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November, 1938

Balanced Feed-Back Amplifiers

BY EDWARD L. GINZTON

IN RECENT years an important change in amplifier design was introduced by the development of the stabilized feedback or the negative feedback principle.[1] This design represented a substantial improvement in the performance of amplifiers; by means of this principle the amplifier response can be made linear and practically independent of line-voltage fluctuations, and noise and distortions are reduced. These improvements are made possible by the return of a fraction of the output to the input to be used as a controlling voltage. Since the energy fed back is in opposite direction to the input signal, the feedback reduces the signal output, and in the cases where performance requirements are very strict, the reduction of the overall gain may be so large that it becomes impractical to use such a system. It is desired, then, to develop an amplifier which will possess the advantages of the negative feedback without its disadvantage—the reduction of the overall amplification. Such a design is possible by means of application of the balanced feedback principle.

[1] H. S. Black, "Stabilized Feedback Amplifiers," *Bell Sys. Tech. Jour.*, vol. 13, p. 1; January, (1934).

Balanced Feed-Back Amplifiers

1. *The Balanced Feedback Principle*

The name balanced feedback is derived from the fact that two controlling voltages, balanced against each other, are used at the input of the amplifier for the purpose of controlling its performance. One of these voltages is obtained from the output of the amplifier and is the conventional negative feedback which regulates the performance of the amplifier, and will be referred to in this paper as the *negative feedback voltage*. The other feedback voltage, in opposite polarity to the negative feedback, and hence called the *positive feedback voltage*, is obtained in such a way that it is always proportional to the input sig-

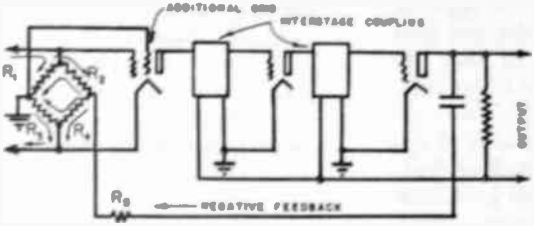


Figure 1. An idealized balanced feedback amplifier. An additional grid is used for the control of the performance.

nal and is independent of frequency over the range of frequencies it is desired to amplify linearly. The positive and negative feedbacks are made normally equal to each other, and therefore, when the performance of the amplifier is normal, they cancel each other and, hence, have no effect on the output. But if the output should for some reason differ from proportionality to the input, the feedback circuits introduce voltages at the input of the amplifier in such a direction and of such a magnitude that the output is changed back to normal. In its operation, the balanced feedback principle is very similar to the ordinary mechanical governor in steam engines, turbines, etc., in that the governor is acting only when the output differs from the desired normal operating conditions.

The principle of the balanced feedback is shown in the idealized circuit, figure 1. Except for the two feedback circuits and additional control grid in the first tube, the amplifier is of the conventional design using whatever interstage coupling may be required for the specific application. Across the resistances of the bridge in the input circuit there are two voltages, one being the signal input, and the other being a fraction of the output returned to the input. Across the resistance R_5 the two voltages are in the opposite direction, as shown by current arrows in figure 1, and therefore, by proper choice of various resistances, the voltage across resistance R_5 can be made zero. As is seen in figure 1, resistance R_5 is connected between the cathode and the additional grid of the first tube; if the output is proportional to the input, the voltage across R_5 is zero and the additional grid has no effect on the plate current of the first tube. But if the output deviates from proportionality, a voltage will be introduced across R_5 and the additional grid in the first tube will be at some potential with respect to its cathode. The output of the amplifier will be changed, accordingly, so as to tend to eliminate the original deviation and restore perfect proportionality.

2. *Polarity of the Two Feedbacks*

The feedback voltages impressed at the input of the amplifier must satisfy two conditions. (1) The two feedbacks must be in opposite polarity. Since each tube and each interstage transformer, if they are used, produce a reversal of polarity, care must be taken to have the negative feedback voltage actually of opposite polarity to the positive feedback. (2) The additional grid must be in proper polarity with respect to the control grid of the first tube. For example, if the amplifier output should become too low for some reason, then the voltage produced on the additional grid must be of the same polarity as the voltage of the control grid to increase the output to the proper level. Accordingly, the negative feedback must be of opposite polarity to the input and the positive feedback must be of the same polarity as the input.

These two conditions are obviously essential. Actual polarity of the two feedbacks depends upon the manner in which the positive feedback is obtained.

3. Performance Equations for Balanced Feedback

The effect of balanced feedback as compared to the negative feedback is shown by the following derivation:

Let,

$e =$ signal input voltage

$A =$ amplification constant for the entire amplifier

$Ae =$ signal output voltage without feedback

$n =$ noise output voltage without feedback

$d(E) =$ distortion output voltage without feedback

$\beta =$ propagation constant of the negative feedback circuit, i.e., the fraction of the output returned to the input

$\alpha =$ propagation constant of the positive feedback circuit, i.e., a number times the input voltage. May be greater or less than 1

$E =$ signal output voltage with balanced feedback

$N =$ noise output voltage with balanced feedback

$D =$ distortion output voltage with balanced feedback

The above notation is perfectly general and applies to an amplifier which utilizes both positive and negative feedback. All of the above symbols, except α and β, are obvious and have the usual meanings for all amplifiers. Definition of factor α, however, depends upon the particular amplifier and the way that positive feedback is introduced into the input. In general, α is defined by the ratio of the voltage developed by the positive feedback circuit to the signal input voltage at the input grid of the first stage. Definition of β is perfectly general as defined above. For instance, in figure 1, assuming that R_1, R_2, R_3, and R_4 are equal, $\beta = R_3/[2(R_3 + R_5)]$. Assuming that the two control grids in figure 1 have the same amplification factor, then $\alpha = R_3/[R_3+R_1] = 1/2$.

The output voltage without feedback is $Ae+n+d(E)$. The balanced feedback voltage is composed of positive feedback voltage αe, and negative feedback voltage $\beta(E+N$

+D) The total feedback voltage is (at the input of the amplifier)

$$\alpha e + \beta(E+N+D). \quad (1)$$

The output voltage with balanced feedback is composed of the output voltage without balanced feedback plus the output due to the balanced feedback at the input. Hence, the output with the balanced feedback is

$$E + N + D = Ae + n + d(E) + \alpha Ae + \beta A\,(E + N + D) \quad (2)$$

$$(E + N + D)(1 - \beta A) = Ae(1+\alpha) + n + d(E) \quad (3)$$

$$E + N + D = \frac{Ae(1+\alpha)}{1-\beta A} + \frac{n}{1-\beta A} + \frac{d(E)}{1-\beta A} \quad (4)$$

If the amplifier is so adjusted that the positive feedback is equal and opposite to the negative feedback, i.e., $\alpha = -\beta A$, the performance equation for the balanced feedback amplifier becomes

$$E + N + D = Ae + \frac{n}{1-\beta A} + \frac{d(E)}{1-\beta A} \quad (5)$$

Equation (5) shows that distortion, noise, etc., are reduced by the factor $1/(1-\beta A)$, while the over all gain of the amplifier is not affected by the introduction of the balanced feedback. Note that if the positive feedback is zero, $\alpha = 0$, and (4) becomes the performance equation for the conventional negative feedback amplifiers.[3]

$$E + N + D = \frac{Ae}{1-\beta A} + \frac{n}{1-\beta A} + \frac{d(E)}{1-\beta A} \quad (6)$$

Equations (5) and (6) show the main difference between the balanced feedback and the negative feedback. In the negative feedback, equation (6), the gain, noise, and distortion are all reduced by the same factor. In the balanced feedback amplifiers there is a definite discrimination against noise and distortion, while the gain is not affected.

It must be remembered, however, that the only essential difference between (5) and (6) is the reduction of gain in the latter case. The same result can be achieved by means of negative feedback alone, if the amplifier possesses excessive gain, or if it is possible to increase sufficiently the mutual conductance of one or more tubes, or by addition of another stage. *If this is possible* the results obtained by means of negative feedback alone will be identical with those obtained by means of balanced feedback, with the additional advantage that the negative feedback circuits tend to be simpler than those employed with balanced feedback. But as mentioned before, there are cases where the particular requirements do not allow the reduction of the overall gain of the amplifier.

From these equations the performance of the amplifier with balanced feedback may be determined. Frequency response, stability, delay distortion, critical points, etc., may be determined by proper manipulation.

4. *Frequency Response of Balanced Feedback Amplifiers*

The amplification constant of an amplifier is a complex quantity and is a function of frequency. The problem of calculation of the response of the amplifier can be subdivided for convenience into the calculation of the absolute value and the calculation of the corresponding phase-shift angle. The two problems are very similar and, as can be shown mathematically, the phase shift and amplitude distortion take place simultaneously. In the following analysis, only the absolute value of the response will be considered, with the understanding that the balanced feedback affects the phase shift in a similar manner and can be easily determined.

Referring to figure 2, let $\phi(f)$ be the factor by which the amplification of the balanced feedback amplifier changes with frequency, $\phi'(f)$ be the factor by which the amplification constant A changes with frequency, and $\phi''(f)$ be the factor by which the positive feedback α changes with frequency. Assuming zero noise or other distortion, (4) becomes

$$E = A\phi'(f)\,e\,\frac{1+\alpha\phi''(f)}{1-\beta A\phi'(f)} \qquad (7)$$

$$= Ae\phi(f) \qquad (8)$$

where,

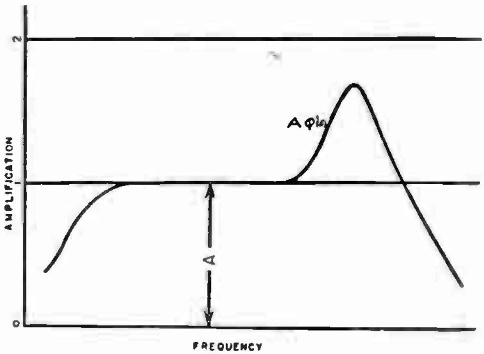
$$\phi(f) = \phi'(f)\frac{1+\alpha\phi''(f)}{1-\beta A\phi'(f)} \qquad (9)$$

If $\alpha\phi''(f) >> 1$ and $\beta A\phi'(f) >> 1$, and $\alpha = -\beta A$. Then,

$$\phi(f) = \phi''(f). \qquad (10)$$

This means that if the positive and the negative feedback voltages are made normally equal and very much larger than one, the output will be a function of the performance of the positive feedback voltage which can be made independent of frequency over the range of frequencies that it is desired to amplify without distortion, as is discussed later. If this condition is fulfilled, the performance of the entire amplifier will be independent of frequency over approximately the same range as the

Figure 2



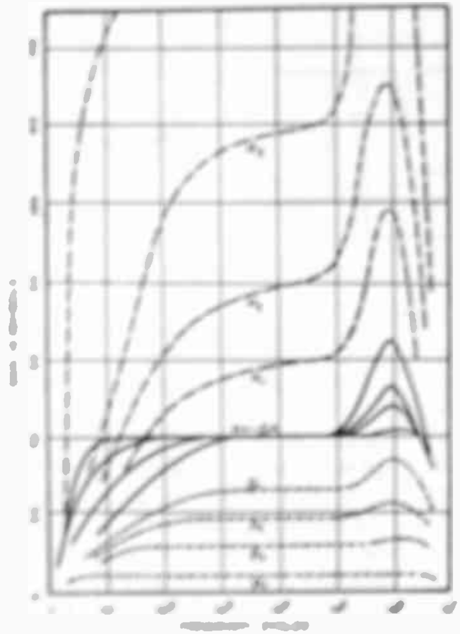


Figure 3. Theoretical curves showing the effect of balanced feedback.

distortionless range of the positive feedback circuit.

Figure 3 shows the theoretical frequency-response curves obtained from (7) and a known typical curve for a two stage resistance-capacitance-coupled amplifier. The dotted curves show the effect of the negative feedback alone; these show that the negative feedback makes the response of the amplifier linear over a large range of frequencies, but at the same time decreases the gain. The dashed curves show the effect of positive feedback alone. These are essentially the same as the response without any feedback, the difference being in the larger gain and the sharper cutoff outside the desired range. Balanced negative and positive voltages applied at the same time give a family of curves which approaches a straight line more and more as the ratio of the feedback to the input is made larger.

- **Practical Balanced Feedback Amplifiers**

1. *Methods of Obtaining Positive Feedback*

The above discussion and figure 3 show that it is desirable to have as high a value of balanced feedback as possible. There is no difficulty in obtaining a high value of negative feedback; the positive feed-

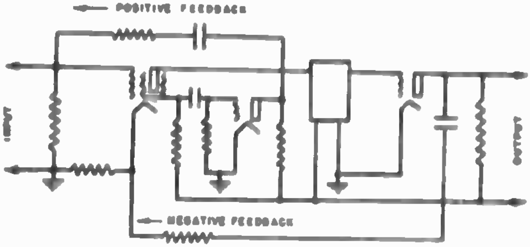


Figure 4

back is limited, however, by the type of circuit employed and tubes used. If a circuit similar to the one shown in figure 1 is used, and it is assumed that the additional grid has the same degree of control as the control grid, then the maximum value of positive feedback is one. This value is ordinarily too low, and either a more sensitive additional grid must be used or the positive feedback must be obtained in another way. At the present time there are no tubes on the market with two extremely sensitive grids, and therefore other methods must be devised to obtain the sufficiently high value of positive feedback.

Figures 4 and 5 show possible methods of obtaining a high value of positive feedback. In figure 4, the second tube amplifies the output from the screen-grid circuit of the first stage. The output of the second tube is returned to the input of the amplifier as positive feedback, since the output of the second tube is in phase with the input of the amplifier. By proper adjustment of the circuit, the effective positive as can be seen from (6) and from

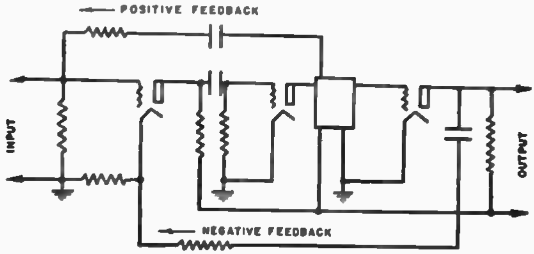
$$E' = \frac{A'e'}{1 - \gamma A'} \qquad (11)$$

where A′ is now the amplification of the positive feedback circuit and γ is its feedback ratio. If $\gamma A'$ is made almost equal to 1, the output becomes very large, thus making the effective input to the amplifier much higher. Figure 5 shows a similar circuit, except that the positive feedback circuit is also a part of the main amplifier.

In either of these two cases, the part of the amplifier that is involved in the positive feedback circuit must be designed to give a linear response over the entire range of frequencies it is desired to amplify linearly. Since the gain of this part of the circuit does not have to be large, this requirement is usually not very difficult to fulfill in practice.

In all of the circuits considered, i.e., figures 1, 4, and 5, there are three voltages present at the input of the amplifier. One of these is the signal input voltage, the second is the conventional negative feedback voltage obtained from the out-

Figure 5



put of the amplifier, and the third is a voltage proportional to the signal input voltage and is used to balance out the negative feedback voltage when the operation of the amplifier is perfect. This last voltage, termed above as the positive feedback voltage, may be obtained in several ways mentioned above and shown in figures 1, 4, and 5. Its magnitude is always defined by its propagation constant α

$$\alpha = \frac{\text{positive feedback voltage at input}}{\text{signal input voltage}}. \quad (12)$$

The propagation constant of the negative feedback circuit is defined as β and is always equal to

$$\beta = \frac{\text{negative feedback voltage at input}}{\text{signal output voltage}}. \quad (13)$$

The positive feedback voltage is determined by the type of the circuit used. For instance, in figure 1, the positive feedback voltage is simply a fraction of the input voltage, depending upon the setting of the bridge. In circuits such as are shown in figures 4 and 5, the positive feedback is obtained by means of a regenerative network, the exact value of positive feedback voltage being determined by means of (11).

If in the future a tube with a very sensitive additional grid, not necessarily linear, is developed, the circuit shown in figure 1 will become practical and ideal, since no additional parts are required to produce positive feedback.

2. *Construction of Balanced Feedback Amplifiers*

In actual construction of the amplifier used care was taken to minimize all stray capacitances between the feedback leads and ground, as well as the stray capacitances between the various stages. By arranging the tubes horizontally in series, with shields in between, it was possible to make the stray capacitance of each stage small. By placing the tubes in a zigzag arrangement between two shields so that the input and the output of the amplifier are very close together, the feedback leads are made very short and the feedback circuits become practically independent of frequency.

• Design of a Balanced Feedback Amplifier

The general scheme of applying the balanced feedback principle to an amplifier of any type is as follows:

(1) Design of the high-gain amplifier so that the amplitude of the output is sufficiently high over the entire range of frequencies it is desired to amplify linearly. It is necessary to design it so that the amplification does not drop very far *below* the desired normal; it is unimportant how high it may become over certain ranges of frequencies The design of the amplifier is conventional, the type of interstage coupling depending upon the specific requirements. In resistance-capacitance-coupled amplifiers the response curve, however, should be kept from dropping too low by means of small inductances placed in the plate leads of each tube, as suggested by Kell.[2] The value of the inductance depends upon the stray capacitance of each stage and the highest frequency desired to amplify.

(2) The two feedback circuits must be designed so that they are absolutely linear over the entire working range of frequencies. If both of the feedback circuits are properly designed, the negative feedback will reduce the distortion and make the amplifier linear; the positive feedback will restore the gain to the former level, thus giving a high overall gain without appreciable distortion of any kind.

(3) The stability of the amplifier depends upon the performance of the positive and negative feedback circuits. Providing the positive feedback circuit is properly designed, that is, the regeneration is not allowed to become too great, it cannot cause any instability. If the main amplifier uses negative feedback across more than two stages, or in cases where transformer coupling is used, phase reversals may produce oscillations or "singing." However, H. S. Black[1] has shown that negative feedback can be applied over as many as five stages without producing instability. Since the design of the negative feedback circuits in a balanced feedback amplifier in no way differs from the conventional negative feedback amplifiers, the practical and theoretical limitations of balanced feedback amplifiers are essentially the same as those of negative feedback amplifiers. A simplified discussion of the question of stability, its dependence upon the phase shift of the amplifier, and the effect of feedback on phase distortion, will be found very well discussed in Black's article.[1]. A rigorous treatment of the question of stability is given by H. Nyquist,[3] and E. Peterson, J. G. Kreer, and L. A. Ware.[4]

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[2]R. D. Kell, "Description of Experimental Television Transmitting Apparatus," *Proc. I. R.E.*, vol. 21, pp. 1674-1691; December, (1933).

[3]H. Nyquist, "Regeneration Theory," *Bell Sys. Tech. Jour.*, vol. 11, p. 126; July, (1932).

[4]E. Peterson, J. G. Kreer, L. A. Ware, "Regeneration Theory and Experiment," *Proc. I.R.E.*, vol. 22, pp. 1191—1210; October, (1934).

The main factors to consider in design of the feedback circuits are:

(a) The type of stabilization required, either current or voltage. If the negative feedback is proportional to the current output, the balanced feedback will tend to keep the current output constant, whereas, if the negative feedback is proportional to the output voltage, the latter will be stabilized.

(b) Polarity. As previously stated, the negative feedback must be of opposite polarity to the input and the positive feedback must be of the same polarity as the input.

• Experimental Results

1. *Restoration of Wave Shape*

Experimental tests, made with the aid of a cathode-ray oscilloscope, were run upon a badly overloaded audio amplifier. Without feedback of any kind the output voltage of the amplifier was very distorted, almost approaching the square-top condition. With a small amount of balanced feedback the improvement in the output waveform of the overloaded amplifier was noticeable but the wave was still badly distorted. However, as the balanced feedback was increased to a fairly large value, the waveform was greatly improved until it approached a sine wave with reasonable harmonic content. The gain of the amplifier was not changed under these tests; the improvement given by the balanced feedback was obtained without any sacrifice in gain.

2. *Frequency Characteristics of a Balanced Feedback Amplifier*

Application of the balanced feedback principle to a resistance-capaci-

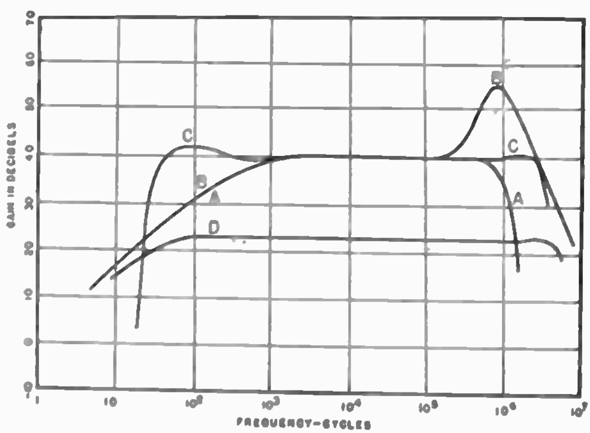


Figure 6. Frequency response of an amplifier under various conditions. Curve C represents the response with balanced feedback, curve D with negative feedback.

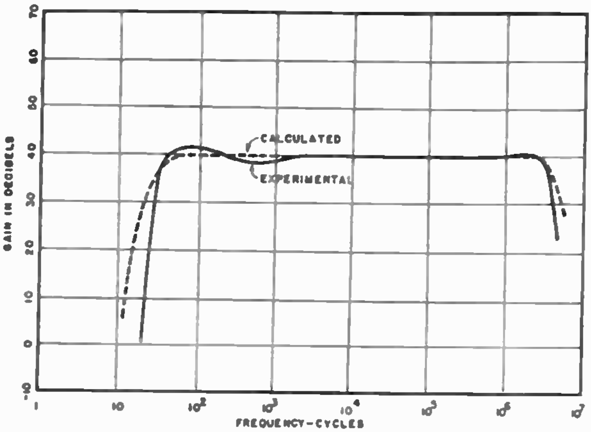


Figure 7. Degree of predictability.

tance-coupled amplifier (two stages (figure 4) improved its frequency-response characteristic as shown in figure 6. Curve A in figure 6 shows the response of the amplifier without any feedback and without inductances in the plate leads. Curve B shows the response without feedback, but with inductances in the plate leads, which cause the large hump at the higher frequencies. The inductances are used, as described above, to prevent a too low cutoff frequency. Curve C shows the response with balanced feedback; the hump is practically entirely removed, and the regions of amplification that are not too low are restored to normal amplification. The same linear range can be obtained by means of negative feedback alone as shown by curve D, but only at reduced gain.

3. Degree of Predictability from Theoretical Considerations

Using the value of stray capacitance per stage, which depends upon the quality of construction, and the desired cutoff frequency, it is possible to calculate the performance of the amplifier. The response curve for the amplifier without feedback (this depends upon the type of coupling between stages, tubes used, stray capacitance, etc.) may be either calculated or obtained experimentally. The response curve for the amplifier with the balanced feedback may then be calculated from the theoretical considerations developed above, and by making use of (7). The accuracy with which these curves may be predetermined can be seen in figure 7. The theoretical curve, within the experimental errors in measurements, is the same as measured in the laboratory.

• Conclusions

The experimental results verify

the theoretical expectations and show that balanced freedback can be applied to various amplifiers, for various purposes, without undue elaborations. The theory agrees very closely with actual results, and therefore the design procedure is simple.

Balanced feedback principle can readily be applied to wide-range television amplifiers. An amplifier using ordinary receiving-type tubes, i.e., RCA-57, has been built and its linear output was extended from a range of 1000 to 600,000 cycles to a range of essentially linear response from 30 to 2,500,000 cycles. By means of smaller tubes, such as RCA-954, it is to be expected that linear response up to 5,000,000 cycles can be obtained at a high gain.

Application of balanced feedback to audio-frequency amplifiers in radio sets may be of value. It would tend to eliminate noises that are developed in the last stage due to aging of the tube, gases, etc., and thus prolong the usable life of the tube.

●

Balloon Antenna

BEHIND the recent application of the Westinghouse Company to move the WBZ transmitter from Millis, Mass. to Hull, Mass. is a long series of tests conducted by engineers to obtain data on a more suitable location. The town of Hull has several miles of sea water between it and the mainland, and the salt marsh of the proposed location makes for a very high antenna efficiency. In order to prove the point, a test was made with a so-called kite balloon. The balloon, hydrogen filled to a capacity of 1700 cu.ft., was held aloft at a height of 250 ft. by a copper wire which acted as a quarter-wave antenna. During a period of approximately two weeks many field intensity measurements were made throughout the coverage area. As a result of these tests, the application claims that much better service can be given to a larger population from the Hull location than from the present Millis location. If the application is granted, a directional antenna consisting of two vertical 500-ft. towers, space one-quarter wave apart and excited with equal antenna currents at 90 degrees out of phase, will be employed. The result signal strength in the direction of Boston will be that corresponding to 100 kw., as against 50 kw. with a non-directional system.—Electronics.

¶ From Electronics,
November, 1938

ELECTRON MICROSCOPES

THE relatively new branch of physics known as electron optics is opening up new avenues of research in its application to electron microscopy. In the more advanced types of electron microscopes magnification and resolving power are obtainable which are far in excess of those possible with the ordinary light microscope. Not only may one expect that electron optics, per se, will make new contributions to man's knowledge, but the greater useful magnifications resulting from the electron microscope should prove an invaluable aid to other fields of research.

Perhaps it is well to recognize that electron microscopes may be divided into two types. In the first of these, usually characterized by relatively low magnification, an image of an electron emitting surface is formed by a suitable electron-optical system and is projected onto a fluorescent screen where it may be observed visually or photographically. The purpose of this type of microscope is usually the study of cathode materials and surfaces, and only electron emitting surfaces may be examined.

