TP-105
Application Guide for BURLE Power Tubes

This publication is intended to be used as both a guide for and supplement to the tube type bulletin or technical data on individual tube types in which information unique to each type is given. The general approach is necessarily broad. Some of the recommendations may seem economically unattractive particularly on the smaller, less costly tube types but in all cases they should be weighed against the economic penalties of increased equipment downtime, maintenance expense, and replacement tube costs.

If additional information is required, contact your BURLE field representative or BURLE INDUSTRIES INC., Tube Products Division, Power Tube Applications, 1000 New Holland Avenue, Lancaster, PA 17601-5688, Telephone 800-233-0155 or 717-295-6888.

BURLE Electron Tubes

TABLE OF CONTENTS

GENERAL

Ratings

Individual tube ratings are established to guide equipment designers in utilizing to best advantage the performance and service capabilities of each type. Rating values are provided for those tube characteristics for which study and experience has indicated limiting values are required to insure satisfactory performance. To be of value, the rating system used must be accurately defined and properly applied.

Rating System

The ratings for BURLE Power Tubes are established in accordance with the standard EIA/JEDEC Absolute-Maximum Rating System; i.e., "Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specific type as defined by its published data, and should not be exceeded under the worst probable conditions.

"The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in device characteristics.

"The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions and variations in device characteristics."

The user is cautioned against using tubes above maximum ratings or for services other than those for which ratings are given. Tube warranty is contingent upon operation within these specified ratings. BURLE establishes control tests to assure satisfactorytube operation within the published ratings. Following good manufacturing practice, the average product capability is frequently better than the control test limits to accommodate normal product variation.

Consequently, limited user evaluation may indicate individual tubes of a given type will operate satisfactorily above the maximum ratings or in classes of service other than those for which ratings aregiven. Avoid this trap! If modified or extended ratings on a given type appear economically justified, contact BURLE before committing to any such use.

Identification

Small BURLE Power Tubes manufactured in volume are not individually identified. Large BURLE Power Tubes are assigned unique serial numbers for identification purposes. The location of the serial number on a tube may be indicated on the Dimensional Outline in the published data for the particular tube type. The complete serial number consists of a letter followed by one or more numerals and, possibly, by an alpha-numeric suffix. Use the complete serial number, including the letter(s), in any communication regarding the tube. Other numbers appearing on the external tube surfaces are for tube manufacturing use only.

Handling

All BURLE Power Tubes are sturdily built to withstand the rigorous treatment encountered when they are installed in electronic equipment. However, careless or rough handling of tubes not installed in equipment may subject the tubes to shock or stresses exceeding those the tubes were designed to withstand when mounted in sockets. For example, bumping a tube against a solid surface, such as a table, can easily cause irreparable internal damage to the tube. Bumping or improper assembly of connectors must be avoided to prevent distortion and other damage to the electrical terminals or coolant connections.

During transportation, a tube must be protected from rough handling that might damage the vacuum envelope or internal parts. BURLE Power Tubes are packaged in a variety of containers. Each container is designed to safeguard its tube against shock, bumps, and other mishaps and to assure the tube's arrival at its destination in good operating condition.

To avoid tube damage during use or storage, the larger power tubes must be supported only by the surface designated for that purpose. The support surfaces are identified in the published data. It is recommended that tubes in this category be held or stored in their original shipping containers because shipping containers provide support at the designated surfaces. The original shipping container should always be used for transporting the tube.

Smaller tubes may be carried by hand; larger tubes require the use of a crane or other lifting device. Lifting accessories are supplied for some large tube types, If the lifting accessory can be removed from the tube, save the accessory for later use when the tube is removed from the socket. For cylindrical-terminal types, remove the tube from its mounting with a slight twisting, upward motion to release the spring-contact fingers. Lift the tube straight out to prevent the terminals from striking the edge of the mounting. Use care to assure that the gap in the radiator retainer band of some tubes does not "catch" and damage the finger stock of the anode contact ring.

Storage

BURLE recommends that a tube be clean and that it be tested in the equipment where it is to be used before being placed in storage. Tubes in storage and tubes in equipment should be exchanged or rotated periodically where practicable to minimize the necessity for "break-in" periods described in "Break-In" Procedure.

It is recommended that tubes be stored in the shipping containers in the same manner in which they were received. During storage, tubes must be protected from moisture and from extreme temperature changes. Before placing a liquid-cooled tube in storage, tip it so that coolant can be poured from the coolant ducts and blow the ducts free of any residual coolant. Removing all coolant will prevent corrosion due to voltaic action and avoids the possibility of coolant freezing in the tube at low temperatures. Use care to prevent any foreign matter from entering the coolant courses. For safety, cover the coolant connectors with plastic caps or other suitable covers during storage.

Cleaning

Tube cleanliness is an important consideration. As with other high-voltage equipment, it is essential that external parts of power tubes be kept free from accumulated dirt and moisture to minimize surface leakage and the possibility of arc-over.

Some tube configurations contain re-entrant areas at the edge of the ceramic seals. These areas collect dirt rapidly as a result of electrostatic forces and the nature of the air circulation around the tube. Particular care should be taken to prevent foreign matter from coming in contact with these areas by the use of adequately filtered air.

The air cooling fins of high power tubes need periodic cleaning to maintain essential cooling efficiency. The frequency of this required maintenance procedure is determined by each specific environment. Every 4,000 hours or six months normally is sufficient. More frequent cleaning and tube handling is to be avoided unless absolutely necessary. Cleaning the tubes when the cavity circuit is being maintained is a good practice.

If high pressure air is available, accumulated dust from the fins and around the tube should be blown out. If high pressure air is not available, the tubes may be washed. Place sponges or some other soft material in the bottom of a sink and carefully lower the tube on to this pad, cathode end up. Fill the sink with hot water and a solution of "Calgon," "Cascade" or some other similar automatic dishwasher detergent, and let the tube soak for ten minutes. Drain off the wash water and rinse the tube with hot tap water, flushing the water through the fins; then wipe dry with a cloth.

Marks on ceramics can be cleaned with "glass-wax" or with an eraser such as Eberhard Faber No. 100 or equivalent'. Following cleaning, the ceramic should be wiped off with acetone or denatured alcohol. If the dirt cannot be removed by an eraser, hand-rub with an abrasive such as Norton Crystalon Abrasive No. 204-284, grade 3FX[2], or equivalent. For more severe dirt conditions, it may be necessary to dry-blast with a fine abrasive propelled by compressed dry gas through a pencil-lead-size nozzle. Complete units such as S. S. White Model C Industrial Unit[3], or equivalent, with an aluminum-oxide abrasive such as Carborundum Grit No. 320[4], or equivalent are available.

Caution: Maintain sandblaster nozzle in continuous motion so that the blast will not hold in one spot. Do not allow sandblast to strike any plated surface because the plating will be damaged; avoid area adjacent to ceramic-metal seal. Masking of adjacent metal surfaces with masking tape is recommended. Improper sandblasting can cause failure of the tube.

Arc marks on the tube terminal contacts can be removed by the gentle use of a very fine emery paper or Scotch Brite, Type A, after masking any adjacent ceramic to prevent buffing. Rub gently to prevent excessive removal of plating, avoiding damage to potting compounds that are used at the metal-to-ceramic interface. If excessive deposits have accumulated on the ceramic insulators or if adequate cleaning facilities are not readily available, the tube should be returned to the manufacturer for factory reconditioning.

