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RMA Release # 390

U.S. CONFIDENTIAL

RCA

4AP10
SKIATRON

Magnetic Deflection **4-Inch Bulb** **Magnetic Focus**

The RCA-4AP10 is a special form of cathode-ray tube having a screen that absorbs light. When the screen is brightly illuminated, the trace caused by the electron beam absorbs light in the middle range of the visible spectrum, and thus produces a dark image on a white background. This image may then be projected onto a viewing screen by means of a reflection-optics system involving the Schmidt principle. The system must be designed for use with the tube. For use in this system, the 4AP10 has a high-quality polished face plate having accurate radii of curvature and four dots in the screen surface to facilitate accurate positioning of the screen in the optical system. The electron gun of the 4AP10 is so designed that the tube is capable of producing an unusually fine spot on the screen.

GENERAL

HEATER VOLTAGE (A.C. or D.C.)	6.3 ±10%	Volts
HEATER CURRENT	0.6	Ampere
FOCUSING METHOD	Magnetic	
DEFLECTION METHOD	Magnetic	
MAXIMUM SOLID DEFLECTION ANGLE	40	Degrees
PHOSPHOR	No.10	
Contrast	30	Per cent
Decay Ratio (Approx.) at 10 seconds	5	
DIRECT INTERELECTRODE CAPACITANCES:		
Grid No.1 to All Other Electrodes	8	μμf
Grid No.2 to All Other Electrodes	6	μμf
Cathode to All Other Electrodes	6	μμf
OVERALL LENGTH	14-3/4" ± 3/8"	
GREATEST DIAMETER of BULB	4-1/8"	
MINIMUM USEFUL SCREEN DIAMETER	3-5/8"	
FACE-PLATE RADIUS of CURVATURE	5.8" ± 0.2"	
CAP	Medium	
BASE	Long Medium-Shell Octal 8-Pin	
DEFLECTION YOKE:		
Location on Tube Neck	End flush with Reference Line (See *Outline Drawing*)	
Length of Field	3 *max.*	Inches
FOCUSING COIL:		
Location on Tube Neck	See *Outline Drawing*	

Maximum Ratings Are Absolute Values

MAXIMUM RATINGS and TYPICAL OPERATING CONDITIONS

ANODE (High-Voltage Electrode) VOLTAGE	9900 *max.*	Volts
GRID No.2 (Accelerating Electrode) VOLTAGE	500 *max.*	Volts
GRID No.1 (Control Electrode) VOLTAGE RANGE	0 (never +) to -125 *max.*	Volts
D-C HEATER-CATHODE POTENTIAL*	125 *max.*	Volts
GRID No.1 CIRCUIT RESISTANCE	1.5 *max.*	Megohms
FACE-PLATE TEMPERATURE	90 *max.*	°C
TYPICAL OPERATION:		
Anode Voltage #	9000	Volts
Grid No.2 Voltage ##	300	Volts
Grid No.1 Voltage for Cut-Off **	-45	Volts
Focusing-Coil Current (Approx.)***	100	Ma.

* With heater negative. Cathode should be connected to one side or mid-tap of heater-transformer winding.

** For anode current of 2 microamperes. Grid voltage should be adjustable between -30 and -60 volts.

*** For coil described in text and for anode and grid voltages as shown: electron-beam microamperes, 100; center of air-gap in focusing coil from reference line, 2-3/4". Value of coil current should be adjustable to ±15% of this value.

\# In general, anode voltage should not be less than 8000 volts.

\## The maximum beam current and grid No.1 voltage for cut-off decrease with decreasing grid No.2 voltage. In general, grid No.2 voltage should not be less than 250 volts.

SPOT POSITION

The center of the undeflected focused spot will fall on the screen within a circle of 4-mm radius concentric with the rotational axis. Suitable test conditions are: anode volts, 9000; grid No.2 volts, 300; the spot focused; the tube shielded from all extraneous fields. To avoid damage to the tube, grid No.1 voltage should be near cut-off before application of anode voltage.