In the second type of electron microscope, an electron beam is employed to irradiate some independent object whose form and relative mass may be defined on a fluorescent screen or photographic plate in much the same way as in a photomicrographic camera. But the light rays and glass lenses of the light microscope are replaced, respectively, by the electron beams and electric or magnetic fields of the electron microscope.

The first type of electron microscope has its electrical analogue in the ordinary magnifying glass. Several special tubes have been built experimentally for the construction of electron microscopes of this type, some of which have been fairly elaborate, in an effort to reduce to a minimum the various aberrations. At least two electron microscope tubes have been made available commercially—one by the Allen B. Du Mont Laboratories in this country and one by the General Electric Co., Ltd. of England. Special tubes are not always required, however, for by proper adjustment of its first and second anode potentials, an ordinary cathode-ray tube may be converted into an electron microscope for the examination of its cathode surface.

The great importance of the electron microscope of the second type —to which the majority of this article is devoted—lies in the fact that it extends the magnification and resolving power considerably beyond that obtainable with the visual or even the ultra-violet microscope. The practical limit of magnification with the visual microscope is about 2,000 ×, whereas with the ultraviolet microscope, magnifications of 6,000 × have been attained. Magnifications of as much as 30,000 × have been obtained with the electron microscope, and the resulting photographs are sufficiently sharp and clear as to permit an additional optical enlargement of 3 ×. Thus is it possible to obtain magnifications of the order of 100,000 × and thereby make visible the form and outline of bacteria, viri, colloids and other very small particles which, up to now, could be detected only by the effects they produce. The benefits which will accrue to the medical and biological sciences alone through the extention of this new aid to visual observation can hardly be estimated.

In passing it is interesting to observe that the electron microscope is the practical embodiment of pure and perhaps highly abstract research; the electron microscope is also an excellent example of the illustration that when one form of scientific approach appears to have established limitations on man's ability to probe nature, a totally new and refreshing approach may often extend well-known avenues of activity as well as open up entirely new ones.

• Principle of the Electron Microscope

Comparatively few electron microscopes are, to date, in complete operation, and each of the existing models is different in some of its details from the others. Electron microscopes of the second type have been built by Siemens and Halske in Germany under the pioneering efforts of Ruska, in the College of Technology in London with the assistance of the Metropolitan-Vickers Electrical Co., the California Institute of Technology in this country and perhaps by others as well. Complete details of all of these instruments are, at present, not available. But the laws of physics are no respector of national borders; consequently the general principles of operation outlined here may be regarded as applying, in general, to high magnification electron microscopes. Details of the three instruments enumerated above, however, may be expected to show variations from one another.

The modus operandi of the electron microscope is indicated in the diagram which also shows the corresponding optical analogue. The essential elements consist of a source of radiation, the electron-optical system composed of properly constructed electric or magnetic fields which refract the electron beam, and the necessary screens or photographic plates for making visual or photographic observations. Auxiliary equipment which, although not indicated in the diagram, is very essential to the practical operation of the microscope, includes pumps for maintaining the desired degree of vacuum within the microscope tube, the necessary high voltage transformer-rectifier-filter-regulator voltage supply, and the various voltage and current controls which are used for obtaining the desired conditions of focussing and magnification by properly refracting the electron beam through the magnetic coil systems shown.

The source of electron radiation, corresponding to the light source in the visual microscope, may be either a hot or a cold cathode. The emitted electrons are accelerated with voltages which may be as high as 100,000 volts. The high voltage electron beam is necessary to obtain the high resolving power and magnification which is the main advantage of the electron microscope. The useful portion of the beam passes through an aperture in the anode after which it is acted upon by a condensing coil which condenses the beam in a manner similar to the collimation of the light rays in the optical system.

The condensed beam then impinges upon the object under observation which is held in a special locking and adjusting chamber since the object is contained within the vacuum system of the microscope. The electron beam is then refracted to form an image on a fluorescent screen in the intermediate image plane. This intermediate image is especially useful when making preliminary adjustments, since it is observed and accurately focussed at relatively low magnification. In the Siemens instrument, the magnification in the intermediate plane is about 80 ×. By means of an object shifting device, that part of the image which is to be further magnified is brought over an opening in the center of the intermediate screen. The electron rays for this part of the image are then condensed by a projection coil in such a way that the intermediate image is further magnified as much as 350 ×. The resultant magnification is the product of the magnification of the individual electron-lens systems. The final image, which may be magnified as much as 30,000 ×, may be photographed directly from a flourescent screen which also makes the image visible, or, as is done in the Siemens instrument, the photographic plate may be introduced within the vacuum system of the microscope and an image can then be formed by the electron beam falling directly on the photographic plate.

The most important part of the microscope are the electron lenses, for the refraction of the electron beams in traversing the electric or magnetic fields provides the basis for electron microscopy. Unlike the light optical lenses, the refractive indices of electron lenses are not constant for a given medium. The electron lenses may consequently be

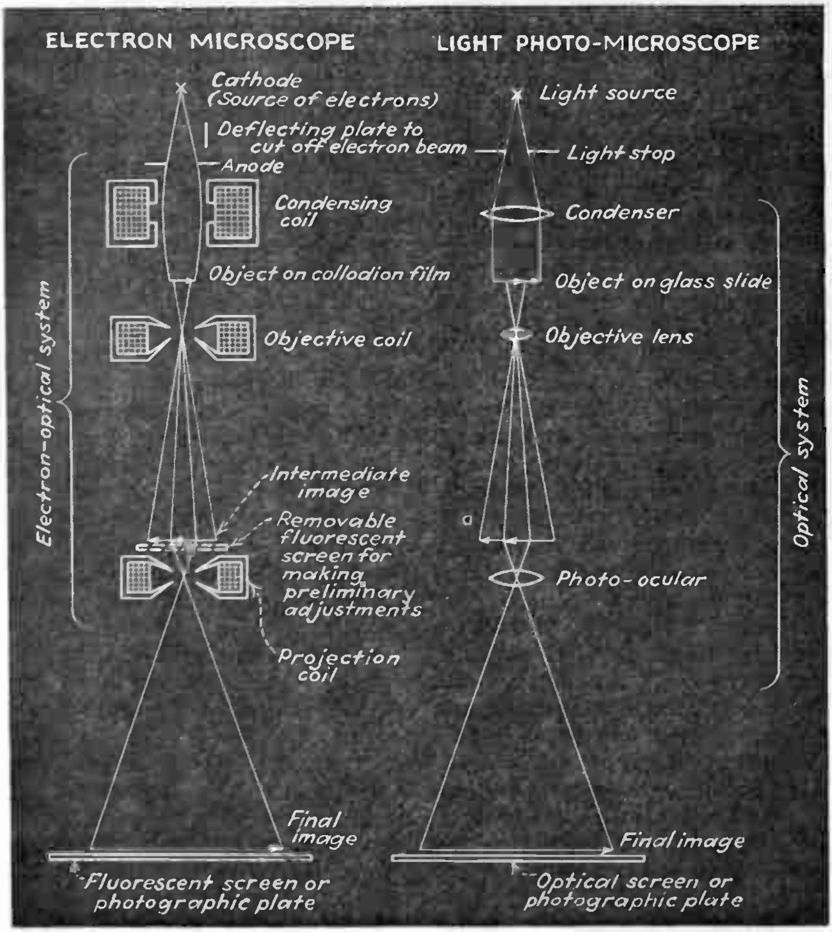


Diagram showing the geometric optics of the two stage electron microscope and its optical analogue. The light rays and glass lenses of the light microscope are replaced in the electron microscope by electron beams and electric or magnetic fields, respectively, but the situation in the two systems is very similar.

regarded as possessing varying indices of refraction, depending upon the electric or magnetic constants of the system. As a result, the focal length of the electron lenses is not fixed, but may be adjusted by varying the electric or magnetic fields of the electron lens. It is customary, where large magnifications are required, to use magnetic fields for bending the electron beams. Lenses of short focal length, which are required for large magnifications, are obtained by large magnetic fields, i.e., by increasing the current through the coils, or by using coils of many turns of wire. The shape of the ferro-magnetic circuit, and the use of materials of high permeability, with proper distribution of air gaps, is an important consideration in designing a practical electron-optical lens system for electron microscopes. To maintain the focal lengths of the electron-optical system sufficiently constant during the time necessary for the exposure of the photographic plate, the current through the various coils must be maintained to a high degree of precision, for current variations would produce various types of aberrations and distortions.

Due to the large magnifications obtained, great care is required in the design and construction of the component parts of the microscope. Since the object may be magnified as much as 30,000 ×, a horizontal displacement caused by vibration and amounting to only 10^{-4} mm would result in displacements or variations of as much as 3 mm on the photographic plate; such swings would make it impossible to obtain sharp images of the object.

In order that the form and mass distribution of the object may be determined, it is necessary that the object be suspended on some electron-optically transparent substance, much as the object in a light microscope is placed between transparent glass slides on the mechanical stage. The medium selected for the electron microscope should be characterized by low absorption of the electron beam, ability to withstand the effects of the beam for fairly long periods of time, and appreciable mechanical strength. These requirements can be met by selecting a high accelerating potential for the electrons, and employing a very thin membrane of only 1/100,000 mm thickness for the support of the object under observation. Highly satisfactory membranes may be made of a weak solution of collodion in amyl-acetate which is dipped on a large surface of water. The amyl-acetate evaporates quickly and leaves a thin film of collodion on the water. Then the water is drained from the bottom of the container and the collodion is allowed to set over an aperture of perhaps 0.03 to 0.3 mm.

The object to be observed is placed on the extremely small surface of the stage. Then the microscope is focussed by means of a suitable trial object or fine wire mesh so that after inserting the real object through the locking chamber, only a slight amount of further adjustment is required. Upon placing the object with its support into the microscope, the object is moved around until the most desirable portion is found in the screen in the intermediate image plane. Final adjustments are then made on the final image plane, after which the photograph may be made.

The object, which often consists of bacteria, very fine tissues, or other organic matter is subjected to the electron beam for the duration of the adjustments and the exposure of the photographic plate. To minimize the bombardment of the object, provision is made to deflect the beam through the use of deflecting plates or magnetic coils which may be arranged inside or outside of the instrument above the upper locking chamber.

(See pages 52, 53 and 54 for photographs.)

According to "Radio News" . . .

THE BEST country in which to operate is Iraq where there are two hams. One is King Ghazi and the other a British Army officer. What, no b.c.l. trouble?

AN INTERESTING sidelight on our neighbor Mexico is that their laws provide that all broadcasts (including that of their amateurs) must be in **good** Spanish!!

TALKING about the QRM situation: It does not exist in Anglo-Egyptian Sudan. There are as many as three (count 'em) amateurs in that country of over a million square miles. For that matter, Norway has only 120. One of the longest named associations of amateurs is that of Finland, which is called "Suomen Radiomatoorilittio." Its official magazine is called "Radio OH," which may or may not give you an idea!

¶ From Communications
July, 1938

Carrier Current on Power Systems

BY OLAN RICHARDSON

IT IS PROBABLE that most communication and radio engineers are familiar with carrier-telephone equipment as used by the communication companies, but it is doubtful if many are acquainted with power-line carrier equipment and its various uses. A list of the most important of these applications includes carrier telephony, carrier telemetering, carrier pilot relaying and carrier supervisory control.

Carrier equipment was first introduced to the power industry through carrier telephony. As early as 1920 power-system engineers foresaw the possibilities of carrier telephony on power transmission lines. The idea carried special appeal to engineers concerned with the operation of widespread power-transmission networks, because one of the prime requisites in such operation is reliable communication between load dispatcher and important substations and switching stations throughout the network.

Until the advent of carrier for use on power lines, communication was confined to facilities provided by local telephone companies, and in cases of remotely located stations to telephone circuits constructed by the power companies along power-line right-of-way, or on the same structures as the power lines. Power-line carrier telephony offered the possibility of economical high-quality communication whose reliability was as high as that of the power lines themselves. The rugged construction of power lines enables them to withstand such natural hazards as ice formation, wind storms, etc., which would wreck telephone lines and interrupt communication.

• Coupling Methods

After the practicability of power-line carrier communication had been established by tests both in this country and in Europe, several American manufacturers began development to meet a demand for carrier-telephone equipment, which was created by the published results of the early tests. Telephone-line carrier had already been developed and had demonstrated its practicability in the service of the telephone companies so that the major problem confronting engineers in the development of power-line equipment was a satisfactory method of coupling the carrier equipment to high-voltage power lines. Transformer coupling was tried and ruled out due to prohibitive cost in constructing high voltage transformers. The field was quickly narrowed to antenna and condenser coupling.

Satisfactory high-voltage condensers had not been developed at that time, and field tests indicated that it would be necessary to carry out extensive research operations before a condenser that would withstand extreme high voltage steep wave front surges, such as are encountered on transmission systems during lightning storms and severe system disturbances, could be made commercially available. Manufacturers, therefore, in order to put carrier telephone equipment on the market resorted to the use of antennas for coupling facilities. By late 1924 several operating power companies had installed carrier-telephone channels, and elaborate operating records were being kept.

The antenna-type coupling had several shortcomings. It was necessary to string the antenna conductors on the same structures with the power line in order to take advantage of the capacity between the antenna and power conductors for coupling. This arrangement not only placed the supporting structures under additional load, but also created a hazard to service of the power system and communications, due to the close proximity of the antennas to the high-voltage power conductors. Another weakness was the fact that the antenna constituted a part of the tuned circuit of the carrier equipment and so could serve for only a single channel. This feature limited the number of channels that could be installed at a communication center, because multiple antennas could not be economically installed.

In 1925 several experimental installations of a newly developed oil-insulated tank-type condenser were made. These units proved too weak for service on 100-kv. and 132-kv. lines, but did serve to accumulate data on which to base more extensive development. Between 1925 and 1930 several different types of coupling capacitors made their appearance. One company brought out a unit consisting of a large porcelain shell which was metallized on its surfaces down to a point at which it flared in brown-glazed petticoats. A suitable metal external sheath and hardware were attached for mounting purposes. The unit presented the appearance of a large milk can. Its capacity was .001 μfd. and it had a rated voltage of 50 kv. In order to provide adequate voltage and capacity ratings these units were assembled in stacks of series and parallel connections. For instance, a typical stack for 110-kv. operation would be 3 groups of 3 in series, or nine units, to obtain a rating of 150 kv. and .001 μfd. capacity.

Another manufacturer brought out mica-insulated units encased in porcelain with metal fittings at each end to facilitate mounting. These units present the appearance of a large post-type insulator, and may be connected in series and parallel to obtain the desired values of capacity and voltage.

Another later type of condenser presents very much the same appearance, the difference being that it is oil and paper insulated.

Still another type consists of a loop of oil-insulated cable mounted on a steel frame, the entrance to the cable being made through a high-voltage porcelain bushing. The capacity is obtained between the center conductor and the sheath of the cable. All of the above capacitors have proven satisfactory for service, although, of course, each has its advantages and disadvantages.

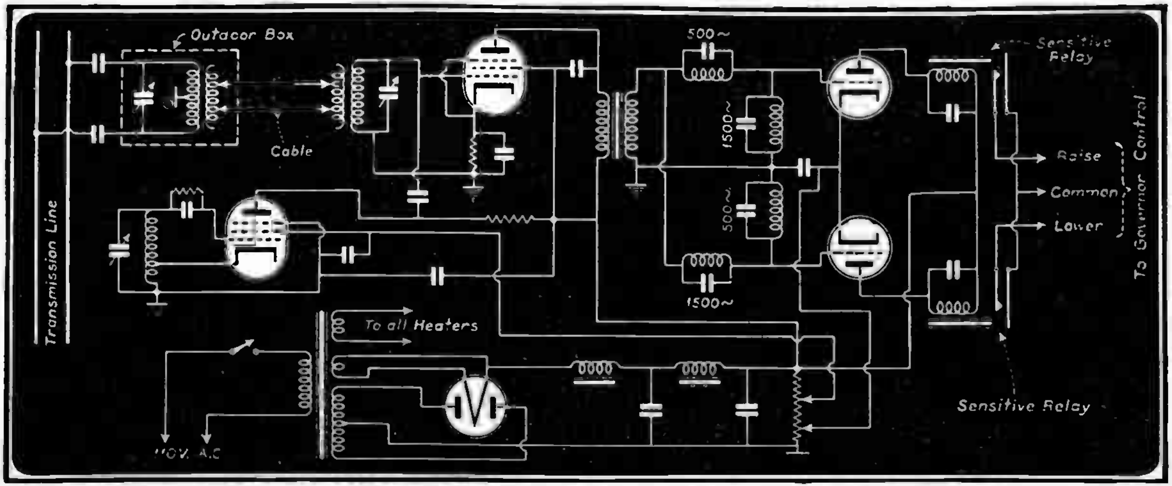
• Types of Equipment

The fact that capacitors could be put to a number of different uses, such as potential devices and current transformers, as well as handle more than one carrier channel simultaneously, served economically to justify many installations which could not otherwise have been "proved-in," so carrier telephony progressed rapidly. The quality of power-line carrier-telephone communication has followed closely in the footsteps of radio advancement and there are now in service many different types of equipment, many being the very earliest types which have been transferred to less im- "proved-in," so carrier telephony equipment may be generally classified as follows:

(1) Simplex single frequency
(2) Duplex—two frequency
(3) Duplex—single frequency
(4) Duplex—suppressed carrier —single sideband

The simplex single-frequency system is the type which requires manual switching from "send" to "receive." It uses the same frequency for transmission and reception. It may be operated with other single-frequency equipment either simplex or duplex. A typical installation is at patrolmen's "call-in" booths, or isolated sectionalizing switches. The weakness of this type equipment is that it requires some skill to use, and it cannot be operated from normal telephone extensions.

The duplex two-frequency system employs one frequency for transmitting and one for receiving. In this system the carrier is transmitted throughout the conversation. The transmitter frequency is blocked out of its associated receiver by filters. Duplex operation is thus accomplished without the necessity for the manipulation of a push-button switch. There are two of these systems, one in which the calling station always transmits on one frequency, and the carrier of the



Carrier Impulse Load-Control Receiver.

calling station automatically switches the called station transmitter to the other frequency when he answers.

The other two-frequency system is set up so that the transmitters and receivers of both terminals remain on the frequencies to which they are tuned, and consequently only two stations can be assigned to a single channel unless the third station is set up to change over and operate its transmitter and receiver on either of the other two frequencies. Both of the two-frequency systems may be connected to conventional telephone extensions. The weakness of these two systems is that only two stations on a channel may talk at one time, and if a third station attempts to place a call, the conversation is interrupted. These systems also take up two frequency allocations, thus limiting available carrier channels.

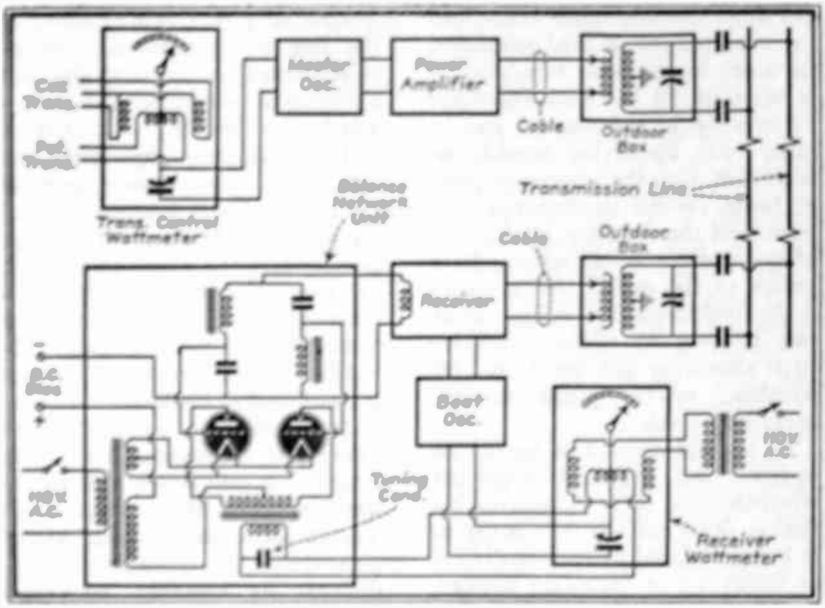
The single-frequency duplex system has a decided advantage over the two-frequency systems. This system operates with all receivers and transmitters tuned to the same frequency. Modulation - controlled Thyratron relays start and stop the transmitted carrier, and block the receiver when its associated transmitter is in operation. The transmitter operates only during the time the operator is speaking and at all other times the receiver is in the "receive" position. This allows a number of stations to carry on a conversation simultaneously as long as the conversation is orderly and no two stations attempt to talk at once.

The advantages of this system are numerous. In operating a large power network it is often desirable that the dispatcher engage more than one operator in conversation. It is sometimes imperative that the dispatcher be given information which may alter switching orders being given and the ability of a third party to break into the conversation is valuable in this case. Another advantage of single frequency is that it allows more separate channels to be applied to the limited portion of the frequency spectrum available for carrier work.

The suppressed-carrier, single sideband carrier was announced after success of that type of radio transmission in transoceanic service; however, it was on the market only a short time and was then withdrawn. None of this equipment has come within the scope of the author's experience.

• Telemetering

After carrier-current equipment had become established on power systems as a means of communication, power-system engineers began to find other uses for carrier equipment. There appeared on the market carrier supervisory-control systems for the control of remotely located switching stations. This equipment made it possible for personnel in a centrally located station to control switching in remote stations, at which no personnel was located. It permits the operator to locate faulty sections of line and restore service without the delay involved in patrolling. This was all



Variable-Frequency Carrier Telemeter System

accomplished by the operation of selector circuits, similar to those used in automatic telephone exchanges, by the transmission of coded carrier impulses. This practice in due time brought about a demand for knowledge concerning load and voltage conditions at remote stations and various devices were developed to meet this demand. They all came under the general term of "telemetering."

Telemetering has been defined by one authority as the indicating, recording, or integrating of a quantity at a remote point by electrical translating means. Telemetering is applied in numerous industries for remotely metering flows, levels, pressures, heads, voltage, current, kilowatts, etc. Probably the most common application of telemetering on power systems is in connection with tie line loads.

One of the first duties of the load dispatcher on a power system is the supervision of the generation and distribution of electric power. He must follow prearranged schedules of generation and distribution, which have been worked out to supply his system and probably other interconnecting systems with power. The operating economy of various plants, rainfall, contracts with other companies and numerous other considerations enter into the arrangement of load schedules. In order to maintain schedules, it is necessary for the load dispatcher to have up to the minute, and in many cases up to the second, information as to the amount of power being carried by important tie lines, and the direction of the flow of this power. Power systems have grown to the extent that at times if the load dispatcher delays one or two minutes in taking corrective steps after a tie line has drifted off schedule, severe system disturbances may result.

So the old method of having an operator call the load dispatcher when the load on lines entering his station drifts off schedule is rapidly being replaced by the installation of indicating or recording telemeters in the load dispatcher's office so that he may directly supervise the important lines at all times. It has even been found necessary to control automatically certain generating stations in order properly to control load shifts in certain areas. This arrangement removes all delays involved in telephone conversation and causes the generating station to begin to make corrective changes the very second they become necessary, and continue until the "off-schedule" condition is corrected.

- Impulse System

One system which was developed for the telemetering of kilowatts is known as the impulse system. The transmitter transmits impulses at a rate determined by the amount of power being carried by the line being metered. The receiver translates the impulses into a deflection on a meter, the scale of which is calibrated in kilowatts.

The transmitting equipment consists of a watthour meter upon the shaft of which is mounted a small commutator. The current and potential coils are wired in the conventional manner to current and potential transformers on the line to be telemetered. The shaft of the watthour meter rotates at a speed proportional to the amount of power being metered, so that brushes riding the commutator close their circuit at a rate determined by the speed of the watthour meter. These contacts close the "keying" circuit of a simple r.f. transmitter which, through its coupling equipment transmits carrier impulses over the power transmission line to the receiving station.

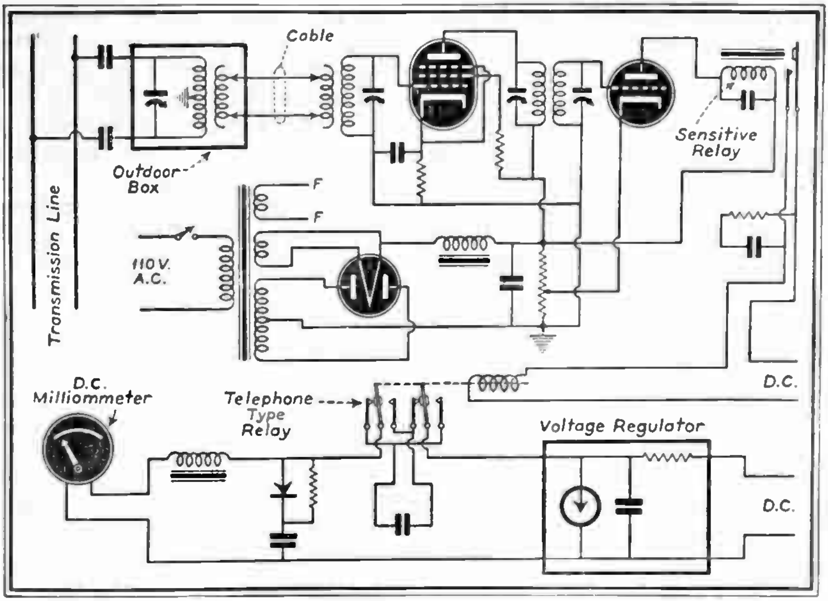
The receiving equipment consists of a simple receiver with its detector biased to "cutoff," and with a relay in the plate circuit so that when the carrier impulses come into the receiver through the coupling capacitors the detector plate current rises with excitation, causing the relay to close its contacts. The contacts of this detector relay operate a reversing relay which charges a condenser, reversing its polarity on each alternate impulse. A d.c. milliammeter is connected in series with a constant source of voltage so that the current being fed into the condenser causes a deflection on the meter. The speed at which the impulses are fed to the condenser controls the amount of deflection on the milliammeter. A smoothing network of capacity, resistance and reactance is connected in parallel with the milliammeter in order to prevent vibration of the pointer. The receiving meter scale is calibrated so that it reads kilowatts corresponding to the kilowatts driving the transmitting watthour meter.

