Cathode-Ray Oscillograph

Stock No. 151 and 151A

IB-23357

Part III
OPERATING INSTRUCTIONS

WARNING — WHEN POWER IS ON, THERE IS A POTENTIAL OF 400 VOLTS FROM THE AMPLIFIER TUBE GRIDS TO GROUND. DISCONNECT POWER CORD BEFORE WITHDRAWING CHASSIS.

Introduction

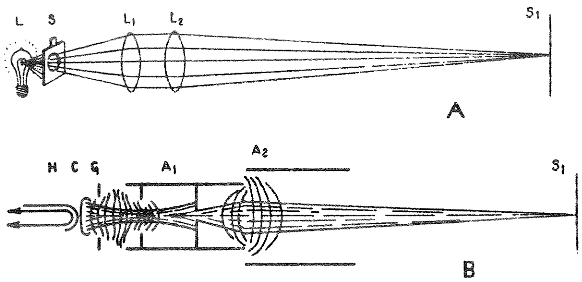
These instructions cover the installation, operation, maintenance and servicing of the No. 151 Cathode-Ray Oscillograph, designed especially for high-quality servicing of radio receiving sets and other communication devices. This Oscillograph provides a reliable instrument for the study of wave shapes, measurement of modulation, adjustment of radio receivers and transmitters, determination of peak voltages, 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 9¼ inches high by 13¾ inches wide by 7¾ inches deep, and the weight is approximately 15 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, 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.

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-913 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 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 one inch 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.



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

Figure 3—Focusing Cathode Rays

The "Electron Gun" in the cathode-ray tube may be compared to a simple optical system as shown in Figure 3-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_1" 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_1," is fixed, then the focus will depend solely on the adjustment of the position of lens, "L_2." 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_2," 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-B 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.

Figure 4 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.) A similar pair of plates at right angles to the first pair would effect a deflection at right angles to the first deflection. By applying voltages of the proper value and polarity to each pair of plates the spot may be moved to any point on the screen. If an alternating voltage is applied to one pair of plates the spot will move in response thereto, the location of the spot at any instant of time resulting from the value of the voltage at that instant. If the voltage alternates more rapidly than about ten cycles per second, the retentivity of the screen and the observer's eye cause the spot to blend into a continuous line.

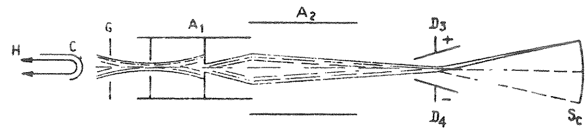


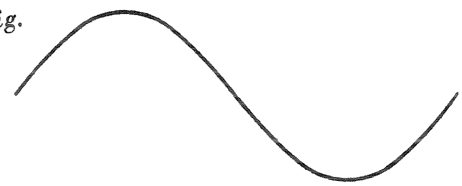
Figure 4—Deflection in One Direction

In the No. 151 Oscillograph there are controls (centering—V and H) for effecting permanent displacement of the spot by applying a direct voltage to the deflecting plates. They are intended to correct any accidental eccentricity of the cathode-ray spot itself, or as a means for centering those patterns (such as that obtained in I.F. amplifier alignment) having a greater deflection in one direction than in the other. These controls move the axis, or zero point about which the alternating voltage deflects the spot. Moving these controls simply transfers the whole pattern's physical position relative to the dimensions of the screen, and introduces no distortion, change in sensitivity, or other harmful effect.

In order to study the wave shape of any voltage causing a vertical deflection, it is necessary to move the spot horizontally too, so that the pattern may be spread out. Since a curve of voltage vs. time is usually desired, a circuit is incorporated giving a voltage having the unusual characteristic of a constant, steady rise to a maximum value and then a sudden drop to its starting value (a "saw tooth" shape). Under influence of this voltage the spot moves horizontally from one side of the tube to the other at a constant speed and then snaps back suddenly to its starting position. By this means the pattern on the end of the tube is made exactly the same as a curve of the unknown voltage vs. time, and the oscillograph operating in this manner may be considered an automatic plotting machine wherein the scales may be changed by merely setting the control knob. Examples of such curves are shown in Figure 5-11, wherein the unknown voltage (vertical) is a sine wave. The ratios shown

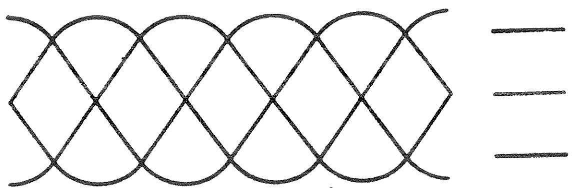
Fig.

5



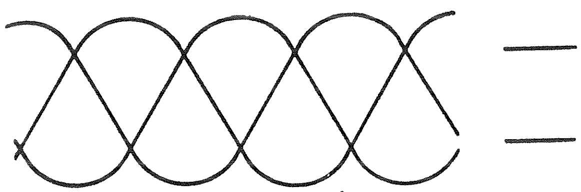
1:1

6



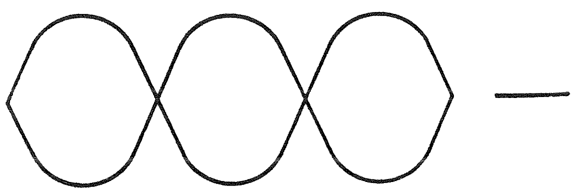
5.4 $1\frac{1}{4}:1$

7



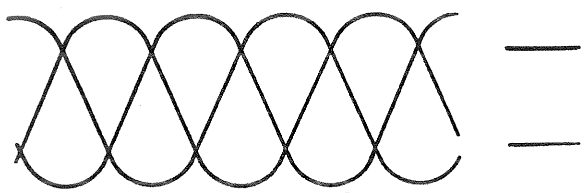
4:3 $1\frac{1}{3}:1$

8



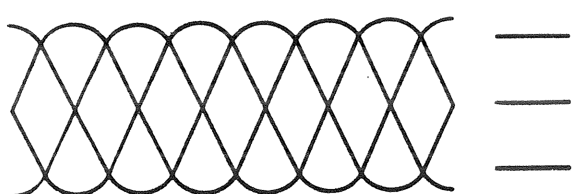
3:2 $1\frac{1}{2}:1$

9



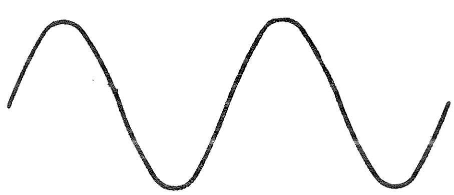
5:3 $1\frac{2}{3}:1$

10



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

11



2:1

are the ratio of unknown voltage frequency to "saw tooth" oscillator frequency.