INSTALLATION and APPLICATION

The *base* pins of the 4AP10 fit sockets whose contacts have the standard octal arrangement. The socket may be installed to hold the tube in any position. The socket alone, however, should not be used to support the tube; other support such as a yoke or saddle arrangement should be used at or near the screen end of the tube. Since this tube is part of a precision optical system, it is necessary to position the tube accurately and to hold it firmly in place.

Pins 1 and 6 are connected together to serve as a convenient means for operating an electrical interlock circuit to prevent application of tube voltages when the tube is not in the socket. The connection between pins 1 and 6 is insulated to withstand 250 volts rms from the other electrode leads and has a maximum current-handling capacity of one ampere.

The *bulb*, except for the screen face, should be enclosed in a shield made of high-permeability metal having low residual magnetism, if appreciable extraneous magnetic fields are present.

The *heater* is designed to be operated at 6.3 volts ±10 per cent. The transformer winding supplying the heater should be designed to operate the heater at the rated voltage under average line-voltage conditions. The mid-tap or one side of the heater should be connected to the cathode. If the circuit design is such as to cause a high voltage between heater and cathode, the voltage value should be limited to 125 volts (with heater negative).

The *cathode* is connected to base pin 7 to which the circuit returns should be made.

The *screen* of the 4AP10 employs phosphor No. 10 which, when excited by electron bombardment, has the characteristic of absorbing radiant energy in the middle range of the visible spectrum. With normal room illumination, phosphor No. 10 fluoresces with a faint blue light during bombardment by the electron beam. When the screen is brightly illuminated, the screen reflects light except in the path of the electron beam, and the resulting dark trace can be projected onto a viewing screen by means of an optical system. The tube is designed for use with a Schmidt-type optical system. A conventional lens system does not produce satisfactory results.

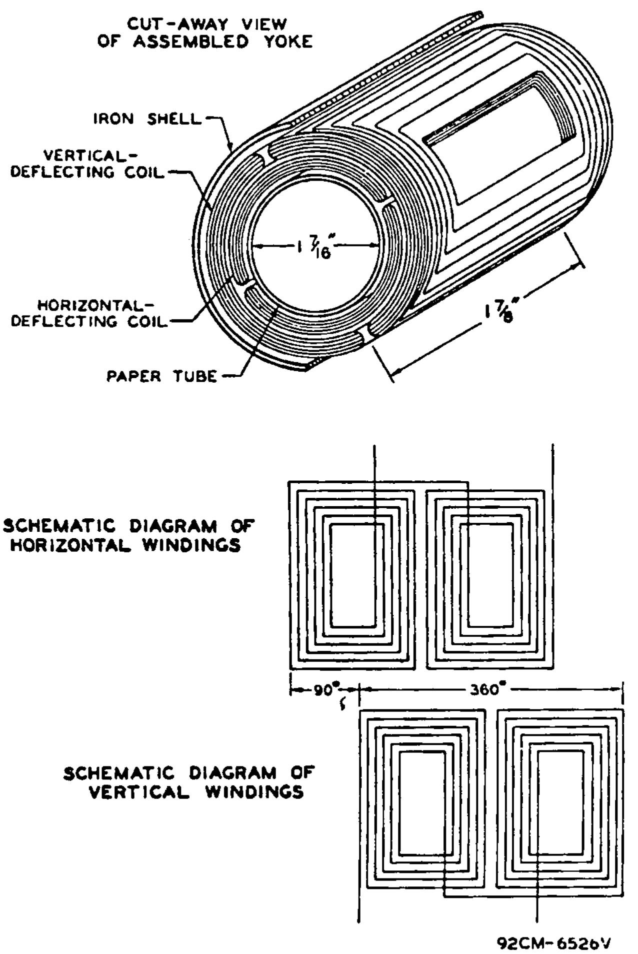


Fig. 1 - Wide-Angle Deflecting Yoke Assembly and Winding Scheme.

The degree and duration of darkening of the screen are dependent on several factors: screen temperature, amount of screen illumination, and duration and electron energy density of bombardment. The darkening under bombardment is approximately proportional to the electron energy density to the point where reflection is reduced to 30 per cent of the normal value obtained without bombardment. Electron energy density, in turn, is proportional to electron beam current and sharpness of focus. Bombardment will cause darkening which persists indefinitely unless intense illumination, elevated temperature, low-intensity electron bombardment, or a combination of these factors is utilized to make the darkening disappear. For normal operation, 8000 foot-candles at the screen from tungsten-filament sources and a face temperature of 60° ±10°C are suitable conditions. A supply of cooling air is required to maintain the temperature at this level. Heat filters between the light sources and the face of the tube may also be used.

