Electrode-Terminal Connections for Pencil-Type UHF Triodes

Pencil-type uhf triodes are designed primarily for use as amplifiers at frequencies up to at least 1000 megacycles or as low-power oscillators at frequencies up to at least 3000 megacycles. They are suitable for use in coaxial-line, parallel-line, or lumped circuits. This Note discusses the mechanical and thermal problems involved in the use of these tubes, and describes several types of electrode-terminal connections suitable for use with them.

A number of considerations should be taken into account in the selection of electrode-terminal connections for use with pencil-type uhf triodes. The connectors, for example, must furnish adequate electrical contact without introducing undue mechanical strain. The connectors must also have low inductance. In addition, the anode connector should provide sufficient heat conduction to maintain the temperature of the glass-to-metal anode seal below 175 degrees Centigrade at all times.

Mechanical Considerations

The glass-to-metal seals used in pencil-type triodes are very strong in compression, but less strong under conditions of tension, torque, or bending. Connections to the electrode terminals, therefore, should be such that they place a minimum of tension, torque, or bending stress on the tube. Sufficient allowance should be made in the connectors for a small amount of terminal eccentricity or grid-flange tilt in the tubes. Precautions should be taken to prevent any distortion of the grid flange by the grid connector, because twisting or bending this flange will crack the glass-to-metal seals. In general, one of the three electrode terminals of the tube - the cathode cylinder, the grid flange, or the anode cylinder - should be fastened fairly rigidly. Connectors to the other two terminals should have sufficient spring to allow for dimensional variations within the range of manufacturing tolerances. An outline drawing of a pencil-type triode is shown on page 8; the maximum variations encountered under present specifications are indicated by dotted lines.

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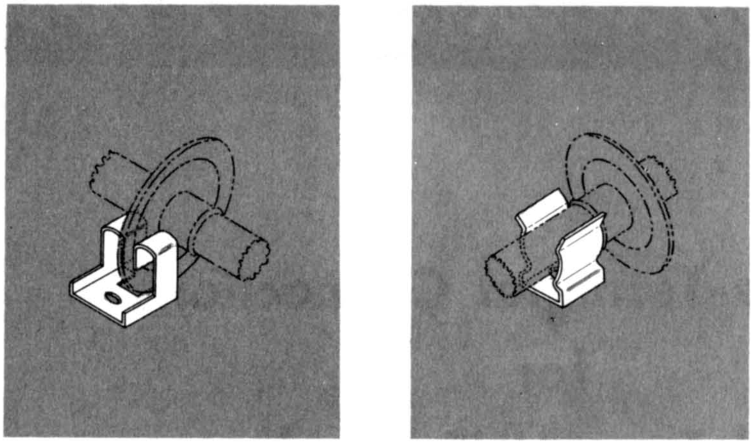

Fig. 1 - Electrode-Terminal Connectors for Use at Relatively Low Power Inputs and Frequencies.

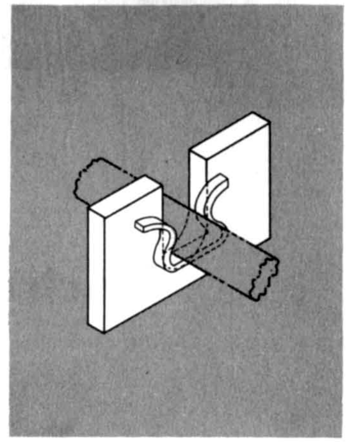

Fig. 2a - Anode Connector for Use at Higher Power Inputs and Frequencies.