When sinusoidal alternating voltages are applied to both deflection axes, the resultant patterns are closed continuous lines known as Lissajous Figures. If the two frequencies are equal the pattern will be as shown in Figure 12 A-E depending of course upon the phase. If the two frequencies are very slightly different, the phase angle is continually changing and the pattern changes with it, passing through the whole series of shapes shown. Figure 12 F-J shows the patterns obtained when the horizontal frequency is twice the vertical frequency. Figures 13, 14, and 15 show the patterns obtained with the marked frequency ratios, the vertical frequency being the higher in each case. Whenever such a figure stands still, the two frequencies are in an exact ratio, any slight variation from such ratio being indicated by motion of the pattern.

In thinking of any of these patterns it must be remembered that the electrons strike only one point at a time, the apparent line being caused entirely by the retentivity or "holding over" of the screen and the human eye.

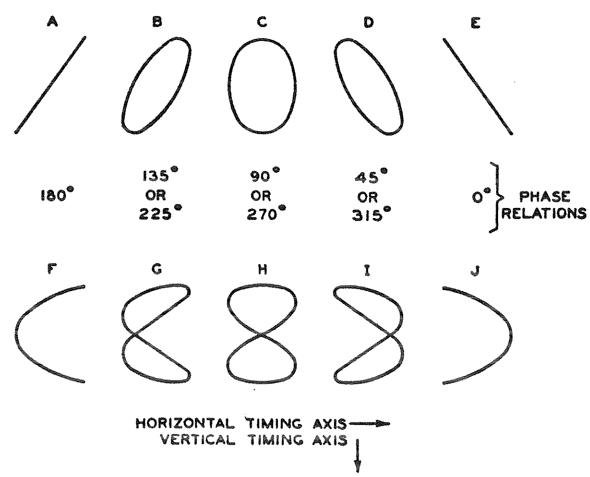


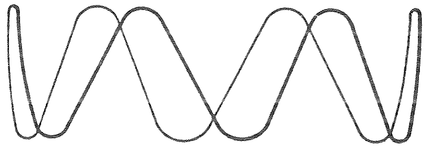
Figure 12

***Figures 5-11, inclusive, adapted from "The Cathode Ray Oscillograph in Radio Research," R. A. Watson Watt. Published by His Majesty's Stationery Office, London, England.**

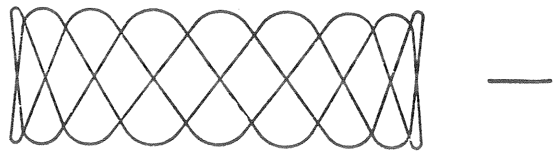
***Figures 12 to 15, inclusive, adapted from "Frequency Measurements with the Cathode Ray Oscillograph," Frederick J. Rasmussen, A. I. E. E. Transactions, November, 1926, Vol. XLV., Pages 1256-65.**

Fig.

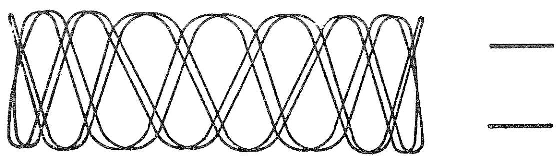
13



14



15



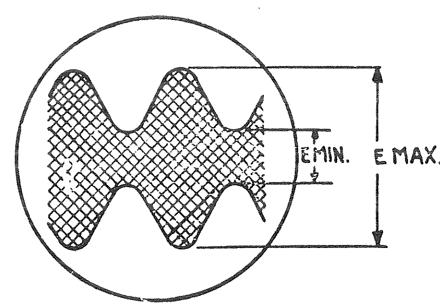
General Applications

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 later voltage is usually obtained from an oscillator having a "saw-tooth" characteristic. 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 information on Lissajous Figures 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 12 (A to E). If the above electrical device happened to be a frequency doubler, Figures 12F to 12J would apply.

The vertical 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."

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 1,000-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 16 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 17. This obviously necessitates removal of modulation. A third method is shown at Figure 18. The 1,000-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 16 or 18 by removing modulation from the r-f oscillator and noting whether the



R. F. Modulated at 1,000 Cycles
Timing Axis Supply: 500-Cycle Saw-Tooth

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

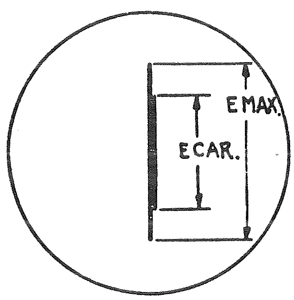
Figure 16

carrier height is mid-way between the positive and negative modulated heights.

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. (The No. 150 Oscillator performs all these functions simultaneously.) 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 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 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 every "saw-tooth" pulse. This point is the calibration point. All other points on the screen represent two frequencies, one above and one below the calibrating frequency.

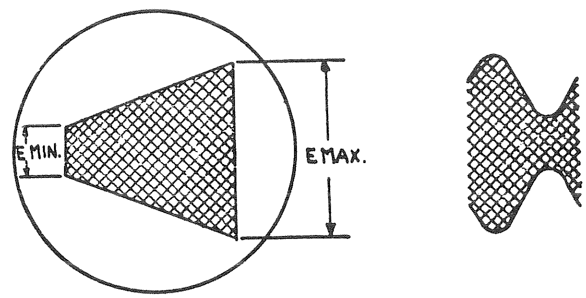
When a circuit is incorrectly aligned it is not symmetrical about the calibrating frequency; that is, its response at 1 KC. above the calibrating frequency is not the same as the response at 1 KC. below. Since any point on the cathode-ray screen (except the calibrating point) represents two frequencies equally spaced above and below the calibrating frequency, there must appear two curves, one representing the circuit's response to high frequencies and the other the response to low frequencies. The gain characteristic of such a circuit and the resultant cathode-ray trace are shown in Figure 19A and B.



