TUBE TOPICS

ECONCO

A Guide for Vacuum Tube Users in a Transistorized World

TUBE TOPICS

Despite the inroads of transistors, there are still applications where vacuum tubes work best. Due to the specialized nature of vacuum tubes and the limited exposure of engineers and operators to them in todays transistorized and integrated circuit world, Econco has prepared this booklet. The information contained is a result of our twenty-five years of rebuilding tubes and talking with you, the users. We hope it helps you in working with these products. If this booklet proves helpful to tube users, it is our intention to periodically update the information. Your comments and suggestions would be appreciated.

The most important assets of any business are its employees and its customers. This booklet was produced to assist our customers and is dedicated to our most important asset, our employees.

ECONCO

STAFF - December 1994

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DR. GRIEBELFRITZERS RULES FOR LONG TUBE LIFE

1. *Promptly check tubes when received for shorts or freight damage.*
2. *Install and run tube for several weeks at rated normal filament voltage as soon as possible after receipt.*
3. *Reduce filament voltage to increase tube life after initial run in.*
4. *Store tube in a dry location in original box, safe from shock and bumping.*
5. *Always tune equipment with filament at rated normal voltage.*
6. *Replace or clean filters as required.*
7. *Maintain proper water quality and flow on all water and vapor cooled tubes.*
8. *Keep an accurate and up to date log of equipment behavior and meter readings.*
9. *Always sell excess duds to Econco.*

TUBE TOPICS

BASIC DESIGN

Tube Elements

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 which is not transferred to the load is converted to heat at the anode.

Interior elements of a tetrode. Mesh filament on the left, control grid center and screen grid on right

Mounted and aligned interior elements

Interior elements are parallel and concentric with each other but are electrically isolated. Each bar and spiral of screen grid is "Hidden" from the filament by a corresponding control grid bar.

Electron Emitter Types

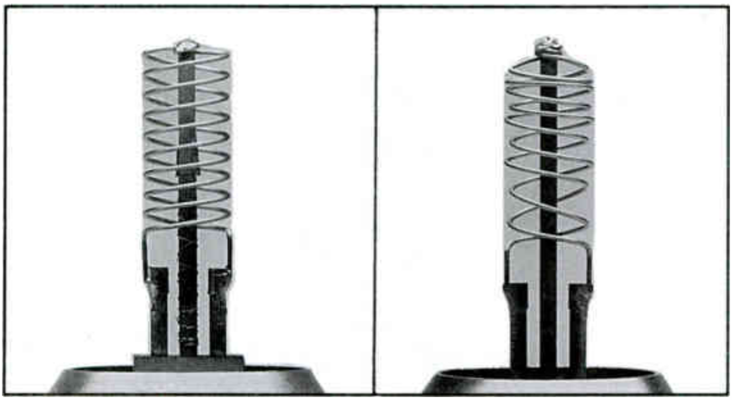
The electron emitters in vacuum tubes are either directly heated or indirectly heated. The tube types we are concerned with in this booklet are directly heated, filamentary tubes.

Operating techniques which 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 which 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.



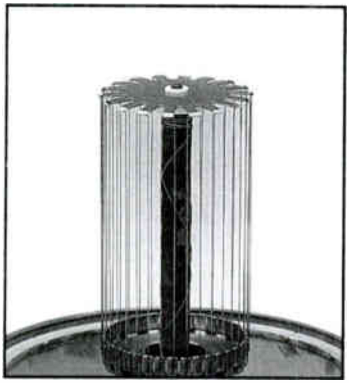
5762/7C24 Spiral Filaments

Filament on the left is normal while the filament on the right has sagged due to excess filament voltage. These tubes operate inverted. Note the shorted turns on the top right.

The hairpin structure is found in the majority of tubes currently installed. It consists of a number of parallel elements bent into the shape of a hairpin. The hairpin filament support structures have built in spring compensation for the thermal expansion of the filament. These filament structures can have all voltages applied without filament warm-up. Tuning will drift slightly due to 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.

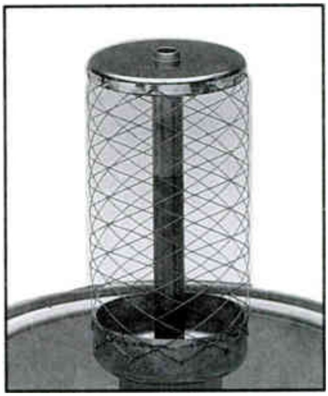
Hairpin Filament Structure

Current path is up one leg, across the top and down the adjacent leg.