The time required for the trace to disappear depends on the degree of darkening. Since under given conditions of illumination and temperature, darkening depends on the density and duration of electron bombardment, it follows that when rapid removal of the trace is needed the lowest beam current should be used. With continued use, even under the conditions described, those sections of the screen subjected to repeated bombardment may show darkening which does not disappear during normal operation. This semi-permanent dark-

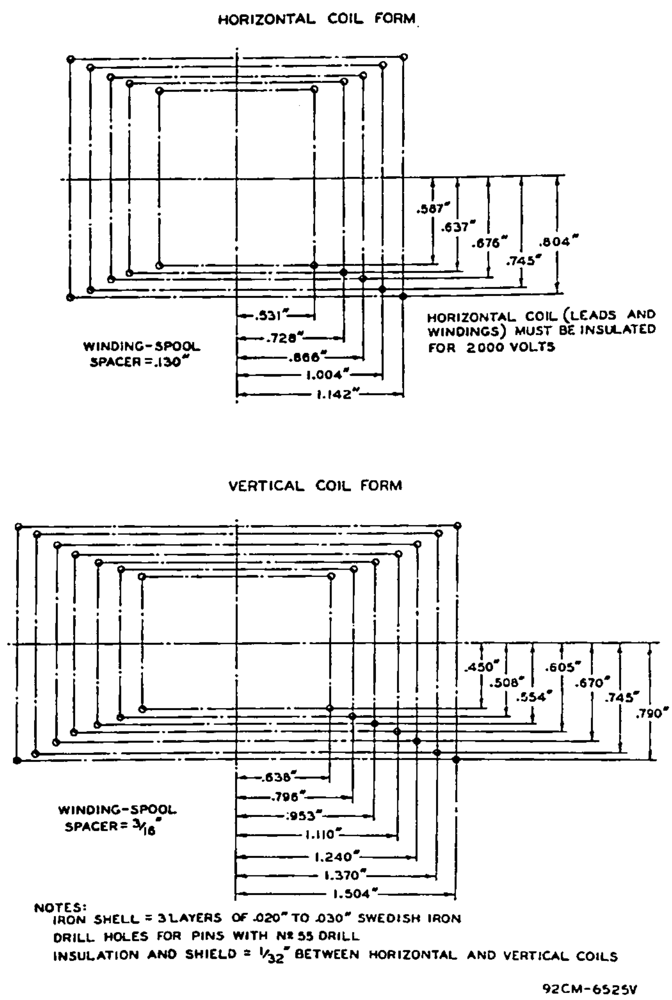


Fig. 2 - Coil Form Details of Wide-Angle Deflecting Yoke.

ening may be removed by either of two methods, or preferably a third method combining the two. First, the face temperature may be raised to about 125°C (never higher than 150°C) for about twenty minutes. This heating may be accomplished by reducing the flow of cooling air. Second, the darkening may be removed by scanning the screen with a slightly defocused spot. With this method, the beam current should be slightly less than that used in regular operation and, during the process, the beam current should be gradually reduced as the darkening disappears. Third, the two preceding methods may be combined for increased speed of removal. It is important to note that operation at high temperature reduces the sensitivity of the screen to darkening. For this reason, the total time of such high-temperature operation should be limited to about one and one-half hours during the useful life of the tube.

The degree of darkening of the screen in the path of the electron beam is termed the "contrast" and is given as a percentage. The contrast is defined as the ratio of the difference between the light reflected from the unexcited areas and that reflected from the excited areas to the light reflected from the unexcited areas.

