CONDITIONING OF LARGE RADIO-FREQUENCY POWER TUBES

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GENERAL

Large power tubes are subjected to very rigorous processing during exhaust pumping at the time of manufacture. Active elements are processed at temperatures several hundred degrees Celsius higher than that to be expected in actual use. This is done to drive off surface and subsurface gas from the metals to minimize the possibility of these being released during service life of the tube.

Free gas molecules will always be present to some degree in a fully processed tube. Gas, particularly oxygen-containing compounds, may chemically combine with cathode material to either permanently or temporarily destroy the electron emission capability. Free gas molecules, when struck by electrons moving from cathode to anode, may be ionized by having one or more electrons knocked from their systems. If enough such ions plus the freed electrons are present, a conduction path is provided which is not subject to control by the grid. This can result in runaway arcing which may involve all elements. Current may be limited only by source voltage and impedance, since space charge to some degree is neutralized by the presence of both electrons and positive ions.

Electrons from sources other than the heated cathode provide low-current paths between elements when the voltage gradient is high enough at the negative element for pure field emission. Voltage gradient at the negative element is determined by the applied voltage between elements, spacing between elements and by surface contour of the negative element. A large voltage gradient can exist in front of a point on the negative element, or in front of a particle adhering to the negative element, or in front of a clump of gas molecules on the surface of the negative element. Field emission occurs readily from a cold surface if the conditions provide the necessary voltage gradient.

Ionization of free gas may occur from bombardment by field-emitted electrons. Arcing is likely to occur as a result of field emission in operating equipment because plate voltage is maximum during that part of the signal cycle when ordinary plate current from the cathode is shut off by the control grid. For this reason an important part of tube processing is high voltage conditioning to remove sharp points or small particles from tube elements. This part of tube processing may, and sometimes should be, repeated in the field after shipment or storage if the tube is intended for use at plate voltage above 10 kilovolts.

HIGH VOLTAGE CONDITIONING

High voltage conditioning (sometimes called spot-knocking, or debarnacling) consists of applying successively higher voltage between tube elements, permitting the tube to spark internally at each voltage level until stable (no sparking). The voltage is then raised to the next higher level until the tube is stable at a voltage approximately 15% higher than the peak signal voltage it will encounter in service.

The equipment for tube conditioning is simple but specialized. It may provide dc or ac voltage, or both. Current required is small. Voltage should be continuously variable from practically zero to the highest value required for proper conditioning of the tube. Energy per spark is controlled by the internal resistance of the supply plus any external series resistor used. In dc conditioning it is valuable to include a dc milliammeter to measure the level of field emission current prior to sparking, or simply to determine if the field emission current is within the specified range for a tube being tested. Also in dc conditioning a capacitor may be placed across the tube under test to closely control the energy released for each spark. If the conditioning is to proceed effectively the amount of energy delivered by the capacitor must be great enough to condition the surfaces, but not so large as to cause any permanent damage.

SAFETY

Personnel protection dictates that the tube being processed, as well as the power supply, should be enclosed in a metal cabinet with access doors interlocked so no high voltage can be applied until the doors are closed. The material, wall thickness, and dimensions of the cabinet must be chosen to restrict X-ray radiation from the device under test to safe levels. A steel enclosure six and a half feet high, three feet wide, and deep enough to accept the tube-handling cart has been found to provide protection adequate for daily use in dc tube conditioning at EIMAC. A steel wall thickness of 3/32-inch has been found adequate for dc testing up to 70 kVdc. For conditioning up to 100 kVdc, it is necessary to add 0.05-inch of lead sheet as a lining to the steel enclosure.

The field of health standards as regards X-radiation safe dosage for any given time is complex and should be discussed with people familiar with the subject. The safest procedure is to consult with such experts, then test the enclosure with calibrated film badges (or other reliable measuring devices) over a period of time while several samples of tubes are put through the conditioning process. This will measure the radiation external to the enclosure so the user has assurance that safe radiation levels established by local codes and authorities are not being exceeded.

POWER SUPPLIES

The heart of the high-voltage conditioning test for power tubes is the power supply. There are a number of makers of both ac and dc variable-voltage power supplies. Five such companies are:

Del Electronic Corp
521 Homestead Ave.
Mt.Vernon, NY 10550

Hipotronic Inc.
Route 22
Brewster, NY 10509

Universal Voltronics
27 Radio Circle Drive
Mt.Kisko, NY 10549

Kilovolt Corporation
238 High Street
Hackensack, NJ 07601

Lambda Electronic Corp
515 Broad Hollow Road
Melville, NJ 11746

SUGGESTED SUPPLY SPECIFICATIONS
FOR CONDITIONING OF LARGE TUBES

DC CONDITIONING

Output voltage at specified current:
0 to 65 kVdc minimum
to: 0 to 100 kVdc maximum

Load current (this includes field emission, internal and external leakage paths):
10 mAdc for the 65 kVdc unit
30 mAdc for the 100 kVdc unit

dc voltmeter ranges: 0 to 30 kVdc and 0 to 75 kVdc
or: 0 to 125 kVdc

dc milliammeter ranges: 0 to 100 mAdc
0 to 10 mAdc
0 to 2.0 mAdc

High-voltage polarity: positive to terminal, negative to ground.