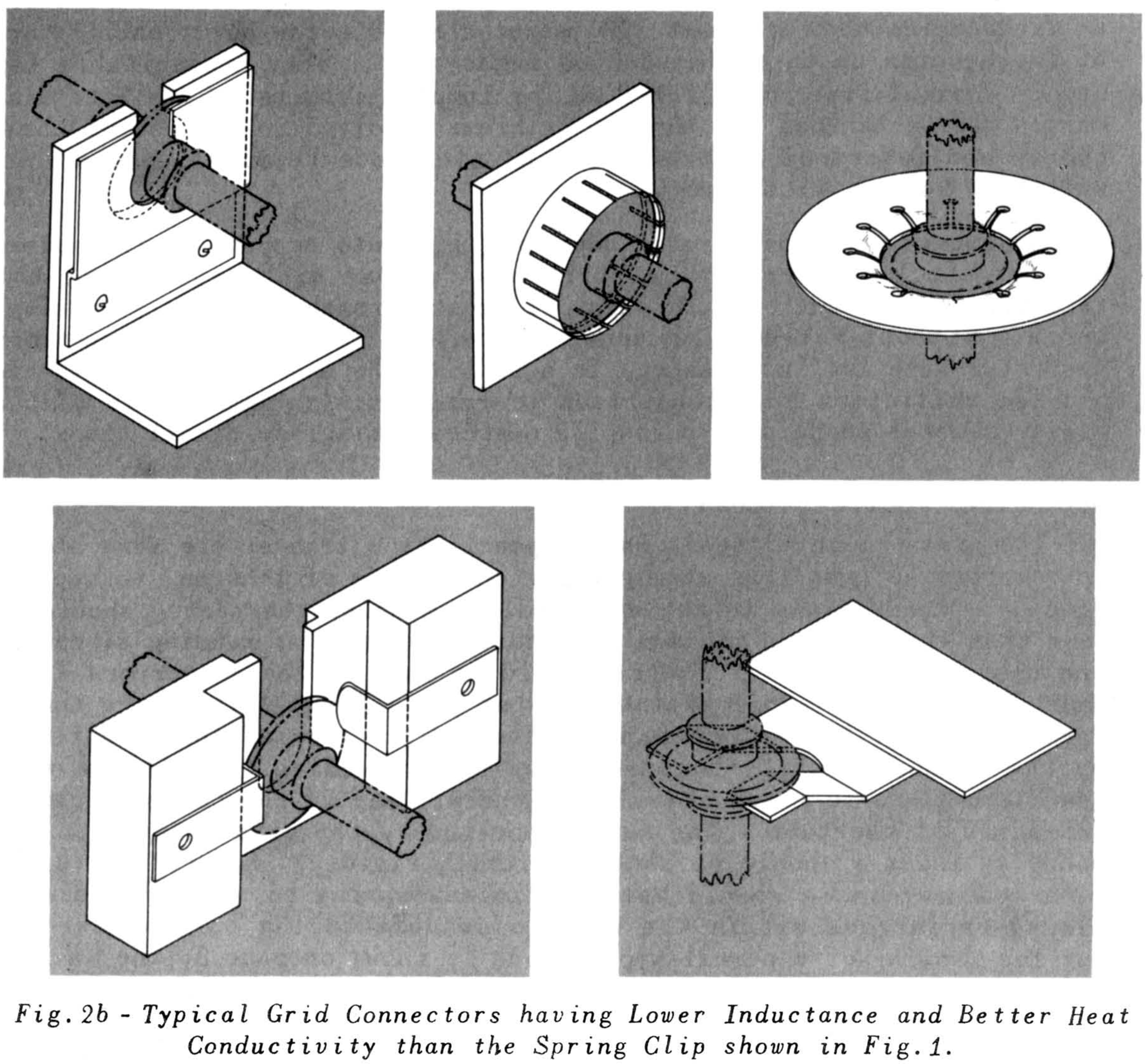

Fig. 2b - Typical Grid Connectors having Lower Inductance and Better Heat Conductivity than the Spring Clip shown in Fig. 1.

At lower power inputs and frequencies, where circuit inductances and thermal conductivity are not major considerations, fuse clips may be used for anode and cathode connections, and various types of spring clips for grid connections. Typical connectors suitable for applications in which power inputs and frequencies are relatively low are shown in Fig. 1. For somewhat higher power inputs or frequencies, the anode connector shown in Fig. 2a and the grid connectors of Fig. 2b provide appreciably lower inductance and better heat conductivity than those of Fig. 1.

In re-entrant-type oscillator circuits*, the grid flange acts as a support for the cylindrical grid connector. The connector, therefore, must exert a clamping action on the grid flange. Fig. 3 shows a grid connector for a re-entrant oscillator operating at 3375 megacycles. Clamping action is provided by means of a bevelled groove which forms a seat for the grid flange. The shape of this groove is such that the cathode side of the grid flange always rests on the slope of the groove.

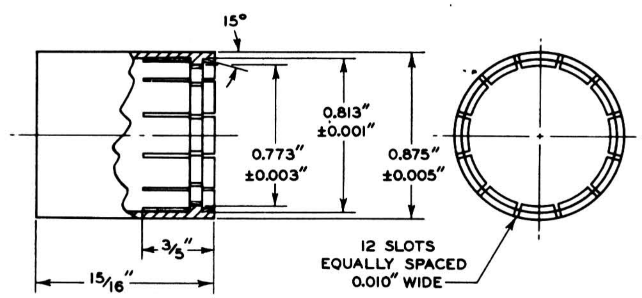

Fig. 3 - Cylindrical Grid Connector for use in Re-entrant Oscillator Circuits.