1 .Faber Castell Corp., Century Drive, Parsippany, NJ 07054.
2. Norton Abrasive Co., 50 New Bond St., Box X15008, Worcester, MA.
3. S.S. White Industrial Products, Old New Brunswick Rd., Piscataway, NJ 08854.
4. Electro Minerals (US) Inc., PO Box 423-1, Niagara Falls, NY 14302.

MECHANICAL

General

Careful attention to the mechanical design of equipment will insure mechanical interchangeability of tubes as well as helping to insure satisfactory electrical operation. It is the responsibility of the user to assure that the equipment is designed to accommodate all tubes meeting the published dimensions, BURLE reserves the right to make any outline modifications allowable within the dimension limits.

Mounting

The direction of positioning, the method of clamping or securing, and the mounting surfaces vary with the specific tube configurations. All tubes must be mounted in the position specified in the published data.

In any mounting arrangement the electrical, mechanical and thermal aspects of the tube must be considered. Electrical considerations of mounting are discussed under **Connections.** Mechanical considerations must include observance of Operating Position given in the published data and should include provisions to protect the tube from appreciable shock or vibration. Thermal considerations require that the mounting arrangement permit the free flow of air unless other arrangements are made to limit the tube surface temperatures.

Most high-power tubes are designed to operate in coaxial cavities or sockets. Contact fingers engage each element simultaneously. These contact fingers must be clean, unbroken and free from burns or arcing. If more than three fingers are missing from a particular ring, or show arcing or burning, the entire ring should be replaced. Oxidized or dirty contacts may be cleaned with crocus cloth or with "Scotch Brite" Type A, a fine abrasive cleaning pad. Contact fingers that appear overheated should be bent inward slightly after cleaning to increase the contact pressure.

In most cases, a tube socket alignment gauge is available from theequipment manufacturer for use in cavitymaintenance. This gauge will hold the various contact rings in alignment while the bolts and nuts are being tightened. After socket alignment or as part of the normal preventative maintenance, the finger contact can be checked by inserting a tube which has previously had its contact rings painted with a water or alcohol soluble ink. Check the socket alignment by viewing the wiping action on the contact rings. The ink on the tube and the socket contacts must be cleaned off with water or alcohol prior to placing the tube back in service. It is essential that the tube contact rings make firm contact with the socket spring fingers to maintain good electrical connection. Contact should be on the vertical surfaces of the rings. If the spring fingers contact only the bottom edges of the tube contact rings, thermal stress and vibration may cause unseating of the tube from the socket. This may result in arcing, excessive current density or even oscillation.

When socketing a tube, begin the insertion by pressing the tube straight into the socket fingers to settle it into the socket contact surfaces. Do not insert or remove the tube by rocking the tube back and forth as this action crushes the contact fingers and results in poor electrical contact.

Connections

When low-voltage, high-current filaments or heaters are employed, the connections should be kept short to minimize voltage drop. Because connectors differ for the various types, details are given in the published data.

Flexible contacts are recommended for the RF connections to compensate for thermal expansions, eccentricities, and variations in the manufacturing dimensions of circuit components and tubes. The spring-contact type of connectors is recommended for RF terminals having cylindrical contact surfaces. A compressible metal braid may be used for RF terminals having flat contact surfaces.

When power is applied to the tube, there may be some motion of various parts of the tube and their associated circuits due to thermal expansion. In order that no undue stress be placed on the ceramic-metal seals of the tube, the connectors should be flexible. The connecting leads and hoses should be installed so that the slack portion has sufficient clearance to prevent arcing to the tube or circuit parts, and, where applicable, leads dressed to minimize feed-back capacitance.

During the connecting or disconnecting of coolant hoses and electrical connections, it is essential that no undue stress be placed on the tube connectors. When making connections, THE DIRECTION OF COOLANT FLOW MUST BE AS INDICATED IN THE PUBLISHED DATA.

COOLING

General

Envelope temperature is a primary factor in determining tube life. Tube life can always be extended by maintaining envelope temperature substantially below the maximum temperature rating. Tube temperature ratings should be observed in the same manner as other tube ratings.

The user is cautioned that typical cooling characteristics in the published data are offered only as a guide, and that maximum envelope temperature in the intended application is the final rating criterion. Adequate safety factors in cooling techniques should be utilized to (1) increase life expectancy and (2) insure against other factors; e.g., RF heating, high ambient temperature, high altitude, which frequently increase envelope temperatures.

Forced-Air Cooling

The external-anode construction of most BURLE medium and large power tubes lends itself to compactness, high frequency operation, high power capability and effective cooling techniques. The simplest forced-cooling technique is forced-air. All BURLE forced-air-cooled external-anode types use integral radiators brazed, pressed or otherwise secured to the anode to assure effective thermal contact. In general, there are two types of radiators: the "stacked-disc" type of finned radiator for transverse forced-air cooling, and the radial-fin type of radiator for axial forced-air cooling.

For transverse cooling, air flow is directed across the radiator from an orifice in a plane normal to the major axis of the tube and at the center of the radiator. A cowling to confine and direct the air will make the most efficient use of the cooling air. Pressure drop across the radiator itself is normally insignificant.

For axial cooling, air flow is directed through the radiator by suitable ducts. Air flow may be in either direction unless otherwise specified. In some of the axially cooled types, louvers formed in the fins assure turbulent flow and provide more efficient cooling than solid fins. Louvered fins, however, are more susceptible to dirt build-up than are solid fins.

BURLE provides information on air-coolingtubes in Application Note TP-118 "Application Guide for Forced-Air Cooling of BURLE Power Tubes". This application note clarifies questions about cooling curves in tube bulletins, correction factors required for altitude and temperature, sample calculations of a specific air cooling problem, and recommendations for measuring temperature, air pressure, and air flow.

The temperature of incoming air used for cooling directly affects the amount of cooling air required. If cooling air is drawn directly from the outside, daily and seasonal temperature fluctuations should be considered. If cooling air is drawn from the room housing the equipment, air temperature may be further modulated by operation of a variety of equipment in the room.

Air filters should be checked and cleaned every 1 to 4 weeks depending on the location and environment. Accumulated dirt in the cooling system will reduce the cooling effectiveness of the radiator fins, thereby increasing the tube's operating temperature. Filters which start to disintegrate should be replaced because granular filter material will clog the louvered radiator fins, reducing air flow and allowing dangerous increases in the tube's operating temperature.

If necessary, some manufacturers of air systems and air system components may provide design services or suggested air system designs. An air cooling system should be designed and installed to insure safe operation of the tube under all circumstances. For this reason, the system should be electrically interlocked to remove high voltage from the tube in the event of insufficient air flow, thereby preventing overheating of the tube.

Liquid Cooling

General

The liquid-cooling system consists, in general, of a source of cooling liquid, a liquid regeneration loop, flow regulators, gages, a feed-pipe system which carries the liquid to the ducts of the tube, and flow switches for interlocking the power supplies with the liquid flow through the coolant courses.

It is essential that the tubing between the cooling-system piping and each of the high-voltage cooling connectors have good electrical insulating qualities and be of sufficient length to minimize leakage currents and/or electrolysis effects.

To insure adequate cooling, the piping system must be arranged so that the direction of coolant flow through the various coolant connections is in accord with the published data. Series or parallel arrangement of the coolant ducts is permissible so long as the specified flow, pressure, and outlet temperature ratings are observed.

Caution: The feed-pipe system should be so designed that all the cooling liquid indicated by the flow meter for each electrode course passes through its associated coolant ductwithin the tube, and is not shunted inadvertently by any other path.

