ECONCO

Tube Topics

Section 2: Tube Maintenance

With the single exception of the temperature necessary to obtain proper filament electron emission, heat is the primary enemy of vacuum tubes.

2.1 Air Cooled Tubes

Air cooled power tubes generally do not require maintenance throughout their normal operating life, provided that the socket is in good condition and the filter on the cooling fan is cleaned or replaced periodically. Most equipment air cooling is done with squirrel cage blowers. It is extremely important to check the impeller blades on these blowers. The blades can fill with dirt, drastically reducing their efficiency and therefore airflow through the tube. The blades should be scrapped with either a screw driver blade or knife to remove caked on dirt. In conditions where dirt, bugs or dust are present, the cooling fins on the anode should be checked for dirt. If they are plugged, remove the tube and use an air hose to blow the dirt from the fins. Blow the cleaning air in the reverse direction of normal air flow through the tube. Particular attention should be paid to the area of the tube where the cooling fin is attached to the anode. The greatest blockage occurs at the point where the cooling air first hits the fins. This is also the point of maximum temperature and therefore maximum heat transfer to the airflow.

Air cooled tubes require greater air flow when operated at higher altitudes because of the decreased density of the cooling air. Tube data sheets give cooling system correction information for high altitude operation. External arcing at high altitude may also require a lowering of plate and screen voltages because of the lower insulating value of air at high altitudes.

Air cooled tubes should have an air interlock switch on the cooling fan to prevent application of any voltages to the tube unless cooling air is flowing. Check the switch for proper operation. The heat generated by the filament alone can destroy a tube without cooling air flow.

Equipment should never have air duct work fastened directly to the cabinet top. Ducting increases backpressure, restricting airflow, which can result in excess tube temperature. Some exhaust ducting includes fans to help move exhaust air. However, if not properly designed, such devices can actually reduce airflow. Also, if the booster fan fails it will significantly reduce the cooling air flow. In situations where it is felt necessary to install ducting to remove exhaust air, it is advisable to construct a hood over the equipment with a six inch open air gap between the equipment and the ductwork.

2.2 Liquid Cooled Tubes

Water and vapor cooled tubes should be supplied with clean, filtered, low conductivity water, ideally from a closed system. Install a strainer on the tube input side. A screen mesh of 36×36 per inch should provide adequate filtering. The system must be free of solid materials such as Teflon pipe tape and rust to prevent blockage of small cooling passages and subsequent tube overheating. Install a flow interlock switch on the tube outlet line.

Certain liquid cooled tubes are sensitive to the direction of water flow. The direction of water flow may be a function of whether the tube is mounted with its anode up or down. Adequate water flow is critical in water cooled tubes to prevent localized boiling and destruction of the tube. Check the tube data sheet for information on direction of flow and cooling water volume requirements.

Vapor cooled tubes require the correct water level be maintained. Check for scale buildup on the anode every six months, as scale can destructively reduce the heat transfer from the anode to the cooling water. Water condition is very important in vapor cooled installations; steam is active chemically and will react with the materials in the system to form contaminants.

2.3 Tuning

Each equipment manufacturer provides instruction or guidelines for proper tuning and operation of their systems, which should be followed closely when adjusting the equipment.

Operate the power tubes in the equipment at their rated filament voltage whenever tuning or adjusting the equipment—not at reduced levels. This assures adequate emission levels from the tube and reduces the chances of low filament voltage masking performance levels that should be achieved through proper tuning and adjustment. After all adjustments are complete, the filament voltage may be set (as described in Section 2.5) to achieve maximum tube life.

2.4 Normal Tube Operation

Whenever a tube is received from the supplier it is a good idea to inspect the package and check the tube for physical damage as soon as possible. Tubes are fragile and subject to shipping damage despite the care taken in packaging. Open the box and remove the tube. A check with a VOM meter can make a quick evaluation for broken filaments. Carefully lay the tube on its side and check for continuity (a short) between the two filament contacts. The filament contacts should indicate a short as the filament resistance is very low when cold. Also, check to see that there is no continuity (open circuit) between either filament connection and the other tube elements. The only continuity should be between the filament contacts, with all other elements being electrically isolated from the filament and each other. If the tube shows a short-circuit, contact the supplier. Do not attempt to install it.

2.5 Filament Voltage

The proper adjustment and regulation of filament voltage is the single most significant area where a tube user can affect tube life and performance.

