cgc* is shown in dotted lines since we are particularly concerned with *Cgp* reflected into the grid circuit in parallel with *Cgc*.

The potential difference across *Cgp* is $Vc = Vg + Vp = (1+A)\ Vg$, where A is the amplification of the tube.

The current $i_{gp} = jVc/Xgp = j\ (1+A)Vg.\ \omega\ Cgp$.

This current is passing through both generators so that *Vg* generator must supply i_{gp} as well as the current through *Cgc*. The effect is that of a reflected capacitance, C_{ref}. The reactance of this capacitance reflected into the grid circuit $= Vg/Igp = 1/j\omega\ C_{ref}$, so that

$$C_{ref} = Igp/j\omega Vg = \frac{j(1+A)Vg.\omega Cgp}{j\omega Vg}$$
$$= (1 + A)Cgp.$$

The total input capacitance is accordingly $Cgc + Cgp\ (1+A)$. This is only true for an 180° phase difference. For an inductive plate load *Vp* will be advanced by ϕ degrees, leading the current. By repeating the above steps for this more practical case, there is obtained, as shown in *Fig. 9*, the resultant voltage $Vp = Avg \cos\phi + jAVg \sin\phi$. Also, $Vc = Vg + AVg\cos\phi + jAVg\sin\phi$. Then $i_{gp} = jVc/Xgp = i\ (Vg + AVg\cos\phi + jAVg\sin\phi)\ \omega\ Cgp = jVg\ (1 + A\cos\phi)\ \omega\ Cgp - AVg\sin\phi\ \omega\ Cgp$. The reflected capacitance $Cref = i_{gp}/j\ \omega\ Vg = (1 + A\cos\phi)\ Cgp\ \frac{-A\sin\phi\ Cgp}{j}$

[Continued on page 68]

Radio-Frequency

POWER MEASUREMENTS

A. C. MATTHEWS

A comprehensive survey of methods and instruments used in making r-f measurements, and data regarding their advantages and limitations

In radio engineering one of the most difficult quantities to measure is that of r-f power. Several methods are available depending upon the magnitude and frequency of the power to be measured. These will be discussed with particular reference to their limitations as well as their accuracy for high frequency measurements.

The measurement of r-f power is based upon one of two effects, namely: (1) heat and (2) the voltage drop across, or current through, a known impedance. A compilation of the most commonly used methods of power measurements is given in *Table 1*.

In an a-c circuit the power in watts is defined by the expression

$$P = I^2 Z \cos \phi \qquad (1)$$

where I is in amperes, Z in ohms and $\cos \phi$ the power factor. Fortunately, most power measurements can be made with a resistive load, so the power factor is essentially unity, then equation (1) simplifies into

$$P = I^2 R \qquad (2)$$

This is particularly true where the power to be measured is available at the end of a transmission line of known impedance. In this case it is only necessary to match the end of the line with a non-inductive resistor (several of which are available commercially within a range of from 13 to 600 ohms) and either measure the current through the load or the voltage across its terminals. The attenuation of the transmission line must be known at the operating frequency, otherwise a very short line should be used to avoid introducing appreciable loss.

Requirements

Before discussing a particular method of measurement let us consider the requirements of an r-f power measuring device.

a. The instrument or method used should have no deleterious effect on the operation of the apparatus being measured.

b. The method should have adequate sensitivity in order that precision measurements may be made.

c. The calibration should be independent of frequency; if lacking this feature, a known correction factor should be available.

Having decided on the desirable requirements for a measuring device, we will now consider each of the methods as given in *Table 1*.

Wattmeters

Wattmeters of the electrodynamometer type having separate voltage and current coils are unsuited for r-f measurements. In general, their power range is inadequate and the losses, except at very low r-f frequencies, are prohibitive.

An electron tube wattmeter for measuring power of a few microwatts or more has been described in the literature.[1]. Its operation depends upon obtaining a voltage proportional to the load current from a low resistance in series with the power source, and also a voltage from a high resistance across the power source which is proportional to the load voltage. The sum of the instantaneous values of the two voltages is impressed on the grid of one tube and their difference on the grid of another tube as shown in *Fig. 1*. The loss in the series element must be made quite small, and obviously the shunt resistance element should be sufficiently large to make the total power dissipated by the instrument negligible as compared with the load.

The power capacity of the electron tube wattmeter is limited by the maximum allowable grid input voltage. Its use at high frequencies is limited only by the interelectrode tube capacities.

R-F Ammeter

One method of determining high fre-

TABLE I

R-F MEASUREMENT METHODS

Instrument	Measurement based on	Order of Accuracy	Usual Power Capacity	Usual High-Frequency Limit
Electrodynamic Ammeter	*Phyiscal parameters*	*0.3%*	*Medium*	*100 mc*
Electron Tube Wattmeter	*Voltage difference*	*2-5%*	*Low*	*30 mc*
Thermocouple Ammeter	*Heat*	*2-5% to 10 mc*	*Medium*	*100 mc*
Diode Voltmeter	*Voltage*	*2-10%*	*Medium*	*100 cm*
Calorimeter	*Heat*	*3%*	*High*	*10 cm*
P. M. Lamp	*Heat*	*5-10%*	*Medium*	*200 mc*
Bolometer	*Heat*	*3%*	*Low**	*10 cm*

** For high power capacity an attenuating cable is used*

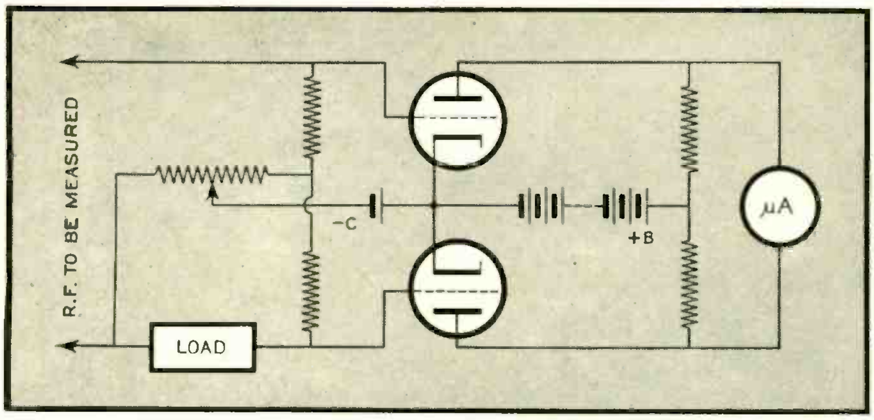


Fig. 1. Schematic diagram of electron tube wattmeter

quency power, depending upon the heating effect of the current, is by the use of a thermocouple ammeter in conjunction with a known resistance. Knowing the magnitude of the current through the resistance, the power can be readily calculated. This method has had widespread application notwithstanding that in certain applications its value as a power measuring device is mediocre. Under proper conditions, however, the thermocouple ammeter may be relied upon for extremely precise measurements.

Basically, the thermocouple ammeter consists of a d-c voltmeter which measures the potential developed across an internal thermal junction (thermocouple). The voltage produced is the result of current passing through the heater, which raises the temperature of the thermal junction. Since the heater has a definite resistance, the power, and likewise the temperature is proportional to the square of the current flowing through it. The voltage developed by virtue of the heater temperature is then proportional to the square of the current. For this reason, unless the indicator portion of the meter has specially shaped pole pieces the pointer deflection will be approximately proportional to the current squared.

Whenever possible the ammeter should be connected into the circuit at a low potential point, although this is not always feasible, in which case a shielded meter should be employed. This consists of a regular meter with a metal shield around its body, the shield and internal parts being bonded together and connected to the "low potential" meter terminal. This terminal should be connected to the r-f source, while the "high potential" terminal is connected to the load. The use of a shield[2] and the bonding together of internal parts, where possible, greatly increases the accuracy of the meter when operated above ground potential. These refinements in design eliminate to a large degree capacitive charging currents which would result in additional heat being transmitted to the heater and thereby cause an erroneous indication. Since the current is through a dielectric path the error increases with frequency.

Thermocouples

Some thermocouples are simply mounted on studs set into an insulating material. This type is not particularly sensitive and furthermore is subject to air convection currents and changes in ambient temperature. The better grade units are enclosed in a glass envelope and evacuated to approximately 0.01 mm of mercury. Since the elements are mounted in an evacuated bulb the cooling of its surface is thru radiation therefore a given current will result in a higher heater temperature and greater sensitivity will be obtained. Polished metal elements are usually employed since these are poor radiators of heat.

The resistance of the thermocouple heater increases with frequency, due to skin effect. Increased resistance increases the total heat produced and, since the voltmeter is responsive only to the changes in temperature of the thermal junction, the current indicated at high frequencies is greater than that at low frequencies. Knowing the increase in resistance due to skin effect at a given frequency the approximate correction factor can be determined. *Fig. 2* shows a typical correction factor curve of a commercially available instrument.

Another cause of frequency error in r-f ammeters occurs when the impedance due to capacity of the heater terminals becomes comparable with the impedance of the heater element. At frequencies where this is true, some of the current which would normally go through the heater is bypassed, due to the capacitive path, to the instrument terminals. Eddy currents induced in the thermocouple by current passing through the heater is sometimes troublesome, but in most cases this effect is negligible. By far, the most serious error in high frequency measurements is due to skin effect in the heater elements.

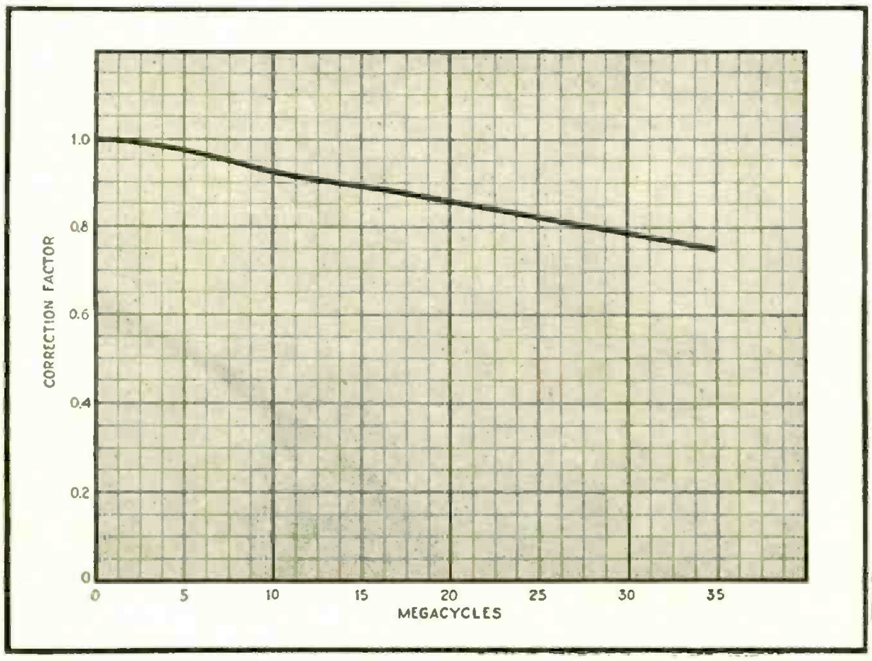


Fig. 2. Typical r-f ammeter correction factor curve

Calibration

Usually r-f ammeters are calibrated at 60 cycles and the frequency correction factor is calculated for the desired range. Photoelectric methods have also been used to some extent. These methods, while fairly satisfactory, are limited in accuracy.

A new method has been developed[3] and improved[4] wherein the characteristics of an ammeter can be calculated from measurements of length, mass and time. The improved instru-

TABLE II

SYLVANIA P. M. LAMP CHARACTERISTICS

Type	PM-3	PM-6	PM-8
Maximum frequency for $Z = R$	15	25	55 mc
Maximum frequency for $R_{ac} = R_{dc}$	100	200	900 mc
Resistance at normal power	40	110	110 ohms
Resistance at Maximum power	70	175	195 ohms
Power Dissipation (Maximum)	25	3.5	1 watt
Inductive Reactance 55 mc	125	140	*ohms
Inductive Reactance 110 mc	300	250	90 ohms

**Reactance is negligible compared to the resistance*

ment known as an electrodynamic ammeter employs jewel bearings in place of the quartz suspension originally used. This permits a more sturdy construction and makes the instrument a practical standard for the measurement of current up to at least 100 megacycles.

Briefly, the ammeter resembles an air-cooled transformer with a single-turn primary and a smaller closed turn secondary, which is free to turn on its bearing-pivoted axis with respect to the primary. The primary carries the current to be measured. When the secondary is displaced angularly from the position of zero coupling, it is acted upon by forces which produce mechanical oscillation about its axis. The mechanical oscillation frequently is directly proportional to the amplitude of the current being measured, and is independent of frequency. The induced voltage in the secondary lags the primary current by 90°, and since the secondary current lags its voltage by 90°, the two currents are 180° out of time phase. When current is applied through the primary the secondary will tend to orient itself perpendicular to the primary (zero coupling.) However, because of kinetic energy, the moving secondary will be carried through this point into a region of opposing torque until the secondary finally comes to rest and reverses in direction, thus producing mechanical oscillation which is proportional (cycles vs time) to the current being measured.

Design Requirements

The following design features are desired in an r-f ammeter for high-frequency operation:

a. Heater leads should be short and preferably straight.

b. Heater mounts should utilize a minimum amount of material and be as nearly self-supporting as practical.

c. Meter should be shielded electrostatically and its internal parts bonded together.

VOLTAGE METHOD

The determination of r-f power by the measurement of voltage across a known load resistor is commonly used in radio engineering practice. The accuracy of this metnod at low radio frequencies is entirely satisfactory with the usual vacuum tube voltmeter, but as the frequency increases the accuracy decreases unless special precautions are taken to insure maintenance of calibration and proper connections to the power source. A well designed voltmeter will have negligible influence on the circuit being measured. It will also have adequate sensitivity and its calibration will not change appreciably with frequency.

As previously mentioned, dummy load resistors are available which can be employed as the dissipative element for the power source. The choice of a suitable load is of prime importance and should be carefully considered before attempting to make measurements. Once the load has been chosen and matched to the power source it is then a matter of correctly measuring the voltage across its terminals and using the formula

$$P = \frac{E^2}{R} \qquad (3)$$

where E is in volts, P in watts and R in ohms to determine the power.

Limitations

The matter of correctly measuring the voltage, however, requires some serious consideration, particularly if the frequency is above a few megacycles. The ordinary vacuum tube voltmeter begins to contribute an appreciable loss to the circuit around 30 megacycles, due to its decreased input impedance and the transit time effect. Even the acorn type tubes have their limitations, although with these tubes measurements can be satisfactorily made at frequencies of the order of 200 centimeters if the load resistance is low. This is usually the case, since most measurements are made at the end of low-impedance transmission lines.

Where the load resistance is high a method described by Nergaard[5] has been found very satisfactory. Briefly, this consists of using a small diode as a rectifier to charge a condenser as shown in *Fig. 3*. The potential developed across the condenser is then measured by means of a microammeter in series with a fairly high resistance. This arrangement produces only a very small loading effect on the power source being measured. Precautions should be taken to insure that no resonance occurs due to interelectrode tube capacity and lead inductance. With an acorn type 955 connected as a diode, the resonant frequency of interelectrode capacity and leads occurs at approximately 50 centimeters.

When making measurements at very high frequencies it is imperative that all connecting leads be as short as possible because at these frequencies leads constitute self-inductances which have impedances that can no longer be neglected.

Transit-time effects are still a factor when the electrons traveling between the tube elements require time comparable with the period of the power being measured. In such cases the condenser is not able to charge to the peak amplitude of the measured voltage and the voltmeter will indicate a lower voltage than actually present.

Voltmeter Calibration

A method of diode voltmeter calibration applicable to wavelengths down to 20 centimeters has been described by Strutt and Knol.[6] An r-f voltage source is fed to a parallel open wire transmission line through a resistor equal to the surge impedance of the line. The line is then terminated by a thermocouple having a known resistance at the calibrating frequency as shown in *Fig. 4*. Small capacitors are connected in series with the thermocouple heater to balance out the self-inductance of its leads. The diode voltmeter to be calibrated is now connected across the line at a distance of one-half wavelength from the heater

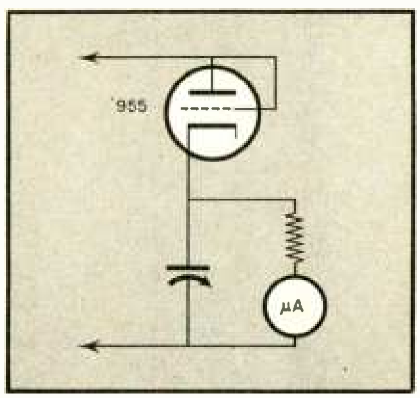


Fig. 3. Schematic of diode v-t voltmeter

termination. After balancing the compensating condensers for a minimum indication at the diode, the voltage is calculated by multiplying the heater resistance in ohms by the current in amperes, as measured with the thermocouple. Because the diode is one-half wavelength from the heater termination, the voltage across its terminals will be the same as the voltage at the terminals of the thermocouple heater.

PHOTOMETRIC METHOD

For rough checks of power output, many engineers simply couple an incandescent lamp to the source of power to be measured, and judging from the brilliancy of the filament estimate the power output. Such remarks as "It lights a 100-watt bulb" have frequently been heard in this connection. While this method does give an indication of the power output, obviously it lacks accuracy and cannot be relied upon to probably closer than plus or minus 30%, as it is nearly impossible to judge the brilliancy of a light source. It is therefore necessary to employ another incandescent lamp operated from d.c. or low frequency a.c. as a comparison. In this way it is possible to match the brilliancy of the unknown lamp to one which is operated from a known source of power. A light-intensity or exposure meter is sometimes used to assist in the matching process.

Several power-measuring lamps are available on the market which have been specially designed for measuring power output. Characteristics of some are shown in *Table 2.* These lamps consist of two filaments of similar characteristics mounted in one bulb. Their small size permits easy connection to the circuit to be measured with a minimum of lead inductance. One filament is connected in the high-frequency circuit while the other is connected to a variable source of low frequency a-c or d-c power. The power in the second filament can be determined to an accuracy of 5% with an ordinary voltmeter and a characteristic curve, as shown in *Fig. 5,* when the brilliancy of the two filaments is adjusted to be the same.

Skin Effect

Skin effect decreases the accuracy very little because the depth of penetration of the power being measured is equal to, or greater than, the radius of the filament of the lamp. Furthermore, the small filament with its high thermal conductivity makes for uniformity of temperature regardless of whether the heat is liberated from the entire cross-section or just from the outside layer. Of course, if the frequency is high enough the ratio of d-c to r-f resistance becomes appreciable, but the r-f current will then be less than the d-c current so the power will still be equal.

In view of the above design features it is practicable to make power measurements at any frequency so long as it is possible to couple the power into the lamp.

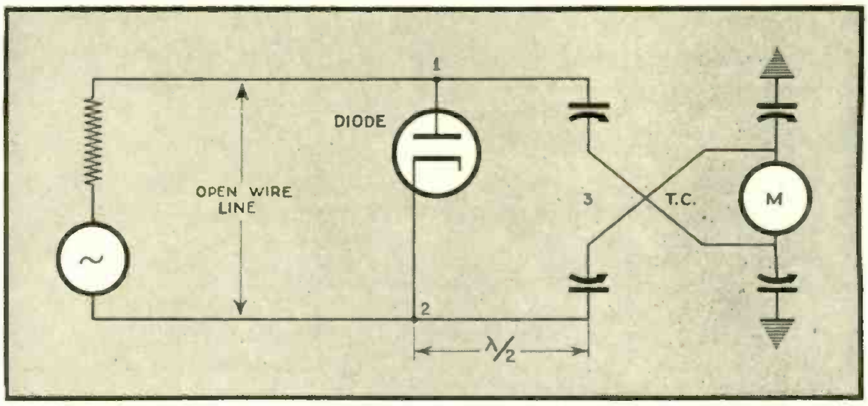


Fig. 4. Diode voltmeter calibrating circuit (after Strutt and Knol)

CALORIMETER METHOD

The calorimeter methods of measuring r-f power is based on the rise in temperature of a fluid surrounding, or circulating around, the load element. When the power to be measured is of the order of a few hundred watts it is general practice to insert two carbon elements into a double-walled container holding a known quantity of water. An ordinary chemical beaker or mason jar will suffice for the container, if it is cooled approximately ten degrees below room temperature before making measurements. The tests should then be continued until the temperature of the calorimeter is an equivalent amount above room temperature. In this way errors due to the cooling effect of the ambient temperature are balanced out.

The load impedance may be adjusted by adding salt or distilled water until the desired load resistance is obtained. Should the load be reactive (determined by detuning effect on the final amplifier) it will be necessary to connect a parallel tuned circuit across it and any losses in this circuit must be added to the power measured in order to obtain the true power output. *Fig. 6* shows a typical measurement setup.

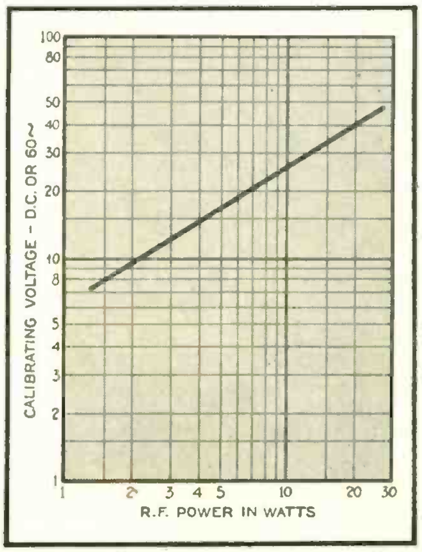


Fig. 5. Characteristic curve of Sylvania Type PM-3 power measurement lamp

Calibration

We know that one watt is equal to 10^7 ergs per second, and, since one gram calorie of heat equals 4.187 x 10^7 ergs, it is obvious that

$$\text{Heat in gram calories per second} = \frac{\text{watts}}{4.187} \qquad (4)$$

From the above it can be seen that if the heat in gram calories per second is known, we can calculate the power. This can be readily obtained by measuring the total weight of the components making up the calorimeter, and multiplying each by its respective specific heat. Next, measure the temperature rise of the liquid in degrees centigrade per minute, with the power being dissipated in the calorimeter load, and multiply the two results to-

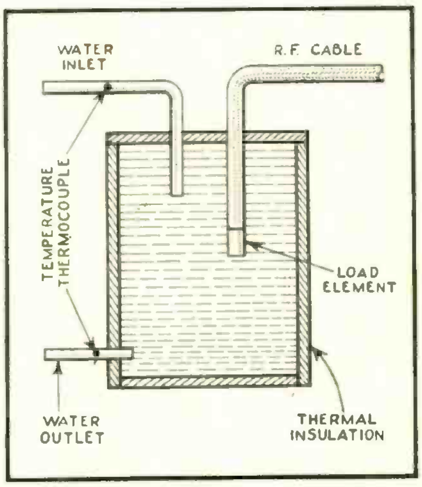
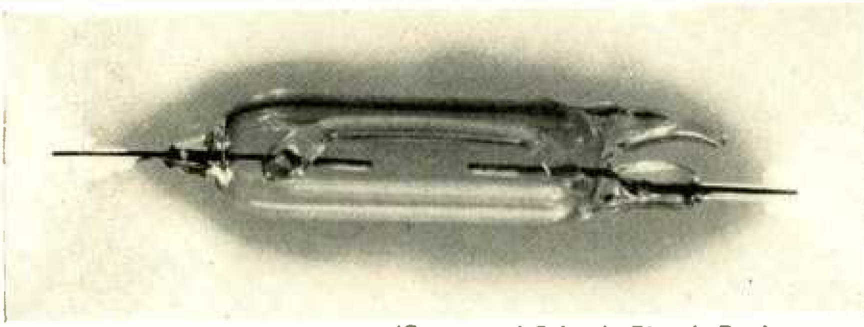


Fig 6. Calorimeter setup for high power measurements



(Courtesy of Sylvania Electric Products, Inc.)

Fig. 7. Type B bolometer

gether. The result is divided by 60 to convert the time into seconds which gives us the heat in gram calories per second. Substituting in equation 5 we have the power in watts.

$$W = 4.187 \times C_s \qquad (5)$$

where C_s is the heat in gram calories per second.

An alternate calorimeter method particularly suited to the measurement of high power output makes use of a small carbon element which is designed to properly match the transmitter. The load element is inserted in a thermal-insulated container which has provisions for circulating distilled water through it. The power can be determined by measuring the rate of flow of the water and the input and output temperatures. These quantities are then substituted in the expression,

$$W = 4.18 \frac{V}{60} (t_i - t_o) \qquad (6)$$

where V is the volume in litres per minute of the circulating water, t_o and t_i are the incoming and outgoing water temperatures respectively in degrees centigrade, and W is in kilowatts.

TUBE DISSIPATION METHOD

In transmitters having water-cooled final amplifier tubes, the power output may be determined by measuring the d-c or a-c power delivered to the filament, grid and plate circuits with ordinary meters. The power dissipated by the cooling fluid is then determined by its temperature rise and rate of flow. The difference between these two power measurements is approximately equal to the power output. By subtracting the loss in the output circuit, if appreciable, the power being delivered to the load will be determined.

BOLOMETER METHOD

The bolometer, like the calorimeter depends upon the heating effect of the current being measured. In this case the heat changes the value of a specially designed resistor which is used as one arm of a Wheatstone bridge. Various circuit arrangements may be employed.[7] This resistor usually consists of a fine platinum wire which has the property of changing its resistance as its temperature is varied. The element is often enclosed in a small evacuated bulb as shown in *Fig. 7*. The characteristics of one commercially available unit is given in *Table 3*.