- Variable-Carrier Frequency System

Another system (which the author assisted in developing) employs variable-carrier frequency as the translating medium. This system may be applied to the telemetering of any quantity capable of being metered, as well as used for a position indicator. The transmitting equipment consists of a simple electron-coupled oscillator-controlled r.f. transmitter. The e.c. master-oscillator frequency is controlled by a variable condenser attached to the controlling meter shaft or controlling position indicator. The receiving equipment consists of a heterodyne receiver, a balanced network, and a recording or indicating instrument. For the purpose of description a typical installation will be used.

This equipment was installed for the purpose of giving the load dispatcher of a large power system supervision over the load being carried by a tie line terminating at a station located about 70 miles from the dispatcher's office. The controlling meter is a 60,000/0/-60,000 scale recording kilowatt meter. The variable condenser controlling the transmitter master oscillator is mounted on the shaft of the controlling meter, so that every variation in the deflection of the meter will vary the transmitter frequency accordingly.

The receiver is a heterodyne-type equipment with a special noise-suppressing circuit built in. The frequency of the beat e.c. oscillator is controlled by a variable condenser mounted on the shaft of receiving instrument. The output of the heterodyne receiver is delivered into a bridge-type network composed of inductance and capacity. To this bridge network two power-amplifier type vacuum tubes are connected so that the grid of one is excited by voltage appearing across a condenser, and the grid of the other is excited by voltage appearing across an inductance. The plate circuits of the two tubes are connected differentially (or push-pull) to an output transformer, the secondary of which is connected across the potential coil of a recording wattmeter. The grids of these tubes are biased to cutoff, and raw a.c. is applied to the plates through the center tap of the plate winding of the output transformer. The potential coil of the wattmeter is tuned to 60 cycles with a condenser and the current windings are excited by a constant source. The torque-balancing springs of the wattmeter are replaced by flexible leads so that the shaft is free to rotate. As stated before, a variable condenser is mounted on the shaft of the wattmeter



Impulse Telemeter Carrier Receiver.

for controlling the beat-oscillator frequency.

- Operation

In setting up the circuit for calibration in the laboratory, the transmitter and receiver are coupled by a dummy transmission line, and the two oscillator tanks adjusted so that the scales of the two instruments check throughout. To clarify the operation of the system we will follow it through. Start by adjusting the transmitter frequency, with the controlling meter set at zero, to the desired frequency, say 50 kc. With the transmitter and receiver in operation, block the receiving meter at zero and adjust the beat oscillator to a frequency of 52 kc. which will give a 2-kc. beat note. Adjust the balance network to give equal excitation to the grids of the meter driving tubes. At this point the receiving meter will develop no torque, because there will be no potential across its potential coil. The absence of potential from the output of the driving tubes is the result of the grids being excited equally and in phase while the plates are connected 180° out of phase. Now suppose the receiving meter is left free to swing with any torque that appears, and we go through the operation caused by changing the position of the transmitter controlling meter.

Move the pointer of the transmitting meter to a position of, say, 60,000-kw. to the right of zero on the scale. The condenser attached to the shaft will cause the transmission of 51 kc. because its plates have moved toward the unmeshed position. Now since the receiver beat oscillator was set for 52 kc. the audio output will be 1 kc. and the network will be unbalanced for that frequency, because it was adjusted to balance at 2 kc. This unbalance will cause the driver tube connected across the condenser to be excited higher than the one connected across the inductance, so the plate currents will not be balanced and a potential will be applied to the coil of receiving wattmeter causing it to develop torque and rotate in the direction to unmesh the plates of the beat-oscillator variable condenser raising the beat-oscillator frequency to 53 kc., at which point the 2-kc. balance frequency will again be applied to the network and the torque will disappear from the receiving meter and it will come to rest at a point at which its needle will read 60,000 kw. to the right of zero. Now suppose the transmitting meter is moved back to zero; the transmitted frequency will again be 50 kc., but the beat-oscillator frequency is now 53 kc., and the output of the receiver is 3 kc. Now the network is unbalanced so that the driver tube across the inductance is receiving the highest excitation and the a.c. output is of a polarity reverse to that in the first case and the torque developed in the receiving wattmeter is in the reverse direction causing the pointer to move back to zero before it comes to rest.

In actual operation the receiving meter follows the transmitter so closely that the oscillator frequencies are seldom as much as 100 cycles off balance. All that is necessary in the calibration of the two instruments is the adjustment of the oscillator tanks so that the controlling condensers must move through the same number of degrees to cause identical changes in frequency in their respective oscillators. Of course, oscillator stability of a high order is necessary in order that the system retain its calibration because frequency variations due to causes other than the movement of the condensers will register as an error. This equipment provides an accuracy of plus or minus 2%, which is within specifications for other standard recording equipment. The speed at which the recording or indicating instrument operates is comparable to that of any high-speed graphic meter, the charts at the receiving station being exact duplicates of those made by standard switchboard instruments at the transmitting station.

An addition to this system of telemetering includes the control by carrier of generating stations which are used for regulating the flow of power from one part of a system to another. This equipment consists of a transmitter installed at the telemeter receiving station and a receiver at the generating station, connected so that received carrier impulses automatically cause the generators to "pick-up" or "drop-off" load. The transmitter is controlled by an e.c. master oscillator which is connected to contacts in the telemeter receiver. These contacts constitute a single-pole double-throw switch, the pointer of the meter being the movable pole. When one contact is made, impulses at 70 kc. are transmitted, and the other contact causes 71-kc. transmission. The receiver is a heterodyne circuit with the beat oscillator set at 69.5 kc. The output of the detector is fed through selective filters, one passing 500 cycles and the other 1500 cycles. The output of each of the filters is connected to the grid of a tube biased to cutoff. The plate circuit of each tube is fed through a sensitive d.c. relay. One relay operates the generator governors to "pick-up" load, the other relay operates to "drop-off" load. By adjusting the contacts so that the pointer floats free when on schedule, the automatic equipment then causes the load regulating plant to "pick-up" or "drop-off" load when the pointer moves above or below the scheduled setting.

One system of the above telemetering and remote-control equipment now in operation is set up so that personnel at two locations may supervise the load on an important tie line, and any one of three generating stations may be controlled automatically. The telemeter carrier channels aggregate 200 miles, the equipment consists of one transmitter, two receivers and one repeater. The carrier remote-control channels operating in connection with the telemetering system aggregate 115 miles and the equipment consists of two transmitters, two receivers and one local equipment.

- Carrier-Pilot Relaying

In recent years the use of carrier transmission as a means of accomplishing the high-speed clearing of faults from power-transmission networks has become widespread. On high-voltage transmission lines the occurrence of a flashover between phases or phase to ground will produce serious system disturbances if the faulty line or section of line is not quickly cleared from the system. Pilot-wire protective-relay schemes have been developed to meet this need, but the necessity for the use of pilot wires brought the cost of this equipment up to a point that was prohibitive where long or remotely located lines were involved. Carrier and relay engineers combined their efforts to develop a system of carrier-pilot relaying which is simple, and reasonably enough priced to promote its widespread use.

The system consists of directional and fault-detecting relays and a carrier transmitter and receiver at each end of the section of line to be protected. The receivers are energized continuously and the transmitter filaments burn continuously.

The receiver relays, which operate to trip the oil circuit breakers in the power line, trip in the de-energized position. These relays are normally held energized by station-control battery potential. When a fault occurs within the protected section of line the directional relays take up a position which prevents the transmitters from being energized, and fault-detector relays open the battery circuit to the tripping relay allowing it to drop out and trip the associated o. c. b. When a fault occurs external to the protected section of line, the directional relay farthest from the fault takes up a position indicating an internal fault, because the direction of flow of the fault current is toward the protected section, but the directional relay nearest the fault takes up a position indicating an external fault. In this position the transmitter nearest the fault transmits carrier energy which holds both the near and far tripping relays energized, when the battery potential is removed from these relays by the fault detectors, so they remain in the energized position preventing their associated o. c. b.'s from tripping. Under operating conditions all the necessary relays operate and trip circuit of the oil circuit breaker is energized within one cycle, on a 60-cycle system. The o. c. b. then takes from 4 to 20 cycles to break the arc, the o. c. b. time depending on the type.

The Wound-Core

SINCE the time early in electrical engineering history when sheet metal stampings were first used for transformer cores instead of the bundle of wires of primitive induction coils, the sheet iron laminated core has been the standard. A new development, the wound-core, now makes possible an economical, more efficient, and less bulky transformer. The core is made of a continuous strip of sheet iron wound around the completed coils.—Ohmite News.

THE ENGLISH Air Ministry, as a part of the British war preparedness program, is now training English hams for the Royal Air Force Reserve.—Radio

From Radio
November, 1938

Five-Meter DX

• An Explanation

BY E. H. CONKLIN

PROBABLY most amateurs pay no attention to the ionosphere, or to the way their signals travel from transmitter to receiver. This is a natural tendency on 14 Mc. or lower frequencies because one is apt to work anyone that is heard and not worry about the absence of signals from other points. But on ten and five meters, it becomes essential to understand what goes on, in order to make the most of conditions. Furthermore, these "marginal" bands help us to learn more about the machinery of working dx.

It doesn't require advanced mathematics to explain the nature of "skip"; drawing-board arithmetic is sufficient if you don't know trigonometry. We can take the word of others that there are two regions above the earth that are of major importance in sky-wave transmission—the **E** layer at around 120 kilometers (75 miles) which is important at broadcast frequencies, and the F layer with its subdivisions, ranging seasonally upward from 230 kilometers (143 miles) which is important for communication on most amateur bands.

Figure 1 shows how a signal leaving the transmitter may be turned down from the sky so as to arrive at the receiver. The wave acts as if it had traveled via the heavy line, reaching the height H, called the *virtual* height, though actually it may have turned gradually, following the broken line in what appears to be a short cut.

Almost everyone realizes that if the layer will not reflect a signal leaving the transmitter vertically, the waves will pierce the layer at high angles above the horizon. At some lower angle they will be turned down and be received at R, but not closer, as shown in figure 2. In this case, the space from T to R is a silent or skip zone for the frequency being used.

To find the maximum distance that the signal can travel in one hop, it is necessary to consider the

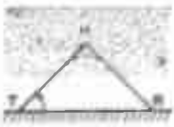


FIGURE 1

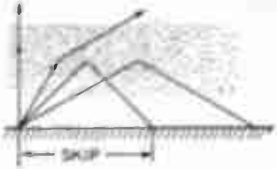


FIGURE 2

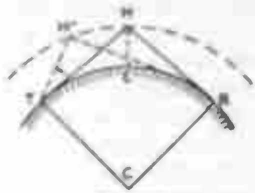


FIGURE 3

curvature of the earth, as shown in figure 3. A signal supposedly leaving the transmitter horizontally (that is, at right angles to the radius of the earth, and grazing the surface) will travel outward until the curvature of the ionosphere brings the layer in line with the wave going out, such as at H. At this point, the wave is turned back down and reaches the earth again at R. The distance T to R would give the maximum one-hop distance were it not for one other thing: *all* radiation manages to cancel itself along the earth, making it impossible to radiate much power, or to receive any appreciable signal, at *very* low angles—below, let us say *three* degrees. Even at that angle in order to get the maximum hop, it may be necessary to use high power or an antenna capable of radiating most of its power at relatively low angles. Such antennas are (1) a properly designed rhombic as was in use at W5EHM, or (2) stacked antenna elements, one above another, as used at W9CLH, W8VO, W8JLQ and W6DNS, or (3) reflectors and directors as at W4EDD, W8CIR and elsewhere.

With the assumed minimum angle of radiation above the horizon, the E layer maximum distance for a single hop figures out to be around 1200 miles, while for the F layer it varies rather widely around 1800 to 2200 miles.

It is possible to determine if the ionosphere is capable of turning back a very high frequency wave, by measuring the highest frequency that will be reflected back vertically to a point near the transmitter, and then to apply some calculations or use a special chart to find out how much higher a frequency could be heard at the maximum one-hop distance. The National Bureau of Standards constantly records such reflections and advises that the highest frequencies are returned from the F region (F_2 layer) in the winter, shortly after noon at the point of reflection; and from occasional sporadic E-layer reflections in summer. This sporadic condition may be the result of a change in the position of the free electrons or ions, so as to produce a sharp lower boundary to the E layer from which reflection, rather than refraction, takes place. The sporadic condition occurs at random times in the day or night. It happens a little more often in the late forenoon and during the evening than at other times during the day or night. Sometimes it is confined to a single hour and may be localized to the extent of being above only part of a single state.

So much for a general discussion of the ionosphere; let us now turn to five-meter dx reports to see if any connection can be drawn with what has happened "upstairs."

In the summer of 1937 five-meter dx was reported on about 33 days in the May through August period. By sending out hundreds of letters, some 280 cases of 56-Mc. reception were confirmed as probably being accurate. These were compared with hourly sporadic E layer data provided by the National Bureau of Standards, and some connection was found in every correlation made. The increased probability of five-meter dx at distances of 400 to 1200 miles, whenever sporadic E layer reflections were reported, is rather convincing. The complete study will be published shortly.

The distances of all the reports were tabulated according to the percentage of reports occurring at each distance. This appears in figure 4. It is seen that only two reports are at distances between 400 and 500 miles, with few approaching 1200 miles. By far the majority of cases are in the middle of the 400-1200 mile range, as would be expected from consideration of the

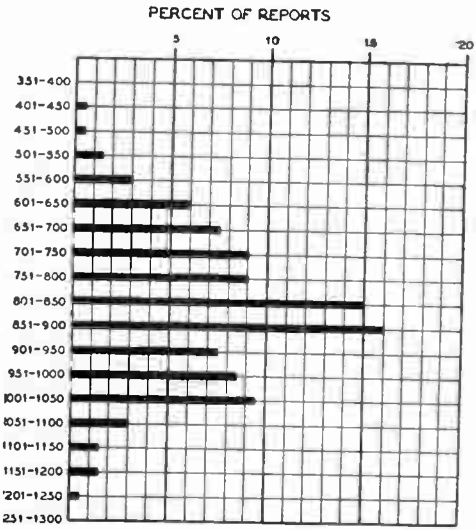


Figure 4. Percentage of reports plotted against distance shows a definite peak at about 800 miles.

factors limiting E layer reflections. This distribution is taken as a further indication that summer 56-Mc. dx is probably the result of sporadic E layer reflections, as proposed by the National Bureau of Standards.

Let us look at it in still another way. During the summer of 1938 W4EDD contacted stations in every district except the sixth and seventh. The longest distances from Coral Gables (near Miami) are as follows:

Kansas City	1243 miles
Fairhaven, Mass	1222 "
W9CLH near Elgin, Ill.	1210 "
Wilmette, Ill.	1204 "
Zearing, Ill	1200 "
Chicago, Ill.	1192 "

All distances have been calculated from the latitude and longitude, and are subject to a slight adjustment for the part of town in which the stations are located.

Of most interest in this figure is the fact that just beyond 1250 miles, especially in Massachusetts and Wisconsin, are numerous stations known to have been successful in 56-Mc. dx work this summer. None of these has reported W4EDD, though other W4's farther north have been heard. Here again one is convinced that there is some reason for the 1200-mile limit —which is entirely explainable by the sporadic E layer reflection.

Of course, 100- or 200-mile communication has occasionally taken place by low-atmosphere bending as explained several years ago by Ross Hull. This type of bending conceivably might take place at both ends to extend somewhat the limit of a single E layer hop.

In August *QST* it was mentioned that several reports covered distances of 1200 to 1500 miles. These distances have been rechecked. Some are just within 1200 miles rather than one or two hundred miles beyond. In other cases a careful check has uncovered the fact that the station reported has not been on the air for several years. Such bootlegging or erroneous reporting *will* slip in, but confirmation of all questionable cases will save us from obtaining faulty conclusions.

And yet there have been cases where summer five-meter dx has taken place over distances substantially beyond 1200 miles. On a few nights in June and July W5EHM in Dallas heard some W1's (though only one W2 shows in his detailed reports) when eighth and ninth district stations were working W1's and W5's simultaneously. This obviously makes two-hop transmission possible. The distance from W5EHM to W1CSR in Boston, whom he finally raised, is 1549 miles, or just about twice the most common one-hop distance as shown in figure 4.

There were other even more astonishing things this summer. On July 24, W6DNS worked W1EYM, W8AGU, W8CIR, W8JLQ, W8NED, W5ASU, W5EHM, W7FDJ and W6OIJ, and he was called by every district but W4. W6PEX worked three W8's and one W9 that evening. W8JLQ worked five W6's. W8CIR, W8JLQ, W8VO and W9ZHB have now worked eight of the nine districts.

On that evening the usual 400- to 1200-mile hops were being reported everywhere along the path of the cross-country signals, indicating that multiple reflections were possible, and thus explaining the very long distance work.

It is important to realize that the sporadic condition must occur at three equally spaced points along the great circle path between the transmitter and the receiver for three-hop transmission. At each point the layer must be capable of reflecting the 56-Mc. signal at the proper angle. This can occur by chance with separate clouds of sporadic E, or could happen as a result of a very general condition over all of the transmission path. Either possibility is considered not highly probable, but the improbable happened on July 24 because the W6DNS-W1EYM contact was probably three hop.

Now we come to the future possibilities of the band. With little doubt summer dx will continue for a few more years, or longer, before becoming scarce around the sunspot minimum scheduled for about 1944. April and September may also bring some cases of the summer type of dx, but the ionosphere data show that relatively few hours will support E layer reflection at five meters.

Nevertheless, all is not lost. The much more predictable F_2 layer will be most favorable for high-frequency communication from October to February, and five-meter dx at distances just under 2200 miles and multiples may then be possible. For F_2 layer hop the time at the point of reflection probably will be a little after noon and all such communication will be in daylight except that it may be later afternoon or early evening at the eastern end.

In this connection five-meter dx tests are being arranged for weekends during November. The British stations already have voiced their desire to participate in the hope of running up a score in the 1938 R.S.G.B five-meter c.w. contest.

Assuming the truth of the theory that dx is a result of sporadic E layer reflections in summer and F_2 reflections or refractions in winter, some very helpful conclusions can be drawn. In the first place summer five-meter work almost invariably accompanies ten-meter communication at a distance of perhaps 400 miles—and both occur in about the same direction. The same is true of winter dx except that because of the longer single hops ten-meter signals might be coming in at perhaps 700 miles and permit five-meter communication. A little calculation will give more accurate figures, but due to the spotty nature of sporadic E in summer the normal connection between five and ten meters may be upset, inasmuch as the point of reflection for a 1200-mile hop is 600 miles away, while for a 400-mile hop it is only 200 miles away and the layer may not have the same characteristics over the whole difference of 400 miles. At any rate, the normal connection between skip on the two bands, and with the police frequencies in between, has been verified a hundred times or more during the last two years.

Another interesting result of an ionosphere study is its help in antenna design. Because the communication takes place via a reflection or refraction the polarization of the wave in space — that is, whether it has left a horizontal or vertical antenna — is not so important except as it affects the radiated power at the proper angle. The angle at which the signal arrives at the receiver will normally be the same as the angle at which the same ray leaves the transmitting antenna. Furthermore, knowing the distance and the layer height, it is possible to calculate the angle at which the received signal left the transmitting antenna and, of course, to decide how high an angle of radiation has any chance of being returned to earth. For maximum efficiency, practically the entire antenna radiation should be concentrated between the horizontal and the upper limiting angle.

In the case of summer dx, stations closer than 400 miles are seldom heard and relatively few have been reported between 400 and 500 miles. Using the chart designed by the National Bureau of Standards and assuming an E layer height of 120 kilometers, 400-mile work requires radiation 18 degrees above the horizon. But with most five-meter work, which according to figure 4 takes place at 800 to 900 miles, the most useful angles are around 7 degrees above the horizontal. The heavy ionization of June 5 brought the peak of the distance curve in to 650 miles, equivalent to 10½ degree radiation.

In winter it is not likely that sufficient F_2 layer density will occur during this sunspot cycle to turn 56-Mc. signals down within about 1700 miles, which indicates a maximum vertical angle of 4 degrees; in fact, 2100-mile communication would be much more likely, requiring a nearly horizontal angle at both the transmitting and receiving ends.

Radiation at low angles can be aided over a salt marsh by using a vertical antenna rather than a horizontal. Over very poor ground the horizontal may have an advantage. Ground sloping down in the direction of transmission, at least as far away as the point where the ground reflection takes place, will improve the low angle radiation. A hill of salt water would be an excellent, though impossible, location. A high antenna will have its first maximum of radiation at a low angle, but if the antenna is too high, it may have its first null at a useful angle—creating a blind angle—something which should be avoided (especially for the summer E layer work, which can involve moderately high angles on the shorter, 400-mile communication).

In any event, a well-designed rhombic, the use of a number of directors, or the stacking of a number of half-wave antennas one above another will with little doubt improve the signal and will often permit dx work when the band opens only for distances close to the maximum one-hop distance. In trying to stretch this maximum, low-angle antennas at the receiving as well as at the transmitting end will probably help substantially.

Phototubes As Traffic Safety Aid

A PROBLEM confronting traffic engineers in New York recently was a trolley-car stop in a narrow tunnel which had become a scene of numerous accidents. The motorist, driving rapidly into the dark tunnel, all too often neglected to see the halted trolley-car. The result was that passengers, debarking from the street-car, as well as those crossing to it from the curb, were in constant danger from passing automobiles.

To remedy this, the engineers turned to the phototube. A bank of two of these cells was erected at the entrance to the eastbound trolley-car, and a similar "bank" at the entrance to the tunnel of the westbound car. Then, in the middle of the tunnel, just before the trolley stop, were placed traffic lights on stonchions, as well as lights overhead near the roof of the tunnel. When this beam is interrupted by the trolley pole the two troffic lights in the middle of the tunnel turn red, and by the time the trolley gets to them traffic hos been effectively halted. To allow the motorist ample warning that he will be stopped in the tunnel, a light at each entrance turns from green to yellow at the some time the inside lights become red.

Some meons had to be provided to turn the lights back to green when it was no longer necessary to halt traffic. For this purpose a second bank of cells wos so arranged that when the trolley starts up again, the beam of light falling upon them is interrupted by the trolley pole.—Electronics.

¶ From QST*
December, 1938

455-Kc. Quartz CRYSTAL FILTERS

BY D. K. ORAM
HAMMARLUND MFG. CO., INC.

Here's a new 455-kc. quartz crystal filter which can be adjusted to give any desired degree of selectivity between normal i.f. and crystal maximum—continuously variable, if one likes. Its advantages for phone reception are obvious. One-knob control, substantially uniform output over the whole selectivity range.

THE use of quartz crystal filters to increase the selectivity of intermediate frequency amplifiers in communications receivers has become almost universal.

However, from a perusal of the material available on the subject, one conclusion seems inescapable; crystal filters of today are *sharp* enough, but despite the many improvements made, the variable selectivity feature has not been carried far enough on the *broad* side to bridge completely the gap between "crystal" and "non-crystal" selectivity at 455 kc., which for obvious reasons is still the most popular frequency for intermediate amplifiers. There is no denying the fact that such a complete range of crystal selectivity would aid materially in voice reception, regardless of receiving conditions.

It is the purpose of this article to describe a new 455-kc. quartz crystal filter which does meet this variable selectivity requirement, and in addition affords several other operating advantages. Its circuit diagram is shown in figure 1. T is a permeability-tuned stepdown transformer having a high-impedance tuned primary to provide efficient loading in the plate circuit of the first i.f. amplifier tube. Its secondary is of relatively low impedance in order to deliver a substantially constant voltage to the quartz crystal and its variable impedance load. The secondary is center-tapped to ground by

*Journal of the American Radio Relay League, Inc., West Hartford, Conn.

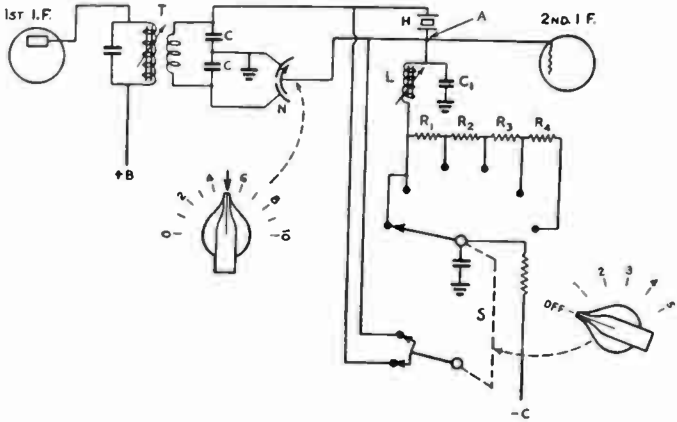


Figure 1. Circuit Diagram of the Wide-Range Variable-Selectivity Crystal Filter.

