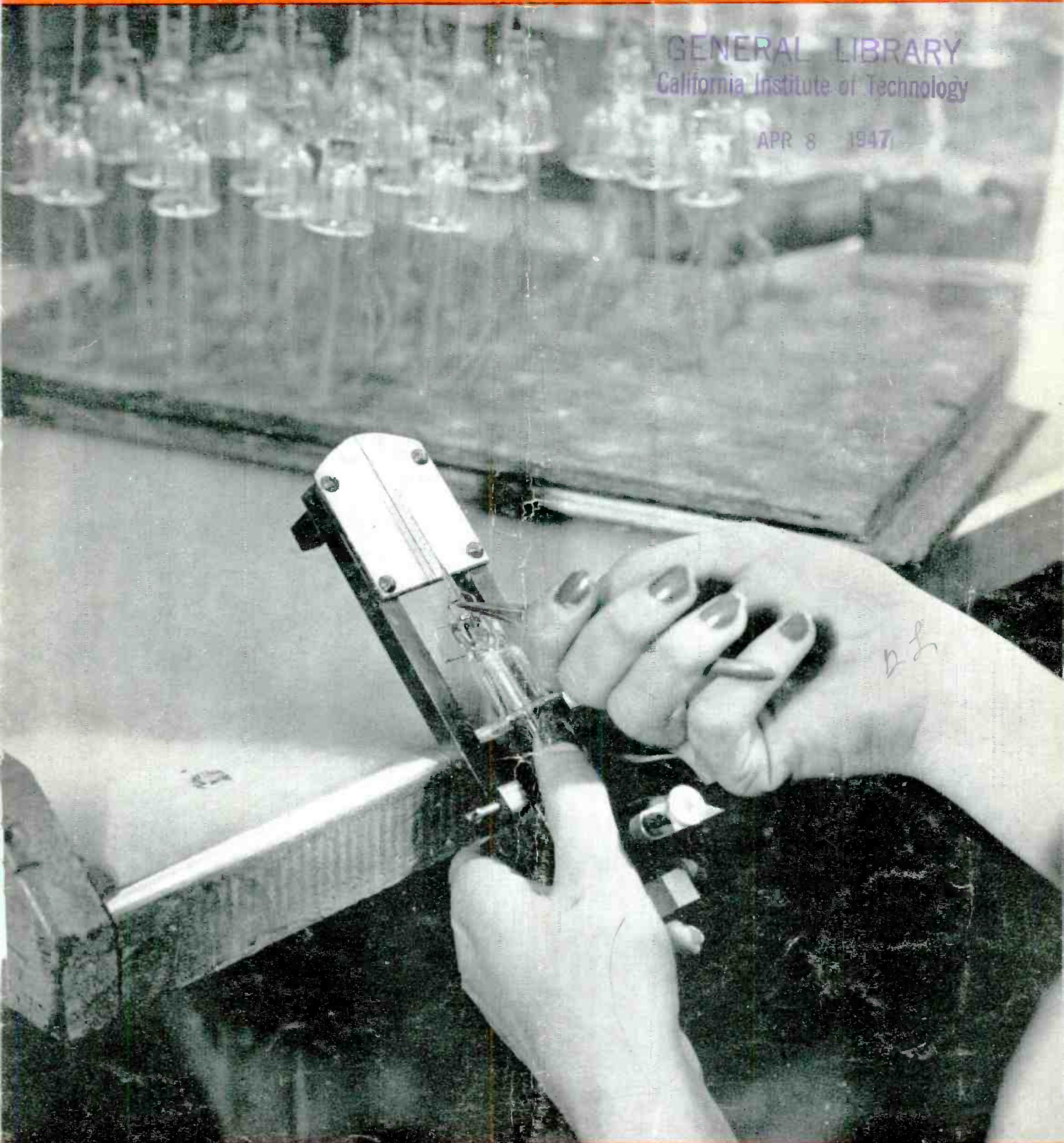
FEBRUARY-MARCH, 1947

RADIO

MANUFACTURING AND BROADCASTING

The Journal for Radio & Electronic Engineers



Design • Production • Operation

RADIO

RADIO MAGAZINES, INC.
342 MADISON AVE., NEW YORK 17, N. Y.
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March 10th, 1947

Dear Subscriber:

Recently we sent you an announcement of a change in editorial slant of RADIO magazine, to take effect with our May, 1947, issue. We pointed out that the industry is becoming so highly specialized that groups engaged in one branch of the radio-electronic field often find little interest in the other widely differing branches.

The one branch of the industry which is of common interest to all groups in such diverse fields as transmitter and receiver manufacturing, sound on film, public address, broadcasting, and industrial sound, is audio engineering. Because there has been no technical magazine devoted solely to this field, all engineers interested in audio engineering have had to gather piecemeal, from a large number of sources, such information on the subject as is published.

To render greater service to our readers and to the industry, we have decided to devote our magazine exclusively to the audio engineering field. For this reason, Radio Magazines, Inc. will change the name of RADIO magazine to AUDIO ENGINEERING. The first issue incorporating these changes will be released late in April. The magazine's format will be radically new, enlarged, and the articles will be attractively presented and easy to read, besides being authoritative.

Our decision to specialize in audio engineering has aroused tremendous interest among engineers prominent in the field. Co-operating with the editorial staff are such well known authorities as Howard A. Chinn, chief audio engineer, Columbia Broadcasting System, Dr. Richard P. Bolt, director, Acoustic Laboratories, Massachusetts Institute of Technology, John D. Colvin, American Broadcasting Company, George Nixon, National Broadcasting Company, and Joseph P. Maxfield, authority on sound engineering, Bell Telephone Labs. All will contribute articles to AUDIO ENGINEERING.

Your present subscription to RADIO was entered at $3.00 for one year or $5.00 for two years. AUDIO ENGINEERING subscriptions will be accepted at the same rate. You will receive a copy of the first issue of AUDIO ENGINEERING. If you do not find it acceptable in place of RADIO, we will make a cash refund for the unexpired balance of your subscription to RADIO.

Cordially yours,

RADIO MAGAZINES, INC.

John H. Potts

Editor

MEMBER AUDIT BUREAU OF CIRCULATIONS

RADIO

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MIDWEST OFFICE
H. S. Laufman, Manager
82 West Washington St., Chicago 2, Ill.
ANDover 1395

PACIFIC COAST REPRESENTATIVE
JAMES C. GALLOWAY
816 W. 5th St., Los Angeles 13, Calif.

FOREIGN SUBSCRIPTION REPRESENTATIVES
Radio Society of Great Britain, New Ruskin House, Little Russell St., London, W.C. 1, England. Harris & Floyd, 297-299 Swanston, St., Melbourne, C. 1. Victoria, Australia

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COVER

Operator checks the "line-up" of the filament for an 834 transmitting tube at the Brooklyn plant of the Amperex Electronic Corp. Manufacturing methods require that the exhaust tubing and center filament support be in perfect alignment. Any variation shows up when the tube is laid in the "V" holder and rotated 360 degrees.

ARTICLES

RADIO Magazine (title registered U. S. Pat. Off.) is published monthly at Boston Post Road, Orange, Connecticut, by Radio Magazines, Inc. Executive and Editorial Offices at 342 Madison Avenue, New York 17, N. Y. Subscription rates—United States, U. S. Possessions & Canada, $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 May 10, 1945 at the Post Office at Orange, Conn., under the Act of March 3, 1879.

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Transients

I. R. E. CONVENTION — WINTER 1947

★ As we go to press, the Institute of Radio Engineers has just concluded its most successful convention. The attendance of 12,549 was 71 per cent greater than the previous high. last year, and is believed to be the highest attained by any engineering convention. A total of 124 engineering papers was presented, covering the entire radio-electronic field. Exhibitors numbered 170, and many of the exhibits were far more elaborate than have hitherto been shown. The committee in charge handled the entire project with a degree of efficiency which merits the approbation of the entire radio-electronic industry.

Because the attendance far exceeded expectations, many who wished to hear some of the more popular lectures could not be accommodated. The wide variety of branches of the radio-electronic field becomes apparent simply from noting the subjects covered by the papers presented. Even so, some subjects were neglected, but three papers being devoted to audio engineering.

From our viewpoint, one of the features of the exhibits was the large number of high-grade recording units shown. Further development of the unique system of printing circuit connections with conducting metallic paint, introduced last year, attracted much attention. It seems difficult for many to realize that this method of making connection does not save much space, but may be more economical of labor. After all, radio equipment usually requires some source of power, and the highly publicized wrist-watch radio with printed circuits is viewed with some amusement by most radio engineers.

The general spirit of the convention was in marked contrast to that of last year. Then, most manufacturers were battling with labor troubles, material shortages, and OPA restrictions. Many felt they would have to go out of business soon. Now, production is exceeding expectations, and while profits are generally disappointing, optimism prevails.

The success of the convention will do much to stimulate confidence among the few pessimistic factors in the field. Even though it seems that the peak has now been reached, we feel that the variety and excellence of the new products should keep most manufacturers operating at full production for some time to come. Undoubtedly there will be a slight recession this summer in some lines—that is to be expected—but it should be followed by a period of even greater expansion than we have yet experienced.

ANNOUNCEMENT

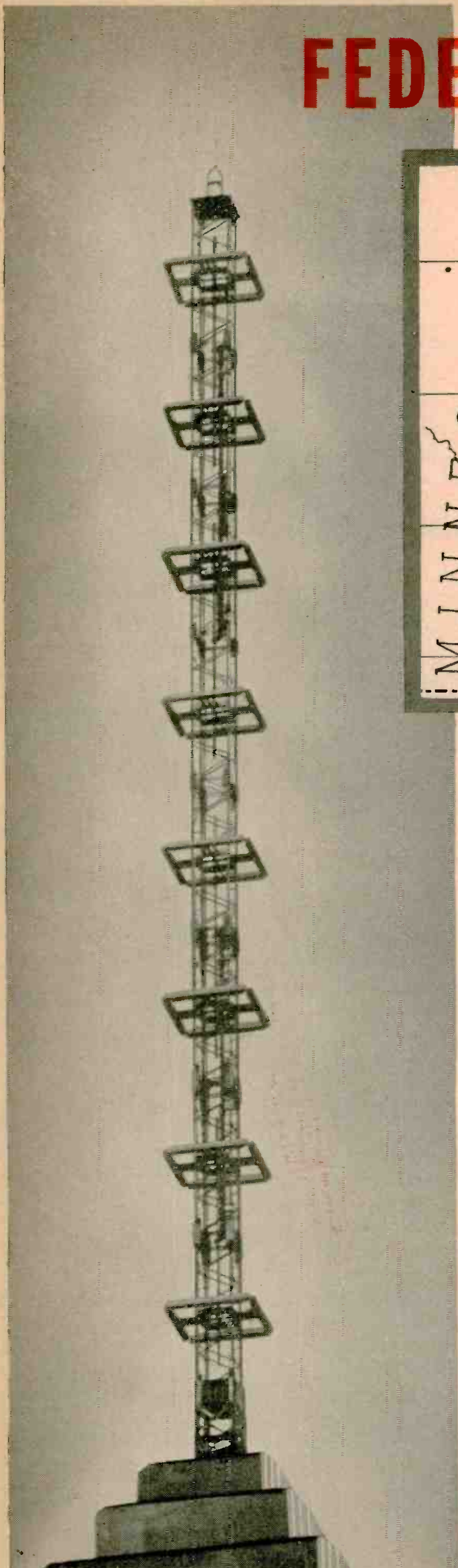
★ As stated in our letter reproduced on the inside cover of this issue, RADIO magazine will henceforth appear under the new title, AUDIO ENGINEERING. To prepare for the change, which involves preparation of special articles, a larger format and more attractive layout, we have combined the February and March issues of RADIO. Although the first issue of AUDIO ENGINEERING will appear at about the same time as the April issue of RADIO is normally mailed, it will be dated May. Each subscriber will have his subscription extended two months to make up for these changes.

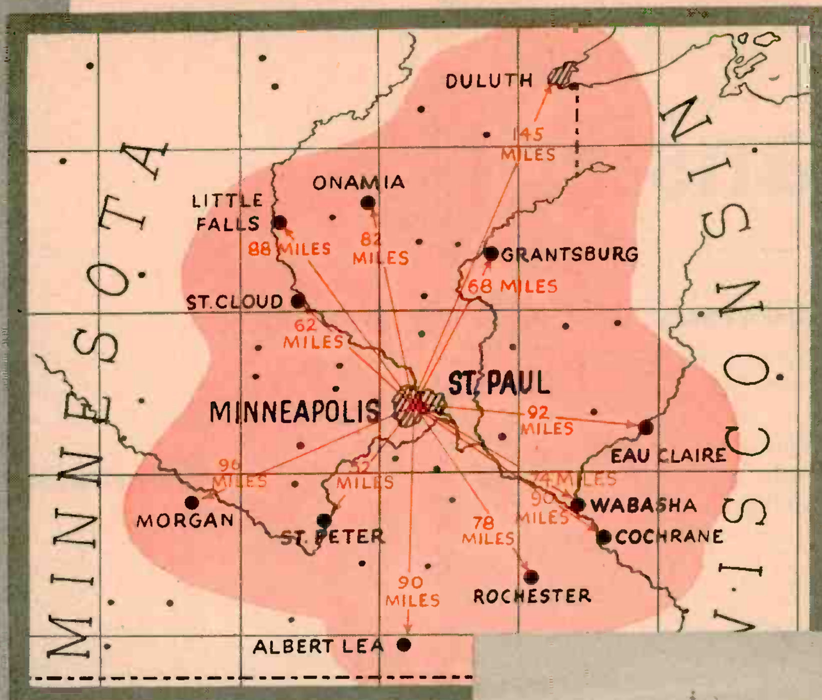
We shall welcome your comments about AUDIO ENGINEERING. A question-and-answer column will be a regular feature of the magazine, and you are invited to take full advantage of this opportunity to bring your audio engineering problems to our board of well-known authorities. Questions of general interest will be published with our answers. Your name or affiliation will be withheld if you so desire. In any event, all letters will be answered as soon as possible, so that you will not have to wait until our reply is published.

Many outstanding articles are already scheduled for AUDIO ENGINEERING. For example, Howard A. Chinn writes about magnetic tape recording, Joseph P. Maxfield on microphone placement, Norman C. Pickering on high-quality phonograph pickups, John B. Colvin on audio systems in FM broadcasting, Samuel Milborne on industrial sound, Grieveson and Wiggins on a comparative db meter which greatly simplifies microphone calibration, and many others of similar high caliber. Reviews and abstracts of audio engineering articles appearing in foreign publications will be a special feature of each issue. Also, our regular practice of including a chart to simplify design problems in audio engineering will be continued. In addition, many new features will be added which will be announced later.

J.H.P.

FEDERAL'S 8-ELEMENT





A survey of surrounding cities indicates a radiation pattern approximately as shown by the shaded area above. Listeners almost 150 miles away reported excellent volume and clarity of reception. The remarkable coverage is due to the power gain of Federal's Square-Loop Antenna. The clarity and tone quality is made possible by the exceptional fidelity and mean carrier stability of Federal's "Frequematic"* Modulator — an exclusive feature of every Federal FM transmitter.

*Trade Mark

Federal's 8-Element Square-Loop Antenna dominates the Minneapolis skyline from the top of the Foshay Tower — highest building in the Northwest. Ruggedly constructed to withstand heavy winds and icing loads, this 80-foot antenna has already proved its dependability in temperatures down to 22 degrees below zero!

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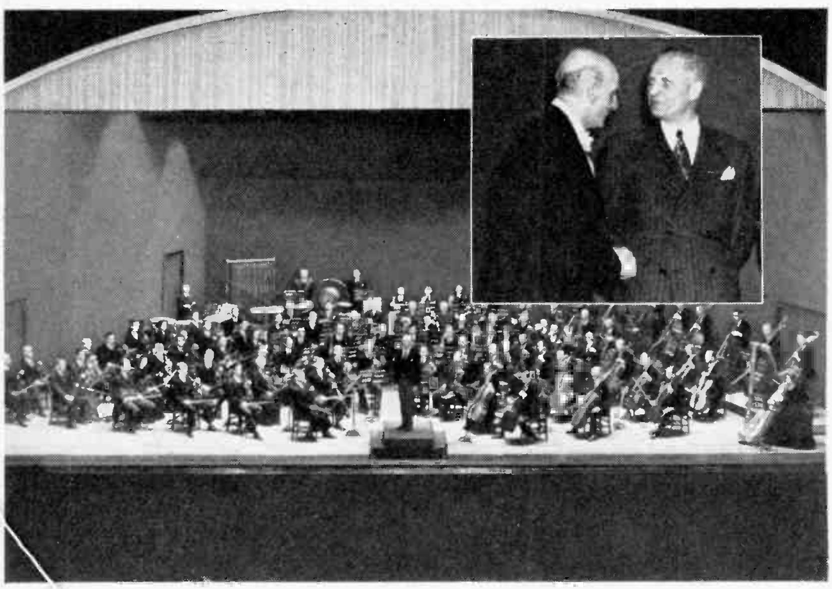
SQUARE-LOOP FM ANTENNA MAKES WORLD DEBUT!

WTCN-FM, Minneapolis, goes on the air with most efficient FM Antenna installed anywhere . . . boosts 3kw transmitter to 25kw . . . with coverage of 30,000 square miles

FEDERAL'S 8-Element Square-Loop Antenna made radio history with the opening of the Twin Cities FM station, WTCN — the first super-directive antenna of its type and power gain to be installed anywhere. It gives the 3kw Federal transmitter an effective radiated power of 25kw — providing excellent reception over an area of approximately 30,000 square miles. This makes WTCN the world's *most efficient* FM station—and, with an FCC permit for an output of 400kw, it will eventually be one of the country's *most powerful* stations, too. With Federal's high-gain antenna, this maximum rating of 400kw can be achieved with the installation of only a 50kw transmitter!

WTCN is among the FM stations with permits for the most powerful ratings in the country. Others are KWK, St. Louis, with 369kw — and WTMJ, Milwaukee, with 349kw. These three stations have *all* selected *FM by Federal!* And Federal can equip your new FM station, too — from microphone to antenna. Write today for complete information. Dept. B343.



Station WTCN was officially opened by a gala inaugural program featuring the Minneapolis Symphony Orchestra, Dimitri Mitropoulos conducting. With FM by Federal, listeners at home were enabled to hear this famous orchestra with the same brilliance and tonal color as the studio audience. Insert shows Mr. Mitropoulos and Governor Luther W. Youngdahl of Minnesota, at opening of ceremonies.

"Wonderful! Magnificent! A terrific step of progress." This was the comment of the famed conductor, Dimitri Mitropoulos, when he heard his own orchestra over an FM receiver, during an on-the-air rehearsal.

