CATHODE-RAY TUBES
and ALLIED TYPES

TECHNICAL SERIES TS-2
PRICE TWENTY-FIVE CENTS

CATHODE-RAY TUBES

and

ALLIED TYPES

TECHNICAL SERIES

TS-2

Photolithographed in U.S.A.

RCA RADIOTRON DIVISION
RCA MANUFACTURING COMPANY, INC.
HARRISON, NEW JERSEY

Foreword

THIS BOOKLET provides technical information on the features and applications of listed RCA Cathode-Ray Tubes and allied types. In convenient reference size, it will be found helpful by everyone interested in the application of cathode-ray tubes.

The various cathode-ray tubes described in the following pages have been designed to meet the general requirements of oscillographic applications. These types, therefore, may not meet the specific requirements of certain special oscillographic applications. If you have a problem of this kind, we invite you to bring it to our attention.

Should you desire additional technical information on any of the tube types described in this booklet, we shall be glad to be of further service.

RCA RADIOTRON DIVISION

RCA MANUFACTURING COMPANY, INC.

Harrison, New Jersey

The sale of tubes described in this booklet carries a license for use in all fields other than communications for hire or toll, power, medical, therapeutic, railway signalling or commercial sound recording, but the sale of this device does not carry a license under patent claims on combinations of the device with other devices or elements as, for example, in various circuits and hook-ups except only for legitimate renewals and repairs in apparatus and systems already licensed for use under such patent claims on combinations.

Information contained in this booklet is furnished without assuming any obligations.

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CATHODE-RAY TUBES

and

ALLIED TYPES

Introduction

The rapid progress of the electronic art in the last few years is a matter of common knowledge. Radio tubes, of course, have received a major share of the public's attention, because of their numerous improvements, spectacular increase in types, and seemingly endless applications.

It is not so well known that cathode-ray tubes have made equally important advances. For many years, the cathode-ray tube has been known to possess unique properties making it indispensable for certain research investigations. Although its usefulness and versatility were recognized at an early date, the cathode-ray tube has not until recently acquired extensive use in the fields of applied engineering. This slow utilization by engineers of a device having such excellent theoretical possibilities has undoubtedly been due in part to the lack of rugged, reliable, and low-cost tubes.

Cathode-ray tubes have now reached a state of development such that the user can depend upon them for information previously obtainable only by more costly and more delicate apparatus. A modern, high-vacuum cathode-ray tube operated at easily obtainable voltages shows a clear, sharp trace even in a well-lighted room and is readily calibrated so that quantitative measurements can be made. It is easily applied to a wide variety of practical engineering uses.

The recent advances in high-vacuum cathode-ray tube design tend toward lower cost, longer tube life, more stable characteristics, and less complicated auxiliary equipment. These improvements have resulted in a real expansion in the every-day application of cathode-ray tubes. Cathode-ray oscillographic equipment is no longer confined to the laboratories of large universities and industrial plants, but is found in many amateur radio and broadcast stations, as well as in the laboratories of numerous schools, small industrial companies, and private experimenters.

General Theory

RCA Cathode-Ray Tubes are designed for use in oscillographic applications. In order that the operation of and the results obtained with the oscillograph can be better understood, a brief review of high-vacuum cathode-ray tube fundamentals may be of interest.

One arrangement of the electrodes in a high-vacuum cathode-ray tube is shown schematically in Figure 1. The tube is seen to possess the following attributes: a containing envelope (E) of glass for the purpose of maintaining a vacuum in the tube; a cathode (K) for

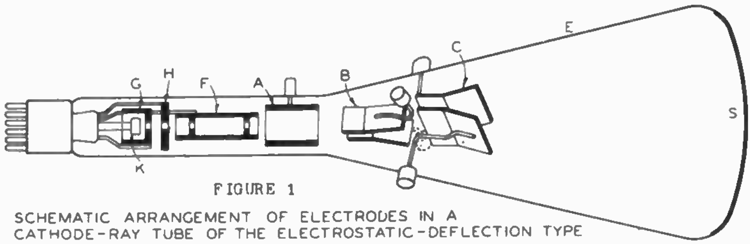


FIGURE 1

SCHEMATIC ARRANGEMENT OF ELECTRODES IN A CATHODE-RAY TUBE OF THE ELECTROSTATIC-DEFLECTION TYPE

the production of free electrons; an electrode (H) for accelerating the electrons; a focusing electrode (F), identified as *anode No.1*, for concentrating the electrons into a "cathode ray" or beam; a high-voltage anode (A), known as *anode No.2*, for further accelerating the electrons; a control electrode (G), referred to as *grid No.1*, for controlling the beam current; two sets of electrostatic deflecting plates (B) and (C), for deflecting the electron beam; and a screen (S) which is coated on the inner surface of the enlarged end of the bulb with a material which shows a fluorescent glow at the impact point of the electron beam. The electrodes K, G, H, F, and A are collectively called an *electron gun*, inasmuch as their function is to generate a beam of electrons and to direct it toward the viewing screen (S)

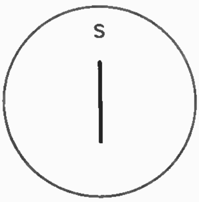


FIGURE 2a

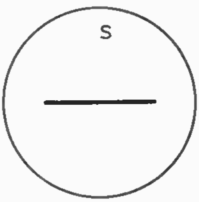


FIGURE 2b

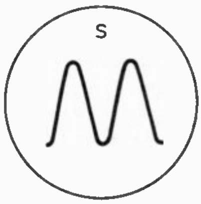


FIGURE 2c

Since the electron beam consists of rapidly moving electrons, it constitutes a current having both electromagnetic and electrostatic properties. Because no material conductor is required to carry the electrons, the beam has negligible mass and negligible inertia. Due to this inertialess characteristic, the electron beam can be deflected easily and rapidly by either electromagnetic or electrostatic fields. In the cathode-ray tube shown in Figure 1, the deflecting force produced by the phenomenon under investigation takes the form of an electrostatic field produced by a voltage applied across the deflecting plates (B). If this is an alternating voltage, the field produced causes the fluorescent spot viewed from the front of screen (S) to move up and down. This movement of the spot traces a vertical line, as in Figure 2a. A "time sweep" voltage of suitable wave form is applied across the deflecting plates (C), causing the beam to move back and forth horizontally, as in Figure 2b. The combined deflecting forces of the two fields may be caused to produce a pattern such as that in Figure 2c. The fluorescent pattern which the electron beam traces on the screen can be viewed (even in a well-lighted room), measured, and photographed.

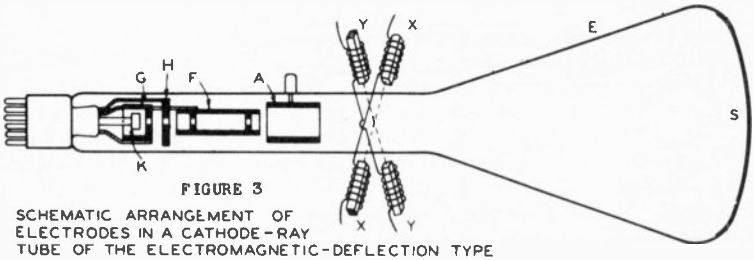


FIGURE 3

SCHEMATIC ARRANGEMENT OF ELECTRODES IN A CATHODE-RAY TUBE OF THE ELECTROMAGNETIC-DEFLECTION TYPE

Another type of cathode-ray tube is shown schematically in Figure 3. In this case, no electrostatic deflecting plates are employed. Deflection of the beam both horizontally and vertically is accomplished by means of two electromagnetic fields, produced by two pairs of coils, X and Y. In other respects, this type of tube functions essentially the same as the electrostatic-deflection type.

General Features of RCA Cathode-Ray Tubes

RCA Cathode-Ray Tubes are of the high-vacuum, hot-cathode type with fluorescent viewing screens of various sizes and characteristics, and are designed to meet the requirements of a wide variety of applications.

Deflection of the electron beam is accomplished by electromagnetic or by electrostatic means, or by a combination of both. Where electrostatic control is used, the tubes are designed with two sets of deflecting plates, as in the case of the 906. The 903 illustrates the type where only electromagnetic deflection is employed, while the 904, equipped with one set of deflecting plates, is of the electrostatic-magnetic type.

The *fluorescent screen* material used in some types (such as the 905 and 906) produces a brilliant, luminous spot which is easily visible even in a well-lighted room; this material is identified as *Phosphor No.1*. The 907 and 908 employ a different screen material, known as *Phosphor No.5*. This type of screen produces a highly actinic spot of short persistence, suitable for moving-film recording of the phenomena under observation. Either type of screen is suitable for the observation and photography of many recurrent and transient phenomena. RCA cathode-ray tubes are available with screen diameters of 3, 5, and 9 inches. Additional information on features of the fluorescent screens is given on page 88.

The *electron source* of each RCA cathode-ray tube is a substantial cathode, indirectly heated. The heater is operated at its rated voltage from a transformer winding without any special adjustments such as are sometimes used with other types of cathode-ray tubes. The cathode, control electrode, accelerating electrode (in types 903 and 904), focusing electrode, and high-voltage anode serve to generate and direct a beam of electrons toward the fluorescent screen. The resulting luminous spot can be regulated as to size and intensity by suitable choice of electrode voltages.

Cathode-Ray Tube Installation

The *base* pins of RCA cathode-ray tubes are designed to fit standard receiving tube sockets of the five-, six-, and seven-contact type, which may be installed to operate the tubes in any position The socket should be made of good insulating material and should be designed with adequate spacing between contact springs to prevent voltage breakdown. A socket constructed with insulating baffles between contacts provides an additional factor of safety. Some types, such as the 906 and 908, have all leads brought out to base pins. Other types, such as the 903 and 904, have some of the electrode leads brought out to caps on the bulb. Base and cap connections as well as essential dimensions are given under each tube type on its outline drawing.

The *bulb* of each tube type, except for the screen surface, should be enclosed in a grounded metal case. If an iron or steel case is employed to minimize the effect of extraneous fields on tube operation, care should be taken in its construction to insure that the metal is completely demagnetized.

The *heater* of each type is designed to operate at 2.5 volts. The transformer winding supplying the heater power should be designed to operate the heater at the rated voltage under average line-voltage conditions. IN THE USUAL CIRCUIT WHERE THE DESIGN IS SUCH AS TO CAUSE A HIGH POTENTIAL DIFFERENCE BETWEEN THE HEATER WINDING AND GROUND, THE HEATER WINDING SHOULD BE ADEQUATELY INSULATED TO WITHSTAND THE MAXIMUM HIGH VOLTAGE THAT WILL BE APPLIED.

The *cathode* of every type except the 903 and 904 is connected internally to one side of the heater. In the 903 and 904, the cathode is connected to the No.5 base terminal. The cathode socket terminal for these two types should be tied to one side or to the mid-tap of the heater winding. Grid and anode returns should be made to the cathode in each case.

The *fluorescent screen* material used in present RCA cathode-ray tubes is of two types, identified as *Phosphor No.1* and *Phosphor No.5*. For additional information on fluorescent screens, refer to pages 4 and 88.

Two sets of *deflecting plates*, in the electrostatic tube types, are placed in the bulb neck so as to produce two electrostatic fields at right angles to each other. In the 906 and 908, one plate of one set is tied to one plate of the other set and to anode No.2 within the tube. In order to maintain the free plate of each set at essentially the d-c potential of anode No.2, each free plate should be connected through a resistor of one to ten megohms to the No.2 anode socket terminal (usually grounded). This arrangement, when suitable resistor values are chosen, assists in preventing the pattern on the viewing screen from being distorted by d-c potentials built up on the deflecting plates. In general, the resistance of the deflecting-plate resistors should be as low as external circuit conditions will permit.

If the zero axis should be permanently deflected during operation, it is usually because the beam current is too high for the resistors used. The beam current should ordinarily be kept low. At times when it is necessary to use a high value, as when photographs are taken, the value of the deflecting-plate resistors should be reduced so that the zero-axis shift will not carry the spot off the viewing screen; if desired, the deflecting-plate resistors can be connected to a variable d-c bias voltage to compensate for the shift, or to provide a pattern-centering adjustment.

Other electrostatic types, such as the 904 and 905, have their deflecting plate and No.2 anode leads brought out to separate terminals. In such cases, each deflecting plate of each pair should ordinarily be connected to anode No.2 through resistors of one to ten megohms. Again, suitable choice of resistor values assists in preventing distortion of the pattern and in making the zero-axis shift negligible. However, a pattern-centering adjustment is frequently desirable, especially for patterns which are non-symmetrical about the zero axis.

The *deflection sensitivity* of the "top" pair of plates is somewhat less than that of the "bottom" set, since the sensitivity is a function of the distance of the plates from the fluorescent screen. The exact values for a particular tube type depend upon the No.2 anode voltage employed. Deflection sensitivity values, expressed in millimeters per volt, are given under CHARACTERISTICS for each electrostatic tube type.

Four *electromagnetic coils* for deflecting the electron beam in electromagnetic tube types, such as the 903, operate in pairs, the coils of each pair being placed diametrically opposite each other and as close as possible to the bulb-neck constriction. The fields produced by the two pairs of coils should give uniform flux density and the axis of each magnetic field should intersect the axis of the electron beam perpendicularly. The axis of one magnetic field is usually located so that it is perpendicular to the axis of the other. When the electromagnets employ an iron core to concentrate the magnetic flux, the core should close the external magnetic path.

The design of the magnetic coils will depend on the requirements of the application. A typical iron-core magnet design for the 903 is given in the drawing on page 29. The curve on this drawing shows the deflection sensitivity in millimeters deflection per ampere turn versus No.2 anode voltage. For additional information on electromagnetic deflecting systems, refer to page 108.

The *d-c supply voltages* for the electrodes may be conveniently obtained from a high-voltage, vacuum-tube rectifier. Since a cathode-ray tube requires very little current, the rectifier system can be of either the half-wave or voltage-doubler type. For the same reason, the filter requirements are small. A 0.5 to 2.0 µf filter condenser will ordinarily provide sufficient filtering. If this is inadequate for a particular application, a two-section filter is recommended.

When the metal parts of the cathode-ray gun are exposed to a strong magnetic field, they may, on rare occasions, retain a small amount of residual magnetism. If this occurs, the spot may appear somewhat blurred. To correct this condition, it is advisable to subject the magnetized parts to a strong but gradually decreasing a-c magnetic field.

THE HIGH VOLTAGES AT WHICH CATHODE-RAY TUBES ARE USED ARE DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF EQUIPMENT, TO GUARD THE OPERATOR FROM COMING IN CONTACT WITH THESE VOLTAGES. Precautions include the enclosure of high-potential terminals and the use of "interlock" switches to break the primary circuit of the high-voltage power supply when access to the apparatus is required. In most installations it is recommended that the positive high-voltage terminal be grounded, rather than the cathode terminal. With this method, which places the cathode and heater at a high negative potential with respect to ground, the dangerous voltages can more easily be made inaccessible.

In the use of cathode-ray tubes, it should always be remembered that high voltages may appear at normally low-potential points in the circuit, due to condenser breakdown or to incorrect circuit connections. Therefore, before any part of a cathode-ray tube circuit or its associated circuit is touched, the power-supply switch should be turned off and both terminals of any charged condensers grounded.

Cathode-Ray Tube Application

The cathode-ray oscillograph is an extremely versatile instrument which can be adapted to a wide variety of applications. A few of the more important are the study of wave shapes and transients, measurement of modulation and peak voltages, adjustment of radio receivers, comparison of frequencies, and the indication of balance in bridge circuits. It is not practical to list here all of the present known applications of the cathode-ray oscillograph. However, the material presented in this booklet should serve as a guide so that the user of oscillograph equipment can quickly obtain satisfactory results in the more important applications which are likely to be encountered. A thorough understanding of the cathode-ray oscillograph in connection with these applications will enable the ingenious engineer or experimenter to find numerous other uses to which the equipment can be advantageously applied.

An *oscillograph circuit* (employing the 906) is shown on page 50. The electrode voltages are obtained from a bleeder circuit connected across the high-voltage supply. A bleeder current of one or two milliamperes is usually satisfactory; considerably larger values may require the use of more filtering than that provided by a single condenser shunted across the d-c supply. With small bleeder currents, a single condenser filter is usually adequate. A variable d-c voltage for the control electrode and for anode No.1 can be obtained from potentiometers in the bleeder circuit. Some RCA cathode-ray tube types have an additional accelerating electrode; the d-c voltage for this electrode can be taken from a fixed tap on the voltage divider.

Focusing of the fluorescent spot produced by the beam is controlled by adjustment of the ratio of the voltages on anodes No.2 and No.1. The focusing is ordinarily accomplished by adjustment of the No.1 anode voltage.

Regulation of *spot size* and *intensity* can be accomplished by the variation of No.2 anode current and/or voltage. The current to anode No.2 may be increased by reducing the bias voltage applied to the control electrode (grid No.1). An increase in the No.2 anode current increases the size and intensity of the spot. An increase in the voltage applied to anode No.2 increases the speed of the electrons, which increases spot intensity and decreases spot size. When any of these adjustments are made, consideration should be given to the limiting voltage and power ratings shown in the tabulated data under each tube type.

In applications involving *extremely accurate measurements*, the No.2 anode current should be reduced to the minimum value consistent with the desired brilliance of pattern. Where high brightness is an important consideration, the No.2 anode voltage may be increased to the maximum rated value. This procedure, however, is not always desirable since the greater electron speed causes reduced deflection sensitivity.

RCA Cathode-Ray Tubes are designed to provide the greatest possible current in the electron beam consistent with good focusing qualities. This high-current capability is a distinct advantage for obtaining high brightness of patterns covering considerable area, but must be used with caution when the spot traverses slowly any portion of a large pattern or when the pattern size is small. In such cases, particularly when recurrent phenomena are involved, a pattern, or some portion of it, having too high a power input per unit area may exceed the rating of the screen. A *slowly-moving spot* is tentatively defined as a spot which is traveling slowly enough to be seen *as a spot*, rather than as a trace or line. With patterns of this type, the power input to the fluorescent screen should be calculated on the basis of a stationary spot.

It is important to note that the maximum input power to the fluorescent screen should not exceed 10 mw per sq cm, except for short-interval operation as explained in the paragraph on high-speed photographic work. The use of screen-input power in excess of this value will adversely affect the fluorescent coating, depending on the magnitude and the duration of the power input. The resultant injury to the screen may be a temporary loss of sensitivity, or a permanent destruction of the active screen material.

A high-intensity spot should be kept in motion by applying voltage to the deflecting system, in order not to exceed the maximum fluorescent-screen input rating. Until this voltage is applied, the fluorescent-screen input power should be kept low, either by applying a high negative control-electrode bias or removing the voltage from anode No.2.

Deflection of the electron beam may be accomplished by electrostatic or electromagnetic means, or by a combination of both, as explained under CATHODE-RAY TUBE INSTALLATION. In practice, one deflecting field is controlled by the phenomena under observation; the other may then be used to provide a suitable time sweep. The latter field serves to spread the tracing across the viewing screen.

Time-sweep circuits are of various types. The choice of circuit depends upon the type of phenomena under observation as well as upon the type of cathode-ray tube used. For recurrent phenomena, a periodic sweep with a repetition frequency adjustable to a simple multiple relation with the frequency of the phenomena is generally employed. For transient phenomena, a single sweep of the electron beam across the screen is ordinarily desirable; the starting of this sweep essentially coincident with the starting of the transient can be controlled manually, or automatically by electrical circuits, depending upon the application.

A means of synchronizing the time-sweep frequency with the frequency of recurrent phenomena is necessary if a stationary pattern is desired. One method of obtaining synchronization is explained on page 20. A mechanically-controlled sweep can be used when it is desired to synchronize the sweep with the movement of some mechanical device, such as a rotating condenser. An example of this type of sweep is given on page 107.

A sweep which is linear with respect to time (displacement proportional to time) is generally most useful. For some applications, it may be desirable or more convenient to use a non-linear sweep; this may be sinusoidal, logarithmic, or of some other relation with respect to time. The sweep can cortrol the electron beam either electromagnetically or electrostatically, depending upon the type of cathode-ray tube used. Data on linear sweep circuits for electrostatic deflection are given on pages 15-21. A system of obtaining current for electromagnetic timing is described on page 108. One convenient method of obtaining a non-linear time sweep which is suitable for some applications employs an a-c voltage of the desired peak value, obtained from the power line preferably by means of a separate transformer winding so as to isolate the control voltage.

A different method of timing involves the use of a recording film moving at a constant speed, or a system of mirrors rotating at a uniform velocity. Cathode-ray tubes such as the 907 and 908, which have a short-persistence (No.5 phosphor) screen, are especially designed for use with these latter timing systems. Blurring of the trace does not occur because of the extremely short after-glow or phosphorescence of the No.5 screen.

A *photographic record* of many types of phenomena can be made if desired. Such records may be helpful in the study of phenomena and are sometimes necessary for wave-analysis work. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86. Formulas and data, based on laboratory experiments, are given for several types of tubes. It should be noted that considerable variations in results can be expected, due to variations in tubes, emulsions, and technique.

RCA-878

HALF-WAVE HIGH-VACUUM RECTIFIER

The 878 is a high-vacuum, half-wave rectifier of the hot-cathode type for use in suitable rectifying systems to supply the d-c voltage requirements of cathode-ray tubes. Because of the high voltage and low-current demand of this service, a tungsten cathode of the filament type is employed.

CHARACTERISTICS

FILAMENT VOLTAGE (A.C.)	2.5	Volts
FILAMENT CURRENT	5.0	Amperes
A-C PLATE VOLTAGE (RMS)	7100 *max.*	Volts
PEAK INVERSE VOLTAGE	20000 *max.*	Volts
D-C OUTPUT CURRENT (Continuous)	5 *max.*	Milliamperes
BULB (For dimensions, see page 12)	T-14	
CAP (For connection, see page 12)	Medium Metal Skirted	
BASE (For connections, see page 12)	Medium 4-Pin	

INSTALLATION

The *base* pins of the 878 fit a standard, four-contact socket, which should be mounted to hold the tube in a vertical position with the base down. In order to provide additional filament-pin contact area, base pins No.1 and No.2 are connected together within the base; also, pins No.4 and No.3. A socket making firm, wiping contact with the base pins and capable of carrying five amperes continuously should be used. The plate connection is made to the cap on top of the bulb.

The *bulb* becomes hot during operation. Sufficient ventilation should be provided to prevent overheating.

The *filament* of the 878 is designed for operation at 2.5 volts. The transformer supplying the filament power should be designed to operate the filament at this rated value under average line-voltage conditions. *It is important that the filament winding be insulated to withstand the maximum peak inverse voltage encountered in the installation.*

The *plate supply* is obtained from a high-voltage winding of a power transformer. This winding should be designed to deliver an a-c voltage not exceeding 7100 RMS volts under varying conditions of supply-line voltage. The positive high-voltage connection is made to one of the filament terminals at the socket. Variation of the d-c output voltage may be conveniently obtained by means of a rheostat in the primary of the plate transformer, provided the filament is supplied by a separate transformer.

The *maximum peak plate current* of the 878 is limited by the available emission from the filament. In normal operation, the peak current is practically independent of the size of the input filter condenser and is approximately 20 milliamperes.

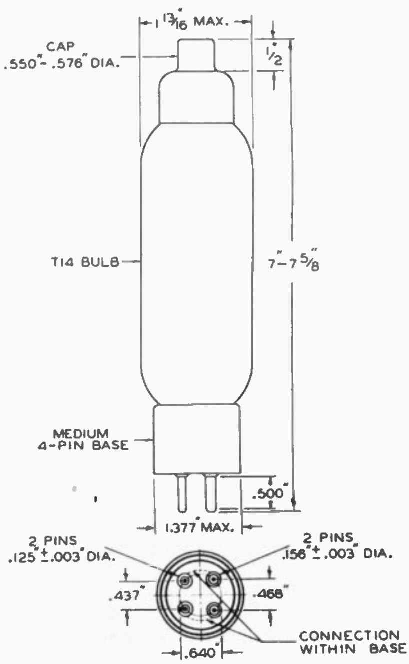
Filter requirements, due to the low-current demand of cathode-ray tubes, are usually met by the use of a single condenser (0.5 to 2.0 μf) shunted across the bleeder circuit. The voltage rating of the filter condenser should be large enough so that the condenser will withstand the instantaneous peak value of the a-c input voltage. If this filtering is inadequate for a particular application, a two-section filter is recommended.

THE HIGH VOLTAGES FOR WHICH THE 878 IS DESIGNED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS USING THIS TUBE SO THAT THE OPERATOR WILL NOT COME IN CONTACT WITH THESE HIGH VOLTAGES.

APPLICATION

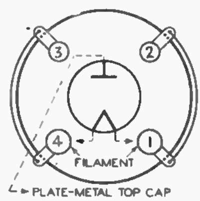
As a *half-wave rectifier* for supplying the high-voltage, d-c requirements of cathode-ray tubes, the 878 may be operated in conventional rectifier circuits under conditions not to exceed those given under CHARACTERISTICS.

In *voltage-doubler circuits*, two 878's will deliver approximately twice the voltage obtainable from the half-wave system for the same a-c input voltage. In this service, a separate filament-supply winding is required for each tube.



BOTTOM VIEW OF BASE

TUBE SYMBOL & TOP VIEW
OF
SOCKET CONNECTIONS



RCA-879

HALF-WAVE HIGH-VACUUM RECTIFIER

The 879 is a high-vacuum, half-wave rectifier of the hot-cathode type for use in suitable rectifying systems to supply the d-c voltage requirements of cathode-ray tubes.

TENTATIVE CHARACTERISTICS

FILAMENT VOLTAGE (A.C.)	2.5	Volts
FILAMENT CURRENT	1.75	Amperes
A-C PLATE VOLTAGE (RMS)	2650 *max.*	Volts
PEAK INVERSE VOLTAGE	7500 *max.*	Volts
PEAK PLATE CURRENT	100 *max.*	Milliamperes
D-C OUTPUT CURRENT (Continuous)	7.5 *max.*	Milliamperes
BULB (For dimensions, see page 14)	ST-12	
CAP (For connection, see page 14)	Small Metal	
BASE (For socket connections, see page 14)	Small 4-Pin	

INSTALLATION

The *base* pins of the 879 fit a standard, four-contact socket, which should be mounted to hold the tube preferably in a vertical position with the base down. The plate connection is made to the cap on top of the bulb.

The *bulb* becomes hot during operation. Sufficient ventilation should be provided to prevent overheating.

The *filament* of the 879 is of the coated type and is designed for operation at 2.5 volts. The transformer supplying the filament power should be designed to operate the filament at this rated value under average line-voltage conditions. *It is important that the filament transformer secondary be insulated to withstand the maximum peak inverse voltage encountered in the installation.*

The *plate supply* is obtained from a high-voltage winding of a power transformer. This winding should be designed to deliver an a-c voltage not exceeding 2650 RMS volts under varying conditions of supply-line voltage. The positive high-voltage connection is made to one of the filament terminals at the socket. Variation of the d-c output voltage may be conveniently obtained by means of a rheostat in the primary of the plate transformer, provided the filament is supplied by another transformer.

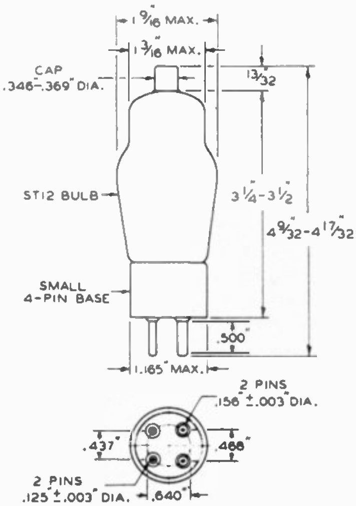
Filter requirements, due to the low-current demand of cathode-ray tubes, are usually met by the use of a single condenser (0.5 to 2.0 μf) shunted across the bleeder circuit. The voltage rating of the filter condenser should be large enough so that the condenser will withstand the instantaneous peak value of the a-c input voltage. If this filtering is inadequate for a particular application, a two-section filter is recommended.

THE HIGH VOLTAGES FOR WHICH THE 879 IS DESIGNED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS USING THIS TUBE SO THAT THE OPERATOR WILL NOT COME IN CONTACT WITH THESE HIGH VOLTAGES.

APPLICATION

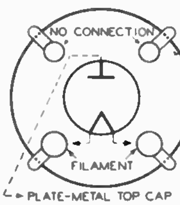
As a *half-wave rectifier* for supplying the high-voltage d-c requirements of cathode-ray tubes, the 879 may be operated in conventional rectifier circuits under conditions not to exceed those given under CHARACTERISTICS.

In *voltage-doubler circuits*, two 879's will deliver approximately twice the voltage obtainable from the half-wave system for the same a-c input voltage. In this service, a separate filament supply winding is required for each tube.



BOTTOM VIEW OF BASE

TUBE SYMBOL & TOP VIEW
OF
SOCKET CONNECTIONS



RCA-885
GAS-TRIODE

The 885 is a grid-controlled, gaseous-discharge tube of the heater-cathode type. It is designed for use as a sweep-circuit oscillator in cathode-ray tube circuits.

Operation of the 885 as a sweep-circuit oscillator is made possible by the feature that a negative voltage on the grid either maintains plate-current cut-off or promptly loses control, depending on the value of the plate voltage. After grid control is lost, it can be restored only (except in very special cases) by reducing the plate voltage below the ionization potential of the gas in the tube. This action can be controlled by means of a condenser shunted across the plate circuit and charged through a current-limiting device (see circuit, page 23). When the plate voltage reaches breakdown potential, the condenser discharges through the tube, the plate voltage drops, the grid resumes control, and a new cycle starts. The shape of the waves produced in this manner resembles the teeth of a saw. This form of wave for sweep-circuit control of cathode-ray tubes permits a quick recovery of the beam to the starting position and keeps dim the fluorescent pattern of the return sweep so that it may not be perceptible. The 885 is characterized by its extremely low de-ionization time, its corresponding practicability for high-frequency operation, and its stability in sweep-circuit oscillator service.

GAS-TRIODE AND SWEEP-CIRCUIT OSCILLATOR CONSIDERATIONS

The function of the grid in the 885 is to control the starting of plate current. For a given grid voltage, there is a particular plate voltage at which the discharge will just occur. Once the discharge has been set up, it cannot be further influenced by the grid (except in very special cases), but it may be stopped by reducing the plate potential below the ionization potential of the gas in the tube. The ratio of the plate voltage which will just cause "breakdown" and permit current discharge, to the grid voltage at which this action occurs is called the "grid control ratio." Fig. 10 shows the break-down potentials at various control-grid bias values. The grid control ratio calculated from this curve averages about 10.

Since the rate of de-ionization is extremely rapid, a drop in plate voltage below the ionization potential causes prompt current cut-off. This is a desirable characteristic of this tube for use in sweep circuits, because it makes practical its operation at unusually high frequencies for a gaseous type of tube. The voltage drop from plate to cathode when the tube is carrying current is between 10 and 20 volts.

In the study of electrical wave forms, a plot of the magnitude of the wave with respect to time is frequently useful. Such a plot or pattern can conveniently be made for recurrent waves by means of a time-sweep circuit using a type 885 tube in conjunction with a cathode-ray tube. This is done by means of two fields which deflect the electron beam. One field is varied according to the magnitude of the wave at any instant; the other field, placed at right angles to the first, is controlled by a varying voltage representing time. The deflection representing time must start at some pre-determined point on the fluorescent screen of the cathode-ray tube, travel across the screen at a uniform rate, and return to begin a new cycle. Since the return period of the beam is not of special interest, is usually non-uniform, and superimposes a second and interfering wave-form on the screen, it should be made as small a proportion of the total sweep-cycle as possible. A return sweep having a relatively short duration makes an almost invisible trace on the viewing screen of a cathode-ray tube. It is an additional convenience to have the sweep-cycle synchronized with the wave-form under observation. These requirements are adequately realized by the use of the 885 in a relaxation-oscillator circuit to provide the time-sweep voltage.