Another unit known as a *Thermistor* has also been widely used. These units are physically small and may readily be matched in an r-f transmission line. In this way all of the r-f power traveling down the line is utilized in heating the element. Caution should, of course, be taken to insure a minimum of standing waves on the line, otherwise the element might be located at a current node and a false measurement would be obtained.

Measurements of high power are usually made with an attenuating cable between the power source and the bolometer, since the device ordinarily has a low power capacity. The "lossy" cable also helps minimize mismatching effects which might subject the instrument to excessive power.

One type of bolometer employed where production measurements are required and time is particularly valuable, uses d-c power to heat the bolometer element to a predetermined point. This point is so chosen that the galvanometer across the Wheatstone bridge indicates a balanced condition. This initial d-c power is read and noted. Next, the r-f power is applied and the bolometer element increases in resistance due to the heating effect of the additional current which causes the bridge to become unbalanced. To rebalance the bridge galvanometer, the d-c power is reduced sufficiently to cool the bolometer element to where its decreased resistance restores the balance. The difference in d-c power readings is equivalent to the r-f power being measured.

When an attenuating cable is placed between the power source and the bolometer it is convenient to measure the power in terms of db above a zero level of six milliwatts. In other words, suppose the power indicated by the bolometer is 1.2 milliwatts. This is —7 db. Now, if the cable attenuation is 10 db, the actual power output is —7 + 10 or 3 db.

Measurement of Pulsed Transmitters

It is often necessary to know the power output of a pulsed oscillator or transmitter, as for instance a transmitter employed to send out pulses for ionosphere soundings in determining layer heights. Transmitters for this purpose usually emit pulses of the order of several kilowatts, but since the percentage operating time is small the average power is relatively low. To determine the peak power, if both the width of the pulse and the repetition rate at which it occurs are known, it is only necessary to measure the average power and divide it by the pulse width multiplied by the repetition rate.

$$\text{Peak power} = \frac{\text{average power}}{\text{repetition rate} \times \text{pulse width in seconds}}$$

The pulse width should be carefully measured, otherwise a considerable error will result in calculating peak power output.

TABLE III

CHARACTERISTICS OF TUNG-SOL TYPE B-100 BOLOMETER ELEMENT

Characteristic	Rating
Resistance at 0.5 ma	*200 ohms (nominal)*
Maximum current, rms	*1.25 ma*
Optimum Bias Current, rms	*0.50 ma*
Sensitivity (1% change in resistance)	*4.5 microwatts*
Skin Effect to 10,000 mc	*5/16" dia. x 1½"*
Capacitance and Inductance	*Negligible (to 10,000 mc)*
Physical Dimensions (maximum(	*Negligible (below 1000 mc)*

References

1. Turner and McNamara—An Electron Tube Wattmeter—*Proc. I.R.E.*, Oct. 1930; also E. Peterson, Bell Telephone Labs., U. S. Patent 1,586,553.
2. Wallace—The Shielding of R-F Ammeters—*Proc. I.R.E.*, Jan. 1941.
3. Turner and Michel—An Electrodynamic Ammeter—*Proc. I.R.E.*, Nov. 1937.
4. Meahl—A Bearing-type H.F Electrodynamic Ammeter—*Proc. I.R.E.*, June 1938.
5. Nergaard—Measurement at Less Than 2 Meters—*Proc. I.R.E.*, Sept. 1936.
6. Strutt and Knol—Measurements of Currents and Voltages—*Proc. I.R.E.*, Dec. 1939.
7. Radio Instruments and Measurements—*Bureau of Standards Circular C74*, page 162.

U-H-F Communications Receiver

ALBERT H. CARR
Chief Engineer, Fada Radio and Electric Co., Inc.

The design and construction of an airport communications receiver to cover the frequency range of 109 to 144 mc, is discussed

EFFICIENT radio communication facilities are the backbone of modern airway network operation. In view of the tremendous strides that air transportation has taken during the past few years, authorities have felt the need for a more comprehensive, reliable and practical air traffic control system. Control over approaching aircraft has always constituted an active problem. Additionally, it has been further aggravated by the introduction of new elements of physical hazard due to increased size and weight of aircraft and increased numbers approaching a limited landing area.

Many of the disadvantages prevalent in present-day systems present definite limitations to the extent of the expansion of this control, which in turn would present a limitation to the expansion of air traffic itself. Thus a great need was created for the type of equipment about to be described.

Limitations

Basically, some of the limitations experienced with the present operating setup were:

1. Limitation of the number of channels available because of the frequency ranges employed.
2. An increase in the number of stations operating in this frequency range would result in an unendurable state of interference between different control towers, operating on the same frequencies, even though widely separated.
3. Inherent troubles experienced in this frequency range due to atmospheric noises could not be tolerated if reliable liaison was to be maintained.
4. Reliable communication demanded the employment of equipment from which fading, echo and other similar atmospheric effects were completely absent.

It was felt that these disadvantages could be overcome by operation within the ultra-high frequency range and although it presented some problems, of course, in so far as design was concerned, it had the following points very definitely in its favor:

1. Complete localization of transmissions. Inasmuch as this range is governed entirely by line of sight, the waves are not inclined to follow the curvature of the earth nor are they subject to deflection to the extent which the longer waves are.
2. Complete freedom from atmospheric disturbances as well as elimination of the fading and echo effects which at present are encountered on the more conventionally employed frequencies.

The advantages realized from these features are that a number of control towers may operate simultaneously on the same band of frequencies without interference to each other if they are located with a separation of 100 or more miles between them. This results in a definite localization of the sphere of control to within the area over which the control tower is the supreme arbiter. The reliability of air-ground liaison is definitely enhanced by the elimination of atmospheric disturbances, as well as fading and echo effects. Materially, this should result in increased safety of operation as well as greatly increasing the control facilities which a single control unit may reasonably and efficiently handle.

Basically, the model RUP Radio Receiving Equipment is designed to cover the frequency range of 109 to 144 megacycles, inclusive, in one continuous tuning range covering approximately 500 dial divisions.

Design Considerations

When this design was embarked on, considerable consideration was given to the employment of the super-regenerative type of receiver for operation within this frequency range. It was felt that there were many advantages of this type receiver which were desirable, namely, extremely high sensitivity in consideration of the number of tubes employed as well as the general ease of operation and construction of this type of equipment. However, it was felt that if proper care was given to the design, a superheterodyne receiver, which presents of course many additional advantages, could be satisfactorily operated within this tuning range with a consequent reduction in the number of tuning controls employed as well as much more stable operation. The much greater selectivity of the superheterodyne type of receiver was also a very large factor in determining the type of equipment ultimately to be designed. Therefore, it was felt that if proper care was given to the elementary phases of design the advantages of the superheterodyne type would far outweigh those of the super-regenerative type. Considerable advantage in noise reduction is of course achieved in this type of equipment as well as much greater frequency stability. Both of these factors also influenced the initial decisions.

General Description

The equipment is designed for mount-

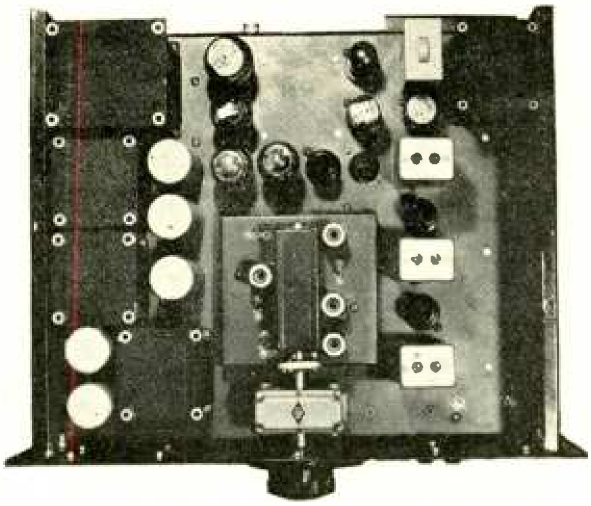


Fig. 2. Top view of new u-h-f communications receiver (experimental model)

ing a standard cabinet type relay rack. The main chassis of the receiver and power supply is formed of .062 steel, which is seam-welded to present a very rigid type of construction. The finish applied to the chassis has proved to be of some importance in the radio frequency section because of the frequency range employed. The initial finish consists of .002″ cadmium plate, followed by .002″ of copper plating. This has resulted in very good surface conductivity of the chassis and has served to keep the entire chassis at a more uniform potential. The exterior finish of blue glyptal is applied to protect the copper from corrosion.

The receiver as well as the power supply are mounted on a standard seven-inch relay rack panel which in turn carries all operating controls. The power supply for the receiver is an integral part of the chassis and is located in the left rear portion of it. The entire unit is enclosed within a dust cover which may readily be removed for inspection and maintenance. The speaker panel, which may be mounted either adjacent to or remote from the receiver portion of the equipment, is a separate seven-inch relay rack panel on which is mounted a six-inch permanent-magnet type dynamic speaker, together with the output coupling transformer. The receiver itself is a thirteen-tube superheterodyne of conventional design, but modified to meet certain rigid CAA specifications. Two voltage regulator tubes are employed in the equipment bringing the total number of tubes used to fifteen. Rugged construction together with excellent mechanical design and construction make this a piece of equipment which is capable of withstanding the arduous requirements of control tower operation. Front, top and below deck views of the equipment are shown in *Figs. 1, 2* and *3*.

Controls

The following controls are provided on the receiver front panel:

1. Tuning Control
2. R-F Gain Control
3. A-F Gain Control
4. Power on-off switch
5. Indicator Light
6. A.V.C. on-off switch
7. CONS, on-off switch
8. Phone Jack
9. Two fuse receptacles.

The gain controls are equipped with bar type knobs and switches are all of the standard toggle type.

Circuit Description

The circuits, both tuned and untuned, employed in the type RUP receiver are fundamentally those of the conventional superheterodyne receiver, encompassing such modifications as are necessary for high-frequency operation and to conform to CAA specifications. In the original model of this equipment, "hairpin" type single-turn inductances were used in all radio frequency circuits. These were, however, replaced in later models by this use of a more conventional spiral wound inductance. The radio-frequency circuits, of which there are four, including the oscillator, are tuned by means of a single gang condenser which is back-geared through a National NPW-O gear reduction drive to the 500-division National dial employed for tuning the equipment.

The intermediate-frequency amplifier circuits are of conventional design which, however, feature extremely high sensitivity coupled with an exceptional order of stability. Output circuits of the receiver are designed to feed into a 20,000 ohm load, which may consist of the speaker previously mentioned or a suitably loaded headphone circuit tapped at 600 ohms. A relay is provided in the output circuit to allow remote control of the output of the equipment. This relay is operated from a six-volt d-c source. A jack is provided for the headphones, which should be of the low-impedance (600 ohm) type to match the output circuit provided for moniting purposes. The schematic diagram of the complete equipment is shown in *Fig. 4*.

The following tubes are employed in the equipment in the positions designated below:

Circuit Position	*Type*	*Function*
V-1	9001	First R. F. Amplifier
V-2	9001	Second R. F. Amplifier
V-3	9001	Converter
V-4	9002	Oscillator
V-5	6AC7	First I. F. Amplifier
V-6	6AC7	Second I. F. Amplifier
V-7	6SL7	Detector in CONS
V-8	6SL7	First Audio & Noise Peak Limiter
V-9	6V6	Output
V-10	6SJ7	AVC
V-11	6SL7	CONS Control
V-12	84	Rectifier for output stage
V-13	80	Main Rectifier
V-14	VR-150	Voltage Regulator
V-15	VR-105	Voltage Regulator

Radio Frequency Circuit

Two radio-frequency amplifier stages are employed in the receiver in order to achieve the desired sensitivity, which is in the order of five microvolts for an output of ½ watt. The first radio-frequency amplifier, *V-1*, employs a 9001 pentode, and the radio-frequency

Fig. 1. Front view of experimental model of receiver

signal is fed from a 70-ohm concentric line, which is plugged into *J-1*, the input of the receiver. A trimmer condenser is provided across this input circuit so that the circuit may be tuned to resonance within the frequency range of the receiver.

The output of the first radio-frequency amplifier is coupled by means of a tuned circuit *L-2, C-6,* to the grid of the second radio frequency amplifier stage through a coupling condenser *C-19*. Resistors *R-5* and *R-6* are provided in this circuit in order to properly load the circuit to provide uniform amplification over the entire tuning range.

A sensitivity control *R-4* in the cathode circuit of *V-1* is provided in order to control the sensitivity of the receiver circuits and to provide for the adjustment of the sensitivity to a constant or reference value at any frequency within the range of the receiver.

The second radio-frequency amplifier *V-2,* which is similar in most respects to the first radio-frequency amplifier, is coupled to the converter *V-3* by means of a coupling condenser *C-20*.

The converter circuit and its associated components, which include a Hartley oscillator *(V-4)* circuit, comprise the frequency-conversion portion of the equipment. Here the incoming radio frequency signal amplified through *V-1* and *V-2* is fed into one portion of *V-3*, while the local oscillator signal generated by *V-4* is fed into another portion of *V-3*. Screen-grid injection is employed and every effort has been made to maintain the value of the oscillator voltage constant by means of slight loading of the circuit through the medium of the relatively low impedance of the cathode-coupling point on the oscillator coil.

Complete and satisfactory single-dial tuning operation is achieved through the medium of the four-gang condenser and the National NPW dial through its associated gear box. No additional tuning controls for bringing any receiver circuits or input circutis to resonance are provided. Careful alignment of all radio-frequency circuits, as well as the excellent design achieved therein, make this type of operation entirely feasible within this frequency range.

Frequency stability is a particularly outstanding feature of this receiver. After a preliminary warm-up period of four hours, the resonant frequency does not change more than .01% during a period of four hours at constant room temperature and humidity, and the resonant frequency does not change more than .05% during a corresponding period with a variation in ambient temperature from —10 to +50 degrees. It is felt that this frequency stability is more than ample considering the stability of the transmitters which will be employed in this type of operation as well as the possibility of drift emanating therefrom.

I-F Circuits

The i-f amplifier in this receiver is conventional in circuit design *V-5* is the first i-f amplifier and *V-6* the second.

The i-f transformers employed deserve special mention, however, due to their relatively high-gain characteristics coupled with a rather broad tuning characteristic which is desirable for the type of operation which it was hoped to achieve. The band-pass characteristic of this amplifier is in the order of 80 kcs wide at 2 × down, which has been found ample for most communications work falling within this frequency range.

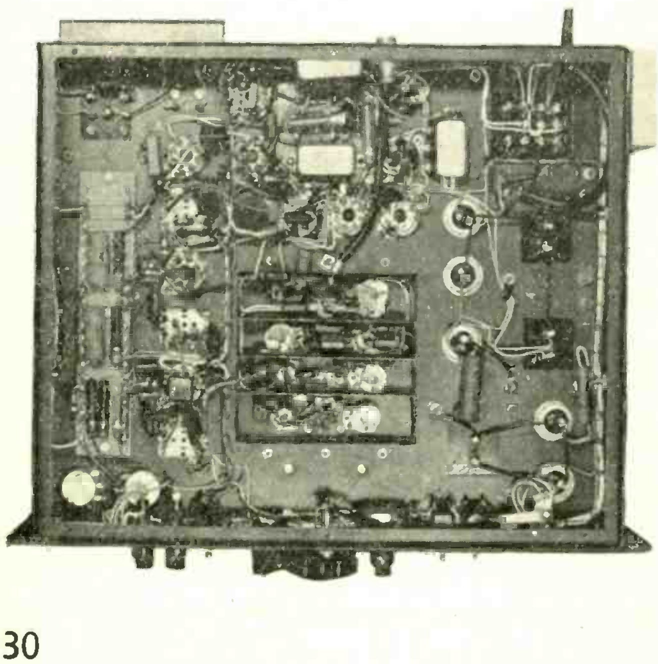


Fig. 3. Under chassis view of experimental model of set

Detection

A conventional diode system of detection is employed in this equipment resulting in the audio output voltage being directly proportional to the percentage of modulation of the R. F. input signal for modulations falling within the range of 5 to 100%. The noise limiter employed is of the shunt type which automatically adjusts itself to any carrier level between approximately 20 microvolts and 1 volt and is so adjusted that effective limiting action, i.e., (limitations of noise peaks) takes place when their amplitude exceeds that corresponding to 100% modulation.

Automatic Volume Control

Automatic volume control is, of course, provided and may be cut in or out at will by means of a switch provided on the front panel. With the AVC switch in the ON position and the R-F Gain Control at maximum, the power output does not vary over three decibels when a modulated r-f signal of 20 microvolts is applied and the a-f Gain Control adjusted so that 50 milliwatts audio output is achieved, compared to increasing the input to one-half a volt. In other words, over the range of from 20 microvolts to one-half volt input, the power output of the receiver does not vary more than three decibels.

Second Detector—CONS—Noise Peak Limiter

The first audio amplifier, which employs the second section of the type 6SL7G as a noise peak limiter, is conventional as well as the output stage which employs a type 6V6 tube. The volume control placed in the input of the first audio amplifier permits attenuation of the audio amplifier from its maximum output down to 1 milliwatt or less. This gain control is so tapered that, in the absence of an AVC or CONS action an approximate logarithmic increase in audio output is achieved as the control knob is rotated clockwise.

Noise Suppressor

The carrier-operated noise suppressor circuit employed in this receiver is conventional in design insofar as it renders the receiver inoperative until the input signal has increased in amplitude to a certain definite value. This value is of course a function of the setting of the sensitivity control; however, with the sensitivity control set

[*Continued on page 60*]

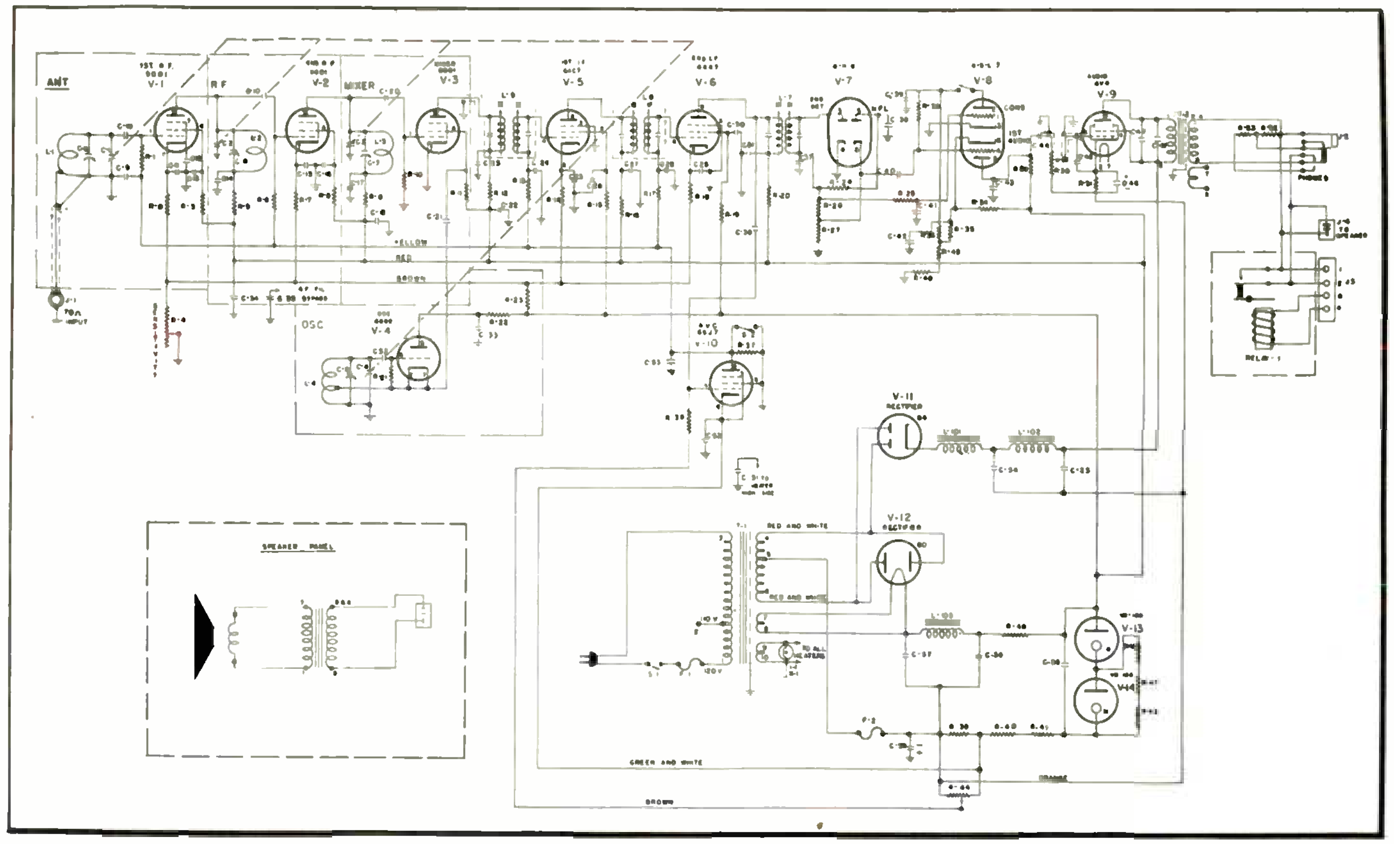


Fig. 4. Schematic diagram of communications receiver

SYMBOL	DESCRIPTION
R-1	1 megohm, ½ watt, 10%
R-2	1000 ohm, ½ watt, 10%
R-3	250,000 ohm, ½ watt, 10%
R-4	5,000 ohm, watt, 10%, ww. pot.
R-5	1,000 ohm, ½ watt, 10%
R-6	1 megohm, ½ watt, 10%
R-7	1,000 ohm, ½ watt, 10%
R-8	150,000 ohm, ½watt, 10%
R-9	1,000 ohm, ½ watt, 10%
R-10	1 megohm, ½ watt, 10%
R-11	1 megohm, ½ watt, 10%
R-12	1000 ohm,½ watt, 10%
R-13	1 megohm, ½ watt, 10%
R-14	250 ohms, ½ watt, 10%
R-15	40,000 ohms, ½ watt, 10%
R-16	1000 ohms, ½ watt, 10%
R-17	1 megohm, ½ watt, 10%
R-18	250 ohms, ½ watt, 10%
R-19	40,000 ohms, ½ watt, 10%
R-20	1000 ohms, ½ watt, 10%
R-21	47,000 ohms, ½ watt, 10%
R-22	6800 ohm, ½ watt, 10%
R-23	160,000 ohms, 1 watt, 10%
R-24	1 megohm, ½ watt, 10%
R-25	1 megohm, ½ watt, 10%
R-26	100,000 ohm, ½ watt, 10%
R-27	100,000 ohm, ½ watt, 10%
R-28	1 megohm, ½ watt, 10%
R-29	220,000 ohms, ½ watt, 10%
R-30	500,000 ohms potentiometer
R-31	250 ohms, 2 watt, 10%
R-32	20,000 ohms, 10 watt, 10%, ww.
R-33	600 ohms, ½ watt, 10%
R-34	47,000 ohms, 2 watt, 10%
R-35	200 ohms, ½ watt, 10%
R-36	100,000 ohm, ½ watt, 10%
R-37	1 megohm, ½ watt, 10%
R-38	4 megohm, ½ watt, 10%
R-39	200 ohms, 2 watt, 10%
R-40	200 ohms, 2 watt, 10%
R-41	250 ohms, 2 watt, 10%
R-42	22,000 ohm, 2 watt, 10%
R-43	250 ohms, ½ watt, 10%
R-44	10,000 ohms, potentiometer
R-45	10,000 ohms, ½ watt, 10%
R-46	1750 ohms, 20 watt, 10%, ww.
R-47	150 ohms, ½ watt, 10% ww.
R-48	10,000 ohms, ½ watt, 10%

SYMBOL	DESCRIPTION
C-1	P/O 4 section variable
C-2	P/O 4 section variable
C-3	P/O 4 section variable
C-4	P/O 4 section variable
C-5	25 mmf. variable
C-6	25 mmf. variable
C-7	25 mmf. variable
C-8	25 mmf. variable
C-9	500 mmf. 500 V., 10%, mica
C-10	500 mmf. 500 V., 10%, mica
C-11	500 mmf. 500 V., 10%, mica
C-12	500 mmf. 500 V., 10%, mica
C-13	500 mmf. 500 V., 10%, mica
C-14	500 mmf. 500 V., 10%, mica
C-15	500 mmf. 500 V., 10%, mica
C-16	500 mmf. 500 V., 10%, mica
C-17	500 mmf. 500 V., 10%, mica
C-18	500 mmf. 500 V., 10%, mica
C-19	100 mmf. 500 V., 10%, mica
C-20	50 mmf. 500 V., 10%, mica
C-21	50 mmf. 500 V., 10%, silver mica
C-22	500 mmf. 500 V., 10%, silver mica
C-23	.01 mfd. 500 V., 10%, mica
C-24	.01 mfd. 500 V., 10%, mica
C-25	.01 mfd. 500 V., 10%, mica
C-26	.01 mfd. 500 V., 10%, mica
C-27	.01 mfd. 500 V., 10%, mica
C-28	.01 mfd. 500 V., 10%, mica
C-29	.01 mfd. 500 V., 10%, mica
C-30	.01 mfd. 500 V., 10%, mica
C-31	.025 mfd. 600 V., 10%, mica
C-32	250 mmf. 500 V., 10%, mica
C-33	250 mmf. 500 V., 10%, mica
C-34	.01 mfd. 500 V., 10%, mica
C-35	250 mmf. 500 V., 10%, mica
C-36	100 mmf. 500 V., 10%, mica
C-37	.01 mfd. 500 V., 10%, mica
C-38	.1 mfd. 600 V., 10%, paper oil filled p/o 3 sect.
C-39	.1 mfd. 600 V., 10%, paper oil filled p/o 3 sect.
C-40	.01 mfd. 500 V., 10%, mica
C-41	.1 mfd. 600 V., paper oil filled p/o 3 sect.
C-42	1 mfd. 600 V., 10%, paper oil filled
C-43	100 mmf. 500 V., 10%, mica
C-44	.01 mfd. 500 V., 10%, mica
C-45	.001 mfd. 500 V., 10%, mica
C-46	16 mfd. 150 V., electrolytic
C-47	.02 mfd. 500 V., 10%, mica
C-48	Deleted
C-49	Deleted
C-50	Deleted
C-51	.01 mfd. 500 V., 10%, mica
C-52	.01 mfd. 500 V., 10%, mica
C-53	.15 mfd. 600 V., 10%, paper oil filled
C-54	4 mfd. 600 V., 10%, paper oil filled
C-55	4 mfd. 600 V., 10%, paper oil filled
C-56	4 mfd. 600 V., 10%, paper oil filled
C-57	4 mfd. 600 V., 10%, paper oil filled
C-58	4 mfd. 600 V., 10%, paper oil filled
C-59	16 mfd. 150 V., electrolytic
C-60	Deleted
C-61	.01 mfd. 500 V., 10%, mica

COILS

L-1	1st R.F. coil
L-2	2nd R.F. coil
L-3	Converter R.F. coil
L-4	Oscillator coil
L-5	1st I.F. transformer
L-6	2nd I.F. transformer
L-7	3rd I.F. transformer
L-101	Filter reactor, 10 H, 125 MA
L-102	" " " " " "
L-103	" " " " " "
T-1	Power transformer, 600 V CT @ 125 MA; 6.3 v @ 4 amp.; 5 v @ 2 amp.
T-2	Audio transformer

SWITCHES

S-1	Power switch, SPST
S-2	AVC switch, SPST
S-3	CONS switch, SPST

MAGNETRON
Microwave Oscillators

R. H. MIDDLETON
Engineer, Templetone Radio Co.

WHILE spark gaps were used for generation of microwaves back in 1890 by Hertz, Lecher, and others, the present-day trend is toward continuous wave generators.