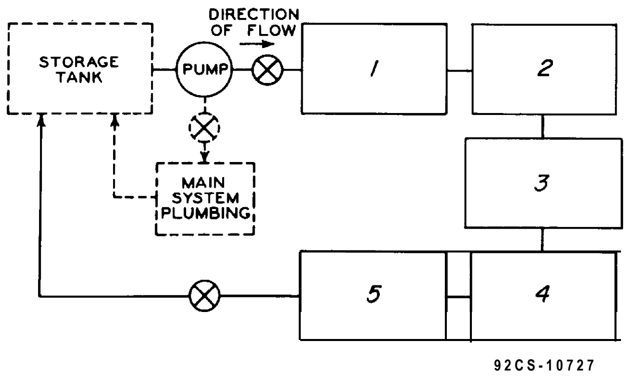
A test for proper design and functioning of the feed-pipe system can be made as follows: with all fittings in place, disconnect the inlet and outlet fittings to one electrode course; plug the holes of the two system-end, disconnected fittings; and fully open all coolant valves. Under these conditions, and with all voltages removed from the tube, no liquid flow should be indicated by the flow meter for the electrode course under test. Repeat the steps above for each electrode course in turn.

Precautions

Proper functioning of the cooling system during tube operation is of utmost importance to long tube life. Momentary failure of liquid flow during tube operation will damage the tube. For some tubes, operation of just the filament or heater without liquid cooling may cause serious tube harm. Therefore, a method of preventing tube operation must be provided in the event the cooling system should malfunction. Use of coolant-flow interlocks which open the primary circuits of the power supplies in the event of low flow during tube operation is a suitable method of tube protection. If such an interruption of the power supplies occurs, the interlock system should be designed to return the filament or heater to zero and restart in the normal manner. Coolant flow must start before the application of any voltages, and, preferably, continue for several minutes after removal of all voltages.

The absolute minimum coolant flows required through the coolant ducts and the pressure differentials across the cooled elements are given in the published data. The use of an outlet coolant thermometer and a coolant flow meter at each of the outlets is recommended. Under no circumstances should the temperature of the coolant from any outlet ever exceed the maximum value given in the published data.

In spite of the usual precautions taken to eliminate contamination of the coolant by oil, dust, etc., some impurities are likely to enter the fluid. The use of a strainer having at least 60-mesh screen is recommended in the coolant supply line as near to the tube as possible to trap any foreign particles likely to block the coolant flow through the tube ducts. A regeneration loop followed by a submicron filter should also be employed as shown in **Figure 1.** Size of the regenerating components depends on the operating parameters of the system and the coolant volume. For example, a regeneration loop having a 10-to-20 gallon-per-hour capacity will usually be adequate for use with a cooling system containing about 50 gallons. Consult the manufacturer of regenerating components for proper sizes.



Block No.	Water	Ethylene-Glycol-Water Solution	FC75
1.	Purity Meter and Cell (Note 1)	Purity Meter and Cell (Note 1)	Silica-Gel Cartridge
2.	Oxygen-Removal Resin (Note 2)	Organic-Removal Resin (Note 5)	
3.	Cation &Anion Exchange Resin (Note 3)	Cation & Anion Exchange Resin (Note 3)	
4.	Filter (Note 4)	Filter (Note 4)	Filter (Note 4)
5.	Flow Meter	Flow Meter	Flow Meter

Note 1 - Resistivity cell (0.1 cell constant) and meter, such as Barnstead PM-6 meter. The cell and meter are optional test equipment.

Note 2 - Oxygen-removal resin such as Barnstead No. DO810 cartridge in Bantam Demineralizer (D0800) or equivalent.

Note 3 - Mixed bed demineralizer, such as Barnstead Ultra Pure (00808) in Bantam Demineralizer (D0800) or equivalent.

Note 4 - Sub-micron filter, such as Barnstead MF-25 or equivalent.

Note 5 - Organic-removal resin such as Barnstead No. DO812 cartridge in Bantam Demineralizer or equivalent.

The above items may be purchased from Barnstead Co., 225 Rivermoor St., Boston, MA 02132.

Figure 1 - Suggested Liquid Regeneration Loop

The quality of the fluid in the system is maintained by the regeneration loop only when the system is in operation. When the system is off, air begins to enter the liquid and triggers a sequence of both bacterial and chemical contamination. Circulate the fluid during the electronic system's inoperative period by using an auxiliary pump. Following prolonged shutdowns, operate the system long enough to eliminate accumulated contamination before applying tube voltages.

Although a distinctive odor may indicate bacterial contamination of the coolant liquid, an organic analysis is the best method of checking system fluid for bacteria. In the event of excessive bacteria, the system must be drained, flushed and refilled with new fluid.

When the coolant fluid is water and the tube is used in equipment under conditions such that the ambient temperature is below 0° C (32° F) precautions must be taken to prevent freezing of the water in the tube ducts.

Coolant Liquids

For availability and ease in handling, water is recommended as the coolant wherever possible.

The use of other coolants, such as FC75 or a mixture of ethylene, glycol, and water, may be required in specialized applications where there is a hazard of water coolant freezing.

Water As Coolant

It is of utmost importance to maintain a high quality of water in the cooling system. Contamination in the water will hasten scale formation, corrosion, and electrolysis; any one of these conditions can greatly reduce tube or equipment life. Corrosion and electrolysis, for example, can destroy the tube elements, ducts, and fittings. Initial introduction of pure distilled water into the system is essential, but this precaution alone is not enough because the water becomes contaminated by the system components. For example, in a copper plumbing system the presence of oxygen and carbon dioxide enhances the dissolution of copper into the system water and its subsequent deposition as copper oxide on the hot surfaces of the coolant course. The rate of formation of this oxide depends on the operating anode dissipation of the tube and the amount of copper, oxygen, and carbon dioxide in the water system. Eventually the amount of precipitated oxide may reach such magnitude that it will thermally insulate the anode from the water and cause the anode to fail because of insufficient cooling.

It is essential that (1) high-quality water be used to fill the system initially, (2) provision be made for continuous regeneration (purification) of the system water, (3) steps be taken to eliminate the sources of contaminations as far as possible, and (4) the cooling system be inspected periodically for proper performance **(see Instructions for Cleaning Coolant Courses).**

Some of the contaminants which are conducive to scale formation include oxygen, carbon dioxide, metal ions, and organic solids. The most thorough means for determining the quality of the system water is a complete chemical analysis. Such an analysis, although difficult, can be performed by a qualified testing laboratory. In a well-maintained system, the following contaminants should not be present in excess of the following concentrations:

Copper	0.05 part per million by weight
Oxygen	0.5 part per million by weight
Carbon Dioxide	0.5 part per million by weight
Total Solids	3.0 parts per million by weight

Although an accurate chemical analysis is the absolute method of checking system water quality, a measurement of the water resistivity may be used as a guide for determining whether or not ionized contaminants are excessive. Dissolved gases, metals, and other contaminants reduce the resistivity of the water in varying amounts. Some contaminants, such as oxygen, greatly reduce the resistivity. However, if the specific resistivity of the water falls below 1 megohm-cm at 25° C, it can be assumed that the contaminants are excessive. Also, if the pH of the water is outside the range from 6.8 to 7.2, the water contains excessive contaminants.