SIMPLE SWEEP-CIRCUIT OSCILLATOR
WITH CURRENT-LIMITING RESISTOR

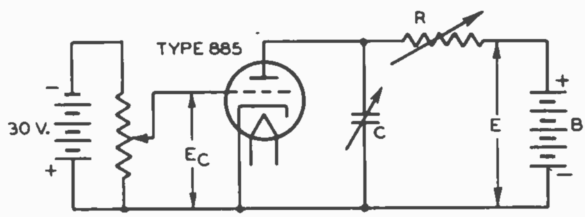


FIGURE 4

A simple sweep-circuit oscillator is shown in Fig. 4. Condenser (C) is charged by battery (B) through resistance (R). The grid-bias voltage (E_C) prevents current flow through the tube until the voltage across the condenser and plate circuit reaches the breakdown value. At this point, the condenser discharges through the tube and loses its potential. As soon as the condenser voltage drops below the ionization potential of the tube, the negative grid attracts any positive ions to itself and drives any electrons to the other tube elements, thus de-ionizing the space between cathode and plate. During the de-ionization period, the discharge current ceases to flow, the grid resumes control, and the condenser starts to recharge for a new cycle.

A simple sweep-circuit oscillator using a resistor to limit charging rate does not give a linear time sweep unless the sweep voltage is limited to about 5 per cent of the supply voltage. The current flow to the condenser at any instant is

$$i = \frac{E}{R} (\varepsilon^{-\frac{t}{RC}})$$

where E is supply volts, R is resistance in ohms, C is capacity in farads, t is interval in seconds after the circuit is closed, and ε is base of matural logarithms. The voltage across the condenser at any instant is

$$e = E\left(1 - \varepsilon^{-\frac{t}{RC}}\right)$$

The exponential charging curve starts linearly so that if e/E is less than 0.05, a linear sweep can be obtained. To obtain a linear time sweep with a supply voltage only slightly greater than the desired sweep voltage, it is necessary to replace the resistor (R) of Fig.4 by a device which will limit the current flow to a constant rate. Methods for limiting current flow may employ an emission-saturated diode, a tetrode, or a pentode. The use of either a tetrode or a pentode is preferable since the diode may not have a definite saturation current. A pentode as compared with a tetrode supplies uniform current over a larger voltage-charging range. Fig.7 illustrates the use of a pentode as a current-limiting device. The resistance (R_1) connected in series with the plate of the 885 is used to limit the peak current during discharge to a safe value for the tube. Ordinarily, this resistor does not appreciably increase the discharge period.

The time required to charge C_1, C_2, C_3, or C_4 of Fig.7 to any voltage (V) is VC/I, where I is a uniform charging rate in amperes. The number of sweeps or sawtooth pulses per second is then I/VC. This expression neglects the time required for discharge, a factor of importance only at very high frequencies, and hence can be used to calculate sweep frequency without appreciable error for the low-frequency ranges. The relationship between sawtooth pulses per second and C/I for several peak condenser voltages (peak sawtooth voltages) is shown graphically in Fig.9. It should be remembered that C represents the total capacitance of the circuit and includes tube as well as wiring capacitances. The size of the condenser employed for any operating condition will, therefore, be smaller than the values taken from Fig.9.

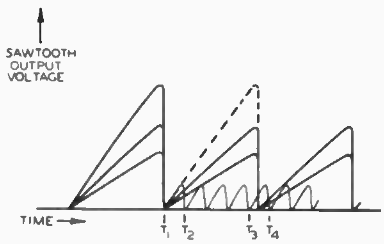


FIGURE 5

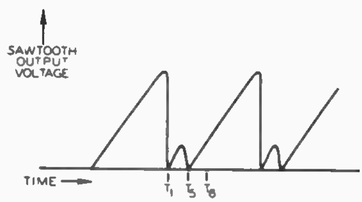


FIGURE 6

For any peak sawtooth voltage, the time required for de-ionization sets a definite maximum limit to the frequency obtainable. Fig. 5 indicates the wave form at several peak values of sawtooth wave for constant frequency. De-ionization starts at T_1 and continues to T_2. If the condenser charging rate is excessive, the output voltage will rise above the value required to start a discharge before de-ionization is completed. This high voltage causes a new flow of current so that the tube continues to oscillate at a higher frequency having a period of T_3 to T_4. Under conditions of small over-voltage prior to complete de-ionization of the tube, action as illustrated in Fig.6 is possible. The higher-frequency oscillation starts but is not maintained because discharge energy and ionization at T_5 are less than at T_1. Thus, de-ionization is completed at T_6 before the output voltage rises sufficiently to cause a new current flow.

For stable operation, condenser (C) must not be too small. This statement depends on the requirement that, for a definite frequency and peak sawtooth voltage, charging current decreases with condenser size. Since any leakage currents, such as residual ionization current (at high frequencies) in the 885 and that due to shunt resistances in the circuit, may be an appreciable percentage of the charging current for small values of the latter, some distortion of the time-sweep wave with resulting non-linearity may occur with charging currents that are too low. Fig.8 shows for the 885 the maximum peak sawtooth voltage obtainable at any frequency for different values of condenser charging current. These curves should be used in conjunction with those of Fig.9 and Fig.10.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	1.4	Amperes
GRID-PLATE CAPACITANCE	3.5	μμf
GRID-CATHODE CAPACITANCE	3.5	μμf
PLATE-CATHODE CAPACITANCE	2.5	μμf
TUBE VOLTAGE DROP (Approx.)	16	Volts
MAXIMUM OVERALL LENGTH	4-1/4"	
MAXIMUM DIAMETER	1-9/16"	
BULB	ST-12	
BASE	Small 5-Pin	

As a Sweep-Circuit Oscillator

HEATER VOLTAGE	2.5	Volts
PLATE VOLTAGE (Instantaneous)	300 *max.*	Volts
PEAK VOLTAGE BETWEEN ANY TWO ELECTRODES	350 *max.*	Volts
PEAK PLATE CURRENT	300 *max.*	Milliamperes
AVERAGE PLATE CURRENT:		
For Frequencies below 200 Cycles per Second	3 *max.*	Milliamperes
For Frequencies above 200 Cycles per Second	2 *max.*	Milliamperes

GRID RESISTOR:
Should be not less than 1000 ohms per maximum instantaneous volt applied to the grid. Resistance values in excess of 500000 ohms may cause circuit instability.

As a Grid-Controlled Rectifier
For Frequencies below 75 Cycles per Second

HEATER VOLTAGE *	2.5	Volts
PEAK VOLTAGE BETWEEN ANY TWO ELECTRODES	350 *max.*	Volts
PEAK PLATE CURRENT	300 *max.*	Milliamperes
AVERAGE PLATE CURRENT **	75 *max.*	Milliamperes

GRID RESISTOR:
Should be not less than 1000 ohms per maximum instantaneous volt applied to the grid. Resistance values in excess of 500000 ohms may cause circuit instability.

* Should be applied 30 seconds before plate load current flows.
** Averaged over period of not more than 30 seconds.

INSTALLATION

The *base* pins of the 885 fit a standard, five-contact socket, which may be mounted to hold the tube in any position.

The *bulb* becomes hot during operation. Althcugh sufficient ventilation should be provided to prevent overheating, operation of this tube is not critical to changes in bulb temperature.

The *heater* of the 885 is designed for operation at 2.5 volts. The transformer winding supplying the heater power should be designed to operate the heater at the rated voltage under average line-voltage conditions.

The *cathode* should preferably be connected directly to the mid-tap of the heater winding. In circuits where the cathode and heater are not connected directly, the heater may be made negative with respect to the cathode by not more than 100 volts, provided the peak voltage between any electrode and the heater does not exceed 350 volts. It is recommended that the heater never be made positive with respect to the cathode. If the use of a large resistor is necessary between heater and cathode, the resistor should be by-passed by a suitable filter network or objectionable variation of the time-sweep wave may result.

APPLICATION

As a *sweep-circuit oscillator*, the 885 should be operated under conditions which do not exceed the maximum values given under CHARACTERISTICS.

Since the average plate current through the 885 is limited to the values shown in the tabulated data, the constant charging current to the condenser C_1, C_2, etc. (in circuit on page 22) is also limited to the same values. The condenser should be kept as small as practical, consistent with the desired freedom from distortion, in order to keep the average plate current of the 885 low.

The circuit shown on page 22 illustrates the use of a pentode as a current-limiting device to maintain a constant charging current to the condenser. A pentode provides exceptional sweep-uniformity for output voltages up to about 85 per cent of the supply voltage. The resistor (R_1) is employed to limit the discharge current to a safe value for the 885.

The sweep output voltage may be approximately doubled if R_1 is replaced by an inductance, but the frequency will be halved. The desired frequency, however, may be obtained by adjustment of the shunt capacity. The value of the inductance is not critical, but it must be large enough to limit the peak discharge current of the 885 to 300 ma. at the lowest operating frequency of each range. Too large an inductance interferes with high-frequency operation. Suitable minimum values of inductance for the corresponding capacitances are:

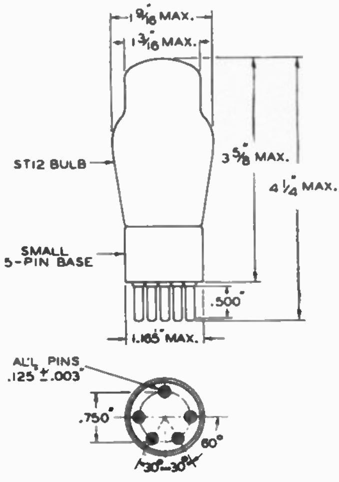
For C_1, L_1 = 100 Millihenries, Minimum
C_2, L_2 = 25 Millihenries, Minimum
C_3, L_3 = 5 Millihenries, Minimum
C_4, L_4 = 1 Millihenry, Minimum

For sweeps per second above approximately 20000, a condenser may not be necessary because the capacity of the 885 and its circuit is sufficient. Very high sweep rates may require the use of an amplifier to provide the desired deflection voltage. Coupling leads from the sweep circuit to the amplifier and from the amplifier to the cathode-ray tube should be placed so as to minimize capacity effects.

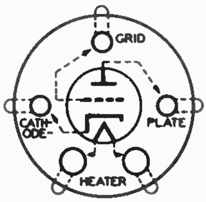
The usual procedure for the observation of recurrent phenomena is to operate the sweep-circuit oscillator at a submultiple of the observed frequency, so that several complete cycles will appear on the viewing screen. For example, a 100-cycle sweep voltage will show three complete cycles of a 300-cycle wave. Since the pattern will drift across the screen unless the ratio of observed frequency to sweep frequency remains constant at a definite value, it is usually desirable to synchronize the sweep-voltage oscillator. For synchronizing purposes, a voltage of a few volts a.c. (preferably adjustable from zero) is suitable. Any means of introducing this voltage into the grid circuit of the 885 is satisfactory, provided the total effective grid-circuit resistance to both alternating current and direct current is in accord with recommended grid-resistor values.

If transient phenomena are under observation, the sweep-voltage frequency is not critical and synchronizing is often of no advantage. In some cases, however, it is desirable to synchronize the starting of the phenomena with the sweep-voltage, which may involve only one sweep of the beam across the screen.

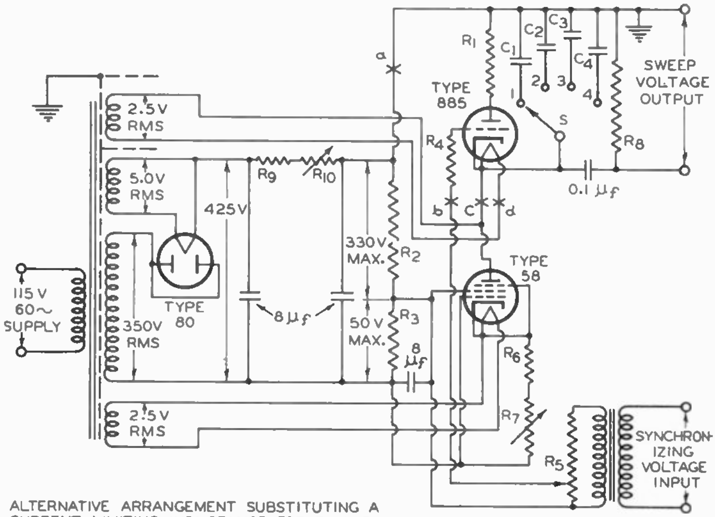
As a *grid-controlled rectifier,* the 885 may be used under conditions which do not exceed the maximum ratings given under CHARACTERISTICS.



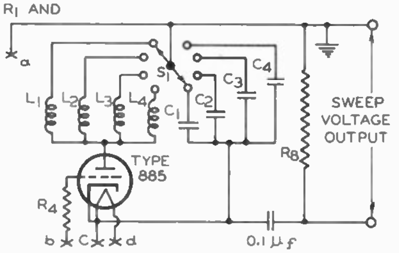
TUBE SYMBOL & TOP VIEW
OF
SOCKET CONNECTIONS



LINEAR SWEEP-CIRCUIT OSCILLATOR DIAGRAM WITH CURRENT-LIMITING PENTODE (A-C OPERATED)



ALTERNATIVE ARRANGEMENT SUBSTITUTING A CURRENT-LIMITING INDUCTANCE FOR R_1 AND PROVIDING AUTOMATIC SELECTION OF PROPER INDUCTANCE FOR EACH CONDENSER SETTING



R_1 = 1000-OHM RESISTOR TO LIMIT PLATE DISCHARGE CURRENT OF TYPE 885 TO SAFE VALUE

R_2 = 38000-OHM RESISTOR TO GIVE VOLTAGE DROP OF 330 VOLTS MAXIMUM

R_3 = 6000-OHM RESISTOR TO GIVE VOLTAGE DROP OF 50 VOLTS

R_4 = 300000-OHM GRID-CURRENT-LIMITING RESISTOR

R_5 = 10000-OHM POTENTIOMETER

R_6 = 1500-OHM RESISTOR

R_7 = 50000-OHM VARIABLE RESISTOR, WITHOUT BY-PASS CONDENSER, FOR FREQUENCY CONTROL

R_8 = 10-MEGOHM RESISTOR

R_9 = 7500-OHM RESISTOR

R_{10} = 0 TO 50000-OHM VARIABLE RESISTOR FOR SWEEP AMPLITUDE CONTROL

S = FREQUENCY-RANGE SWITCH

S_1 = FREQUENCY-RANGE SWITCH PROVIDING FOR SELECTION OF PROPER INDUCTANCE

$\left.\begin{array}{l} C_1 = 0.1\ \mu f \\ C_2 = 0.025\ \mu f \\ C_3 = 0.005\ \mu f \\ C_4 = 0.001\ \mu f \end{array}\right\}$ CONDENSERS TO PROVIDE SEVERAL FREQUENCY RANGES:

SWITCH S ON	1	2	3	4
CYCLES RANGE	12 TO 60	50 TO 250	240 TO 1200	1000 TO 5000

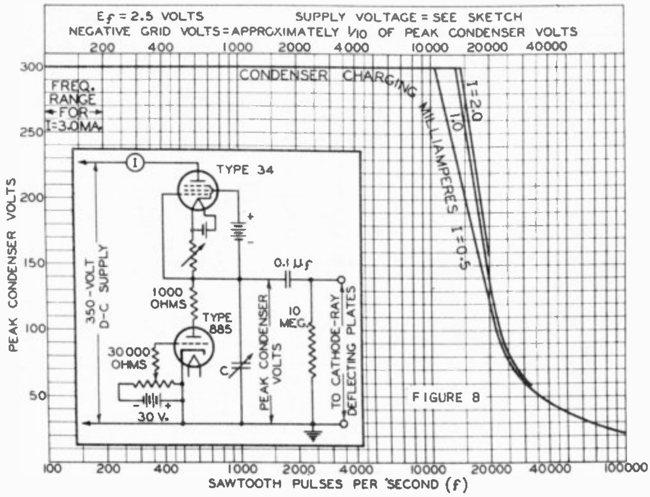
WITH SMALLER CONDENSERS AND WITH CARE IN CIRCUIT LAYOUT AND WIRING, THE OPERATING RANGE MAY BE EXTENDED TO HIGHER FREQUENCIES

NOTE: SWEEP OUTPUT VOLTAGE MAY BE APPROXIMATELY DOUBLED IF R_1 IS REPLACED BY AN INDUCTANCE, BUT THE FREQUENCY WILL BE CUT IN HALF. THE DESIRED FREQUENCY, HOWEVER, MAY BE OBTAINED BY ADJUSTING CONDENSER VALUE. THE VALUE OF INDUCTANCE IS NOT CRITICAL BUT MUST BE LARGE ENOUGH TO LIMIT THE PEAK DISCHARGE CURRENT OF TYPE 885 TO 300 MA. AT THE LOWEST OPERATING FREQUENCY OF EACH RANGE. TOO LARGE AN INDUCTANCE INTERFERES WITH HIGH-FREQUENCY OPERATION. SUITABLE MINIMUM VALUES OF INDUCTANCE FOR THE CORRESPONDING CAPACITANCES ARE:

FOR C_1, L_1 = 100 MH. MINIMUM
C_2, L_2 = 25 MH. "
C_3, L_3 = 5 MH. "
C_4, L_4 = 1 MH. "

FIGURE 7

OPERATING CHARACTERISTICS



<u>FOR A 0.5 MILLIAMPERE CHARGING CURRENT</u>, SWEEP VOLTAGES MAY BE OBTAINED BETWEEN ESSENTIALLY 0 AND 300 VOLTS FOR A FREQUENCY RANGE UP TO ABOUT 10000 CYCLES. AT HIGHER FREQUENCIES, THE MAXIMUM OBTAINABLE SWEEP VOLTAGE FALLS OFF AS SHOWN ON THE CURVE.

<u>FOR A 1.0 MILLIAMPERE CHARGING CURRENT</u>, SWEEP VOLTAGES MAY BE OBTAINED BETWEEN ESSENTIALLY 50 AND 300 VOLTS FOR A FREQUENCY RANGE UP TO ABOUT 15000 CYCLES. BETWEEN 5000 AND 30000 CYCLES, IT IS ADVISABLE TO OPERATE TOWARD THE UPPER VOLTAGE BOUNDARY OF THE CURVE FOR BEST RESULTS.

<u>FOR A 2.0 MILLIAMPERE CHARGING CURRENT</u>, SWEEP VOLTAGES MAY BE OBTAINED BETWEEN ESSENTIALLY 150 AND 300 VOLTS FOR A FREQUENCY RANGE UP TO ABOUT 2500 CYCLES. BETWEEN 2500 AND 20000 CYCLES, IT IS ADVISABLE TO OPERATE TOWARD THE UPPER VOLTAGE BOUNDARY OF THE CURVE FOR BEST RESULTS.

<u>FOR A 3.0 MILLIAMPERE CHARGING CURRENT AND A MAXIMUM RANGE OF 0 TO 200 CYCLES</u>, IT IS ADVISABLE TO OPERATE WITH A 300-VOLT SWEEP VOLTAGE.

APPROX. CHARGING-CONDENSER VALUES (μf) VS. SAWTOOTH-PULSE FREQUENCIES (f)
FOR SWEEP VOLTAGE OF 300 VOLTS AND INDICATED CONDENSER-CHARGING CURRENTS

f(cycles)	I = 0.5 Ma.	I = 1.0 Ma.	I = 1.5 Ma.	I = 2.0 Ma.
100	0.015	0.033	0.05	0.065
500	0.003	0.0065	0.01	0.013
1000	0.0015	0.0033	0.005	0.0065
5000	0.0003	0.0006	0.001	0.0013
10000	Variable	Variable	0.0003	0.0004

FOR HIGHER FREQUENCIES, A VARIABLE CONDENSER IS RECOMMENDED SO THAT INDIVIDUAL ADJUSTMENT CAN BE MADE TO MEET REQUIREMENTS. AT HIGH FREQUENCIES, THE DISTRIBUTED CAPACITY OF THE CIRCUIT SHUNTS AN APPRECIABLE CAPACITY ACROSS THE CHARGING CONDENSER. IT IS NECESSARY, THEREFORE, TO KEEP DISTRIBUTED CAPACITY TO A MINIMUM. PRACTICAL MINIMUM VALUES OF DISTRIBUTED CAPACITY ARE BETWEEN 100 AND 200 μμf.

DESIGN CONSIDERATIONS
FOR SWEEP-CIRCUIT OSCILLATORS

NOTE 1: C VALUES ARE TOTAL FOR CIRCUIT.
NOTE 2: C SHOULD BE MADE AS SMALL AS PRACTICAL CONSISTENT WITH FREEDOM FROM TIMING VARIATIONS.
NOTE 3: THESE CALCULATED CURVES NEGLECT THE EFFECT ON SWEEP FREQUENCY OF THE RETURN INTERVAL. THIS EFFECT IS IMPORTANT ONLY AT VERY HIGH FREQUENCIES WHERE A C/I RATIO SOMEWHAT LOWER THAN SHOWN WILL APPLY.

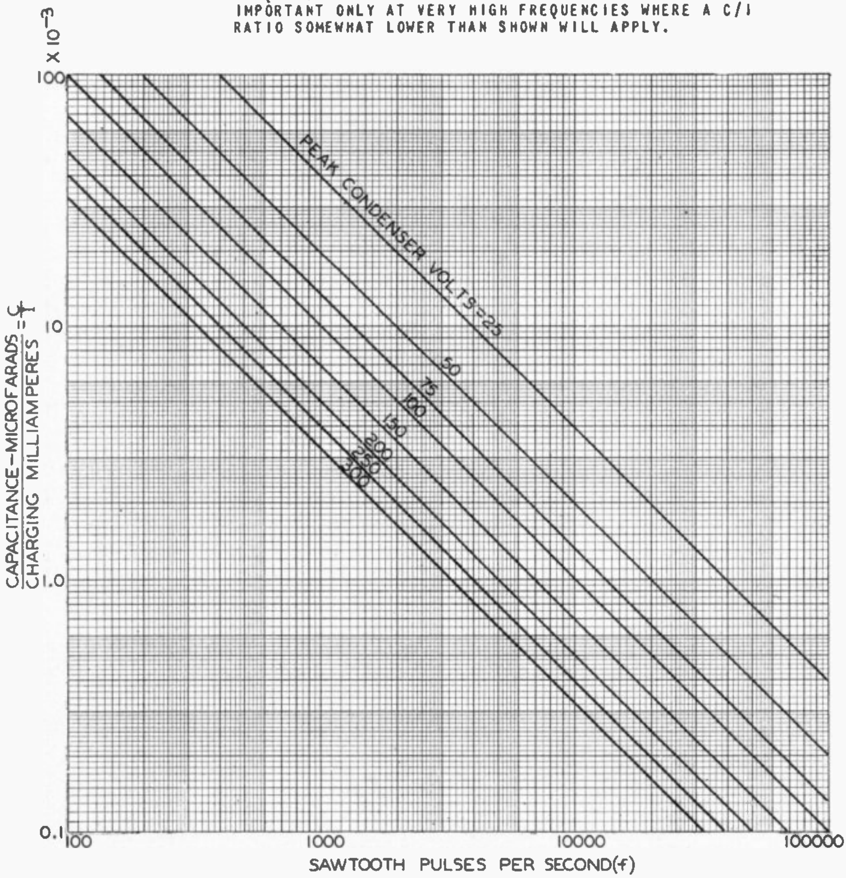


FIGURE 9

885

AVERAGE CONTROL CHARACTERISTICS

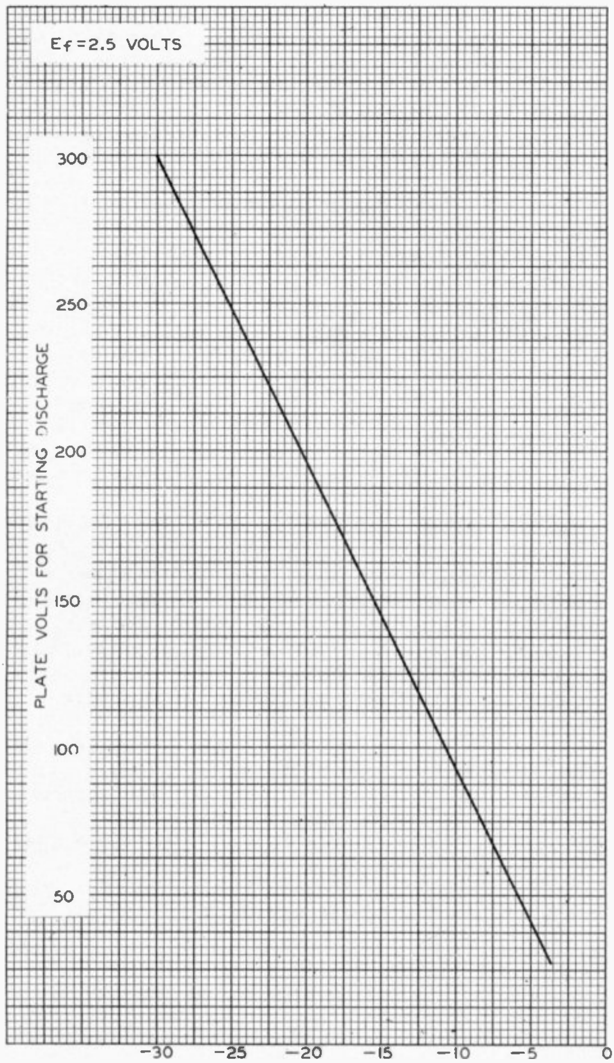


FIGURE 10

RCA-903

CATHODE-RAY TUBE

High-Vacuum Electromagnetic Type

The 903 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen nine inches in diameter. This tube, designed for oscillographic applications, provides for electromagnetic deflection of the electron beam. An accelerating electrode (grid No.2) gives additional control of the beam. The 903 produces a brilliant, luminous spot having a greenish hue, and is suitable for the observation and photography of recurrent and transient phenomena.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No.1	
DIRECT INTERELECTRODE CAPACITANCE:		
Control Electrode to All Other Electrodes	12 *max.*	μμf
OVERALL LENGTH	20-3/8" ± 3/8"	
MAXIMUM DIAMETER	9-1/8"	
BULB	J-72	
CAP	Medium Metal	
BASE (Refer to page 28)	Medium 6-Pin	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE				7000 *max.*	Volts
FOCUSING-ELECTRODE (Anode No.1) VOLTAGE				2000 *max.*	Volts
ACCELERATING ELECTRODE (Grid No.2) VOLTAGE				250 *max.*	Volts
CONTROL ELECTRODE (Grid No.1) VOLTAGE				Never Positive	
NO.1 GRID VOLTAGE FOR CURRENT CUT-OFF *				-120 *approx.*	Volts
FLUORESCENT-SCREEN INPUT POWER PER SQ CM				10 *max.*	Milliwatts
TYPICAL OPERATION:					
Heater Voltage	2.5	2.5	2.5	2.5	Volts
No.2 Anode Voltage	1000	3000	4600	7000	Volts
No.1 Anode Voltage	195	580	900	1360 *approx.*	Volts
No.2 Grid Voltage	100	250	250	250	Volts
No.1 Grid Voltage	Adjusted to Give a Suitable Luminous Spot				

* With 250 volts (approx.) on Grid No.2.

INSTALLATION

The *base* pins of the 903 fit a standard, 0.75-inch pin-circle diameter, six-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base connections and essential dimensions of the 903 are given on page 28. Connection to anode No.2 is made to the cap on the bulb cone.

For *bulb shielding, heater operation, and d-c voltage supply,* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6.

The *cathode* should be connected directly to one side or to the mid-tap of the heater winding. Grid and anode returns should be made to the cathode.

The *fluorescent screen* employed in the 903 is of the No. 1 phosphor (medium persistence) type. For the characteristics of this screen, refer to page 4.

Four *electromagnetic coils* used in pairs for deflecting the electron beam are placed at the constriction of the bulb neck. The coils of each pair, located diametrically opposite each other, should produce a field of uniform flux density for the deflection of the beam. The axes of the two fields ordinarily intersect at right angles in the axis of the electron beam and should be perpendicular to it.

The design of the magnetic coils will depend on the requirements of the application. The curve on page 29 shows the deflection sensitivity in millimeters deflection per ampere turn versus No. 2 anode voltage, for a typical iron-core magnet design.

THE HIGH VOLTAGES AT WHICH THE 903 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 29 illustrates the essential circuit for the use of the 903 in an oscillograph. One magnetic field is controlled by the current under observation, amplified if necessary; the other field is controlled by an alternating current which gives the desired timing action. A typical method of obtaining an amplified current for electromagnetic deflection is discussed on page 108.

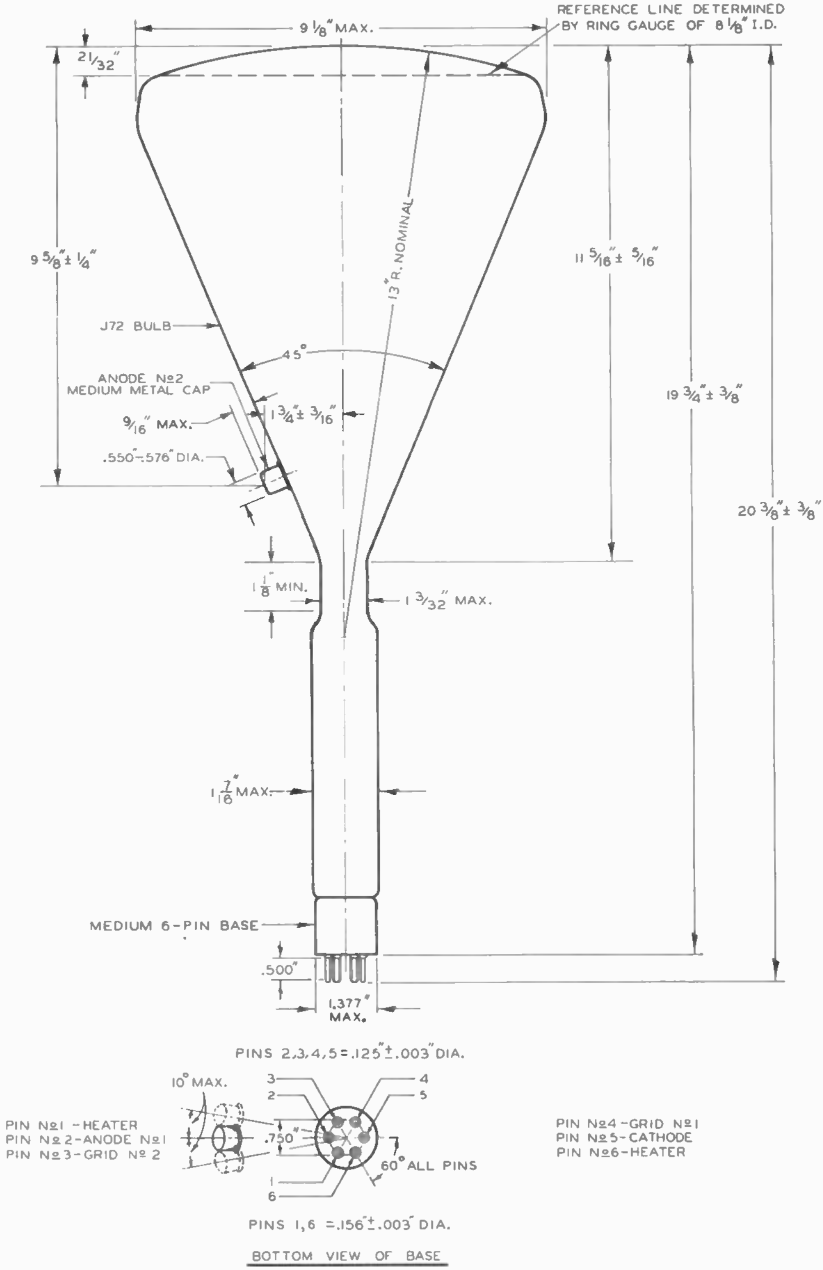
A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of current to one pair of deflecting magnets or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLICATION. Other details on the application of the 903 are also included in that section.

