

MIL-STD-750D

1000 Series

Environmental tests

MIL-STD-750D  
NOTICE 2

METHOD 1001.2

BAROMETRIC PRESSURE (REDUCED)

1. Purpose. The purpose of this test is to check the device capabilities under conditions simulating the low pressure encountered in the nonpressurized portions of aircraft in high altitude flight.
2. Apparatus. The apparatus used for the barometric-pressure test shall consist of a vacuum pump and a suitable sealed chamber having means for visual observation of the specimen under test when necessary. A suitable pressure indicator shall be used to measure the simulated altitude in feet in the sealed chamber.
3. Procedure. The specimens shall be mounted in the test chamber as specified and the pressure reduced to the value indicated in one of the following test conditions, as specified. Previous references to this method do not specify a test condition; in such cases, test condition B shall be used. While the specimens are maintained at the specified pressure, and after sufficient time has been allowed for all entrapped air in the chamber to escape, the specimens shall be subjected to the specified test.

Test condition	Pressure - Maximum		Altitude	
	Inches of mercury	Millimeters of mercury	Feet	Meters
A - - - - -	8.88	226.00	30,000	9,144
B - - - - -	3.44	87.00	50,000	15,240
C - - - - -	1.31	33.00	70,000	21,336
D - - - - -	0.315	8.00	100,000	30,480
E - - - - -	0.043	1.09	150,000	45,720
F - - - - -	17.300	439.00	15,000	4,572
G - - - - -	$9.436 \times 10^{-8}$	$2.40 \times 10^{-6}$	656,000	200,000

In addition the following is required:

- a. Twenty minutes before and during the test, the test temperature shall be  $+25^{\circ}\text{C} \pm 3^{\circ}\text{C}$ .
  - b. The specified voltage shall be applied and monitored over the range from atmospheric pressure to the specified minimum pressure and returned so that any device malfunctions, if they exist, will be detected.
4. Failure criteria. A device which exhibits arc-overs, harmful coronas, or any other defect or deterioration that may interfere with the operation of the device shall be considered a failure.
  5. Summary. The following conditions must be specified in the detail specification:
    - a. Voltage (see 2.).
    - b. Minimum pressure (see 2.).

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METHOD 1011.1

IMMERSION

1. Purpose. This test is performed to determine the effectiveness of the seal of component parts. The immersion of the part under evaluation into liquid at widely different temperatures subjects it to thermal and mechanical stresses which will readily detect a defective terminal assembly, or a partially closed seam or molded enclosure. Defects of these types can result from faulty construction or from mechanical damage such as might be produced during physical or environmental tests. The immersion test is generally performed immediately following such tests because it will tend to aggravate any incipient defects in seals, seams, and bushings which might otherwise escape notice. This test is essentially a laboratory test condition, and the procedure is intended only as a measurement of the effectiveness of the seal following this test. The choice of fresh or salt water as a test liquid is dependent on the nature of the component part under test. When electrical measurements are made after immersion cycling to obtain evidence of leakage through seals, the use of a salt solution instead of fresh water will facilitate detection of moisture penetration. This test provides a simple and ready means of detection of the migration of liquids. Effects noted can include lowered insulation resistance, corrosion of internal parts, and appearance of salt crystals. The test described is not intended as a thermal-shock or corrosion test, although it may incidentally reveal inadequacies in these respects.

2. Procedure. The test consists of successive cycles of immersions, each cycle consisting of immersion in a hot bath of fresh (tap) water at a temperature of 65°C +5°C, -0°C (149°F +9°F, -0°F) followed by immersion in a cold bath. The number of cycles, duration of each immersion, and the nature and temperature of the cold bath shall be as indicated in the applicable test condition listed in table 1011-1, as specified.

Test condition	Number of cycles	Duration of each immersion (Minutes)	Immersion bath (cold)	Temperature of cold bath (°C)
A - - - - -	2	15	Fresh (tap) water	25, +10, -5
B - - - - -	2	15	Saturated solution of sodium chloride and water.	25, +10, -5
C - - - - -	5	60	Saturated solution of sodium chloride and water.	0 ± 3

The transfer of specimens from one bath to another shall be accomplished as rapidly as practicable. After completion of the final cycle, specimens shall be thoroughly and quickly washed and all surfaces wiped or air-blasted clean and dry.

3. Measurements. Unless otherwise specified, measurements shall be made at least 4 hours, but not more than 24 hours, after completion of the final cycle. Measurements shall be made as specified.

4. Summary. The following details are to be specified in the individual specification:
- a. Test condition letter (see 2).
  - b. Time after final cycle allowed for measurements, if other than that specified (see 3).
  - c. Measurements after final cycle (see 3).

## METHOD 1015.1

## STEADY-STATE PRIMARY PHOTOCURRENT IRRADIATION PROCEDURE (ELECTRON BEAM)

1. Purpose. This test procedure establishes the means for measuring the steady-state primary photocurrent ( $I_{PH}$ ) generated in semiconductor devices when these devices are exposed to ionizing radiation. In this test method, the test device is irradiated in the primary electron beam of a linear accelerator (LINAC).

1.1 Definitions. The following definitions shall apply for this test method.

1.1.1 Primary photocurrent ( $I_{PH}$ ). The flow of excess charge carriers across a P-N junction due to ionizing radiation creating electron-hole pairs in the vicinity of the P-N junction.

1.1.2 Measurement interferences. A current measured in the test circuits that does not result from primary photocurrent (see appendix).

2. Apparatus.

2.1 Ionizing pulse source. The ionizing pulse shall be produced by an electron LINAC. The ionizing pulse shall have dose rate variations within  $\pm 15$  percent of nominal during the pulse and shall consist of electrons with an energy equal to or greater than 10 MeV.

2.2 Pulse recording equipment. Pulse recording equipment shall be provided that will display and record both the photocurrent and the pulse-shape monitor signal. It may consist of oscilloscopes with recording cameras, appropriate digitizing equipment, or other approved recording equipment. The equipment shall have an accuracy and resolution of five percent of the pulse width and maximum amplitude of the ionizing source.

2.3 Test circuits. One of the following test circuits shall be selected, radiation-shielded, and close enough to the DUT in order to meet the requirements of 3.2.

2.3.1 Resistor sampling circuits. The resistor sampling circuits shall be as shown on figure 1015-1.

2.3.2 Current transformer circuit. The current transformer circuit shall be as shown on figure 1015-2.

2.4 Irradiation pulse-shape monitor. One of the following devices shall be used to develop a signal proportional to the dose rate delivered to the DUT. Any time constants which degrade the linear response of the monitor signal shall be less than 10 percent of the beam pulse width. The dose rate at the monitor shall be proportional to the dose rate at the DUT and the variation from proportionality shall not exceed  $\pm 3$  percent.

2.4.1 Signal diode. The signal diode selected shall have a response that is linear within  $\pm 5$  percent of the dose rate over the selected irradiation range. Depending on the sensitivity of the diode, it may be positioned at a point within the beam from the ionizing source at which it will remain in the linear region. The signal diode shall be placed in one of the test circuits described in 2.3, and it shall be back biased at not more than fifty percent of the diode breakdown voltage.

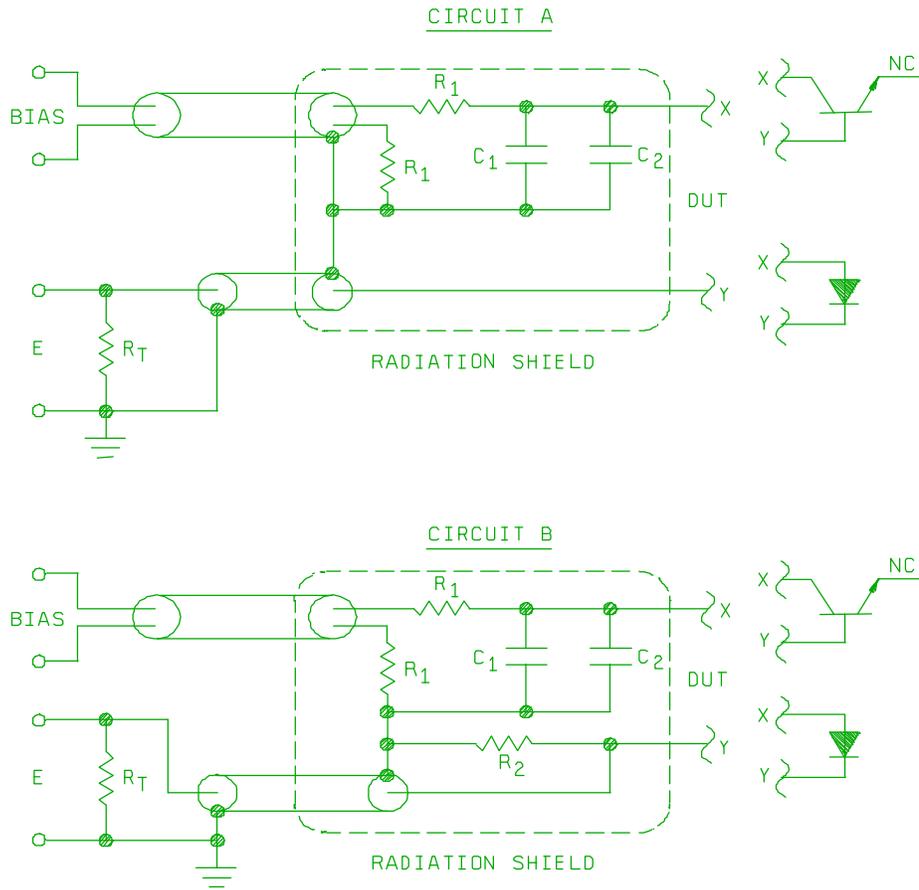
2.4.2 P-type-intrinsic-N-type (P-I-N) diode. A P-I-N diode shall be used as stated in 2.4.1.

2.4.3 Current transformer. A transformer with a hollow central axis that shall be mounted around the output of the ionizing source.

2.4.4 Secondary-emission monitor. The secondary-emission monitor shall consist of a thin foil mounted in a chamber evacuated to  $\leq 134$  Pa (0.01 mmHg) which is located in the path of the beam from the ionizing source. The foil shall be biased negatively with respect to ground, or shielded with positively biased grids.

2.5 Dosimeter. The dosimeter shall be used to calibrate the output of the pulse-shape monitor in terms of dose rate. The dosimeter type shall be a commercial thermoluminescent detector (TLD), thin calorimeter or other system as specified. The dosimetry measurement technique shall be accurate to  $\pm 20$  percent.

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NOTES:

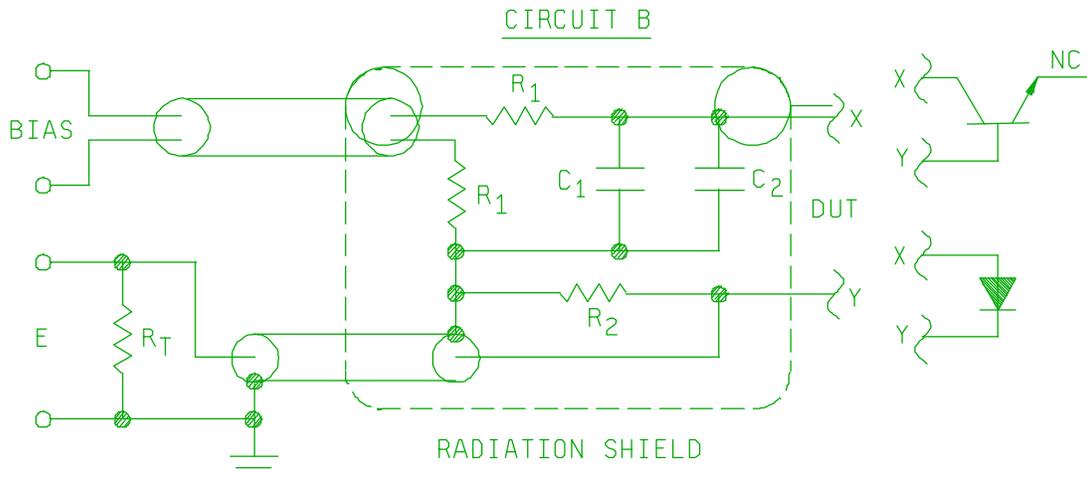
1.  $R_1 = 1,000 \Omega$ , 5 percent.
2.  $R_2 = 5 \Omega$ , 1 percent.
3.  $C_1 = 15 \mu F$ , 5 percent.
4.  $C_2 = .01 \mu F$ , 5 percent.
5.  $R_T$  = Characteristic termination for coaxial cable.
6. Circuit B shall be used for large photocurrents (those for which more than 10 percent of the bias appears across resistor  $R_T$  in circuit A).
7. Photocurrent for circuit A:

$$I_{PH} = \frac{\text{Steady - state signal (E)}}{\text{Cable termination ( } R_T \text{ )}}$$

8. Photocurrent for circuit B:

$$I_{PH} = \frac{[\text{Steady - state signal (E)}][\text{Cable termination ( } R_T \text{ )} + R_2]}{[\text{Cable termination ( } R_T \text{ )}][R_2]}$$

FIGURE 1015-1. Resistor sampling circuits.