Of these, the most useful are oscillators of the magnetron type. The magnetron is undergoing rapid and dramatic evolution, and is challenged only by the Klystron developed by the Varian brothers.

One of the most interesting developments concerns tubes in which the resonant element is but a fraction of the anode structure and which are capable of realizing power outputs up to 300 watts.

Operation

The conventional magnetron is illustrated in *Fig. 1*. The space current is controlled by the positive potential applied to the anode as well as by magnetic lines of force parallel to the cathode.

When the magnetic field is raised to a certain critical value, electrons emitted from the cathode and drawn to the anode by the electrostatic field no longer are able to reach the anode; this is due to the acceleration experienced by the electrons in the magnetic field, introducing a component of force which results in a circular path of travel. Indeed, electrons may be caused to travel in a diminishing spiral, returning to the cathode and inducing back-heating effects.

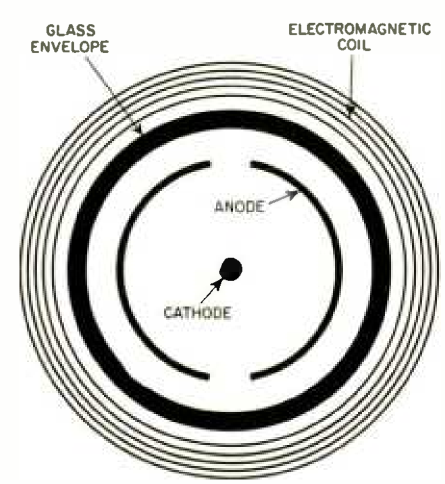


Fig. 1. Conventional magnetron

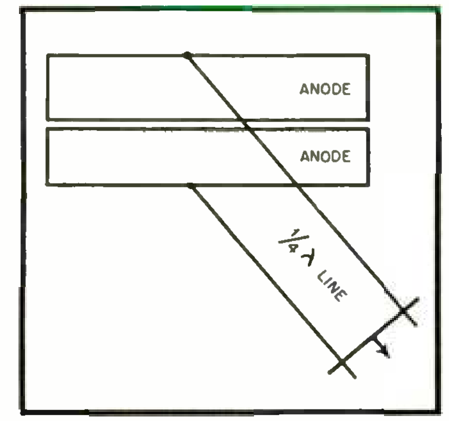


Fig. 2. Analogous circuit of magnetron

With the circuit of *Fig. 2*, operating in conjunction with a magnetic field near the critical (cut-off) value, a negative resistance is seen by the line which accordingly oscillates and develops power at its resonant frequency.

It will be appreciated that the highest frequency which may be attained by such a tube must be limited by the dimensions of the anode structure, and that the highest power which may be dissipated must be in the inverse relation. Thus a conflict between power and frequency becomes at once apparent. In the present effort to realize appreciable power in the microwave range (10^3 to 10^5 mc), the line which has found extensive application in the UHF region gives way to the cavity.

The concept of the line is useful, as it stands in a position intermediate to the resonant *LC* circuit and the cavity. Whereas, in classical theory, electrical energy is regarded as flowing in wires and plates of capacitors, analysis of lines has led to the point of view of guided energy. The field between the conductors of the line is now regarded as the important aspect of the circuit, while the conductors do no more than point out a direction for the fields to travel.

If one of the conductors of the line is developed into a tube enclosing the other conductor, we arrive at the concentric line. It has been found possible to take a further step, removing the central conductor and arriving at the wave guide, or in another guise the cavity resonator. In the primary analysis, cavity resonators need be no more mysterious than resonance of sound frequencies in a rain barrel. In the case of sound the agitated air in the barrel represents a field of sonic energy. The resonant rise of energy at the natural frequency of a cavity resonator is quite similar, if the analogy is not pressed too far.

[*Continued on page 74*]

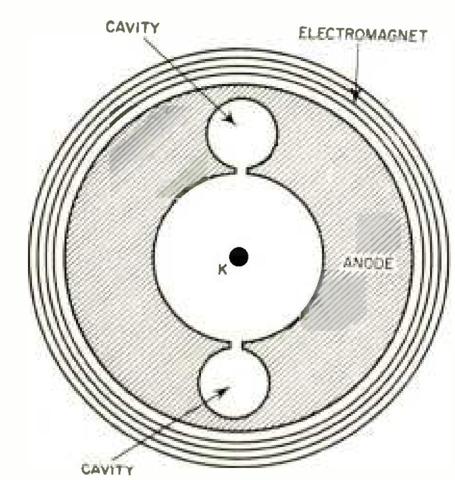
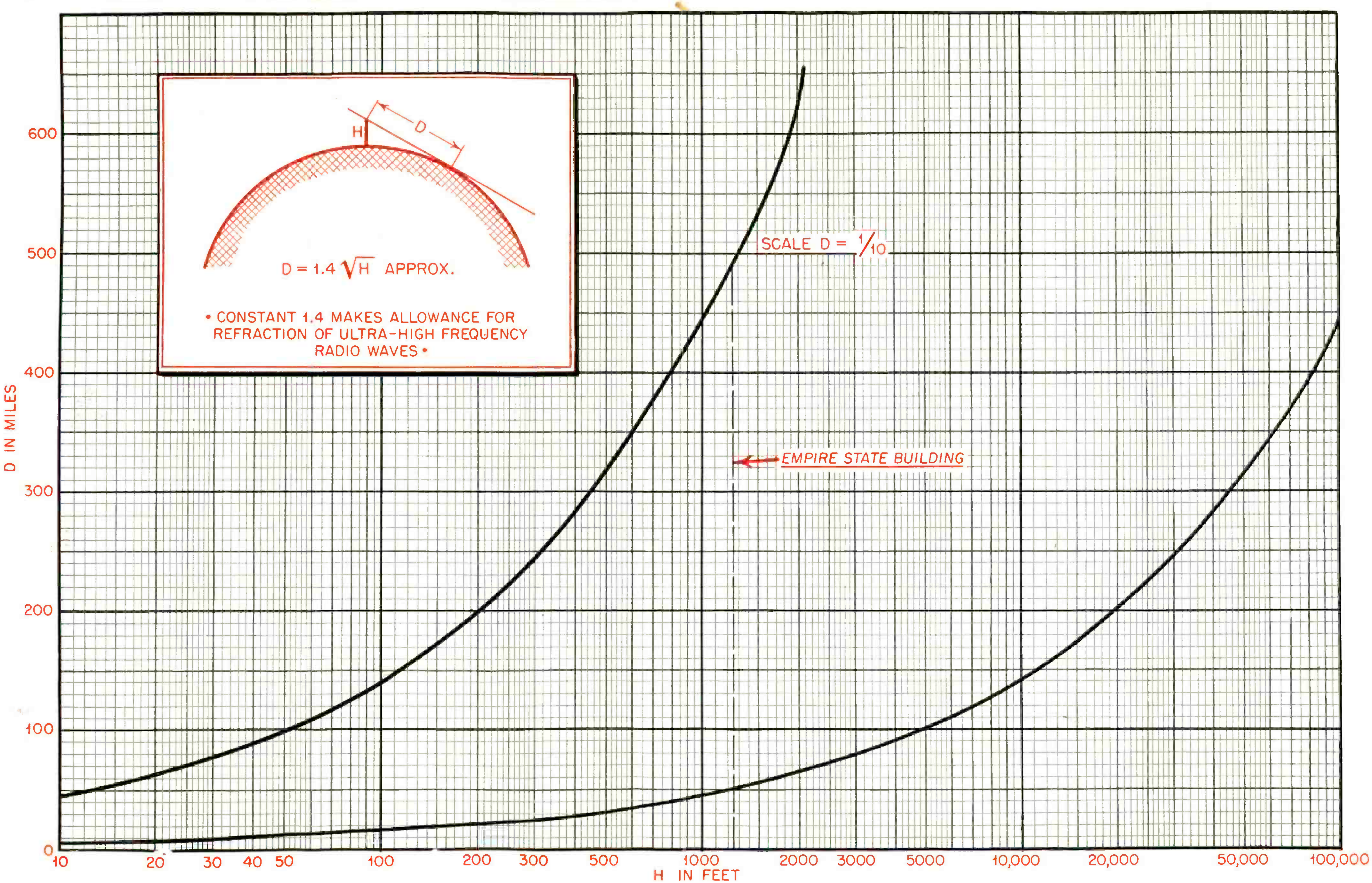


Fig. 3. Cavity resonator magnetron

OPTICAL PATH CHART

Path of Quasi-Optical Waves



RADIO DESIGN WORKSHEET

NO. 29

VECTOR RELATIONS; CONSTANT CURRENT CIRCUITS; POWER SUPPLY NOISE REDUCTION; IMPEDANCE RELATIONS OF AUDIO TRANSFORMER

VECTOR RELATIONS

One interesting property of vectors is that the vector sum of two equal vectors differing in phase by an angle other than 0 or π radians always differs in phase from the difference of the two equal vestors by π_2 radians. To show this, let a be one vector and b the other, as shown in *Fig. 1*.

Let I_1 = vector sum of a and b
Let I_2 = vector difference of a and b
Let θ = phase difference between a and b
$I_1 = a^2 + b^2 + 2ab \cos \theta$
$I_2 = a^2 + b^2 - 2ab \cos \theta$
Let $\theta = \pi/2$ radians

Then I_1 bisects θ and differs from a and b by $\pi/4$ radians.
I_2 bisects the angular difference between $-b$ and a or differs from $-b$ by $\pi/4$ radians.
In any case I_1 bisects θ and I_2 bisects $\pi - \theta$.
Whence the angle α and between I_1 and I_2

$$\text{is } \alpha + \frac{\pi - \theta}{2} + \frac{\theta}{2} = \pi$$

$$2\alpha + \pi - \theta + \theta = 2\pi$$

$$2\alpha = \pi$$

$$\alpha = \pi/2$$

CONSTANT CURRENT CIRCUITS

Fig. 2 shows a common constant circuit which has found much use in remote controlled unattended wire and fixed point-to-point radio stations. Such a circuit might be used to supply filament current, for example, over a wire line. It was first developed for use in series arc light systems.

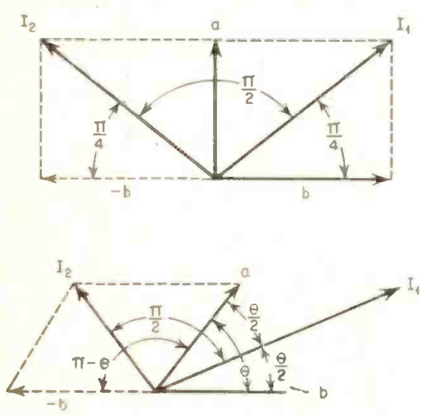


Figure 1

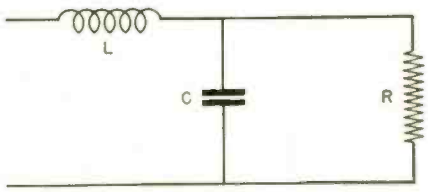


Figure 2

In order to determine the relations that must exist between the series arm and shunt arm, refer to *Fig. 3*. Here series arm A and shunt arm B are generalized impedances. To determine the mathematical relations we can use Thévenin's Theorem, which states that a network containing a single source of voltage and a load impedance connected across two terminals may be replaced, so far as the load impedance is concerned, by a voltage in series with an impedance. This voltage is the one which would appear across the load terminals with the load removed and the impedance is that looking into the load terminals with the source of voltage short circuited. The open-circuit voltage *(R disconnected in Fig. 3)* across terminals 3, 4 is:

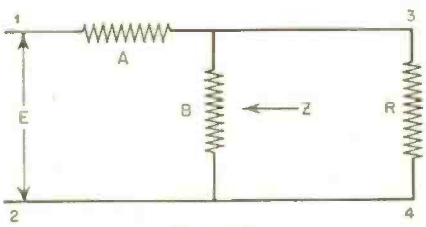


Figure 3

$$E_1 = BI_1 = BE/A + B$$

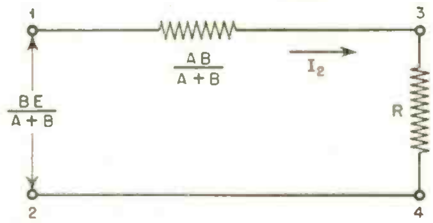
The impedance E looking into terminals 3 and 4 with E short circuited is:

$$Z = AB/A + B$$

Whence the equivalent circuit of *Fig. 3* is that shown in *Fig. 4*.

$$I_2 = \frac{BE/A+B}{(AB/A+B)+R}$$

$$= \frac{BE}{AB+R(A+B)} \quad \ldots.(1)$$



Let A be an inductance and B a capacitance. At the resonat frequency

$$A + B = 0$$

Whence equation (1) becomes

$$I_2 = \frac{BE}{AB} = \frac{E}{A} = \frac{E}{j\omega L}$$

Thus the current is determined by the magnitude of the applied voltage and the impedance of the series arm and is independent of the value of R. The series arm might have been a capacitance, as shown in *Fig. 5*, in which case

$$I_2 = jE\omega C$$

Which holds when:

$$j\omega L = 1/j\omega c \text{ or } \omega^2 LC = 1 \ldots\ldots(2)$$

It is obvious that *Fig. 2* is also a low-pass filter circuit, the cutoff frequency

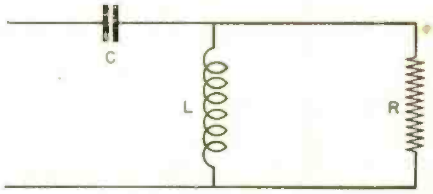


Figure 5

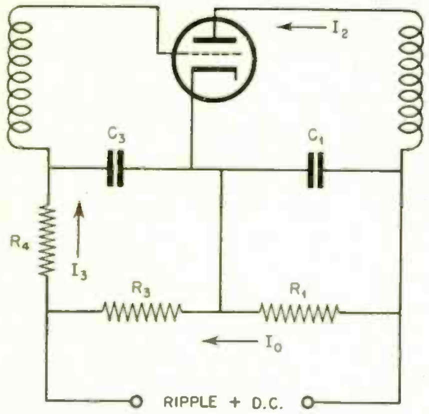


Figure 6

of which is

$$f = 1/\pi\sqrt{LC}$$

But from (2) we have

Resonant frequency $= f' = 1/2\pi\sqrt{LC}$

Therefore, $f'/f = 1/2$, or $f' = f/2$

That is, the low-pass filter circuit of *Fig. 2* is a constant current circuit at ½ the cutoff frequency.

POWER SUPPLY NOISE REDUCTION

A number of interesting circuits have been devised to reduce power supply noise now in amplifier circuits. Some have been sufficiently practical to be widely used. Many others have been critical in adjustment and have had little use in apparatus. In general, circuits involving a balancing of voltages or phase or both have been too critical in adjustment for general usage. One circuit which has been widely used is shown in *Fig. 6*. It does involve a balance of voltages but the balance is broad and considerable improvement can be shown in noise reduction even though the circuit is out of balance by 20%.

μ = amplification factor of tube
R_p = plate impedance of tube
ε = ripple voltage
I_o = ripple current

$$Xc_1 = \frac{1}{2\pi fC_1} = \frac{1}{\omega C_1}$$

$$Z = -\frac{jXc_1\,R_1}{R_1 - jXc_1}$$

Applying Kirchhoff's law to the circuit of *Fig. 6* yields:

$$I_3\,(R_3+R_4+Zc_3) = R_3\,I_o$$
$$I_o\,(R_3+Z_1) + I_3\,Z_1 = \varepsilon$$
$$I_o\,Z_1 + I_2\,(R_p+Z_2+Z_1) = \mu\,Zc_1\,I_2$$

at minimum ripple in plate circuit of tube:

$$I_2 = 0$$

Whence

$$I_oZ_1 = \mu Zc_1I_3$$

And:

$$R_3/Z_1 = (R_3+R_4+Zc_3)I_3$$

Admittance:

$$Y_1 = (1/R_1) - j\omega C_3$$
$$Y_3 = -j\omega C_3$$
$$\mu R_3Y_1 = (R_4+R_3+Zc_3)Y_3$$
$$\mu R_3\,[(1/R_1)-j\omega C_1] = -j\omega C_3(R_3+R_4) + 1$$

and

$$\frac{C_1}{C_3} = \frac{1}{\mu}\,[(R_1/R_3) + 1]$$

Whence: $R_1 = \mu R_3$

Other balances can be had which will reduce the noise equally well but are somewhat more critical. One of these involves reducing R_4 to zero and

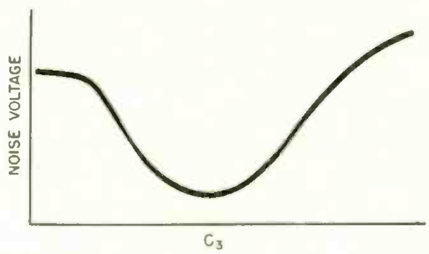


Figure 7

replacing C_1 and C_3 with a resistor and capacitor in series.

IMPEDANCE RELATIONS OF INTERSTAGE AUDIO TRANSFORMER

The secondary winding of an interstage or input transformer is customarily terminated in a vacuum tube, which has a complex input impedance. In the audio range this impedance can be considered as a positive resistance in series with a capacitance. The equivalent circuit of an interstate transformer is shown in *Fig. 8*.

Z_1 represents the primary impedance with the secondary transformer winding open circuited. Z_2 represents the impedance looking into the transformer secondary with the primary on open circuit. Thus:

$$Z_1 = R_2 + jX_1$$
$$Z_2 = R_2 + jX_2$$

The turns ratio of the transformer is:

$$N = \sqrt{L_2/L_1} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

At low audio frequencies the input impedance of the tube fed by the secondary is very high. Thus to a first approximation the secondary termination for very low audio frequencies can be considered infinite. Therefore the impedance looking into the primary at low audio frequencies is the same (to a few approximations) as if the secondary were on open circuit. That is:

$$Z_1 = R_1 + jX_1$$
$$I_1 = E_1/R_p+jX_1 \text{ (to a first approximation)}$$

Again, at low frequencies Z_2 can generally be neglected in comparison with Z_3 without appreciable error. And we have:

$$I_2 = \omega ME_1/(R_p+jX_1)Z_3 \quad \ldots\ldots (2)$$

The coefficient of coupling of the transformer is by definition:

$$K = M/\sqrt{L_1\,L_2}$$

At unity coupling:

$$K = 1$$
$$M = \sqrt{L_1\,L_2}$$
$$\omega M = \sqrt{X_1\,X_2}$$

From (1) we have:

$$N^2 = X_2/X_1$$
$$N^2X_1^2 = X_2\,X_1$$
$$NX_1 = \sqrt{X_1\,X_2} = \omega M$$

And, from (2)

$$I_2 = \omega ME_1/(R_p+jX_1)Z_3 = NX_1E_1/(R_p+jX_1)X_3$$
$$E_2 = Z_3I_2 = NX_1E_1/(R_p+jX_1) = \omega ME_1/R_p + jX_1$$

let:

$$\beta = E_2/E_1$$
$$\beta^2 = N^2X_1^2/(R_p+jX_1)^2 = \omega^2M^2/R_p^2 + X_1^2 = N^2X_1^2/R_p^2 + X_1^2 \quad \ldots\ldots (3)$$

It may be shown that to a first approximation

$$\frac{\omega^2M^2}{X_1} = N^2X_1 = \alpha \quad \ldots\ldots\ldots (4)$$

And it follows that, from (4)

$$X_1 = \alpha/N^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\beta^2 = \frac{N^2X_1^2}{R_p^2+X_1^2} = \frac{\alpha X_1}{R_p+X_1^2} \quad \ldots\ldots (6)$$

Substituting (5) in (6) yields

$$\beta^2 = \frac{\alpha^2}{N^2(R_p^2+X_1^2)}$$

Multiplying by $\frac{N^2}{N^2}$

$$\beta^2 = \frac{N^2\alpha^2}{N^4(R_p^2+X_1^2)} = \frac{N^2\alpha^2}{N^4R_p^2+\alpha^2}$$

To determine a maximum voltage ration, let:

$$\frac{\delta}{\delta X}(\beta^2) = 0$$

Whence:

$$N^2\alpha^2(4N^2R_p^2) = 2N\alpha^2(N^4R_p^2+\alpha^2)$$

Therefore β is a maximum when

$$\alpha = N^2R_p$$
$$\text{or } R_p = X_1$$

For higher frequencies, say ω_1 we have:

$$X_1 = \omega_1\,L_1 = \frac{\omega_1}{\omega}\,R_p$$

$$\beta^2 = \frac{N^2R_p^2\;\omega_1/\omega^2}{R_p^2\,(\omega^2+\omega_1^2/\omega^2)}$$

And $\beta = N$ when ω_1 is very much greater than ω. It therefore follows that the frequency at which $X_1 = R_p$ holds should be well below the desired low frequency cutoff of the transformer.

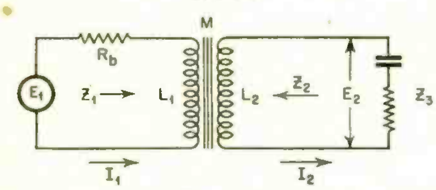


Figure 8

New Products

NEW L-F TRANSMITTER

Federal Telephone and Radio Corporation has developed a low-frequency transmitter for use in Arctic regions by the CAA. It is necessary to use low frequencies in this area because they are not seriously affected by magnetic storms, so prevalent in these regions, which make communication at high frequencies extremely uncertain.

The various units comprising this transmitter include an Exciter Unit, Main Rectifier Unit, and Antenna Tuning House. The entire transmitter operates from a 230-volt, 3-phase, 60-cycle power supply. Complete remote control of the transmitter for single-frequency operation can be accomplished through the use of a dial and relays similar to those used on home telephones.

The Exciter Unit, shown in *Fig. 1,* is a complete, continuous wave transmitter in itself and can be used independently of the Power Amplifier and Main Rectifier Unit. It will deliver at least 500 watts of power on any frequency between 80 and 200 kilocycles. Keying speeds up to 200 words per minute are obtained through the use of an electronic keyer.

The Power Amplifier Unit is shown in *Fig. 2.* This unit is normally used at one operating frequency but it can be set up for use on any frequency in the range of the Exciter Unit. At any operating frequency within this range it will deliver

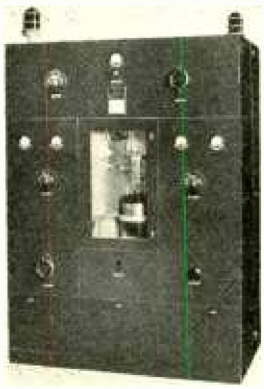


Figure 1

10 kilowatts of power. This output is obtained through the use of a single, Type 892R, tube with conventional grid and plate tuning circuits. Since this tube is of the air-cooled type, the danger of freezing, that would be present with a water-cooling system, is eliminated.

The Main Rectifier Unit (*Fig. 3*) employs 6, Type 872A, mercury-vapor rectifier tubes in a conventional three-phase, full-wave circuit. It supplies all of the plate power required by the Power Amplifier Unit. Included in this unit are the contactors required for starting the rectifier and for remote control.