A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

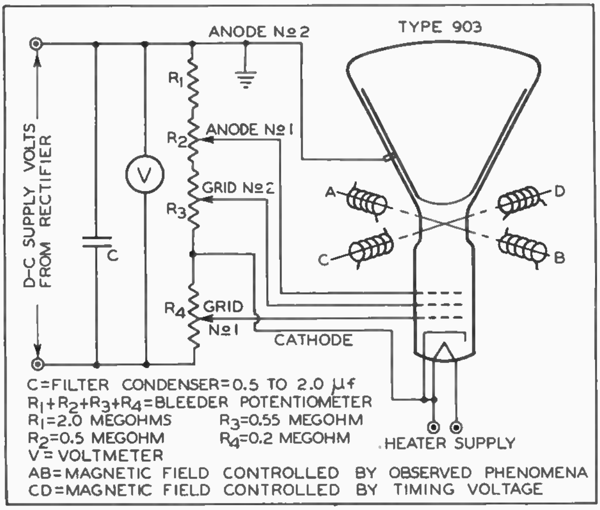
903

OUTLINE DRAWING

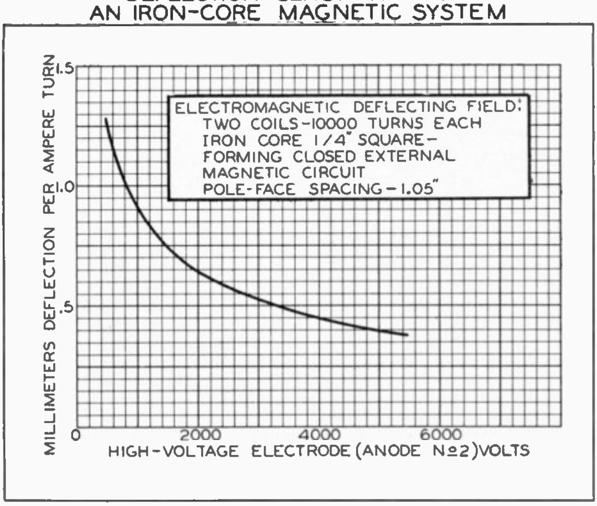


903

TYPICAL OSCILLOGRAPH CIRCUIT

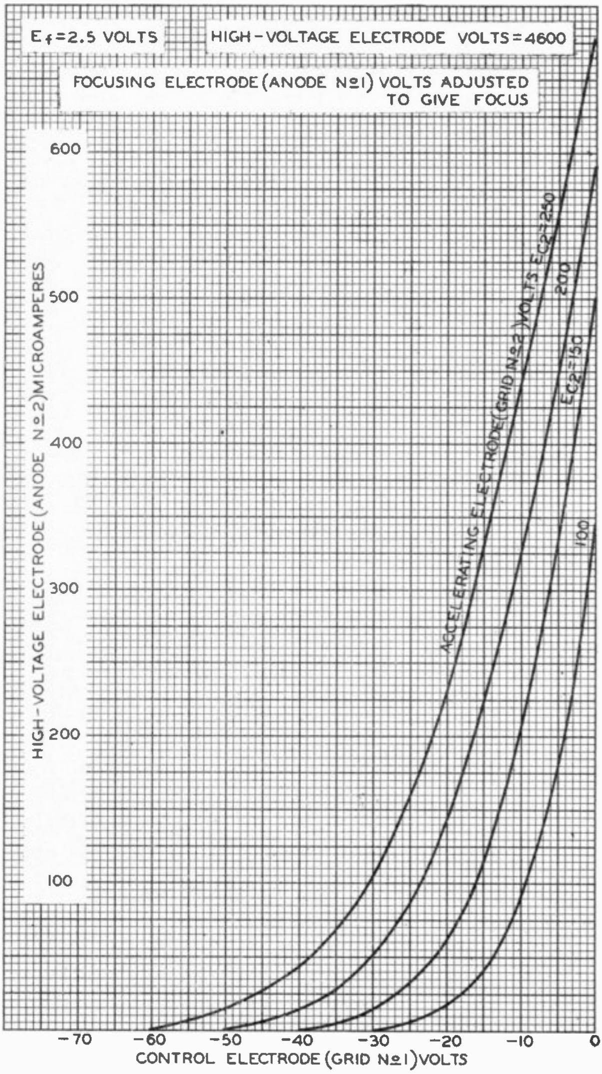


DEFLECTION SENSITIVITY OF AN IRON-CORE MAGNETIC SYSTEM



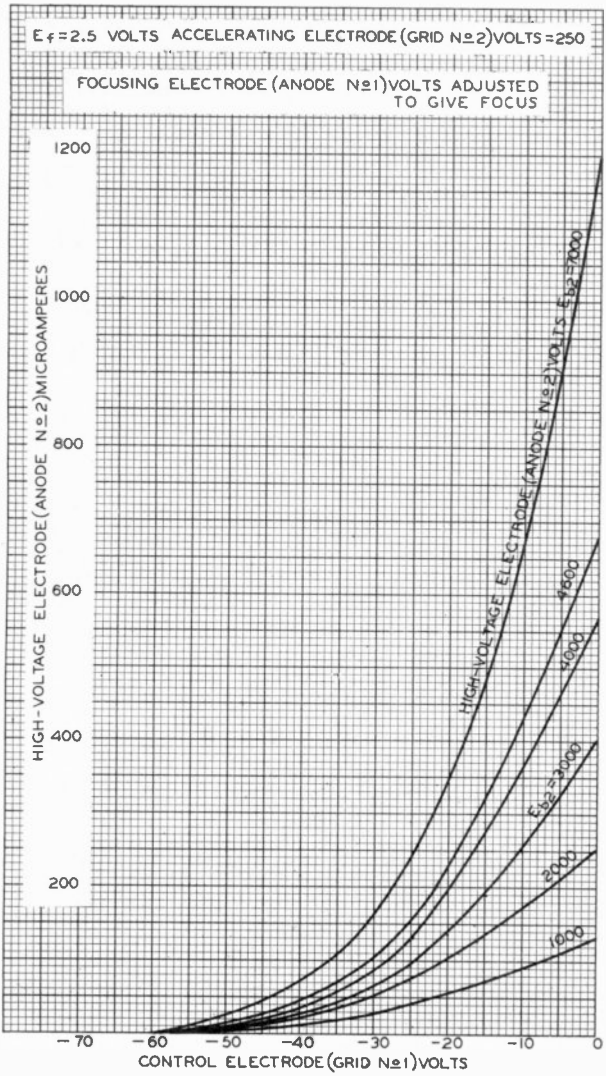
903

AVERAGE CHARACTERISTICS



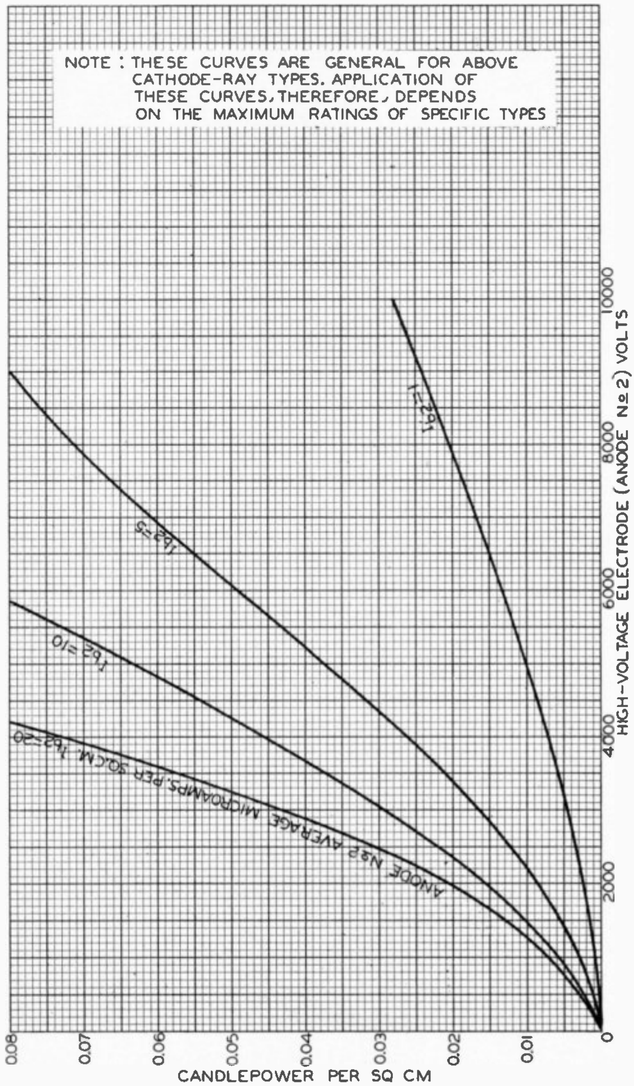
903

AVERAGE CHARACTERISTICS



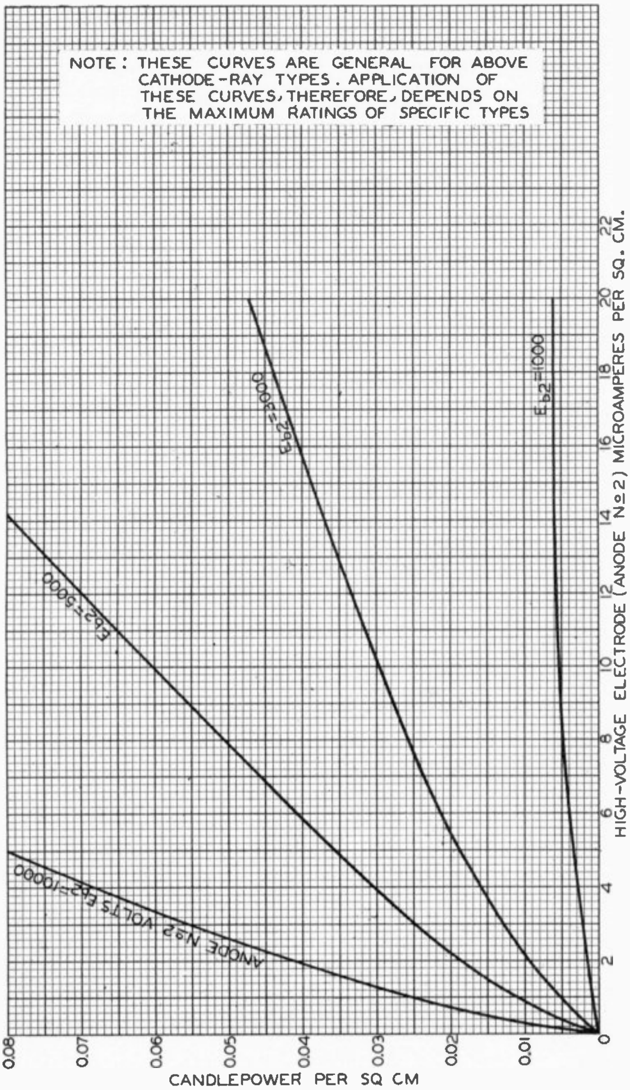
TYPES: 903, 904, 905, 906

AVERAGE FLUORESCENT-SCREEN CHARACTERISTICS



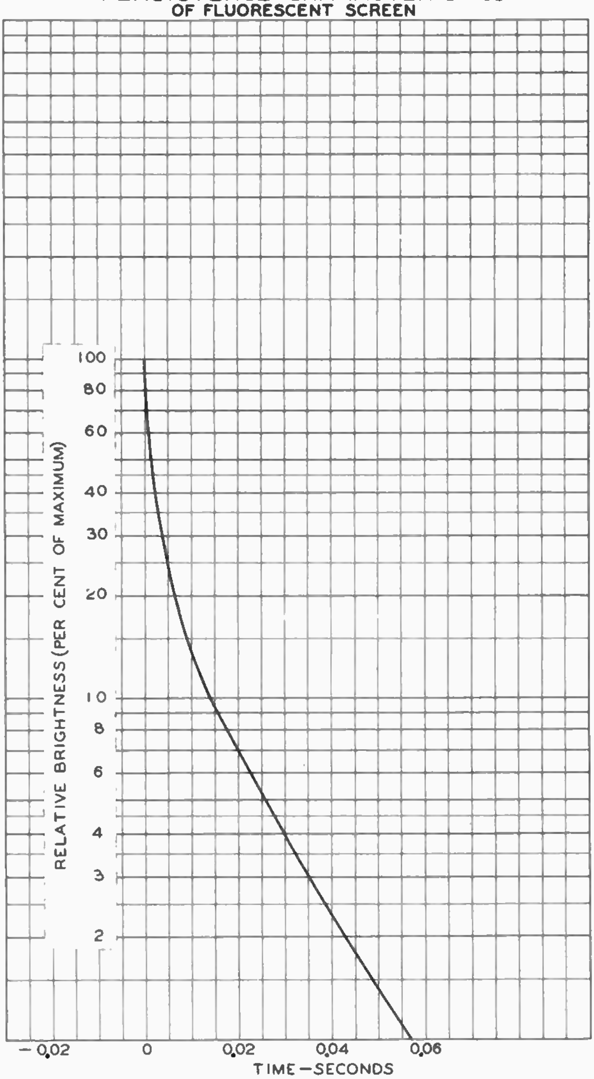
TYPES: 903, 904, 905, 906

AVERAGE FLUORESCENT-SCREEN CHARACTERISTICS



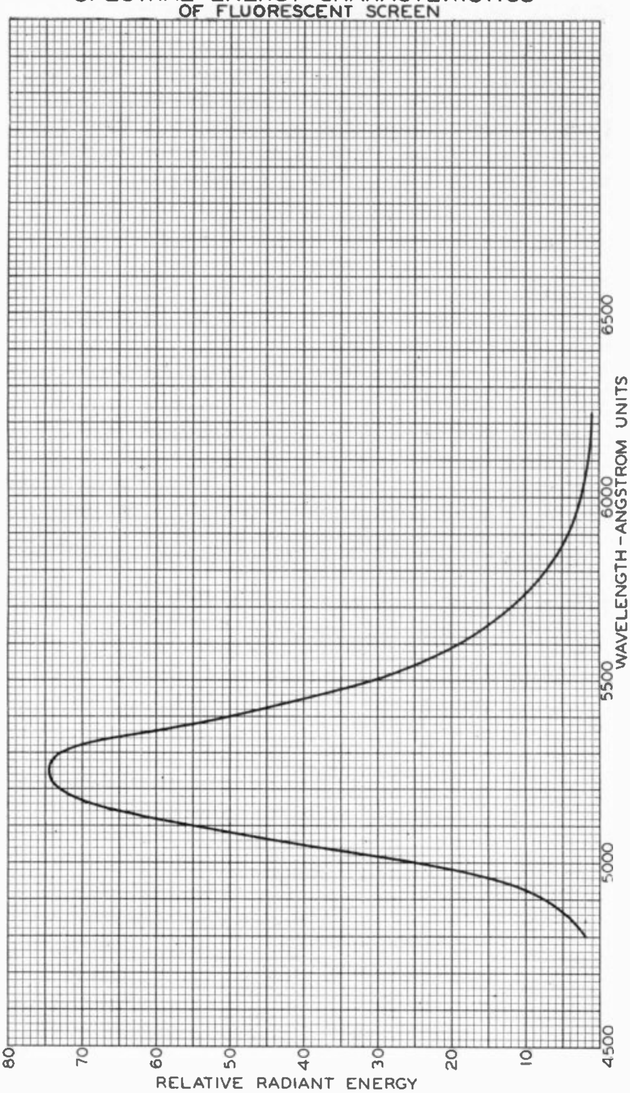
TYPES: 903, 904, 905, 906

PERSISTENCE CHARACTERISTICS
OF FLUORESCENT SCREEN



TYPES: 903, 904, 905, 906

SPECTRAL ENERGY CHARACTERISTICS
OF FLUORESCENT SCREEN



RCA-904

CATHODE-RAY TUBE

High-Vacuum Electrostatic-Magnetic Type

The 904 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen five inches in diameter. This tube, designed for oscillographic applications, provides for a combination of electrostatic and electromagnetic deflection control. Like the 903, this type has an accelerating electrode (grid No.2) which gives additional control of the electron beam. The 904 produces a brilliant, luminous spot having a greenish hue, and is suitable for the observation and photography of recurrent and transient phenomena.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No.1	
DIRECT INTERELECTRODE CAPACITANCES:		
Control Electrode to All Other Electrodes	10 *max.*	μμf
Deflecting Plate to Deflecting Plate	1 *max.*	μμf
OVERALL LENGTH	16-1/4" ± 3/8"	
MAXIMUM DIAMETER	5-1/16"	
BULB	J-40	
CAPS (Three)	Small Metal	
BASE (Refer to page 39)	Medium 6-Pin	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE			4600 *max.*	Volts
FOCUSING ELECTRODE (Anode No.1) VOLTAGE			1500 *max.*	Volts
ACCELERATING ELECTRODE (Grid No.2) VOLTAGE			250 *max.*	Volts
CONTROL ELECTRODE (Grid No.1) VOLTAGE			Never Positive	
NO.1 GRID VOLTAGE FOR CURRENT CUT-OFF *			-140 *approx.*	Volts
PEAK VOLTAGE BETWEEN ANODE NO.2 and ANY DEFLECTING PLATE			4000 *max.*	Volts
FLUORESCENT SCREEN INPUT POWER PER SQ CM			10 *max.*	Milliwatts
TYPICAL OPERATION:				
Heater Voltage	2.5	2.5	2.5	Volts
No.2 Anode Voltage	1000	3000	4600	Volts
No.1 Anode Voltage (Approx.)	210	630	970	Volts
No.2 Grid Voltage	100	100	250	Volts
No.1 Grid Voltage	Adjusted to Give a Suitable Luminous Spot			
Deflection Sensitivity:				
Electrostatic	0.33	0.11	0.07	Mm/Volt D.C.

* With 250 volts (approx.) on Grid No.2.

INSTALLATION

The *base* pins of the 904 fit a standard, 0.75-inch pin-circle diameter, six-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base and cap connections as well as essential dimensions of the 904 are given on page 39

For *bulb shielding, heater operation, and d-c voltage supply,* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6

The *cathode* should be connected directly to one side or to the mid-tap of the heater winding. Grid and anode returns should be made to the cathode.

The *fluorescent screen* employed in the 904 is of the No.1 phosphor (medium persistence) type. For the characteristics of this screen, refer to page 4.

Two *electrostatic plates,* located within the tube neck, provide one means for deflecting the electron beam; the deflection is parallel to the axis of the electrostatic field. In order to maintain the plates at essentially the d-c potential of anode No.2, each deflecting plate should be connected through a resistor of one to ten megohms to anode No.2 (ordinarily grounded). The deflection sensitivity of the deflecting plates for several No.2 anode voltages is given in the tabulated data.

Two *electromagnetic coils* provide a second means for deflecting the beam; the deflection is at right angles to the axis of the magnetic field. The coils are placed opposite each other, as close to the bulb neck as practical, and are concentric with a diameter of the bulb neck. This arrangement locates the axis of the magnetic field so that it intersects the axis of the electron beam perpendicularly. The electromagnetic field is usually placed so that its axis coincides with that of the electrostatic field, in order that the deflection produced by one field will be at right angles to that produced by the other.

The design of the magnetic coils will depend on the application. The curve on page 40 shows the deflection sensitivity of an air-core coil system for various values of No.2 anode voltage.

THE HIGH VOLTAGES AT WHICH THE 904 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 40 illustrates the essential circuit for the use of the 904 in an oscillograph. By means of potentiometers in the bleeder circuit, the voltages for anode No.1, grid No.1, and grid No.2 can be adjusted to meet operating requirements. Either the electromagnetic or the electrostatic deflecting system may be used for the voltage under observation. The other may then be used for the time sweep. A typical method of obtaining an amplified current for electromagnetic deflection is discussed on page 108.

A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of voltage or current to the deflecting system or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLICATION. Other details on the application of the 904 are also included in that section.

A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

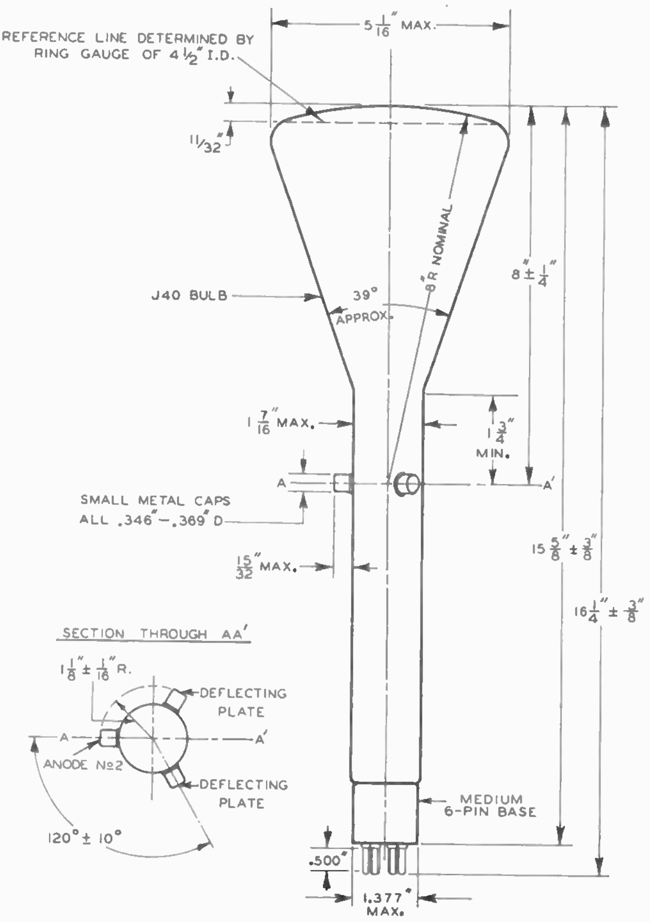
FLUORESCENT-SCREEN CHARACTERISTICS

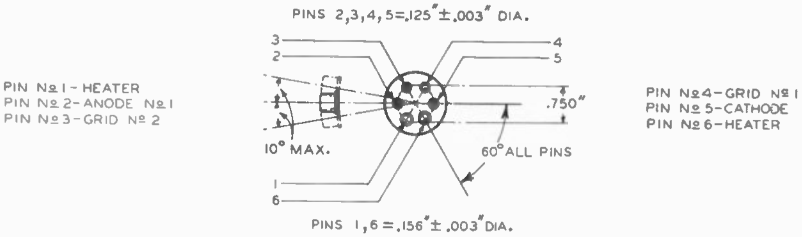
THE FLUORESCENT-SCREEN MATERIAL USED FOR THE 904 IS THE SAME AS THAT FOR TYPES 903, 905, AND 906. FLUORESCENT-SCREEN CHARACTERISTICS APPLYING TO EACH OF THESE TYPES ARE SHOWN ON PAGES 32, 33, 34, and 35.

RCA

904

OUTLINE DRAWING

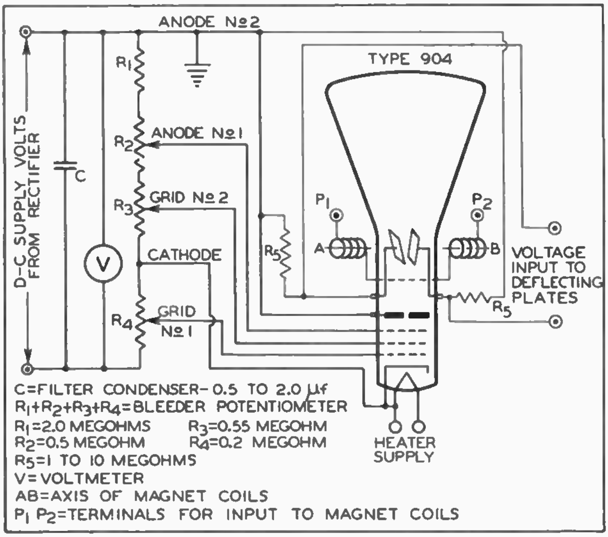




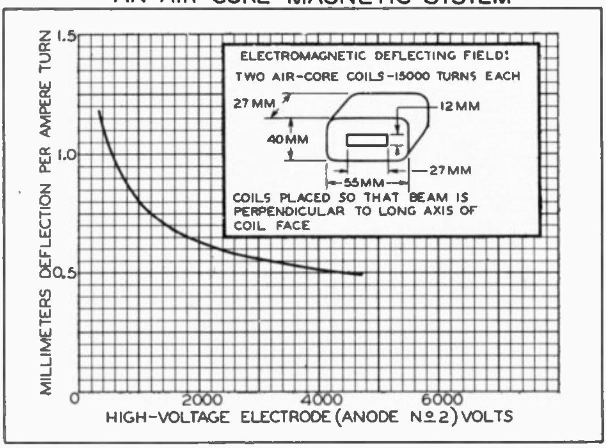
BOTTOM VIEW OF BASE

RCA
904

TYPICAL OSCILLOGRAPH CIRCUIT

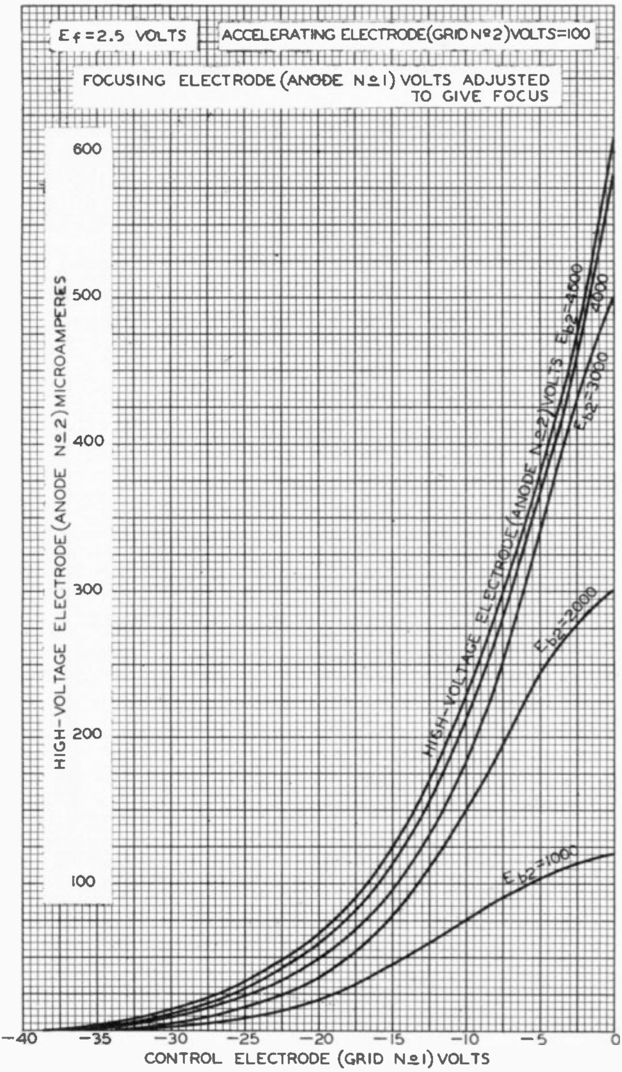


DEFLECTION SENSITIVITY OF AN AIR-CORE MAGNETIC SYSTEM



904

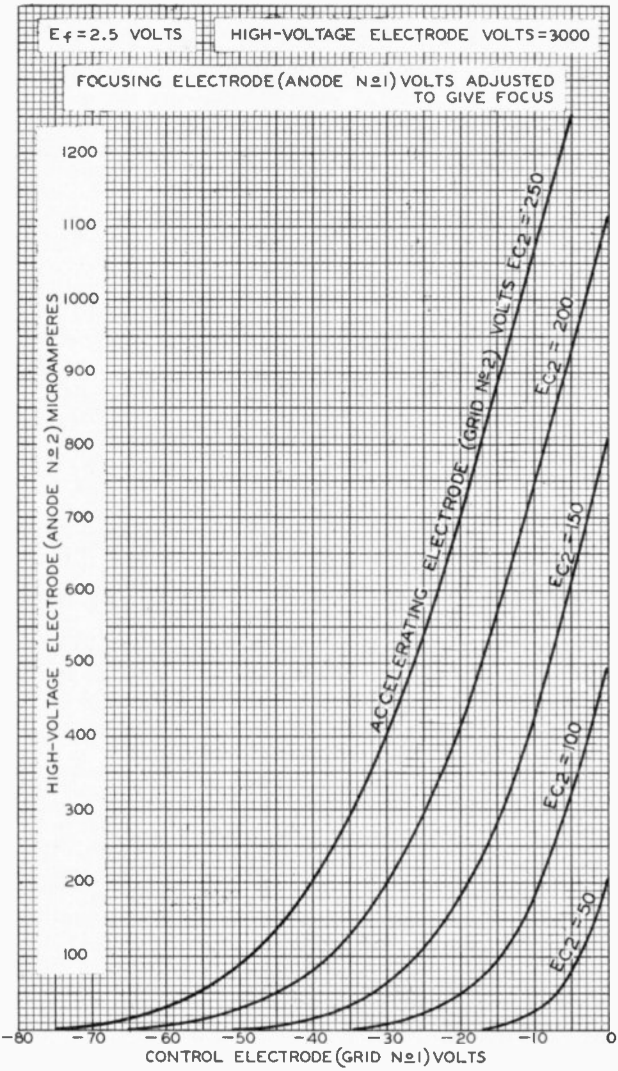
AVERAGE CHARACTERISTICS



RCA

904

AVERAGE CHARACTERISTICS



RCA-905

CATHODE-RAY TUBE

High-Vacuum Electrostatic Type

The 905 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen five inches in diameter. This tube, designed for oscillographic applications, is provided with two sets of electrostatic plates for deflection of the electron beam. The 905 produces a brilliant, luminous spot having a greenish hue, and is suitable for the observation and photography of recurrent and transient phenomena.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No.1	
DIRECT INTERELECTRODE CAPACITANCES:		
Control Electrode to All Other Electrodes	10 *max.*	μμf
Deflecting Plate D_1 to Deflecting Plate D_2	3 *max.*	μμf
Deflecting Plate D_3 to Deflecting Plate D_4	1.5 *max.*	μμf
OVERALL LENGTH	16-1/2" ± 3/8"	
MAXIMUM DIAMETER	5-5/16"	
BULB	J-42	
CAPS (Four)	Small Metal	
BASE (Refer to page 46)	Medium 5-Pin Ceramic	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE		2000 *max.*	Volts
FOCUSING ELECTRODE (Anode No.1) VOLTAGE		600 *max.*	Volts
CONTROL ELECTRODE (Grid) VOLTAGE		Never Positive	
GRID VOLTAGE FOR CURRENT CUT-OFF*		-60 *approx.*	Volts
PEAK VOLTAGE BETWEEN ANODE NO.2 and ANY DEFLECTING PLATE		1000 *max.*	Volts
FLUORESCENT SCREEN INPUT POWER PER SQ CM		10 *max.*	Milliwatts
TYPICAL OPERATION:			
Heater Voltage	2.5	2.5	Volts
No.2 Anode Voltage	1000	2000	Volts
No.1 Anode Voltage (Approx.)	225	450	Volts
Grid Voltage	Adjusted to Give a Suitable Luminous Spot		
Deflection Sensitivity:			
Plates D_1 and D_2	0.38	0.19	Mm/Volt D.C.
Plates D_3 and D_4	0.46	0.23	Mm/Volt D.C.

