IMPROVED TESTING PROCEDURES FOR SPACECRAFT DISCHARGE PULSES

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A new set of discharge laws has been developed, if only qualitatively in some ways, which guides one to better develop testing procedures for spacecraft pulse discharge testing. Other papers indicate how the discharge is generated by a burst of gas. The physics of that gas discharge provides an additional set of discharge phenomena that must be considered when designing ground tests for insulator discharges applied to spacecraft systems. The following test procedures are suggested and are based upon actual tests.

1. The component at issue must be analyzed to determine how it charges, and which surfaces may be discharged by a burst of gas in adjacent vacuum. An equivalent circuit (Fig.1.) must be generated which shows the path of the gas discharge, the location of all charges injected by radiation, and the locations of image charges in nearby conductors.

2. The location of the possible gas discharge is considered. Based on the flow of the gas discharge current, one determines the image currents that must flow in the surrounding electrodes. Usually, the image currents are the actual threat to the spacecraft, not the gas current itself.

3. One must consider the divergence of the electric field in vacuum into which the gas will evolve from the initial discharge. The ground tests should reproduce this condition, and not dramatically change the divergence over a large region of space.

4. One can protect circuits by the use of series resistance to limit peak pulse current. However, ground proof tests must properly simulate the discharge impedance by creating gas burst similar to those that will occur in space.

5. The most critical parameter that controls the pulse current waveform is the electric field inside the insulator. It is this electric field that controls the amount of gas evolved, and the amount of gas controls the pulse current. In spacecraft situations, higher internal fields generate more gas which, in turn, generates more peak current. Ground tests must simulate the real internal electric field.

6. The pulse rate can be used as a crude indicator of the internal electric field. Many experimenters were impatient and drove the internal electric fields to 1E6 V/cm in order to generate sufficient data before lunch. This produces misleading data with excessively large pulse size, and excessively frequent pulsing.

7. Pulse amplitude has only small dependence upon beam current density. Only in cases where conductivity in the sample affects the internal electric field will beam current density affect pulse amplitude. It still appears reasonable to use enhanced beam current

in order to more rapidly charge surfaces. But test fidelity will be sacrificed if this affects maximum internal electric fields.

8. Radiation dose can affect the rate and size of gas bursts. FR4 circuit board pulsed more frequently after six months in space, PTFE pulsed less frequently. Ground tests indicate that this was due to total dose, not due to vacuum exposure or beam current effects. Gradient of the dose may be very important as having an effect on the size and frequency of gas bursts. Therefore, good testing must include the effects of dose.

9. Resistivity values for the samples must be developed in vacuum using spacecharge as a virtual electrode. We obtained a factor >200 between spacecharge resistivity measurements and metal electrode measurements on kapton. A spacecharge test properly simulates the conditions of dielectrics in space radiation. Handbook values of resistivity are too low, being tainted by the effects of mobile charge injection at metal electrodes.

10. It can be very important to simulate the actual path through which the gas carries the discharge current. Coupling into external circuits may be critically dependent on the path of the discharge current. The gas can carry current through tortuous paths.

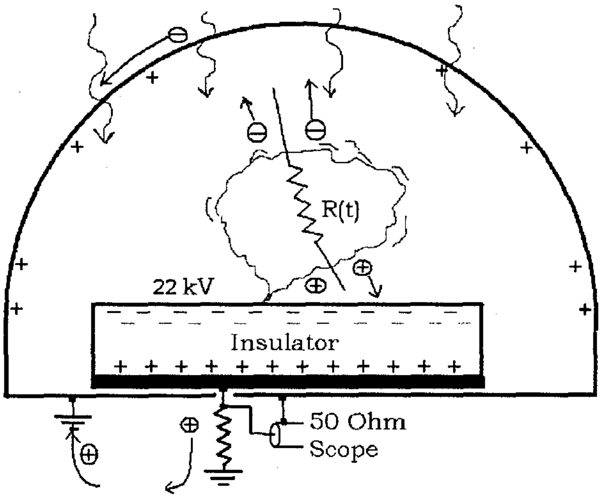

Figure 1. Description of the Current Pulse Formed by the Gas in the Vacuum. The gas forms a resistive path, **R(t),** from the surface of the insulator to the walls of the chamber, and to any other surfaces in the vacuum. The pulsed current flow in the case depicted in Fig. 1 is comprised of positive images on the electrode flowing to ground, then to the chamber walls, and finally images flowing from the chamber walls through the gas, R(t), and onto the surface of the insulator. This brings the images as close as they can be to the trapped electrons.

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