Metering

The metering of filament voltage on the majority of equipment is not accurate. Often the metering is a multimeter that is switched to read various operating parameters. To be useful for filament metering, the meter must be calibrated to read voltage at the tube socket and must be capable of being read accurately to one tenth of a volt. Often the filament voltage is measured at the output of the filament transformer. In high current circuits such as the filament, the voltage drop in the wires going to the tube can be significant. All filament meters should be calibrated with an accurate iron-vane or rms-responding digital meter. The object is to determine the *heating value* of the power being supplied to the filament. The calibration voltage should be taken at the tube socket or connections with the filament operating. This will compensate for any line drop losses. In locations where the line voltage fluctuates more than 5 percent, the supply to the filament transformer should be equipped with a constant-voltage transformer (i.e., Sola transformer). A diagram of a filament supply circuit capable of precise adjustment over the most beneficial voltage range is shown in Figure 7. The circuit given assumes a 240 V supply to the circuit. Specific design criteria include the following:

- **Component 1.** Sola constant-voltage transformer connected to the supply line; sized for the KVA rating of filament.
- **Component 2.** Variac variable auto transformer controlling a fixed step-down transformer connected in a buck or boost configuration; KVA rating equal to 10 percent of the filament KVA.
- **Component 3.** A 240-to-24 volt secondary fixed transformer; KVA rating ≥ 10 percent of the filament KVA.
- **Component 4.** The existing filament transformer.

Mount the variable transformer such that it is adjustable from the control panel of the equipment. This will allow adjustment of the filament voltage while the equipment is operating. Unfortunately many transmitters and most industrial equipment are built with a filament transformer that has, at the most, taps located inside the equipment for the adjustment of filament voltage. If the equipment is operated for long periods of time, the filament circuit should be modified as shown.

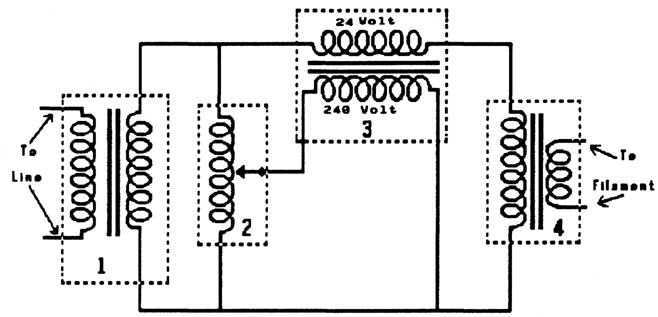


Figure 7. Adjustable filament supply circuit.

Filament Operation

The thoriated tungsten filaments used in power vacuum tubes depend upon sufficient filament temperature to provide adequate electron emission for normal operation. Power tubes should not be operated in the *emission-limited* mode. The use of filament voltage to control output power is not the correct method of operation. It will destroy a tube quicker than operation at higher than permissible voltages.

The operator, by adjusting the filament voltage, can control the operating temperature. Each tube is unique; while one tube may make full operating power at a filament voltage of 7.3 V, a replacement device may require 7.4 V to attain the same power. It is for this reason that we recommend all tuning be done at the rated filament voltage. After tuning is complete, then the voltage can be reduced to provide extended life.

Though cathodic type tubes can be damaged by operation of the heater at reduced filament voltage, we have never seen a case where operation at the proper reduced voltage after tuning is anything but beneficial to directly heated filamentary tubes. It is important, however, to operate the tube at rated voltage for the first 100 to 200 hours before reducing it as described in the next section.

Initial Operation and Tuning

Upon initial installation, the filament should be run for a period of 100 to 200 hours at its rated filament voltage. This initial operation allows the *getters*, materials that absorb and hold residual gas, to finish the vacuum of the tube in its actual operating environment. After this initial run-in time, it is good practice to operate the filament at reduced voltage, provided that proper operating parameters can be obtained at the reduced voltage.

