CROSS TALK

▶ **FOR BROADCASTERS** . . . The longest article on a technical subject ever to appear in *Electronics* will be found in this issue. This deals with the important subject of applying feedback to an existing broadcast amplifier. It should appeal to every broadcast engineer whether he operates a 100 watt job or one of the big strong voices. The editors would like the reactions of the readers to this article, not on its technical content but to the advisability of running it all in one piece. Do they want articles of similar length on other important technical subjects?

Many readers think that long articles are continued in the rear of the magazine because the editors want the reader to look at the advertising. This is not the reason why *Electronics* "turns over" long articles. The reason is simply the fact that we believe that a long article run continuously gives the average reader the impression that the whole issue is devoted to this one article, and that there is not much in the issue. The one other reason for turnover is the fact that articles do not always break right to end exactly at the bottom of a page. They must be cut or continued somewhere else.

Speaking of broadcasters—much of this issue is devoted to a sort of midsummer broadcasting issue. A fortunate accumulation of material of interest to broadcast engineers happened along at the proper time—and so here it is. The editors are concerned with the problems of the broadcast men; especially of the fellows in the smaller stations, with less opportunity to contact other engineers, and with less easy ways to contact FCC engineers than are available to engineers working for large stations. But even a small-station man may learn something from articles directed at big-station men, if he is wide awake.

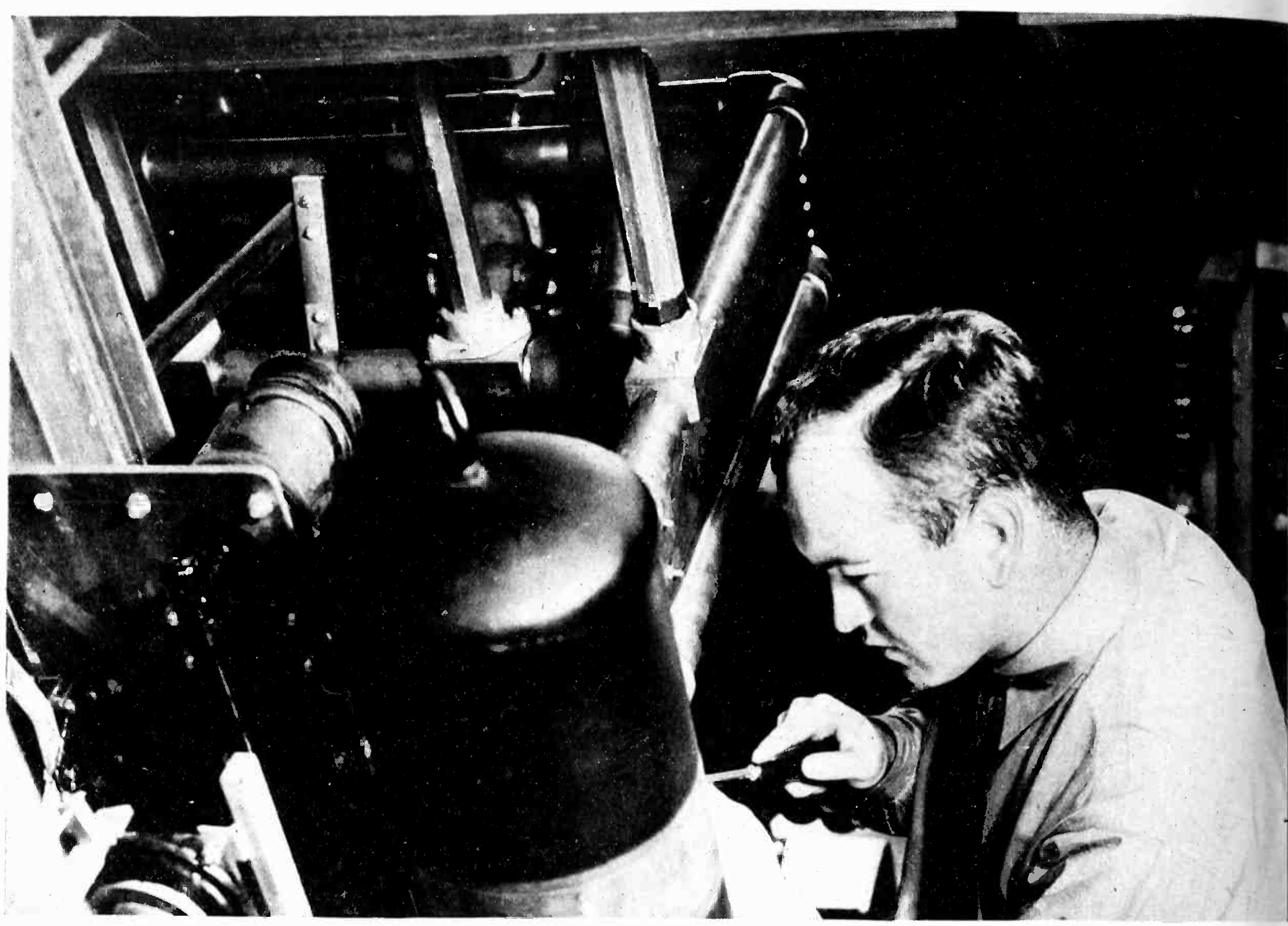
▶ **VOTES** . . . In the June issue we related the story about a certain large department store that asked its employees to rate certain desirable job characteristics, and asked the reader to register his vote. Scattering returns are not conclusive evidence that *Electronics* readers think alike on these matters. So we give below the way in which 3,000 men and women voted:

Employees Rating	Job Factor	Employers Rating
1.	Credit for all work	7
2.	Interesting work	3
3.	Fair pay	1
4.	Opportunity to learn	—
5.	Understanding, appreciation	5
6.	Personal counsel	8
7.	Departmental planning	—
8.	Promotion on merit	4
9.	Physical working conditions	6
10.	Job security	2

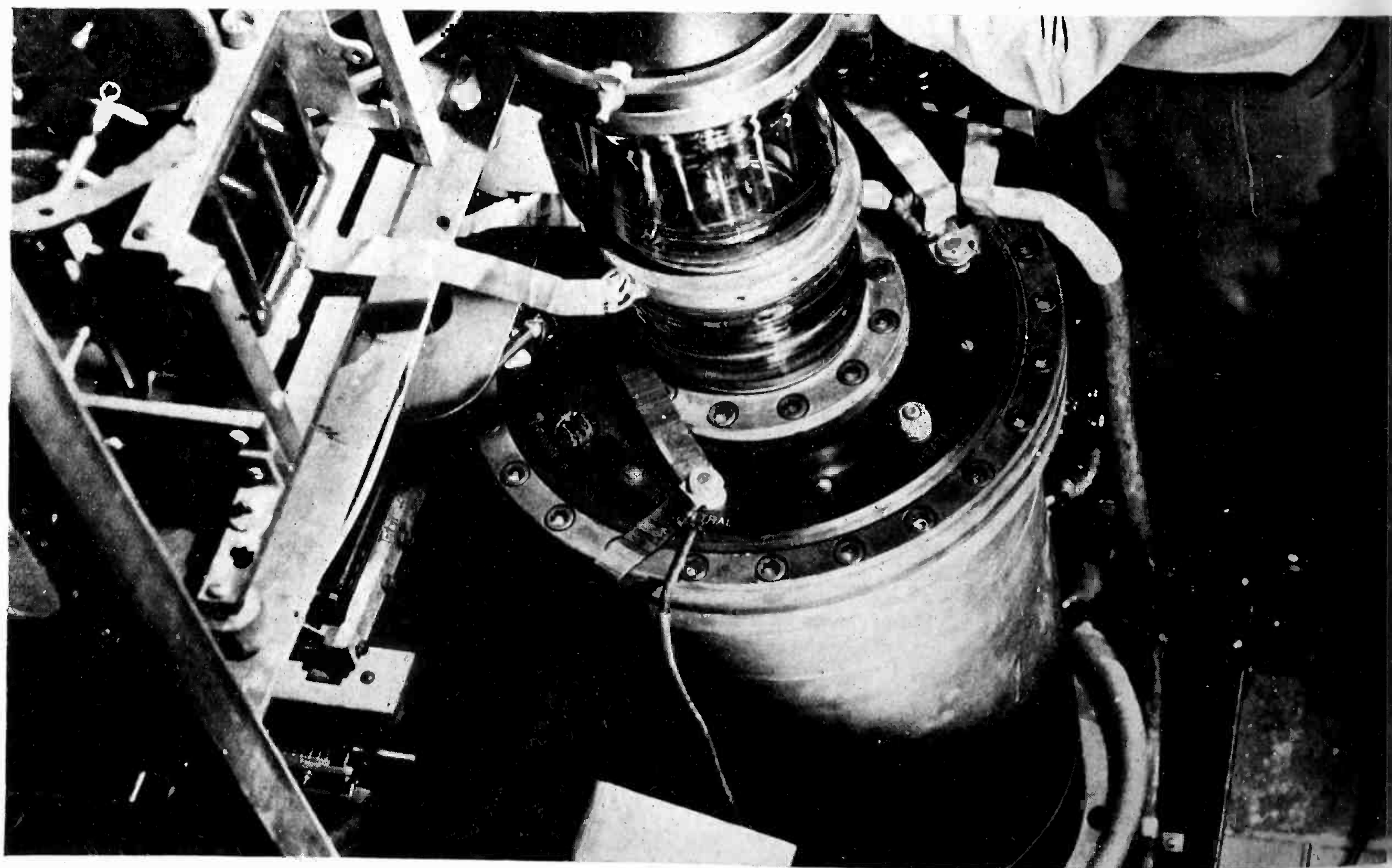
▶ **PATENT REFORM** . . . Newspapers carry accounts of proposed changes to the United States Patent laws. Time will tell whether some of the proposals are for the benefit of the people of the country or not. There is so much loose thinking about monopolies like patents by people who have no practical experience with patent problems that any reforms (?) must be considered as mighty serious matters. What seem good suggestions to us (we admit our lack of experience in these matters) have been put forth by C. P. Coe, United States Commissioner of Patents. Among them are the establishment of a single patent appeals court, and abolition of practices whereby a patent's life may be extended beyond 17 years by various legal devices.

One of the most fallacious beliefs is that every patent which a large company gets by purchase or by its own research that is not put to immediate use is deliberately suppressed for the company's good. There may be cases of such suppression, but it is our hunch that every patent which discloses a cheaper and better way to make an existing product is put to use.

▶ **THINK!** . . . Dr. de Forest sends us a query addressed to him. "I am working to get scientists interested in my thought phone. It is composed of a metal bulb a hundred or more feet in height. The interior parts are analogous to a triode radio bulb. The sounds emitted by the brain as it thinks can be picked up by a radio amplifier of great power and selectivity and rendered audible." . . . Some of the old friends of Lee de Forest are sponsoring a de Forest day at the New York World's Fair during Radio Week when the IRE convention is being held. The date will probably be September 21 or 23. Frank Butler, 2912 Rockwood Place, Toledo, de Forest's assistant throughout his 1904 experiments is serving as clearing house for this de Forest Day celebration.



600 KILOWATTS ON SHORTWAVES: This 100-kw triode was designed by G. E. engineers for W2XAF. By the use of a directive antenna, the effective power in the direction of South America will be raised to 600,000 watts. The new tubes are pumped continuouy, and their construction permits replacing the filamt in event of burnout or loss of emission. They are ie largest demountable tubes ever built in this couny.



RULES and STANDARDS for Broadcast Stations

An expert review of the recently promulgated F.C.C. Rules and Regulations and Standards of Good Engineering Practice, which became effective the first of this month—of particular interest to station engineers and operators

By RAYMOND F. GUY *Radio Facilities Engineer, National Broadcasting Company*

WITHIN the last few weeks the Federal Communications Commission has released the new Rules Governing Standard Broadcast Stations. They have been in preparation for over a year, were adopted on June 23, 1939, and with one exception become effective August 1, 1939. To supplement these Rules there will soon be released the new Standards of Good Engineering Practice. Both of these F.C.C. documents are of vital interest and importance to all persons connected with the construction and operation of broadcast transmitting facilities. They warrant careful and detailed study by all broadcast engineers. The new Rules first appeared in the Federal Register, Volume 4, Number 126, June 30, 1939. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. The General Rules and Regulations were adopted by the F.C.C. on May 16, 1939 to become effective June 15, 1939. They appeared in the Federal Register, Volume 4, Number 100, May 24, 1939. It is suggested that the interested reader obtain copies and study them in conjunction with this article.

A knowledge of the background of radio regulation is of importance in understanding the need for these Rules and Standards and should lead to a true appreciation of their merits. Government regulation of radio, to all intents and purposes, began in 1912. Prior to that time it was every man for himself. Stations were few in number, the only limit on power was financial and one appropriated the frequency which struck his fancy, or just operated without worrying much about it. Interference frequently resulted and the arguments which ensued by radio were interesting if not genteel. In some respects it was a ham's paradise. However, the Radio Act of 1912 produced a semblance of order.

The frequencies 1000 kc, 670 kc and 500 kc were set aside for ships and amateurs were assigned all frequencies above 1500 kc. For the first time, the assignments of calls by international agreement were made. The excursions of the amateurs into the commercial channels, of which the writer was not altogether innocent, ceased and peace reigned for the next ten years.

The advent of broadcasting shortly after the war, brought a host of new problems. 835 kc was assigned to this new service. Soon 750 kc had to be added. As more and more stations clamored for licenses the frequencies of 1000 kc and 670 kc were taken away from the marine

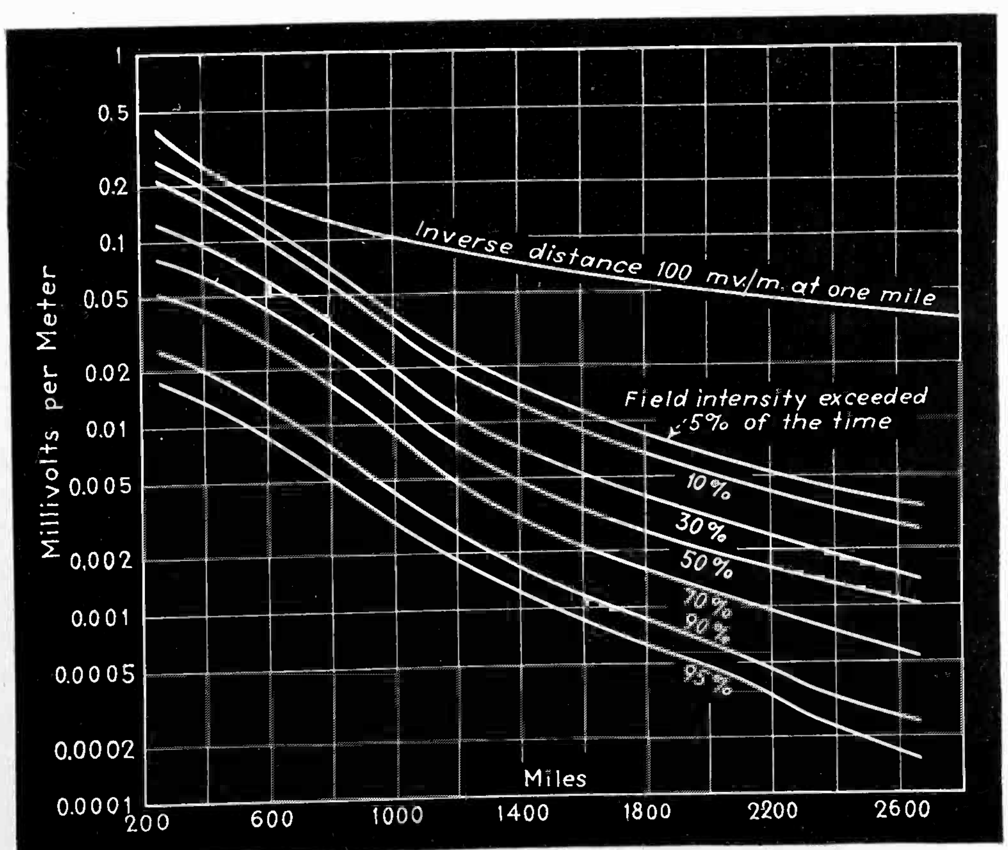


Fig. 1 — Nighttime average field strengths at distances from 250 to 2700 miles, compiled by the F.C.C. for allocation purposes

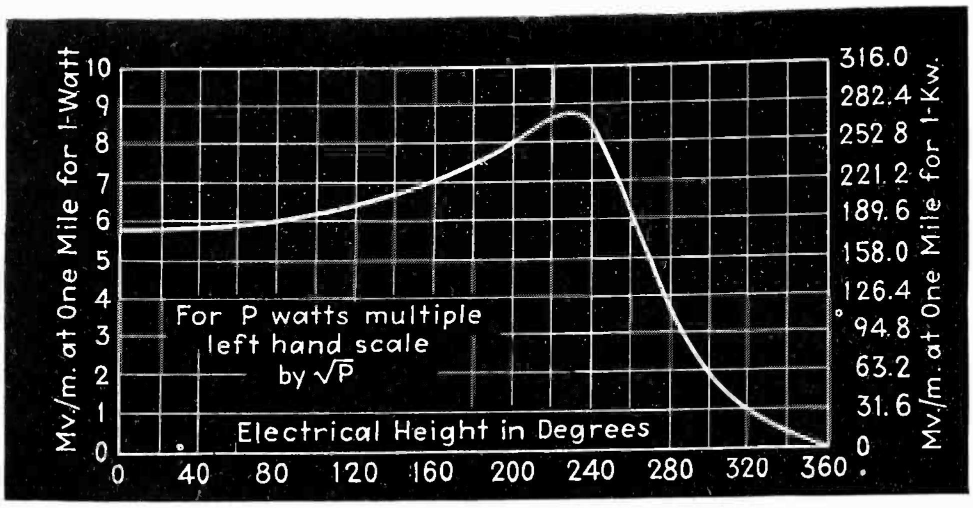


Fig. 2—Field strength as a function of antenna height (Data from Fitch and Duttera, NBC). Note the advantage of using an antenna longer than one-half wavelength

services and gradually the spectrum between 1500 and 500 kc was occupied. Continued crowding made it necessary to duplicate assignments and a climax resulted when a Chicago station proved that the Radio Laws did not have sufficient teeth in them to prevent pirating of frequencies. This was the condition which led to the Radio Act of 1927 and the formation of the Federal Radio Commission, later reorganized as the Federal Communications Commission. The problems which faced this body were many and complex.

Under the Radio Act of 1927 and the Communications Act of 1934, the Commission is given broad regulating power over radio communication including the right to adopt Rules and Regulations not inconsistent with the terms of the Act, which Rules and Regulations have the full force and effect of a law.

The Standards of Good Engineering Practice give interpretations and further considerations concerning these Rules and Regulations. While the Rules provide the basis of good engineering practice, the Standards go further and set up engineering principles for use in solving allocation problems. The Standards published are those deemed necessary to ensure compliance with the requirements of the Rules and for operation in public interest along technical lines not specifically enunciated elsewhere. The Standards are based upon the best engineering data obtained in formal and informal hearings and surveys conducted in the field. They were prepared after conferences with engineers, manufacturers and others and supersede all previous announcements or policies of a similar nature enunciated by the F.C.C. on engineering matters concerning standard broadcast stations.

The Commission Engineers early recognized the need for comprehensive data as a guide to satisfactory allocation of frequencies. Take the case of a 5 kw station as an example. It could produce good day-time or night-time service out to a distance of roughly 50 miles. Beyond that distance the signal would no longer be serviceable but, nevertheless, it would be still strong enough to produce interference to other stations on the same frequency, and particularly so at night. Everyone knew that there would exist a "service area" surrounded by a "nuisance area" which became very large at night. But, in terms of potential interference, how large was this nuisance area?

It was desirable that places on the airwaves be found for more and more new stations, that the existing frequencies be used as economically as possible to provide the maximum of public service. These demands could be met only by duplicating more stations on existing channels. However, in order to do so, better technical data on long distance propagation was needed. With the cooperation of broadcast licensees the F.C.C. planned and executed a program of measurements in 1934–1935 which provided the data required. Recordings over various long distances and directions, when analyzed yielded invaluable information. One chart of particular value is shown as Fig. 1. It is the average value of night-time sky-wave field intensity based upon an antenna which produces a field intensity of 100 millivolts at one mile. Knowing the one mile field intensity of any station, it is possible with this curve to estimate the average field at any point within a radius of 2700 miles. This curve is for the second hour after sunset and is generally used to represent average night-time conditions.

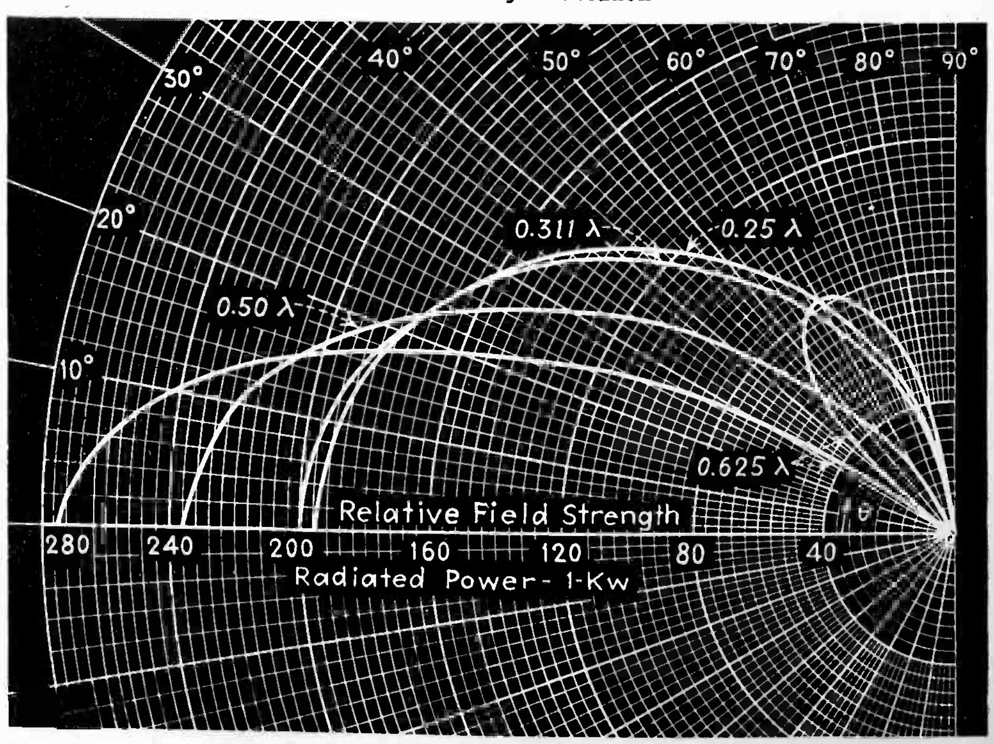
Now suppose we work out a problem in frequency allocation and see how the average night-time curve of Fig. 1 is applied. The problem: In a certain city there is a 1 kw regional station. We wish to see how close to it we could locate a second 1 kw regional station which would produce service to its own 2½ millivolt contour without interference from the existing station.

In the new Rules, Section 3.22, we find the various classes of stations defined. Paragraph (C) (1) states:

"Class IIIA Station"—"A Class IIIA Station is a Class III Station which operates with power not less than 1 kw nor more than 5 kw, and the service area of which is subject to interference in accordance with the "Engineering Standards of Allocation."

Referring to the Standards of

Fig. 3—Vertical radiation patterns of antennas of different height (FCC data) showing the advantage of long antennas in producing useful low-angle radiation



Good Engineering Practice we find Table IV "Protected Service Contours and Permissible Interference Signals for Broadcast Stations." This shows that a Class IIIA Station is normally protected, to its 2½ millivolt contour, so our station is in Class IIIA.

The first step is to determine the field intensity of the undesired station that is necessary to cause interference to the desired station. It has been standard practice for many years in the F.C.C. and in the industry generally to consider that when a ratio of 20:1 between the desired and undesired stations is exceeded, interference exists. Accordingly the permissible interfering signal would be 2500/20 microvolts = 125 microvolts.

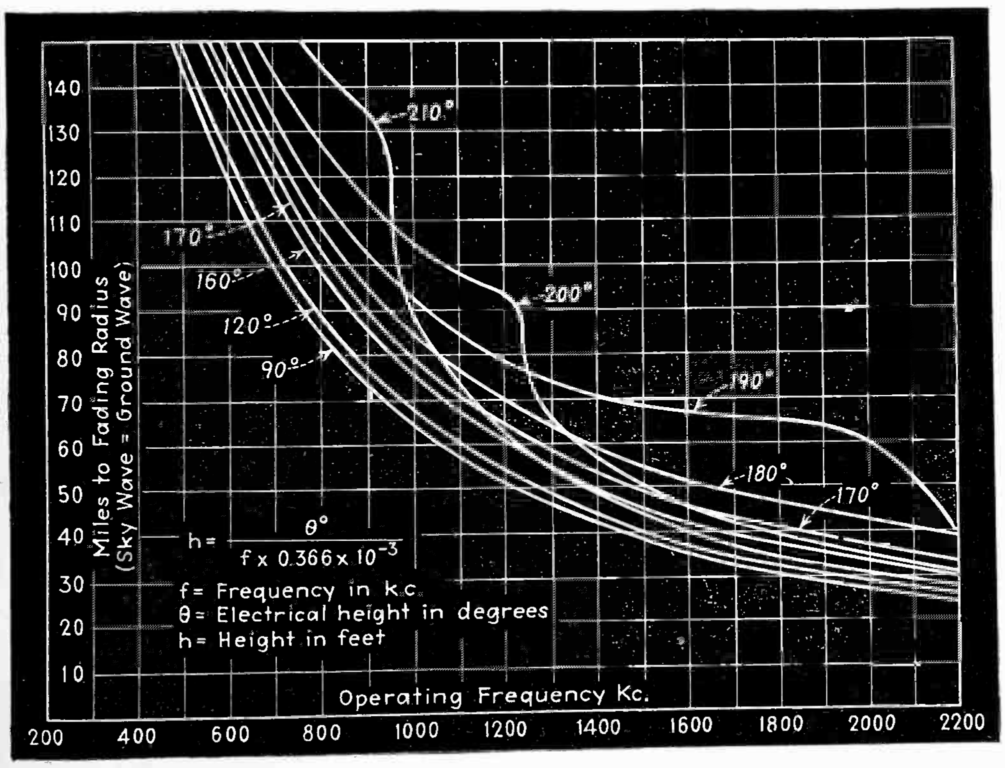


Fig. 4—Influence of antenna height on the fading radius, as a function of the operating frequency (NBC data)

Now let's consider further the matter of interference. Is it necessary that the 20:1 ratio be maintained 100 per cent of the time, or could it be exceeded momentarily without seriously degrading service? Since sky waves fluctuate widely in amplitude short bursts of interference occur, and to some degree may be tolerated. After study the F.C.C. and the industry have adopted the figure of 10 per cent as the portion of the time during which the 20:1 ratio could be violated before interference is considered to exist.

Assume that our IIIA Stations use antennas one-quarter wavelength in height. Reference to Fig. 2 shows that such an antenna, operating on 1 kw will produce about 190 millivolts per meter at a mile. We now refer to Fig. 1, the F.C.C. curve of average night-time field intensity. Since this curve is based upon a one mile field intensity of 100 millivolts and our antennas produce 190 millivolts, we must use a simple conversion factor. Multiplying 125, the value of interfering signal, by 100/190 will give the value of the ordinate corresponding to the distance we seek on the abscissa. It is 66.5 microvolts.

Reading from the 10 per cent curve of Fig. 1, the distance is found to be close to 735 miles. It is in this manner that the Separation Tables in the Standards of Good Engineering Practice were derived. Tables VI, VII, and VIII on the Recommended Standards are complete allocation tables and constitute a valuable guide to the engineer concerned with allocation problems. Broadcast engineers may consider the time very well spent in studying them. It should be noted in passing that the use of directive antennas makes it possible to reduce the field intensity radiated in certain directions and thus operate stations in some cases with less separation than indicated in the tables.

The allocation tables cover daytime conditions as well as night time. The method of determining the required daytime separations differs somewhat, however. The daytime interfering field is produced by ground waves only. These fields are quite steady in amplitude and therefore the 10 per cent time allowance used for nighttime interference does not apply. Also the method of determining the required separation makes use of daytime attenuation data instead of the nighttime curve of Fig. 1. The daytime separations are so close that careful allowance must also be made for the distances from the stations to their contours which are to be protected.

Daytime attenuation is caused by two factors:

1. Dispersion, which varies directly with distance.

2. Losses in the earth, caused by its imperfect conductivity and the resulting heating.

Space does not permit further discussion of attenuation. For a simplified treatment of the subject, including easily used curves, the reader is referred to an article by William A. Fitch in the September, 1936, issue of *Electronics*.

The night time secondary service area of a station not limited by interference, is considered to be the ½ millivolt, 50 per cent contour. In other words, when ½ millivolt service is obtained 50 per cent of the time, secondary service is rendered. Fig. 1 includes a 50 per cent curve.

It was important that standards of frequency allocation be adopted, specifying transmitter powers, etc. It is, naturally, also important that stations operate on the power, etc. for which they are licensed, if the allocation system is to work satisfactorily. It is in such matters as this that stations occasionally run afoul of the efficient F.C.C. inspectors, either by exceeding specified tolerances of one kind or another, or almost equally important, not having suitable indicating instruments to indicate accurately compliance with the Rules.

Power Measurements

Section 3.51 (a), (1), (2), (b) of the new Rules is of particular interest to station engineers.

All new stations are required to use the direct method of power measurement (antenna I^2R) and all

(Continued on page 67)

Trigger Circuits

A valuable vacuum-tube function is that in which negative resistance is used to produce rapid changes of voltage or current, here reviewed by the author of "Theory and Application of Electron Tubes"

By H. J. REICH

Department of Electrical Engineering
University of Illinois

CIRCUITS in which one or more currents or voltages change abruptly from one stable value to another stable value at a critical value of some voltage or resistance and change back abruptly to approximately their original values at a different critical value of the controlling voltage or resistance are called "trigger circuits." A discussion of trigger circuits is of interest because of their numerous applications.

The criterion as to whether a circuit element can serve as the basis of a trigger circuit can be determined from the characteristic current-voltage curve of the element. In Fig. 1, X represents the circuit element, R the resistance in series with the element, and E_b the supply voltage. From this figure it is evident that the voltage across the terminals of the element X is given by the relation

$$E = E_b - IR \qquad (1)$$

The voltage across the element is also a function of the current through the element, as indicated by the equation

$$E = f(I) \qquad (2)$$

Since the form of Equation (2) is not in general simple, equilibrium values of current may be found most readily graphically. Equation (2) represents the characteristic curve of the element X. Equation (1) is that of a straight line MN through a point on the voltage axis corresponding to the supply voltage E_b, having a negative slope in amperes per volt equal to the reciprocal of the resistance in series with the element. Equilibrium values of current are determined by the intersection of the characteristic curve with the resistance line.

It can be seen from Fig. 2 that if the characteristic curve has a portion whose slope is negative, the resistance line may intersect the curve in three points, 1, 2 and 3, indicating that there are three possible equilibrium values of current. Since an increase of current at constant E_b and R from that represented by point 2 is accompanied by a decrease of voltage across the element, more voltage is thus made available to send current through the resistance, and the current will rise further. Conversely, any decrease in current through the element reduces the voltage available across the resistance and thus causes a further reduction of current. Point 2 therefore corresponds to unstable equilibrium and is not observed experimentally. If the applied voltage is raised progressively from zero, the intersection will move along the branch OA of the characteristic curve. When the intersection is at A, an infinitesimal increase of voltage will cause the current to fall abruptly to the value at E. Further increase of supply voltage causes the intersection to rise toward C. If the battery voltage is then continuously decreased, the intersection will move down the branch BC until point B is reached, at which the current will again jump abruptly to the value corresponding to point D. It can be seen that similar abrupt changes of current result if the slope of the resistance line is varied by changing the resistance R, or if the characteristic curve is displaced vertically or horizontally. With trigger elements incorporating vacuum tubes, this displacement can be accomplished by varying the electrode voltages.