Each of the three transmitter units is provided with convenient terminal boards and is arranged so that interconnecting

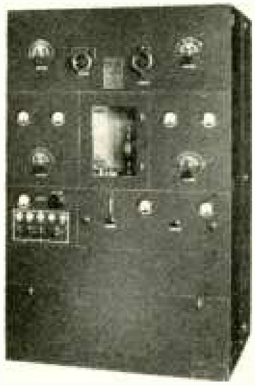


Figure 2

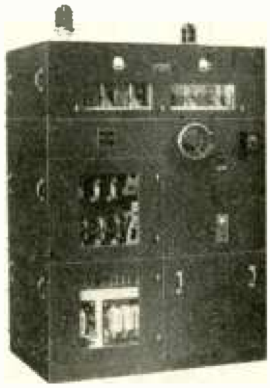


Figure 3

leads can be placed in sheet metal ducts located in the floor. The radio-frequency connection between the Exciter Unit and the Power Amplifier Unit can be made with a two-conductor, shielded r.f. cable placed in these same ducts. Connections to the Antenna Tuning House can be made with a flexible coaxial cable. Both of these cables have a characteristic impedance of 70 ohms.

The antennas commonly used with this transmitter are of the flat-top type and their effective lengths are considerably less than a quarter wave. Their effective ca-

To properly tune these antennas, considerable loading is required and for efficient operation this loading should intro-

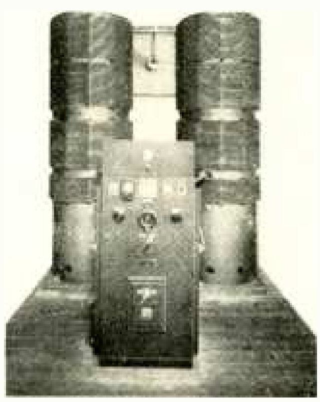


Figure 4

duce little loss in the antenna circuit. The inductors, shown in *Fig. 4,* have been designed to meet these conditions and include a number of features which are normally disregarded at higher radio frequencies. Their Q at the operating frequencies is at least 1500. Losses, which would arise if the materials normally used to construct a building entered the field of the Inductors, are kept to a minimum by surrounding the inductors with a Faraday screen.

Some of the circuit details employed in the equipment shown may appear quite novel to those accustomed to high-frequency equipment. For example, all tuned circuits are adjusted by means of variometers. If variable capacitors were employed for this purpose, they would be either excessively large or would give only a very limited tuning range.

NEW ACME CATALOG

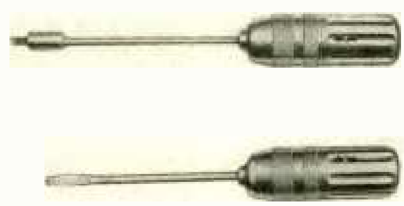
A new, standard size, 8½ x 11, two-color illustrated catalog entitled Radio Transmission Transformers has been prepared for engineers and designers by The Acme Electric & Mfg. Co. of Cuba, New York.

This new catalog lists specifications and other essential data on plate supply transformers, both air-cooled and oil insulated types; filament transformers, high leakage-reactance transformers, filter reactors, interstage transformers, and plate modulation transformers.

TORQUE DRIVER

Said to completely eliminate all danger of over or under-tightening, thread stripping, material-damaging, a new torque screw and bolt driver has been announced by Richmont, Inc., 215 W. 7th Street, Los Angeles. It is 7¾" long, with a 1.30" diameter handle.

This new driver, known as the Livermont Roto-Torq, may be adjusted to any torque desired between 1 inch pound and



25 inch pounds for setting screws, small nuts, bolts, etc. Because it disengages itself to the proper torque, it is impossible for the operator to tighten beyond the prescribed fit or tightness.

The mechanism operates on a new spring principle and is not to be confused, it is said, with a clutch, cam or friction principle. Torque tolerances are very close and the torque is not influenced by excessive oil or other normal foreign material, nor by the way it is held or used by the operator.

[*Continued on page 58*]

CRYSTAL PHONOGRA

ROY DALLY
Consulting Engineer, Electrovox Corporation

An analysis of the characteristics of crystal pickups and their applic

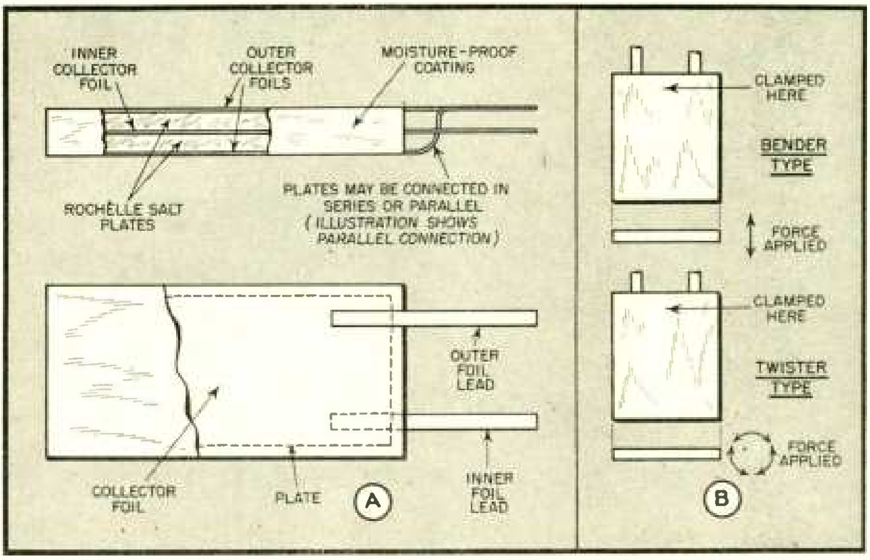


Fig. 1. In (a), bimorph crystal construction. Direction of applied force in bender and twister types is shown in (b)

THE MOST IMPORTANT and, in many respects, the most satisfactory phonograph pickup device in use today makes use of a Rochelle salt crystal element for generation of signal voltage. The completed assembly is known as a crystal cartridge.

The elements may be had in a variety of sizes and shapes, the practical result of which is a variation of capacity, hence, impedance. Thus we find in use elements which vary in impedance from 75,000 ohms to 225,000 ohms. measured at 1000 cycles.

Rochelle salt elements are subject to certain temporary changes of characteristics with changes in temperature, the most important of which is an increase of impedance with increase of temperature. Prolonged exposure to ambient temperatures in excess of 130 degrees F. will usually cause a permanent change in characteristics, so some thought should be given to proper cabinet ventilation in radio-phonographs, that tube heat be not permitted to rise and concentrate in the closed phonograph compartment.

Humidity Protection

Since Rochelle salt is soluble in water, the element is carefully coated to avoid absorption of moisture and to prevent dehydration as well, since a certain amount of moisture content is essential to proper operation.

The majority of elements in use are known as bimorphs which, as the word indicates, are made up of two plates, cemented together with a conducting metallic foil between. Such construction provides a great deal more stability in characteristics, particularly from a temperature standpoint, and increased sensitivity as well. *Fig. 1 (a)* illustrates a bimorph element.

Bimorph Types

Bimorph elements are usually supplied in two types. commonly known as benders and twisters. Each has its own particular advantages, depending on the mechanical forces to be applied, and the choice should be made accordingly. Both have been used in pickup construction, with the twister or torsional type the most acceptable. See *Fig. 1 (b)*.

A conventional crystal cartridge assembly is shown in *Fig. 2 (a)*. A housing, or half-shells, to complete the assembly is not shown. The assembly consists of a crystal element, two mounting blocks, one clamp rubber, one or two damping blocks, a chuck, two rubber sleeve bearings, a needle screw and a needle. Half shells provide proper clamping of the bearings, the damping blocks and the mounting blocks. The crystal used is of the torsional type.

In operation, the mounting blocks secure the crystal element against any appreciable loss of torsional force applied to the opposite end: they do, however, permit vertical motion of the free end of the element so that strains in assembly will not cause damage. The mounting blocks are of resilient material, preferably with some damping ability. The choice of material is important, and will be given consideration later.

The chuck, usually of die-cast metal, is slotted in such a way that by means of a thin sheet of rubber, the free end of the element is resiliently held in the chuck, and torsional force appearing in the chuck is thus transferred to the element. Damping blocks, resilient material with great damping ability, are held by pressure between flat faces of the chuck and the half shells, which are not shown. One or two such blocks may be used, dependent upon desired characteristics. Two rubber bearings clamped by the half-shells surrounding round portions of the chuck, limit substantially all motion of the chuck other than torsional. The needle screw secures the needle to the chuck. Conventional lateral cut records impart a reciprocating motion to the needle point, which appears in the chuck as a torsional force, being in turn transmitted to the element through the clamp rubber, and hence a proportional voltage is generated. *Fig. 2 (b)* illustrates a conventional bender type assembly.

Mechanical Resonance

Now that we have the fundamentals covered, let us see what complications can occur, even in so simple an assembly. We assume that the pickup is to cover the frequency range of from

PH PICKUPS

ation in reproducing apparatus

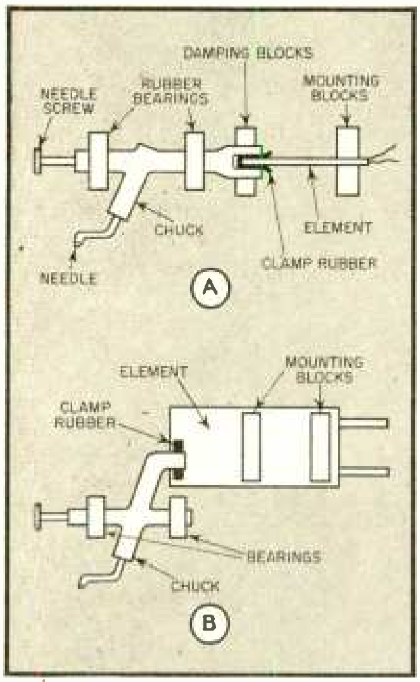


Fig. 2. Conventional crystal cartridge and, (b), bender type assembly

40 to 10,000 cycles, that it will be a torsional type, and that the needle is perfect, in that it will act only as a connecting link between the record groove and the chuck, without adding to or subtracting anything whatsoever from the groove characteristic. A record groove is not a simple thing; quite to the contrary, it is extremely complex, since the sound to be reproduced is made up of many fundamental frequencies and their harmonics, at any one given instant of time. A reciprocating motion is imparted to the needle point by the groove, and the forces generated are startling indeed when one considers the thousands of times per second the entire moving system must be made to start and stop. While the amplitudes are not high, the velocities encountered are extreme for a mechanical device. The obvious result is mechanical resonance.

In considering resonance, we may ignore the crystal since it is inherently stiff, and it is a simple matter to so proportion the element that its free air resonance is above the frequency range to be reproduced. In addition, the mounting blocks through their damping ability, further help to overcome element resonance. The remaining parts in the moving system are the needle screw and chuck. The needle screw should be kept as short as possible. More recent practice makes use of headless set screws to hold long-playing needles; these have negligible effect on the pickup characteristics, because their length lies along the axis of the chuck, where torsional motion only is encountered. The chuck, however, has appreciable mass, irregular shape, some parts of it have torsional forces applied, other parts reciprocating, and stiffness is controlled by the material used as well as shape. Therefore a definite mechanical resonance will occur at some frequency, determined by the above factors. When such an uncontrolled resonance occurs, the voltage output of the pickup attempts to resemble that of a sine wave.

Groove Characteristics

Before considering resonance further, let us see what a perfect crystal response curve should look like. Lateral cut records are so recorded that from the lowest frequency cut up to the change-over point, which we assume to be 250 cycles, the width of the groove is constant, or equal, for all frequencies. It is therefore known as a constant amplitude groove. From the change-over point to the highest frequency cut, the amplitude decreases as the frequency increases and, as the velocity is constant, it becomes known as a constant velocity groove.

Since a crystal will generate a voltage proportional to amplitude, our hypothetically perfect cartridge would be flat from 40 to 250 cycles, and from 250 to 10,000 cycles it would fall off 6 db per octave. See curve *(a), Fig. 3*. If, however, due to its mechanical characteristics, the chuck should resonate at 3000 cycles, the response would be changed to something approximating curve *(b)*. The exact shape and peak amplitudes would depend on the chuck material and damping applied, if any, to the moving system.

Such a response would not be desirable, since it would introduce frequency distortion, transient response, and a very considerable amount of noise, both mechanical and electrical. Harmonic distortion would also occur.

The frequency at which the chuck will resonate can be changed by altering the mass and stiffness, and applying efficient damping means. Controlled damping may also be used to alter the shape of the response curve. Therefore, by using die-cast metal chucks of varying mass, such as zinc, aluminum and magnesium, and carefully controlling the damping applied, various response curves may be had, with predetermined cut-offs, as illustrated in *Fig. 4*.

While such mechanical cut-off means are convenient to use, and are inexpensive where the response is to be limited, distortion, poor tracking and noise will certainly be the result. One cannot deviate from curve *(a), Fig. 3,* without paying the penalty in inferior reproduction. Any deviation indicates that something is being done contrary

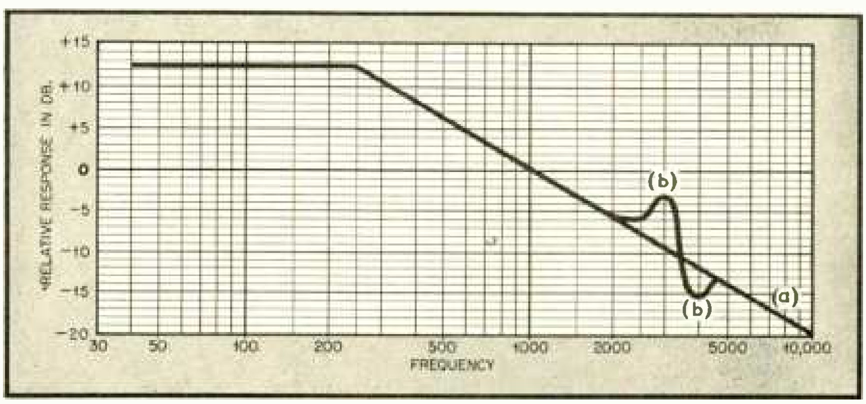


Fig. 3. Ideal response curve of crystal pickup shown in (a)

to the desire of the groove, and discord will surely occur.

A very common thought still encountered among engineers is that a cut-off at perhaps 5000 cycles will reduce or eliminate surface noise or scratch, and that it is worth while even though everything above that frequency be taken from the reproduction. Nothing could be further from the truth. To a large extent, noise and distortion usually associated with high-frequency response can be traced directly back to the use of a pickup with such a mechanical cut-off. Any part of the moving system which resonates at a frequency or frequencies within the audible range, even though damped, will produce poor tracking, record wear, noise and distortion. If, however, curve *(a)* in *Fig. 3* is approximated without the use of any more damping than is necessary to control transients, really astounding fidelity and quiet operation may be had from commercial records.

It is assumed, of course, that the records played have not been previously worn out by mediocre pickups. If, for commercial reasons, it is desirable to cut off the response at some medium frequency, a simple electrical filter may be used. As a matter of fact, curve *(a)* lends itself very well to any type of electrical compensation, due to its straight characteristic. Furthermore, since all known damping material of any efficiency is seriously affected by temperature, the use of it to control a critical mechanical resonance can only result in severe response changes with changes in temperature.

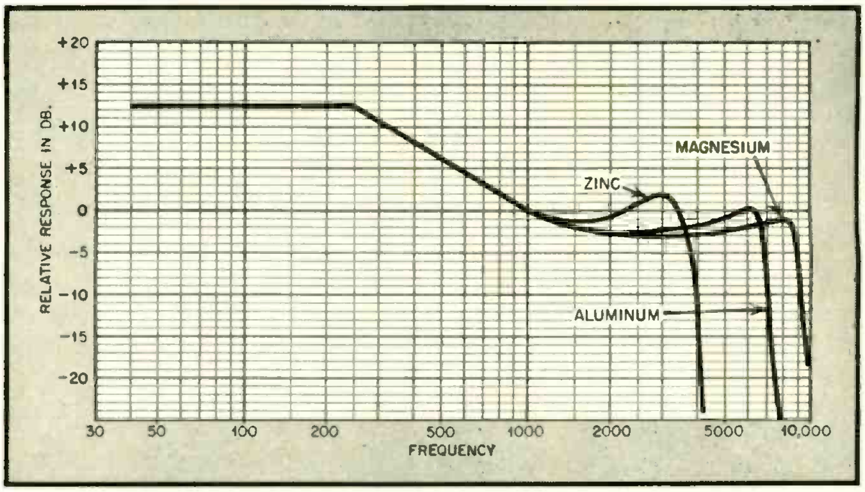


Fig. 4. Relative response characteristics with different metals in head

The perfect moving system should be sufficiently light and stiff to avoid resonating below 10,000 cycles, and would have applied to it a minimum amount of efficient damping material, relatively free from temperature changes, such as gum rubber, sufficient to overcome transients. In considering such a system, we must take into account the needle, and the damping effect obtained from the record through the needle.

Noise

Mechanical reproduction, or "off-the-record" noise is receiving a great deal of thought. It has always been considered one of the most annoying factors in phonograph reproduction. Some efforts to reduce such noise are being made at the expense of better reproduction, and can hardly be justified. There are three distinct noises commonly heard directly from the record, normal undistorted musical reproduction, distorted musical reproduction, and a steady hiss. The undistorted concerting, and as a matter of fact, is volume level. But the distorted repro- musical reproduction is the least dis- not objectionable, since it blends perfectly with the speaker output, and cannot be heard even at very low speaker duction characterized by unexpected shrieks and blasts, is certainly most objectionable. This is the direct result of mechanical resonance somewhere in the moving system.

Most needles are notorious offenders in this respect. Eliminate all resonance in the entire moving system and this most objectionable noise will be accordingly eliminated. The steady hiss is caused by improper tracking, and can be traced directly to the needle in most cases. Needles however, are beyond the scope of this article, and will be taken up separately.

Reduced area of moving parts exposed to the air will reduce mechanical reproduction, since less air is disturbed, but this alone will not overcome noise due to resonance and poor tracking. Summarizing: mechanical reproduction and noise will be reduced *(1)* by eliminating mechanical resonance from all moving parts, *(2)* by proper tracking at all frequencies, *(3)* by avoiding the use of mechanical cut-offs, *(4)* by a careful selection of the needle used, and, *(5)* by reduction of area of moving parts. By thus reducing mechanical disturbances, an equivalent

[*Continued on page 46*]

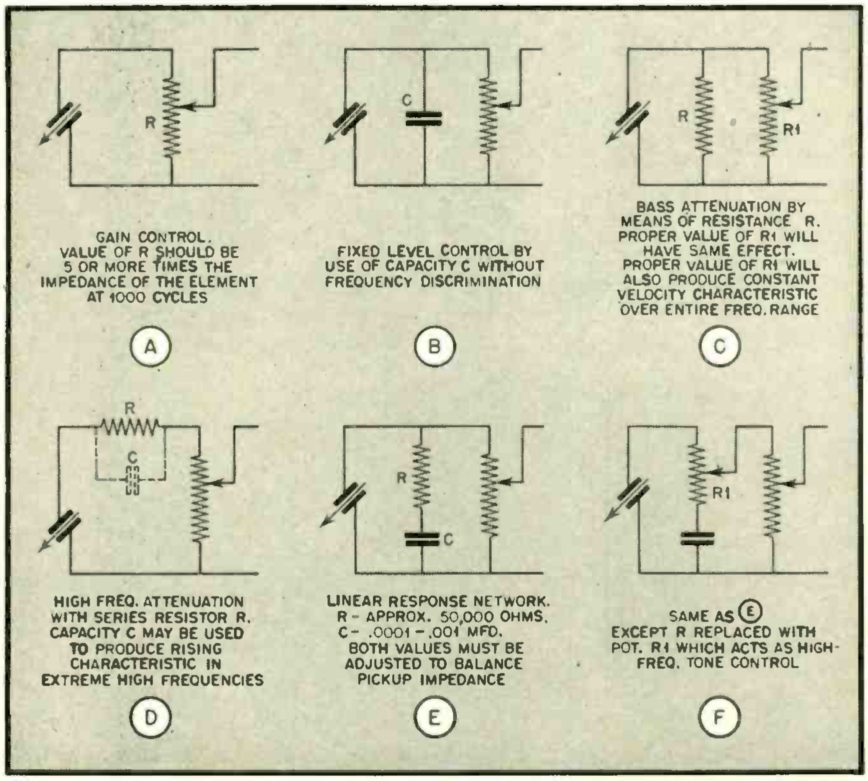


Fig. 5. Frequency-compensating networks for crystal pickups

RADIO BIBLIOGRAPHY

F. X. RETTENMEYER
RCA Victor Division
Radio Corporation of America

17—AIRCRAFT RADIO, PART 1

A Method for the Investigation of Upper Air Phenomena and Its Application to Radio Meteorography — H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore—*I.R.E. Proceedings*, Vol. 26, No. 10, Oct. 1938, page 1235.

This paper describes the experimental work conducted towards the development of a radio meteorograph system for use in the aerological service of the United States Navy for transmitting from unmanned balloons information on upper-air pressures, temperatures and humidities. The work done has lead to radio methods applicable to the study of a large class of upper-air phenomena.

The miniature transmitter sent aloft on a small balloon employs an ultra-high-frequency oscillator and a modulating oscillator; the frequency of the latter is controlled by resistors connected in its grid circuit. These may be ordinary resistors mechanically varied by instruments responding to the phenomena being investigated or special devices, the electrical characteristics of which vary with the phenomena. The modulation frequency is thus a measure of the phenomena studied. Several phenomena may be measured successively, the corresponding resistors being switched into circuit in sequence by an air-pressure-driven switching unit. The air-pressure switching unit may also serve for indicating altitude.

At the ground receiving station a graphic frequency recorder connected in the receiving set output provides an automatic chart of the variations of the phenomena with altitude. The availability of a modulated carrier wave during the complete ascent permits tracking the balloon for determining its azimuth and its distance from the receiving station. Such data are required in measuring the direction and velocity of winds in the upper air. This paper illustrates the circuit of the transmitter in considerable detail. Several pictures of the equipment set up and of the recorded charts are also included. This is probably one of the most complete papers on this subject which has been published.

Instrument and Radio Flying, K. S. Day —Text—Air Associates, 1938, page 177.

The Weather Bureau's Radio Meteorograph Program—L. T. Samuels—*Jour. of Aeronautical Sciences*, Vol. 5, No. 19, Aug. 1938, page 410.

This paper is a report of the progress that has been made on the development of radio meteorographs, and the status of each of the five different developments. It also discusses the status of an investigation of the structure of Polar Continental Air and the development of cold waves in North America. Indication is given of the percentage of observation balloon readings from a number of weather observation stations.

Radio Direction Finding on Wavelengths Between 6 and 10 Meters, R. L. Smith-Rose—*I.E.E. Jour.*, Vol. 83, No. 499, July 1938, page 87.

This paper describes the development of simple experimental direction finder for wavelengths between 6 and 10 meters and its use in an investigation of the accuracy in direction finding on these wavelengths.

Detailed experiments have shown that the site on which the direction finder is used must be clear of obstacles, particularly trees and vertical wires, for a radius of at least 50 to 100 yards, and there are indications that similar conditions are necessary for the site of the transmitter. When such conditions are satisfied, the bearings observed at distances up to 22 miles from the transmitter may be in error by as much as 8 degrees, although in the majority of cases the error was less than 2 degrees. Such errors tend to diminish in magnitude as the range increases, and they may or may not be affected by small changes in position of the direction finder, by changes in frequency of the transmitter, or in the orientation of the transmitting aerial.

For a given set of conditions, the changes in bearings observed from day to day do not exceed about 2 degrees for ranges of 20 miles, although in some long-distance observations made on signals from American stations at a range of 3000 miles, the variations in bearings were much larger.

A brief study has been made of the behavior of the loop direction finder when horizontally polarized waves are emitted at the transmitting station. It is shown that the errors experienced in this case can be almost entirely eliminated by the use of a rotating spaced vertical aerial arrangement in place of the loop. The evidence resulting from the use of this Adcock type of direction finder indicates that the errors with the loop set are due to the reception of horizontally polarized waves.

The Radiotelemeter and its Importance to Aviation, R. W. Knight, Planning & Development Div.—*Civil Aeronautics Authority Report* #1, Sept. 1938.

The Measurement of the Lateral Deviation of Radio Waves by Means of a Spaced-Loop Direction Finder — R. H. Barfield—*I.E.E. Jour.*, Vol. 83, No. 499, July 1938, page 98.

This paper gives an account of some systematic measurements of the lateral deviations of wireless waves received at Slough, England from various short-wave transmitters over a period of several months. The measurements were made by means of a spaced-aerial direction finder of the four fixed-loop type, and apparatus, together with an account of its performance in respect of instrumental accuracy, pick-up factor, and other characteristics.

The second part of the paper describes the measurements themselves, which were made photographically from a cathode ray oscillographic goniometer. Some of the observations were made on pulse transmissions from Nauen at 30 meters and Dorchester at 37.3 meters, and the remainder on continuous-wave transmissions from Zeesen at 31.4 meters, Prague at 44.6 meters and various American stations.

The results obtained show that the variations in bearings which arise from instrumental causes do not exceed about 2 degrees, and are usually of the order of 1 degree. The records demonstrate that lateral deviation occurs for the above cases to an extent which depends on the range and type of the reflected waves observed. Deviations of 10 degrees and 20 degrees were recorded from the more distant stations, while in the case of Dorchester, distant 160 kilometers, the deviations were as much as 50 degrees on occasions. From a study of these observations it is concluded that the effective points of reflection at the ionosphere may be as much as 50-100 km. out of the great-circle path.