First, tune and run the equipment to normal operation with the filament at rated voltage; then, without changing any other adjustments, reduce the filament voltage until the tube deviates from normal operating conditions. This point is the beginning of emission limited operation. Continued operation at this point can be destructive to the tube. Raise the voltage to one or two tenths of a volt above the lowest voltage where the tube worked properly. This should maximize tube life at no reduction in performance. The one to two tenths setting above the emission

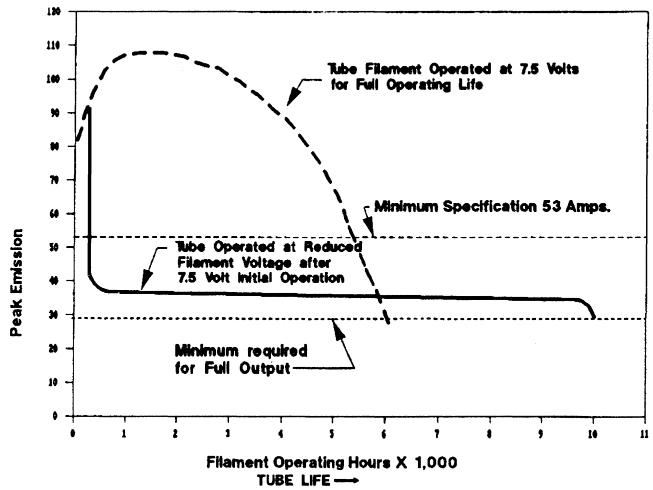


Figure 8. Filament life vs. peak filament emissions for a 4CX5000A.

limited voltage allows for minor line fluctuations and requires less frequent adjustment as the tube ages.

A power tube operated in this manner will generally yield life 50 percent greater than a tube run continuously at rated filament voltage. If the tube is removed and then replaced, it is not necessary to run it at rated voltage beyond the time necessary to tune the equipment.

Figure 8 illustrates the impact of filament voltage on peak emissions with a common tetrode. Figure 9 charts filament current as a function of operating hours.

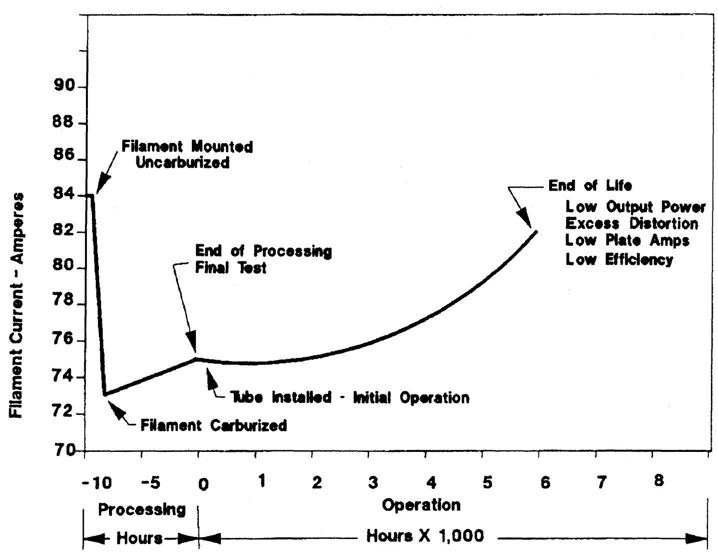


Figure 9. The effect of filament current on the operating hours of a 4CX5000A.

2.6 Tube Life

In the majority of applications, normal end of life for a power tube is determined when, due to decarburization of the filament, the electron emission of the filament falls below the point where, at rated filament voltage, it is no longer adequate to sustain full output power or distortion levels exceed allowable limits.

Carburization is the process where in manufacturing, carbon is—under specific conditions of temperature and pressure—burned into the raw *thoriated tungsten* filament. This process is monitored by a decrease in the filament current at rated voltage. As a tube operates, carbon slowly is burned out of the filament.

Three factors are primary in determining the number of hours a tube will operate before reaching end of life:

- The amount of carbon originally processed into the filament. The maximum amount of carbon that can be burned into a filament is limited by increasing fragility as the carbon level is increased and by a lowering of the filament temperature to the point where the tube lacks adequate emission to make power at rated filament voltage.
- The residual vacuum level in the tube. The quality of the vacuum affects life because the rate of decarburization is a function of residual gasses, primarily oxygen and nitrogen, reacting with the filament to cause decarburization. Good vacuum processing and proper gettering result in the lowest residual gas levels. Getters are materials placed within the tube envelope that when heated absorb and hold residual gasses within the tube. This gettering action improves the ultimate vacuum within the tube envelope. Gettering action continues throughout the life of the tube, however the most beneficial action occurs in the first few hours of operation.
- The rate of decarburization, which increases with the operating temperature of the filament. The filament temperature is determined by power on the filament and therefore controllable by adjustment of the filament voltage.

These various items, taken together, determine the normal life of a power tube. In broadcast transmitters that operate into a fixed load, the vast majority of failures result from a loss of emission caused by decarburization. Industrial applications, such as dielectric or induction heating, often experience a higher percentage of catastrophic failures.