From the above analysis it follows that a circuit element whose current-voltage characteristic has a portion with negative slope may serve as the basis of a trigger circuit. This is

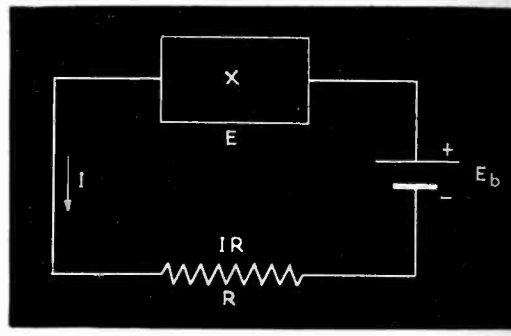


Fig. 1—Basic trigger circuit, incorporating the general element X

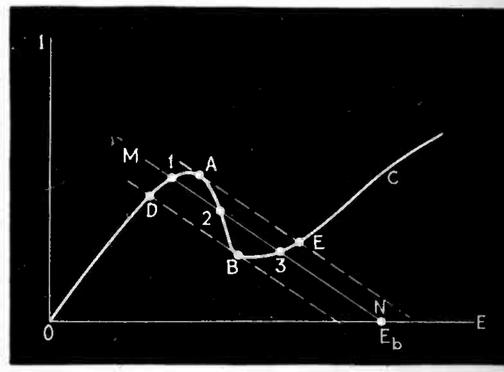


Fig. 2—Equilibrium points when X has the E-I form shown

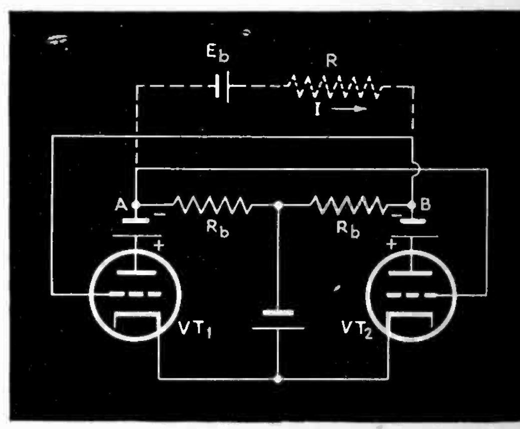
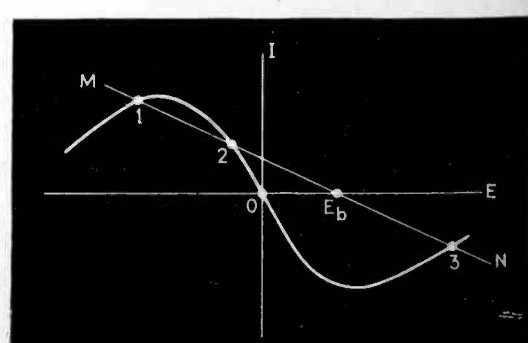


Fig. 3—The Eccles-Jordan trigger circuit

Fig. 4—E-I relationship across points A-B in Fig. 3



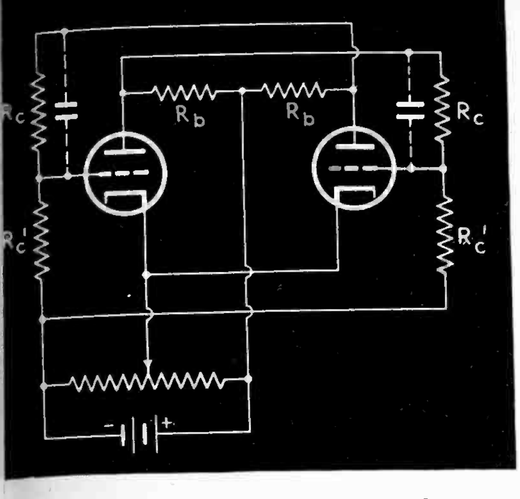


Fig. 5—Form of Fig. 3 requiring but one power supply

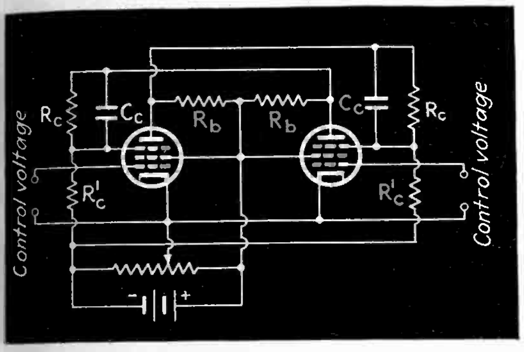


Fig. 6—Suppressors of two tubes used as coupling electrodes

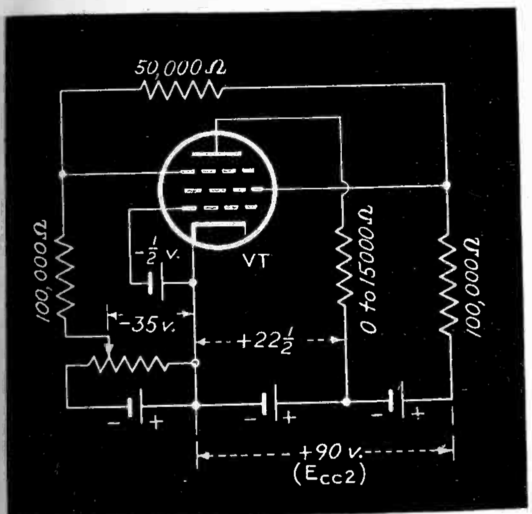


Fig. 7—Circuit employing coupling between suppressor and screen

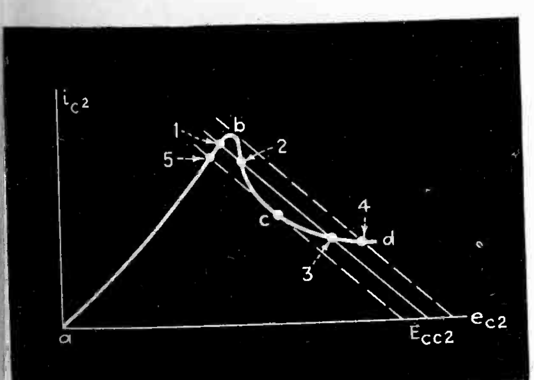


Fig. 8—Screen current vs. voltage used as basis of above circuit

equivalent to saying that the element must have negative a-c resistance over a portion of the current range. This fact is of particular interest because it may be readily shown that sustained oscillations may occur when a negative-resistance element is shunted by an oscillatory circuit.[1]

An element which may be used as the basis of a negative resistance oscillator may, therefore, also be used as the basis of a trigger circuit. Conversely, a trigger circuit may be transformed into a negative resistance oscillator. Any trigger circuit may also be used as the basis of a relaxation oscillator. It is merely necessary to design the circuit so that the abrupt change of some circuit current is followed by the charging or discharging of a condenser, the voltage of which in turn causes a displacement of the characteristic curve or of the resistance line.

Practical Trigger Circuits

The best-known trigger circuit is that of Eccles and Jordan,[2] shown in basic form in Fig. 3. This circuit functions by virtue of the fact that only one tube at a time passes plate current. Let it be assumed that both tubes can conduct simultaneously. Then an increase of current in either tube increases the negative grid voltage of the other tube, which reduces the plate current of that tube. This in turn reduces the negative grid voltage of the first tube and causes further increase of plate current of the first tube. The action is cumulative and only one tube conducts at a given time. In verification of the general theory, it may be readily shown theoretically that a negative resistance exists between points A and B.[3] This may also be shown experimentally by applying voltage between points A and B and measuring the resulting external current. The curve of external current versus voltage between A and B is found to be of the form of Fig. 4.

When a battery E_b is connected to the points A and B through a resistance R, as shown by the dotted lines of Fig. 3, then the corresponding resistance line is of the form of MN in Fig. 4. If R exceeds in magnitude the value of the reciprocal of the slope of the curve at point O, then abrupt changes of current through R and of voltage between A and B can be made to occur by varying E_b or shifting the characteristic by changing the operating voltages of the tubes. As R is increased, MN becomes more nearly horizontal and in the limiting case, when R is infinite, becomes the voltage axis. The external current is then zero, but changes in electrode voltages can cause an abrupt transfer of current from one tube to the other and a reversal of voltage between A and B. The equilibrium voltage between A and B is then equal to the product of R_b and the equilibrium plate current of one tube. Usually this circuit is used without the external resistance R and the battery E_b, the circuit being triggered by voltages introduced in series with the grids or plates. It should be noted, however, that the use of an external resistance R only slightly smaller that the absolute value of the reciprocal of the slope of the curve at O makes possible an abrupt reversal of current through the resistance as the result of only a very small change in the voltage E_b. This method of using the circuit is sometimes advantageous.

The need of more than one voltage supply is avoided by the use of the circuit of Fig. 5, in which the coupling between tubes is made by means of voltage dividers. Another modification of the basic circuit is shown in Fig. 6, in which the suppressor grids of pentodes serve the same function as the triode control grids of the circuit of Fig. 5.[4] The screen grids are used in the normal manner and the control grids are used for triggering the circuit. One very desirable characteristic of this circuit is that the circuit may be triggered by a very small negative voltage impressed upon the control grid of the conducting tube, but it is insensitive to positive voltages applied to the control grid of either tube. For this reason the application of negative voltage pulses of short duration simultaneously to both grids causes the current to transfer with each pulse. When the circuit is used in this manner the condensers C_c are essential. The functions of the control and suppressor grids of Fig. 6 may also be interchanged, but the resulting circuit is then sensitive to triggering voltage of either polarity.

The condensers C_c serve several functions. When a negative pulse is impressed upon both grids, the plate currents of both tubes are momentarily reduced to zero. By applying a higher negative voltage to the suppressor of the tube which has been conducting, the condensers insure the transfer of current to the other tube.[5] These condensers also avoid the loss in sensitivity resulting from the interelectrode capacitances and from the voltage-divider type of coupling.[4, 8b] Because of the time required for the condensers to change voltage, any change of voltage of either plate results in a nearly equal change in voltage of the grid of the other tube. For this reason condensers in parallel with R_c improve the operation of any of the Eccles and Jordan circuits, even when the triggering impulse is impressed upon only one tube at a time. The time taken for the condensers to change voltage between the two equilibrium values should be large in comparison with the duration of the triggering impulse, but small in comparison with the time between successive pulses. 50 $\mu\mu$f condensers are usually satisfactory.

The values of the resistances R_b, R_c and R_c' are not critical, but R_c and R_c' should be appreciably larger than R_b and may usually be equal. The plate currents decrease with increase of R_b, and the voltage across R_b increases. Typical resistance values are: $R_b = 10{,}000$ ohms and $R_c = R_c' = 250{,}000$ ohms. Supply voltages as low as 22½ volts may be used in the circuits of Figs. 5 and 6.

A second type of trigger circuit is shown in Fig. 7. In this circuit the coupling between the screen and suppressor grids of a pentode causes the suppressor grid voltage to change with screen grid voltage. Figure 8 shows a typical curve of screen current as a function of screen voltage, when the change in suppressor voltage is proportional to the change in screen voltage.[1] If the resistance in series with the screen grid is high enough, then the resistance line intersects the characteristic in three points and abrupt changes in circuit currents and voltage occur when the supply voltages or the screen circuit resistance are varied. By proper choice of voltages and circuit constants, the plate current corresponding to the higher value of screen current may be made zero. The possibility of reducing the plate current to zero is important in certain applications of the circuit. The triggering impulses may be introduced in series with any of the electrodes, but the control grid is the most sensitive electrode for this purpose. The values of the supply voltages are not critical, but the proper relation must be maintained between them. The circuit constants given in Fig. 7 are typical.

The shape of the plate characteristics of a screen-grid tetrode suggests that a trigger circuit should result from the introduction of a high resistance in the plate circuit. In practice this type of circuit functions satisfactorily with the older type 24A tube. The negative slope of the characteristics of present 24A tubes is so low, however, that extremely high resistance must be used and circuit adjustments are very critical.

The interesting applications that have been made of trigger circuits have by no means exhausted the possibilities. Any of the circuit currents may be used directly to operate a relay or other device, or the voltage drop across one of the resistors may be applied to the grid of another tube to control its plate current. The circuits may be triggered by voltages applied to the tube electrodes. That of Fig. 5 may be triggered by changes of resistance of R_c or R_c' and may be modified to incorporate phototubes by connecting the latter in series with or in place of the resistors R_c or in parallel with or in place of the resistors R_c'. Usually any of these trigger circuits may be triggered by touching one of the electrodes. Two useful applications of trigger circuits are made in the measurement of small time intervals and in high-speed counting. A circuit for the measure-

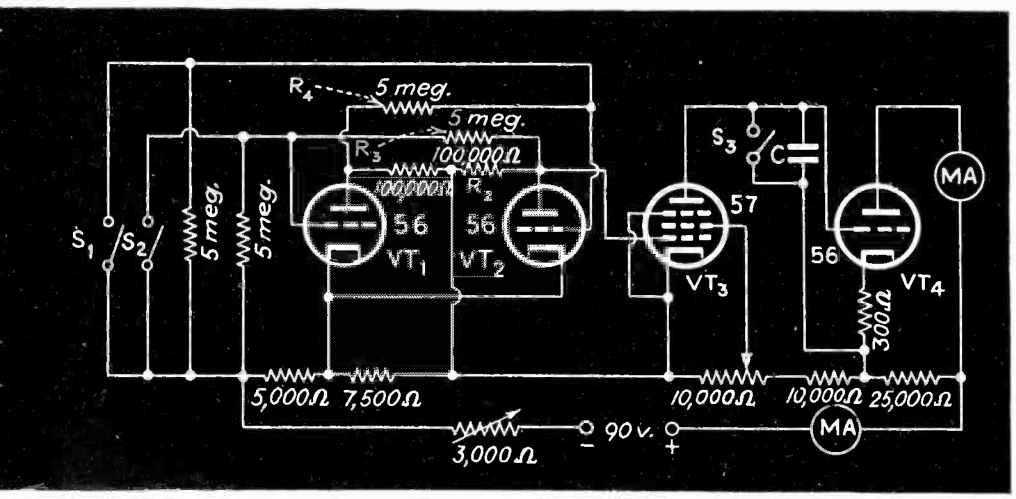
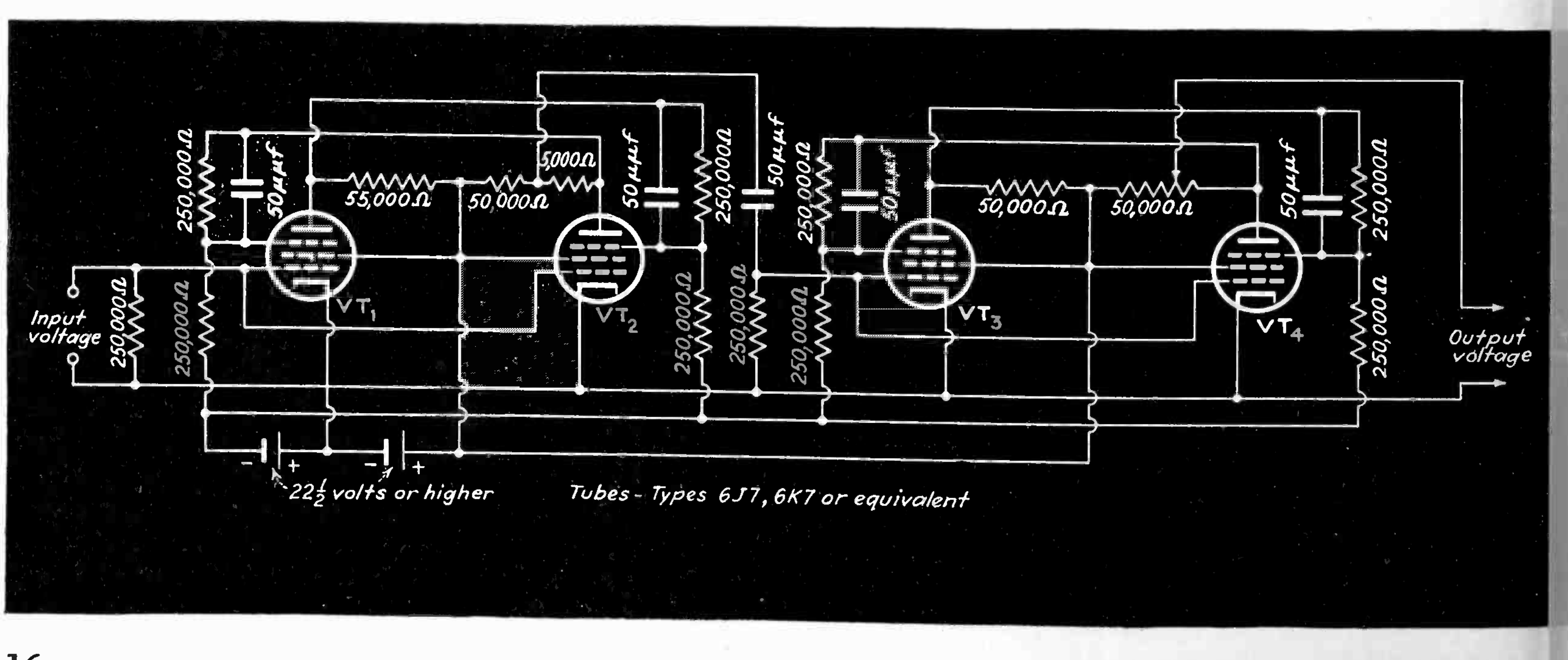


Fig. 9—Left, circuit for measurement of time intervals

Fig. 10—Below, successive trigger action between two stages



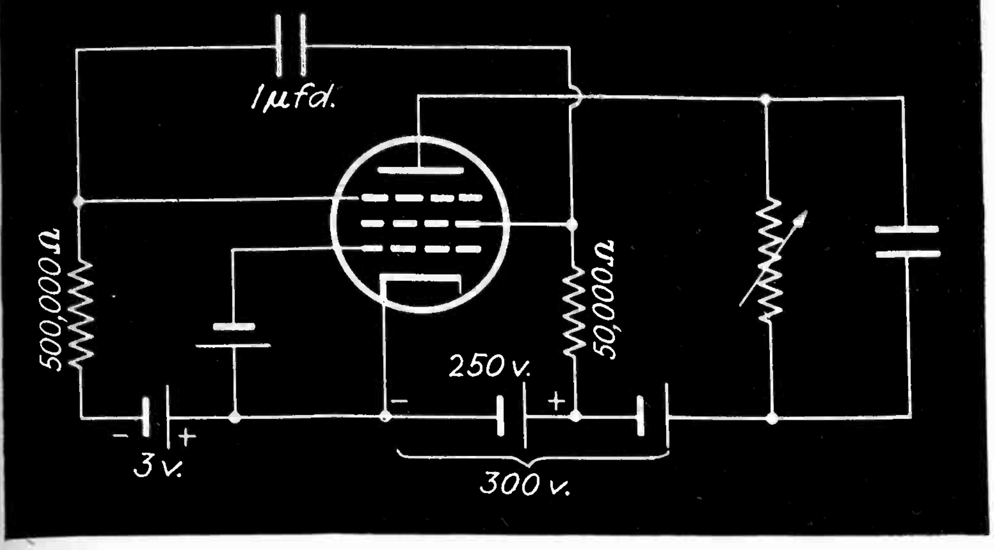
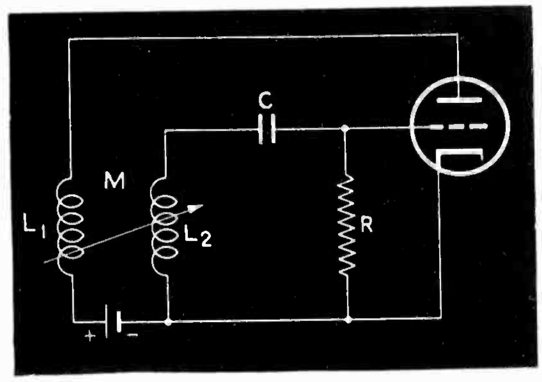


Fig. 11—Left, sawtooth oscillator based on trigger action

Fig. 12—Below, inductively coupled relaxation oscillator useful for trigger action



ment of time intervals or the speed of moving objects is shown in Fig. 9.[7] In this circuit the instantaneous closing of switches S_1 and S_2, or the interruption of light falling upon phototubes inserted in series with R_3 and R_4, causes the transfer of current from VT_2 to VT_1 and vice versa. The voltage across R_2 produced by the plate current of VT_2 serves as bias for VT_3. Thus plate current starts flowing in VT_3 when S_1 is closed, and stops when S_2 is closed. The resulting change of voltage of the condenser C, which is a measure of the elapsed time, is read by means of the voltmeter tube VT_4 and the milliammeter *MA*.

The circuit of Fig. 6 is particularly suited to high-speed counting.[4, 6, 8] The fact that the circuit is sensitive only to negative pulses of voltage makes it possible to use the change of voltage across one of the resistors R_b to trigger a second stage, as in the circuit of Fig. 10.[10] The application of random or periodic pulses simultaneously to the grids of the first stage initiates the flow of plate current of VT_4 at every fourth impulse. If the plate current or voltage of VT_4 is used to operate a mechanical counter, then every fourth pulse is counted. As many stages as necessary may be used. Another interesting application of the circuit of Fig. 6 is being made in a synchronous switch for the simultaneous observation of two waves with a cathode-ray oscillograph.[9]

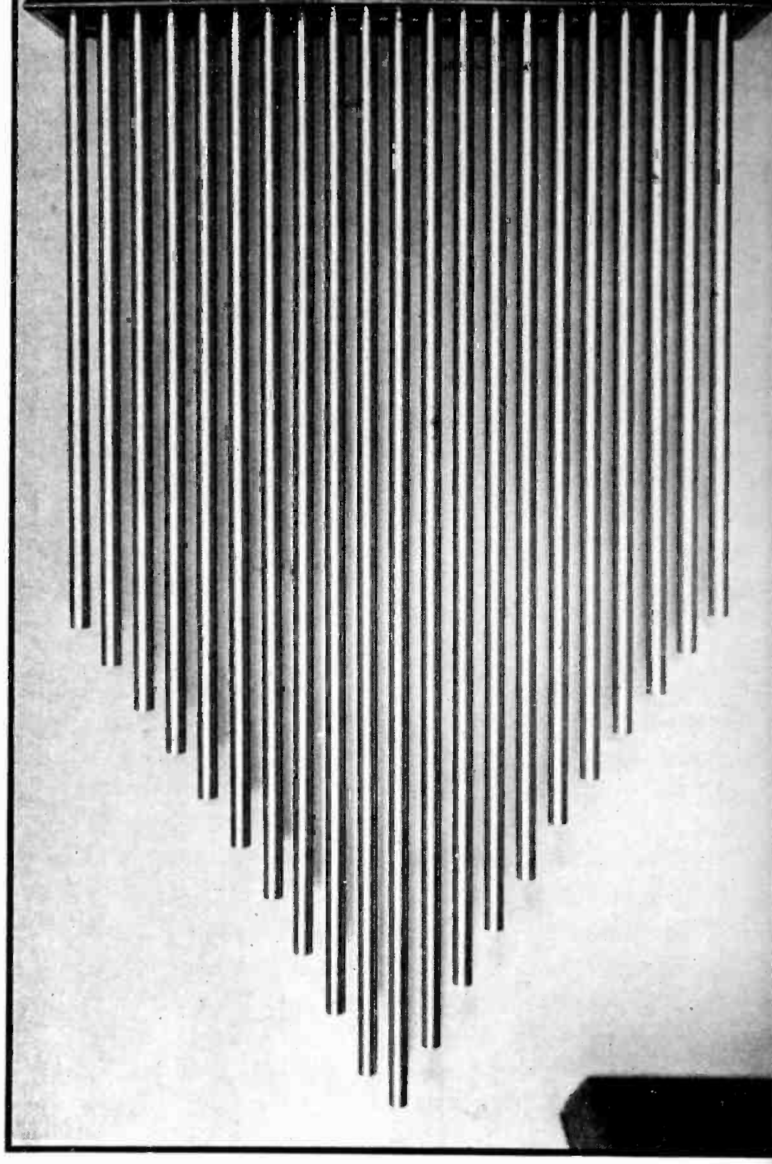
It has already been pointed out that any trigger circuit may be used as the basis of a negative resistance or of a relaxation oscillator. The Eccles-Jordan circuit is the basis of a very stable negative resistance oscillator of excellent wave form.[10] The "negative transconductance" or "transitron" oscillator is based upon the circuit of Fig. 7.[1] The dynatron oscillator usually makes use of the negative resistance of a screen-grid tetrode. The multivibrator relaxation oscillator is formed from the circuit of Fig. 5 merely by replacing the resistors R_c by condensers.[11] The van der Pol relaxation oscillator is formed from the circuit of Fig. 7 by substituting condensers in place of the coupling resistors.[12] It does not appear to be generally known that relaxation oscillations may be produced if a parallel combination of high resistance and capacitance is used in the plate circuit of a 24A tube operated in the negative-resistance range of the plate characteristic. Neon tubes and thyratrons, which are essentially trigger devices, are the basis of neon-tube and thyratron relaxation oscillators.

By designing the circuit so that a condenser charges essentially linearly, it is possible to make a relaxation oscillator that gives a triangular wave of voltage. The best known oscillators of this type are the neon-tube and thyratron oscillators. Recently several types of saw-tooth oscillators have been devised that are based upon high-vacuum-tube trigger circuits.[13] One that is derived from the circuit of Fig. 7 is illustrated in Fig. 11.[14] The circuit is adjusted so that the lower value of plate current is zero. When the plate circuit is first closed the condenser is uncharged and the plate voltage is high. This causes the plate current to assume its higher value and thus charge the condenser. As the condenser charges, the plate voltage falls, finally reaching a critical value at which the plate current abruptly falls to zero. The condenser then discharges through the shunting resistance. If the circuit is properly adjusted, the discharge of the condenser is nearly linear. This oscillator has proved to be very satisfactory over a wide range of frequency.

Negative resistance can also be attained by the use of inductive coupling between the grid and plate of a vacuum tube. Because the coupling is effective only as long as the plate current is changing, however, two stable values of current cannot be maintained in such circuits. They may be used as the basis of relaxation oscillators and may also be triggered periodically at a frequency that equals or exceeds the relaxation frequency. A typical relaxation oscillator employing inductive coupling is shown in Fig. 12. The coupling must be such that a decrease of plate current induces a voltage in L_2 of such polarity that the grid end of L_2 is negative. It is of interest to note that this circuit may readily be converted into a tuned feed-back oscillator by the addition of capacitance across one or both inductances.

1. E. W. Herold, *Proc. I. R. E.*, **23**, 1201 (1935). Includes a bibliography of 55 items on negative resistance.
2. Eccles, W. H., and Jordan, F. W., *Radio Rev.* **1**, 143 (1919).
3. Stewart, J. A., "The Roberts Neutralizer Circuit" (Bachelor's thesis), Purdue University, June, 1935. See also H. J. Reich, *Proc. I. R. E.*, **25**, 1387 (1937).
4. Reich, H. J., *Rev. Sci. Instr.*, **9**, 222 (1938).
5. Toomim, H., *Rev. Sci. Instr.*, **10**, 191 (1939).
6. Stevenson, E. C., and Getting, I. A., *Rev. Sci. Instr.*, **8**, 414 (1937). See also reference 4 above.
7. Reich, H. J., and Toomim, H., *Rev. Sci. Instr.*, **8**, 502 (1937). Includes a bibliography of 9 items on the measurement of time and speed by electronic circuits.
8. (a) Lewis, W. B., *Proc. Camb. Phil. Soc.*, **33**, 549 (1937); (b) Lifschutz, H., and Lawson, J. L., *Rev. Sci. Instr.*, **9**, 83 (1938); (c) Lifschutz, H., *Rev. Sci. Instr.*, **10**, 21 (1939).
9. G. Parr, "The Low Voltage Cathode Ray Tube," page 165, Chapman and Hall, Ltd., London, 1937; H. J. Reich, "Theory and Applications of Electron Tubes," page 597, McGraw-Hill Book Co., New York, 1939.
10. Reich, H. J., *Proc. I. R. E.*, **25**, 1387 (1937).
11. Abraham, H., and Bloch, E., *Ann. Physik*, **12**, 237 (1919).
12. Van der Pol, B., *Phil. Mag.* **2**, 978 (1926).
13. Puckle, O. S., *J. Sci. Instr.*, **13**, 78 (1936); Potter, J. L., *Proc. I. R. E.*, **26**, 713 (1938). For additional bibliography see G. Parr, reference 9.
14. Reich, H. J., *Proc. Illinois Academy of Science*, **31**, 209 (1938).

The space behind the dummy pipes contains the chimes, microphones, and loudspeakers which radiate electronic organ music to the interior of the church



The chimes are driven by an electrically driven mechanism mounted in the top casing and are played by a keyboard mounted on the console of the organ

Electronic CHURCH CHIMES

By FRANK DOSTAL

Transformer Corp. of America

THE electronic arts have made such tremendous contributions to economic and social life, and so much has been written concerning these applications, that we often fail to appreciate the advantages they provide in what we might term their more aesthetic applications.

An application which brings these thoughts to mind is an installation of church chimes recently made in an Eastern city where, in the space normally required by one good-sized bell, and at not much greater cost than one bell, the equivalent of a 21-bell carillon is obtained. That no appreciable sacrifice in tone, timbre, or volume is suffered is attested by the fact that not more than a handful of the population of that city is aware that there are no bells in the tower from which the sound emanates, and that during the first playing of the chimes congratulations poured in from points up to several miles distant. Coverage would perhaps be greater over level country. As it is this church is located in a valley in the center of a cup-shaped formation of hills about two miles in diameter, and, drawing its congregation from this valley, the voice of the chimes is more than adequate. The installation employs a set of twenty-one tubular chimes, the output of which is picked up by unidirectional microphones and fed through an amplifier to a group of four heavy-duty loudspeakers mounted in the belfry.

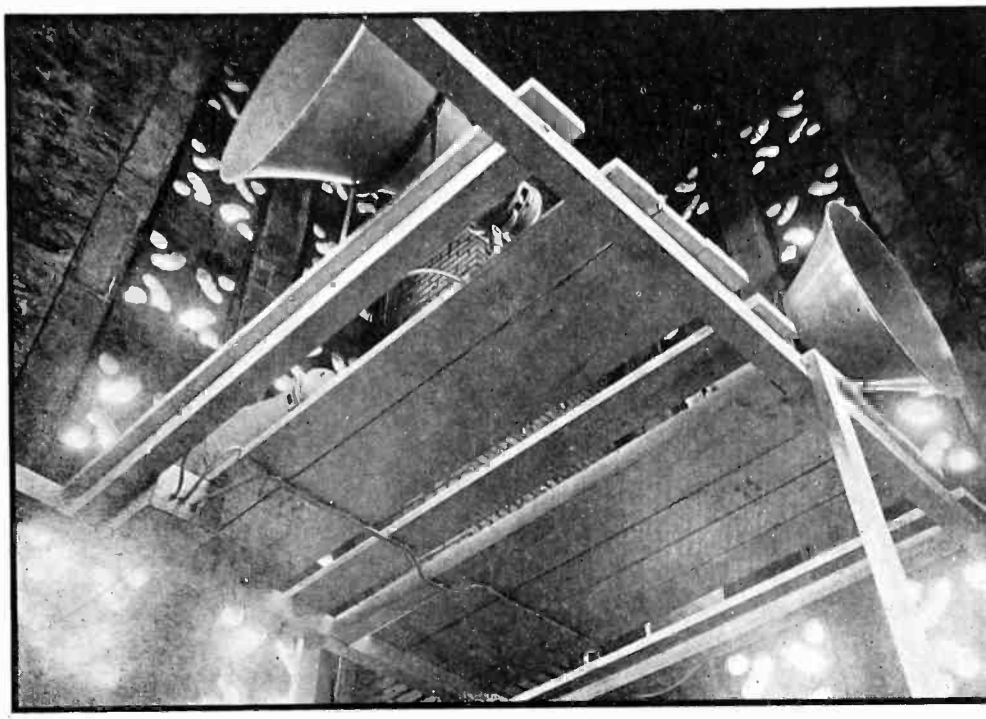
The Maas Cathedral chimes are of the type employed in some orchestras and in many large organ installations. They are electrically driven and are played from a small keyboard mounted on the organ console. In fact they are a part of the organ installation, serving as the regular chimes common to better organs. The longest one is approximately five feet and they range in size down to about three feet. The striking mechanism is housed in the case at the top of the tubes. The chimes, together with the two microphones used for pick-up are mounted in the organ loft behind the dummy pipes shown in one of the photographs. This same space contains two of the loudspeakers which are a part of the Hammond organ, also an electronic device. It is this location of the chimes within the church proper that permits them to serve both as a part of the organ (heard directly by the congregation) and as outside church bells.

The number, type, placement and mounting of the microphones calls for a considerable amount of skill on the part of the installation engineer as the conditions encountered in different locations vary greatly, with the result that there is no "rule of thumb" that can be followed. First, the pick-up must be such that all chimes are reproduced in proper proportion. Second, there must be ample pick-up, yet not enough to introduce extraneous sounds, acoustic feed-back, etc. Third, where the chimes compartment is closed or partially closed there must be complete avoidance of anything like cavity resonance; or where the chimes are mounted in the open any undesirable characteristics of the room must be offset. In this installation two crystal microphones are employed with some acoustic deadening in the semi-open chimes compartment and with extensive baffling around the microphones.

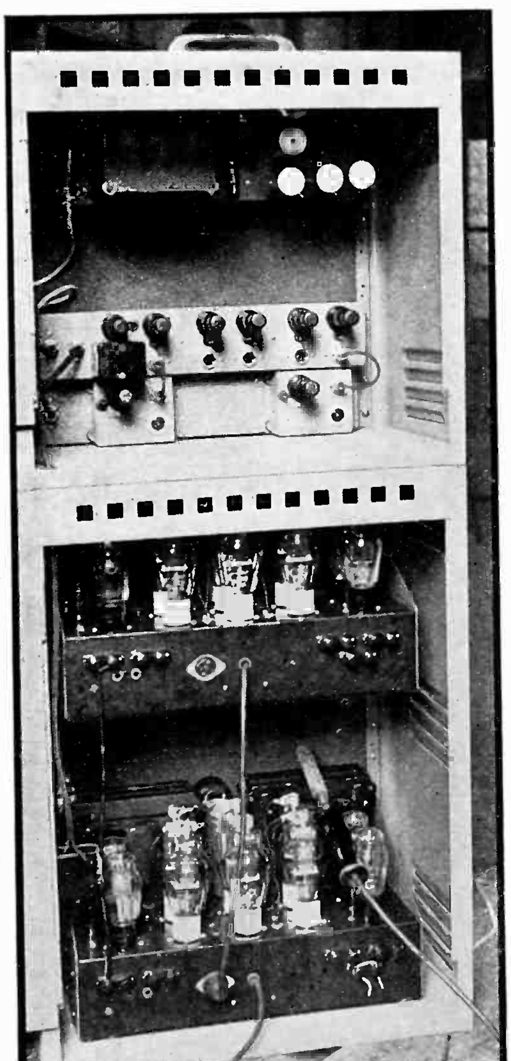
The amplifier is a high-output sound system capable of delivering 250 watts. It is custom-assembled to specifications and provides not only the high output required for this purpose but likewise the wide flexibility. The two microphones feed into individual 6J7 preamplifier units which are shown at the bottom of the upper rack compartment, rear view. These in turn work into an electronic mixer unit, utilizing only two of its five channels and leaving three as a reserve for later expansion if desired. This mixer unit also includes a triode-connected 6J7 voltage amplifier stage which works out of the parallelled plates of the mixers, each of which is connected into an isolating network that presents a low-distortion load and thus effectively eliminates non-linear distortion resulting from the usual direct parallel connection of tube plates. The two 125-watt main amplifiers have their inputs connected in parallel. Each of these consists of a 6C5, a pair of 2A3's as a push-pull driver, six 809's on push-pull-parallel as the output stage, and its own power supply utilizing a pair of 83's. Each also has its own gain control so that the two groups of speakers may be operated at different levels if desired.

This amplifier system is also located in the organ loft. Each main amplifier feeds two speakers through 500-ohm lines which are run through conduit and BX to the speaker platform in the tower. Here the speakers are mounted, facing in four directions to correspond with the large windows which constitute the vertical central panels of each tower wall. The speakers are each designed to handle 35 watts continuously and much higher power on surges.

An interesting and advantageous feature of this installation is the fact that down on the street in the immediate vicinity of this church the chimes are by no means uncomfortably loud. Presumably due to the foresight of the architect who designed the tower (it was originally intended to hang standard bells), all openings in the tower walls are such that the sound radiates principally in a horizontal plane. The use of directional, horn-type loudspeakers enhances this effect with the result that the sound intensity on the ground at distances up to a half mile or so is substantially uniform. Beyond this distance the level falls off gradually but on the surrounding hillsides, a mile or more distant it is still well up. Had the belfry been one of the type with louvres, the peal of the chimes would have been little short of deafening in the immediate vicinity, and their distance range would have been severely limited.