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TECHNICANA

THERMINDEX COLORS

★ Determination of annealing and bulb temperatures in the glass industry may be facilitated by use of paints formulated to change color at a definite temperature, according to an article by G. A. Williams entitled "Temperature Indicating Compounds" which appears in *Electronic Engineering* for July 1946. Other radio applications include determination of temperature of ceramics under r-f load. The majority of these paints show successive color changes as the temperature increases, so that localized heating and heat distribution can be determined at a glance.

Sixteen paints are now available which provide a total of 48 indications between 80° and 800° C. The thermindex paints are not expected to give an exact temperature measurement but rather give a quick indication within useful limits. When the time of heating is not taken into account, the author states that indication of temperature over a certain area is accurate to 15°C, while greater accuracy is attainable when the heating time is known and reference is made to prepared charts.

The paints are manufactured at present in Great Britain.

MIDGET EARPHONES

★ Midget receivers were redesigned during the war to meet requirements for a high-quality unit to fit under combat helmets. Some of the methods utilized to obtain adequate performance in quantity production and test equipment devised for the purpose are described in an article by H. A. Pearson et al. in the *Journal of the Acoustical Society of America* for October 1946.

A 256-ohm magnetic hearing-aid type of receiver was selected, with an 8000-ohm matching transformer contained at the crotch of the cord in a plastic case carrying a rubber-jawed clothing clip to relieve cord tension on the earpieces. Commercially available units were found to possess unsuitable frequency response characteristics which varied among themselves within a 10 db spread.

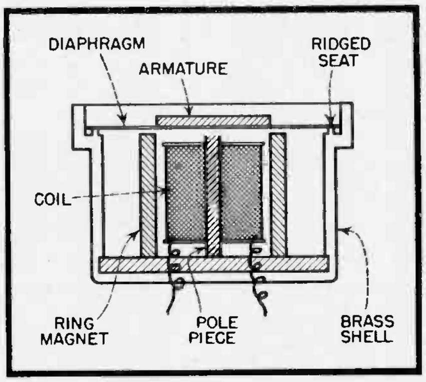
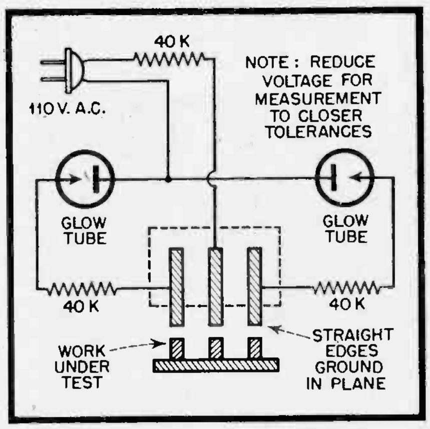


Figure 1, above, Fig. 2, below



Acoustic performance specifications were established to provide a slowly rising characteristic from 400 to 1200 cps, maintenance of initial response at 2500 cps, followed by a sharp cut-off approximately 17 db down at 3500 cps. A 6 μw input corresponds to a comfortable conversational level, while 15.6 μw produces sound pressures on the threshold of pain.

A longer permanent magnet was specified which could withstand the discharge of a 1 μf capacitor charged to 90 v, to meet service abuse. Later, a concentric system was devised as shown in *Fig. 1*, for which an optimum flux level of 12,500 gauss was determined. A nickel-iron alloy was used.

Resonance occurs at 1200 cps as a result of diaphragm inertia and net system stiffness, and is limited by a damping cloth in the cap. Resonance occurs again at 2500 cps as a result of the acoustic cavity above the diaphragm.

One of the test devices used in production is the "electrical straight-edge" shown in *Fig. 2*, which carries three electrical contact members ground to lie in a plane. When contact is made between a center pin and either edge member, a glow tube is energized. By controlling the power supply a tolerance of flatness may be set. The work under test is straight within allowable limits when both glow tubes are lighted.

GLASS AT UHF

★ Dielectric constants and dielectric losses of 104 glasses of a wide range of compositions have been measured at 10 and 3 cm wavelengths by Louis Navias and R. L. Green. The report is in the *Journal of the American Ceramic Society* for October 1, 1946. By correlating the power-factor data with the compositions of the glasses, the authors propose a qualitative explanation of the mechanisms producing energy absorption and dielectric losses in the microwave range.

These mechanisms are determined by the nature of the bonds joining atoms and ions in the randomly oriented atomic network of glasses. The rigid and continuous networks of SiO_2 and B_2O_3 glasses are relatively transparent to centimeter wavelengths. Energy absorption and dielectric losses are low. Addition of network-modifying oxides yields glasses of greater energy absorption because of the oscillation of the interstitial ions thus introduced. Increasing the content of any one of these ions in a glass results in higher losses while the coexistence of a variety of these ions generally results in lower losses.

Alkali ions in glasses give rise to high losses, but losses of high-lead glasses are reduced by alkalis, because dissimilar interstitial ions interact in u-h-f fields and reduce energy absorption. Alumina increases the dielectric losses of glasses in much the same manner as other network modifiers. In the original article, the authors describe their measuring technique and supply details of the investigation.

CERAMIC STRESS-STRAIN PROPERTIES

★ Engineers have disagreed whether ceramic materials behave as truly elastic substances, and whether Hooke's law is applicable. An investigation has accordingly been undertaken by Marjorie Lassettre and J. O. Everhart, and reported in the *Journal of the American Ceramic Society* for September, 1946 in an article entitled "Stress-Strain Relations in Ceramic Materials." An electric strain gage was used to study the deformation under stress of several ceramic materials. Hard and soft firing were both investigated for various ceramics typified by dinner ware. General conclusions are drawn for all ceramic substances.

It is found that ceramics behave as elastic materials, and that general engineering formulas based on elastic substances may be applied. Hard-fired materials exhibit straight-line deformation to failure, while the softer-fired varieties have a proportional elastic limit beyond which the stress-strain curve deviates from a straight line. Formulas for modulus of elasticity and modulus of rupture may be accepted as valid.

Ceramics exhibit a hysteresis characteristic and the strain equilibrium lags any change in stress. This lag decreases with increased firing temperature. Permanent sets are acquired by ceramics, even when stressed below the elastic limit. The conclusions noted are stated to be true for all ceramic substances.

TUBE SPACERS

★ Conventional insulators and filament spacers used in electronic tubes can easily be replaced in the manufacturing process with machine fabricated fused quartz parts, according to Crystal Research Laboratories, Inc., Hartford 3, Conn. It has the lowest coefficient of linear expansion and the highest dielectric strength of any material known. Recently improved processing methods make it possible to obtain extremely fine dimensional tolerances for any size or shape.

ULTRASONIC MICROPHONE

★ Designed for use as a laboratory standard in measurement of ultrasonic waves, a small condenser microphone is described by Theodore H. Bonn in the *Journal of the American Acoustical Society* for October 1946. Its free-field calibration is essentially constant at a level of 51 db below 1 v/dyne/cm² up to 32 kc. An error of 5 or 10 degrees

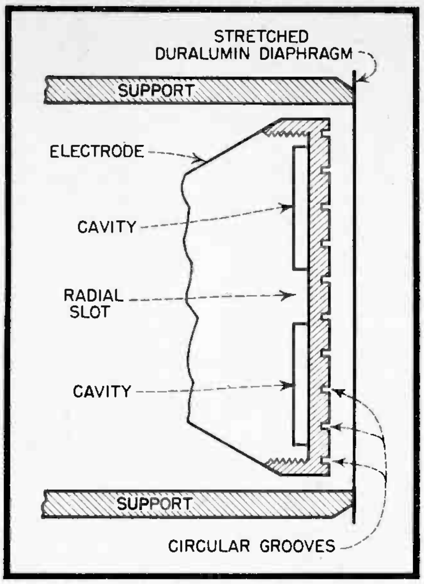


Figure 3

in orientation of the instrument results in a rather negligible alteration of response.

Acoustic characteristics of the microphone are obtained by the small-sized duralumin diaphragm which is 0.875 inch in diameter and 0.001 inch thick. It is stretched almost to its elastic limit, and yields a mechanical resonance point which is flattened by means of the orifices shown in *Fig. 3*. The electrode of the instrument carries circular grooves in its face to decrease the stiffness of the air film between it and the diaphragm, as well as to increase resistance to radial motion of the air.

Radial slots are milled on the back of the electrode, and the orifices formed by intersection of grooves and slots introduce additional mechanical resistance as noted above. A cavity 0.003 inch deep is placed behind the electrode to afford additional resonance needed to flatten the overall characteristic. The result is a rugged and dependable microphone which meets all the requirements implicit in the term of laboratory standard.

RECIPROCITY THEOREM FAILS

★ One of the most cherished laws in the analyst's kit, the reciprocity theorem, has been shown to break down when applied to certain electro-mechanical systems, such as that of a crystal transducer coupled to an electrodynamic transducer. The investigation was made by E. M. McMillan and reported in the *Journal of the American Acoustical Society* for Oct. 1946.

It was found that some of the simpler electro-mechanical systems violate the reciprocity theorem in sign, while dual units violate the theorem in both sign and magnitude.

SCOPE WITH D-C AMPLIFIER

★ An interesting new oscilloscope with frequency response from 0 to 3 mc is described in an article by F. R. Milsom and J. H. Reyner in *Electronic Engineering* for October 1946. The chief feature of the instrument is the vertical and horizontal amplifier circuit, shown in *Fig. 4*, which provides for operation with the link to 3 mc, or without the link to 1 mc. The sensitivity of the instrument is respectively 24 mv/cm and 8 mv/cm, r.m.s., with response 3 db down at the upper limits.

The sensitivity with input from grid-to-grid is several hundred times that of tied grids-to-ground, and the amplifier may be effectively used with appreciable leakage to ground of the source. It is designed for general application in the laboratory, and is capable of presenting i.f., r.f., and microsecond television pulses as well as extremely slow voltage variations. It has been recognized by the designers that slave sweeps are better adapted to pulse work, but a free-running sweep has been used from the standpoint of general utility. The authors state that a microsecond pulse may be effectively presented with 5 mm width.

Further details of the instrument are presented in the original article.

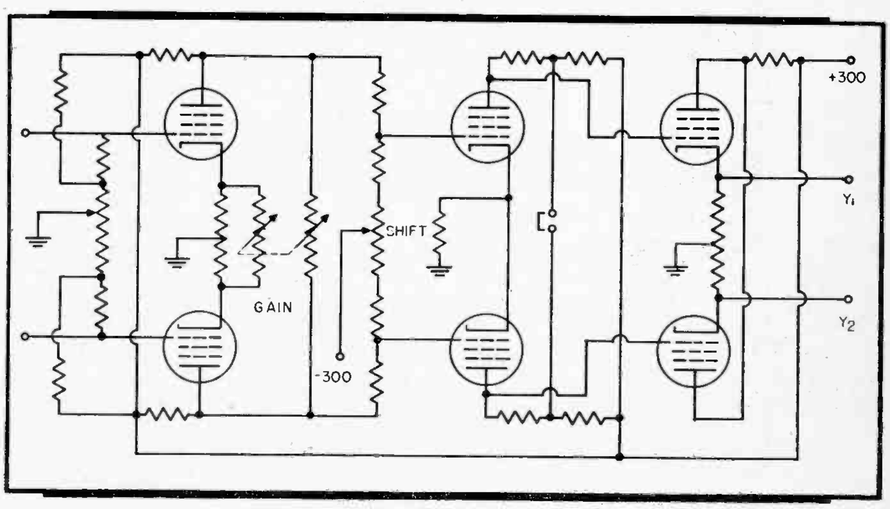


Figure 4

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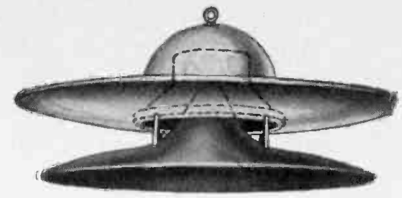

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Design of Electronically Regulated Power Supplies

BEN A. PENNERS and WILLIAM DAVIS

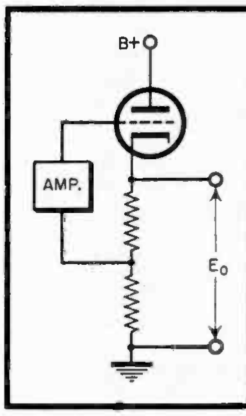
The authors point out the factors which affect the operation of electronically regulated power supplies and present complete design data.

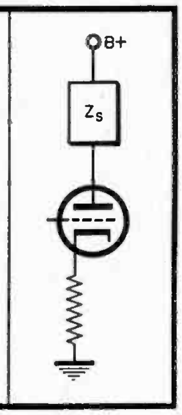
DURING THE PAST FEW YEARS there has been a great increase in the number of electronically regulated power supplies in general use. In most cases they have proven to be a great boon to the engineer for both "bench" and equipment use.

Regulated power supplies are subject to limitations that have, at times, been unrecognized. As a result of improper use they have caused erroneous readings and false conclusions. In this article we hope to point out some of the pertinent design factors, as well as the factors which influence the power supply limitations.

Fundamentals

Figure 1 illustrates a simple degenerative type of regulator. The operation of this circuit is as follows: an increase in the load current will cause the regulated output voltage, E_o, to drop. As the grid of the amplifier tube, *V2*, is directly coupled to the output by the resistance network *R2, R3*, and *R4*, any change in the output voltage will cause a change in the grid-to-ground voltage of *V2*. The cathode of *V2* is maintained at a fixed voltage above ground by the gaseous regulator tube, *V3*, across which the voltage drop is substantially independent of the current passing through it. A decrease in output voltage, E_o, causes a decrease in the grid-to-cathode voltage of *V2*, an increase in the plate voltage of *V2* and, because the grid of *V1* is connected to the plate of *V2*, the grid voltage of *V1* changes in a positive direction. Then the voltage drop across *V1* is reduced, so that the output voltage, E_o, tends to increase. It is seen that each voltage change tends to be offset by a change in the opposite direction, so the effect is degenerative and the output voltage changes, resulting from changes in output current, are greatly reduced.





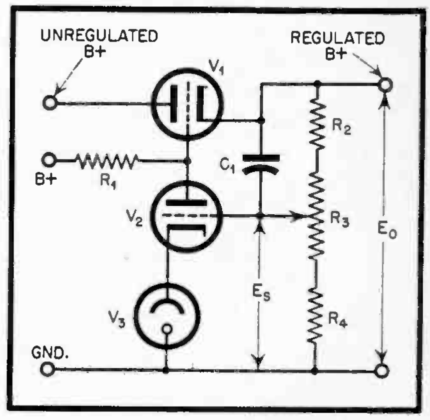


Fig. 1. (left) Simple degenerative regulator. Fig. 2. (center schematic) Simple regulator redrawn as a cathode follower with voltage feedback. Fig. 3. (right) Regulator with series impedance in the source.

The Ripple Reduction Factor

One of the factors by which the merit of a regulated power supply may be judged is the ripple reduction factor.

Referring to *Fig. 1*, if the regulated output voltage, E_o, is increased by an amount ΔE_o, there will be a certain fraction of this voltage change that will appear at the grid of *V2*. The fraction of the output voltage change, ΔE_o, appearing at the grid will be equal to the voltage change actually appearing at the grid, divided by the total output voltage change, and will be expressed as β in this article.

Ripple voltage from grid to ground =

$$\beta = \frac{\Delta E_s}{\Delta E_o} \quad \text{...............(1)}$$

The absolute value of β varies with frequency because the capacity *C1* increases β as the frequency is increased. The value of β at d.c. is usually about 0.5, and varies to about 0.8 at the higher frequencies. The value of β for a.c. can be increased by increasing the size of *C1*. Capacities from 0.1 to 1.0 μf are commonly used.

The voltage change at the amplifier grid will be equal to the output voltage change times β, or $\Delta E_o \beta$. This voltage is amplified and appears at the grid of *V1* as $\Delta E_o A\beta$, where *A* is the gain of the amplifier stage. When the output voltage, E_o, changes in a positive direction, the plate of the amplifier will change in a negative direction. Therefore the change from cathode to grid of the series tube will be the algebraic sum of these voltages, ΔE_o and $\Delta E_o A\beta$, which equals $\Delta E_o(1+A\beta)$. When the plate current of a vacuum tube is essentially constant, the change in voltage drop across the tube is equal to aE_g, where a is the amplification of the series tube and E_g is the a-c grid voltage. a is equal to $\mu R_L / R_L + R_p$, where R_L is the load resistance and R_p is the dynamic plate resistance of the tube. The expression $R_L / R_L + R_p$ has a value near .85 under ordinary conditions; thus a will in general be equal to .85 μ. In this case, E_g has the value noted above, and

$$E_g = \Delta E_o(1+A\beta) \quad \ldots\ldots\ldots (2)$$

By substitution, aE_g then equals $a\Delta E_o(1+A\beta)$. The absolute value of input ripple voltage is equal to the ripple across the series tube plus the output ripple voltage.

$$\text{Input ripple} = \Delta E_i = a\Delta E_o(1+A\beta) + \Delta E_o \quad \ldots\ldots\ldots (3)$$

To find the ripple reduction factor, $\Delta E_i / \Delta E_o$, equation (3) is transposed by dividing both sides of the equation by ΔE_o.

$$\frac{\Delta E_i}{\Delta E_o} = \frac{a\Delta E_o(1+A\beta)+\Delta E_o}{\Delta E_o} = 1 + a + aA\beta \quad \ldots\ldots\ldots (4)$$

It follows, then, that the output ripple voltage, ΔE_o, will be given by the following expression:

$$\Delta E_o = \frac{\Delta E_i}{1 + a + aA\beta} \quad \ldots\ldots (5)$$

This formula shows that both the μ of the series tube and the gain of the amplifier should be high for maximum ripple reduction. The gain A of the amplifier stage is the factor most easily varied when specifications for a power supply are given in terms of the desired output ripple voltage. When a single-stage amplifier does not provide enough ripple reduction, cascade stages may be used, as shown in *Fig. 6*.

The value of input ripple voltage that a regulator can handle is limited by the grid bias voltages of the amplifier and series tubes, as neither of these grids should be driven positive. The maximum value of input ripple voltage to the grid of the series tube is determined in the following manner: As shown by equation (2), the ripple voltage at the grid of the series tube equals $E_o(1+A\beta)$. When equation (5) is substituted for ΔE_o in equation (2), it is seen that

$$E_g = \frac{\Delta E_i(1+A\beta)}{1 + a + aA\beta}$$

The peak value of ripple voltage at the grid, E_{c1}, must not exceed E_g. Assuming r-m-s values

$$.707\ E_{c1} = \frac{\Delta E_i(1+A\beta)}{1 + a + aA\beta}$$

Transposing

$$\Delta E_{i(max)} = \frac{.707\ E_{c1}(1+a+aA\beta)}{1+A\beta} \quad \ldots (6)$$

This gives the maximum permissible value of input ripple voltage.