A suggested method of achieving suitable quality of the system water is as follows:

1. Use only distilled or properly filtered deionized water to fill the system.
2. Usecontinuous regeneration (purification) of the water in the system to maintain acceptable quality, even during inoperative periods as noted in **Precautions.** This regeneration can be achieved bypassing a portion of the flowthrough suitable ion exchangers and filters. A recommended regeneration loop is shown in **Figure 1.** Operation of the regeneration loop should be in accord with the recommendations of the manufacturer of each component with regard to pressure, temperature, and maintenance of the individual components.
3. Connect pipe lines to the water tank below the water level to minimize turbulence and thus to decrease absorption of gases by the water. Exclude any contaminating gases from the storage tank in the closed water system by replacing the air above the water with nitrogen under slight pressure. The efficiency and life of the regeneration loop may be improved by retarding the rate or recontamination of the water by foreign matter.
4. Maintain anode-water-column (water path between anode and ground) resistance to a value not less than 4 megohms per kilovolt of anode voltage or 10 megohms, whichever is less, at water temperature of 25° C in order to minimize electrolysis.

The values for anode-water-column resistance indicated above and the value for specific resistivity of the water indicated in **Coolant Liquids (Water as Coolant)** are minimum values. In practice, higher values should be realized with a properly operating regeneration loop. For example, the specific resistivity of water can have a theoretical maximum value of 18 megohm-cm at 25° C.

The value of anode-water-column resistance and the value for specific resistivity of the water measured at a temperature other than 25° C can be converted approximately to the corresponding 25° C values for comparison with the specified values by means of the following equation:

$$R_{25} = R_t [1 + 0.025 (t-25)] \quad (1)$$

Where:

R_{25} is the water resistance or resistivity at 25°C.

R_t is the measured resistance or resistivity of the water at temperature t.

t is the measured temperature in degrees Centigrade.

Other Coolant Liquids

For applications where there is a hazard of freezing water, other insulating liquids may be used. Ratings for some tube types using ethylene-glycol-water solution or FC75 have been established. (See published data.) For tube types not rated for such use, contact your BURLE representative or BURLE INDUSTRIES, INC. for recommendations.

Ethylene-Glycol-Water Solution

Caution: Because the ethylene-glycol-water solution is not as effective a coolant as water, it is essential that the maximum anode dissipation and the flow data for ethylene-glycol-water solution shown in the published data be observed.

The use of chemically pure ethylene glycol mixed with distilled water in the proportion of 60% ethylene glycol to 40% water by weight is permissible only for tube types rated for such use.

A suggested method of achieving suitable quality of the ethylene-glycol-water solution in the cooling system is as follows:

1. Use only pure ethylene glycol mixed with distilled water in the specified proportion. Do not use ethylene glycol with rust inhibitors or other additives.
2. Maintain a minimum resistivity of the solution to 10 megohm-cm at a solution temperature of 25° C.
3. Use continuous regeneration (purification) of the solution in the system to maintain acceptable quality. This regeneration can be achieved by passing a portion of the flow through suitable ion exchangers and filters. A recommended regeneration loop is shown in **Figure 1.** Operation of the regeneration loop should be in accord with the recommendations of the manufacturer of each component with regard to pressure, temperature, and maintenance of the individual components.
4. Exclude air from the storage tank in the closed cooling system to prevent contamination of the ethylene-glycol-water solution by replacing the air above the solution with nitrogen under slight pressure.

FC75

Caution: Because the FC75 is not as effective a coolant as water, it is essential that the maximum anode dissipation and the flow data for FC75 shown in the published data be observed.

The use of FC75[1] is permissible only for tube types rated for such use.

This inert liquid has the advantages of thermal stability, good insulating qualities, good heat-transfer characteristics, and no clean-up of spillage or residue. Because FC75 is also non-toxic and nonflammable, it is safe to handle. The chemical inertness of FC75 simplifies the choice of system materials.

A suggested method of achieving satisfactory operation of FC75 in the cooling system is as follows:

1. Use continuous regeneration (purification) of the FC75 in the system to maintain acceptable quality. A recommended regeneration loop is shown in **Figure 1.** Operation of the regeneration loop should be in accord with the recommendations of the manufacturer of each component with regard to pressure, temperature and maintenance of the individual components.
2. Use plumbing connections and good refrigeration plumbing practices as employed with the freons to prevent undue loss of the coolant.

1. Manufactured by Commercial Chemicals Division/3M, 223-6 SE., 3M Center, St. Paul, MN 55101.

Inspection of Coolant Courses

A practical indication of cooling-system performance is the condition of the plate coolant course. Visual inspection of the anode coolant course is possible in some tube types to provide an indication of the cooling-system performance. For most tubes, however, the anode coolant course is not accessible and inspection can only be done indirectly by flushing the course with a cleaning solution and viewing the solution color. The suggested cleaning solution and method of cleaning the anode coolant course is described below.

Inspection of the anode coolant course should be performed after the first 5 hours of operation, and then after the next 200 hours of operation for an appraisal of the cooling system. Thereafter, it is recommended that the inspections be made each 500 or 1000 hours.

If the anode coolant course requires cleaning more frequently than every 500 hours, analysis of the system is recommended. A properly operating system should not require cleaning more than every 1000 hours of tube operation.

Instructions for Cleaning Coolant Courses

1. Prepare a solution of pure citric-acid powder in distilled water in the ratio of 250 grams of citric-acid powder per liter of water (or 2 pounds per gallon).
2. Support the tube with the anode terminal up in a suitable holder. Fill the anode coolant course of the tube with the citric-acid solution.
3. Allow the citric-acid solution to remain in the anode coolant course for 10 to 12 hours.
4. Pour the solution from the anode coolant course. The color of this solution is an indication of the amount of deposit removed from the anode coolant course. A blue-green color indicates that a substantial amount of deposit existed. Lack of color or a faint greenish-tint indicates the lack of appreciable deposit.
5. If the color of the solution in step 4 indicates that there is a substantial deposit, repeat steps 2, 3 and 4 until the solution in step 4 has only a faint greenish-tint.
6. Wash the anode coolant course thoroughly by allowing tap water to flow at a moderate rate through the anode coolant course for at least 15 minutes.
7. Rinse the anode coolant course thoroughly several times with distilled or demineralized water. This step is necessary before reconnecting to the coolant system in order to avoid reducing the system coolant resistivity with acid or tap water residue.

Conduction Cooling

A conduction-cooling system uses an electrical insulator with good heat conductivity to drain heat from the anode of an operating tube to a lower-temperature heat sink. Reference 6 discusses the design of conduction-cooling systems.

The heat sink must be designed to serve as a constant-temperature device, keeping the tube's anode within temperature ratings by absorbing and dissipating excess heat. In many existing applications, an anode line, output cavity, or equipment chassis serves as heat sink. The heat sink itself may require supplemental cooling in order to provide adequate thermal capacity for the designed heat load.

Materials such as beryllium oxide (beryllia)[1], high-aluminum oxide (high alumina), mica, and others can serve as the coupling between tube and heat sink. The thermal conductivity of these materials varies considerably as noted in Reference 6. Therefore, the choice of material will depend in large measure on the anode dissipation of a given application.

In HF operation, the inductor in the anode circuit is usually a relatively long coil which presents a rather poor thermal path from anode to chassis. However, a larger shunt capacity can be tolerated, and heat conducted to the chassis through the increased area. In UHF operation, shunt capacity must be minimized, but now the inductive element is short and can often be made with cross section area sufficient to form an excellent thermal path. In VHF operation, a careful compromise of both characteristics is required to obtain adequate RF performance and sufficient cooling.

1. WARNING: Beryllia dust and fumes are highly toxic to mucous membranes and may cause serious ulcers when imbedded under the skin. See References 3, 4, and 5.