The sound is projected horizontally from the belfry to give substantially uniform sound intensity at ground level over a large area



Rear view of the 250-watt amplifier unit. The soldering iron is not a permanent part of the installation

This installation, which was designed and made by Francis J. Rybak & Company, New York City, specialists in organ installations and electronic applications in music and sound reinforcement, suggests a solution of the problem of the empty bell towers in many of today's churches. With so many other uses for such funds as they may have at their command many modern churches, architecturally designed for large chimes installations have had to be satisfied with a modest arrangement of two or three bells, or perhaps none at all. Yet a properly designed system of amplified chimes such as that described here could be installed at a cost insignificant as compared with that of a set of bells providing equal tone range and output.

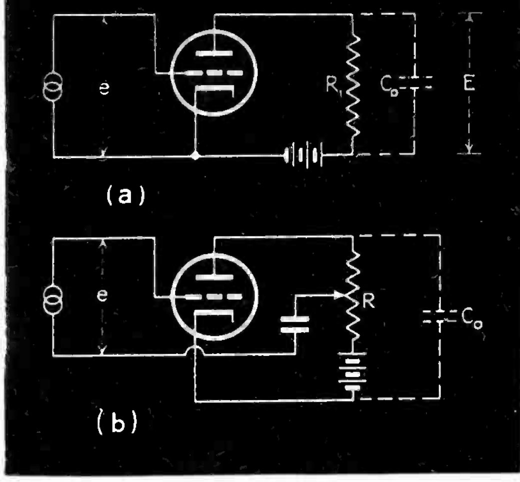


Fig. 1—Feedback applied to a single stage, from which phase relationships may be derived

Applying Feedback

A practical outline of procedure for improving noise and distortion characteristics by applying inverse feedback to existing r-f and audio equipment

By L. G. YOUNG

Bell Telephone Laboratories

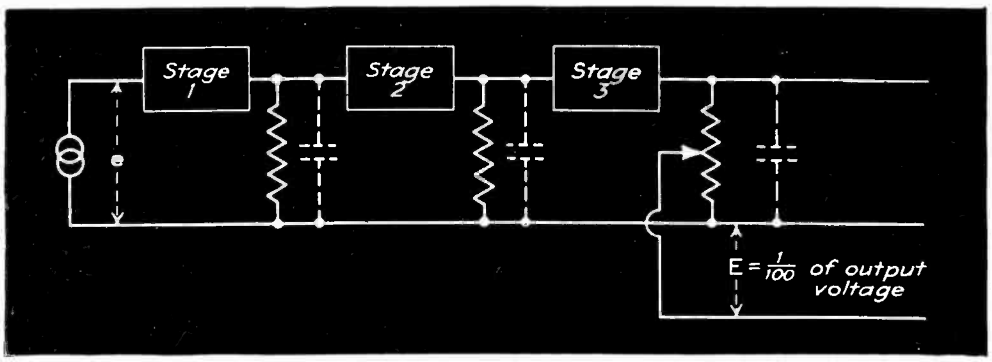


Fig. 2—Three-stage amplifier, whose performance is predicted in terms of the single stage analysis

DUE to sound design and excellent maintenance by the station operators many broadcasting transmitters whose inauguration dates back a decade or more ago are still giving satisfactory service with every promise of continuing to do so for many years to come. In spite of the advances in the art which are incorporated in the newer style broadcasting equipment many owners of the older transmitters feel that they cannot at this time economically justify the purchase of newer equipment to obtain the lower annual tube charges, lower power bills and more faithful reproduction obtained in latest type transmitters since the old style equipment keeps them "on the air" with so nearly a trouble free record that any improvement the new transmitter could offer on this score would be of negligible moment. Nevertheless, high fidelity performance is desired by most of these owners and some have asked if inverse feedback cannot be applied to their equipment to effect an improvement on this score.

In the case of a great many of the transmitters feedback may be applied satisfactorily with gratifying results on the score of distortion and noise. Even if it is practicable to incorporate only 6 or 8 db of feedback over the useful range of audio frequencies the improvement is well worthwhile since 6 db of feedback represents a 50 per cent reduction in distortion and a similar reduction in carrier noise. This may well represent the difference between meeting present day high fidelity standards and not meeting them.

The theory of feedback and the beneficial results to be obtained by its use are well covered in the literature and generally recognized by people in the broadcasting business. In fact, manufacturers of radio transmitters are prepared to offer station owners conversion services for obtaining satisfactory feedback action in the older style transmitters. However, some station operators would elect to do the job themselves if supplied with sufficient information on the subject. This article, therefore, will be confined to the task of assisting those station operators, who are desirous of applying a feedback loop to their transmitters, to a better understanding of the important factors and principles which control the successful application of feedback to an amplifying system.

The first consideration in applying feedback to an amplifying system is how many stages of amplification are included in the loop. The second is, how severe is the phase shift of the interstage coupling circuits at the very high frequencies. Where it is desired to utilize a large amount of feedback, phase shift at very low frequencies usually of the order of a fraction of a cycle is also of interest, since low frequency singing or "motorboating" sometimes occurs when the circuits are not properly designed and feedback of 25 db or more is attempted. However, difficulties on the high frequency end of the spectrum usually limit the amount of feedback obtainable long before low frequency singing is encountered.

To illustrate the importance of the number of stages and coupling circuits consider a single-stage amplifier as in Fig. 1a in which e is an alternating current voltage of variable frequency applied to the grid and E is the amplified voltage developed across the plate circuit of the tube. If e is held to constant amplitude and frequency varied from a very low value to a very high value and relative values of e and E plotted with respect to their respective magnitudes and phase relations for all frequencies considered it will be found that at frequencies where C_o, the unavoidable stray capacity of the circuit coupled with the plate capacitance of the tube, is high in impedance with respect to R, that e and E will be 180 degrees out of phase and of relative magnitudes determined by the effective amplification constant of the tube. However, at very high frequencies the impedance of C_o decreases in magnitude and

To Broadcast Transmitters

at some frequency will equal R, and, assuming the tube to be a constant current generator, will reduce the gain approximately three db and shift the phase of the output voltage 45 degrees towards the input voltage e. At still higher frequencies the plate circuit impedance will be still further reduced with a corresponding reduction in gain and a phase shift of E toward that of e. However, it is seen that the phase of the E can never swing around sufficiently to be the same as that of e in this rather ideal type of amplifier and consequently no singing trouble should be experienced if a portion or indeed all of the output voltage were coupled in series with the generator voltage e to obtain feedback action as shown in Fig. 1b. Obviously, the single-stage amplifier offers little difficulty to the application of feedback, and usually little advantage also, because if the amplifier stage under question is the final stage (and this is the one which usually requires the corrective action of feedback) the gain of the stage is reduced and requires a larger input voltage which in turn means a larger driving stage resulting in uneconomical tube complement. The economical way is to feed back around several stages and make up the loss of gain on the lower power end of the system where the addition of a tube if necessary involves little in expense or power consumption.

Unfortunately, complications in the form of singing trouble are encountered when this is attempted, since the phase shift is not limited to 90 degrees as in the single stage just discussed, but may amount to hundreds of degrees depending upon the number of coupling circuits involved and the complexity of each circuit. Each simple circuit of the type shown with the single-stage amplifier has an ultimate phase shift of 90 degrees at some frequency and it usually happens in a multi-stage system that at some high frequency, the phase shift of the output voltage has rotated 180 degrees without its magnitude being reduced sufficiently to prevent singing. Consider a 3-stage amplifier as in Fig. 2 and a 5-stage amplifier having the same arrangement, each stage of each amplifier having an amplification at low frequencies of 10. If the output impedance of each stage consists of a resistance of 30,000 ohms shunted by a stray capacitance of 200 $\mu\mu$f, the gain characteristic of each complete amplifier, assuming each tube to be a generator of the constant current type, may be computed by plotting a curve for a single stage as in Fig. 3a and multiplying the gains of the stages for each frequency and adding the phase departures. Also, the gain-phase characteristic at extremely low frequencies has been omitted from the diagrams for simplicity's sake. In plotting, 1/100 of the output voltage has been used in the three-stage case and 1/10,000 in the 5-stage case so that the same voltage will be available in each case for feedback. Comparing the curves (Figs. 3a, b, c) of the single stage, the 3-stage and the 5-stage amplifiers it is seen that the single-stage output phase departs only 90 degrees from its 180 degrees low frequency relation to the grid voltage even at an extremely high frequency, with consequently no feedback restrictions from a singing standpoint while the 3-stage amplifier shifts a total of 270 degrees and still has a gain of 1.2 at 45,000 cps, the 180 degrees shift point where the output voltage is in phase with the voltage of the grid of the first tube. Since the gain at this frequency is 1.2 the amplifier will sing if an attempt is made to feed back 1/100 of the output voltage into the grid input circuit. To prevent singing it is necessary that the output voltage fed back into the grid circuit at the frequencies where the output voltage is in phase with the input voltage be less than the voltage which it would be necessary to impress upon the grid to produce it. This condition may be fulfilled if instead of feeding 1/100 of the output voltage a little less than 1/1.2 times 1/100 is fed back. Assume that the figure is $2/3 \times 1/100$. In this case the fed back voltage at low frequencies will be 6.6 times the voltage necessary to produce it on the grid of the first tube and a feedback action of approximately 17 db will be effected at these frequencies. The corrective action of this feedback does not cease, as is quite commonly supposed, at frequencies where the phase has rotated to within 90 degrees of the input voltage but continues, in diminished effect, of course, to a point much closer to the 180 degree position. In Fig. 3b the dotted curve represents $2/3 \times 1/100$ of the output voltage. The small dotted circle has a radius equal to the input voltage on the grid of the first tube. Frequencies represented by vectors terminating within the circle will be raised in gain by the action of the feedback. All other frequencies will be reduced in gain and a corrective action obtained.

Considering the 5-stage amplifier it is seen that the phase shift is 180 degrees at approximately 20,000 cps and the gain 3.4 at this frequency. Consequently, the output voltage must be reduced to less than 1/3.4 times 1/10,000 or singing will occur. If it is reduced to about

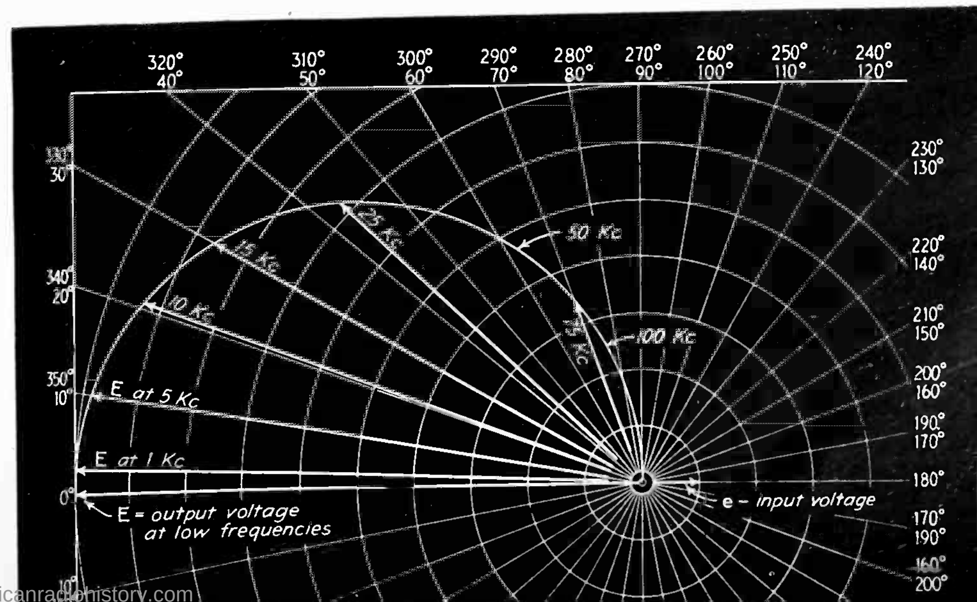


Fig. 3a—Relationship between input and output voltages in a single stage

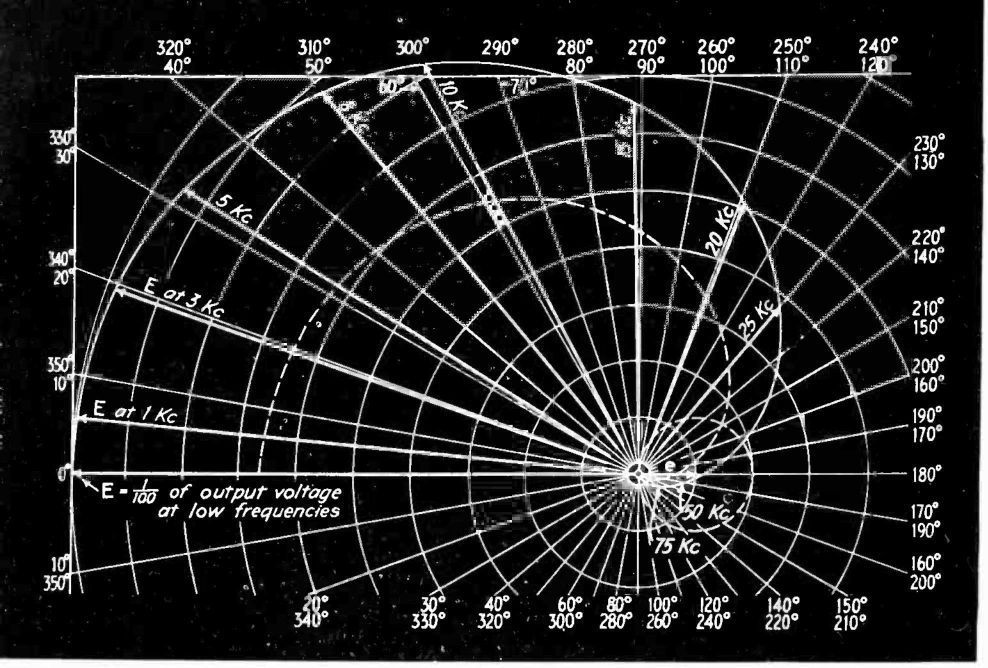


Fig. 3b — Three-stage amplifier, showing relationship between feedback voltage and input voltage

1/4 × 1/10,000, the fed back voltage at low frequencies will be 2.5 times the initial voltage and a corrective action of about 11 db of feedback obtained at the low frequencies. Some corrective action will be obtained up to a frequency of about 13,000 cps. Thus it is seen that as a number of stages is increased the amount of feedback obtained without alteration of the circuits becomes less and the band of the frequencies over which the corrective action is obtained becomes narrower.

Since most radio transmitters not designed specifically to facilitate the application of feedback have many stages and, in all probability, coupling circuits which produce a large phase shift, it is apparent why only a small amount of feedback can be obtained without alteration of the circuits.

It is also apparent that if the gain characteristic of the amplifier in the vicinity of the frequencies having phase shifts of 180 degrees could be attenuated without affecting the gain and phase of lower frequencies more feedback could be utilized without singing. This is not possible in an idealized sense. Any device which produces increasing attenuation as the frequency is raised will produce an adverse phase shift at frequencies lower than those being attenuated. Moreover, the extent of the phase shift is considerable before any appreciable attenuation is produced, and any workable device which does produce sufficient attenuation at the high frequencies appreciably narrows the band of frequencies over which feedback may be applied. A device which is commonly used consists of a condenser and resistance in series across one of the coupling circuits. This arrangement probably effects as satisfactory a compromise as regards curtailment of band width and singing frequency attenuation as can be had. The values of capacity and resistance to be used can be approximated by calculation and if in the case of the 5-stage amplifier it were desired to obtain a full 20 db of feedback at low frequencies the following procedure and reasoning could be followed. If 1/10,000 of the output voltage were fed into the grid circuit of the first tube the desired 20 db feedback would be obtained if singing could be suppressed at a frequency of 20,000 cycles per second where the output voltage is in phase with the grid voltage and has a value of 3.4. It is necessary for the device we contemplate using to reduce the output voltage at this frequency to a value that is, say, 8/10 of the grid voltage to produce it and this without appreciably changing the phase at this frequency. This represents a reduction in gain of 4 or about 12 db at 20,000 cps. Let us assume that the device will be placed across the output circuit of the first tube whose gain at 20,000 cps is 8, or 18 db. Since the plate circuit of this tube has an impedance of 16,000 ohms at 20,000 cps, and since the tube has been assumed to be a generator of the constant current type a reduction in gain of 12 db could be effected at this point if the device reduces the impedance to 4,000 ohms. If a resistor of 5,000 ohms were placed across the plate circuit of the tube this impedance reduction would be effected not only at frequencies of the sing order but at the low frequencies also where no reduction is wanted. However, by selecting a condenser value in series with the resistor such that the impedance of the condenser at 20,000 cycles per second is ⅓ to ⅕ that of the resistance the reduction in gain at 20,000 cps is accomplished without much shift in phase for frequencies of this order and without seriously affecting the lower frequencies and the amplifier should operate with 20 db of feedback without singing.

Numerous devices including combinations of tuned circuits and multiple feedback paths have been tried in an effort to obtain high frequency attenuation without adversely altering the phase of lower frequencies, but it appears to be a law of nature that any device which offers increasing attenuation as the frequency is increased, will produce a retarded phase over a band of frequencies lower in value than those to be attenuated. The attenuation circuit consisting of a resistance in series with a capacity for reducing the gain at high frequencies in general gives more satisfactory results than any other. The characteristics of the 5-stage amplifier just considered can be radically improved and the application of feedback over a much broader band of frequencies incorporated if the coupling circuits can be "broadened" by reducing the values of stray capacitance from plate to ground. For example, if the strays of each coupling circuit could be reduced to a value of 100 $\mu\mu f$ instead of the 200 $\mu\mu f$ indicated, the band of frequencies over which feedback would be effective would be doubled.

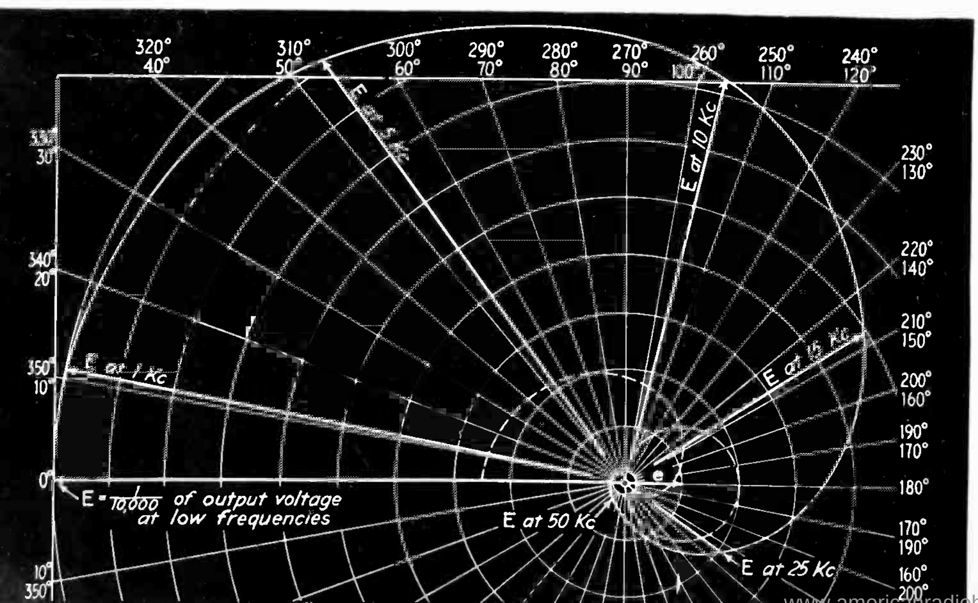


Fig. 3c — Five-stage case. A greater reduction in feedback voltage is required to avoid singing

In fact, if the strays could be made very small for all but one stage and this one stage loaded up with either additional capacity or the resistance capacity circuit already discussed a large amount of feedback could be applied and would be effective over a wide band of frequencies. However, in a 5-stage amplifier it is rarely possible to broaden out the circuits sufficiently so that the band width is much greater than is required for correction purposes over the speech band of a broadcasting transmitter, since for proper corrective action, it is necessary for feedback action to take place not only at the frequency under consideration but also at harmonics of that frequency. Thus, if a 5000-cps wave is to be improved by the corrective influence of feedback, feedback must be present and effective at 10, 15, and 20,000 cps.

The 5-stage amplifier just discussed has been used for illustrative purposes to make clear the importance of reducing the phase shift in the coupling circuits for obtaining feedback over satisfactory band width, and also to indicate why and to what extent the difficulties and restrictions increase as the number of stages included in feedback loop are increased. The principles involved in applying feedback to a radio transmitter and the factors which control its successful operation are the same as in the audio amplifier. It is somewhat more difficult in the case of a radio transmitter since a high grade rectifier is necessary to obtain an audio frequency which is a true sample of the radio frequency envelope at the output of the transmitter. It is more difficult and expensive also to broaden out the radio frequency coupling circuits for obtaining satisfactory band width than to broaden out an audio frequency circuit. Each radio frequency coupling circuit included within the feedback loop retards the envelope phase in the same fashion that the stray capacity which shunts the audio interstage circuit retards the phase, and it is just as important to minimize this effect as in the case of the audio system.

The most widely used transmitter type consists of a low-level plate-modulated amplifier and several higher level r-f amplifiers.

Assuming that the latter is the style of transmitter which an operator desires to improve by a feedback loop the following procedure should be followed:

Broadening the Audio Circuits

This is perhaps the easiest of all operations to be performed. The audio amplifier will probably have the circuit equivalent to that shown in Fig. 4. The plate circuit load resistance of the first audio tube, calculated from values of R_1 and R_2, and assuming C_1 to be a low impedance at all usable frequencies, will be R_1R_2/R_1+R_2. An approximation of the effective plate circuit shunt capacity can be obtained by disconnecting R_1 and R_2 at the low potential ends and measuring the capacity from the plate of the first tube to ground with a capacity bridge. The grid of the first tube should be grounded during the measurement. This measured capacity is the plate filament capacity of the first tube plus the plate grid capacity of the first tube plus the grid filament capacity of the second tube plus the stray of the leads plus the capacity of the insides of the condenser C_1 to its case. The effective capacity will be somewhat more than the measured value by an amount which is the amplification constant (effective) of the second tube times the grid plate capacity of the second tube. This can be calculated and added on to the measured value. The total value of capacity at this point should be reduced as much as possible by disconnecting and insulating the case of condenser C_1 from ground and by minimizing the capacity of the leads to ground. After this has been done, the frequency at which the reactance of the total shunting capacity (in $\mu\mu$f) is equal to R (in ohms) should be calculated, i.e.

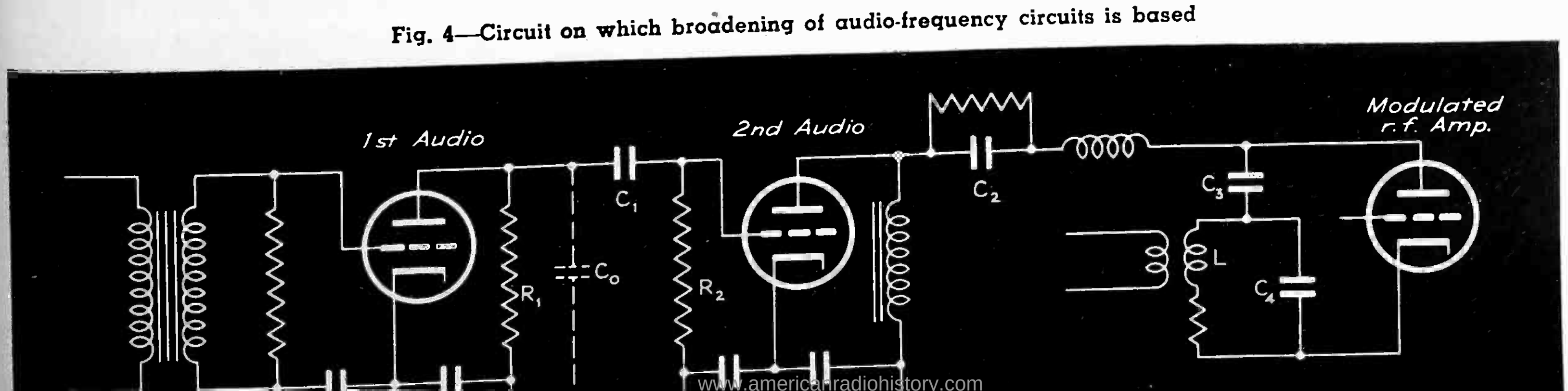
$$f=\frac{10^{12}}{2\pi RC}$$

The value of f as here calculated has no particular significance except that it is the frequency where a 45 degree phase shift occurs and is a handy and easily calculated standard upon which to judge the broadness of the circuit. A value of 50,000 cps or more for f is highly desirable. The same procedure should be followed for the plate circuit of the second audio stage. In this case the resistance which the tube works into will be the plate circuit resistance of the modulated amplifier. This will be equal in ohms to the direct current plate voltage applied to the tube divided by the plate current in amperes under operating conditions. The shunt capacity to ground will be the plate filament capacity of the second audio stage plus the strays of the leads plus the capacity of the insides of C_2 to its case plus C_3 the radio frequency plate blocking condenser for the modulated stage plus the plate filament capacity of the modulated amplifier plus the plate grid capacity and neutralizing capacity of the modulated amplifier. The probable places where reductions can be effected are the strays of the leads and the case of C_2 which should be insulated from ground, and the value of C_3 which can probably be reduced radically after the radio frequency tuned circuit of this stage is broadened out by increasing L and decreasing C_4. The broadening of radio frequency circuits will be discussed later.

The grid input circuit of the first audio tube should be modified as in Fig. 5a keeping the stray capacity of leads as low as possible by having the input transformer located in the close vicinity of the tube.

A circuit as in Fig. 5b is sometimes used to advantage where peculiar phase shifts are encountered due to the secondary winding of the audio transformer. However, its use is usually unwarranted if a

Fig. 4—Circuit on which broadening of audio-frequency circuits is based



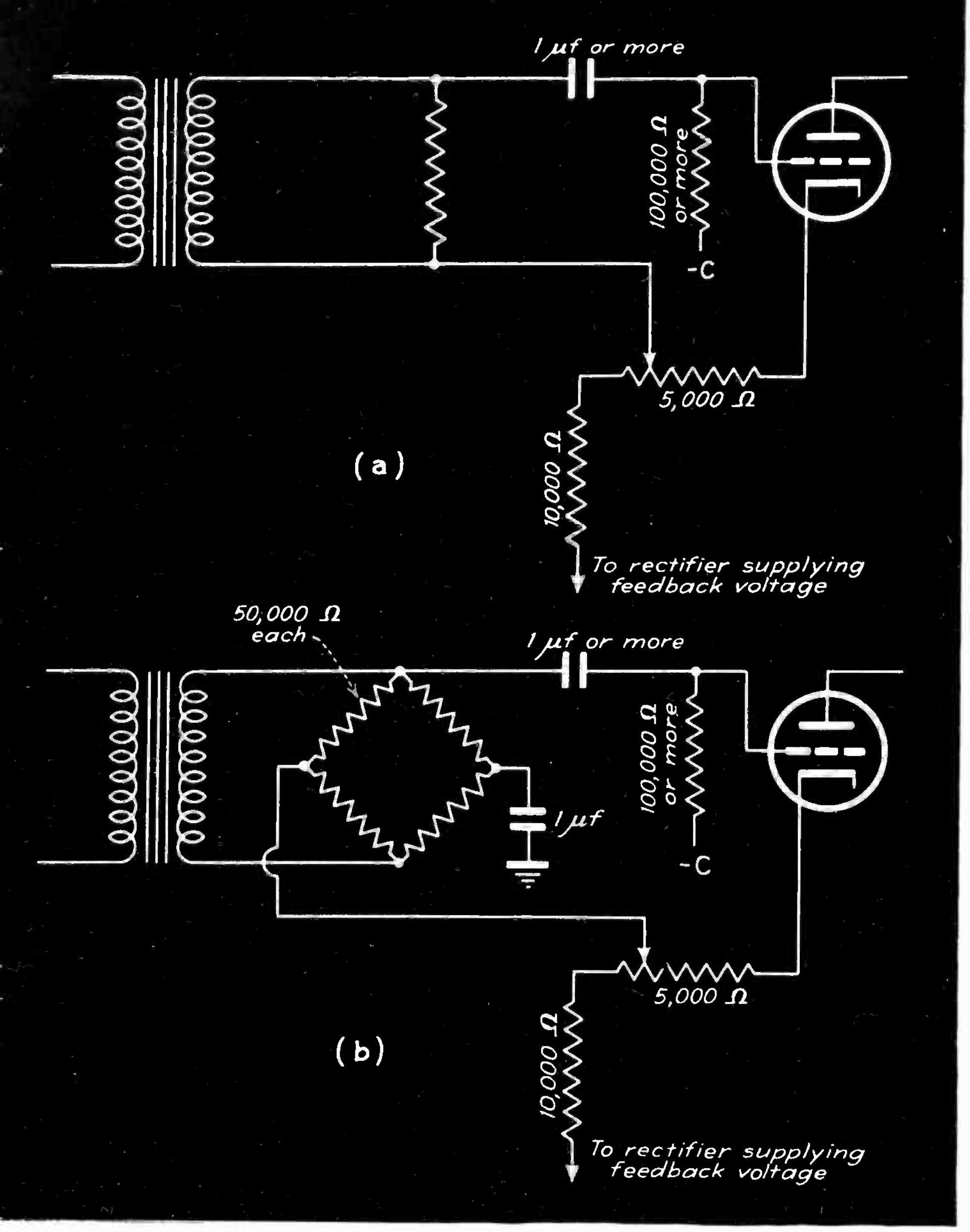


Fig. 5—Modification of audio grid circuits to minimize input capacitance

high grade wide band input transformer is used. This circuit reduces the gain 6 db. The parts involved are small and low-priced and it can be readily tried after the system is lined up to see if any improvement is effected. The values of resistance and capacity shown in Fig. 5a and b are for illustrative purposes only and may be varied to suit the individual transmitter requirements.

Broadening the Radio Frequency Circuits

This is the most difficult and expensive procedure involved and the extent to which it is carried out is usually compromised by the cost.

Neglecting neutralizing means, direct current feed chokes and blocking condensers, most radio frequency coupling circuits are as in (a), (b), or (c) of Fig. 6.

Of these three, (a) is the most desirable for obtaining a satisfactory band width and (c) is the least desirable having double the phase shift capabilities of (a).

In a circuit such as Fig. 6a the impedance seen by the plate of the tube is R at the carrier frequency since L and C are adjusted to have exactly equal reactances and so shunt R with a very high impedance. Under modulated conditions the upper sideband will be retarded in phase and the lower sideband advanced resulting in the envelope phase appearing on the plate of the tube being retarded from that impressed upon the grid of the same tube. The amplitude also is smaller than if the plate circuit could be made of purely resistance load at all frequencies. Thus, this circuit so far as amplitude and phase shift are concerned has exactly the same effect upon the modulated envelope as the capacity shunting a resistance has on the phase and amplitude of an audio wave. Just as the effect may be reduced in the case of an audio amplifier by reducing the shunting capacity (it is rarely practicable to achieve the same result by reducing the value of the load resistance) so the effect may be reduced in a radio frequency amplifier by increasing L and decreasing C.

Thus if in Fig. 6a R has a value of 10,000 ohms, L and C 500 ohms each at the carrier frequency the ratio of $\frac{\text{kva}}{\text{kw}}$ would be 20 for this circuit and the frequency at which a 45 degree envelope phase shift occurred could be calculated by dividing the carrier frequency by twice this ratio. If the carrier frequency were 1,000,000 cps the envelope would be retarded 45 degrees at $\frac{1{,}000{,}000}{40}$ or 25,000 cps. It would be decidedly advantageous to make this phase shift less. In all probability L and C could be made 2,000 ohms each which would raise the frequency where a 45 degree shift occurred to 100,000 cps. Observe that it is easier to obtain a broad band with a higher carrier frequency. The application of feedback should, therefore, be easier for a transmitter operating on a high carrier frequency than for one on a low frequency, other things being equal. The extent to which this broadening out can be extended in the case of the circuit as in Fig. 6a is determined by the stray capacity of the circuit. However, the harmonic content of the voltage wave impressed on the grid of the next tube rises rather sharply when the "Q" or ratio of reactive to real power in such a circuit is made less than 3. Ordinarily harmonics have little ill-effect even though of appreciable magnitude. However, circuits having "Q's" of less than 3 permit the magnitude to rise to a point where the efficiency of the next stage is impaired by the poor shape of the grid voltage wave. It is not recommended that the broadening be carried out beyond this point. In circuits shown by (b) and (c) of Fig. 6 the same procedure can be used to broaden out circuits by increasing all values of tuning inductance and decreasing all values of tuning capacity in proper proportions to maintain the same ratio of voltage between the plate of the driving tube and the grid of the driven tube. Circuits of this type in which an impedance transformation takes place cannot be broadened out beyond a certain point which is determined by the ratio of the voltages at the input and output ends of the circuit. Thus if a 4-to-1 stepdown in voltage is to be effected the ratio of kva:kw in the circuit must be at least 4-to-1. This is usually no undue handicap in broadening out circuits because large voltage stepdowns between stages are rarely used or required.

To illustrate how a coupling circuit of the type shown in Fig. 6b may be broadened let us assume that the constants of such a circuit are now as follows at a carrier frequency of 1,000 kilocycles.

$C_1 = 0.0005 = 317$ ohms
$L =$ sufficient to tune the circuit to 100 per cent power-factor
$R = 500$ ohms
$C_2 = 0.0016 = 100$ ohms

The equivalent series resistance of the parallel circuit consisting of R and C_2 will be

$$\frac{100^2 \times 500}{100^2 + 500^2} = 19.2 \text{ ohms.}$$

When L is adjusted to make the circuit appear entirely resistive at the plate of the tube the circuit will have an impedance of $317^2/19.2 = 5200$ ohms. The ratio of reactive kva to the real power in this circuit will be $5200 \div 317 = 16.4$. The voltage transformation effected is

$$\sqrt{\frac{5200}{500}} = 3.25.$$

This circuit could, therefore, be broadened out until the ratio of reactive to real power approached 3.2 without affecting the operating conditions of the tube. If a ratio of 4 is selected the coil L would be required to have approximately $16.4/4 = 4.1$ times its present inductance, C_1 would be $5200/4 = 1300$ ohms $= 0.00012\ \mu$f at 1,000,000 cps. C_2 would be a value such that the equivalent series resistance of its combination with R would be $1300^2/5200$ or 324 ohms, or

$$324 = \frac{X^2_{c2} \times 500}{500^2 + X^2_{c2}}$$

Solving, $X_{c2} = 678$ ohms or $0.00023\ \mu$f at 1,000,000 cps. Circuits which have been broadened out by this process will have considerably less current in their circuit elements than before the broadening process so any r-f meters which are in the inductive or capacitative branches of the circuit will probably need replacement with lower scale instruments, if it is necessary to have such indication. The values of current through the resistive paths are not affected.