The value of ripple voltage at the amplifier grid is equal to $\Delta E_o\beta$. As with the series tube, the r-m-s ripple voltage must not exceed .707 E_{c2}. Relating two previous expressions, $.707\ E_{c2} = \Delta E_o\beta$. Equation (5) is substituted for ΔE_o as before, giving $.707\ E_{c2} = \dfrac{\Delta E_i\beta}{1+a+aA\beta}$

When this equation is transposed, we find

$$\Delta E_{i(max)} = \frac{.707\ E_{c2}(1+a+aA\beta)}{\beta} \quad \ldots (7)$$

If the conditions given by either equation (6), or equation (7) are exceeded, the power supply will not operate satisfactorily.

Output Impedance

Another factor for evaluating the merit of a regulated power supply is the effective impedance looking into the output terminals. The output impedance, Z_o, is important through the range from d.c. to the highest frequency present in the load. The output impedance at d.c. is found by varying the load resistance and then dividing the change in output voltage by the change in output current.

Common values of d-c impedance found in simple degenerative regulators range from 5 to 10 ohms.

If the circuit of *Fig. 1* is redrawn as shown in *Fig. 2*, it is seen that the series regulator tube is a cathode follower, with voltage feedback around it. Thus the operation of the circuit permits analysis by the method that follows below.

The output impedance of an amplifier in the presence of feedback is given by*

$$Z_o = \frac{R_p - \mu A a}{1 + \mu A\beta}$$

where

R_p is the dynamic plate resistance of the series tube

μ is the amplification factor of the series tube

A is the gain of the amplifier stage

a is the current feedback factor, which in this case is equal to zero.

When a is equal to 0, this equation reduces to

$$Z_o = \frac{R_p}{1+\mu A\beta} \quad \ldots\ldots\ldots (8)$$

In a cathode follower, R_p is modified by $(1+\mu)$ to a new value of $\dfrac{R_p}{(1+\mu)}$. The value of μ of the cathode follower is also modified by the quantity $(1+\mu)$ to a new value of $\dfrac{\mu}{(1+\mu)}$. When these modified values are substituted in equa-

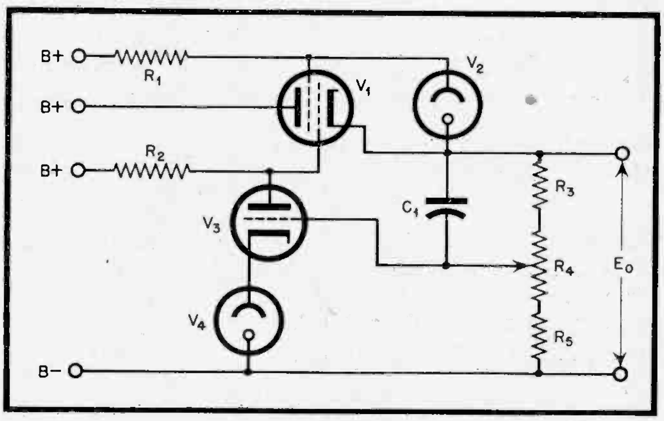


Fig. 5. (right) Regulator using a tetrode series tube.

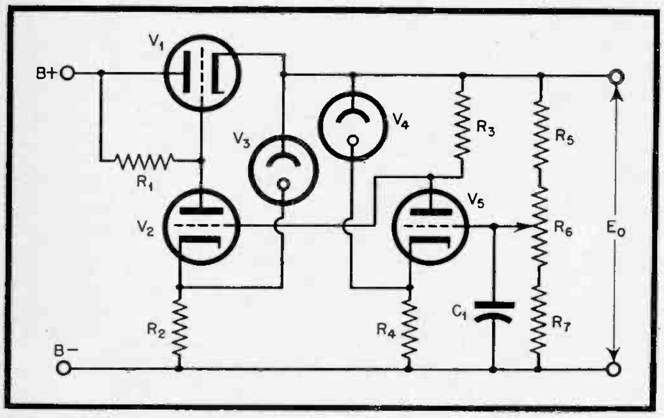


Fig. 6 (left) Regulator using a double triode amplifier tube.

*Terman, F. E.—Radio Engineering Handbook, page 402.

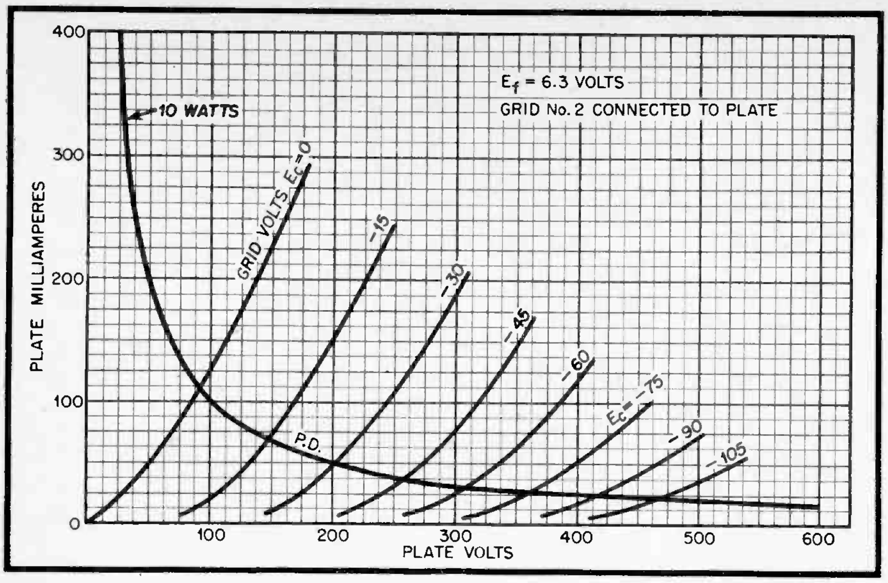


Fig. 4. Average plate characteristics of the triode connected 6Y6-G tube.

tion (8) and the expression simplified, the output impedance is found to be

$$Z_o = \frac{R_p/(1+\mu)}{1+A\beta[\mu/(1+\mu)]} = \frac{R_p}{1+\mu+\mu A\beta} \quad (9)$$

It is seen that the μ of the series tube and the gain of the amplifier stage should be high to assure low output impedance.

When a cathode follower has an impedance, Z_s, in series with its plate circuit, as in *Fig. 3,* the series impedance will appear as though it were added to the plate resistance of the cathode follower tube, and R_p then becomes R_p+Z_s. In a regulated power supply the impedance of the unregulated supply will appear as an impedance added to the plate impedance of the series tube, and the formula for calculating the output impedance of the supply is then

$$Z_o = \frac{R_p+Z_s}{1+\mu+\mu A\beta} \quad \ldots\ldots\ldots\ldots (10)$$

In general the value of Z_s will not be large and can be neglected. There are times, however, when unregulated power supply resonances, i.e., choke and condenser resonances at very low frequencies, may pass unnoticed because impedance measurements between d.c. and 10 cycles are difficult to make. A resonant condition at 2 cycles, for instance, could raise the supply impedance at that frequency and cause motorboating, or instability, in an amplifier.

Two basic formulae, equations (5) and (10), have now been found by which to predict the operation of a regulated power supply.

Selecting the Series Tube

The series tube or tubes must carry the total regulated current. The conditions of operation must be such that the grid is never driven positive and the plate dissipation never exceeded.

The operating range for any given series tube may be found by drawing a line which represents the maximum plate dissipation upon the plate voltage-plate current curves for the tube. This may be drawn by taking several voltage points and placing a dot at the current which corresponds to maximum plate dissipation. *Figure 4* illustrates the operating range of a 6Y6G triode-connected. The plate dissipation is 10 watts. The curve marked P.D. is the maximum plate dissipation line. The safe operating area is enclosed by the zero bias line and the maximum plate dissipation line.

When the output current requirements for the power supply are higher than one series tube can safely pass, two or more tubes can be put in parallel. For a given voltage and current output, a cathode type series tube will usually have less output ripple than a filament type tube. When other factors are equal, tubes with high μ are to be preferred.

Tetrodes may be used instead of triodes as series tube. For a given voltage drop across the tube they are capable of carrying higher currents than triodes, and the μ is higher. There are advantages in using tetrodes that should be seriously considered in any design. The tetrode will have a higher plate impedance, but the increased μ tends to offset this, so that the output impedance of the power supply remains essentially the same as that of an equivalent triode.

The increased plate impedance and μ will sometimes be found an advantage where they may be used to obscure relatively high impedances in the unregulated portion of the power supply. This feature is brought out in *Fig. 12.* The screen voltage should be stabilized with reference to the cathode. This can be accomplished by means of a VR tube, *V2,* between screen and cathode, as shown in *Fig. 5.* If the screen supply voltage has a high ripple voltage, the regulated current will be modulated by the ripple. Measurements show that 0.5 volts ripple is about the maximum amount permissible on the screen. It is interesting to note that an 807, tetrode connected, can carry 200 ma with only a 25-volt drop from plate to cathode. This is a much higher current rating than can be used with most triodes.

Amplifier Stage Design

The selection of the amplifier is largely determined by the amount of gain needed. Pentode amplifiers in general have higher gain, but are subject to screen degeneration at d.c., and they have a high plate impedance which may be a disadvantage, as will be shown later.

A gaseous regulator tube is generally used in the cathode circuit of the amplifier to provide a stable reference voltage. The impedance of the regulator

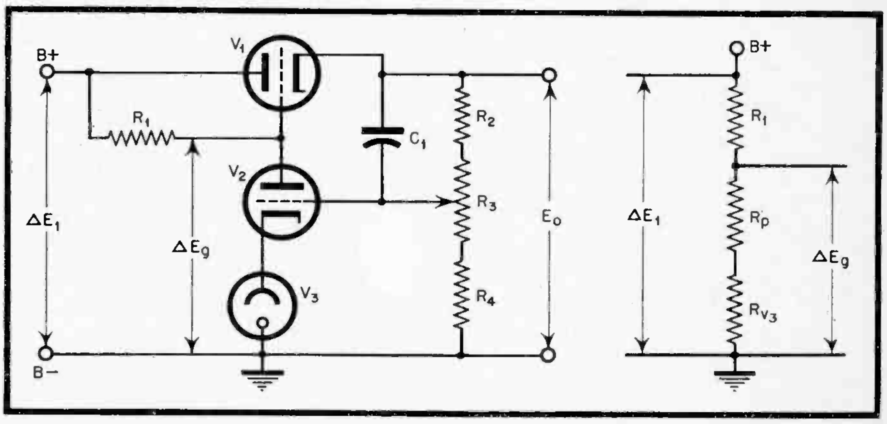
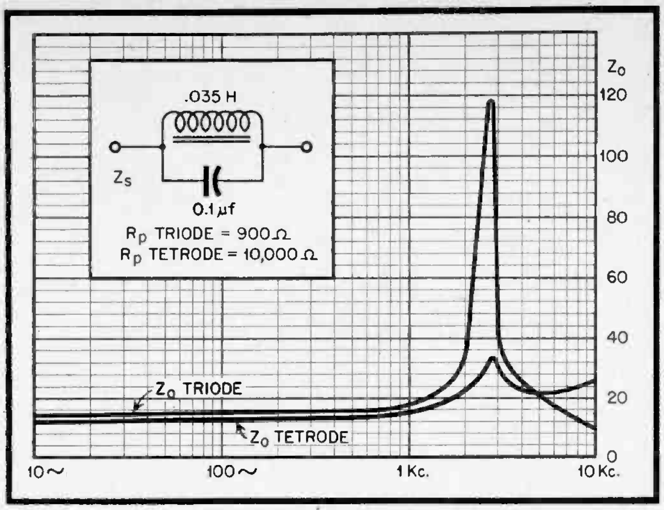


Fig. 7. Amplifier circuit redrawn to show the ripple voltage distribution. The equation for determining the ripple, ΔE_g, is given in the text.

Fig. 12. (right) A plot of Z_o as a function of frequency. The higher values of R_p tend to obscure the effect of the series impedance Z_s.



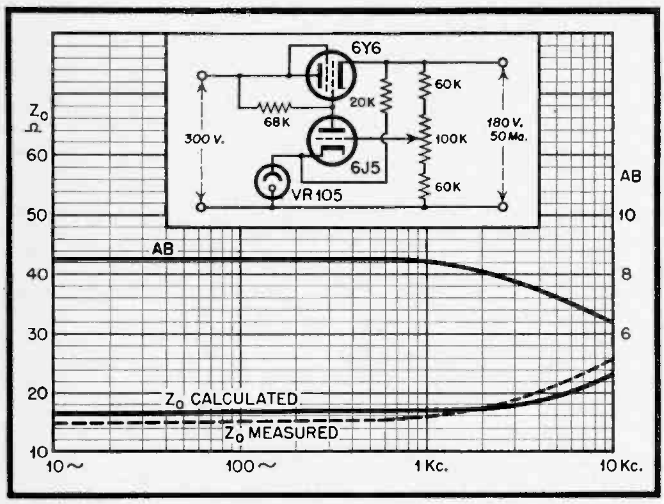


Fig. 13. (left) Comparison of calculated and measured values for Z_o. Note the increase of Z_o when AB decreases.

tube is a function of d-c current through the tube and the frequency of the a-c component of this current. A set of curves showing the performance of a number of VR105 and VR150 tubes picked at random are shown. As shown, the impedance of the VR tubes rises as the frequency of the a-c component is increased. This introduces an increasing amount of negative feedback into the amplifier stage as the frequency is increased, and drops its gain. From the curves the current through the VR tubes should be between 10 and 20 ma for optimum operation.

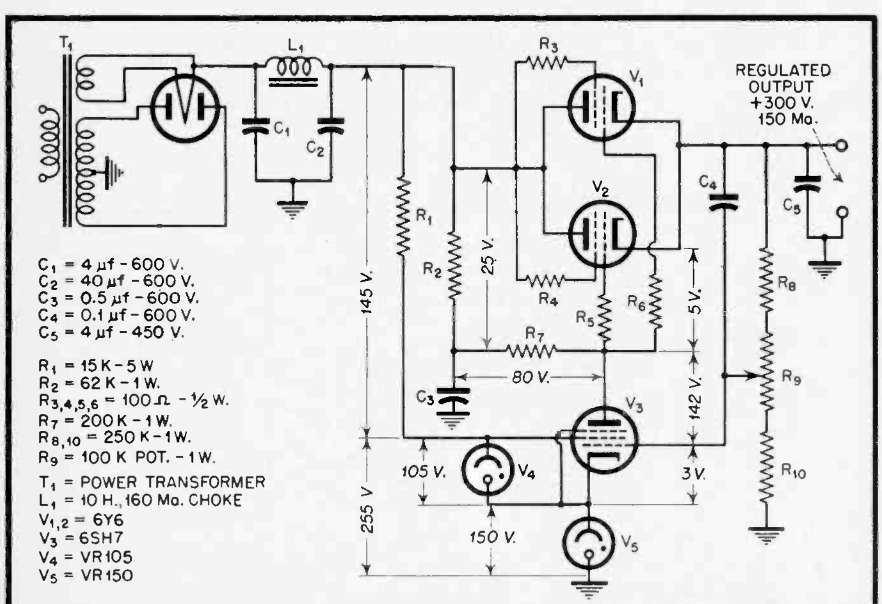


Fig. 11. Schematic of typical electronically regulated power supply. Values for components are given at left.

There are two possible sources of voltage for the amplifier, the unregulated supply voltage or the regulated power supply output voltage. If the unregulated voltage is used, the ripple voltage present must be considered. Refer to *Fig. 7*. The ripple, ΔE_g, at the amplifier plate will be the total ripple times the ratio of the plate resistance plus the VR tube resistance to the total resistance;

$$\Delta E_g = \frac{\Delta E_i (R_p + R_{vs})}{R1 + R_p + R_{vs}} \quad \ldots\ldots (11)$$

From this equation it is seen that a high value of R_p, such as that of a pentode amplifier, will give a greater percentage of the total ripple voltage at the amplifier plate. Two components of ripple voltage are present at the amplifier plate. One is the ripple due to the amplification of the amplifier tube, and the other is due to the effect stated in equation (10). These two voltages are 180° out of phase and must be added algebraically to determine the phase and amplitude of the ripple voltage at the amplifier plate.

It can be seen that the ripple from the unregulated voltage will subtract from the amplifier ripple voltage, and is objectionable in that it lowers the effective amplification of the stage. A reasonably simple method of reducing this effect is to use an RC filter in the amplifier plate circuit, as shown in *Fig. 8*, where *R1* and *C1* constitute a filter for the supply voltage to the amplifier. This filter will attenuate the ripple to approximately

$$\Delta E_a \cong \frac{\Delta E_i X_{c1}}{\sqrt{R1^2 + X_{c1}^2}} \quad \ldots\ldots\ldots (12)$$

In a typical case, $R = 10K\Omega$, and $C1 = 10$ µf. This provides a 37.5 db reduction in the ripple voltage at the amplifier plate. It can be seen from the discussion above that it is well worth adding the extra filter in the regulator circuit.

If a pentode amplifier is used, a new problem is presented—screen-grid degeneration. This is not very serious at ripple frequencies, as a by-pass condenser can be used from screen to cathode. This will provide a low impedance return circuit from screen to cathode. But at very low frequencies, or when considering the conditions at d.c. it is difficult to by-pass the screen adequately. It may be thought that the screen voltage could be taken directly from the regulated output of the power supply, since the usual output voltage is sufficiently higher than the amplifier cathode to provide approximately the correct amount of screen voltage. This, however, will result in a loss of gain because this source of voltage is degenerative when considered with respect to the amplifier. The best by-pass at all frequencies was found to be a VR type of gaseous regulator tube. This will maintain a fairly low impedance path from screen to cathode even at d.c. *Figure 8* shows a pentode amplifier with *V3* acting as the screen by-pass.

If low output ripple voltage is more important than low d-c impedance, a circuit such as that of *Fig. 9* might be used. The ripple reduction factor will not differ greatly from what it would be if gaseous regulator tubes were used in place of *R4* and *R5*. The values of *C2* and *C3* should be such that at the ripple frequencies the reactances are about one-tenth the resistance values across which they are connected. The output impedance will be low for alternating currents and will increase as the frequency is lowered.

General Design Considerations

In general, a capacitive load on a cathode follower will reflect a negative resistance into the grid circuit of the cathode follower.* This negative resistance component is most easily shown as a parallel resistance, i.e., a resistanse from grid to cathode. If two resistances with different signs, that is, positive or negative, are connected in parallel the sign of the lower of the two will determine the character of the combination. In general, the variation of the input resistance as a function of C_o will have a curve similar to *Fig. 10*. As shown, the input resistance has a high negative value for extremely low and high values of *C*. Some intermediate value of C_o will give an extremely low value of negative input resistance. If this value becomes lower than the positive input resistance of the tube, the circuit will oscillate. Because the load may present the proper amount of capacity to make the power supply oscillate, it is recommended that a sufficiently large value of C_o be used that any capacity in the load will not result in a total capacity which will produce the conditions required for oscillation. Experiments indicate that approximately 2.0 µf is about the minimum value that will effect a reasonably sure cure for this trouble. This has the added advantage of maintaining a low output impedance at high frequencies.