T—Permeability-tuned i.f. transformer with low-impedance secondary
H—455-kc. crystal and holder
C, C—Fixed condensers, 100 μμfd. each
C_1—85 μμfd. silvered mica
N—Phasing condenser, see text
L—Iron core i.f. coil, 1.14 millihenrys
R_1—25 ohms
R_2—50 ohms
R_3—300 ohms
R_4—2000 ohms
S—6-point tap switch, with extra contacts for shorting crystal

means of two matched fixed condensers, C-C, to provide a neutralizing voltage 180° out of phase with the voltage fed to the crystal. N is the neutralizing or phasing condenser, and is of the opposed-stator type. While the capacity of the rotor to each stator of this condenser varies in the normal manner as the rotor is turned, the capacity between rotor and *both* stators in parallel remains constant regardless of the angular position of the rotor. The importance of this feature will appear later.

The crystal holder H is made of isolantite. Its unusual design reduces its capacity to a minimum and provides a uniform air-gap between the crystal and its electrodes, which are of stainless steel, surface-ground to insure flatness. The quartz crystal itself is of special cut, having a very high Q and complete absence of spurious responses within ± 40 kc. of its 455-kc. natural period.

We now come to the load or crystal output circuit, which constitutes the most interesting feature of this new filter, since it provides the expanded control of selectivity which is admittedly so desirable. It consists of the permeability-tuned coil L and its associated fixed condenser C_1.

• Output Circuit Operation

It will be necessary at this point to depart somewhat from routine description in order to consider the effect of this load circuit on the selectivity characteristic of the crystal filter unit as a whole. There is no doubt whatever that a higher load impedance results in wider filter response. There are, however, at least two ways of explaining this well-known effect. To date, the most generally accepted idea has been to regard the load impedance as an addition to the effective series resistance of the quartz crystal, thus decreasing its Q. In the present discussion, since the voltage feed to the crystal is essentially constant over the narrow band width involved, as previously explained, the crystal and its load circuit in series will be considered as the two sections of a voltage divider. The actual voltage in which we are interested is that existing at the junction of the two sections of this divider, which is directly connected to the grid of the succeeding i.f. amplifier tube (point **A** in figure 1). Since both sections are tuned circuits (although one is the quartz crystal) it is obvious that the impedance of such a voltage divider will vary considerably with frequency. Since the voltage across it remains substantially constant, it necessarily follows that the amplitude of the voltage at point **A** will depend directly on the relation of the impedances of the two divider sections, which in turn will depend on the impressed frequency. The constants of the two sections differ so enormously from each other that small changes in the impressed frequency produce correspondingly great differences in their respective

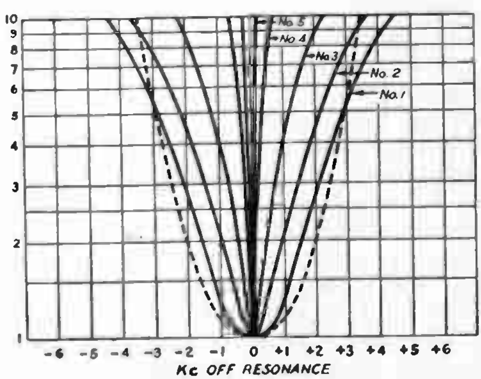


Figure 2. Variation in crystal-filter selectivity with different values of resistance. The dotted curve shows, for reference, the selectivity of the two-stage i.f. amplifier without the filter; solid lines are crystal filter alone.

voltage drops, with consequent changes in the potential of point A. To illustrate it: if we assume that the phasing condenser N has been adjusted to neutralize exactly the capacity of the crystal holder, the quartz crystal can be considered as a series-tuned circuit having inductive and capacitive reactances, X_L and X_C (equal at resonance) of about 60,000,000 ohms, series resistance of R of 4000 ohms and Q of 15,000. Coil L, forming the lower section of the divider, together with its tuning condenser C_1 becomes a parallel-tuned circuit having reactances of 3200 ohms, R of 24 ohms, and Q of 133. At precise resonance the crystal presents but 4000 ohms resistance, while the parallel-tuned circuit presents a resistance of 425,000 ohms . . . ($Q \times X$ or $\frac{\omega^2L^2}{R}$). Therefore, at the frequency of crystal resonance, substantially all the voltage supplied to the crystal by transformer T appears at point A and is applied to the grid of the second i.f. amplifier tube.

For frequencies slightly above or below the crystal resonance frequency, the impedance relations of the two sections of the voltage divider change appreciably. Because of the very high value of the reactance components of the quartz crystal, even a slight departure from its resonant frequency causes a relatively large increase in its net reactance. On the other hand the impedance of the parallel-tuned circuit, due to its much lower Q, changes very slowly with slight departures from resonance. To give a clear picture of these impedance changes they are listed below for several degrees of departure from the frequency of exact resonance.

Departure from Resonance*	Impedance: Quartz Crystal	Impedance: Parallel Tuned Circuit
0 cycles	4,000 ohms	425,000 ohms
± 20 "	6,500+ "	425,000— "
± 50 "	13,600 "	425,000— "
± 100 "	26,400 "	424,000 "
± 500 "	132,000 "	408,000 "
± 1000 "	264,000 "	367,000 "
± 1500 "	395,000 "	320,000 "
± 2000 "	528,000 "	277,000 "
± 3000 "	792,000 "	211,000 "

* While not strictly the same on both sides of resonance, the differences are too slight to affect this discussion. For very great departures from resonance, the differences are significant.

As the impressed frequency departs from the crystal resonance frequency its series impedance rises steeply and, due to the extremely high Q, is almost entirely reactive, even for the small departure of 100 cycles. On the other hand, the impedance of the parallel-tuned circuit falls but slowly and the resistive component remains large even for departures as great as 3000 cycles. Therefore, it will introduce no great error to assume 528,000 ohms as the *reactance* of the crystal, and 277,000 ohms as the *resistance* of the load circuit at ± 2000 cycles from resonance. Since the total impedance of a reactance and a resistance in series is given by $\sqrt{X^2 + R^2}$, the total impedance of the voltage divider at 2000 cycles off resonance amounts to 596,000

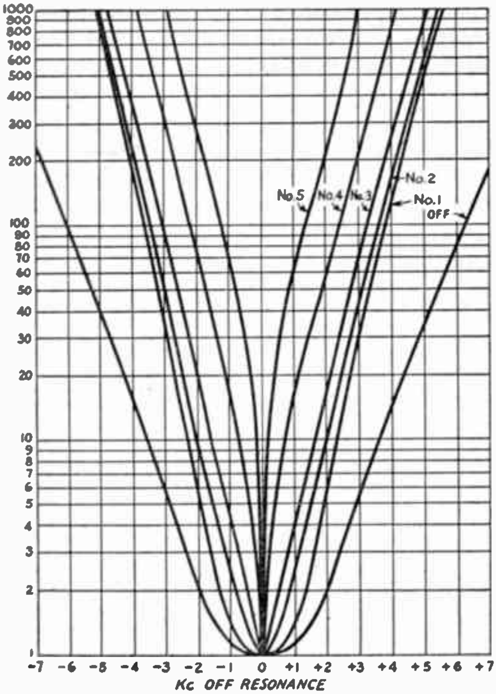


Figure 3. Overall resonance curves (crystal filter plus i.f. amplifier) with phasing condenser set to neutralize the crystal-holder capacity.

ohms, and $\frac{277{,}000}{596{,}000}$ or 46.5 per cent of the total voltage impressed on the crystal will appear at point A. This corresponds to an attenuation of slightly more than 2, or a little more than 6 db. Under these conditions the selectivity curve of the filter will be strictly symmetrical, and the band width at an input ratio of 2 will be almost exactly 4 kc. This degree of selectivity is of the same order as that provided by a two-stage tuned i.f. amplifier designed for communications work. Consequently, if filter and amplifier are cascaded, the band width will be approximately 3 kc. at the same input ratio of 2. This degree of selectivity is just about ideal for the first step from "crystal out" to "crystal in." So much for the broad extreme of crystal selectivity.

• Practical Methods

From the above, it is apparent that the range of selectivity obtainable from a crystal filter unit is limited by but two factors. Maximum, or sharp, selectivity is limited only by the Q of the quartz crystal itself. Minimum, or broad, selectivity is limited only by the magnitude of the *average* load impedance into which the crystal works. *Average* impedance means the impedance throughout the narrow band of frequencies either side of resonance, where but slight attenuation is desired. Any intermediate degree of selectivity may therefore be secured merely by choosing the proper value of load impedance. By consulting the chart of impedance variations previously given, it is a simple matter to choose appropriate values for this impedance to meet the several degrees of selectivity desired. As the impedance of a parallel-tuned circuit (at resonance) is equal to the reactance multiplied by the Q, reducing either reactance or Q results in a decrease in impedance. The reactance of L and C_1 cannot conveniently be reduced (both would have to be reduced in order to maintain resonance), but the Q can be easily reduced to any desired value by simply inserting resistance in series with either the coil L or the condenser C_1. Accordingly a tap switch S has been inserted between the low-potential end of L and ground. This switch has six positions marked "off," 1, 2, 3, 4 and 5. In the "off" position (extreme counter-clockwise) the crystal holder is short-circuited by means of two auxiliary contacts. In position no. 1 this short-circuit is removed and the crystal feeds into the parallel-tuned circuit LC_1, which has previously been tuned precisely to the resonant frequency of the actual quartz crystal used. In this position of the switch, L and C_1 present their maximum possible impedance, as explained above in detail, and the crystal filter then provides the first step of increased selectivity over that obtainable from the tuned i.f. stages alone. In positions nos. 2, 3, 4 and 5, successively greater amounts of resistance are introduced in series with L, resulting in smaller values of Q and lower load impedance into which the crystal works. Each increase in series resistance causes a corresponding increase in selectivity until position no. 5 is reached. This position provides the maximum selectivity of which the crystal is capable.

The preceding description and explanation, together with the curves showing the actual performance of this new crystal filter, prove conclusively that such a design does provide the complete range of selectivity required of communications receivers. The most important departure from previous designs is the rearrangement providing a sufficiently high-impedance load for the quartz crystal. The design and production of such a load circuit as an integral part of a practical filter is quite a problem in itself. To begin with, it must be very accurately tuned if it is to present maximum impedance to the crystal. By referring to the impedance figures previously listed, it will be noted that if mistuned only 3 kc. (2/3 per cent) its impedance is reduced to less than half its maximum. For this reason alone this circuit should be of the semi-permanently tuned type; that is, adjusted accurately during alignment, rather than by a panel control that would have to be adjusted during the stress and strain of actual operating. For the same general reason it is felt that six accurately adjusted and definite degrees of selectivity, each instantly available by the flick of a switch, would prove highly desirable from the practical operating standpoint, although it has undoubtedly occurred to most readers that a continuously variable resistor could be used in place of R_1, R_2, R_3, and R_4. After being accurately tuned, this most important load circuit must remain in exact resonance during the varying conditions of actual operating. Since the grid of the second i.f. amplifier tube is directly across the circuit, certain precautions should be taken to prevent variations of the tube input capacity when the receiver's sensitivity control (either manual or a.v.c.) is altered. Otherwise optimum crystal filter performance will be obtained only at that setting of the gain control where the original tuning adjustment was made. The phasing control presents a similar problem, which was solved by the use of the double-stator condenser previously described. Since the capacity between its rotor and *both* stators remains constant, variations in its setting have no effect whatever on the tuning of the crystal load circuit.

The phasing control works very symmetrically in this new filter circuit. Its action is absolutely independent of the setting of the selectivity switch—another important advantage to the practical operator. When set to the center of its scale the crystal holder capacity is exactly neutralized, and the selectivity characteristics of the filter are truly symmetrical regardless of the position of the selectivity switch. When turned either side of center the familiar rejection dip is introduced in the filter response curve, above or below resonance depending on whether the control is turned above or below center scale. These rejection settings are equally independent of the position of the selectivity switch. For example, if the phasing control is set for rejection of a 1000-cycle beat note from an interfering transmitter, the degree of selectivity of the crystal can be altered at will with no effect whatever on the *frequency* of rejection, although the rejection dip in the response curve of the filter is deeper at the more selective settings of the selectivity switch.

• Performance Data

By far the best conclusion to any description and discussion such as the foregoing is a complete set of data showing the actual performance of the device. One very interesting characteristic of this new filter is the extremely slight variation in output throughout the six steps of selectivity. This was investigated by means of constant c.w. input to the receiver, the output being recorded

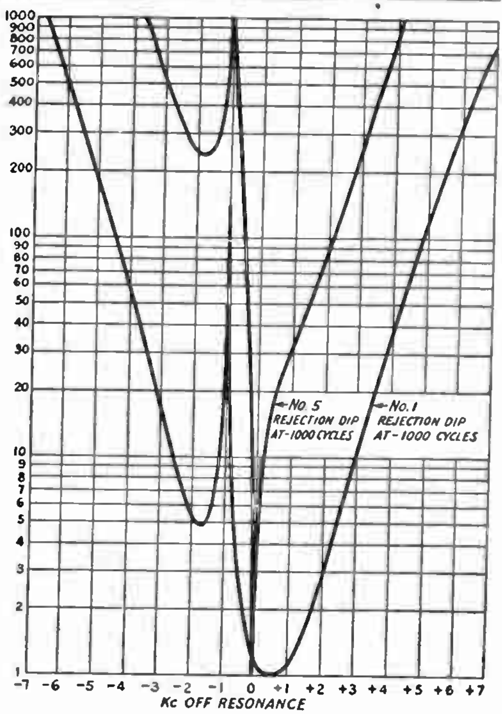


Figure 4. Illustrating rejection action for two different degrees of selectivity.

by a microammeter in series with the load resistance of the diode second detector. The sensitivity control was adjusted to produce a reading of 100 on the microammeter with the selectivity switch in the "off" position (crystal out), after tuning the receiver accurately to the signal with the selectivity switch on position no. 5. Readings were then taken at all six positions of the switch. There was no drop on positions nos. 1 and 2, and the drop on position no. 3 was negligible. On no. 4 the reading was 96 and on no. 5 it dropped to 86. This is only slightly more than 1 db variation in output throughout the entire selectivity range, and constitutes a further operating advantage, inasmuch as carrier-strength meter readings will be practically independent of crystal filter selectivity; actually the total variation amounts to about one-fifth of an "S" unit.

Figure 2 shows the selectivity characteristics of the crystal filter unit alone, with the curve of the tuned i.f. amplifier only shown in dashed lines, for comparison. It will be noted that the curve marked no. 1 (minimum crystal selectivity) is not quite as wide as predicted in the preceding analysis. Part of the discrepancy is due to the fact that the selectivity of transformer T was not taken into account in the calculation. In addition it is quite likely that some of the constants assumed for the crystal and its load circuit were slightly different in the actual filter unit measured. One significant fact is strikingly illustrated in figure 2. Quartz crystal filters can be built to give wide variations of selectivity for input ratios up to 10 or thereabouts, but several cascaded tuned circuits are needed to give the steep-sided selectivity curves at input ratios of 1000 and over. Naturally a combination of the two is ideal.

Figure 3 shows the overall curves obtained from the entire i.f. amplifier for each of the six positions of the selectivity switch. These curves, as well as those of figure 2, were made with the phasing control set at neutral, in which position the crystal-holder capacity is exactly neutralized. Although the curves of figures 2 and 3 appear almost *too* smooth and symmetrical, they were nevertheless drawn from accurate measurements. The method of measurement itself was so precise that errors usually arising from that source were practically non-existent. In addition the entire amplifier was aligned by the visual method using the two-image system on the oscillograph screen. No difficulty was experienced in making the two images coincide exactly, even with the crystal in circuit; hence the high degree of symmetry.

Figure 4 shows the effect of setting the phasing control to reject an interfering carrier 1000 cycles below crystal resonance. The setting of the phasing control was made with the selectivity switch on position no. 5. After completing the selectivity run, the selectivity switch was set on no. 1 and observations for the second curve were immediately made without disturbing the setting of the phasing control. It will be noted that the rejection dip is about 20 db deeper in the no. 5 position, although the frequency of

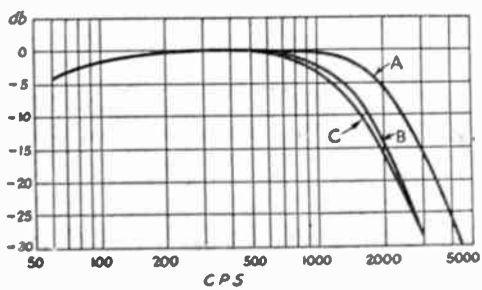


Figure 5. Audio Response Curves. A, with switch in "off" position. B, with switch in no. 1 position (broad), and phasing condenser at neutralization; C, same as B but with phasing condenser set for rejection at 1000 cycles below resonance.

rejection remains unchanged.

Figure 5 shows three audio fidelity curves which are an interesting check on the selectivity curves. Curve A is the fidelity of the complete i.f. amplifier with the selectivity switch in the off position; that is, with the crystal short-circuited. Curve B is with the switch on position no. 1 and with the phasing control in neutral. Curve C is taken under the same conditions as B except that the phasing control has been set to provide a rejection dip at 1000 cycles below resonance. Curve C is therefore the audio fidelity curve of the i.f. end of the receiver when its selectivity is as shown in the no. 1 selectivity curve of figure 4. It is interesting to note the slight difference between curves B and C in view of the great difference in their corresponding selectivity curves as shown by curve no. 1 of figure 3 and curve no. 1 of figure 4.

Of course, many of these performance curves depend on the choice of resistors, R_1, R_2, R_3 and R_4. Other values than those used will result in different band widths for curves 2, 3 and 4. However, the resistance values actually chosen result in what is considered an ideal selectivity range for a communications receiver.

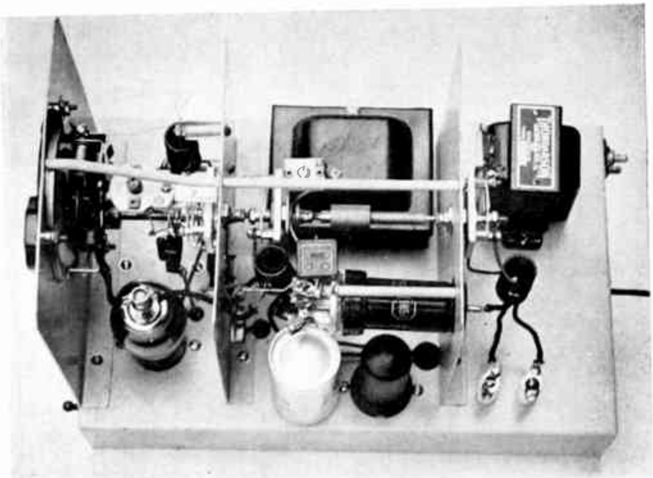
(See page 51 for photograph.)

Invisible Product

AN AUTOMOBILE manufacturer can look at it, test it. A candy manufacturer can see, smell and taste his product, but a broadcaster who manufactures nothing but sound waves is at a disadvantage. All he can do is listen, and who ever heard of a broadcaster having time to listen to his complete product!

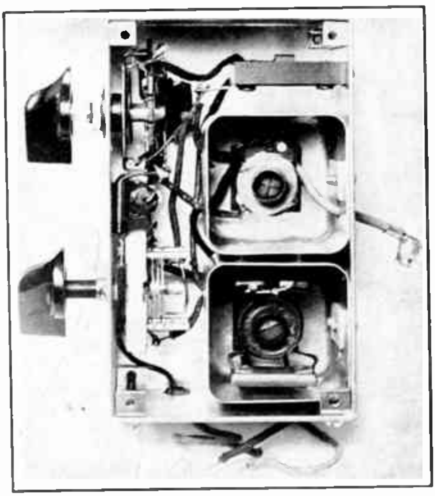
It might be a good idea, however. A prominent advertising man, ordered to bed by his doctor, spent most of his time listening to the radio. At the end of three weeks his ideas about radio had completely changed. What would a broadcaster think of his product if he had to do this?—Pick-Ups.

Pictorial Section



FIVE- AND TEN-METER CONVERTER

• Top view of the completed unit described by Roy L. Dowley on page 60, with the 28-Mc. coils in place. The placement of the components is indicated quite clearly in this photograph.



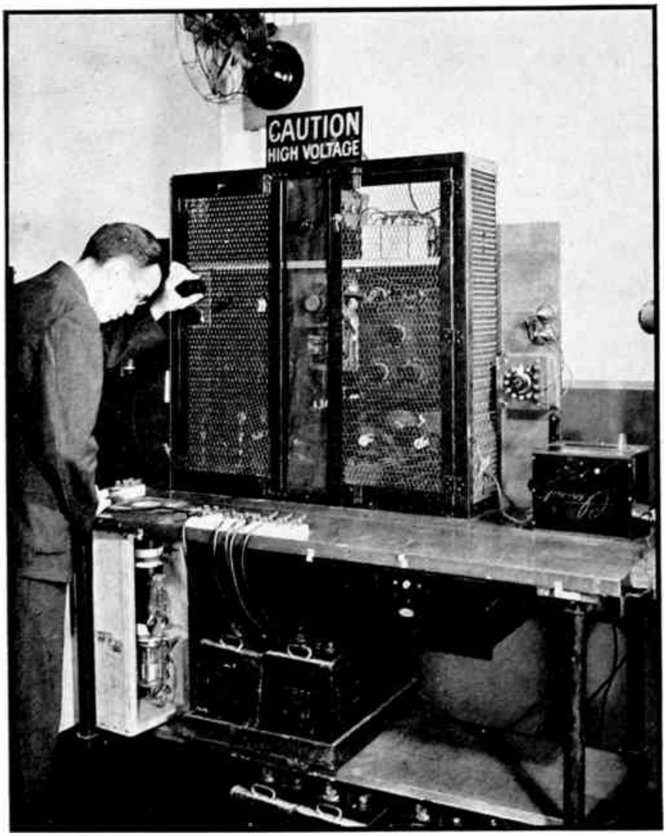
• The complete wide-range variable-selectivity crystal-filter unit described by D. K. Oram on page 41. The switch and resistors are in the upper left corner, with the crystal and holder to the right. The phasing condenser is at the lower left. Transformer T is in the lower right corner, with the output circuit, LC_1, in the con just above. The unit is approximately 2 x 3 x 5 inches.

(Cut courtesy QST)

Shown here are two laboratory applications of the electron microscope, a technical discussion of which is given in the article beginning on page 16.
(Cuts courtesy ELECTRONICS)

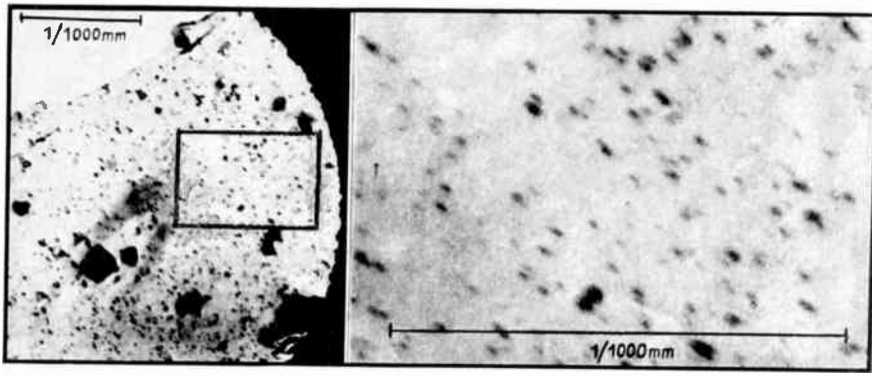
● An electron microscope for studying photoelectric emission is being constructed at the California Institute of Technology under the direction of Prof. W. V. Houston. It is shown here undergoing preliminary tests.

ELECTRON

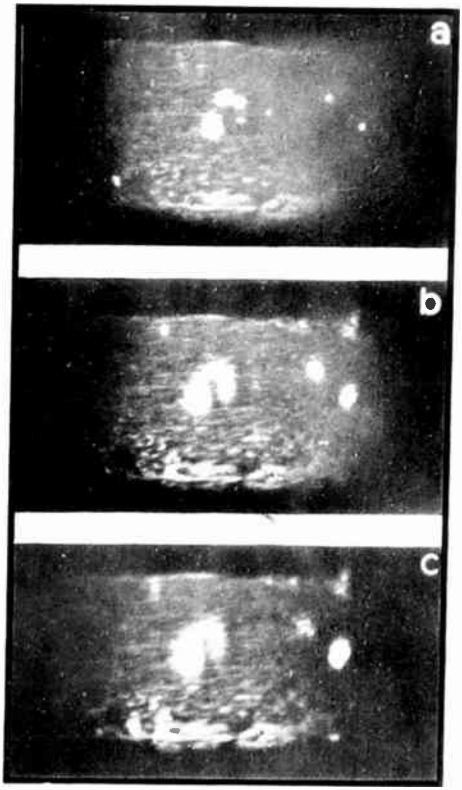


● An electron microscope at the Bell Telephone Laboratories for studying thermionic emission of various cathode materials. The thorium eruptions on page 54 were photographed with the aid of this equipment.

MICROSCOPES



● Small colloids of only 5 to 10 × 10^{-6} mm in size may be examined visually or photographically with the aid of the electron microscope, opening up new fields of research to the physicist and chemist. The picture above shows colloidal silver magnified 15,500×. The part within the rectangle is magnified to 59,000×.