Feedback Rectifier

A hum-free distortionless rectifier of the full wave type will be required for rectifying a portion of the output of the transmitter to produce an audio frequency voltage which is an accurate replica of the envelope of the modulated wave at the output of the transmitter. Any noise or distortion originating in this rectifier will be radiated on the antenna so it is imperative that these factors be kept as nearly zero as possible.

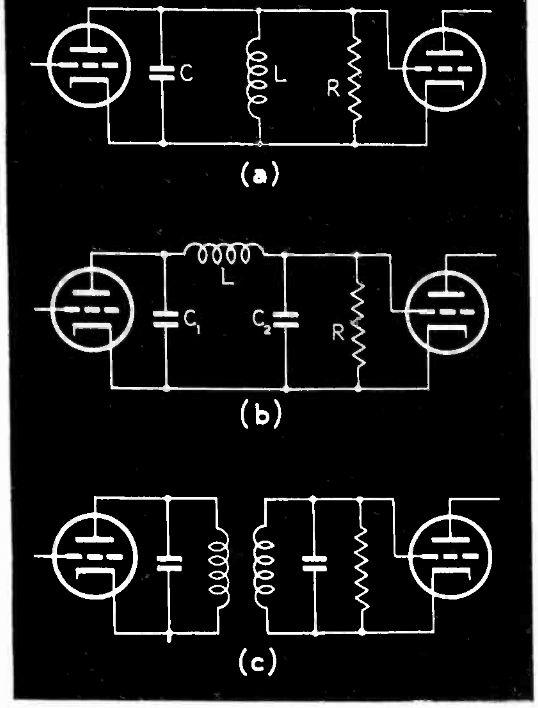


Fig. 6—Basic circuits on which broadening of r-f characteristic is based

A full wave rectifier rather than one of the half wave type is desirable because the carrier frequency component is cancelled out without the use of a filter. The filter required in the case of a half-wave rectifier quite often produces an appreciable phase shift at the higher audio frequencies and complicates the phase shift problem. If omitted from the circuit in the case of the half-wave rectifier sufficient carrier frequency voltage is impressed upon the grid of the first audio tube to cause trouble. In the case of the full wave rectifier harmonics of the carrier frequency are impressed on the first grid but are of insufficient magnitude to cause trouble and since difficulty is rarely experienced in balancing the rectifier sufficiently well to effect a virtual cancellation of the carrier frequency no filter is required. A type 84 tube has been used and found satisfactory for most broadcasting transmitter feedback applications. It will work without excessive distortion into a wide range of impedances provided the rectified direct current voltage does not exceed 200 volts. Thus, if the rectifier load resistor is chosen to be 15,000 ohms as indicated in the grid input circuit the direct current through the resistor should not exceed 0.013 ampere. If a higher voltage than 200-volts is required four 84s in a bridge circuit may be used or if this is inadequate four 836s in a bridge circuit. It should be kept in mind that where a large amount of feedback is employed the requirements on the feedback rectifier require voltages many times the audio voltage required on the grid of the first tube to produce complete modulation. That is, if a radio transmitter without feedback requires one volt on the grid of the first audio tube to produce 100 per cent modulation the application of 20 db feedback will necessitate the rectifier's supplying 9 volts to the grid at complete modulation. In cases where the station operator elects to cut out a stage of audio from the feedback loop and thus introduce the feedback voltage at a higher level point in the transmitter it is seen that the voltage requirements of the feedback rectifier become rapidly more severe and the level obtainable from the small size rectifier tubes becomes inadequate.

The method of obtaining a sample of the output of the transmitter for rectification should be such as to minimize the envelope phase shift produced by the pickup and transforming devices. If the first audio tube is any appreciable distance from the output of the transmitter it will be of advantage from the phase shift standpoint to install the feedback rectifier close to the first audio tube to keep the audio circuit of the rectifier short and thus minimize the adverse effect of stray capacity on this part of the circuit. It will be necessary to transmit the radio frequency sample obtained from the output circuit in this case over a small sized concentric transmission line. In an idealized case the complete system could appear as in Fig. 7. In a great many cases it will be necessary to compromise somewhat from this circuit on two points which affect the phase shift. Untuned permalloy-dust core radio frequency transformers have been made and are used by manufacturers of radio transmitters for applications as shown but are not manufactured in a variety of sizes and voltage ratios nor are they readily available. It may be necessary, therefore, to substitute an air core tuned secondary type of transformer. Care should be taken to make the tuned circuit as broad as possible, since envelope phase shift will be produced by this device as in any tuned circuit. The pickup arrangement indicates that the sample of the plate current rather than the closed circuit or antenna current is fed into the transmission line circuit. In general, only a small amount of reactance between the point of connection of the closed circuit and the filament of the tube is permissible and since the current is small at this point it is difficult to get sufficient voltage induced into the pickup coil feeding the transmission line. In the case of a push-pull stage it is still more difficult because the coupling point in this case would be in the plate lead of the tube itself involving insulation and electrostatic shielding problems due to the high voltage involved at this point. In all probability the station operator applying feedback to a transmitter will decide to couple to the closed circuit or the tank coil of the output circuit and accept the additional phase shift involved with this type of pickup.

Procedure for Adjusting Circuits

After broadening out all the circuits and checking the operation of the transmitter with the broadened circuits to make sure normal operation is obtained the pickup to the feedback rectifier may be adjusted until a direct current of 0.010 to 0.013 amperes is obtained through the 15,000-ohm rectifier load resistor, having, of course, the slider on that part of the feedback load resistor which varies the feedback voltage applied to the first audio tube in the zero position. Next the transmitter may be modulated with a low frequency signal of, say, 400 cps and about 50 per cent modulation as viewed on a cathode ray tube. A small amount of feedback may now be tried by adjusting the slider on the resistance so as to apply some of the rectified voltage to the grid circuit. If the percentage modulation decreases when this is done the feedback rectifier is poled properly for negative feedback operation. If the percentage modulation increases it is incorrect and the connections must be reversed. That is, the cathode of the rectifier tube should be grounded and the load resistance connected to the center tap of the radio frequency transformer secondary. It is easy to figure out in advance which way the connections should be for the desired negative action but it is still easier by the trial just described. The next procedure will be to determine how much feedback is obtainable without adding special high frequency attenuation circuits. Apply sufficient 400-cycle voltage to the input of the transmitter to modulate 100 per cent and record the audio level required without feedback. Apply feedback until the transmitter sings and then back off to just below the sing point. Raise the audio input level until the transmitter is again 100 per cent modulated and record the audio level now required to obtain this degree of modulation. The difference in levels required with and without feedback for a given percentage of modulation is a measure of the amount of feedback obtained. Next apply a high frequency (about 5,000 cps) to the transmitter terminals and modulate the transmitter 100 per cent or nearly so. Increase the feedback to almost the sing point while viewing this 5,000-cycle wave on the cathode ray oscilloscope. The wave shape will probably be distorted and as the feedback is increased to just below the singing condition the harmonic of 5,000 cycles which is nearest the sing frequency will be accentuated by the action of feedback and will appear as a series of jagged points on the wave. It will appear as in Fig. 8. Count the bumps from the crest of one wave to the crest of the succeeding wave or from valley to valley and thus determine the approximate sing frequency of the feedback loop. In Fig. 8 an accentuation of the ninth harmonic is indicated and the sing frequency is in the vicinity of 45,000 cps. Other high frequencies of 4,000 to 8,000 cps may be used and the results checked; for example, on a 7500-cycle wave about 6 bumps would be expected. The sing frequency cannot be determined, strangely enough, by increasing the feedback until the loop is actually in a state of oscillation, because the tube overloading which takes place under a state of oscillation changes the gain-frequency characteristic of the loop sufficiently to make it oscillate at a widely different frequency.

Having determined how much feedback at low frequencies is obtainable and what order of frequency must be attenuated if a greater amount of feedback is to be utilized it is now possible to calculate approximately what the constants of the high frequency attenuation circuit should be to permit the application of more feedback. For example, let us assume that 5 db of feedback was obtained and that the apparent singing frequency was 50,000 cps and that it is desirable to increase the amount of feedback to 20 db. An additional attenuation of 15 db is necessary at 50,000 cps to permit this. The grid circuit or plate circuit of the first audio tube is usually the most desirable place to apply the attenuation circuit. If the plate circuit is selected and the further assumption is made that the plate load resistance in the first tube is 20,000 ohms the gain may be reduced 15 db at 50,000 cps at this point in a circuit by shunting the 20,000 ohms with a circuit which reduces the plate circuit impedance to 20,000/5.623=approximately 3500 ohms. The 20,000 ohms should be

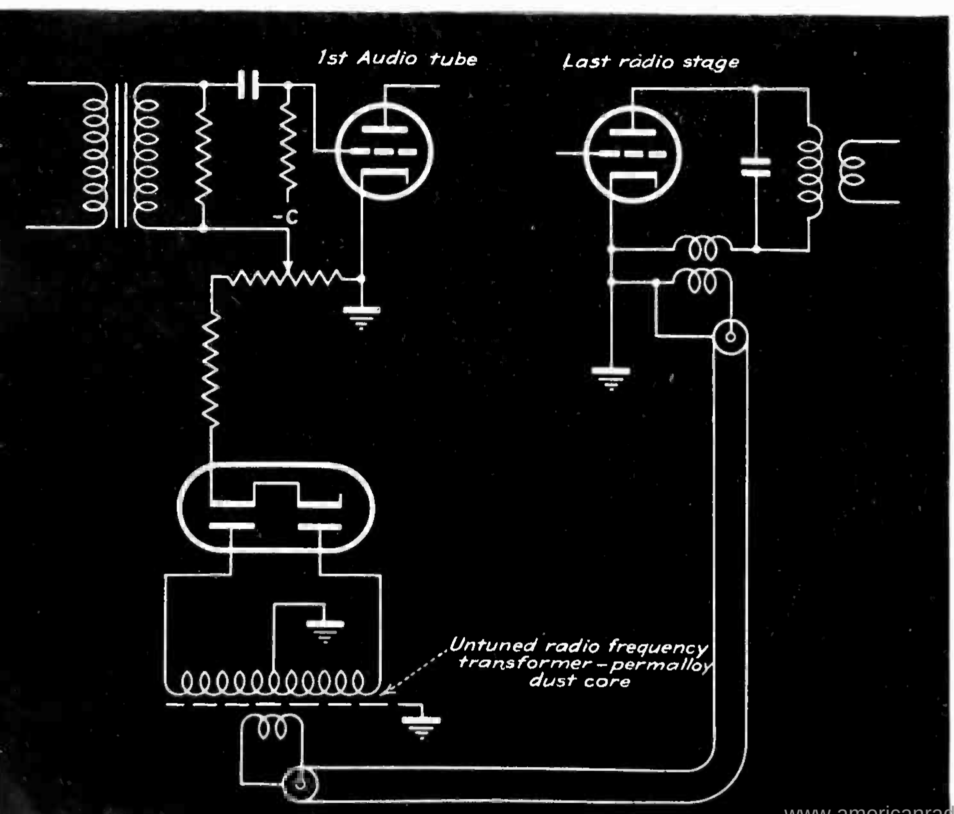


Fig. 7—The feedback rectifier circuit, which must be distortionless and hum-free

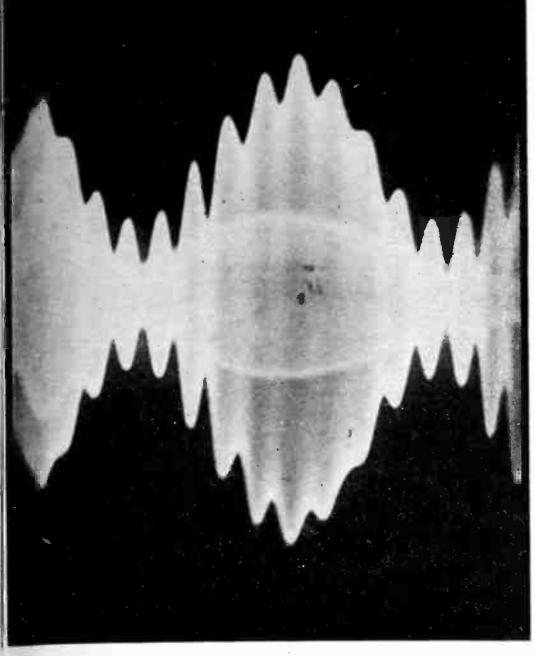


Fig. 8—Oscillogram showing accentuation of ninth harmonic

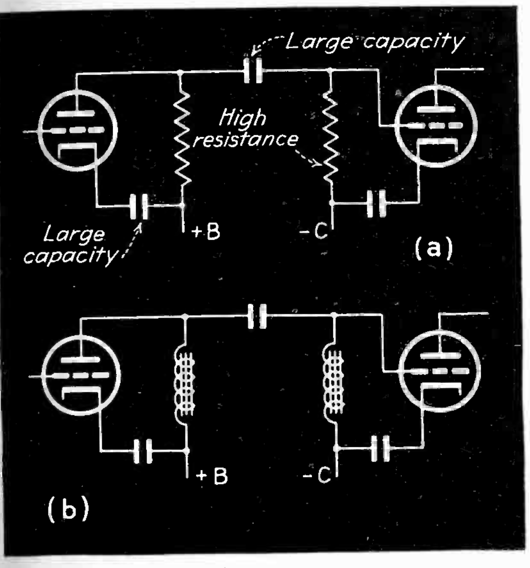


Fig. 9—Circuits of importance in minimizing low-frequency feedback

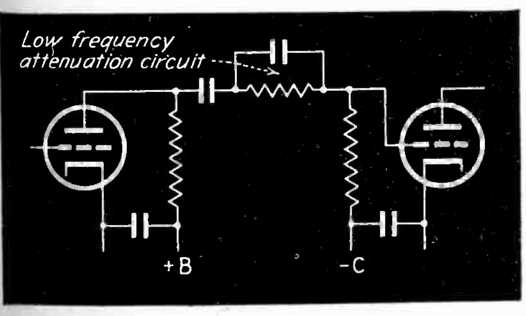


Fig. 10—Low frequency attenuator circuit to counteract motor-boating

shunted at 50,000 cps with approximately 4,000 ohms to accomplish this. A condenser having about $\frac{1}{3}$ of 4,000 ohms or 1330 ohms at 50,000 cps should be connected in series with the 4,000-ohm resistor to prevent shunting the normal 20,000 ohms by an appreciable impedance at low frequencies. The capacity value representing 1330 ohms at 50,000 cycles would be approximately 0.0024 microfarads. The next step is to connect the 4,000 ohms and 0.0024 capacity element across the plate circuit of the first tube and measure the amount of feedback now obtainable. The full 20 db may not be realized because our assumption that reducing the impedance seen by the plate of the first audio tube reduces the gain a like amount pre-supposes that the tube is a generator of the constant current type. If it is a triode this is not true and our anticipated reduction in gain at high frequencies will not be fully obtained. However, the values of resistance and capacity calculated for the high frequency attenuation circuit may be readily varied and the effect noted. It will probably require a lower value of resistance than the calculated 4,000 ohms and possibly a higher value of capacity also. Since these two items are inexpensive it is practicable to construct a capacity of a number of smaller capacity units in parallel so that the total capacity may be readily adjusted, and to utilize a resistor of a continuously variable slide wire type. An appreciable advantage from a high frequency distortion standpoint can frequently be obtained by shunting that portion of the feedback rectifier load resistance which is not included in the grid circuit by a small capacity. If this resistance is 10,000 ohms the value of capacity will be 50 to 200 $\mu\mu$f.

After a considerable amount of feedback has been obtained free from high frequency singing at all percentages of modulation and at all frequencies in the audio band (50 to 10,000 cps) it may be discovered that the transmitter has a tendency to oscillate at very low frequencies or "motorboat" if the amount of feedback is further increased.

The usual remedy for this is to make all interstage blocking condensers in the audio circuit of large capacity and to make the terminating impedance into which the condenser works, a very high resistance. Arranging the feedback loop to omit one audio stage is a big help also. In Fig. 9a the diagram indicates which elements should be altered to minimize the low frequency singing tendency. In Fig. 9b is shown the type of circuit which should be altered, if possible, to avoid low frequency trouble since this circuit will produce a large amount of phase shift at the very low frequencies. If at all practicable, the choke coil coupling impedances should be replaced with resistances. As mentioned previously low frequency singing trouble is rarely encountered unless a large amount of feedback is attempted. However, if it should cause difficulty, a broadening out of the circuits with regard to the low frequency end of the spectrum as mentioned, the reconnection of the feedback loop to omit one audio stage, or as a last resort, the inclusion of a low frequency attenuation circuit in the loop will usually correct the condition. The low frequency attenuation circuit consists of a high resistance shunted by a small condenser. For example, if low frequency singing were encountered at about 14 db feedback and it is desired to operate stably with 20 db of feedback, a device of this kind may be inserted as shown in Fig. 10, making the resistance large enough to give the required attenuation at the "motorboat" frequency and the condenser small enough to be a very high impedance at this frequency and yet large enough to not cause too much reduction in gain over the useful audio band. In the case mentioned the required loss is 6 db. Therefore, the resistance used will be equal in resistance to that used for supplying bias to the grid of the tube. A condenser having a reactance at 100 cps equal to the grid resistor could probably be tolerated without undue sacrifice.

After all singing conditions have been corrected, the envelope wave shape of various modulating frequencies should be observed on a cathode ray oscilloscope at different degrees of modulation. If a moderately large amount of feedback has been obtained and the indicated sing frequency above 30,000 cps, the shape should be as nearly a perfect sine wave as can be told by visual observation up to a frequency of about 2,000 cps and at all percentages of modulation. Above this frequency distortion will undoubtedly become progressively more evident at the higher percentages of modulation. However, no ill effect has been observed due to this high frequency distortion for the principal reason that most of the energy of a speech or music program is contained in the lower frequencies (below 1,000 cps) where feedback action is most effective in its corrective action.

ELECTRONIC ENGINEERING

Geophysical surveying, by which subterranean geology may be explored for valuable oil deposits, has drawn increasingly on the electronic arts. Here are reviewed some of the applications of tubes to the seismic method

---

UP to about twenty years ago the demand for petroleum products was satisfied by the production of crude oil from comparatively shallow oil wells. In recent years the use of petroleum has greatly increased and it has become necessary to tap oil producing strata at much deeper levels. The use of surface geology, which is quite adequate for the delineation of shallow geologic structures, is unsuitable for the determination of the nature of the deeper strata. Therefore, a new technique, geophysics, was developed to extend the depth range at which geologic formations might be determined.

Typical seismic record of geophysical exploration by means of which the contours of subterranean strata may be determined. Reproduced by courtesy of the Petroleum Engineer

Drilling a hole for dynamite. The landscape is typical of Southern Louisiana at the Gulf

Marsh buggy which is used to transport equipment through marshes and swamps

Geophysics has developed into a valuable tool in geologic mapping. Contrary to general opinion, it does not prove or disprove the presence of petroleum, but the knowledge of the geologic structure, gained by the use of geophysics, does indicate whether or not it is possible for petroleum to be present. There are several methods of approach in this new technique, but this article is confined to the problems of the design of field equipment of the seismic branch of the science.

Reflection and Refraction

The fundamentals of seismic geophysics may be illustrated by the following analogy. Several glass plates are laid in a horizontal position, one on top of another, and a pulse of light projected through the several plates. A portion of the light will be reflected and a portion refracted at each of the interfaces. The angles of reflection and refraction are determined by the angle of incidence and the velocities of light in the adjacent layers of glass. This relation is given by Snell's Law.

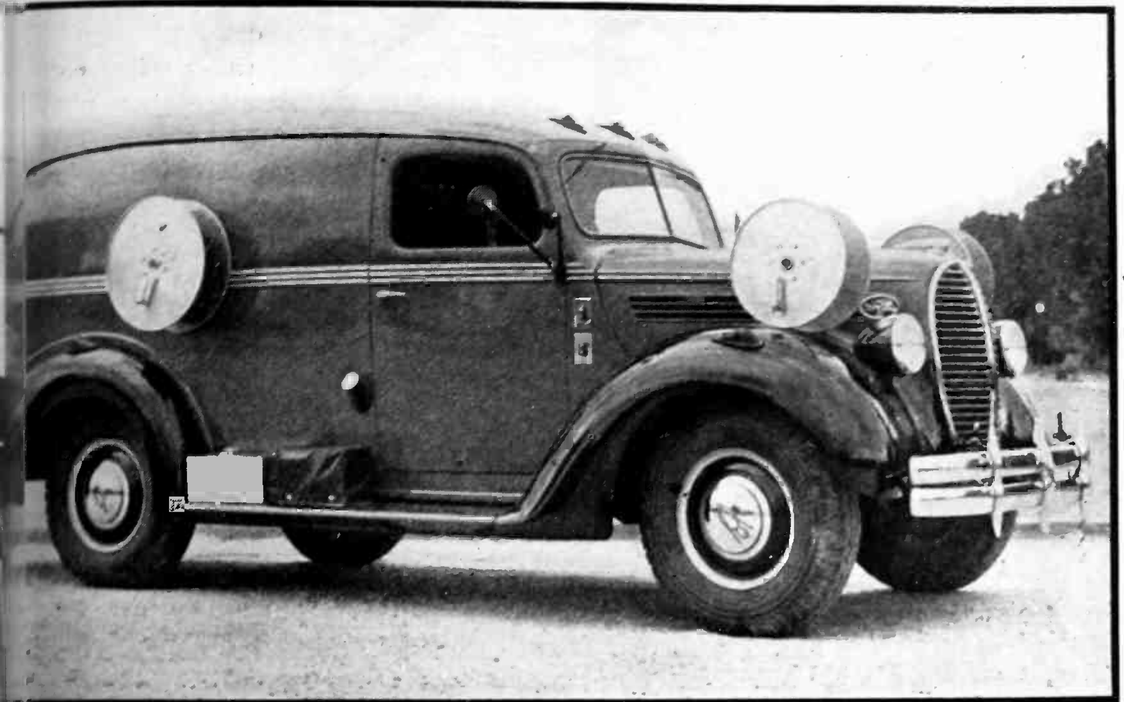
$$\frac{\sin I}{\sin R} = \frac{V_I}{V_R}$$

in which $\sin I$ = sine of the angle of incidence
$\sin R$ = sine of the angle of refraction
V_I = velocity of light in the incident layer of glass
V_R = velocity of light in the refracting layer of glass.

Also from the relationship $Vt = D$, it follows that if the time of transmission of the incident and reflected light beams and the velocity of light in each layer are known, the depth to any reflecting layer may be determined.

In commercial geophysics, sound waves generated by an explosion of dynamite replace the light pulse and geologic strata replace the glass

in GEOPHYSICS



By
FRANK S. McCULLOUGH

The recording truck, the headquarters of operation, from which lines radiate to geophones

Marsh buggy and boat carrying recording apparatus being towed to location by a motor boat

plates of the analogy. The explosion beneath the surface of the ground generates vibrations of a wide range of frequencies, but the range used is from fifteen to sixty cps. From the relation $Vt = D$, it is seen that a definite geometric pattern must be followed in locating the shot point and the earth vibration detector units. The breaking of the firing circuit at the shot instant indicates the zero time point for calculations. The velocity is determined by various methods such as by the use of wells or special shooting patterns.

Field Equipment

The field equipment consists of the following: Several pick up instruments known as geophones buried in the ground according to the shooting pattern (A typical shooting pattern is in the form of an X with adjacent geophones separated by 100 to 200 feet) and the recording truck which contains the amplifiers, recording camera, developing solutions, timing device, communication system and batteries. Geophysical equipment must function under extremely varied and adverse conditions. Normal operation may be in areas of water, mud, swamp, desert, mountains, rocks, brush or forest. Extremes of temperature and humidity and very salty atmosphere may be encountered. There are times when the conditions of terrain prohibit the use of the recording trucks and the recording equipment must be transported by hand, boat or wagons. These conditions impose severe limitations on the equipment as to circuits, components, construction, size and weight.

The geophone, or phone, is used to transform the very slight motion of the earth caused by the explosion into electrical impulses. Two types of phone are used extensively at the present time, the variable reluctance and the dynamic. Both types have a magnetic circuit rigidly fastened to the case and a moving element supported so that it can move freely in the magnetic field. Any movement of the case, as caused by a slight movement of the earth, will cause a relative movement between the fixed and movable elements. In the variable reluctance type of phone, the motion causes a change of reluctance, which in turn causes an induced voltage proportional to the motion of the case. The dynamic type is similar to the dynamic microphone except that it has no diaphragm. The motion of the coil in the magnetic field induces a voltage which is proportional to the motion.

The classes of geophone are further subdivided into the group having the natural frequency of vibration within the useful range and the other group with the natural frequency below the useful range. If the phones are tuned within the band of 20 to 60 cps, they must have almost identical characteristics. They must be rugged enough to maintain their closely identical characteristics during long periods of rough handling. To avoid free oscillation, the correct damping must be provided. Overdamping must be avoided and therefore a good compromise is made by the use of approximately 0.7 of critical damping. Tuning the phones below the useful frequency range, between 5 and 10 cps, gives the advantage of decreased matching difficulties, but results in a less rugged instrument because of the greatly increased spring flexibility. It is necessary in this case to provide stops for the moving element so that the springs will not be damaged because of rough handling.

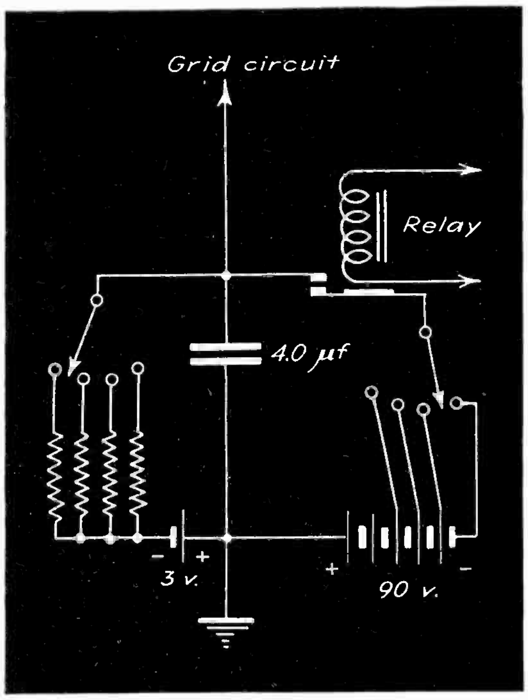
Two methods of damping are used, oil damping and electric damping. The first method has the disadvantage that the viscosity of the oil changes with temperature. Considerable trouble is caused because of the wide range of temperatures encountered in normal operation. Electric damping uses some of the output energy as a dynamic brake, but the loss of energy is more than justified because temperature does not affect the damping factor and it can be readily altered if desired. It is of great importance that the moving element be very light because the energy used for damping is a function of the mass. In the variable reluctance type the weight of the moving element almost prohibits the use of electric damping.

The phones are tested on what is known as a shaking table. The phone is rigidly fastened to a large mass mounted on a flexible mounting so that it is free to move in the horizontal plane. An automobile inner tube serves very well as the flexible mounting. The mass is then driven in the longitudinal direction, relative to the position of the phone, through the frequency range of five to 60 cps and measurements of the geophone's performance are made.

Field Operation

During the survey, the recording truck is placed in a central location and cables to the geophones radiate from it. As many as eight phones may be accommodated by one cable and the composite signal is fed to a single amplifier. The number of amplifier channels used will vary with each particular set up, but the number most often used is twelve, or a total of 96 geophones to pick up the signals from one explosion. From the amplifiers the signal is fed to the recording galvanometer and camera. To provide a means of timing the signals, a precision tuning fork of 50 or 100 cps is connected to the recording unit. The complete record of one shot is made in from two to four seconds.

An illustrative record or seismogram is shown. The signal from each



Time delay circuit which increases the gain of the amplifier shortly after the explosion

cable together with the timing signal are recorded simultaneously. With a knowledge of the locations of the shooting points and geophones with their cable connections, and by properly interpreting the curves of the seismogram, it is possible to determine the nature of the subterranean strata. This in turn indicates the possibilities of the presence of oil.

For computation of the required amplifier gain the minimum earth displacement which is useful in these measurements is taken as 10^{-8} cm. The sensitivity of the galvanometer used indicates that a gain such as provided by three to five tubes is suitable. A filter to pass the band from 20 to 60 cps is incorporated in the amplifier. It is also desirable at times to have a response with variable band widths and variable peaks. When a shot is fired, the first waves to reach the phones have tremendous energy and may cause the system to overload if the gain is set at the maximum necessary for the deeper reflections. It is therefore necessary to have some means of setting the gain at a low level for the initial wave and increasing it for the succeeding waves. This can be done by a manually operated control in the signal circuit. The voltage decay curve of a battery-resistor-condenser circuit as shown in the diagram. The relay is closed by the operator to reduce the gain just before the shot is fired. The shot is fired and the relay is closed at the same instant. The time delay before the gain is increased is determined by the voltage applied by the battery and the resistance across the condenser. An automatic gain control is now being developed to give full control under all conditions.

The frequency of the timing element must not vary more than plus or minus one-half cps from the rated frequency. This accuracy is easily attainable if the tuning fork is mounted properly. The fork with its driving and pickup units are rigidly fastened to a heavy base which is spring mounted to the protective case. The characteristics of the mounting springs are such that the fork is completely isolated. If the fork is incorrectly mounted, the frequency of vibration may be decreased by as much as 20 per cent. The driving and pickup units are both of the magnetic type, mounted on opposite tines of the fork.

Line- or radio-telephone is used for communication between the operator and the shooter and also for carrying the zero time pulse from the shooting circuit to the recording unit. In some localities such as swamps, carrying a telephone line is a back-breaking and sometimes an impossible task and radio is the only reasonable method of communication. The FCC has assigned several channels for geophysical work in the 1600-kc and the 30-Mc regions. The function of carrying the zero time impulse is very important and care must be taken to see that sharp, distinct time breaks are given. This can be done by having the surge trip a gaseous triode such as the 884.

In designing equipment for geophysical work, the operating conditions must be kept in mind. All parts such as resistors, condensers and vibrators must be securely strapped down. Resistors and transformers must be especially impregnated to withstand the ravages of moisture. Wire insulation must withstand the salt air, mildew and appetites of ants. All screws and nuts must be secured with lock washers and all moving parts be dirt proofed.

Many of the difficulties described herein have been successfully overcome. A degree of sensitivity has been reached that the crawling of an ant near a geophone will be in evidence in the record and all work must cease while trains or highway traffic are in the vicinity.

Coaxial Line Installation—II

Concluding his treatment of coaxial line installation procedures, Mr. Epperson discusses above-surface and below-surface installations, and the protection of the line from lightning strokes and sustained arcs

By J. B. EPPERSON

Chief Engineer
Scripps Howard Radio, Inc.

Fig. 11—A clever expansion system in use at WMPS, consisting of a loop in the line

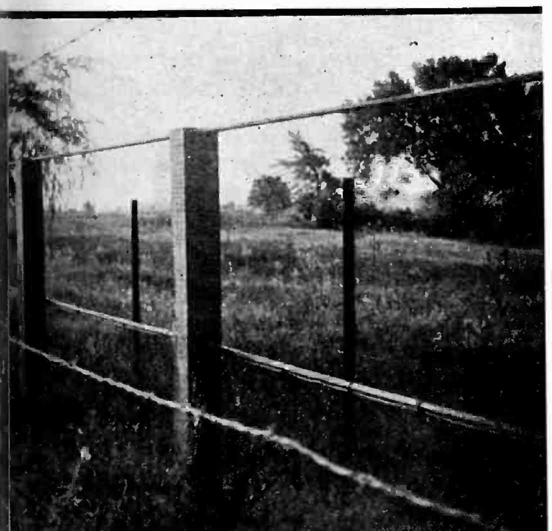


Fig. 12—A 7/8-inch line mounted on slotted posts to allow free movement under expansion or contraction

IT IS common practice to fill concentric lines with dry or oil-pumped nitrogen which is maintained at a pressure of from 5 to 45 pounds per square inch depending upon the size line and the power at which it is operated. Nitrogen gas greatly increases the power handling capacity of the line; for each atmosphere (14.7 lbs.) of nitrogen gas added, one can double the voltage through the line. In addition, the gas prevents water from seeping into the line should a leak develop and aids in detecting leaks when they occur.

Where a line is gas filled, the gas may be introduced at any convenient point along the line. Usually this connection is made inside the transmitter building. One method of making the connection is by means of a tee and reducing bushing (see Fig. 2, Part I) connected in the line and fed from the gas tank by a standard ¼-inch brass pipe. The nitrogen cylinder is connected to the ¼-inch feed line with $\frac{3}{16}$-inch single ply welding hose.

Testing and Drying the Line

After all soldered joints have been completed, the line should have gas admitted slowly until the pressure is brought up to about 30 pounds. All joints should then be tested with liquid soap for leaks. If no leaks are discovered, the pressure may be raised to approximately 50 pounds and all joints and end seals re-tested. The gas should always be admitted slowly, especially in small diameter or long lines. It may take some time for the entire line to reach a uniform value of pressure due to the obstruction to gas flow caused by the insulators. If any leaks are in evidence after testing, it will be necessary to allow all the gas to escape from the line before an attempt is made to resolder the defective joints.

Surface Versus Underground Installation

A concentric line may be installed either by burying it below the frost level or by supporting it above the surface of the ground. Each method has its advantages and disadvantages. Surface installation reduces initial installation expense, facilitates installation in rocky or swampy areas and provides immediate accessibility to the line for repairs in case of trouble. On the other hand, the line must be provided with expansion joints to take care of expansion and contraction and the pipe and mounting present an obstruction above ground.

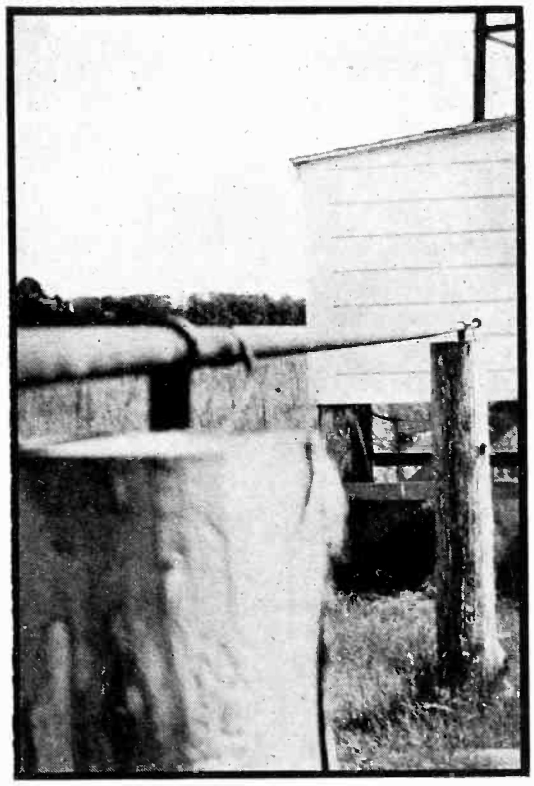


Fig. 13—Free-running mounts used on wood poles at WIS, in a typical above-ground installation

The underground installation eliminates the unsightly exposed pipe and supports, does not present a surface obstruction, is protected from mechanical injury and eliminates the necessity for expansion joints. The obvious disadvantage is that in case of failure of the line, it must be dug up for repairs.