PROTECTION CIRCUITS

General

Protection circuits serve a threefold purpose: safety of personnel, protection of the tube in the event of abnormal circuit operation, and protection of the tube circuits in the event of abnormal tube operation. Most powertubes require mechanical protective devices such as interlocks, relays, and circuit breakers. Circuit breakers alone may not provide adequate protection in certain large-power-tube circuitswhen the power-supply filter, modulator, or pulse-forming network stores much energy. Additional protection may be achieved by the use of high-speed electronic circuits or electronic “crowbars” (see Reference 6) to bypass the fault current until mechanical circuit breakers are opened. These circuits may employ a controlled gas tube, such as a thyratron or ignitron, depending on the amount of energy to be handled. References 6, 7, and 8 are suggested for further information on electronic protection circuits.

The supply voltages of power tubes are extremely dangerous. Great care should be taken during the adjustment of circuits. The tube and its associated apparatus, especially all parts which may be at high potential above ground, should be housed in a protective enclosure. The protective housing should be designed with interlocks so that personnel can not possibly come in contact with any high-potential point in the electrical system. The interlock devices should function to break the primary circuit of the high-voltage supplies and discharge high-voltage capacitors when any gate or door on the protective housing is opened, and should prevent the closing of this primary circuit until the door is again locked.

Anode Protection Circuits

A time-delay relay should be provided in the anode-supply circuit to delay application of anode voltage until the filament has reached normal operating temperature.

An interlocking relay system should be provided to prevent application of anode voltage prior to the application of sufficient bias voltage and/or RF drive to grid No.1; otherwise, with insufficient bias, the resultant high anode current may cause excessive anode dissipation with consequent damage to the tube. RF-load shorts or other causes of high output VSWR may also cause high dissipations, excessive voltage gradients, or insulator flashover. The load VSWR should be monitored and the detected signal used to actuate the interlock system to remove the anode voltage in less than 10 milliseconds after the fault occurs.

CW Types

For CW-type tubes, a typical high-speed electronic protective device for removing the anodevoltage is shown in **Figure 2.** The thyratron is normally kept in a nonconductive condition. When a fault current flows in the protected tube, the thyratron fires within a few microseconds. When the thyratron conducts, the fault current is bypassed from the protected tube and the circuit breaker of the power supply is actuated. In effect, the fault current which might reach proportions of a short circuit is handled by the thyratron until the circuit breaker opens.

The resistor R_1 in combination with the impedance of the power supply limits the fault current to a value not exceeding the peak-current rating of the thyratron. The resistor R_2, through which the fault current flows, provides the triggering voltage for the thyratron. The resistor R_3 need only have a value large enough (a few ohms) to provide adequate voltage on the thyratron anode to insure conduction under overload conditions in the protected tube and circuit. The value of R_4 is determined by the characteristics and ratings of the thyratron used.

The grid bias for the thyratron should be adjusted to trigger at a value that will provide adequate protection as determined by the "foil" test described below.

The following test involves extremely dangerous high voltages and should be made only after suitable precautions and safety measures have been taken to protect personnel.

A test of the effectiveness of the protective devices during steady-state operating conditions may be made as follows: disconnect the anode power supply lead from the tube; fasten to the "disconnected" anode power-supply lead a small sheet (approximately 2" x 2") of 0.001" -thick aluminum foil, such as household aluminum foil. **(See Figures 2** and **3.)** Discharge the full rated voltage of the power supply by bringing a grounding rod slowly up to the metal foil. The protective device is functioning properly when the anode supply produces not more than a single pinhole (approx. 0.010" diameter) in the foil attached to the anode-power supply lead.

Pulse Types

When tubes are operated in pulse applications, a suitable high-speed electronic protective device must be considered when the pulse duration exceeds 10 microseconds. The protective device should remove the anode voltage from the tube in the event of abnormal operation, such as internal arcing in the tube or circuits. In certain practical cases, the energy stored in the modulator is limited and in these cases a protective device will not be required. When the anode modulation system passes the aluminum foil test which follows, simple interruption of the modulator trigger, following the occurrence of a fault, will be adequate and the use of a high-speed electronic protection system will be unnecessary. Failure to pass the aluminum foil test indicates the need for a suitable high-speed electronic protective device that is capable of removing the anode voltage during the pulse. In general, intrapulse protection will be necessary for pulse lengths longer than 20 microseconds. With pulse durations of several thousand microseconds, considerable damage can result from a fault that continues for a sizable portion of the pulse duration. In this service, it is important to have suitable protective devices that are capable of de-activating the anode pulse voltage supply during the pulse.

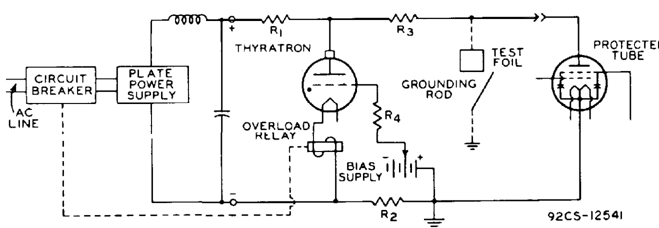


Figure 2 - High-Speed Electronic Protective Device for Removing Anode Voltage in the Event of Abnormal Operation

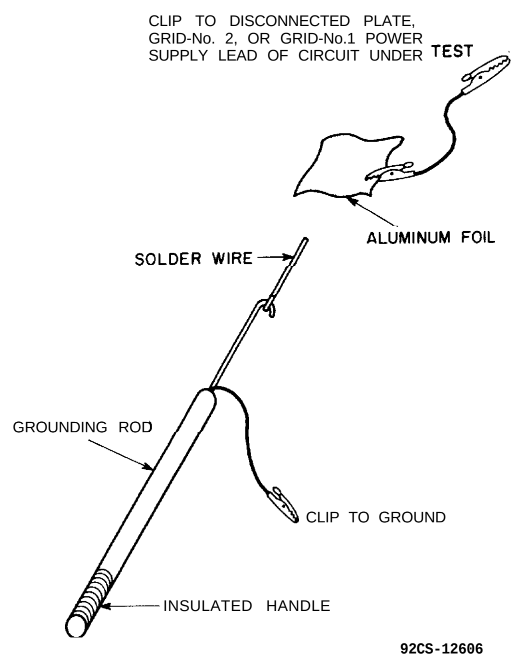


Figure 3 - Suggested Arrangement for Effectiveness Test of Protective Devices During Steady-State Operating Conditions

In systems that utilize a hard-tube modulator type of anode supply, protection can generally be achieved by providing a suitable grid bias signal to block conduction of the switch-tube. In most pulse systems, the interpulse interval is sufficient to permit recovery from the "fault" by the tube or its associated circuitry and the next consecutive pulse in the pulse train may be applied. Operation with this type of protection method permits continuity of operation with only an occasional missing pulse from the continuous train. The pulsing must be stopped completely only in the event that the tube and its circuits do not recover completely from a "fault" in the interpulse interval. Digital counter circuitry can be used to discriminate between a single missing pulse due to a "fault" and consecutive missing pulses which require additional protective measures, such as blocking of the switch tube conduction until such time as the system operator can determine that the "fault" has been cleared. This protection should be further enhanced by the use of a high-speed electronic protective device that will operate in the event the switch-tube "faults" or is not adequately blocked.

A test of effectiveness of the protective device under pulse operating conditions may be made as follows: disconnect the anode power supply lead from the tube; fasten to the "disconnected" anode power supply lead a small sheet (approximately 2" x 2") of 0.001" -thick aluminum foil, such as ordinary household aluminum foil. (See **Figure 3.)** Apply the full rated voltage of the pulse power supply by bringing a grounding rod or other suitable device slowly to the metal foil. The protective device is functioning properlywhen the anode supply produces not more than a single pinhole in the foil.