*With approximately 600 volts (to focus) on Anode No.1.

INSTALLATION

The *base* pins of the 905 fit a standard, five-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base and cap connections as well as essential dimensions of the 905 are given on page 46. The base of the 905 is made of a ceramic material.

For *bulb shielding, heater operation, and d-c voltage supply,* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6.

The *cathode* is connected within the tube to one side of the heater. Grid and anode returns should be made to this common terminal, which is base pin No.5.

The *fluorescent screen* employed in the 905 is of the No.1 phosphor (medium persistence) type. For the characteristics of this screen, refer to page 4.

Two sets of *electrostatic plates,* producing fields at right angles, are located within the bulb neck to provide for deflection of the electron beam. The electrostatic field of each pair of deflecting plates deflects the beam parallel to the axis of the field; therefore, the deflections produced by the two fields are at right angles. In order to maintain each set of plates at essentially the d-c potential of anode No.2, each plate of each set should be connected through a resistor of one to ten megohms to anode No.2, which is ordinarily grounded. The deflection sensitivity of each set of plates for typical operating No.2 anode voltages is given in the tabulated data.

THE HIGH VOLTAGES AT WHICH THE 905 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 45 illustrates the essential circuit for the use of the 905 in an oscillograph. One set of electrostatic deflecting plates is used for the phenomena under observation; the other set may then be used for the time sweep. The voltages for anode No.1 and grid No.1 can be adjusted to meet operating requirements by means of potentiometers in the bleeder circuit.

A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of voltage to the deflecting plates or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

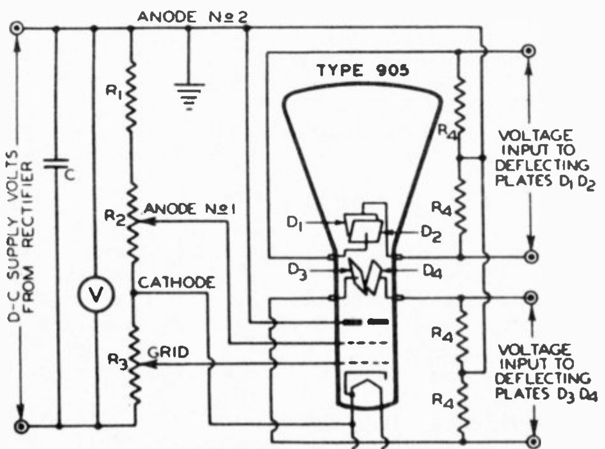
For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLICATION. Other details on the application of the 905 are also included in that section.

A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

FLUORESCENT-SCREEN CHARACTERISTICS

THE FLUORESCENT-SCREEN MATERIAL USED FOR THE 905 IS THE SAME AS THAT FOR TYPES 903, 904, AND 906. FLUORESCENT-SCREEN CHARACTERISTICS APPLYING TO EACH OF THESE TYPES ARE SHOWN ON PAGES 32, 33, 34, AND 35.

TYPICAL OSCILLOGRAPH CIRCUIT

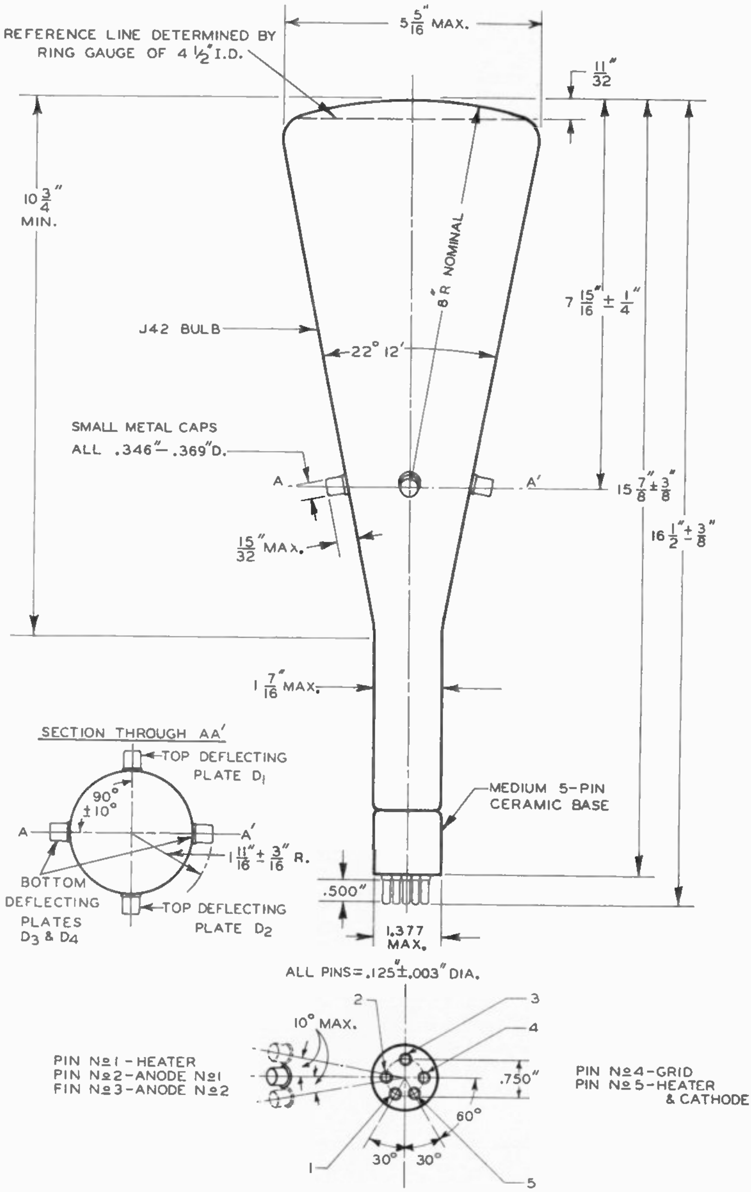


C=FILTER CONDENSER-0.5 TO 2.0μf
$R_1+R_2+R_3$=BLEEDER POTENTIOMETER
R_1=0.5 MEGOHM
R_2=0.2 MEGOHM
R_3=0.02 MEGOHM
R_4=1 TO 10 MEGOHMS
V= VOLTMETER

RCA

905

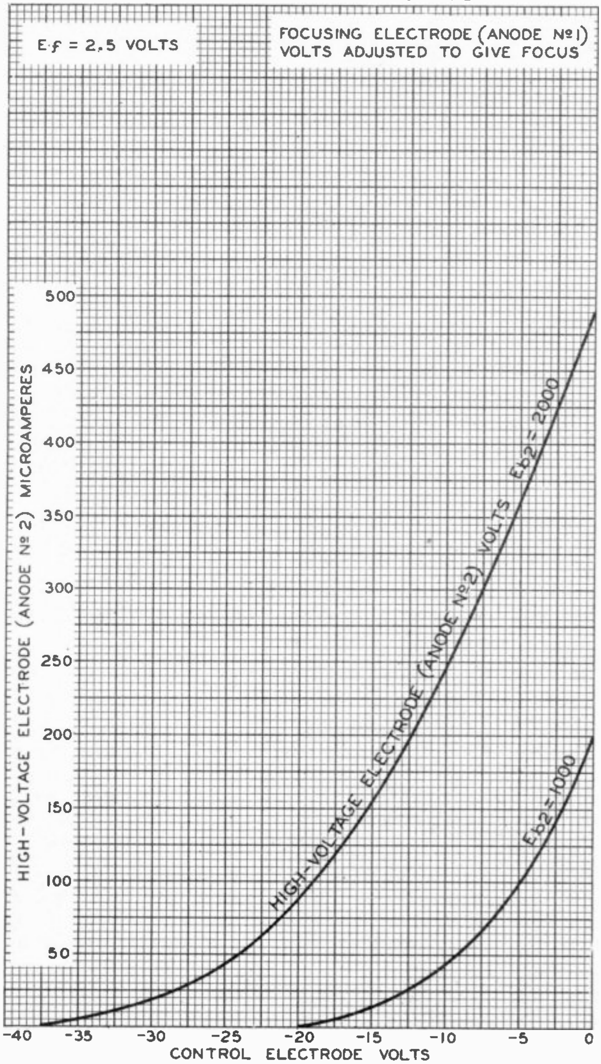
OUTLINE DRAWING



BOTTOM VIEW OF BASE

905

AVERAGE CHARACTERISTICS



RCA-906

CATHODE-RAY TUBE

High-Vacuum Electrostatic Type

The 906 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen three inches in diameter. This tube, designed for oscillographic applications, is provided with two sets of electrostatic plates for deflection of the electron beam. The 906 produces a brilliant, luminous spot having a greenish hue, and is suitable for the observation and photography of recurrent and transient phenomena. Due to its small size, the 906 is especially suited for compact, portable oscillographic equipment.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No. 1	
DIRECT INTERELECTRODE CAPACITANCES:		
Control Electrode to All Other Electrodes	10 *max.*	μμf
Deflecting Plate D_1 to Deflecting Plate D_2	4 *max.*	μμf
Deflecting Plate D_3 tp Deflecting Plate D_4	3 *max.*	μμf
OVERALL LENGTH	11-1/2" ± 3/8"	
MAXIMUM DIAMETER	3-1/16"	
BULB	J-24	
BASE (Refer to page 51)	Medium 7-Pin	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE	1200 *max.*	Volts
FOCUSING ELECTRODE (Anode No.1) VOLTAGE	400 *max.*	Volts
CONTROL ELECTRODE (Grid) VOLTAGE	Never Positive	
GRID VOLTAGE FOR CURRENT CUT-OFF *	-60 *approx.*	Volts
PEAK VOLTAGE BETWEEN ANODE NO.2 and ANY DEFLECTING PLATE	600 *max.*	Volts
FLUORESCENT SCREEN INPUT POWER PER SQ CM	10 *max.*	Milliwatts

TYPICAL OPERATION:

Heater Voltage	2.5	2.5	2.5	2.5	Volts
No.2 Anode Voltage	600	800	1000	1200	Volts
No.1 Anode Voltage **	170	230	285	345	Volts
Grid Voltage	Adjusted to Give a Suitable Luminous Spot				
Deflection Sensitivity:					
Plates D_1 and D_2	0.55	0.41	0.33	0.27	Mm/Volt D.C.
Plates D_3 and D_4	0.58	0.44	0.35	0.29	Mm/Volt D.C.

* With approximately 400 volts (to focus) on Anode No.1.

** Approximate.

INSTALLATION

The *base* pins of the 906 fit a standard, 0.855-inch pin-circle diameter, seven-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base connections and essential dimensions of the 906 are given on page 51.

For *bulb shielding, heater operation, and d-c voltage supply* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6.

The *cathode* is connected within the tube to one side of the heater. Grid and anode returns should be made to this common terminal, which is base pin No.7.

The *fluorescent screen* employed in the 906 is of the No.1 phosphor (medium persistence) type. For the characteristics of this screen, refer to page 4.

Two sets of *electrostatic plates*, producing fields at right angles, are located within the bulb neck to provide for deflection of the electron beam. The electrostatic field of each pair of deflecting plates deflects the beam parallel to the axis of the field; therefore, the deflections produced by the two fields are at right angles. One deflecting plate of one set is connected within the tube to one plate of the other set and to anode No.2, as shown in the drawing on page 50. In order to maintain the free plate of each set at essentially the d-c potential of anode No.2, each of these plates should be connected through a resistor of one to ten megohms to the No.2 anode socket terminal (ordinarily grounded). The deflection sensitivity for each set of plates for typical No.2 anode voltages is given in the tabulated data.

THE HIGH VOLTAGES AT WHICH THE 906 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 50 illustrates the essential circuit for the use of the 906 in an oscillograph. One set of electrostatic deflecting plates is used for the phenomena under observation; the other set may then be used for the time sweep. The voltages for anode No.1 and grid No.1 can be adjusted to meet operating requirements by means of potentiometers in the bleeder circuit.

A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of voltage to the deflecting system or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLI-

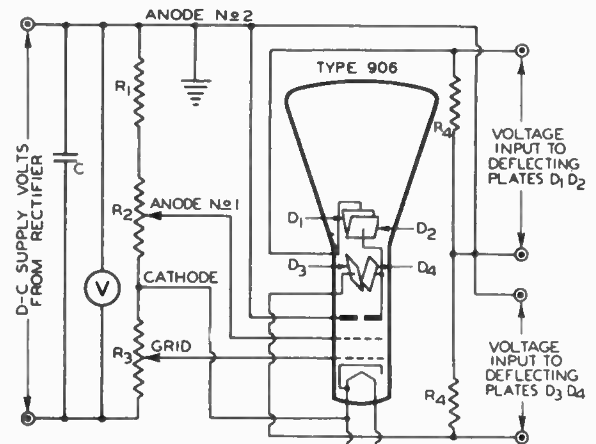
CATION. Other details on the application of the 906 are also included in that section.

A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

FLUORESCENT-SCREEN CHARACTERISTICS

THE FLUORESCENT-SCREEN MATERIAL USED FOR THE 906 IS THE SAME AS THAT FOR TYPES 903, 904, AND 905. FLUORESCENT-SCREEN CHARACTERISTICS APPLYING TO EACH OF THESE TYPES ARE SHOWN ON PAGES 32, 33, 34, AND 35.

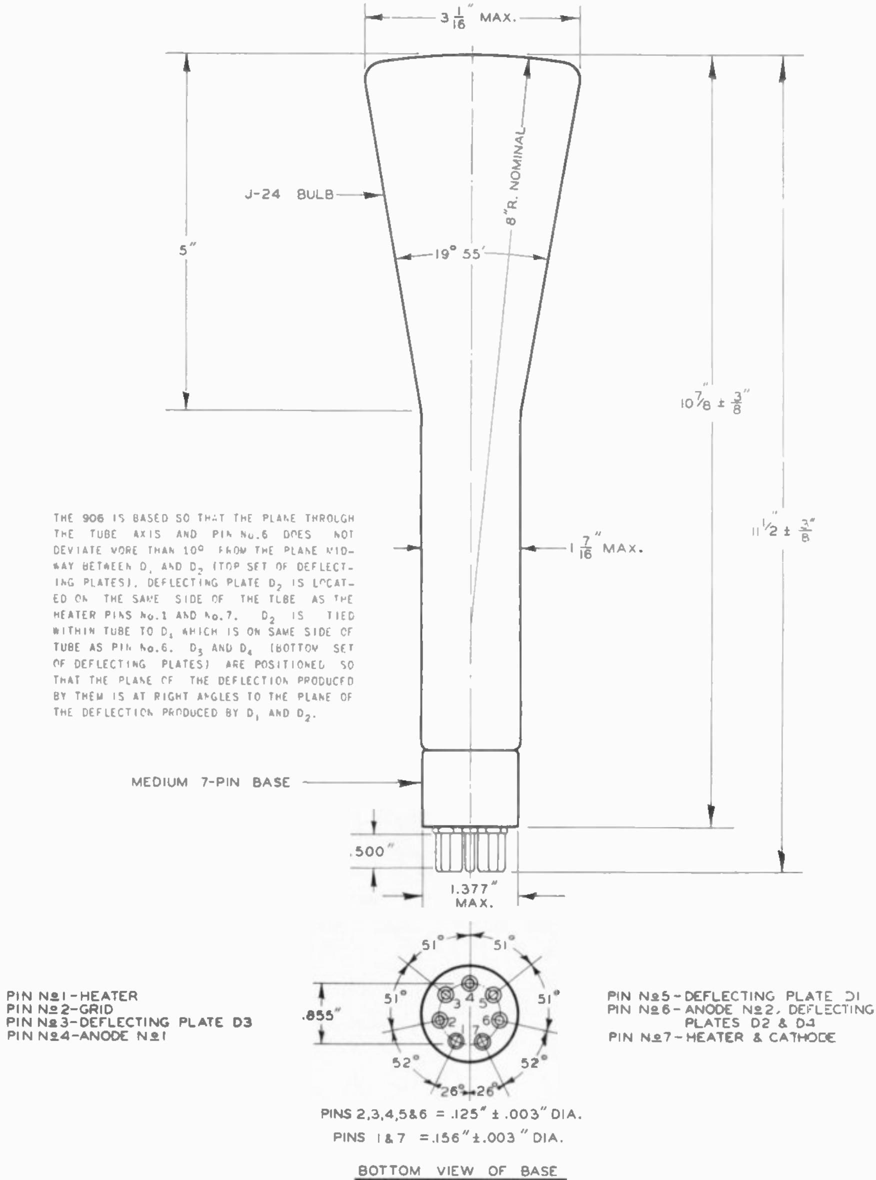
TYPICAL OSCILLOGRAPH CIRCUIT



C=FILTER CONDENSER-0.5 TO 2.0µf
$R_1+R_2+R_3$= BLEEDER POTENTIOMETER
R_1=0.5 MEGOHM R_3=0.02 MEGOHM
R_2=0.2 MEGOHM R_4=1 TO 10 MEGOHMS
V= VOLTMETER

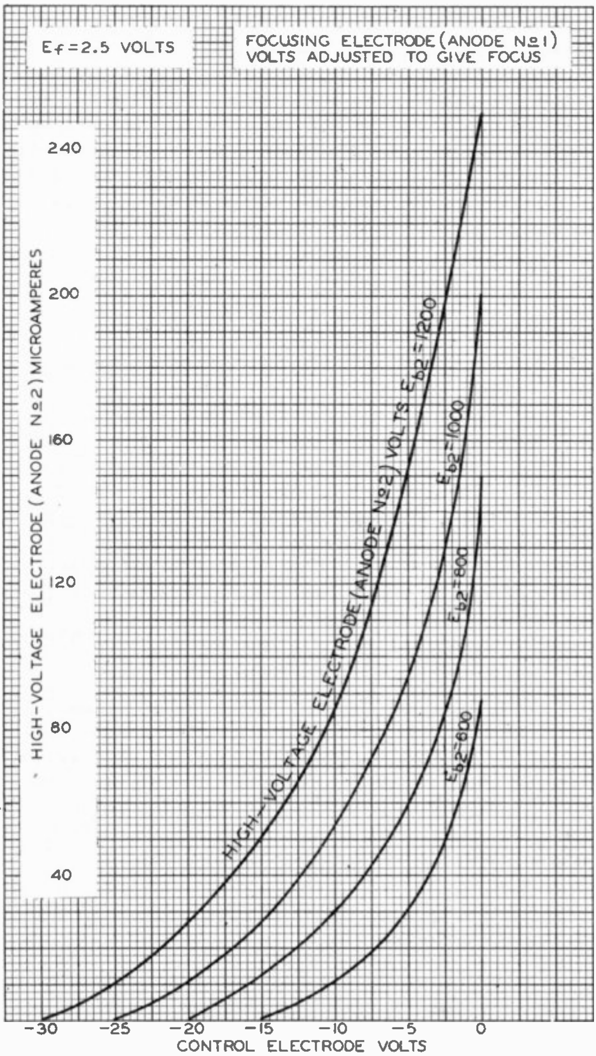
NOTE 1: TYPE 906 HAS NO BULB TERMINALS. ALL LEADS ENTER THROUGH BASE
NOTE 2: PLATES D_2 AND D_4 ARE CONNECTED WITHIN THE TUBE TO ANODE №2

OUTLINE DRAWING



906

AVERAGE CHARACTERISTICS



RCA-907

CATHODE-RAY TUBE

High-Vacuum Electrostatic Type with Short-Persistence Screen

The 907 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen five inches in diameter. This tube, designed for oscillographic applications, is provided with two sets of electrostatic plates for deflection of the electron beam. The 907 produces a highly actinic spot having a bluish hue. The extremely short persistence of the image is due to the special screen material used in the 907, and makes this tube especially suited for applications where moving-film recording or observation by means of a system of rotating mirrors is desired.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No.5	
DIRECT INTERELECTRODE CAPACITANCES:		
Control Electrode to All Other Electrodes	10.0 *max.*	μμf
Deflecting Plate D_1 to Deflecting Plate D_2	3.0 *max.*	μμf
Deflecting Plate D_3 tp Deflecting Plate D_4	1.5 *max.*	μμf
OVERALL LENGTH	16-1/2" ± 3/8"	
MAXIMUM DIAMETER	5-5/16"	
BULB	J-42	
CAPS (Four)	Small Metal	
BASE (Refer to page 56)	Medium 5-Pin Ceramic	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE		2000 *max.*	Volts
FOCUSING ELECTRODE (Anode No.1) VOLTAGE		600 *max.*	Volts
CONTROL ELECTRODE (Grid) VOLTAGE		Never Positive	
GRID VOLTAGE FOR CURRENT CUT-OFF *		-60 *approx.*	Volts
PEAK VOLTAGE BETWEEN ANODE NO.2 and ANY DEFLECTING PLATE		1000 *max.*	Volts
FLUORESCENT SCREEN INPUT POWER PER SQ CM		10 *max.*	Milliwatts
TYPICAL OPERATION:			
Heater Voltage	2.5	2.5	Volts
No.2 Anode Voltage	1000	2000	Volts
No.1 Anode Voltage (Approx.)	225	450	Volts
Grid Voltage	Adjusted to Give a Suitable Luminous Spot		
Deflection Sensitivity:			
Plates D_1 and D_2	0.38	0.19	Mm/Volt D.C.
Plates D_3 and D_4	0.46	0.23	Mm/Volt D.C.

* With approximately 600 volts (to focus) on Anode No.1.

INSTALLATION

The *base* pins of the 907 fit a standard, five-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base and cap connections as well as essential dimensions of the 907 are given on page 56. The base of the 907 is made of a ceramic material.

For *bulb shielding, heater operation, and d-c voltage supply,* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6.

The *cathode* is connected within the tube to one side of the heater. Grid and anode returns should be made to this common terminal, which is base pin No.5.

The *fluorescent screen* employed in the 907 is of the No.5 phosphor (short persistence) type. For the characteristics of this screen, refer to page 4.

Two sets of *electrostatic plates,* producing fields at right angles, are located within the apex of the bulb cone to provide for deflection of the electron beam. The electrostatic field of each pair of deflecting plates deflects the beam parallel to the axis of the field; therefore, the deflections produced by the two fields are at right angles. In order to maintain each set of plates at essentially the d-c potential of anode No.2, each plate of each set should be connected through a resistor of one to ten megohms to anode No.2, which is ordinarily grounded. The deflection sensitivity of each set of plates for typical operating No.2 anode voltages is given in the tabulated data.

THE HIGH VOLTAGES AT WHICH THE 907 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 55 illustrates the essential circuit for the use of the 907 in an oscillograph. One set of electrostatic deflecting plates is used for the phenomena under observation; the other set may then be used for the time sweep. The voltages for anode No.1 and grid No.1 can be adjusted to meet operating requirements by means of potentiometers in the bleeder circuit.

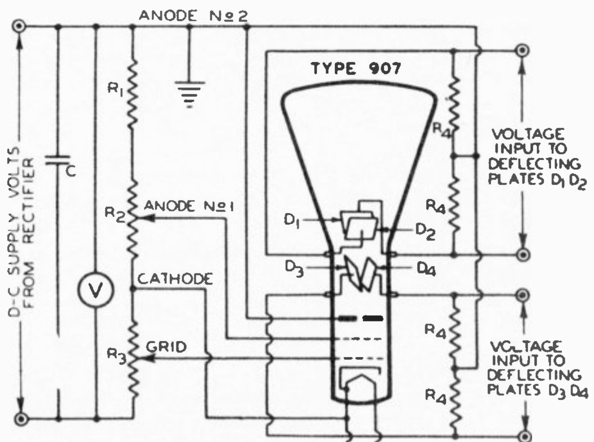
Because of the very short time of phosphorescence of its screen (less than 30 microseconds), the 907 is recommended especially for applications where it is desirable to employ a recording film moving at a constant speed across the front of the viewing screen or a system of mirrors rotating at a uniform velocity. With either of these methods of timing, the 907 will give a clear, sharp tracing.

A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of voltage to the deflecting plates or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLICATION. Other details on the application of the 907 are also included in that section.

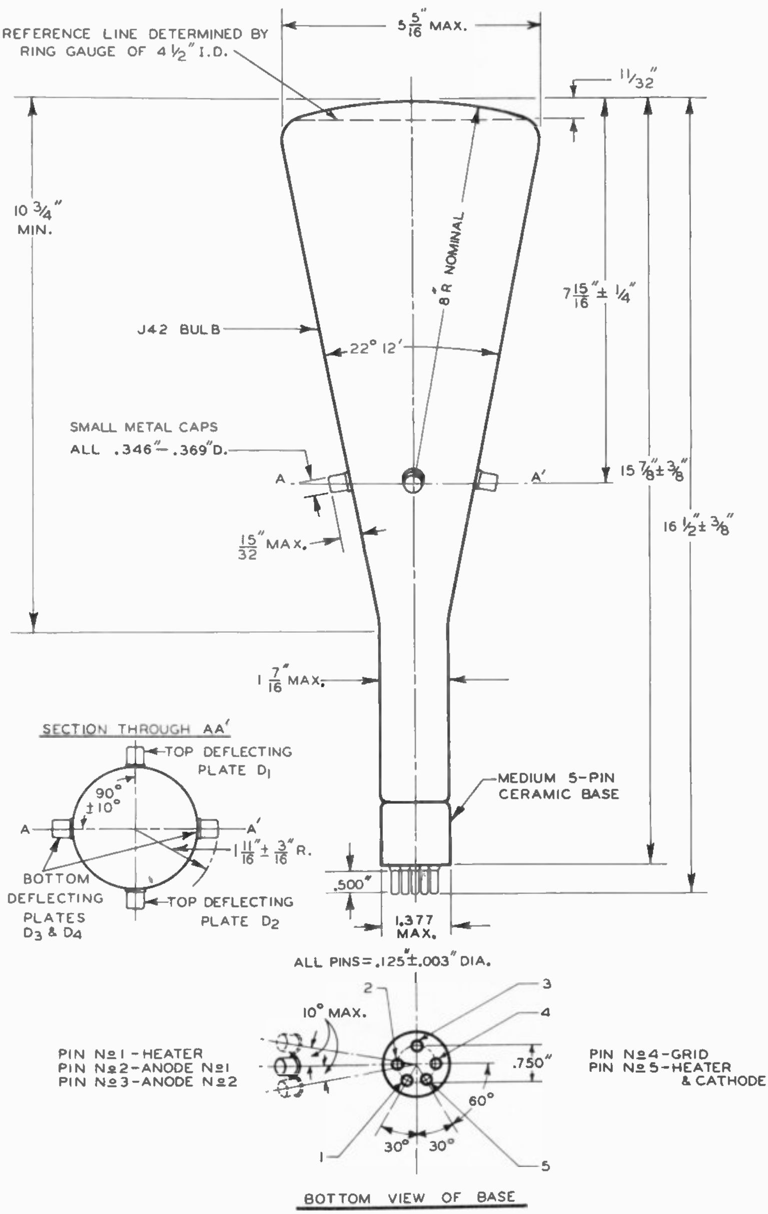
A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

