PREFERRED RELIABILITY PRACTICES

HIGH VOLTAGE POWER SUPPLY DESIGN AND MANUFACTURING PRACTICES

Practice:

Thoroughly test high voltage power supply packaging on flight configured engineering models, in a simulated space flight environment, to evaluate corona effects.

Benefits:

Process controls on design, manufacturing, and testing operations reduce component failure rates and improve reliability. The goal is production of power supplies that will operate in space for the mission duration.

Programs That Certified Usage:

Space Electronic Rocket (SERT) Tests I and II, Communication Technology Satellite (CTS), 30 cm Thruster Bi-module.

Center to Contact for More Information:

Lewis Research Center (LeRC)

Implementation Method:

There are special requirements in packaging HV power supplies for space use. The power processor should be voltage-partitioned and the low voltage circuits should be separated from the high voltage circuits. This is usually done with a metal wall. There still will be signals transmitted between the sections. All grounds should be isolated to provide a means to predict the currents when transients or arcs occur. When capacitors discharge, there can be current flows of several hundred amperes. The low voltage section should be protected from these current and voltage surges.

Table 1 shows recommended design practices used for an 11 kV CTS TWT power supply. All volumes must be vented. The pressure in any unvented volume will decrease gradually and result in corona or arcing. Allow for screens, RF traps, etc.; and count only the holes in the screens. Interior volumes, down to the capped nut plates, must also be vented.

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TABLE 1. HIGH VOLTAGE POWER SUPPLY DESIGN GUIDELINES

PHYSICAL LAYOUT	
Voltage Partitioning	(Separate high and low voltage components)
Isolated Grounds	(Provide known current path for transients)
Voltage Suppression	(Suppress signal from high voltage to low voltage circuits)
ELECTRIC FIELDS	
Solid Dielectric:	
DC Stress	50 Volts/MIL
AC Stress	10 Volts/MIL
Surface Creepage	8 Volts/MIL
Air or Vacuum Gap	20 Volts/MIL
VENTING	
>2 cm^2 per 1000cc of enclosed volume (screens and RF traps reduce vent size), including:	
	Capped nut plates
	Dielectric spacers
	Polyolefin shrinkable tubing
	High voltage connectors

Figure 1 shows the fabrication methods used to build this supply. Round off all edges on metal as well as dielectric materials. Use anti-corona spheres. Void-free encapsulation is important. Remove excess RTV from bolts to keep vent paths open. Use shrink tubing in strips for hold downs, to avoid trapped air. Dielectric separators must be sized correctly for surface creepage. Anti-corona spheres should have a vent hole to eliminate voids in the solder. Dielectric inserts should be slotted to vent the interior volume.