In the use of continuity of operation circuitry, described above, the number of pulses that may be missing due to "faults" before the anode supply voltage must be removed, can be determined also by the aluminum foil test. The maximum number of consecutive missing pulses that should be permitted is that number which, when discharged onto the same foil spot, produces not more than a single pinhole in the foil. The number of missing pulses that may be permitted will vary with the pulse duration, pulse repetition rate, and energy storage capabilities of the pulse supply.

In pulse service the sensing of "faults" requires different circuitry than that used for CW types. Most frequently it utilizes appropriate comparison circuitry to distinguish between the current or voltage pulse encountered in normal tube operation and the abnormal changes in current or voltage encountered during a "fault".

Grid-No.2 Protection Circuits for Beam Power Tubes

The grid No.2 in a beam power tube must be protected by a time-delay relay, interlocking relay, and high-speed electronic protective devices as described under **Anode Protection Circuits.**

The anode voltage should be applied before the grid-No.2 voltage; otherwise, with voltage on grid No.2 only, its current may be large enough to cause excessive grid-No.2 dissipation.

For additional grid-No.2 protection in large beam power tubes, it is recommended that a spark gap be used to prevent excessive grid-No.2 voltage transients. Such transients may cause breakdown of the internal mica bypass capacitors making the tube inoperable. The spark gap may be an adjustable air-gap type set for 2500-volt breakdown or a solid-state type. It should be connected from the grid-No.2 to cathode terminals with short, low-inductance leads.

CW Types

For CW-type tubes, a recommended circuit for a high-speed electronicdevice to remove the grid-No.2 voltage in the event of abnormal operation is shown in **Figure 4.** The thyratron is normally kept in a nonconductive condition. A sudden excessive increase in grid-No.2 current produces a steep wave-front pulse across resistor R_2. Under overload conditions, the positive peak of the pulse overrides the protection circuit grid bias and causes the thyratron to fire and safely bypass the fault current until the grid-No.2 power-supply circuit breaker opens. The resistor R, in combination with the impedance of the power supply limits the fault current to a value not exceeding the peak-current rating of the thyratron. The resistor R_3 prevents the anode voltage of the thyratron from dropping too low under overload conditions, and helps insure conduction when a fault occurs. The value of R_4 is determined by the characteristics and ratings of the thyratron used.

The following test involves extremely dangerous high voltages and should be made only after suitable precautions and safety measures have been taken to protect personnel.

Tests of the effectiveness of the protective devices during steady-state operating conditions and during switching transient conditions are identical to those tests described for the anode except for the addition described below. For the steady-state operating conditions, disconnect the grid-No.2 supply-voltage leads; attach a similar small sheet of 0.001 "-thick aluminum foil to the "disconnected" grid-No.2 power supply lead **(see Figure 3).** The protective device is functioning properly when the grid-No.2 supply produces no hole in the foil (but may have melted spot) attached to the grid-No.2 power-supply lead.

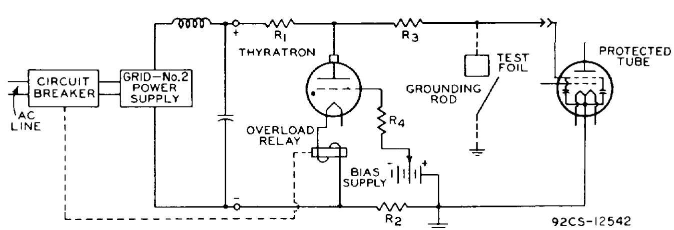


Figure 4 - High-Speed Electronic Protective Device for Removing Grid-No.2 Voltage in the Event of Abnormal Operation

Pulse Types

For pulse-type tubes, protection against damage from an anode-to-grid-No.2 arc must be provided to prevent the grid-No.2 voltage from rising during the "fault" pulse to a value in excess of the maximum rated voltage specified in the published data.

Protection against damage from a grid-No.2-to-ground arc must be provided for pulse types in the same manner as CW types. A test of effectiveness of the protection for the grid No.2 in the event of abnormal operation is discussed in **CW Types.** In some systems, a high-speed electronic protection circuit must be considered for pulse durations in excess of 10 microseconds. A recommended high-speed electronic device is described in **CW Types.**

Grid-No.1 Protection Circuits

The design of the bias-voltage supply should include an instantaneous over-current relay. The action of the over-current relay and the inherent regulation of the supply should be such that no damage to the tube or supplywill result from an accidental short at the tube connection or from an internal tube “fault”. It is recommended that the effectiveness of the protection provided be checked as follows: disconnectthe grid-No.1 -supply voltage lead from the tube. Fasten to the “disconnected” grid-No.1 power-supply lead a small sheet (approximately 2” x 2”) of 0.001 “-thick aluminum foil, such as household aluminum foil. **(See Figure 3.)** Discharge the operating bias voltage by bringing a grounding rod slowly up to the piece of foil. Adequate protection is indicated when the grid-No.1-supply voltage produces no more than a single pinhole in the foil.

The RF-power-input transmission line should be provided with VSWR protection to remove drive power as well as plate (and grid No.2) voltage within 10 milliseconds in the event of abnormal changes in input VSWR during operation.

OTHER ELECTRICAL CONSIDERATIONS

Cathodes

General

The operation of all power tubes requires thermionic emission of electrons from one or more cathodes. A power tube cathode should be operated at constant temperature: hot enough to emit an adequate supply of electrons, cool enough to avoid melting the cathode and to minimize evaporation of cathode constituents.

Cathodes fall into two basic categories: directly-heated cathodes, called filaments, and indirectly-heated, unipotential cathodes. Metal heaters, electrically insulated from other tube elements, supply heat energy to unipotential cathodes by radiation and/or conduction. Various thermoemissive materials, chosen to meet the requirements of the intended application(s), are used in BURLE power tubes. The published data on each BURLE tube identifies the cathode configuration and the thermoemissive material used in the tube.

Thevarieties of thermoemissive materials used in BURLE power tubes are as follows:

Pure tungsten cathodes withstand momentary overloads by resisting high-energy gas ions that can damage oxide-coated and thoriated-tungsten cathodes. Tungsten cathodes have moderate electron emission density for long-pulse operation. They require high input power to reach the high temperature needed to overcome tungsten’s low emission efficiency.

Thoriated-tungsten cathodes have moderate emission efficiency (much higher than pure tungsten cathodes). Thoriated-tungsten cathodes have moderate electron emission density for long-pulse operation, withstand moderate momentary tube overloads, but are more susceptible to damage by high-energy gas ions than are pure tungsten cathodes.

Oxide-coated cathodes have high electron emission density and low-temperature operation because of their high emission efficiency. They can deliver extremely high current in short-pulse, low-duty-factor operation. However, this capability decreases with increasing pulse lengths and duty factors. Oxide-coated cathodes are less resistant to momentary overloads than are their tungsten counterparts.

Matrix cathodes are similar in characteristics to oxide-coated cathodes. However, they require somewhat higher input power and are more resistant to momentary overloads.

Cathode life can be conserved by adjusting filament or heater supply voltage to the lowest value that will give normal performance. Exceeding the filament or heater voltage’s maximum value (normally listed in the tube bulletin) may damage the cathode and will severely shorten its life. Begin tube operation with the filament or heater set at the design voltage, then reduce voltage to a point just above that at which performance begins to degrade. Good regulation of filament or heater voltage about the value determined above is usually economically advantageous in terms of improved tube life.

Filamentary Cathodes

Each grid-controlled large power tube contains a number of interconnected matrix-oxide or thoriated-tungsten filaments to constitute the filamentary cathode. Tubes having the thoriated-tungsten type have single-section or 2-section filaments. Filament characteristics and method of excitation are described in the published data.