Equipment problems related to tubes fall into three categories:

- Catastrophic
- Intermittent
- Performance

Table 1 lists general guidelines for extended tube life.

Table 1. Checklist for Long Tube Life

	Promptly check tubes when received for shorts and freight damage.
	Store tube in a dry location in its original box, safe from shock and bumping.
	Install the tube and tube equipment with the filament at its rated normal voltage.
	Run tube for several weeks at rated normal filament voltage.
	Reduce filament voltage to increase tube life after initial run-in.
	Replace or clean filters as required.
	Maintain proper water quality and flow on all water and vapor cooled tubes.
	Keep an accurate and up to date log of equipment behavior and meter readings.

Catastrophic Failures

A catastrophic failure can take on a number of forms, however, the symptoms are usually the same: overload relay trips and/or circuit breaker trips. Repeated attempts to restart the equipment can cause damage to the circuitry so it is good practice to troubleshoot the system immediately upon the first indication of overload. To begin, make a visual inspection of the high voltage areas of the equipment. Look for burned wires and components. If you have reason to suspect the tube, remove it, making sure that the high voltage connections are located so as to prevent shorting to ground or other components. With the tube removed, reapply voltages. If the equipment does not trip off, then you can be reasonably sure that the problem is the tube or the tube/circuit interface. At this point, unless a specific problem has been found, we recommend that the tube be sent to ECONCO for testing and analysis.

Catastrophic failures can be caused either by broken or warped elements shorting to each other within the tube, or a puncture in the vacuum envelope allowing air to enter the device. Air in a tube causes a loss of dielectric standoff between the internal tube elements. Both shorted elements and loss of vacuum will cause overloads in operating equipment.

Catastrophic failures that occur during initial installation are usually the result of broken elements. Those that occur after initial operation are more likely the result of a loss of vacuum. In either case, continued efforts to bring the tube up can result in considerable damage to the tube and other components. Overloads and circuit breakers are not fast enough to forestall many types of damage.

Intermittent Failures

Intermittent overloads (*kickoffs*) are the hardest to pin down. They can be caused by circuit operating conditions or internal tube failures. In transmitters, they can be the result of a broken or warped filament moving around and occasionally short-circuiting to the grid, causing loss of grid bias. Loss of grid bias in tubes requiring a bias voltage allows full plate current to flow, activating the overload protection circuit(s). In industrial applications, intermittent overloads can also be caused by shorting across the load.

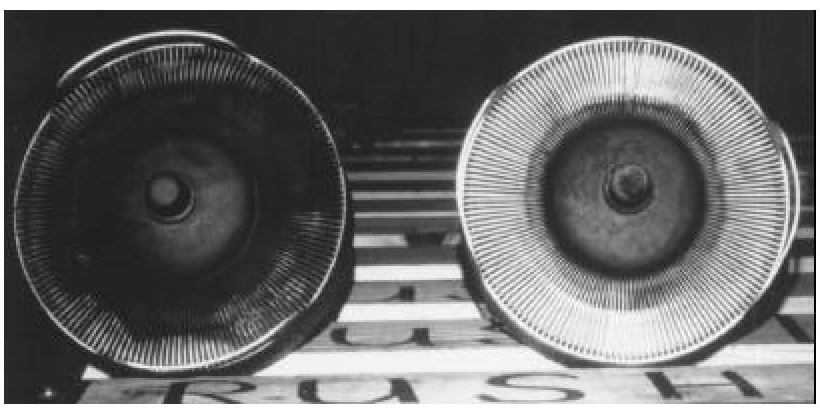
Performance Failures

Performance failures occur when the equipment will not produce normal output with the normal operating values set. One method of quickly checking to determine if low emission in the tube is the likely cause is to raise the filament voltage several tenths of a volt. If the output increases dramatically, then you can be quite sure that the problem is low emission. No danger of burning out the filament exists, as most designs are capable of temporarily withstanding twice their rated filament voltage. Raise the filament voltage to a point where the output returns to normal. If voltage in excess of rated normal is required, the tube is due for replacement. For short periods of time, you can run the filament in excess of normal rated voltage, however in a tube with a mesh or spiral filament, the risk of thermal shorting is increased. In any case, the tube should be replaced as soon as possible when full output can no longer be obtained at rated filament voltage.