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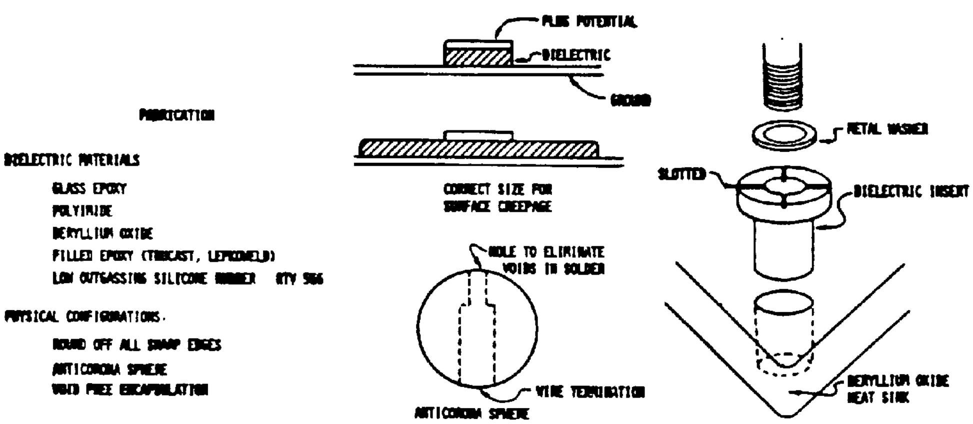
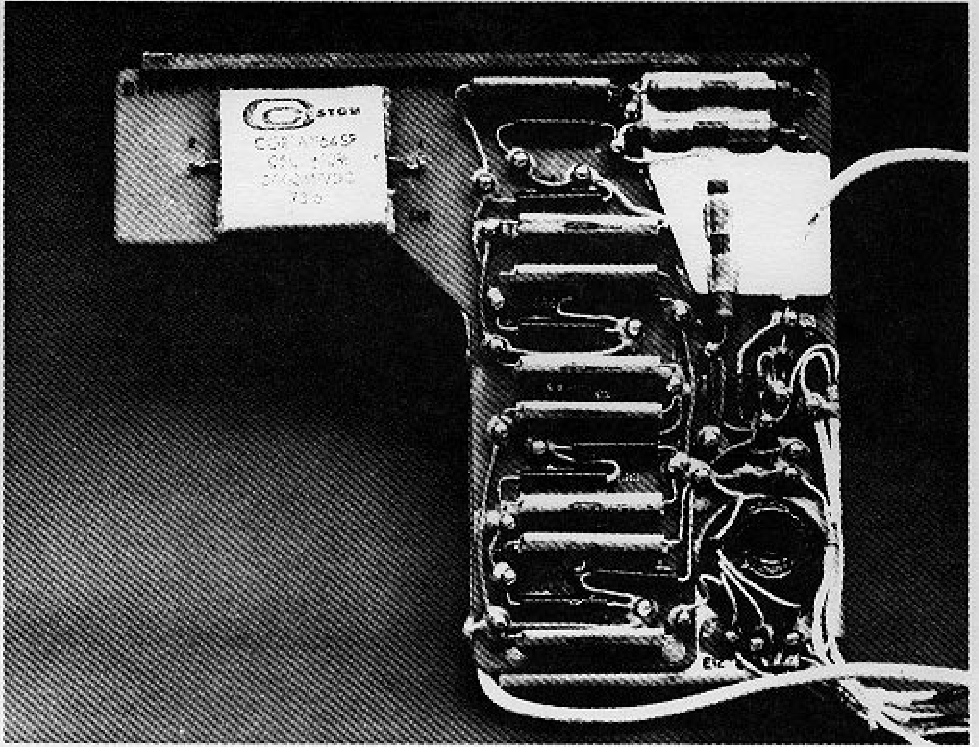


Figure 1. High Voltage Power Supply Fabrication

Figure 2 illustrates the special construction methods used in the HV compartment for the equipment to operate in the thermal and vacuum environment of space.

Table 2 shows the testing methods that should be used to check out the HV power supply. The glass epoxy boards should be scanned ultrasonically to check for density differences. The transformers and components mounted on the boards should be corona-tested. Corona discharges of less than 5 picocoulombs are allowed. Induced voltage in the dielectric testing should be done in vacuum at temperature per MIL-T-27. The corona tests should be repeated to detect internal degradation from the high voltage stress. Be careful to bake out the components at 65°C for 72 hours in the vacuum chamber and cool the components down before the power supply is turned on.