Contrast as measured immediately following scanning of the screen is called "initial contrast." With intense illumination and elevated screen temperature, contrast falls after excitation. The ratio of the initial contrast to that measured at a later time is the decay ratio. In practice, the decay ratio after ten seconds is in the order of five. The decay ratio is increased, in general, by high temperature; however, care should be taken when the temperature is increased for the purpose of increasing the decay ratio because, as previously explained, operation at high temperature causes decreased sensitivity to darkening in normal operation. The decay ratio may also be controlled in operation by adjustment of the beam current since the increased darkening depends on electron beam density.

The bulb cone is coated externally with a dull black material to avoid the reflection of stray light which would reduce the contrast in the projected image. Care should be taken to avoid rubbing this coating since the material tends to polish and, therefore, to reflect light.

The *d-c voltages for the electrodes* may be obtained from a high-voltage, high-vacuum rectifier. Since the 4AP10 requires very small current, the rectifier system can be of either the half-wave or the voltage-doubler type. For the same reason, the filter requirements are simple. A 0.1 to 1 μf capacitor will ordinarily provide sufficient filtering. If this is inadequate, a two-section filter is recommended. A small amount of voltage regulation in the anode supply acts to maintain sharp focus as the beam current is increased, since slightly more focusing-coil current is required with higher beam current. A regulation corresponding to that provided by an equivalent internal resistance of the rectifier system of one megohm gives good compensation. Such compensation is effective, in general, only

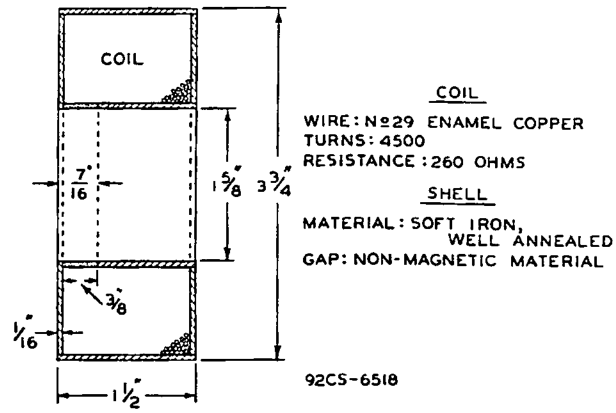


Fig.3 - Focusing-Coil Details.

for slow changes in current such as those determined by the time constant of the filter circuit. It should be noted, however, that variations in anode voltage cause changes in deflection sensitivity; therefore, better regulation may be required than that which produces the best focus compensation with changes in beam current.

The current to grid No.2 is practically zero and, consequently, voltage for this electrode may be supplied from a high-resistance bleeder connected across the high-voltage power supply rather than from a separate low-voltage source.

If the electrode voltages are obtained from a bleeder circuit, a bleeder current of less than 0.5 milliampere usually is satisfactory. Considerably higher values may require the use of more filtering than that provided by a single capacitor shunted across the d-c supply. A variable d-c voltage for the control electrode (grid No.1) can be obtained from a potentiometer in the bleeder circuit. It may be more desirable in some cases to operate the control electrode at ground potential and to bias the cathode positive with respect to ground by means of the amplifier power supply.

A *d-c voltage from a well-regulated source* is required for the focusing coil. With the coil positioned as shown in the Outline Drawing, the coil current required for focus will be as shown under TYPICAL OPERATION. For other anode voltages than the one shown, the coil current will be proportional to the square root of the anode voltage. Provision should be made for adjusting the coil current over the specified range.

A *deflecting yoke* consisting of four electromagnetic coils may be employed for deflecting the electron beam. These coils are used in pairs; the coils of each pair, located diametrically opposite each other, produce fields of uniform flux density. The axes of the two fields ordinarily intersect at right angles to each other and to the tube axis. The deflection of the electron beam is at right angles to the magnetic fields. By the use of two pairs of coils at right angles the beam may be deflected to any part of the screen. A deflecting yoke designed for wide-angle deflection is shown in Figs. 1 and 2. The yoke should be placed as close as possible to the junction of the bulb neck and the bulb flare (reference line). This yoke is designed so that deflection of the beam is accomplished in the axial space of not more than two inches. If desired, a yoke designed for a narrower deflection angle (maximum solid angle of 40°) may be used. A yoke of this kind with construction similar to that described will have a maximum length of three inches. A long yoke will have greater deflection sensitivity but the focusing coil will be closer to the electron gun, and thus the spot size will be slightly larger.