NOTES:

1.  $R_1 = 1,000 \Omega$ , 5 percent.
2.  $C_1 = 15 \mu\text{F}$ , 5 percent.
3.  $C_2 = .01 \mu\text{F}$ , 5 percent.
4.  $R_T$  = Characteristic termination for coaxial cable.
5. Photocurrent calculation:

$$I_{PH} = \frac{\text{Steady - state signal (E)}}{\text{Sensitivity of current transformer}}$$

FIGURE 1015-2. Current transformer circuit.

3. Procedure.

3.1 General. The test facility shall select a test fixture and pulse shape monitor. The test fixture and monitor shall be aligned with the beam from the ionizing source. In addition, any shielding, collimation, or beam scattering equipment shall be properly positioned. If repositioning of any equipment or the test circuit is required to accomplish the device testing, the repositioning shall be demonstrated to be reliable and repeatable.

3.2 Test circuit check-out. The ionizing source shall be pulsed either with an empty device package or without the DUT in the test circuit and with all required bias applied. The ionizing source shall be adjusted to supply the dose rate required for this test. The recorded current from the pulse recording equipment shall be no more than 10 percent of the steady-state photocurrent expected to be measured for this test (see 3.4.3). If this condition is not met, see appendix.

3.3 Ionizing source calibration. Mount the selected dosimeter in place of the DUT. Pulse the ionizing source, record the pulse-shape monitor signal, and determine the radiation dose measured by the dosimeter. Calculate a dose rate factor as follows:

$$Doseratefactor = \frac{Measureddosimeterdose[rad(Si)]}{Integratedpulseshapemonitorsignal(voltsxseconds)}$$

This measurement shall be repeated five times, and the average of the six dose rate factors obtained shall be the dose rate factor used for the test. One dosimeter may be used repetitively if the dose is read for each pulse.

#### 3.4 Device test.

3.4.1 Mounting. Mount the DUT in the beam from the ionizing source and connect it to the rest of the test circuit. The bias applied shall be as specified in the device specification; or if not specified, the bias shall be fifty percent of the specified breakdown voltage of the DUT.

3.4.2 Dose rate. Either adjust the ionizing source beam current or use an alternate method (i.e., scatterers or a different sample location) to obtain the specified dose rate  $\pm 20$  percent. Pulse the ionizing source and record the pulse-shape monitor signal and the photocurrent signal from the DUT.

3.4.3 Calculate photocurrent. The steady-state photocurrent shall be calculated as expressed on the figure selected for the test circuit in 2.3.

3.4.4 Verify test circuit. Check the current recorded in the test circuit in 3.2 and verify that the value of the current does not exceed 10 percent of the photocurrent recorded in 3.4.3.

3.5 Test circuit checkout. Repeat the device test (see 3.4) for each dose rate that is required by the device specification. The calibration (see 3.3) shall be performed for each dose rate to be tested. The test circuit checkout (see 3.2) shall be performed when a new device type is tested or when any change is made in the position of the test circuit or DUT supporting structure.

#### 4. Summary. The following conditions shall be specified in the detail specification:

- a. The pulse width requirements of the ionizing pulse source. (The pulse width must exceed the semiconductor minority lifetime by at least a factor of 2.)
- b. The bias applied to the device (see 3.4.1).
- c. The irradiation dose rate(s) applied (see 3.4.2).
- d. When required, any total dose restrictions.
- e. When required, a description of the placement of the device in the beam with respect to the junction.
- f. When required, for multi-junction devices, the device terminals that are to be monitored.
- g. When required, the procedure for approval of the test facility and dosimetry.

APPENDIX

MEASUREMENT INTERFERENCES

The following problems commonly arise when electronics are tested in a radiation environment. Most of these interferences are present when the test circuit is irradiated under bias with the DUT removed.

1. Air ionization.

The irradiation pulse can ionize the air around the test circuit and provide a spurious conduction path. The air ionization contribution to the signal is proportional to the applied bias. The effect of air ionization is minimized by reducing the circuit components exposed to the beam pulse, by coating exposed leads with a thick nonconducting layer or by performing the test in a vacuum.

2. Secondary emission.

The beam pulse irradiating any electrical lead or component can cause a net charge to enter or leave the exposed surfaces. This spurious current alters the measured photocurrent. Secondary emission effects are reduced by minimizing the circuit components exposed to the direct beam.

3. Perturbed irradiation field.

Any material exposed to the beam pulse will scatter and modify the incident radiation of the beam. A nearby DUT or dosimeter will then be exposed to a noncharacterized and unexpected form of radiation. These field perturbations are reduced by minimizing the mass of the structure supporting the DUT and the dosimeter that is exposed to the beam. All materials should have a low atomic number; e.g., plastics and aluminum.

4. RF pickup.

The ionizing pulse source discharges large amounts of electromagnetic energy at the same time the photocurrent is being measured. Good electrical practice is necessary to eliminate resonant structure, noise pick-up on signal cables, common mode pick-up, ground loops, and similar interferences.

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METHOD 1016

INSULATION RESISTANCE

1. The device shall be tested in accordance with method 302, MIL-STD-202.

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METHOD 1017.1

NEUTRON IRRADIATION

1. Purpose. The neutron irradiation test is performed to determine the susceptibility of discrete semiconductor devices to degradation in the neutron environment. This test is destructive. Objectives of the test are:

- a. To detect and measure the degradation of critical semiconductor device electrical characteristics as a function of neutron fluence.
- b. To determine if specified semiconductor device electrical characteristics are within specified limits after exposure to a specified level of neutron fluence (see 4).

2. Apparatus.

2.1 Test instruments. Test instrumentation to be used in the radiation test shall be standard laboratory electronic test instruments such as power supplies, digital voltmeters and picoammeters, capable of measuring the electrical parameters required. Parameter test methods and calibration shall be in accordance with MIL-STD-750.

2.2 Radiation source. The radiation source used in the test shall be in a TRIGA Reactor or a Fast Burst Reactor. Operation may be in either pulse or steady-state repetitive pulse conditions as appropriate. The source shall be one that is acceptable to the acquiring activity.

2.3 Dosimetry equipment.

- a. Fast-neutron threshold activation foils such as  $^{32}\text{S}$ ,  $^{54}\text{Fe}$ , and  $^{58}\text{Ni}$ .
- b.  $\text{CaF}_2$  TLD.
- c. Appropriate activation foil counting and TLD readout equipment.

2.4 Dosimetry measurements.

2.4.1 Neutron fluence. The neutron fluence used for device irradiation shall be obtained by measuring the amount of radioactivity induced in a fast-neutron threshold activation foil such as  $^{32}\text{S}$ ,  $^{54}\text{Fe}$ , or  $^{58}\text{Ni}$ , irradiated simultaneously with the device. A standard method for converting the measured radioactivity in the specific activation foil employed into a neutron fluence is given in the following Department of Defense adopted ASTM standards:

E263	Standard Test Method for Measuring Fast-Neutron Flux by Radioactivation of Iron.
E264	Standard Test Method for Measuring Fast-Neutron Flux by Radioactivation of Nickel.
E265	Standard Test Method for Measuring Fast-Neutron Flux by Radioactivation of Sulfur.

The conversion of the foil radioactivity into a neutron fluence requires a knowledge of the neutron spectrum incident on the foil. If the spectrum is not known, it shall be determined by use of the following DoD adopted ASTM standards, or their equivalent:

E720	Standard Guide for Selection of a Set of Neutron-Activation Foils for Determining Neutron Spectra used in Radiation-Hardness Testing of Electronics.
E721	Standard Method for Determining Neutron Energy Spectra with Neutron-Activation Foils for Radiation-Hardness Testing of Electronics.
E722	Standard Practice for Characterizing Neutron Energy Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics.

Once the neutron energy spectrum has been determined and the equivalent monoenergetic fluence calculated, then an appropriate monitor foil (such as  $^{32}\text{S}$ ,  $^{54}\text{Fe}$ , or  $^{58}\text{Ni}$ ) should be used in subsequent irradiations to determine the neutron fluence as discussed in E722. Thus, the neutron fluence is described in terms of the equivalent monoenergetic neutron fluence per unit monitor response. Use of a monitor foil to predict the equivalent monoenergetic neutron fluence is valid only if the energy spectrum remains constant.

2.4.2 If absorbed dose measurements of the gamma-ray component during the device test irradiations are required, then such measurements shall be made with  $\text{CaF}_2$  TLDs, or their equivalent. These TLDs shall be used in accordance with the recommendations of the following DoD adopted ASTM standard:

E668	Standard Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices.
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### 3. Procedure.

3.1 Safety requirements. Neutron irradiated parts may be radioactive. Handling and storage of test specimens or equipment subjected to radiation environments shall be governed by the procedures established by the local Radiation Safety Officer or Health Physicist.

NOTE: The receipt, acquisition, possession, use, and transfer of this material after irradiation is subject to the regulations of the U.S. Nuclear Regulatory Commission, Radioisotope License Branch, Washington, DC 20555. A by-product license is required before an irradiation facility will expose any test devices. (U.S. Code, see 10 CFR 30-33.)

3.2 Test samples. Unless otherwise specified, a test sample shall be randomly selected and consist of a minimum of 10 parts. All sample parts shall have met all the requirements of the governing specification for that part. Each part shall be serialized to enable pre and post test identification and comparison.

#### 3.3 Pre-exposure.

3.3.1 Electrical tests. Pre-exposure electrical tests shall be performed on each part as required. Where delta parameter limits are specified, the pre-exposure data shall be recorded.

3.3.2 Exposure set-up. Each device shall be mounted unbiased and have its terminal leads either all shorted or all open. For MOS devices all leads shall be shorted. An appropriate mounting fixture which will accommodate both the sample and the required dosimeters (at least one actuation foil and one  $\text{CaF}_2$  TLD) shall be used. The configuration of the mounting fixture will depend on the type of reactor facility used and should be discussed with reactor facility personnel. Test devices shall be mounted such that the total variation of fluence over the entire sample does not exceed 20 percent. Reactor facility personnel shall determine both the position of the fixture and the appropriate pulse level or power time product required to achieve the specified neutron fluence level.

3.4 Exposure. The test devices and dosimeters shall be exposed to the neutron fluence as specified. The exposure level may be obtained by operating the reactor in either the pulsed or power mode. If multiple exposures are required, the post-irradiation electrical tests shall be performed (see 3.5.1) after each exposure. A new set of dosimeters are required for each exposure level. Since the effects of neutrons are cumulative, each additional exposure level will have to be determined to give the specified total accumulated fluence. All exposures shall be made at  $20^\circ\text{C} \pm 10^\circ\text{C}$  and shall be correlated to a 1 MeV equivalent fluence.

#### 3.5 Post-exposure.

3.5.1 Electrical tests. Test devices shall be removed only after clearance has been obtained from the health physicist at the test facility. The temperature of the sample devices shall be maintained at  $+20^\circ\text{C} \pm 10^\circ\text{C}$  from the time of the exposure until the post-electrical tests are made. The post-exposure electrical tests shall be made within 24 hours after the completion of the exposure. If the residual radioactivity level determined by the local radiation safety officer is too high for device handling purposes, the elapsed time before post-test electrical measurements are made shall be extended to 1 week or remote testing shall be utilized. All required data must be recorded for each device after each exposure.

3.5.2 Failure analysis. Devices which exhibit anomalous behavior (e.g., non-linear degradation of  $1/\beta$ ) shall be subjected to failure analysis.

3.6 Reporting. In reporting the results of radiation tests on discrete devices, adequate identification of the devices is essential. As a minimum, the report shall include the device type number, serial number, the manufacturer, controlling specification, the date code, and other Part or Identifying Numbers (PINs) provided by the manufacturer. Each data sheet shall include radiation test date, electrical test conditions, radiation test levels, and ambient conditions as well as the test data. When other than specified electrical test circuits are employed, the parameter measurement circuits shall accompany the data. Any anomalous incidents during the test shall be fully explained in footnotes to the data.

4. Summary. The following conditions shall be specified in the request for test or when applicable, the detail specification:

- a. Device types.
- b. Quantities of each device type to be tested if other than specified in 3.2.
- c. Electrical parameters to be measured in pre- and post-exposure tests.
- d. Criteria for pass, fail, record actions on tested devices.
- e. Criteria for anomalous behavior designation.
- f. Radiation exposure levels.
- g. Test instrument requirements.
- h. Radiation dosimetry requirements if other than 2.3.
- i. Ambient temperature if other than specified herein.
- j. Requirements for data reporting and submission, where applicable.

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METHOD 1018.2

INTERNAL GAS ANALYSIS

1. Purpose. The purpose of this test is to measure the water-vapor content of the atmosphere inside a metal or ceramic hermetically-sealed device. It can be destructive (procedures 1 and 2) or nondestructive (procedure 3).