Figure 2.
HV Compartment
Construction



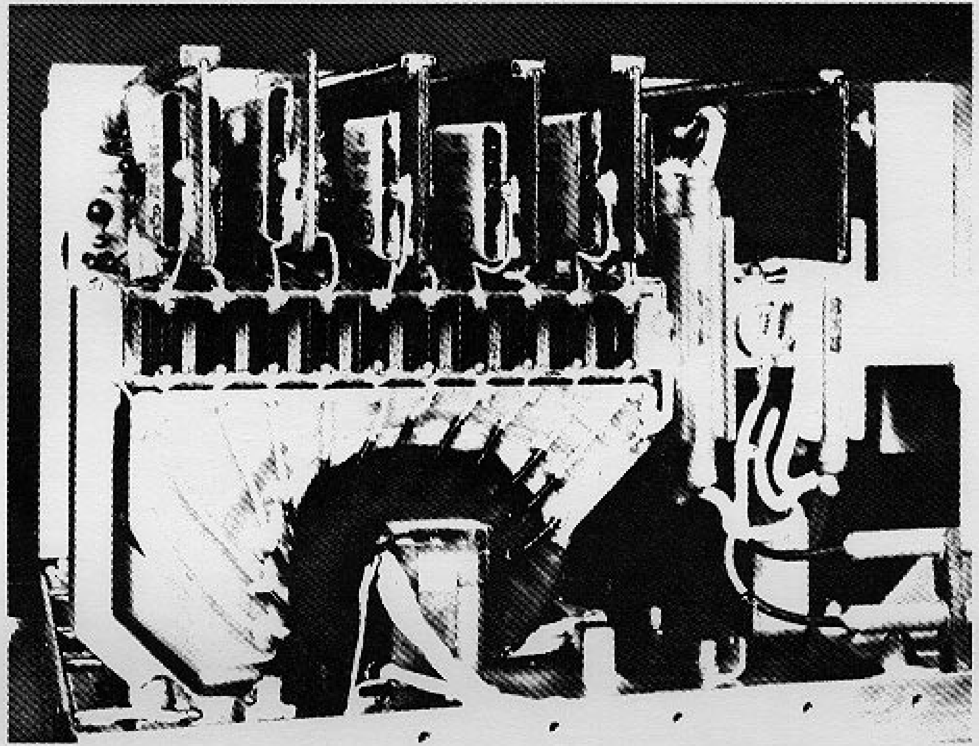


Figure 2. HV Compartment Construction (Continued)

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TABLE 2. TESTING

Corona Testing:	Transformers Component Configuration on Boards <5 Picocoulombs
Electric Testing:	Induced voltage (twice-rated voltage) Dielectrical withstanding (2.5 times rated AC and DC) Important to perform in vacuum at temperature
Thermal Testing:	Minimum of 10 temperature cycles at component level Minimum of 3 temperature cycles at box level
Initial thermal-vacuum test preceded by bakeout of 65° C for 72 hours	
Ultrasonic Scanning of Glass Epoxy Boards (NASA TM X-73432)	

Technical Rationale:

These design criteria were developed experimentally. The various component configurations, board layouts, and component assemblies were tested to 125% of expected working voltage in air, vacuum, and full operating temperature with a requirement that the corona inception measured less than 5 picocoulombs.

An example of an early flight failure caused by corona was a short that developed between two pins of a high voltage connector. Gas trapped inside connector voids gradually decreased in pressure until corona discharge began to decompose the insulating material. When the insulating material thickness was reduced to the point that leakage started increasing, a carbon tree formed and a short occurred, disabling the experiment. This can be easily avoided by running corona tests on all high voltage parts to ensure that no gases are trapped in high voltage circuits.

Impact of Nonpractice:

Allowing High Voltage power supplies that have not been thoroughly tested for corona to operate in space has resulted in corona-caused shorts that disabled the power supply.

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References:

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3. NASA TMX-3287, Lalli, Vincent R., Nueller, Larry A., and Koutnik, Ernest A., "System Reliability Analysis Through Corona Testing," September 1975. Presented at Power Electronics Specialist Conference (sponsored by IEEE), Culver City, CA (June 9-11, 1975).

4. NASA TMX-73432, Klima, S. J. and P. J. Riley, "Ultrasonic Evaluation of High Voltage Circuit Boards," June 1976.

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6. NAVMAT P4855-1, "Navy Power Supply Reliability Design and Manufacturing Guidelines," December 1982.

7. Foster, W.M., "Thermal Test Report for the Space Acceleration Measurement System Circuit Boards", NASA Lewis Code 6730 Internal Report, November 1987