Cathode-Ray Oscillograph

Type TMV-122-B

Part I

OPERATING INSTRUCTIONS

WARNING—WHEN SAFETY SWITCH IS CLOSED, 1300 VOLTS IS PRESENT AT CATHODE-RAY TUBE SOCKET AND OTHER POINTS ON THE CHASSIS. ALWAYS DISCONNECT POWER CORD BEFORE REMOVING CHASSIS FROM CABINET.

Introduction

These instructions cover the installation, operation, maintenance and servicing of the Type TMV-122-B Cathode-Ray Oscillograph, designed especially for high-quality servicing of radio receiving sets and other communication devices. This Oscillograph provides a reliable instrument for the study of wave shapes and transients, measurement of modulation, adjustment of radio receivers and transmitters, determination of peak voltages, tracing of vacuum-tube characteristics and other similar applications. Its chief (although not the only) advantage over older types of measuring instruments is its freedom from inertia, allowing the observation of very rapid changes of current or voltage without appreciable distortion. The unit is entirely portable, the dimensions are approximately 14 inches high by 7¼ inches wide by 17¾ inches deep, and the weight is approximately 39½ pounds. The illustration on the opposite page shows the general appearance of the instrument and the operating controls. It operates entirely from an a-c source of 110 volts, 60-cycle current, an integral power unit supplying all operating voltages required for operation of the equipment.

The purpose of these instructions is to give the fundamentals of operation. As the use of cathode-ray apparatus becomes more widespread many new applications will be found for this equipment so that a thorough understanding of these fundamentals will enable the operator to readily adapt the equipment to his particular use. Since the equipment is built around the cathode-ray tube, a discussion of cathode-ray tubes and images obtained follows, which serves to explain the operation of the equipment and aids in analyzing figures which appear on the screen. The operator is urged to read this section thoroughly so that the numerous applications of the equipment may be readily understood and also that optimum performance may be obtained at all times.

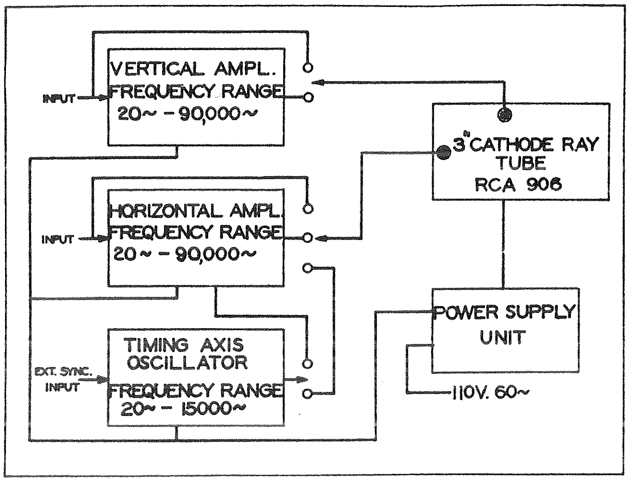


Figure 1—Block Diagram

Figure 1 shows the essential units of the instrument, which include an RCA-906 cathode-ray tube, a vertical amplifier, a horizontal amplifier, a timing axis oscillator (saw-tooth generator) and a power unit for supplying all operating voltages required.

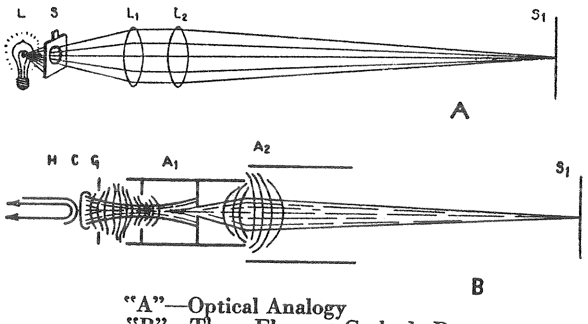
General Discussion of Cathode-Ray Tube

Fundamentally, a cathode-ray tube consists of (1) an electron-beam source, (2) provision for deflecting the beam, (3) provision for focusing the beam on a screen, and (4) a fluorescent screen for visibly indicating the position of the beam.

In the RCA-906 tube the electron source is a substantial cathode, indirectly heated. The cathode, control electrode (grid), and focusing electrodes constitute an electron gun, used to project a beam of electrons (Function 1). Two sets of electrostatic plates at right-angles to each other are located within the neck of the bulb to provide for deflection of the electron beam (Function 2). Focusing (Function 3) is accomplished by adjusting the ratio between the voltages on anodes No. 2 and No. 1. This ratio is in the neighborhood of 5:1. In practice, the anode No. 2 voltage is generally held constant and the anode No. 1 voltage is varied, since it is the smaller potential to control. The screen (Function 4) forms one end of the tube. It is three inches in diameter, and the inside is coated with material which emits light when struck by the electron beam. The control electrode (grid) constitutes a means of controlling the quantity of electrons admitted into the stream, and thus allows control of spot intensity (also called "brilliancy")—the more negatively the grid is biased, the fewer electrons in the beam, the smaller the spot, and the less the intensity.

The RCA-906 requires a high potential between cathode and anode No. 2 (in the order of 1000 volts). The voltage on anode No. 1 is usually around one-fifth of the high voltage, and is made variable to provide a means of focusing. The bias supply to the control electrode (grid) is also made variable to provide a means of controlling intensity. Since the anode current is usually less than 0.1 milliamperes, it is entirely satisfactory to use a rectifier tube in the power supply rated at only a few milliamperes, and to employ only capacity in the filter circuit. With such a small current drain imposed on this power supply, a condenser of 0.4 mfd. or more will filter very effectively.

The following few paragraphs constitute a very elementary development of cathode-ray tube deflection, and should be omitted by anyone familiar with the basic theory of operation of cathode-ray tubes. Those desiring to make this omission may start at "Study of Lissajou's Figures."



"A"—Optical Analogy
"B"—Three Element Cathode Rays

Figure 2—Focusing Cathode Rays

The "Electron Gun" in the cathode-ray tube may be compared to a simple optical system as shown in Figure 2-A. In this diagram the light emitted from the lamp, "L," is focused on the screen, "S_1," by means of a double lens system, "L_1," "L_2," and the amount of light is controlled by the shutter, "S," which, when closed, shuts off the light completely. The brilliancy of the image on the screen depends on the size of opening in the shutter, "S," and the candle power or wattage of the lamp, "L." If the candle power of the lamp is fixed (that is if we select a lamp of a given wattage) then the brilliancy is solely controlled by the shutter, "S." The size or definition of the image on the screen, "S," is controlled by adjusting the position of the lenses, "L_1" and "L_2," to the correct distance, which is called focusing. If the position of the lens, "L_2," is fixed, then the focus will depend solely on the adjustment of the position of lens, "L_1." Furthermore, with both lenses, "L_1 and L_2," adjusted correctly, it would be possible to change the focus by actually substituting for the lens, "L_1," various lenses until the one having the correct index of refraction is obtained. This is essentially the method of controlling the focus in the cathode-ray tube.

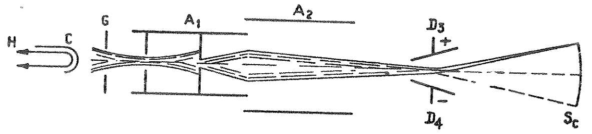


Figure 3—Deflection in One Direction

Figure 2B shows the elements constituting the "electron gun" previously mentioned. "C" is the cathode which radiates electrons when warmed by the heater, "H." The bias voltage of the grid "G" controls the number of electrons allowed to pass through it. The distance from the "gun" at which the electrons converge to a point, or "focus," is determined by the ratio of the voltages on the two anodes, A_1 and A_2. Obviously then, there is a particular ratio of these two voltages which will cause the beam to focus at the screen distance. In practice, the A_2 voltage is usually fixed and the A_1 voltage is made variable through sufficient range to assure that the beam can be focused on the screen.

Figure 3 shows the addition of one pair of deflecting plates, D_3 and D_4, to the previous figure. If these two plates are at the same potential, that is if no voltage difference exists between them, the electron stream is unaffected by their presence. However, if a difference of potential does exist between D_3 and D_4 the electron stream will be deflected toward the plate which is more positive (D_3 in the figure). (A positive charge attracts electrons, which are negative, while a negative charge repels. Both plates therefore bend the electron beam up as shown.)

Assume that a cathode-ray tube has both pairs of deflecting plates connected to a d-c source through potentiometers, as shown in Figure 4A. The center position of the "electron spot" on the luminescent screen, with zero voltage on both axes, is shown at B. At C, E_1 has been raised from zero, and it can be seen that the electron beam has been deflected upward and the spot now appears near the top of the screen. At D, E_1 has been returned to zero, and E_2 raised. A horizontal deflection is obtained. The directions of deflection, BC and BD are essentially at right-angles, due to the physical position of the electrostatic deflecting plates in the cathode-ray tube. At E, both E_1 and E_2 are impressed simultaneously, and with deflections on both axes, the spot has assumed the position resulting from the displacement in the two directions.

