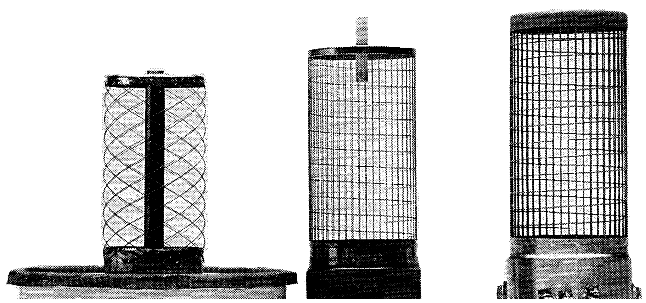
ECONCO

Tube Topics

Section 1: Basic Tube Design

A vacuum tube consists of a vacuum envelope containing various electronic elements used to emit, control, and collect a flow of electrons. A *filament* or *cathode* provides a source of electron emission. Up to three grids; the *control*, *screen*, and *suppressor* grids control the flow of electrons within the tube and a *plate* or *anode* collects the electron flow. Electrical energy that is not transferred to the load is converted to heat at the anode.

Figure 1 shows the interior elements of a tetrode. These elements are mounted and aligned parallel and concentric with each other but are electrically isolated, as shown in Figure 2. In the example device, each bar and spiral of the screen grid is “hidden” from the filament by a corresponding control grid bar.



(a) (b) (c)

Figure 1. The interior of a tetrode: (a) mesh filament, (b) control grid (c) screen grid

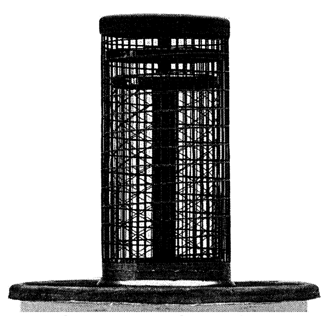


Figure 2. Interior assembly of a power tetrode.

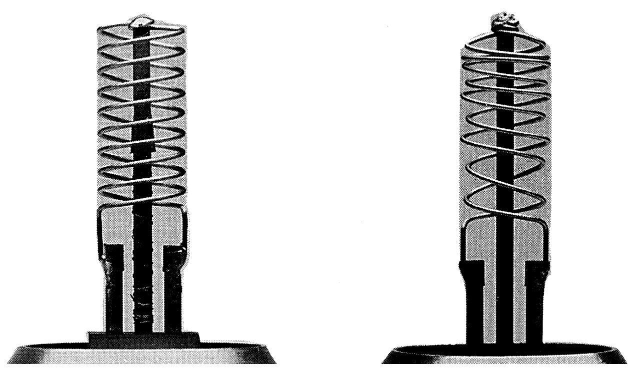
1.1 Electron Emitter Types

The electron emitters in vacuum tubes are either directly heated or indirectly heated. The tube types we are concerned with in this booklet are directly heated, filamentary tubes.

Operating techniques that are proper for filamentary tubes are not necessarily correct for tubes with indirectly heated cathode emitters. In particular, the operation of cathode types at reduced heater voltage can be destructive to the tube.

Filament Designs

Directly heated tubes have either *spiral*, *parallel bar*, *hairpin*, or *mesh* filament structures. The spiral filament structure consists of one or two strands of wire that are spiral wrapped around a central support rod. They are found in older, lower power designs. Spiral filaments are subject to sagging and shorting between the turns. As illustrated in Figure 3, the filament in (*a*) is normal while the filament shown in (*b*) has sagged because of excess filament voltage. These particular tubes operate inverted. Note the shorted turns at the top of (*b*).



(a) (b)

Figure 3. 5762/7C24 spiral filaments: (a) normal filament, (b) abnormal filament

The hairpin structure is found in many power tubes currently installed. It consists of a number of parallel elements bent into the shape of a hairpin (thus the name). The current path is up one leg, across the top, and down the adjacent leg. Hairpin filament support structures have built in spring compensation for thermal expansion of the filament (Figure 4.). These filament structures can have all voltages applied without filament warm-up. Tuning will drift slightly because of relative movement of the tube elements as they reach thermal equilibrium, but there is no danger of shorting. Some tube designs require surge current limitation for the filament when initially turned on. This protection should be provided for by the equipment manufacturer and should not be bypassed.