Radiometric Measurements of Ultra-violet Solar Intensities in the Strato-

[*Continued on page 64*]

This Month

TELEVISION FORECAST

With 63 applications for television broadcasting stations on file with the Federal Communications Commission, approximately 50 million people throughout the country may have sight-and-sound broadcasting six months to two years sooner than even the most optimistic previous estimates, according to Thomas F. Joyce, Radio Corporation of America executive.

This forecast, he told the National Association of Broadcasters war conference, is based on the supposition that the FCC would grant all these licenses and that television equipment can be manufactured and installed rapidly enough.

In 18 months to two years after the end of the war, rather than in three to four years as originally estimated by RCA, television service may cover 46 per cent of the potential video market as a result of television license applications now actually on file, which increased from seven to 63 in the past ten months, Mr. Joyce, general manager of the radio, phonograph, and television department of the RCA Victor Division, told the broadcasters.

Turning to the question of whether present-day television standards are satisfactory, Mr. Joyce declared that the people who now own television home receivers should be considered as best qualified to answer that question. He then revealed the results of recent attempts to re-purchase at a liberal price television sets now in the hands of the public.

Out of 36 owners approached, the RCA executive declared, only one agreed to sell his set. The television set owners unanimously praised television reception, he disclosed, with many refusing to consider any offer while others set re-purchase prices ranging up to $1500 for receivers which were purchased five years ago for $395.

"If the present owners of television receivers, in these times of limited broadcasting conditions and meager program fare place such a high valuation on their pre-war instruments," Mr. Joyce declared, "how much more eager will they be, and how much more eager will be the great public they represent, under the vastly more favorable conditions that will soon prevail."

The public definitely expects and wants television, he said, in quoting results of several recent surveys. He pointed out that in the survey conducted by Newsweek Magazine, over 32 per cent declared they would be in the market for a television home receiver, ranking second only to automobiles.

Television was first among members of the post-war savings plan inaugurated by the Franklin Square National Bank of Franklin Square, Long Island, the RCA executive disclosed. Of the post-war products for which depositors have earmarked their accounts, he told the broadcasters, television receivers headed the list, with cars second and electric washers third.

In another survey made by McCall's Magazine, in the form of a contest, he went on, the editors said the results showed that over two-thirds of all contestants were television home instrument prospects.

"In the light of these statistics," Mr. Joyce said, "it would be presumptious of me to argue that the public wants television—the figures speak for themselves."

ELECTRONIC PARTS CONFERENCE

Registrations are still piling up for the Electronic Parts & Equipment Industry Conference to be held at Hotel Stevens, Chicago, October 19-20-21, 1944. The total already indicates more than a thousand registrants, and more keep coming in, according to Conference officials.

In keeping with the limitations of wartime, this will be a streamlined Conference. While there will be booths for manufacturers, these are only conference booths, where manufacturers can conveniently meet with jobbers and others, for visits and discussions, but no merchandise, displays, decorations or other trimmings are permitted. This is not an exposition or show, but simply a conference. Booths are all of uniform size. They are already equipped with tables and chairs. The registrants do not have to concern themselves about furnishings, decorations or displays of any kind. Manufacturers may bring along such literature or records as they might carry in their pockets or at most in a brief case, when making a call on a customer, but nothing beyond that.

Correspondence regarding registration and other details should be addressed to the Electronic Parts and Equipment Industry Conference, P. O. Box 5070-A, Chicago 80, Ill. Registrations should be made immediately.

I.R.E. PROGRAM

Listed below is the schedule of the 1944 Fall meeting of the Institute of Radio Engineers, to be held at the Sheraton Hotel, Rochester, November 13 and 14, 1944.

Monday, November 13

8:30 A.M.—Registration.

9:30 A.M.—Technical Session.

The Reactance Theorem for a Resonator —W. R. MacLean, Polytechnic Institute of Brooklyn.

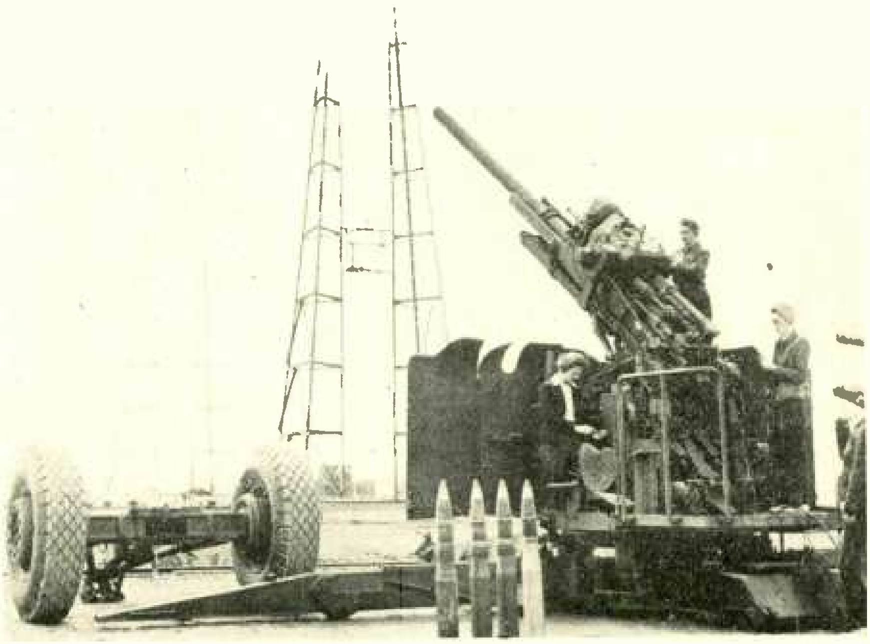
A Resonant Cavity Method for Measuring Dielectric Properties at Ultra-High Frequencies—C. N. Works, T. W. Dakin, F. G. Boggs, Westinghouse Electric & Mfg. Company.

The RCA Laboratories at Princeton—E. W. Engstrom, Radio Corporation of America.

12:30 P. M.—Group Luncheon.

2:00 P.M.—Technical Session.

[*Continued on page 52*]



Measuring projectile speed by calculating the time interval for the projectile to pass through the fields of two antennas spaced a known distance apart and operating at a known frequency —*Courtesy of RCA Mfg. Co.*

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.

Electric Displacement-D— In any medium, two sorts of positive and negative charge may be distinguished. One is called free charge and the other dipole charge. Free charge has a given sign and is separated from other charges while dipole charge is a combination of closely paired positive and negative charges. Dipole charges, when oriented at random in a medium, are without effect on any measuring instrument; when free charge is present in the same neighborhood, however, these paired charges are aligned or polarized and a test charge introduced into the neighborhood feels forces that are dependent on the location of both the free and bound charges.

As described under the heading *Electric Field-E* all charges contribute to the value of E. *The electric displacement is the field resulting from free charge alone.* It may be computed at any point by summing vectors which are directed toward negative charge or away from positive charge, each with a magnitude given by Q/r^2, where Q is the charge in question and r is the separation.

D is somewhat analogous to *Magnetic Field-H* in that it too is a field quantity dependent on the cause of an electromagnetic state.

In the MKS system D is expressed in terms of coulombs per square meter. In the electrostatic system of units it would be the e.s.u. of charge per square cm.

Electric Field-E— A complete knowledge of any field requires information concerning both the direction and magnitude of a vector quantity at every point in the neighborhood of space in which there is interest. The electric field is this sort of quantity. Like other fields, such as that of gravitation or a vector field describing the flow of a liquid, it may be analytically expressible as a relation which specifies a vector for each point of space or it may be represented graphically by a family of directed curves, which are often called electric lines of force.

These curves, or interpolated ones drawn between the given curves, pass through every point of space and by their direction at any point in question, show the direction of the electric field at that point. The magnitude of the field is often indicated by the density with which the lines are drawn in the region of the point in question.

The electric field at any point in space may be found by (1) *introducing a small positive charge, Q, at that point;* (2) *observing the electrical force, F, exerted on it; and* (3) *performing a calculation according to* $E = F/Q$. It is assumed in such a measurement that Q is small enough to only negligibly effect other charge in the neighborhood by its presence.

E is somewhat analogous to *Magnetic Induction-B*. It is a measure of electric field in terms of its ability to influence a test instrument. In the electrostatic system of units E is expressed in terms of dynes per e.s.u. of charge, which is equivalent to e.s.u. volts per cm. In the MKS system the units are volts per meter.

Electrically Long Lines— The treatment and action of long electrical lines is very different from that of short or constant voltage lines. In the first place, if we consider only a pair of ordinary conductors and make no reference to any circuit parameter except resistance, the resistance alone may nevertheless be so great that a very high voltage is required at the sending end in order to obtain a readable signal at the receiving end. The power which flows from the source is mostly dissipated in the line and, as far as the drain on the source is concerned, the nature of the load may be quite immaterial.

The problem of design is then no longer one of directly arranging for the maximum power transmission from source to load but instead is the twofold job of first matching the source to the line and second the matching of the line to the load. In such a case to increase the response of the load to the source we may separately consider methods of increasing energy flow into the line and ways of extracting it at the far end.

With microwave transmission in wave guides the problem of electrically long lines is not usually concerned with resistance. The dissipative losses are generally quite negligible even with moderately long wave guides. The reactance components, however, have much the same sort of problems connected with them as do long lines at low frequency, such as are encountered in telephone transmission.

If an electrically long line is defined as one in which the physical length is large compared to a wave length, then all microwave transmission is in long lines. The merit of such a line is usually best measured in terms of standing wave ratio. It is important to know that such a measurement is valid only for the portion of the line farther away from the source than the point where the measurement is made. With electrically long lines, changes in the source may of course affect the amplitude of the signal at the far end but cannot make any change in the impedance-matching situation as it exists at points farther along the line than at the point where the change is made.

Electromagentic Units-e.m.u.— *The electromagnetic system of units is based upon the study of magnetism quite apart from electric charge except as electric currents give rise to magnetic fields.*

To start with, the unit magnetic pole, which is an imaginary entity useful in setting up the system, is defined in analogy to a statcoulomb as a magnetic pole of sufficient strength to exert a force of just one dyne on a similar pole one cm away. Since permeability, μ_o, is defined as unity in a vacuum, either B or H can be measured in terms of the force in dynes exerted on such a pole. Furthermore, an e.m.u. ampere is defined as the current in a circular loop of wire of one cm radius which will cause a force of 2π dynes to act on a unit pole placed at the center of the loop.

Fermat's Principle— In the study of geometrical optics, Fermat's principle allows a nice and very general statement of the path that a ray of electromagnetic radiation will follow even though it passes through varying media and is subject to refraction. Similarly, the principle may be applied to rays of microwave radio beams and, although as in the optical case its value is of a theoretical nature, still it does possess interest because of its generality.

The principle states that *the path of a ray between two points will be such that the time required to traverse the path is a minimum (or in some cases a maximum).*

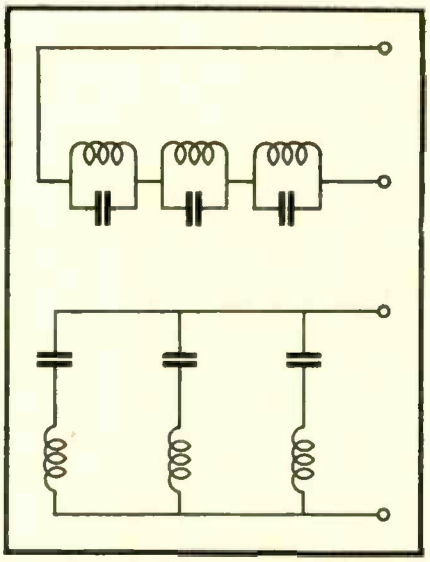
In a homogeneous medium where the velocity of propagation is everywhere the same, it is as once apparent that Fermat's principle is obeyed by the passage of radiation along a straight line connecting the source and the receiver. The proposition of geometry that a straight line is the shortest distance between two points is proof of the statement.

If, however, the source is located in one medium which supports a high velocity of propagation, and the receiver is in another medium in which the propagation is slower, it is not so easy to see that Fermat's principle can predict the actual path. A straight line between source and receiver is still the shortest distance but less time may be consumed by following a somewhat longer path. The extra distance may be more than made up by allowing more of the travel to occur in the source medium where a high velocity is possible.

For the case in which there are only two media, each having definite velocities of propagation, it can be shown that Snell's law of refraction may be derived from Fermat's principle. When one medium shades into another or the velocity of propagation varies throughout a volume in an irregular way and Snell's law cannot be applied, Fermat's principle is still valid as a description of the path that any given ray will follow.

Foster's Reactance Theorem— If a four-terminal network is imagined to serve as a transmission line by virtue of a source connected at two of the terminals and a load connected at the other two, the network may take on any one of an infinite number of forms even if its elements are all pure reactances. For example, it may be made up of like or unlike sections containing combinations of inductance and capacitance in series and in parallel, or it may even be a wave guide assembly equipped with input and output coupling loops or probes. Together with the load, such a system will have a certain source impedance which is a function of frequency.

Foster's reactance theorem indicates that there are limitations on the sort of source impedance characteristics which are physically realizable. It does so by showing that complicated networks may always be replaced by relatively simple ones which have the same impedance characteristics. Specifically the theorem says, *if two reactance networks have the same resonant and anti-resonant frequencies they can be made to have identical reactances at all frequencies by a proper choice of a multiplication factor.*



Network with infinite input impedance (above) and zero input impedance (below)

A resonant frequency is one in which the input impedance to the network is zero; an anti-resonant frequency is one at which the network has infinite impedance.

It may be demonstrated that any type of reactance curve may be secured from one of the two general configurations shown. This is the basic proposition which sometimes allows us to use transmission line theory for the solution of wave guide problems. Unfortunately this sort of argument does not comprehend problems concerned with the various modes of transmission possible in wave guide, nor does the simple theorem as we have stated it here take account of attenuation due to resistance.

Fresnel's Equations — When a beam of microwave radiation passes through a plane interface between two media, it is in general both reflected and refracted. If the incident beam approaches the interface at an angle θ to the normal the reflected beam also travels back at an equal angle in the same way that light is specularly reflected from a mirror. The transmitted beam is bent and proceeds into the second medium at a new angle θ'.

The relation between these angles θ and θ' which tell the respective direction of the beams with respect to a line perpendicular to the interface at the point where the beam passes through, is given by Snell's law. *The ratio of the amplitude of the reflected beam to that of the incident beam is given by Fresnel's equations.*

Actually, in the form which the equations are stated, it is necessary that the permeability of the two media be the same. This is almost always true and when it is not, it is quite feasible to write the equations in a different form to take account of the variation.

At oblique angles of incidence two cases must be distinguished, one when the electric vector of the wave is tangent to the surface of the interface and the other when the magnetic vector is tangent to that surface. Since the electric and magnetic vectors are always perpendicular to each other, no generality is lost in writing relations for these two cases alone. If an intermediate degree of polarization is present in an actual beam, that beam may always be resolved into two beams which fit into these specifications.

Fresnel's equations for tangent E and tangent H beams are respectively $B/A = \sin(\theta - \theta')/\sin(\theta + \theta')$, and $B/A = \tan(\theta - \theta')/\tan(\theta + \theta')$. B is the amplitude of the reflected beam and A is the amplitude of the incident beam. Thus B/A gives the fraction of the beam reflected. The fraction of the beam transmitted is $1\text{-}B/A$.

It is interesting to notice that in the case of a tangent magnetic field the reflection may be zero. Specifically, if $\theta + \theta' = 90°$, $\tan(\theta + \theta')$ will be infinite and no reflection will take place.

Fresnel Zones—In analogy to the optical case, we may under certain conditions use Huygen's principle to find the radiation intensity at some point in an unknown radiation pattern. The general method is to choose an aperture nearer the antenna where the beam intensity is known and then find, by the use of Huygen's principle, the contribution of each point in that aperture to the radiation intensity at the point under discussion. A vector sum of these components then yields the desired intensity.

This was the method first used to find the free space pattern of radiation out of the open end of an unterminated wave guide. It is in error there, as it may be in some other cases, because it does not include the portion of the pattern arising from currents induced into the outside surfaces of the wave guide. It obtains a good approximation of the pattern in the forward direction, however, and is often useful.

The aperture chosen may be, for example, the focal plane of a parabolic antenna or in certain cases it may be the region surrounding an obstruction to the beam. In the latter case, the calculations may well be aimed toward an examination of the shadow cast by the obstruction.

The main difficulty in such calculations lies in performing the integration necessary to sum the components arising from the various points in the aperture. The use of Fresnel zones allows a rather simple approximation of this integration to be made in many cases. The aperture space is imagined to be divided up into zones in such a way that the optical distance from the center of one zone to the point where a field value is desired is just one-half wavelength different than the distance from an adjoining zone. In other words, *a Fresnel zone is an area in the aperture of a radiating system which is so chosen that radiation from all parts of it reach some point at which the radiation is desired at a common phase within 180°.*

When such zones are set up it is often feasible to assume an average value of the phase and intensity of radiation from each whole or fractional zone and replace the integration mentioned above by a simple

[*Continued on page 48*]

ECHOPHONE MODEL EC-1

(Illustrated) a compact communications receiver with every necessary feature for good reception. Covers from 550 kc. to 30 mc. on 3 bands. Electrical bandspread on all bands. Six tubes. Self-contained speaker. 115-125 volts AC or DC.

ECHOPHONE RADIO CO., 540 NORTH MICHIGAN AVE., CHICAGO 11, ILLINOIS

PICKUPS

[*Continued from page 40*]

reduction in objectionable noise from the speaker will be noted.

High Compliance Pickups

Low pressure or "high compliance" pickups are also a subject of considerable thought for new phonographs. The natural and desirable results of using such a pickup will be longer record life, less noise, and if properly designed, better reproduction. Needle life will also be increased. The present conception of low pressure is anything less than one ounce, with about 21 grams being the average. When applied to a changer, such designs may introduce a problem in tripping, but recent advances in changer design indicate that this difficulty will be overcome.

Low vertical pressure alone is of no value unless the pickup tracks properly at all frequencies, and insofar as the cartridge is concerned, particular care must be taken to insure tracking at all frequencies above 1000 cycles. Tracking below 1000 cycles is usually a function of the tone arm design and has been covered in a previous article.* It must also be kept in mind that good tracking includes vertical compliance as well as lateral, wherein the needle plays a very important part. Without going further into the subject of needles, one must use every caution in selecting a needle design for a given cartridge, since it is not possible to track at pressures of less than one ounce without having the two complement each other in performance. If the cartridge is so designed that the needle may be changed, precautions should be taken so that no other needle may be used except the one intended.

Low tracking pressures are dependent on low mass of the moving parts, great inherent stiffness, lack of mechanical resonance, a minimum of damping, and conparatively low voltage output. The presence of mechanical resonance in the moving system will result in disturbances at the resonant frequency which will not permit the needle point to move smoothly along the groove, which in itself is poor tracking, and if adequate damping is added to overcome resonance, the entire moving system is stiffened against motion, which requires greater vertical pressure to overcome. Thus low pressure tracking is very definitely tied in with a pickup design having characteristics similar to that of curve *(a), Fig. 3,* and not the characteristics of *Fig. 4.*

Voltage Output

If relatively high voltage outputs are required, a little study of *Fig. 2 (a)* will show why both high compliance and high voltage cannot be had simultaneously. Voltage output is proportional to the amount of mechanical strain set up in the free end of the element. Thus it is common practice to increase the width of the clamp rubber in order to obtain higher voltage. In effect, greater work must be done, and such greater effort can only reflect itself back to the moving parts as increased stiffness, which must be overcome in the same manner as damping, with added vertical pressure. For conventional cartridge designs, tracking at approximately 21 grams, about .4 volts RMS at 1000 cycles, may be obtained.

In conclusion, it should be pointed out that a properly designed crystal cartridge lends itself very well to frequency response adjustment, and *Fig. 5* illustrates a number of simple networks which may be used to advantage. These may also be combined for multiple effects. The values given are approximate, since they depend on the impedance of the crystal element.

* Tone Arm Design, RADIO, June, 1944.

[Continued from page 44]

sum. Moreover, because of the obliquity factor of Huygen's principle, it often happens that the average intensity of successive zones decreases slowly. Often each zone except the first may be considered as canceled by half of the preceding plus half of the following zone. In that case the radiation from the whole aperture may be calculated in terms of only half of the first zone.

Gauss—The gauss is a common unit for the measurement of magnetic fields. In the gaussian system of units it is now well accepted as the name of the unit for *B*. The unit of *H* is the oersted. In the older literature this distinction is not always made. Especially among physicists,, the gauss was once used indiscriminately for both *B* and *H*. This led to some confusion.

Actually, in the most recent books published in the field, most authors have adopted the MKS system of units which does not make use of the gauss at all. However, because so much experimental data is available in terms of gauss it is generally desirable to reduce results to that unit even when the MKS system is used throughout the calculations. Since the numerical factor between webers per square meter is used in the MKS system and gauss is an even 10^4, this is not hard to do.

A definition of a gauss may be satisfactorily made in any one of several ways. It may be defined as that amount of flux of *B* which will appear at the center of an evacuated long solenoid which is wound with n turns per cm and which is carrying a current of $4\pi/10n$ amperes. It may equally well be defined in terms of the force on a wire carrying current through a magnetic field, or it may be defined by the potential generated in a loop which is rotated in the field. Since actual measurements of magnetic fields are ordinarily made with search coils or, in the case of steady fields with flip coils, a definition based on induction is the most fruitful.

The magnetic induction at a point is one gauss when the maximum voltage that can be induced in a conductor moving through the point with a velocity of one cm per second is one emu volt. The maximum voltage will be obtained when the magnetic flux is perpendicular to the plane in which the wire moves.

Gaussian Units — Except for the Giorgi, or MKS, system of units which has fairly recently become very popular, the so-called Gaussian system of units is most used in calculations related to Maxwell's equations. If the centimeter, gram, and second are taken as basic quantities on which to build a unit system, the gaussian units are logical ones to use. If electric and magnetic phenomena were entirely dissociated from each other, two systems of units might suffice and would logically be needed. The e.m.u. (*electromagnetic unit*) system would be used for magnetic measurements and the e.s.u. (*electrostatic unit*) system would serve for electrostatic work.

Actually, we find a need to define e.m.u. currents as well as e.s.u. currents and we know by actual measurement that the ratio of these unit sizes is c, where c is a number equal to the velocity of light in free space. It turns out that this factor of c or c^2 is invariably the ratio of the unit sizes in the two systems.

The Gaussian system of units is a combination of e.m.u. and e.s.u. which uses each in places where they are most logical and overcomes the discrepancy of unit size between the two systems by inserting c into the equations in a proper manner.

An example of the way e.m.u. and e.s.u. are mixed in writing equations in Gaussian units is afforded by the expression for the force on a charge. If the equation is naïvely written, we would have $F = qE + q(v \times B)$ where the first term which represents an electrostatic force is written in terms of the e.s.u. system and the latter term for the magnetic force is in e.m.u. It is obviously bad to have charge written in two sets of units in the same equation. The Gaussian system gets around this by writing the equation as $F = qE + (q/c)(v \times B)$ whereupon q is in e.s.u. throughout the equation, even though B remains in e.m.u.

Gauss' Theorem—In dealing with vector fields such as those of *E* and *H*, there are several simple relations that are often helpful in making calculations. Gauss' theorem is one of them. It deals

[Continued on page 50]

"The high quality of their product, which comprises telephones, switchboards and electrical supplies, has placed them in the position of the largest manufacturer of their goods in this section of the country."

. . . from

A CENTURY OF MERIDEN

published in 1906

If "skill to do comes of doing," this thirty-eight year old commentary explains the record of Connecticut Telephone and Electric in manufacturing telephones, switchboards, and electrical supplies for the military needs of this war.

We look forward to the *next* thirty-eight years, confident that this is the dawn of the most important era yet, in the development of communications, and every other branch of electrical science.

If our seasoned, but progressive, experience can be of help to you in connection with your communications requirements or the development and manufacture of electrical or electronic devices, we shall be glad indeed to talk with you.

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

TERMINOLOGY

[*Continued from page 48*]

with the so-called vector flow out of a volume and shows an equivalence between the net flow outward through the surface and the integrated effect of the divergence of the vector field throughout the volume.

For example, a vector field may be expressed by equations into which the coordinates of any point in space can be substituted and the magnitude and direction of a vector associated with that point in space found as a result of the substitution. In this way a vector may be associated with every point in the space and the resulting array called a vector field.

If enough such vectors are plotted into a given space and especially if their magnitude is shown by the density of the plot, we approach a situation like that in which electric or magnetic fields are portrayed by lines of force. Since these lines of force have a direction, they appear to be like lines of flow, as indeed they actually would be in the hydrodynamic case in which the vector field is one specifying the velocity of motion of various small measures in a liquid. Whether or not the problem is one of actual flow, however, the concept is useful.

For example, in the electrical case, if we know the number of lines of E which pass through a surface of area A, we need only to divide the number by A to get the average value of E.

Gauss' theorem states that

$$\iiint_{\text{volume}} \text{div } A \, dv = \iint_{\text{surface}} A_n \, dA$$

or in words, that the volume integral of the divergence of a vector is equal to the surface integral of the normal component of the vector. A_n is considered positive when it points outward from the volume. If we understand the meaning of div A (i.e., that it gives the excess of the efflux over the influx for any very small volume, dv) it is easy to see that the left member of the equation gives the total flux generated in the large volume.

Gauss' formula simply says that the net amount of this generated flux added up over the whole volume must leave the volume and show up as an outwardly directed flux through the surface. If a certain volume contains a charge density ρ, the integral over the divergence will be $4\pi\rho v$, since 4π lines of force arise from each charge.