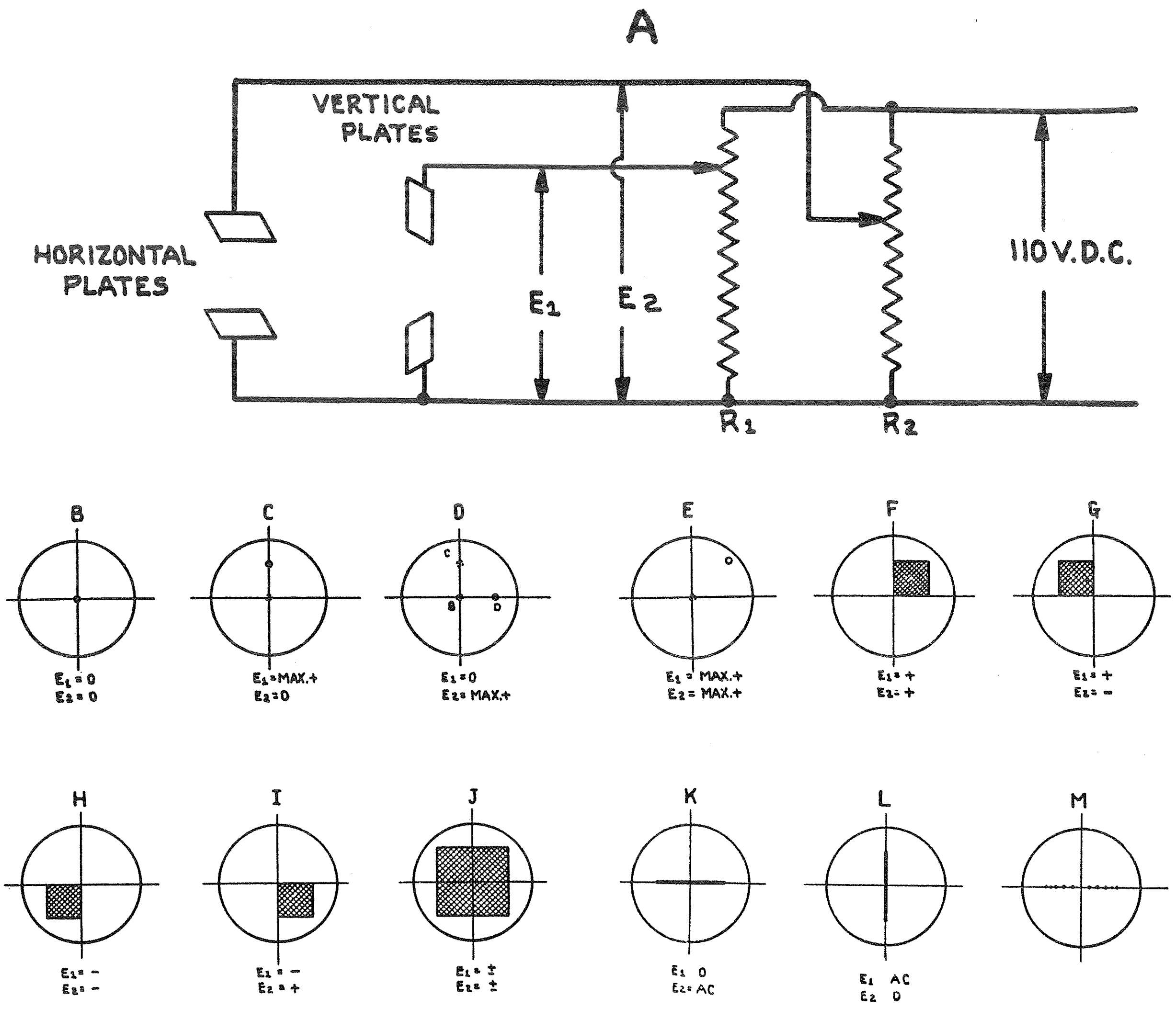


Figure 4—Application of Voltage to Deflecting Plates

It is readily apparent that by proper choice of E_1 and E_2 the spot may be made to assume any position within the shaded area of F. If the supply to R_2 is reversed, the beam will move to the left of center position as the E_2 voltage is increased from zero, and the shaded area of G applies. H and I need no explanation. J shows in shade the area the spot can be made to cover by changing polarity and value of the impressed voltages, E_1 and E_2. Now assume that a 2-cycle a-c voltage is impressed at E_2 ($E_1=0$). The spot will be seen to traverse the screen (see M) four times a second, and if the voltage is sinusoidal, the spot will move rapidly in the center of its travel and slowly at each end. If the 2-cycle source is replaced by a higher frequency (20 cycles or more) the spot will no longer be seen, but instead will cause a horizontal line to appear as shown at K. A similar voltage impressed on E_1, with $E_2=0$, gives a vertical line as in L. It should be borne in mind that the electron stream is always causing only a small spot to become luminous (assuming correct focus, etc.), but due solely to the illusion of persistence of vision (neglecting screen retentivity) the course of the spot appears as a line or image. A familiar analogy is the motion picture, in which a rapid series of still pictures gives apparent motion.

Study of Lissajou's Figures

When varying voltages are applied to the deflecting plates of a cathode-ray tube, a pattern is obtained on the fluorescent screen. The shape of this pattern depends upon the wave forms of the applied voltages, their frequencies and phase relationships. The following study of these patterns, or Lissajou's figures, is made with particular attention to their development, their use in identifying frequency ratios, and the effect of phase shift.

Figure 5 represents a sine-wave voltage (A) applied to the vertical pair of deflecting plates of a cathode-ray tube and an identical voltage (B) applied to the horizontal deflecting plates. The resulting pattern, shown by (C), is a straight line having a 45-degree slope. The direction of the slope of this line is determined by the phase relation of the two voltages as illustrated in Figures 10A and 10E.* Figure 6 illustrates the case of two identical voltages having the same amplitude but 90 degrees, or 270 degrees, out of phase. In this case, the resulting figure is a circle. If one of the figures is of greater amplitude

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*Figures 10 to 16 inclusive, and Figures 26 and 27 adapted from "Frequency Measurements with the Cathode Ray Oscillograph," Frederick J. Rasmussen, A. I. E. E. Transactions, November, 1926, Vol. XLV, Pages 1256–65.

than the other, the resulting figure will be an ellipse as shown by Figure 10C. If the phase relation is such that one voltage leads by 45 degrees, or 315 degrees, the resulting pattern will be that of Figure 10D; if leading by 135 degrees, or 225 degrees, the resulting pattern will be that of 10B. Figures 5 to 9 inclusive, show a graphical method for determining the resulting pattern, where the wave shapes, the relative amplitudes, the phase relation, and the frequencies of the two deflecting voltages are known. By means of the cathode-ray tube, the resultant pattern is traced on the fluorescent screen. Conversely, from this pattern, the frequency, and the phase relations of the two deflecting voltages can be determined. Where, in addition, the wave form is known for one of the deflecting voltages, the wave form of the other can readily be obtained by graphical analysis.

Figures 5, 6, and 10A to 10E are for a 1:1 frequency ratio. When a 2:1 frequency ratio of the voltages applied to the deflecting plates is the case, the wave shapes of Figures 10A to 10E become those shown by Figures 10F and 10J.

As the ratio of the frequencies increases, the pattern becomes more complex. In Figure 7, A and B, are the voltages applied to the deflecting plates. In this case, the frequency of A is three times that of B. The resultant figure (C) shows a 1:3 pattern in which both voltages start in phase. Figure 8 is the same as Figure 7 except that voltage A is started 90 degrees out of phase with respect to voltage B. Figure 9C shows the resultant pattern obtained where B is a saw-tooth wave and A a sine wave. This is of interest because this type of wave form results when a linear timing axis is used. Figures 11, 12, and 13 show patterns of increasing complexity, Figure 13 being an 8:6 pattern.

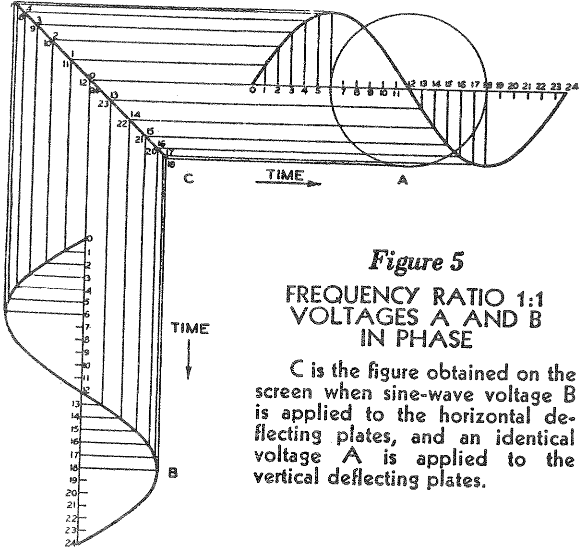


Figure 5

FREQUENCY RATIO 1:1
VOLTAGES A AND B
IN PHASE

C is the figure obtained on the screen when sine-wave voltage B is applied to the horizontal deflecting plates, and an identical voltage A is applied to the vertical deflecting plates.

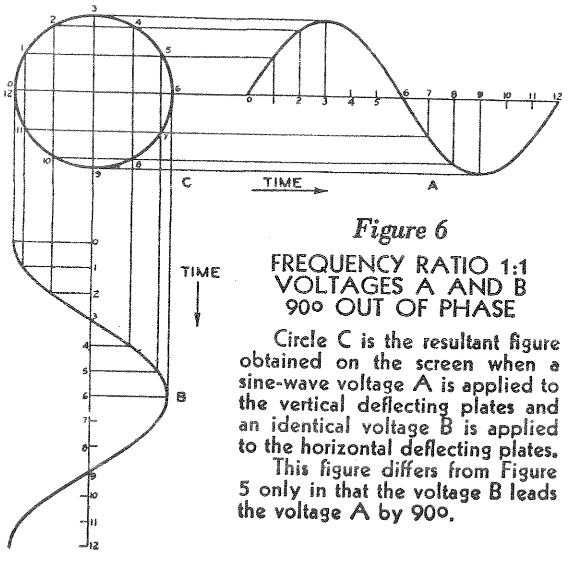


Figure 6

FREQUENCY RATIO 1:1
VOLTAGES A AND B
90° OUT OF PHASE

Circle C is the resultant figure obtained on the screen when a sine-wave voltage A is applied to the vertical deflecting plates and an identical voltage B is applied to the horizontal deflecting plates.

This figure differs from Figure 5 only in that the voltage B leads the voltage A by 90°.

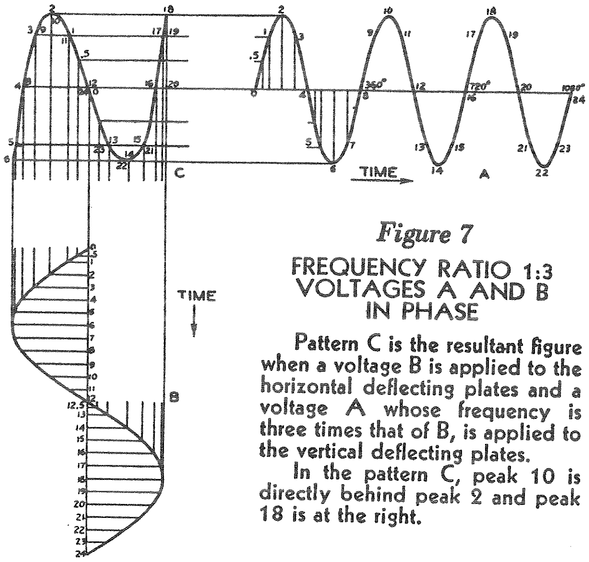


Figure 7

FREQUENCY RATIO 1:3
VOLTAGES A AND B
IN PHASE

Pattern C is the resultant figure when a voltage B is applied to the horizontal deflecting plates and a voltage A whose frequency is three times that of B, is applied to the vertical deflecting plates.

In the pattern C, peak 10 is directly behind peak 2 and peak 18 is at the right.

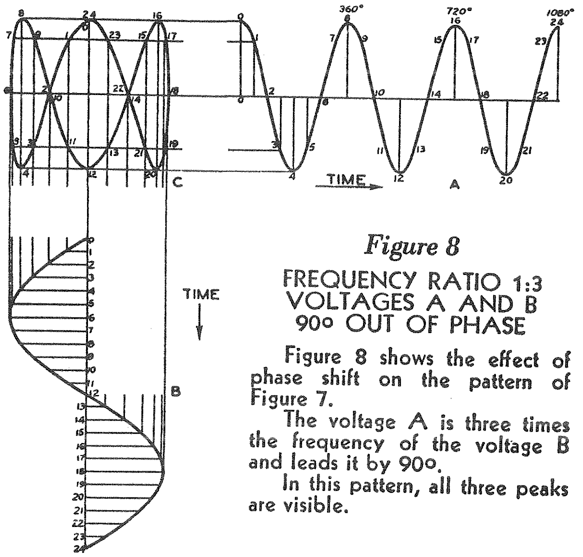


Figure 8

FREQUENCY RATIO 1:3
VOLTAGES A AND B
90° OUT OF PHASE

Figure 8 shows the effect of phase shift on the pattern of Figure 7.

The voltage A is three times the frequency of the voltage B and leads it by 90°.

In this pattern, all three peaks are visible.

When the cathode-ray oscillograph is used for calibration purposes, frequency ratios of less than 10:1 can be readily determined by visual inspection of the image. For frequency ratios greater than 10:1, the complexity of the pattern makes visual determination difficult and requires determination by means of photography. In general, the standard frequency selected should be one whose multiples and submultiples will cover the desired range and provide the simplest patterns.

In examining Lissajou's figures, one should consider them as the side view or elevation of a picture traced on a glass cylinder on which the observer may view the wave as it travels around the cylinder. The illusion is clearest when the whole figure rotates slowly. Figure 14 is a simple single-line pattern having a frequency ratio of 6:1. With a base frequency of 60 cycles, this pattern would be the picture for 360 cycles, or with a base frequency of 100 cycles, would be the picture of 600 cycles. The frequency ratio is determined by counting the peaks (six in number) of the waves in the horizontal plane and the number of end loops which for this case is one; hence, a frequency ratio of 6:1. In Figure 14, the front tracing has been made heavy and the back tracing light so that the two can be readily distinguished. If the figure were to be shifted slightly, the front and back waves might appear to be one. This condition might mislead the observer to believe that the frequency ratio was less than 6:1. Adjustment of the unknown frequency so that the pattern rotates very slowly, or stands still with the rear peaks uncovered by the front peaks, will make determination simplest.