2. Apparatus. The apparatus for the internal water-vapor content test shall be as follows for the chosen procedure:

2.1 Procedure 1. (Procedure 1 measures the water-vapor content of the device atmosphere by mass spectrometry.) The apparatus for procedure 1 shall consist of:

a. A mass spectrometer meeting the following requirements:

- (1) Spectra range. The mass spectrometer shall be capable of reading a minimum spectra range of 1 to 100 atomic mass units (AMUs).
- (2) Detection limit. The mass spectrometer shall be capable of reproducibly detecting the specified moisture content for a given volume package with signal to noise ratio of 20 to 1 (i.e., for a specified limit of 5,000 parts per million volume (ppmv), .01 cc, the mass spectrometer shall demonstrate a 250 ppmv minimum detection limit to moisture for a package volume of .01 cc). The smallest volume shall be considered the worst case.
- (3) Calibration. The calibration of the mass spectrometer shall be accomplished at the specified moisture limit ( $\pm 20$  percent) using a package simulator which has the capability of generating at least three known volumes of gas  $\pm 10$  percent on a repetitive basis by means of a continuous sample volume purge of known moisture content  $\pm 10$  percent. Moisture content shall be established by the standard generation techniques (i.e., 2 pressure, divided flow, or cryogenic method). The dew point analyzer shall be recalibrated a minimum of once per year using equipment traceable to NIST or by a suitable commercial calibration services laboratory using equipment traceable to NIST standards. Calibration records shall be kept on a daily basis. Gas analysis results obtained by this method shall be considered valid only in the moisture range or limit bracketed by at least two (volume or concentration) calibration points (i.e., 5,000 ppmv between .01 - .1 cc or 1,000 - 5,000 ppmv between .01 - .1 cc). A best fit curve shall be used between volume calibration points. Systems not capable of bracketing may use an equivalent procedure as approved by the qualifying activity. Corrections of sensitivity factors deviating greater than 10 percent from the mean between calibration points shall be required.

NOTE: It is recommended that the percentage of water vapor contained in a gas flowing through the gas humidifier be compared to the dewpoint sensor reading for accuracy of the sensor. The following equation may be used to calculate the percent of water vapor contained in a gas flowing through the gas humidifier.

$$\% H_2O = \frac{100 (P_v \text{ mb})}{68.95 \text{ mb/psi } P_g + 1.33 \text{ mb/mm } P_a}$$

Where:

$P_v$  = vapor pressure of water in the GPH based on water temperature in degrees centigrade,

$P_g$  = gauge pressure in psi, and

$P_a$  = atmospheric pressure in mm Hg.

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\*(4) Calibration for other gases. Calibration shall be required for all gases found in concentrations greater than .01 percent by volume. As a minimum, this shall include all gases listed in 3.1c. The applicable gases shall be calibrated at approximately 1 percent concentrations as part of the yearly calibration requirements, with the exception of fluorocarbons, which may use a concentration of approximately 200 ppmv; nitrogen, which may use a concentration of approximately 80 percent; helium, which may use a concentration of approximately 10 percent; and oxygen, which may use a concentration of approximately 20 percent.

(5) Calibration check. The system calibration shall be checked on the day of test prior to any testing. This shall include checking the calibration by in-letting a 5000 ppmv  $\pm 20$  percent moisture calibration sample of the required volumes and comparing the result with the calibration sample. The resulting moisture reading shall be within 250 ppmv of the moisture level in the calibration sample. Calibration performed on the day of test prior to any testing may be substituted for this calibration check.

b. A vacuum opening chamber which can contain the device and a vacuum transfer passage connecting the device to the mass spectrometer of 2.1a. The system shall be maintained at a stable temperature equal to or above the device temperature. The fixturing in the vacuum opening chamber shall position the specimen as required by the piercing arrangement of 2.1c, and maintain the device at  $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$  for a minimum of 10 minutes prior to piercing.

NOTE: A maximum 5 minute transfer time from prebake to hot insertion into apparatus shall be allowed. If 5 minutes is exceeded, device shall be returned to the prebake oven and prebake continued until device reaches  $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$ .

For initial certification of systems or extension of suitability, device temperature on systems using an external fixture shall be characterized by placing a thermocouple into the cavity of a blank device of similar mass, internal volume, construction and size. This shall be a means for proving the device temperature has been maintained at  $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$  for the minimum 10 minutes. This also applies to devices prebaked in an external oven but tested with the external fixture to adjust for any temperature drop during the transfer. These records shall be maintained by the test laboratory.

c. A piercing arrangement functioning within the opening chamber or transfer passage of 2.1b, which can pierce the specimen housing (without breaking the mass spectrometer chamber vacuum and without disturbing the package sealing medium), thus allowing the specimen's internal gases to escape into the chamber and mass spectrometer.

NOTE: A sharp-pointed piercing tool, actuated from outside the chamber wall via a bellows to permit movement, should be used to pierce both metal and ceramic packages. For ceramic packages, the package lid or cover should be locally thinned by abrasion to facilitate localized piercing.

2.2 Procedure 2. (Procedure 2 measures the water-vapor content of the device atmosphere by integrating moisture picked up by a dry carrier gas at  $50^{\circ}\text{C}$ .) The apparatus for procedure 2 shall consist of:

a. An integrating electronic detector and moisture sensor capable of reproducibly detecting a water-vapor content of 300 ppmv  $\pm 50$  ppmv moisture for the package volume being tested. This shall be determined by dividing the absolute sensitivity in micrograms  $\text{H}_2\text{O}$  by the computed weight of the gas in the device under test, and then correcting to ppmv.

b. A piercing chamber or enclosure, connected to the integrating detector of 2.2a, which will contain the device specimen and maintain its temperature at  $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$  during measurements. The chamber shall position the specimen as required by the piercing arrangement. The piercing mechanism shall open the package in a manner which will allow the contained gas to be purged out by the carrier gas or removed by evacuation. The sensor and connection to the piercing chamber will be maintained at a temperature of  $50^{\circ}\text{C} \pm 2^{\circ}\text{C}$ .

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2.3 Procedure 3. (Procedure 3 measures the water-vapor content of the device atmosphere by measuring the response of a calibrated moisture sensor or an IC chip which is sealed within the device housing, with its electrical terminals available at the package exterior.) The apparatus for procedure 3 shall consist of one of the following:

- a. A moisture sensor element and readout instrument capable of detecting a water-vapor content of 300 ppmv  $\pm$ 50 ppmv while sensor is mounted inside a sealed device.
- b. Metallization runs on the device being tested isolated by back-biased diodes which when connected as part of a bridge network can detect 2,000 ppmv within the cavity. The chip shall be cooled in a manner such that the chip surface is the coolest surface in the cavity. The device shall be cooled below dew point and then heated to room temperature as one complete test cycle.

NOTE: Suitable types of sensors may include (among others) parallel or interdigitated metal stripes on an oxidized silicon chip, and porous anodized-aluminum structures with gold-surface electrodes.

Surface conductivity sensors may not be used in metal packages without external package wall insulation. When used, the sensor shall be the coolest surface in the cavity. It should be noted that some surface conductivity sensors require a higher ionic content than available in ultraclean CERDIP packages. In any case, correlation with mass spectrometer procedure 1 shall be established by clearly showing that the sensor reading can determine whether the cavity atmosphere has more or less than the specified moisture limit at 100°C.

3. Procedure. The internal water-vapor content test shall be conducted in accordance with the requirement of procedure 1, procedure 2, or procedure 3. All devices shall be prebaked for 16 to 24 hours at 100°C  $\pm$ 5°C prior to hot insertion into apparatus. External ovens shall have a means to indicate if a power interruption occurs during the prebaking period and for how long the temperature drops below 100°C  $\pm$  5°C. Devices baked in an external oven which loses power and whose temperature drops below 100°C  $\pm$  5°C for more than 1 hour shall undergo another prebake to begin a minimum of 12 hours later.

NOTE: It is recommended that samples submitted to the labs shall include information about the manufacturing process including sealing temperature, sealing pressure, sealing gas, free internal cavity volume, lid thickness at puncture site, lid material, and the location of the puncture site.

3.1 Procedure 1. The device shall be hermetic in accordance with test method 1071, and free from any surface contaminants which may interfere with accurate water-vapor content measurement.

After device insertion, the device and chamber shall be pumped down and baked out at a temperature of 100°C  $\pm$ 5°C until the background pressure level will not prevent achieving the specified measurement accuracy and sensitivity. After pumpdown, the device case or lid shall be punctured and the following properties of the released gases shall be measured, using the mass spectrometer:

- a. The increase in chamber pressure as the gases are released by piercing the device package. A pressure rise of less than 50 percent of normal for that package volume and pressurization may indicate that (1) the puncture was not fully accomplished, (2) the device package was not sealed hermetically, or (3) does not contain the normal internal pressure.
- b. The water-vapor content of the released gases, as a percent by unit volume or ppmv of the total gas content.
- c. The proportions (by volume) of the other following gases: N<sub>2</sub>, He, Mass 69 (fluorocarbons), O<sub>2</sub>, Ar, H<sub>2</sub>, CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub>, and other solvents, if available. Calculations shall be made and reported on all gases present greater than .01 percent by volume. Data reduction shall be performed in a manner which will preclude the cracking pattern interference from other gas specie in the calculations of moisture content. Data shall be corrected for any system dependent matrix effects such as the presence of hydrogen in the internal ambient.

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3.1.1 Failure criteria.

- a. A device which has a water-vapor content greater than the specified maximum value shall constitute a failure.
- b. A device which exhibits an abnormally low total gas content, as defined in 3.1a, shall constitute a failure, if it is not replaced. Such a device may be replaced by another device from the same population; if the replacement device exhibits normal total gas content for its type, neither it nor the original device shall constitute a failure for this cause.

3.2 Procedure 2. The device shall be hermetic in accordance with test method 1071, and free from any surface contaminants which may interfere with accurate water-vapor content measurement.

After device insertion into the piercing chamber, gas shall be flowed through the system until a stable base-line value of the detector output is attained. With the gas flow continuing, the device package shall then be pierced so that a portion of the purge gas flows through the package under test and the evolved moisture integrated until the base-line detector reading is again reached. An alternative allows the package gas to be transferred to a holding chamber which contains a moisture sensor and a pressure indicator. System is calibrated by injecting a known quantity of moisture or opening a package of known moisture content.

3.2.1 Failure criteria.

- a. A device which has a water-vapor content (by volume) greater than the specified maximum value shall constitute a failure.
- b. After removal from the piercing chamber, the device shall be inspected to ascertain that the package has been fully opened. A device package which was not pierced shall constitute a failure, if the test is not performed on another device from the same population; if this retest sample or replacement is demonstrated to be pierced and meets the specified water-vapor content criteria, the specimen shall be considered to have passed the test.
- c. A package which is a leaker in the purge case will be wet and counted as a failure. In the case of evacuation, a normal pressure rise shall be measured as in 3.1a.

3.3 Procedure 3. The moisture sensor shall be calibrated in an atmosphere of known water-vapor content, such as that established by a saturated solution of an appropriate salt or dilution flow stream. It shall be demonstrated that the sensor calibration can be verified after package seal or that post seal calibration of the sensor by lid removal is an acceptable procedure.

The moisture sensor shall be sealed in the device package or, when specified, in a dummy package of the same type. This sealing shall be done under the same processes, with the same die attach materials and in the same facilities during the same time period as the device population being tested.

The water-vapor content measurement shall be made, at 100°C or below, by measuring the moisture sensor response. Correlation with procedure 1 shall be accomplished before suitability of the sensor for procedure 3 is granted. It shall be shown the package ambient and sensor surface are free from any contaminating materials such as organic solvents which might result in a lower than usual moisture reading.

3.3.1 Failure criteria. A specimen which has a water-vapor content greater than the specified maximum value shall constitute a failure.

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4. Implementation. Suitability for performing method 1018 analysis is granted by the qualifying activity for specific limits and volumes. Method 1018 calibration procedures and the suitability survey are designed to guarantee  $\pm 20$  percent lab-to-lab correlation in making a determination whether the sample passes or fails the specified limit. Water vapor contents reported either above or below (water vapor content - volume) the range of suitability are not certified as correlatable values. This out of specification data has meaning only in a relative sense and only when one laboratory's results are being compared. The specification limit of 5,000 ppmv shall apply to all package volumes, with the following correction factors permitted, to be used provided they are documented and shown to be applicable:

For package volumes less than .01 cc internal free volume which are sealed while heated in a furnace:

$$C_T = \frac{T_r + 273}{T_s + 273}$$

Where:

$C_T$  = correction factor (temperature)

$T_r$  = room temperature ( $^{\circ}\text{C}$ )

$T_s$  = sealing temperature ( $^{\circ}\text{C}$ ).

For package volumes of any size sealed under vacuum conditions:

$$C_P = \frac{P_s}{P_a}$$

$C_P$  = correction factor (pressure)

$P_s$  = sealing pressure

$P_a$  = atmospheric pressure (pressures may be in Torr or mm Hg).

The correction factor, if used, shall be applied as follows:

Water vapor (corrected) = Water vapor (measured)  $\times C_X$ ; where  $C_X$  is the applicable correction factor.