Mesh filaments are composed of filament wires woven to form a basket weave filament structure. The wire joints are spotwelded or diffusion bonded at the intersections. Mesh filaments are being designed into most new tube designs due to the belief 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. 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. Proper operation of the filament as detailed in the section titled, "Filament Operation" is vital to long life and stable operation of filamentary tubes.



Mesh Filament Structure

Current path is from base, up through mesh filament, across top and down through center support rod

Grids

Grid structures are generally formed of wires spotwelded together to form a circular structure which 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 suppress the emission of electrons from the grid. Emission of electrons from the grid is uncontrolled. It can result in high distortion or runaway of the tube.

Anodes

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

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Plating

The external metal parts of tubes are plated with nickel or silver. Tubes which go into sockets should be 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 very resistant to discoloration due to 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 which 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 (Widow Stick). It should be directly grounded. The bar should be used to ground all high voltage areas before reaching into them to work or inspect the components.

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

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Tube Installation

Sockets

Prior to installing a tube it is wise to inspect the socket to determine if there are any broken pieces of finger stock. Broken pieces of finger stock 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% of finger stock 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 may be obtained.

Socket Problems

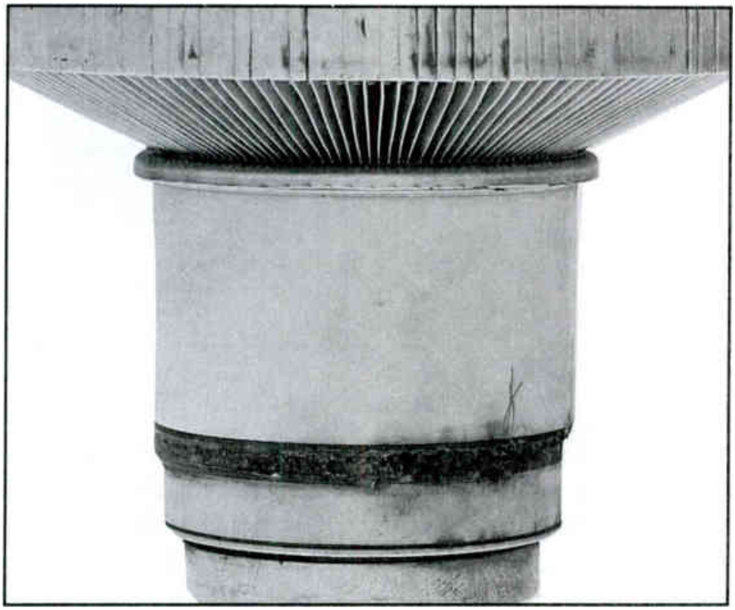
Loose contact on a tube socket will always lead to problems. Some socket designs have a wire wound spring encircling the outside circumference of the finger stock to increase individual finger contact pressure. These should be replaced if they break or lose tension. Adequate contact pressure is vital for proper operation and long life. Some sockets have stops which are set so that the tube has the grid contacts in the middle of the contact area when the tube is 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.

Tube Insertion

Gently rock and slightly rotate the tube as it is being inserted into the socket. This helps avoid bending and breaking of finger stock. 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 contact 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 AM radio 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.



Burned and melted grid ring on an industrial triode. Failure was caused by poor contact between grid ring and socket.

All bolted or screwed connections should be tight. It is important to see that the clamps are snug providing good electrical contact around the entire circumference of the contact area. Due to 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.

Maintenance

Heat

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

If your tubes look like this !!

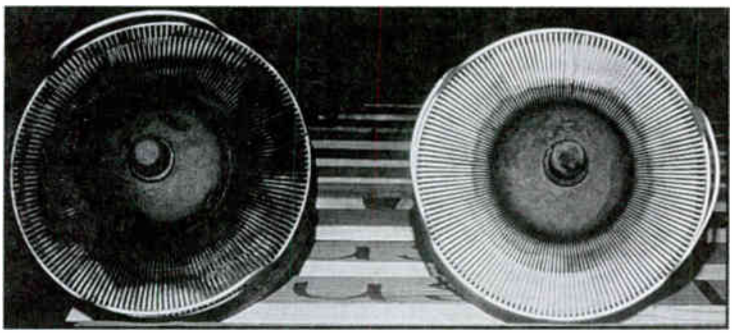
You have a problem !