Methods of exciting the 2-section thoriated-tungsten filament types are shown in **Figure 5.** A reduction of hum associated with the electromagnetic fields produced by ac filament excitation may be obtained by utilizing the 2-phase (quarter-phase) operation. For applications extremely critical to hum, it is recommended that dc filament excitation be used for either single-section or 2-section type of thoriated-tungsten filament.

The filament voltage should be measured across the respective filament terminals on the tube; it should NOT be measured at the socket. This procedure is essential to obtain an accurate reading, because a small contact or lead resistance can cause a large error in reading. It is also essential that the voltmeter be adequately shielded from extraneous magnetic fields which may cause an inaccurate reading.

A filament starter should be used to raise the filament voltage and current gradually in order to limit the high initial surge of current through the filament when the circuit is first closed. The starter may be a system of time-delay relays which cut resistance or reactance out of the circuit, a high reactance filament transformer, or an adjustable auto-transformer. Regardless of the method of control, it is important that the filament current never exceed the value specified in the published data. In equipment which utilizes automatic “run-up” of filament voltage with voltage regulators, provision should be made for a limit-switch cut-off of the filament-voltage supply in the event of malfunction or “runaway” of the regulator to prevent damage to the filament due to overvoltage. The limit switches should be set at or below the maximum permissible filament voltage for the tube involved and should be checked periodically to assure proper operation.

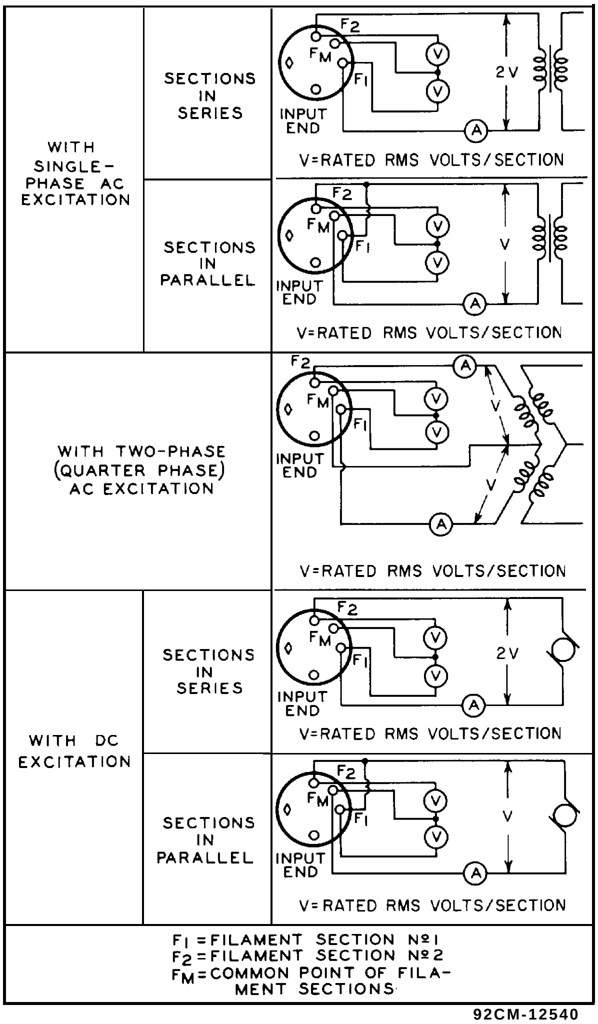


Figure 5 - Filament Excitation Circuits for Beam Power Tetrodes Having 2-Section Filaments

Furthermore, a static regulator should be added to the primary line voltage to prevent filament overvoltage due to line surges or long term line voltage variation.

After the filament voltage and current are raised to the rated value, a minimum heating time is then required as specified in the published data to permit the filament to come up to operating temperature before anode (and grid-No.2) voltages may be applied to the tube.

Filament power can be controlled by either filament voltage or filament current. In general, it is more economical to monitorthe voltage. However, for high-current, low-voltage filaments, it is mandatory to monitor the current since very small changes in resistance can produce misleading changes in voltage. The recommended controlling parameter is listed first under **General Data** in the published data for a specific tube type.

The life of the filament can be conserved by operating it at reduced voltage as described under **Cathodes (General).** Good regulation of the filament voltage/current is, in general, economically advantageous from the viewpoint of tube life.

In some applications it may be necessary to decrease or increase filament voltage slightly below or above the typical value to achieve stable operation initially. See **“Break-in” Procedure.** Following the stabilization period, the filament voltage should be adjusted for adequate emission requirements as outlined in the preceding paragraph.

Unipotential Cathodes

The unipotential cathode is a hollow metal cylinder with a heater positioned inside it. The unipotential cathode is rugged, has low inductance, and offers flexibility of external circuitry. Heater voltage should be applied for at least the time listed in the tube bulletin, allowing the cathode to reach its normal operating temperature before current is drawn.

The cathode may be subject to a temperature increase from electron back bombardment of the cathode as operating frequency increases. In pulse types with short duty cycle, the effects of back bombardment may be ignored; in long duty cycle and CW applications, heater voltage should be further reduced as described in **Cathodes (General).**

Beam Power Tube Grids

Grid-No.2

Electron bombardment of grid-No.2 under some circuit conditions may cause it to emit secondary electrons which will be indicated by very low or negative grid-No.2 current. Negative grid-No.2 current does not adversely affect performance providing a low-impedance source is used. See Reference 9 for further information.

The grid-No.2 current is an indication of plate-circuit loading. High grid-No.2 current indicates insufficient loading (high load resistance); low grid-No.2 current indicates excessive loading (low load resistance). To avoid damage to the tube, extreme care should be taken during tuning of the output circuit to prevent exceeding the peak grid-No.2 current rating.

Grid-No.1

Electron bombardment of grid-No.1 under some circuit conditions may cause it to emit secondary electrons which will be indicated by very low or, occasionally, slightly negative grid-No.1 current. The negative grid-No.1 current does not adversely affect performance so long as the grid-No.1 bias voltage supply is of the type that can be loaded externally to handle the negative grid current.

Operating Practice

“Break-in Procedure

The following “break-in” procedure should be followed with a new tube before it is placed in service. It is recommended that the procedure be followed with equipment in which the tube is to be used when new circuits are tested or when adjustments are made.

1. Be sure the air and liquid cooling systems and protective devices are functioning properly.
2. If the tube has an attached electronic high-vacuum pump, apply high voltage to the pump.

3. With no voltage other than pump voltage, apply filament/heater voltage following tube bulletin recommendation and operate at typical filament voltage for 15 minutes. For complete stabilization of matrix-oxide cathodes, continue to operate near the typical operating voltage given in the published data for about 50 hours. After 50 hours, conserve cathode life by following the recommendations of **Cathodes (General).**
4. Apply approximatelythree-quarters normal drive power and grid-No.1 voltage for 15 minutes.

   Caution: During the following steps, the high-speed electronic protective devices must be functioning properly to protect against abnormal conditions.

5. Apply reduced anode and grid-No.2 voltage (approximately one-half normal values) until stable performance is obtained.
6. Increase RF drive power and grid-No.1 voltage to normal.
7. Gradually increase anode voltage and grid-No.2 voltage to normal. Operate the tube until stable performance is obtained at each voltage level.

When the tube is operating normally at the desired output, it is good practice to record the readings of meters, flow indicators, and control settings.

Circuit Returns

To insure proper operation, the circuit return(s) should be connected to the contact surfaces specified on the Dimensional Outline in the published data. These contact surfaces are specially designed to provide low-loss connections to the proper electrodes within the tube, for example, to providethe necessary isolation between the input circuit and the output circuit.