Timing Axis Supply—None

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

Figure 17



Timing Axis Supply—The Modulating Signal

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

Figure 18

If the circuit be properly aligned, its response curve will be symmetrical about the calibrating frequency; that is, its response at a number of kilocycles above the calibrating frequency is the same as its response at the same number of kilocycles below. Since the responses are equal the heights of the two curves will be equal, the curves will be superimposed and appear as one. The circuit of Figure 19, after being properly aligned, gives the response curve and cathode-ray trace shown in Figure 20A and B.

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.

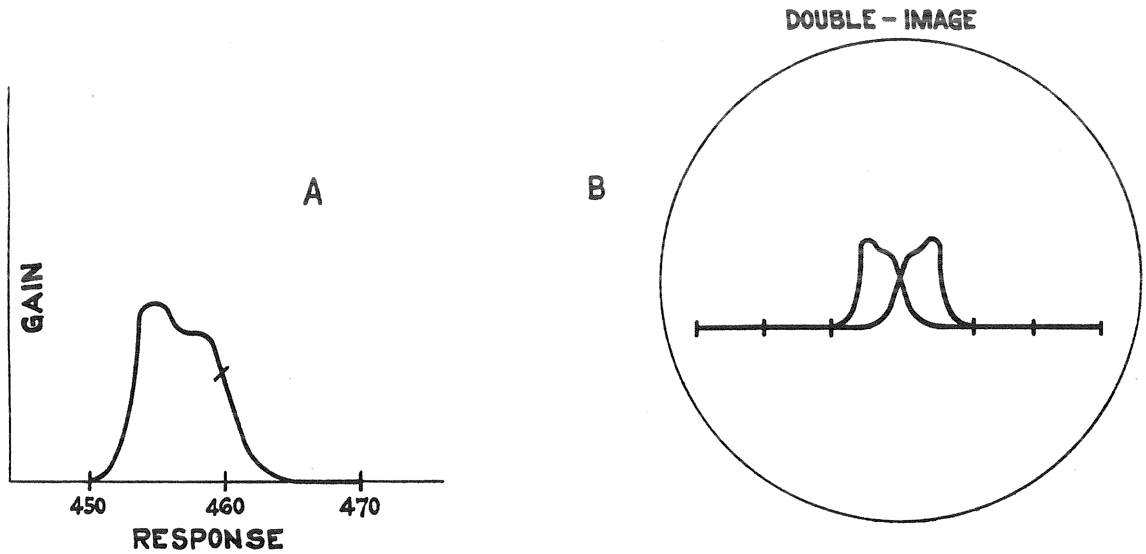


Figure 19

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.
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.

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. Should the deflecting plates in the cathode-ray tube not be in the proper plane it will be necessary to twist the tube to its proper position. However, do not correct its position with the set in operation.

Next 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, AC supply. The instrument is then ready for operation.

NOTE: DO NOT ATTEMPT TO OPERATE THE EQUIPMENT WHEN WITHDRAWN FROM THE CASE AS THE HIGH POTENTIALS USED ARE DANGEROUS.

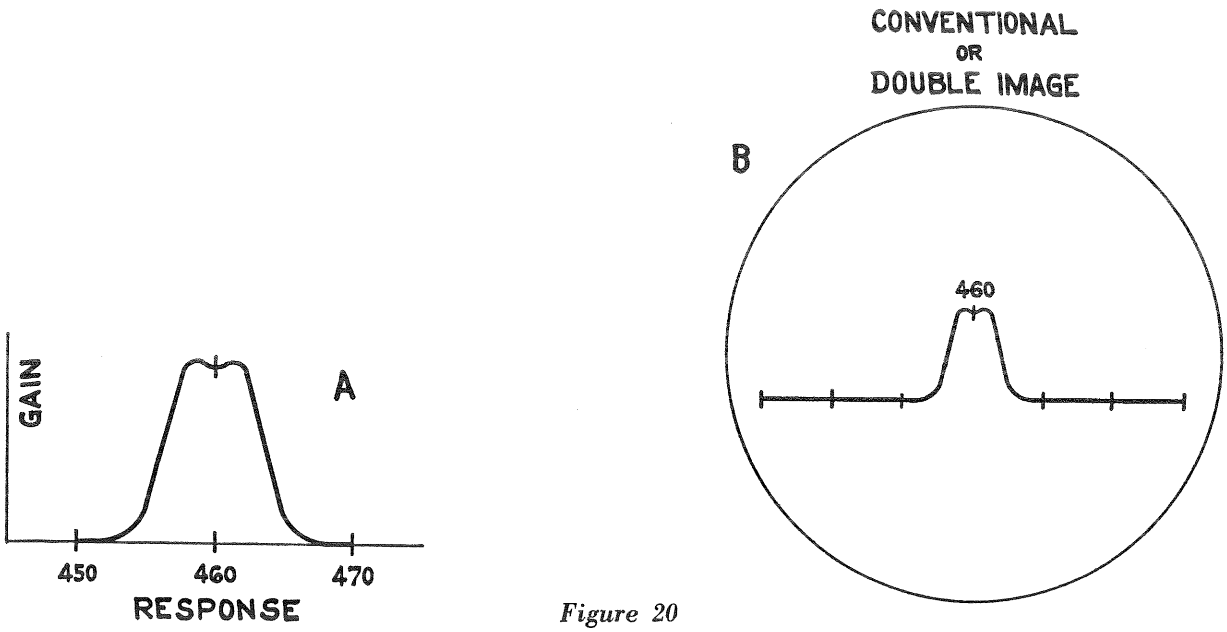


Figure 20

Operation

Controls

(Refer to the Schematic and Wiring Diagrams, Figures 21 and 22, for location of circuit units designated by symbols.)