*Radio Receiver Design, Part 1—Sturley—page 43.

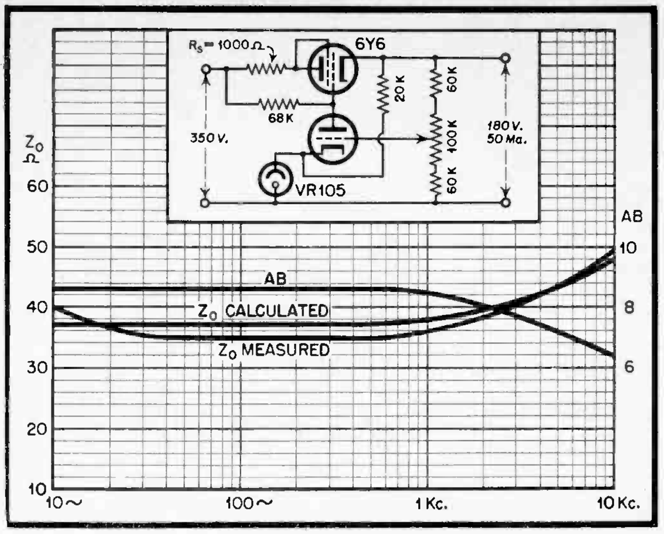


Fig. 14. (left) How Z_o increases when Z_s is in the form of a 1000-ohm resistance. Comparison with Fig. 13 indicates a considerable increase.

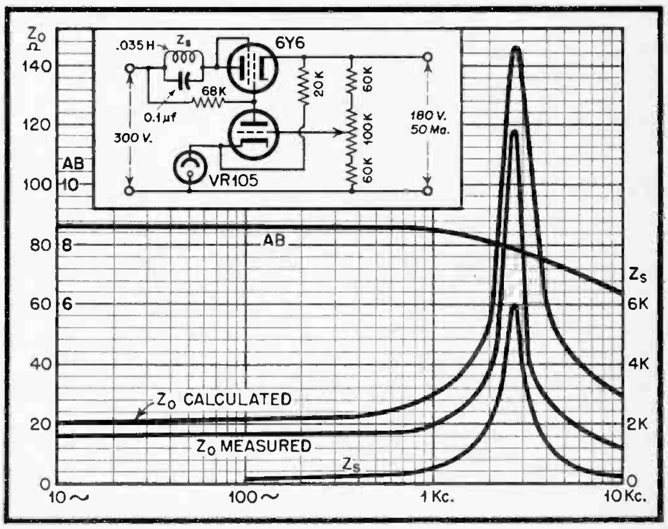


Fig. 15. (right) A parallel resonant circuit having 6000 ohms impedance at 2700 kc, is used as Z_s to demonstrate the effect of resonances in the filter system.

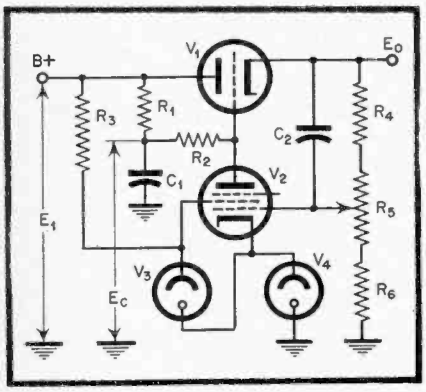
A Typical Design

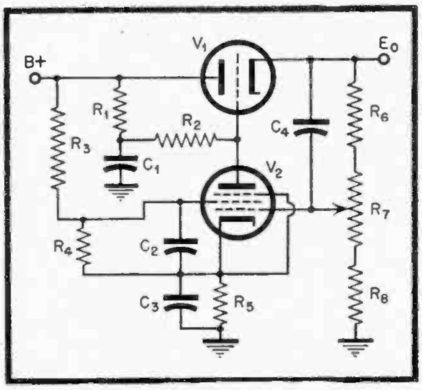
To illustrate the design factors of a typical regulated power supply the design of a power supply to fit the following specifications is presented:

Output voltage—300 volts

Maximum load current—150 ma

Inspection of the curves of the available tubes shows that the 6Y6G tube, triode connected, seems to be the most suitable choice for the series tube, and





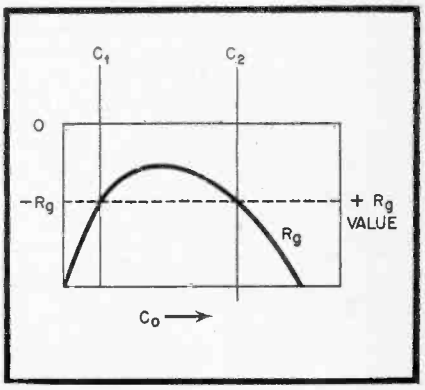


Fig. 8 (left) Illustrating the use of an RC filter for the amplifier. Also shown is the use of the VR screen voltage stabilizer. Fig. 9. (center) This circuit shown will serve if low ripple is more important than low d-c impedance. Fig. 10. (right) Between the values C_1 and C_2 the negative resistance is lower than the positive value of R_g and their combination will be negative.

two tubes in parallel will be required to obtain 150 ma. The plate voltage coordinates represent the actual d-c voltage drop across the series tube. If the grid is to be kept negative, the curves show that this voltage must never fail below 75 volts for the desired load current. It can also be seen that the maximum drop across the tube must not exceed 125 volts, or the maximum plate dissipation of the tube will then be exceeded.

The unregulated supply must furnish a voltage equal to the sum of the regulated output voltage and the voltage drop across the series tube. Variations in the unregulated voltage must be absorbed by increasing or decreasing the voltage drop across the series tube. A design center for the line voltage is chosen midway between expected limits. If only one of these two limits need be considered, it will nearly always be that of the zero bias limit on the series tube. In any case, the tube must not be operated at zero bias, at the lowest expected value of line voltage. Thus the voltage drop across the 6Y6G is taken as 100 volts for this power supply. The curves for the 6Y6G show that at this point the bias on the tube should be 5 volts.

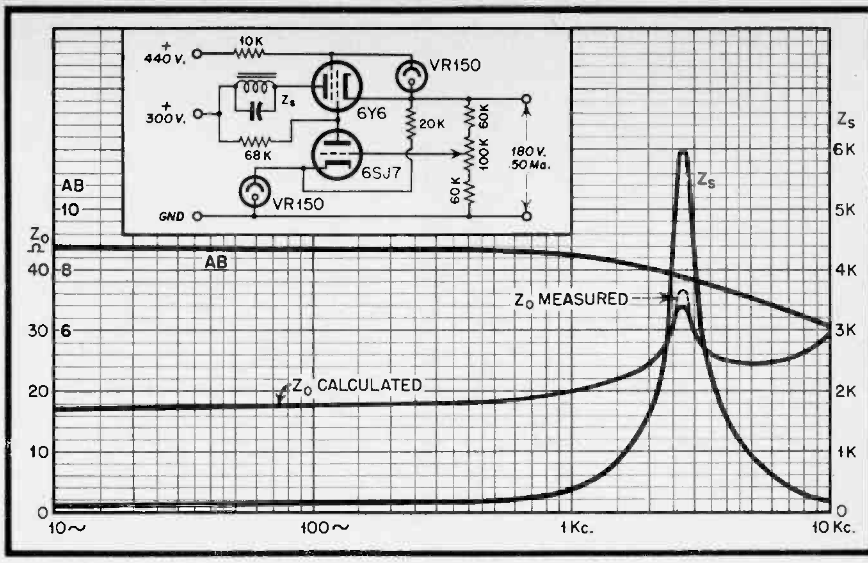


Fig. 18. Use of the tetrode connected series tubes reduces resonant effects. Compare with Fig. 15.

From the conditions set forth in the previous paragraph it is seen that the unregulated portion of the power supply must furnish 400 volts at the full load current of 150 ma, plus the added drain of the stabilizing current which will flow through the VR tubes. Assuming a total added drain of approximately 10 ma, the supply must furnish 160 ma. Allowing approximately 30 volts for the drop in the filter choke, the input voltage to the filter must be 430 volts. Inspection of the tube curves for the 5U4G rectifier shows that this voltage may be obtained at 160 ma from a transformer which has an 850-volt, center-tapped secondary, if the input filter condenser has a capacity of 4.0 μf. Using standard component values for the remainder of the filter, one 10-henry choke, and an output filter condenser of 40 μf, the ripple output of the unregulated supply is reduced to approximately 300 mv.

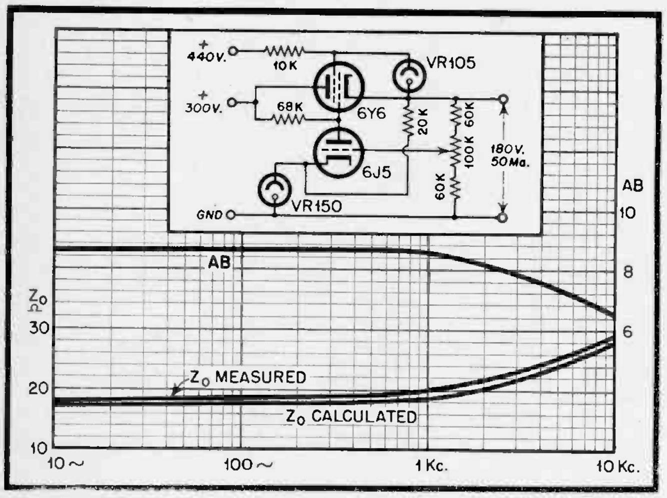


Fig. 16. (left) Even though R_p is higher with tetrode connection, the increase in μ holds Z_o at about the same level. Compare with Fig. 13. The ripple reduction factor is lower, however, with this connection.

For maximum ripple reduction, the gain of the amplifier stage should also be as high as possible, so a high transconductance pentode, such as the 6SH7, is used for this stage.

It can be seen in *Fig. 11* that the unregulated voltage drop of 400 volts appears across the series combination of *R2*, *R7*, the plate-to-cathode impedance of *V3*, and the VR-150 tube. The cathode of *V3* is fixed at 150 volts above ground by the VR tube, and since the plate of *V3* is connected to the grids of *V1* and *V2*, the voltage at the plate of *V3* must also be 5 volts less than the output voltage, or 295 volts above ground. This means that the voltage drop across *V3* must be 145 volts, or the difference between these two voltages. If we allow 25 volts drop for the decoupling filter in the plate circuit *V3*, the voltage drop across *R7* must then equal 375—295, or 80 volts. The current flowing in the plate circuit of V3 is then 80/*R7*. If the load resistor, *R7*, is selected as 200,000 ohms, the resulting plate current is 0.4 ma. From the curves for the 6SH7, for this amount of plate current at this value of load resistance, the bias voltage on the grid will be 3 volts, and the transcon-

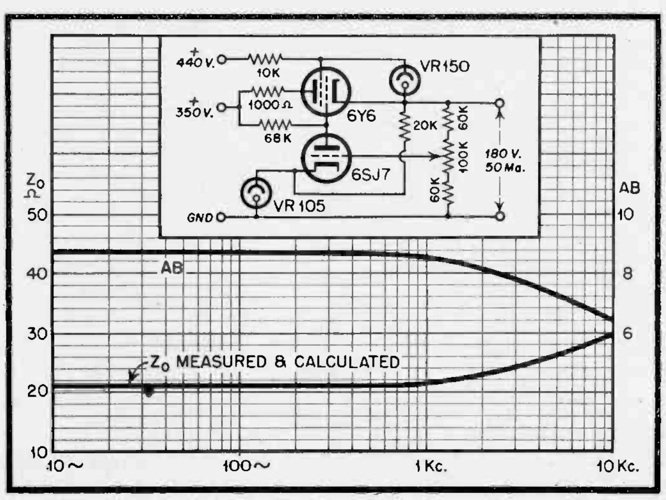


Fig. 17. (right) Comparison with Fig. 14 shows how the higher R_p and μ tend to decrease the effect of any series resistances in the unregulated source.

ductance will be 1000 μmhos. The gain of the amplifier stage will then be $0.2 \times 10^6 \times 2000 \times 10^{-6}$, or 200. The screen current at this bias will be 0.2 ma. The value of *R2* can now be determined as being equal to 25/.0004, or 62,500 ohms. *R1* carries the screen current and the bleeder current for the VR tubes, but not the plate current. Therefore the current through *R1* will be equal to 10 − 0.4 ma, or 9.6 ma. The resistance of *R1* will then be 145/.0096, or 15000 ohms.

When high transconductance tubes, such as the 6Y6G are connected in parallel, they may oscillate unless parasitic suppression resistors are connected in series with the grids of the individual tubes. This is the only function of the resistances *R3, 4, 5,* and *6*. The value of these resistors are not too critical, 100 ohms being about average.

Since approximately one-half the output voltage is applied to the grid of *V3*, *R8* and *R10* are made of equal value, and *R9* is a potentiometer to allow exact adjustment of the output voltage. The resistances are made fairly high to limit the amount of current drawn.

The power dissipation in each resistor may be found by the conventional E^2R method, and in this case it will be found that one-watt resistors are adequate for all values except that of *R1*, which will be dissipating 1.4 watts, and a 5 or 10-watt resistor should be used.

Equation (12) may be used as a guide for the choice of *C3*. It is only necessary that *C3* be large enough that the ripple voltage across *C3* be small in comparison with that across *R7*. A 0.5 μf condenser has a reactance of approximately 3000 ohms at 120 cycles, and will in this case be adequate. *C4* should have a reactance small in comparison with the resistance which it bridges. A 0.1-μf condenser has a reactance of 15000 ohms at 100 cycles, so ordinarily it will be adequate for the values of resistance used for *R8*. To prevent any possibility of oscillation, *C5* is chosen as 4.0 μf.

The feedback factor β will vary as the reactance of *C4* varies. At d.c. it will be equal to the voltage ratio, or 147/300, which is approximately equal to 0.5. At the ripple frequency of 120 cycles the reactance of *C4* will be very small in comparison with the resistance of *R8*, and β will be approximately equal to 0.95.

We now have the information necessary to calculate the output ripple voltage and the output impedance of the power supply. At the operating point of the 6Y6Gs, μ equals 10 so *a* will be taken as 8.5 from equation (5)

$$\Delta E_o = \frac{\Delta E_i}{1+a+aA\beta}$$

$$= \frac{300}{1+8.5+(8.5\times200\times0.95)} = \frac{300}{1625}$$

$$= 0.184 \text{ mv}$$

Consideration of equation (6), for maximum input ripple voltage gives the following value

$$\Delta E_i = \frac{.707\, E_{c1}(1+a+aA\beta)}{1+A\beta}$$

$$\cong \frac{5800}{191} = 30 \text{ v.}$$

Consideration of equation (7) for maximum permissible input ripple voltage gives the following value

$$\Delta E_i = \frac{.707\, E_{c2}(1+a+aA\beta)}{\beta}$$

$$\cong \frac{3400}{.95} = 3600 \text{ v.}$$

Both of these values are well in excess of the 300 mv ripple output of the filter system, so neither of the tubes will be operated with their grids driven positive by the ripple voltage.

Again using the tube curves we find the plate impedance of the 6Y6Gs at the operating point is approximately 675 ohms. Since two of them are used in parallel, the effective plate impedance will be 675/2, or 338 ohms. From equation (10) it can be seen that Z_s must also be considered. At d.c. this consists of the series resistance of the choke, rectifier tube, and power transformer resistance. Typical values range from 300 to 500 ohms, so a compromise value of 400 ohms will be used here. The output impedance from equation (10) is then

$$Z_o = \frac{R_p+Z_s}{1+\mu+\mu A\beta} = \frac{778}{1911} = 0.4 \text{ ohms}$$

From equation (10) it is seen that Z_o is inversely proportional to β, and directly proportional to Z_s, therefore as the frequency increases, the output impedance of the power supply goes down. As the frequency is further increased, the gain of the amplifier, *A*, falls off, and the output impedance of the power supply is increased. However, the reactance of *C5* is inversely proportional to frequency, and will maintain the output impedance at a low value at high frequencies.

These values of ripple reduction and output impedance neglect the degenerative impedances of the VR tubes on the gain of the amplifier stage. The reduction in gain caused by these impedances will increase both the output ripple voltage and the output impedance found from these formulas unless allowance is made for the actual gain of the stage including all degenerative effects.

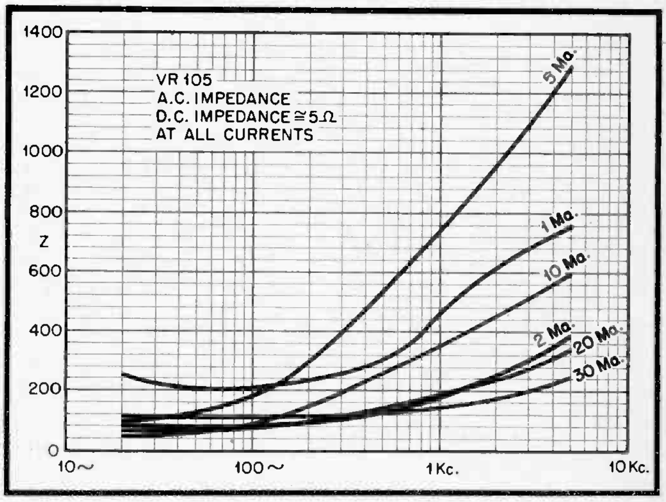


Fig. 19. (Right) Impedance characteristics of VR-105 at various frequencies.

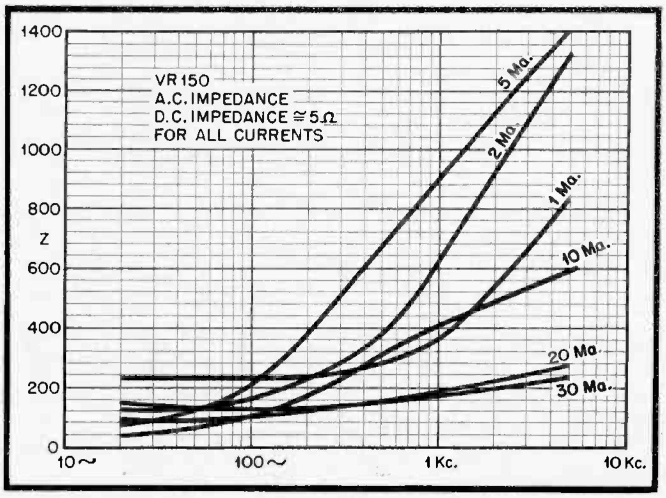


Fig. 20. (Left) Impedance characteristics of VR-150.

UNIVERSAL COIL DESIGN

A. W. SIMON

A previously lengthy and laborious process, the author gives the formulas necessary to reduce the job of coil winding design to a few simple calculations.