TYPICAL OSCILLOGRAPH CIRCUIT



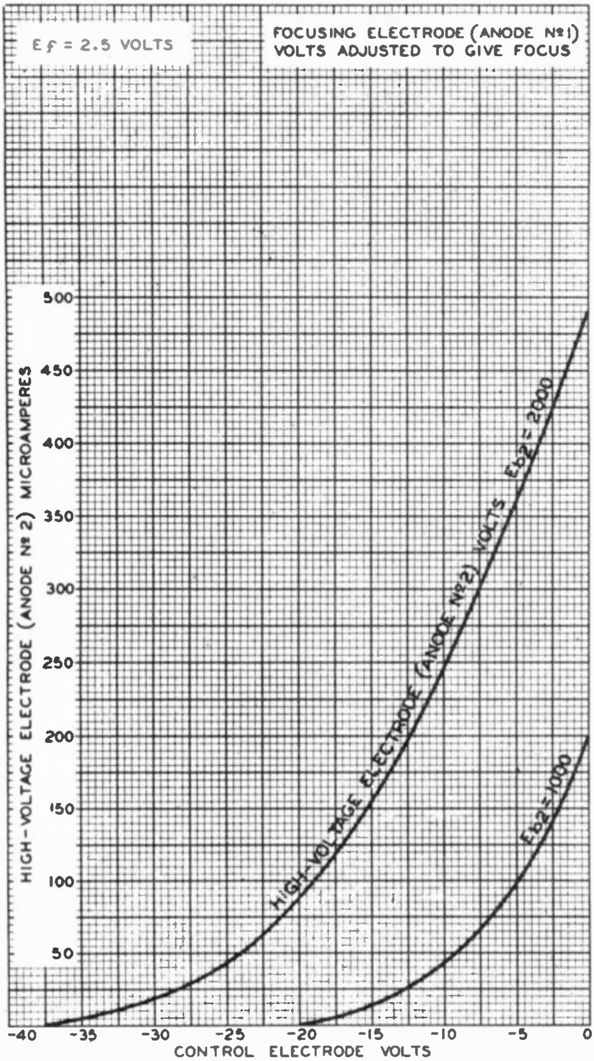
907

OUTLINE DRAWING



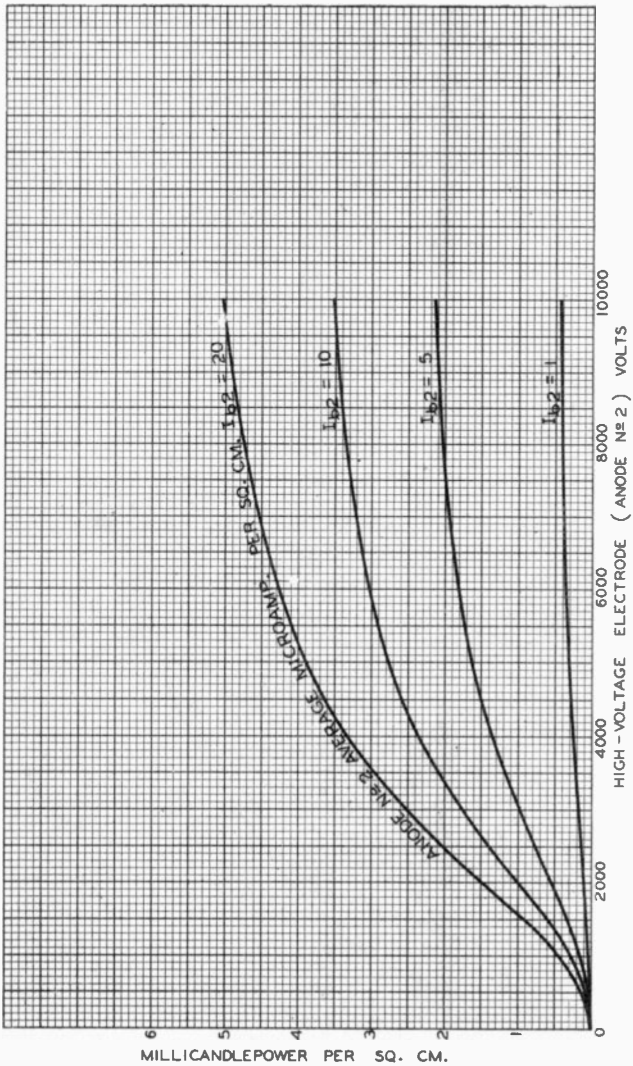
907

AVERAGE CHARACTERISTICS



TYPES: 907, 908

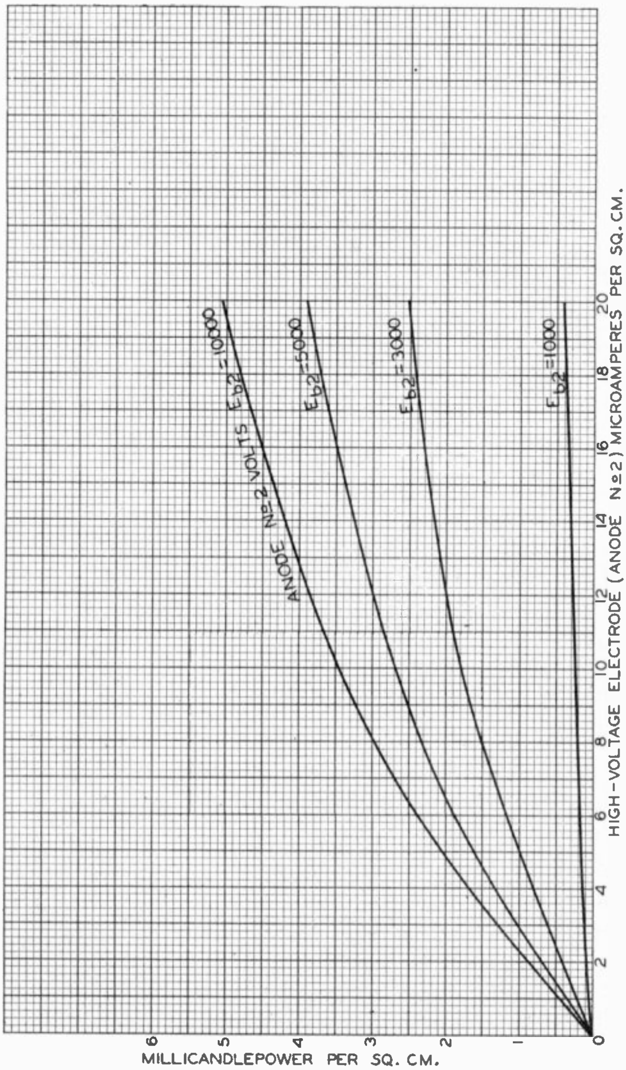
AVERAGE FLUORESCENT-SCREEN CHARACTERISTICS



RCA

TYPES: 907, 908

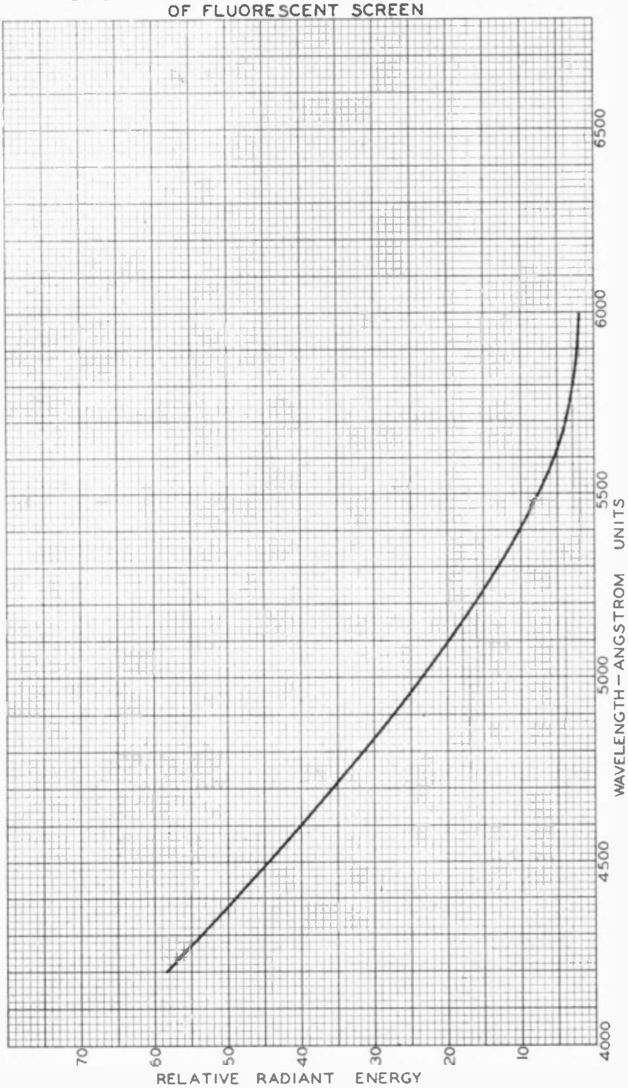
AVERAGE FLUORESCENT SCREEN CHARACTERISTICS



92S-5560

TYPES: 907, 908

SPECTRAL ENERGY CHARACTERISTICS
OF FLUORESCENT SCREEN



RCA-908

CATHODE-RAY TUBE

High-Vacuum Electrostatic Type with Short-Persistence Screen

The 908 is a high-vacuum, cathode-ray tube with a fluorescent viewing screen three inches in diameter. This tube, designed for oscillographic applications, is provided with two sets of electrostatic plates for deflection of the electron beam. The 908 produces a highly actinic spot having a bluish hue. The extremely short persistence of the image is due to the special screen material used in the 908, and makes this tube especially suited for applications where moving-film recording or observation by means of a system of rotating mirrors is desired.

CHARACTERISTICS

HEATER VOLTAGE (A.C. or D.C.)	2.5	Volts
HEATER CURRENT	2.1	Amperes
FLUORESCENT SCREEN MATERIAL	Phosphor No.5	
DIRECT INTERELECTRODE CAPACITANCES:		
Control Electrode to All Other Electrodes	10 *max.*	μμf
Deflecting Plate D_1 to Deflecting Plate D_2	4 *max.*	μμf
Deflecting Plate D_3 to Deflecting Plate D_4	3 *max.*	μμf
OVERALL LENGTH	11-1/2" ± 3/8"	
MAXIMUM DIAMETER	3-1/16"	
BULB	J-24	
BASE (Refer to page 64)	Medium 7-Pin	

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

HIGH-VOLTAGE ELECTRODE (Anode No.2) VOLTAGE	1200 *max.*	Volts
FOCUSING ELECTRODE (Anode No.1) VOLTAGE	400 *max.*	Volts
CONTROL ELECTRODE (Grid) VOLTAGE	Never Positive	
GRID VOLTAGE FOR CURRENT CUT-OFF *	-60 *approx.*	Volts
PEAK VOLTAGE BETWEEN ANODE NO.2 and ANY DEFLECTING PLATE	600 *max.*	Volts
FLUORESCENT SCREEN INPUT POWER PER SQ CM	10 *max.*	Milliwatts

TYPICAL OPERATION:

Heater Voltage	2.5	2.5	2.5	2.5	Volts
No.2 Anode Voltage	600	800	1000	1200	Volts
No.1 Anode Voltage**	170	230	285	345	Volts
Grid Voltage	Adjusted to Give a Suitable Luminous Spot				
Deflection Sensitivity:					
Plates D_1 and D_2	0.55	0.41	0.33	0.27	Mm/Volt D.C.
Plates D_3 and D_4	0.58	0.44	0.35	0.29	Mm/Volt D.C.

* With approximately 400 volts (to focus) on Anode No.1.

** Approximate.

INSTALLATION

The *base* pins of the 908 fit a standard, 0.855-inch pin-circle diameter, seven-contact socket, which may be mounted to hold the tube in any position. The socket should be made of good insulating material; a type of socket having insulating baffles between contacts provides an additional factor of safety. Base connections and essential dimensions of the 908 are given on page 64.

For *bulb shielding, heater operation, and d-c voltage supply,* refer to CATHODE-RAY TUBE INSTALLATION on pages 5 and 6.

The *cathode* is connected within the tube to one side of the heater. Grid and anode returns should be made to this common terminal, which is base pin No.7.

The *fluorescent screen* employed in the 908 is of the No.5 phosphor (short persistence) type. For the characteristics of this screen, refer to page 4.

Two sets of *electrostatic plates,* producing fields at right angles, are located within the bulb neck to provide for deflection of the electron beam. The electrostatic field of each pair of deflecting plates deflects the beam parallel to the axis of the field; therefore, the deflections produced by the two fields are at right angles. One deflecting plate of one set is connected within the tube to one plate of the other set and to anode No.2, as shown in the drawing on page 63. In order to maintain the free plate of each set at essentially the d-c potential of anode No.2, each of these plates should be connected through a resistor of one to ten megohms to the No.2 anode socket terminal (ordinarily grounded). The deflection sensitivity of each set of plates for typical No.2 anode voltages is given in the tabulated data.

THE HIGH VOLTAGES AT WHICH THE 908 IS OPERATED ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN IN THE DESIGN OF APPARATUS TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. It is recommended that the protective measures given on page 7 be employed in the design and application of cathode-ray tube equipment.

APPLICATION

The diagram on page 63 illustrates the essential circuit for the use of the 908 in an oscillograph. One set of electrostatic deflecting plates is used for the phenomena under observation; the other set may then be used for the time sweep. The voltages for anode No.1 and grid No.1 can be adjusted to meet operating requirements by means of potentiometers in the bleeder circuit.

Because of the very short time of phosphorescence of its screen (less than 30 microseconds), the 908 is recommended especially for applications where it is desirable to employ a recording film moving at a constant speed across the front of the viewing screen or a system of mirrors rotating at a uniform velocity. With either of these methods of timing, the 908 will give a clear, sharp tracing.

A beam producing a high-intensity spot will burn the fluorescent screen if the spot is allowed to remain stationary. To avoid this possibility, it is recommended that the beam be kept in motion by the application of voltage to the deflecting system or that the brilliancy be reduced to a low value by adjustment of the control-grid voltage.

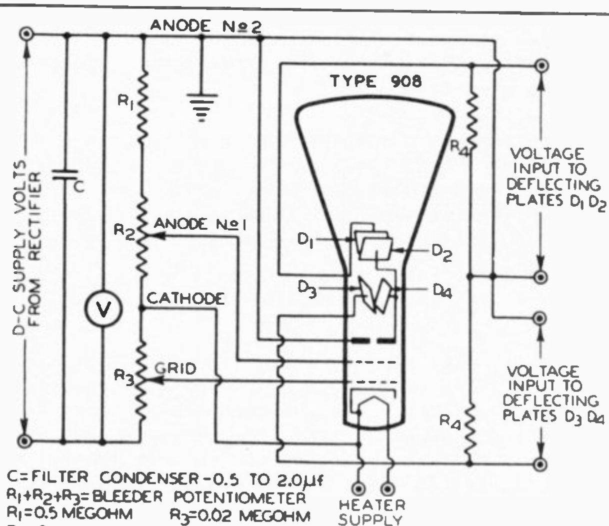
For information on focusing of the spot and regulation of its size and intensity, refer to page 8 under CATHODE-RAY TUBE APPLICATION. Other details on the application of the 908 are also included in that section.

A photographic record of many types of phenomena can be made if desired. A discussion of the photography of cathode-ray tube patterns is given in the text starting on page 86.

FLUORESCENT-SCREEN CHARACTERISTICS

THE FLUORESCENT-SCREEN MATERIAL USED FOR THE 908 IS THE SAME AS THAT FOR THE 907. FLUORESCENT-SCREEN CHARACTERISTICS APPLYING TO EACH OF THESE TYPES ARE SHOWN ON PAGES 58, 59, AND 60.

TYPICAL OSCILLOGRAPH CIRCUIT



C=FILTER CONDENSER-0.5 TO 2.0µf
$R_1+R_2+R_3$= BLEEDER POTENTIOMETER
R_1=0.5 MEGOHM R_3=0.02 MEGOHM
R_2=0.2 MEGOHM R_4=1 TO 10 MEGOHMS
V= VOLTMETER

NOTE 1: TYPE 908 HAS NO BULB TERMINALS. ALL LEADS ENTER THROUGH BASE

NOTE 2: PLATES D_2 AND D_4 ARE CONNECTED WITHIN THE TUBE TO ANODE №2

![RCA]

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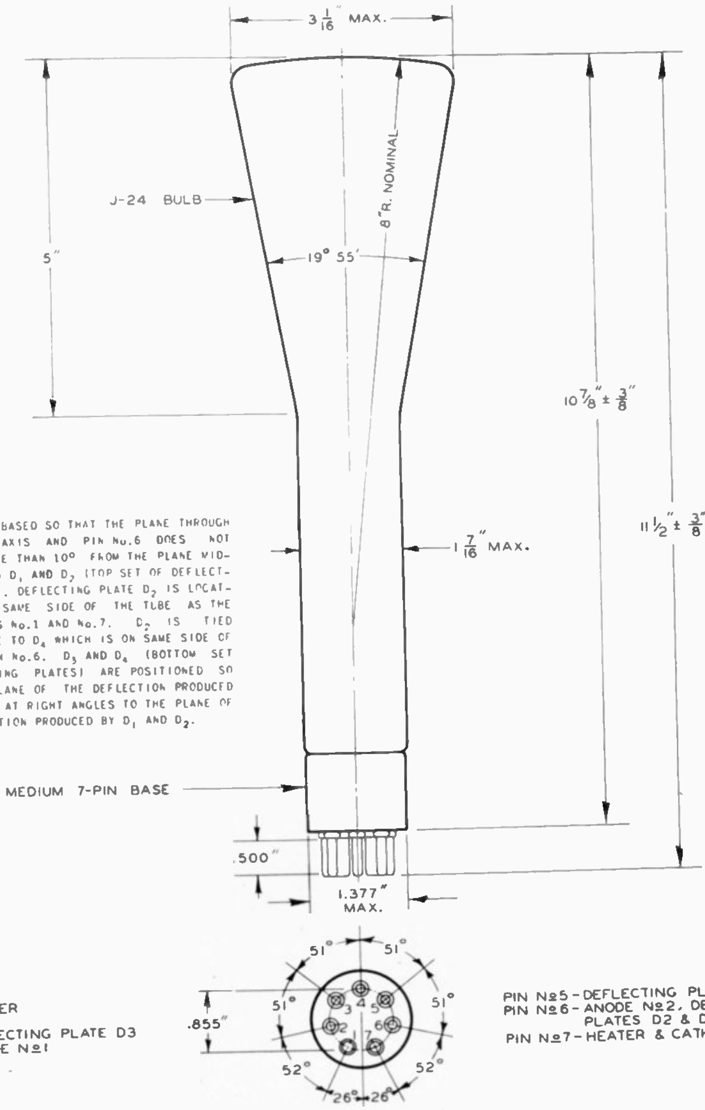
OUTLINE DRAWING



THE 908 IS BASED SO THAT THE PLANE THROUGH THE TUBE AXIS AND PIN No.6 DOES NOT DEVIATE MORE THAN 10° FROM THE PLANE MID-WAY BETWEEN D_1 AND D_2 (TOP SET OF DEFLECTING PLATES). DEFLECTING PLATE D_2 IS LOCATED ON THE SAME SIDE OF THE TUBE AS THE HEATER PINS No.1 AND No.7. D_2 IS TIED WITHIN TUBE TO D_4 WHICH IS ON SAME SIDE OF TUBE AS PIN No.6. D_3 AND D_4 (BOTTOM SET OF DEFLECTING PLATES) ARE POSITIONED SO THAT THE PLANE OF THE DEFLECTION PRODUCED BY THEM IS AT RIGHT ANGLES TO THE PLANE OF THE DEFLECTION PRODUCED BY D_1 AND D_2.

PIN No1-HEATER
PIN No2-GRID
PIN No3-DEFLECTING PLATE D3
PIN No4-ANODE No1

PIN No5-DEFLECTING PLATE D1
PIN No6-ANODE No2, DEFLECTING PLATES D2 & D4
PIN No7-HEATER & CATHODE

PINS 2,3,4,5&6 = .125" ± .003" DIA.
PINS 1&7 = .156" ±.003" DIA.

BOTTOM VIEW OF BASE

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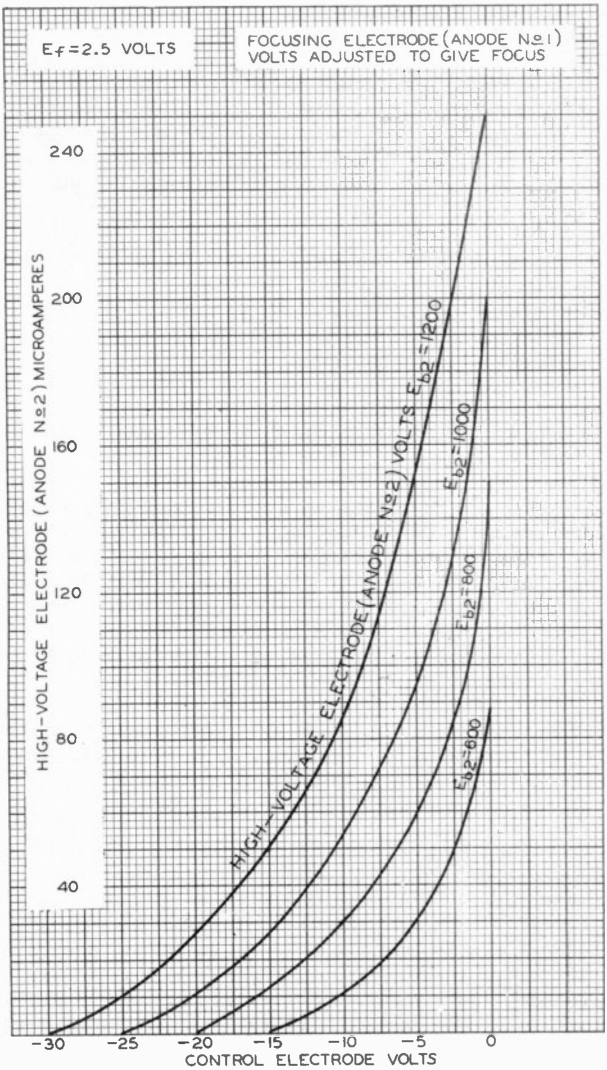
AVERAGE CHARACTERISTICS



Voltage Supplies to Provide 1000 or 2000 Volts for Cathode-Ray Tubes

Also Description of a Simple, Portable Oscillograph

The cathode-ray oscillograph is becoming increasingly popular as new applications are found for it in the laboratory and in the radio industry. This popularity is chiefly due to the simplicity of construction, convenience of operation, portability, and low cost of modern oscillographic equipment employing high-vacuum cathode-ray tubes. Experience with various oscillographic applications has shown that the equipment required for many every-day purposes can be constructed at low cost, can be made portable enough to be carried about by hand, and is as easily constructed as the power supply for an a-c operated receiver.

For those who prefer complete oscillographic equipment that is carefully engineered and constructed, reliable and convenient instruments are available from manufacturers. Some of these are designed with numerous desirable features such as linear and sinusoidal sweep circuits, beam-centering controls, sweep-length adjustments, sweep-frequency controls, deflection-voltage amplifiers, and synchronizing circuits. For those who prefer the experience of building their own equipment, the oscillograph to be described is an example of a practical instrument.

In this discussion are shown circuits and design information on voltage supplies to provide 1000 or 2000 volts for the operation of cathode-ray tubes. Illustrations are given of a small portable oscillograph which has been found very convenient for laboratory use and admirably suited for many industrial applications. This oscillograph, shown in Figures 15 and 16 on page 74, is constructed in a case whose outside dimensions are 17 inches in length, 8 inches in height, and 6 inches in width.

The circuits of the 1000- and 2000-volt power supplies are shown on page 71 in Figures 11 and 12, respectively. The 1000-volt supply is suitable for cathode-ray tubes such as the 906 and 908; the 2000-volt supply can be used with other tube types.

The transformer specified is designed to supply 1000 volts in a half-wave rectifier circuit employing one 879; it is also used for the 2000-volt supply with two 879's in a voltage-doubling circuit. The design specifications for this high-voltage transformer are included in this discussion under identification number S-122 (page 68). Specifications are also given for the filament and sweep-voltage transformer, identified as S-124 (page 69). Both of these transformers have been designed to have small physical dimensions.

If it is inconvenient to obtain a transformer such as the S-122, any transformer capable of supplying to the rectifier a peak voltage of 1000 volts at 5 milliamperes may be used. The desired rectified d-c potential is assumed to be equal to the peak voltage, provided the charging of the condenser C_1 (Figures 11 and 12) takes place during a small part of the a-c cycle, and provided the direct current taken from the condenser is so small that the condenser voltage is practically constant throughout the cycle. This assumption is justified when a low value of ripple voltage is a design requirement.

The value of condenser (C_1) depends upon the amount of ripple that can be tolerated and the permissible ripple in turn depends upon the application of the cathode-ray tube. Too much ripple varies the potential on the control grid of the cathode-ray tube and produces flicker, or an intermittent trace, and also some defocusing of the beam. In addition, if the ripple is too great, hum may become troublesome in the anode circuit and manifest itself in distortion of the image. In general, the ripple voltage for good filtering should not exceed one per cent.

The curves of Figure 14 (page 73) show per cent ripple voltage vs. effective load in megohms for various values of filter capacitance (C_1). The following example illustrates the use of these curves. In Figure 11, the parallel resistance of the voltage divider and the voltmeter is 1.4 megohms. From Figure 14, the corresponding capacitance for one per cent ripple voltage is read as approximately 0.3 microfarad. The voltage supplies of Figures 11 and 12 employ a condenser (C_1) of 2 microfarads and have a ripple of only 0.2 per cent.

Figure 13 (page 72) shows the voltage regulation for the 1000-volt and 2000-volt supplies. These curves indicate that the desired voltages of 1050 volts for the half-wave circuit and 2050 volts for the voltage-doubler circuit are obtained when the load current is adjusted to 1.25 milliampere and 1.6 milliamperes, respectively. In each case, these voltages include an allowance of 50 volts to provide for control-grid bias of the cathode-ray tube. This bias is taken from the potentiometers R_4 and R_9 (Figures 11 and 12).

The anode current of the 905, 906, 907, and 908 is very small; it normally does not exceed 200 microamperes. Care should be taken that the combined bleeder and anode current is not high enough to reduce the anode voltage below the desired value. The resistance values shown for the voltage dividers of Figures 11 and 12 were selected to provide as large a bleeder current as is consistent with voltage requirements in order that the anode current might be a minimum percentage of the total divider current. This was done to insure optimum voltage regulation from the divider when adjustment either of the No.1 anode voltage or of the control-grid voltage is made. The regulation curves and divider values are based on an input supply of 115 volts RMS to the primary of transformers S-122 and S-124.

If a voltage divider of lower resistance is used so that the anode current becomes a sufficiently small percentage of the bleeder current, defocusing due to adjustment of the control-grid voltage will be minimized and readjustment of the anode voltage made unnecessary.

In case a high-voltage transformer other than the S-122 is used (whose regulation permits operation with higher bleeder currents than those discussed above), the voltage divider should be designed to supply to anode No.2 a voltage approximately one-fifth of that applied to anode No.1; in addition, the voltage divider should supply a variable negative bias up to 50 or 60 volts for the control grid.

There are two 110-volt secondaries on the filament and sweep-voltage transformer. One of these is used to supply the control grid with a voltage of the same frequency as that of the sweep voltage (in this instance, 60 cycles), but 90 degrees out of phase. This procedure causes a brightening of the front wave and a darkening or elimination of the back wave of the screen trace and thus simplifies the pattern for purposes of frequency determination or wave study. The other 110-volt winding provides the 60-cycle sweep voltage for one pair of deflection plates. These plates are connected to terminals on the case of the oscillograph in order that an external sweep-voltage source may be conveniently utilized. The 905 and 907 may in some cases require a sweep voltage of 220 volts RMS, or 310 volts peak (approx.).

THE HIGH VOLTAGES EMPLOYED IN THE OSCILLOGRAPH DESCRIBED IN THIS DISCUSSION ARE VERY DANGEROUS. GREAT CARE SHOULD BE TAKEN TO PREVENT THE OPERATOR FROM COMING IN CONTACT WITH THESE HIGH VOLTAGES. Precautions should include grounding the case of the instrument during operation, discharging the filter condenser before the case is opened, and completely enclosing all parts carrying high voltage. An interlock switch should be used to break the power-supply circuit when the case is opened.

As previously stated, this compact cathode-ray oscillograph has been found very useful in the laboratory. It has provided a ready means of making frequency determinations, examining wave forms, checking percentage modulation, and observing voltages of high or low frequency. It can also be used as an indicator for high-frequency bridge measurements and for curve-drawing applications.

TRANSFORMER S-122* SPECIFICATIONS

High-Voltage Transformer

Core

Material	Dynamo Steel, Allegheny Steel Company or Equivalent
Punching	EI-12
Window	1.5 in. x 0.5 in.
Tongue	1.0 in.
Stack	1.0 in.
Stacking Factor	0.88
Joint	Lap
Net Section	5.7 sq cm
Mean Length of Magnetic Path	17.78 cm
Weight	1.47 lbs

Primary (115 Volts RMS)

Wire	No.30 enameled
Number of Turns	800
Winding Order	1st
Turns per Layer	100
Number of Layers	8
Insulation under Winding	0.063 in.
Clearance under Winding	0.015 in.
Insulation between Layers	0.003 in.
Depth of Winding	0.110 in.
Mean Length of Turn	5.0 in.
Total Wire Length	334 ft
Resistance at 25°C	36 ohms

Secondary

Wire	No.40 enameled
Number of Turns	5500
Winding Order	2nd
Turns per Layer	280
Number of Layers	20
Insulation under Winding**	0.030 in.
Insulation over Winding**	0.025 in.
Insulation between Layers	0.003 in.
Clearance over Winding	0.050 in.
Depth of Winding	0.130 in.
Mean Length of Turn	6.2 in.
Total Wire Length	2840 ft
Resistance at 25°C	3200 ohms

* Laboratory design reference number.
** Built up with varnished cambric.

TRANSFORMER S-124* SPECIFICATIONS

Filament and Sweep-Voltage Transformer

Core

Material	Dynamo Steel, Allegheny Steel Company or Equivalent
Punching	EI-12
Window	1.5 in. x 0.5 in.
Tongue	1.00 in.
Stack	1.50 in.
Stacking Factor	0.88
Joint	Lap
Net Section	8.52 sq cm
Mean Length of Magnetic Path	17.78 cm
Weight	2.2 lbs

Primary (115 Volts RMS)

Wire	No.27 enameled
Number of Turns	412
Winding Order	1st
Turns per Layer	72
Number of Layers	6
Insulation under Winding	0.045 in.
Clearance under Winding	0.015 in.
Insulation between Layers	0.003 in.
Depth of Winding	0.110 in.
Mean Length of Turn	6.0 in.
Total Wire Length	206 ft
Resistance at 25°C	11 ohms

Secondaries (5)

Number	1 and 2	3 and 4	5
Rating of Winding**	110V/0.027A	2.6V/1.75A	2.58V/2.1A
Voltage Insulation°°	2000 volts	2000 volts	2000 volts
Wire	No.38 enam	No.19 enam	No.20 enam
Number of Turns	405	9.5	9.5
Winding Order	2nd-3rd	4th°	5th
Turns per Layer	230	9.5	9.5
Number of Layers	2	1	1
Insulation under Winding	0.025 in.	0.036 in.	0.025 in.
Insulation over Winding	-	-	0.025 in.
Insulation between Layers	0.0015 in.	-	-
Clearance over Winding	-	-	0.03 in.
Depth of Winding	0.011 in.	0.038 in.	0.034 in.
Mean Length of Turn #	6.5 in.	7.0 in.	7.0 in.
Total Wire Length#	220 ft	5.5 ft	5.5 ft
Resistance at 25°C #	150 ohms	0.046 ohms	0.058 ohms

* Laboratory design reference number.

** Voltages are given for full-load current.

° Secondaries 3 and 4 on same layer, spaced for 2000-volt insulation.

°° Built up with varnished cambric.

\# Approximate values.