1. "Intensity" control, R-23, is a potentiometer in the high side of the 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_4 is located on this potentiometer. Initial clockwise rotation of this control turns on the power; additional rotation increases the spot intensity.

2. "Focus" control, R-21, is a potentiometer in the 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. V" 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. H" switch, S_2, has two positions: "Timing" and "On." On "Timing" the "saw-tooth" or timing axis oscillator feeds through an amplifier to the horizontal deflecting plates on the cathode-ray tube and the "Horizontal" binding post is the synchronizing input terminal. When "On" the "Horizontal" binding post is connected through an amplifier to these deflecting plates.

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

6. "Ampl. H Gain" control, R_7, is a potentiometer on the input circuit of the horizontal amplifier. With "Amplifier H" switch on "Timing" or "On" this potentiometer controls the horizontal deflection. Due to the capacity load on this input potentiometer, when operating on "Timing" at the higher audio frequencies, linear sweep will not be obtained at all settings of this control.

7. "Range" switch, S_3, selects one of six timing capacitor values. It thus changes the timing axis oscillator frequency in steps giving six ranges approximately as follows: No. 1, 20-130; No. 2, 50-300; No. 3, 100-900; No. 4, 350-3,000; No. 5, 1,100-10,000, and No. 6, 3,000-12,000 cycles.

8. "Freq." control, R_{13}, 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.

9. "Sync." control, R_{11}, 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 counterclockwise as is consistent with a locked image, as oversynchronization causes poor wave-form from the timing axis oscillator.

10. "Centering V and H" are potentiometers to 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.

11. There are two pairs of binding posts labeled "Vert. High," "Gnd. 0," "Horiz. High," and "Sync. High." As indicated by the word "High" on the posts, the Vert., Horiz., and Sync. posts all connect to internal circuits, the only ground posts being marked "Gnd. 0." To connect to the vertical amplifier, connect to Vert. and Gnd. To connect to the horizontal amplifier, connect to Horiz. and Gnd. To connect to the synchronizing circuit, connect to Horiz. and Gnd. The Horiz. binding post is controlled by the "Amp.-H" switch so that when the switch is "On" the post connects to the amplifier input and when the switch is on "Timing" the post connects to the synchronizing circuit. The Sync. post carries a fraction of the amplified vertical voltage and is to be connected to the "Horiz." post whenever it is desired to synchronize on the signal being examined.

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 waveshape 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. 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 centering controls.

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. V" switch "On" and adjust "Ampl. V Gain" control until the length is as desired. Application of the same 60-cycle source to the "Horizontal" binding posts with "Ampl. H" switch "On" will similarly show a horizontal line on the screen, the length of which may be varied by manipulation of "Ampl. H Gain" control.

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

Apply the horizontal 60-cycle supply on the screen through "Ampl. H" and its gain control, then apply the 60-cycle vertical supply through "Ampl. V" and its gain control. The result will be a straight line. (See Figure 12.)

AC VOLTMETER WITHOUT AMPLIFIER—For this application, the characteristics of the unit are as follows: Input resistance—2 megohms; input capacity—approximately 40 mmf.; voltage range—85 r-m-s volts (higher with external attenuator); calibration—approximately 250 peak-to-peak volts per inch or 85 r-m-s volts per inch. Insulated for 200 volts d.c.

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 250. 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—1 megohm; input capacity—approximately 30 mmf.; frequency range—20-10,000 cycles; maximum voltage—500 volts (higher with external attenuator); calibration—(roughly) 5 peak-to-peak volts per inch, or 2 r-m-s volts per inch. Insulated for 100 volts d.c.

Procedure — Make connections and adjust controls according to Application No. 7 on the chart. With "Ampl. V Gain" control in the extreme clockwise position a line one inch long is obtained on the screen for about 2 volts r-m-s 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.

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. When the direct potential exceeds 100 volts it will be necessary to add a capacitor of .1 to .5 mfd. in series, and a 1 megohm leak across the input terminals, to prevent damage due to high direct potentials on the input condenser.

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.

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 synchronizing 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 "Horiz." binding post of the Oscillograph to transmitter audio amplifier at a point providing a 2–4-volt signal at low impedance. Turn controls to positions given in Application No. 9 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 to the grid of the RCA-885 tube. Adjustment of "Ampl. H 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, and 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. 10. Adjust "Ampl. H Gain" control until desired horizontal deflection is obtained. The percentage modulation can then be readily determined. (See Figure 18.)

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 "Horiz." binding post 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 No. 150 Oscillator takes the place of both of these units, performing all the necessary functions without moving parts.

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. V" switch "On" and adjust the gain control. Turn "Ampl. H" switch on "Timing." 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 "Horiz." binding post. Turn motor "On" 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. (This readjustment is necessary to compensate for the added capacity of the cable and one-half of the sweep condenser capacity when the TMV-97C Test Oscillator, TMV-128 Frequency Modulator are used. This whole preliminary adjustment is unnecessary with the No. 150 Frequency Modulated Oscillator.) 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.

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 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 1,000-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. When synchronizing on 60 cycles, the saw-tooth oscillator can be locked at 30 or 60 cycles, as desired. This allows accurate calibration at frequencies up to about 600 cycles. Refer to Application No. 13 on the chart.

CHECKING PHASE SHIFT—To check phase shift of a device with the Oscillograph, set controls as shown on Application No. 12 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.