Call Econco

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 transmitter 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 due to the decreased density of the cooling air. The tube data sheets give correction information for high altitude operation. External arcing at altitude may also require a lowering of plate and screen voltages due to the lower insulating value of air at altitude.



Comparison of normal heat dissapation on anode on the right versus indication of excessive dissapation on the anode on the left. Cause is either restricted cooling air flow or improper loading.

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. The switch should be checked for proper operation. The heat generated by the filament alone can destroy a tube without cooling air flow.

AM and FM transmitters should never have air duct work fastened directly to their tops. Ducting increases backpressure, restricting airflow which can result in excess tube temperature. Some exhaust ducting has fans to help move exhaust air. If not properly designed, they can actually reduce airflow. If this fan fails it will definitely reduce 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 transmitter with a six inch open air gap between the transmitter and the ductwork.

Liquid Cooled Tubes

Water and vapor cooled tubes should be supplied with clean, filtered, low conductivity water ideally from a closed system. A strainer should be installed on the tube input side. A screen mesh of 36 X 36 per inch should provide adequate filtering. The system should be free of solid materials such as Teflon pipe tape and rust to prevent blockage of small cooling passages and subsequent tube overheating. A flow interlock switch should be installed 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. Scale build up on the anode should be checked 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 very active chemically and will react with the materials in the system to form contaminants.

Tuning

Each equipment manufacturer provides instruction or guides for proper tuning and operation of their equipment. They should be followed closely when adjusting the equipment.

The power tubes in the equipment should be operated at their rated filament voltage whenever tuning or adjusting the equipment and not at reduced levels. This assures adequate emission levels from the tube masking performance levels which should be achieved by proper tuning and adjustment. After all adjustments are complete, the filament voltage may be set as described in the Normal Tube Operation section of this booklet to achieve maximum tube life.

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 very 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. 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 circuit is of very low resistance 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, contact the supplier. Do not attempt to install it.

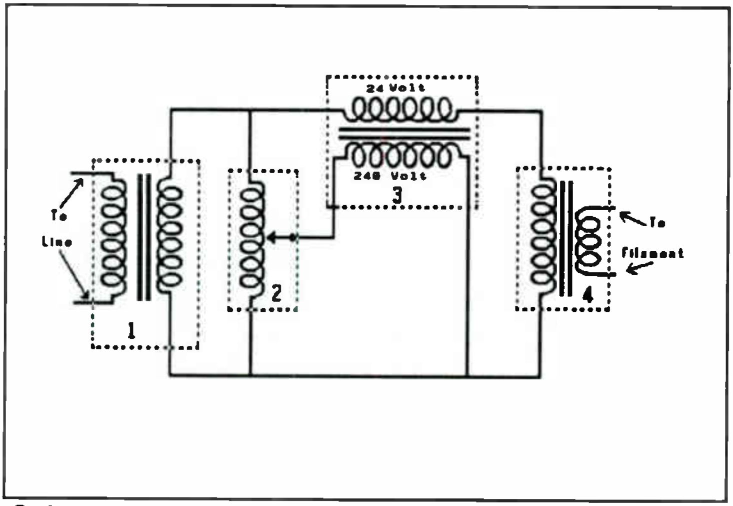
Filament Voltage

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

Metering

The metering of filament voltage on the majority of equipment is not accurate. Often the metering is a multimeter which 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 input to the filament transformer. In high current circuits such as the filament, the voltage drops 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 linedrop losses. In locations where the line voltage fluctuates more than 5%, 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 range is included in this section. It assumes a 240 volt supply to the circuit.

The variable transformer should be mounted 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 for proper tube operation and as an aid in troubleshooting. Unfortunately many transmitters and most industrial equipment is built with a filament transformer which has, at the most, taps located inside the equipment for the adjustment of filament voltage. We recommend that if the equipment is operated for long periods, then the filament circuit should be modified as shown.



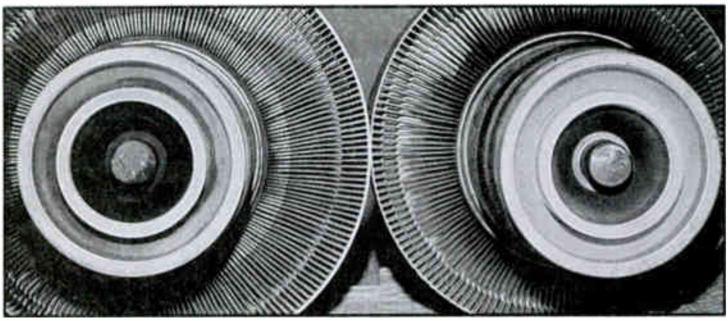
Schematic diagram for an optimum filament voltage supply circuit.