2.7 Evaluating Tube Performance

Examination of a power tube after it has been removed from a transmitter or other type of generator can reveal a great deal about how well the equipment-tube combination is working. Contrast the appearance of a new power tube with a component at the end of its useful life. If a power tube fails prematurely, the device should be examined to determine whether an abnormal operating condition exists within the transmitter. Consider the following examples:

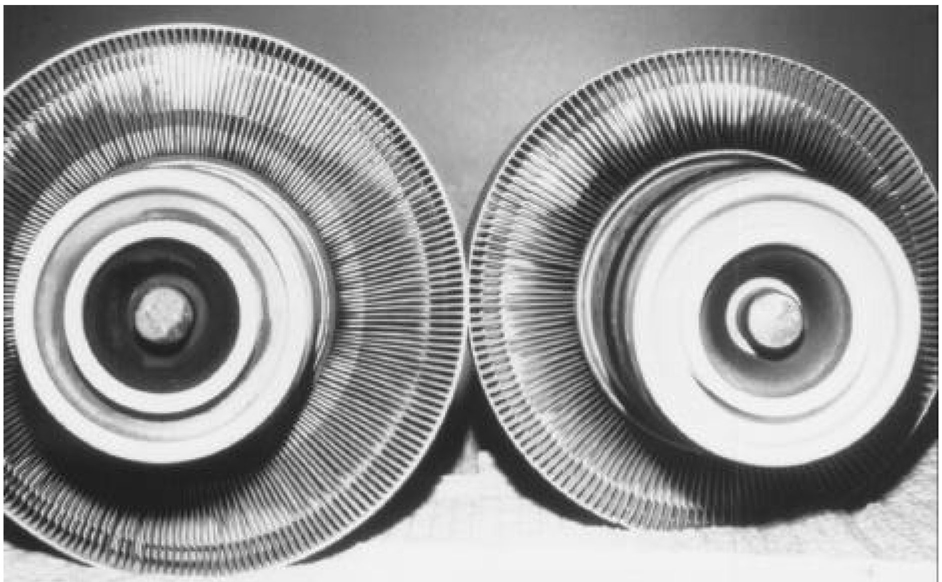
- Figure 9. Two 4CX15000A power tubes with differing anode heat-dissipation patterns. Tube (*a*) experienced excessive heating because of a lack of PA compartment cooling air or excessive dissipation because of poor tuning. Tube (*b*) shows a normal thermal pattern for a silver-plated 4CX15000A. As mentioned previously, nickel-plated tubes do not show signs of heating because of the high heat resistance of nickel.



(a) (b)

Figure 9. Anode dissipation patterns on two 4CX15000A tubes: (a) excessive heating, (b) normal wear

- Figure 10. Base-heating patterns on two 4CX15000A tubes. Tube (*a*) shows evidence of excessive heating because of high filament voltage or lack of cooling air directed toward the base of the device. Tube (*b*) shows a typical heating pattern with normal filament voltage.



(a) (b)

Figure 10. Base heating patterns on two 4CX15000A tubes: (a) excessive heating, (b) normal wear

- Figure 11. A 4CX5000A tube with burning on the screen-to-anode ceramic. Exterior arcing of this type generally indicates a socketing problem, or another condition external to the tube.
- Figure 12. The stem portion of a 4CX15000A tube that had gone down to air while the filament was on. Note the deposits of tungsten oxide formed when the filament burned up. The grids are burned and melted because of the ionization arcs that subsequently occurred. A failure of this type will trip overload breakers in the RF generator. It is indistinguishable from a short-circuited tube in operation.
- Figure 13. A 4CX15000A tube that experienced arcing typical of a bent finger-stock, or exterior arcing caused by components other than the tube.

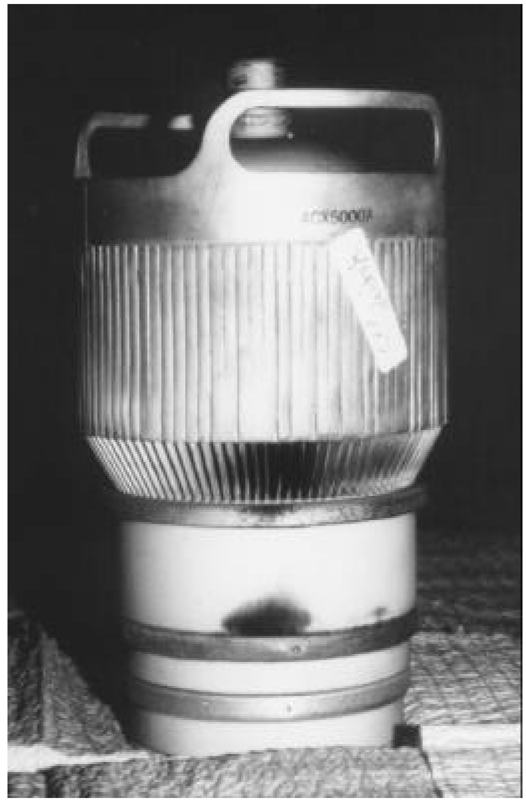


Figure 11. A4CX5000A tubes that appears to have suffered socketing problems.