Gauss' theorem states that the total efflux of the force lines out of the volume will also be $4\pi\rho v$.

Giorgi Units—MKS—In the last few years the Giorgi, or meter-kilogram-second, system of units has made great gains in popularity. In general there are four reasons for preferring one set of units over another. These are: (1) convenient magnitudes, which make the use of very small or very large numbers unnecessary in most calculations, (2) familiarity, that makes it unnecessary to constantly refer to tables and which makes magnitudes easy to visualize, (3) logical definitions, which make it possible in practice to define the units in a logical manner, and (4) avoidance of the use of factors such as π in most equations written in the units.

The Giorgi system of units meets these requirements as well or better than any other system. Electric field intensity, E, is measured in volts per meter. The volts are the same as those used with simple circuits. Magnetic induction, B, is in webers per square meter where one weber per square meter equals 10^4 gauss. Charge density, ρ, is in coulombs per square meter. Current density, J, is in amperes per square meter. Both the coulombs and amperes of the Giorgi system are the same as those ordinarily used in circuit theory.

The use of all these and other units so that they fit in with the scheme used in practical circuits and so that they are of useful magnitude is made possible in the theory of electromagnetism by assigning numerical values to ϵ_o and μ_o, the dielectric constant and the permeability of free space.

These numerical values, $\mu_o = 4\pi 10^{-7}$ henry per meter and $\epsilon_o = 8.85\ 10^{-12}$ farad per meter are basic constants of this system of units and must be remembered. In this respect the Gaussian system of units is preferable since there both these constants are unity.

It is now agreed by many workers in the field, however, that for most calculations it is better to have numerical values of ϵ_o and μ_o than to keep straight all the powers of 10 and c that must be remembered in changing from the Gaussian system to practical units in order to interpret results in terms of voltmeters and ammeters.

Gradient-Grad—The gradient is an operator which has no physical meaning by itself but takes on such meaning when it operates on a scalar quantity. For example, if each point in a certain space is labeled with Cartesian coordinates x, y, z, then $V\ (x, y, z)$ may be a scalar function giving the voltage, with respect to some reference level, of each point in that space. $V\ (x, y, z)$ is a symbol indicating an equation containing x, y, z, and V.

For a given point x, y, and z are certain numbers; substituting these numbers into the equation causes it to specify a value for V at that point. Now if the gradient operator works on $V\ (x, y, z)$, a new equation is obtained which specifies a vector at each point in space. This vector turns out to be one which points in the direction in which the voltage is most rapidly changing, and one whose magnitude gives the rate of change of voltage per unit length along that direction.

In other words, the gradient of the voltage is the electric field. Grad $V = -E$.

More generally, *the gradient of a scalar is a vector which shows the direction and rate of change of that scalar in space.* It is an operator that is generally useful in working with scalar and vector fields. It is encountered in the study of hydrodynamics, aerodynamics, acoustics, etc., as well as in electrodynamics.

[*Continued on page 62*]

Featuring

The New HARVEY Regulated Power Supply 206 PA

RANGE 500 to 1000 VOLTS

This new Harvey development is bound to be a star, because it fills the need for a Regulated Power Supply in upper voltages. It may be operated in two ranges, 500–700 at ¼ of an ampere and 700 to 1000 at .2 of an ampere. Both ranges have accurate regulation to *one per cent or less*.

The new HARVEY Regulated Power Supply 206 PA is a model of efficiency and operating convenience. All parts are readily accessible to the operator. It is equipped with spare fuses, a 6 ft. heavy duty Tyrex cord with a handy two prong plug.

The HARVEY 206 PA is fused on the primary side and has both an overload relay and time delay relay. Two interlocks on the chassis afford the operator complete protection. A black, crackle-finish panel and copper plated chassis make the 206 PA an instrument of beauty as well as precision.

Although the HARVEY 206 PA is too new to picture publicly, it has been thoroughly tested and proved and is now in production. Made by the makers of the HARVEY 106 PA that is providing fine, dependable performance in the 200 to 300 volt range, the HARVEY 206 PA will provide equally fine performance in the higher voltages.

Now is the time to get the complete story on this important new contribution to the radio-electronics field. Write, phone or wire

HARVEY
OF CAMBRIDGE

HARVEY RADIO LABORATORIES, INC.

454 CONCORD AVENUE • CAMBRIDGE 38, MASSACHUSETTS

THIS MONTH

[Continued from page 42]

Low Frequency Compensation of Multistage Video Amplifiers—M. J. Larson and A. E. Newlon, Stromberg-Carlson Company.

Trends in Receiving Tube Design and Application—L. R. Martin, Radio Corporation of America.

Standardization of Capacitors for Civilian Equipment—J. I. Cornell, Solar Manufacturing Corporation.

4:00 P.M.—Committee Meetings.

6:30 P.M.—Group Dinner.

8:15 P.M.—Technical Session.

One Look Backwards—and Two Ahead—K. W. Jarvis, Sheridan Electro Corporation.

Tuesday, November 14

8:30 A.M.—Registration.

9:00 A.M.—Technical Session.

Report of RMA Director of Engineering—W. R. G. Baker.

The Organization of Research in the Radio Industry after the War—Rupert Maclaurin, Massachusetts Institute of Technology.

Electronic Tube Trends—R. M. Wise, Sylvania Electric Products, Inc.

12:30 P.M. Group Luncheon.

2:00 P.M.—Technical Session.

Silicone Products of Interest to the Radio Industry—Shailer L. Bass and T. A. Kauppi, Dow Corning Corporation.

Designing Thoriated Tungsten Cathodes—H. J. Dailey, Westinghouse Electric & Mfg. Company.

4:00 P.M.—Committee Meetings.

6:30 P.M.—Stag Banquet.

F. S. Barton—Toastmaster.

Major-General Roger B. Colton—Speaker.

ABSTRACTS OF N.E.C. PAPERS

The following are abstracts of some papers to be delivered at the National Electronics Conference, which will be held at the Medinah Club of Chicago on October 5, 6, and 7.

The Electroencephalograph and Its Applications

By R. W. Gerard,
University of Chicago

The development of electrical methods in neurophysiology will be considered in relation to the electrical phenomena encountered in the nervous system. The advent and types of electroencephalographic equipment will be reviewed and its applications to medical science and clinical medicine presented. Special attention will be given to the electrical waves obtainable from the intact human, normally and in disease, and to some of the electrial and medical problems to be solved in the future development of this borderline field of electronics and physiology.

Electronic A. C. Power Regulator

By R. F. Wild and L. B. Cherry

The object of this paper is to describe an electronic a-c power regulator which is instantaneous and independent of frequency.

The theory and design considerations governing a conventional circuit using gaseous discharge tubes are presented. The effect of the extent of voltage limiting by the gas tubes on the degree of regulation is discussed.

The application of these circuits for regulation of low power, particularly the use in electronic apparatus, is treated and performance data on both circuits is given.

Aircraft Electronic Applications

By A. P. Upton,
Minneapolis Honeywell Regulator Co.

Alternating-current operated resistance bridges provide flexible control circuits since several can be combined to give net control voltages with minimum phase shift problems. These voltages and the corresponding required corrections are more accurately obtained with an amplifier consisting of a voltage amplifier and a pair of a-c operated discriminator tubes.

Discriminator action, giving alternate relay operation or motor reversal, is possible through a common power supply for discrimintor plates and bridge excitation.

Control voltages are applied through the mediums of manual resistance changes; through temperature or pressure variations translated into resistance changes; or resistance changes resulting from gyroscopic influences.

The last method is applied to stabilized bombing approach and autopilot systems made for the Air Corps. An added knob providing manual resistance changes makes possible coordinated turns by the human pilot with extreme ease.

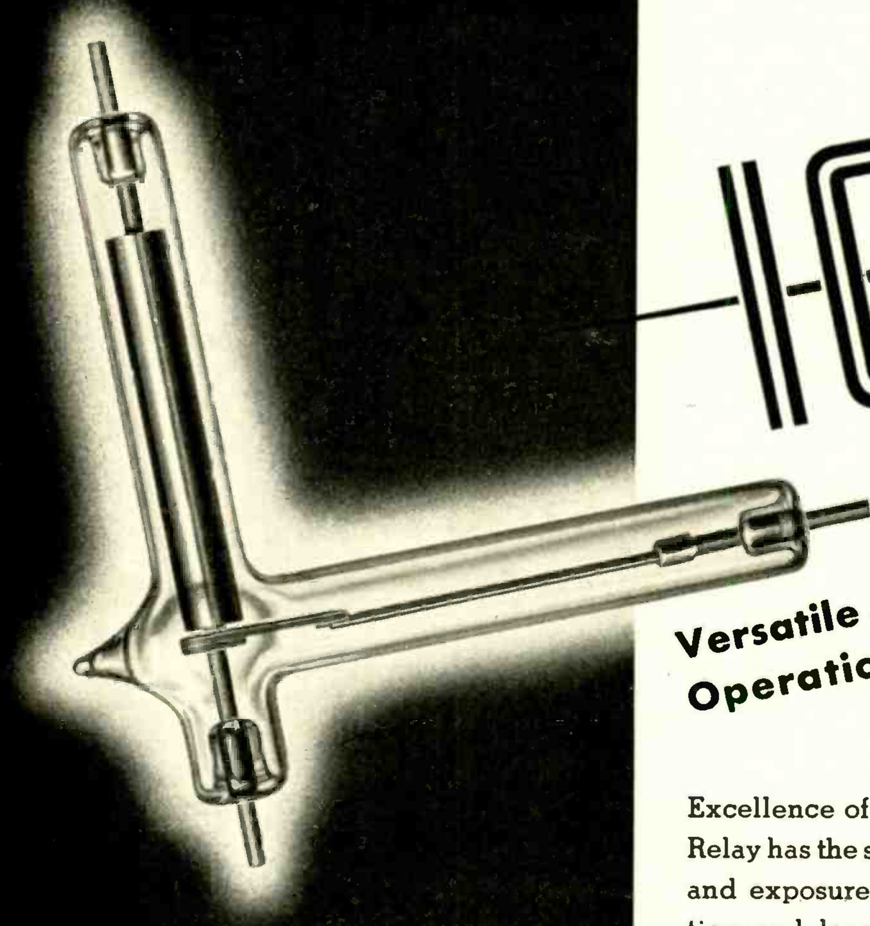
A pressure operated variable resistance senses engine manifold pressure changes and causes supercharger waste gate position corrections through the use of an amplifier and a two phase motor in another aircraft application. The same system includes an overspeed and acceleration sensing device for preventing damage to the turbo and crew, and to prevent manifold pressure overshooting.

UHF Converters and Conversion Diagrams

By Harry Stockman
Cruft Laboratory, Harvard University

A broadcast frequency converter functions as a fixed-path-of-operation device or as a changing-path-of-operation device. The action can frequently be explained by means of a few measured characteristics and a mathematical alnalysis of these characteristics. As the frequency is increased, the conventional changing-path-of-operation device ceases to function properly, and the action of the other type of converter becomes more and more intricate. This action usually cannot be explained by a few measured characteristics and simple additional mathematical analysis. The Chaffee method avoids direct graphical and analytical treatment of the mixer circuit, and is centered on

[Continued on page 54]



I·C·E

VACUUM RELAYS are Rugged and Versatile . . . Give you Reliable Operation and Long Life

Insulation between open contacts, 20,000 volts peak R. F. or A. C. Contacts break 4 amperes. With suitable coil, requires approximately 4 watts actuating power. Contact D. C. resistance less than 0.05 ohms in either open or closed position.

Excellence of construction means this I. C. E. Relay has the strength to resist vibration, shock and exposure . . . resulting in reliable operation and long life. Versatility means that it can be used to do a score of different jobs for you. And of course . . . I. C. E. *precision engineering* is your assurance of correct adjustment to close tolerances. Large quantities of these I. C. E. vacuum relays are proving themselves on battlegrounds all over the world. We can give immediate delivery, in quantity, of these fine relays . . . your inquiries are invited.

I·C·E
ELECTRONIC TUBES

INDUSTRIAL & COMMERCIAL ELECTRONICS
BELMONT, CALIFORNIA

THIS MONTH

[*Continued from page 52*]

the behavior of the nonlinear element and its i-f load, the technical data being collected in the form of so-called Conversion Diagrams. The coefficients inhere in the slopes, spacings and scales of such diagrams are linked to the input voltage, output voltage and output current by means of equations, which permit calculations pertaining to the output for unmodulated and modulated input waves. Several series of conversion diagrams provide information for useful design quantities, when such parameters as local oscillator voltage and i-f load impedance are given different values.

The measurement set-up used at Cruft Laboratory is briefly described. Several curves read from the obtained conversion diagrams are discussed in the text.

The Use of Radio Frequencies to Obtain High Power Concentrations for Industrial Heating Applications

By W. M. ROBERDS,
Radio Corporation of America

The use of radio frequencies makes possible the application of power to metal objects in concentrations up to 100 kw. per sq. inch. This may amount to 20,000 kw. per cubic inch under favorable conditions.

For some industrial applications such as surface hardening or welding, high power concentrations permit heating of the desired parts in 2/10 second. Thus, the high temperature regions are accurately limited.

These power concentrations are attained with the use of electronic generators with output powers up to 200 kw. at 400 kc. The generator is coupled to the work through a current transformer and a single turn inductor loop.

Very high frequencies are used to heat dielectric substances in power concentrations up to 1000 times as great as can be obtained by heat conduction into the work. The size and shape of the work and the power output capacities of the r.f. generators are the principal limiting factors. The thicker the work, the greater is the advantage of the r.f. heating method. Practical power concentrations range from 10 watts per cubic inch at 10 Mc.—used for gluing thick wood sections—to 20,000 watts per cubic inch at 200 Mc. used to seal thin plastic films.

New Methods and Techniques in High Frequency Heating

By EUGENE MITTELMANN,
Illinois Tool Works

Most industrial applications of high frequency power are characterized by the fact that the output terminals of the generator (which may be either of the self-excited or of the master control power amplifier type) have to deliver power to a large variety of load impedances. Furthermore, in the great majority of industrial applications the impedance value of the once selected load itself varies in wide limits during the heating cycle. Characteristic examples of such load behavior are (1) the heating of ferrous metals beyond the point of magnetic transformation, at which the permeability becomes unity and hence the originally low impedance load changes to one of high impedance; (2) the heating of thermo plastic materials, where the power factor increases with temperature; (3) the curing of rubber, where the power absorption by the load goes through a maximum and minimum during the heating cycle.

Such load behavior means that the generator is unable to deliver its rated power output to the load except for a short fraction of the total heating cycles when matching conditions happen to exist between load and generator. Increased efficiency and greater effectiveness can be obtained if generators are designed which are able to deliver a constant rated power to a varying load. It can be shown that the equivalent circuit of a loaded generator can be reduced to a diagram in which the resistance in series with a reactance is coupled to the terminals of the generator. The reactance includes the combination of the reactive component of the external load and of a reactive coupling element. It can be further shown that to maintain matching between load and generator for changing load conditions the orbit of the end of the impedance vector must be a circle with a diameter equal to the equivalent parallel loss resistance referred back to the terminals of the generator. The value of this equivalent loss resistance must be so selected that it satisfies matching conditions for maximum power delivery.

Both induction heating and dielectric heating generators, up to 20 kw. useful high frequency output, are described, incorporating methods which satisfy the above conditions. In the induction heating generator the rematching takes place automatically at the magnetic point of transformation. In dielectric heating units, where the heating cycle is considerably longer than the one used in induction heating, the rematching is continuous. Practical examples are discussed demonstrating that by utilization of the rematching principle generators of smaller ratings can be used.

Industrial Fluoroscopy of Light Materials

By SCOTT W. SMITH, Ph.D., Physicist
Kelley-Koett Manufacturing Company

The possibility of using fluoroscopy for x-ray inspection of light materials, as a means of relieving radiography of part of its burden, offers strong appeal in spite of the disadvantages of lower sensitivity and of not furnishing a permanent record. Fluoroscopy does offer the means of directly viewing the image while the object is in motion, supplying a three dimensional impression; and it also eliminates the expense and delay of films. This paper discusses the factors which limit the sensitivity attainable in fluoroscopy from two standpoints: forming the image and viewing it. Photographs of the fluoroscopic image show that greater detail exists than can be seen by viewing the faint image directly. The loss in sensi-

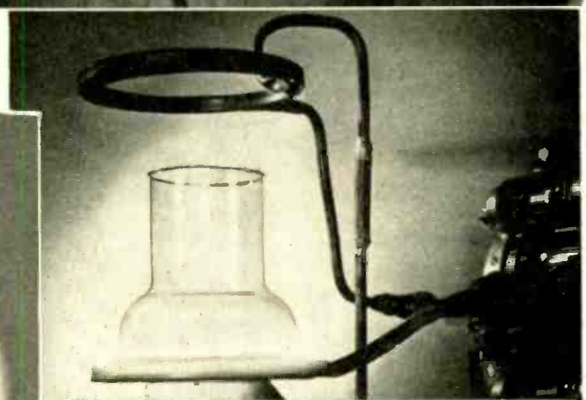
[*Continued on page 56*]

Many complex glass structures go into a modern vacuum tube

Forming special quartz part at 1800° Centigrade

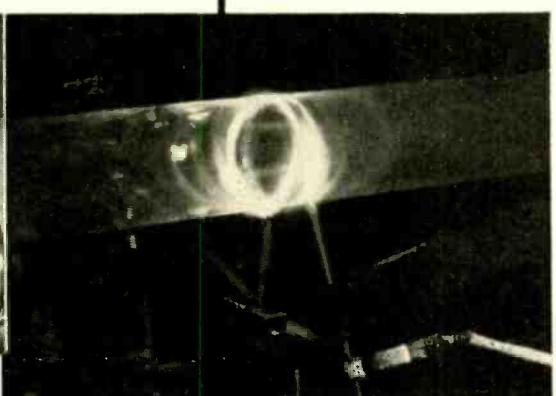
In vacuum tubes many complicated shapes, large and small, must be made within very close tolerances. Eimac's know-how of handling glass is just one reason why electronic engineers throughout the world submit their special problems to Eimac with complete confidence in Eimac's ability to do a superior job.

There are four complicated glass to metal seals in this vacuum tube part



The use of R. F. heat in making glass to metal seals simplifies and speeds many such sealing operations

Making very large glass seals requires expert handling. Two 17" glass cylinders are being joined



Heavy glass tubing is accurately and rapidly sealed with a Radio Frequency Arc

Electronic Telesis — a sixty-four page, completely illustrated handbook has been designed especially to assist you in explaining the fundamentals of Electronics to laymen. Send for your copy today.

Follow the leaders to

Eimac REG. U. S. PAT. OFF.
TUBES

EITEL-McCULLOUGH, INC., 872 San Mateo Avenue, SAN BRUNO, CALIFORNIA

Plants located at: San Bruno, California and Salt Lake City, Utah

Export Agents: Frazar & Hansen, San Francisco 11, California, U. S. A.

THIS MONTH

[*Continued from page 54*]

tivity is mainly due to the low brilliance of the image and the deterioration of both apparent contrast and visual acuity at low brightness levels. Proper dark adaptation of the eyes is required for maximum sensitivity. A study of the limitations set by the fluoroscopic screen, x-ray tube, and other factors in our present methods of fluoroscopy, indicate that a sensitivity of at least 5% is feasible in examining light alloy castings and other objects of light material.

Field Emission Applied to Ultra-Speed X-Ray Technique

By C. M. Slack,
Research Department,
Westinghouse Lamp Division

The making of "ultra-speed" radiographs, using exposure times of the order of (1) micro-second requires the passage of electron currents of 2000-3000 amperes. Currents can be supplied by an electron source utilizing field emission from a cold cathode electrode in a high vacuum. An auxiliary focussing electrode connected to the anode through a high resistance, and spaced very close to the cathode, serves to initiate the discharge which is then transferred to the anode with consequent generation of x-rays.

The use of a Marx circuit enables one to charge the necessary condenser bank at relatively low voltage and obtain sufficient x-ray output to make useful radiographs through one inch of steel at 300 kw.

The very short exposures possible with this tube and generator have permitted sharp radiographs to be made of extremely rapidly moving objects such as high speed bullets, rapidly moving machine parts, etc. The chief use of this development has been in ballistics research in various arsenals and manufacturing plants in this country and abroad. Possible post-war uses should be found in analysis of rapidly moving parts of machinery where distortion or displacement of enclosed parts is suspected, inspection of parts on a continuously moving conveyor belt, and any application for which the conventional x-ray tube is too slow.

Possible applications of this intense electron source to other electronic devices will be discussed.

A Method for the Generation of Quasi-Continuous Frequency Spectra for Use With Secondary Frequency Standards

By Harold Goldberg and
Richard G. Talpey

The general question of secondary frequency standards as applied to frequencies in excess of 100 mc. and particularly in the microwave region is discussed. The limitations of the usual type of standard are discussed and alternative systems applicable to the microwave region are analyzed. It is pointed out that the silicon crystal is an excellent non-linear element for the generation of harmonics in the microwave range. A secondary frequency standard is described which makes use of a multiplier chain based on a stabilized quartz crystal oscillator supplying a frequency *f*. The frequencies occurring in the chain are summed and applied to a final silicon crystal harmonic generator. The result is a frequency spectrum starting with *f* and supplying frequencies *nf* for orders of *n* which may exceed 1000. In the particular standard described, standard frequencies are generated to at least 10,000 mc.

The question of identification and detection of these frequencies is also discussed. Identification is made with a coaxial line type wavemeter and detection by means of a superheterodyne detector. This superheterodyne detector uses no preselection, a silicon crystal mixer, a broad band i-f amplifier, and an audio amplifier. The output of the secondary standard is audio modulated. The standard has been successfully used in the microwave range and is no more difficult to use than the conventional secondary standard used for frequencies below 50 mc.

TAYLOR SALES POLICY

Rex L. Munger, sales manager of Taylor Tubes, Inc., states that effective September 1, 1944 various radio distributor-jobbers will act as Taylor representatives in the areas which they serve. This means that on industrial business, which is usually handled by the manufacturer's representative, these distributors will do the work, and get the commissions.

Rex Munger

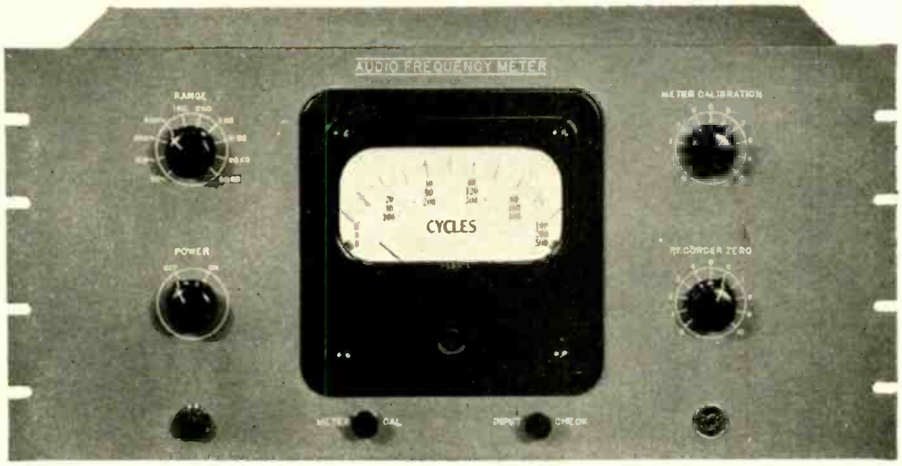
MERIT APPOINTS CROCKETT

Chas. H. Koch, President of Merit Coil & Transformer Corp., 311 No. Desplaines St., Chicago, 6, Ill., announces the appointment of John I. Crockett, Jr., as sales manager. Previously with Thordarson Electric Mfg. Co. where he was chief expediter, Mr. Crockett brings to Merit a long background of sales and distribution experience.

Although all of its expanding facilities are now devoted to the war effort, Merit is perfecting plans for post-war manufacturing and distribution.

RCA WIDE-RANGE AUDIO FREQUENCY METER

306-A



10 Cycles to 50,000 Cycles

A BASIC INSTRUMENT IN LABORATORY AND INDUSTRIAL WORK

- Checks calibration of beat frequency oscillators or other generators.
- Indicates beat note frequency produced by a standard high frequency oscillator and a radio transmitter.
- Used extensively with recorders in crystal laboratories for checking crystal characteristics.
- Used with an accurate crystal oscillator and radio receiver for checking transmitters at distant points.
- Used with special generator as a highly accurate tachometer for indicating or recording rotational speeds.

DESIGN AND OPERATING ADVANTAGES:

Quick, accurate, direct reading. Has six-inch indicating meter with ten scales respectively calibrated for 50, 100, 200, 500, 1,000, 2,000, 5,000, 10,000, 20,000, and 50,000 cycles.

Limiting circuit makes readings independent of input voltage over a range of several hundred to one.

Self-contained regulated power supply compensates for changes in line voltage. Operated from 110 volts, 50 to 60 cycles.

Wave form errors practically eliminated by unique circuit.

Operates recording meter directly—with no additional amplifier.

Accurate to within 2% of full scale.

Please Note Deliveries are subject to the regulations of WPB Limitation Order No. 265.

WRITE FOR BULLETIN

containing complete description and specifications. Address Engineering Equipment Department, Radio Corporation of America, Camden, New Jersey.

BUY MORE WAR BONDS

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, N. J.