● Right—A series of photographs with the electron microscope which shows the increase in area of the electric discharge from a hot filament as a globule of thorium is ejected from the incandescent filament. Magnification is about 110×.

From Bell Laboratories
Record, November, 1938

Magnetic Shields

BY W. B. ELLWOOD

SHIELDS are often used to protect electric and magnetic apparatus from stray magnetic fields which come from neighboring equipment, or even from the earth's field. Iron boxes have served this purpose for over a century and many investigations have been carried out to determine their shielding characteristics. The results are not well known, however; and since new magnetic alloys far superior to iron for shielding have recently been developed, the subject justifies reviewing.

The mechanism of shielding may be illustrated by the line-of-force diagram of figure 1, where a cylindrical shield is shown at right angles to a uniform horizontal field in the plane of the diagram. The lines of force are diverted at the boundaries of the shield from the space within because the shield offers a path of less magnetic resistance. Not all of the lines are eliminated, but by careful design the residual field inside can be made very small. In the attempt to obtain effective shielding heavy cast iron or permalloy boxes have often been used, but thin shields are actually more effective per unit weight than thick ones and the shielding can be increased considerably by using several concentric shields with air space between adjacent units. Multiple shields are better because they have more boundary surfaces to deflect the field.

The theory of shielding design involves an equation which expresses the ratio of the original field at any point to the field at the same point when protected by the shield. This ratio, usually designated as "G," is a function of the magnetic properties and geometrical distribution of the material employed to form the box or boxes which constitute the shield. The equation can be solved for only a very few practical cases, and the problem of shield design thus reduces to the proper choice and fabrication of materials to fulfill as nearly as possible the require-

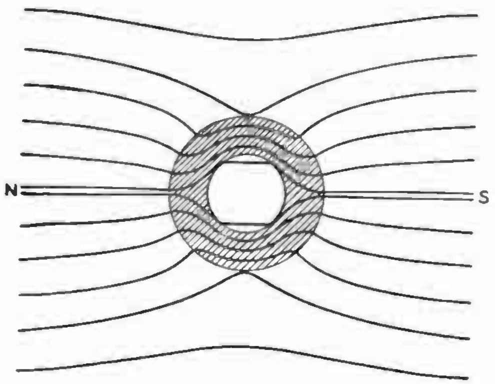


Figure 1. A magnetic shield diverts most of the lines of force from the space inside the shield because it offers a path of less magnetic resistance. The lines of force are refracted at the boundaries of the shield.

ments of the mathematical theory within the economic and space limitations prescribed.

The simplest practical case amenable to theoretical treatment is that of a single spherical shell surrounding the device to be shielded. An approximate formula for the shielding ratio is $G = \frac{2\mu}{9}(1 - \beta^3)$. In this formula μ is the reversible permeability of the material as measured ballistically in a ring specimen and is assumed very much larger than unity. The ratio of the internal to the external radii of the spherical shell is β. For an infinitely long cylindrical shield magnetized perpendicularly to its axis the ratio is $G = \frac{\mu}{4}(1 - \beta^2)$. Experiment has shown that G is reduced only by a factor of two in some cases, as for instance when the field is parallel to the axis.

The values of G versus $1/\beta$ for silicon steel shields in these two forms are shown in figure 2, curves A and B. Shells which are geometrically similar though of different size have the same shielding ratio. Curves A′ and B′ give the relative shielding per unit weight of material. For a value of $1/\beta$ equal to 1.15 the shielding ratio is twenty; beyond that point the shielding per unit weight falls off so rapidly that thicker shields are uneconomical.

The curves of figure 2 are for a silicon steel for which the initial permeability is about 400. By using 3.8 per cent molybdenum permalloy which has an initial permeability of approximately 20,000, a shielding ratio fifty times greater can be attained. Thus a shielding ratio of more than 1,000 is now obtainable with a single permalloy shield of economical dimensions.

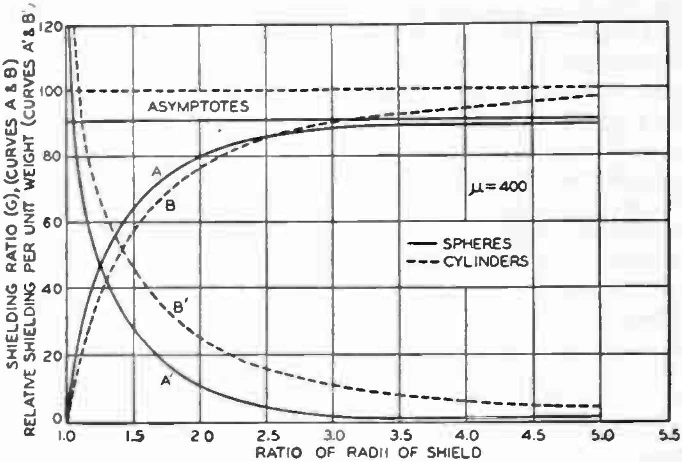


Figure 2. The effectiveness of a magnetic shield depends not only on its permeability but also on the thickness of its walls. These curves show, however, that it is not economical to use very thick shields. Multiple shields are preferable when space permits.

The cylindrical shields just discussed were assumed to be infinitely long to eliminate end effects, but it has been found experimentally that a cylinder with a ratio of length to mean diameter of 1.25 gave about sixty per cent of the shielding of the infinitely long cylinder. Closing the ends of the shield with plates of the same material increased this to eighty per cent.

Shields are ordinarily employed to protect against stray external fields, but they may also be used to prevent neighboring parts from being affected by the apparatus inside the shield. Thus the magnetic field set up by relays, inductance coils, transformers and permanent magnet structures may be practically restricted to a definite region by surrounding them with a shield. Equal and opposite magnetic poles, however, must be included within the same shield, since there is no shielding effect if only one pole is enclosed. A pair of straight parallel wires which carry and return a current, for example, may be shielded by enclosing the wires in a cylindrical tube of magnetic material. If such a pair, occupying a space of 1/10 centimeter in radius, is provided with a shield with walls 0.015 centimeter thick and $\mu = 500$, the shielding ratio will be approximately 30.

If greater shielding is desired than can be provided by a single shield and if the ratio of the external to the internal diameters of the shield may be greater than 1.5, multiple concentric shields may be employed. With them almost any amount of shielding can be attained except for the limitations of space and cost. The design of multiple concentric shields is very complicated. In general the shielding factor of a system of two concentric shields is roughly equal to the products of their individual shielding ratios multiplied by the ratio of the volume of the air space between them to the volume occupied by the shield system. This relation does not apply where the clearance space between shields is small. No great advantage is gained by multiple shielding unless the volume occupied by the shielding system is more than four times the volume to be shielded. For example, if the shield shown in figure 1 were made of silicon steel ($\mu = 400$), the shielding ratio, G, would be approximately eighty since the ratio of the internal to the external radii is two. The shielding ratio could be increased to more than 500 by using two concentric shields of silicon steel separated by an air space, if the ratio of successive radii were 1.26, i.e. 1:1.26::1.6:2. This would require about thirty per cent less material. If instead of two shields separated by a single air space we divided the steel into four shields separated by three air spaces, with successive radii in the ratio of 1 to 1.1, the shielding ratio would become 2000. The shielding obtainable by using one of the shells of the double shielding system of silicon steel would be about thirty-eight; for the quadruple system a single shell would give about eighteen.

In a single shell the shielding is proportional to the permeability of the material. For multiple shields, however, the shielding varies roughly as μ^n where n is the number of shields. This shows the advantage of using a high-permeability material such as 3.8 molybdenum permalloy with its initial permeability of 20,000.

Remanent magnetization of the shield material will cause it to produce a steady field in the absence of an external field but this field may be compensated by that of another permanent magnet.

The theoretical considerations presented here have assumed constant fields but they can also be applied with caution to alternating or transient fields provided the material is sufficiently laminated. Shielding against transient or alternating fields is sometimes impaired by having the material as a thick unlaminated wall. Eddy currents are then induced and may prevent the instantaneous change in magnetization of the shell walls which is needed to compensate for the changing field. Under those conditions it is desirable to laminate the material in a direction to eliminate the eddy currents. In practice, shields have been made of piles of ring stampings separated by insulation or of a long spiral of material with insulation between turns. For a sufficiently short cylinder the effect of eddy currents in a ferromagnetic shield is to decrease its efficiency as the frequency increases. On the other hand for a non-ferromagnetic cylinder the efficiency increases with increase in frequency. The two effects may be superimposed in any practical case. A combination of a copper shell inside a ferromagnetic shield will produce a shield good for all frequencies as well as for steady fields.

Magnetic shields should have high permeability in the range of field intensities to which they are subjected and for this reason several of the new magnetic alloys are especially useful as shield materials. If the field to be shielded out is very small, 3.8 molybdenum permalloy may be used because of its high permeability, high resistivity, and the fact that it can be obtained in sheet form. One heat treatment will produce the desired properties. A single shield having a shielding ratio of 1000 may be made of this material and where multiple shields are used, ratios of more than 1,000,000 can be obtained. For intermediate fields up to five gauss the perminvars are suitable, especially where the effects of residual magnetization must be minimized and the field must be uniform, because these alloys have low remanence and constant permeability. If shielding is used at high fields, 50:50 iron-cobalt alloy is preferable since it has high permeability at high flux densities.

Contrast

FCC spends a barrel of money investigating monopoly in communications; produces material which will be forgotten in a year or so; raises big rumpus, gets in the papers, etc., etc. The engineering work of the Commission, however, is largely buried, unappreciated, disregarded by politicians. Who knows of the long serious study of receiving conditions on shipboard where radio is of vital importance; of the investigation of tropical noise, static, engine room disturbances, all endeavoring for the first time to make a real approach to the problem of how much power a ship transmitter ought to have and of what signal strength it ought to receive? This work is of lasting benefit and its effect will be felt long after the fuss and fury of the non-technical investigations have been forgotten.—Electronics.

¶ From Radio
December, 1938

A Five- and Ten-Meter *Converter*

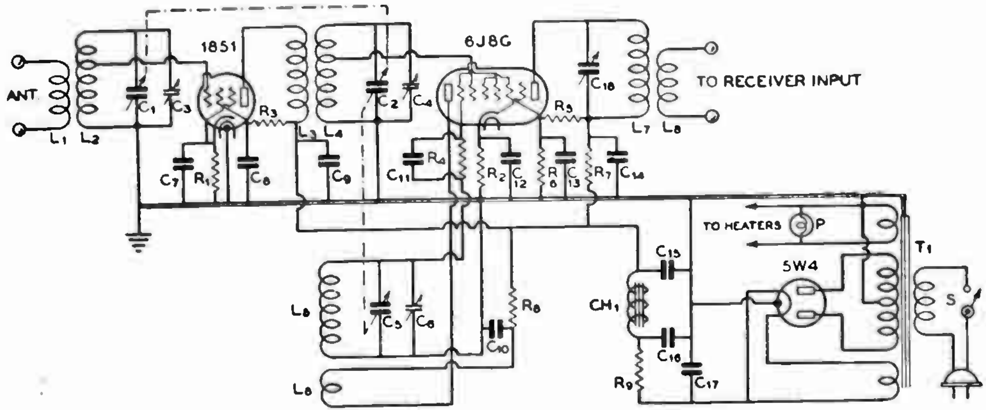
BY RAY L. DAWLEY

In response to a large number of requests since the recent 56-Mc. dx spree for a superhet converter especially designed for use on the 28- and 56-Mc. amateur bands, we offer the model to be described.

There are quite a few important reasons for the need of a good high-frequency converter. In the first place, very few of the commercially available receivers give coverage of the 56-Mc. band; if they do, the inherent losses and inefficiencies, tuning difficulties and instabilities of the receiver make the band almost useless. Second, while nearly all of the commercial receivers cover the 28-Mc. band, only a very few of them are really satisfactory on this high frequency. It is an almost insurmountable problem to design a single high-frequency "front end" which will adequately cover the 160-meter or the broadcast band and still retain some semblance of efficiency on 28 Mc.

To the grid coils (and their switching mechanism, if used) can be attributed most of the inefficiencies of the conventional receivers when used on frequencies above about 20 Mc. To obtain high gain these coils must be compact, wound with large diameter conductor, must be virtually self-supporting, and in the clear with respect to surrounding masses of metal. These are in addition to the obvious requirements that the coils be as high in inductance as possible, that their leads to the tuning condenser be short and that they have low distributed capacity.

With these requirements in mind, take a look at the 28-Mc. r.f. and detector coils of your favorite communications receiver. The reason for their lack of sensitivity is immediately apparent; the 28-Mc.



C_1, C_2—10 µµfd. midget variable

C_3, C_4—3-to-30-µµfd. mica trimmer

C_5—15-µµfd. midget variable

C_6—25-µµfd. air trimmer

C_7, C_8, C_9, C_{10}—.004-µfd. mica

C_{11}, C_{12}, C_{13}, C_{14}—.01 µfd. 400-volt tubular

C_{15}, C_{16}—Dual 8-µfd. 450-volt electrolytic

C_{17}—.001-µfd. mica

C_{18}—50-µµfd. midget variablo

R_1, R_2—300 ohms, 1 watt

R_3, R_4, R_5—50,000 ohms, ½ watt

R_6—60,000 ohms, ½ watt

R_7—3000 ohms, ½ watt

R_8—5000 ohms, ½ watt

R_9—3000 ohms, 10 watts

T_1—600 volts c.t. 50 ma.; 6.3 volts, 2 amp.; 5 volts, 2 amp.

CH_1—15-hy. 85-ma. filter choke

Coils—See coil table

coils of one of the most widely used bandswitching superhets consist of two turns of wire, about 3/8-inch in diameter, with long leads up to the bandswitch and then to the tuning condenser.

We are not finding fault with these receivers; the compromise between operation on both the low- and the high-frequency spectrum has been very carefully made and it is a credit to the engineers that the receivers operate as well as they do on 28 Mc. But, by designing the high-frequency end of the receiver specifically for frequencies above 28 Mc., it is not necessary that these compromises be made. Notice the 14-turn 28-Mc. coils used in this converter. And, through the principles of double conversion (the operation of a superheterodyne with two frequency converters and two intermediate frequency channels) it is possible to combine a standard low-frequency receiver and an especially designed high-frequency converter to produce an excellent h.f. receiver.

An additional advantage that can be obtained through the use of double superhet operation is the virtual elimination of images. Images are undoubtedly the most annoying fault of most commercial receivers on the 28-Mc. band. If the converter to be described is operated into a receiver that has no images on the 7-Mc. band, and few of them have, the combination of the receiver and the converter will exhibit no images on the 28- to 30-Mc. band or the 56- to 60-Mc. band. That fact in itself is enough to recommend the use of a converter and good low-frequency receiver in preference to a single-i.f. high-frequency receiver. Of course, it is possible to eliminate images in a single-conversion high-frequency receiver if the i.f. is made high enough. But the use of *only* a high i.f. in an h.f. receiver leads to poor selectivity, low gain and high inherent noise level.

While the converter is primarily designed to operate with conventional receivers that do not provide for the 28- or 56-Mc. bands, it gave a very worth-while improvement in both image rejection and signal-to-noise ratio when used ahead of some of the well-known makes that do include the 28-Mc. band. As a matter of fact, the easily noticeable improvement in signals would indicate that the converter is a worth-while addition to most communication receivers that already cover 28 Mc. even if 56-Mc. operation is not contemplated.

- The Circuit

The circuit of the converter is more or less conventional and employs an 1851 in a high-gain preselector r.f. stage with a 6J8G combined oscillator-mixer. The power supply is self-contained, making the unit entirely independent of the receiver with which it operates. A low-impedance output link is provided from the plate circuit of the mixer tube to be connected to the antenna circuit of the receiver into which the converter is to operate.

This also increases the versatility of the unit.

• The 1851 R.F. Stage

The 1851 tube used in the preselector r.f. stage operates at maximum gain at all times to improve the signal-to-noise ratio. Regeneration was tried in this stage but it was found to be unnecessary since the gain of the stage is already very high and no increase in the signal-to-noise ratio was obtained.

The antenna is coupled to the grid coil by a small air supported coil of hookup wire wound on a pencil and inserted into the grid coil. The grid coil itself has a small 3-30 μμfd. mica trimmer connected across it in conjunction with the regular tuning condenser. To match the high impedance of the coil to the lower grid impedance of the 1851, the tap for the grid of the tube is taken off one turn above the center of the coil on both the 28- and 56-Mc. bands.

The plate of the 1851 is inductively coupled to the grid tank of the mixer tube by another small coil of hookup wire. The plate coupling coil is changed at the same time that the succeeding grid coil is changed. A 300-ohm cathode biasing resistor is employed on the r.f. stage. It is important that all the by-passing returns for this stage (cathode, screen grid and plate) be made at a common point if oscillation in the 1851 is to be prevented. As can be seen in the photograph, a heavy wire is run from the tuning condenser for the grid circuit of the mixer down toward the 1851; all the by-pass returns are made to this point. It was necessary to make all these returns very short and direct before oscillation in the 1851 could be prevented.

• The Combined Oscillator-Mixer

A 6J8G is employed as a combined high-frequency oscillator and mixer. As in the grid circuit of the r.f. stage, the grid of the 6J8G is taken one turn above the center of its associated grid coil. Although this expedient is not required from an impedance-matching standpoint, it does assist in tracking the two stages and ample driving voltage is still available at the tapped point to excite the mixer.

The circuit employed for the oscillator section of the mixer is the conventional tuned-grid tickler-plate arrangement. The use of this circuit puts one side of the tuning condenser and trimmer at ground potential. While only a three-plate tuning condenser is used on the r.f. and mixer grid circuits, a five-plate condenser is used on the oscillator. This allows higher C to be used in the oscillator circuit to give the requisite stability and still allows the band to be covered. The padder condenser on the oscillator circuit is an air-dielectric type in contrast to the mica condensers used on the r.f. and mixer. The air padder condenser contributes greatly to stability over a period of time in the oscillator circuit. Room and compartment temperature variations have little effect on the air condenser. While these variations do affect the mica condensers on the r.f. and detector grid circuits, small variations at these points have no measurable effect on the alignment.

When operating on the 56-Mc. band the oscillator is operated lower in frequency than the r.f. and detector by the amount of the intermediate frequency. This contributes to the stability of the receiver since the oscillator is operating in the vicinity of 49 Mc. when the receiver is tuning a signal on 56 Mc. However, when operating on the 28-Mc. band the oscillator is operated in the conventional manner, higher in frequency by i.f. than the detector. Since there is very little difference in frequency of the oscillator when operating either on five or ten meters, only the grid coil of the oscillator need be changed; the same tickler coil is employed on both bands.

By operating the oscillator lower in frequency than the received signal on the 56-Mc. band the stability of the receiver is considerably improved over operating the oscillator in the vicinity of 65 Mc. The stability on the 28-Mc. band is ample with the oscillator higher in frequency than the detector.

The plate of the mixer section of the 6J8G is connected to an output circuit that is tuned to the same frequency as the receiver into which the converter is to operate. This tank circuit will tune to any frequency within the range of approximately 5500 to 8000 kc.; hence, the receiver into which the converter is to operate may be tuned to any frequency within this range. Actually, best operation and most accurate tracking was obtained with the output circuit of the converter tuned to approximately 6500 kc. A five-turn link wound over the output coil serves to couple the output of the converter to the input of the receiver.

• Power Supply

The power supply employs a 5W4 (an 80 in metal) with a resistor-input filter system. With choke input the output voltage was too low and with condenser input it was too high; so a compromise was made in using a 3000-ohm 10-watt resistor between the filament

COIL TABLE

Coil	Band: 28 Mc.	Band: 56 Mc.
L_1, Antenna coupling	7 turns hookup, ¼" dia.	7 turns hookup, ¼" dia.
L_2, R.f. stage grid	14 turns no. 14, ½" dia.	7 turns no. 14, ½" dia.
L_3, Detector coupling	14 turns hookup, ¼" dia.	7 turns hookup, ¼" dia.
L_4, Detector Grid	14 turns no. 14, ½" dia.	7 turns no. 14, ½" dia.
L_5, Oscillator grid	7 turns no. 14, ½" dia.	6 turns no. 14, ½" dia.
L_6, Oscillator plate	7 turns no. 14, ½" dia.	Same coil as for 28 Mc.
L_7, Mixer output	34 turns no. 24 d.c.c., 1" diameter form	
L_8, Output link	5 turns hookup wire wound over L_7	

of the 5W4 and the first filter condenser. With this arrangement the voltage delivered to the plates of the tubes is in the vicinity of 275 volts. In addition to lowering the voltage to the proper value, the input resistor contributes its share to the filtering action of the supply. All the power supply components are placed behind the oscillator compartment where heating will not cause the oscillator to drift. Their heating has no detrimental effect on the r.f. stage. Incidentally, it is important that the shields of both the 5W4 and the 1851 be grounded to eliminate any coupling that might exist.

- Layout

The layout shown is not necessarily the best one that could be made. However, it is the result of considerable experimentation with the placement of components and has been found to give excellent results. The reasons for this placement of the power supply components have been cited. The antenna input is placed well to the back so that this circuit will be well away from the other circuits of the converter and so that the antenna connection will be short and direct. The 1851 is mounted horizontally with its grid end protruding into the input circuit compartment and with the plate end very close to the coupling coil to the next stage. This results in very short leads into and out of the r.f. amplifier.

The oscillator compartment is placed at the very front with the oscillator tuning condenser the first one to be driven from the dial. This placement of the oscillator tuning condenser is quite important if freedom from backlash is to be had. In one of the preliminary layouts the oscillator condenser was the last one to be driven by the dial and the backlash was, to put it mildly, quite bad. Placing this condenser directly behind the dial cured the trouble. A slight amount of backlash in the r.f. and detector tuning condensers causes no trouble as they tune broadly as compared to the oscillator.

A suggested improvement on the layout as shown would be to slide the chassis into a small but deep cabinet and to mount the dial upon the front panel of the cabinet. This would eliminate any possible tendency for the three shields to move back and forth as the knob is turned. The tendency is but slight in the unit shown but is sufficient to indicate the desirability of the improvement. In addition, the shielding action of the cabinet would be quite effective in reducing the possible effects of extraneous fields as appear in the vicinity of a high-frequency transmitter.

The link from the output tuned circuit is brought out to a pair of binding posts on the rear of the chassis.

Since the converter was primarily designed to be operated as a fixed-band affair on either the 28- or 56-Mc. band, no provision for quick coil change has been made. Each of the coils is bolted in place at one end and soldered at the other to give firm, low resistance connections. If it is desired to change bands rapidly from five to ten meters some sort of a simple plug and jack arrangement could be employed. A set of miniature pin jacks could be mounted on strips of victron or other good high-frequency insulating material and small prongs soldered to the ends of each of the coils.

• Tuning Up

Placing the unit into operation is comparatively simple providing proper precautions have been taken to make all leads short and to make all ground by-passing returns for a stage as direct as possible to one point.

Connect an antenna (cut to the band upon which it is desired to operate the converter) to the input terminals. It is suggested that the unit be tuned first in the 28-Mc. band. Then connect the output of the converter to the antenna and ground or the doublet terminals of the receiver into which it is desired to operate the unit. The receiver should preferably have two r.f. stages on the 7-Mc. band, although a single stage, if it is operating properly, will be satisfactory. If the receiver does not have an r.f. stage, images will be apparent on the 28- and 56-Mc. bands. Incidentally, the converter may be operated, if desired, into a *good* t.r.f. receiver, although the selectivity will not be nearly as good as when operating into a superhet and some trouble may be had from images. This latter arrangement (the converter working into a good t.r.f. on 7 Mc.) would make an excellent receiver for the wobbulated type of 56-Mc. signals, providing someone wants to listen to them.

With the receiver tuned somewhat below the bottom edge of the 7-Mc. band to a spot that is free of signals, with the dial on the converter set so that it reads about one-third out from maximum capacity, and with the trimmers on the r.f. and detector closed but not screwed down tightly, tune the oscillator padding condenser until 10-meter signals are heard. Now tune this padder until some signal known to be in the vicinity of 28,500 is being received. Then tune the output tank circuit of the mixer until the signal peaks up (this condenser can be seen in the under-chassis view but the knob above chassis is obscured by the oscillator padder condenser). Then adjust the trimmers on the r.f. and detector of the converter until the signal is at maximum. That's all there is to the adjustment except that the preliminary adjustments can be gone over once to make sure that they are on the nose. A similar tune-up procedure would be used for the 56-Mc. band.

If the results do not sound reasonably "hot" there is probably something out of adjustment and it might be well to check tubes, operating voltages and the various circuits to be sure that everything is in order. With this converter operating a "jalopy" all-wave b.c. receiver that had a poorly tuned r.f. stage ahead of it, really excellent results were obtained on 28 Mc. The all-wave set was tuned just below the 49-meter broadcast band.

All in all, the converter has been tried on about eight entirely different types of receivers of widely different vintages and the results on all of them have been startling. Two of the receivers (jalopy "skip band" affairs) were almost useless on the 7-Mc. band by themselves, but they seemed to make very good i.f. channels when the converter was worked into them. The converter puts such a strong signal into the receiver into which it is operating that almost any receiver will operate satisfactorily. And when the unit is operating into a really good communications superhet — it will pull in signals you never knew were there.