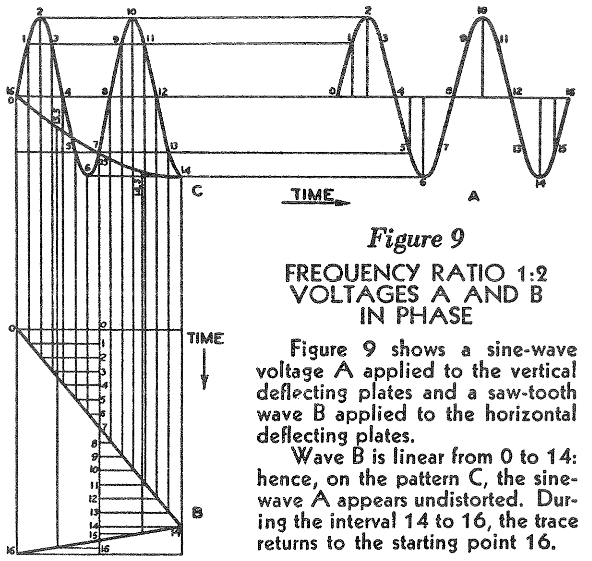


Figure 9

FREQUENCY RATIO 1:2
VOLTAGES A AND B
IN PHASE

Figure 9 shows a sine-wave voltage A applied to the vertical deflecting plates and a saw-tooth wave B applied to the horizontal deflecting plates.

Wave B is linear from 0 to 14: hence, on the pattern C, the sine-wave A appears undistorted. During the interval 14 to 16, the trace returns to the starting point 16.

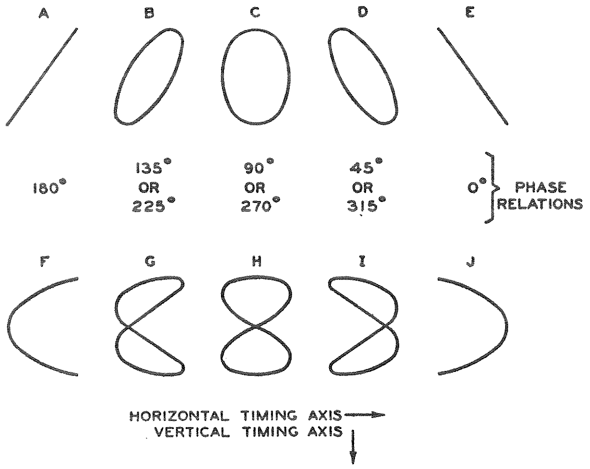
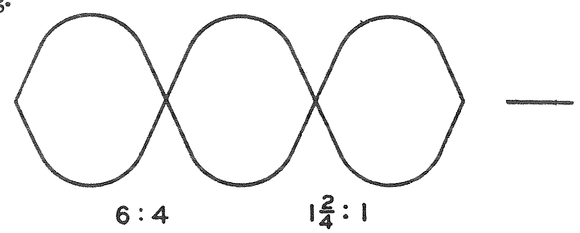


Figure 10

It will be observed that the wave form of Figure 14 corresponds to that of Figure 17,* a single-line pattern whose back trace is not visible. Figure 23 shows the simplest 2:1 wave or two-line figure. Figure 15 is a complete two-line figure illustrating a ratio of 9:2, which again, is readily determined by counting the number of peaks along the top of the figure and the number of loops at the end. Figure 16 has 16 peaks and is a three-line pattern, indicating a frequency ratio of 16:3.

Fig.

11



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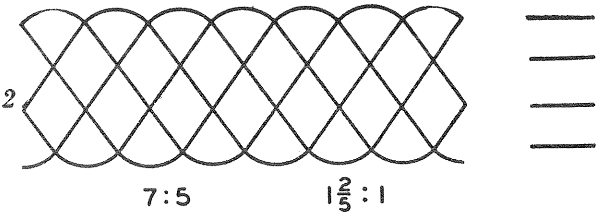

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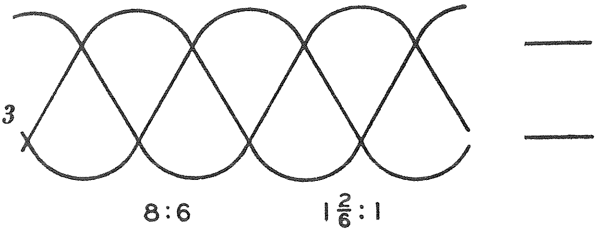

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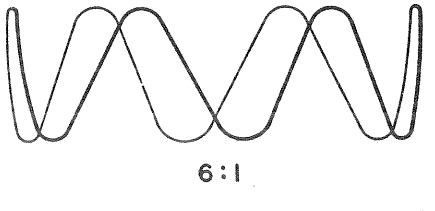

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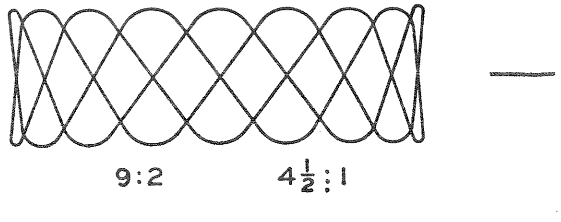

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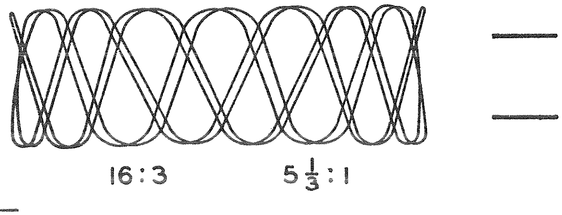

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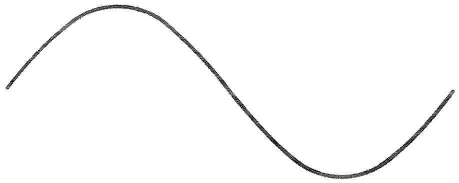
*Figures 17 to 25, inclusive, adapted from "The Cathode Ray Oscillograph in Radio Research," R. A. Watson Watt. Published by His Majesty's Stationery Office, London, England.

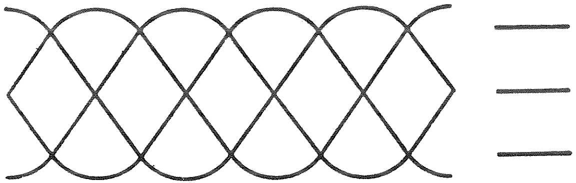
Fig.

17



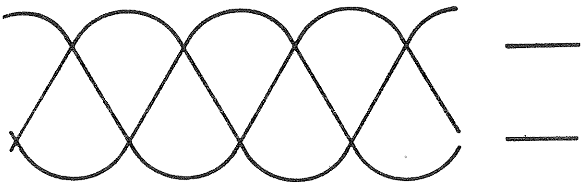
1:1

18



5.4 $1\frac{1}{4}:1$

19



4:3 $1\frac{1}{3}:1$

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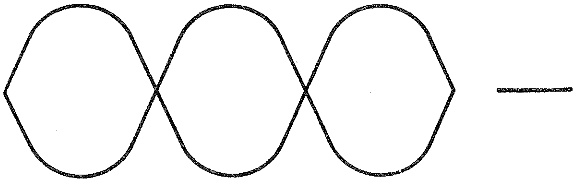

3:2 $1\frac{1}{2}:1$

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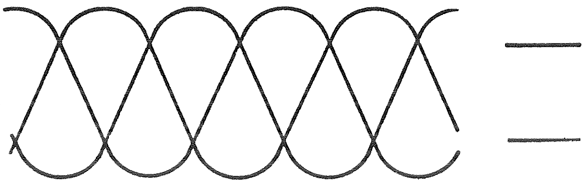

5:3 $1\frac{2}{3}:1$

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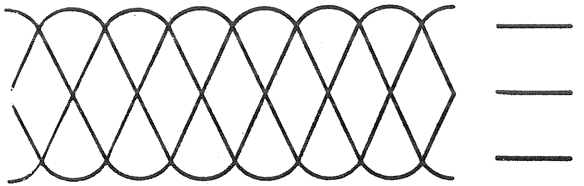
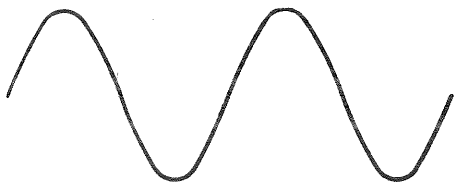


7:4 $1\frac{3}{4}:1$

23



2:1

Figures 14, 15, and 16 illustrate patterns as they generally appear on the fluorescent screen. Figures 11 to 13, and 17 to 23 are shown as pictures whose appearance suggests that the pattern has been developed on a plane. They have been shown in this fashion to facilitate study.

An optional method for determination of the frequency ratio is that of comparing the number of peaks on a given figure with the horizontal lines of intersections on the figure instead of with the number of loops at the end of the figure. A study of some of the patterns will make this clear. In Figure 20, there is a single line of intersections along the axes of the figures. It can easily be seen that this is a two-line figure by comparing it with the single line Figures 17 and 23. Figures 16, 19, and 21 having two horizontal lines of intersections, each spaced approximately one-third from the top and bottom, are three-line patterns. In the same manner, the four-line patterns of Figures 11, 18, and 22 are distinguished by three lines of intersection, the five-line pattern of Figure 12 by four lines of intersection, and the six-line pattern of Figure 13 by five lines of intersection with characteristic positions for these lines in each case. Thus, the frequency ratio is also equal to the number of peaks on circumference divided by the term, one + number of horizontal lines of intersection.

Of the patterns from 5 to 23, those of Figures 17, 23 and 7 show simple ratios of 1:1, 2:1, and 3:1. Both these direct multiples and fractional multiples of the base frequency are available to the user of the cathode-ray oscillograph. For example, with a base frequency of 60 cycles, the following tabulation will serve to illustrate the sequence of relatively simple patterns obtained as the frequency of the variable unit is decreased from a 1:1 ratio of frequencies to a 3:1 ratio.

Frequency In Cycles-Sec.	Frequency Ratio* Whole Number	Fractional	Illustrated By Figure
60	1:1	1 :1	17
75	5:4	1¼:1	18
80	4:3	1⅓:1	19
90	3:2	1½:1	20
100	5:3	1⅔:1	21
105	7:4	1¾:1	22
120	2:1	2 :1	23
135	9:4	2¼:1	—
140	7:3	2⅓:1	—
150	5:2	2½:1	—
160	8:3	2⅔:1	—
165	11:4	2¾:1	—
180	3:1	3 :1	7

*The frequency ratio is expressed either as a ratio of two integers, the first of which represents the number of peaks and the second the number of lines in the patterns, or as a ratio of a whole number and a fraction to unity. The denominator of the fraction is equal to the number of lines in the figure.

If the base frequency is 1000 cycles instead of 60, the same ratios hold. Thus, instead of 60 to 180 cycles, the frequencies for these patterns would be those for 1000 to 3000 cycles with intermediate values of 1250, 1333⅓, 1500, 1666⅔, 1750 cycles, 2000 cycles, 2250 cycles, 2333⅓ cycles, 2666⅔ cycles, and 2750 cycles.

When waves having frequency ratios greater than 10:1 are compared, accurate determinations may be difficult with the front and back portions of the figures in the same horizontal plane. To separate the back and front portions, the figures can be displaced to show either on an ellipse or a circle.

For an ellipse, a phase-splitting device as shown in Figure 28 is employed. Resistance (R_1) is connected across one set of deflecting plates and capacitance (C) is connected across the other pair. With R_2 at maximum resistance the phase shift is almost 90 degrees. As R_2 is decreased, the phase shift decreases. Figures 24 and 25 show the same single-line pattern and were obtained by adjusting the circuit of Figure 28 for different vertical amplitudes. Figure 26 is a two-line pattern having a frequency ratio of 31:2. The frequency ratio of this figure would be much more difficult to determine without displacement.