As a result, the bevelled groove presses against the grid flange to seat it on the shoulder of the grid connector. The angle of the bevel is determined by the type of material used in the connector, the thickness of the material, and the amount of clamping action desired. For the 1/16-inch thick brass connector shown in Fig. 4, a suitable angle of the bevel is 15 degrees. For applications where the oscillator may be subjected to vibrations, it may be advisable to increase the angle. A large angle of bevel, however, tends to produce a clamping action so tight that it is difficult to remove the connector from the grid flange without the use of special tools.

The heater leads of all pencil triodes in current production fit sockets such as Cinch No. 54A16325. Heater leads should not be soldered directly to circuit elements, because the heat of soldering may crack the glass seals around the heater leads and damage the tube.

Thermal Considerations

When the anode dissipation of a pencil-type triode exceeds 2.5 watts, special measures are necessary to cool the anode and thus to keep the temperature of the anode seal below 175 degrees Centigrade. Cooling can

* KLYSTRONS AND MICROWAVE TRIODES, D.R. Hamilton and J.K. Knipp, M. I. T. Radiation Laboratory Series, Vol.7, Sec. 7.2 page 173.

be accomplished by the use of a connector which makes a firm and large-area contact with the anode and, therefore, conducts as much heat as possible to elements of the external circuit. Heat conducted to the external circuit can then be removed by radiation or by convection. The heat-conducting path may conveniently be a part of the electrical circuit, such as the center conductor of a coaxial line.

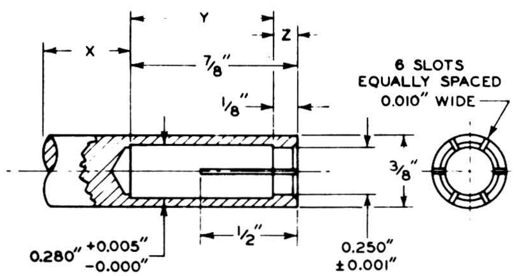

Fig. 4 - Anode Connector for Use in Concentric-Line Circuits.

Fig. 4 illustrates a satisfactory type of anode contact for use in concentric-line circuits. Such a contact provides both good electrical connection and good cooling. The cathode connector for a concentric-line circuit may be of the same form, except that it should be hollow throughout its entire length to accommodate the heater leads and socket. Where lumped-circuit techniques are used, radiator cooling may be employed for the anode cylinder. A diagram of a suitable radiator is shown in Fig. 5.

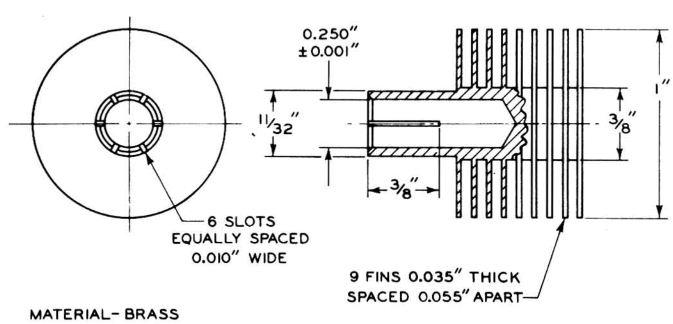

Fig. 5 - Radiator Suitable for Cooling the Anode in Lumped Circuits.

In addition to having good thermal conductivity, the material used for the anode connector should be non-magnetic and have good spring properties so that the connector can provide a good electrical connection without introducing excessive mechanical strain. Some of the materials which may be used for such connectors are hard brass, phosphor bronze, beryllium copper, and special resistance-welding alloys such as Mallory 100▲. Actual choice of the proper material may be governed by considerations of cost, durability, heat conductivity, and availability. Electrical conductivity may be only a secondary consideration if the material is to be silver plated.

▲ P. R. Mallory and Co., Inc., Indianapolis, Indiana.

Material	*Relative Conductivity in per cent* •	*Thermal Conductivity* ••
Mallory 100	50	2.93
Brass		
85 Copper, 15 Zinc	37.2	1.58
66 Copper, 34 Zinc	26	1.2
Beryllium Copper		
2 Beryllium, 98 Copper	20.8	0.94
Phosphor Bronze		
4 Tin, 0.5 Phosphor, Balance Copper	18.2	0.81

• Pure copper = 100 per cent.