TYPICAL CIRCUITS FOR PORTABLE CATHODE-RAY OSCILLOGRAPH

HALF-WAVE CIRCUIT TO SUPPLY 1000 VOLTS FOR OPERATION OF TYPE 906

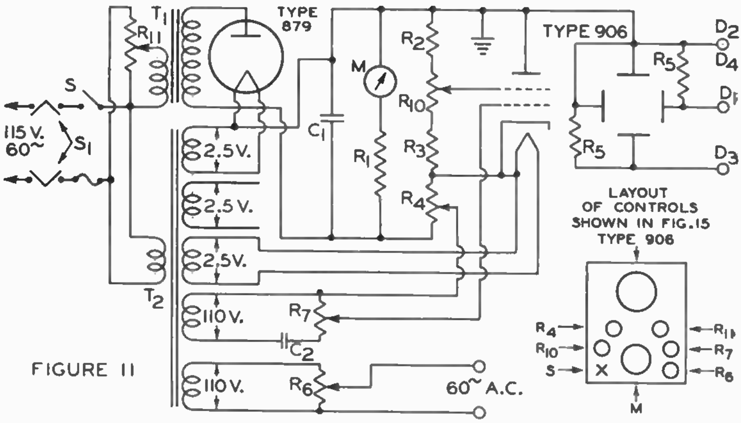


FIGURE 11

VOLTAGE-DOUBLER CIRCUIT TO SUPPLY 2000 V. FOR OPERATION OF TYPE 905

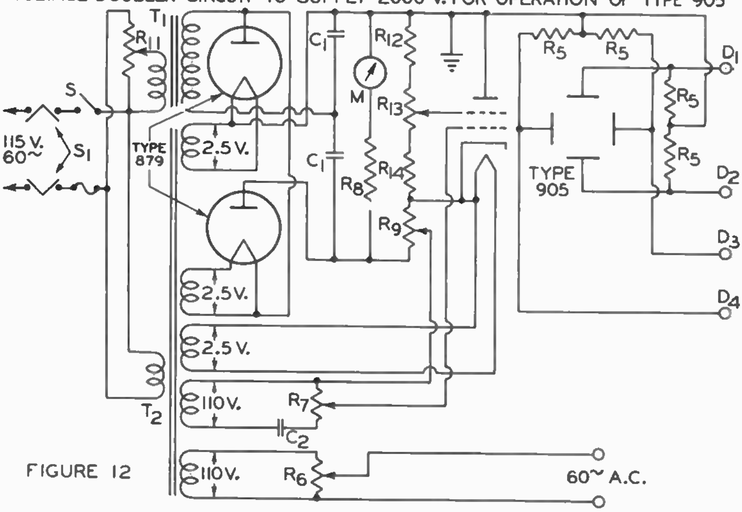


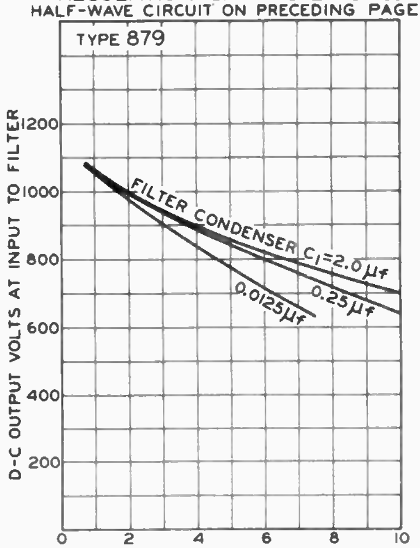
FIGURE 12

VALUES OF COMPONENT PARTS

C_1 = 2 µf (1000 V.)
C_2 = 0.015 µf (200 V.)
R_1 = 5 MEGOHMS
R_2 = 1.0 MEGOHM
R_3 = 0.4 MEGOHM
R_4 = 0.1 MEGOHM
R_5 = 1 TO 10 MEGOHMS
R_6 = 50000 OHMS
R_7 = 50000 OHMS
R_8 = 10 MEGOHMS

R_9 = 30000 OHMS
R_{10} = 0.5 MEGOHM
R_{11} = 1000 OHMS
R_{12} = 0.75 MEGOHM
R_{13} = 0.4 MEGOHM
R_{14} = 0.25 MEGOHM
M = MICROAMMETER (0-200 µ AMP)
S = SWITCH
S_1 = INTERLOCK SAFETY SWITCH

T_1 = TRANSFORMER-OUR DESIGN IDENTIFICATION № S-122
T_2 = TRANSFORMER-OUR DESIGN IDENTIFICATION № S-124


REGULATION CHARACTERISTICS
HALF-WAVE CIRCUIT ON PRECEDING PAGE
TYPE 879
D-C OUTPUT VOLTS AT INPUT TO FILTER
1200
1000
800
600
400
200
FILTER CONDENSER C1=2.0 μf
0.25 μf
0.0125 μf
0
2
4
6
8
10
D-C LOAD MILLIAMPERES

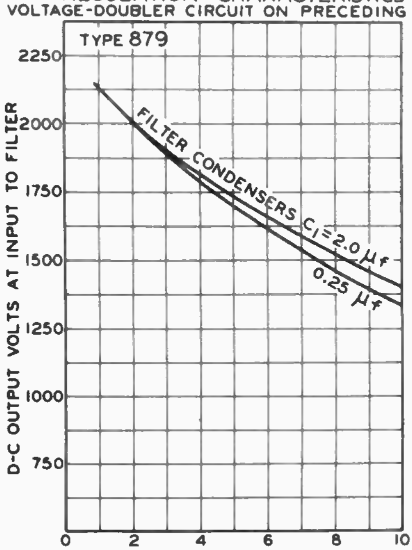

REGULATION CHARACTERISTICS
VOLTAGE-DOUBLER CIRCUIT ON PRECEDING PAGE
TYPE 879
D-C OUTPUT VOLTS AT INPUT TO FILTER
2250
2000
1750
1500
1250
1000
750
FILTER CONDENSERS C1=2.0 μf
0.25 μf
0
2
4
6
8
10
D-C LOAD MILLIAMPERES

FIGURE 13

FILTER DESIGN CONSIDERATIONS
FOR POWER SUPPLY OF CATHODE-RAY TUBES

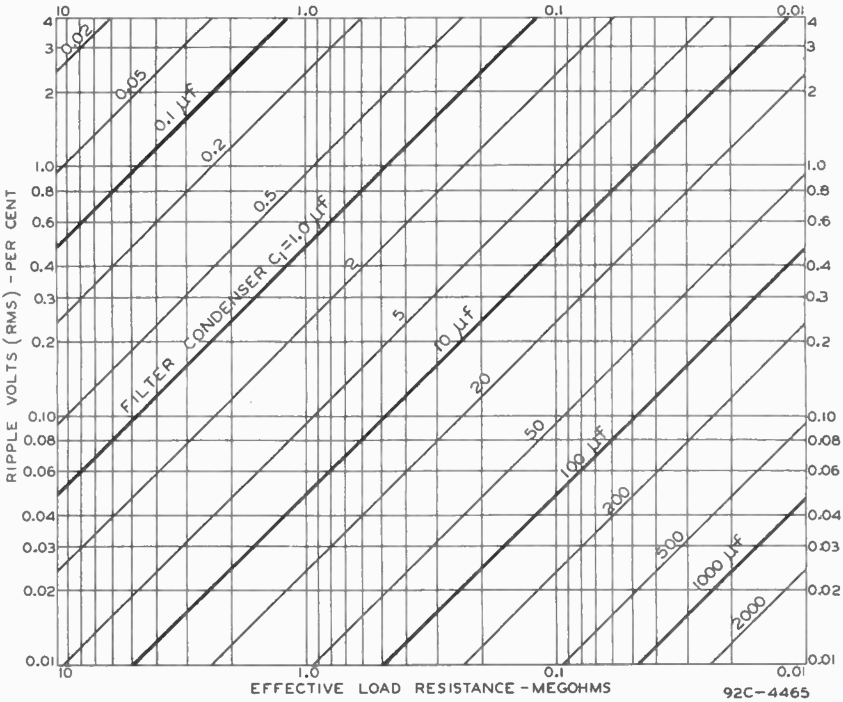
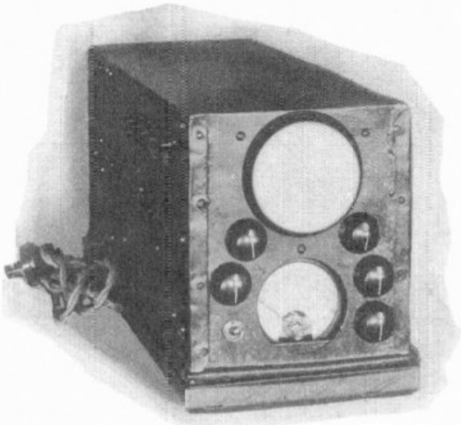


FIGURE 14



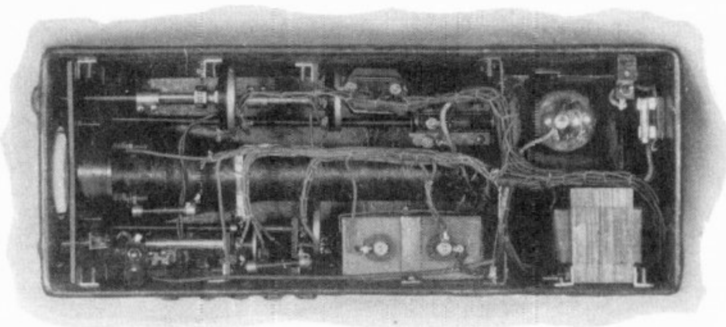


FIGURE 15 (above) Portable Cathode-Ray Oscillograph Using the RCA-906.

FIGURE 16 (below) Interior of the Oscillograph Showing Arrangement of Parts.

Lissajous Figures

When varying voltages are applied to the deflecting plates of a cathode-ray tube, a pattern is obtained on the fluorescent screen, as has been discussed previously. The shape of this pattern depends upon the wave forms of the applied voltages and upon their phase relationships. In this discussion, a study of these patterns, or Lissajous figures, will be made with particular attention to their development, to the effect of phase shift, and to their use in identifying frequency ratios.

Simple Figures

Figure 17 represents a sine-wave voltage (A) applied to one pair of deflecting plates (vertical axis) of a cathode-ray tube and an identical voltage (B) applied to the other pair of deflecting plates (horizontal axis). 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 22A and 22E*. Figure 18 illustrates the case of two identical voltages having the same amplitude but 90°, or 270°, out of phase. In this case, the resulting figure is a circle. If one of the figures is of greater amplitude than the other, the resulting pattern will be an ellipse, as shown by Figure 22C. If the phase relation is such that one voltage leads by 45°, or 315°, the resulting pattern will be that of Figure 22D; if leading by 135°, or 225°, the resulting pattern will be that of 22B. Figures 17 to 21, 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 a cathode-ray tube, the resultant pattern can easily be reproduced on the fluorescent screen. Conversely, the frequency and the phase relation of the two deflecting voltages can be determined from this pattern. 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 17, 18, and 22A to 22E are for a 1 : 1 frequency ratio. When the frequencies have a 2 : 1 ratio, the wave shapes of Figures 22A to 22E become those shown by Figures 22F to 22J.

Complex Figures

As the ratio of the frequencies increases, the pattern becomes more complex. In Figure 19, 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 20 is the same as Figure 19 except that voltage A is started 90° out of phase with respect to voltage B. Figure 26 illustrates a 6 : 1 frequency ratio. Patterns

* Figures 22 to 28 inclusive, and Figures 38 and 39 adapted from "Frequency Measurements with the Cathode Ray Oscillograph," Frederick J. Rasmussen, A. I. E. E. Transactions, November, 1926, Vol. XLV, Pages 1256-65.

having integral frequency ratios are distinguished from the more complex patterns by the way in which the complete trace is repeated for each cycle of the lower frequency. When the pattern consists of a sine wave for both horizontal and vertical deflections, the true waveform of either voltage is not easily visualized when the frequency ratio is low. However, if the ratio becomes as high as the 6 : 1 pattern of Figure 26, the higher frequency cycles appear more nearly in their true form near the center (most linear part) of the lower frequency sweep. In order, therefore, for waveforms to be viewed in their true shape with respect to time, a linear sweep circuit is usually employed (see data on the 885, page 15). Figure 21C is a 2 : 1 pattern obtained with a linear sweep (21B) of the saw-tooth type.

Determination of Frequency by Inspection of Pattern

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 a photograph. 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 Lissajous 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 26 is a simple, single-line pattern having a frequency ratio of 6 : 1. With a base frequency of 60 cycles per second, this pattern is the picture for a 360-cycle wave; or with a base frequency of 100 cycles, it is the picture of a 600-cycle wave. The frequency ratio is determined by the number of peaks (six) of the waves in the horizontal plane and by the number of end loops, which for this case is one; hence, a frequency ratio of 6 : 1. In Figure 26, 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 may mislead the observer to believe that the frequency ratio is less than 6 : 1. Adjustment of the unknown frequency so that the pattern rotates very slowly, or stands still with the rear peaks separated from the front peaks, will make the determination simplest. It will be observed that the wave form of Figure 26 corresponds to that of Figure 29*, a single-line pattern whose back trace is not visible.

When one frequency is not an integral multiple of the other, the successive cycles of the lower frequency do not fall upon each other on the pattern. If the trace of Figure 27 is followed and the

* Figures 29 to 35 inclusive, and Figures 36 and 37 adapted from "The Cathode Ray Oscillograph in Radio Research," R. A. Watson Watt. Published by His Majesty's Stationery Office, London, England.

upper peaks of the cycles are numbered, it is necessary to make two horizontal excursions across the pattern before the trace is repeated. The same analysis shows that in Figure 28 three cycles of the low horizontal frequency are completed before the pattern begins to repeat. Figure 27 is then said to be a two-line pattern having a 9 : 2 frequency ratio. The "vertical" frequency is, therefore, 4-1/2 times the "horizontal" frequency. In the same manner, Figure 28 is found to be a three-line pattern having a 16 : 3 ratio where the vertical frequency is 5-1/3 times the horizontal frequency.

Figure 35 shows the simplest 2 : 1 wave, or two-line figure. Figure 27 is a complete two-line figure illustrating a ratio of 9 : 2, which again is readily determined by the number of peaks along the top of the figure and the number of loops at the end. Figure 28 has 16 peaks and is a three-line pattern, indicating a frequency ratio of 16 : 3.

Figures 26, 27, and 28 illustrate patterns as they generally appear on the fluorescent screen. Figures 23 to 25, and 29 to 35 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 the determination of frequency ratio is that of comparing the number of peaks on a given figure with the horizontal lines of intersections, rather than with the number of end loops. A study of some of the patterns will make this clear. In Figure 32, there is a single line of intersections along the axis of the pattern. It can easily be seen that this is a two-line figure by comparing it with single-line Figures 29 and 35. Figures 28, 31, and 33, 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 23, 30, and 34 are distinguished by three lines of intersections, the five-line pattern of Figure 24 by four lines of intersections, and the six-line pattern of Figure 25 by five lines of intersections, with characteristic positions for these lines in each case. Thus, the frequency ratio is equal to the number of peaks on the circumference divided by the term, one plus the number of horizontal lines of intersections.

Sequence of Patterns

Of the patterns from 17 to 35, those of Figures 29, 35, and 19 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 a 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	19
75	5 : 4	1-1/4 : 1	20
80	4 : 3	1-1/3 : 1	21
90	3 : 2	1-1/2 : 1	22
100	5 : 3	1-2/3 : 1	23
105	7 : 4	1-3/4 : 1	24
120	2 : 1	2 : 1	25
135	9 : 4	2-1/4 : 1	-
140	7 : 3	2-1/3 : 1	-
150	5 : 2	2-1/2 : 1	-
160	8 : 3	2-2/3 : 1	-
165	11 : 4	2-3/4 : 1	-
180	3 : 1	3 : 1	19

* 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 pattern, or as a ratio of a whole number and a fraction, to unity.

If the base frequency is 1000 cycles per second instead of 60, the same ratios hold. Thus, instead of 60 to 180 cycles per second, the frequencies for these patterns would be those for 1000 to 3000 cycles with intermediate values of 1250, 1333-1/3, 1500, 1666-2/3, 1750, 2000, 2250, 2333-1/3, 2500, 2666-2/3, and 2750 cycles per second.

Elliptical and Circular Figures

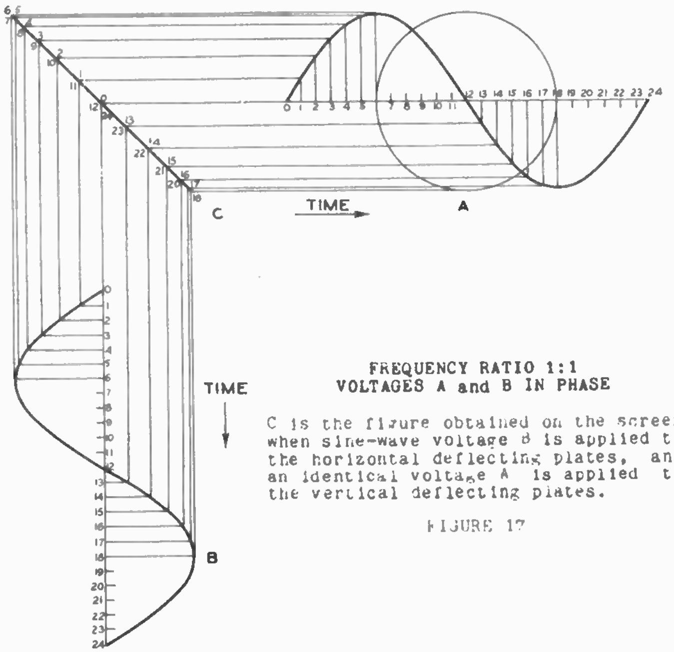
When waves having frequency ratios greater than 10 : 1 are compared, accurate determinations may be difficult with the front and back portions of the figures in the same horizontal plane. To separate the front and back portions, the figures can be displaced to show either on an ellipse or on a circle.

For an ellipse, a phase-splitting device consisting of a resistance and a capacitance is employed (Figure 40). Resistance (R) is connected across one set of deflecting plates and capacitance (C) is connected across the other pair. Figures 36 and 37 show the same single-line pattern and are obtained when the circuit of Figure 40 is adjusted for different vertical amplitudes. Figure 38 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.

To produce the type of pattern shown in Figure 39, a circular axis is developed using the circuit of Figure 40, 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 No.2 anode circuit. Defocusing can be minimized if this voltage is kept at a low amplitude.

Simplification of the Pattern

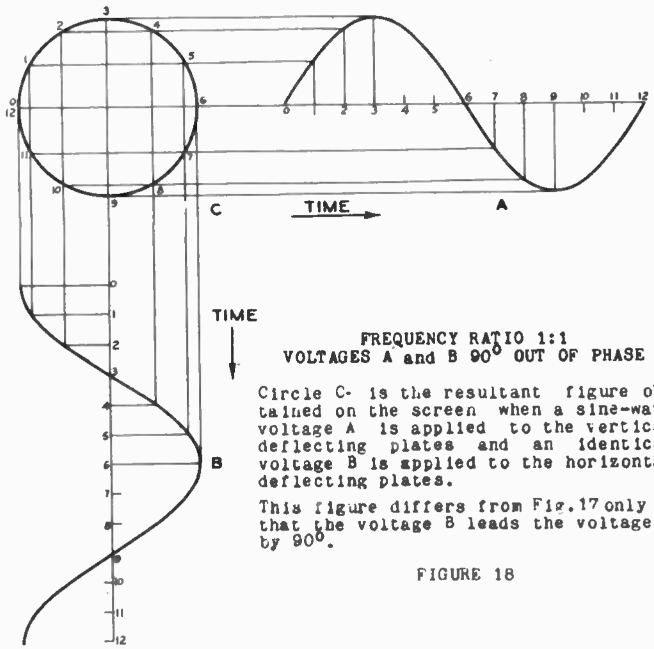
It has been pointed out that the patterns of Figures 23 to 25 and 29 to 35 are developed on a plane. The resulting patterns are much simpler than they would be with their normal appearance because the back wave has been removed by spreading it out in the same plane with the front wave. The advantages 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 27, for instance, is a two-line pattern, as shown by the two loops at the end of the figure. However, because of the shift of the figure, the intersections made by the lines of the back wave with the lines of the front wave give it the same appearance as the four-line pattern of Figure 23. 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 eliminating the back wave entirely.



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 17

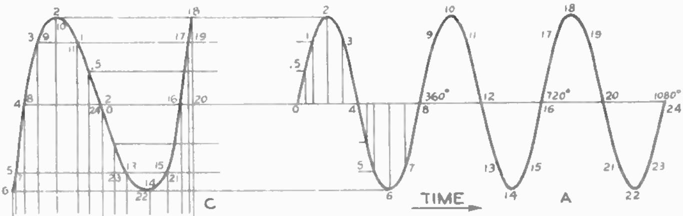


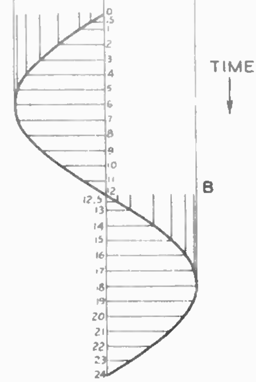
FREQUENCY RATIO 1:1
VOLTAGES A and B 90° OUT OF PHASE

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 Fig.17 only in that the voltage B leads the voltage A by 90°.

FIGURE 18



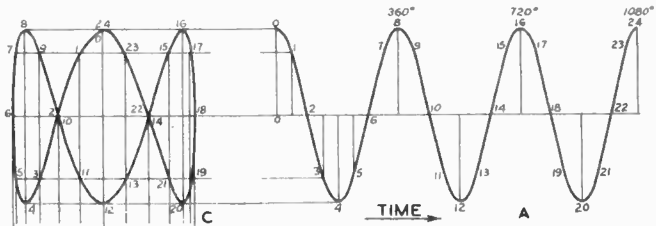


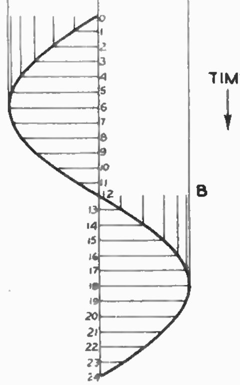
FREQUENCY RATIO 1:3
VOLTAGES A and B IN PHASE

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 19





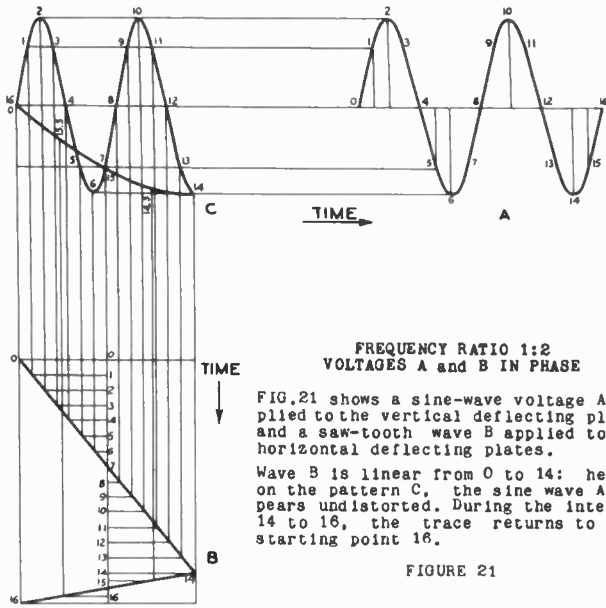
FREQUENCY RATIO 1:3
VOLTAGES A and B 90° OUT OF PHASE

FIG.20 shows the effect of phase shift on the pattern of FIG.19.

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.

FIGURE 20



FREQUENCY RATIO 1:2
VOLTAGES A and B IN PHASE

FIG.21 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 21

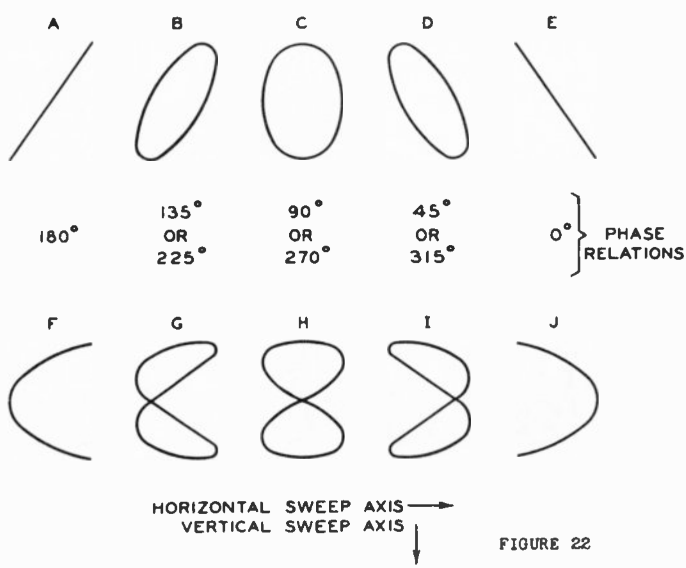
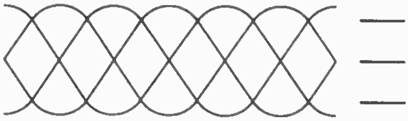
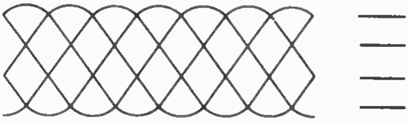


FIGURE 22



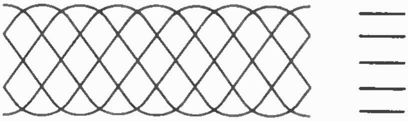
6:4 $1\frac{2}{4}:1$

FIGURE 23



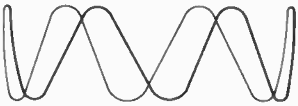
7:5 $1\frac{2}{5}:1$

FIGURE 24



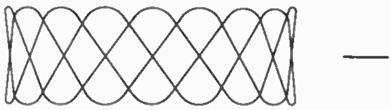
8:6 $1\frac{2}{6}:1$

FIGURE 25



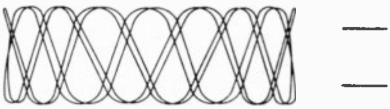
6:1

FIGURE 26



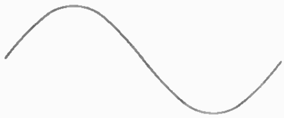
9:2 $4\frac{1}{2}:1$

FIGURE 27



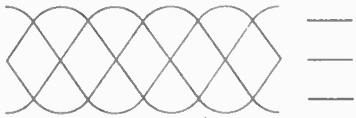
16:3 $5\frac{1}{3}:1$

FIGURE 28



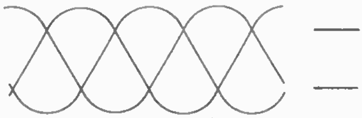
1:1

FIGURE 29



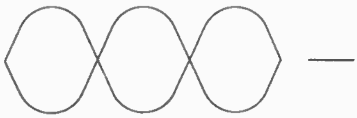
5:4 $1\frac{1}{4}:1$

FIGURE 30



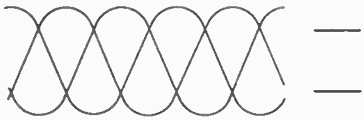
4:3 $1\frac{1}{3}:1$

FIGURE 31



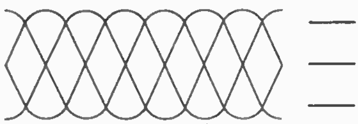
3:2 $1\frac{1}{2}:1$

FIGURE 32



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

FIGURE 33

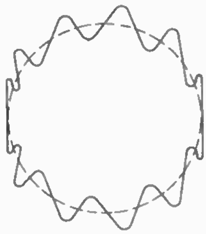


7:4 $1\frac{3}{4}:1$

FIGURE 34

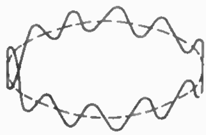
2:1

FIGURE 35



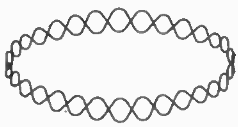
10 : 1

FIGURE 36



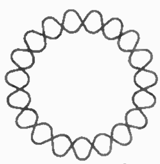
10 : 1

FIGURE 37



31:2 $15\frac{1}{2}:1$

FIGURE 38



19:2 $9\frac{1}{2}:1$

FIGURE 39

PHASE-SPLITTING CIRCUIT FOR OBTAINING ELLIPTICAL OR CIRCULAR AXIS

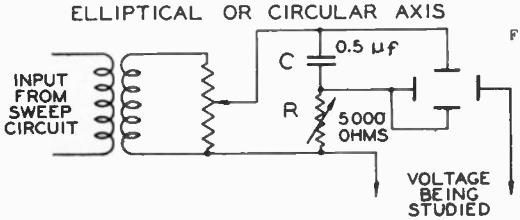


FIGURE 40

Photography of Cathode-Ray Tube Patterns

A photographic record of the phenomena appearing on the viewing screen of a cathode-ray tube can be made with the aid of an ordinary camera. The making of the photographic record is done preferably in subdued light in order to obtain as much contrast as possible between the fluorescent pattern and the background. The camera should be solidly supported, and should be sharply focused on the fluorescent pattern.

When the usual roll-film type of camera is used, a portrait attachment will permit the taking of larger photographs. The focusing scale on this type of camera can be calibrated with the aid of a piece of ground glass, before the camera is loaded with film. The distance from the camera lens to the cathode-ray tube screen and the magnification, or ratio of the size of the photographic image to the size of the fluorescent pattern, should be recorded for each position marked on the focusing scale of the camera.

The exposure time will depend on the speed of the camera lens (stop opening usually expressed as an f/value), the kind of film or plate emulsion used, the magnification of the pattern, the brilliancy of the pattern, and the type of cathode-ray tube screen. Since the record is usually smaller than the pattern, the magnification is generally a value which is less than unity.

For recurrent patterns, the brilliancy is determined by the power input per unit fluorescent area on the screen. The power input to the fluorescent screen (in a high-vacuum cathode-ray tube) is equal to the product of the No.2 anode voltage and the beam current (current collected by No.2 anode and deflecting plates). The fluorescent area can be estimated from the line width and length of the trace. A calibration factor for any particular cathode-ray tube, operating at a definite anode voltage and being used in conjunction with a certain film or plate emulsion, is readily obtained by means of a series of trial exposures for different lens stops or exposure times. Several trial exposures may be made on one film if the camera is moved slightly after each exposure; a single-line pattern is convenient for this purpose. If a suitable photograph is obtained in time (t_1) with a lens stop of F_1, a magnification of M_1 and a power input of w_1 watts per sq cm of fluorescent area, then the calibration constant (K) is given by the following expression:

$$K = \frac{t_1 w_1}{F_1^2 (M_1 + 1)^2} \qquad (1)$$

The time exposure (t) required for any other values of lens stop (F), watts (w) per sq cm of fluorescent area, and magnification (M) is given by the following expression:

$$t = \frac{K F^2 (M + 1)^2}{w} \qquad (2)$$

The value of K does not change unless the cathode-ray tube, the photographic emulsion, or the No.2 anode voltage is changed. Since the characteristics of different cathode-ray tubes of the same type and of different batches of the same photographic emulsion show variations, the values of K given in the table on page 89 are intended only as a rough guide. They may be used to estimate approximate values of the exposure times required for satisfactory photographs. In general, it is recommended that a more accurate value of K be determined by trial for each particular set-up.

For transient phenomena where only a single trace of the pattern occurs, the photographic effect depends upon how fast the fluorescent spot moves across the screen. That is, the velocity of the spot on the screen is the determining factor. A calibration constant (C) is readily determined for any particular cathode-ray tube operating at a certain No.2 anode voltage in conjunction with a certain film or plate emulsion. Any non-recurrent pattern of known velocity can be used for calibration. A convenient pattern covering a wide velocity range consists of a spiral produced by the application of an alternating, sine-wave voltage to each pair of deflecting plates, the voltage applied to one pair of plates being 90 degrees out of phase with the voltage applied to the other pair. Likewise, currents of proper phase relation can be applied to a tube having a magnetic deflecting system. An example of a spiral pattern is shown on page 90. When the amplitudes of the two voltages are equal, a circular pattern is produced. When the supply voltage controlling both components is increased, the circle diameter is increased. A single transit of the circle occurs once each cycle. Thus, a rapid increase in the supply voltage produces a spiral pattern. The velocity of the spot at a given point in the pattern can be determined from the diameter of the circle at that point and from the frequency of the supply voltage (60 c.p.s. is often convenient). If a suitable photograph is obtained at velocity (V_1), magnification (M_1), and total watts input to the screen (W_1), then the calibration constant (C) is given by:

$$C = \frac{V_1 F_1^2 (M_1 + 1)^2}{W_1} \qquad (3)$$

For any other velocity (V) not too far different, the corresponding exposure can be calculated with the value of C determined above and the relation:

$$V = (C) \frac{W}{F^2 (M + 1)^2} \qquad (4)$$

where W is the total watts input to the screen (line width is the same as that used for calibration), F is the lens stop, and M is the magnification.

Values of C suitable for a rough estimate of the velocity in inches per second which will allow the trace to be photographed are given in the table on page 89. In general, it is recommended that more accurate values of C be determined by trials for the particular set-ups employed.

The fluorescent screens used in present types of RCA cathode-ray tubes are of two general kinds; these are identified as phosphor No. I and Phosphor No. 5. RCA types 903, 904, 905, and 906 have the No. I phosphor screen. RCA types 907 and 908 employ the No. 5 phosphor screen. The No. I screen has good visual and photographic properties, as well as high luminous efficiency. The No. 5 screen is especially suitable for photographic recording. For moving-film recording, it is necessary to use a type of fluorescent screen which has a short phosphorescent effect in order to avoid blurring of the recorded trace. The No. 5 phosphor screen is of this type, since it has a very short persistence time (less than 30 microseconds). The medium persistence of the No. I screen is an aid in visual work, and has no undesirable effect on the photographing of cathode-ray tube patterns when a stationary film is employed. Curves giving the characteristics for each type of screen are given on pages 32-35 and 58-60.

Due to the difference in spectral distribution and luminous efficiency of the No. I screen and the No. 5 screen, the photographed trace appears narrower than the visible trace when the No. I screen is used. When the No. 5 screen is employed, the visible trace is narrower than the photographed trace. As a result, when adjustments are made to give the same *visible* line width the No. 5 screen may have greater beam current and power input than the No. I screen. A larger power input to the No. 5 screen will produce some additional photographic action.

For photographic work involving high-speed non-recurring phenomena, it is permissible to exceed the rated maximum fluorescent screen input power per sq cm for the short interval required to make the exposure. The extent to which the anode current may be increased without harming the screen is a direct function of the rate of beam travel and pattern size, and an inverse function of duration.

Short-interval operation at increased input can be obtained by means of a temporary decrease in the control-grid bias voltage. A switching arrangement should be provided to switch the grid bias voltage rapidly between two different negative values. The exposure is made while the grid voltage is at the less-negative value.