A *focusing coil* is required to concentrate the electron stream into a focused spot at the screen. Design data for a coil which may be used with the 4AP10 are shown in Fig. 3. This coil is cylindrical and has an air gap of short axial length. The coil should be spaced from the deflecting yoke to reduce interaction between the focusing and deflecting fields. A space of approximately one-half inch should be left between the yoke and the coil. The recommended position of the focusing coil on the tube is indicated in the Outline Drawing. This location is shown in terms of the axial distance from the reference line to the center of the focusing-coil gap. Further information on the focusing coil is given in the paragraph on *focusing*.

The coil described has been used to provide a standard focus current test; other designs may be required for specific equipments. In general, it will be desirable to keep the overall diameter within four inches to avoid cutting off part of the light in the optical system.

The coil shell should be made of soft iron. The face pieces of the shell should be well annealed. When the material is rolled in manufacture, a non-uniform magnetic characteristic may be introduced. If, in assembly of the coil shell, the two face pieces are oriented so that their directions of rolling are aligned, distortion of the pattern may result from lack of symmetry of the magnetic field. It is desirable, therefore, to cut the face pieces from a single sheet of material and to rotate one piece 90° with respect to the other when they are assembled.

The high voltages at which the 4AP10 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. Precautions must include safeguards which definitely eliminate all hazards to personnel. All circuit parts which may be at high potential should always be enclosed and interlock switches should be used to break the primary circuit of the high-voltage power transformer when access to the equipment is required.

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 because of capacitor breakdown or incorrect circuit connections. Before any part of the circuit is touched, the power-supply switch should be turned off and both terminals of any charged capacitors grounded.

Focusing of the spot produced by the electron beam is controlled by adjustment of the strength of the focusing-coil magnetic field. This adjustment is accomplished by control of the current through the coil. The value of this current depends on the position of the coil with respect to the electron gun and the screen, the construction of the coil itself, and the operating conditions of the tube. In general, the focusing coil should be as far as practical above the electron gun in order to obtain a small-sized spot. On the other hand, if the focusing coil is too close to the deflecting fields, interaction may cause distortion of the pattern. A space of approximately one-half inch between the focusing coil and the deflecting yoke is recommended.

Four dots are located in the screen surface of the 4AP10 to assist in accurately positioning the surface in the reflection-optics system. The position of the tube is adjusted, by tilting or decentering the tube, in order to make the spherical screen surface concentric with that of the lens mirror. The correct position is indicated by equally sharp focus for all four dots. During this adjustment, the screen surface should be illuminated as for normal operation but it is not necessary to apply voltages to the tube. This feature permits adjustment without danger of accidental contact with the high voltage. When the four dots have been brought into focus, a slight axial adjustment of the tube may be necessary to obtain the best average focus over the whole screen face.

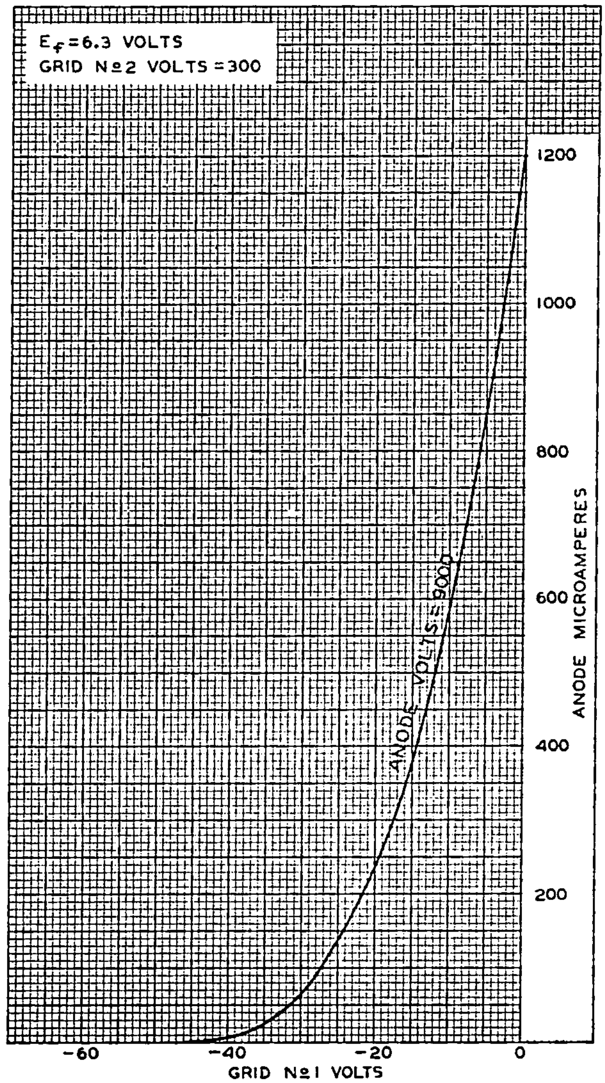
It is convenient in aligning the tube to provide for movement of the tube in the directions of the two pairs of opposite dots; a three-point or universal-joint support is less desirable in this respect. Provision should also be made for tilting the tube about its face as a center or for decentering the tube axis with respect to the mirror.