Where a concentric line is installed above ground and the length exceeds 100 feet, some form of expansion joint should be used or one or both ends of the line left free. The line should be supported in such manner as to allow free movement throughout its length. Due to ambient temperature changes the inner conductor may contract or expand at a different rate from that of the outer conductor. For this reason it is desirable to allow for inner conductor expansion independent from that of the outer conductor.

A typical expander fitting (see Fig. 8, Part I) is manufactured by Doolittle & Falknor, based on suggestions from Mr. Scott Helt, Chief Engineer of WIS, Columbia, S. C. The operation of this expander fitting is explained by Mr. Doolittle as follows:

approximately 1½ inches in one direction or ¾-inch in either direction from the normal position. The normal position is, of course, where there is no pressure exerted by the inner conductor in either direction.

Another type of joint which permits proper expansion of both outer and inner conductors is manufactured by the E. F. Johnson Co. A special packing is used to retain the gas. This packing insulates one section of the outer conductor from the other and therefore, a special spring connection is used for making the electrical connection between the two outer conductor sections. Inner conductor expansion is made possible by a special spring connection which allows this conductor to follow the movement of the outer conductor.

This expansion fitting has a travel

of the 370 foot line. Figure 12 shows how the ⅞-inch line at this installation is supported above ground on slotted wood poles spaced eight feet apart.

Similar expansion joints with a similar method of mounting has been used on a ⅞-inch 500 foot line at WNOX, Knoxville for the past 20 months. No trouble whatever has arisen due to contraction and expansion difficulties.

In any installation where the line is placed above ground, care should be exercised to see that the line may move freely throughout its length. Figure 13 shows how this problem was solved by Mr. Scott Helt at WIS. As shown in the photograph, this line is mounted on wood poles and secured by mounting brackets which are obtainable from manufacturers of transmission lines.

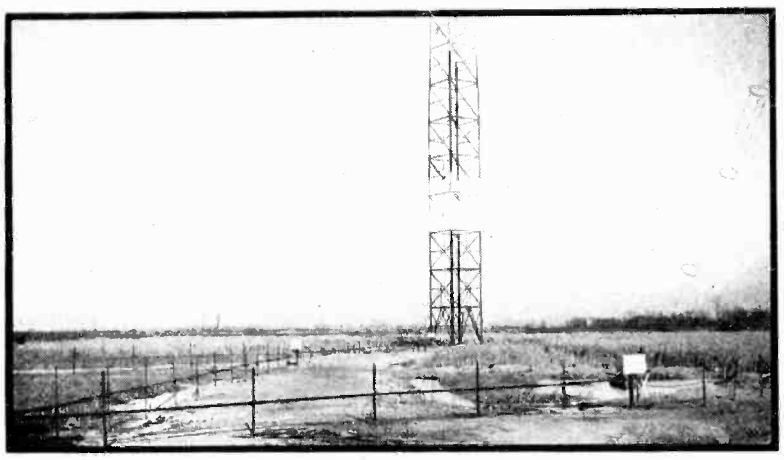


Fig. 14—Above-surface installation at WHIP. Ordinary steel fenceposts, used for support, have enough "give" to allow expansion

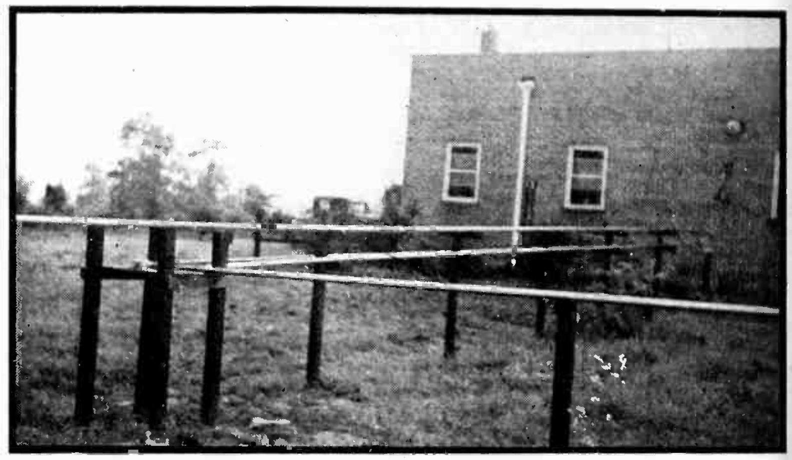


Fig. 15—A large diameter line (1-⅝ inch) at WAPI consists of branch feeders to two elements of a directional array

This attachment permits the inner conductor to expand or contract independent from the outer conductor. It consists of a small bellows approximately 3 inches long and 1½ inches in diameter and is screwed on to the brass fitting in the center of the insulator where the inner conductor is normally soldered. When this fitting is installed, the inner conductor is extended throughout the brass fitting to the outer end of the bellows attachment where it is soldered. It is not soldered at the brass fitting on the insulator. The bellows attachment is usually installed at the factory but it may also be done in the field. In either case installation consists merely of screwing the attachment on to the brass fitting, sealing it at this point with Crane plumbing cement and soldering the inner conductor onto the outer end with streamline solder. The overall obtainable movement is

of 3 to 3½ inches but it is recommended by the manufacturer that enough expansion joints be used so that the travel does not exceed 2 inches. For a total extreme temperature change of 160 degrees F., one expansion joint per 100 feet of line should be used. For a total extreme temperature change of 110 degrees F., one expansion joint per 150 feet of line should be used.

Figure 11 shows still another simple arrangement for taking care of the contraction and expansion problem in a ⅞-inch line. This loop expansion joint was installed by the writer at WMPS, Memphis. A single turn cut from a 50-foot coil of soft-drawn line is used and made to serve as a right angle bend. As the line contracts or expands, the circular section opens or closes by the required amount. A similar expansion joint is provided at the entrance to the antenna tuning unit

The brackets are greased monthly to keep friction to a minimum. At this installation the ends of the line are left free and the line enters the transmitter building and tuning house through a special bushing made from a section of conduit and filled with oil waste.

Figure 14 shows the coaxial cable installation at WHIP. This line is 1⅝-inch in diameter and is supported on iron fence posts spaced approximately 10 feet. This is a very practical and economical installation since the fence posts are very cheap and are easily driven into the ground. In this particular installation there is sufficient give at the ends to take care of expansion. Figure 15 shows the method of supporting a 1⅝-inch coaxial cable above ground at WAPI, Birmingham, Ala.

Underground Installation

If the line is installed from three

to four feet underground (below frost level) it is usually not necessary to worry about contraction and expansion difficulties. The installation procedure for an underground line is covered essentially by the general installation instructions. It is advisable, however, where the line is placed underground, to protect it by tile or wood duct. Figure 16 gives a drawing furnished by Mr. Ben Ackerman, Chief Engineer, WGST, Atlanta, of the ⅞-inch line installation at that station. This drawing shows the method used by Mr. Ackerman in placing the transmission line in cresote wood duct. The duct was split so that the two halves could be assembled after the line installation was complete. This 340 foot line is not fastened at any point and the entire length of line can be withdrawn for repairs in case of failure.

The following paragraphs appeared in an article by Mr. Raymond F. Guy in the July 1938 issue of *Broadcast News*. The material was found so appropriate to the subject of this paper that special permission was obtained to reproduce it here. The material has reference to the 2.125 inch coaxial installation at WRC, Washington:

"The WRC line is buried a minimum of three feet in the earth. The experience gained in connection with making the buried line gas-tight may be of interest to readers of these pages. The first attempt to make it gas-tight was with the use of ordinary solder and blow torches at the joints. Sections of 40 feet were connected together in the transmitter building, where soldering conditions were best, and then moved to the trench for assembly to adjacent sections. It was found that when joined with ordinary solder the sections could not be moved appreciably without leaks developing. Accordingly the attempt to solder sections together in the transmitter building was abandoned and the entire line was assembled in the trench. The sections were suspended by 2-by-4's laid across the trench and the complete line was lowered into position simultaneously after assembly.

"A few joints had been made in the line before the use of ordinary solder was discontinued in favor of a much harder product containing silver. The temperatures required for hard soldering were very much higher but the joints were much stronger and once tight would remain so. The joints were all completed with hard solder before leakage tests were made. Despite careful workmanship and close inspection of each joint by several interested people, over a dozen severe leaks were found.

"Coarse leaks can be found by the use of liquid soap but it was found that this method is not satisfactory for discovering those minute leaks which make the difference between a line which is tight and one which is not. The final operations consisted of closing small leaks caused by minute glow holes in the castings. Such leaks cannot be detected by any practical method except immersion in clean water. The line maintained 40 pounds pressure, with no loss for three days, before it was finally placed into position and covered. At the end of the next five weeks there was still no loss so the pressure was reduced to normal. In final position the line rests on planks and is protected by split tile."

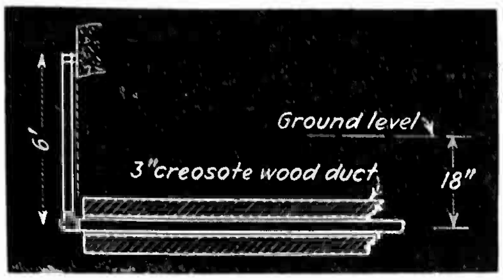


Fig. 16—A duct of creosoted wood, split in the middle, is used to house the underground line at WGST

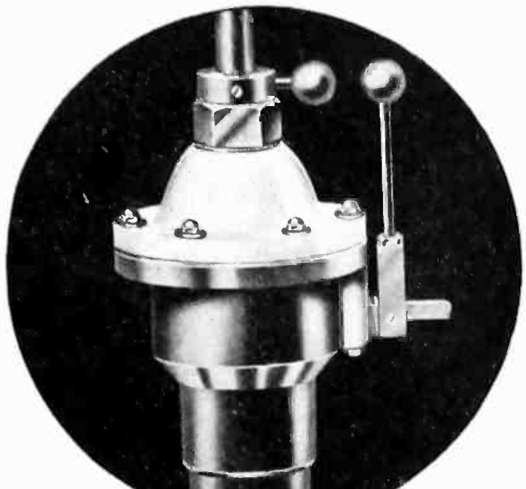


Fig. 17—Typical safety gap installed on coaxial line end-seal

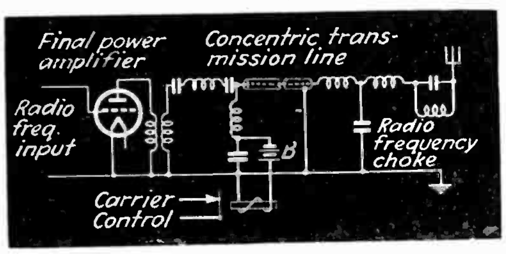


Fig. 18—Protective circuit to disconnect power following arc-over, to break sustained arc

Lightning Protection

A considerable amount of damage caused by lightning to transmission lines and coupling apparatus is brought about by too wide a spacing on the tower base lightning protective gaps. Where this condition prevails a direct hit to the tower or a hit in its immediate vicinity may cause voltages to be induced in the tower which are of sufficient magnitude to damage seriously apparatus in the antenna coupling unit and the concentric line. For this reason it is very essential that the tower gap spacing be sufficiently close to provide effective lightning protection. This reasoning does not apply, of course, to the shunt-fed antenna which, with its direct ground connection, helps to avoid troubles caused by lightning.

For additional protection of transmission lines from lightning discharges, arc gaps should be provided on the end of the line next to the antenna, and, in case of lines approximating one-half wavelength or longer, additional gaps at the transmitter end of the line are recommended. Figure 17 shows the method used by the Isolantite Company for mounting the gap spheres directly on the end terminal of the line. The spacing of the gaps will depend upon the power at which the line is operated. For a ⅞-inch line operated at 5 kw power, ⅛ inch has been found to be a satisfactory spacing. With powers below 5 kw, the spacing can be further reduced in proportion.

If the power output of the transmitter is sufficiently high, an arc once established across a ball-type gap by a lightning discharge or other disturbance, will be sustained by the r-f transmitter power and will continue to burn until the r-f power is cut off or until the arc burns itself clear. Standing waves may also be set up along the concentric line feeder due to the resonance of the tuned circuits having been destroyed by the arc. This may result in a flashover at a voltage maximum point along the line with a consequent burn-out of the line. The obvious remedy for this condition is to provide a means for clearing the arc immediately after it has been struck by a surge voltage. The arc may be cleared by the use of power interruption circuits which will interrupt the r-f power momentarily each time the gap terminals are arced over, or by a specially designed horn gap which will be described.

Figure 18 shows a protective circuit which is especially suited for use with coaxial cables. This circuit was developed by the Bell Telephone Laboratories and the circuit diagram appeared on page 59 of the May 1938 issue of *Electronics*.

It will be noted from the Figure that a high impedance r-f choke, a relay and a battery are connected in series between the outgoing end of the transmission line and ground. The contacts of the relay are connected to the transmitter in such manner as to provide carrier cut-off when the contacts are opened and immediate restoration of the carrier when the contacts are again closed. Normally the d-c potential from the battery is isolated from ground and the relay contacts are closed. If an arc occurs to ground at any point between the transmitter end of the line and the antenna circuit, the d-c battery current follows the arc to ground and operates the relay. This in turn interrupts the carrier power momentarily thus extinguishing the arc, opening the circuit to the relay, allowing the relay to close its contacts and finally restoring transmitter power. In the circuit shown, the protective device is connected to a transmission line which employs a harmonic filter at the transmitter end and a "T" matching network at the antenna end of the line. In this case, the harmonic filter serves to isolate the d-c potential from ground. In transmitters where a harmonic filter or series condenser is not already in use, it will be necessary to insert a low reactance condenser in series with the line to its coupling coil. The added condenser may be compensated for by a slight re-adjustment of the coupling turns. It will be noted also that the antenna series condenser is bridged by a high impedance choke to provide a low resistance path for the d-c battery current. With this arrangement no static drain choke can be used directly from antenna to ground at the tower but a static drain path is provided through the transmission line and protective apparatus.

Self-extinguishing Type Spark Gap

Another method of lightning protection by means of a self-extinguishing arc horn gap arrangement is shown in Fig. 19. The drawing and description is taken from an article by Mr. J. E. Young which appeared in *Broadcast News* for November 1937. The figure shows the dimensions and methods of installation of the horn gap which is designed to clear the arc which follows a static discharge. The angle made by the horn surfaces is such that any arc is extremely unstable and tends to travel rapidly up both horns until it reaches a gap too great for it to sustain itself. It will be noted that a 2 turn inductor is placed between the lead-in insulator and the antenna tuning equipment. This inductor serves to increase the effective impedance of the circuit to steep wave fronts such as that developed by lightning hits. This effect results in a more rapid build up of voltage across the horn gap and consequently the gap breaks down more rapidly than would otherwise be the case. Mr. Young points out that a gap adjustment of ⅛-inch will not break down under a stress of 5,000 volts and therefore may be used with most conventional antennas for powers up to 5 kw. Mr. Young also mentions the fact that in addition to the tower horn gap, it is highly desirable to employ the same sort of protection on transmission lines to safeguard them from voltages induced in the system by pick-up from the antenna and to provide additional protection against direct hits. If the line is more than 500 feet in length, horn gaps should be provided at each end of the line. A static drain choke should be connected between the transmission line and ground unless a static drain path is provided through coupling coils or other apparatus.

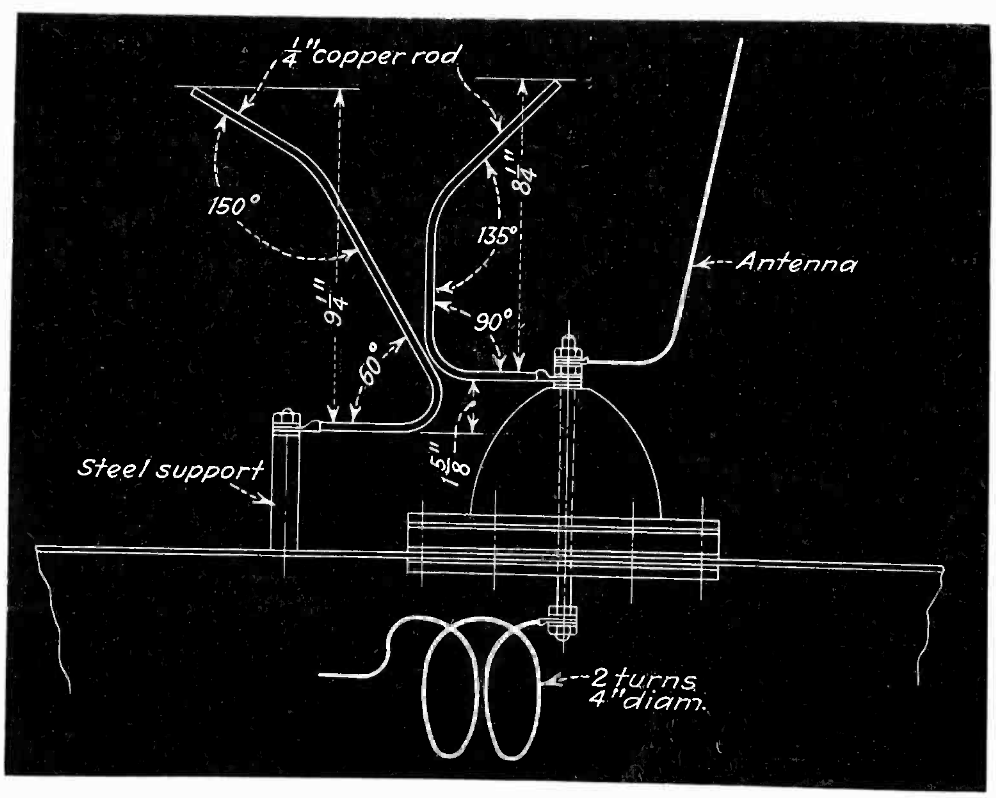


Fig. 19—Dimensions of horn gap described by J. E. Young, which breaks sustained arc automatically as the arc climbs upward

The writer wishes to take this opportunity to thank Mr. J. R. Wightman of the Mueller Brass Co. for the use of material regarding Streamline solder fittings and their installation. He desires also to thank those stations which returned the concentric line questionnaires thus making possible the tabulation on concentric line operation; Mr. Ben Akerman and Mr. Scott Helt for specific information regarding their line installations; and the following manufacturers of concentric lines: Mr. Victor J. Andrew, Isolantite, Inc., Communication Products, Inc., Doolittle & Falknor, Heintz & Kaufman and the E. F. Johnson Co. for the use of material contained in their bulletins and for the photographs used in the illustrations.

Condenser-Lead Resonance Chart

More effective use of capacitors in radio frequency circuits may be made if the series resonance of the units with their leads is taken into account. The chart (reverse side) shows measured values of such resonant frequencies

By R. L. HASKINS

Tobe Deutschmann Corporation
Canton, Mass.

A MEANS of applying well known but hitherto little used principles to the selection of capacitors for radio frequency circuits is suggested by the data graphically presented in Fig. 1 (reverse side). The principle involved is that for any frequency, there is a series combination of inductance and capacitance which will provide minimum impedance and consequently, maximum filtering or by-passing effect and that the inherent inductance of a capacitor and of its connecting leads may be utilized to secure series resonance at the desired frequency. The data from which the curves of Fig. 1 were plotted were secured by measuring the resonant frequency of a quantity of commercially constructed, non-inductively wound, tubular capacitors with various lengths of #18 bare tinned copper connecting lead.

Tests on paper capacitors of standard construction indicate that the residual inductance of such capacitors is approximately the same regardless of the voltage at which the unit is designed to operate. For condensers with ratings of 200 to 800 volts, tests show residual inductance in the order of 7–10 millimicrohenries. Since this inductance is usually small in comparison to the inductance of the leads, the accompanying curves may be considered practical for use in connection with condensers of any normally employed voltage rating.

Through the use of these graphs, it is possible to choose the value of capacitance vs lead length that will provide maximum $C{:}L$ ratio and thus secure maximum width of frequency band in which effective filtering or by-passing is secured. For example: series resonance at one megacycle results from the use of a 0.05 μf condenser with 10 inch leads on each side or from the use of a 0.5 μf condenser with 1 inch leads on each side. Obviously, the selectivity of the former circuit will be much greater than that of the latter so that if mechanical considerations permit the use of the shorter lead better performance will result.

This point is graphically illustrated by the curves given in Fig. 2. It will be seen that, although capacitances of 0.1 μf and 1.0 μf provide the same peak attenuation when each is adjusted for resonance at the same frequency, the effective band width covered by the 1.0 μf section is much greater than that covered by the 0.1 μf section. This allows more effective filtering through the desired range of frequencies. Although the 4.0 μf curve shows good filtering characteristics at frequencies between 500 and 2,000 kc, in practice it is difficult to resonate this value of capacitance at 1,000 kc due to the extremely low value of residual inductance necessary for resonance. Analysis of Fig. 1 shows that a 4.0 μf condenser has a resonant frequency of approximately 620 kc.

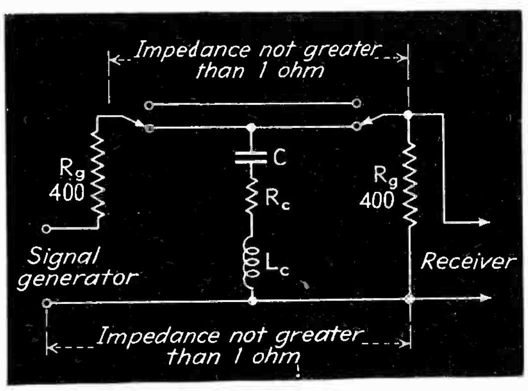


Fig. 3—Circuit for measuring effectiveness of filter action

In utilizing these graphs in design work, it is important to note that the condenser leads must be of equal length for each side of the condenser because the use of unequal lead lengths will materially alter the resonant frequency. Although the test specimens with which the data was secured had bare wire leads, the use of insulated wire or of wire differing considerably in cross sectional area does not seriously affect the performance of the capacitor.

To determine the effectiveness of a condenser as a filter unit, the circuit shown in Fig. 3 is employed. This provides a convenient method of determining not only the condenser's resonant frequency, but also its attenuation characteristics. In this circuit the attenuation becomes.

$$\text{Atten (db)} = 20 \log_{10}\left(1 + \frac{R_g}{2Z}\right) \qquad (1)$$

$$= 20 \log_{10}\left\{1 + \frac{R_c R_g \omega^2 C^2}{2\left[R_c^2\omega^2 C^2 + (\omega^2 LC - 1)^2\right]} - j\,\frac{R_g \omega C\,(\omega^2 LC - 1)}{2\left[R_c^2\omega^2 C^2 + (\omega^2 LC - 1)^2\right]}\right\} \qquad (2)$$

when $j\omega L = \dfrac{-j}{\omega C}$ and $R_g > R_c$

$$\text{Atten} = 20 \log_{10} \frac{R_g}{2R_c} \qquad (3)$$

If R_g is chosen at approximately 400 ohms, the peak attenuation frequency can be easily determined and attenuations up to 80 db can be measured.

Another application for this circuit is in the calculation of effective series resistance at resonance. The formula for this calculation is

$$R_c = \frac{R_g\, E_2}{2\, E_1}$$

Attenuation tests on high grade commercially manufactured non-inductive condensers indicate an average series resistance value of approximately 0.02 to 0.05 ohms. Since it has been found in practice that any loss in filtering efficiency is usually the result of high contact resistance between the lead and the condenser itself, the importance of measuring effective series resistance is apparent.

Condenser Lead-Resonance Chart

By R. L. HASKINS
Tobe Deutschmann Corp.

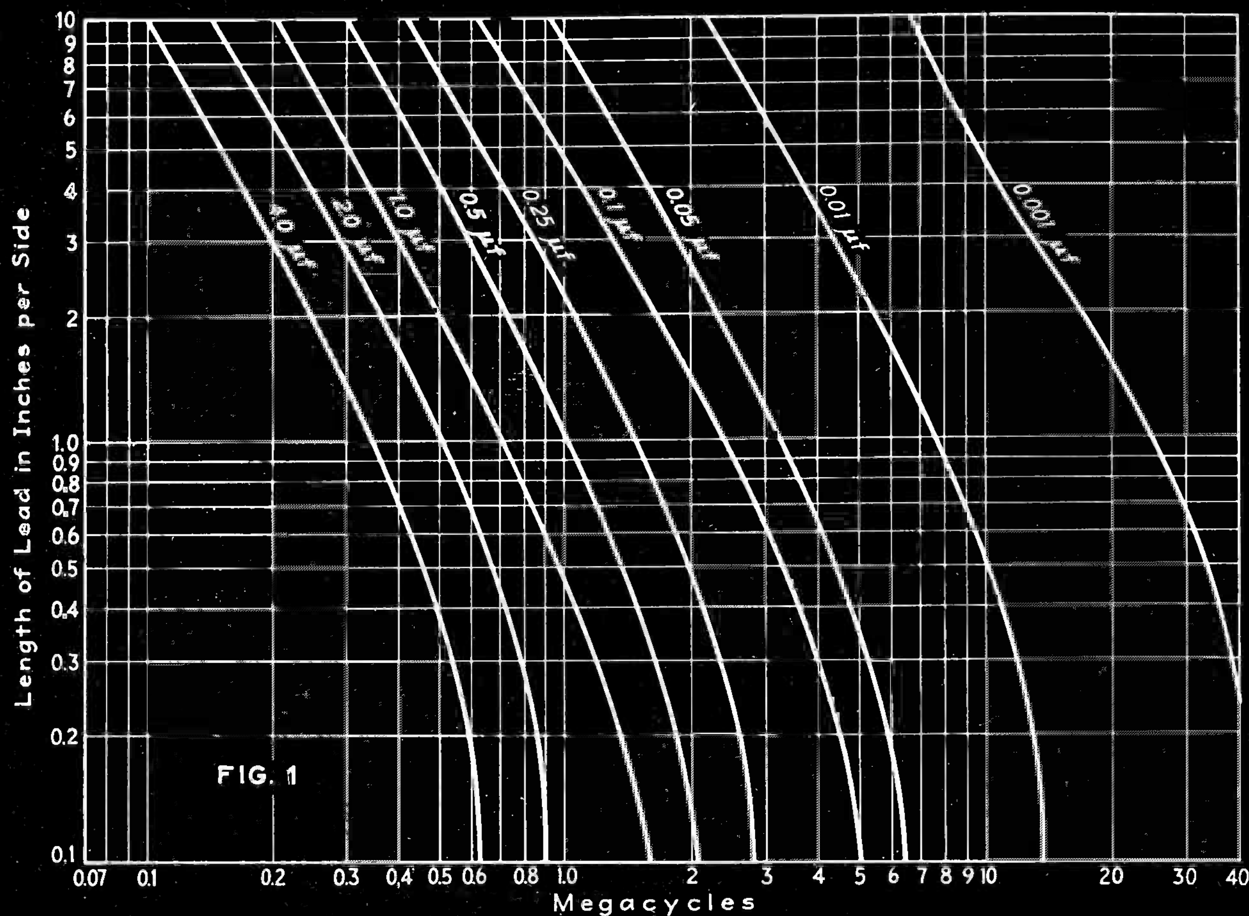


FIG. 1

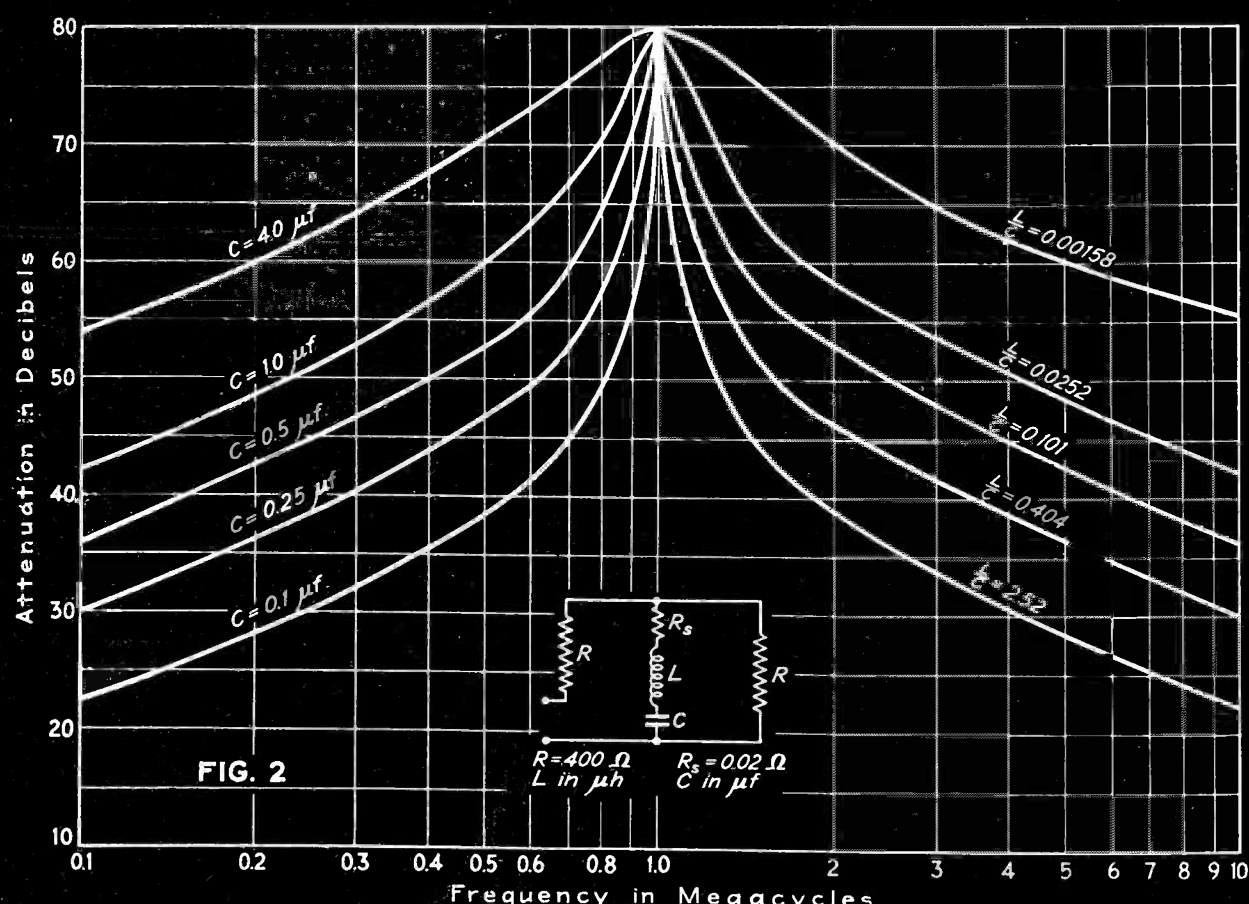


FIG. 2

NEW BOOKS

Electron Optics—Theoretical and Practical

By L. M. MYERS, *Research Department, Marconi's Wireless Telegraphic Co. Ltd. D. Van Nostrand Co., Inc., New York, 1939. 618 pages, 379 illustrations. Price, $12.00.*

For years it was a deplorable fact that no book on electron optics was available in English, while several good treatises existed in other languages. Now it appears that this lack has been well filled. The first book in English to appear (Electron Optics in Television by Maloff and Epstein) has already been reviewed in these columns; its emphasis is mainly on the problems of applying electron optical principles to the practice of television. Dr. Myers' book is somewhat broader in scope and occupies more than twice the number of pages. Beyond this, comparisons would be odious. Both books serve admirably their intended purpose.

The subtitle "Theoretical and Practical" is a good description of the book, since the author throughout has maintained an excellent balance between the theory of the subject and its application in television, in electron microscopy, in electron multipliers and in image transfer devices. Moreover the author has elected to use a very logical method of presentation, namely, to bring forward ordinary optical principles and their electronic analogs side by side (rather than the alternative method of stating the ordinary optical principles briefly and once for all). As a result the book is made very much easier to read for those who have a knowledge of ordinary optics.

By now most electronic engineers are well aware that the study of bodies in motion in three dimensions requires familiarity with the notation of three dimensional vector calculus, and those who cannot or will not follow demonstration in these terms had best leave the book alone. But with this background available, the book is as clear and as easy to read as the subject allows.

The work is divided into eight chapters. The first treats the analogy between electron motion and light rays, and states in simple terms (after demonstrations) the six analogous quantities: conditions for rectilinear propagation; refraction and reflection at boundaries; chromatic dispersion and aberration; diffraction; wavelength and frequency; transverse nature of waves. The next chapter, over 100 pages in length, treats the trajectory of electrons in magnetic and electric fields. This chapter is extraordinarily complete; equations in four coordinate systems (Cartesian, curvilinear, spheroidal and meridian forms) and conformal representation are set forth completely. Practical methods of determining and plotting electron trajectories are described.

The third chapter deals with electron lens, and here again 100 pages are devoted to an exhaustive demonstration of lens types side by side with their optical analogs. The several types of electrostatic lenses (cylindrical, immersion objective, etc.) are analyzed and their characteristics plotted. Magnetic methods of focussing, and the effects of gas in the transit space are treated. Following in logical order is a chapter on the aberrations peculiar to electron optical systems, many of which are of interest at present (or should be) to the designer of television cathode-ray tubes. Defocussing with control grid potential and similar items are discussed from a practical point of view.

The following chapter, on the electron multiplier, is one of the first collections of information on this important subject to appear in print. The Marconi Company (Dr. Myer's employer) has been very active in developing multiplier structures and the chapter shows good evidence of this experience, but not to the exclusion of the work done by Farnsworth, Slepian and Zworykin in this country. Another chapter deals with the important applications in electron microscopy, and this chapter is illustrated with excellent examples of images obtained from various forms of microscope. The concluding chapter is on miscellaneous applications, including the image-transfer devices (electron telescopes) and the various pick-up devices used as camera tubes for television. Cathode-ray tubes for television, both of the conventional and projection forms are also treated. The book is a most important addition to the literature of electronics.—D. G. F.