Part IV
SERVICE DATA

Electrical Specifications

Power Supply Rating	Voltage	110–120 Volts AC
	Frequency (Stock No. 151)	50–60 Cycles
	(Stock No. 151A)	25–60 Cycles
	Wattage Consumption	35 Watts
	Fuse Protection	1 Amp.
Operating Limits	Deflection sensitivity at amplifier inputs	5 peak-to-peak volts per inch (max. "gain.") or 1.75 volts (RMS)
	Deflection sensitivity at cathode-ray tube inputs	250 peak-to-peak-volts per inch
	Input Characteristics:	
	(1) With amplifier	1 megohm, approximately 30 mmfd.
	(2) Without amplifier	2 megohms, approximately 40 mmfd.
	Frequency response range of amplifiers	20–15,000 Cycles
	Maximum signal input (with amplifier)	500 Volts (RMS)
	Frequency range of timing axis	30–10,000 Cycles
	Maximum d-c voltage across input binding posts.	100 Volts with amplifiers 200 Volts direct
Radiotrons Used and Functions	1 RCA-6C6	Signal amplifier for vertical deflection
	1 RCA-6C6	Signal amplifier for horizontal deflection
	1 RCA-885	"Saw-tooth" oscillator
	1 RCA-913	Cathode-ray tube (1-inch)
	1 RCA-80	Full-wave rectifier

Physical Specifications

Overall Dimensions	Height (including carrying-handle)	$9\frac{1}{4}$ inches
	Width	$13\frac{3}{4}$ inches
	Depth	$7\frac{3}{4}$ inches
Weight: 60 cycle		$14\frac{1}{2}$ pounds
25 cycle		16 pounds

Circuit Description

The schematic arrangement of the entire circuit is shown in Figure 21.

There is one usual feature to this circuit that causes surprising voltage distributions but doesn't affect the operating theory. Since the shell of the cathode-ray tube is connected to the second anode, which must be at a positive potential from the cathode, and since the shell must be grounded for safety, the positive side of the power supply has been connected to ground. This is common practice in Cathode-Ray Oscillographs, but in this case the power supply is common to the oscillograph and amplifier tubes, so the cathode, grid, suppressor and screen grids of the amplifiers are all at a high potential to ground and the plate is nearly at ground. It may be argued that no improvement has been made since the grid clips are at high voltage, but the grid clips cannot be reached when the equipment is in the case, and the resistance of the circuit is sufficiently high to limit the current to safe values at all but very low settings of the gain control.

While the voltage distribution, as shown in Figure 24 is quite unusual, the method of operating the amplifier tubes has not been affected. The grids are maintained about two volts negative from the cathode, the suppressor is connected to the cathode, the screen grid is about 35 volts positive from the cathode and the plate still more positive.

An amplifier consisting of a single RCA-6C6 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 d-c which may be associated