Parasitic Oscillations

Parasitic oscillations may be experienced under certain operating conditions. Such oscillations result in erratic performance and may cause damage to the tube and/or associated circuitry. Adjust operating conditions and external circuits for operation without oscillations. Reference 10 is suggested for further information on the detection and suppression of parasitic oscillations.

Standby Operation

The thoriated tungsten filaments of tubes used in broadcasting applications should be operated continuously after being put in service. Continuous filament operation following the instructions of **Cathodes (Filamentary Cathodes)** achieves optimum tube life by minimizing the stresses associated with repeated filament heating and cooling.

During standby periods, tubes other than those above may be operated at reduced filament/heater voltage to conserve cathode life. For standby periods of up to2 hours, voltage should be reduced to 80% of normal. For longer periods, heater voltage should be turned off.

Pulse Operation Precautions

The length and phasing of the dc pulses applied to a tube should be such that the grid-No.1 bias and/or RF drive pulse reaches full value before the dc anode voltage pulse or the dc grid-No.2 voltage pulse begins. The grid-No.1 bias and/or RF drive pulse should remain at full value until the dc anode voltage pulse and the grid-No.2 voltage pulse have returned to zero. However, to avoid excessive dissipation, the grid-No.1 bias and/or RF drive pulse width should not exceed the anode and grid-No.2 voltage pulse widths by more than 10%.

All voltage supplies, pulse or dc, must pass the "foil effectiveness" test regardless of the pulse length or type of circuit used. Further, protection circuit effectiveness should be checked weekly and immediately after any system changes are made.

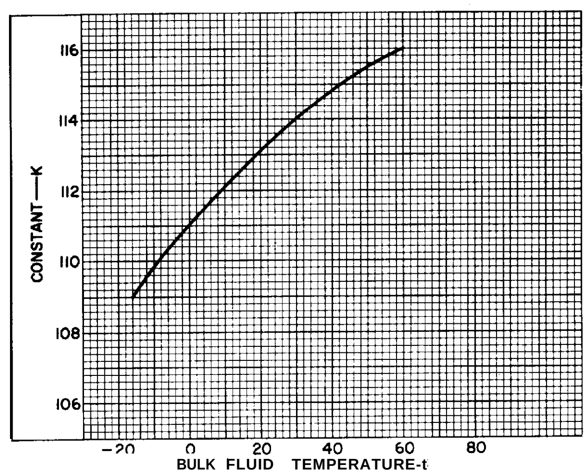


Figure 6 - Determination of Constant for FC75 in Plate-Dissipation Calculation

Anode Dissipation Calculation for Liquid-Cooled Tubes

An approximate value of anode dissipation may be calculated from this equation:

$$P = (n)\ (t_o - t_i)\ (264)\ (d)\ (c) \qquad (2)$$

where: P = power in watts

n = flow through anode coolant course in gallons per minute

t_o = coolant temperature at outlet in °C

t_i = coolant temperature at inlet in °C

d = density of coolant

c = specific heat of coolant

When the anode coolant is water, equation (2) becomes:

$$P = (n)\ (t_o - t_i)\ (264) \qquad (3)$$

When the coolant is ethylene-glycol-water solution, equation (2) becomes:

$$P = (n)\ (t_o - t_i)\ (K) \qquad (4)$$

where K equals approximately 218 over the temperature range from -15° to 60° C.

When the coolant is FC75 fluid, equation (4) applies. K may be determined from **Figure 6** for the appropriate bulk fluid temperature.

In the preceding equations, the flow rate n is determined from a flow meter properly calibrated for the coolant used. Values for t_o and t, are read from thermometers or thermocouples installed in the coolant lines as close to the tube as possible.

Electronic High-Vacuum Pump

On some large tubes, an electronic high-vacuum pump is incorporated to aid in achieving long tube life. The pump must be operated during normal tube operation, unless otherwise specified.

The pump maintains a clean, high vacuum in the tube under most operating conditions. It uses a cold-cathode gaseous discharge in a magnetic field to sputter titanium from a titanium cathode. Pumping is achieved by chemical combination of gas with the sputtered titanium and by "burial" of gas molecules in the titanium. Self-regulation of titanium consumption is achieved because the sputtering rate is a function of gas pressure. Pumping action is accomplished by applying a suitable electric potential and a magnetic field to the pump. The operating potential for each tube equipped with a pump is specified in the published data for that tube. A special permanent magnet provides a magnetic field of sufficient intensity for pump operation.

When the pump is attached to the anode terminal of the tube, its power supply must be insulated for anode potential and, in addition, its primary power must be supplied by a suitable isolation transformer. The power supply should also provide metering for monitoring currents from several microamperes to several milliamperes.

With normal tube operation, use of the pump is necessary during the initial several hundred hours and is recommended thereafter. Pump use is required in cases where gas evolution may occur: prolonged storage periods, excessive operating temperature or repeated arcing. The pump can serve as a protective device when integrated into the protective system, discontinuing high voltage operation until pump current (gas pressure) is reduced to a safe operating level. After such a gas pressure overload, the "break-in" procedure under **Operating Practice** must be followed to return the tube to full power service.

Periodic checks of the tube's condition in storage by use of the pump are recommended to assure satisfactory performance when the tube is placed in operation.

REFERENCES

1. TP-118, Application Guide for Forced-Air Cooling of BURLE Power Tubes, Lancaster, PA: BURLE INDUSTRIES, **INC.,** 1989.
2. J.W. Gaylord, “The Conduction Cooling of Power Tubes in Vehicular Communication Equipment,” IEEE Transactions on Vehicular Communications, (September, 1963).
3. D.W. White, Jr. and J.E. Burke, The Metal Beryllium, Cleveland, OH: American Society for Metals.
4. D.P. O’Neil, “Toxic Materials Machined Safely,” American Machinist, (June 4, 1955).
5. S. Laskin, R.A.N. Turner, and H.E. Stokinger, “Analysis of Dust and Fume Hazards in a Beryllium Plant,” Washington, DC: U.S. Atomic Energy Commission, MDDC-1355.
6. W.N. Parker and M.V. Hoover, “Gas Tubes Protect High-Power Transmitters,” Electronics, (January 12, 1962).
7. J.T. Mark, “Improved Power Fault Protection,” Electronic Design, (March 5, 1958).
8. T.E. Yingst, “Circuits to Control and Protect High-Power Modulator Tubes,” Electronics, (January 12, 1962).
9. TP-122, Screen-Grid Current, Loading, and Bleeder Considerations, Lancaster, PA: BURLE INDUSTRIES, INC., 1989.
10. F.E. Terman, “Electronic and Radio Engineering,” New York: McGraw Hill Book Company, Inc., 1955, pp503-506.

DEFINITIONS

CCS - Continuous Commercial Service

Duty Factor - Ratio of “ON” time to indicated interval.

“On Time” - The sum of the duration of all individual pulses which occur during an indicated interval.

Pulse Duration -The time interval between the two points on the pulse at which the instantaneous value is 70% of the peak voltage value.

Peak Value - The maximum value of a smooth curve through the average of fluctuations over the top portions of the pulse.

Single-Tone Modulation - Single-Tone Modulation operation refers to that class of amplifier service in which the grid-No.1 input consists of a monofrequency RF signal having constant amplitude. This signal is produced in a single-sideband suppressed-carrier system when a single audio frequency of constant amplitude is applied to the input of the system.

Two-Tone Modulation -Two-Tone Modulation operation refers to that class of amplifier service in which the input consists of two monofrequency RF signals having equal peak amplitude.