APPROXIMATE VALUES OF THE CONSTANTS K AND C

FOR SATISFACTORY PHOTOGRAPHS *

Tube Type	No.2 Anode Voltage	Photographic Emulsion #	K Recurrent Phenomena Use Formula (2)	C** Transient Phenomena Use Formula (4)
906	1000	Ordinary	0.000200	20000
906	1000	Verichrome	0.000050	80000
906	1000	Kodak S.S.Pan.	0.000025	160000
908	1000	Ordinary	0.000150	27000
908	1000	Verichrome	0.000150	27000
908	1000	S.S.Panchromatic	0.000150	27000
905	2000	Ordinary	0.000040	100000
905	2000	Verichrome	0.000010	400000
905	2000	S.S.Panchromatic	0.000005	800000
905	1000	Ordinary	0.000120	33000
905	1000	Verichrome	0.000030	133000
905	1000	S.S.Panchromatic	0.000015	267000
907	2000	Ordinary	0.000030	133000
907	2000	Verichrome	0.000030	133000
907	2000	S.S.Panchromatic	0.000030	133000
907	1000	Ordinary	0.000090	44000
907	1000	Verichrome	0.000090	44000
907	1000	S.S.Panchromatic	0.000090	44000
904	4600	Ordinary	0.000040	100000
904	4600	Verichrome	0.000010	400000
904	4600	S.S.Panchromatic	0.000005	800000
904	2000	Ordinary	0.000040	100000
904	2000	Verichrome	0.000010	400000
904	2000	S.S.Panchromatic	0.000005	800000
904	1000	Ordinary	0.000080	50000
904	1000	Verichrome	0.000020	200000
904	1000	S.S.Panchromatic	0.000010	400000

*If the traces on a No.1 screen and on a No.5 screen are adjusted to give the same *visible* line width, the No.5 screen will have approximately 7.5 times as much No.2 anode current (the total screen input power is equal to the product of this current and the No.2 anode voltage) as the No.1 screen. Under this condition, the exposure time for the No.5 screen will be with ordinary film 10% of that for the No.1 screen; with Verichrome film, 40%; and with S.S.Panchromatic, 80%.

#Or equivalent emulsions.

**Determined with 60-cycle spirals and a line width of approximately one millimeter.

Typical Oscillograms

The oscillograms shown in Figures 41 to 52 were recorded photographically* and are typical of the results which can easily be obtained by the user of a cathode-ray oscillograph. These examples illustrate only a few of the possibilities of cathode-ray-tube photography. They have, however, been chosen to show typical procedure for a wide range of applications involving audio, radio, recurrent, and transient phenomena.

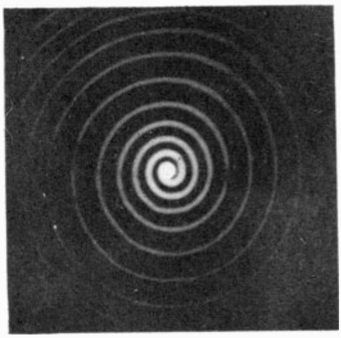


FIGURE 41

FIGURE 42

FIGURE 41 - Type RCA-905; No.2 anode voltage and current, 2000 volts, 25 microamperes; lens stop f/4.5; magnification, 1.0.

FIGURE 42 - Data are the same as for Figure 41 except that the magnification is 0.25.

Figure 41 is a 60-cycle spiral made with a two-phase voltage supply. The magnification is 1.0. The two-phase source is obtained by means of a step-up transformer having an output voltage of approximately 300 volts. Figure 40 shows the essential circuit employed. The potentiometer across the transformer secondary may be one having a resistance of 10000 ohms. The series resistor (variable) and condenser may be 50000 ohms and 0.075 µf, respectively. The voltage drop across the condenser is 90 degrees out of phase with the drop across the resistor with the result that an elliptical pattern is produced on the screen of the 905. The ellipse is changed to a circle when the 50000-ohm resistor is adjusted so that the voltage drop across it is approximately equal to the drop across the condenser. Then, as the 10000-ohm potentiometer is changed, the diameter of the circle may be varied. If the potentiometer is moved rapidly, a spiral pattern results, as shown in Figure 41. Information on the practical use of a spiral pattern for photographic calibration purposes is given on page 87 under PHOTOGRAPHY OF CATHODE-RAY TUBE PATTERNS.

* The camera employed for these oscillograms was a studio-portrait type, capable of taking 5" x 7" photographs. The photographs were taken on Verichrome film and developed 3 minutes in a solution of one Eastman M.Q. developer tube per 4 ounces of water (65°C). They were then washed in weak acetic-acid short stop, fixed 20 minutes in a fresh solution of 16 ounces of hypo, 64 ounces of water, and 16 ounces of Velox liquid hardener, and finally, washed at least an hour before being allowed to dry. Prints were made on #5 Azo glossy paper, developed, washed, fixed, and washed in a manner similar to that described above for Verichrome film, with identical solutions.

Figure 42 is a spiral taken in the same manner as that of Figure 41, except that the magnification is 0.25.

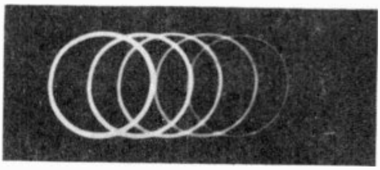


FIGURE 43

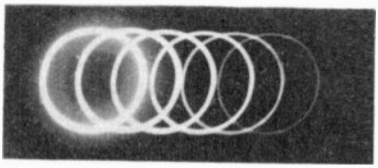


FIGURE 44

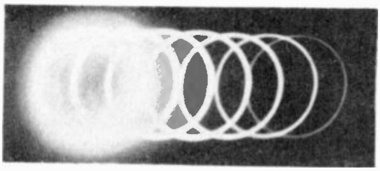


FIGURE 45

FIGURE 43 - Type RCA-906; No.2 anode voltage and current, 1000 volts, 5.0 microamperes; lens stop f/6.3; magnification, 1.0; see text for time of exposure.

FIGURE 44 - Data are the same as for Figure 43 except that exposure time was held constant at 40 seconds and lens stop was varied; see text for lens stop values.

FIGURE 45 - Data are the same as for Figure 44 except that exposure time was held constant at 80 seconds.

Figure 43 is a series of circles made with the two-phase supply just described, the potentiometer being set for a convenient circle diameter. A series of circles can easily be obtained if the lens board of the camera is moved in steps, a new time exposure beimg made at each position of the board. The most dense circle has an exposure of 8 seconds; the next, 4; then, 2, 1, 0.5, 0.25, and 0.12 seconds. The latter exposure did not record on the original print, and the 0.25-second circle is hardly perceptible in the reproduction of Figure 43. With this type of pattern, the densities of the negative for various exposures may be judged, since the adjacent circles intersect and the points near the intersections are conveniently located. If the camera is not fitted with a lens board, the camera itself may be rotated slightly about a vertical axis in order to get the series of circles on one film.

Figure 44 was obtained much the same as Figure 43, except that the lens stop was varied while the exposure time was held constant at 40 seconds. The most dense circle was taken with a lens stop of f/6.3; then, in order, the stops are f/8.9, 12.6, 17.8, 25.2, 35.6, and 50.4. The latter reproduced faintly on the original print.

Figure 45 is the same as Figure 44, except that the time for each exposure was made 80 seconds instead of 40 seconds. In Figure

43, no blurring of the most dense circle occurs and yet it is made with 32 times as long an exposure as the least dense circle. It is apparent, therefore, that the exposure may vary over wide limits before the trace either blurs due to over-exposure or fails to record due to inadequate exposure.

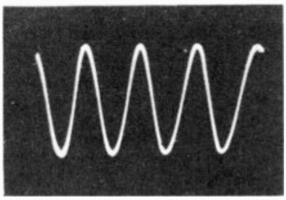


FIGURE 46

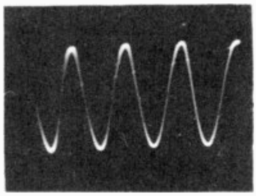


FIGURE 47

FIGURE 46 - Type RCA-905; No.2 anode voltage and current, 2000 volts, 0.8 microampere; exposure time, 8 seconds; magnification, 1.0.

FIGURE 47 - Type RCA-905; No.2 anode voltage and current, 500 volts, 0.8 microampere; exposure time, 2 minutes.

Figure 46 is a time exposure of a 60-cycle sinusoidal supply voltage spread out by a reasonably linear time sweep. In this case, the frequency of the linear sweep voltage is a one-fourth sub-multiple of the frequency of the supply voltage, or 15 cycles per second. This is easily determined by the fact that four complete cycles of the 60-cycle voltage appear on the viewing screen.

Figure 47 is a time exposure of an r-f voltage having a 200 000-cycle frequency; it is spread out by a linear time-sweep voltage of 50000 cycles per second, another one-fourth sub-multiple. A difference occurs between Figures 46 and 47 in that the time of return for the sweep voltage (which is of the saw-tooth wave-form type) is negligible at 60 cycles but is nearly 1/4 cycle at 200 000 cycles. Since one cycle occurs in 1/200 000 part of a second, the return sweep takes only 1/800 000 of a second, in the case of Figure 47.

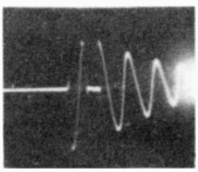


FIGURE 48

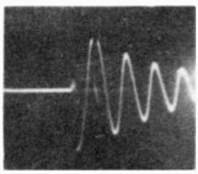


FIGURE 49

FIGURES 48 and 49 - Type RCA-905; No.2 anode voltage and current, 2000 volts, 150 microamperes (instantaneous value); lens stop, f/6.3; magnification, 0.25.

Figures 48 and 49 show two transients caused by the discharge of a 0.5-μf condenser across a 0.25-henry choke. The center line is the normal trace of the time-sweep voltage, before the transient occurred. At the peak of the cycle, the contacts of the switch (which closed the condenser across the inductance) chattered; this caused a gap in the crest of the first wave. These pictures were taken with one sweep of the spot across the screen. A damping resistance of 3000 ohms was used across the inductance to shorten the length of the wave train. Even with this damping, the transient had not subsided when the spot completed its sweep across the viewing screen.

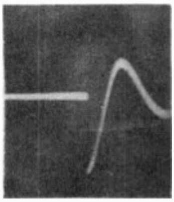


FIGURE 50

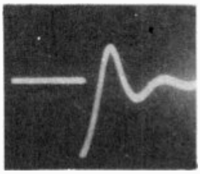


FIGURE 51

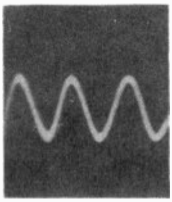


FIGURE 52

FIGURES 50 and 51 - Data are the same as for Figures 48 and 49.
FIGURE 52 - Data are the same as for Figures 48 and 49.

Figures 50 and 51 show the same transient as Figures 48 and 49, except that a 500-ohm damping resistor and a 4.5-μf condenser were employed. In addition, a special, non-chattering switch was used so that the wave, once started, would not be broken.

Figure 52 was taken as a transient but is a 250-cycle wave from a known frequency source, to be used as a calibrating means for the patterns of Figures 50 and 51. This wave was obtained by disconnecting the transient-signal lead to the oscillograph and substituting the 250-cycle voltage lead in its place. No other change was made in the circuit or camera setting, except that the lens board was moved so as to place the 250-cycle pattern on another part of the same film. Thus, the known amplitude and frequency of the calibrating voltage form a basis for calculation of the voltage and frequency of the transient. This calibration does not apply to Figures 48 and 49, which were taken with different transient and sweep-circuit constants.

Use of the Cathode-Ray Oscillograph for Checking Modulated R-F Waves

One of the most useful applications for the cathode-ray oscillograph is that of checking modulated radio-frequency wave forms. Although vacuum-tube voltmeters and conventional d-c meters have value in the determination of radiophone transmitter performance, the methods employing such meters are slow and cumbersome and, at best, give only partial results. The cathode-ray oscillograph, however, provides a convenient, rapid, accurate, and complete check, whether the r-f carrier, the modulating audio voltage, or the combination of both is under investigation.

There are two principal methods in which the oscillograph is employed for checking modulated wave forms. One is commonly known as the *trapezoidal* method; the other, as the *modulated-envelope* method. The name in each case is derived from the shape of the pattern obtained on the cathode-ray-tube screen. The two methods differ only in the type of time sweep used with the cathode-ray tube.

THE TRAPEZOIDAL METHOD

The *trapezoidal* method employs an audio-frequency time-sweep voltage taken directly from the output of the modulator, usually by means of a potentiometer in series with a fixed resistor (Figure 53). If the secondary of the modulation transformer is at a high d-c potential, a high-voltage blocking condenser must be placed in series with the voltage-divider lead going to the modulation transformer. This lead, as well as deflecting plate lead (a) in Figure 53, should be short and should have as little capacity to ground as possible, to avoid phase distortion at the higher audio frequencies. If no high

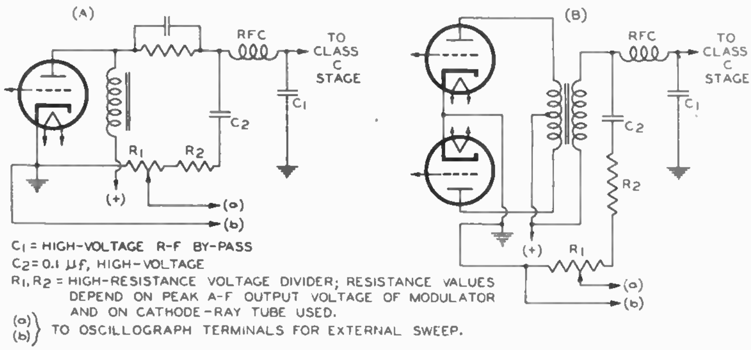


FIGURE 53 - Method of coupling modulator to oscillograph for trapezoidal patterns.
(A) Constant-current Class A modulator.
(B) Push-pull Class A or Class B modulator.

d-c voltage is connected to the secondary of the modulation transformer (as when parallel choke-and-condenser feed is employed), the blocking condenser can be omitted.

It is important to note that the audio voltage for the "horizontal-axis" time sweep should be taken directly from the output of the modulator and not from some intermediate stage in the pre-amplifier. The audio voltage at any other point than at the output of the modulator may be (and usually is) out of phase with the audio envelope of the carrier, especially at the very low and at the very high audio frequencies. Such an out-of-phase voltage applied to the time-sweep circuit of the cathode-ray tube results in a meaningless, distorted trapezoid, which usually has peculiar double-curved sides instead of straight-line sides. Figure 55(l) shows such a pattern.

The source of the audio signal for test purposes is preferably an audio oscillator having good wave form, variable frequency, and adjustable output voltage. A simple sine-wave audio oscillator is shown in Figure 56. The output voltage of this oscillator has very good wave form, as illustrated by Figure 57(a). The signal voltage may be coupled directly to the grid of the first or second pre-amplifier tube, usually without any change in its normal input circuit. A wide range of frequencies can be obtained if various values of inductance and capacitance are employed for L_1 and C_1 (Figure 56). A trapezoidal pattern can be held stationary with a steady a-f signal from such an oscillator, whereas a fluctuating signal such as that produced by music or voice causes the pattern to expand and contract about the vertical r-f carrier line; the amount of expansion depends on the percentage of modulation.

The r-f carrier voltage is applied to the "vertical-axis" deflecting plates of the cathode-ray tube by any convenient system. Typical methods are shown in Figure 54. With the r-f carrier volt-

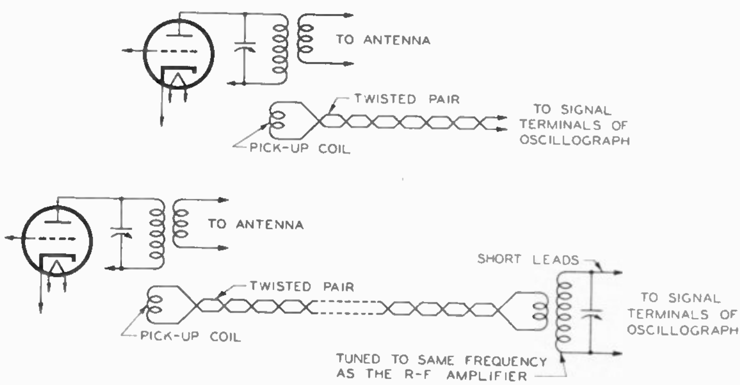


FIGURE 54 - Two methods of coupling r-f amplifier to oscillograph.

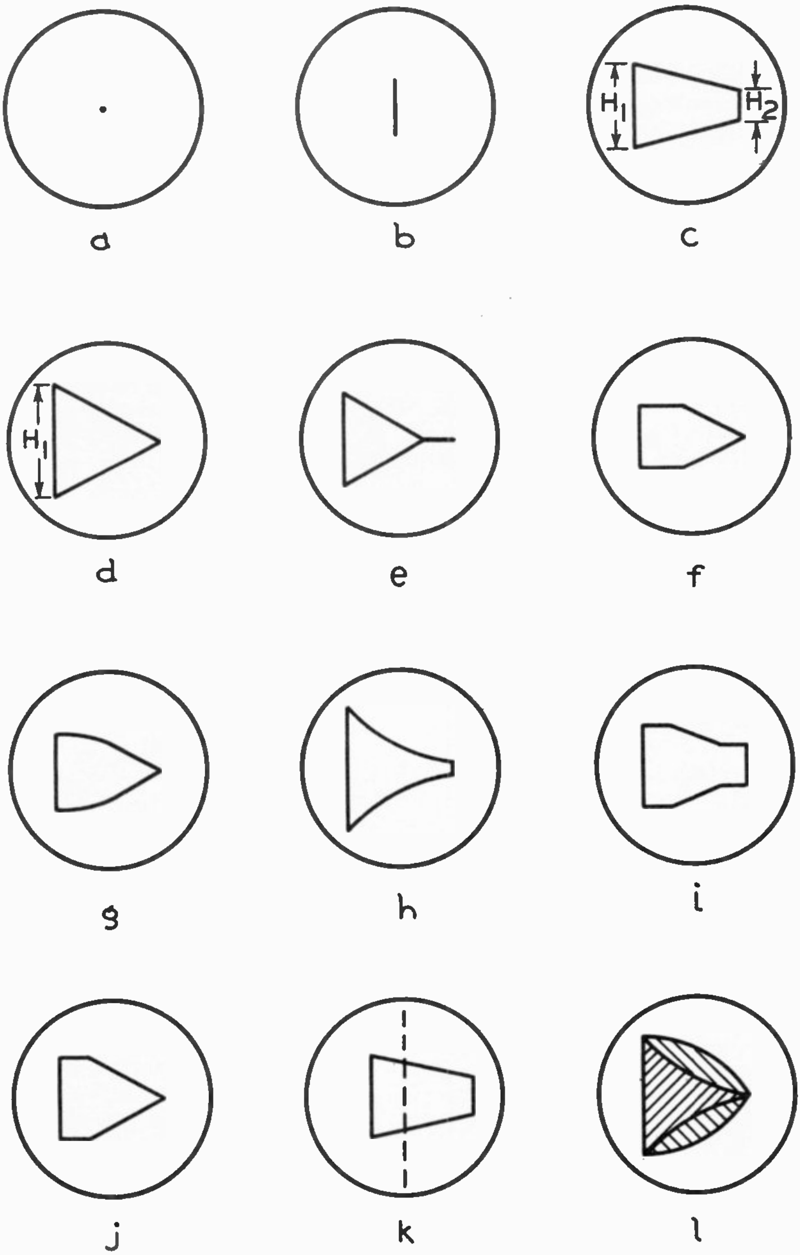
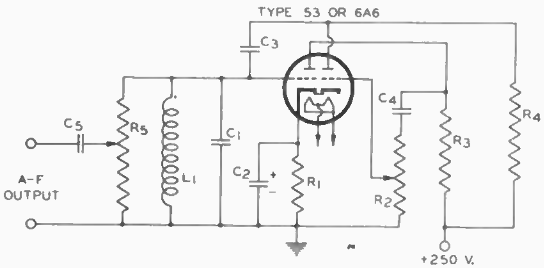


FIGURE 55 - Patterns obtained by the trapezoidal method; see text for interpretation.

age adjusted to the proper amplitude (without modulation), the pattern is a straight vertical line, as in Figure 55(b). If the a-f sweep voltage from the modulator is now applied, and the carrier is modulated 100 per cent, an isosceles triangle (a special case of the trapezoid) should be formed (Figure 55d). Less than 100 per cent modulation should produce a pattern such as 55(c), which is the trapezoid in its usual form. The actual percentage of modulation may be determined by measurement of the dimensions H_1 and H_2 (Figure 55c) and the following relation:

$$\text{Modulation Percentage} = \frac{H_1 - H_2}{H_1 + H_2} \times 100$$

From this equation, it is apparent that when H_2 is zero (the trapezoid then assumes the triangular shape of Figure 55(d), the modulation of the carrier is 100 per cent.



C_1, C_3, C_4, C_5 = 0.1 µf
C_2 = 16 µf ELECTROLYTIC, 15 V.
R_1 = 750 OHMS, 0.5 WATT
R_2 = 0.5-MEGOHM POTENTIOMETER
R_3, R_4 = 50000 OHMS, 0.5 WATT
R_5 = 50000-OHM POTENTIOMETER
L_1 = 1500-TURN (160 MH) HONEYCOMB COIL

FIGURE 56 - A simple sine-wave audio oscillator of the capacity-feedback type. Figure 57(a) shows the wave form of the output, the frequency being about 1250 cycles per second for the LC constants given above.

The reason for the pattern taking the trapezoidal (or triangular) shape can easily be understood from the following considerations (refer to Figure 55c): When the modulating a-f voltage reaches a positive maximum, the beam of the cathode-ray tube is deflected to one end of its horizontal traverse (the left end in Figure 55c). At the same instant, the r-f carrier is at a maximum value; thus, the larger end of the trapezoid is formed. When the modulating voltage swings to its negative maximum, the cathode-ray tube beam is deflected to the opposite end of its horizontal traverse — the right end of Figure 55(c). At this instant, the r-f voltage is at a minimum; thus, the smaller end of the trapezoid is produced. For a true Class C amplifier, the r-f output voltage increases in *direct proportion* to the amplitude of the modulating a-f voltage; thus, the sides of the trapezoid should be straight lines. A pattern having this characteristic indicates linear modulation. *Regardless of the frequency or wave form of the modulating voltage, the pattern produced is the same.* This fact makes the trapezoidal method of great value in the adjustment and checking of Class C or linear Class B r-f amplifiers, inasmuch as there is no possibility of audio distortion from the modulator giving a pattern similar to one caused by trouble in the r-f amplifier — a situation which can arise when the modulated-envelope method of checking is employed. However, the trapezoidal method is of little or no use for checking the actual audio wave form on the carrier.

Interpretation of Patterns

The group of drawings shown in Figures 55(a) to 55(l) illustrates typical patterns obtained with the trapezoidal method.

Figure 55(a) shows the spot focused on the screen of the cathode-ray tube before either r-f or a-f voltages are applied to the deflecting plates.

Figure 55(b) shows the non-modulated r-f carrier applied to the "vertical-axis" deflecting plates, with no time-sweep voltage applied to the other pair of deflecting plates.

In Figure 55(c), the a-f time sweep from the modulator is applied to the "horizontal-axis" deflecting plates; this spreads the pattern out on the viewing screen an equal distance each side of center. The modulation is linear and is less than 100 per cent.

Figure 55(d) is the pattern for an r-f amplifier modulated 100 per cent; the straight sides of the triangle show that the modulation is linear. The base (H_1) of the figure should be just twice the length of the non-modulated r-f carrier line of Figure 55(b).

Figure 55(e) shows over-modulation of the carrier. The "tail" at the tip of the triangle indicates zero r-f voltage over that portion of the modulation cycle; this means that the peaks of the negative audio swings are being clipped off. Such over-modulation causes distortion of the transmitted signal and makes the r-f carrier broader. The latter effect can cause severe interference with carriers on adjacent channels.

Figure 55(f) indicates that the modulated amplifier is not receiving enough r-f grid excitation. The positive a-f peaks are cut off because the r-f amplifier is unable to produce output proportional to the peak modulating voltage.

Figure 55(g) appears to be similar to 55(f), but it may be produced by a different cause. Such a pattern can be obtained from a Class C amplifier modulated by a Class B a-f amplifier, especially when the modulator plate supply is connected to the r-f buffer stage which furnishes grid excitation to the Class C modulated amplifier. On large a-f signal swings, the heavy current drawn by the Class B modulator may cause the plate-supply voltage to drop due to poor regulation in the power supply. This decreases the output of the r-f buffer stage, decreases the excitation to the final Class C stage, and thus limits the peak output of the latter. A separate power supply for the Class B modulator is a good remedy for this kind of trouble. Low-emission tubes in either the modulator or r-f amplifier can also cause a flattening of modulation peaks, which produces a pattern similar to Figure 55(g).

Figure 55(h) can be caused by a regenerative Class C r-f amplifier. The r-f output increases *more rapidly* than the modulating a-f voltage; thus, a pattern with curved sides is produced. An improperly neutralized triode amplifier can give such a pattern.

Figure 55(i) is the pattern for a screen-grid r-f amplifier whose plate is modulated but whose screen is operated at a fixed voltage. On the negative a-f swings, the r-f carrier does not go to zero because the fixed screen voltage causes some plate current to flow even when the plate potential is zero. On the positive a-f swings, the carrier peaks do not rise as high as they should because the screen voltage does not increase with the plate voltage. A screen-grid tube properly modulated in both screen and plate circuits will give a correct pattern such as that of Figure 55(d). If the screen by-pass condenser is made too large, the resulting pattern may look like Figure 55(i) even though the screen is modulated. The large condenser tends to flatten out the peaks of the a-f voltage on the screen. Feed-back and oscillation may result if the screen by-pass condenser is made too small.

Figure 55(j) is the pattern for a screen-grid r-f amplifier whose screen alone is modulated. The r-f output rises linearly from zero, but because the plate potential is fixed, the output cannot increase to the point corresponding to 100 per cent modulation. The screen may also become over-heated; therefore, modulation of the screen alone is not generally to be recommended.

Figure 55(k) shows how a trapezoidal pattern can shift to one side of the carrier line (instead of spreading equally on both sides as it should), due to an unsymmetrical audio wave form. In the example shown, the negative a-f peaks are greater than the positive peaks; this causes the trapezoid to expand more to the right than to the left, as indicated by the figure. In other respects, the trapezoidal method tells little about the wave form of the modulating voltage.

THE MODULATED-ENVELOPE METHOD

The *modulated-envelope* method of checking a radiotelephone signal differs from the trapezoidal method in that a linear time-sweep voltage is applied to the "horizontal-axis" deflecting plates of the cathode-ray tube. A linear sweep circuit using the RCA-885 is suitable. Such a circuit is shown on page 22.

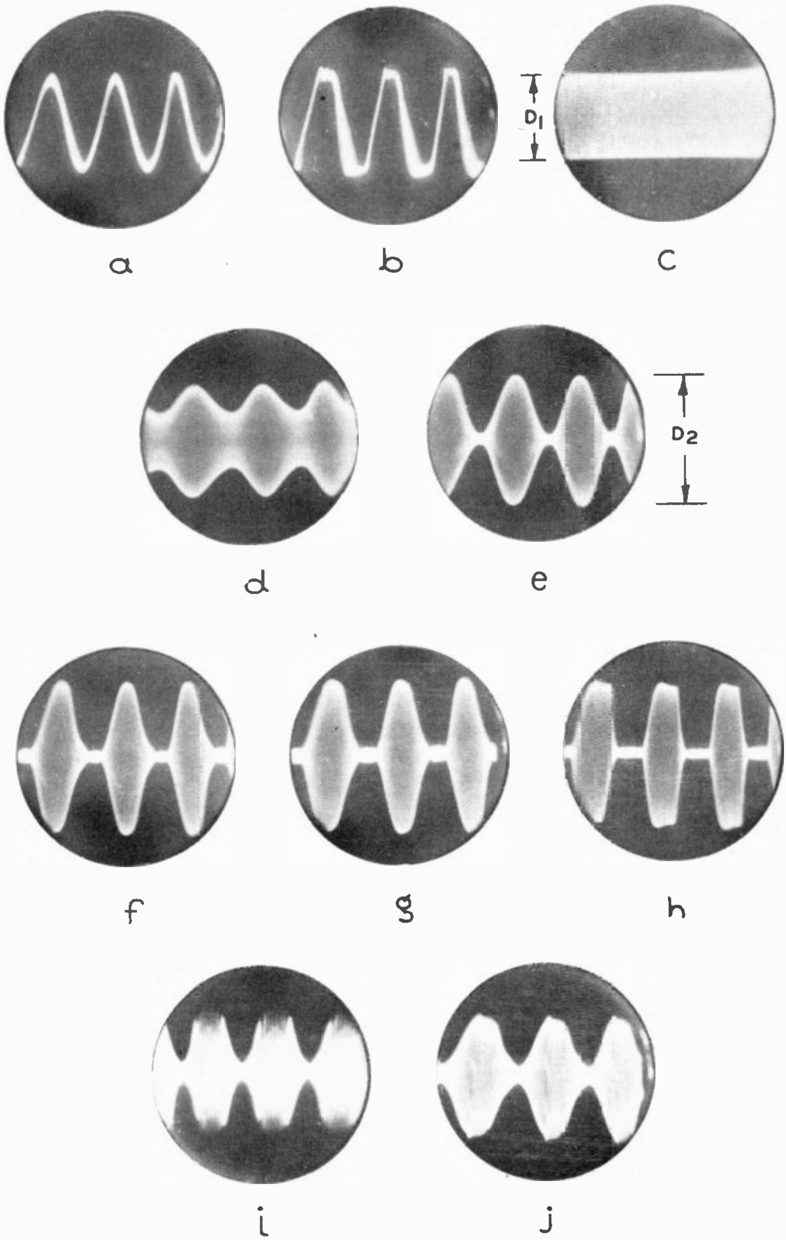


FIGURE 57 - Patterns (d) to (j) obtained by the modulated-envelope method; see text for interpretation.

To obtain an envelope pattern, it is necessary to apply the r-f carrier voltage to the "vertical-axis" deflecting plates of the cathode-ray tube and to adjust the carrier to a suitable amplitude. The linear time-sweep voltage from the 885, preferably synchronized with the audio-signal frequency, is applied to the other pair of deflecting plates. It is usually desirable to adjust the frequency of the linear time sweep to some small sub-multiple of the modulating frequency so that several complete modulation cycles of the r-f carrier will appear on the viewing screen. If the modulating frequency is 600 cycles per second, a time-sweep frequency of 200 cycles will produce an envelope pattern of three full cycles.

The modulated-envelope pattern provides a true, undistorted picture of the modulated r-f carrier. Any distortion of the audio wave can easily be detected by an inspection or an analysis of the envelope pattern, provided the output of the r-f amplifier is linear. If a tracing of the pattern from the original signal source (a-f oscillator) is superimposed on a tracing of one-half of the modulated-carrier pattern, the two should coincide almost perfectly, provided the same sweep frequency, signal frequency, and wave amplitude are used for both patterns.

Interpretation of Patterns

The group of patterns in Figures 57(a) to 57(j) illustrates the results that can be expected from the modulated-envelope method.

Figure 57(a) is the 1250-cycle test voltage from the audio oscillator shown in Figure 56. This is the signal used to modulate the carrier shown in subsequent illustrations.

Figure 57(b) shows the same audio signal with severe distortion resulting from the over-driving of a Class A stage used as a driver for a Class B modulator.

Figure 57(c) shows the unmodulated carrier, which in this case is oscillating at a frequency of about 14 megacycles. It appears as a solid band across the screen, since the 14 000 000-cycle frequency is too high to show individual r-f cycles. The height of the pattern may be controlled by the r-f input coupling.

Figures 57(d) and 57(e) show, respectively, a partially-modulated and a 100-per-cent-modulated carrier having a modulation envelope of good audio wave form. The percentage of modulation can easily be determined from the dimensions of the pattern. For a modulation percentage of 100, the peak-to-peak vertical deflection of the modulated signal should equal twice the height of the unmodulated carrier, provided the positive and negative r-f peaks are equal (as they should be). For a *properly modulated* carrier,

$$\text{Modulation Percentage} = \frac{D_2 - D_1}{D_1} \times 100,$$

where D_1 is the overall height of the unmodulated carrier and D_2 is the peak-to-peak height of the modulated carrier, as shown in Figures 57(c) and 57(e). The coupling of the r-f amplifier to the oscillograph should not be changed during a modulation measurement, because this would make the results of no value.