Centering of the spot on the screen should preferably be done by passing a d-c current through each pair of deflecting coils. Separate coils may also be used; the location of such centering coils is subject to the same considerations as those applying to the deflecting coils. The movement of the spot is at right angles to the axis of each pair of coils. An alternate method of centering the spot over small distances is to skew the focusing coil on the tube neck, but this method is likely to introduce distortion.

Regulation of spot size and intensity can be accomplished by varying the focus and anode current, respectively. The current to the anode may be increased by decreasing the bias applied to grid No. 1. Over the grid No. 1 voltage range between zero and cut-off, the beam current increases with grid No.2 voltage. Grid No.2 can be used as a control electrode, if desired. An increase in the voltage applied to grid No.2 increases the maximum obtainable beam current and increases the grid No. 1 voltage for cut-off. The grid No. 1 voltage for cut-off is increased in direct proportion to the increase in grid No.2 voltage. The tube may be operated at lower anode and grid No.2 voltages than the recommended values but contrast and definition decrease with decreasing voltages. Minimum recommended anode and grid No.2 voltages are shown under TYPICAL OPERATION. When any of these voltages are adjusted, consideration should be given to the absolute MAXIMUM RATINGS.

It is important to note that a high-intensity spot will burn the screen if the spot is allowed to remain stationary or if the beam travels slowly over the screen. To prevent this possibility, the spot should be kept in motion constantly or the beam current should be reduced. It is possible in some cases to recondition the screen by methods described in the paragraph under *screen*. Such treatment requires great care because of the possibility of permanent damage to the screen material.