The gear ratio employed in winding a universal coil is more important than any other single factor entering into its design because *the gear ratio determines directly the number of turns per layer of the coil* and, therefore, in a large measure, also its mechanical and electrical characteristics. Selection of the gear ratio itself, however, is based primarily on mechanical considerations, since a prime requisite of a coil is that it can be produced economically; in particular, that it can be wound at high speed, that it be inherently stable, and that it can be held to close tolerances.

Parenthetically, it might be noted that it is not good practice to attempt to vary the electrical characteristics of the coil, especially the Q and the distributed capacity, by varying the gear ratio, since this may lead to a departure from the optimum value. On the contrary, the electrical characteristics should be varied by means of other parameters, such as the cam throw, the dowel diameter, the gauge of the wire and the thickness of the insulation.

Fortunately, the desired electrical characteristics can be obtained in every case by means of a coil wound with the optimum mechanical ratio merely by suitable choice of the other factors mentioned. As a guide in this connection, it can be stated that in the range of frequencies in which universal coils are applicable, Q will increase with the form diameter and decrease with the wire diameter used; the distributed capacity will decrease with the thickness of the insulation and form factor of the coil (pancaked coils have lower distributed capacity).

Mechanical Considerations

Two purely mechanical considerations in general govern the gear ratio to be employed in winding a universal coil: firstly, that there be adequate frictional force between the wire and the surface of the dowel[1] in the first layer, and between the wire and the surface of the underlying layer in subsequent layers, so that the turns will stay as wound[2];

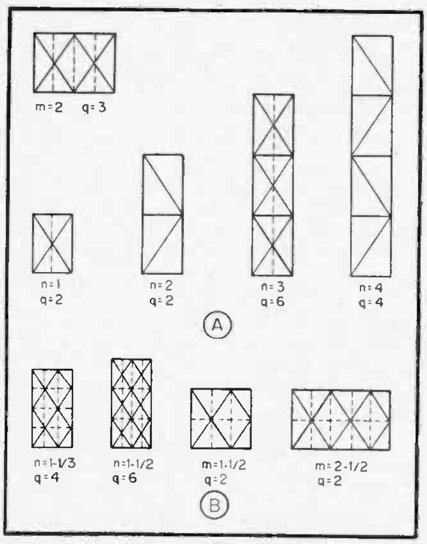


Fig. 1. (A) Commonly used integral winding patterns. Dotted lines indicate the "herringbones". No herringbones occur when the number of crossovers is even (n = 2, 4, etc.). (B) Less commonly used functional winding patterns.

and, secondly, that proper space be allotted between centers of adjacent wires so that the latter are fitted easily and firmly into place.

The first of these considerations is satisfied by selecting as the approximate, or integral, number of crossovers per turn (of the dowel) the nearest integer (or, in special cases, integer plus a simple fraction, such as 1/2 or 1/3) which *is equal to or less than* the value calculated from the empirical formula:

$$n = 0.67\ d/c \quad \ldots\ldots\ldots\ (1)$$

If the value of n calculated from (1) is less than unity, it is more convenient to work with the number of turns per crossover, designated by m, and to select as this quantity the nearest integer (or, in special cases, integer plus a simple fraction, such as 1/2 or 1/3), which *is equal to or greater than* the value calculated from the empirical formula

$$m = 1/n = 1.50\ c/d \quad \ldots\ldots\ (2)$$

The second consideration is satisfied by selecting the spacing between centers of adjacent wires at the dowel diameter,[3] in accordance with the empirical formula

$$s = 1.25\,\delta \quad \ldots\ldots\ldots\ (3)$$

The spacing factor cannot be taken equal to unity, as in a close-wound solenoid, because in a universal coil the wire executes a bend at the point of reversal, for this maneuver more space is required than would correspond to contiguous, parallel wires.

Gear Ratio

The gear ratio itself, which, for convenience in calculation, is defined as the ratio of the number of teeth in the cam gear to that in the drive gear,[4] is found by substituting in the formula

$$r = \frac{T_C}{T_D} = \frac{2}{n}\left(1 + \frac{1}{P}\right) \quad \ldots\ (4)$$

for P the nearest integer (or in special cases integer plus a simple fraction) to the value calculated from the equation

$$P = 1/(a^2 \pm \sqrt{a^2 + b^2}) \quad \ldots\ldots\ (5)$$

where

$$a^2 = (s/qc)^2 \quad \ldots\ldots\ldots\ (6)$$

$$b^2 = (ns/q\pi d)^2 \quad \ldots\ldots\ (7)$$

and the positive sign is taken for progressive layering, while the negative is used for retrogressive layering.[5]

In these formulas n represents the approximate or integral number of crossovers per turn of the dowel, while q represents the number of crossovers required to complete a winding cycle, as obtained from the winding pattern, or otherwise. The values of q and the winding patterns corresponding to commonly occurring values of n, are given in *Fig. 1.*

The outstanding characteristic of a properly wound universal coil is the appearance of a precisely regular and wholly flawless pattern on the side of the coil, in the form of a number of "spokes" or "spirals" radiating outward, as shown in *Fig. 2.*

Method of Designing Universal Coils

(1) Determine c, d, and δ from the desired electrical characteristics of the coil.

(2) Determine the required number of crossovers per turn from the formula: $n = 0.67\ d/c$ or the number of

turns per crossover, if n is less than unity, from the formula: $m = 1.50\ c/d$.

(3) Determine the corresponding q by drawing the winding pattern as in *Fig. 1* or otherwise. (If n is an even integer $q = n$; if n is an odd integer, $q = 2n$; for all integral values of m, $q = 2$.

(4) Calculate P from (5) by inserting the value of s found from (3) into (6) and (7), and the values of a and b so found, into (5).

(5) Select the nearest integral value to the value of P so found and insert the same into (4) to find the actual gear ratio.

It is assumed that the cam gear is attached directly to the cam shaft, the drive gear to the drive shaft, and an idler gear of any convenient number of teeth interposed.

Example of a Simple Gear Ratio Calculation

Let it be desired to wind a coil ¼″ wide ($c = .250''$) on a ⅜″ O.D. dowel ($d = .375''$), using No. 36 SSE wire ($\delta = .0071''$) and retrogressive layering. For this case, we have

$$n = .67 \times .375/.250 = 1$$

that is, one crossover per turn should be used, which corresponds to $q = 2$, or two crossovers per winding cycle. Accordingly, we have further

$$a^2 = 1.25 \times .0071/2 \times .250 = 3.15 \times 10^{-4}$$
$$b^2 = 1 \times 1.25 \times .0071/2 \times \pi \times .375 = 1.42 \times 10^{-5}$$
$$a^2+b^2 = 3.29 \times 10^{-4}$$
$$-\sqrt{a^2+b^2} + a^2 = -1.78 \times 10^{-2}$$
$$-P = 1/1.78 \times 10^{-2} = 56.2$$

The nearest integer is 56, so that finally

$$r = 2(1 - 1/56) = 55/28 = T_C/T_D$$

that is, a drive gear of 28 teeth and a cam gear of 55 teeth should be used.

Example of a More Involved Gear Ratio Calculation

Let it be desired to wind a coil ¾″ wide ($c = .750''$) on a ½″ O.D. dowel ($d = .5''$), using No. 36 SSE wire ($\delta = .0071''$) and retrogressive layering. For this case, we have

$$n = .67 \times .5/.75 = 4/9$$

that is, n is less than unity. Accordingly, we employ the alternate formula and find

$$m = 1.5 \times .75/.5 = 2¼$$

Hence we could wind the coil either with 2¼ or 2½ turns per crossover. In practice, the second would probably be preferable. However, to illustrate the application of the formulas, we shall take $m = 2¼$, which corresponds to $q = 4$. Accordingly, we have

$$a^2 = 1.25 \times .0071/4 \times .750 = 8.75 \times 10^{-6}$$
$$b^2 = 2.25 \times 1.25 \times .0071/4 \times \pi \times .5 = 3.94 \times 10^{-7}$$
$$a^2+b^2 = 9.14 \times 10^{-6}$$
$$-\sqrt{a^2+b^2} = -3.02 \times 10^{-3}$$
$$\sqrt{a^2+b^2} + a^2 = 3.02 \times 10^{-3}$$
$$-P = 1/3.02 \times 10^{-3} = 332.2$$

The nearest integer is 332, so that we would require

$$r = 2 \times \frac{9}{4}(1 - 1/332) = (9/2) \times (331/332)$$

which would be a very inconvenient combination. In order to convert this into something more manageable, we try, without departing too far from 332, to find the value for P which would allow some cancellation. The desired value is 333, which would give

$$r = (9/2) \times (330/333) = 166/37$$

which is still an inconvenient calculation. However, this can be written

$$r = (2/1) \times (88/37)$$

that is, if we employ a 2:1 idler, for example, an 80/40, we have

$$r = (80/40) \times (88/37)$$

which is a practical combination. Hence, a drive gear of 37 teeth, a cam gear of 88 teeth, and an 80/40 idler mounted so that the 80 gear meshes with the 37 gear, should be used. In fact, this combination winds a beautiful coil and a rather unusual one.

Needless to add, it would be very difficult to find a combination of this type by cut-and-try methods.

Notation and Terminology Used in Universal Coil Winding

Crossover: a passage of the wire from one side of the coil to the other.

Winding cycle: a complete excursion of the wire from a given point to a point adjacent thereto in the direction of the winding.

a, b—quantities entering into the calculation of P, defined by (6) and (7).

C—the cam throw.

D—the diameter of the dowel or form on which the coil is wound.

J—the over-all diameter of the wire used (obtained from wire tables).

M—the integral or approximate number of turns of the dowel per crossover ($m = 1/n$).

N—the integral or approximate number of crossovers per turn of the dowel.

N'—the exact number of crossovers per turn of the dowel.

P—the gear ratio parameter defined by (4) and (5).

R—the gear ratio, in particular the ratio of the number of teeth in the cam gear to that in the drive gear.

S—the spacing between centers of adjacent wires in the first layer.

T_C—the number of teeth in the cam gear.

T_D—the number of teeth in the drive gear.

---

[1]Winding on glazed or polished dowels imposes an unnecessary handicap and should be avoided. The dowel surface should be rough.

[2]Coils wound with the proper mechanical ratio are inherently stable mechanically and do not require the use of binders or lacquers in winding.

[3]The spacing increases automatically from layer to layer in a universal wound coil, hence is a minimum at the dowel diameter.

[4]It will be noted that this is opposite to the usual way of taking gear ratios in which the drive gear is specified first.

[5]A. W. Simon, *Electronics*, vol. 9, p. 22, October 1936; *Proc. I.R.E*, vol. 33, pp. 35-37, January 1945. Retrogressive layering is more widely used.

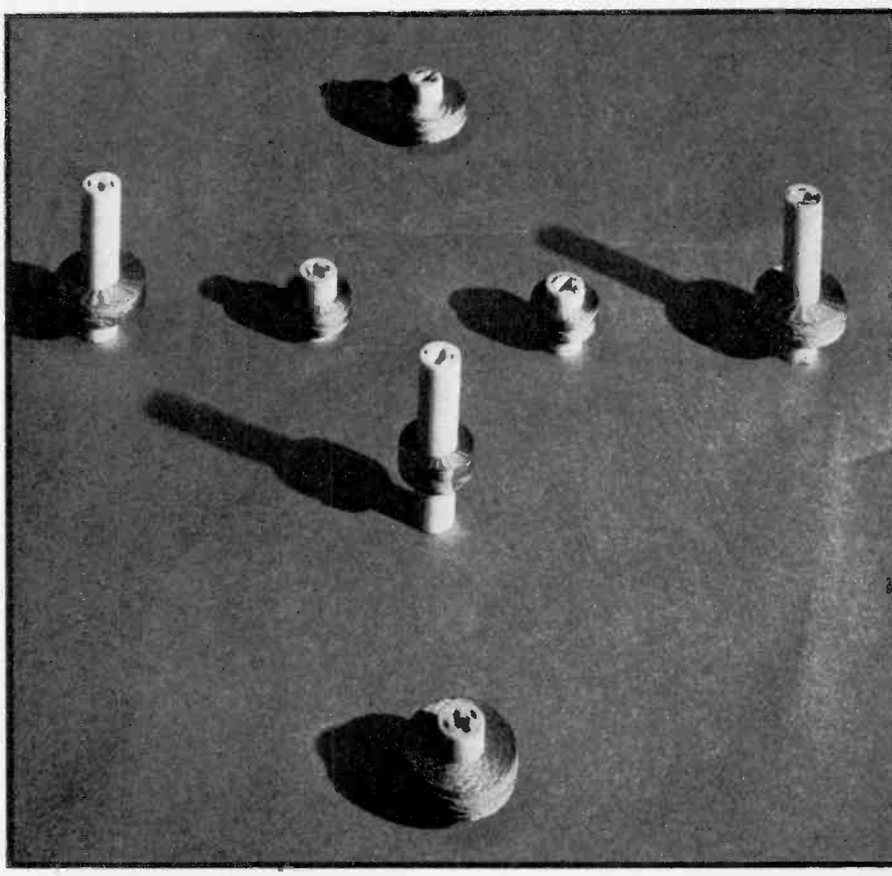
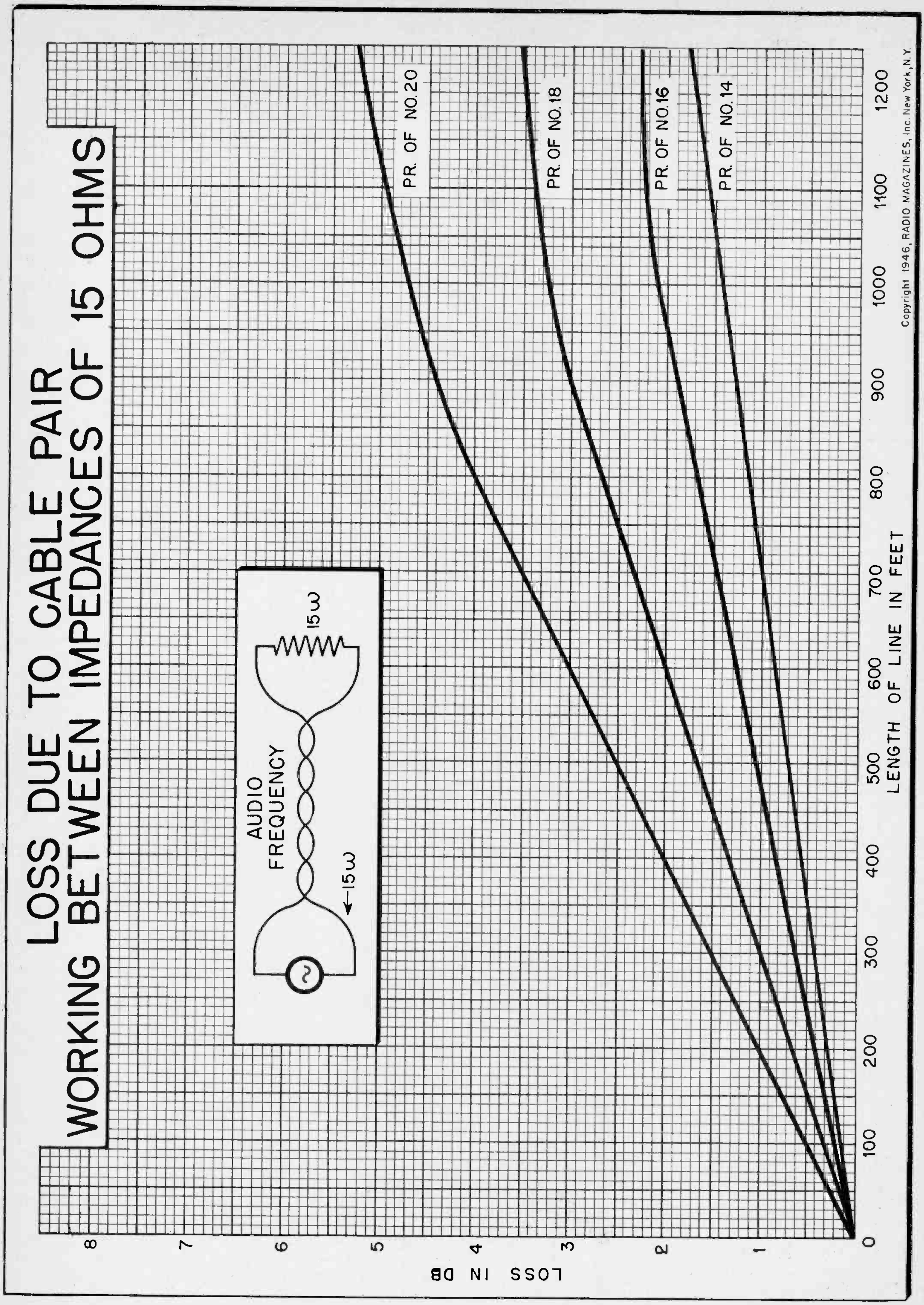


Fig. 2. Shown clearly are properly wound universal coils. The winding around the dowel appears to be a regular and flawless pattern.
(Courtesy of Sidney S. Lovitt)


LOSS DUE TO CABLE PAIR
WORKING BETWEEN IMPEDANCES OF 15 OHMS
AUDIO FREQUENCY
15 ω
15 ω
PR. OF NO.20
PR. OF NO.18
PR. OF NO.16
PR. OF NO.14
LOSS IN DB
1
2
3
4
5
6
7
8
LENGTH OF LINE IN FEET
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
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The photograph shows the multi-carrier v-h f communication system at work. Here is a British operator using the radio equipment.

(Courtesy General Electric Co., Ltd.)

Multi-Carrier V-H-F COMMUNICATION SYSTEM

New and effective methods for increasing the efficiency of mobile radio are discussed.

M. G. SCROGGIE

RADIO FOR MOBILE SERVICES, such as police and fire, is allocated v-h-f bands because

1) the lower frequency bands are already overcrowded,
2) v.h.f. penetrates built-up areas better,
3) small aerials radiate better at v.h.f., and
4) mutual interference between widely separated stations is prevented by the limited range.

Unfortunately, in areas where there are many buildings, bridges, embankments, and other prominences, and in valleys—the areas in which mobile radio communication is most wanted—coverage is very patchy, owing to shadows and destructive interference by reflected waves. Further difficulties are encountered when it is desired to extend the area served by a single transmitter.

Both for "illuminating" a small area more uniformly, and for enlarging the area served, the natural solution to consider is using more transmitters. The question then arises, should they all work on the same frequency or on different frequencies? If working on different frequencies necessitates retuning receivers, the idea can be dismissed at once. Apart from the inconvenience (police generally have plenty to think about without tuning a receiver) it is ineffective when in motion, because of the suddenness and frequency of fluctuations in field strength from any one transmitter. If the transmitters are to work on the same frequency, they must be exactly synchronized. Difficult enough at much lower radio frequencies, even if it could be perfectly achieved at v.h.f. there would be space phase troubles. Recent tests with frequency-modulated transmitters truly synchronized by a harmonically related linking frequency have in fact evinced such troubles.