The range of suitability for each laboratory will be extended by the qualifying activity when the analytical laboratories demonstrate an expanded capability. Information on current analytical laboratory suitability status can be obtained by contacting Defense Supply Center, Columbus, ATTN: DSCC-VQE, P.O. Box 3990, Columbus, OH 43216-5000.

5. Summary. The following details shall be specified in the applicable acquisition document:

- a. The procedure (1, 2, or 3) when a specific procedure is to be used (see 3).
- b. The maximum allowable water-vapor content falling within the range of suitability as specified MIL-PRF-19500.

\* 6. Surrogate monitors. Surrogate monitors are only applicable for packages less than .01 cc to evaluate the process baseline. Surrogate monitors will be subject to RGA testing in accordance with method 1018 herein. A production lot will be validated by the performance of its monitors. It is well known and established that pre-seal bake and storage conditions of packaging materials will severely impact the levels of moisture detected in almost any package type. The use of the surrogate monitors without a controlled and disciplined manufacturing line is of questionable value. The proposed test is not, nor is it intended to be a direct measurement of small packaged product internal moisture. However, it is a quantifiable indicator that the process and controls used are consistent. This is an improvement over the existing situation in which there is a requirement for control of internal moisture and no accurate and repeatable method of measurement.

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\* 6.1. Requirements. Surrogate monitors are to be procured from the same manufacturer and be manufactured in the same technology as the production headers, using the same materials, plating, processing and technology. For example, the UB packages: Kyocera header, multilayer cofired ceramic technology; SemiAlloys lid, Alloy 52, nickel underplate, gold plate.

- a. The device manufacturer shall use the same preconditioning on surrogate monitors and production product, i.e. vacuum bake time and temperature, storage conditions, die attach materials and process, etc.
- b. Surrogate monitors shall be sealed at the same time and using the same process as the production parts.
- c. To optimize the effect of preconditioning the transit time from the oven to the seal furnace shall be controlled and minimal.
- d. A typical process would include:
  - (1) Batch high-vacuum bake headers and lids.
  - (2) Store baked material in dry nitrogen.
  - (3) Second vacuum bake overnight (min. 12 hrs) just prior to seal.
  - (4) Minimize the post-2nd bake exposure to atmosphere.
- e. Surrogate monitor packages will be under baseline documentation control. Full traceability from procurement to utilization shall be maintained.
- f. Initially, the surrogate monitors will be used at the beginning of the seal operation and at 2 hour intervals. A minimum of six monitors must be processed for each seal lot (a "seal lot" may consist of multiple production lots if they go through sealing without interruptions (other than the scheduled breaks) and have identical traceability of headers and lids).
- g. It is expected that it will take approximately 6 months for a manufacturer to collect enough lots and data to establish a baseline. Later modifications of the preconditioning process will be evaluated against this baseline.
- h. The device manufacturer will submit to DSCC the results from a minimum of three "seal" lots to establish the effectiveness of the process baseline. Additional testing will be retained and available to DSCC upon request.

## METHOD 1019.4

## STEADY-STATE TOTAL DOSE IRRADIATION PROCEDURE

1. Purpose. This test procedure defines the requirements for testing discrete packaged semiconductor devices for total dose effects by ionizing radiation from a Cobalt-60 ( $^{60}\text{Co}$ ) gamma ray source. This procedure includes only steady-state irradiations, and is not applicable to pulse type irradiations. This test may produce severe degradation of the electrical properties of irradiated devices.

1.1 Definitions. Definitions of terms used in this procedure are given below:

- a. In-flux tests: Electrical measurements made on devices during radiation exposure.
- b. Not in-flux tests: Electrical measurements made on devices at any time other than during irradiation.
- c. Remote tests: Electrical measurements made on devices which are physically removed from the irradiation location for the measurements.
- d. Ionizing radiation effects: The changes in the electrical parameters of a device or integrated circuit results from radiation-induced charge. It is also referred to as total dose effects.

2. Apparatus. The apparatus shall consist of the radiation source, electrical test instrumentation, test circuit board(s), cable, interconnect board or switching system, if used, and appropriate dosimetry measurement system, if used. Adequate precautions shall be observed to obtain an electrical measurement system with sufficient insulation, ample shielding, satisfactory grounding, and with suitable low noise from the main power supply.

2.1 Radiation source. The radiation source used in the test shall be the uniform field of a Cobalt-60 gamma ray source. Unless otherwise specified, uniformity of the radiation field in the volume where devices are irradiated shall be  $\pm 10$  percent as measured by the dosimetry system. Changes in geometry from one test to another require remeasurement of the field uniformity.

2.1.1 Cobalt-60 source. The gamma ray field of a Cobalt-60 source shall be calibrated at least every three years to an uncertainty of no more than  $\pm 5$  percent as measured with an appropriate dosimetry system whose calibration is traceable to the NIST. Corrections for Cobalt-60 source decay shall be made monthly.

2.2 Dosimetry system. The gamma ray field of the radiation source shall be characterized by appropriate dosimetry (traceable to NIST) methods prior to irradiation of test devices. The following DoD adopted American Society for Testing and Materials (ASTM) standards or their equivalents shall be used:

- |                 |   |  |
|-----------------|---|--|
| ANSI/ASTM E 666 | - | Standard Method for Calculation of Absorbed Dose from Gamma or X Radiation.  |
| ANSI/ASTM E 66  | - | Standard Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices.                     |
| ASTM E 1250     | - | Standard Method for Application of Ionization Chambers to Assess the Low Energy Gamma Component of Cobalt 60 Irradiators Used in Radiation Hardness Testing of Silicon electronic Devices. |
| ASTM E 1275     | - | Standard Practice for Use of a Radiochromic Film Dosimetry System.   |
| ASTM E 1249     | - | Minimizing Dosimetry Errors in Radiation Hardness Testing of Silicon Electronic Devices.   |

These industry standards address the conversion of absorbed dose from one material to another and the proper use of various dosimetry systems. <sup>1/</sup>

<sup>1/</sup> Copies may be obtained from ASTM, 1916 Race Street, Philadelphia, PA 19103.

2.3 Electrical test instruments. All instrumentation used for electrical measurements shall have stability, accuracy, and resolution required for accurate measurement of the electrical parameters. Any instrumentation required to operate in a radiation environment above 10 REM per hour shall be appropriately shielded, or the radiation level must be less than the instrumentation manufacturers recommended maximum.

2.4 Test circuit board(s). Devices to be irradiated shall be mounted on or connected to circuit boards together with any associated circuitry necessary for device biasing during irradiation or for in-site measurements. Unless otherwise specified, all device input terminals and any others which may affect the radiation response shall be electrically connected during irradiation, i.e., not left floating. The geometry and materials of the completed board shall allow uniform irradiation of the DUTs. Good design and construction practices shall be used to prevent oscillations, minimize leakage currents, prevent electrical damage, and obtain accurate measurements. All apparatus used repeatedly in radiation fields shall be checked periodically for physical or electrical degradation. Components which are placed on the test circuit board, other than DUTs, shall be insensitive to the accumulated radiation, or they shall be shielded from the radiation test fixtures, shall be made in such a way that materials will not disturb the uniformity of the radiation field intensity at the DUT.

2.5 Interconnect or switching system. This system shall be located external to the radiation environment location, and provides the interface between the test instrumentation and the DUTs. It is part of the entire test system and subject to the limitation specified in 2.4 for leakage between terminals.

3. Procedure. The test devices shall be irradiated as specified by a test plan. This plan shall specify the device description, radiation conditions, device bias conditions, dosimetry system operating conditions and measurements, and conditions.

3.1 Sample selection. Unless otherwise specified, the test samples shall be randomly selected from the parent population and identically packaged. Each part shall be individually identifiable to enable pre- and postirradiation comparison. For device types which are ESD-sensitive, proper handling techniques shall be used to prevent damage to the devices. Only devices which have passed the electrical specification as defined in the test plan shall be submitted to radiation testing.

3.2 Dosimetry measurements. The radiation field intensity at the location of the DUT shall be determined prior to testing by dosimetry or by source decay correction calculations, as appropriate, to assure conformance to test level and uniformity requirements. The dose to the DUT shall be determined one of two ways: (1) by measurement during the irradiation with an appropriate dosimeter, or (2) by correcting a previous dosimetry value for the decay of the Co 60 source intensity in the intervening time. Appropriate correction shall be made to convert the measured or calculated dose in the dosimeter material to the dose in the DUT.

3.3 Lead/aluminum (Pb/A1) container. Test specimens shall be enclosed in a Pb/A1 container to minimize dose enhancement effects caused by low-energy, scattered radiation. A minimum of 1.5 mm Pb, surrounding an inner shield of at least 0.7 mm A1, is required. This Pb/A1 container produces an approximate charged particle equilibrium for S1 and for TLDs such as CaF<sub>2</sub>. The radiation field intensity shall be measured inside the Pb/A1 container (1) initially, (2) when the source is changed, or (3) when the orientation of configuration of the source, container, or test-fixture is changed. This measurement shall be performed by placing a dosimeter (e.g., a TLD) in the device-irradiation container at the approximate test-device position. If it can be demonstrated that low-energy scattered radiation is small enough that it will not cause dosimetry errors due to dose enhancement, the Pb/A1 container may be omitted.

3.4 Radiation level(s). The test devices shall be irradiated to the dose level(s) specified in the test plan within  $\pm 10$  percent. If multiple irradiations are required for a set of test devices, then the postirradiation electrical parameter measurements shall be performed after each irradiation.

3.5 Radiation dose rate.

3.5.1 Condition A. The dose-rate range shall be between 50 and 2,000 rads (Si)/s (0.5 and 20 Gy(Si)/s) for 60 Co. <sup>2/</sup> The dose rates may be different for each radiation dose level in a series; however, the dose rate shall not vary by more than  $\pm 10$  percent during each irradiation.

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<sup>2/</sup> The SI unit for the quantity absorbed dose is the gray, symbol Gy. 100 rad = 1 Gy.

3.5.2 Condition B. As an alternative, the test may be performed at the dose rate of the intended application, if this is agreed to by the acquisition activity.

3.6 Temperature requirements. Since radiation effects are temperature dependent, DUTs shall be irradiated in an ambient temperature of  $+24^{\circ}\text{C} \pm 6^{\circ}\text{C}$  as measured at a point in the test chamber in close proximity to the test fixture. The electrical measurements shall be performed in an ambient temperature of  $+25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . If devices are transported to and from a remote electrical measurement site, the temperature of the test devices shall not be allowed to increase by more than  $+10^{\circ}\text{C}$  from the irradiation environment. If any other temperature range is required, it shall be specified.

3.7 Electrical performance measurements. The electrical parameters to be measured and functional tests to be performed shall be specified in the test plan. As a check on the validity of the measurement system and pre- and postirradiation data, at least one control sample shall be measured using the operating conditions provided in the governing device specifications. For automatic test equipment (ATE), there is no restriction on the test sequence provided that the rise in the device junction temperature is minimized. For manual measurements, the sequence of parameter measurements shall be chosen to allow the shortest possible measurement period. When a series of measurements is made, the tests shall be arranged so that the lowest power dissipation in the device occurs in the earliest measurements and the power dissipation increases with subsequent measurements in the sequence. The pre- and postirradiation electrical measurements shall be done on the same measurement system and the same sequence of measurements shall be maintained for each series of electrical measurements of devices in a test sample. Pulse-type measurements of electrical parameter should be used as appropriate to minimize heating and subsequent annealing effects.

3.8 Test conditions. The use of in-flux or not in-flux shall be specified in the test plan. (This may depend on the intended application for which the data is being obtained.) The use of in-flux testing may help to avoid variations introduced by postirradiation time dependent effects. However, errors may be incurred for the situation where a device is irradiated in-flux with static bias, but where the electrical testing conditions require the use of dynamic bias for a fraction of the total irradiation period. Not-in-flux testing generally allows for more comprehensive electrical testing, but can be misleading if significant postirradiation time dependent effects occur.

3.8.1 In-flux testing. Each test device shall be checked for operation within specifications prior to being irradiated. After the entire system is in place for the in-flux radiation test, it shall be checked for proper interconnections, leakage (see 2.4), and noise level. To assure the proper operation and stability of the test setup, a control device with known parameter values shall be measured at all operational conditions called for in the test plan. This measurement shall be done either before the insertion of test devices or upon completion of the irradiation after removal of the test devices or both.

3.8.2 Remote testing. Unless otherwise specified, the bias shall be removed and the device leads placed in conductive foam (or similarly shorted) during transfer from the irradiation source to a remote tester and back again for further irradiation. This minimizes postirradiation time dependent effects.

3.8.3 Bias and loading conditions. Bias conditions for test devices during irradiation shall be within  $\pm 5$  percent of those specified by the test plan. (If known, the bias applied to the test devices shall be selected to produce the greatest radiation induced damage or the worst-case damage for the intended application.) The specified bias shall be maintained on each device in accordance with the test plan. Bias shall be checked immediately before and after irradiation. Care shall be taken in selecting the loading such that the rise in the junction temperature is minimized.

3.9 Postirradiation procedure. Unless otherwise specified, the following time intervals shall be observed:

- a. The time from the end of an irradiation to the start of electrical measurements shall be a maximum of one hour.
- b. The time to perform the electrical measurements and to return the devices for a subsequent irradiation, if any, shall be within two hours of the end of the prior irradiation.