AVERAGE CHARACTERISTIC



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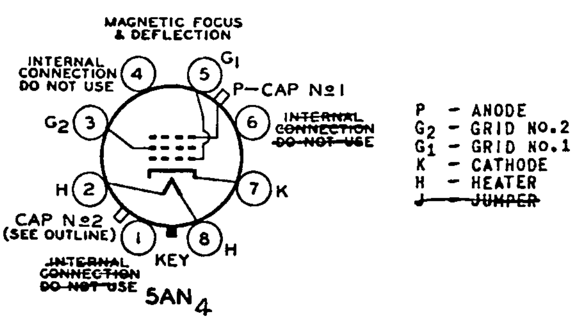
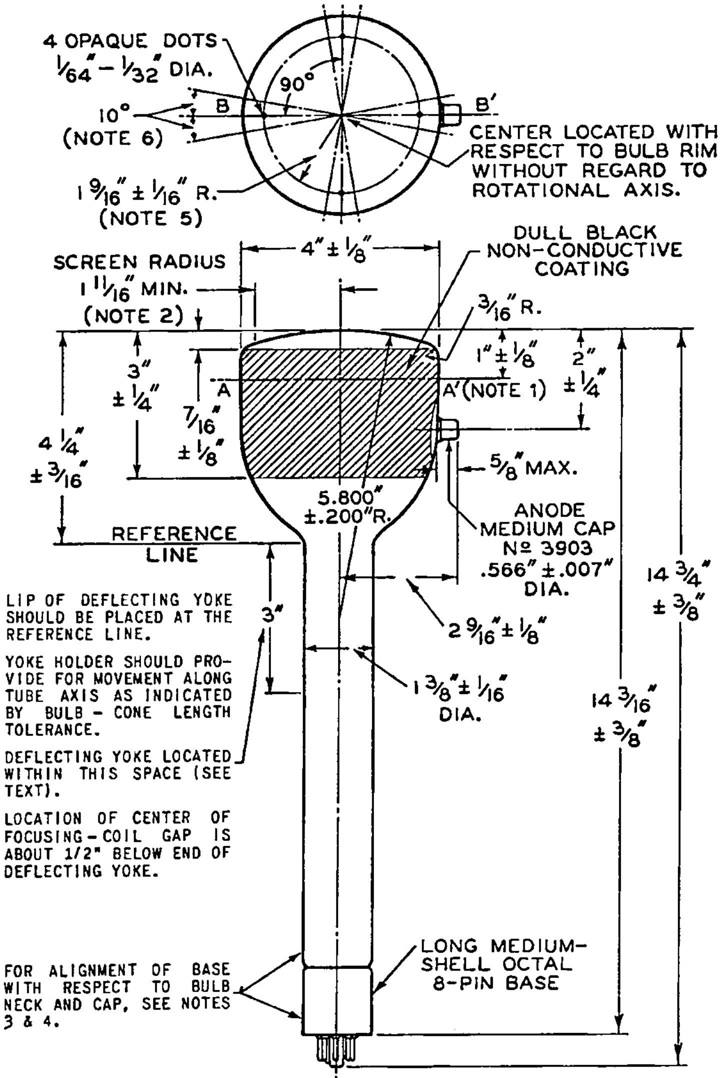
Bottom View of Socket Connections



JUMPER CONNECTED WITHIN BASE
BETWEEN PINS 7 & 6



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AS USED BELOW, "REFERENCE LINE," "ROTATIONAL AXIS," AND "FACE TILT" HAVE THE FOLLOWING DEFINITIONS:

a. REFERENCE LINE IS DETERMINED BY POSITION WHERE GAUGE 1.430" ± 0.003" I.D. AND 2" LONG WILL REST ON BULB CONE.

b. ROTATIONAL AXIS IS DETERMINED BY ROTATING BULB NECK IN TWO SETS OF "VEE WHEELS," ONE SET OF WHICH IS POSITIONED ON NECK 1/2" ± 1/4" FROM THE REFERENCE LINE, AND THE OTHER IS SPACED ALONG NECK 7" FROM THE FIRST.

c. FACE TILT IS VARIATION OF THE DISTANCE FROM ANY OUTSIDE PERIPHERAL POINT OF THE 1-11/16" RADIUS CIRCLE ON THE FACE PLATE TO A PLANE OUTSIDE THE TUBE AND NORMAL TO THE ROTATIONAL AXIS.

NOTE 1 - ECCENTRICITY OF BULB AT LINE AA' WITH RESPECT TO ROTATIONAL AXIS DOES NOT EXCEED ± 1/8".

NOTE 2 - FACE TILT DOES NOT EXCEED 0.050".

NOTE 3 - BASE AND BULB NECK WILL PASS THROUGH GAUGE 7" LONG AND 1.469" ± 0.003" I.D.

NOTE 4 - PLANE THROUGH ROTATIONAL AXIS AND PIN 5 MAY VARY FROM THE PLANE THROUGH ROTATIONAL AXIS AND ANODE CAP BY 10°. PIN 5 IS ON SAME SIDE OF TUBE AS ANODE CAP.

NOTE 5 - RADIAL POSITIONS OF THE 4 DOTS ARE GIVEN WITH RESPECT TO CENTER OF BULB RIM AND WITHOUT REGARD TO CENTER ESTABLISHED BY ROTATIONAL AXIS.

NOTE 6 - ANGULAR VARIATIONS OF DOTS ARE MEASURED FROM QUADRANT LINES INTERSECTING AT BULB-RIM CENTER AND WITH QUADRANT LINE BB' LOCATED AT ANODE-CAP POSITION.