One of the advantages claimed for frequency modulation is the "capture effect," by which the stronger of two transmissions takes charge of the receiver, even if the ratio of strengths is not very great. However, unless the disparity in strength is assisted by terrain screening, there is a substantial area between the two transmitters where neither rules the receiver, and distortion is serious.

An alternative solution, using two or more amplitude-modulated transmitters working on frequencies sufficiently close together to be received simultaneously, but not close enough to interfere audibly with one another, has been developed and proved satisfactory by the British Government.

Amplitude-Modulated In Synchronism

Receivers used in development tests had a bandwidth of about 100 kc, and could therefore receive several carrier waves spaced at 20-kc intervals (*Fig. 1*). These carrier waves are amplitude-modulated in synchronism, and it is found that phase differences resulting from differences in distance of the transmitters do not cause noticeable distortion. The probability of the receiver aerial being in a dead spot is very greatly reduced even with only one additional transmitter radiating from a different site, and instead of reception fluctuating violently when in motion, it is comparatively uniform. With three transmitters the uniformity is still greater.

Service within an area is therefore vastly improved. Moreover, by spacing transmitters at suitable intervals, the service area can be enlarged indefinitely.

A traveling car comes within the influence first of one transmitter and then of another, but it is not evident which is contributing most at any one moment, or when there is a change-over. The effect is somewhat analogous to diversity reception, and is sometimes called (not strictly accurately) diversity transmission.

A form of diversity reception is used, however, for communication in the reverse direction, from the mobile station, which of course cannot readily operate several spaced transmitters simultaneously. Instead, its single transmitter is picked up at the several fixed stations, and the results combined.

A three-carrier system of this type,

covering the rural and rather hilly area of three English counties, has been given extensive field trials, described in a paper before the (British) Institute of Electrical Engineers by J. R. Brinkley. The details of the system are shown in *Fig. 2,* from which it will be seen that radio links are used to connect the three transmitting stations and the control center. Land lines could be substituted if more convenient. The *f3* receiver at the Master Control station and the *f5* receivers at the Satellites are normally kept switched on. When the former receives a carrier wave from Area Control, the trigger circuit switches on the other transmitters. These in turn switch on the transmitters and the *f2* receivers at the Satellites. The speech for the 100-watt transmitter at the Master Control is picked up by a receiver in the same way as at the Satellites, with the object of equalizing phases by having the same chain of equipment for all three outgoing routes. This refinement was not extended to the incoming chains in the tests described.

Two-Carrier System In London

A two-carrier system covering the greater London area has also been demonstrated.

In both cases, the service was a great improvement, with respect to uniformity of signal strength, on single-carrier systems, using either amplitude or frequency modulation. A nearly constant signal level was obtained over the whole of the two areas, in spite of the artificial and natural screening offered by the largest built-up area in the world and by the Chiltern valleys respectively. In addition, the three-carrier waves covered a larger area than any single station could have done, even though the station spacing was not ideal.

It may be noted that the frequencies used, which are in the bands allocated for such services in Britain (78.5-82, 95.5-100, and 128-131 mc), are much higher than the American police band (30-40 mc). There are several advantages in this. First, the higher frequencies penetrate streets, steel-framed buildings and tunnels better, in much the same way that waves higher than a certain critical frequency pass along waveguides while lower frequencies are rapidly attenuated. They are also less subject to electrical noises from trams, trolley-buses, etc., and are entirely free from long-distance interference, to which the lower frequencies are liable. For example, American police messages have often been heard in Europe. The experience gained in developing these high frequencies was of great value during the war, when their adoption by the British for aircraft communication was an outstandingly successful innovation.

Frequency modulation, generally favored for v.h.f. in America, is claimed to be much freer from thermal and ignition noise, thus giving better service, usable down to lower field strengths and therefore at greater ranges. V-h-f range is limited more by propagation characteristics than by over-riding noise, however, especially at frequencies higher than those used in the U.S.A. The multi-carrier amplitude-modulated system enables range to be extended in-

[*Continued on page* 32]

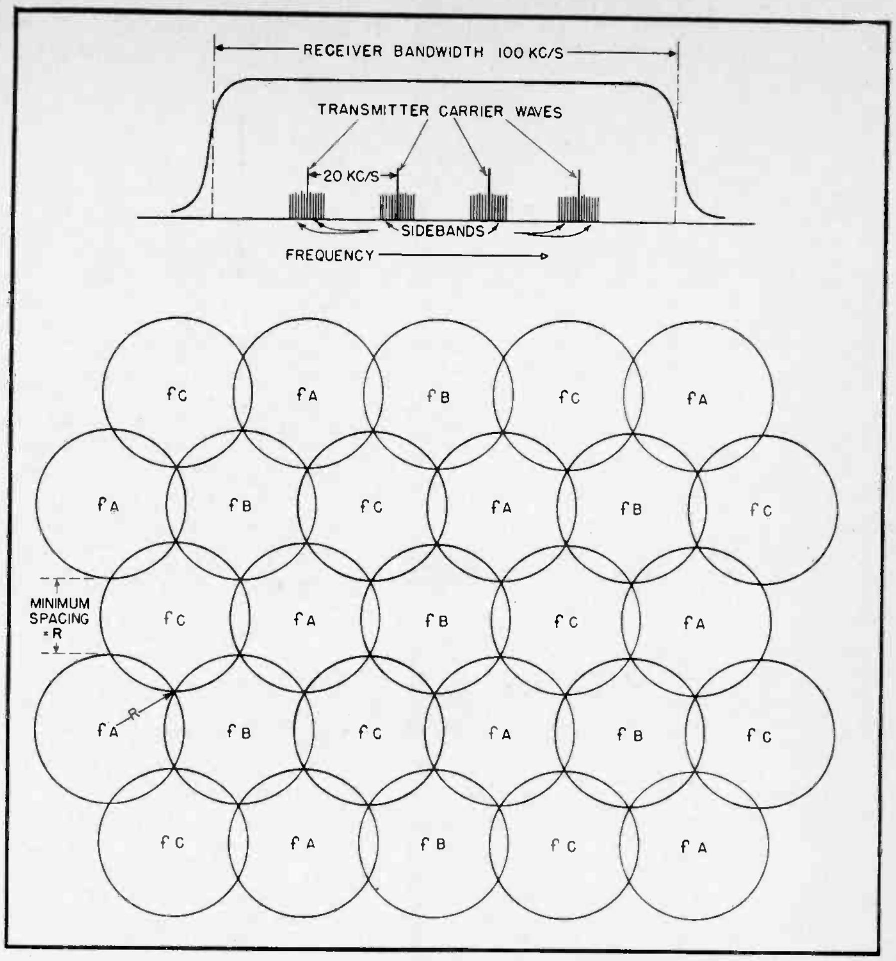


Fig. 1. (top) In the multi-carrier system, a number of transmitters, synchronously amplitude-modulated, are accepted simultaneously by the receivers, ensuring that in all locations at least one is adequately received. The above band widths, used in the development tests, are now being reduced to about one half.

Fig. 3. (bottom) Coverage diagram showing how transmitters using only three frequencies could serve an unlimited area or distance.

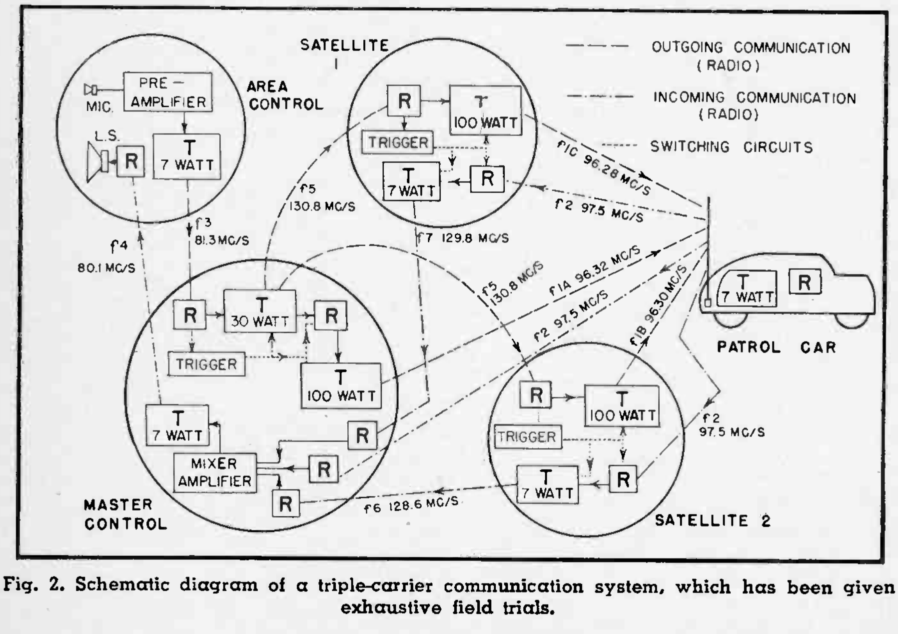


Fig. 2. Schematic diagram of a triple-carrier communication system, which has been given exhaustive field trials.

RECENT RADIO INVENTIONS

These analyses of new patents in the radio and electronic fields describe the features of each idea and, where possible, show how they represent improvements over previous methods

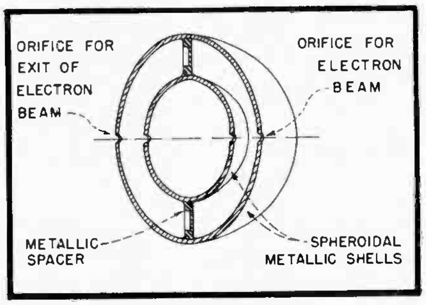
U-H-F Resonant Cavity

● A new class of u-h-f resonant cavities and design factors involved in their construction has been granted a patent, issued to S. A. Schelkunoff August 13, 1946. Essentials of the cavity are shown in sectional form.

Continuously varying transmission lines constitute the central concept of the new cavity, which is composed of two concentric spheroids. Excitation of the cavity is obtained from a velocity-varied beam of electrons directed through the orifices. By changing the axis of excitation from the major to the minor axis, the resonant frequency of the device becomes altered. The frequency defined by the space between the shells may be the same or different from that defined by space within the smaller cavity, depending upon the constructional dimensions.

Rigorously exact methods of computing the resonant frequency of cavities are available only for the simplest geometrical contours. Dr. Schelkunoff, however, has succeeded in deriving mathematical solutions for cavities of spheroidal form upon the basis of continuously varying transmission line theory. The cavities are of convenient mechanical design.

The patent, No. 2,405,612, is assigned to Bell Telephone Laboratories.



Patent No. 2,405,612.

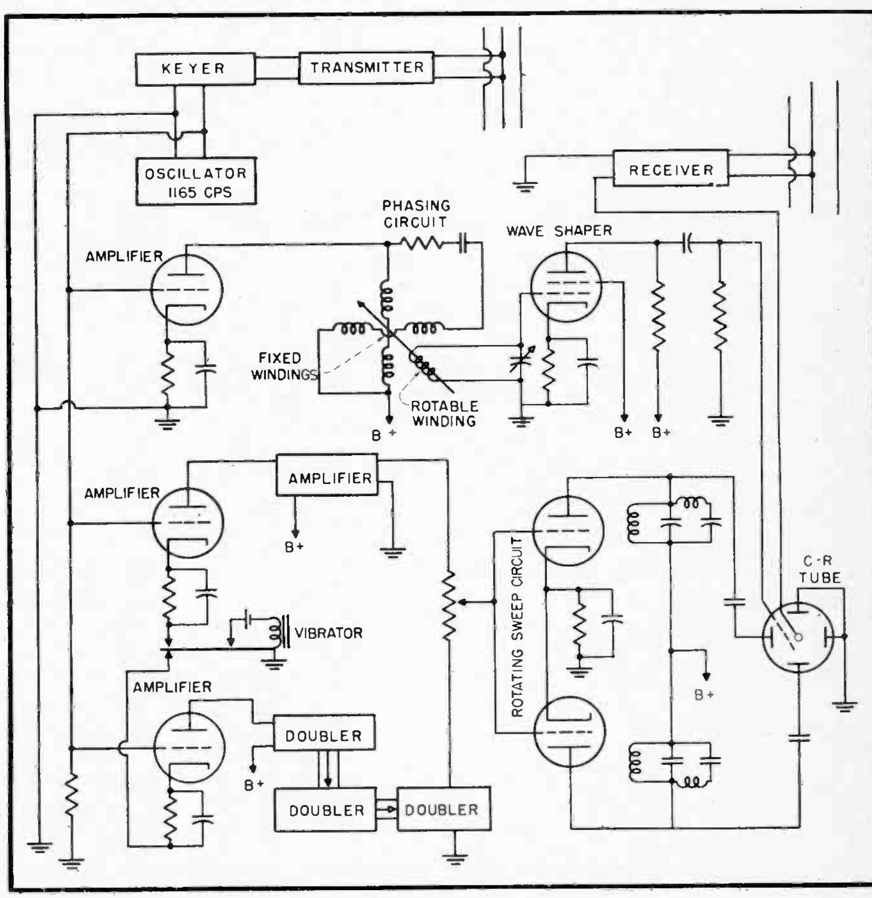
Vernier Circular Sweep

● Circuits for obtaining a vernier concentric sweep, for expansion of a selected portion of an outer sweep, were granted a patent July 2, 1946 to William D. Herschberger. The system is used in conjunction with radar receivers.

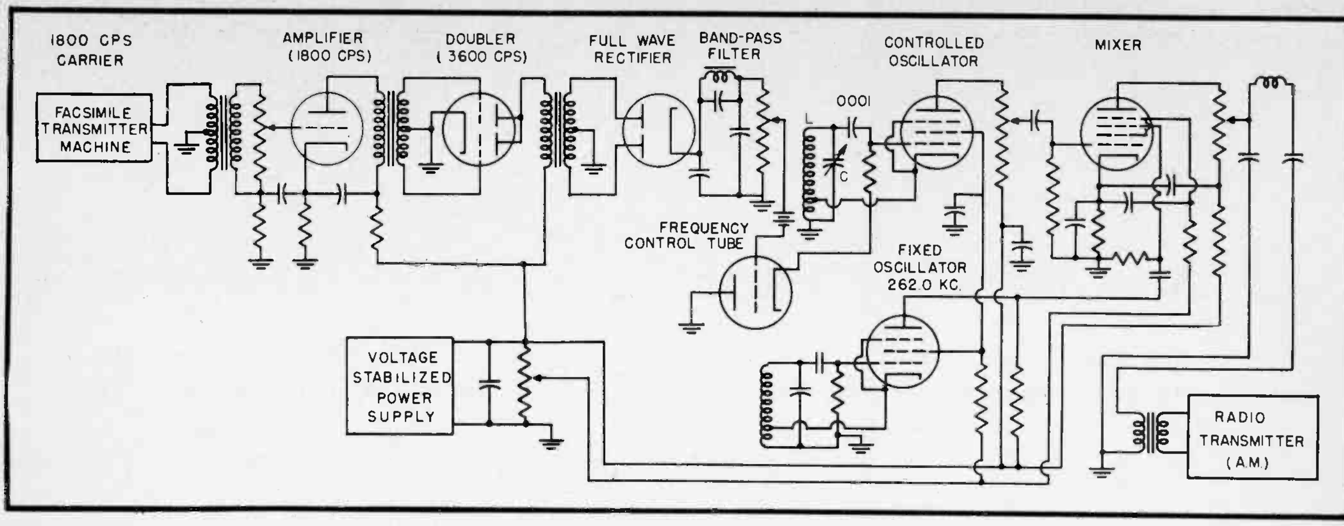
Illustrated is a cathode-ray tube and its associated circular sweep generator. The circular sweep voltages appear when alternating current is applied to the grids of the generator tubes, as developed in another patent application, No. 358,462. In brief, the networks in the plate circuits of the sweep generator tubes are respectively inductively and capacitively reactive to the two sweep frequencies so that a two-phase voltage is made available to the deflection plates of the CR tube to produce a rotating sweep.

Sweep excitation voltage is obtained from the 1165-cps generator, which may be applied directly to the sweep generator, or multiplied before application. These fundamental and multiplied frequencies may be applied alternately with sufficient rapidity to appear simultaneously by means of the vibrator indicated. In the circuit described, the initial 1165-cps frequency is multiplied by six for use as a vernier sweep voltage.

Selection of the expanded portion is accomplished by means of the waveshaper tube, which develops a blanking voltage of approximately square shape when energized by the 1165-kc oscillator voltage. This voltage blanks all but a selected portion of the main trace, while the vernier trace, being six times as rapid, is developed around 360° and constitutes a vernier presentation. By adjusting the rotatable winding of the phasing circuit as required, the phase



Patent No. 2,403,278.



Patent No. 2,403,358, Figure 1.

of grid voltage applied to the wave shaper tube may be controlled at will and the selected portion of the main trace varied accordingly.

The patent, No. 2,403,278, is assigned to Radio Corporation of America.

Improved Facsimile System

• Selective fading and harmonic distortion are reduced in an improved FM facsimile system patented July 2, 1946, by Anthony E. Gerhard. A novel frequency-modulated oscillator circuit is a feature of the new system.

As illustrated in *Fig. 1*, an amplitude-modualted audio-frequency carrier is obtained in any conventional manner, or in accordance with U. S. Patent No. 2,015,742 which describes a suitable machine. The modulated carrier is doubled, rectified, and passed through a band-acceptance filter as indicated. The purpose of the filter is to eliminate frequency flutter.