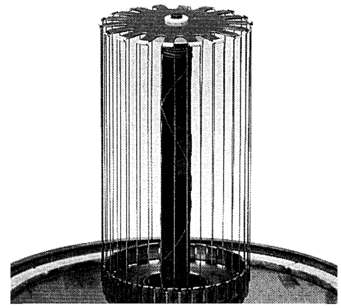


Figure 4. The hairpin filament structure

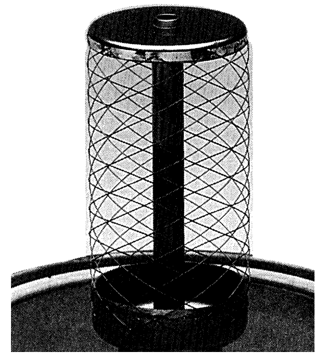


Figure 5. Mesh filament structure

Mesh filaments are composed of filament wires woven to form a basket weave filament structure. (Figure 5.) The wire joints are spotwelded or diffusion bonded at the intersections. Mesh filaments are being designed into most new tube designs on the theory that a mesh filament permits a denser, more closely spaced structure. This allows higher stage gain, increased efficiency and higher frequency operation.

The mesh structure relies on thermal expansion of the ridged upper filament support structure to compensate for thermal expansion of the filament. The current path is from the base, up through mesh filament, across top, and down through the center support rod Mesh filaments require slower warm-up as the thin, low mass filament wires come to temperature immediately as voltage is applied. As they heat, they expand, and until the more massive and slower to heat support structures reach their operating temperature to compensate for this expansion, the filament wires warp in and out. A warped filament greatly increases the possibility of a thermal grid-to-filament short circuit. Common precautions for filament operation are detailed in Section 2.5 ("Filament Voltage"). Attention to filament voltage is vital to long life and stable operation of filamentary tubes.

1.2 Grids

Grid elements are generally formed of wires spotwelded together to form a circular structure that completely surrounds the emitting surface of the filament. The grid controls the flow of electrons from the filament. Grids are coated with various materials compounded to manage the emission of electrons from the grid. If emission of electrons from the grid is uncontrolled, it can result in high distortion or a destructive *runaway* effect in the tube.

1.3 Anode

Anodes are copper cylinders or drawn cups that collect the flow of electrons within a tube. They have air cooling fins, vapor cooling surfaces, or water cooling jackets brazed to their exterior in order to remove the heat generated by the power not transferred to the load.

Plating

The external metal parts of tubes are plated with nickel or silver. Tubes that go into sockets are normally silver plated. The soft silver provides a better contact interface than the much harder nickel; it deforms slightly under contact pressure providing greater contact area. Silver plating has a dull, whitish cast, whereas nickel has a hard metallic appearance.

Nickel is resistant to discoloration resulting from heat at normal tube operating temperatures, while silver will tarnish easily. Often, the heat patterns on silver plated tubes are helpful in problem analysis. If a nickel plated tube shows any sign of heat discoloration, a significant cooling or operational problem exists. Nickel will not discolor until it reaches a temperature much higher than a tube will reach under normal conditions. If a nickel plated tube discolors, abnormal operating conditions are present.

Safety

Power tubes and the equipment they are installed in have electrical voltages present that can be lethal. The access panels to all high voltage cabinets should be installed. All interlocks should be operating and never bypassed. High voltage cabinets should be equipped with a shorting bar, which should be directly grounded. The bar is used to ground all high voltage areas before reaching into them to work on or inspect any components.

Proper equipment design requires that all high voltage circuits have *bleeder resistors* to bleed off any residual charge to ground when the equipment is turned off. Full discharge by these bleeder circuits may take several seconds.