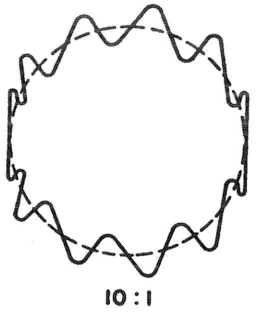


Figure 24

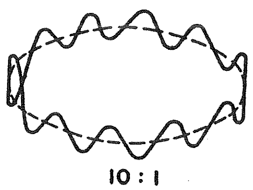


Figure 25

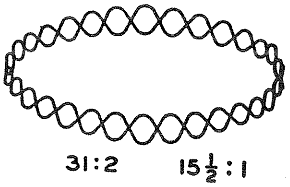


Figure 26

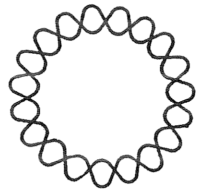


Figure 27

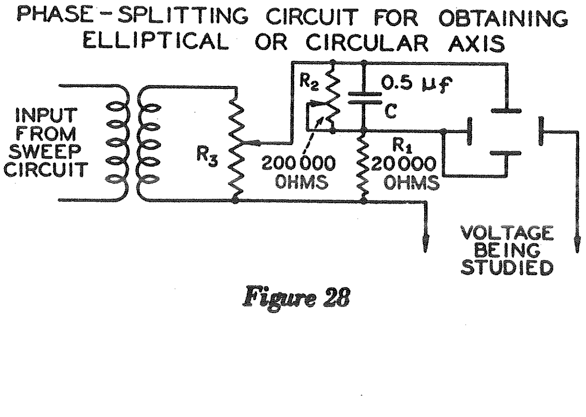


Figure 28

To produce the type of pattern shown in Figure 27, a circular axis is developed using the circuit of Figure 28, with the exception that the voltage under study is introduced in series with anode No. 2. It will be found that the peaks on this type of pattern will be somewhat blurred due to the defocusing effect caused by introduction of the voltage under study into the anode No. 2 circuit. Defocusing can be minimized by keeping this voltage at a low amplitude.

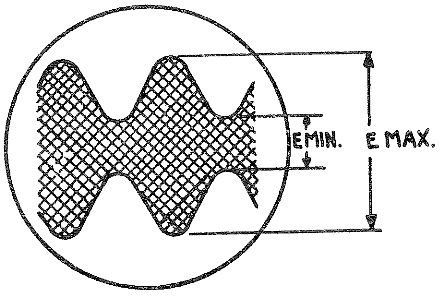
It was pointed out that the patterns of Figures 11 to 13, and 17 to 23 are developed on a plane. The resulting patterns are much simpler than they would be with their normal appearance because the back wave has been removed by spreading it out in the same plane with the front wave. The advantages of this simplified appearance can be obtained in practice by total elimination of the back wave. Where there is some doubt as to the number of lines in a pattern because of the presence of the additional lines of intersections observed in the back wave, this method will be of considerable assistance. Figure 15, for instance, is a two-line pattern, as is shown by the two loops at the end of the figure. However, because of the shift of the figure, the intersection made by the lines of the back wave with the lines of the front wave give it the same appearance as the five-line pattern of Figure 12. To eliminate the back wave, voltage of the same frequency as that used for the spreader, but 90 degrees out of phase, is applied to the control grid of the cathode-ray tube. Adjustment of this voltage will permit weakening the back wave and brightening the front wave, or the total elimination of the back wave.

General Applications

The most universal method of employing a cathode-ray tube is to impress the voltage to be observed on the vertical deflecting plates and to impress a voltage varying linearly with time on the horizontal axis. The latter voltage is usually obtained from an oscillator having a "saw-tooth" characteristic, as in Figure 32B. The true wave form of the signal on the vertical axis can then be observed without distortion, since none is introduced by the horizontal signal source. The conventional procedure when observing recurrent phenomena is to operate the timing axis supply at a sub-multiple of the observed frequency, so that several complete cycles will appear on the screen. Since the image will drift across the screen unless the ratio of the two frequencies remains constant and of a certain value, it is usually desirable to synchronize the timing axis oscillator. For the observation of transient phenomena the timing axis supply frequency is, of course, not critical and synchronizing is often useless. In some cases, however, it is desirable to synchronize the start of the phenomenon with a timing axis impulse.

Although use of a linear timing axis is fairly general, there are quite a few applications of the tube which do not employ one. From the table on page 8 it can be seen that if a sine-wave source of known frequency is impressed on one axis, a variable-frequency source can be impressed on the other axis and calibrated at a number of points other than the known frequency. The phase shift in an electrical device can be observed by impressing the input on one axis and the output on the other axis. If there is 0 or 180-degree phase displacement in the unit, a sloping straight-line image will appear. Refer to Figure 10 (A to E). If the above electrical device happened to be a frequency doubler, Figures 10F to 10J would apply.

Either set of deflecting plates can be used as a peak voltmeter. The impedance can be made very high, and the input capacitance very low, so that the voltmeter will show no discrimination between d-c and reasonably high radio frequencies. Transients can be observed almost as effectively with a sine-wave timing axis supply as with a linear one, as in this case the supply functions purely as a "spreader."

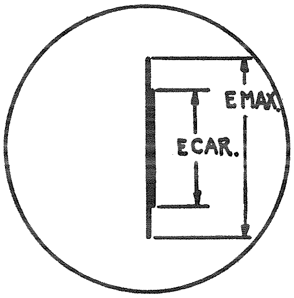


R. F. Modulated at 1000 Cycles
Timing Axis Supply: 500-Cycle Saw-Tooth

$$\text{Percent Modulation} = \frac{\text{EMax.} - \text{EMin.}}{\text{EMax.} + \text{EMin.}} \text{ X } 100$$

Figure 29

In order to illustrate the flexibility of such apparatus, a desired measurement will be assumed and several methods of obtaining the unknown quantity outlined. An r-f oscillator is being modulated an unknown amount with a 1000-cycle tone, and it is desired to determine the percentage modulation. One method is to observe the modulated r-f envelope by impressing either a sine-wave or linear supply on the horizontal axis and impressing the modulated r-f signal on the vertical axis. Figure 29 shows this method graphically. Incidentally, if a linear timing axis is used, as shown, the true wave-shape of the envelope will appear, and an appreciable lack of symmetry or other irregularities will be immediately apparent, indicating distortion. If no timing axis voltage is used, the percentage can be determined as shown at Figure 30. This obviously necessitates removal of modulation. A third method is shown at Figure 31. The 1000-cycle audio voltage which is modulating the r-f signal is impressed on the horizontal axis (modulated r-f remains on vertical). A trapezoid results which allows ready measurement of the peak deflections. Symmetry of modulation can be checked with methods of Figures 29 or 31 by removing modulation from the r-f oscillator and noting whether the carrier height is mid-way between the positive and negative audio heights.

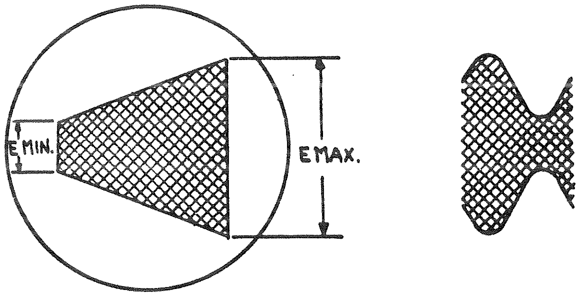


Timing Axis Supply—None

$$\text{Percent Modulation} = \frac{\text{EMax.} - \text{ECar.}}{\text{ECar.}} \text{ X } 100$$

Figure 30

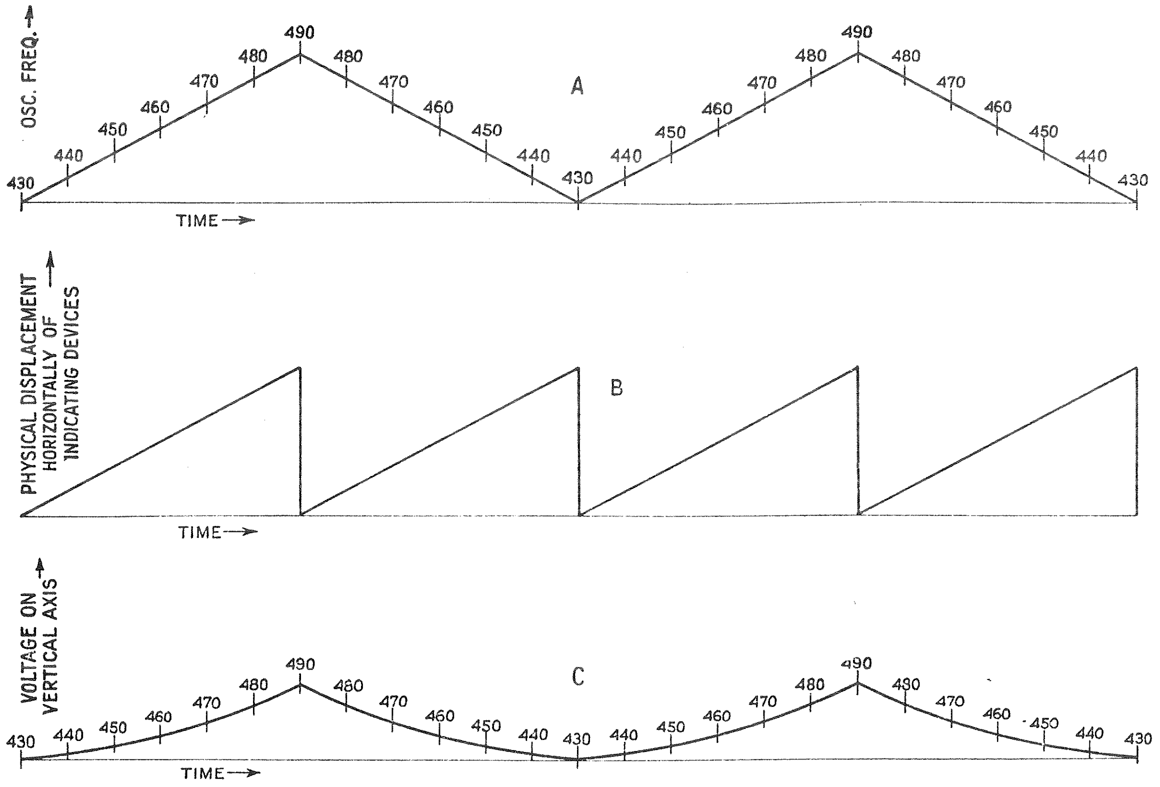
Another application of the cathode-ray tube is as a "visual" or curve-tracing device. This consists of an r-f oscillator being varied at an audio rate between two extremes of frequency, a means of displacing the indicating device horizontally in synchronism with the change of radio frequency, and a means of obtaining vertical deflection of the indicating device proportional to the output of the unit whose performance is to be observed. Usually, a condenser is arranged so that it "sweeps" the frequency of the r-f (test) oscillator continually, and at the same time an impulse generator, driven in synchronism with the "sweep" condenser varies an oscillator providing horizontal displacement of the indicating device in synchronism with the "sweep" condenser. Perhaps the greatest use of such a device is for the alignment of the intermediate frequency stages of superheterodyne receivers. A frequency-response curve of the circuit under test is continually before the aligner, which allows rapid and very accurate adjustment of the stage in question. The greatest advantage from such a system is realized when the circuit to be aligned has sufficiently greater than critical coupling



Timing Axis Supply—The Modulating Signal

$$\text{Percent Modulation} = \frac{\text{EMax.} - \text{EMin.}}{\text{EMax.} + \text{EMin.}} \text{ X } 100$$

Figure 31



NOTE: C is the resultant curve when the signal of A is fed into a circuit with characteristics of D. With signal B on the horizontal plates and C on the vertical plates, E is the resultant image on the screen.