1. *"Sola" constant voltage transformer connected to supply. Sized for KVA rating of filament.*
2. *"Variac" variable auto transformer controlling a "Buck/Boost transformer. KVA rating equal to 10% of filament KVA.*
3. *240 to 24 volt secondary fixed transformer. KVA rating => 10% of filament KVA.*
4. *Existing filament transformer.*

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 overvoltage.

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 volts, its replacement may require 7.4 volts to attain the same power. It is for this reason, we recommend that all tuning be done at the rated filament voltage. After tuning is complete, then the voltage can be reduced to provide extended life.



Normal heating of filament base on the right versus excessive heating on the left. Note that the left base is black on the entire center rod and inverted cone. This is usually the result of excess filament voltage.

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 to operate the tube at rated voltage for the first 100 to 200 hours before reducing it as described in the section below on Initial Operation and Tuning.

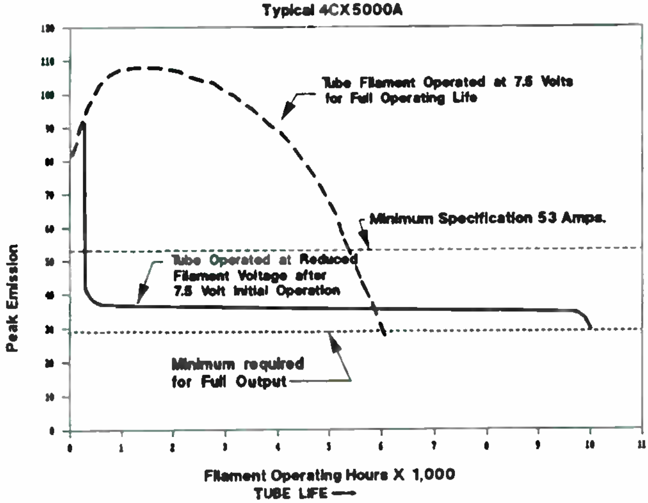
Initial Operation and Tuning

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 which 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 excellent 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 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% 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

FILAMENT LIFE versus PEAK FILAMENT EMISSION
Typical 4CX5000A



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. The 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.

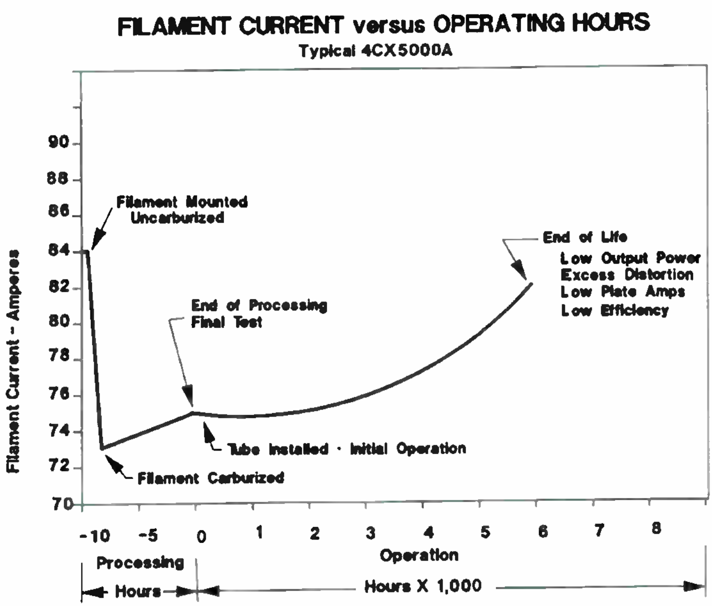
Three factors are primary in determining the number of hours a tube will operate before reaching end of life.

First, the amount of carbon originally processed into the filament. The maximum amount of carbon which can be burned into a filament is limited by increasing fragility as carbon level is increased and by lowering of the filament temperature to the point where the tube lacks adequate emission to make power at rated filament voltage.