LEADS THE WAY.. *In Radio..Television..Tubes..Phonographs..Records..Electronics*

NEW PRODUCTS

[*Continued from page 37*]

MINIATURE SCREWS

Manufacturers Screw Products, 216-222 W. Hubbard Street, Chicago (10), Illinois, manufacturers of the Stronghold line of fastening devices, has increased the range of sizes of its "Perfection in Miniature" Machine Screws.

These screws, "so tiny they might have been designed for your watch," are now available in 0-80, 1-64 and 1-72 thread diameters, both in steel and brass. The fasteners are used in vitally important precision equipment such as head phones, microphones, hearing aids and delicate instruments.

HOLE-CUTTING TOOL

A new all-purpose adjustable hole-cutting tool is announced by Bruno Tools of Beverly Hills, California. Two sizes are available, each equipped with an easily resharpened High Speed steel blade. One model cuts holes to any diameter from 5/8 inch to 1¼ inch through 1/8 inch thickness. The other model covers all expansions from 1 to 2½ inches through thicknesses up to 3/8 inch. The tools are designed to operate in light drill presses, portable drills, or breast drills and are also available with square shanks for use in hand braces.

NEW KOOLOHM CATALOG

A new 28-page catalog just issued includes specifications and engineering data on the complete line of Sprague Koolohm wire wound resistors, in addition to listing various Koolohm types not included in previous publications. Among the types presented are both standard and hermetically-sealed power wire wound resistor types up to 120 watts; 10- and 15-watt voltage divider sections; bobbin-type resistors; hermetically-sealed precision meter multipliers; and Megomax high-voltage, high temperature resistors.

Copy of the new catalog will be sent on request to Resistor Division, Sprague Electric Company, North Adams, Mass. Ask for Koolohm Catalog 10E.

NEW TRANSFORMERS

This constant voltage transformer is indicative of the general trend towards built-in automatic voltage regulation of filament supplies in army and navy electronic equipment.

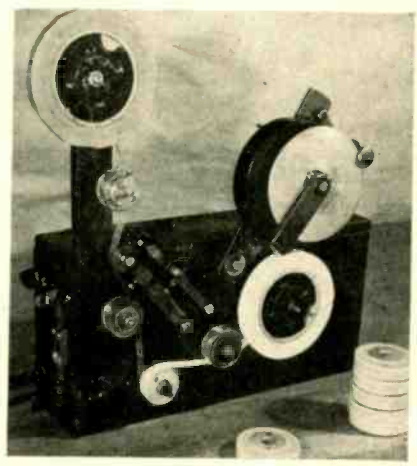
The illustration shows small, compact unit in hermetically sealed case, designed for chassis mounting. Rated at 6.3 Volts, 17 VA output, it will maintain that value within plus or minus 1% regardless of line voltage variations as great as plus or minus 12 to 15%. It is specially valuable for the stabilization of E-C oscillator circuits. Electronic equipment, in which this transformer is a built-in component of the basic design, does not require filament voltmeters or manual controls.

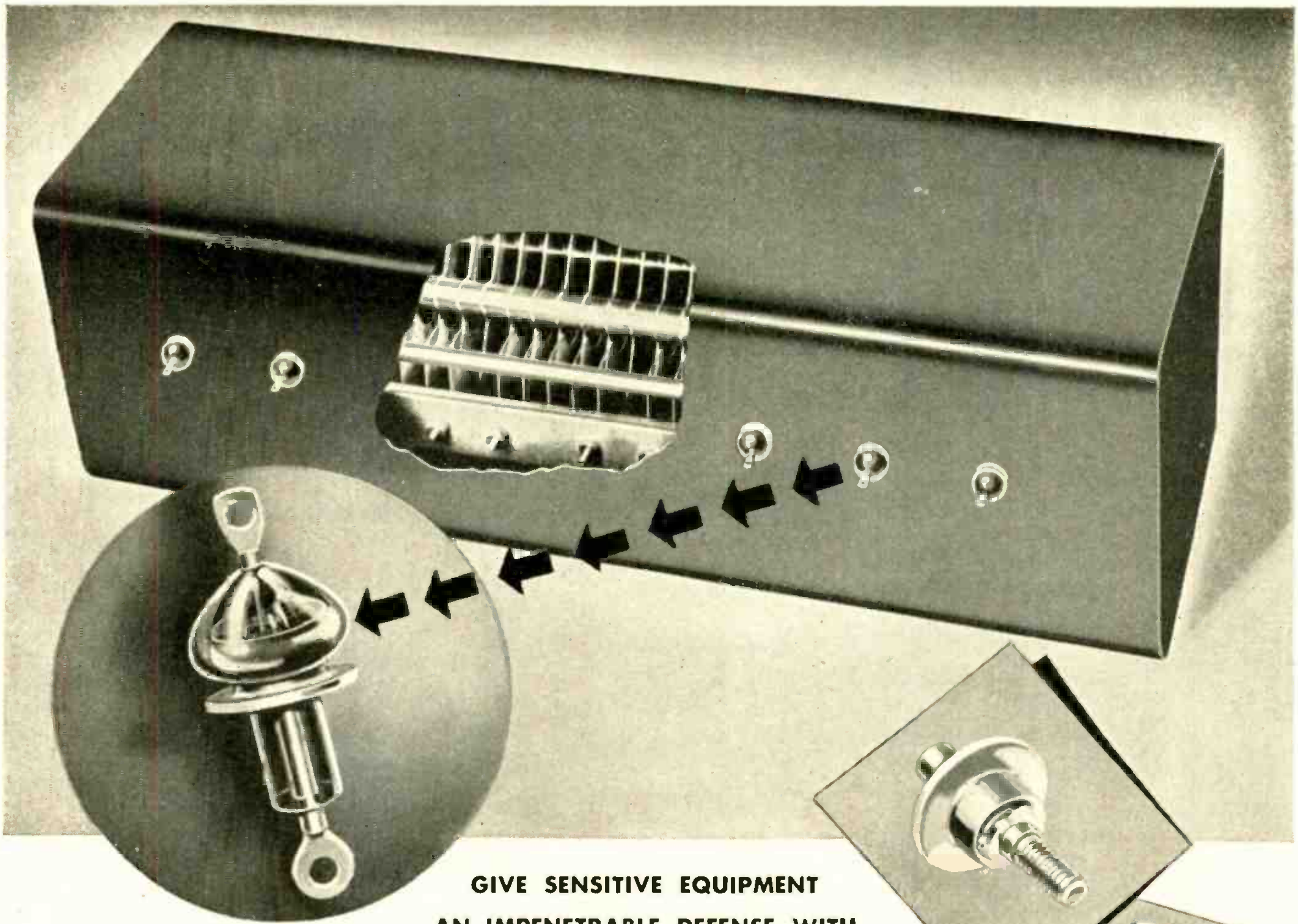
Many new designs in Constant Voltage Transformers are fully described in a new manual (Bulletin 11 CV-102) to be released soon by Sola Electric Company, 2525 Clybourn Ave., Chicago 14, Ill.

TAPE MARKER

Proper identification of the hundreds of wires and tubes going into a modern warplane has been greatly simplified by employees of the Army Division Electrical and Tubing Departments at The Glenn L. Martin Company, Baltimore, Maryland, with the development of a new machine for making cellulose numeral tape—the means of identification specified by the Army and Navy.

With the new Martin machine it is possible to print up the tape as needed, thus removing the necessity for stocking large quantities of tape and relieving the tape manufacturers of one of their greatest wartime headaches. Prior to the development of this machine it was necessary to stock large quantities of previously printed tape, and since some numbers were used up more rapidly than others with requirements constantly changing, this resulted in delays due to shortages in some numbers while others went bad before they could be used.





UHF RECEIVER

[*Continued from page 30*]

for maximum gain, the noise suppressor circuit operates to allow operation of the receiver on any signal in excess of 5 microvolts on the grid of the 1st r-f tube. Reducing the sensitivity of the receiver by means of the sensitivity control causes the noise suppressor circuit to operate at a correspondingly higher value of signal input. Very sharp ON and OFF action is obtainable with this circuit with no appreciable intermediate condition wherein the receiver is partially operative and partially blocked.

Harmonic Distortion

Harmonic distortion of this receiver is comparatively low considering the type of service in which it will be employed. For an output of one watt over the frequency range of 90 to 3000 cycles per second, it does not exceed 10% at any point and for its maximum rated output of three watts, the total distortion does not exceed 20%.

Regeneration

During the development stages of this equipment some difficulty was experienced with both r-f and a-f regeneration, which finally was completely eliminated by the unique method of shielding employed in the r-f section of the equipment. It will be noted from *Fig. 2* the r-f portion of this receiver is completely self-contained on a separate small chassis measuring approximately 5 inches × 5 inches × 1 inch deep. This chassis contains the gang tuning condenser, the four associated inductances, the trimmer condensers for each of these circuits as well as the coupling condensers which interconnect them. It is to be noted that each stage is shielded from each other stage by means of a partition which extends to the entire height of the r-f chassis and condensers employed to couple the stages extend through apertures in these shields. Proper placement of parts as well as strict adherence to fundamental principles of ultra-high-frequency circuit design resulted in a radio-frequency section of excellent frequency stability as well as one which was almost completely free from the effects of mechanical vibration.

General

The receiver has been designed to be fed from the antenna by means of a 70 ohm concentric line which attaches directly to a receptacle provided at the rear of the chassis which, in turn, is coupled to a point of proper impedance on the first r-f inductance.

TERMINOLOGY

[*Continued from page 50*]

In the case of Cartesian coordinates the gradient is

$$i\frac{\delta}{\delta x} + j\frac{\delta}{\delta y} + k\frac{\delta}{\delta z}$$

In other coordinate systems the form is somewhat more complicated.

Group Velocity-U—There are two velocity quantities associated with wave motion. These are group velocity and wave velocity. Very often group velocity is represented by U and wave velocity by V. If only a steady signal having a single frequency is employed, we are never concerned with group velocity. The concept of group velocity needs to be used only when we deal with transients or have a modulation present on the carrier. *Group velocity is the velocity with which a signal is transmitted along a wave and is numerically different from wave velocity only if the medium is such that the wave velocity varies with frequency.*

Suppose, for example, we have two waves of slightly different wavelength, both traveling in the same direction through a medium. Suppose, further, that these two waves are continuous so that by measuring over a long portion of the wave train, we can accurately specify the wave lengths. Now, since the wave-lengths are different, it must be true that if a snapshot of these waves could be taken, the picture would show cancellation in some regions and reinforcement in others. If, at one point along the path, the two waves are cooperating so as to violently disturb the medium then, at other points which are an even number of half wavelengths distant for one wave, and an odd number for the other, there will be complete cancellation. Thus the medium will appear to be excited by groups of waves which appear at points of reinforcement and to be separated by null points where the interference is complete.

The velocity of these bundles of waves is called group velocity. The velocity of the individual constant frequency waves is called wave velocity. If the wave velocities of the two constant frequency waves are the same, it is clear that the group velocity will also have that value. On the other hand, if the wave velocities of the two continuous waves are different, then the group velocity will be different from both the wave velocities. This is true because the velocity of the group depends not only on the velocity of the continuous waves but also upon the way in which one wave catches up with the other and thus influences the position of the reinforcement regions.

Velocity measurements of electromagnetic waves in actual apparatus usually yield group velocities. In general it is only possible to make the measurement by marking a point on the wave by the use of modulation. Energy in a wave travels with the group velocity. The relation between the two velocities is

$$U = V - \lambda dv/d\lambda.$$

[*To be continued next month*]

BIBLIOGRAPHY

[*Continued from page 41*]

sphere—R. Stair and W. W. Coblentz—*J. Research NBS* 20, 1938, page 185, RP 1075.

Navy Radio-Meteorograph System—National Bur. of Stds. Tech. News Bulletin No. 250, February 1938, page 13, *Franklin Institute Jour.*, Vol. 225, March, 1938, page 351.

Analyzing Air Mass Analysis—C. H. Pierce—*The Sportsman Pilot,* Vol. 20, No. 2, Aug. 1938, page 8.

An Electric Hygrometer and Its Application to Radio Meteorography — F. W. Dunmore — *Nat'l Bureau of Standards Jour. of Research.* Vol. 20, No. 6, June 1938, page 723.

Weather by Radio—Dr. Karl O. Lange —*The Sportsman Pilot,* Vol. 19, No. 2, Feb. 1938, page 8.

Instructions for Airway Meteorological Service, Published by U. S. Dept. of Agriculture Weather Bureau.

Weather Forecasting on the Hughes Flight—*Aero Digest,* Vol. 33, No. 2, Aug. 1938, page 55.

Tabulation of Air Navigation Radio Aids—Issues on the first of each month by Dept. of Commerce, Bureau of Air Commerce.

The Development of a Radio Meteorograph System for the Navy Dept.—H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore—*American Meteorological Soc. Bul.,* March 1937, page 73.

Radio in the Sky; Instruments Carried by Balloons to Investigate Meteorological Conditions in the Upper Atmosphere—*Electronics,* Vol. 10, No. 12, Dec. 1937, page 28.

Radio Equipment for the Harvard Radio-Meteorographs and the 1936 Radio-Meteorograph of Blue Hill Observatory —A. E. Bent and K. O. Lange—*American Meteorological Soc. Bul.*, Vol. 18, No. 3, March 1937, pages 99 and 107.

A Radio-Meteorograph System with Special Aeronautical Applications — H. Diamond, W. S. Hinman, and F. W. Dunmore — *Jour. of the Aeronautical Sciences,* Vol. 4, No. 6, April 1937.

Radio Meteorograph System — *Tech. News Bulletin of the Bureau of Standards No. 239,* March, 1937.

A Radiometric Method of Measuring Ultraviolet Solar Radiation Intensities in the Stratosphere—W. W. Coblentz and R. Stair—*Radiologica,* 1, 1937, page 12.

Winds in Upper Troposphere and Lower

[*Continued on page 66*]

BIBLIOGRAPHY

[*Continued from page 64*]

Stratosphere over United States — *Air Commerce Bulletin*—Vol. 8, No. 5, Nov. 15, 1936, page 117.

A Receiver for Radio-Meteorographs—A. V. Astin and L. L. Stockman—*Review of Scientific Instruments*, Vol. 7, Dec. 1936, page 462.

Radio-Meteorographs (Survey)—K. O. Lange — *American Meteorological Soc. Bul.*, May 1936, 24 pages.

On the Accuracy of the Atmosphere Investigations by Means of Radio-Meteorographs — (Russian) P. Moltchanoff — *Meteorol. Hydrologia* 2, Nr. 2, 1936, page 30.

Radio Meteorograph—*Comm. & Broadcast Engineering*, Vol. 3, No. 6, June, 1936, page 24.

The Galcit Radio-Meteorograph—O. C. Maier and L. E. Wood — *Aero. Sci.*, 4, 1937, page 417.

An Electric Motor for Radio-Meteorographs, L. F. Curtiss and A. V. Astin—*Rev. Sci. Instru.* 7, 1936, page 358.

The 1935 Radio-Meteorograph of Blue Hill Observatory — K. O. Lange — *Bul. American Meteorological Society*, 17, 1936, page 136.

A Practical System for Radio-Meteorograph—*Aero. Science*, 3, 1935, page 35.

Eine Neue Radiosonde, *Mitt. Meteorol. Inst. Univ. Helsingfore*, 29, 1935, page 1012, and The Finnish Radio-Sound, *Mitt. Meteorol. Inst. Univ. Helsingfore*, 35, 1937, page 1.

Les Radiosondages Meteorologiques — R. Bureau—*Onde Éléctrique*, 14, 1935, page 10.

Radio-Meteorography as applied to Unmanned Balloons—W. H. Wenstrom—*I.R.E. Proceedings*, Vol. 23, No. 11, Nov. 1935, page 1345.

Recording of Rapid Changes in Temperature, Humidity and Barometric Pressure during Airplane Flights with the Use of an Improved Type of Meteorograph—*Science* — Vol. 81, Supp., Feb. 1, 1935, page 36.

Negative Resistances and Devices for Obtaining It—E. W. Herold—*I.R.E. Proceedings*, Vol. 23, 1935, page 1201.

Weather Forecasting by the Air-Mass System—H. R. Byers—*Air Commerce Bulletin*, Vol. 6, No. 7, Jan. 15, 1935, page 159.

New Six-Hour Airway Weather Service —D. M. Little—*Air Commerce Bulletin*, Vol. 6, No. 10, April 5, 1935, page 224.

Aviation Training—*Aeronautics Bulletin No. 19*, July 1, 1935, U. S. Dept. of Commerce Government Printing Office, Washington, D. C.

Icing of Aircraft—E. J. Minser—*Air Commerce Bulletin*, Vol. 6, No. 6, Dec. 15, 1935, page 144.

Zur Messung der Oberen Wolken-und Nebelgrenze auf Drahtlichen und Drahtlosen Wege—R. Feige—*Z. Instrumentenk.* 54, 1934, page 23.

Maps Showing Upper Air Wind Velocity and Directions for Airmen—*Air Commerce Bulletin*, Vol. 5, No. 1, July 15, 1933, page 7.

Teletypewriter Transmission for Aeronautical Weather Reports — *Air Commerce Bulletin*, Vol. 5, No. 1, July 15, 1933, page 8.

Das Radiosondemodell Telefunken und Seine Anwendung — P. Duckert — *Beitr. Physik Freien Atm.*, 20, 1933, page 303.

Neue Neteorographen fur Drahtlose Fernübertragung—L. Heck and G. Sudeck—*Gerlands Beitr.* 31, 1932, page 291.

The Modern Radio-Meteorograph — L. Heck and G. Sudeck—*Nature* (London) 130, 1932, page 1006.

New System of Schedules for Broadcast of Airway Weather Information — *Air Commerce Bulletin*, Vol. 3, No. 8, page 438, March 15, 1932.

Tracing Balloon Drift by Wireless—*Wireless World*—Vol. 28, June 3, 1931, page 603.

A Visual Signaling Meteorograph — J. Peterson—*Trans. Roy. Soc. Canada*, 25, Section 3, 1931, page 115.

Radio Tracking of Meteorological Balloons — W. R. Blair & H. M. Lewis—*I.R.E. Proceedings*, Vol. 19, Sept. 1931, page 1531.

Zur Technik der Erforschung der Atmosphare—P. Moltchanoff—*Beitr. Physik Freien Atm.* 14, 1928, page 45.

Panoramic Reception Makes Possible New Type of Radio Compass Using Cathode-Ray Tube—*Aviation*, Vol. 37, June 1938, page 46.

Special Number Devoted to the Subject of Safety in Aviation—*Elektrotechnische Zeit.*, Vol. 58, No. 33, Aug. 19, 1937, page 894.

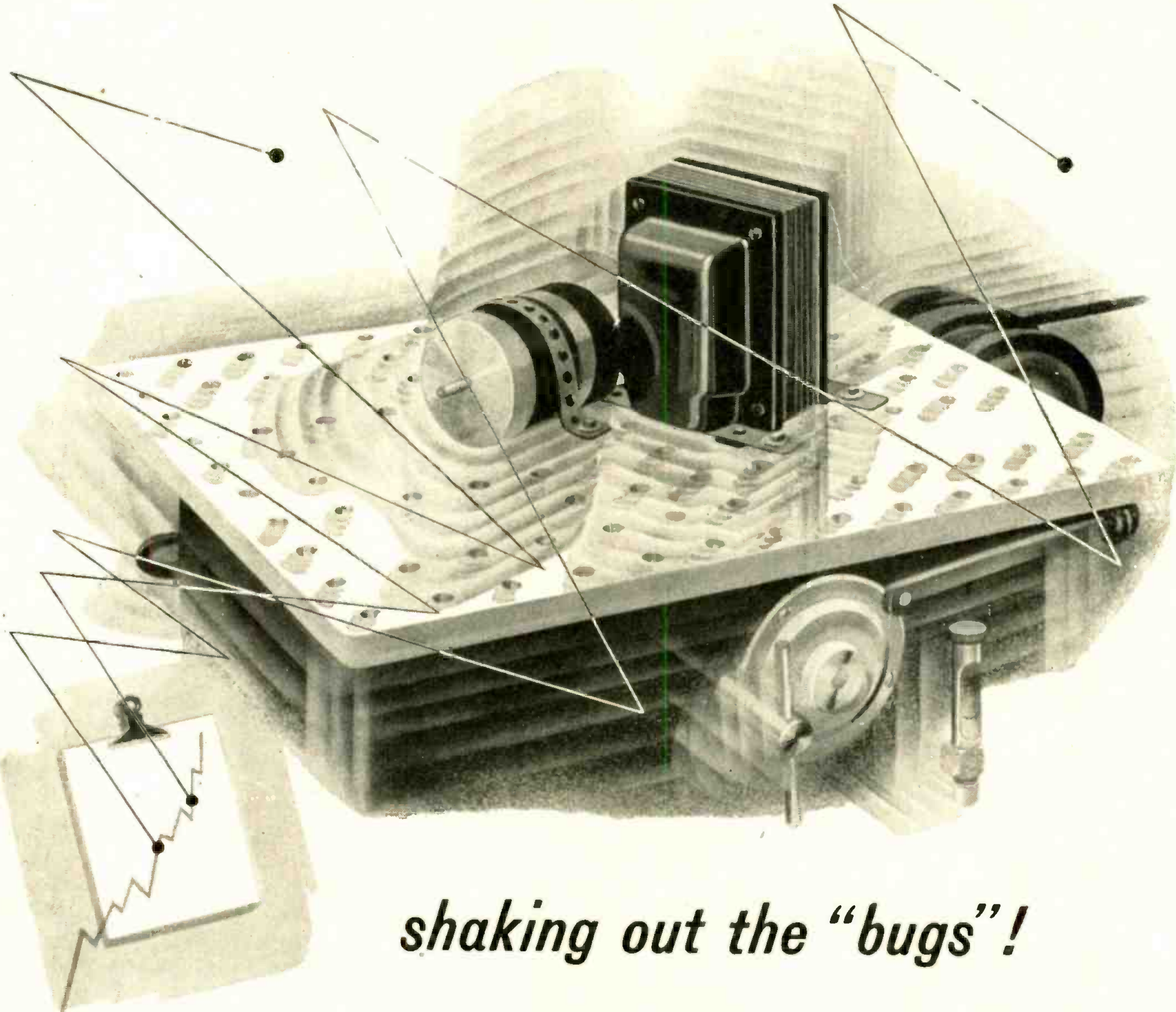
Aerial Navigation by the Valoris Radio Beacon—Valoris—*Les Ailes*, No. 837, July 1, 1937, page 8.

U. S. Patent #2,094,333—Smith—Radio Beacon System—Issued Sept. 28, 1937.

U. S. Patent #2,038,873 — Purington — Position Determining Apparatus—Issued April 28, 1936.

U. S. Patent #2,050,276—Chubb—Posi-

[*Continued on page 70*]



shaking out the "bugs"!

Vibration is a deadly enemy. Unless equipment and parts can withstand its destructive force, irreparable damage results at crucial moments.

Parts tested on Utah's *Vibration Life-test Equipment* have the "bugs" shaken out of them before they are ready for quantity production; are again proved by this "power dive" test of production runs... assuring unfailing performance.

Equipment being tested is subject to vibration up to 25G.

As a result of this and other tests, many engineers' "brain children" grow up in the Utah Laboratories and on the production lines to play their parts in today's war effort. *Tomorrow*, these war-created radio and electronic improvements will be adapted to peacetime needs — aided by these new and more comprehensive testing techniques.

* * *

Every Product Made for the Trade, by Utah, Is Thoroughly Tested and Approved

Keyed to "tomorrow's" demands: Utah transformers, speakers, vibrators, vitreous enamel resistors, wirewound controls, plugs, jacks, switches and small electric motors.

utah

Utah Radio Products Company, 846 **Orleans Street, Chicago 10, Ill.**

TECHNICANA

[Continued from page 20]

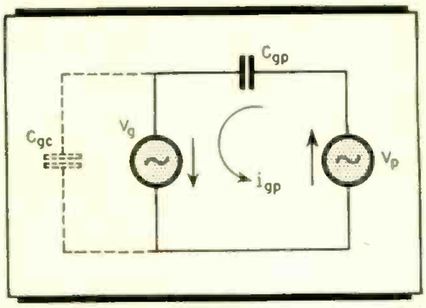


Figure 8

The real value of this expression, when added to the grid-cathode capacitance, gives $(1 + A \cos \phi)\ C_{gp} + C_{gc}$, the effective input capacitance. The second term represents a reflected resistance to the input which is the input voltage divided by the power component of the current.

$$R_{input} = \frac{V_g}{-AV_g \sin \phi\ \omega C_{gp}} = \frac{-1}{A \sin \phi\ C_{gp}}$$

Examination shows that a phase shift in the plate circuit results in an actual reduction in the value of the effective input capacitance, but introduces a resistive component. If ϕ is positive, as shown above, the resistance is negative and the selectivity of the circuit is increased. If the power supplied by the reflected negative resistance is greater than the losses, the tube will break into oscillation.

If the reflected resistance is positive, power is taken from the source and the grid input is attenuated, reducing selectivity.