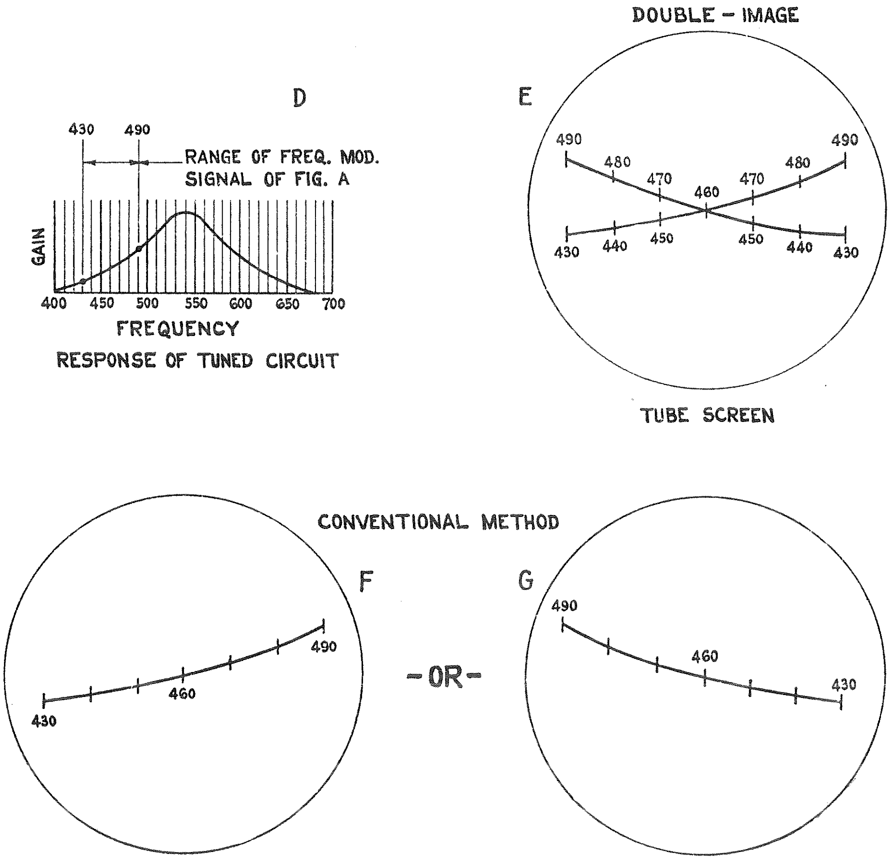


Figure 32

to give a flat-topped or double-peaked response. The same result can eventually be obtained by manually plotting a curve each time an adjustment on the unknown is made. However, this latter method is very laborious and requires considerable time.

A rather new development in such "visual" equipment has been made. The system dispenses with the conventional electrical or mechanical shutter and instead of employing one series of curves corresponding to a sweep through the r-f range in one direction, it employs two series of curves, one corresponding to an r-f sweep in one direction, and the other to an r-f sweep in the reverse direction. In other words, two curves (except in one case to be described later), appear on the screen, and the side of the screen which represents high frequency on one curve represents low frequency on the other. If on the first, third, fifth, ..."saw-tooth" pulses the left side of the

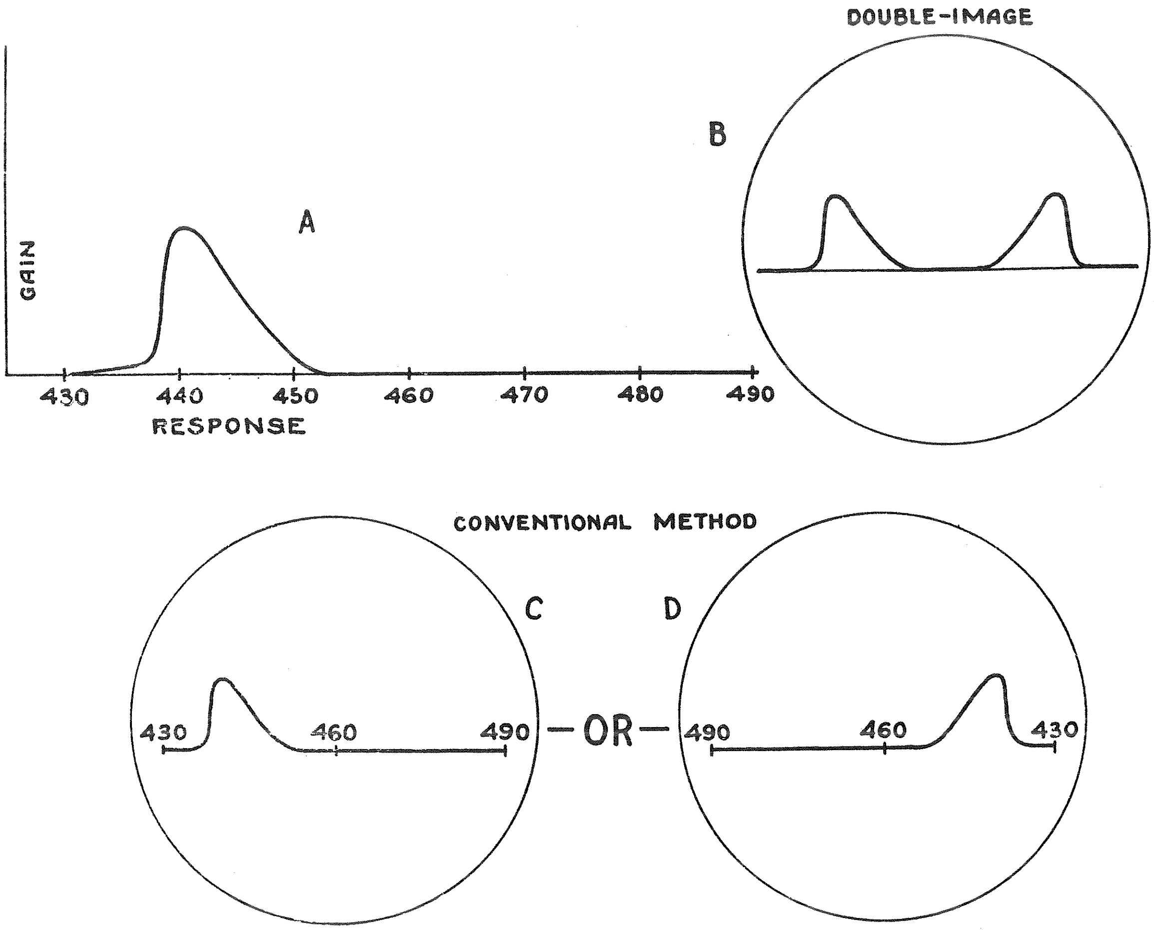


Figure 33

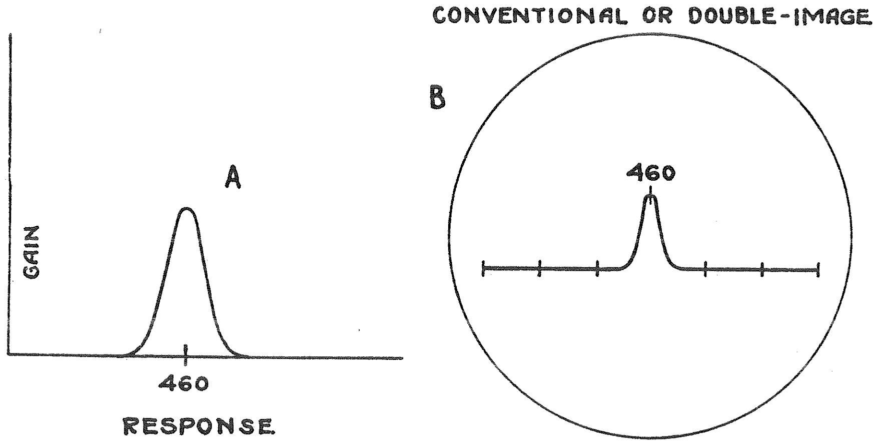


Figure 34

screen represents low frequency, then on the second, fourth, sixth .... pulses the left side represents high frequency. There is only one point on the screen which represents the same frequency on alternate "saw-tooth" pulses. This point is the calibration point; it is also the point at which equal capacity is obtained on the sweep condenser at two points 180 degrees apart. All other points on the screen represent two frequencies, one above and one below the "periodic" frequency. The term "periodic frequency" is used to designate the frequency of the oscillator when the sweep condenser is set at the point at which equal capacity would be obtained if the condenser were rotated 180 degrees. Since the condenser rotates at constant speed, this value of capacity is the only one which occurs at equal time intervals (other than the two extreme values, which repeat themselves half as frequently) and hence is termed the "periodic" capacity. The corresponding frequency is the periodic frequency, and, of course, is dependent upon the value of the periodic capacity and upon the remainder of the oscillator circuit. The value of periodic capacity is determined by the physical construction of the sweep condenser, and in a straight-line-capacity condenser with low minimum is close to half maximum capacity. It is a fixed value for a given condenser and will be affected only by physical change of the condenser.

Figure 32A shows a curve of oscillator frequency against time, demonstrating how the oscillator is periodically increasing and decreasing in frequency. Figure 32B shows the horizontal displacement of the indicating device. In the string galvanometer oscillograph this is accomplished by the rotation of the mirror; in the cathode-ray tube oscillograph by the action of the "saw-tooth" oscillator output on the pair of horizontal deflecting plates. Figure 32D shows the frequency response of a tuned circuit (very broad, for illustration). Figures 32F and 32G show how it may look with conventional method, Figure 32E with "double-image" method. (For explanation of Figure 32C, see note under diagram.)