The converter is quite versatile in that it requires practically no effort at all to connect it to any receiver. Merely disconnect the antenna, connect it to the converter, and connect the output of the converter to the input of the receiver. As a matter of fact, it is not absolutely necessary that the receiver be tuned to the vicinity of 7 Mc.; a lower output frequency may be used providing the oscillator coil is changed, but the image rejection will not be as good.

As the performance of the best receiver can be improved with a good antenna, so will this converter give best results when an antenna worthy of the name is used. The antenna should preferably resonate near the frequency of operation and have a balanced, low-loss feeder system. A transmitting antenna designed for use on the same band usually fulfills these requirements for a good antenna.

(See page 51 for photograph.)

MEASURING millionths of an inch by means of color films now makes possible a new method of measurement of molecular dimensions. A film of oil seven-millionths of an inch thick is straw colored, while a film only two-millionths thicker appears red, both colors due to light wave interference. Because a layer of barium stearate one molecule thick is .0000001 inch and because films of any required number of layers can be built up, it has been possible to make films of definite thickness. Comparison of colors enables calculation of the thickness of other transparent films.—Ohmite News.

From the T & R Bulletin
November, 1938

OPTIMUM PLATE TANK VALUES

BY G. W. SLACK (G5KG)

ONE of the most ill-used and abused parts of a radio frequency amplifier is the plate tank circuit. It is usually dismissed with a few words in many text books, which seems unfortunate when we consider that it is from this section of the circuit that all the power output is obtained. Further, it is here that all the energy to be radiated is stored.

In the case of audio equipment we can compare the primary of the output transformer to our tank circuit in question. To obtain good-quality and intelligible speech this winding must be constructed so that it will operate under optimum conditions; if this is not done bad quality and poor output will result.

When some of the r.f. tank circuits which are specified from time to time are examined, it is to be wondered that any output is obtained under certain of the conditions in which they are expected to operate.

The present tendency among amateurs is to employ a "ready-made" tank inductance, with no more specification than that "it is suitable to operate on one specific band." No mention is made of the type of circuit it is designed for use with, or whether split stator or ordinary condensers are to be used. Furthermore, no indication is given as to whether push-pull or single-ended operation is intended and never is the plate resistance or plate voltage to plate current ratio mentioned.

An investigation will quickly prove that the plate tank circuit should be operated under optimum conditions in order to obtain maximum output and to do this the above conditions must be carefully observed.

Optimum L/C Ratio

If a high tank impedance is used with large grid bias values and excessive excitation voltages, a large proportion of output power may be converted into harmonic frequencies. These harmonic frequencies are of no practical use in the stage which feeds the radiating system and are of no use for communication purposes on the band in question. Also as our bands do not altogether fall in harmonic relationship, it is quite possible, if harmonics are radiated, that we shall be confronted with the problem of off-frequency operation. Additionally, all power which is generated in harmonics is wasted and if the quantity is such as to cause circulating currents, a large falling off in efficiency will result. Therefore, any steps that can be taken to reduce harmonic output will result in better efficiency. It should also be remembered that if a lower tank impedance than necessary is used, a low transfer of energy will result.

From these considerations it follows that there must be an optimum point in the adjustment of plate tank circuits where a maximum transfer of energy can be maintained with low harmonic output. This is known as *optimum L/C ratio.*

The plate tank circuit can be described as analogous to the fly-wheel used in engineering, where the fly-wheel is used as a store house for the energy output from any type of motive power. When a fly-wheel is designed it must be of such dimensions as to be large enough to supply an efficient transfer of the stored energy to any load that may be applied to it, but it must not be so large as to apply a damping effect to the source of energy. In other words, the fly-wheel, although sufficiently large to maintain an efficient output of power, should only require a minimum of energy or power to maintain the "fly-wheel effect." So it is in the case of the plate tank circuit. As with the fly-wheel there is only one *correct* tank circuit for any one given set of conditions. This consideration is very important in the case of modulated systems where large fluctuations in output occur and where, for best results, the output must be of a linear character.

The optimum L/C ratio to be used is governed by the ratio of the d.c. plate voltage to the d.c. plate current feeding the final amplifier. For a given input the higher the plate voltage and the lower the plate current, the higher the L/C ratio required, and *vice versa.* It is therefore only necessary to know the plate voltage and plate current ratio, or the d.c. resistance, to determine the amount of inductance and capacity required to obtain resonance at the desired frequency, so that optimum operating conditions are observed. This can be brought about by calculating the capacitive reactance of the capacity in question at the desired frequency and, as at resonance, this is equal to the inductive reactance. Knowing the inductive reactance, the inductance can be computed and from the inductance the physical dimensions of the coil required can be calculated.

As the value of capacity is inversely proportional to the frequency or, conversely, directly proportional to the wavelength, it makes it possible to express the capacity in μμfd. per meter. Thus, to obtain the required capacity, all that is required is to multiply the number of μμfd. per meter by the wavelength in meters. The number of μμfd. per meter in relation to the plate voltage current ratio is also governed by the type of circuit employed in the final amplifier. For instance, in the case of a neutralized single-ended amplifier the capacity and inductance values employed would be entirely unsuitable to give optimum push-pull conditions.

Before proceeding further it will not out of place to show what a wide variation of conditions exists so far as plate tank circuits are concerned. In telegraphy transmitters conditions are generally not so bad because no attempt is made to conform the d.c. plate resistance to any given set of circumstances, but in the case of phone operation, the d.c. plate resistance must be of a definite value so that efficient match is made to the modulator. Usually the operator of a phone transmitter in his endeavor to obtain good modulation, forgets the tank circuit, yet it requires just as careful "matching" as the modulator, if efficient r.f. output is to be obtained. In the case of the telegraphy transmitter the final amplifier is generally designed and operated according to the specifications laid down by the maker of the valve. In other words, the valve is operated under optimum conditions. It is very doubtful, however, if the tank circuit operates in the same way, especially in the case of multi-band transmitters.

• A Practical Case

Let us now look at a circuit using a valve with a d.c. plate resistance of 10,000 ohms in single-ended operation and designed for multi-band operation. The optimum values of inductance and capacity for 28-Mc. operation are 2.5 µhy. and 13 µµfd., respectively. (How these values were arrived at will be described briefly later.) For 1.7-Mc. operation under the same conditions a capacity of 220 µµfd. with an inductance of 40.0 µhy. would be required. It will be seen immediately that it would be impossible to expect a 220-µµfd. condenser to open out to 13 µµfd., ignoring altogether valve and circuit capacities. Usually a 100 µµfd. per section split-stator condenser is specified in a circuit of this type and to tune to the 1.7-Mc. band an inductance of about 177 µhy. would be required and this would require to have a reactance of about 1,880 ohms at 1.7 Mc. For optimum operation and best efficiency the reactance *should* be about 435 ohms. To obtain optimum operation using an inductance with a reactance of 1,880 ohms, the plate d.c. resistance would require to be adjusted to about 44,000 ohms which means a plate current ratio of 44:1. In the case of a T55 valve the plate current would have to be reduced to 34 ma. at 1,500 volts.

Often when a valve which has a d.c. resistance of, say, 10,000 ohms is working under optimum telephony conditions, it has to be adjusted to, say, 5,000 ohms to match up to the modulation transformer. The reactance of the L/C conditions would then require to be about 220 ohms for correct operation.

These examples indicate how

wide of the mark the designer is liable to be in choosing tank circuit values.

It is beyond the scope of this contribution to explain in great detail how the values of μμfd. per meter are arrived at, because to do so would necessitate going into a very lengthy description entailing a mass of algebraical formulas which would have no direct bearing on the article itself. In any case the values themselves vary somewhat according to the opinions held by those who have investigated the subject. The writer would rather not attempt to lay down any hard and fast rule on this particular matter but would prefer to state that the particular calculations used to produce the values of μμfd. per meter referred to herein and employed to produce figure 1 are based on a "Q" value of 12 when the amplifier is under operating conditions and fully loaded.

The term "Q" value, which can be briefly described as a measurement of the "goodness" of a tuned circuit or as an indication of "sharpness of resonance," can be expressed by the formula:

$$Q = \frac{2\pi f\ L}{R}$$

Those readers who wish to work out for themselves the values shown in figure 1 will find that for curve (A) the value of μμfd. per meter for a plate voltage/current ratio of unity is 12.5 μμfd. per meter so all that is required in order to find the value for any other ratio is to divide 12.5 by the new ratio.

Example: When Va/Ia ratio is 5 or d.c plate resistance is 5,000 ohms, the μμfd. per meter value for curve A will be 12.5 ÷ 5 = 2.5 μμfd. In the case of curve B the value at unity is 4 μμfd. per meter.

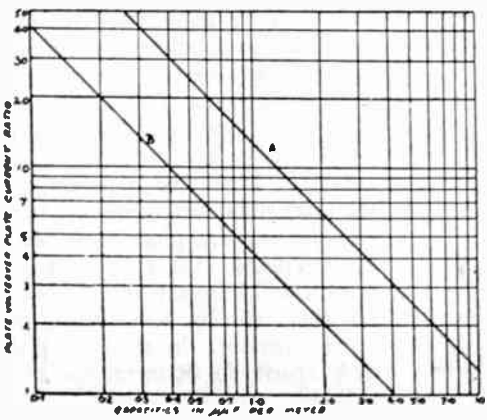


Figure 1. Chart for computing optimum capacity per meter. A, single ended; B, push-pull final amplifier.

Now to proceed, all that has to be decided is whether single-ended or push-pull operation is to be employed. If split stator tuning is used, the values given have to be multiplied by two as well as by the wavelength in meters; this will give the capacity of *each section* of the split stator condenser which will be required to be in mesh when resonance of the desired frequency is obtained.

- Practical Examples

Details will now be given of the procedure used to calculate (a) the plate current/plate voltage ratio; (b) the plate d.c. resistance; (c) the capacitive and inductive reactance; (d) the inductance in μhy.; and (e) the way in which the physical dimensions of the coils can be obtained.

(a) Plate voltage, plate current ratio is obtained by dividing the plate voltage by the plate current when the final amplifier is fully loaded and operated under the correct conditions for the valve in question.

Thus: $$\frac{Va}{Ia}$$

Example:

$$\frac{1{,}000 \text{ volts}}{100 \text{ ma.}} = \text{a ratio of } 10{:}1$$

(b) This formula will also give the d.c. plate resistance: Thus

$$\frac{Va}{Ia/ma.} \times \frac{1{,}000}{1} \text{ or}$$

$$\frac{1{,}000}{100\text{ma.}} \times \frac{1{,}000}{1} = 10{,}000 \text{ ohms.}$$

It is therefore easy to obtain both the plate voltage/current ratio and the d.c. plate resistance of an amplifier under any working conditions. Knowing the plate voltage/current ratio, the optimum capacity per meter can be obtained from the chart (figure 1) for the type of amplifier it is intended to use. After this has been calculated the optimum tank capacity can be worked out for any frequency and for any type of operation (phone or continuous wave). In the phone section optimum values for any circuit can be obtained using either anode modulation, control grid, suppressor grid or class B linear modulation.

(c) When the optimum capacity is known for a given set of conditions the exact value of inductance can be calculated. For example, consider a Taylor T55 valve working under optimum conditions (1,500 volts at 150 ma. on the anode). It will be apparent that the plate volts/current ratio is 10:1, and that the d.c. plate resistance is 10,000 ohms. On examining figure 1 it will be seen that the capacity for this ratio is 1.25 μμfd. per meter; therefore the optimum plate tank capacity for 40-meter operation will be:

$$1.25 \times 40 = 50 \ \mu\mu\text{fd.}$$

If split stator tuning is used, that value is again multiplied by two giving 100 μμfd. and this capacity represents *each section* of that condenser.

Now with the optimum capacity known, it is required to find the value of inductance which will resonate with *exactly* that capacity. To obtain this we must first calculate the capacitive reactance of that capacity at resonant frequency, *because at resonance the capacitive reactance must equal the inductive reactance*. Therefore if Xc equals Xl, then the capacitive reactance of 50 μμfd. is calculated in the following manner for 7.5-Mc. operation:

$$Xc = \frac{10^6}{2\pi\ fc}$$

Where:

10^6	equals	1,000,000
2π	"	6.28
f	"	frequency in megacycles (in this case 7.5 Mc.)
C	"	capacity of condenser in μμfd.

Therefore:

$$Xc = \frac{1{,}000{,}000}{6.28 \times 7.5 \times 50} = 427 \text{ ohms.}$$

and as at resonance the capacitive reactance must equal the inductive reactance (to produce a pure resistance) Xc equals Xl.

By the formula $2\pi\ fL = \dfrac{1}{2\pi\ fC}$

therefore to resonate with 50 μμfd. at 7.5 Mc. the inductive reactance must be 427 ohms.

(d) To find the inductance required (in μhy.), the following formula is used:

$$L = \frac{Xl}{2\pi\ f\text{Mc.}} \quad \text{when } Xl = 2\pi fL$$

Therefore:

$$L = \frac{427}{6.28 \times 7.5} = 9.1 \ \mu\text{hy.}$$

(e) As we wish to construct a coil having exactly that value of inductance, we may calculate its physical dimensions by using the formula

$$N = \sqrt{\frac{3A+9B}{0.\ A^2} \times L}$$

Where:

L is the inductance in μhy.
A " " mean diameter of the coil in inches
B " " length of the winding in inches
N " " number of turns.

The tables given in figure 2 show the number of turns required to make each inductance a standard size of 2.75 inches diameter with a winding length of 4 inches, this

Plate D.C. Resistance in Ohms. Va/Ia Ratio Divide by 1,000.	VALUES FOR SINGLE-ENDED OPERATION: Optimum Capacities in micro-micro farads. Wavelength in metres						Optimum Inductance Values in micro-henrys. Wavelength in metres.						Number of turns to produce optimum inductance when wound to a diameter of 2.75 inches spaced 4". Wavelength in metres.					
	160	80	40	20	10	5	160	80	40	20	10	5	160	80	40	20	10	5
10,000 ohms.	200	100	50	25	12.5	6.25	36	18	9	4.5	2.3	1.2	32	23	16	11.5	8	6
9,000 ,,	224	112	56	28	14	7	32	16	8	4.0	2.0	1.0	31	22	15	11.0	7.5	5.5
8,000 ,,	250	125	62.5	31.25	15.6	7.8	29	14.5	7.3	3.6	1.8	0.9	29	21	14.5	10.5	7.0	5.2
7,000 ,,	286	143	71.5	35.8	17.8	8.9	25.5	12.7	6.4	3.2	1.6	0.8	28	19	14	9.5	7	4.8
6,000 ,,	336	168	84	42	21	10.5	21.5	10.7	5.8	2.9	1.4	0.7	25	18	12.5	9.0	6.3	4.5
5,000 ,,	400	200	100	50	25	12.5	18.0	9.0	4.5	2.3	1.1	0.6	24	16	12.0	8.0	6.0	4.0
4,000 ,,	500	250	125	62.5	31.3	15.6	14.4	7.2	3.6	1.8	0.9	0.5	21	15	10.5	7.5	5.2	3.8
3,000 ,,	666	333	166	83	41.5	20.7	11.0	5.5	2.8	1.4	0.7	0.4	18	13	9.0	6.5	4.5	3.3
2,000 ,,	1000	500	250	125	62.5	31.3	7.2	3.6	1.8	0.9	0.5	0.3	15	10	7.5	5.0	3.8	2.5
VALUES FOR PUSH-PULL OPERATION																		
10,000 ohms.	64	32	16	8	4	2	113	56.5	28.3	14.2	7.1	3.5	58	41	29	20.5	14.5	10.3
9,000 ,,	72	36	18	9	4.5	2.3	100	50	25	12.5	6.3	3.2	54	38	27	19.0	13.5	9.5
8,000 ,,	80	40	20	10	5	2.5	00	45	22.5	11.3	5.6	2.8	51	37	25.5	18.5	12.8	9.3
7,000 ,,	92	46	23	11.5	5.8	2.9	78	39	19.5	9.8	4.9	2.5	48	34	24	17.0	12.0	8.5
6,000 ,,	106	53	26.5	13.3	6.6	3.3	68	34	17	8.5	4.3	2.2	45	32	22.5	16.0	11.3	8.0
5,000 ,,	128	64	32	16	8	4	57	28.5	14.3	7.1	3.6	1.8	41	29	20.5	14.5	10.3	7.3
4,000 ,,	160	80	40	20	10	5	45	22.5	11.3	5.6	2.8	1.4	37	26	18.5	13.0	9.3	6.5
3,000 ,,	216	108	54	27	13.5	6.8	33	16.5	8.6	4.3	2.1	1.1	31	22	15.5	11.0	14.8	5.5
2,000 ,,	320	160	80	40	20	10	22	11.0	5.5	2.8	1.4	0.7	26	18.0	13.0	9.0	6.5	4.5

Figure 2. The resistance values represent the d.c. plate resistance of the final amplifier when fully loaded. All capacity values are in micro-micro farads and all inductance values in micro-henrys. The number of turns given in each case will produce the stated inductance when wound to a diameter of 2.75 in. and the turns spaced out to a length of 4 in. The condenser values are for single-section condensers. If split stator condensers are used the capacities given must be multiplied by two. This will give the size of each section of the split stator condenser. Note.—The values given in this chart hold good only for plate-neutralized circuits.

....

being a convenient size for a wide range of frequencies and input power.

Therefore, when: L is 9.1 µhy.
B " 4 inches.

$$N=\sqrt{\frac{8.25+36}{0.2\times 7.56}}\times 9.1=$$

$\sqrt{267}=16$ turns to the nearest whole number.

When a coil has been constructed to these dimensions, all that is now required is to make sure that the tank condenser will have sufficient capacity to tune to the required frequency. We can then be sure that at resonance the optimum L/C ratio has been accomplished and the amplifier will deliver maximum output with minimum harmonic content.

It will be noticed that, although the optimum capacity is the first point to be considered, it can be forgotten as soon as the inductance values are obtained. It will also be seen that it is a simple matter to construct a coil of definite inductance. When that is achieved, the capacity automatically adjusts itself to the optimum capacity at resonance.

As some readers may not wish to take the trouble of making all the above calculations themselves, the writer has compiled a chart, figure 2, which gives all the required information needed for frequencies from 1.7 to 56 Mc., and with plate d.c. resistances ranging from 2,000 to 10,000 ohms. Both single-ended and push-pull circuits are catered for.

By carefully studying the chart a choice of L/C values can be made for operation near to optimum conditions on a number of bands, although it will be evident that it will be difficult to obtain optimum conditions on more than two bands if the voltage/current ratio remains constant. It will also be noticed that optimum conditions for operation on the frequencies of 28 and 56 Mc. will be difficult to obtain when valve and circuit capacities are taken into account, which of course explains the desirability of using special valves and circuits for these frequencies.

A careful study of the chart will show the reader that it is a good plan to construct separate final amplifiers for each frequency band, for only then can true optimum conditions be maintained. It is also advantageous to construct separate inductances when phone operation is desired, especially when the plate voltage/current ratio has to be altered appreciably from the normal c.w. settings in order to "match" the d.c. plate resistance to the impedance of the modulation transformer. If this practice prevailed the writer believes that many of the present "broad" phone signals would disappear, being replaced by good transmissions which tune sharply and occupy only a minimum of space in the spectrum.

¶ From Service
November, 1938

DIAL LAMPS

AT FIRST GLANCE it might seem that a dial lamp is merely a small light source of low-power requirements, and that no great problem enters into its manufacture. Such a view greatly underestimates the complexity of the factors that enter into the design and use of these small lamps.

When first introduced they were used only to indicate whether the receiver was on or off. As an incidental function they also served to illuminate the markings on the opaque dials used at that time. The lamp was mounted to permit the light to fall directly on the surface of the dial. No severe problems in design or mounting were entailed.

With the advent of highly sensitive receivers, transparent dials, tuning meters, small sized remote control heads, complicated flash-tuning arrangements and the like, new problems in design, shape and placement of these bulbs arise.

• A.C. D.C. Sets

Among the many new problems was the means of providing a source of voltage for the dial lamp in the a.c., d.c. set. Some of the earliest of these receivers used lamps rated at 2.5 volts, 0.5 amperes, in series with the 0.3-ampere heaters. However, the meager illumination provided and the fact that failure of the lamp caused the receiver to be inoperative, led to discarding of this method.

In the circuit employed today, a no. 40, 44, 46 or 47 type (see figure 2) lamp is used. The necessary voltage is developed across a suitable resistor connected in series with the tube filaments and in shunt with the dial lamp. In case of lamp failure the heater circuit is not opened.

Due to the fact that the initial current is considerably greater than the normal operating current, the value of this dial-lamp shunt resistor is very critical. These high starting currents are encountered because the cold resistance of the heaters is considerably lower than the resistance at operating temperatures. In the case of the 25-volt heater,

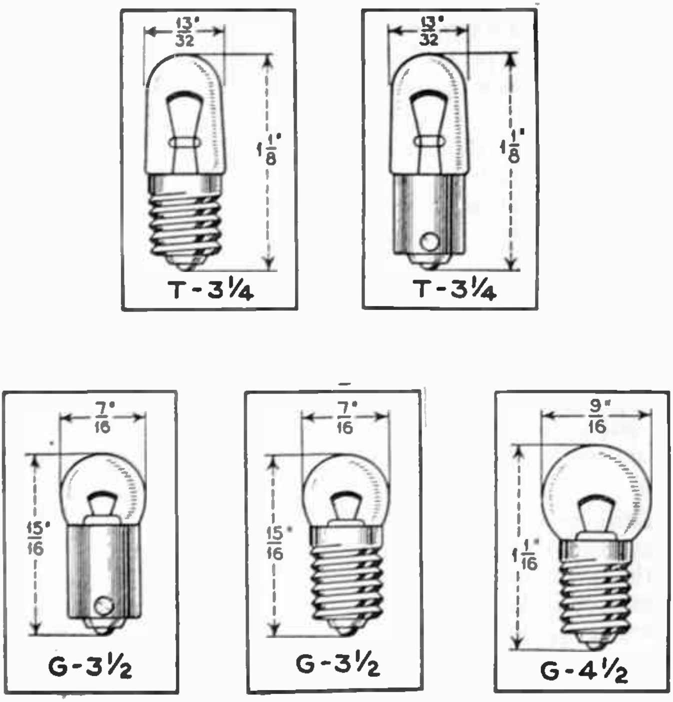


Figure 1. Sketches showing the several bulb shapes and base types of typical dial lamps. These are drawn to actual size.

for instance, the hot to cold heater resistance ratio is approximately 7 to 1. The situation may be further aggravated by the use of voltage dropping resistors whose cold resistance is considerably lower than the resistance at operating temperatures.

The initial surge voltage across a lamp, connected as indicated above, increases at a greater rate than the operating voltage for a given increase in the value of the dial-lamp shunt resistor. In cases where more than two 25-volt tubes are employed in one series circuit, the starting current will be considerably higher for the same total number of tubes.

A shunt resistor of 45 ohms would be required in the circuit described, to obtain rated operating voltage on a type 40 lamp. But this resistor will produce an initial voltage of 14 volts (in a 4-tube set) or an overvoltage of 130 per cent. This overvoltage will cause premature lamp failure.

An attempt to remedy this condition has been made by using special a.c., d.c. ballast tubes in which the original or cold value of the pilot light shunt resistor is low enough to protect the lamp and whose final or hot value is high enough to provide the recommended operating voltage with its accompanying high illumination. Such resistors utilize the heat generated in the main resistor section for their operation.

In making replacements in a.c., d.c. receivers it is important to determine the history of the dial lamp, before making replacement. If its life is persistently short it may also be necessary to replace the dial-lamp shunt resistor. In cases where this is impossible or impractical, an additional resistor may be shunted across the dial light terminals. When replacing ballast resistors in these sets, the new ballast should be matched to the dial light, or the dial light should be changed to suit the new ballast.

- Tuning Meters

It is the practice, in tuning meters of the shadow producing type, to place the lamp directly behind a small aperture of predetermined size so that the light shines directly past the edges of a movable vane to cast a shadow of the vane on a translucent screen. The vane, which is actuated by a small magnetic coil through which the tube current flows, will show a minimum deflection for the condition of resonance in the receiver circuits. The shadow of the vane on the screen will, correspondingly, have a minimum width.

To have maximum contrast it is necessary for the edges of the vane to be sharply delineated on the screen and free from penumbra effects. This requires a special straight line form of filament. This filament must be placed in the bulb so that the images reflected from the bulb walls will not pass through the aperture and act as secondary sources of light.

It is extremely important in making lamp replacements in tuning meters to replace with the same type of lamp.

- Life

Figure 3 is a curve showing the mortality of dial lamps as obtained from tests on vibration-free, accurately controlled life test racks. The no. 40 lamp is designed for 3000 hours and the no. 50 for 1000 hours. These life ratings are based on operation at their respective design voltages. The no. 50 has a 7.5 volt, 0.2 ampere rating as compared with a 6.3 volt, 0.15 rating for the no. 40 (see figure 2). The shorter life expectancy for the no.