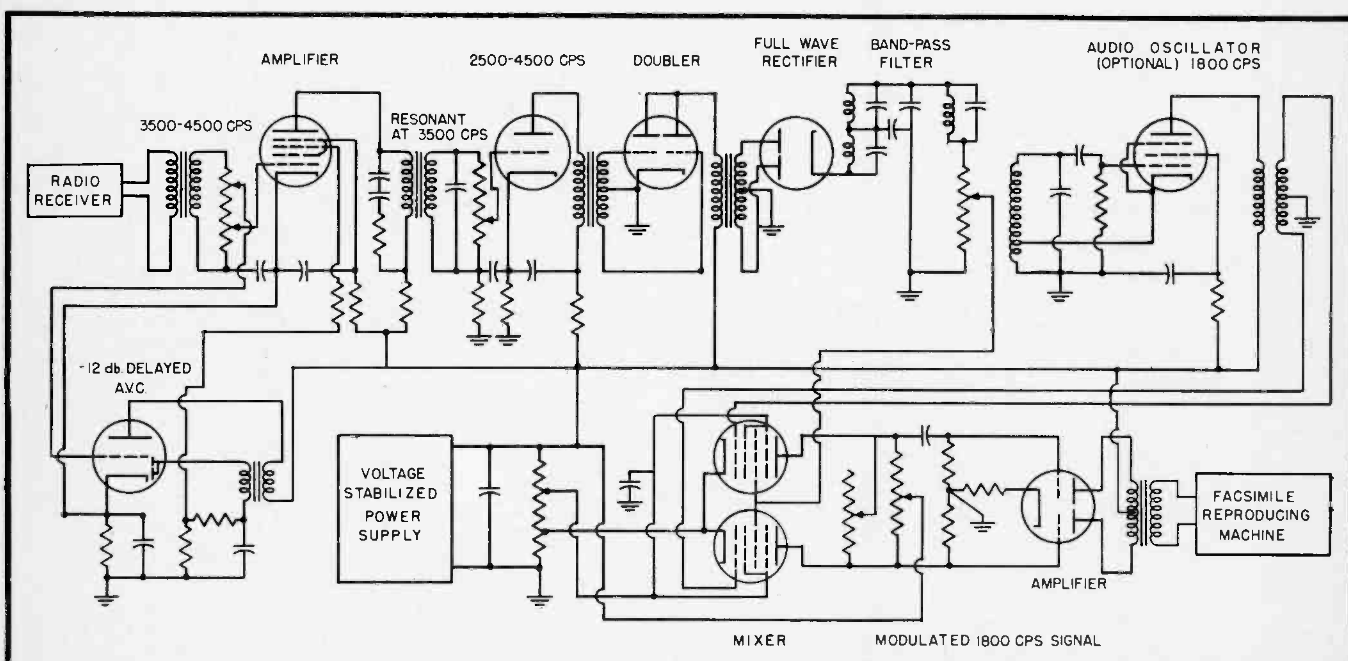
There is thus made available at the filter output a varying d-c voltage proportional to the tonal values of the transmitted copy. This signal voltage varies the frequency of the controlled oscillator through variable capacitance developed across the frequency-control tube. Change of potential on the grid of the frequency control tube varies the effective grid-leak resistance of the controlled oscillator, and hence changes the effective shunt capacitance of the 0.0001 µf capacitor acting across the LC mesh.

The fixed oscillator heterodynes with the controlled-oscillator output to yield a modulating frequency of 3.5 kc for pure white and 4.5 kc for pure black. The transmitter is amplitude-modulated with this particular frequency band.

This same band is recovered at the receiver diagrammed in *Fig. 2*. The band-pass filter confines the output frequency range between the limits of 2500-4500 cps, which serves to eliminate any harmonic distortion incurred in doubling, since the second harmonic of the lowest signal frequency (3500 cps) is not passed.

This output is doubled and passed through a full-wave rectifier as indicated, followed by a band-pass filter to eliminate frequency flutter. The resulting d-c signal with amplitude proportional to the tonal values of the transmitted copy may energize the reproducing mechanism directly, or through the agency of a modulated audio-frequency carrier, as shown.

The patent, No. 2,403,358, is assigned to Press Wireless, Inc.



Patent No. 2,403,358, Figure 2.

RADIO DESIGN WORKSHEET

No. 56 — PHASE MODULATION

PHASE MODULATION

• PM can be analyzed best by comparison with its twin.[1] FM, and with closely-related AM.[2] FM and PM are characterized by r-f vectors that vary in instantaneous angular velocity but not in magnitude. Only details of this variation enable FM and PM, to be distinguished from each other.

Practically, FM can be produced from AM by filtering out the carrier, shifting its phase 90°, and recombining with the AM sideband components. Analysis[3] leads to the conclusion that for conventional modulators, resulting distortion is largely third harmonic and less than 5%.

Conversely, AM may be produced from an FM wave by filtering out the carrier, shifting it 90°, and recombining with the FM sidebands.[4] AM may likewise be produced from a PM wave by mixing the unmodulated carrier from a common source with the PM-output of a phase-shift bridge.[5]

It will be evident that the foregoing techniques are not based upon precise analytical transformations, since FM and PM waves contain an infinite array of sidebands, whereas AM waves exhibit a finite group of sidebands.[6] These are practical techniques that result in distortion products sufficiently low that they may be neglected.

In a PM system, the a-f modulating voltage is modified by a network the output of which is proportional to frequency. This modulating voltage applied to the grid of a reactance tube results in a constant modulation index.[7] When phase-shift circuits are used to develop the PM wave, the modulator

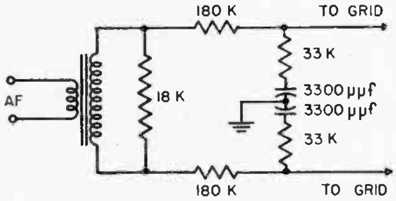


Figure 1.

output is made inversely proportional to audio frequency. The network used by Bendix Radio is shown in *Fig. 1.*

Thus the sidebands of significant orders do not change in PM, i.e., if the third order sideband is significant at the highest modulating frequency, it will also be significant at the lowest modulating frequency. In the Bendix system, a modulation index of 5 is specified. A maximum deviation of ±15 kc is obtainable at an audio frequency of 3 kc, and at 300 cps the maximum deviation falls to ±1500 cps. Thus the maximum a-f output voltage at 3000 cps and 300 cps respectively is 100% and 10%.

Presentation of a PM wave on the screen of a spectrum analyzer with changing modulation is suggestive of an AM presentation, although the former is not sharply terminated and occupies a considerably wider channel. The similarity lies in the movement of significant sidebands in and out from the carrier during modulation. In contrast with FM, slight change in channel-width is observed during modulation.

Modulation index is defined by the ratio of deviation to modulating frequency. Since deviation is proportional to modulating voltage, the basis of constant modulation index in PM is evident. In FM, the modulation index is made inversely proportional to modulating frequency. It will be seen that the modulating network for FM yields an output that does not change with modulating frequency. This consideration is of course exclusive of pre-emphasis and de-emphasis circuits used at transmitter and receiver respectively, for improving the signal-noise ratio. These circuits affect the modulation index during modulation, and in general PM receivers require de-emphasis circuits with longer time constants than FM receivers.

It is well to note that a PM modulator used in conjunction with a reactance tube requires an a-f output proportional to frequency, but if the PM modulator is to be used with a phase-shifting circuit, its a-f output must be made inversely proportional to frequency.

To summarize the properties of the PM wave, it may be regarded as a type of angular-velocity modulation (a form of FM) in which the modulation index does not alter with changing modulation frequency. This requires an audio modulating voltage proportional to audio frequency, resulting in a deviation proportional to the modulating frequency. The receiver requires suitable audio correction circuits which equalize the rising frequency characteristic of the PM transmitter.

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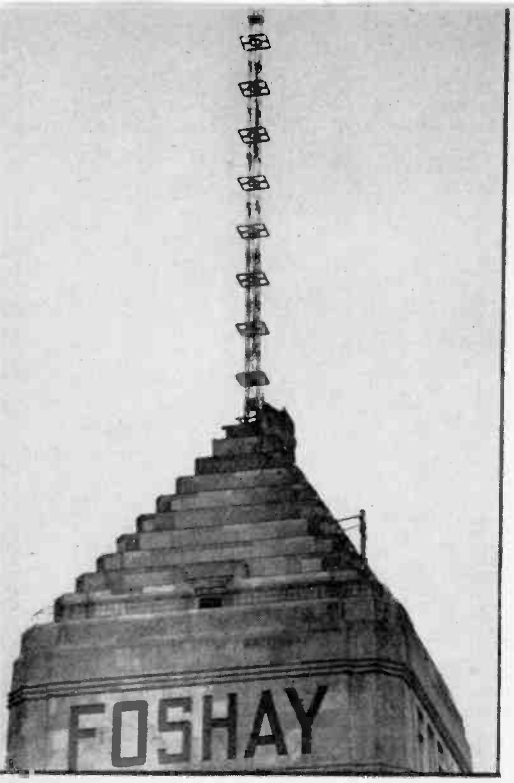
[2]E. H. Armstrong, *Proc. I.R.E.,* vol. 24, p. 689
[3]D. L. Jaffe, *Proc. I.R.E.,* vol. 26, p. 475
[4]M. G. Crosby, *Proc. I.R.E.,* vol. 27, p. 126
[5]John Beckwith, RADIO, October 1946, p. 9
[6]Hund, August, *Frequency Modulation,* pp. 2-37
[7]RADIO, Nov. 1946, p. 23



The world's first permanent super-efficient FM antenna erected by Radio Station WTCN-FM atop the Foshay Tower, Minneapolis, Minn. The eight-element square-loop antenna and FM broadcast transmitter installed by WTCN-FM were manufactured by Federal Telephone and Radio Corporation, associate of the International Telephone and Telegraph Corporation. Radiated power is 400 kw.

This Month

HIGH-POWER FM STATION

Radio history was made in Minneapolis recently when Station WTCN-FM, the city's new frequency modulation broadcasting center, went on the air with a most efficient commercial FM broadcasting system, using the first permanent highly directive FM antenna.

A point of interest in the opening of the new station on December 27 was the 74-foot Federal FM Square-Loop Broadcast antenna which dominates the Minneapolis skyline from the top of the Foshay Tower. Designed and manufactured by the Federal Telephone and Radio Corporation, of Newark, N. J., it is the first FM broadcast antenna of its efficiency to be erected. This higher efficiency, plus the location of the antenna at the apex of the tallest structure in the local area, resulted in reception of static-free, finer quality programs over an unusually wide area.

John M. Sherman, technical director of WTCN, received reports of consistent service to St. Cloud, 60 miles from the transmitter; Rochester, 78 miles; St. Peter, 58 miles; all in Minnesota, and Grantsburg, Wisconsin, 64 miles. Other reports from Little Falls, 80 miles from Minneapolis and Duluth, 130 miles distant, also reported noise-free reception at those distances.

WTCN-FM's large radiation area, accomplished with a Federal 3-kw FM transmitter, will be further increased when the contemplated final WTCN-FM effective radiated power of 400 kw is achieved by the installation of a 50-kw transmitter.

According to Federal Telephone and Radio Corporation engineers the 8-element square-loop antenna multiplies the power of the transmitter by over eight times. As a consequence, with a 3-kw transmitter now in operation an effective radiation of better than 25 kw is recorded. When the power of the transmitter is increased to 50 kw, the antenna will provide an effective radiated power of 400 kw with resulting advantages to WTCN-FM audiences.

ELECTRONIC FORECASTER

Control of hurricanes, prevention of killing frosts, and precipitation of rain in dry areas are possibilities of an electronic weather forecaster now in its early stage of development, Dr. V. K. Zworykin, director of electronic research, RCA Laboratories, Princeton, N. J., recently told a joint meeting of the American Meteorological Society and the Institute of Aeronautical Sciences at the Hotel Astor in New York City.

Pointing to the great economic significance the new development may have for transportation, agriculture, and the saving of human life, Dr. Zworykin disclosed that the electronic forecaster also holds promise for accurate weather predictions over the entire globe.

The principles of an electronic computer now being developed at RCA Laboratories, with the cooperation of Dr. John Von Neuman of the Institute for Advanced Study at Princeton, N. J., Dr. Zworykin said, can be used in the construction of an electronic forecaster. This would enable the making of reliable weather forecasts for days ahead in a matter of minutes. But even more important, Dr. Zworykin pointed out, may be it application in the control of weather, not over vast areas but in modifying such local condition as dangerous storms, droughts, frosts, and fogs.

Previous methods of changing the weather have been successful only on a small scale because of their cost and the fact that it has been impossible to determine where the control should be applied for maximum effect. The electronic forecaster, he said, will supply this guidance.

Two methods are available, Dr. Zworykin explained, for providing the energy needed to alter the evolution of weather changes. A combustible substance such as oil might be spread on water over a considerable area and ignited. This would add energy directly to the air, causing an updraft and affecting the air movement in the surrounding region. Similar results, he said, might be obtained by using the sun's radiations to modify weather conditions. This, he said, could be accomplished in several ways.

Weather control patches blackened by deposits of carbon could be established at various points to act similarly to the large burned-over blackened land areas in South Africa which have been found to be centers of repeated thunderstorms. In contrast, he said, these same areas could, at will, be converted into highly reflecting areas by covering them with artificial fog using techniques widely applied in the war. Here again, Dr. Zworykin pointed out, the electronic forecaster could be used to deduce the most advantageous location and the required magnitude of such patches to produce the desired effect.

IMPROVED WIRE RECORDING

An instrument which may make possible further improvements in the recording of music on magnetized wire was reported recently before the winter meeting of the American Institute of Electrical Engineers.

The instrument, called a "cathode-ray oscilloscope hysteresis loop tracer," was announced in a paper by D. E. Wiegand and W. W. Hansen, both of the Armour Research Foundation of the Illinois Institute of Technology, Chicago, prepared for presentation before the Convention's Communications Section. Both men have been prominent in research on wire recording.

Designed as a research tool, the instrument continuously pictures on a lighted screen the magnetic properties of the recording wire being tested, thus making possible rapid and detailed analysis of new combinations of alloys. It can test samples much smaller than can be used conveniently with the present ballistic test method, the authors stated, and magnetic readings with a consistent accuracy within five per cent are possible.

Engineers are searching for new types of recording wire because an improved wire means greater fidelity in the recorded program or, where cost is a prime consideration, will allow the present high fidelity characteristics to be maintained with a reduction in wire speed.

The new instrument can also be used to test the magnetic properties of alloys at each stage of their manufacture into

[*Continued on page* 30]

MONEY ISN'T EVERYTHING—

(OR IS IT?)

BY GROUCHO MARX

WHAT do you want to save up a lot of money for? You'll never need the stuff.

Why, just think of all the wonderful, wonderful things you can do *without* money. Things like—well, things like—

On second thought, you'd better keep on saving, chum. Otherwise you're licked.

For instance, how are you ever going to build that Little Dream House, without a trunk full of moolah? You think the carpenters are going to work free? Or the plumbers? Or the architects? Not those lads. They've been around. They're no dopes.

And how are you going to send that kid of yours to college, without the folding stuff? Maybe you

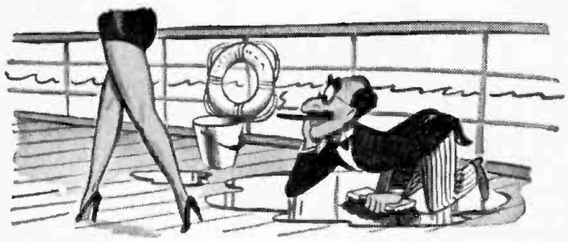
think he can work his way through by playing the flute. If so, you're crazy. (Only three students have ever worked their way through college by playing the flute. And they had to stop eating for four years.)

And how are you going to do that world-traveling you've always wanted to do? Maybe you think you can stoke your way across, or scrub decks. Well, that's no good. I've tried it. It interferes with shipboard romances.

So—all seriousness aside—you'd better keep on saving, pal.

Obviously the best way is by continuing to buy U. S. Savings Bonds—through the Payroll Plan.

They're safe and sound. Old Uncle Sam *personally*



guarantees your investment. And he never fobbed off a bum I.O.U. on *anybody*.

You get four bucks back for every three you put in. And that ain't hay, alfalfa, or any other field-grown product.

Millions of Americans—smart cookies all—have found the Payroll Plan the easiest and best way to save.

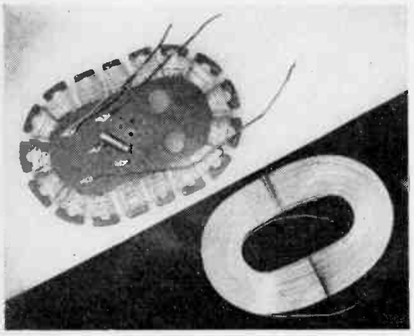
So stick with the Payroll Plan, son—and you can't lose.

SAVE THE EASY WAY... BUY YOUR BONDS THROUGH PAYROLL SAVINGS

New Products

HIGH Q LOOP WIRE

A small-diameter, polyethylene insulated wire loop antennas for home radio receiver loop antennas has been developed by



Federal Telephone and Radio Corporation, Newark, N. J., manufacturing associate of International Telephone and Telegraph Corporation. Identified as K-1044, the wire is constructed of bare soft copper #24 AWG. The size of the conductor is .0201 inches, and the over-all diameter only .038 inches.

A radio receiver equipped with Federal's K-1044 gains additional sensitivity and selectivity. Electrical losses at radio frequencies are extremely low. The Q factor of an average size loop—6 by 9 inches—often exceeds 200. Treatment of the wire with polyethylene makes it possible to design a coil without support. The wire is wound and heated between plates. When the polyethylene begins to melt, the coil is removed and the polyethylene on re-hardening provides the necessary rigidity. Since the material used in coil supports introduces added electrical losses, the Q factor of receivers using the K-1044 is further increased.

IMPROVED SOLDERING FLUX

Handy, greater convenience in use, elimination of containers and brush and stick applicators and greater efficiency are features of the new Flux-Stik, a specially designed soldering flux molded into stick

form. It eliminates waste, permitting just enough flux for the joints.

Flux-Stik is non-acid and non-running. It is useful for overhead, inaccessible and out-of-the-way soldering locations where cleaning of the metal is clumsy and inconvenient. It can be used for sweat joints of copper or brass tubing, manifolds, traps, elbows, piping, sheet metal, cabinet work, refrigeration and heating coils, etc.

Flux-Stik is made by Lake Chemical Co., 607 N. Western Ave., Chicago 12, Ill.

HIGH-POWER TRIODE

Federal Telephone and Radio Corporation, Newark, N. J., manufacturing associate of International Telephone and Telegraph Corporation, has developed a high-performance power triode designed to meet the specific requirements of FM transmission service in the 88 to 108 mc band, with a maximum output up to 110 mc. Desig-

nated as the 7C27, it is one of the first tubes to reach the market that, in pairs, provides 10-kw output. A pair of the tubes is used in the final amplifier stage of Federal's 10-kw FM Transmitter.

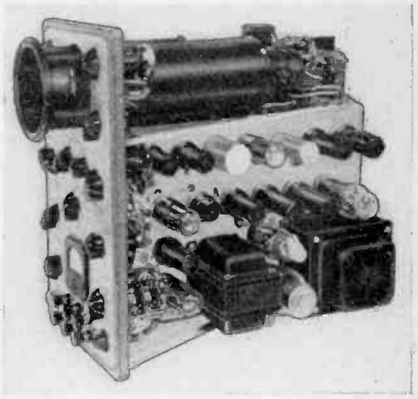
Radial cooling fins provide a large surface area and an unrestricted airflow path. The use of pure copper anodes, joined to the cooling fins by a thin solder film of high thermal conductivity, assures a highly efficient forced-air cooling. The required air flow for cooling, at maximum output is 175 cubic feet per minute.

Grid ring construction results in relatively low capacitance between filament and plate and makes the 7C27 especially adaptable to the use of a grounded-grid circuit.

Measuring approximately 8 inches high and 3½ inches in diameter, the 7C27 is ruggedly constructed and designed to give long tube life. The maximum plate dissipation is 3000 watts, filament voltage 16.0 volts, and filament current 28.5 amperes.