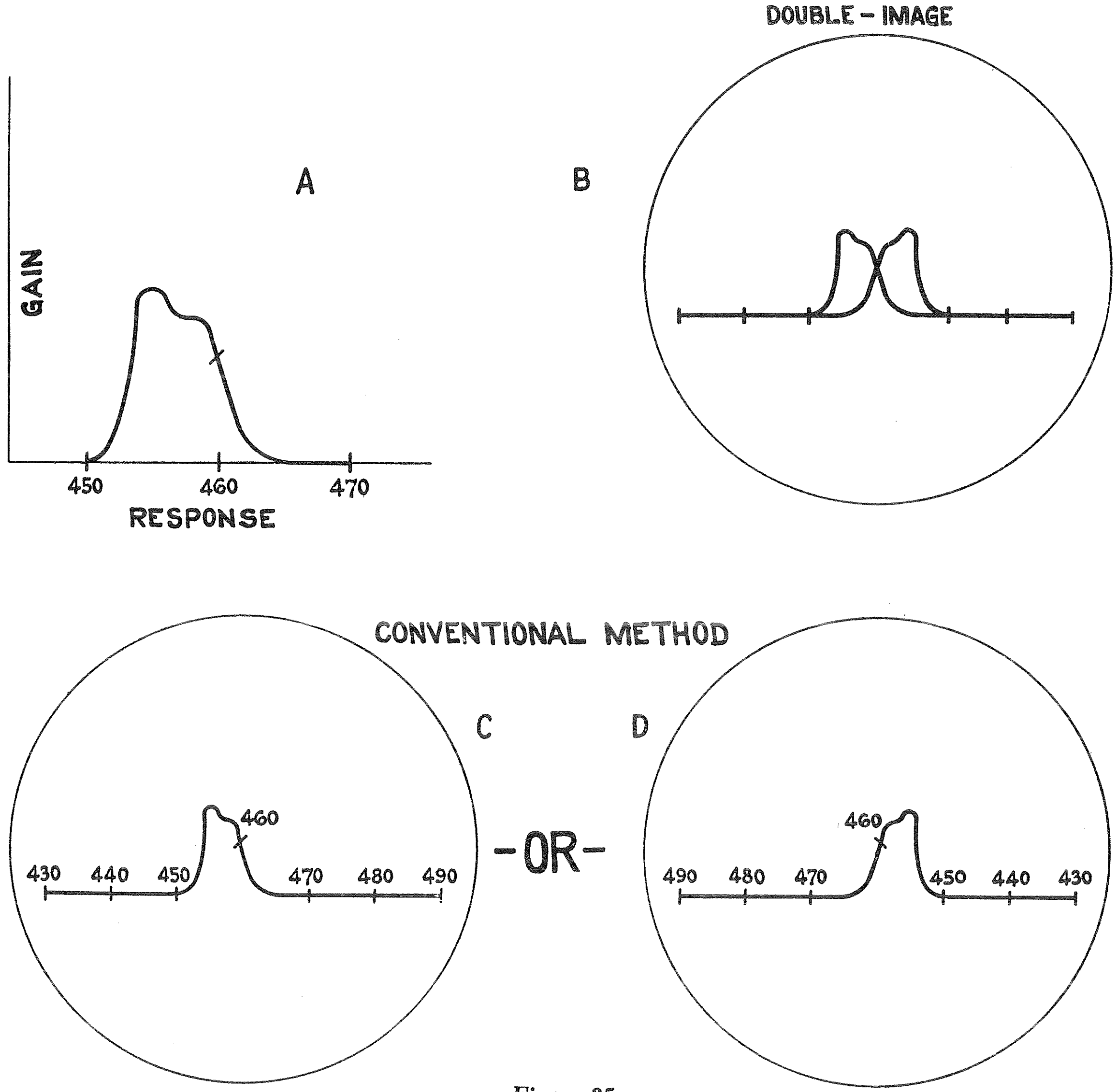


Figure 35

In Figure 33A is shown the response of an asymmetrical circuit resonant about 20 KC below the "periodic" frequency. Figures 33B, C and D show screen images obtained. Figure 34A shows response of a symmetrical circuit resonant at exactly the "periodic" frequency. In this case, Figure 34B, the image seen with the two systems is identical, for with the "double-image" method the two curves coincide and resolve into a single curve. Figure 35A gives response of a closely coupled transformer, slightly asymmetrical, and about 4 KC below the periodic frequency. Figure 36A shows response of a closely coupled transformer, symmetrically aligned at the periodic frequency. Here again the two curves of the "double-image" method resolve into a single image. The only difference between 34A and 36A is in selectivity, 34A representing a sharp and 36A a relatively broad circuit.

The chief advantages of the "double-image" over the conventional method are:

1. The superposition or "folding back" of the high and low-frequency sides makes symmetrical adjustments easy and very accurate.
2. The probability of frequency error in aligning is reduced to less than half. For a given frequency error the separation between the two curves of the "double-image" method is twice the displacement of the one curve of the conventional method. Also any small error is much more obvious with two images on the screen.

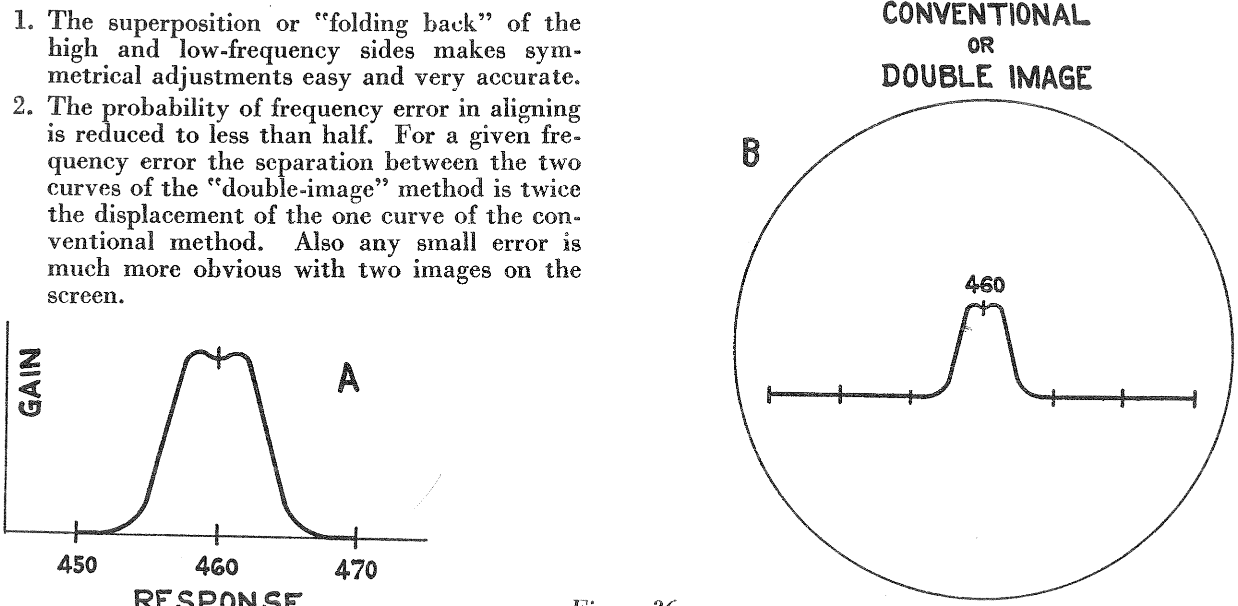


Figure 36

3. The necessity of employing an electrical or mechanical shutter is eliminated.
4. Distortion in the detector or audio amplifier does not cause error in aligning. If appreciable audio distortion is present, the images on the screen will not be true response curves of the tuned circuit. Nevertheless, the actual response is still truly symmetrical when the two curves are made to completely coincide.
5. The necessity of marking a vertical reference line on the screen for use in frequency calibration and alignment is avoided.
6. The advantage (4) above further allows frequency calibration of the variable frequency oscillator by zero-beating with a standard-frequency oscillator, *without* regard to displacement of the curve by any audio distortion.

Alignment of the radio frequency stages of receivers can be made using the same method discussed above for i-f alignment. The single-frequency source and output meter method may be used, if desired, but from the standpoint of demonstrating the performance of the r-f stages or explaining their operation, the oscillographic method is preferable.

Another type of visual, commonly known as a "universal" type, has as its primary function the measurement of capacity and inductance. Fundamentally it is the same as the visual described above for aligning i-f stages, but the i-f stage, instead of being the part under test, is permanently incorporated in the equipment. In other words, the output of the r-f oscillator, instead of feeding the grid of an i-f tube, is coupled to a tuned tank circuit which is across the grid circuit of a detector tube. Parts are tested by comparing the resonant frequency of this tank circuit with a part of known characteristics to the resonant frequency with a part of unknown values. (In either case the part forms a portion of the tank circuit.) The universal visual is chiefly applicable for quantity testing of coils and condensers. Very rapid testing can be done, as there is only the necessity of connecting the part to be tested and observing the position of the curve on the screen. Small fixed condensers have been tested manually as rapidly as 2,000 per hour on equipment of this type, though this is somewhat above average. The visual also has the advantage of affording a test at any radio frequency, so that difficulties from skin effect, distributed capacity and inductance can be greatly lessened by employing a frequency at or near the one the part will be subjected to in use.

The "double-image" method has a minor disadvantage when applied to the universal visual whenever it is desired to segregate the high and low rejects. No distinction can be made between them by merely observing the screen. However, by adding a small increment of inductance or capacity and

CATHODE-RAY OSCILLOGRAPH

TYPE TMV-122-B

POSITION OF CONTROLS FOR VARIOUS APPLICATIONS

No.	APPLICATION OR DEMONSTRATION	SWITCH POSITIONS				CONTROLS						APPLIED VOLTAGES			REMARKS
		Ampl. A	Ampl. B	Synchronizing	Range	Intensity	* Focus	Freq.	Ampl. A Gain	Ampl. B Gain	Sync.	"A" Bdg. Posts (Vertical)	"B" Bdg. Posts (Horizontal)	"Ext. Sync." Bdg. Posts	
1	FIRST OBTAINING SPOT	Off	Off	*	*	First clockwise rotation closes power switch Adjust for desired briliancy of image Remember tube screen can be burned	Adjust for maximum concentration of electron beam (smallest line or spot) after setting for desired intensity	*	*	*	*	None	None	None	Do not burn screen; adjust the two beam shift controls to center spot on screen.
2	LOCATING TUBE POSITION	Off	Timing	Ext.	**			**	*	Set for line about 2" long	*	None	None	None	Rotate cathode-ray tube so line is exactly horizontal.
3	APPLYING VERTICAL DEFLECTING VOLTAGE	On	Off	*	*			*	Vary	*	*	60 cycle supply between 2 and 150 volts	None	None	Elementary Demonstration Preliminary Adjustments
4	APPLYING HORIZONTAL DEFLECTING VOLTAGE	Off	On	*	*	↓	↓	*	*	Vary	*	None	60 cycle supply between 2 and 150 volts	None	Elementary Demonstration
5	APPLYING DEFLECTING VOLTAGE ON BOTH AXES	On	On	*	*	↓	↓	*	Vary	Vary	*	60 cycle as above	60 cycle supply as above	None	Guard against shorting 60 cycle supply; all "O" binding posts are common.
6	AC VOLTMETER WITHOUT AMPLIFIER	Off	Off	*	*	↓	↓	*	*	*	*	Voltage to be measured	None	None	Set up is same for calibrating; use substitution method.
7	AC VOLTMETER WITH AMPLIFIER	On	Off	*	*	↓	↓	*	Max. or other calibrated point	*	*	Voltage to be measured	None	None	Set up is same for calibrating; use substitution method.
8	OBSERVING WAVE-SHAPE OF AUDIO VOLTAGE	On	Timing	Int.	Depends on freq. of observed audio	↓	↓	Depends on freq. of observed audio	For desired amplitude	For desired spread	Just enough to lock image	Voltage to be observed	None	None	Probably greatest application.
9	OBSERVING WAVE-SHAPE OF RADIO-FREQUENCY VOLTAGE	Off	Timing	Ext.	Depends on freq. of modulating audio	↓	↓	Depends on freq. of modulating audio	*	For desired spread	Just enough to lock image	Voltage to be observed (50 volts or more)	None	1 volt or more of audio from modulator	If frequency is less than 100 KC, Ampl. A can be used.
10	MEASURING PERCENTAGE OF MODULATION	Off	Timing	Ext.	Depends on freq. of modulating audio	↓	↓	Depends on freq. of modulating audio	*	For desired spread	Just enough to lock image	Voltage to be observed	None	1 volt or more of audio from modulator	Wave-shape method.
11	MEASURING PERCENTAGE OF MODULATION	Off	On	*	Depends on freq. of modulating audio	↓	↓	*	*	For desired spread at 100% mod.	*	Voltage to be observed	2 volts or more of audio from the modulator	None	Trapezoid method.
12	"VISUAL," I. E., RF CURVE TRACING	On	Timing	Ext.	Tap "2"	↓	↓	For about 51 cycles	For desired amplitude	For desired spread	Just enough to lock image	Audio output of chassis 2nd detector	None	Bdg. posts on TMV-128-A Freq. Mod.	Output of TMV-97 impressed in grid circuit of tube preceding stage to be aligned. Cable connects TMV-97 and TMV-128-A
13	CHECKING PHASE SHIFT OF AMPLIFIER	On	On	*	*	↓	↓	*	For desired vertical defl.	For desired horiz. defl.	*	2 volts or more of audio output of amp.	2 volts or more of audio input to amp.	None	Watch out for phase shift in internal amplifiers; if sufficient voltage is available do not use Ampl. A and B.
14	FREQUENCY MEASUREMENT UP TO 100,000 CYCLES	On	Timing	Ext.	Depends on freq. desired	↓	↓	Depends on freq. desired	For desired vertical defl.	For desired horiz. defl.	Just enough to lock image	2 volts or more of signal freq. to be measured	None	1 volt or more of standard frequency	Saw-tooth oscillator in step at 1, 1/2, 1/3, etc. times standard frequency. For frequencies above 100,000 cycles use Lissajou figures; set up as 13 with standard voltage on "Ampl. B" binding posts, unknown on "A" posts.