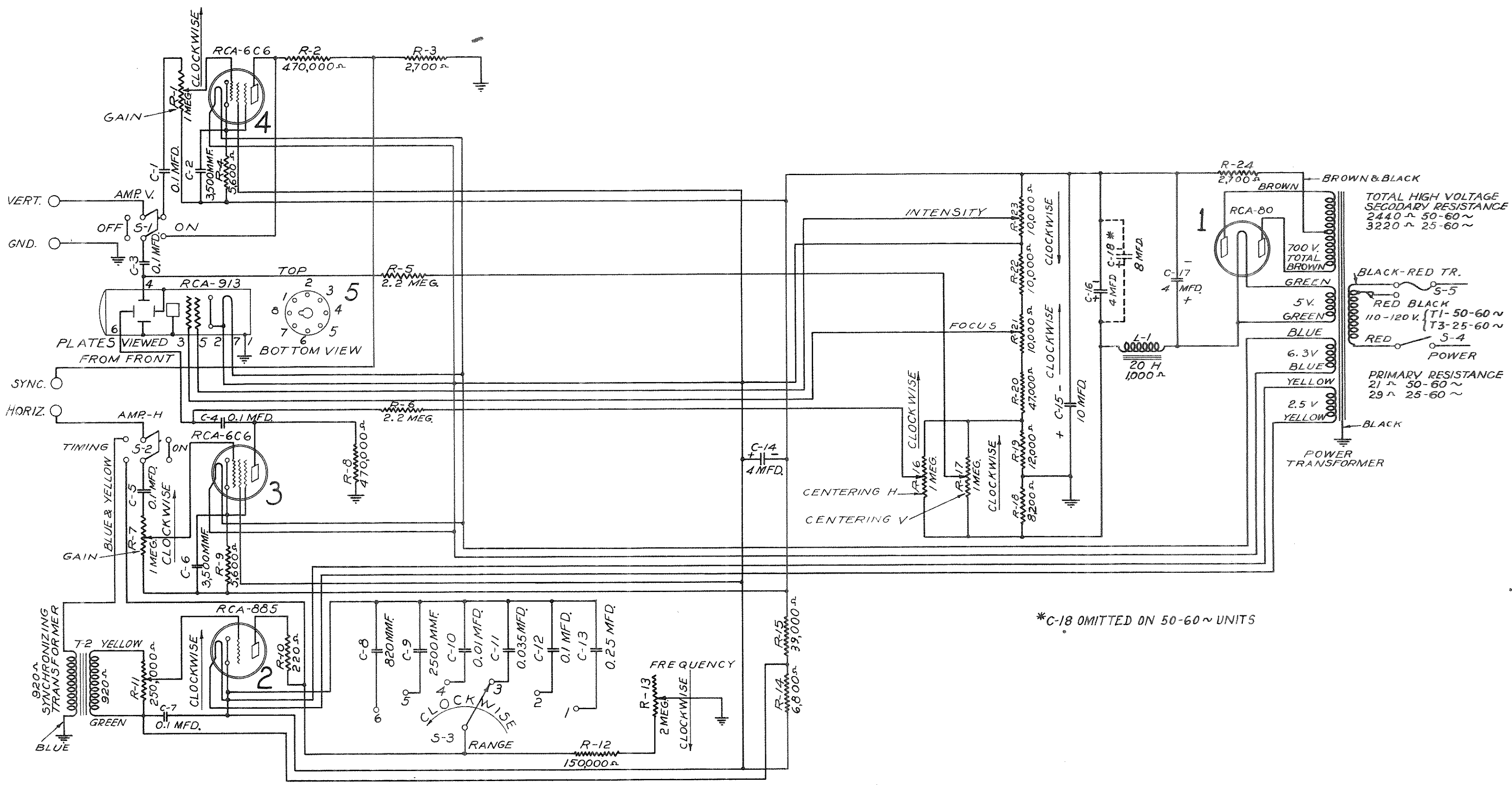


Figure 21—Schematic Diagram (Stock No. 151 and 151A) T-611032

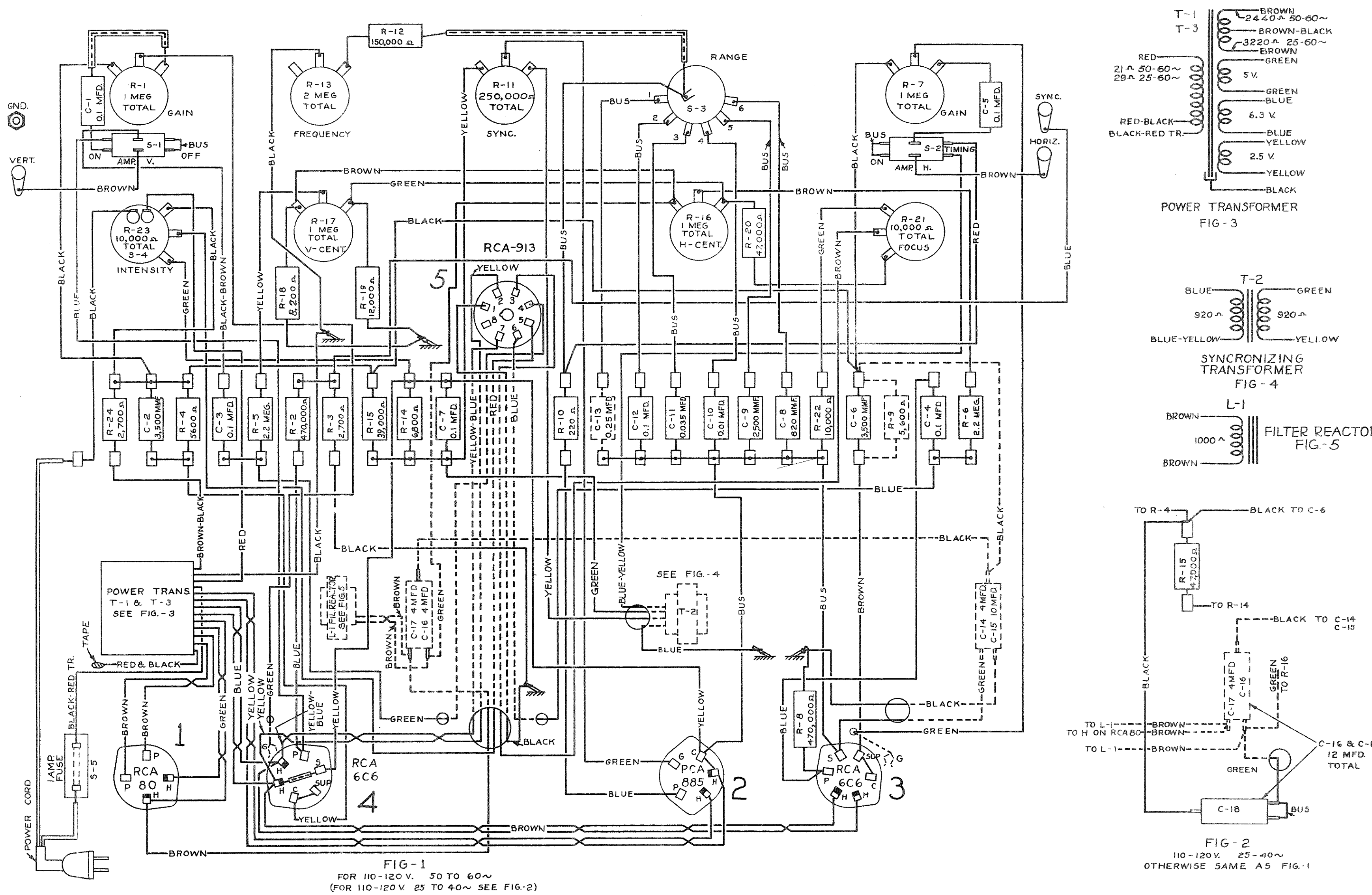


Figure 22—Connection Diagram (Stock No. 151 and 151A) T-611033

with the circuit being observed. The plate, or output circuit of the RCA-6C6 is a resistor whose value is 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. A switch is provided to disconnect the vertical amplifier, thereby applying the voltage to be studied directly to the deflecting plates. There is an 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" circuit described under "Operation." The timing axis oscillator stage, using the RCA-885, is designed to have a frequency range of 30-10,000 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 deionizes and allows the capacitor to start charging again. In this manner, the voltage across the capacitor has a "saw-tooth" characteristic. The capacitor referred to above is selected by the position of the "Range" switch as described in "Operation." With "Ampl. H" switch on "Timing," the voltage across this capacitor passes through the horizontal amplifier to the plates of the RCA-913.

Power required for operation of the instrument is obtained through the power unit from a 110–120-volt, AC supply. Voltage rectification is accomplished by an RCA-80 connected in the secondary windings of the power transformer.

Maintenance

(1) Radiotrons

Under ordinary usage within the ratings specified for voltage supply, tube life will be consistent with that obtained in other applications. The rectifier, oscillator, and amplifier tubes will wear in accordance with loss of emission; whereas the determining factor in the life of the RCA-913 cathode-ray tube is the deterioration of the fluorescent screen. It is therefore advisable to avoid leaving a bright, concentrated "spot" on the screen.

It is not ordinarily possible to test the Radiotrons in their respective sockets, due to the likelihood of circuit effects causing error. Their removal and check with standard tube-testing apparatus is therefore desirable. Replacement of the questionable tube with one known to be in good condition, is another acceptable and definite means of tracing tube troubles.

To remove the RCA-913, it is necessary to slide the tube toward the back of the chassis, then snap the tube out of its clip. Replacement is the reverse operation, sliding the tube into the panel opening.

(2) Fuse Replacements

A small 1-ampere cartridge fuse is used in the primary circuit of the power transformer. This fuse is intended for protection of the entire power system of the Oscillograph, and should, therefore, not be replaced by one having a higher rating, nor be shorted out. A fuse failure should be carefully investigated before making a replacement, as usually in the use of fuses of accepted quality, there must be a definite cause for the fuse breakdown. The cause may originate from a surge in the power-supply line, but the greater percentage of causes may be centered in the apparatus protected, such as shorted rectifier elements, and so forth.