To minimize time dependent effects, these intervals shall be as short as possible. The sequence of parameter measurements shall be maintained constant through the test series.

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3.10 Test report. As a minimum, the report shall include the device type number, CAGE code of the manufacturer, package type, controlling specification, date code, and any other PINs given by the manufacturers, the bias conditions during radiation, the radiation level, time, temperature, and the pre- and postirradiation recorded readings. The following information is available on request only and is not a requirement for the report:

- a. Each data work sheet shall include the test date, the radiation source used, the bias conditions during irradiation, the ambient temperature around the devices during irradiation and electrical testing, the duration of each irradiation, the time between irradiation and the start of the electrical measurements, the duration of the electrical measurements, and the time to the next irradiation when step irradiations are used, the irradiation dose rate, electrical test conditions, dosimetry system and procedures, and the radiation test levels. The pre- and postirradiation data shall be recorded for each part and retained with the parent population data in accordance with the requirements of MIL-S-19500. Any anomalous incidents during the test shall be fully documented and reported.
- b. The bias circuit, parameter measurements circuits, the layout of the test apparatus with details of distances and materials used, and electrical noise and current leakage of the electrical measurement system for in-flux testing, shall be reported using drawings or diagrams as appropriate.

4. Summary. The following details shall be specified in the applicable acquisition document as required.

- a. Device-type number(s), quantity, and governing specification (see 3.1).
- b. Radiation dosimetry requirements (see 3.2).
- c. Radiation test levels including dose and dose rate (see 3.4 and 3.5).
- d. Irradiation, electrical test, and transport temperature; if other than as specified in 3.6.
- e. Electrical parameters to be measured and device operating conditions during measurement (see 3.7).
- f. Test conditions, i.e., in-flux or not-in-flux type tests (see 3.8).
- g. Bias conditions for devices during irradiation (see 3.8.3).
- h. Time intervals of the postirradiation measurements (see 3.9).
- i. Documentation required to be delivered with devices (see 3.10).

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METHOD 1020.2

ELECTROSTATIC DISCHARGE SENSITIVITY (ESDS) CLASSIFICATION

1. Purpose. This method establishes the procedure for classifying semiconductors according to their susceptibility to damage or degradation by exposure to electrostatic discharge (ESD). This classification is used to specify appropriate packaging and handling requirements in accordance with MIL-S-19500, and to provide classification data to meet the requirements of DOD-STD-1686.

1.1 Definitions. The following definitions shall apply for the purposes of this test method.

1.1.1 ESD. A transfer of electrostatic charge between two bodies at different electrostatic potentials.

2. Apparatus.

2.1 Test apparatus. ESD pulse simulator and DUT socket equivalent to the circuit of figure 1020-1, and capable of supplying pulses with the characteristics required by figure 1020-2.

2.2 Measurement equipment. Equipment including an oscilloscope and current probe to verify conformance of the simulator output pulse to the requirements of figure 1020-2.

2.2.1 Oscilloscope and amplifier. The oscilloscope and amplifier combination shall have a 350 MHz minimum bandwidth and a visual writing speed of 4 cm/ns minimum.

2.2.2 Current probe. The current probe shall have a minimum bandwidth of 350 MHz (e.g., Tektronix CT-1 at 1,000 MHz).

2.2.3 Charging of voltage probe. The charging voltage probe shall have a minimum input resistance of 1,000 M and a division ratio of 4 percent maximum (e.g., HP 34111A).

2.3 Calibration. Periodic calibration shall include but not be limited to the following.

2.3.1 Charging voltage. The meter used to display the simulator charging voltage shall be calibrated to indicate the actual voltage at points C and D of figure 1020-1, over the range specified in table 1020-I.

2.3.2 Effective capacitance. Effective capacitance shall be determined by charging C1 to the specified voltage (see table 1020-I), with no device in the test socket and the test switch open, and by discharging C1 into an electrometer, coulombmeter, or calibrated capacitor connected between points A and B of figure 1020-1. The effective capacitance shall be 100 pF  $\pm$ 10 percent over the specified voltage range and shall be periodically verified at 1,000 volts. (NOTE: A series resistor may be needed to slow the discharge and obtain a valid measurement.)

2.3.3 Current waveform. The procedure of 3.2 shall be performed for each voltage step of table 1020-I. The current waveform at each step shall meet the requirements of figure 1020-2.

2.4 Qualification. Apparatus acceptance tests shall be performed on new equipment or after major repair. Testing shall include but not be limited to the following.

2.4.1 Current waveform verification. Current waveform shall be verified at every pin of each test fixture using the pin nearest terminal B (see figure 1020-1) as the reference point. All waveforms shall meet the requirements of figure 1020-2. The pin pair representing the worst case (closest to the limits) waveform shall be identified and used for the verification required by 3.2.

3. Procedure.

3.1 General.

3.1.1 Test circuit. Classification testing shall be performed using a test circuit equivalent to figure 1020-1 to produce the waveform shown on figure 1020-2.

3.1.2 Test temperature. Each device shall be stabilized at room temperature prior to and during testing.

3.1.3 ESD classification testing. ESD classification testing of devices shall be considered destructive.

3.2 ESD simulator current waveform verification. To ensure proper simulator operation, the current waveform verification procedure shall be done, as a minimum, at the beginning of each shift when ESD testing is performed, or prior to testing after each change of the socket/board, whichever is sooner. At the time of initial facility certification and recertifications, photographs shall be taken of the waveforms observed as required by 3.2c. through 3.2e. and be kept on file for purposes of audit and comparison. (Stored digitized representations of the waveforms are acceptable in place of photographs.)

- a. With the DUT socket installed on the simulator, and with no DUT in the socket, place a short (see figure 1020-1) across two pins of the DUT socket and connect one of the pins to simulator terminal A and the other pin to terminal B.
- b. Connect the current probe around the short near terminal B (see figure 1020-1). Set the simulator charging voltage source  $V_S$  to 4,000 volts corresponding to step 4 of table 1020-I.
- c. Initiate a simulator pulse and observe the leading edge of the current waveform. The current waveform shall meet the rise time, peak current, and ringing requirements of figure 1020-2.
- d. Initiate a simulator pulse again and observe the complete current waveform. The pulse shall meet the decay time and ringing requirement of figure 1020-2.
- e. Repeat the above verification procedure using the opposite polarity ( $V_S = 4,000$  volts).
- f. It is recommended that the simulator output be checked to verify that there is only one pulse per initiation, and that there is no pulse while capacitor C1 is being charged. To observe the recharge transient, set the trigger to the opposite polarity, increase the vertical sensitivity by approximately a factor of 10, and initiate a pulse.

TABLE 1020-I. Simulator charging voltage ( $V_S$ ) steps versus peak current ( $I_p$ ).

Step	$V_S$ (volts)	$I_p$ (amperes)
1	500	0.33
2	1,000	0.67
3	2,000	1.33
4	4,000	2.67

3.3 Classification testing.

- a. A sample of devices (see 4.c) shall be characterized for the device ESD failure threshold using the voltage steps shown in table 1020-I, as a minimum. Finer voltage steps may optionally be used to obtain a more accurate measure of the failure voltage. Testing may begin at any voltage step, except for devices which have demonstrated healing effects, including those with spark gap protection, which shall be started at the lowest step. Examination of known technology family input or output V/I damage characteristics (i.e., curve tracer), or other simplified test verification techniques may be used to validate the failure threshold (e.g., cumulative damage effects may be eliminated by retesting at the failure voltage step using a new sample of devices and possibly passing the step).

- b. A new sample of devices shall be selected and subjected to the next lower voltage step used. Each device shall be tested

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- b. A new sample of devices shall be selected and subjected to the next lower voltage step used. Each device shall be tested using three positive and three negative pulses using each of the pin combinations shown in table 1020-II. A minimum of one-second delay shall separate the pulses.
- c. The sample devices shall be electrically tested to group A, subgroup II applicable (room temperature dc parameters).
- d. If one or more of the devices fail, the testing of 3.3b. and 3.3c. shall be repeated at the next lower voltage step used.
- e. If none of the devices fail, record the failure threshold determined in 3.3a. Note the highest step passed, and use it to classify the device according to table 1020-III.

TABLE 1020-II. Junction polarities for ESD conditions test.

Device type	Junction/polarity
Bipolar transistor (NPN)	E+ to B-
Bipolar transistor (PNP)	E- to B+
Junction FET's (N-channel)	G+ to S-
Junction FET's (P-channel)	G- to S+
MOSFET's (N- or P-channel)	G to S (both polarities)
Gate protected FET's (P-channel)	G to S (both polarities)
Rectifiers (include hot carrier and schottky)	A- to K+
Thyristors	G to K (both polarities)
Unijunctions	G to B1 (both polarities)
Darlington	E to B (both polarities)
Small signal diodes	A to K (both polarities)

3.4 Pin combinations to be tested.

Using table 1020-II, select the terminal to be used for the ESD tests.

TABLE 1020-III. Device ESD failure threshold classification.

Class 1	0 volt to 1,999 volts
Class 2	2,000 volts to 3,999 volts
Class 3	4,000 volts to 15,999 volts
Nonsensitive	Above 15,999 volts

3.5 Classification criteria.

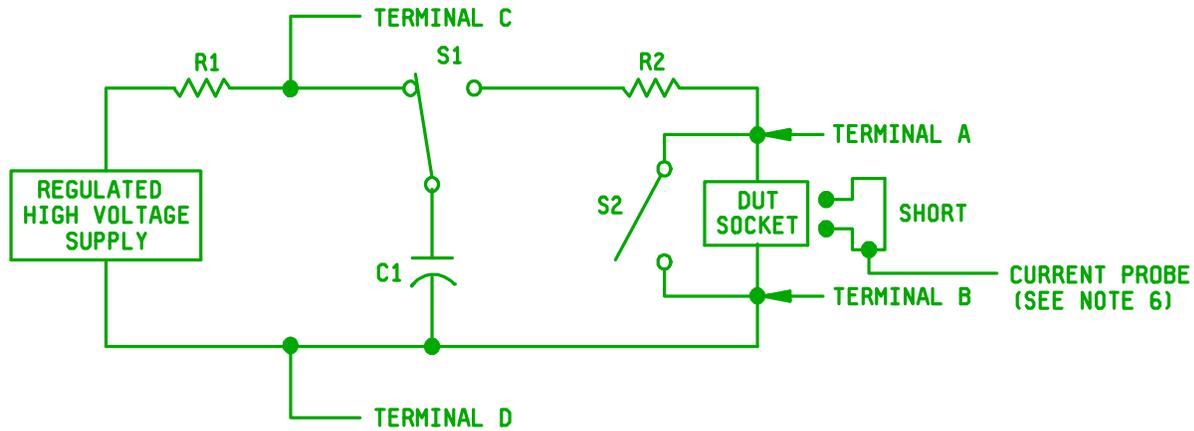
Devices which fail the post test electrical at +25°C of group A, subgroup 2 of the detail specification shall be considered class 1 devices.

All devices subjected to this test shall be considered destroyed and shall not be shipped for use in any application.

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4. Summary. The following details shall be specified in the applicable purchase order or contract, if other than specified herein.
- a. Post test electricals.
  - b. Special additional or substitute pin combinations, if applicable.
  - c. Sample size, if other than three devices.



$R1 = 10^6 \Omega$  to  $10^7 \Omega$

$C1 = 100 \text{ pF} \pm 10 \text{ percent}$

$R2 = 1,500 \Omega \pm 1 \text{ percent}$

S1 = High voltage relay

S2 = Normally closed switch

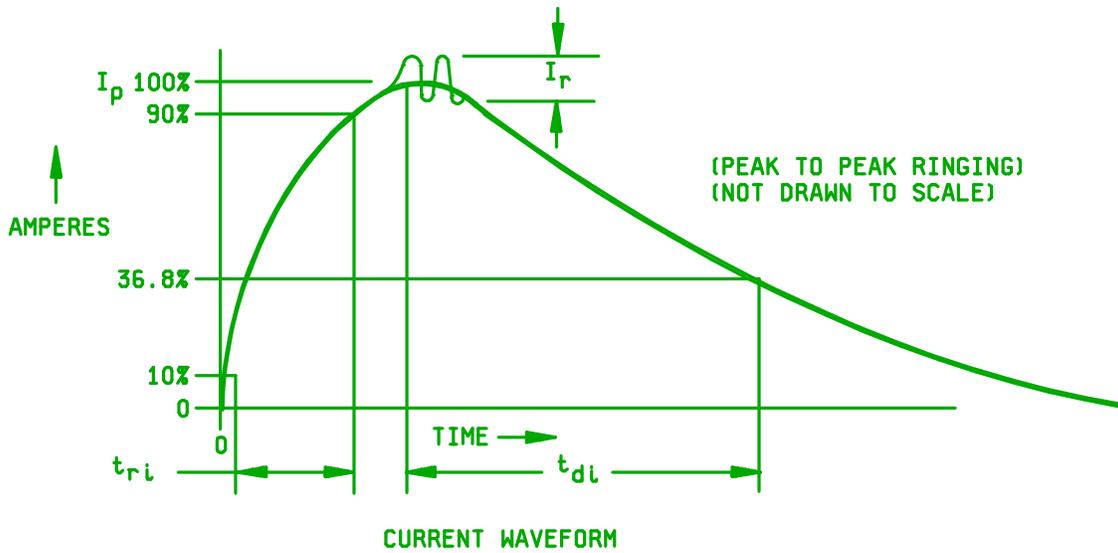
(Insulation resistance  $10^{12} \Omega$  minimum)

(Bounceless, mercury wetted, or equivalent  
(Open during discharge pulse and capacitance  
measurement))

NOTES:

1. The performance of this simulator circuit is strongly influenced by parasitics. Capacitances across relays and resistor terminals, and series inductance in wiring and in all components shall be minimized.
2. As a precaution against transients upon recharge of C1, the supply voltage  $V_S$  may be reduced before switch S1 is returned to the charging position.
3. Piggybacking DUT sockets is not permitted during verification or classification testing.
4. Switching terminals A and B internal to the simulator to obtain opposite polarity is not recommended.
5. C1 represents the effective capacitance (see 2.3.2).
6. The current probe connection shall be made with double shielded cable into a  $50 \Omega$  termination at the oscilloscope. The cable length shall not exceed 3 feet.