NEW RCA SCOPE

A new portable three-inch oscilloscope meeting laboratory requirements for accuracy is now in production, it was an-



Oscilloscope with case removed.

nounced by W. W. Watts, Vice-President in Charge of the RCA Engineering Products Department. The new oscilloscope's frequency range and high-gain characteristics permit close examination of high-speed transients and pulsed voltages for test analysis. This oscilloscope, Type WO-79A, makes possible the accurate measurement and display of frequency components up to 6 mc in transient and pulsed voltages of the order of one microsecond.

The centering controls on the oscilloscope permit expansion of a waveform under test over a distance which is twice the diameter of the screen, without causing visible distortion. This makes it possible to center any portion of a complex wave on the screen for analysis. The voltage amplitude of a signal can be determined by means of a calibrated voltmeter which is built into the front panel of the instrument.

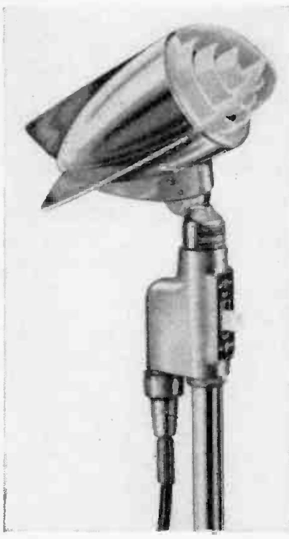
The triggered sweep feature makes the unit particularly suitable for photographic study of transient waveforms, for tele-

vision signal expansion for checking square-wave time, and for checking irregularly timed pulses. The intensifying amplifier increases the brilliancy of the waveform after the time-base generator is triggered, permitting examination and photography of small, otherwise, faint, and extremely short pulses. Signal-triggered deflection, line frequency deflection, and blanking are some of the other unusual features of this new RCA oscilloscope.

Some of the applications of the new oscilloscope include square wave testing for frequency response characteristics; adjustment of radio, television, telegraph and telephone channels, and r-f and i-f amplifiers; observation of common types of waveforms; measuring speed and time intervals; measuring impedance and power factor in loudspeakers and other devices; timing fine watches; and measuring percentage of modulation.

NEW ASTATIC MIKE

Among recent acquisitions to the Astatic line of microphones is "The Conneaut." This is a crystal microphone with relatively high output and wide frequency range, is especially desirable for use with public address and paging systems, amateur rigs and countless other communica-

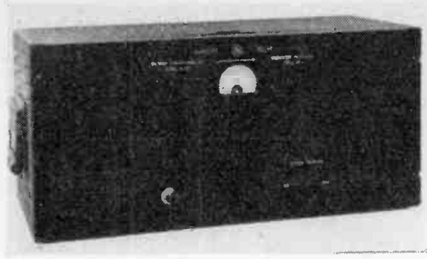


tion applications. This new microphone has an over-all frequency response up to 10,000 c.p.s. Model 600-S, illustrated, is supplied with Type S On-Off Switch.

CAPACITANCE RELAY

A sensitive capacitance relay is announced by Browning Laboratories, Inc., of Winchester, Mass. Designated as Model DD-20, this new equipment enables changes in capacitance to control external devices or circuits. A panel meter indicates capacitance changes in addition to the relay operation. A change of as little as 0.01 $\mu\mu f$ is discernible on the meter, and relay operation can be obtained with changes of 0.05 $\mu\mu f$ or more. Sensitivity is variable to suit demands. Output provisions are made for supplying 115 volts a.c., closed circuit, or open circuit upon operation of relays. Self-contained power supply is regulated electronically for best stability and is designed to operate from 115-volt 60-cycle a-c source.

Applications include control of machin-



ery where direct contact with machine or material is undesirable, safety control for machine operators, automatic illumination control for stairways or corridors in presence of persons, advertising display control, or limiting of linear motion.

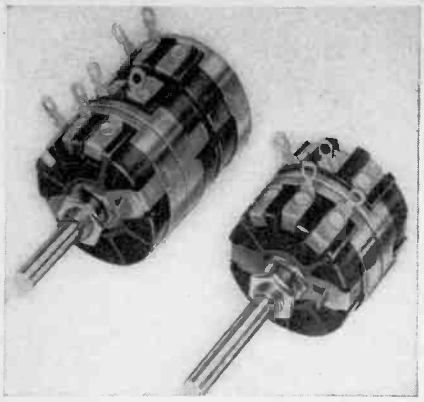
The unit is suitable for rack mounting and is supplied with 8¾" rack panel and enclosing cabinet. Dimensions: 9" x 19" x 11". Weight: 34 lbs.

PADS FOR SOUND SYSTEMS

Wire-wound L-Pads and T-Pads for sound systems, covering impedance ranges from 8 to 600 ohms, have been announced by G. E.

The T-Pads may be used as variable attenuators in stable line impedance circuits while the L-Pads have application as individual volume controls for multiple speakers or as attenuation controls for constant impedance at either the source or load.

Rated at a maximum power dissipation of 2.5 watts, the units have a continuous



range of from 0.5 to 30 db attenuation in 90 degrees of rotation, the last 10% affording infinite attenuation.

Further information or specification sheets on the new T-Pads or L-Pads may be obtained on request to the Specialty Division, G. E. Electronics Department, Wolf Street Plant, Syracuse, N. Y.

MINIATURE ROTO SWITCH

A new miniature roto switch only 3/4" in diameter and 13/32" depth — yet with a contact pressure of 2½ lbs. — has been developed by Grayhill, 1 N. Pulaski Road, Chicago 24, Ill. Termed the Series 5000 Roto Switch, the novel apparatus can be used in almost any circuit combination up to 5 amps., breaking up to 1 amp. at 110 volts.

Featuring 360° rotation in either clockwise or counterclockwise direction, it may be moved, for example, from position #1 to #10 without going through positions 1, 2, 3, etc. Or, if desired, stops can be placed to allow rotation only through a given number of positions.

The switch is available in both shorting and non-shorting types. Shafts either for knob or screw adjustments are provided.

SECO BULLETIN

A new 12-page bulletin has been released by The Superior Electric Company of Bristol, Conn., specialists in the manufacture of voltage control equipment.

The bulletin describes their complete line of Powerstat variable transformers, Automatic Voltage Regulators, Voltbox a-c power supplies, and special custom-built equipment such as remote positioners.

Detailed description including many charts, graphs, and dimensional drawings makes this bulletin complete for engineers seeking the answer to voltage control problems.

The Superior Electric Company shall be pleased to forward copies to all interested parties.

TUBE BROCHURE

A new 156-page receiving tube brochure, Recommended Types (ETR-19), for equipment designers and radio set manufacturers, has been published by the Tube Division of General Electric Company's Electronics Department.

Covering the complete G-E and Ken-Rad receiving tube line and its associated circuit, the new publication lists tube types in numerical order by sections. Each section includes a typical circuit, complete ratings, curves, and companion technical data for each tube type.

Practically any receiver circuit is outlined in the new publication. Distribution of the Recommended Types Brochure will be made to receiver manufacturers, designers, and engineers.

Equipment manufacturers and radio set designers may obtain a copy of the new publication by writing W. Hayes Clarke, G-E Electronics Department's Tube Division, Schenectady, N. Y.

TRANSMISSION MEASURING SET

This set combines an accurate vacuum tube voltmeter, an audio oscillator with

four fixed frequencies, and a precision attenuator. All are mounted in a cabinet which is easily carried by the operator.

Specifications are as follows: Gain—up to 80 db; loss—60 db max.; VTVM: range —40 db to 40 db (1 mv reference level). AF-OSC. Freq. Range: 100 to 10.000 cycles. Attenuator: Flat to 20 kc: 93 db in 0.1 db steps. Operates from 115 v., 60 cycles; 70 watts.

This instrument is manufactured by Tech Laboratories, Inc., 337 Central Ave., Jersey City 7, N. J.

NEW UNIMETER

A new Unimeter, Type YMW-1A, designed for simplicity of operation and high accuracy, has been announced by the Specialty Division of General Electric Company's Electronics Department.

Designed for rapid, accurate measurement of volts, ohms, current and decibels, the YMW-1A is especially adapted for service work but also may be used in general laboratory and industrial applications.

It is a 20,000 ohms per volt multi-range instrument.

All functions of this nine-pound equipment except the 50 microamps and output meter capacitor jacks, are available without changing the test leads. A single rotary selector switch controls all the operations and ranges.

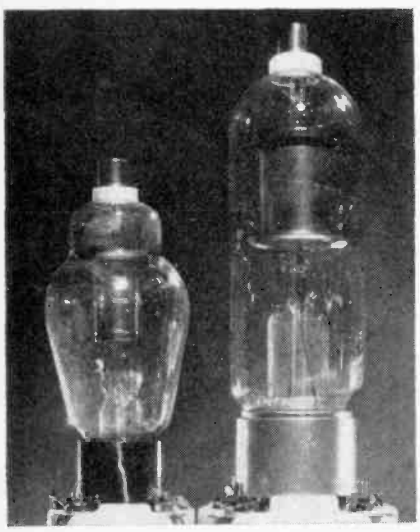
The YMW-1A specifications include resistance with a total coverage of 1 ohm to 20 megohms; voltage, a-c and d-c, 0-1000 volts; current, 0 to one-half ampere; decibels, minus 4 to plus 62, all designed in convenient ranges.

Further information on the new Unimeter may be obtained on request to the Wolf Street Plant, G-E Electronics Department's Specialty Division, Syracuse, N. Y.

EIMAC RECTIFIERS

Further completing their line of electron tubes, Eitel-McCullough, Inc. announces the availability of Eimac type 866A and 872A mercury-vapor rectifiers. These new low-price Eimac rectifiers are directly interchangeable with types 866A/866 and 872A/872 of other manufacture.

Type 866A/866 operates with 2.5 fila-



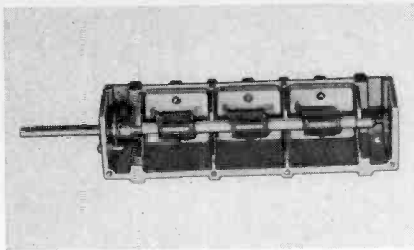
ment volts, peak inverse voltages as high as 10,000 volts, and a maximum average plate current of .25 amp. The 872A/872 has a 5-volt filament and carries a maximum peak inverse voltage rating of 10,000 volts and a maximum average current rating of 1.25 amp.

Complete operating characteristics and technical data may be had by writing Eitel-McCullough, Inc., 1018 San Mateo Ave., San Bruno, Calif.

INDUCTUNER

P. R. Mallory & Co., Inc., Indianapolis, Ind., has issued a new technical information bulletin on the Mallory "Inductuner," which is now in production.

This patented Mallory development is a device providing infinitely variable inductance tuning for all television, FM and other stations from 44 to 216 mc within the range of the receiver. This entire band is covered in 3600° rotation (10 turns) of the shaft, which may be rotated by hand or motor driven.



Accredited manufacturers and engineers are invited to write P. R. Mallory & Co., 3029 E. Washington St., Indianapolis 6, Ind., for the new complete technical information bulletin.

CTC CATALOG

A new 20-page tabbed-section catalog with specification sheets giving exact data on individual products is available from Cambridge Thermionic Corporation.

The catalog is bound for insert sheets and is broken down sectionally into terminal lugs, terminal boards, slug-tuned coils, and swagers — with reprint of loan agreement form on pressure swagers.

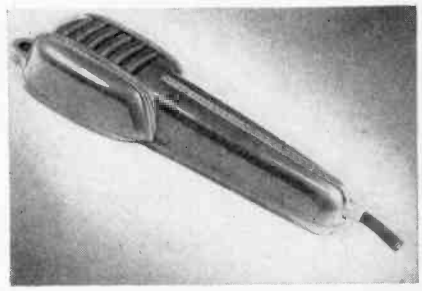
Copies of the catalog are available from Department 11, Cambridge Thermionic Corporation, 445 Concord Ave., Cambridge 38, Mass.

SHEET-METAL FABRICATION

Describing custom-built cabinets, racks, chassis, and enclosures, an 8-page color-printed bulletin issued by Karp Metal Products Co., 129 30th St., Brooklyn, N. Y., also provides numerous interesting production illustrations and sidelights on economy-resulting techniques.

NEW TURNER MIKE

A newly developed hand microphone has been added to the line of microphones by Turner manufactured by The Turner Company, Cedar Rapids, Iowa. Designated the Model 20X, it features a metalseal crystal which withstands humidity conditions not tolerated by the ordinary crystal. Range is 50-7000 cycles. Effective output level is 54 db below 1 volt/dyne/sq. cm. A high



impedance unit, it can be used with any standard amplifier employing high impedance input. Other features include attached 7 ft. cable with spring type protector to reduce wear at point cable enters case.

THIS MONTH

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wire, thus ensuring uniform wire quality. Some variations exist in the magnetic quality of recording wire now being produced. These variations do not cause noticeable distortion of tone or volume, but engineers are striving to make magnetic recording more nearly perfect in this respect also.

"The alloys presently used in the manufacture of recording wire depend on cold working for their magnetic properties and by measuring these properties at various stages in the drawing process, it is possible to predict the properties of the wire when drawn to the final size," the authors stated.

"Magnetic measurements on a particular alloy at various diameters in the drawing process, moreover, make possible determining the annealing and drawing schedule required to produce a wire of given magnetic properties."

The instrument consists of a 35-pound exciting coil with pickup coil at its center, an amplifier and integrating circuit, and a cathode ray oscillograph. It operates at power line frequency, making practically unlimited power available without the use of oscillators or motor generator sets, and is described by the authors as "rugged and simple in operation."

IRE CONVENTION

The Institute of Radio Engineers held its annual "latest-in-electronic developments" Convention, March 3-6 inclusive. It proved to be one of the most consequential meetings in the history of the I.R.E.

Over 150 manufacturers exhibited the most recent fruits of radio and electronic research at New York's Grand Central Palace over the four-day period.

For non-members as well as members of the Institute, there was the reading of 124 highly technical papers of vital consequence to the most recent developments in radio and electronic engineering (see program for times and locations).

CATHODE RAY SPECTROGRAPH

Development of a cathode-ray spectograph, which makes a continuous analysis of rapidly changing colors and permits detailed study of the chemical changes these colors reflect, was revealed at the Winter Meeting of the American Institute of Electrical Engineers in New York City.

The electronic instrument is expected to be valuable in jet engine and rocket research, chemical and industrial plants, radar and television as well as in basic scientific research, Rudolph Feldt and Carl Berkley of Allen B. DuMont Laboratories, Inc., Passaic, N. J., reported.

The new instrument combines a spectograph and a cathode-ray tube, which converts the color band into a single wave-like line on a colored screen, with the pattern of the line indicating the nature of the original compound giving off the light.

The authors stated that the instrument will prove useful in studying optimum combustion conditions for jet engineers, "particularly when it is desired to use the instrument in the small amount of space available in airborne missiles." Since the spectrograms or color bands have already been converted into electrical form by the instrument, they may be transmitted over a wire or by radio to a cathode ray "screen" miles away and there projected as a picture.

"Since this instrument can analyze colors which are constantly changing, it is expected to prove superior in measurements such as the color of television screens," the authors noted. "Such colorimetry is, at present, quite difficult, because of the presence of flicker and the continuous change of color, due to phosphorescent decay."

CHICAGO I.R.E. CONFERENCE

Dr. W. R. G. Baker, president of the Institute of Radio Engineers, will present the opening address at the forthcoming Chicago I.R.E. Conference, to be held at Northwestern Technological Institute on April 19. This all-day conference, sponsored by the Chicago Section of the I.R.E., will consist of a series of technical papers and discussions designed to present practical information of value to engineers in all branches of electronics.

FREQUENCY SHIFT TELEGRAPHY

Frequency shift telegraphy markedly reduces the disruption of long-distance communications caused by variations in transmission conditions, members of the American Institute of Electrical Engineers were informed at their winter meeting in New York City. The great advantage of frequency shift telegraphy is its ability to avoid errors and interruptions caused by fading and static. When these are at their peak, frequency shift telegraphy will usually get messages through long after amplitude modulation telegraphy has failed, members of the Institute's Communications Section were told by J. R. Davey and A. L. Matte of Bell Telephone Laboratories, Inc., New York.

"It is expected that the next few years will witness a greatly expanded application of this method of operation by commercial telegraph companies and others interested in long distance telegraphy," the authors stated. "Frequency shift carrier telegraphy may be applied to any carrier telegraph circuit, but it provides particularly striking advantages in high frequency radio transmission."

Personal Mention

H. F. Randolph

★ The appointment of Harry F. Randolph as General Plant Manager of the RCA Tube Department was announced by L. W. Teegarden, Vice President in charge of that department of the RCA Victor Division, Radio Corporation of America.

In his new capacity, Mr. Randolph, who continues as acting plant manager of the Harrison, N. J., tube plant, supervises and coordinates all of the company's tube manufacturing activities, which include the production of receiving tubes at the Harrison plant, the production of television, transmitting and special tubes at Lancaster, Pa., and the production of receiving tubes at RCA's Indianapolis plant.

Grant Shaffer

★ Grant Shaffer, sales representative with offices at 6432 Cass Avenue, Detroit, Mich., has been appointed representative for the Michigan territory by Jensen Manufacturing Company of Chicago, according to a recent announcement.

Grant Shaffer

ADVERTISING INDEX

V-H-F System

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definitely by adding transmitters of moderate power without increasing the number of frequency channels occupied. *Figure 3,* proposed by H. Stanesby in connection with the I.E.E. paper already mentioned, shows how an unlimited area might be covered by transmitters working on only three carrier frequencies, so arranged that the nominal service areas of any two stations on the same frequency are separated by distances never less than the range of a station. This offers interesting possibilities for broadcasting, and for communication with aircraft and trains throughout the length of their routes. Simple low-gain receivers without high frequency-stability could be used.

Abolishing Ignition Noise

The distadvantage of AM relative to FM, as regards ignition noise, has been removed and may soon be reversed, by the use of suitable noise-limiting devices, and by pre-emphasis of the high modulation frequencies at the transmitter and de-emphasis at the receiver. In addition, AM has important advantages besides applicability to the multi-carrier system, for which FM seems to be impracticable. Receivers can be of a simpler type, requiring less maintenance, because precise frequency control is unnecessary, and for other reasons. One FM channel with a frequency deviation giving useful results may occupy a frequency band wider than the three used in a multi-carrier AM system, especially as the carrier spacing for the latter is now being reduced to 12 kc, with a receiver bandwidth of 50 kc. AM is used by at least 37 separate police and other forces in Britain, with very satisfactory results. It definitely cannot be assumed that FM is necessarily better for v-h-f communication, even in a single-carrier system.

Among the applications of the multi-carrier AM system are

1) Extending the service area beyond the horizon of a single transmitter by using several transmitters at different sites.

2) Obtaining higher and more uniform field strength in a single station-area, and so enabling simpler and cheaper receivers to be used, by using several transmitters at the same site, feeding spaced aerials.

3) Overcoming difficulties or expense that might be incurred in obtaining a single site and aerial capable of covering an area, by using two or more separate sites.

4) Filling in dead spots with low-power transmitters or perhaps only a few watts.