•• Watts per unit area per degree Centigrade times unit length.

Table I

Table I lists the relative electrical conductivity and the thermal conductivity of the materials suggested for use in anode connectors. Beryllium copper and phosphor bronze, which are generally used for conventional spring connectors, have rather low thermal conductivity. Brass has reasonably high thermal conductivity, but spring fingers made from it tend to weaken and break after repeated flexing. Mallory 100 alloy has superior thermal conductivity to brass and about the same spring properties as brass, but withstands repeated flexing at high temperatures somewhat better.

Temperature Measurements

Because maintenance of the maximum anode-seal temperature below 175 degrees Centigrade is of the utmost importance, the ultimate test of the cooling capabilities of any anode connector is an actual measurement of the temperature of the seal. Either of the following two methods may be used for this measurement:

(1) with the tube under normal anode-dissipation conditions, but without radio-frequency voltages present, measure the temperature of the anode seal by means of a thermocouple;

(2) with the tube under actual operating conditions, use temperature-sensitive paint or crayon⊕ to determine the anode-seal temperature.

The second method is usually more convenient because of the difficulty of determining accurately the anode dissipation of the tube under actual operating conditions.

The heat-dissipation capabilities of an anode connector are determined by such factors as the area of contact, the effective length of the conducting path, the thermal conductivity of the metal used, and the ambient temperature of operation. A method of calculating the heat-dissipation capabilities of a connector is given in Appendix 1.

⊕ Such as Tempilaq or Tempil Stik, made by the Tempil Corporation, 132 W. 22nd. St., New York 11, N. Y.

When a radiator is used for anode cooling, the amount of heat dissipated by the radiator is a function not only of the factors mentioned above, but also of the air circulating past the cooling fins. If no blower is used, the amount of air circulating past the fins may be limited by the proximity of other circuit components or shields. In a typical circuit arrangement, a pencil triode using the radiator shown in Fig. 5 and no blower was operated at an ambient temperature of 90 degrees Fahrenheit (32.2 degrees Centigrade), with a solid shield 6 inches long and 6-1/2 inches wide on opposite sides of the radiator at a distance of 2-1/2 inches from it, and no shield on the other two sides of the radiator or above it. The radiator, shielded in this manner, maintained the seal temperature below 175 degrees Centigrade when the anode dissipation of the tube was 5.5 watts. The allowable dissipation obviously would be much higher if a blower were used.

Appendix 1

The heat-dissipation capabilities of an anode connector can be estimated quite accurately through the use of the relation

$$\Delta t = \frac{WL}{KA}$$

where Δt = temperature drop across the connector in degrees Centigrade (difference between anode-seal temperature and temperature at end of connector)

W = anode dissipation of tube in watts

L = length of connector in centimeters

K = thermal conductivity of material used in connector in watts per unit area (in square centimeters) per degree Centigrade times unit length (in centimeters).

A = cross-sectional area of connector in square centimeters

If the cross-sectional area and the thermal conductivity of the connector are not uniform throughout the entire length, the temperature drop should be computed separately for each uniform section, and the values added to obtain the total temperature drop. In the connector shown in Fig. 4, for example, if Mallory 100 alloy is used throughout, then the thermal conductivity, as given in Table 1, is 2.93 watts per centimeter per degree Centigrade. There are differences, however, in cross-sectional area. The area in square centimeters of X, the solid portion of the connector, is

$$A_X = \pi\left(\frac{d}{2}\right)^2$$

When the 3/8-inch diameter is converted to centimeters, therefore,

$$A_X = 3.14\left(\frac{0.375 \times 2.54}{2}\right)^2 = 0.712\ \text{cm}^2$$

To find the area of the "fingers" of the connector, it is necessary to subtract the area of the hollow portion from the area of the solid cylinder. The area of the slots may be neglected. Thus, the area in square centimeters of portions Y and Z of the connector, respectively, are

$$A_Y = 0.712 - 3.14 \left(\frac{0.280 \times 2.54}{2}\right)^2 = 0.315 \text{ cm}^2$$

$$A_Z = 0.712 - 3.14 \left(\frac{0.250 \times 2.54}{2}\right)^2 = 0.396 \text{ cm}^2$$

Then, if the anode dissipation of the tube is 6.5 watts, and if the section X is 4 inches long, the temperature drop across section X is

$$\Delta t_X = \frac{6.5 \times 2.54 \times 4}{2.93 \times 0.712} = 31.7^\circ C$$