FIGURE 1020-1. ESD classification test circuit (human body model).



NOTES:

1. The current waveforms shown shall be measured as described in the waveform verification procedure of 3.2, using equipment meeting the requirements of 2.
2. The current pulse shall have the following characteristics:

$t_{ri}$ (rise time) -----	Less than 10 ns.
$t_{d1}$ (delay time) -----	$150 \pm 20$ ns.
$I_p$ (peak current) -----	Within $\pm 10$ percent of the $I_p$ value shown in table 1020-II for the voltage step selected.
$I_r$ (ringing) -----	The decay shall be smooth, with ringing, break points, double time constants, or discontinuities less than 15 percent $I_p$ maximum, but not observable 100 ns after start of the pulse.

FIGURE 1020-2. ESD classification test circuit waveforms (human body model).

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METHOD 1021.3

MOISTURE RESISTANCE

1. Purpose. The moisture resistance test is performed for the purpose of evaluating, in an accelerated manner, the resistance of component parts and constituent materials to the deteriorative effects of the high-humidity and heat conditions typical of tropical environments. Most tropical degradation results directly or indirectly from absorption of moisture vapor and films by vulnerable insulating materials, and from surface wetting of metals and insulation. These phenomena produce many types of deterioration, including corrosion of metals; constituents of materials; and detrimental changes in electrical properties. This test differs from the steady-state humidity test and derives its added effectiveness in its employment of temperature cycling, which provides alternate periods of condensation and drying essential to the development of the corrosion processes and, in addition, produces a "breathing" action of moisture into partially sealed containers. Increased effectiveness is also obtained by use of a higher temperature, which intensifies the effects of humidity. The test includes a low-temperature subcycle that acts as an accelerator to reveal otherwise indiscernible evidences of deterioration since stresses caused by freezing moisture tend to widen cracks and fissures. As a result, the deterioration can be detected by the measurement of electrical characteristics (including such tests as voltage breakdown and insulation resistance) or by performance of a test for sealing. Provision is made for the application of a polarizing voltage across insulation to investigate the possibility of electrolysis, which can promote eventual dielectric breakdown. This test also provides for electrical loading of certain components, if desired, in order to determine the resistance of current-carrying components, especially fine wires and contacts, to electrochemical corrosion. Results obtained with this test are reproducible and have been confirmed by investigations of field failures. This test has proved reliable for indicating those parts which are unsuited for tropical field use.

2. Apparatus. The apparatus used for the moisture resistance test shall include temperature-humidity chambers capable of maintaining the cycles and tolerance described on figure 1021-1 and electrical test equipment capable of performing the measurements in 3.6 and 4.

3. Procedure. Specimens shall be tested in accordance with 3.2 through 3.7 inclusive, and figure 1021-1. Specimens shall be mounted in a manner that will expose them to the test environment.

3.1 Initial conditioning. Unless otherwise specified and prior to mounting specimens for the moisture resistance test, the device leads shall be subjected to a bending stress, initial conditioning in accordance with test condition E of method 2036. Where the specific sample devices being subjected to the moisture resistance test have already been subjected to the required initial conditioning, as part of another test employing the same sample devices, the lead bend need not be repeated.

3.2 Initial measurements. Prior to step 1 of the first cycle, the specified initial measurements shall be made at room ambient conditions, or as specified. When specified, the initial conditioning in a dry oven (see figure 1021-1) shall precede initial measurements and the initial measurements shall be completed within 8 hours after removal from the drying oven.

3.3 Number of cycles. Specimens shall be subjected to 10 continuous cycles, each as shown on figure 1021-1. In the event of no more than one unintentional test interruption (power interruption or equipment failure) prior to the completion of the specified number of cycles (except for the last cycle) the cycle shall be repeated and the test may continue. Unintentional interruptions occurring during the last cycle require a repeat of the cycle plus an additional uninterrupted cycle. Any intentional interruption, or any unintentional interruption of greater than 24 hours requires completion of missing cycles plus one additional cycle.

3.4 Subcycle of step 7. During at least 5 of the 10 cycles, a low temperature subcycle shall be performed. At least 1 hour but not more than 4 hours after step 7 begins, the specimens shall be either removed from the humidity chamber, or the temperature of the chamber shall be reduced, for performance of the subcycle. Specimens during the subcycle shall be conditioned at  $-10^{\circ}\text{C} +2^{\circ}\text{C}$ ,  $-5^{\circ}\text{C}$ , with humidity not controlled, for 3 hours minimum as indicated on figure 1021-1. When a separate cold chamber is not used, care should be taken to assure that the specimens are held at  $-10^{\circ}\text{C} +2^{\circ}\text{C}$ ,  $-5^{\circ}\text{C}$  for the full period. After the subcycle, the specimens shall be returned to  $+25^{\circ}\text{C}$  at 80 percent RH minimum and kept there until the next cycle begins.

3.5 Applied voltage. During the moisture resistance test as specified on figure 1021-1, when specified (see 4), the device shall be biased in accordance with the specified bias configuration which should be chosen to maximize the voltage differential between chip metallization runs or external terminals, minimize power dissipation and to utilize as many terminals as possible to enhance test results.

3.6 Conditions (see figure 1021-1). The rate of change of temperature in the chamber is unspecified; however, specimens shall not be subject to the radiant heat from the chamber conditioning processes. Unless otherwise specified, the circulation of air in the chamber shall be at a minimum cubic rate per minute equivalent to five times the volume of the chamber. The steady-state temperature tolerance is  $\pm 2^{\circ}\text{C}$  of the specified temperature at all points within the immediate vicinity of the specimens and at the chamber surfaces. Specimens weighing 25 pounds or less shall be transferred between temperature chambers in less than 2 minutes.

3.7 Final measurements. Following step 6 of the final cycle (or step 7 if the subcycle of 3.3 is performed during the tenth cycle), devices shall be conditioned for 24 hours at room ambient conditions after which either an insulation resistance test in accordance with method 1016, or the specified  $+25^{\circ}\text{C}$  electrical end-point measurements shall be performed. Electrical measurements may be made during the 24 hour conditioning period. However, any failures resulting from this testing shall be counted, and any retesting of these failures later in the 24 hour period for the purpose of obtaining an acceptable result is prohibited. No other test (e.g., seal) shall be performed during the 24 hour conditioning period. The insulation resistance test or the alternative  $+25^{\circ}\text{C}$  electrical end-point measurements shall be completed within 48 hours after removing the devices from the chamber. When the insulation resistance test is performed, the measured resistance shall be no less than  $10\text{ M}\Omega$  and the test shall be recorded and data submitted as part of the end-point data. If the package case is electrically connected to the die substrate by design, the insulation resistance test shall be omitted and the specified  $+25^{\circ}\text{C}$  electrical end-point measurements shall be completed within 48 hours after removal of the device from the chamber. A visual examination and any other specified end-point electrical parameter measurements (see 4.c) shall also be performed.

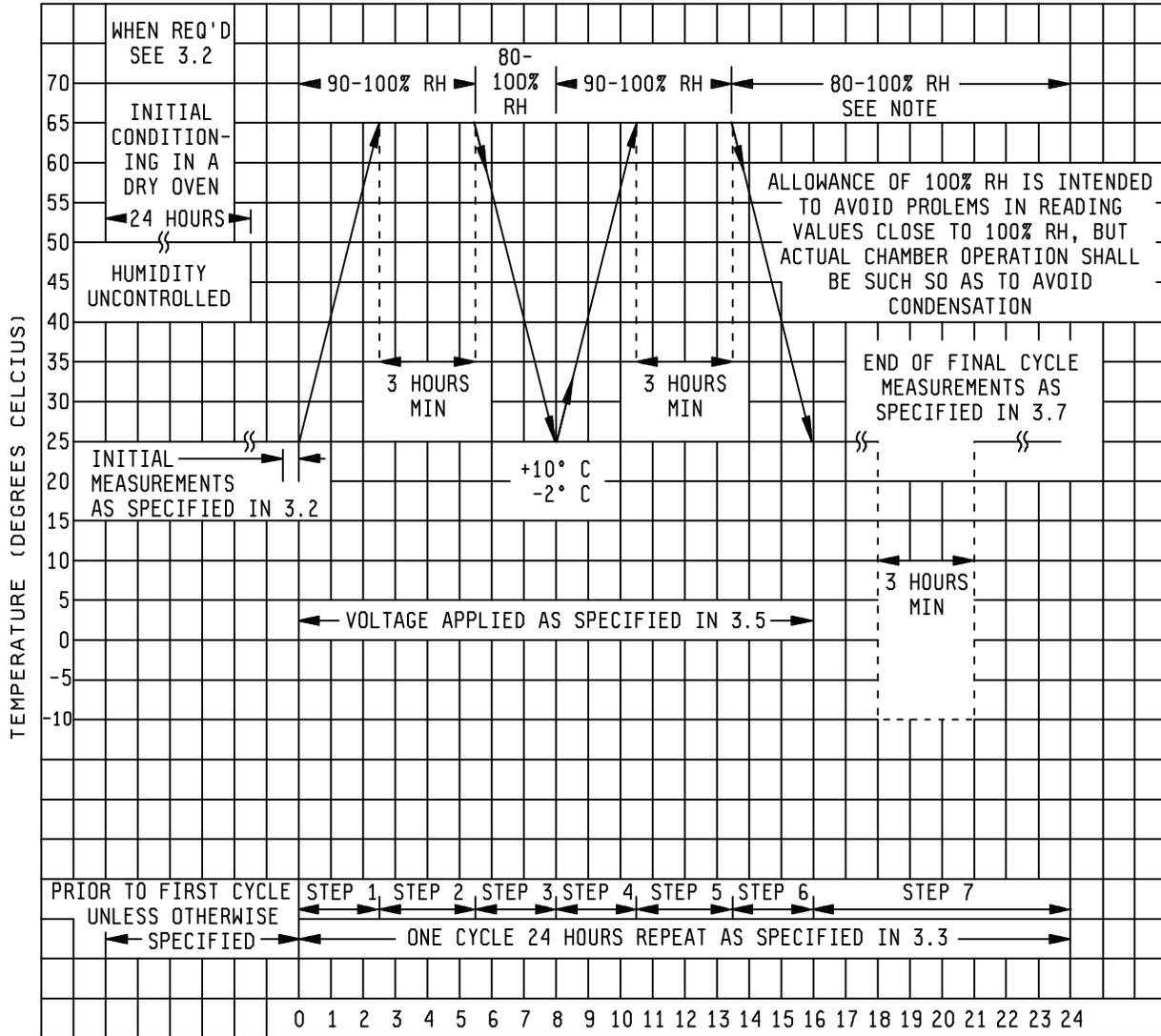
3.8 Failure criteria. No device shall be acceptable that exhibits:

- a. Specified markings which are missing in whole or in part, faded, smeared, blurred, shifted, or dislodged to the extent that they are not legible. This examination shall be conducted with normal room lighting and with a magnification of 1X to 3X.
- b. Evidence of corrosion over more than five percent of the area of the finish or base metal of any package element (i.e., lid, lead, or cap) or any corrosion that completely crosses the element when viewed with a magnification of 10X to 20X.
- c. Leads missing, broken, or partially separated.
- d. Corrosion formations which bridge between leads or between leads and metal case.
- e. Electrical end-point or insulation resistance test failures.

NOTE: The finish shall include the package and entire exposed lead area from meniscus to the lead tip (excluding the sheared off tip itself) and all other exposed metal surfaces.