Second, the residual vacuum level in a tube affects life as 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 which 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 hours of operation.*

Third, the rate of decarburization is proportional to 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 tube. In broadcast transmitters which operate into a fixed load the vast majority of failures are due to loss of emission as a result of decarburization. Industrial applications such as dielectric or induction heating do result in a higher percentage of catastrophic failures. At Econco efforts are made to rebuild tubes in such a manner so as to minimize these types of failures.



Troubleshooting

Equipment problems related to tubes fall into three categories: catastrophic, intermittent and performance.

Catastrophic Failures

A catastrophic failure has occurred when the overload relays or circuit breakers trip. Repeated attempts to restart the equipment can cause damage to the circuitry so it is good practice to trouble shoot the equipment 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 returned 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 the tube has a puncture in the vacuum envelope allowing air to enter the tube. Air in a tube causes loss of dielectric standoff between the internal tube elements. It is not possible to distinguish between shorting or loss of vacuum in operating equipment.

Catastrophic failures which occur during initial installation are usually due to broken elements. Those which occur after initial operation are more likely due to 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 damage.

Intermittent Failures

Intermittent 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 shorting to the grid causing loss of grid bias. Loss of grid bias in tubes requiring a bias voltage allows full plate current to flow kicking the overload protection. 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. A quick check to determine if low emission in the tube is the likely cause is too 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 withstanding filament voltages twice their rated 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 as end of life has been reached.

Shipping and Handling

Packing

Due to 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 wise to put them in their 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 tube. Larger tubes require more protection. The 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 due to dropping or shock and not stored in high moisture environments.

Handling

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

Marking

Some engineers are in the habit of writing notes on the tube bodies for record keeping purposes. You should never write on any portion of the ceramic or on any contact surface which is used.

Shelf Life

Modern power tubes with metal and ceramic vacuum envelopes are not prone to gassing up while in storage. Our 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 finger stock 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 which 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. They 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, then the greater the possibility of gassing up.

Degassing

Tubes which 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 materials designed into tubes called getters to soak up and hold residual gasses. In directly heated filamentary tubes these are generally zirconium bearing materials. They 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.

Duds

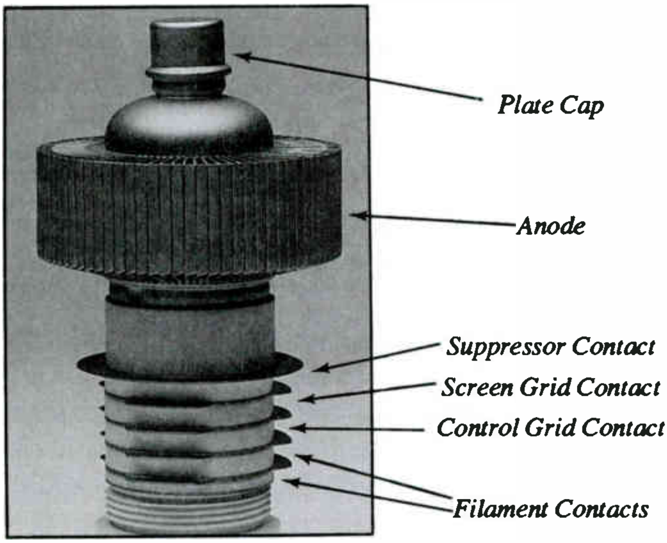
Duds are the lifeblood of the tube rebuilding business. Econco believes that all tube users should sell their duds to Econco whether they choose to use our services or not.

Our continued presence in the industry creates competition and acts as a restraint on price increases of new tubes.

Component Identification

The occasional user may have trouble identifying the various component parts of a tube. The pictures below are an aid in identifying these parts. Feel free to contact Econco @ (800) 532-6626 if we can be of assistance.

5CX1500A & 5CX1500B



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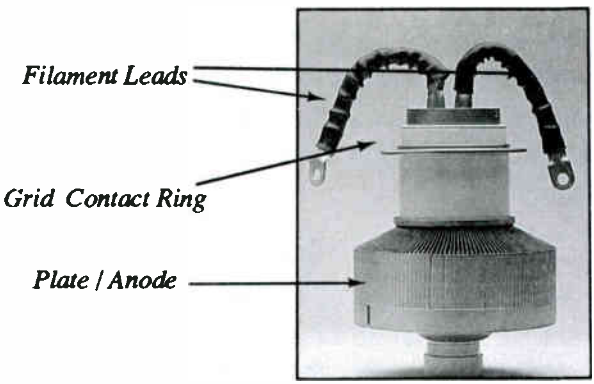