*Denotes position immaterial.
**Denotes frequency immaterial.

noting whether the two curves move closer together or farther apart, the direction from nominal of the part under test can be readily determined. Since this extra operation is necessary only in the case of a rejected part, normally it is not of much consequence.

In using cathode-ray tubes, quite often the voltage to be observed is not of sufficient value to give the desired amount of deflection. In this case a voltage amplifier is employed. The amplifier should have an essentially flat output over a sufficient frequency range to avoid appreciable distortion of the observed signal. For ordinary use it is not objectionable if the amplifier is non-linear above the sixth harmonic of the frequency of the observed voltage.

Installation

Unpack the instrument from the shipping container and remove the screws securing the front panel to the case. Withdraw the chassis from the case, supporting the panel at the bottom, and feeding the power cable through the hole in the back. Make certain that all tubes are firmly in their sockets and all grid cap connections are in place, then replace the chassis in the case and replace the securing screws. With "Intensity" control in extreme counter-clockwise position ("Off"), plug the power supply cable into an electrical outlet supplying 110–120 volt, 50–60 cycle alternating current. The instrument is then ready for operation.

NOTE: A safety switch is incorporated in the instrument, located at the rear of the chassis. This breaks the power supply connection when the chassis is withdrawn from the case. DO NOT ATTEMPT TO OPERATE THE EQUIPMENT WHEN WITHDRAWN FROM THE CASE AS THE HIGH POTENTIALS USED ARE DANGEROUS.

Operation

Controls

(Refer to the Schematic and Wiring Diagrams, Figures 37 and 38, for location of circuit units designated by symbols.)

1. "Intensity" control, R-17, is a potentiometer in low side of 1200-volt bleeder. Its position controls the bias on the grid of the cathode-ray tube, which in turn determines the quantity of electrons emanating from the "gun," thus controlling spot size. The power switch S_5 is located on this potentiometer. Initial clockwise rotation of this control turns on switch, additional rotation increases spot size.

2. "Focus" control, R-19, is a potentiometer in the 1200-volt bleeder. Its position controls the anode No. 1 voltage, which (with constant A_2 voltage) determines the distance at which the electron beam focuses. In general, for a given "Intensity" setting, the "Focus" control should be set for maximum distinctness of spot or image.

3. "Ampl. A" switch, S_1, connects the "Vertical" binding posts either straight through to the vertical deflecting plates on the cathode-ray tube or through an amplifier to these deflecting plates. In either case there is a condenser in the input circuit.

4. "Ampl. B" switch, S_2, has 3 positions: "Timing," "On," and "Off." On "Timing" the "saw-tooth" or timing axis oscillator feeds through an amplifier to the horizontal deflecting plates on the cathode-ray tube. When "On" the "Horizontal" binding posts are connected through an amplifier to these deflecting plates. When "Off" the binding posts are connected straight through to the deflecting plates. In either of the latter two cases there is a condenser in the input circuit.

5. "Ampl. A Gain" control (vertical), R_1, is a potentiometer on the input circuit of the vertical amplifier. With "Amplifier A" switch "On," this potentiometer controls the vertical deflection.

6. "Ampl. B Gain" control (horizontal), R_4, is a potentiometer on the input circuit of the horizontal amplifier. With "Amplifier B" switch on "Timing" or "On" this potentiometer controls the horizontal deflection.

7. "Range" switch, S_4, selects one of four timing capacitors and on alternate positions it places a resistor, R_{11}, in and out of the circuit. It thus changes the timing axis oscillator frequency in steps, giving 8 ranges as follows: No. 1, 20–37; No. 2, 37–120; No. 3, 120–205; No. 4, 205–700; No. 5, 700–1100; No. 6, 1100–3700; No. 7, 3700–5700, and No. 8, 5700–15000 cycles.

8. "Freq." control, R_{12}, is a rheostat in series with the timing condenser. It changes the timing axis oscillator frequency gradually as it is rotated, and in conjunction with "Range" switch above gives continuous range between the extremes of frequency (20–15,000 cycles).

9. "Sync." control, R_9, is a potentiometer controlling the amount of synchronizing voltage fed to the grid of the RCA-885 tube. In general it should be set as far counter-clockwise as is consistent with a locked image, as over-synchronization causes poor wave-form from the timing axis oscillator.

10. "Synchronizing" switch, S_3, has three positions, "Int.," "60 Cycle," and "Ext." On "Int." the voltage drop across resistor R_9 in the plate circuit of the vertical amplifier is fed through the "Sync." control and input transformer to the grid of the RCA-885 tube. Thus the timing axis oscillator can be synchronized with the signal on the vertical axis at fundamental frequency or any small sub-multiple, such as ½, ⅓ . . . . Synchronization is not effective if it is attempted to operate the timing axis oscillator at a higher frequency than that of the synchronizing voltage. On "60 Cycle," a 2.5 V. 60 cycle source is impressed across the "Sync." control, and can be used for locking the timing axis oscillator at 60, 30, or 20 cycles. On "Ext." the "Ext. Sync." binding

posts are connected across the "Sync." control. This allows the use of an external source for synchronizing.

11. On the right-hand side of the cabinet, toward the rear, there are two potentiometers slotted for screw-driver control. These potentiometers control the amount of d-c potential between the two deflecting plates of each pair, and thereby allow adjustment of the position of the spot or image. The rear potentiometer controls the horizontal deflection and the front one controls the vertical deflection.

12. There are three pairs of binding posts on the unit. Voltage impressed on the "Vertical" posts will give deflection vertically. Voltage impressed on the "Horizontal" posts will give deflection horizontally. The "Ext. Sync." posts are used when it is desired to synchronize the timing axis oscillator with some external source. (See [10] above.) The binding posts marked "O" are all common ground and the ones marked "HIGH" are insulated from ground, which is the chassis.

Applications

General. The following procedures are included in order to familiarize the operator with the operations and connections involved in the particular applications. All applications of the equipment are not described, but analysis of the particular problem involved will show wherein it is similar to or differs from those given, enabling the operator to work out his own sequence of operation.

As has been previously pointed out, most applications of this instrument are carried out with the output of the unit under test connected to the vertical plates of the cathode ray tube, and the wave shape studied by application of known constants on the horizontal plates of the tube. Before any measurements are attempted, the operator is urged to go through the following procedure in order to familiarize himself with the controls and their location and to get the "feel" of their operation:

1. Connect the power plug to an a-c source of 110 volts, 60 cycles. Turn "Intensity" control clockwise, causing a spot to appear on the screen, increasing in size as the "Intensity" control is advanced further clockwise. The "Focus" control should then be adjusted until maximum distinctness of spot or image occurs.

CAUTION. DO NOT ALLOW A SMALL SPOT OF HIGH BRILLIANCY TO REMAIN STATIONARY ON THE SCREEN FOR ANY LENGTH OF TIME, AS DISCOLORATION OR BURNING OF THE SCREEN WILL RESULT.

With the spot on the screen and with the "Intensity" control retarded so that the spot is not too brilliant, adjust the position of the spot to the center of the screen by rotation of the two screw-driver controls near the rear of the cabinet on the right-hand side. The control at the rear adjusts the spot horizontally and the one nearer the front adjusts the spot vertically. After initial adjustment, these controls will rarely require re-adjustment, except when the RCA-906 tube is replaced.

To turn the equipment off, turn "Intensity" control to its extreme counter-clockwise position, until a distinct "snap" is heard.

2. Apply a source of 60-cycle current to the "Vertical" binding posts. To adjust the length of the resultant line appearing on the screen turn "Ampl. A" switch "On" and adjust "Ampl. A Gain" control until the length is as desired. The line will be as shown in Figure 4L. Application of the same 60-cycle source to the "Horizontal" binding posts with "Ampl. B" switch "On" or "Off" will similarly show a horizontal line on the screen, the length of which may be varied (with "Ampl. B" switch "On") by manipulation of "Ampl. B Gain" control. See Figure 4K.

3. To expand (2) further, have 60 cycles available at both "Horizontal" and "Vertical" terminals.

CAUTION. Since all "Ground" or "O" binding posts on the Oscillograph are common, it is advisable to use an isolating transformer for one supply, so that there is no common connection between the two.

Apply the horizontal 60-cycle supply on the screen, preferably through "Ampl. B" and its gain control, then apply the 60-cycle vertical supply through "Ampl. A" and its gain control. The result will be a straight line. (See Figure 5 and explanation.)

AC Voltmeter without Amplifier—For this application, the characteristics of the unit are as follows: Input resistance—400,000 ohms, input capacity—approximately 10 mmf.; voltage range—150 volts (higher with external attenuator); calibration—approximately 75 peak volts per inch or 27 r-m-s volts per inch.

Procedure—Make connections to the Oscillograph and turn controls to the positions specified in Application No. 6 on the enclosed operating chart. Measure or estimate the length of line appearing on the screen in inches (depending on accuracy desired) and multiply by 75. This gives the approximate peak-to-peak value of the unknown voltage. For approximate effective value, if voltage being measured is sinusoidal, divide peak value by 2.8.

AC Voltmeter with Amplifier—For this application, the characteristics of the unit are as follows: Input resistance—500,000 ohms; input capacity—approximately 20 mmf.; frequency range—20-90,000 cycles; maximum voltage—700 volts (higher with external attenuator); calibration—(roughly) 2 peak volts per inch, or 0.7 r-m-s volts per inch.

Procedure—Make connections and adjust controls according to Application No. 7 on the chart. With "Ampl. A Gain" control in the extreme clockwise position a line one inch long is obtained on the screen for about 2 volts peak input. Intermediate positions of the gain control give different calibrations, of course, and if considerable use is made of this feature it may be advisable to plot a curve of the inputs required to give a one-inch deflection at various intermediate positions of the gain control. If working at a frequency above 10,000 cycles, it must be remembered that retarding the gain control from maximum destroys the linearity of the amplifier.

A particular application of operation as an a-c voltmeter is in making hum measurements in a power supply unit. In this case the "O" binding post ("Vertical") is connected to the common lead of the filter circuit of the unit under test and a clip lead, connected to the "High" binding post, is used to check the a-c ripple present at the various circuit component terminals.

AC Ammeter with Amplifier—For this application, the unit is used as an a-c voltmeter with an external shunt. The range with a one-megohm shunt is, roughly, 1–2100 microamperes, and the audio frequency impedance is about 330,000 ohms; with a 1000-ohm shunt the range is, roughly, 0.3–700 milliamperes.

Procedure—The Oscillograph should be connected as for the a-c voltmeter with amplifier, except the circuit with the unknown current should be connected to the "Vertical" binding posts across an external shunt of 1000 ohms or one megohm, depending on the amplitude of the current. Variation of the "Ampl. A Gain" control will adjust the length of line appearing on the screen. As when used as an a-c voltmeter, it may be advantageous to plot a curve of inputs vs. gain control settings for one-inch deflection on the screen in order to obtain the values of unknown currents more quickly.

Audio Quality Measurements — Use of the "saw-tooth oscillator" feature of the Oscillograph provides a check which cannot be made with an ordinary voltmeter. This is extremely helpful in discovering the audio quality of a receiver or similar instrument and also in locating causes of audio distortion.

Procedure—Apply the output from a constant frequency record or audio oscillator to the "Vertical" binding posts, with controls set as in Application No. 8. Turn "Range" switch to that tap giving a range including the frequency of the input signal and adjust "Freq." control until the saw-tooth oscillator frequency is near that of the input signal. If the two frequencies are identical, one cycle of the input signal will be observed on the screen; if the saw-tooth oscillator frequency is one-half that of the input signal, two cycles of the latter will appear; if one-third, three cycles; etc. Next, connect this constant frequency record or audio oscillator output to the audio input of the unit under test and connect the output of the unit under test to the "Vertical" binding posts of the Oscillograph, all adjustments of which are as previously set. If the resultant wave does not correspond to that obtained when the input was direct to the Oscillograph, audio distortion is present.