4. Summary. The following details shall be specified in the applicable acquisition document:

- a. Initial measurements and conditions, if other than room ambient (see 3.1).
- b. Applied voltage, when applicable (see 3.5), and bias configuration, when required. This bias configuration shall be chosen in accordance with the following guidelines:
  - (1) Only one supply voltage (V) either positive or negative is required, and an electrical ground (GND) or common terminal. The magnitude of V will be the maximum such that the specified absolute maximum ratings are not exceeded and test conditions are optimized.
  - (2) Unless otherwise specified, all normally specified voltage terminals and ground leads shall be connected to GND.
  - (3) Unless otherwise specified, all data inputs shall be connected to V. The polarity and magnitude of V is chosen to minimize internal power dissipation and current flow into the device. Unless otherwise specified, all extender inputs shall be connected to GND.
  - (4) All additional leads (e.g. clock, set, reset, outputs) considered individually, shall be connected to V or GND, whichever minimizes current flow.
  - (5) Leads with no internal connection shall be biased to V or GND whichever is opposite to an adjacent lead.
- c. Final measurements (see 3.7). Final measurements shall include all electrical characteristics and parameters which are specified as end-point electrical parameters.
- d. Number of cycles, if other than 10 (see 3.3).
- e. Conditioning in dry oven before initial measurements, if required (see 3.2).



NOTE: The subcycle of step 7 (See 3.4) shall be performed for a minimum of 5 of the 10 cycles. Humidity is uncontrolled for the -10°C portion of step 7.

FIGURE 1021-1. Graphical representation of moisture-resistance test.

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METHOD 1022.5

RESISTANCE TO SOLVENTS

1. Purpose. The purpose of this test is to verify that the markings will not become illegible on the component parts when subjected to solvents. The solvents will not cause deleterious, mechanical or electrical damage, or deterioration of the materials or finishes.

1.1 Formulation of solvents. The formulation of solvents herein is considered typical and representative of the desired stringency as far as the usual coatings and markings are concerned. Many available solvents which could be used are either not sufficiently active, too stringent, or even dangerous to humans when in direct contact or when the fumes are inhaled.

1.2 Check for conflicts. When this test is referenced, care should be exercised to assure that conflicting requirements, as far as the properties of the specified finishes and markings are concerned, are not invoked.

2. Materials.

2.1 Solvent solutions. The solvent solutions used in this test shall consist of the following:

a. A mixture consisting of the following:

- (1) One part by volume of isopropyl alcohol, A.C.S. (American Chemical Society) Reagent Grade, or isopropyl alcohol in accordance with TT-I-735, grade A or B, and
- (2) Three parts by volume of mineral spirits in accordance with TT-T-291, type II, grade A, or three parts by volume of a mixture of 80 percent by volume of kerosene and 20 percent by volume ethylbenzene.

b. A semiaqueous based solvent (defluxer (e.g., a turpene)) consisting of a minimum of 60 percent Limonene and a surfactant heated to +32°C ±5°C. 1/

c. At +63°C to +70°C, a mixture consisting of the following: 2/

- (1) 42 parts by volume of deionized water.
- (2) 1 part by volume of propylene glycol monomethyl ether.
- (3) 1 part by volume of monoethanolamine.

2.1.1 Solvent solutions, safety aspects. Solvent solutions listed in a. through d. above exhibit some potential for health and safety hazards. The following safety precautions should be observed:

- a. Avoid contact with eyes.
- b. Avoid prolonged contact with skin.
- c. Provide adequate ventilation.
- d. Avoid open flame.
- e. Avoid contact with very hot surfaces.

-----  
1/ Or any equivalent EPA approved HCFC or terpene solvent or demonstrated equivalent.

2/ Normal safety precaution for handling this solution (e.g., same as those for diluted ammonium hydroxide) based on O.S.H.A. rules for monoethanolamine.

2.2 Vessel. The vessel shall be a container made of inert material, and of sufficient size to permit complete immersion of the specimens in the solvent solutions specified in 2.1.

2.3 Brush. The brush shall be a toothbrush with a handle made of a nonreactive material. The brush shall have three long rows of hard bristles, the free ends of which shall lie substantially in the same plane. The toothbrush shall be used exclusively with a single solvent and when there is any evidence of softening, bending, wear, or loss of bristles, it shall be discarded.

3. Procedure. The specimens subjected to this test shall be divided into three groups. Metal lidded leadless chip carrier (LCC) packages shall be preconditioned by immersing the specimens in room temperature RMA flux (in accordance with MIL-F-14256, flux, soldering, liquid, rosin base) for 5 to 10 seconds. The specimens shall then be subjected to an ambient temperature of  $+215^{\circ}\text{C} \pm 5^{\circ}\text{C}$  for 60 seconds  $+5$ ,  $-0$  seconds. After the preconditioning, each device lid shall be cleaned with isopropyl alcohol. Each group shall be individually subjected to one of the following procedures:

- a. The first group shall be subjected to the solvent solution as specified in 2.1a. maintained at a temperature of  $+25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ .
- b. The second group shall be subjected to the solvent solution as specified in 2.1b. maintained at a temperature of  $+32^{\circ}\text{C} \pm 5^{\circ}\text{C}$ .
- c. The third group shall be subjected to the solvent solution as specified in 2.1c. maintained at a temperature of  $+63^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$ .

The specimens and the bristle portion of the brush shall be completely immersed for 1 minute minimum in the specified solution contained in the vessel specified in 2.2. Immediately following immersion, the specimen shall be brushed with normal hand pressure (approximately 2 to 3 ounces) for 10 strokes on the portion of the specimen where marking has been applied, with the brush specified in 2.3. Immediately after brushing, the above procedure shall be repeated two additional times, for a total of three immersions followed by brushings. The brush stroke shall be directed in a forward direction, across the surface of the specimen being tested. After completion of the third immersion and brushing, devices shall be rinsed and all surfaces air blown dry. After 5 minutes, the specimens shall be examined to determine the extent, if any, of deterioration that was incurred.

3.1 Optional procedure for the third group. The test specimens shall be located on a test surface of known area which is located  $6 \pm 1$  inches ( $15.24 \pm 2.54$  centimeters) below a spray nozzle(s) which discharges 0.139 gpm ( $0.6 \pm 0.02$  liters/ minute) of solution (see 2.1c)  $1 \text{ in}^2$  ( $6.5$  square centimeters) of surface area at a pressure of  $20 \pm 5$  psi ( $137.90 \pm 34.41$  kilopascal). The specimens shall be subjected to this spray for a period of 10 minutes minimum. Within five minutes after removal of the specimens, they shall be examined in accordance with 3.1.1. The specimens may be rinsed with clear water and air blown dried prior to examination.

3.1.1 Failure criteria. After subject to the test, evidence of damage to the device and any specified markings which are missing in whole or in part, faded, smeared, blurred, or shifted (dislodged) to the extent that they cannot be readily identified from a distance of at least 6 inches ( $15.24 \text{ cm}$ ) with normal room lighting and without the aid of magnification or with a viewer having a magnification no greater than 3X shall constitute a failure.

4. Summary. The number of specimens to be tested shall be specified in the individual specification (see 3.).

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METHOD 1026.5

STEADY-STATE OPERATION LIFE

1. Purpose. The purpose of this test is to determine compliance with the specified lambda ( $\lambda$ ) for devices subjected to the specified conditions.

2. Procedure. The semiconductor device shall be subjected to the steady-state operation life test at the temperature specified for the time period in accordance with the life test requirements of MIL-S-19500 and herein. The device shall be operated under the specified conditions.

Unless otherwise specified, lead-mounted devices should be mounted by the leads with jig mounting clips at least .375 inch (9.5 mm) from the body or from the lead tubulation if the lead tubulation projects from the body. Unless otherwise specified, mounting and connections to surface mount devices shall be made only at their terminations. Unless a free-air life test is specified, case mounted device types (e.g., stud, flange, disc) shall be mounted by their normal case surface. The point of connection shall be maintained at a temperature not less than the specified temperature.

After the termination of the test, or in accordance with the period specified in MIL-S-19500 and the detail specification, if otherwise defined, the sample units shall be removed from the specified test conditions and allowed to reach standard test conditions. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified test conditions. Additional readings may be taken at the discretion of the manufacturer. If end-point measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before post test measurements are performed.

3. Summary. The following conditions shall be specified in the detail specification:

- a. Test type and details; rectifying or forward dc current and  $V_f$  for rectifiers and signal diodes, dc power (or current) for zener diodes, power (and range of  $V_{CE}$  and  $V_{DS}$ ) for bipolar and FETs (see 2.).
- b. Test temperature, if other than room ambient.
- c. Test mounting, if other than that specified (see 2.).
- d. End-point measurements (see 2.).

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METHOD 1027.3

STEADY-STATE OPERATION LIFE (SAMPLE PLAN)

1. Purpose. The purpose of this test is to determine compliance with the specified sample plan for devices subjected to the specified conditions.

2. Procedure. Unless otherwise specified, the semiconductor device shall be subjected to the steady-state operation test at the temperature specified for 340 hours minimum. The device shall be operated under the specified conditions.

Unless otherwise specified, lead-mounted devices should be mounted by the leads with jig mounting clips at least .375 inch (9.5 mm) from the body or from the lead tubulation if the lead tubulation projects from the body. Unless otherwise specified, mounting and connections to surface mount devices shall be made only at their terminations. Unless free-air life test is specified, case mounted device types (e.g., stud, flange, disc) shall be mounted by their normal case surface. The point of connection shall be maintained at a temperature not less than the specified temperature.

After the termination of the test, or in accordance with the period specified by MIL-S-19500 and the detail specification if otherwise defined, the sample units shall be removed from the specified test conditions and allowed to reach standard test conditions. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified test conditions. Additional readings may be taken at the discretion of the manufacturer. If end-point measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before post test measurements are performed.

3. Summary. The following conditions shall be specified in the detail specification:

- a. Test type and details; rectifying or forward dc current and  $V_F$  for rectifiers and signal diodes, dc power (or current) for zener diodes, power (and range of  $V_{CE}$  and  $V_{DS}$ ) for bipolar and FETs (see 2.).
- b. Test temperature, if other than room ambient.
- c. Test time, if other than 340 hours (see 2.).
- d. Test mounting, if other than that specified (see 2.).
- e. End-point measurements (see 2.).

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METHOD 1031.5

HIGH-TEMPERATURE LIFE (NONOPERATING)

1. Purpose. The purpose of this test is to determine compliance with the specified lambda (I) for devices subjected to the specified conditions.

2. Procedure. The device shall be stored under the specified ambient conditions (normally the maximum temperature) for a time period in accordance with the life test requirements of MIL-S-19500. In accordance with the life test period specified by MIL-S-19500, the sample units shall be removed from the specified ambient conditions and allowed to reach standard test conditions. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified ambient conditions. If measurements can not be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before post test measurements are performed. Additional readings may be taken at the discretion of the manufacturer.

2.1 Visual examination. The markings shall be legible after the test. There shall be no evidence (when examined without magnification) of flaking or pitting of the finish or corrosion that will interfere with the mechanical and electrical application of the device.

3. Summary. The following conditions shall be specified in the detail specification:

- a. Test conditions (see 2.).
- b. End-point measurements (see 2.).

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METHOD 1032.2

HIGH-TEMPERATURE (NONOPERATING) LIFE (SAMPLE PLAN)

1. Purpose. The purpose of this test is to determine compliance with the specified sample plan for devices subjected to the specified conditions.

2. Procedure. Unless otherwise specified, the device shall be stored under the specified ambient conditions (normally the maximum temperature) 340 hours minimum. The sample units shall be removed from the specified ambient conditions and allowed to reach standard test conditions. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified ambient conditions. If measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 hours before post test measurements are performed. Additional readings may be taken at the discretion of the manufacturer.

2.1 Visual examination. The markings shall be legible after the test. There shall be no evidence (when examined without magnification) of flaking or pitting of the finish or corrosion that will interfere with the mechanical and electrical application of the device.

3. Summary. The following conditions shall be specified in the detail specification:

- a. Test conditions (see 2.).
- b. Test time, if other than 340 hours (see 2.).
- c. End point measurements (see 2.).

MIL-STD-750D  
NOTICE 4

METHOD 1033

REVERSE VOLTAGE LEAKAGE STABILITY

1. Purpose. This test method is designed to evaluate the short term leakage stability of product under reverse bias conditioning. It is not intended to replace, nor does it duplicate the high temperature reverse bias conditioning. The failure mechanisms that are addressed in this test method are not sustained upon the removal of applied bias to the device. As an example; certain semiconductor designs are quite susceptible to unstable reverse leakage due to the presence of Hydrogen in the device. This method can be used to ascertain the susceptibility of a technology to this type of a problem or the effectiveness of countermeasures.

2. Procedure. Condition A: Apply to the device under test (DUT) at room temperature, +25°C, a minimum of 80 percent of the specified  $V_{cb}$ ,  $V_{ds}$ ,  $V_r$  as applicable. Apply bias and measure and record the leakage current.

Retain uninterrupted bias on the device for 1 hour minimum.

After 1 hour minimum re-measure and record the reverse leakage of the device. Interruption of the applied bias for any reason between the pre and post leakage measurements invalidates the test. Bias shall not be interrupted to make the reverse leakage measurement.