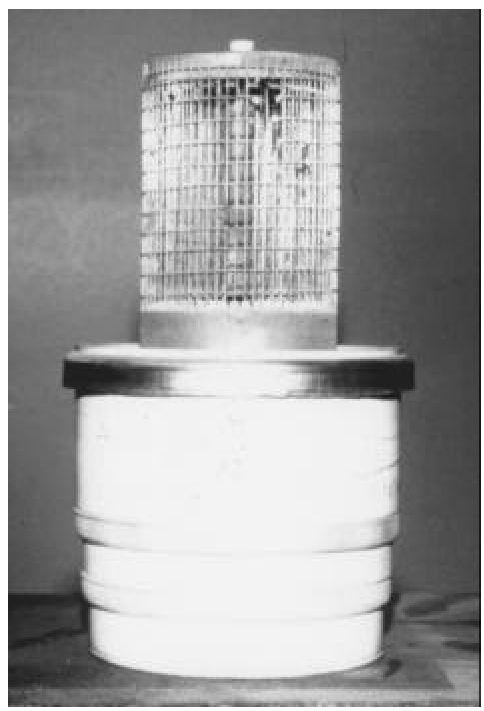


Figure 12. The interior elements of a 4 CX15000A tube that had gone to air while the filament was lit.

Figure 13. A 4CX15000A tube showing signs of external arcing.

2.8 Shipping and Handling

Because of their fragile nature, tubes are packaged for shipment in foam filled or spring supported shipping containers. When it is necessary to ship or transport a tube from one location to another, it is good practice to put them in their original shipping containers. If the original packing is unavailable, for tubes weighing up to 25 pounds, a minimum of two inches of bubble pack will protect the device. Larger tubes require more protection. Vacuum tubes should be removed whenever the equipment is moved. Tubes should never be left installed during an equipment move.

Storage

Tubes should be wrapped in a plastic bag to protect them from moisture and stored in their shipping boxes. If it is necessary to store tubes loose, they should be located so as to reduce the chance of accidental breakage resulting from dropping or shock. Also, the should not stored in high-moisture environments.

Handling

Power tubes are fragile. Filaments can be broken by setting the tube down too hard on a solid surface. Do not lie a tube on its side; the filaments can break if it rolls along a surface. Some radio frequency industrial equipment is routinely moved to various locations within a plant. Equipment used in this manner should be equipped with air filled casters, never solid casters

Marking

Never write on any portion of the ceramic or on any contact surface. Some engineers are in the habit of writing notes on the tube bodies for record keeping purposes, but this is not a good practice. Use a separate note card instead.

Shelf Life

Modern power tubes with metal and ceramic vacuum envelopes are not prone to *gassing up* while in storage. Experience indicates that these tube types can be stored indefinitely without deterioration. It is not necessary to periodically rotate them through an operating socket to degas the tube. Experience shows that you stand a greater chance of breaking the tube or socket fingerstock than any benefit gained by degassing.

Older designs, using glass as an insulating medium, do tend to leak gas over time. It is not the glass that is porous to gas, but the Kovar alloy used to seal the glass to metal parts in the tube. Kovar is also subject to rusting when moisture is present. Such devices should be kept in a sealed plastic bag in storage and rotated through the equipment at least once every twelve months. Physically, the larger the tube, the more surface area of Kovar, and the greater the possibility of gassing up.

Degassing

Tubes that may have gassed up can be partially degassed by putting them in the equipment and running them for several hours with filament voltage only applied. After the initial filament-only degassing; operation for an hour or so at reduced plate and screen voltages is desirable. This allows the getter to soak up and hold any residual gasses. In directly-heated filamentary tubes, the getters are generally zirconium-bearing materials, which depend on heat to activate the gettering action.

Manufacturers Support

ECONCO is happy to provide telephone support to any tube user who is experiencing problems with a tube. This service is available to all tube users regardless of their source of tubes. We can provide copies of data sheets for most common power tubes.