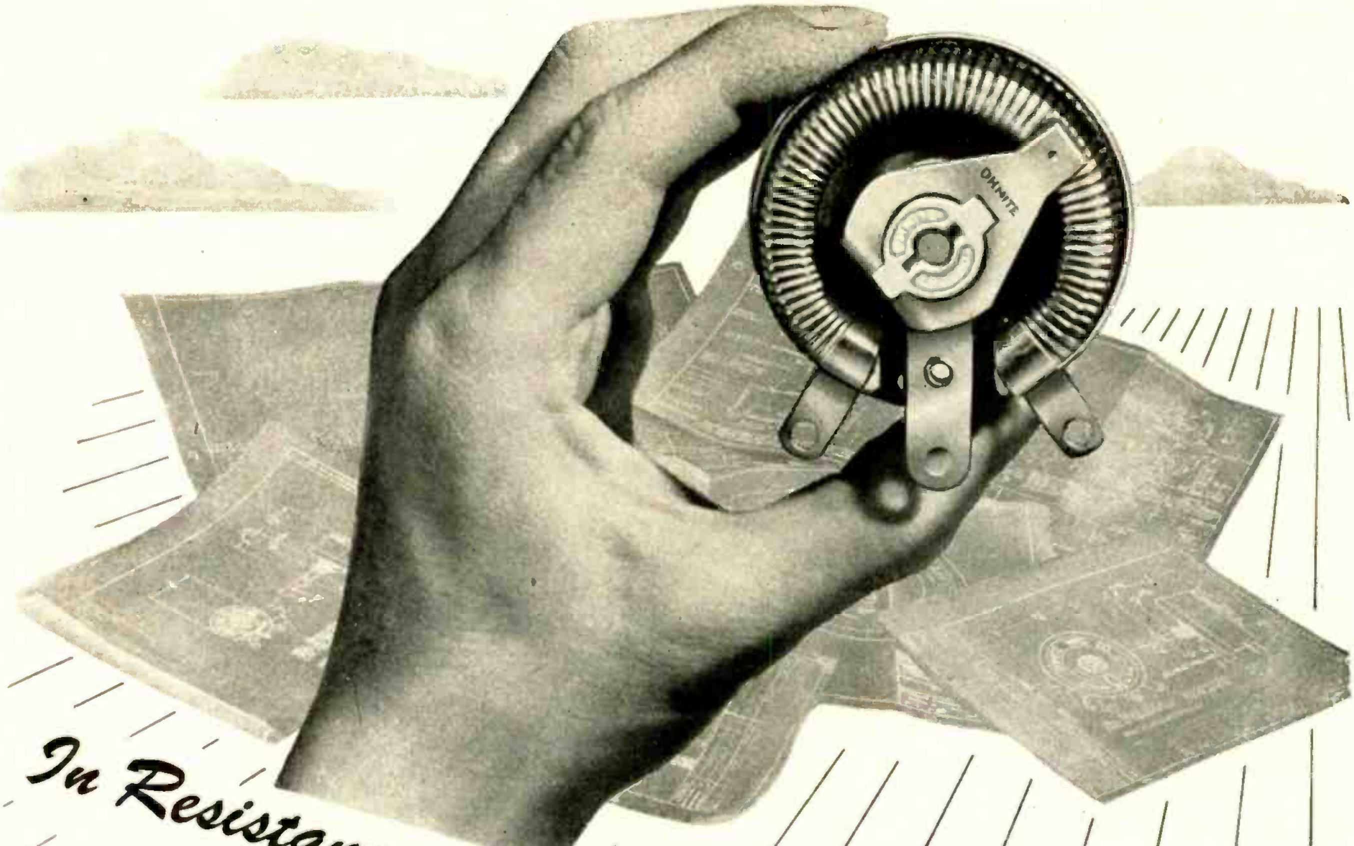
In a tuned-plate, tuned-grid amplifier, tuned to the frequency in the plate circuit, the Miller effect is that of reflected capacitance only, which will tend to correct the grid tuning. If neither circuit is exactly in tune a positive resistance will be reflected and the grid circuit will be damped.

This apparent "pulling" effect is characteristic of the circuit. Tetrodes and pentodes are recommended but it is pointed out that since tube gain is higher, reflected capacitance will be proportionately greater.

BENDIX TO MAKE HOME RADIOS

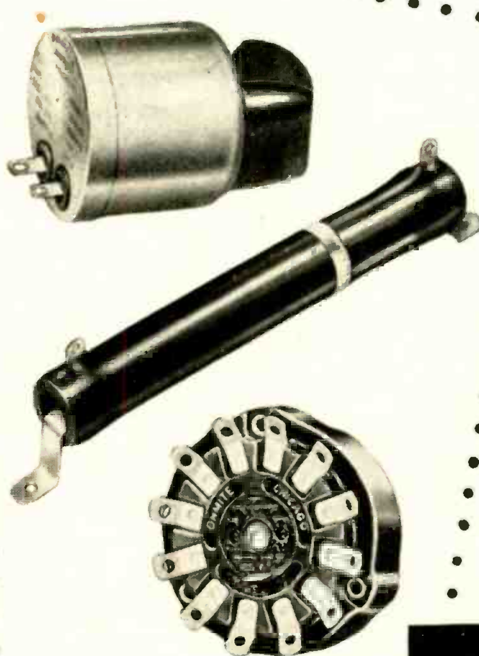
The Bendix Radio division of Bendix Aviation Corporation will for the first time manufacture and market a complete line of AM-FM home radio sets as soon as the military situation permits, it was announced by Ernest R. Breech, president.

Home radios will be manufactured in the company's plants in Baltimore, it was stated.



In Resistance Control

OHMITE EXPERIENCE MAKES A DIFFERENCE



You get the benefit of Ohmite experience in meeting the varied requirements of innumerable applications . . . in pioneering new rheostat, resistor and tap switch developments . . . in producing the widest range of types and sizes to answer every control need. Add to this, the long service-record of Ohmite Units—their proved ability to function under the most severe operating conditions.

Such experience in resistance control is invaluable to engineers designing new devices to defeat the enemy or planning new products for the postwar era.

Your Answer Book to Resistance Problems

Write on company letterhead for helpful 96-page Industrial Catalog and Engineering Manual No. 40.

OHMITE MANUFACTURING COMPANY

Foremost Manufacturers of Power Rheostats, Resistors, Tap Switches

4861 FLOURNOY STREET ★ CHICAGO 44, U. S. A.

Be Right with OHMITE

RHEOSTATS • RESISTORS • TAP SWITCHES

BIBLIOGRAPHY

[*Continued from page 66*]

tion Finding System — Issued Aug. 11, 1936.

Radio Beacons, Bajenov and Miasoebov, (Text) 1936.

Sinterae Beacon for the Penetration of Fog by Vibratory Light—*Engineer*—Vol. 160, Oct. 11, 1935, page 375.

Sinterae for Beacon—*Engineering*—Vol. 140, July 5, 1935, page 26.

U. S. Patent #1,991,474—Taylor—Radio Beacon System—Issued Feb. 19, 1935.

U. S. Patent #1,992,197 — Diamond — Method and Apparatus for Multiple Course Radio Beacon—Issued Feb. 26, 1935.

U. S. Patent #1,992,927 — Dunmore — Method and Apparatus for Radio Beacon Course and Quadrant Identification—Issued Feb. 26, 1935.

U. S. Patent #1,998,834—Englund—Radio Guiding System—Issued April 13, 1935.

U. S. Patent #2,010,968—Smith—Direction and Distance Measurement—Issued Aug. 13, 1935.

U. S. Patent #1,941,585—Silbey—Radio Beacon System (Combines teletype and radio range)—Issued Jan. 2, 1934.

U. S. Patent #1,942,262 — Shanklin — Method for Determining Location in Progress—Issued Jan. 2, 1934.

U. S. Patent #1,949,256—Kramar—Radio Direction Finder—Issued Feb. 27, 1934.

U. S. Patent #1,953,239 — Kramar — Supervisory Apparatus for Radio Beacons—Issued April 3, 1934.

U. S. Patent #1,961,206 — Diamond — Twelve-Course Aural-Type Triple-Modulated Directive Radio Beacons — Issued June 5, 1934.

U. S. Patent #1,910,427 — Diamond — Method of Adjusting Radio Beacon Courses—Issued May 23, 1933.

U. S. Patent #1,913,918 — Diamond — Triple-Modulation Directive Radio Beacon System—Issued June 13, 1933.

U. S. Patent #1,919,556—Jocquemin—Process for Radio Direction, Locating Observation and the Like—Issued July 25, 1933.

U. S. Patent #1,922,677—Greig—Radio Direction Finding System—Issued Aug. 15, 1933.

U. S. Patent #1,923,920—Diamond, et al. —Course Shift-Indicator for the Double-Modulation Type Radio Beacon—Issued Aug. 22, 1933.

U. S. Patent #1,923,934—Kear—Radio Beacon Course Shifting Method—Issued Aug. 22, 1933.

U. S. Patent #1,937,876—Donovan—Radio Beacon (relates to radio range keying)—Issued Dec. 5, 1933.

U. S. Patent #1,938,624 — Eckersley — Direction Finder—Issued May 12, 1933.

U. S. Patent #1,865,826 — Brockstedt — Radio Signal Apparatus and Method—Issued July 5, 1932.

A Radio System for Flying and Landing Aircraft in Fog—H. Diamond and F. W. Dunmore—*Mechanical Engineering*—Vol. 54, June 1932, page 439. Abstract of *ASME* Transaction Papers.

Directive Radio Beam Channel to Guide Pilots—*Radio Engineering*—Vol. 12, July 1932, page 30.

Energized Cables Lower Hazards of Fog —*Electric World*—Vol. 99, April 9, 1932, page 642.

Radio Guidance — J. E. Miller — *I.R.E. Proceedings*, Vol. 20, Nov. 1932, page 1752.

Guidage Radio-Electrique des Navires et Aeronefs—David Pierre—Rec. Scientifique—Vol. 69, pp. 592-597, Oct. 10, 1931.

Telecompas et Stabilisateur Automatique de Cap Systeme—Genie Civil—Vol. 100, April 30, 1932, page 443.

Radiogoniometrie et Vole de Nuit—Q.S.T.-Francais—Vol. 12, pp. 52-55, March 1931.

Le Guidage et le Sondage Aeriens. Vue d'ensemble sur las situation generale en France—Emile Fromy—Rev. Gen. De-*L'Éléctricité*—Vol. 29, Feb. 14, 1931, page 269.

Radio Charts the Air-Course — H. K. Hudson—Radio News—Vol. 12, Feb. 1931, page 708.

Les Procèdes Loth Pour le Guidage des Avions par Ondes Hertziennes—Dantin ch. Genie Civil—Vol. 98, pp. 473-475, May 9, 1931.

A Twelve-Course Radio Range—H. Diamond and F. G. Kear—*I.R.E. Proceedings* —Vol. 18, No. 6, June 1930, page 939.

Sur un Procede de Guidage des Avions-Biot—M. *L'Onde Éléctrique*—Vol. 9, pp. 520-526, Nov. 1930.

Les Procèdes Radio-Éléctriques pour la Guidage des Navires et des Aeronefs-David—P. *L'Onde Éléctrique*—Vol. 9, pp. 197-227, May 1930.

U. S. Patent #2,045,904—Furnival—Radio Beacon—Issued June 30, 1930.

Blind Flying—A Race against Death with only Dials to Guide You—A. Jordanoff—*Popular Science*—Vol. 117, pp. 38-39, 151-153, November 1930.

[*Continued on page 72*]

RADIO

GROUP SUBSCRIPTIONS SAVE YOU UP TO 50%!

TEAR OUT—MAIL TO RADIO

RADIO MAGAZINES, INC.
342 Madison Ave., New York 17, N. Y.

Kindly enter the following subscriptions. Remittance is attached. (1 to 6 subscriptions may be ordered on this form).

- ☐ One 1-year subscription $3.00
- ☐ Two 1-year subscriptions $5.00
- ☐ Three 1-year subscriptions $6.00
- ☐ Four 1-year subscriptions $7.00
- ☐ Five 1-year subscriptions $8.00

Groups of 6 or more subscriptions in the U.S.A. will be accepted at the rate of $1.50 each. For Canadian groups add $.50 to each subscription ordered.

PLEASE PRINT

Name ....
Address ....
....
Position .... Company ....

Name ....
Address ....
....
Position .... Company ....

Name ....
Address ....
....
Position .... Company ....

Name ....
Address ....
....
Position .... Company ....

Name ....
Address ....
....
Position .... Company ....

Name ....
Address ....
....
Position .... Company ....

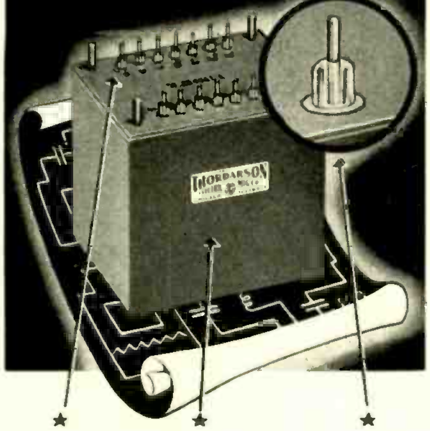
NOTE. If you do not wish to tear out this order blank, print or type a list giving each subscriber's name, address, employer's name and their respective positions. Mail it in today!

You and your co-workers can now save up to half the regular cost of a RADIO subscription by using the Group Plan. The more men in a Group the more each saves, up to 50%. Present subscriptions may be RENEWED or EXTENDED as part of a group.

The combination of exclusive, fine and timely articles plus this low-rate subscription offer makes RADIO a must-have publication. So fellows, form a Group today and send it to—

RADIO MAGAZINES, INC.

342 MADISON AVENUE NEW YORK 17, N. Y.



BIBLIOGRAPHY

[*Continued from page 70*]

Le Guidage par Cable Sous-Marin, Procède William Loth, est Definitivement au Point—Labadie, Jean—*Science et La Vie*—Vol. 37, pages 306-314, April 1930

A Tuned-Reed Course Indicator for the Four- and Twelve-Course Aircraft Radio Range—F. W. Dunmore—*I.R.E. Proceedings*—Vol. 18, No. 6, June 1930, page 963.

Unmittelbare Steuerung der Lnft durch Elektrische Schwingungen—*E.T.Z.*—Vol. 50, Oct. 17, 1929, page 1526.

Electric Cables Buried Underground Would Guide Airplanes Across Treacherous Mountain Ranges and into Airports, According to a New System Devised by a French Aviator named Loth—*Teleg. and Teleph. Age*—No. 13, July 1, 1929, page 302.

Au Sujet du Guidage des Navires ou Aeronefs par Ondes Dirigées — Loth — *Comptes Rendus*—Vol. 189, Oct. 28, 1929, pages 682-684.

U. S. Patent #1,726,474 — Delavalle — Method of Radio Signalling—Issued Aug. 27, 1929.

Navigation of Aircraft—Ramsey—Ronald Press 1929—page 102.

Radio Guidance of Aircraft—H. Pratt—Radio—10, Feb. 1928, page 19.

Some Experiments on the Application of the Rotating Beacon Transmitter to Marine Navigation — R. L. Smith-Rose and S. R. Chapman—*Journal I.E.E.* (London), 66, March 1928, page 256.

Rotating Loop Radio Transmitters and Their Application to Direction Finding and Navigation—T. H. Gill and E. S. Hecht — *Journal I.E.E.* (London), 66, March 1928, page 241.

A Theoretical Discussion of Various Possible Aerial Arrangements for Rotating Beacon Transmitters—R. L. Smith-Rose—*Journal I.E.E.* (London), 66, March 1928, page 270.

Recent Developments in Low Power and Broadcasting Transmitters—I. F. Byrnes —*I.R.E. Proceedings,* 16, May 1928, page 614.

Apparent Night Variations with Crossed Coil Radio Beacons — H. Pratt — *I.R.E. Proceedings*, 16, May 1928, page 652.

Sur un Nouveau Dispositif d'Alignement par Emissions Hertziennes—J. Aicardi—*Comptes Rendus,* 186, Jan. 30, 1928, page 305; *Experimental Wireless* (London), 5, May 1928, page 288.

Development of Radio Aids to Air Navigation—J. H. Dellinger and H. Pratt—*I.R.E. Proceedings,* 16, July 1928, page 890.

Robbing Fog of Its Perils. Waves of Radio and of Light and Sound Guide Planes and Steamships through Blinding Vapor — McLoud, Norman C. — *Popular Science*—Vol. 112, March 1928, pages 47-48.

Some Experiments on the Application of the Rotating Beacon Transmitter to Marine Navigation—R. L. Smith-Rose—*Experimental Wireless*—Vol. 5, Feb. 1928, pages 88-90.

A Theoretical Discussion of Various Possible Aerial Arrangements for Rotating-Beacon Transmitters—R. L. Smith-Rose—*Experimental Wireless*—Vol. 5, pages 90-92; discussion, 92-93, Feb. 1928.

Rotating Loop Radio Transmitters and Their Application to Direction Finding and Navigation—T. H. Gill and N. F. G. Hecht — *Experimental Wireless* — Vol. 5, Feb. 1928, pages 85-88. (Abstract of paper read before the I.E.E. Jan. 4, 1928.)

Designed of Tuned Reed Course Indicators for Aircraft Radio Beacon—F. W. Dunmore—*Bureau of Standards Journal of Research*—Vol. 1, No. 5, Nov. 1928, page 751.

Unidirectional Radio Beacon for Aircraft —E. Z. Stowell—*Bureau of Standards Journal of Research*—Vol. 1, No. 6, Dec. 1928, page 1011.

Applications of Radio in Air Navigation. Radio-Telephone Communication; the Double Beam Directive Beacon; Marker Beacons; Field Localizers; Direction Finders; Landing Altimeters; etc.—H. J. Dellinger—*Mechanical Engineering*—Vol. 49, Jan. 1927, page 29-32.

Radio Along the Airways, Invisible Beams Guide Birdmen in Flights between European Cities—Orrin E. Dunlap—*Sci. Am.* —Vol. 83, Jan. 1927, pages 32-33.

Directional Wireless as an Aid to Navigation—R. L. Smith-Rose—*Nature*—Vol. 120, Nov. 26, 1937, pages 774-776.

The Possibilities of Directional Radio Transmission—J. H. Dellinger—*Franklin Institute,* 204, Aug. 1927, page 239.

The Stationary and Rotating Equisignal Beacon—*S.A.E. Journal*—Vol. 19, Sept. 1926, pages 209-220.

A Wireless Beam for Ships—*El. Rev.*—Vol. 99, Sept. 17, 1926, page 459.

Stationary and Rotating Equisignal Beacon—W. H. Murphy and L. M. Wolfe—*S.A.E. Journal*—Vol. 19, Sept. 1926, page 209.

[*Continued on page 74*]

BIBLIOGRAPHY

[Continued from page 72]

Beam Direction Finding — *Electronics* — Vol. 95, Sept. 11, 1925, pages 296-297.

Radio Beacons Non-Directive and Directive—F. W. Dunmore—*Radio News*—Vol. 5, May 1924, pages 1554-1556 and 1685-1686.

MAGNETRONS

[Continued from page 32]

Cavity Resonators

Alekseev and Malairov have developed a magnetron utilizing cavity resonators integral with the anode. A diagrammatic scheme of the tube is shown in *Fig. 3*, although in the actual apparatus certain refinements such as water-cooled anodes are used. Likewise, the number of cavities was increased in many of the experimental tubes. The interested reader may refer to the *I.R.E. Proceedings* for March 1944 for detailed specifications presented by I. B. Bensen.

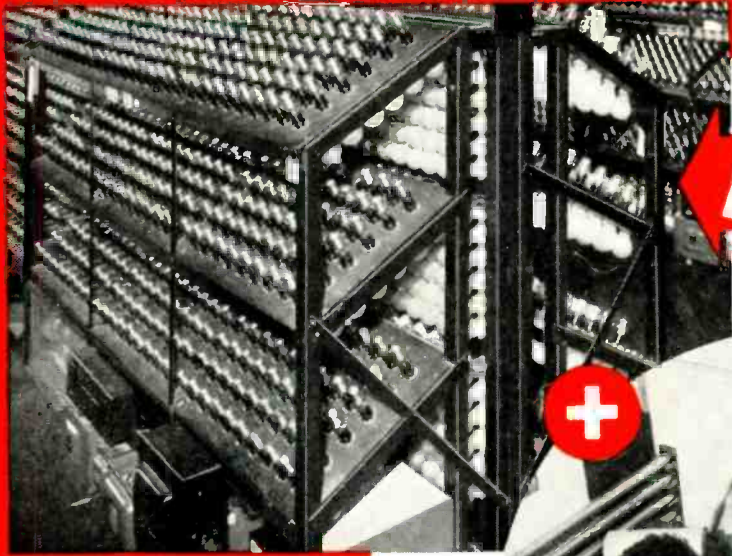
The cavity magnetron has been found capable of developing up to 300 watts at a wavelength of 9 centimeters, which is in the middle range of wavelengths usually regarded as constituting the microwave range.

It will be observed that the resonant frequency is independent of the dimensions of the anode, which may be made of ample size to dissipate the desired power. The investigators find a new limitation to the power output obtainable due to back-heating of the cathode. A power output of 300 watts at 9 centimeters in a four-cavity magnetron represented the maximum level, although the anode was able to dissipate considerably greater powers.

Thus the water-cooled magnetron with the resonant element within the tube itself presents a most attractive path into the field of high-power microwave generation.

ADVERTISING INDEX

A+B=X ★★★

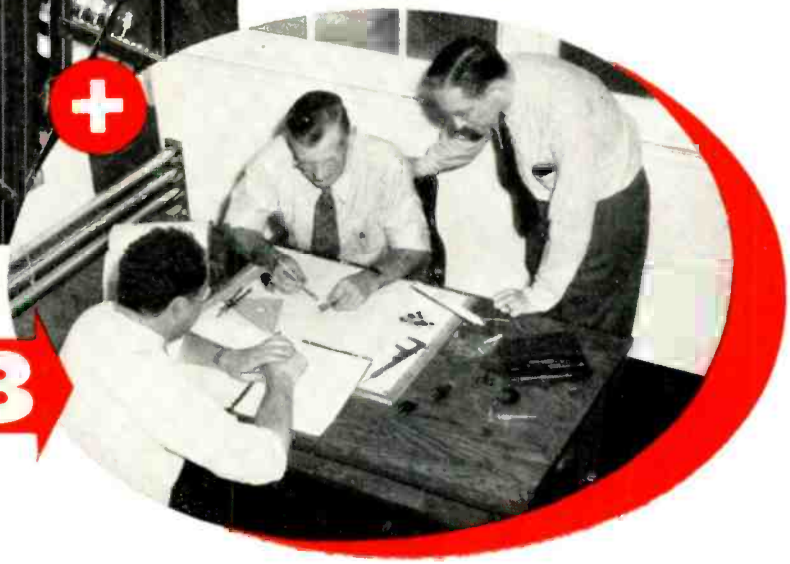


RECEIVING TUBE TECHNIQUE

Oldest manufacturer specializing on radio receiving tubes — the originator of the now standard BANTAM GT — Hytron has been developing skill in high-speed, soft-glass receiving tube technique since 1921.

A

+



SPECIAL PURPOSE ENGINEERING

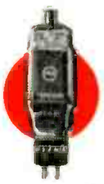
Hytron engineers originated BANTAM JR. hearing-aid tubes —popular U-H-F types HY75, HY114B, HY615—instant-heating beam tetrodes HY65, HY67, HY69, HY1269—and numerous other special tubes.

B

=X

THE ANSWER

Add A to B, and you have the answer Hytron is able to give the Services when they demand special purpose and transmitting tubes in staggering quantities and at economical prices.



1616 Consider a few examples. Substituting soft for hard glass, a mesh for a ribbon filament, Hytron beat the promise by months on requirements for the high-voltage thermionic type 1616 rectifier—through application of mass production methods. Result: The Navy's, "Well done!"

HY65 Typical of Hytron's instant-heating beam tetrodes for mobile communications, the HY65 combines high-speed techniques with a thoriated tungsten filament and special r.f. design features which gave the Services a rugged, power-conserving, all-purpose beam tetrode. (Cf. JAN-1A spec.)

OD3/VR-150 Hytron engineering refinements include new starting electrode, lower starting voltage, painstaking processing. Add to these still-increasing high-speed manufacture. Result: "When we think of the OD3/VR-150, we think of Hytron."*

*Quotation from expediter for one of largest electronic equipment manufacturers.

2C26 Hytron solved a problem for the Services by designing a tube capable of performance and high ratings never before achieved in soft glass. Produced at receiving tube speed and priced at less than a fourth of the cost of tubes replaced, the little 2C26 delivers 2 KW of useful r.f. power under intermittent operating conditions.

WHAT ABOUT POST-WAR? Hytron design, development, and production facilities now serving our fighting men, will be yours to command. The A plus B of Hytron's know-how will supply answers to your special tube problems.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

HYTRON CORPORATION ELECTRONIC AND RADIO TUBES

SALEM AND NEWBURYPORT, MASS.

ARMY NAVY

BUY ANOTHER WAR BOND

4 NEW *Fact-Ful* GUIDES

FOR DESIGNERS OF COMMUNICATIONS EQUIPMENT

SEND FOR THESE NEW BOOKLETS TODAY!

Whether it's a problem of stepping up d-c power... reducing core assembly time... locating the right high-frequency insulators or high-voltage d-c capacitors in a hurry, you'll find the answer in these new Westinghouse publications. Complete listings of sizes, weights and dimensions, together with application guides make these booklets an invaluable aid in designing and ordering.

These are only four examples of the help that Westinghouse can offer in the design and manufacture of communications equipment.

Other helpful publications are available on

- Micarta insulating parts and materials
- Thermostats
- Instruments
- Rectox rectifiers
- Relays
- Contactors

Whatever your problem, Westinghouse Communications Equipment and Communications Specialists can help you find a quick solution. Call on Westinghouse for help. Ask for the booklets you want from your Westinghouse representative, or write Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N.

J-94613

Westinghouse *Communications Products*

PLANTS IN 25 CITIES... OFFICES EVERYWHERE