If it is desired to measure the overall audio fidelity of a receiver, for instance, the procedure is similar to that above except that the voltage modulating an r-f oscillator is fed into the Oscillograph, adjusted as above. Then the modulated oscillator is connected to the r-f input terminals of the receiver and the loudspeaker voice coil connected to the Oscillograph. Comparison of the two resultant waves will indicate how much distortion occurs in the receiver under test. Observing the quality of the input to the receiver from the test oscillator will also show how much distortion is being fed into the receiver from the test oscillator. This is desirable, since it may show that all the distortion present in the receiver output may not be due to the receiver characteristics, but to those of the test oscillator (assuming no distortion from modulation).

Modulation Indicator — (1) One method of measuring the modulation of a transmitter is to place the modulated r-f output of the transmitter into the vertical plates of the cathode ray tube and the audio input signal to the transmitter on the horizontal plates of the tube through the synchronous circuit.

Procedure—Connect a constant frequency input to the transmitter and connect a small pickup coil, located near the transmitter tank coil, to the "Vertical" binding posts. The pickup on this coil should be from 50–75 volts. Connect the "Ext. Synch." binding posts of the Oscillograph to transmitter audio amplifier at a point providing a 2–4-volt signal. Turn controls to positions given in Application No. 10 on the chart. Turn "Range" switch to tap including the frequency of the input signal and adjust "Freq." control until the saw-tooth oscillator interlocks with the signal on the vertical plates. Adjustment of the "Sync." control provides control of the voltage from the pick-up coil to the grid of the RCA-885 tube. Adjustment of "Ampl. B Gain" control varies the horizontal deflection.

(2) Another, somewhat similar, method of modulation measurement is to connect the pickup coil to the "Vertical" binding posts as before, but connect the audio signal (from the transmitter audio amplifier) to the "Horizontal" binding posts. Turn controls to positions given in the chart for Application No. 11. Adjust "Ampl. B Gain" control until desired horizontal deflection is obtained. The percentage modulation can then be readily determined. See Figure 31.

Alignment of Intermediate Frequency Stages —For alignment of the intermediate frequency stages of a receiver it is essential that an auxiliary apparatus be available to sweep the intermediate frequency for which the receiver is designed. The Type TMV-128-A Frequency Modulator is designed for this use. It consists of sweep condenser and a synchronizing generator rotated in synchronism by a driving motor. The condenser is arranged to "sweep" the frequency of the r-f input to the receiver (or i-f stages) and the synchronizing generator connects to the "Sync." binding posts of the Oscillograph so as to synchronize the saw-tooth oscillator with the frequency variation of the test oscillator (such as the TMV-97-C) input to the receiver. A switch on the panel of the Modulator provides two ranges of capacity for "sweeping" the test oscillator output frequency; on "Hi" the range is 20–65 mmf., and on "Lo" the range is 15–35 mmf.

The test oscillator output should be coupled to the grid of the tube preceding the i-f stage under alignment. It is essential that this connection be made without altering any of the operating characteristics of this stage. If the grid of the tube to which connection is to be made is at zero d-c potential with respect to ground, connect the oscillator to the grid of the tube and disconnect the lead normally on the grid, the low side of the test oscillator output returning to chassis ground. If the grid is not at zero d-c potential with respect to ground, connect the high side of the oscillator to the grid (disconnecting the lead on the grid) and the other side to the "—C" lead for this grid.

The "Vertical" binding posts of the Oscillograph should be connected to the audio output of the second detector. For a diode detector this connection may be across the volume control alone or across both the volume control and automatic volume control resistor, if this connection is convenient. When the second detector is a triode, tetrode or pentode, resistance-coupled to the first audio stage, the connection to the "High" binding post may be to the plate of the tube, the "O" post being connected to ground. In the case of a triode, tetrode or pentode, transformer or impedance-coupled to the first audio stage, connect a resistor of approximately 20,000 ohms in series with the plate of the tube and by-pass the inductance in the plate circuit by a 1.0 mfd. or larger capacitor. This changes the impedance of the plate circuit to resistance rather than inductive reactance; the "High" binding post should be connected to the plate of the tube and the "O" post to ground in order to take the audio voltage off this resistor.

Procedure—Connect the test oscillator output to the grid of the tube preceding the i-f transformer being aligned, and connect the "Vertical" binding posts in the second detector as previously explained. The test oscillator should be set at the i-f alignment frequency with modulation "On." Turn Intensity-control "On," adjust "Focus" properly, turn "Ampl. A" switch "On" and adjust the gain control. Turn "Ampl. B" switch on "Timing," turn "Synchronizing" switch to "Int.," adjust "Range" switch to include the frequency of the modulating audio signal. Adjust "Ampl. B Gain" control and set "Freq." control to interlock the signal. Adjust the i-f transformer trimmers for maximum output, *i. e.*, peak them as much as possible. Remove the modulation on the test oscillator, connect the sweep condenser to the r-f oscillator and connect the synchronizing generator to the "Ext. Sync." binding post. Turn motor "On." Turn "Synchronizing" switch to "Ext." and readjust the frequency of the test oscillator until the forward and reverse waves show on the screen of the tube. Raise the frequency of the test oscillator until the highest points of the two waves coincide. See Figure 10. (This readjustment is necessary to compensate for the added capacity of the cable and one-half of the sweep condenser capacity.) Record the dial setting of the oscillator for future reference. Adjust the trimmer condensers of the primary and secondary of the i-f transformer until the two curves coincide throughout their entire length. When this occurs, the stage is symmetrical with respect to the i-f frequency. During i-f alignment, the receiver tuning dial should be set at a point where variation of its position has no effect on the resultant curve. If this point cannot be found, short-circuit the grid or plate coil of the receiver r-f oscillator. The i-f stages should be aligned in order, starting at the last stage and working toward the first detector.

ALIGNMENT OF RADIO FREQUENCY STAGES—The equipment used for r-f alignment is identical to that for i-f alignment, except that the test oscillator output is connected to the antenna lead of the receiver.

Procedure—Set the test oscillator at the r-f alignment frequency of the receiver and set the receiving tuning dial at this same frequency. Connect the second detector to the "Vertical" binding posts and turn the test oscillator "On" with modulation "On." Turn "Intensity" control "On" and adjust the "Focus" control; turn "Ampl. B" switch to "Timing," "Synchronizing" switch to "Int.," "Range" switch to cover the r-f signal, "Ampl. A" switch "On," adjust "Ampl. A and B Gain" controls properly, with the test oscillator disconnected from the sweeping capacitor. Adjust the oscillator and r-f trimmers of the receiver until maximum possible output is obtained. Turn modulation of test oscillator "Off," connect sweep condenser to test oscillator and synchronous generator to "Sync." binding posts of the Oscillograph, turn "Synchronizing" switch to "Ext." Adjust the test oscillator tuning until two curves show on the screen and readjust the oscillator tuning until the two curves coincide at their highest points. Record the dial setting of the test oscillator for future reference. Adjust the receiver oscillator trimmer until the forward and reverse curves coincide as well as possible and then adjust the r-f trimmers until the curves coincide throughout.

FREQUENCY MEASUREMENTS—In using the Oscillograph for frequency measurement, either Lissajou figures (sine waves on both axes) may be used, or the linear timing axis may be employed on the horizontal axis. The most flexible method for frequencies up to 100,000 cycles is the linear timing axis method. The frequency stability of the saw-tooth oscillator running free is not good enough to depend on for accurate measurements, but when this oscillator is synchronized with a standard-frequency voltage its frequency stability is the same as that of the standard, and it can be synchronized at any sub-multiple of the standard frequency down to about one tenth. This allows convenient calibration of a device at many points between one-hundredth of—and ten times a single standard-frequency source, and every point is as accurate as the standard. If a 1000-cycle standard source is used, calibration points between 10 and 10,000 cycles are easily obtained. Using Lissajou figures, calibration points between 100 and 10,000 cycles can be obtained. A frequency standard which is almost universally available is the 60-cycle a-c supply. Since the advent and rapid spread of electric clocks the frequency of nearly all commercial power is held to a very close tolerance. With the "Synchronizing" switch on "60 cycle," the saw-tooth oscillator can be locked at 20, 30, or 60 cycles, as desired. This allows accurate calibration at frequencies up to about 600 cycles. Refer to the table on page 8 and Application No. 14 on the chart.

CHECKING PHASE SHIFT—To check phase shift of a device with the Oscillograph, set controls as shown on Application No. 13 on enclosed chart, observing the screen pattern with input to device on "Horizontal" binding posts and output from device on "Vertical." If no phase shift exists, a sloping straight-line image will appear. The internal amplifiers in the Oscillograph introduce some phase displacement which must be considered. If sufficient voltage is available, the internal amplifiers should not be employed.

Part II

SERVICE DATA

Electrical Specifications

Power Supply Rating	Voltage	110–120 Volts AC
	Frequency	50–60 Cycles
	Wattage Consumption	50 Watts
	Fuse Protection	1.5 Amps.
Operating Limits	Deflection sensitivity at amplifier inputs	2 peak volts per inch (max. "gain.")
	Deflection sensitivity at cathode-ray tube inputs	75 peak volts per inch
	Input Characteristics:	
	(1) Through either amplifier	500,000 ohms, approximately 20 mmfd.
	(2) Without either amplifier	400,000 ohms, approximately 10 mmfd.
	Frequency response range of amplifiers	20–90,000 Cycles
	Maximum signal input (with amplifier)	700 Volts (RMS)
	Frequency range of timing axis or "Saw-tooth" oscillator	20–15,000 Cycles
	Maximum d-c voltage across input binding posts	300 Volts
Radiotrons Used and Functions	1 RCA-57	Signal amplifier for vertical deflection
	1 RCA-57	Signal amplifier for horizontal deflection
	1 RCA-885	"Saw-tooth" oscillator
	1 RCA-906	Cathode-ray tube (3-inch)
	1 RCA-879	High-voltage rectifier
	1 RCA-80	Low-voltage rectifier

Physical Specifications

Overall Dimensions	Height (including carrying-handle)	14 inches
	Width	7¼ inches
	Depth	17¾ inches
Weight packed for shipment		68 pounds
Weight		39½ pounds

Circuit Description

The schematic arrangement of the entire circuit is shown in Figure 37.

An amplifier consisting of a single RCA-57 constitutes the means of obtaining "gain" for the signal applied to the vertical deflecting system. The input to this stage is a high-resistance potentiometer connected to provide "gain" control. An isolation capacitor is made a part of the input circuit to exclude any DC which may be associated with the circuit being observed. The plate, or output circuit of the RCA-57 is composed of two elements in series, a resistor and an inductance whose values are so designed as to effect a broad and uniform frequency response in the amplifier stage. Coupling from the amplifier plate to the cathode-ray tube is made through a capacitor.

The amplifier for the signal applied to the horizontal deflecting plates is identical to that described above. Switches are provided to disconnect either or both amplifiers, thereby applying the voltage to be studied directly to the deflecting plates. Extra contacts are used on the input switch to the horizontal amplifier for feeding in the timing or "Saw-tooth" oscillator signal.

A synchronization system is included, as shown in the input circuit of the RCA-885. This is the "Synchronizing" switch described under "Operation." The timing axis oscillator stage, using the RCA-885, is designed to have a frequency range of 20 to 15,000 cycles, controlled through the "Range" switch and "Frequency" control. The signal from this oscillator has a "saw-tooth" wave shape, obtained as follows: A d-c potential is applied across a capacitor and resistor in series in the plate circuit of the RCA-885 tube. This voltage charges the capacitor until the ionization potential (plate voltage at which the gas in the RCA-885 ionizes) is reached. When the RCA-885 ionizes the capacitor is short-circuited and the voltage across it drops nearly to zero. The RCA-885 immediately de-ionizes and allows the capacitor to start charging again. In this manner, the voltage across the capacitor has a "saw-tooth" characteristic. The capa-