MAZDA LAMP No.	CIRCUIT VOLTS	DESIGN VOLTS	AMPERES AT DESIGN VOLTS	BASE, MINIATURE	BULB	BEAD COLOR	DESIGN LIFE HOURS	APPROX. CANDLE-POWER	TYPE OF SERVICE	REMARKS	MAZDA LAMP No.
40	6-8	6.3	0.15	Screw	T-3¼	Brown	3000	0.5	Dials		40
40-A	6-8	6.3	0.15	Bayonet	T-3¼	Brown	3000	0.5	Dials	Same as No. 47	40-A
41	2.5	2.5	0.5	Screw	T-3¼	White	3000	0.5	Dials		41
42	3.2	3.2	0.35	Screw	T-3¼	Green	1000	0.75	Dials		42
43	2.5	2.5	0.5	Bayonet	T-3¼	White	3000	0.5	Dials and Tuning Meters		43
44	6-8	6.3	0.25	Bayonet	T-3¼	Blue	3000	0.8	Dials and Tuning Meters		44
45	3.2	3.2	0.35	Bayonet	T-3¼	White	3000	0.75	Dials		45
46	6-8	6.3	0.25	Screw	T-3¼	Blue	3000	0.8	Dials and Tuning Meters		46
47	6-8	6.3	0.15	Bayonet	T-3¼	Brown	3000	0.5	Dials	Same as No. 40-A	47
48	2.0	2.0	0.06	Screw	T-3¼	Pink	1000	–	Dials	For Battery Sets	48
49	2.0	2.0	0.06	Bayonet	T-3¼	Pink	1000	–	Dials	For Battery Sets	49
---	2.1	2.1	0.12	Screw	T-3¼	White	–	–	Dials	Replace with No. 48	---
49-A	2.1	2.1	0.12	Bayonet	T-3¼	–	–	–	Dials	Replace with No. 49	49-A
50	6-8	7.5	0.2	Screw	G-3½	White	1000	1.0	Auto Set Dials and Flashlights		50
51	6-8	7.5	0.2	Bayonet	G-3½	White	1000	1.0	Auto Set Dials and Panel Boards		51
---	6-8	6.5	0.4	Screw	G-4½	White	500	1.75	Auto Set Dials and Flashlights		---
55	6-8	6.5	0.4	Bayonet	G-4½	White	500	1.75	Auto Set Dials and Parking Lights		55
292	2.9	2.9	0.17	Screw	T-3¼	–	–	–	Dials	Use in 2.5 V sets where line voltage is high	292
292-A	2.9	2.9	0.17	Bayonet	T-3¼	–	–	–	Dials	Use in 2.5 V sets where line voltage is high	292-A

Figure 2. Complete tabulation of the characteristics of all miniature lamps used in radio receivers.

50 is the result of this increased efficiency.

The no. 50 and its companion the no. 51 are not in a true sense radio dial lamps. They were primarily designed for automotive service and while they are satisfactory for use in the remote control heads of auto-radio sets, they are not as strong nor will they withstand audio-frequency vibration nearly as well as the no. 44, for instance.

As mentioned above, life ratings are based upon operation at design voltage. In average service the operating voltage may be so far below the design voltage that the life exceeds the standard expectancy. Suffice to say, that the effects of voltages higher or lower than the design voltage of the lamp are enormous on the life obtained.

There are many other factors, besides the voltage applied to the lamp, that influence its life. The audio frequency vibration set up in the powerful modern sets, for example, is outstanding among factors that have an adverse effect on lamp life.

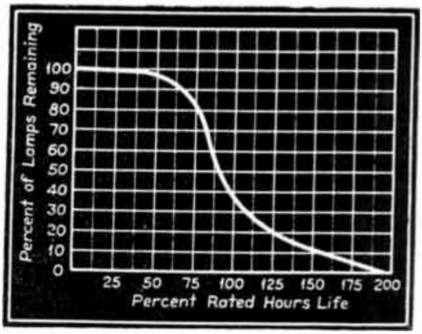


Figure 3. Curve showing the mortality of dial lamps as obtained from tests on vibration-free, accurately controlled life test racks.

• Beads

The filament lead wires of miniature based lamps are mounted through a small colored glass bead, which is located immediately above the bulb press. The color of this bead will enable the serviceman to identify the lamp for replacement purposes, after the manufacturer's markings have been obliterated. It can be seen, from the chart (figure 2) that various colors are used for these beads, and that where any two are identical, other features, such as the type of bulb or base, serve to help identify the lamp.

• Bases

Until two years ago, the only base used for dial lights was the miniature screw base. As receiver design improved, however, it became necessary to consider another form of base in order to remove many of the difficulties inherent in the screw base type. Approximately one-third of the lamp outages in receivers is due to the lamps vibrating loose in the sockets. The loose bulb often sets up growling noises in the sets as well. Various set manufacturers, in an effort to remedy this condition, found in the screw-base lamps, were using such means as crimping the socket and then forcing the lamp into it with pliers so as to lock the lamp in position. This not only made it extremely difficult to replace the lamps, but also resulted in cracking from 20 to 25 per cent of the glass bulbs below the top line of the base where such cracks could not easily be detected. Those lamps then failed early in life due to leakage trouble.

About two years ago, a miniature bayonet base was made available. This base is just like that employed on the common automobile types of lamps, except that it is smaller. The use of this miniature bayonet base has removed many of the troubles formerly encountered with the older screw base types caused by the latter type lamp loosening in the socket. The bayonet base is rapidly gaining in favor and will no doubt eventually supersede the older screw base.

Sketches of the base types are shown in figure 1. These are drawn to actual size.

- **Bulbs**

When dial lamps were first introduced a tubular type bulb was used to distinguish them from flashlight and automotive types. This tubular shape measures approximately 3¼ eighths of an inch and is known as the type T-3-¼. Since that time other forms have been considered, but for the purpose of standardization all panel lamps in home receivers are of the T-3-¼ bulb type.

In auto-radio receivers, however, because of the restricted space available in remote control devices the globular or G type of bulb is now standard.

The sketches of various bulb types are shown in figure 1. These are drawn to actual size.

In the manufacture and use of dial lamps it is important to select lamp bulbs which are free from seeds, chords and mold marks, which imperfections might produce shadows on the dials.

- **Filaments**

There are several outstanding filament forms used in the manufacture of radio dial lamps. The straight horizontal coil mentioned in connection with the lamps used for tuning meters is known as the C-6 form. It is somewhat difficult to obtain a perfect C-6 form in such low-priced lamps, where automatic coiling and mounting machinery must necessarily be used for high production, low cost work. In spite of such difficulty, however, very satisfactory results, which fully meet the requirements, are obtained with the present methods.

The first form of coiled filament used in the early panel lamps was the arched, or C-2, type where the filament is mounted bow-shaped between the two copper lead wires. This filament has the advantage of casting light around the lead wires so as to prevent sharp shadows of the leads being cast on the illuminated dial. In some instances, it is necessary to regulate the degree of

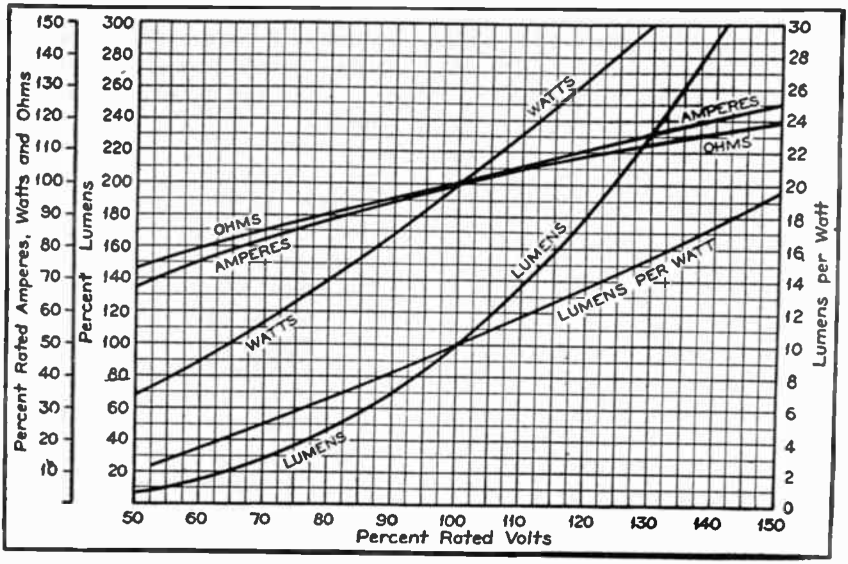


Figure 4. Characteristic curves for Mazda B dial lamps. Variation of lamp characteristics as the operation voltage is altered.

arching to obtain satisfactory results in practice. This filament form is still used in certain types of lamps, but is only suitable for dial illumination, and since the trend is very definitely toward a single filament design, which would be satisfactory for all purposes, it may be superseded by the C-6 form so necessary in shadow meters, and which can also be applied to dial illumination by positioning the lamp so that the filament is parallel to the dial.

In those special forms of lamps used in battery-operated receivers, where the current is of the order of 60 ma. and the voltage is also low, a straight wire filament form, known as S-2, is used because the shortness of the filament almost precludes coiling.

A number of years ago it was found that a small percentage of the radio dial lamps had an imperfect joint between the filament legs and the lead wire, of such slight imperfection that no visible flicker of the light output could be observed. This slight imperfection, however, when the lamps were vibrated in radio sets, was sufficiently great to cause a pulsating current to be picked up by the wires in the set and gave a form of interference. Since that time, in addition to the many regular inspections conducted as a routine matter, special precautions are required so as to prevent the lamp from creating extraneous noises in the receiver.

- Characteristics

The types of dial lamps now available are shown in the chart of figure 2. The current and voltage ratings as well as the rated life, approximate candlepower and other characteristics are given for operation at the design voltage. The curves in figure 4 show how these characteristics vary as the operation voltage is altered. The life of these lamps will necessarily vary as mentioned above, and it can be said that a change of one per cent in applied volts will result in a change of approximately ten per cent in life.

- Recommendations

One of the chief complaints concerning dial lamps is one which has to do with making them accessible in receivers. In a number of models it is necessary to remove the entire chassis from the cabinet in order to replace a burned-out lamp. Since special tools are often required to remove the chassis, from two to three hours may be required for this work. More often than not the set is out of repair pending the visit of a serviceman. It should be only natural to call the set manufacturer to account for such short-sightedness in design.

It is important to remember that while the average life of any given group of lamps is a known factor, the life of any particular lamp is unpredictable. Since greater dependence is being placed upon dial lamps for proper operation of modern receivers, it is only reasonable to expect the manufacturer to make provisions for the easy replacement of such lamps .

Hours spent in replacing a dial lamp cannot prove profitable. For this reason the serviceman should familiarize himself with the type numbers, location and mounting of the dial lamp in as many receiver models as possible. It may be advisable for him to jot these facts down right on the circuit diagrams for the receiver as the sets pass through his hands.

Theme Song

Atisket, atasket, I lost my yellow basket,
And if I hear that song again, I think I'll blow a gasket!

Sylvania News

¶ From Aero Digest
December, 1938

CAA Plans for 1939

BY HENRY W. ROBERTS

AS this year draws to a close, all portents indicate that the entire civil aeronautical industry may confidently look forward to 1939 being a banner year—in new developments as well as in expansion of existing facilities.

Only a few months ago the newly-formed Civil Aeronautics Authority seemed to be greeted by the industry with more misgivings than hopes. Now, for the first time since 1929, there are signs within the industry of a genuine enthusiasm instead of a polite acquiescence. This is a healthy spirit.

This new enthusiasm is also to be found among the personnel of the CAA. The *ésprit de corps,* largely absent until Fred Fagg revitalized the old Bureau of Air Commerce, has been still further enhanced by the new administrators. There have been no "purges." New appointees seem to be allowed to find their own level in the existing organization. The transition of the personnel from the old Bureau to the new Authority seems to have been accomplished with remarkable smoothness.

The auspicious beginnings made by the CAA, within their own organization and in their initial dealings with the industry, augur well for the future.

• Organization

Comparison of the organization chart of the CAA, with the organization chart of the BAC, discloses that the functional division of duties has been retained, despite re-grouping of the former administrative units. The traditional system of checks and balances, so well exemplified in the last BAC organization, has also been retained. The re-grouping clarified interdepartmental relationships and provided for controlled expansion of the Authority within its present framework (if need be); at the same time, the mutual interdependence of the new administrative unit operates as an automatic check, and balances their varied activities.

Heads of Divisions and Sections have been retained from the BAC days, almost without exception. This framework may be regarded as reasonably permanent in character, with but two important modifications now in the offing. The first is the establishment of an independent Private Flying Division (now a section in Private Flying & Planning Division); the second is the possible extension of duties of the Director of Liaison and Information to include public relations in all forms.

A phenomenon of special importance is the Air Safety Board, nominally independent of the Authority, but closely allied in all its functions. Only two of its three members have as yet been appointed, but its staff organization is now practically complete. The Board will, broadly speaking, provide a technical orientation to CAA policies, and act as a catalytic agent in fusing individual developments into a strong national aeronautical industry, governed by the CAA.

- Aircraft Radio

Administratively, aircraft radio activities of the CAA remain essentially as under the BAC. All heads of Divisions and Sections, and their working personnel, have been retained in their entirety. It is extremely probable that CAA's aircraft radio activities will be materially expanded, notably in radio aids to private pilots.

The record-breaking 1938 construction and modernization program, which accounted for 87.3% ($4,400,780) of that year's construction appropriation, is nearing completion approximately on schedule. By the end of January there will be in operation 81 new full-power simultaneous range and communications beacons with vertical radiators; 50 old-style full-power beacons will have been modernized; 30 medium and low-power simultaneous voice and communications beacons added; and 100 ultra-high frequency cone-of-silence and 21 ultra-high frequency fan markers installed. In addition, some 7000 miles of teletype circuits and a large quantity of miscellaneous apparatus and equipment have been placed in operation.

As pointed out last year, this program served only to take up several years' slack in equipping our airways with some of the much-needed aids. Real construction program, real modernization of our airways, is still in the future.

That future has been brought appreciably nearer by CAA's request for a $35,000,000 budget for the next fiscal year.

Almost one-half of the $35,000,000 budget — $15,000,000 — is earmarked for a three-year airway construction program, mostly radio aids, including the $2,000,000 (voted by the last Congress), to be expended after July 1, 1939.

Until the CAA budgetary request is acted upon by the Director of Budget, and until Congress reconvenes and acts upon the recommended appropriation, the exact amount which will be made available to the CAA is a matter of speculation. It may, however, be expected that the appropriation will be substantially as requested.

And it should be. In recent months, aviation has emerged as a crucial factor in national life. Qualitatively, we lead the world in aeronautics; quantitatively, we have been left behind. For peace or an emergency, we will need more ships, more pilots, more mechanics—and a system of airways which will guide those ships to their destinations—safely and promptly.

Civil Aeronautics Authority has been given sufficiently broad powers to bring about a resurgence in the industry. It is not an exaggeration to say that today the CAA is the most powerful and the most important Governmental bureau, almost co-equal with the Government Executive Departments, possibly a nucleus of the inevitable Department of Aeronautics. The interests of the industry are now becoming the interests of the nation.

• Coming Radio Aids

In the aircraft radio field, 1939 will be the ultra-high frequency year. A large part of the new program will be devoted to further development and wider adoption of the many services made possible by the characteristics of radio waves shorter than 10 meters (frequencies of 30,000 kc. and higher.)

Foremost in this field is the development of ultra-high frequency radio beacons, now nearing completion in the Radio Development Section. Three types of beacons are being investigated: the familiar four-course type, such as is now in use on our airways; the two-course type, which provides fewer courses but a greater ease of orientation; and the omni-directional rotary type, which automatically gives the pilot his relative bearing. When adopted, these will probably operate on 63 Mc., where extremely satisfactory results have been obtained.

It appears likely that all three types will be placed in service, since the receiving apparatus on board aircraft may remain the same for use with all three types. Eventually, our entire network of airways will be changed over to the ultra-high frequencies. In the meanwhile, installation of the new u.h.f. beacons will be made in the sections not now served by the existing airways system.

Within the continental United States, installation of u.h.f. radio ranges will probably be deferred until the growth of feeder airlines make additional navigational facilities imperative. Complete change-over of the existing airways system to the u.h.f. system is still too far in the future.

Of more immediate import will be the abolition of the 278 kc. frequency for airport traffic control and its substitution by the 125 Mc. frequency. No further licenses for 278 kc. stations will be granted after January 1, 1939, and, with good luck, the changeover may be put into effect and completed next year.

The ultra-high frequency marker beacons, of which 121 will be in operation by January 31, 1939, have already proved their value in commercial navigation last year. Their number will be further augmented, until every range beacon has its cone-of-silence marker, and every approach to every major airport is equipped with the fan markers.

An important contribution to safety in the air next year will be the adoption of a nation-wide system of instrument landing.

As a further aid to navigation, the CAA will soon place an order for 3 Western Electric Adcok-type radio direction finders, to be located at Newark, Pittsburgh and Washington. Additional orders would be placed if the tests show that these will be satisfactory for regular use.

Work is also nearing completion on development of an u.h.f. radio teletype circuit between ground stations and aircraft in flight. Experiments are under way on radio facsimile transmission for the same purpose.

In addition to these major items, there are several projects dealing with lesser aspects of radio navigation of aircraft.

Meanwhile, research and development work with micro-waves (less than 1 meter long, frequencies of 300 Mc. and higher) has been making progress in several laboratories. The first development to be made available to the industry will be an absolute altimeter, of the type described in *Aero Digest* for November. Several refinements are now being made in the instrument, which should be available commercially in its final form late in 1939.

Development of collision prevention devices is somewhat further away, but preliminary work apparently has already reached a point where their final commercial production may be considered a foregone conclusion.

- **Looking Forward**

We have not yet reached a point where need for collision devices for aircraft has become vitally pressing. Our airways still are comparatively uncrowded. But the fact that they are being developed is an indication of the trend.

We can look, conservatively speaking, to *doubling* our aeronautics in the next 18 months—military, commercial, private, and airway aids to serve them all.

¶ From Electronics
December, 1938

Relay Contacts . . . *their ailments*

BY A. W. CLEMENT

Relays go hand in hand with the vacuum tube in the application of electronics to industrial or other control problems. Relay contacts are, at times, tempermental, they must be treated with respect lest they rebel.

THE increasing attention being given to relays in electronics prompts the writer to offer points concerning telephone and moving coil relays, the results of experiences over thirty years.

Contacts are the most vital part of relays. Their performance depends upon the material used, the shape, pressure, voltage, current, atmospheric and circuit conditions, maintenance methods.

Of primary interest is the pressure of a contact—or rather, two pressures, mechanical and electrical. A deficiency in one can be compensated by an increase in the other. The pressure serves mainly to penetrate film upon the contact surface and is also used to prevent microphonic action (chattering) and to adjust the relay.

Metals will form films due to chemical combination with gas (oxygen in the air being most common), but with the usual "contact metals" such films are easily penetrated by low voltages under two. Platinum is outstandingly superior for minimum film formation, and is followed by gold and silver. Poor metals such as brass, tungsten, phosphor-bronze and as an extreme, lead, require higher voltages or mechanical pressure for penetration.

Films of the greatest seriousness are formed by deposits of grease from the atmosphere and by handling the contacts with files or in other manners. It may be said that over 90 per cent of contact troubles are due to grease. The metal used becomes a minor matter in view of the comparatively high pressure (electrical or mechanical) required to penetrate the grease.

Carbon is the next in order of contact surface troubles. It is the residue of burnt air and grease and forms in small rings about the actual point of contact, building up until the rings hold the contacts open. It is very instructive to examine contacts under a microscope of twenty or so diameters. A good contact pressure will aid in crushing the rings, keeping the contact usable.

Another surface condition is that of "cone and cratering," where the metal of one contact is transferred over to the other, leaving a hole or crater in one and a point or cone upon the other. The crater eventually clogs with carbon and is difficult to clean out. In some cases, with springs of light tension (10 grams or so) the cones can stick in the craters preventing natural opening. Occasional reversal of current will prevent this surface trouble. In some telephone plants using vibrator ringing generators clocks have been installed to reverse the driving current every half-hour: daily or more frequent contact cleaning became a matter of once a week or more.

Again, there is damage caused by the contact of two different metals due to the "contact potentials" of the particular metals used. This also forms a cone and crater effect. Different metals should never be used. A number of years ago a large number of strips of break-jacks were replaced throughout the country by a manufacturer whose assembly department had slipped up and used platinum and silver in the opposed springs.

For telephone relays the contact mechanical pressures may be rated as medium when between 20 and 40 grams. When under 15 grams they tend to be "microphonic," easily disturbed by jars from adjacent relays, etc. At low pressures they might also "sizzle" when currents of a few hundred milliamperes are passed.

Moving coil relays have almost zero mechanical pressure but they operate with reasonably high voltages and are almost always associated with the telephone relays so the microphonic and sizzling effects are less disturbing.

Voltage pressures used with medium mechanical pressures and average "contact metals" ought to be over 20 volts for ordinary operations but for rapid and frequent use 40 or more volts is highly desirable. Manual telephone plants use 22 volts (called 24) where simple relay operations are involved, but automatic plants have used 48 volts for years.

Average good contact metals require only a couple of volts to penetrate their natural films or tarnish but grease will soon appear and demand the higher voltages mentioned, so actually the kind of metal used is a minor matter if it is not subject to heavy tarnish. Phosphor-bronze, for example, is a poor metal that needs about 28 volts to penetrate its tarnish (with almost zero mechanical pressure), though with over 32 volts or so it serves very well, with medium mechanical pressures. Tungsten is another poor metal, worked best with around 50 volts for medium pressures, though at high pressures, 100 grams or more, it can operate with only 3 volts or so.

• What of Contact Shapes?

And now for contact shapes. They should be ball-faced and as small as practical alignment and reserve material for wear permits. Large contacts will not carry more current than small ones.

Two plane surfaces free to align with each other can only touch at three points unless there is sufficient pressure to distort the surfaces. If the surfaces are not free for alignment then they can touch at only one point—one molecule. Practical pressures encountered actually crush the molecules out of position slightly so several will be in contact, but this is still only a microscopic portion of the entire contact face. Therefore a ball contact can function as well as a flat one so far as the amount of metal in contact is concerned, the maximum current capacity being about one amp. at medium pressures: more current can be carried, at greatly less reliability, up to about two amps. Moving coil relays can carry about .25 amp. as a maximum and .10 amp. is safer.

The chance for dust to lodge between contacts is far greater for flat than for ball faces: also, a greater area of film is presented requiring more mechanical pressure for puncture.

Some contact pairs consist of a point and a flat: this type only halfway approaches the ideal with a disadvantage that craters develop in the flats.

Smooth, polished contacts are poor, there being less points to pierce the grease film and actually effect contact. A rough contact is essentially a multiple contact by virtue of the greater number of points crushed together. As a test, two sheets were chromium plated: one was highly polished, the other left with its natural granular surface. With about 5 grams pressure a blunt pointed copper contact upon the sheets showed the polished plate as having eight times the contact resistance of the granular plate.

• Vertical or Horizontal Contacts?

The writer believes this to be immaterial. Theoretically, normally closed vertical contacts can form a rest for floating dust which might settle between the contacts when they open preventing their closing when released. With horizontal contacts the upper spring would catch the dust, sprinkling it over the sides by vibration as the relay operates. However, Brownian movements shoot dust in all directions and potential differences make attractive traps regardless of position. It is a different case with stepping switch bank contacts where the horizontal types are markedly worse.

Freely floating dust is of no consequence in relays. Blowers or vacuum cleaners are positively ruinous, forcing large chunks of dirt into contacts that they could never reach by natural air currents. In the dust plagued industrial belt of India, from damp Bengal to hot and dry Punjab, the writer installed a number of all-relay automatic exchanges, each being *entirely* without dust protection from the moment of unpacking to several weeks after starting service. They were positively filthy yet gave no trouble from dust. On the other hand, one plant in the Jherria Coal Fields (surface mining largely) had abnormal grease trouble. A day would be bright and quiet when suddenly, in five minutes time, the whole plant would go bad from a gas wave. Filtering the air to this plant was of small benefit and it was left up to the maintenance men to do fast washing.

An interesting test was made concerning grease. A bay of 100 relays having three sets of break contacts and a like number of relays with three makes was unpacked, after about two years storage in Bombay. All contacts were ball-shaped gold alloy with tensions of about 30 grams and worked with 40 volts. One would suppose the normally closed contacts to perform better than the open ones but they were worse. Grease had forced apart the normally closed contacts so the applied voltage could not penetrate. Of course there was grease upon the open contacts, but the mechanical force of operation aided the penetration. Further, while the closed contacts that failed would break through if flipped electrically, and repeat properly, yet after being idle for a day would be bad again—the grease had time to creep back.

• Inductive Circuit Hints

Associated circuits have important effects upon contacts. It is highly desirable that contacts spark a little when opening as this burns the grease away quite well, the resulting carbon not being as troublesome. Thus inductive circuits are markedly better than non-inductive, up to the point where excessive sparking causes too much carbon. Useful sparks are such as can be fairly easily seen but not near a "spitting" condition.

Non-inductive circuits (slow relays and particularly lamps) are bad for contacts. Any contact will vibrate or chatter every time it closes, regardless of tension, and each vibration is a current interruption. In an inductive circuit the average transient current is low during the period of vibration whereas in a non-inductive circuit the current is practically full value for the entire period. There are several effects; the carbon-forming sparks are less but their grease burning is also less, so failures increase.

When any contacts carry current they are welded together—very minutely as a rule: in fact, no weld, no current. The non-inductive current welds at each vibration of the contacts, rapidly destroying the contacts. In one case observed, certain relays, operating almost continuously through the day, had two sets of make contacts—one driving a switch magnet, the other a lamp taking about one-fourth the current. The magnet contacts lasted over two years but the lamp contacts had to be replaced once about every three months.