• • •

Getterstoffe und Ihre Anwendung in der Hochvakuumtechnik

(Getter Materials and Their Application to High-Vacuum Technique)

By MARTIN LITTMANN. *C. F. Winter'sche Verlagshandlung, Leipsig, 1938. 103 pages, 45 illustrations.*

This small volume deals with modern getter materials and their application primarily from a practical point of view. After a brief review of the development of getter materials for highvacuum technique, a study of the physical and chemical requirements which modern getters must satisfy is made which clearly indicates the pre-eminence of the alkaline earth metals, barium in particular, as getter agents. Methods for making barium containing getter reasonably stable in air, such as by admixture with more stable protective metals and by metallic sheathing of a pure barium core, are discussed. The specific application of various methods of assembly and exhaust techniques to a large variety of tubes, such as receiving, small transmitting, photo-cells, cathode-ray, gas-filled, etc., is discussed in considerable detail. A special section is devoted to the gettering of metal tubes, including the recently developed "batalum" getter process. Two tables give the form, composition and weight of commercially available getters and complete getter assemblies. Considerable space is devoted to the problems of storing and the handling of getter in air during fabrication.

No attempt is made to present the basic physical and chemical phenomena; indeed the few references in the bibliography indicate the scarcity of publications in this field. An index of important patents is included to supplement the bibliography. Although a large portion of the material is treated from a continental point of view and is hardly adaptable to American practice, nevertheless this book will be useful to tube engineers, physicists and others.—HAROLD HEINS

• • •

Aeronautic Radio

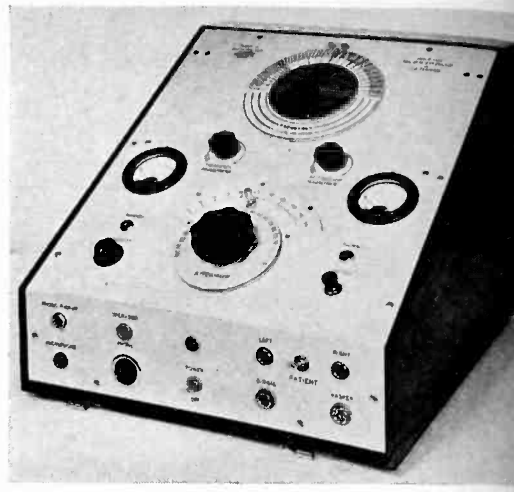
By MYRON F. EDDY, *U. S. N. Ret. Chief Instructor in Aircraft Radio, Stewart Technical School. The Ronald Press, New York, 1939. 502 pages, 178 illustrations. Price, $4.50.*

THIS BOOK is a manual for operators, pilots and radio mechanics, who must install, use, and maintain aircraft radio equipment. Within this domain it does a creditable job of supplying the information such men must have to obtain the most effective radio service. The treatment of fundamentals is elementary, (some algebra and trigonometry are used, but are not essential to an understanding of the text). For the general reader in the electronics field, the book is interesting because of its detailed information on operating procedures and radio navigation. The chapter headings include: Aviation Radio Communications, Fundamentals of Electricity, Radio Electricity, Radio Circuits, Radio Tubes, Batteries, Power Supplies, Radiotelegraph Transmitters, Radio Range Beacons, Radiotelephone Transmitters, Receivers, Direction Finders, Instrument Landing Systems, Radio Traffic Control, Installation of Equipment, Maintenance, Appendices (Symbols and Definitions).—D.G.F.

(*Continued on page* 50)

TUBES AT WORK

A SUPERHETERODYNE with a constant-frequency oscillator, an audiometer design, improvements in RC filters, and a novel diversity receiver



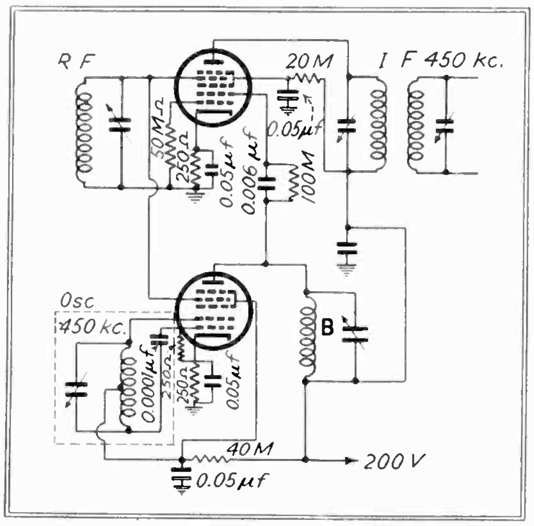
View of the audiometer described by Mr. Penther

Constant Frequency Superheterodyne Receiver

By Braulio Dueño

Mayaguez, Puerto Rico

In a conventional superheterodyne receiver, the frequency of the local oscillator is varied so that it is equal to the frequency of the incoming signal



Circuit of the constant frequency superhet

minus the frequency at which the intermediate frequency transformers are designed to operate. In the receiver circuit described here, the frequency of the oscillator is kept constant for all incoming signals and is numerically equal to the frequency at which the i-f transformers operate. The incoming signal is fed to the grid of the top 6A7 which is used as a mixer and also to the grid of the bottom 6A7 tube which is used as a frequency converter. The output of this latter tube is fed to the mixer grid of the first 6A7.

Thus, if f is the frequency of the incoming signal and 450 kc is the frequency of the local oscillator and if the i-f transformers also operate at 450 kc, then the frequency at which the incoming signal is finally converted is

$$f - (f - 4950) = 4950,$$

in which the quantity in the parenthesis is the operation performed by the lower 6A7 tube. It is evident that in the plate circuit of the converter tube there will be present the following frequencies:

$$(f - 450),\ (f - 450),\ 450$$

and others of minor importance. The purpose of the tuned circuit (marked B in the diagram) in the plate circuit of the converter tube is to select only $(f - 450)$ so that this frequency only is fed to the mixer tube. It is also evident that the top 6A7 tube could be advantageously substituted by a 6L7 pentagrid mixer tube.

The advantages of this superheterodyne circuit are:

(1) No troubles due to the inability of the local oscillator in the ordinary superheterodyne, to oscillate satisfactorily at the very high and very low frequencies;

(2) No frequent shifting of the tuning dial (due to frequency drift of oscillator) is necessary. If the frequency of the oscillator section of the lower 6A7 is controlled by a quartz crystal, this receiver's performance can be greatly improved.

In the diagram, the details of the tuned r-f amplifier circuit and of the i-f amplifier have been omitted, since, any conventional circuits will operate satisfactorily.

• • •

A Modern Audiometer

By C. J. Penther

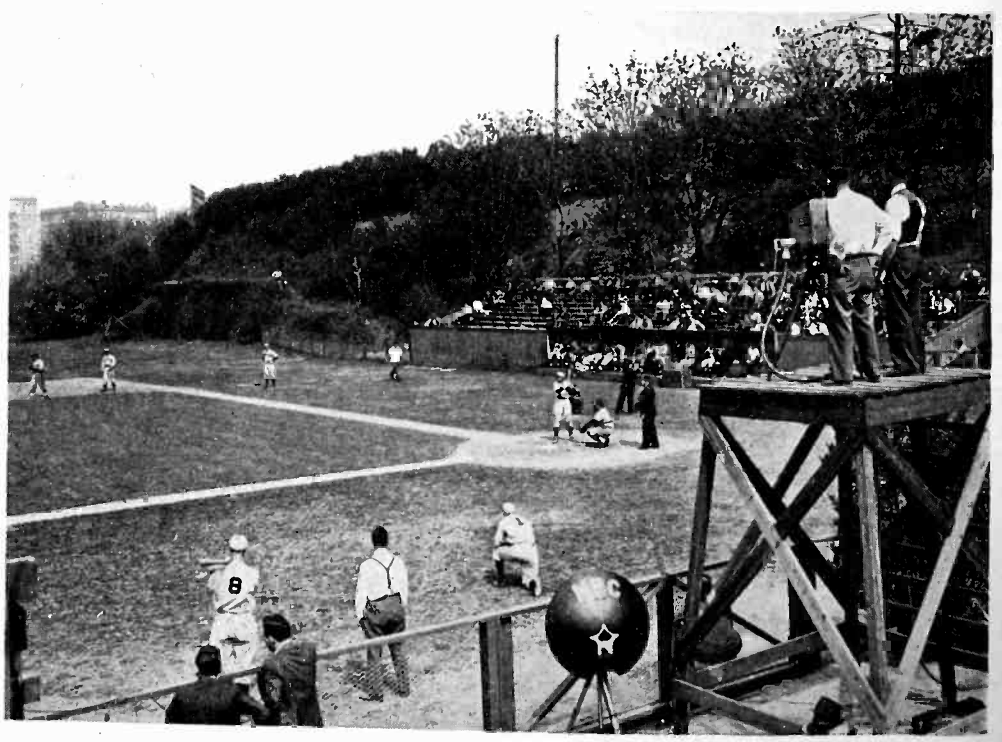
Audiometers are used to measure hearing acuity and several types are available depending upon the use to which they are put. One type is used for group testing in schools, another for simple tests on prospective employees in industry and a third type is used by an otologist to obtain a complete audiogram of the hard of hearing patient in order that he may prescribe the hearing aid which will best help the patient's hearing deficiency.

It is for the third type of audiometer that the Subcommittee on Audiometry and Hearing Aids of the Sectional Committee on Acoustical Measurement and Terminology of the Acoustical Society of America has set up tentative specifications.[1] The instrument described here meets all of these specifications and has a number of desirable features which are not found in the regularly available audiometers.

The basis of any audiometer is a source of pure audio frequencies, preferably continuously variable from 32 to 15,000 cycles per second. A com-

[1] *J. Acoust. Soc. Amer.* 9, 72–73 (July, 1937).

FIRST BASEBALL GAME TO BE TELEVISED

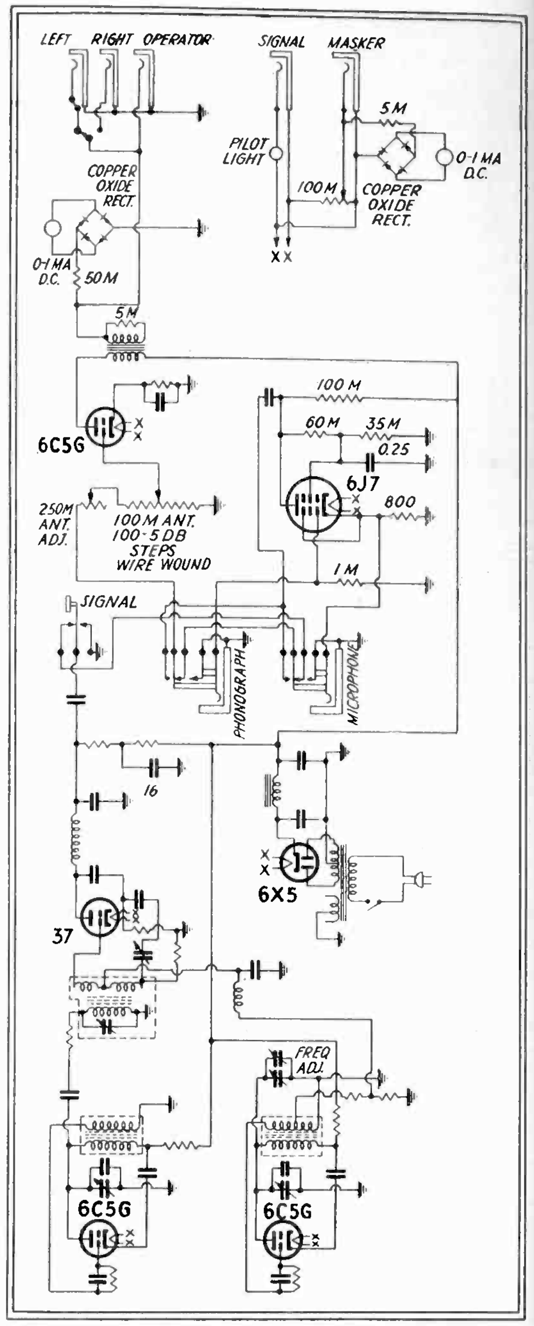


First baseball game was telecast recently from Baker's Field in which Columbia played Princeton. The mobile units of the National Broadcasting Co. picked up the sight and sound and relayed them to the Empire State Building from which they were re-transmitted

These little "CINCH" lugs contribute a big service to radio set manufacturers. With an excellent record of past performance . . . Greater demand, now bring with it new and modern production methods, increased facilities . . . extending the variety, and the service of these small parts. Of the best material and workmanship with "CINCH" special solder coating! Hundreds of sizes and types in stock . . . originally designed for a specific purpose—many now serving in a wide variety of uses—available for prompt delivery.

Cinch and Oak Radio Sockets are licensed under H. H. Eby socket patents

CINCH MANUFACTURING CORPORATION
2335 WEST VAN BUREN STREET, CHICAGO, ILLINOIS
Subsidiary of United Carr Fastener Corp., Cambridge, Mass.

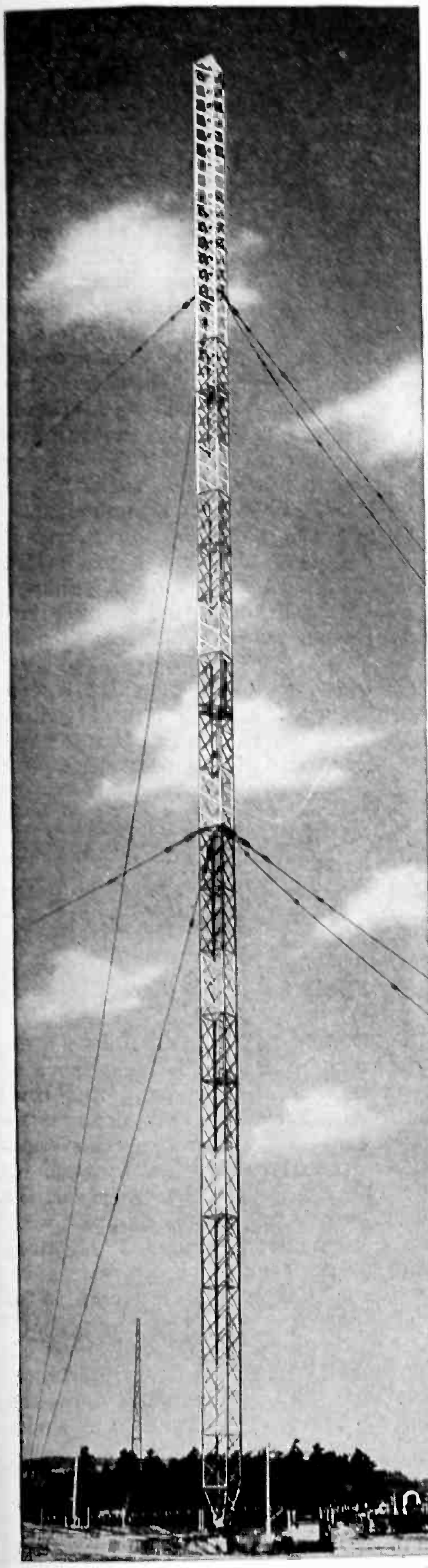


Complete circuit of Mr. Penther's audiometer

mercial beat frequency oscillator was adapted to this unit and is the nucleus of the complete audiometer. The dial is marked at even octaves from 32 to 8192 cycles to facilitate setting to the usual test frequencies.

As will be observed from the wiring diagram, six tubes are used, five from the original oscillator and the sixth added as a microphone amplifier. Two 6C5Gs are used as the fixed and variable frequency oscillators, a type 37 as the mixer and another 6C5G as the audio amplifier. A 6J7 is used as the microphone amplifier and the rectifier is a type 6X5.

In modifying the serviceman type beat frequency oscillator for this precise work, a few changes were found necessary to prevent stray signals from reaching the headphones. It was found that extra filter capacity at the detector plate circuit, shielding the detector r-f plate filter and the signal push button and using the best grade of shielded wire with frequent bonding on all leads, provide an absolute zero signal at the head phones when the attenuator was in its zero position. The attenuator is provided with an adjustable zero index, so that the entire unit, including the



One of the World's *Highest* "Far Speaking Towers"

TOWERING 625 feet, Station WGY's new vertical antenna at South Schenectady, N.Y., enters the list of most recent achievements in tower construction.

This huge cage of structural steel —9 feet square in cross-section and guyed in four directions from two levels—superimposes a vertical load of 475,000 pounds on the tapered porcelain insulator which is its base.

It was designed by American Bridge Company in accordance with specifications approved by the Aviation Division of the Dept. of Commerce. Its construction required some 102 tons of fabricated steel, guy cables and fittings. The entire structure, inclusive of concrete foundations, anchorages and the installation of porcelain base, guy cable insulators, beacon and obstruction lights and miscellaneous materials supplied by others, was erected by American Bridge.

Whatever your specialized tower requirements, whether for radio or electric transmission, you'll find American Bridge fabricating and erecting facilities and technically trained personnel more than equal to the demand.

THE VERTICAL ANTENNA is guyed with American Steel & Wire Company's galvanized steel cables at the 250 and 500-foot elevations. Each cable is strung with insulators and at ground level stretches out 425 feet. High and low-level cables from each corner are paired to a common concrete anchorage. Antenna is painted in alternate orange and white bands. The old antenna supporting towers may be seen in right background.

THE BOTTOM of the steel tower terminates in a point to rest on the porcelain insulator, which was wood-sheathed during erection for protection.

THE TAPERED PORCELAIN insulator at the tower base varies in diameter from 20 inches to 3 feet. It is 4 feet high.

• • •

W. J. Purcell, Chief Engr., Station WGY.

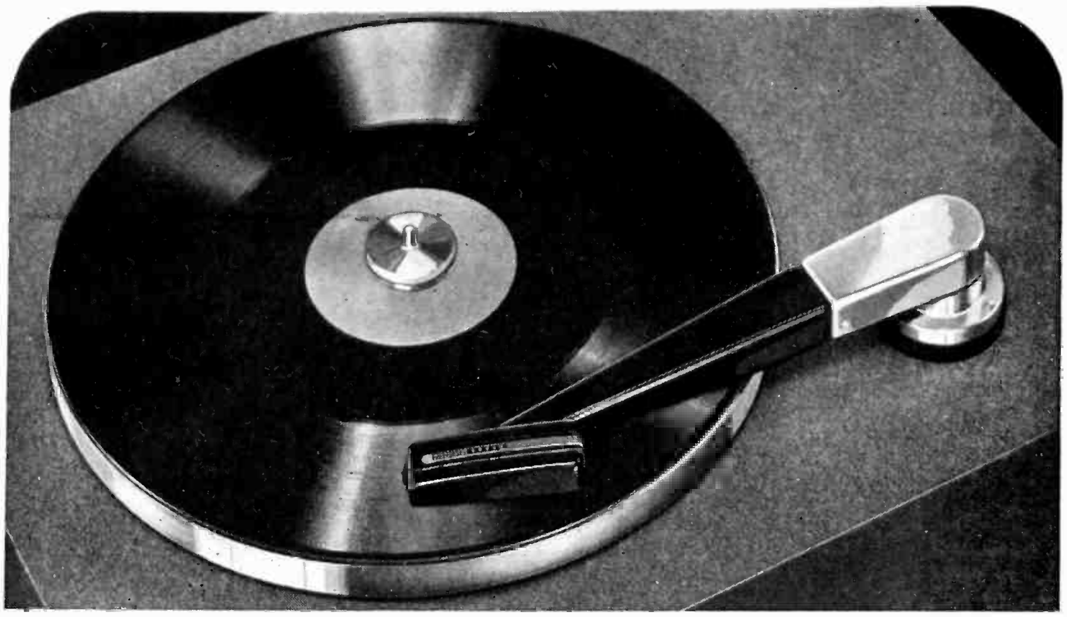
AMERICAN BRIDGE COMPANY

General Offices, Frick Building, Pittsburgh, Pa.

Baltimore · Boston · Chicago · Cincinnati · Cleveland · Denver · Detroit
Duluth · Minneapolis · New York · Philadelphia · St. Louis

Columbia Steel Company, San Francisco, *Pacific Coast Distributors* • United States Steel Products Company, New York, *Export Distributors*

UNITED STATES STEEL



headphones, can be calibrated for all the test frequencies, and set for zero level for normal hearing.

A microphone is provided so that the otologist can instruct the exceedingly deaf person as he proceeds with the test. A jack for a phonograph is also available for playing thru the system phonograph records which are recorded with test words and numerals at constant level. By establishing the zero level for each record, it is possible to use the attenuator as usual. A sixty cycle masking signal is also provided.

A signal on-off push button is provided together with a signal light operated by the patient by another push button on a cord so that the otologist can be certain when the patient hears the signal. This is particularly useful in detecting malingering. An output meter is used to set both the frequency and the attenuator dials to standard conditions, eliminating errors arising when the operator sets them by ear.

The sloping panel provides a convenient operating position, and locating all the cords on the vertical front panel keeps them out of the operator's way.

• • •

Simple Improvements In R-C Power-Supply Filters

By H. H. Scott
General Radio Company

The design of filters for power-supply smoothing has become more or less standardized on conventional combinations of chokes and condensers. Filters composed entirely of resistances and condensers have generally been restricted to applications where the current-carrying requirements were very low, since the normal IR drop through a conventional resistance-capacitance filter is frequently of serious proportions.

Generally speaking, the filtering efficiency of any simple π or T resistance-capacitance filter depends upon the ratio of the resistances in the series

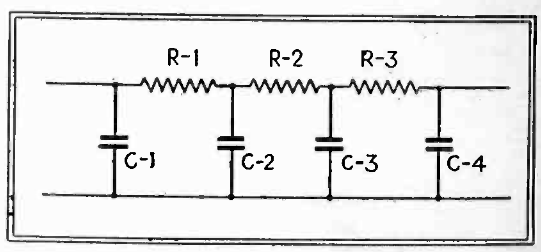


Fig. 1 — Conventional R-C filter circuit

arms to the condensers in the shunt arms, and in order to provide a low *IR* drop through the filter for direct current the resistance of the series arm should be kept as low as possible. The advent of low-cost high-capacitance electrolytic condensers has made possible the use of considerable larger shunt capacitors than had hitherto been practical, with the result that the use of resistance-capacitance filters

has been somewhat expanded. The purpose of this paper, however, is to present a simple means of improving the attenuation of such filters, whereby the characteristics of any existing filter may be improved, or the resistances in the series arms may be reduced to decrease the *IR* drop, while at the same time adequate ripple suppression may be obtained.

In the first place, it is assumed that a reasonably good distribution of capacitances and resistances through-

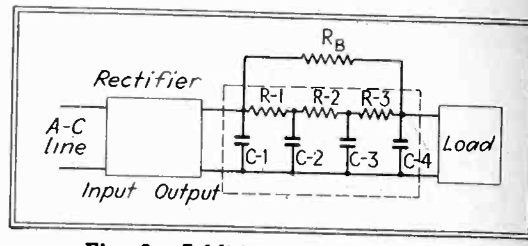


Fig. 2—Addition of R_B element to filter

out the filter has been obtained. In general, it will be found most satisfactory to divide the total capacitance evenly between the several filter sections and to divide the total resistance in the same manner. The actual choice of the values for the input and output condensers sometimes depends, respectively, upon the ripple which may be tolerated across the input condenser and the bypassing required at the filter output. The number of terminals available on a given con-

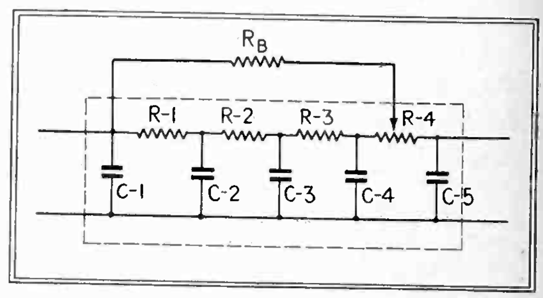
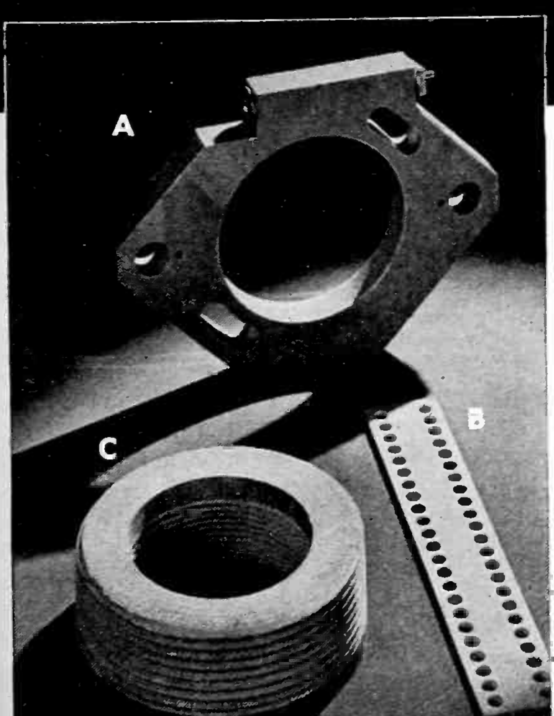


Fig. 3—Slide wire adjustment on filter element

denser can and the practical limitations of the types furnished by manufacturers also will influence the distribution of the capacitors.

Figure 1 shows a conventional *R-C* filter. In order to function satisfactorily it is important that the capacitances have relatively low impedances as compared to the resistances at the frequencies to be attenuated. With a full-wave rectifier and a 60-cycle power supply the highest-amplitude ripple component will be 120 cycles. If the resistance R_B is added to the filter, as shown in Fig. 2, it will be found that at a certain value of R_B the actual attenuation of the filter circuit at any given frequency may be appreciably improved, and, if the ratios of the resistances and condensers in the main body of the filter are sufficiently large to produce practically 90 degrees phase shift per section at any given frequency, it will be possible to balance the circuit almost completely for that particular frequency. If the circuit is balanced for the main hum com-

You can either reload your own cartridges or buy them loaded—but . . .



A—Sawed, milled, drilled & bored Brush Ring
B—Sawed, sanded & drilled Insulating Plate
C—Threaded & tapped Reducing Bushing

in buying parts, as in cartridges, ready-to-use is usually more satisfactory

You could buy lead, powder and the necessary implements and reload your own shells, but it probably wouldn't be worth your trouble. Yet, in your shop, equally valuable time may be wasted in fabricating parts which can be bought from us—more profitably and ready-to-use.

Synthane Bakelite-laminated has so many desirable properties *in combination* that its use, in place of another material, is generally an initial advantage.

You also stand to gain—usually—by letting us machine parts for you because you relieve yourself of the responsibility for mistakes in machining, for rejects and delays in delivery. You benefit from our previous experience and the new, faster ways of machining Synthane which we devise from day to day. We are equipped to make the proper dies, jigs, and fixtures for Bakelite-laminated.

Machining at Oaks saves you the cost of installing new machine tools in case the present equipment of your shop is not well suited for machining Bakelite-laminated. All our equipment is selected for the fabrication of Synthane exclusively.

Of course, if your production requirements justify the installation of machines comparable with those of a modern Bakelite fabricating shop, then do your own machining. We'll supply your sheets, rods and tubes.

At the left are parts machined from Synthane by us for three widely different manufacturers. We believe you, too, will find Synthane materials and machining well worth looking into. Why not send in your application today?

SHEETS • RODS • TUBES • FABRICATED PARTS • SILENT STABILIZED GEAR MATERIAL

SYNTHANE

SYNTHANE CORPORATION, OAKS, PENNSYLVANIA ponent of 120 cycles, it will be found that the attenuation at other frequencies, while affected to some extent, is still sufficient for most purposes, and the actual level of the 120-cycle component at the output of the filter can be reduced to a point where it is no longer serious.

In cases where the resistance-capacitance ratios do not permit sufficiently close balance the arrangement shown in Fig. 3 can be used. Analysis of this circuit indicates that by varying R_B and the slider on R_4 complete balance can be obtained at any frequency.

Figure 4 shows the general type of transmission characteristics obtained with conventional *R-C* filters as compared to those employing the auxiliary balancing resistance. Curve "a" represents the attenuation characteristic of a filter as shown in Fig. 1. The important point concerning this characteristic is that it increases with frequency, and the attenuation is comparatively low in the low-frequency region, where the highest ripple components occur.

Curve "b" in Fig. 4 shows the type of characteristic obtained with filter circuits as shown in Figs. 2 and 3. At the sacrifice of attenuation at higher or lower frequencies, the addition of the resistance R_B has produced a peak of high attenuation, which may be located near the frequency of the largest ripple component. The result

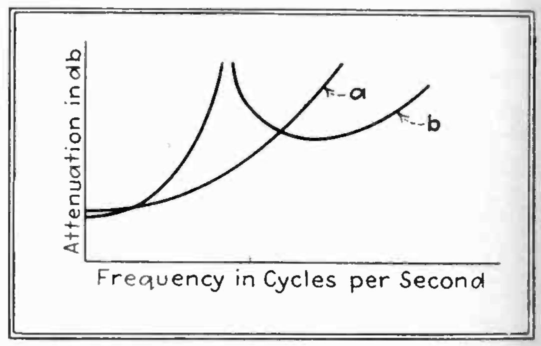


Fig. 4—Transmission characteristics of filters

is an appreciable decrease in the net ripple voltage transmitted by the filter, since those ripple components occurring at frequencies where the addition of R_B has increased the transmission of the filter appreciably are so comparatively low in amplitude that a slight increase is more than offset by the large decrease in the high-amplitude components.

The circuits of Figs. 2 and 3 may both be analyzed on the basis of two parallel transmission paths, one through the main body of the filter and one through R_B, having equal but opposite transfer impedances. It will be obvious that, in general, the values of the input and output capacitances or the section of R_4 between the filter output and the slider do not affect the balance conditions, but do improve the attenuation at other frequencies. The same fundamental principle may be expanded into circuits involving two low-pass filters in parallel, rather than a low-pass filter and a single resist-

ance, but the circuits shown in the figures are generally satisfactory and have the important advantage of simplicity. Similar arrangements may, of course, be applied to high-pass or other types of filters and to filters including inductances, although in this latter case other arrangements may be used to obtain similar results.

Use of either of these arrangements may be made to improve the filtering performance of a given filter or to reduce the *IR* drop while still maintaining the same filtering performance. In any actual instance the addition of R_B will generally result in a distinctly worthwhile reduction in the rms hum voltage at the filter output, providing the other filter elements are kept at the same values. Addition of R_B also produces a parallel transmission path which lowers the d-c series resistance of the filter to some extent, but, more important, with the addition of this balancing resistor it is frequently possible to reduce the values of the series resistors and still maintain adequate filtering. This is particularly true in the circuit of Fig. 3, which is not as dependent upon high *R-C* ratios in the filter sections as Fig. 2. Circuits of this type have been used in several applications (where low cost, light weight, and freedom from magnetic interference were important) and have been found of considerable value.

• • •

Simplified Dual Diversity Radiotelegraph Reception

By Forrest A. Bartlett

There can be little doubt as to the effectiveness of diversity receiving systems in reducing fading on shortwave circuits. Use of diversity apparatus has become virtually universal among the point-to-point telegraph services using automatic equipment where it is essential that a constant signal level be maintained over long periods of time.

However, the application of diversity principles to radio telegraph circuits other than these high-speed commercial services has been largely neglected. There are a number of good reasons for this. Diversity equipment built along present lines is expensive and fairly complex. An elaborate antenna system is usually used and the nature of the receiver adjustment requirements is such as to discourage remote control of the apparatus. Slower speed circuits where reception is by ear rather than by automatic recording equipment do not require the same degree of signal constancy as do the services where the signals are first recorded on tape. In a good proportion of cases the extra cost of a diversity installation would not be warranted.

Fundamentally, diversity reception is based on the principle that a given signal rarely fades in two spaced antennas at the same instant. Important also is the fact that much shortwave fading is due to cancellation of signals arriving at the intercept point over different paths and in constantly changing phase relationship. This is the factor which makes necessary the separate r-f and i-f channels accepted as basic necessities in present diversity systems. It is clear that any effort to combine the signals before final detection will result in cancellation whenever out-of-phase conditions exist, the amount of cancellation, and consequent fading, depending on the amplitude of the two incoming signals. Use of a beat oscillator as is done in single antenna receivers is impossible because of this same phase condition — which is unchanged in transit through the r-f and i-f stages.

Taking these factors into account, it was reasoned that two antennas might be used to furnish signal energy to one receiver if some arrangement could be provided such that the signals were momentarily supplied first by one antenna and then the other. The antennas would, of course, have to be shifted at a rate sufficiently rapid to prevent any loss of intelligibility due to the switching operation. In this manner, the receiver output should approach the average of the signals existing in both antennas plus the audible sideband component the signals would pick up as a result of the rapid switching in the diversity stage.

With this general idea as a starting point, the circuit diagrammed in Fig. 1 was set up. Electrically, the unit consists of two separate r-f amplifier stages, each connected to its own antenna, and made to alternately furnish signal energy to the receiver.

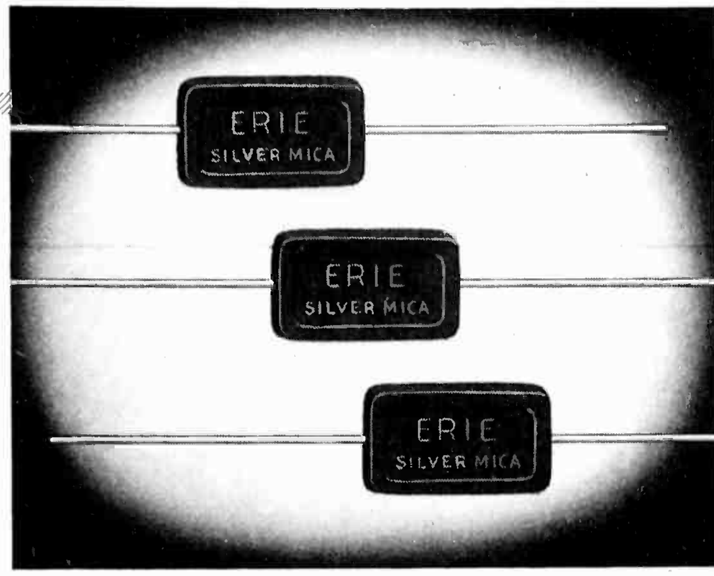
Two 6L7's are used in the r-f portion because of the "extra control" available in the form of these tubes' injection grids. The control grids are connected in a conventional amplifier arrangement. The plates are in par-

• • •

RADIO CONTROLLED PLANE

Radio controlled model airplane built by Joseph Raspante of Brooklyn was recently entered in the International Model Airplane Meet at Detroit

HERE'S *Real* STABILITY



THE NEW

ERIE TYPE K

SILVER-MICA CONDENSER

AT NORMAL CONDITIONS

The excellent operating characteristics of the new molded Erie Silver Micas provide unusual tuning stability essential for really dependable automatic tuning.