AC CONDITIONING

Peak output voltage at specified current:
0 to 65 kv minimum
to: 0 to 100 kv maximum

Peak load current: 15 mA or 30 mA

ac voltmeter ranges: 0 to 30 kv peak
and: 0 to 75 kv peak
or: 0 to 125 kv peak

ac milliammeter ranges: 0 to 25 mAac
0 to 50 mAac

Current-limiting resistance is desirable and the power supplies may have an internal resistance on the order of 100K ohms. In addition to the power supply, a current-limiting resistor of 100K ohms to 300K ohms should be provided in the circuit to the tube being processed. In dc processing a storage capacitor of 1000 pF to 3000 pF can be placed directly across the tube being processed, with a high voltage non-inductive resistor of approximately 50 ohms connected between the tube and the capacitor.

There is some advantage to using both polarities on the tube elements in high-voltage conditioning. This suggests an ac supply might be the best choice for field tube conditioning. The advantage of the dc system is that exact levels of field emission current and breakdown voltage may be determined for comparison with known "clean" tubes, and with the manufacturer's specification. Polarity of the applied voltage may be reversed by mounting the tube being conditioned on an insulating frame so that the positive and negative high voltage leads may be interchanged during processing. Also, the power supply rectifier and the dc meters may be bypassed by suitable switching so that ac is obtained from the power supply for initial cleanup. The storage capacitor across the tube should be disconnected if ac is used.

VERY LARGE TUBE CONSIDERATIONS

High-voltage ac conditioning is NOT recommended for very large tubes such as the EIMAC 8971/X2177, 8972/X2176, 8973/X2170, 8974/X2159, 4CM400,000A, etc. High potential 50 Hz and 60 Hz voltage can excite natural mechanical resonances in the large filament and grid structures in these tube types. Excitation of these resonances can break the filament and/or grids and thus destroy the tube.

If ac conditioning must be used, the following precautions should be taken. Connect all filament terminals together (external to the tube). All terminals of the tube must be connected to a terminal of the high-voltage power supply. (i.e., if high voltage is to be applied between the screen and anode, the filament, grid and screen should be connected together and to one terminal of the supply. If high voltage is to be applied between the filament and grid, then the grid, screen and anode should be connected together and to one terminal of the high-voltage supply.) NO TERMINAL OF THE TUBE SHOULD BE ALLOWED TO FLOAT ELECTRICALLY DURING HIGH-VOLTAGE CONDITIONING. As test voltage is raised listen carefully for vibration inside the tube. If any vibration is detected, remove the ac high voltage immediately.

The above precautions will reduce the risk of damage due to ac conditioning of these very large tubes. However, because of the special procedures to be used with ac conditioning and the risk of damage due to mechanical resonances, Varian EIMAC recommends that only dc conditioning be used for very large tubes.

CONDITIONING PROCEDURE

The EIMAC Test Specifications on larger power tubes specify an upper limit for field emission between the filament, control grid and screen grid connected together, and the anode. Such tubes should be allowed to spark until stable at the voltage where sparking first occurs, then voltage should be raised in steps determined by what voltage initiates sparking again. This process should be continued until the tube is stable with approximately 50 kilovolts (dc or peak ac) applied. It is advisable to reverse polarity, especially between grids and grid and cathode.

There are no field emission specifications for applied voltage between grids and between grid and filament, but these elements should hold off 10 kVdc internally. Need for conditioning between these elements is indicated if internal sparking occurs at significantly lower voltage.

During high-voltage processing, particularly between grids and between grid and filament, some of the redistributed gas molecules may be deposited on the cold filament and cause a temporary loss of emission. If this is observed, the tube should be operated for an hour or so with normal filament power only, to drive off the volatile material. Normal electron emission from the filament will be re-established by this procedure. It is recommended that normal practice include operation of the filament for approximately one hour as an immediate followup to high-voltage conditioning.

It is recommended that the tube be stored in the same position (orientation) as used for high-voltage conditioning and installation in the equipment. Movement of the tube after conditioning should be minimized to prevent any redistribution of particles within the tube.

Questions concerning high-voltage conditioning should be directed to: Varian EIMAC, Attn: Application Engineering, 301 Industrial Way, San Carlos, CA 94070 U.S.A.

Varian EIMAC, July 1984