(3) Resistance and Continuity Tests

The schematic circuit is shown in Figure 21, and the actual wiring layout giving color code and physical relation of the parts is shown in the chassis wiring diagram, Figure 22. All resistor and capacitor values are given to facilitate a rapid and sure test for continuity of circuit and the condition of same. Coils and transformer windings have their d-c resistances shown.

In working on the chassis of the Oscillograph, care must be observed to have the power supply completely disconnected. The high voltages associated with the circuits of the cathode-ray tube make it dangerous to attempt to handle or work on the chassis while the power is "On."

Care should be exercised in replacing any part that may be found faulty. All wiring associated with the part involved must be taken off, and especial attention given to possibility of damage to other wiring or parts. The relation of wiring and parts should be the same as in the original assembly.

RADIOTRON SOCKET VOLTAGE TABLE

120-Volt, Supply Line

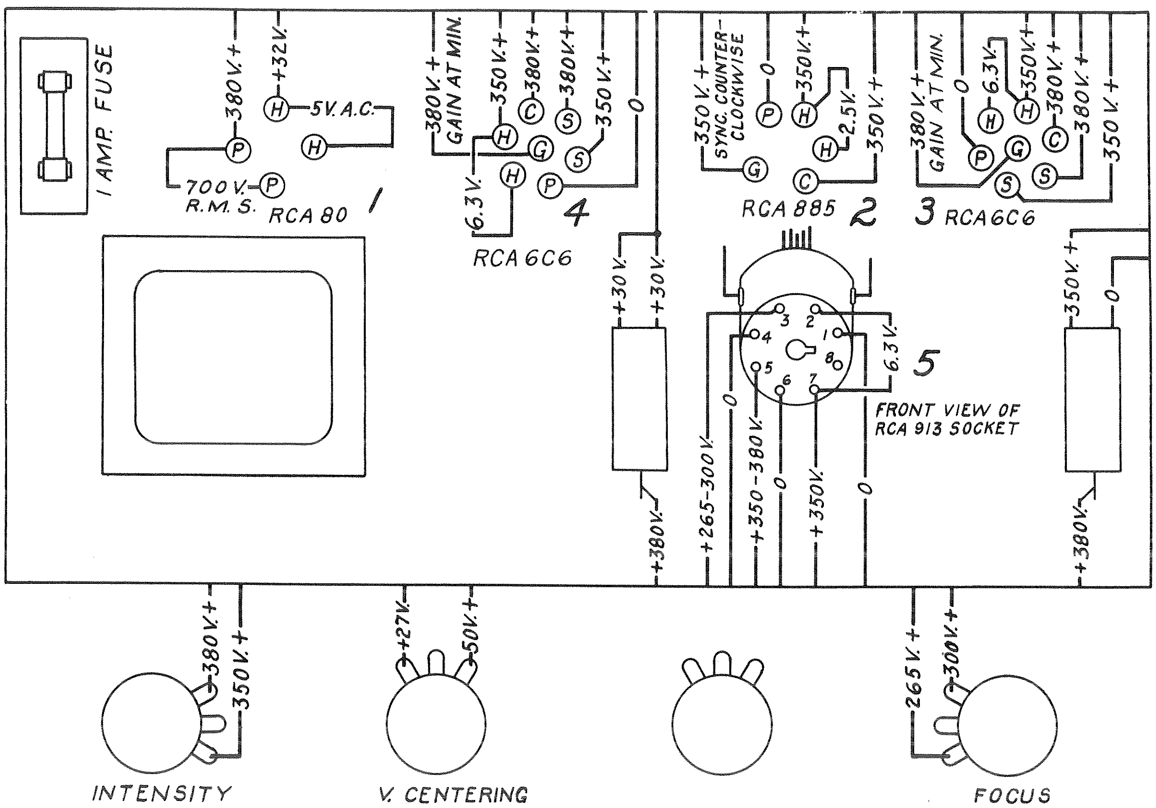
RADIOTRON			Cathode Volts to Ground DC.	Screen Grid Volts To Ground DC.	Plate Volts to Ground DC.	Cathode Current MA-DC.	Anode Volts to Ground DC.		Deflecting Plates to Ground DC.		Filament or Heater Volts AC.
Socket Number	Type	Function					No. 1	No. 2	D_1	D_3	
5	RCA-913	Cathode Ray	−350	—	—	.06	−265 to −300	O	+30 to −50*	+30 to −50*	6.3
1	RCA-80	Rectifier	+35	—	−380	6	—	—	—	—	5.0
3	RCA-6C6	20—15,000 Cycle Amp.	−380	−350	−150*	.3	—	—	—	—	6.3
4	RCA-6C6	20—15,000 Cycle Amp.	−380	−350	−150*	.3	—	—	—	—	6.3
2	RCA-885	30—10,000 Cycle Osc.	−350	—	−30	.2—2ma.	—	—	—	—	2.5

*** Cannot be correctly measured with ordinary voltmeter.**

Figure 23

(4) Voltage Measurements

One means of learning the condition of operation and tracing the circuit faults of the Oscillograph is by checking the correctness of the voltages and currents at the Radiotron sockets. The normal values, which can be expected to be found when the instrument is working properly under the specified power ratings, are indicated adjacent to the socket positions in Figure 24, and also given by the Radiotron Socket Voltage Table. In general, the values shown are measured from the socket contacts to ground; however, the heater or filament voltages are a-c and appear between the F-F or H-H clips. All readings given are actual operating values, and do not allow for any errors likely to be caused by current drain of the measuring instrument. Some of the voltages are not measurable with ordinary test equipment; these have been asterisked (*) in the table.