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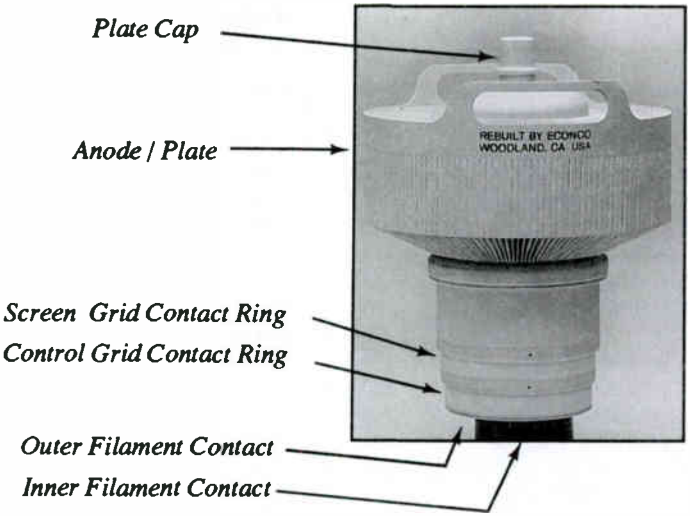

BASIC TUBE RATINGS

Type	Filament Volts	Filament Amps	Grid Watts Control	Grid Watts Screen	Plate Volts	Plate Amps
23165	11.0	101			15,000	10.0
23185	12.6	285	1,200		17,500	15.0
23791	9.0	60	200		9,000	2.0
3CV30,000A3 & H3 . .	6.3	172	500		7,000	5.0
3CW5000A1 & F1 . . .	7.5	53	50		6,000	2.5
3CW5000A3 7 F3 . . .	7.5	53	150		6,000	2.5
3CW5000A7 & F7 . . .	7.5	53	225		5,000	2.5
3CW5000F3 & H3 . . .	7.5	53	150		6,000	2.5
3CW5000H3	7.5	53	150		6,000	2.5
3CW10,000H3	7.5	75	150		10,000	3.0
3CW20,000A1	7.5	100	100		7,000	5.0
3CW20,000A3	7.5	100	250		7,000	5.0
3CW20,000A7	7.5	104	500		7,000	5.0
3CW20,000H3	7.5	104	250		12,000	4.0
3CW20,000H7	7.5	104	500		7,000	5.0
3CW30,000H3	6.3	172	500		12,000	6.0
3CW30,000H7	6.3	160	500		8,000	6.0
3CW40,000H3	10.0	160	750		12,000	9.0
3X2500A3 & F3	7.5	53	150		6,000	2.5
3CX2500A3 & F3 & H3 .	7.5	53	150		6,000	2.5
3CX3000A1 & F1	7.5	53	50		6,000	2.5
3CX3000A7 & F7 & H7 .	7.5	53	225		5,000	2.5
3CX4500A3 & H3 . . .	7.0	78	150		6,000	3.0
3CX5000H3	7.5	78	150		10,000	3.0
3CX10,000A1	7.5	104	100		10,000	5.0
3CX10,000A3 & H3 . .	7.5	104	250		10,000	4.0
3CX10,000A7	7.5	104	500		8,000	5.0
3CX1000A7	5.0	31	45		3,500	1.0
3CX15,000A3 & H3 . .	6.3	160	500		8,000	6.0
3CX15,000A7	6.3	160	500		8,000	6.0
3CX20,000A3 & H3 .	10.0	160	750		12,000	8.0
3CX20,000A7	6.3	160	500		8,000	6.0
4CV8000A	9.0	43	50	175	7,000	2.0
4CV35,000A	6.3	168	200	450	10,000	6.0
4CV50,000E & EP & J	12.0	215	400	1,500	17,500	12.0
4CV100,000C	10.0	300	500	1,750	20,000	15.0
4CV100,000E	15.5	230	500	1,750	17,500	16.0
4CW10,000A	7.5	78	75	250	7,500	4.0
4CW25,000A	6.3	160	200	450	10,000	6.0
4CW50,000E	12.0	215	400	1,500	17,500	12.0
4CW100,000D	10.0	295	500	1,750	20,000	15.0