AVERAGE TEMPERATURE COEFFICIENT
(20° to 80° C) +.000025

MAXIMUM POWER FACTOR
AT 1,000 K.C., LESS THAN .030%

SUBJECT TO HEAT AND COLD

The permanent effect of 5 complete cycles of 5 hours at —30°F and 15 hours at 180°F is so slight that practically any conceivable temperature condition encountered in shipping or in actual use will not affect the tuning stability.

GREATEST CAPACITY CHANGE
+.135%

MAXIMUM POWER FACTOR
AT 1,000 K.C., LESS THAN .05%

SUBJECT TO 100% HUMIDITY

The compact low-loss thermo-setting plastic case provides superior protection against the effects of humidity. After 100 hours in 100% relative humidity at 104°F, maximum capacity change is less than .05% and leakage resistance at 1,000 volts D. C. does not drop below 10,000 megohms.

MAXIMUM CAPACITY CHANGE
.05%

LOWEST LEAKAGE RESISTANCE
(At 1,000 VOLTS D.C.), Over 10,000 MEGOHMS

The above figures, for 175 mmf, will vary slightly for different nominal capacities.

ERIE RESISTOR CORPORATION, *Erie, Pa.*

TORONTO, CANADA • LONDON, ENGLAND • PARIS, FRANCE-J.E.CANETTI CO.

MANUFACTURERS OF RESISTORS • CONDENSERS • MOLDED PLASTICS allel through the common tuned circuit which is link coupled to the receiver input. The injection grids are biased as shown to a negative value slightly greater than required to stop tube operation.

A straight multivibrator circuit generating a controlled frequency of 360 cycles per second is used to accomplish the switching operation. This circuit was chosen because of its near square-wave output and because of the fact that the voltage existing on the plates of the two tubes is of equal amplitude and 180 degrees out of phase. This out-of-phase voltage is applied to the injection grids of the 6L7's so as to alternately overcome the negative bias and cause momentary tube operation.

In this manner each tube is made operative 360 times per second and always at the precise interval when the second tube is inoperative. The common plate circuit of the r-f section will thus be operating on a frequency just double 360 — or 720 cps.

An unmodulated signal of equal amplitude applied to each of the two r-f sections will be heard in the receiver output modulated with a 720 cycle tone. As the signal to either of the two r-f stages is reduced (as in fading), 360 cycle modulation predominates. This follows from the fact that one antenna is furnishing the major share of the signal and this is interrupted 360 times per second.

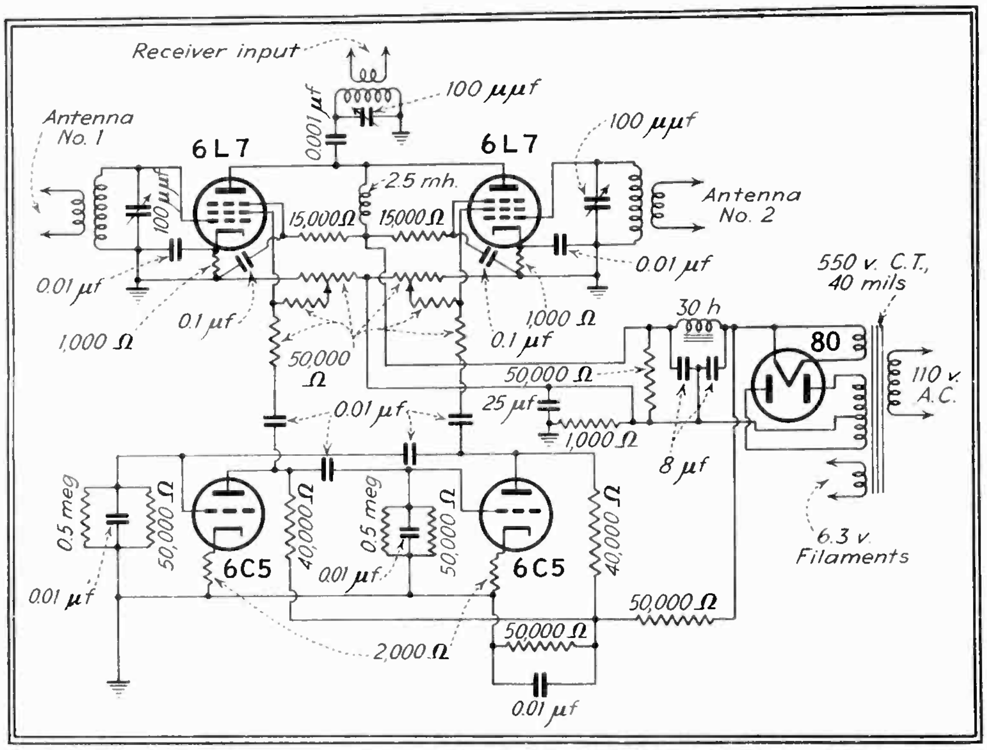
Turning on the receiver beat oscillator results in a complex beat note due to the sideband components added to the original signal in passing through the diversity unit. The beat note changes in tone as signals in one or the other antennas fade. The effective receiver output, however, appears to be proportionate to the maximum signal existing in either antenna — rather than to the average of the two signals. This is probably because of sideband energy added to the incoming signals.

The unit described in this article was built complete with its own power supply on a single chassis. The only connection to the receiver proper is through the twisted-pair coupling link. The tuning condensers were not ganged, but there is no reason why they might not be in adaptations of the circuit.

An oscillograph was found indispensable in obtaining correct operation of the multivibrator. Symmetry and proper amplitude of the output waveform of the respective tubes is essential for peak performance. Too great amplitude results in an effect closely resembling sideband splatter in radiotelephone work whenever a signal is tuned in. Too much harmonic energy must not be present or undue broadening of the signals will result. Capacity and resistor combinations which give satisfactory operation were found by cut and try using the oscillograph as a final check. The 360-cycle frequency was chosen because it gives a pleasing tone to the received signals without causing too great a loss in receiver selectivity due to the sidebands added to incoming signals.

In operation, the diversity unit is tuned in the same manner as an ordinary r-f amplifier. No pickup of the multivibrator tone is audible except when signals are being received. The tuning is not critical and for this reason no additional remote control equipment was needed in the installation for which the unit was originally designed.

In view of the encouraging results achieved through use of the unit described in the foregoing paragraphs, the writer highly recommends use of the circuit in other installations where an economical and simplified diversity system is required.



A relaxation oscillator is employed to alternate between r-f amplifiers in this diversity receiver

NEW BOOKS

(Continued from page 37)

High-Frequency Alternating Currents

Second Edition

By Knox McIlwain and J. G. Brainerd. *Moore School of Electrical Engineering, University of Pennsylvania. John Wiley and Sons, Inc., New York, 1939. 530 pages, 226 illustrations. Price, $6.00.*

Since 1931, when the first edition of this book made its appearance, "High Frequency Alternating Currents" has held a high place among the textbooks in the communications field. The second edition maintains this reputation, for it is a solid academic treatment of nearly all the subject matter with which the communications engineer is concerned. The chapters read like the departments in a communications research organization: Resonance Phenomena, Coupled Circuits, Vacuum Tubes, Amplification, Modulation, Detection, Production of High Frequencies, Wave Filters, Transmission Lines, Electromagnetic Waves, Reflection and Refraction of Waves, and Electromechanical Systems. Throughout the treatment is rigorous, and a good understanding of calculus and differential equations is assumed. A particularly useful arrangement of the book are the many tables which summarize the characteristics of the design and operation of equipment in terms of essential parameters. Thus for example, the treatment of the theory of the triode tube with a general load impedance is very compactly but completely presented in a table which gives the coefficients of the Taylor series for the plate current. A very comprehensive table on filter-section characteristics is also included. The tables make the book not only a good text but a good reference source.

This reviewer has only one regret, and that is that the authors have not taken full advantage of their opportunity to bring the book up to date. For example, frequency modulation would appear to be a topic of definite interest at the present time, but the authors content themselves simply with a statement that such modulation can exist. Likewise the present-day emphasis on the generation and utilization of ultra-high frequency alternating currents should justify a more extended treatment of this subject. Finally, the problem of amplifying a wide band of frequencies, of great and increasing importance in telephony and television, is not given adequate attention. With these exceptions, however, the book is inclusive and the treatment of the subject matter both thorough and utilitarian.—D.G.F.

THE ELECTRON ART

Each month the world's technical literature is scanned to see what physicists and engineers are doing with tubes, for presentation to Electronics' readers

Oscillators for Ultra-High Frequency

THE VARIOUS TYPES of tube oscillators for obtaining ultra-high frequencies are briefly outlined by B. H. Black in an article, "Ultra-Short Wave Oscillators" appearing in the April 1939 issue of *Electrical Communication*. The limitations of negative grid oscillators are enumerated and discussed, and some practical examples of this type of high frequency oscillator are described together with methods of operation. Types of tubes and circuits are described in which the frequency of oscillation is determined by a transmission line forming part of the circuit arrangement. Such "linear" oscillators are most efficient and convenient for frequencies between 200 and 1,000 megacycles per second.

A method of operating several tubes in multiple is described. One form of oscillator is shown consisting of a transmission line with tubes situated at voltage nodes and separated by one electrical half wavelength. Such a multiple oscillator is not limited to two tubes. Three tubes, giving three times the output of a single tube have been operated successfully, and there seems to be no reason why the system should not be extended to a greater number of individual oscillators.

Limitations of the Fourier-Integral

IN A RELATIVELY non-mathematical fashion, Mr. M. P. David deals with the problems involved in the application of the Fourier integral to radio theory, in an article in the November 1938 issue of the *Bulletin of the Society of French Electricians* which is entitled "Remarks on the Use of the Fourier-Integral".

At the outset he points out the well-known paradox which occurs in filter theory wherein the current integral shows a finite value of current at the output terminals prior to the application of voltage to the input terminals. The author undertakes to solve the problem by applying the theory of functions of a complex variable to the appropriate integrals which he rewrites in complex form thereby eliminating the more commonly used trigonometric form.

Following through his analysis he arrives at the conclusion that the Fourier-integral by reason of its use of a differential system will inherently lead to wrong results when used indiscriminately, especially when used in investigations involving approximations.

As a point in support of this contention the author discusses the weakness of the differential method in treating parasites in selective circuits, since as he points out, parasites are not necessarily limited to unique isolated discharges but may likewise be a series or train of discharges whose time interval is short by comparison with the time constant of the circuit.

NOBEL PRIZE WINNERS CONFER

Four Nobel Prize winners recently attended a symposium on cosmic rays at the University of Chicago where they were the guests of Dr. Arthur H. Compton, who directed the symposium. The noted physicists are, from left to right: Dr. Victor F. Hess, professor of physics at Fordham University; Dr. Werner Karl Heisenberg, professor of theoretical physics at the University of Leipzig; Dr. Carl D. Anderson, California Institute of Technology, and Prof. Compton

Electrical Protection for Discharge Tubes

A PAPER by H. M. Barlow, entitled "The Electrical Protection of Cold Cathode Luminous Discharge Tube Installation" was read on February 3 before the Institution of Electrical Engineers in London and will appear in the *J.I.E.E.* The author's summary of this paper is as follows:

The importance of providing adequate protection against the risk of fire and electric shock due to faults developing on high voltage discharge tube circuits has recently come into prominence on account of the extensive use of such apparatus for industrial purposes. The paper explains the peculiar difficulties met with dividing suitable protective devices, and, after describing the principal types of equipment at present available, gives details of certain recent developments for which the author has been responsible.

Automatic Radiogoniometer

A RADIOGONIOMETER which employs a constantly rotating "exploring coil" is described in the March 1939 issue of *L'Onde Electrique* in a paper "A New Automatic Radiogoniometer With Visual Indicator" by Jean Marique. The velocity of rotation is about six times per second. A special neon tube is employed as an indicator. The author's choice was directed to the use of a neon tube because of the inertia effects and other limitations of the galvanometer type of indicator.

The tube construction consists of an anode situated close to the socket and

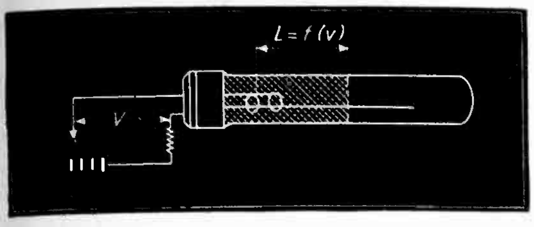


Fig. 1—Diagram of ionizing tube

the cathode is a straight wire extending through the tube as shown in the Fig. 1. The ionization potential is of the order of 180 volts.

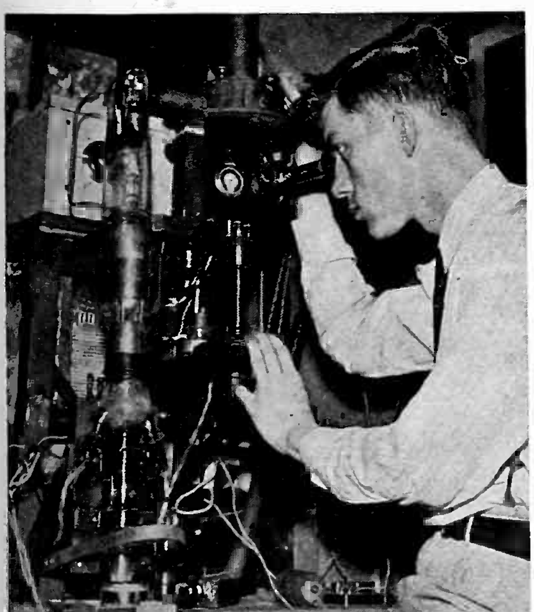
The amplifier feeding this tube is so constructed that the voltage applied to the tube is of the magnitude of 190 volts when the reception is a maximum, the length of the luminous portion of the tube being a function of the voltage in excess of the limiting 180 volt value. The design is such as never to permit the voltage to fall below 190 volts so that the lamp indicates continually.

When the framework is rotated the minimum is approached and the voltage on the lamp rises proportionally so that the length of the luminous portion of the lamp likewise increases. The variation, therefore, in the length of the luminous column is an inverse function of the signal strength.

To obtain a stationary indication the frame and the lamp are rotated at six revolutions per second. The direction of the transmitter is of course associated with the longitudinal axis of the luminous beam. A transparent indicator which rotates on the graduated scale facilitates correct readings.

The tube diameter of the neon lamp is of no importance because the intensely brilliant straight wire cathode

ATOMS FORM CRYSTALS



A way to "see" atoms of metallic elements arrange themselves into the solid state is being demonstrated at the California Institute of Technology by Mar G. Foster. Lead is vaporized in a crucible in a vacuum tube. Atoms of lead, set free by vaporization rain upon a prepared glass plate and form crystals is practically all one sees when the lamp is in operation.

An elliptically rotating field is described by the unequal minimal values when these vary from instant to instant. The method of correction is similar to that used with ordinary apparatus with the added advantage that one sees what he is doing at all times.

The receiver used in actual commercial installation is a superheterodyne covering a range from 160 to 700 kc. Its selectivity curve is down 60 db with a variation of $\pm$ 6 kc from the carrier.

The apparatus requires no special signal characteristics; many times the results are more precise with slightly- or non-modulated signals. It is claimed that this method of direction finding is vastly superior to the aural type.

Negative Resistance Oscillators

A SIMPLE, all-purpose oscillator of the negative resistance type is described by Cledo Brunetti in the March issue of the *Review of Scientific Instruments*, under the title "A Practical Negative Resistance Oscillator." The author claims that the oscillator possesses exceptionally good wave form, is free from drift once a definite frequency of oscillation is selected, is relatively efficient, and may be adapted to frequencies over a wide range by a proper selection of a single coil and condenser. No delicate adjustments of feedback are required since the usual method of back coupling are absent.

A diagram of a suitable oscillator of this type, known as the "transitron oscillator" is shown in Fig. 1. The circuit to the left of terminal *AB* provides

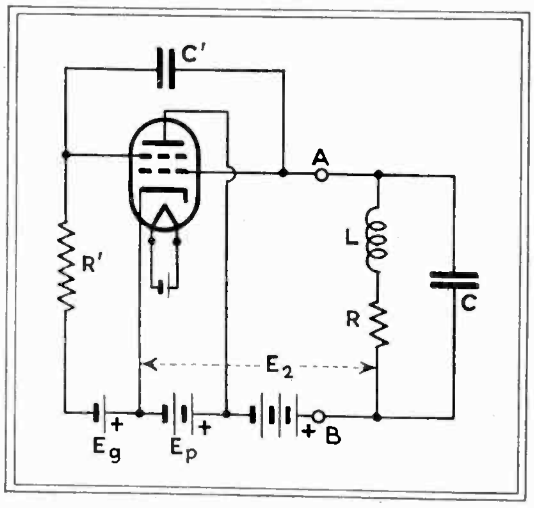


Fig. 1 — The transitron negative resistance oscillator

the negative resistance characteristic which is necessary to keep the tuned circuit (shown to the right of *AB*) in oscillation over a wide range of frequency. The author states that the only precaution which must be observed after oscillation is established, is that the quantity L/RC be kept larger than the minimum negative resistance available with the circuit and its tube. This minimum value may be found by increasing the tuning capacitance, C until the oscillations are on the point of being extinguished. The value of L/RC at this setting is equivalent to the minimum value of negative resistance possible with the given electrode voltages. At this condition, the wave form will be very nearly sinusoidal. If the quantity L/RC is now increased, the amplitude of oscillation will increase very slightly, increasing the average negative resistance.

If one inserts a small emf of frequency f in series with the tuned circuit and the tube, as at *A*, in Fig. 1, the tuning circuit may be made to oscillate at a frequency of $n^{\pm 1} f$, where n is a positive integer. This mode of operation may be obtained by properly adjusting the values of *LC* to the new frequency. When used in this manner, the transitron oscillator may be used as an electrical frequency converter to multiply or divide the frequency.

The article contains a very brief mathematical treatment of the conditions necessary for oscillation.

LONDON TRAFFIC CONTROLLED BY LOUD SPEAKER

Scotland Yard's squad of traffic police have started a six months experiment in South London. Officers equipped with loud speakers on tripods, microphones, and control equipment are stationed at busy intersections and give advice to traffic

Effect of Grids on Electric Waves

A HIGHLY INTERESTING PAPER on the subject of grid-wires as they affect electric waves passing through them is contained in the April 1939 issue of *Hochfrequenz und Elektroakustik* in an article by A. Esau, E. Ahrens and W. Kebbel, entitled "The Effectiveness of Wire Grids on Electric Waves."

The wire grids considered are arranged in parallel order separated a distance d and having the common radius r. They are considered to be in one plane. The grid height and width are large in comparison to the wire separation and diameter and the wavelength of the impinging electromagnetic waves. Such a grid has a reflection coefficient of R, a transmission coefficient D, and an absorption coefficient A for perpendicularly impinging waves.

From experiment it has been determined that the absorption A for good wire materials (copper) is negligible in comparison with D and R. The value of R is determinable from measuring D and using the relation $R = 1 - D$.

The experimental set-up is shown in Fig. 1. A magnetic field tube generator produces undamped waves in the frequency range from 10^{10} to 4×10^9 cycles. The waves are focussed into an approximately parallel group by means of the metal reflector. The receiver used is a bolometer which is

CAMERA RECORDS ATOM PATHS

Atoms are smashed by hurling them at each other with tremendous velocity. Since the nucleus is very small and repels charged particles with considerable force, few "direct hits" are made. Prof. T. R. Wilkins, of the University of Rochester, is shown with the camera he invented to record the tracks of atoms as they are scattered or turned away by the atom at which they are being aimed

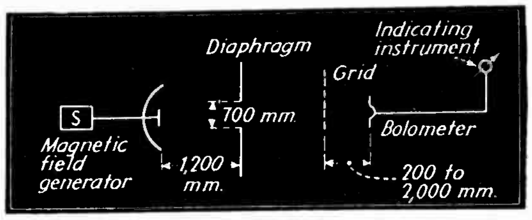


Fig. 1 — Arrangement of experimental apparatus for studying effect of grids on radio waves

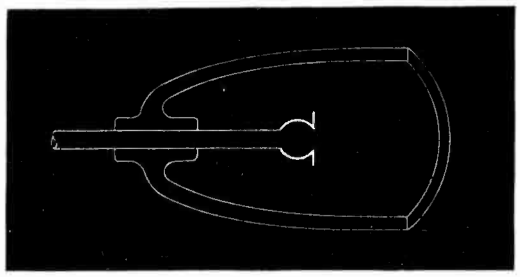


Fig. 2—Diagram of bolometer used for measuring short radio waves

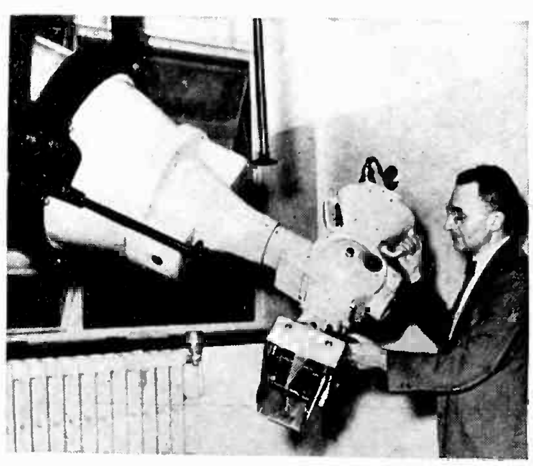
incorporated in one arm a Wheatstone bridge. The indications of the meter in fields which are not too strong is proportional to the square of the field strength.

The form of the bolometer is shown in Fig. 2. It consists of a small dipole at the center section of an evacuated glass bulb, and is made of a Wollaston wire of 0.04 mm diameter. The bolometer possesses the characteristics of a dipole and can be used to determine the direction of polarization of a wave.

Difficulties arise in the transmission measurements due to interference phenomena arising from space reflections. They are further enhanced by wobbling of the frequency of the transmitter. Variations of 3 to 5% in transmitter frequency tends to reduce the interference pattern.

Measurements made with perpendicularly impinging waves in the grid-plane are tabulated. Measurements for varying angles between the transmitter dipole and the wire direction were also made with various values of λ/d. It is shown that with displaced grids the direction of polarization with small angles is in the grid direction.

X-RAY MACHINE FOR CANCER



Dr. G. Failla at the 250,000 volt X-ray machine recently installed in the Memorial Hospital for the Treatment of Cancer and Allied Diseases in New York

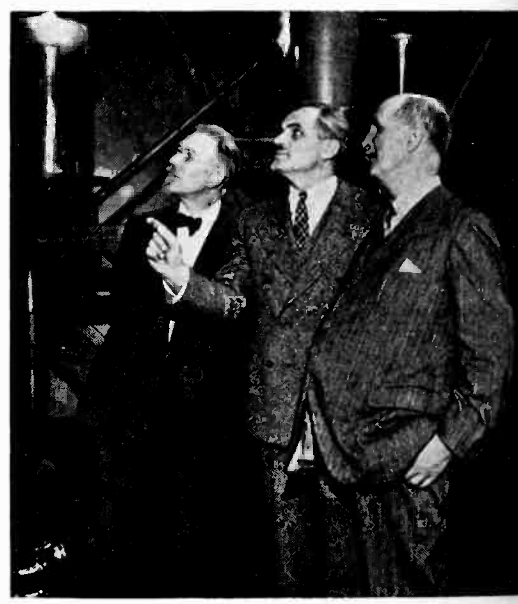
Stereoscopic Television

In a short article on the Problem of Stereoscopic Television, in the Jan. 1939 issue of the *Telegraphen und Fernsprech-Funk und Fernseh-Technik* Manfred von Ardenne, writes on the relative qualities of stereoscopic television and ordinary "flat" television pictures. He points out that to obtain an equivalent "stereo" picture requires twice the frequency band-width of a normal black-and-white picture. For an equivalent number of picture elements per second and for the same frequency band-width the stereoscopic picture corresponds in sharpness to a normally flat picture of half the number of picture elements.

The study was conducted along the lines of a previous experiment by the author in color technique. For the normal two dimensional picture was substituted a stereo picture of the same subject having half the number of picture elements.

The problem arises as to what type of image is the more desirable, the sharper flat picture or the seemingly more realistic stereoscopic picture. This is a matter which depends to some extent on the sharpness of the picture and it remains to be determined what sacrifice in sharpness can be permitted for the sake of three-dimensional pictures, and what are the limiting values for these deciding factors.

NOBEL PRIZE WINNERS AT U. OF C.



Three winners of the Nobel prize, gather at the University of Chicago and discussing matters of mutual interest. Left to right are: Dr. August Krogh, professor of physiology at the University of Copenhagen, 1920 winner for his work in capillarimotor mechanisms, Dr. Arthur H. Compton, who won the prize for research in cosmic rays, and Sir William H. Bragg, who with the collaboration of his son carried out research on x-rays and crystals for which he was awarded the Nobel prize in 1915. The men are shown examining an "atom smashing" device at the University of Chicago

Portable High Voltage Supply

A RATHER UNUSUAL circuit for furnishing a few microamperes of current at voltages of from 600 to 2,500 volts is described by R. B. Huntoon in the June issue of the *Review of Scientific Instruments* under the title, "A Portable High Voltage Supply." The unit is especially advantageous when working with portable Geiger counters, electroscopes, or similar pieces of high impedance equipment. Two wiring diagrams are given in the original paper. Figure 1 shows one of the diagrams

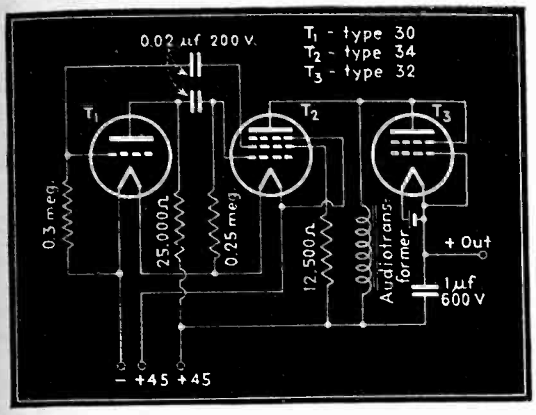


Fig. 1—Wiring diagram of multivibrator and amplifier for producing high voltage

which is particularly useful in explaining the principle of operation.

In Fig. 1 the two tubes, T_1 and T_2, are connected in the usual multivibrator circuit with the exception that the feedback of the first tube comes from the voltage drop across the resistor in the screen circuit of T_2 instead of across the plate circuit load voltage drop. The plate circuit is therefore left free to be used as an electron coupling element to subsidiary circuits.

When the multivibrator circuit is oscillating, the plate circuit of T_2 becomes alternately conducting and non-conducting at a rate dependent upon the circuit *CR* constants. When the tube is conducting, current is built up in the inductance *L* and when the current is T_2 is abruptly stopped, a large voltage appears across the inductance due to the rapid change of current in it. This voltage pulse is fed to the rectifier T_3, and charges the output condenser. On peak positive pulse, the condenser receives an additional charge, thereby building up a voltage which can equal that of the peak voltage across the inductance *L*.

Using the circuit constant as given in Fig. 1, an output voltage of about 600 volts is obtained with a plate supply of 45 volts. At 100 volts on the plate the output voltage is approximately 1,800. The output voltage is approximately independent of filament voltage although for voltages below 2 volts, the output voltage drops about 10 per cent. Of course, the voltage drops considerably and the current drain is increased, as is usual with all *B* supply systems. With a current drain of 10 microamperes, a voltage of 800 may be obtained, whereas if the current drain is increased to 50 microamperes, the output voltage drops to 400 volts.

Another modification of the same idea using two vacuum tubes and a neon gas discharge lamp for producing oscillation is also described.

Air-Cooled Tube

THE ARTICLE by M. van de Beek in the May issue of the *Philips Technical Review*, entitled, "Air-Cooled Transmitting Valve," discusses the use of forced air cooling in order to increase the power output of vacuum tubes without the necessity of installing complicated water cooling systems. The use of forced air cooling is especially advantageous in the range between 1 and 10 kw. While it is true that air cooling is less effective than water cooling, which must be used for higher powers, it nevertheless has the advantage of entailing fewer structural difficulties in connection with the high potential of the anode.

The article by van de Beek is concerned with a discussion of the methods by which heat is transferred in a vacuum tube, and gives design equations for the calculation of the energy which can be dissipated, and the increase in temperature, for a given type of air-cooled system.

An example is given of this type of cooling in which two air-cooled transmitting tubes operating at 6 meters, deliver 6 kilowatts to the antenna with an excitation power of about ½ kilowatt.

BURGLARS GO ON THE AIR

William Noble, San Francisco inventor, demonstrating a model of his short wave burglar alarm which summons police to the scene of a burglary or hold-up through an automatic recording which starts when a key is tripped. The short wave transmitter is operated on police frequency and is silent until an emergency arises, in which case the person held up presses a button putting this station on the air

Zinc Silicate Phosphors

A STUDY of "Phosphorescence of Zinc Silicate Phosphors" is given in the June issue of the *Journal of Applied Physics* by Gorton R. Fonda, in which it is shown that at low content of the manganese activator the decay of phosphorescence takes place in two stages. The initial stage is exponential. It is complete in less than 0.1 sec. and is not affected by temperature. The second stage is at a much lower intensity level. It becomes noticeable after 0.03 sec. and persists for more than an hour. Its speed of decay increases with temperature. At —196° C. it is completely latent. A change in the intensity of the exciting light alters proportionally the luminescence caused by each stage of decay and has no effect upon the shape of the decay curves. About fifty times as many electrons are involved in the second stage of decay as in the first. It is assumed that the second stage is caused by the return of electrons in a metastable state, probably one associated with the presence of lattice.

The exponential decay of the first stage would result from the recombination of manganese ions, relatively in excess with those three electrons which had not been captured in the potential cups of the metastable state.

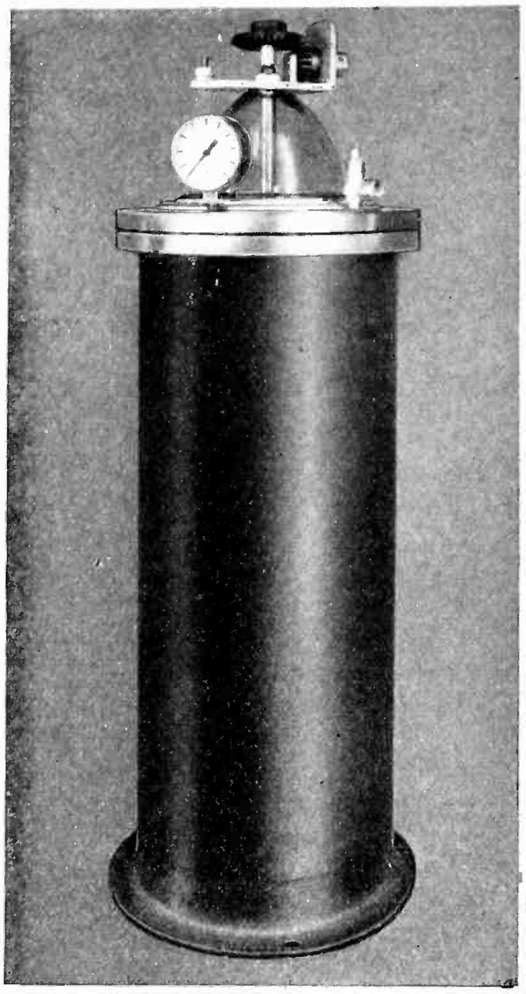
The decay of phosphors rich in manganese is always very abrupt and at a speed which rises rapidly with increase in temperature.

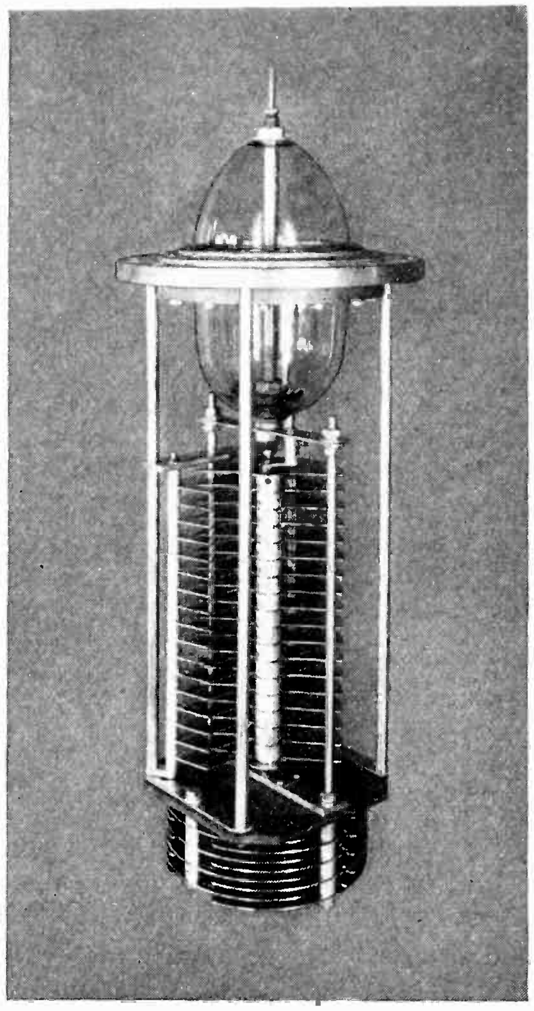
TUNA INDUSTRY USES RADIO

As an aid to its fishing activities boats of the tuna industry have been equipped with radio telephone equipment. As shown here, the radio installation on one boat is in a corner of the mess room. Both telegraph and phone transmitters are employed, and a single receiver covers the broadcast and the short wave bands

THE INDUSTRY IN REVIEW

More on Pressure Capacitors





Exterior and interior views of the Johnson pressure condenser. The tank and its integral bottom is of seamless steel construction

SINCE the publication of the article on Pressure Capacitors in the April issue of *Electronics*, additional information has come to the attention of the editors. Pressure capacitors are manufactured by the E. F. Johnson Co., Waseca, Minn., in addition to the two manufacturers mentioned in the previous article.

The tanks of the Johnson pressure condensers are seamless steel drawn with the integral elliptical bottoms to eliminate joints or welds which would be under pressure. The head is machined from solid rolled steel plate. The original work on heads indicated that the best cast aluminum available was not satisfactory. Later experience showed that cast bronze was generally acceptable, but occasional defects were found and it was found necessary to use steel. The cylindrical portion of the tank is approximately 10¼ inches in diameter and the head and mounting flange is 12 inches. The height of the unit varies with the capacity. Both the tank and head are heavily copper plated on the inside and outside.