The drop across sections Y and Z respectively, is

$$\Delta t_Y = \frac{6.5 \times 0.750 \times 2.54}{2.93 \times 0.315} = 13.42^\circ C$$

$$\Delta t_Z = \frac{6.5 \times 0.125 \times 2.54}{2.93 \times 0.396} = 1.78^\circ C$$

The total temperature drop across the connector is 31.7 + 13.42 + 1.78, or 46.9 degrees Centigrade. Thus, if the temperature at the end of the connector is 30 degrees Centigrade, the temperature of the anode seal is 30 + 46.9, or 76.9 degrees Centigrade.

The relation given above may also be used to estimate the maximum power which can be conducted through a given connector without exceeding the maximum anode-seal temperature of 175 degrees Centigrade or to estimate the length required to obtain a given drop in temperature.

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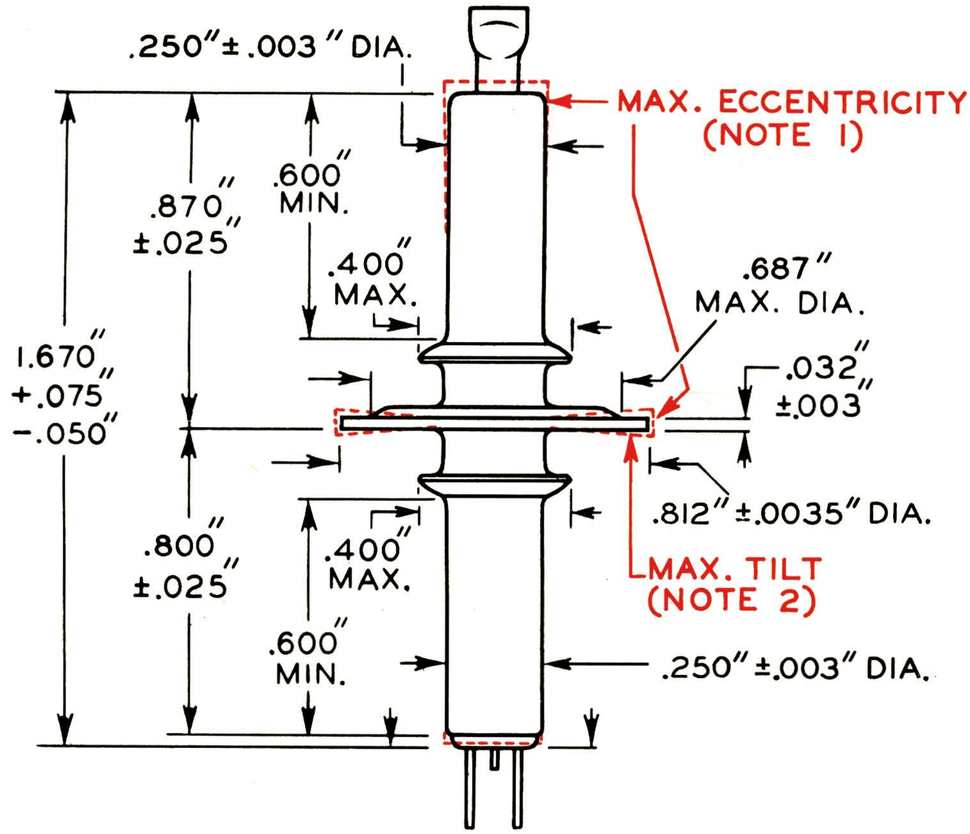
DIMENSIONAL OUTLINE



NOTE 1: MAX. ECCENTRICITY OF ℄ (AXIS) OF ANODE TERMINAL OR GRID-TERMINAL FLANGE WITH RESPECT TO THE ℄ (AXIS) OF THE CATHODE TERMINAL IS 0.008".

NOTE 2: TILT OF GRID-TERMINAL FLANGE WITH RESPECT TO ROTATIONAL AXIS OF CATHODE TERMINAL IS DETERMINED BY CHUCKING THE CATHODE TERMINAL, ROTATING THE TUBE, AND GAUGING THE TOTAL TRAVEL DISTANCE OF THE GRID-TERMINAL FLANGE PARALLEL TO THE AXIS AT A POINT APPROXIMATELY 0.020" INWARD FROM ITS EDGE FOR ONE COMPLETE ROTATION. THE TOTAL TRAVEL DISTANCE WILL NOT EXCEED 0.020".