TOP VIEW

Figure 24—Radiotron Socket Voltage Diagram (Stock No. 151 and 151A)

CATHODE-RAY OSCILLOGRAPH

No. 151 and 151A

POSITION OF CONTROLS FOR VARIOUS APPLICATIONS

No.	APPLICATION OR DEMONSTRATION	SWITCH POSITIONS			CONTROLS						APPLIED VOLTAGES			REMARKS
		Ampl. V	Ampl. H	Range	Intensity	Focus	Ampl. V Gain	Ampl. H Gain	Freq.	Sync.	"Vert." Bdg. Post	"Horiz." Bdg. Post	"Sync." Bdg. Post	
1	FIRST OBTAINING SPOT	Off	*	*	First clock-wise rotation closes power switch Adjust for desired brilliancy of image Remember tube screen can be burned	Adjust for maximum concentration of electron beam (smallest line or spot) after setting for desired intensity	*	0	*	*	None	None	None	Do not burn screen; adjust the two beam centering control to center spot on screen.
2	LOCATING TUBE POSITION	Off	Timing	*			*	Set for line about ¾-in. long	*	*	None	None	None	Rotate cathode-ray tube so line is exactly horizontal.
3	APPLYING VERTICAL DEFLECTING VOLTAGE	On	*	*			Vary	0	*	*	60 cycle supply between 2 and 150 volts	None	None	Elementary Demonstration. Pre-liminary Adjust-ments
4	APPLYING HORIZONTAL DEFLECTING VOLTAGE	Off	On	*			0	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	
6	AC VOLTMETER WITHOUT AMPLIFIER	Off	*	*			*	*	*	*	Voltage to be measured	None	None	Set up is same for calibrating; use substitution method.
7	AC VOLTMETER WITH AMPLIFIER	On	*	*			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	Depends on freq. of observed audio			For desired amplitude	For desired spread	Depends on freq. of observed audio	Just enough to lock image	Voltage to be observed	Jumper to Sync.	Jumper to "Horiz."	Probably greatest application.
9	MEASURING PERCENTAGE OF MODULATION	Off	Timing	Depends on freq. of modulating audio			*	For desired spread	Depends on freq. of modulating audio	Just enough to lock image	RF Voltage to be observed	1 volt or more of audio from modulator	None	Wave-shape method.
10	MEASURING PERCENTAGE OF MODULATION	Off	On	*			*	For desired spread at 100% mod.	*	*	RF Voltage to be observed	2 volts or more of audio from the modulator	None	Trapezoid method.
11	"VISUAL" RF CURVE TRACING	On	Timing	Tap "1" or "2"			For desired amplitude	For desired spread	For double trace	Just enough to lock image	Audio output of chassis 2nd detector	Bdg. posts on Freq. Mod.	None	Output of oscillator impressed in grid circuit of tube preceding stage to be aligned. Center pattern with "Centering V."
12	CHECKING PHASE SHIFT OF AMPLIFIER	On	On	*			For desired vertical deflection	For desired horizontal deflection	*	*	2 volts or more of audio output of amp.	2 volts or more of audio input to amp.	None	
13	FREQUENCY MEASUREMENT	On	Timing or On	Depends on freq. desired			For desired vertical deflection	For desired horizontal deflection	Depends on frequency desired	Just enough to lock image	2 volts or more of signal freq. to be measured	1 volt or more of standard frequency	None	Saw-tooth oscillator in step at 1, ½, ⅓, etc. times standard frequency or use standard frequency direct.

*Denotes position immaterial.

IB-23357

REPLACEMENT PARTS

Insist on genuine factory tested parts, which are readily identified and may be purchased from authorized dealers.

Stock No.	Description		Stock No.	Description	
14118	Power Transformer—110-120 V., 50-60 cyc.	(T-1)	11726	Resistor—6800 Ohms, ¼ W.	(R-14)
14119	Synchronizing Transformer	(T-2)	11322	Resistor—¼ W., 39,000 Ohms	(R-15)
14139	Power Transformer—110-120 V., 25-60 cyc.	(T-3)	14250	Resistor—½ W., 8200 Ohms	(R-18)
6552	Filter Reactor	(L-1)	13915	Resistor—½ W., 12,000 Ohms	(R-19)
4839	Capacitor—0.1 Mfd. 400 V.	(C-1, C-5)	13596	Resistor—2 W., 47,000 Ohms	(R-20)
5005	Capacitor—0.0035 Mfd.	(C-2, C-6)	14126	Potentiometer—10,000 Ohms with Switch	(R-21, S-4)
4841	Capacitor—0.1 Mfd. 200 V.	(C-7, C-3, C-4)	3078	Resistor—½ W., 10,000 Ohms	(R-22)
12536	Capacitor—820 Mmfd.	(C-8)	14125	Potentiometer—10,000 Ohms	(R-23)
5107	Capacitor—0.0025 Mfd.	(C-9)	4750	Switch—D.P.D.T. Toggle	(S-1, S-2)
4858	Capacitor—0.01 Mfd.	(C-10)	14127	Switch—Single Gang 6 Position	(S-3)
5196	Capacitor—0.035 Mfd.	(C-11)	14133	Fuse—1 Amp.	(S-5)
11414	Capacitor—0.1 Mfd.	(C-12)	4794	Tube Socket—4 Prong	
5170	Capacitor—0.25 Mfd.	(C-13)	4814	Tube Socket—5 Prong	
14121	Bypass Condenser—4-10 Mfd.	(C14, C15)	4786	Tube Socket—6 Prong	
14120	Filter Condenser—4-4 Mfd. 475 V.	(C-18, C-16, C-17)	14128	Tube Plug—Octal Base	
14123	Potentiometer—1 Megohm	(R-1, R-7, R-16, R-17)	14129	Tube Support Bracket Ass'y	
11172	Resistor—¼ W., 470,000 Ohms	(R-2, R-8)	14130	Eye Piece	
5144	Resistor—¼ W., 2700 Ohms	(R-3, R-24)	14131	Eye Piece Base	
11647	Resistor—¼ W., 5600 Ohms	(R-4, R-9)	14137	Screen	
11626	Resistor—¼ W., 2.2 Megohms	(R-5, R-6)	4857	Binding Post (High)	
11174	Resistor—¼ W., 220 Ohms	(R-10)	4607	Binding Post (0)	
14124	Potentiometer—250,000 Ohms	(R-11)	7960	Bar Pointer Knob	
14132	Resistor—1 W., 150,000 Ohms	(R-12)	13210	Fuse Term.—Bd. Ass'y	
14122	Potentiometer—2 Megohms	(R-13)			