Condensers when shunted directly across contacts are terrible, ruining the contacts quickly by excess welding. In some cases the weld prevents the contacts from opening. Assume that a condenser of any size is charged to 50 volts: a dead short upon it will produce an initial current limited by the resistance of the short. Assuming the short resistance is .02 ohm then there would be 2500 amps. at the first instant of closing. Just imagine the welding effect. A resistance should always be in series with the condenser and have a value of about one ohm per volt of power supply, limiting the maximum current to one ampere. For moving coil relays about 20 times this resistance is better.

A particular use of this welding was made in the case of about 75 valves used with pneumatic ticket carriers. Tickets and "cleaners" (dipped in powder) shot between the two German silver contact springs, opening a circuit supposed to close when the ticket was removed. A small narrow slot in one spring, aligned with a semi-penetrative embosure upon the other spring helped, but adding a 2.0-μfd. condenser without resistance positively cured all contact troubles. The system operated with 22 volts. Of course, the weld was too small to interfere with ticket entries but it held the contacts electrically.

In many cases spark-killing can be better and more cheaply accomplished by shunting the inductive load (not the contact) with a non-inductive resistance. The value is better found by cut-and-try, depending upon permissible sluggish release of the coil involved. For average apparatus a good starting value to try is around 10 times the resistance of the coil.

Condensers in series with contacts cause much failure but do not damage the contact. In such circuits there is always some appreciable resistance so welding effects are not troublesome. It is really a lack of weld that gives trouble, for by the time a contact has ceased vibrating the condenser voltage will have risen to that of the power supply so the last "make" of the contact finds no current flow to weld it. Shunting the condenser with a few thousand ohms (the less the better) or otherwise maintaining a potential difference across the contacts cures the fault.

Another trouble is the contact that closes when there is no voltage across the pair (no current flow). This is particularly aggravated if the contact remains closed for any number of hours (sometimes minutes) before a potential is applied, allowing time for the grease, displaced by mechanical pressure when the contact closed, to creep back and separate the pair. Such "non-potential" contacts were found by a test in a new plant to give about ten times the trouble found in live contacts. This test was at 40 volts with gold alloy contacts.

Moving coil relays are annoying due to the light mechanical pressures and to the long period of vibration fouling the contacts. Sticking or welding is another nuisance. Further, when operated or released the hair-springs may vibrate excessively since they carry a circular current of several turns in a magnetic field—near a neutral point, but never really neutral. This vibration is carried to the contacts.

Moving coil contacts should always be of platinum-iridium, the iridium supplying a useful degree of stiffness. They should be mounted as close to the axis of coil rotation as possible so that the greatest pressure may be obtained.

• How to Clean Contacts

As for cleaning contacts, the writer is still puzzled. A number of definite comments that can be made. Never use a piece of paper: there is always some fuzz that usually stays upon the contact. Filing a contact often fixes it but frequently the trouble will soon return: the grease that was pushed away returns and the contact shape and mass has been changed. Theoretically, washed files should be used, but who goes to that trouble? Files sometimes put more grease upon the contact.

Having tried it upon thousands of relays, the best but not perfect method is a double operation—washing and wiping. Chamois cemented over the end of a thin strip of bakelite, dipped into carbon tetrachloride, washes the contact (one quick jab is enough) and another dry chamois "stick" wipes off the residue. Most carbon tetrachloride is old enough so it leaves a residue. Thus wiping is quite necessary. Carbon deposits may need a touch with a file followed by washing and wiping.

The argument that filing is bad because it leaves a roughened surface is based upon a wrong premise: rough contacts perform better than smooth ones, unless the roughness is so coarse that slivers or points protrude altering the desired air-gap and subjecting it to change by crushing.

Rubber should never be near contacts, especially if of silver. This applies to the insulating pips that operate the contact springs, rubber insulated wire connecting to the relays, etc. The idea that rubber must be used for wires carrying one or two hundred volts (in fixed wire groups) is not practical. Very slight heating of rubber increases the gas emission greatly, so wiring near power transformers, resistors and warm tubes may easily affect relay contacts a couple of feet away, in open air. Open flames in the same room with relays are bad, particularly some kinds of illuminating gas and oil stoves.

Vitally important relay contacts may be double—in fact, should be. One spring, but better both, is bifurcated, with a contact point in each tine. With only one split spring there is more difficulty in equalizing the contact pressures. Experience shows that most contacts will continue acting after a failure if given a chance: by having double contacts there is very little probability for both to fail at the same instant. Of course, bifurcation reduces the pressure for each contact but this is more than balanced by the gain in general performance.

An interesting application of contacts was made when telephone relays were used to operate 48-volt motors pulling a 4-amp. starting current. The relays worked hundreds of times a day and often with a flipping action, opening the full starting current before the motors started. Solenoids with laminated copper contactors had been furnished with the plant but would burn up in a few days. The telephone relays had been operating about two years when last heard of. One relay per motor was equipped with three sets of make contacts, silver alloy. The widely moving armature gave about .080 in. spring movement. The make springs were staggered in sequence of opening, the first to open being directly connected to the motor, the next spring joined to it through about two ohms and the last spring through an additional four ohms. The resulting current decay characteristic made practically sparkless breaking of the full current which was flowing in a highly inductive circuit.

IF YOU want to hear better—have your head x-rayed! X-ray operators have noted that persons whose heads were x-rayed often showed a temporary improvement in hearing. Recent research has explained this effect as being due to a decrease in the density and viscosity of the fluids in the inner ear brought about by action of the x-ray on the pituitary gland.—Ohmite News

BOOK REVIEWS

BOOKS submitted to the Review Editor will be carefully considered for review in these columns, but without obligation. Those considered suitable to its field will also be reviewed in RADIO.

FUNDAMENTAL ELECTRONICS AND VACUUM TUBES, by Arthur L. Albert, M.S. First edition, November, 1938; published by the Macmillan Company, New York, N.Y. 422 pages, 6" by 9", price $4.50 in U.S.A.

A very up-to-date and well written book for use in college and universiry courses covering the fundamentals of electronics and vacuum tubes. It is written for the students and instructors in such courses; all other uses have been subjugated to this end. It should, however, be of much assistance to practicing engineers and to electrical workers who desire to review, or to study, the basic principles of the subject.

The division of the material is briefly as follows: The fundamentals of electronics and related phenomena; the electronic principles of electronic (including gas) tubes; the use of vacuum tubes as circuit elements; and photo-electric devices, cathode-ray tubes, and measurements. Throughout the book, when discussions are given of electronic phenomena, these discussions are made from the new standpoint of quantum mechanics as well as from the classic theory of electron action. Through the use of the new standpoint the explanations of the operations of electronic emission, photo-electric emission, electronic conduction, gaseous conduction, and allied phenomena are more rigorous and more easily understood.

Throughout the book the latest obtainable standards of the A.I.E.E. and the I.R.E. have been followed closely. Electrical terms, accepted by the profession as a whole, instead of the unfamiliar terms of the specialist, have been used. Also, throughout each chapter numerous references have been made to external sources where more extensive or more detailed discussions of the subject at hand may be found.

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THE RADIO MANUAL, by George E. Sterling. Third edition, published by D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N.Y. 1120 pages, 5" by 7".

This, the third edition of the Radio Manual, has been prepared to serve as a guide and textbook for those entering the radio profession as engineers, inspectors, or operators as well as those already engaged in such activity. The book has been written primarily from the practical viewpoint to serve better the needs of those who are engaged in the installation and operation of radio equipment for the various services. The entire scope of the field is covered from the introductory chapter on electricity and magnetism through the chapters on batteries, motors and generators, and the fundamentals of the electron tube, to the chapters on more advanced subjects such as oscillators, amplifiers and modulation systems.

In addition to the sections mentioned above and the chapters on operating technique of the various services, the book covers the most recent advances in every branch of radio. Among the material on very recent subjects will be found the new Cairo Revisions of the General Radio Regulations (effective Jan. 1, 1939); a complete course in air navigation using the latest aids; the two auto-alarms approved by the FCC; the latest transmitting and receiving equipment for marine and aviation use; all the newest developments in broadcasting—transmitters, modulation systems, modulation and frequency monitors, methods for determining distortion and frequency characteristics, volume indicators and recording systems. In addition, all the U.S. Government Regulations are given, and a specimen examination for operators seeking employment in commercial ground and aeronautical stations is shown.

Each of the major fields of commercial radio communication—broadcasting, aviation radio, marine radio, police radio, and point to point—is exhaustively covered. The work would be an invaluable addition to the libraries of amateurs and other persons who are engaged in, or are desirous of becoming engaged in the above fields of commercial radio.

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THE RADIO HANDBOOK, Fifth (1939) Edition, by the Editors of RADIO. 592 pages, profusely illustrated, comprehensively indexed. Published by Radio, Ltd., 7460 Beverly Blvd., Los Angeles, Calif. Price postpaid, $1.50 in continental U.S.A. Elsewhere, $1.65.

The fifth edition of the Radio Handbook is not just the previous edition brought up to date; it is an enlarged and thoroughly revised reference manual on equipment, construction, theory, and operation of high-frequency and ultra-high-frequency radio. The new edition is characterized by the same completeness, originality, and accuracy that has resulted in previous editions of this work being recognized as the foremost and most authoritative text and reference work on the subjects which it embraces.

Radio amateurs in particular will find the wealth of information in its 592 pages to be invaluable in their work. The chapters on construction are alone worth the price of the book; the apparatus described contains the very latest in improvements and new ideas, and most of it appears for the first time in this book. All of the equipment and circuits described have first been tried in the laboratory by qualified technicians to prove their worth under actual operating conditions.

The enlarged chapter on test instruments and measuring equipment will be found especially timely in view of the new F.C.C. regulations which have just gone into effect.

As in past editions, the theoretical treatment and more useful formulas are supplemented by time-saving tables and charts which make laborious calculations unnecessary.

The data on and the practical application of the many new tubes brought out in the past year and the inclusion of several new antenna systems which give startling results would in themselves justify the purchase of the new edition even though one might have a copy of the previous edition on hand.

While the book contains data of interest to the most advanced engineer, the novice studying for his amateur license will find the book of great assistance in obtaining his "ticket." The book starts right at the beginning, with a discussion of elementary electricity, but advances rapidly by virtue of the fact that no superfluous subjects or data extraneous to the subject at hand are given space.

A list of the chapter headings in themselves give the best story as to what subjects are treated. They are, in order: Fundamental Theory, Vacuum Tubes, Decibels and Logarithms, Antennas, In the Workshop, Learning the Code, Receiver Theory, Receiver Construction, Receiver Tube Characteristics, Transmitting Tubes, Transmitter Theory, Exciter Construction, C.W. Transmitter Construction, Radiotelephony Theory, Radiophone Transmitter Construction, U.H.F. Communication, Power Supplies, Test Equipment, Radio Therapy, Radio Laws, Appendix, Buyer's Guide, Index.

THE TECHNICAL FIELD

in Quick Review

RADIO TECHNICAL DIGEST briefly summarizes for its readers the contents of leading radio articles in current technical publications, some of which may appear later in Radio Technical Digest.

COMMUNICATIONS

Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.
25c a copy—$2.00 yearly
NOVEMBER, 1938

EXPONENTIAL TRANSMISSION LINE. PART II, *by Charles R. Burrows.*—The result of numerous tests made on the exponential line described in a previous article. The effects of shunt capacity caused by tying the line to insulators at its termination and the inherent capacity due to "end effect" are balanced out hy the use of a small amount of inductance in series with the load.

A DUAL-PURPOSE ELECTRONIC SWITCH, *by Norman C. Hall.*—A new electronic switch incorporating features not found in previous instruments. The switching rate may be varied from approximately 6 to 2000 times per second. The switch allows the simultaneous viewing of two traces on a single oscilloscope, thus allowing them to he compared for amplitude, wave shape, and phase relationship.

electronics

50c a copy—$5.00 yearly
McGraw-Hill Pub. Co., Inc.
330 W. 42 St., N.Y.C.
DECEMBER, 1938

REMOTE TUNING OF COMMUNICATIONS RECEIVERS, *by Hans Otto Storm.*—A description of a system for tuning receivers which are located several miles from the receiving operators. The receivers are motor-tuned over the telephone lines which carry their audio output.

A LABORATORY TELEVISION RECEIVER-IV, *by Donald G. Fink.*—The concluding article of the series on *Electronics'* television receiver. A complete diagram of the 25-tube receiver is given. The adjustments necessary for receiving selective sideband transmissions are described.

ELECTRONIC CONTROL CIRCUITS FOR D.C. MOTORS, *by J. D. Ryder.*—A description of a circuit for obtaining reversal and speed control of ¼- or ½-h.p. motors. Thyratron tubes are used, and no relays are necessary. By using a variable inductance to vary the phase of an a.c. voltage applied to the thyratron grid, the portion of the cycle over which the tube passes current, and consequently the motor speed, may be varied.

THERMIONIC EMISSION IN TRANSMITTING TUBES, *by Charles P. Marsden, Jr.*—An analysis of advantages and disadvantages of the various materials commonly used for transmitting tube elements. Tungsten, thoriated tungsten, and oxide-coated filaments are discussed. A chart is given showing the properties of graphite, molybdenum, and tantalum as plate materials.

SPHERICAL TANK U.H.F. OSCILLATOR, *by H. E. Hollman.*—Practical applications of the Kolster axially symmetrical tank circuit. Two flanged metallic shells mounted on a common axial tube provide an exceptionally high Q circuit at ultra-high frequencies.

CHARACTERISTICS OF PHOSPHORS FOR CATHODE RAY TUBES.—The characteristics of screen materials commonly used in cathode ray tubes presented in convenient form. Spectral curves are given for the most commonly used screen materials.

NOVEMBER, 1938

RADIO PROGRAM PRESELECTOR, *by D. R. DeTar.*—A description of the automatic timer and tuner which promises to become increasingly popular for use on broadcast receivers.

TELEVISION SYNCHRONIZATION, *by E. W. Engstrom and R. S. Holmes.*—One of a series of articles describing the various factors entering into the transmission and reception of television signals. The purposes of the blanking and synchronizing pulses are explained and circuit diagrams are given which show how these pulses are separated from the video signal.

AN AUTOMATIC REMOTE AMPLIFIER, *by G. Harold Brewer.*—This amplifier should be of interest to engineers at broadcast stations when operating with a limited staff. The amplifier is left permanently connected at the remote point and turned on and off by relays in series with the telephone line.

SELECTING LOUD SPEAKERS FOR SPECIAL OPERATING CONDITIONS, *by L. B. Hallman.*—A discussion of the various speakers suitable for conveying intelligence through a high noise level without regard to fidelity. Several curves show the response of various types of loud speakers.

A LABORATORY TELEVISION RECEIVER-V, *by Donald G. Fink.*—Constructional data on the i.f., second detector and video amplifier sections of the *Electronics'* television receiver. The construction of the wide-band i.f. coupling units is described in detail. Curves are given showing the frequency characteristics of the i.f. and video amplifier sections.

ADVANCED DISC RECORDING, *by C. J. Le Bel.*—The concluding installment of a series intended to help the engineer obtain the most benefit from his equipment. Extension of frequency range, minimizing of distortion and control of surface noise are discussed.

QST devoted entirely to AMATEUR RADIO

25c a copy—$2.50 yearly
American Radio Relay League
West Hartford, Conn.

DECEMBER, 1939

A SIMPLE TRANSMITTER FOR PORTABLE OR EMERGENCY WORK, *by Byron Goodman*.—A small transmitter designed specifically for battery-powered operation. Since power consumption is a ruling element in this type of equipment, only two tubes are used. A 6C5 Pierce oscillator is followed by a 6L6 amplifier.

A PRACTICAL TELEVISION RECEIVER FOR THE AMATEUR, *by C. C. Shumard*.—With television once more "just around the corner," television receivers are of interest to amateurs living near stations offering such programs. A complete diagram and part of the constructional details of a 14-tube receiver are given.

HOW MUCH CONDENSER SPACING? *by T. M. Ferrill, Jr.*—An analysis of the various plate condenser and circuit arrangements in common use. A chart is given which shows the peak r.f. voltage across single-section and split-stator condensers at various frequencies and power levels.

NOVEMBER, 1938

A NEW AUTOMATIC NOISE LIMITER, *by James E. Dickert*.—A complete description of the Dickert silencer, which is of the peak-limiting type. The operation of the circuit is made automatic by the use of a triode peak rectifier which has its grid connected to the a.v.c. line.

LET'S SETTLE THOSE ANTENNA QUESTIONS, *by T. M. Ferrill, Jr.*—A simplified discussion of antennas and antenna feed systems. Nine different antenna and feed combinations are analyzed. Six curves give antenna and feeder dimensions for frequencies from 1750 to 60,000 kc.

VARIABLE FREQUENCY CONTROL FOR TRANSMITTERS, *by Dana A. Griffin*.—Another one of the increasingly popular electron coupled oscillators. This one uses either a 6F6 or 6L6 and is designed to be used on the operating table. The tuned circuit at the transmitter end of the output link is mounted in a socket, allowing it to be plugged into the transmitter in place of the crystal.

COMBINED BEAT OSCILLATOR AND I.F. AMPLIFIER, *by F. W. Schor*.—A simple method of adding a beat oscillator to a set which does not already have one. The usual 6K7 is replaced by a 6L7 and the injector grid is returned to the lower end of the plate impedance through a tapped coil. The third harmonic of the oscillator section is used for beat purposes.

A TRANSMITTER OF GENERAL UTILITY. *by Don H. Mix*.—Even though the trend today seems to be toward bandswitching transmitters there are many who will sacrifice convenience for the sake of simplicity. The transmitter described employs plug-in coils and allows a wide selection of tubes to be used. Outputs of 30 to 70 watts may be obtained, depending upon the output tube used.

A 1.75- TO 56-MC. CRYSTAL-CONTROLLED LOW-POWER TRANSMITTER, *by Herbert W. Gordon*.—A complete phone and c.w. transmitter and power supply in one small cabinet. A large range of output frequencies is made available by the use of a fundamental-reinforced harmonic generating arrangement using two 6F6's. The output stage is a 6L6G and the modulator a 6N7.

RADIO

30c a copy—$2.50 yearly
RADIO, Ltd.
7460 Beverly, Los Angeles

DECEMBER, 1938

THE "4-25" EXCITER, *by W. W. Smith.*—An exciter which, as the name implies, supplies 25 watts of output on four bands. Using but three inexpensive tubes, the exciter covers the four bands by means of a simple switching system and with but a single crystal. The 807 output stage may be plate modulated for phone work if desired.

VP3THE, THE TERRY-HOLDEN EXPEDITION, *by O. W. Hungerford.*—A description of the work, experiences, and radio equipment of the Terry-Holden expedition into British Guiana. Many amateurs will recall having heard or worked VP3THE when the expedition was at its base at Isherton, British Guiana.

A BANDSWITCHING KILOWATT, *by Thomas S. Chow.*—Bandswitching as applied to a push-pull one kilowatt transmitter. Instead of the usual tapped-coil scheme, separate coils are used to provide three bands at the turn of a knob. One pair of the coils is mounted on plugs, thus allowing coils for seldom used bands to be substituted.

A LOW-COST MEDIUM POWER TRANSMITTER, *by Robert E. Bullock and John T. Chambers.*—A minimum of parts is used in this transmitter which is conservatively rated at 175 watts. A 6F6 crystal oscillator is followed by a 6L6G frequency multiplier and a 35T output stage. The transmitter is also well suited for use as an exciter for a 1-kw. final stage.

GETTING READY FOR THE NEW REGULATIONS, *by Rufus P. Turner.*—A review of the technical requirements of the new amateur regulations, effective December 1, 1938. Numerous suggestions are given as to the design and construction of such equipment as may be necessary under the new regulations.

HOW TO CONSTRUCT A SIMPLE TUBULAR ANTENNA, *by Leonard L. Nalley.*—A method of joining thin-walled electrical conduit with ferrules made from the conduit itself. The resulting rigid tubular assembly may be used as either a vertical antenna or as elements of a rotatable directive array.

RADIO AIDS TO AIR NAVIGATION, *by James Ells.*—Flying is becoming increasingly more dependent upon radio communication. This article deals with the radio equipment and operator's duties at Bureau of Air Commerce ground stations.

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RADIO NEWS AND SHORT WAVE RADIO

25c a copy—$2.50 yearly
Ziff-Davis Pub. Co.
608 S. Dearborn St., Chicago

DECEMBER, 1939

$25 WILL EQUIP YOUR SUPERHET FOR DUAL DIVERSITY RECEPTION, *by McMurdo Silver.*—By taking advantage of the fact that when signal strength decreases on one antenna it usually increases on another, a relay system is used to switch the receiver input from one antenna to another. Control voltage for the relay is taken from the receiver's a.v.c. line and amplified by a 2A4G.

BUILD THE JONES 8-TUBE SUPERHETRODYNE, *by Frank C. Jones.*—Designed for the many experimenters who like to build their own receivers, this receiver has several noteworthy circuit combinations. 1560-kc. i.f.'s and a variable-selectivity crystal filter are used.

INVERSE FEEDBACK AND VOLTAGE REGULATION IN SPEECH AMPLIFIER, *by Gene Turney.*—A general purpose amplifier using 2A3's in the output stage. Inverse-feedback voltage is taken from an 8-ohm winding on the output transformer. The regulated power supply uses a 2A3-6J7 voltage regulator circuit.

NOVEMBER, 1938

CQ PLANE "GUBA," *by Harold Keen.*—A narrative of the personalities and equipment behind the weekly schedule which Barney Boyd, W6LYY, keeps with the flying boat "*Guba*" in Dutch New Guinea.

A VESTPOCKET RECEIVER, *by G. Bradfield.*—An extremely compact self-powered receiver employing British tubes. One unusual feature is the microphone "hummer" power supply which supplies plate voltage from the small filament battery.

A THREE-TUBE FONE XMTR., *by Guy Forest.*—A transmitter costing less than $20 to build, designed for the 1.7- and 3.5-Mc. bands. Push-to-talk and break in c.w. provisions are featured. A c.w. output of 15 watts may be obtained from the single 802.

BUILD THE "HAM AMP," *by J. F. Gordon.*—A small preamplifier designed to allow a crystal microphone or pick-up to be used with amplifiers which are designed for double-button carbon microphones. A 6F5 is transformer coupled to two 6C5's. Output impedances are 500 and 200 ohms.

SIMPLE LOW-ANGLE RADIATORS, *by M. P. Fieldman.*—An analysis of several low-angle radiators employing phased elements. Suggested designs for various methods of feed are given.

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SERVICE

A Monthly Digest of Radio and Allied Maintenance

25c a copy—$3.00 yearly
Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.

NOVEMBER, 1938

VISUAL INDICATOR TUBES, *by R. Lorenzen.*—A continuation of a previous article on "tuning eye" tubes. The mechanical construction and electrical characteristics of two new types of indicator tubes are discussed. The new dual-indicator types are intended for operation with a special control tube which is composed of two separate triodes with internally connected grids. By winding the triode grids in such a manner that one section has a sharp cutoff characteristic while the other has a remote cutoff characteristic, two ranges of control voltage are applied to the dual indicator which may then be used to indicate resonance on both strong and weak signals.

SELF-BALANCING PHASE INVERSION.—Most modern receivers having push-pull output stages employ some form of phase inversion. Phase inverters have inherent disadvantages, however. A circuit is described which overcomes most of these disadvantages. The data are taken from RCA Application Note No. 97.

THE T & R BULLETIN
A JOURNAL FOR RADIO EXPERIMENTERS

1/6 a copy
Radio Society of Gt. Brit.
53, Victoria St., London
NOVEMBER, 1938

56/28 MC. A.C. T.R.F. RECEIVER, *by J. N. Walker.*—A small receiver designed for maximum performance at the ultra-high frequencies. A stage of tuned r.f. is followed by a regenerative triode detector and a pentode audio stage.

A 56-MC. DRIVER PANEL, *by W. F. Holford.*—Employing American tubes, this exciter or transmitter provides an output of approximately 25 watts at 56 Mc. A 6F6 is used as a straight crystal oscillator inductively coupled to a 6L6 doubler which is in turn inductively coupled to an 807 doubler output stage. Modulation may be applied in the cathode circuit of the 807 stage.

OCTOBER, 1938

TRANSMITTER THEORY APPLIED TO PRACTICE, *by S. O'Hagen.*—An article discussing various types of oscillators from a practical point of view. Self-excited and crystal oscillators of all types are discussed and the important operating characteristics of each type are given.

PHYSICAL PROPERTIES OF SUNSPOTS, *by R. J. Baldwin.*—A timely article explaining the effect of sunspots on the earth's ionized layers.

TWO MONTHS IN THE UNITED STATES, *by Robert Jardine.*—Mr. Jardine, whom amateurs will recognize as G6QX, tells of his experiences while touring the eastern part of the United States. Of particular interest to Mr. Jardine is the maze of overhead wiring through which American amateur signals must pass.

SEPTEMBER, 1938

THE 'UTILITY' TWO-VALVE TRANSMITTER, *by J. N. Walker.*—Part 2 of an article describing a simple but efficient low-power transmitter. This second section contains constructional details, coil data and operating notes.

AN INEXPENSIVE ROTATING BEAM FOR 56 MC., *by W. F. Holford.*—Since a Reinartz double loop is one of the most compact beams available, one is easily supported and rotated atop a 40-foot pole. Constructional details for a simple rotating mechanism are given.

THE ECONOMY CRYSTAL CONTROLLED 56 MC. TRANSMITTER, *by J. H. Cant.*—A simple breadboard 56-Mc. two-tube transmitter. 10 watts of output is obtained from the RK34 push-push doubler output stage. The two sections of a 6E6 are used as oscillator and doubler.

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