Figures 57(f) and 57(g) show over-modulation together with a considerable amount of audio distortion. The negative modulation peaks are clipped off and the rest of the modulation envelope does not follow the wave form of the test signal shown in Figure 57(a). The bead-shaped sections along the horizontal axis between the modulation cycles indicate that the modulated r-f amplifier has not been properly neutralized. If it had been, the "beads" would be short, thin, horizontal lines, no wider than the diameter of the spot.

Figure 57(h) is the pattern resulting from severe over-modulation together with high audio distortion. The similarity between this modulation envelope and the flat-topped audio signal shown in Figure 57(b) clearly shows the cause of the flat modulation peaks in the pattern of Figure 57(h).

Figure 57(i) shows a peculiar combination of faults. The r-f grid excitation to the Class C modulated amplifier is too low, the reflected load of the Class C stage on the Class B modulator is incorrect, and the modulator is oscillating at some spurious frequency much higher than the modulating signal frequency. The carrier attempts to follow the positive a-f peaks, but is unable to do so because of inadequate r-f driving power.

Figure 57(j) shows the type of signal emitted when the plate circuit of the modulated Class C amplifier is considerably detuned from resonance. The presence of phase modulation is indicated by this pattern.

SUMMARY

Of the two general methods described, the modulated-envelope system is probably the more desirable, although it requires a linear sweep circuit. With the linear sweep available, however, the operator can check under load conditions the wave form of the a-f voltage at any point in the modulating system. The trapezoidal method requires less apparatus and, for r-f linearity tests, is much more convenient than the envelope system. Either method, however, is considerably superior to systems using only meters. Most of the better broadcasting stations employ a cathode-ray oscillograph as a standard piece of station equipment. Many advanced radio amateurs also find the oscillograph an invaluable aid in adjusting and checking their apparatus.

Cathode-Ray Curve-Tracing Apparatus for Aligning Tuned Circuits

Curve-tracing devices for showing the resonance curves of the intermediate- or radio-frequency stages of broadcast receivers have been in use by receiver manufacturers for some time. The curve tracer is particularly useful where the r-f (or i-f) coupling is such that a double-peaked resonance curve is obtained, since the depth of the valley between the peaks is difficult to determine unless a plot of the curve can be examined. Such a plot is, of course, constantly before the aligner so that the effect of coupling or tuning adjustments can be observed during the adjustment process. Cathode-ray curve-tracing apparatus for this purpose is comparatively inexpensive and will give excellent results. Some of the advantages of a cathode-ray curve tracer are:

1. The trace is brilliant.
2. Overload does not damage the apparatus, but merely causes the beam to deflect off the screen.
3. The apparatus can be made portable.
4. The cost of the apparatus is low.

Since it is believed that an instrument of this type will be of distinct value to many laboratories, manufacturers, and service men who desire to improve their testing facilities, a detailed description of a cathode-ray curve tracer is given in the following discussion. This resonance curve tracer employs a type 906 cathode-ray tube. The instrument has been constructed and has been submitted to practical operating tests, with very satisfactory results. The design allows the device to cover a range of intermediate frequencies of 100 kc to 500 kc; it has an amplifier-detector section which is practically flat over the entire range. Figure 59 is the schematic circuit diagram, while Figure 58 shows the functional layout and a suggested arrangement for a portable instrument. The principles and methods involved in this application can be applied to obtain the curves of any form of tuned circuit and the frequency range is not limited to the 100-500 kc of the apparatus illustrated.

A resonance curve is a plot of the voltage output of a tuned stage for a given frequency band. To obtain this curve, it is necessary to have a voltage source, which in this instance is the oscillator (T_2) of Figure 59 and to have a source of variable frequency covering a range which extends above and below the resonant frequency. The frequency variation to sweep across the frequency range of the tuned circuit can be accomplished manually by hand manipulation of a condenser, or it can be speeded up to thirty times a second as is done in this case by means of an 1800 RPM motor. The fluctuating output voltage of the stage is then amplified, rectified, and again amplified, and finally applied to one set of deflecting plates of a cathode-ray tube. The other set of deflecting plates is supplied with the sweep-frequency voltage.

The frequency sweep is produced by a motor of about 1/20 hp or more, driving a rotating condenser (C_2) having a maximum capacitance of 0.00035 μf. A range switch (S_2) connects different values of capacitance C_3, C_4, C_5, etc., in series with C_2 to adjust the sweep for different frequency ranges. The oscillator is tuned by the adjustment of C_1.

A contactor on the motor shaft controls the linear sweep voltage by periodically short-circuiting condenser (C_7) This condenser charges linearly with time during the half revolution that condenser (C_2) sweeps the frequency. During the remaining half revolution, condenser (C_7) is short-circuited and C_2 returns to the initial position.

The rheostat (P_3) in the cathode circuit of tube (T_1) controls the charging rate of condenser (C_7). When P_3 is properly adjusted, the contactor on the motor causes the voltage of condenser (C_7) to return to zero somewhat before the condenser becomes fully charged. When P_3 is adjusted for too slow a charging rate, the sweep, as viewed on the screen of the cathode-ray tube, returns to zero before the full width of the screen has been traversed. On the other hand, if P_3 is adjusted so that the charging rate is too high, the sweep terminates with the condenser fully charged before the contactor has returned the condenser voltage to zero. Considerable distortion of the resonance curve traced on the screen results from the latter adjustment due to the non-linearity of the sweep voltage at the end of the traverse.

The proper adjustment of P_3 allows a full sweep across the screen without a bright spot occurring at the end of the sweep. The appearance of a bright spot is due to the electron beam remaining in one position for a greater length of time than in other positions. A bright spot will appear in the beginning of the sweep since the beam remains there for one-half of the sweep-voltage cycle.

The centering of the horizontal sweep line along the horizontal axis of the viewing screen is accomplished by the proper adjustment of potentiometer (P_4). The frequency-range switch (S_2) and the tuning condenser (C_1) should be adjusted so that the resonance characteristic appears in the center of the sweep. As condenser (C_1) is varied, the resonance characteristic is shifted along the sweep axis. The best value of C_1 is that which centers the resonance curve on the sweep range.

The grid of the i-f stage to be tested is connected to the rotating contact terminal of potentiometer (P_5). The receiver chassis and the chassis of the curve tracer should have a common ground in order to complete the input circuit. The test signal can be adjusted by means of P_5 to give a suitable height of resonance curve. The range switch (S_3) reduces the signal when an overall test of two or more i-f stages is made.

When intermediate amplifier stages are to be aligned, the output voltage from the plate of the tube following the i-f stage is connected through a blocking condenser, in series with a low resistance (R_3) of approximately 1000 ohms, to the amplifier circuit, as shown in Figure 59. When the tube following the i-f stage in the receiver under test is a diode detector, the resistor (R_3) can be eliminated. In this case, the input lead of the amplifier is connected to the high-potential end of the diode load resistance. Sufficient i-f voltage is generally present across the by-pass condenser of the diode load resistor to give a deflection on the cathode-ray tube. Since the diode load is by-passed, there is no capacity effect from the connecting leads and the resonance adjustment does not change with their removal. The resonance curve obtained on the screen of the cathode-ray tube represents audio frequency and, therefore, appears not as a modulation envelope but as a single-line curve above the horizontal axis.

The constants of the oscillator circuit will depend somewhat upon the arrangement of the wiring, the distributed capacitance, etc. In order to realize the full operating range of frequencies from 100 kc to 500 kc, it is important to have tuning condensers with low minimum capacitance, and to keep wiring capacitances at a minimum. The exact values for the constants of the oscillator circuit are best determined by actual test after the apparatus is in operation. Suggested values for these constants are as follows:

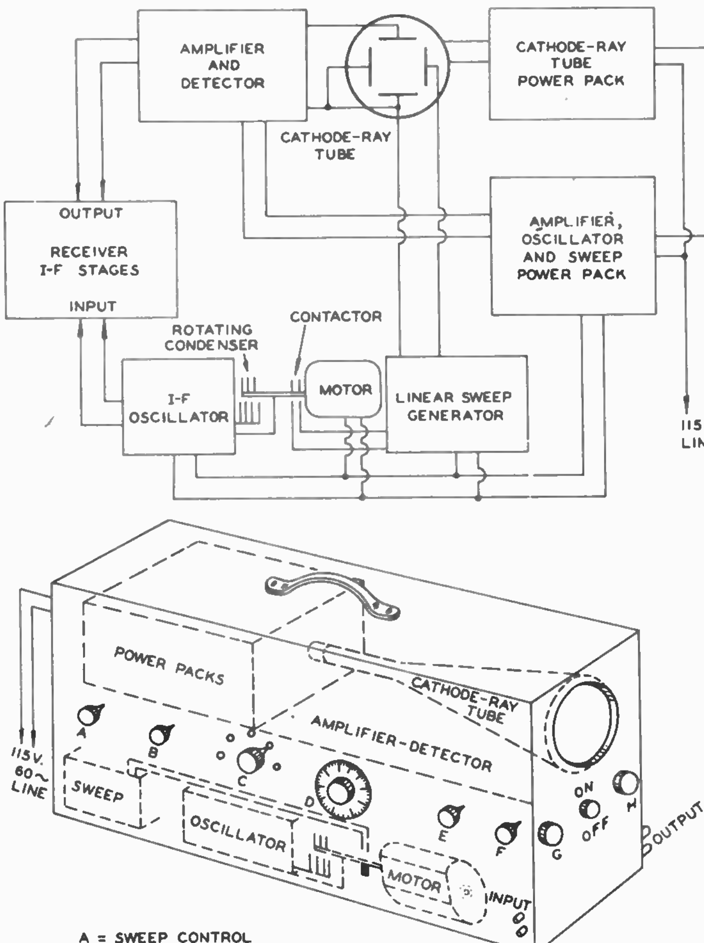
C_1	- 0.00015 *max.*	μf
C_2	- 0.00035 *max.*	μf
C_3	- 0.00005	μf
C_4	- 0.00005	μf
C_5	- 0.0001	μf
C_6	- 0.00035	μf
L_1	- 2.0	mh
L_2	- 2.0	mh
L_3	- 5.0	mh

NOTE: Condenser C_2 should be capable of rotating continuously and should be of the ball-bearing type. Inductances L_1, L_2, and L_3 should be closely coupled.

Desirable characteristics for the oscillator are uniform voltage output, especially throughout the sweep range, and frequency change proportional to the angular rotation of the frequency-sweep condenser (C_2). This condenser should preferably be one of the straight-line-frequency type, although an ordinary semi-circular-plate condenser is easier to balance mechanically in order to avoid vibration. The latter, however, is satisfactory for the usual alignment purposes; that is, with it no distortion of the resonance curve is noticeable to the eye, although it should not be depended upon for precise measurements.

Care should be taken to select a variable condenser that is rugged in construction and revolves on ball bearings. Contact with the rotor can be made by means of a brush or other smooth-riding pressure contact on the condenser shaft. The short-circuiting contactor is a standard automotive ignition breaker, operated by a cam on the motor shaft. A bakelite drum having a metal insert in its periphery can be used as a shorting device if desired.

The information contained in this discussion is given both to illustrate the principles involved in a cathode-ray curve tracer and to assist those who may desire to construct their own equipment. For those who prefer to buy their equipment, rugged, reliable, and well-designed resonance curve tracers are obtainable from manufacturers at a very reasonable cost.



A = SWEEP CONTROL
B = CENTERING CONTROL
C = FREQUENCY-RANGE CONTROL
D = FREQUENCY CONTROL
E = RANGE CONTROL
F = SIGNAL CONTROL
G = FOCUS CONTROL
H = BRILLIANCE CONTROL

FIGURE 58

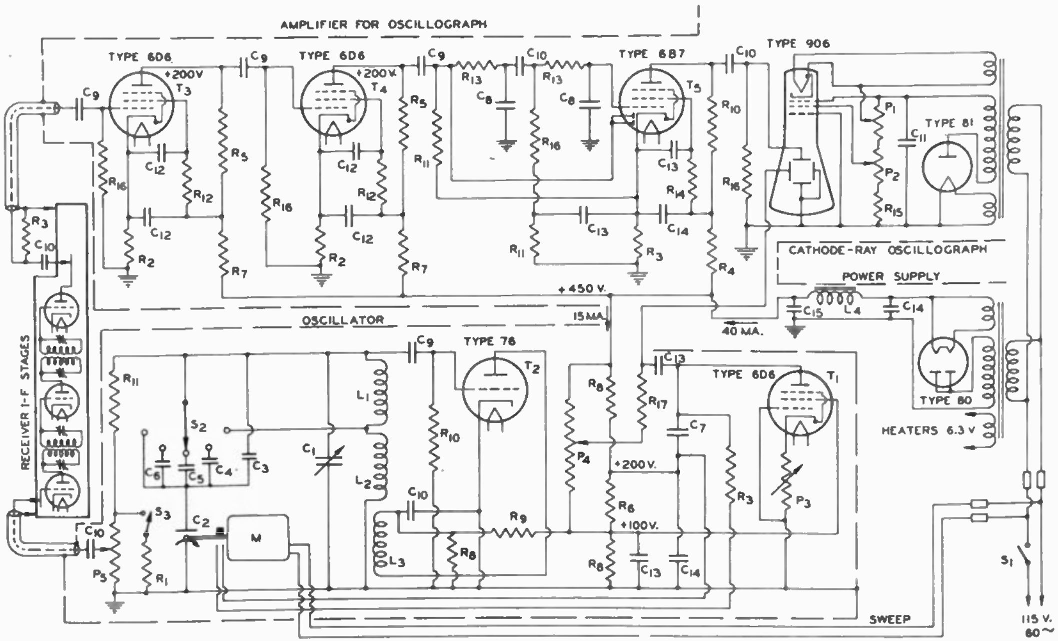


FIGURE 59

C_1 = MAIN TUNING CONDENSER
C_2 = FREQUENCY-SWEEP CONDENSER
C_3 =, C_4 =, C_5 =, C_6 = } FREQUENCY-RANGE CONDENSERS
C_7 = 0.5 μf
C_8 = .0001 μf
C_9 = .0002 μf
C_{10} = 0.1 μf
C_{11} = 1.0 μf
C_{12} = 2.0 μf
C_{13} = 4.0 μf
C_{14} = 8.0 μf
C_{15} = 16.0 μf
R_1 = 50 OHMS
R_2 = 300 OHMS
R_3 = 1000 OHMS
R_4 = 5000 OHMS
R_5 = 10 000 OHMS
R_6 = 11 000 OHMS
R_7 = 14 000 OHMS
R_8 = 15 000 OHMS
R_9 = 25 000 OHMS
R_{10} = 50 000 OHMS
R_{11} = 100 000 OHMS
R_{12} = 120 000 OHMS
R_{13} = 200 000 OHMS
R_{14} = 300 000 OHMS
R_{15} = 500 000 OHMS
R_{16} = 1 MEGOHM
R_{17} = 5 MEGOHMS
L_4 = 40 HENRIES
M = MOTOR, 1/20 H P - 1800 R.P.M.
S_1 = POWER-SUPPLY SWITCH
S_2 = FREQUENCY-RANGE SWITCH
S_3 = TEST-SIGNAL-RANGE SWITCH
P_1 = 50 000 OHMS, BRILLIANCE-CONTROL POTENTIOMETER
P_2 = 200 000 OHMS, FOCUSSING-CONTROL POTENTIOMETER
P_3 = 50 000 OHMS, TIME-SWEEP-CONTROL POTENTIOMETER
P_4 = 200 000 OHMS, CENTERING-CONTROL POTENTIOMETER
P_5 = 400 OHMS, TEST-SIGNAL-CONTROL POTENTIOMETER

A Deflecting-Magnet Current Amplifier For Use With Cathode-Ray Tubes Employing Electromagnetic Deflection

In the application of the 903 and 904 where electromagnetic deflection is employed, a means of amplifying the deflecting currents is often necessary. There are cases where the magnet can be connected directly to the circuit under observation, but a current amplifier is essential if the phenomenon is insufficient in power or would in some way be adversely affected by the impedance of the magnet.

Figure 60 on page 111 shows a typical current amplifier and deflecting-magnet system which is useful for many applications. Two 2A5's or 42's are used in parallel to furnish the current swings for the magnet coils (L_2 and L_3). The circuit constants are selected to minimize phase distortion. If the assumption of sinusoidal input voltage waves is made, the phase displacement angle (using 400 cycles per second as a reference frequency) is less than 3° between 50 and 2000 cycles. The phase shift is, at the higher frequencies, due to the fact that the plate load of the 2A5's is somewhat inductive because of the impedance of the magnet coils. At the lower frequencies, the phase shift is caused by the a-f blocking-condenser and grid-resistor combinations used in the amplifier stages as well as by the inductance and resistance components in the output circuit. The frequency response is essentially flat from 50 to 2000 cycles. The upper frequency limit of 2000 cycles per second only holds where the 2A5's are operated at full plate-current swings in order to obtain maximum deflection of the cathode-ray tube beam. The upper frequency limit can be increased to 6000 cycles if the plate-current swings are held to one-third of their maximum amplitude.

Where the current waves have a high harmonic content, the fundamental frequency should be kept low so that the frequency of the highest harmonic of interest is below 6000 cycles per second. For example, with linear sweep waves of the saw-tooth type (see 885 data, page 15), the upper limit of the fundamental frequency is about 1000 cycles if serious phase distortion is to be avoided. Other frequency ranges may be obtained if the circuit constants and the magnet design are suitably changed.

The magnetic-deflecting system shown in Figure 60 is divided into five parts for convenience of discussion. The magnet coils themselves are part No.5. They may be used as a separate unit in applications where they can be connected directly into the circuit under study. The current available from the circuit under observation will determine the number of turns on the magnet coils. The magnet shown requires about 45 milliamperes peak current to give "full-scale" deflection on a type 904 cathode-ray tube operating with a No.2 anode potential of 2500 volts. In adapting the same magnet to other values of current, one need only remember that with other factors remaining constant the deflection is proportional to the number of ampere turns.

Therefore, if a peak current of 90 milliamperes is available, the number of turns on each magnet coil can be one-half of that specified.

Since some circuits will be disturbed by the introduction of the magnet inductance and will not be suitable for direct connection, the use of a coupling amplifier is required. Such an amplifier is shown as part No.4 in the diagram. Suitable circuit constants are indicated. It should be noted that the grid resistor (R_7) is limited to 0.5 megohm for two 2A5's, and that a value as high as this can be used only if the heater voltage is not allowed to rise more than 10 per cent above the rated value, under any conditions of operation. A peak a-f input voltage of approximately 11 volts will give the peak plate current of 45 milliamperes required for full beam deflection of the 904.

The 0.5-megohm grid resistor may be too low to connect directly to some high-impedance circuits. In such cases, a coupling tube is necessary; this is the amplifier shown as part No.3, employing a type 56. The input circuit for the 56 may be either that shown in part No.2 (with a 1.0-megohm grid resistor) or that of part No.1, which provides more than 10-megohms input impedance. With either No.1 or No.2 circuit feeding the 56, approximately one volt (peak) is necessary across the effective grid resistance (from the 56 grid to ground) to produce a 45-milliampere peak current swing in the magnet coils. Due to the 100 to 1 attenuation of circuit No.1, a peak voltage of 100 volts is necessary across the total resistance of R_1 and R_2. This input arrangement will be found suitable for use with an 885 linear saw-tooth oscillator; the shunt resistor across this type of oscillator, for satisfactory performance, usually should be 10 megohms or greater. Input circuit No.2 is suitable for use with circuit No.3 in cases where a 1.0 megohm resistance can be shunted across the circuit under study and where the full gain of the two amplifier stages is required. Circuit No.2 can be modified, of course, if the peak voltage from the phenomenon under observation is more than one volt; a suitable potentiometer or other attenuating device can be used in place of R_3, as long as the total grid-circuit resistance of the 56 does not exceed one megohm.

The magnet of part No.5 consists of two 1500-turn coils, connected in series aiding. The coils are mounted as near as practicable to the two ends of a square iron core (see Figure 60 for core data) bent in the shape of a large "C". This split-coil arrangement is much better than the concentration of all the magnet turns in a single coil on one end of the core. The axis of the magnetic field should be perpendicular to the normal position of the electron beam and the ends of the core should be placed about 1-1/2 inches beyond the end (toward the screen) of anode No.2 (in the case of the 904). The air gap between the ends of the core should be made as short as the neck of the cathode-ray tube bulb will permit. The gap is about 1-1/8 inches for the 903 and 1-1/2 inches for the 904.

It has been stated that the peak plate current of the 2A5's, necessary to swing the electron beam from the center to one side of the 904, is 45 milliamperes, for a No.2 anode voltage of 2500 volts. With a 903 operating at the same No.2 anode voltage, the peak plate current to produce an equal deflection (approximately 2-1/2 inches) is only 35 milliamperes. The improved sensitivity in the latter case is due to the greater flux density across the shorter air gap and to the difference in the length of the tubes (from the position of the magnet to the viewing screen).

If the lowest frequency at which the amplifier must operate is higher than 50 cycles per second, the capacitance of condensers C_3, C_4, C_6, C_7, and C_8 can be made proportionally smaller. It is important that the plate-load reactor (L_1) be designed to give a flat frequency response over the desired frequency range and to have an inductance of at least 150 henries while carrying a d-c current of 68 milliamperes and having a voltage impressed across its terminals of 165 volts RMS. The inductance preferably should consist of three 50-henry reactors in series, as shown in Figure 60. This arrangement minimizes distributed-capacity effects and gives better performance generally than a single 150-henry unit. The resistance (R_9) is used to limit the tendency of L_2 and L_3 (shunted by the circuit and tube capacitances) to resonate, or "tune", as well as to provide a more suitable plate load for the pentodes when the impedance of L_2 and L_3 is small (at the lower frequencies). The specified value of R_9 flattens the frequency response curve over the operating range. A value for C_7 lower than 12 μf is detrimental to the low-frequency response of the amplifier. Condenser (C_7) can be omitted if one of equal or larger capacitance is already included in the power supply, or if batteries in reasonably good condition are employed.

There are several variations of this type of magnetic-deflecting system which may prove more suitable for certain applications. For very low frequencies, the use of additional turns on the magnet will give a more suitable impedance. For higher frequencies, a larger number of pentodes may be paralleled in the amplifier and used with a magnet having few turns, and, consequently, having low distributed capacitance. As many as ten 2A5's have been paralleled in a test circuit, with satisfactory results. The use of a 50000-ohm (0.1 watt) grid resistor in series with each grid lead at the socket is desirable to prevent oscillation in an arrangement of this type. These modifications as well as others may be required for special applications.

CIRCUIT FOR A DEFLECTING-MAGNET CURRENT AMPLIFIER

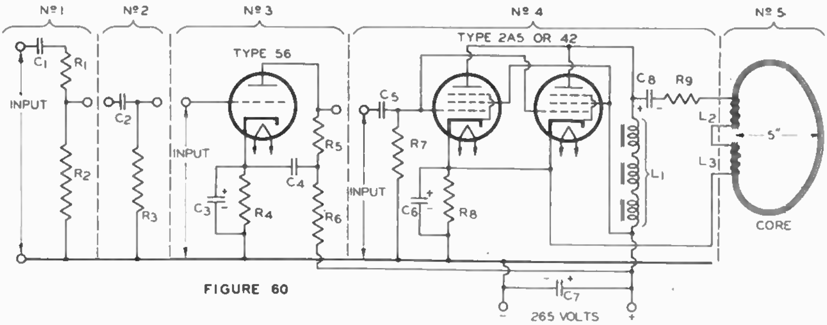


FIGURE 60

C1 = 0.05 µf, 200 V.
C2 = 0.5 µf, 200 V.
C3 = 50 µf, 50 V.
C4 = 5 µf, 400 V.
C5 = 1 µf, 400 V.
C6 = 8 µf, 50 V.
C7 = 12 µf, 400 V.
C8 = 8 µf, 500 V.
R1 = 10 MEGOHMS, 0.5 WATT
R2 = 100000 OHMS, 0.5 WATT
R3 = 1 MEGOHM, 0.5 WATT
R4 = 10000 OHMS, 0.5 WATT
R5 = 100000 OHMS, 0.5 WATT
R6 = 25000 OHMS, 0.5 WATT
R7 = 500000 OHMS, 0.5 WATT
R8 = 200 OHMS, 2 WATTS
R9 = 2000 OHMS, 5 WATTS
L2, L3 = SEE TEXT, P. 109

L1 = AT LEAST 150 HENRIES TOTAL INDUCTANCE WHILE CARRYING 68 MA. D.C. AND HAVING 55 VOLTS RMS IMPRESSED ACROSS EACH SECTION; SHOULD HAVE NO RESONANCE CHARACTERISTICS FOR FREQUENCIES FROM 50 TO 7000 CYCLES PER SECOND.

CORE = SILICON STEEL LAMINATIONS 0.014 INCH THICK, 0.25 INCH WIDE; STACKED 0.25 INCH PROVIDING A GROSS CROSS-SECTIONAL AREA OF 0.063 SQUARE INCH; LENGTH OF MAGNETIC PATH 20 (APPROX.) INCHES.

CATHODE-RAY TUBE TERMINOLOGY*

Apparent Line Width: The apparent line width (the visible or recorded width of the moving spot) can be different from the apparent spot size of the stationary spot because screen luminescence is dependent upon the duration of excitation.

Apparent Spot Size, Apparent Spot Diameter: When the spot size is measured visually or from a photographic record, the resultant spot size is not necessarily the true spot size; therefore, the terms "apparent spot size" and "apparent spot diameter" should be used in such cases.

Beam Current: The current in the electron beam at the screen, usually measured in microamperes.

Beam Voltage: The instantaneous voltage of the electron beam at any point; usually referred to as the voltage of the beam at the point of deflection, where the beam voltage is substantially the same as the second anode voltage.

Candlepower-Distribution Characteristic: The relation which when plotted is invariably represented by a polar curve illustrating the luminous intensity of a cathode-ray tube in a plane of the tube axis and with the screen at the origin. This characteristic shows how the candlepower of a luminescent screen varies when the screen is viewed at different angles.

Deflection Sensitivity, Electrostatic: The ratio of the distance which the electron beam moves across the screen to the change in potential difference between the deflection plates; this is usually expressed in millimeters per volt. The sensitivity varies inversely with the beam voltage at the point of deflection.

Deflection Sensitivity, Magnetic: The ratio of the distance which the electron beam moves across the screen to the change in the flux density producing the motion. The sensitivity may be expressed in millimeters per gauss, but due to the difficulty in the determination of flux density, it is often more practical to express the sensitivity in millimeters per ampere-turn, or simply in millimeters per ampere. It varies inversely as the square root of the beam voltage at the point of deflection.

Defocus: A term used to describe a spot which is not optimum with respect to shape and size.

Efficiency, Gun-Current: The ratio of the beam current to the current which leaves the cathode. This ratio, multiplied by 100, gives the gun-current efficiency in per cent.

* This material is abstracted and adapted from a paper entitled "Cathode-Ray Tube Terminology" by T.B. Perkins (Research and Development Laboratory, RCA Radiotron Division, RCA Manufacturing Company, Inc.). The complete paper will be found in the November, 1935, issue of the Proceedings of the Institute of Radio Engineers.

CATHODE-RAY TUBE TERMINOLOGY

Efficiency, Screen Actinic: The measure of the ability of a viewing screen to convert the electrical energy of the electron beam to radiation which affects a certain photographic surface. This term should be expressed in microwatts per watt, but is often expressed for ease of measurement in terms of actinic power per watt relative to a screen of well-known characteristics.

Efficiency, Screen Luminous: The measure of the ability of a viewing screen to produce visible radiation from the electrical energy of the electron beam. The efficiency should be measured in lumens per watt. For convenience of measurement, however, it is usually expressed in candlepower per watt, because candlepower is a measure of the luminous flux per unit solid angle in a given direction and can be converted to lumens where the candlepower-distribution characteristic of the screen is known. It is usual practice to measure candlepower in the direction normal to the screen.

Efficiency, Screen Radiant: The measure of the ability of a viewing screen to produce luminescence from the electrical energy of the electron beam. The efficiency should be expressed in microwatts per watt, but due to the difficulty of making absolute measurements is more often expressed in radiant energy per watt relative to some screen of well-known characteristics.

Fluorescence: The luminescence emitted by a phosphor during excitation. As applied to a cathode-ray tube, this term refers to the radiation emitted by the viewing screen during the period of beam excitation.

Line Width: The true width of the moving spot measured at right angles to its direction of motion.

Luminescence: The term describing all forms of visible and near-visible radiation which depart widely from the black-body radiation law. It can be divided according to the means of excitation into many classes,such as: candoluminescence - the luminescence of incandescent solids; photoluminescence - the luminescence created by exposure to radiation; chemiluminescence - the luminescence created by chemical reactions; electroluminescence - the luminescence given off by ionized gas; bioluminescence - the luminescence emitted by living organisms; triboluminescence - the luminescence created by the disruption of crystals; crystalloluminescence - the luminescence excited by emissions from radioactive materials; galvanoluminescence - the luminescence phenomena observed at electrodes during some electrolyses; cathodoluminescence - the luminescence produced by the impact of electrons; etc. In cathode-ray tubes, cathodoluminescence is principally involved; therefore, the luminescence of the screen is that radiation which is produced by the impact of the electron beam.

Luminescent Spot: The spot formed on the screen of a cathode-ray tube at the impact point of the focused electron beam.

Pattern Distortion: When the electron beam is moved by changing fields, a pattern is formed on the screen; the waveform of the spot movement will be identical with the resultant waveforms of the electrical phenomena producing these fields unless there is pattern distortion present. This distortion takes many forms, such as: amplitude, frequency, phase, brightness, persistence, spot size. etc.

Persistence Characteristic: The relation showing the brilliance of light emitted by a cathode-ray-tube screen as a function of time after excitation. This characteristic is generally shown in a curve where relative brilliance as the ordinate is plotted on a logarithmic scale against time on a linear scale. "Relative brilliance" is used to denote luminous intensity per unit area evaluated in arbitrary units.

Phosphor: The solid material in the screen which produces luminescence when excited by the electron beam.

Phosphorescence: The luminescence emitted after excitation. As applied to a cathode-ray tube, this term refers to the radiation which persists after the electron-beam excitation has ceased.

Spectral Characteristic: The relation between the radiant energy per element of wavelength and each wavelength of the spectrum. It is generally shown in a curve plotted with relative radiant energy against wavelength in angstroms, microns, or millimicrons. "Relative radiant energy" is expressed in arbitrary units of radiant energy.

Spectral Characteristic, Actinic: The relation between the energy per element of wavelength which affects a certain photographic surface, and each wavelength of the spectrum. This is generally shown in a curve plotted with relative actinic energy against wavelength in angstroms, microns, or millimicrons. "Relative actinic energy" is obtained by multiplying the relative radiant energy values (taken from the screen's spectral characteristic) for each wavelength by the relative sensitivity of a given photographic surface at that wavelength.

Spectral Characteristic, Visual: The relation between the luminous energy per element of wavelength and each wavelength of the spectrum. It is generally shown in a curve plotted with relative luminous energy against wavelength in angstroms, microns, or millimicrons. "Relative luminous energy" is obtained by multiplying the relative radiant energy values (taken from the screen's spectral characteristic) for each wavelength by the relative response of the eye at that wavelength.

Spot Diameter: The term used to express the true size of a round spot.

Spot Distortion: A term used to describe the condition of a spot which is not optimum with regard to shape.

Spot Size: The true dimension or dimensions of the spot. Spot size may be measured under various conditions, and is commonly designated by such names as "spot diameter" or "line width". When the spot is stationary its size can be measured in any direction, but is usually determined by its dimensions along the longest and shortest axes.

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