1.4 Sockets

Prior to installing a tube, it is wise to inspect the socket to determine if there are any broken pieces of fingerstock. Broken pieces of fingerstock can fall into the equipment causing shorts and other damage. They should be located and removed prior to installation of the tube. Individual finger contacts can break off on occasion and as long as they are located and removed, the socket ring does not require replacement. If more than 20 percent of fingerstock are broken off, the contact ring should be replaced. Consecutive gaps around the tube can cause improper tuning, instability, and lead to premature failure.

Repair kits are available for most sockets from manufacturers. This method is far cheaper than replacing the entire socket. ECONCO is happy to advise a tube user as to where specific socket replacement parts can be obtained.

Socket Problems

Loose contact on a tube socket will always lead to problems. Some socket designs have a wire-wound spring encircling the outside circumference of the fingerstock to increase individual finger contact pressure. These should be replaced if they break or lose tension. Adequate contact pressure is vital for proper operation and long life. Some sockets have stops that are set so that the tube has the grid contacts in the middle of the contact area when fully inserted. This positioning can be checked by inserting and then removing a new tube. The scratch marks on the grid contacts will show the position of the tube relative to the socket contacts.

Figure 6 shows a burned and melted grid ring on an industrial triode. This failure was caused by poor contact between the grid ring and the socket.

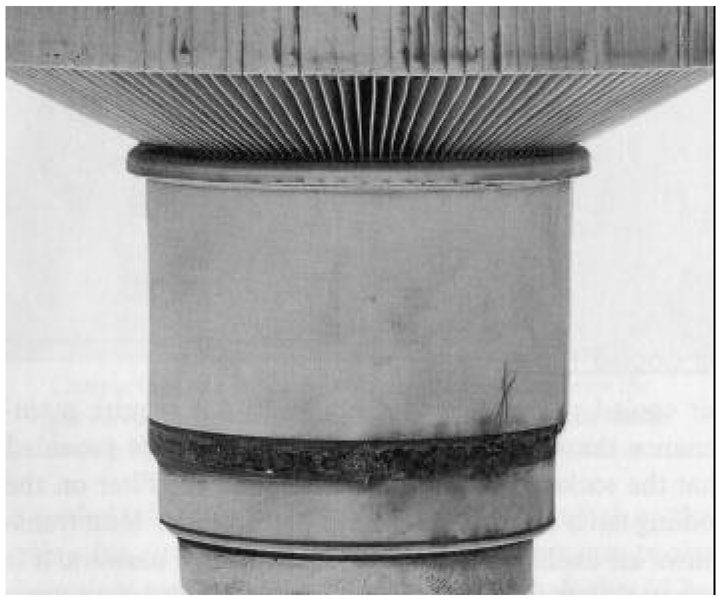


Figure 6. An industrial triode that failed because of socketing problems.

Tube Insertion

Gently rock and slightly rotate the tube as it is being inserted into the socket. This helps avoid bending and breaking of fingerstock. Be sure to apply sufficient force to seat the tube all the way into the socket. Never use a lever or hammer on the tube to set it into the socket. Manual pressure should be adequate. An intermediate point is reached when the grid contact fingerstock slides up the tube sides and first contacts the connection areas. It is important to be sure the tube is fully inserted in the socket beyond this initial point of resistance.

Tubes Without Sockets

Many industrial tubes and tubes used in medium-wave service are not socketed but are installed into the equipment by bolted or clamped connections. Clamped anode connections made of stainless steel should have some method of strain relief to avoid excess pressure collapsing the anode of the tube as it heats up in operation. Stainless steel has a much lower coefficient of thermal expansion than copper.

All bolted or screwed connections should be tight. It is important to check that the clamps are snug, providing good electrical contact around the entire circumference of the contact area. Because of the radio frequency fields present, all clamps and bolts should be made from non-magnetic materials. Copper, brass, or non-magnetic Series 300 stainless steel fasteners are preferred. Stainless steel is not a good conductor of electricity, and while it is used for clamping, it should not be part of the current path.