BASIC TUBE RATINGS

Type	Filament Volts	Filament Amps	Grid Watts Control	Grid Watts Screen	Plate Volts	Plate Amps
4CW100,000E	15.5	215	500	1,750	20,000	16.0
4CX1500A	5.0	38.5	25	75	5,000	1.0
4CX3000A	9.0	43	50	175	7,000	2.0
4CX3500A	5.0	90	50	165	5,500	2.0
4CX5000A	7.5	78	75	250	7,500	4.0
4CX5000R	7.5	78	75	250	7,500	4.0
4CX10,000D	7.5	78	75	250	7,500	4.0
4CX10,000J	7.5	108	75	225	7,500	4.0
4CX12,000A	7.5	120	150	300	10,000	3.5
4CX15,000A	6.3	160	200	450	10,000	6.0
4CX15,000A	6.3	160	200	450	10,000	6.0
4CX20,000A	10.0	140	200	450	10,000	6.0
4CX20,000B	10.0	140	200	450	10,000	6.0
4CX20,000C	10.0	140	200	450	12,500	6.0
4CX35,000C	10.0	295	500	1,750	20,000	15.0
5666	11.0	120			10,000	2.0
5667	11.0	120			10,000	2.0
5668	22.0	60			14,000	2.0
5669	22.0	60			14,000	2.0
5681	12.0	220			15,000	11.0
5682	16.5	325	2,000		16,000	18.0
5918A	11.0	285			17,500	15.0
5924A	12.6	36	120		6,000	1.9
5936	20.0	143			18,000	10.0
5CX1500A	5.0	40	25	75	5,000	1.0
5CX1500B	5.0	40	25	75	5,000	1.0
5CX3000A	9.0	43	50	100	7,000	2.0
6076	6.3	33	30	100	4,000	1.8
6166A/7007	5.0	180	300	400	7,500	4.0
6256	12.6	29			6,000	.2
6366	11.0	29			6,200	1.3
6367	13.0	36			6,200	2.0
6379	11.0	285	1,000		17,500	15.0
6400	13.0	36	200		8,000	2.0
6400A	13.0	36	200		8,000	2.0
6420	7.0	85			10,000	2.2
6421 & F	7.0	85			10,000	2.2
6422	7.0	85	300		12,500	2.5
6423 & F	7.0	85	300		12,500	2.5
6424	7.0	120	400		12,500	3.5
6425 & F	7.0	120	400		12,500	3.5
6426	8.0	200	750		12,500	8.0

BASIC TUBE RATINGS

Type	Filament Volts	Filament Amps	Grid Watts Control	Grid Watts Screen	Plate Volts	Plate Amps
6427	8.0	200	750		12,500	7.0
6623	6.0	63			5,000	1.8
6691	5.0	260			15,000	6.0
6692	5.0	260			15,000	8.0
6696 & 6696A	13.0	205			16,000	11.0
6697 & 6697A	13.0	205			16,000	11.0
6800	7.5	107			15,000	3.5
6926	13.0	36	200		6,500	2.0
6960	12.6	33			7,200	2.2
6961	12.6	33			7,200	2.2
7007	5.0	180	300	400	7,500	4.0
7207	7.0	110	300		8,000	5.0
7237A	12.6	33			7,200	2.2
7480	13.0	205	1,000		16,000	11.0
7482	14.5	450	2,500		20,000	30.0
7560	14.5	450	3,000		20,000	30.0
7753	6.3	65			8,000	1.0
7804	6.3	136			8,000	4.0
7806	8.0	130			13,000	5.0
7900	12.6	32	120		6,000	1.5
8131	9.5	50			6,500	3.0
8132	9.5	50			5,200	2.5
8386	14.5	330			17,000	16.0
8494	7.0	110			8,000	5.0
8670A	12.6	33			9,000	2.2
8680	12.6	380	3,000		16,800	25.0
8734	5.4	65	250		12,000	2.0
8772	13.0	205	1,000		45,000	175.0 P
8773	13.0	205	1,000		45,000	175.0 P
8795	16.5	325	2,500		20,000	20.0
8801	7.0	175	500		9,000	6.0
8918	14.0	555	6,000		19,500	45.0
8935	7.0	175	500		14,400	6.0
8936	7.0	175	500		14,400	6.0
8989	7.5	120	150	300	10,000	3.5
8990	10.0	140	200	450	10,000	6.0
DX475	12.6	33			11,500	2.0
DX516	12.6	33			11,500	2.0
MR-710	6.3	160	500		8,000	6.0
MR-1014	10.0	160	750		12,000	8.0
ML-880 / 5658	12.6	35			12,500	5.0
ML356 / 5771	7.5	170			12,500	5.0

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