Neoprene, which is superior to other available materials for this application, is used for the three gaskets under gas pressure. The inner bowl of heavy molded Pyrex glass takes the entire gas pressure and provides adequate insulation with negligible losses. The outer bowl, also of heavy molded Pyrex and not under gas pressure, serves as a terminal support, but its main function is to prevent accumulation of dust on the surface of the inner bowl, which is not conveniently cleaned. Dust would cause surface leakage which would lead to flashover. The space between the upper and lower bowls is vented to the atmosphere which causes arcing between the head and the high voltage connection stud. This sets the voltage rating of the condenser at 40,000 volts rms. The voltage rating may be increased by the use of oil in the space between the bowls.

These capacitors are available in several different types. The plates may be all variable or all fixed or there may be two sections within one tank one variable and one fixed so tha great flexibility of design of equipment is possible. The unit shown in the photographs is of the last mentioned type and has a capacity range from 405 $\mu\mu$f to 819 $\mu\mu$f. The plates are of aluminum 0.102 inches thick with the edges buffed and rounded. Spring contact brushes provide adequate contact to the rotor. Mycalex is used as insulation. A two to one bevel gear is provided so that full capacity variation is given by a complete turn of the dial. Auxiliary equipment includes small nitrogen tanks, pressure regulators and high pressure hose.

News

✦ Dr. Harry F. Olson, director of acoustical research for RCA, has been appointed by Columbia University to inaugurate new studies in electrical acoustics. The new course will complement and be parallel with two other courses in sound production, one on communication electronics given by Dr. Eugene Peterson of Bell Labs, and the other on the acoustical properties of rooms and buildings conducted by Dr. V. A. Schlenker of the university . . . Westinghouse is conducting an investigation of the properties of lightning in a number of lightning observation stations established over the country in regions of greatest lightning severity. Shortly after the station atop the Cathedral of Learning of the University of Pittsburgh was completed, a direct hit was recorded in its entirety—for the first time—including the initial high-current surge and the long-lasting, low-current tail . . . The Milwaukee (Wis.) *Journal* is building an experimental frequency modulation transmitter . . . A surface indicator to determine the smoothness of metal or painted surfaces has been developed by General Electric. Variations of as small as 1/1,000,000 of an inch are readily detected . . . Morris E. Leeds, founder and president of the Leeds & Northrup Co., has assumed the position of Chairman of the Board of Directors and Charles S. Redding, vice-president in charge of research and engineering, has become president in that company's new executive setup . . . Ansley Radio Corp. is now located in its new enlarged plant at 238th St. and Bronx Blvd., New York, where 15,000 sq ft of floor space are devoted exclusively to th manufacture of special radio cabinets . . . The manufacturing and sales rights to the Rider Chanalyst and Voltohmyst have been acquired by the RCA Manufacturing Co. At the same time RCA announced a new policy of minimized obsolescence in the production of service test equipment . . . Sentinel Radio Corp. is now occupying its new and spacious plant at 2020 Ridge Blvd., Evanston, Ill. Greater capacity and efficiency are expected in the new layout . . . Microvolts, Inc. is the name of a company which has been formed by a group of Boonton, N. J. engineers for the purpose of developing and manufacturing a line of precision radio frequency testing and measuring instruments, with particular emphasis on the u-h-f field. The company's engineers include C. J. Franks, Jerry Minter, J. G. Haas and J. M. vanBeuren, who expect to announce their new models to the trade shortly.

C. J. Franks who is now associated with Microvolts, Inc., Boonton, N. J. in the development of precision radio instruments

Literature

Chart. A reactance-frequency chart and a decibel-voltage and power chart for quick calculation are offered by United Transformer Corp., 150 Varick St., New York.

Recording Heads. Types R7 magnetic and type X26 crystal recording heads are discussed in Sound Advances, Vol. 5, No. 2, June 1939. A publication of Sound Apparatus Co., 150 West Forty-sixth St., New York.

Recorders. Booklet describes recording equipment offered by David Bogen Co., 663 Broadway, New York.

Small Tubing. Small size seamless tubing and its manufacturing technique are described in a booklet by Superior Tube Co., Norristown, Pa.

Relays. Catalog C gives descriptions and list prices of a number of relays for various applications. Advance Electric Co., 1260 West Second St., Los Angeles, Calif.

Combustion Safeguard. Flame-otrol to cut off fuel supply when flame fails is described in Bulletin 1001-1 by Wheelco Instruments Co., 1929-33 S. Halsted St., Chicago.

Broadcast Antennas. Some notes on their design computations are given on page 12 of the July issue of Picks-Ups published by Western Electric Co., 195 Broadway, New York.

Dials, Name Plates, etc. Large variety described in Bulletin 225. Also escutcheons, knobs, and pointers. Crowe Name Plate & Manufacturing Co., 3701 Ravenswood Ave., Chicago.

Close-Ups. Of plant operation in booklet by Aerovox Corp., New Bedford, Mass.

Transmitting Capacitors. Described in Catalog 160-T. Also, Quietone radio interference filters are discussed in Catalog 166-A. Catalog 167-A describes a capacitor analyzer, bridge and decades. Cornell-Dubilier Electric Corp., South Plainfield, N. J.

Antennas. Transmitting and receiving, tubular steel or copper. Also several transmitting switches described in Bulletin 539. Also copper coaxial transmission line fittings and servicing equipment in Bulletin 439. Communication Products, 245 Custer Ave., Jersey City, N. J.

Conductivity Bridge and Dip Cells. Model RC-1-B for 110–125 volt 50–60 cycle operation with 1000 cycle source described in Bulletin RC-115. Insulation resistance testers are described in Bulletin MB-203. Industrial Instruments, Inc., Bayonne, N. J.

Lathes. Three new models of precision lathes are described in Bulletin 43 by South Bend Lathe Works, 425 East Madison St., South Bend, Ind.

Rotary Converter. Features and applications are discussed in Bulletin 13-1 by Janette Manufacturing Co., 556–558 West Monroe St., Chicago.

Loudspeakers. PM and electro-dynamic speakers and speaker transformers are described in Bulletin 391 by Oxford-Tartak Corp., 915 West Van Buren St., Chicago.

Microphones and Pickups. A wide variety of crystal microphones and pickups are described in Catalog No. 12 by Astatic Microphone Laboratories, Youngstown, Ohio.

Zinc Alloys. "Practice in Machining Zinc Alloy Die Castings" is the title of the interesting booklet offered by The New Jersey Zinc Sales Co., 160 Front St., New York.

Marine Radio Telephones. Several different models from 10 to 50 watts output are described in a booklet by Transmitter Equipment Mfg. Co., 130 Cedar St., New York.

Television. "Practical Television by RCA" is the title of a 40-page book outlining the RCA television system particularly receiving circuits, antennas and reception. RCA Mfg. Co., Camden, N. J.

Recording Equipment. A line of record changers, turntables, motors, pickups and other accessories are described in a bulletin by The Webster Co., 5622 Bloomingdale Ave., Chicago.

Studio Console. The 12H console for small and large stations is described in a booklet by Collins Radio Co., Cedar Rapids, Iowa.

Capacitors. For radio and television in large variety are described in Catalog 10 by Solar Manufacturing Corp., Bayonne, N. J.

Monel. A folder which contains basic information on mechanical, corrosion-resistant and other properties of rolled nickel, Monel and other nickel alloys is offered by The International Nickel Co., 67 Wall St., New York.

Tubes. A six-page folder gives characteristics of transmitting tubes, diathermy and high-frequency types. Hytronic Laboratories, 76 Lafayette St., Salem, Mass.

Tubes. Notes on applications of types 35Z5GT and 45Z5GT are given in Bulletin 39-4. Tung-Sol Lamp Works, Radio Tube Division, Newark, N. J.

Tubes. Operation characteristics of type 25C6G are given in Engineering News Letter by Hygrade Sylvania Corp., 500 Fifth Ave., New York.

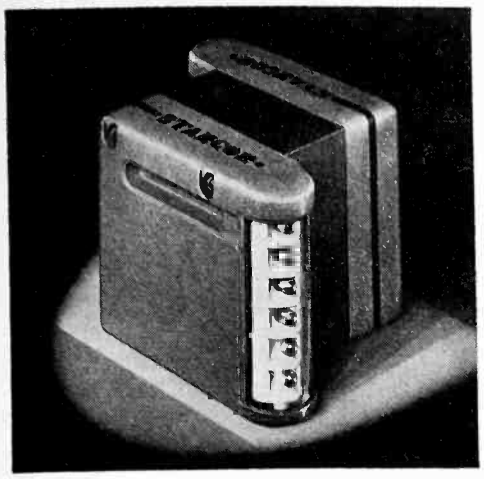
Transcription Record Player. For broadcast stations, advertising agencies, etc., described in a bulletin by Terminal Radio Corp., 68 West 45th St., New York.

Facsimile. Reado radio printers are described and list prices given in a bulletin by The Crosley Corp., Cincinnati, Ohio.

New Products

Transformers

THREE NEW TRANSFORMERS have been announced by Standard Transformer Corp., 1500 North Halsted St., Chicago. The Hi-Fi line of audio transformers have a uniform frequency response from 30 to 15,000 cps which is accomplished by the use of coils having low distributed capacity and of laminations of high permeability alloys. The coils are of pie-wound and hum-bucking construction where necessary with electrostatic shields brought out to a terminal. Tinytrans are small size and lightweight audio transformers for use where small size is a requirement. They measure $\frac{15}{16}$ inch in diameter by $1\frac{1}{4}$ inches in overall height. The transformers carrying d c in the primary are for voice frequencies from 150 to 5500 cps and those not carrying d c in the primary have a uniform curve from 30 to 15,000 cps. The Thorobred power



transformer is enclosed in an ultra-modern case with the mounting feet streamlined into the housing. The danger of exposed high voltage connections has been eliminated by means of visible terminals permitting protected bottom, side or end connections.

Electrolytic Condensers

THE ADDITION of several dual-section electrolytic condensers to its Dandee line is announced by Aerovox Corp., New Bedford, Mass. These are the 8-8 and 8-16 μf 450 v; 8-8, 8-16 and 16-16 μf 200 v; and the 20-20 μf 160 v; and 10-10 μf 25 volt. The 10-10 μf 50 volt, previously included in the line, rounds out the dual-section numbers.

Aerovox, while expanding its Dandee line, continues its policy of pointing out that these midget-can electrolytics are not to be confused with standard-sized large-can electrolytics. The former are suitable for many applications, but the large-can units are still recommended for heavy-duty service over a term of years. The midget type, Aerovox insists, is not a 100% replacement for the standard-sized unit, and should always be considered with that reservation in mind.

Television Components

A NEW LINE of transformers, chokes and yokes for television receivers is announced by Jefferson Electric Co., Bellwood, Ill. These include high voltage power transformers for use with the electrically deflected 5 inch tube and the magnetically deflected 9 inch and 12 inch tubes, respectively; filter choke of 8600 ohms resistance, 1800 henries at 1.5 ma d c; oscillation (horizontal and vertical) transformers for blocking oscillator circuits; output transformers for use in conjunction with scanning yokes, one to work out of pentodes and one out of triodes; and a scanning or deflecting yoke for use with magnetically deflected picture tubes, supplying horizontal and vertical deflection in conjunction with output transformers.

New Tubes

A NEW BATTERY-OPERATED diode-triode-power amplifier pentode tube known as

1D8-GT has been announced by RCA Manufacturing Co., Harrison, N. J. This tube facilitates the design of battery-operated receivers featuring compactness and reduced filament battery drain.

Two new tubes are announced by Arcturus Radio Tube Co., 720 Frelinghuysen Ave., Newark, N. J. The 3Q5GT is a beam power amplifier having a center point connection to the filament so that it may be operated with a series arrangement at 2.8 volts or parallel arrangement at 1.4 volts applied to the filament. The 70A7GT performs the functions of power amplifier and half-wave rectifier.

Recorder

A PORTABLE two-speed turntable, which provides both recording and instantaneous playback of 16-inch records through any public address system when used with a recording attachment, has been announced by RCA Victor, Camden, N. J. Specially designed for use with the new RCA Victor re-

cording attachment, this instrument may be used for both high quality recording and reproduction of records ranging from six to sixteen inches in diameter at either 78 rpm or 33⅓ rpm. The recording attachment, which may be installed on the turntable's motor board panel, makes the instrument a high quality recording and instantaneous playback unit which may be moved about and installed easily. Outstanding feature of the attachment is the new Float Stabilizer which acts as a shock-absorber on the cutter-head and thus assures utmost smoothness in recording. It is available in two models for either outside-in or inside-out recording.

Ratchet Relay

MODEL S-120 RATCHET relay is announced by Guardian Electric Mfg. Co., 1621 Walnut St., Chicago. On-off locking operation requires but a single circuit to the coil. The first impulse opens the contacts and the next impulse closes them. The coil requires 18 watts a c or 10 watts d c to operate a single pole, double throw switch. Coils are furnished for operation on any d-c voltage up to 110 volts or a-c voltages up to 220 volts. The contact capacity is 1500 watts at 110 volts, 60 cycles, non-inductive a c. The armature rotates a four point cam, making and breaking standard Guardian contact switches. The armature is full-floating with the air gap readily accessible for adjustment.

Circuit Breaker

A NEW CIRCUIT breaker which combines switching and over-current protection and sells for about $2.00 is announced by the Square D Co., 6050 Rivard St., Detroit, Mich. The new unit is designated as type MO Multi-breaker and is to be available in 15, 20 and 25 ampere sizes for 115 and 230-volt single and two pole applications where Type D

fusible switches have been used. The unit is compact, being 6⅛ inches high, 4 inches wide and 2⅞ inches deep and is adapted to flush or surface mounting. There are no live parts exposed. It is factory calibrated and sealed and will always interrupt the circuit under the same overload conditions, but will not open the circuit during the brief periods of high inrush circuit encountered in starting motors. There are no parts to replace to restore service—just flip the switch.

Polystyrene Film

THE DEVELOPMENT of Bakelite polystyrene film for electrical insulation purposes is announced by Bakelite Corporation, 247 Park Ave., New York.

All of the many advantageous properties that are found in Bakelite polystyrene molding material are incorporated in this new film which has been developed especially for such uses as wound capacitors in radio sets and other types of electrical equipment. The low power factor of the Bakelite polystyrene film produces capacitors which are extremely efficient. It is also important that these capacitors have stable capacitance not only with changes in temperature but also for various frequencies. The electrical properties of this film remain constant even at varying temperatures. This is made possible because of the stable characteristics of polystyrene and its exceptional water resistance. The film is water white in appearance, but may also be had in a tinted shade of purplish black. It is supplied in ribbons 1½ inches and 2½ inches wide and wound on spools to a diameter of 4 inches. The standard thickness is 1 mil and certain other thicknesses are available.

Oscillator

A CRYSTAL CONTROLLED oscillator (HT-7 Frequency Standard) is announced by Hallicrafters, Inc., 2611 Indiana Ave., Chicago. Fundamental outputs at 1000, 100 and 10 kc are provided, each with harmonics made useful even in the highest frequency ranges by a tun-

able harmonic amplifier stage. A dual type 1000-100 kc crystal controls the outputs at these frequencies. The 100 kc crystal position also locks in a multivibrator which provides the 10 kc output. Provision is made for checking with other standards.

Rechargeable Batteries

RECHARGEABLE BATTERIES for use in the filament lighting of battery operated radio receiving sets have been announced by Portable Electric Power, Inc., 30 Rockefeller Plaza, New York, together with a small silent battery charger which permits recharging the battery at small cost. The rechargeable battery is non-spillable and leak proof, small, light in weight and designed to operate radio receiving sets using one and one-half volt vacuum tubes. The batteries are made in four sizes and weigh from 8 oz to 36 oz. The operating cycle is from 6 to 36 hours. The small silent charger is five inches high, one and one-half inches wide and two and one-half inches deep, weighs less than one pound while the larger size charger measures five inches high, two and one-half by two and three-quarters inches, and weighs one and one-half pounds. The charger operates with either 110 volt, 25, 40, 50, or 60 cycles or 110 volts d c and is silent in operation.

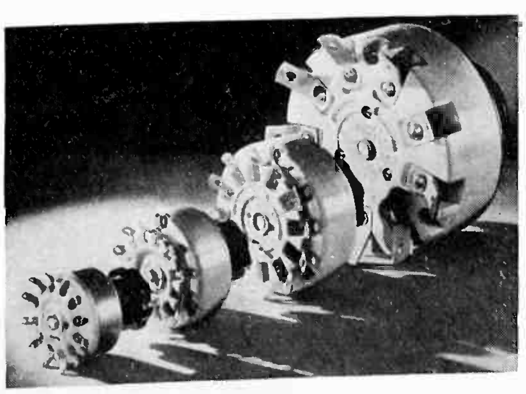
Intercommunicator

AN INTERCOMMUNICATIONS system consisting of up to seven stations, any one of which can converse with any other with privacy, and over which three conversations may be carried on simultaneously between as many pairs

of stations without interference is announced by the Lafayette Radio Corporation, 100 Sixth Ave., New York City, in the Multiple Master model. Each station unit of this system consists of a small ivory and black plastic cabinet which houses the ac-dc amplifier, power supply and combination microphone-speaker. On its face are the simple controls consisting of six station-selector buttons, push-to-talk switch, on-off switch and volume control. Transmission occurs only while the push-to-talk switch is held down.

Power Tap Switch

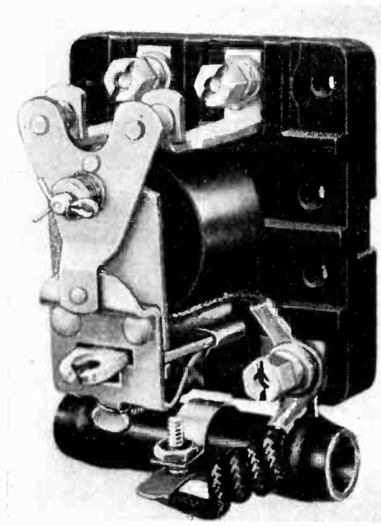
THREE NEW SIZES of power tap switches have been announced by Ohmite Manufacturing Co., 4835 Flournoy St.,



Chicago. There are now four sizes in the series: 10, 20, 40 and 75 amperes at 240 volts ac. Special switches and tandem assemblies are available on order. The large diameter silver-to-silver contacts are self-cleaning and require no maintenance. Positive cam-and-roller mechanism provides desirable slow-break, quick-make action for alternating current, minimizes sparking and increases the life of the contacts.

Underload Relay

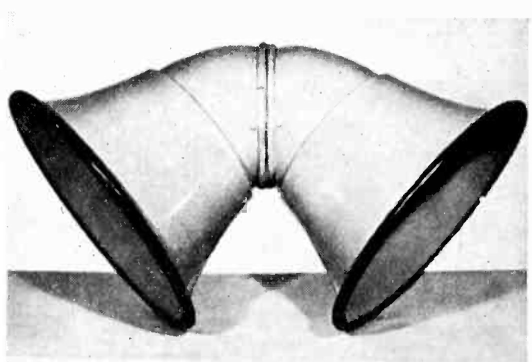
A NEW UNDERLOAD relay for low power transmitters has been announced by Ward Leonard Electric Co., Mount Vernon, N. Y. The new construction is similar to the design of the Ward



Leonard remote control relay with the addition of an adjustohm resistor connected in the coil circuit permitting adjustment for desired pick up of the relay armature. These relays give protection to class B modulator tubes and prevent possible breakdown of the class B modulator transformer secondary should the class C tubes fail to hold the load due to loss of excitation.

Cone Sound Projector

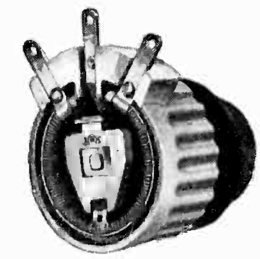
A CONE SOUND projector to utilize the acoustic output of both sides of the cone speaker is announced by University Laboratories, 195 Chrystie St., New York. Increased efficiency and



coverage are obtained from the use of this unit. The placement of the two halves is such that a fan wave of sound is obtained (180 degrees horizontal and 90 degrees vertical). Rubber tire rims on the front edges of both bells of the projector eliminate resonance.

Rheostat

THE CONSTRUCTION of the 50-watt all metal rheostats type PR-50, announced by the International Resistance Company, 401 N. Broad Street, Philadelphia, Pa., results in a reduction of operating temperatures to almost half those obtained with rheostats of conventional design and of the same size. Operation of the rheo-



stat at full load in any portion of the resistance winding down to 25 per cent of full rotation is made possible without exceeding the normal temperature rise by more than 30 degrees C. The 50 watt rating is based on a hottest spot temperature rise of 140 degrees C when unit is mounted on a metal panel and power dissipated over the entire unit. Thus, this rating applies under the same mounting conditions for as low as 25 per cent of full rotation with a temperature rise of only 170 degrees C.

Loudspeaker

A NEW IMPROVED permanent magnet dynamic speaker has been announced by Atlas Sound Corp., 1447-51 Thirty-ninth St., Brooklyn, N. Y. Alnico is used as the magnetic material and the flux density is equal to the Atlas giant type field coil exciter unit. The new Hi-Fi model includes a special sound chamber which provides for the wide range response. The diaphragm is of heat-treated duralumin and is given a special electro-chemical treatment which makes it impervious to corrosion. The voice coil is of aluminum wire and is wound on a preformed coil form.

Loop Antenna

A NEW SELF-CONTAINED loop antenna called Antenna-Scope has just been announced by Consolidated Wire & Associated Corps., 520 S. Peoria St., Chicago. It attaches very easily to any broadcast receiver with two double vacuum cups provided with each unit. It may be matched to the inductance requirements of any trf or super-hot receiver by screw-driver adjustment of the iron core, permeability tuned, tracking coil.

RULES and REGULATIONS

(*Continued from page* 13)

other stations will be required to adopt that method by July 1, 1940. Existing stations using the indirect method (plate power input × given efficiency) are required to use efficiency of 70 per cent, instead of 50-60 per cent as formerly, if the maxi- much more severe and difficult to obtain than was formerly the case.

Transmitters using plate-modulated final stages must use an efficiency of 70 per cent, instead of 50-60 per cent as formerly, if the maximum rated carrier power is from 100 to 1000 watts, and an efficiency of 80 per cent instead of 65 per cent if the maximum rated carrier power is more than 5000 watts. Stations using Class B final amplifiers must use 35 per cent and those using Class BC final amplifiers must use 65 per cent. Stations using different night-time and day-time powers must use the same efficiency for both powers.

In general, stations using the indirect method will find it to their advantage to change to the direct method without delay for two reasons:

1. The new efficiencies are severe and in many cases will be difficult to meet in practice. If they are not met the licensed power can not be radiated.

2. Following the final stage, where the power is determined by the indirect method, there are inevitable losses in transmission line and antenna coupling apparatus which further reduce the radiated power.

Measurement of power by the direct method is considered preferable by this writer because it provides assurance both to the Licensee and the Communications Commission that the antenna input power is what it is supposed to be.

The reader is referred to the Standards of Good Engineering Practice for guidance in making antenna resistance measurements and preparing the necessary application to the F.C.C. for authorization to use the direct method. In the *RCA Review* of April 1938 and January 1939, William A. Fitch and William S. Duttera, in "Measurement of Broadcast Coverage and Antenna Performance," cover the same subject in detail.

Section 11 of the Standards permits short period variations of operating power of 5 per cent above or 10 per cent below the authorized power.

Frequency Tolerance

Rules Section 3.59 "Frequency Tolerance" is of interest. Until July 1, 1940 all stations are permitted a maximum deviation, from their assigned frequency, of 50 cycles. From then until January 1, 1942 new stations must remain within 20 cycles, and thereafter all stations must.

There are good reasons for this rule. Some years ago, before the 50 cycle requirement became effective, 500 cycles was permitted. If two stations on the same channel each deviated 500 cycles, but in opposite directions, the result was a 1,000 cycle beat note. This frequency falls near the range of maximum sensitivity of the human ear, and also that of the average loudspeaker. Therefore even a low value of interfering field intensity was ruinous to service. Reducing the tolerance from 500 cycles to 50 cycles reduced the maximum beat frequency to 100 cycles and in this range the ear, and also most loudspeakers, were relatively insensitive. Therefore a considerably stronger interfering field intensity could be tolerated. The further reduction of the tolerance to 20 cycles confines the maximum beat frequency to 40 cycles, and in this step the gain is perhaps greatest. The ear is quite insensitive to this frequency and the average loudspeaker is conspicuously so.

It would be improbable that the maximum deviations would be experienced. If averages were used they might be, for 500 cycles tolerance, 500 cycles, and for 50 cycles tolerance, 50 cycles. Under these conditions it has been considered that for the larger tolerance, a desired to undesired ratio of signal intensities of 100:1 would be required to prevent interference, but that for the small tolerance 20:1 would produce the same results. It was considered that a ratio of 20:1 between the desired and undesired signals represented a modulation of the desired signal of 5 per cent at 50 cycles, or 5 per cent crosstalk, with equivalent modulating conditions at the two stations.

Sections 3.61 and 3.62 of the Rules require that authorization to modify or replace frequency control apparatus be obtained. However, no specifications are included beyond the requirement that before approval will be considered there must be reasonable assurance that the equipment is capable of maintaining automatically the assigned frequency within the limits specified.

With possibly a few exceptions, equipment now in use, built to meet the 50 cycle requirement, deviates considerably less than 20 cycles. In a great many cases substitution of low-temperature-coefficient crystals should provide the additional factor of safety.

Radiating Systems

Section 3.45 of the Rules and a corresponding section of the Standards of Good Engineering Practice deal with radiating systems. Stations requesting authority to modify or to build new radiating systems are required to equal or exceed certain minimum antenna efficiencies. Ordinarily, these efficiencies are obtained by building antennas to certain minimum heights since over a significant range the height determines the efficiency. There are good reasons for doing so, even if it were not required, and particularly so in the cases of the higher-powered stations. Figure 3 shows vertical cross sections of the field distribution from antenna of various fractions of a wavelength in height. The abscissa to the left is proportional to field intensity units. As the height is increased the wave parallel to the earth is increased at the expense of the high angle component.

Since both local and long distance transmission depend upon the wave energy leaving the antenna at angles within 10 per cent of horizontal, all of the useful functions are served better by compressing the field as nearly as possible to the earth's surface. The high angle radiation not only represents wasted power but it causes the fading which degrades service at the boundaries of the primary service area. Figure 4 shows eloquently the effect the antenna height has upon the distance to the fading wall. The improvement actually obtained by the construction of a new antenna at WJZ was described by the writer in the April 1937 issue of *RCA Review*.

Of the new Standards, Section 1, covering "Engineering Standards of Allocation" is probably the most comprehensive. In it standard broadcast stations are classified and defined, service standards are set up for both day and night operation, and the subject of interference, and methods of determining it, are dealt with at some length. Much new desired material is presented, including the method of evaluating interference produced when two or more stations cause it. In this connection it is not considered that increased objectionable interference is predominently from a single station, when a signal from another station is added which does not equal 70 per cent of the strongest signal already interfering. For two equal interfering signals, the signal added should not equal 85 per cent of either one. The existence or absence of interference may be determined by actual prescribed methods of measurement, reference to the attached propagation curves, or the distance Tables VI, VII, and VIII.

Section 12 of the Standards specifies a maximum of 5 per cent audio harmonic distortion (voltage measurements of arithemetical sum) for transmitters when modulated up to 84 per cent, and not over 7.5 per cent up to 95 per cent. Harmonics up to the tenth are to be measured up to a maximum frequency of 16000 cps, using modulating frequencies of 50, 100, 400, 1000, 5000, and 7500 cps. This Standard may be difficult for some existing stations to meet. Those using Class B final amplifiers with indirect power measurement may find it advantageous to change to direct measurement and then readjust the equipment to improve the distortion characteristics. Operating at 30 per cent efficiency or thereabouts instead of 33 or more will usually permit of considerable improvement if the plate dissipation ratings of the tubes are not exceeded.

The carrier current shift has been made a maximum of 5 per cent. The shift will not be visible on thermocouple instruments but will be observed on the rectifier types, and it may also be observed on the d-c rectified current meters of modulation monitors.

The unweighted RSS carrier noise should be not less than 50 db below 100 per cent modulation from 150 to 5000 cps, and not less than 40 db outside that frequency range. It is not considered that these tolerances apply to the usual long lines network circuit noises since they are beyond the control of the licensee. Elaborate standards are set up covering safety precautions and indicating instruments. The licensee will be wise to study these carefully.

In connection with spurious radiations, including radio frequency harmonics, the Rules and Standards impose only the broad requirement that they do not exceed values conforming with good engineering practice. It is often difficult to determine the degree of harmonic radiation since high frequency harmonic currents produce random standing waves on an antenna which in turn may produce vertical radiation at high angles not measurable at nearby points on the ground. One watt of harmonic power in the antenna can produce a field intensity of over 6000 microvolts per meter at one mile. At one hundred miles it could produce 40 microvolts which could be ruinous to aviation or other services which carry on communication with field intensities that order of magnitude.

Lack of space prevents going into further detail in connection with the new Rules and Standards. To be sure of meeting them stations will need measuring apparatus. A few of the more important instruments would include a variable audio frequency oscillator with very low harmonic content and a meter for measuring carrier noise and audio frequency harmonic distortion.

Years ago the writer inspected a broadcasting station which utilized storage batteries for the plate supply. Following nightly charging cycles, they delivered about 1300 volts for the beginning of each day's transmission. However, the voltage soon began to drop and at signing-off time was barely 400 volts. In an attempt to compensate for this state of affairs, the antenna coupling coil, a well-known standard amateur unit, was pushed along a shelf with a yard stick specially selected for this highly scientific purpose. Fortunately, such bailing wire practices are but a memory. They would be impossible at the present time. And why? Well, in the humble opinion of the writer, with due credit to the licensees who take pride in fine plants, it isn't necessarily because the breed of shoestring operators is extinct.

Broadcast channels are public property entrusted by the F.C.C. to the care of private licensees. The possession of a license imposes upon the licensee the responsibility to serve public interest, convenience, and necessity. Before an applicant can obtain a license he must show that there is a need for service, and he must also show that adequate resources are available to provide it properly. The new technical Rules and Standards are the best and most complete of their kind in the world. Compliance with them will automatically assure high quality transmission, with reasonable efficiency, and will also keep technical departments out of hot water.

U. S. Patents

Miscellaneous Circuits

Hum Reduction. Method of reducing hum in amplifier networks. L. F. Jones, R.C.A. No. 2,161,148.

Frequency Measuring. Circuit including a tachometer responsive to phenomena indicative of the velocity of a mechanism. J. E. Echlin and L. B. Erickson, San Francisco. No. 2,161,146.

Oscillation Generator. In a diathermy machine, device for shifting frequency. A. Senauke assigned to Amperex Electronic Products, Inc. No. 2,156,230.

Band Pass Selector. Means for deriving a first voltage variable in phase in accordance with the frequency of the input to the system, means for deriving a second voltage which varies less rapidly in phase than the first. H. A. Wheeler, Hazeltine Corp. No. 2,156,137.

Radio Circuits. Patents to J. E. Beggs, General Electric Co. No. 2,156,076 on automatic fidelity control; No. 2,156,077 on automatic selectivity control and No. 2,156,078 for producing automatic volume control voltages. Also No. 2,156,079 on a tube construction.

Magnetron. Amplifier comprising a magnetron. Robert Serrell, RCA. No. 2,155,844.

SEARCHLIGHT SECTION

EMPLOYMENT : BUSINESS : OPPORTUNITIES : EQUIPMENT—USED or RESALE

UNDISPLAYED RATE:

10 cents a word, minimum charge $2.00.

Position Wanted: (full or part-time salaried employment only), ½ the above rates, payable in advance.

Proposals, 40 cents a line an insertion.

INFORMATION:

Box Numbers in care of our New York, Chicago, or San Francisco offices count 10 words additional in undisplayed ads. Replies forwarded without extra charge.

Discount of 10% if full payment is made in advance for four consecutive insertions of undisplayed ads (not including proposals).

DISPLAYED—RATE PER INCH:

The advertising rate is $6.00 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

An advertising inch is measured ⅞" vertically on one column, 3 columns—30 inches—to a page.

Copy for new advertisements must be received by August 28th for the September issue

Balance. A force-measuring device for distant reading electromagnetic balance. S. E. Dawson, Washington, D. C. No. 2,141,175.

Gas Analysis Apparatus. Equipment for determining the composition of a gas including a casing through which gas is passed, an elongated device formed of metals having different temperature coefficients of expansion and supported at one end and carrying a contact at its other end, etc. E. A. Keeler, Brown Instrument Co. No. 2,146,300.

Sorting Apparatus. Apparatus for classifying metal sheets as they are sheared from strip, comprising means for continuously gaging a strip of metal as it is fed to the apparatus and before it is sheared. G. A. Kaufman, Jones & Laughlin Steel Corp. No. 2,146,581.

Tension Control. In a strand handling apparatus, motive means for applying tension to a strand, a variable condenser, etc. W. E. White, W.E. Co. No. 2,146,869. See also No. 2,146,857, K. L. Scott, W.E. Co. on apparatus for testing magnetic materials.

Receiver. Radio or television receiver using phototube having surfaces insensitive to light polarized in one plane, controlling gaseous rectifiers; etc. F. W. Lyle, WE&M Co. No. 2,140,368.

Synchronizing System. Generating a series of unidirectional synchronizing pulses and reducing the amplitude of a group of the pulses at regular intervals. P. T. Farnsworth, No. 2,155,479.

Light Modulation. Apparatus for controlling intensity of a beam of light in accordance with several mechanical carrier waves of different frequencies comprising a body capable of transmitting mechanical waves to produce diffraction grating effects. J. H. Jeffree, Scophony, Ltd. No. 2,155,659. See also No. 2,155,660 and 2,155,661 also to Jeffree.

Oscillator. A method of producing high frequency oscillations which comprises projecting a stream of electrons in one direction in conical fashion, causing stream of electrons to first diverge and then converge, projecting another stream of electrons in an opposite direction in a similar manner and reversing the directions of travel of said streams. N. E. Lindenblad, RCA. No. 2,149,024.

Communication System. Several patents to R. H. Campbell, Webster Electric Co. on intercommunication system. No. 2,162,368 to 2,162,372, inclusive. See also 2,162,547 to Campbell.

Indicator. Cathode ray cyclographic bridge balance indicator. T. T. Goldsmith, A. B. Du Mont Laboratories. No. 2,162,009.

Modulator. An absorption modulation circuit. F. E. Terman, Stanford University, Calif. No. 2,152,753.

INDEX TO ADVERTISERS

SEARCHLIGHT SECTION

(Classified Advertising)