3. Failure criteria. The following shall be used as the pass/fail criteria for this test:

For measured $I_r < 100\text{nA}$	Delta $I_r = 100\text{ nA max.}$
For measured $I_r 100\text{ nA} < I_r < 1\mu\text{A}$	Delta $I_r = 200\text{ nA max.}$
For measured $I_r > 1\mu\text{A}$	Delta $I_r = \text{Less than 50 percent of initial measurement.}$

4. Condition B. Sweep the voltage in the BVCEO mode until the breakdown of the device is observed and study the breakdown leakage plot for a minimum of 10 seconds for stability. An unstable plot will be considered any device which exhibits one or more of the following:

- a. Collapsing.
- b. Leakage increasing.

A device will be considered passing when none of the instability modes are noticed from the list above after period of approximate 10 seconds. The device will be then subjected to a leakage test.

Sweep the voltage of the device to the maximum leakage identified on the applicable slash sheet. Observe the amplitude of the leakage. Leakage is defined as  $I_{cbo}$ ,  $I_{ces}$  or  $I_{cex}$  as specified in the applicable detail specification.

After 30 seconds minimum, the maximum change in leakage allowed is as specified for Burn-in in the detail specification.

Perform the breakdown and leakage on the specified number of samples in accordance with the individual specification. One hundred percent must be performed on the entire lot if any device from the sample fails the above tests.

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METHOD 1036.3

INTERMITTENT OPERATION LIFE

1. Purpose. The purpose of this test is to determine compliance with the specified lambda ( $\lambda$ ) for devices subjected to the specified conditions.

2. Procedure. The device shall be subjected intermittently to the specified operating and nonoperating conditions for the time period in accordance with the life test requirements of MIL-S-19500. The on- and off-periods shall be initiated by sudden, not gradual, application or removal of the specified operating conditions. Lead mounted devices should be mounted by the leads with jig mounting clips at least .375 inch (9.5 mm) from the body or lead tubulation, if the lead tubulation projects from the body. The point of connection shall be maintained at a temperature not less than the specified temperature. Within the time interval of 24 hours before to 72 hours after termination of the test, in accordance with the life test period specified by MIL-S-19500, the sample units shall be removed from the specified test conditions and allowed to reach standard test conditions. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified test conditions. Additional readings may be taken at the discretion of the manufacturer.

3. Summary. The following conditions shall be specified in the detail specification:

- a. Test conditions (see 2.).
- b. Operating and nonoperating cycles (see 2.).
- c. Test temperature (case or ambient).
- d. Test mounting, if other than that specified (see 2.).
- e. End point measurements (see 2.).

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METHOD 1037.2

INTERMITTENT OPERATION LIFE (SAMPLE PLAN)

1. Purpose. The purpose of this test is to determine compliance with the specified numbers of cycles for devices subjected to the specified conditions. It accelerates the stresses on all bonds and interfaces between the chip and mounting face of devices subjected to repeated turn on and off of equipment and is therefore most appropriate for case mount style (e.g., stud, flange, and disc) devices.

2. Mounting. Clips or fixtures appropriate for holding the device terminations and reliably conducting the heating current shall be used. This method is intended to allow the case temperature to rise and fall appreciably as the junction is heated and cooled; thus it is not appropriate to use a large heat sink. Lead-mounted devices, when specified, should be mounted by the leads with jig mounting clips at least .375 inch (9.5 mm) from the body, or from the lead tubulation if it projects from the body.

3. Procedure. All test samples shall be subjected to the specified number of cycles. When stabilized after initial warm-up cycles, a cycle shall consist of an "on" period, when power is applied suddenly, not gradually, to the device for the time necessary to achieve a delta case temperature (delta is the high minus the low mounting surface temperatures) of +85°C (+60°C for thyristors) +15°C, -5°C, followed by an off period, when the power is suddenly removed, for cooling the case through a similar delta temperature. Auxiliary (forced) cooling is permitted during the off period only.

DC current shall be used for the power required during the "on" period except, for rectifiers and thyristors, equivalent half sine wave (or full sine wave for triacs) is permissible. The test power, or current, shall be at least the free air rating. For disc types, where functional mounting requires heat sinking, it shall be at least 25 percent of the continuous, case referenced, rating. The on time (leaded and axial leaded devices) shall be at least 30 seconds. Unless otherwise specified, for TO3, DO5, and larger devices it shall be at least one minute. Specified end-point measurements for qualification and quality conformance inspection shall be completed within 96 hours after removal of sample units from the specified test conditions. Additional readings may be taken at the discretion of the manufacturer. If measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 200 additional cycles before post test measurements are performed.

4. Summary. The following conditions shall be specified in the detail specification:

- a. Test conditions (power or current, see 3.).
- b. Number of operating cycles (see 3.), if other than 2,000.
- c. Test mounting, if other than that specified (see 2.).
- d. End-point measurements (see 3.1).

NOTE: Heat sinks are not intended to be used in this test, however, small heat sinks may be used when it is otherwise difficult to control case temperature of test samples, such as with small package types (e.g., TO39).

MIL-STD-750D

METHOD 1038.4

BURN-IN (FOR DIODES, RECTIFIERS, AND ZENERS)

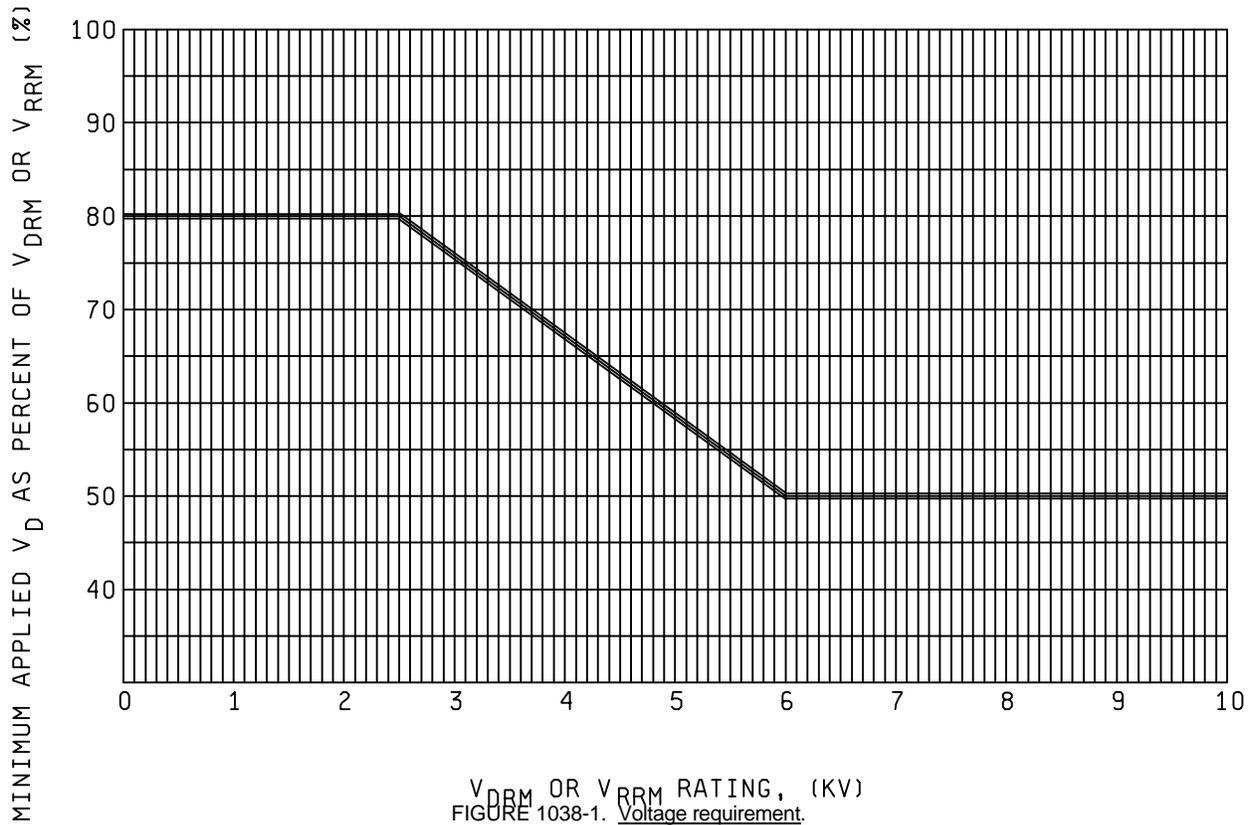
1. Purpose. This test is performed to eliminate marginal devices or those with defects resulting from manufacturing aberrations that are evidenced as time and stress dependent failures. Without the burn-in, these defective devices would be expected to result in early lifetime failures under normal use conditions. It is the intent of this test to operate the semiconductor device at specified conditions to reveal electrical failure modes that are time and stress dependent.
  - a. HTRB screens for mobile or temperature activated impurities within (and without) the device's passivation layers. It is equally effective on most device types including diodes, rectifiers, zeners, and transient voltage suppressors.
  - b. SSOP, when properly specified, simulates actual device operation but with accelerated conditions. Some of the elements of HTRB are combined with screening for die bond integrity. It is effective on some device types including diodes, rectifiers, and zeners<sup>7</sup>. The conditions used for zeners provide the desired HTRB screen concurrently with the SSOP screen.
2. Mounting. Unless otherwise specified in the detail specification, mounting shall be in accordance with the following.
  - 2.1 Test condition A, HTRB. The method of mounting is usually optional for high temperature bias since little power is dissipated in the device. (Devices with normally high reverse leakage current may be mounted to heat sinks to prevent thermal run-away conditions.)
  - 2.2 Test condition B, SSOP.
    - a. Devices with leads projecting from the body (e.g., axial) shall be mounted by their leads at least .375 inch (9.73 mm) from the body or lead tabulation.
    - b. Unless otherwise specified, devices designed for case mounting (e.g., stud, flange, and disc) shall be mounted by the stud or case according to the design specifications for the package. Care must be exercised to avoid stressing or warping of the package. Thermally conductive compounds may optionally be used provided that they are removed afterwards and do not leave a residue on the package.
    - c. Surface mount types shall be held by their electrical terminations.
3. Procedure. The semiconductor device shall be subjected to the burn-in at the temperature and for the time specified herein or on the detail specification. Pre-burn-in measurements shall be made as specified. The failure criteria shall be as specified in the appropriate detail specification. If measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before test measurements are performed.
  - 3.1 Test condition A, HTRB. Unless otherwise specified, HTRB is performed with the cathode positively biased at an artificially elevated temperature for 48 hours minimum. These conditions apply to both rectifiers and to avalanche and zener voltage regulators.
    - a. The junctions of rectifiers shall be reverse biased at 50 to 80 percent in accordance with figure 1038-1 of their rated working peak reverse voltage; avalanche and zener voltage regulators, when specified, shall be reverse biased at 80 percent of their minimum avalanche or zener voltages except when voltage exceeds 2,500, see figure 1038-1. The reverse bias shall be a dc bias with less than 20 percent ripple except where rectified (pulsating) dc is permitted. The ambient or case test temperature shall be as specified (normally +150°C for silicon devices) (see figure 1038-1).
    - b. At the end of the high-temperature test time, as specified, the ambient temperature shall be lowered. The test voltage shall be maintained on the devices until a case temperature of +30°C ±5°C is attained. Testing shall be completed within 24 hours after the removal of voltage. After removal of the bias voltage, no other voltage shall be applied to the device before taking the post HTRB reverse current measurement. Post HTRB measurements shall be taken as specified.

Uni-directional transient voltage suppressors shall be treated as avalanche and zener voltage regulators for the purposes of conducting HTRB.

Bi-directional transient voltage suppressors shall be treated as two discrete avalanche or zener voltage regulators (when specified) with each polarity taking turns receiving HTRB and post HTRB testing. Post HTRB testing of one must be completed before reversing the device and commencing HTRB with opposite polarity bias voltage. The second polarity may be achieved either electrically or by mechanically reversing the devices.

3.2 Test condition B, steady-state operating power. Unless otherwise specified, the devices shall be subjected to the maximum rated test conditions for a minimum of 96 hours. The test temperature shall be as specified. Unless otherwise specified, post burn-in readings shall be taken within 96 hours. If ambient temperature is specified, it shall comply with the general requirements for HTRB or burn-in of this specification (see 4.5). The following indicates the test conditions to be specified for each of the three types of power burn-in tests:

- a. Rectifying test. Unless otherwise specified, average rectified current, peak reverse voltage, frequency, and temperature (case, junction, or ambient) are as specified in the detail specification.
- b. Forward bias test. Unless otherwise specified, forward current and temperature (case or junction) are as specified in the detail specification.
- c. Voltage regulator (zener) test. Unless otherwise specified, voltage regulator diode current and temperature (case or junction) are as specified in the slash drawing. At the end of the test time, the power level shall be reduced to five percent of the operating level. If the ambient is artificially elevated, it shall also be reduced to room temperature. The object is to let the devices cool down under bias. When the junction or case temperature has stabilized to below +50°C, the bias may be removed and the devices tested within 96 hours after removal of reverse bias. No other voltage may be applied to the devices until completion of electrical test.



V<sub>DRM</sub> OR V<sub>RRM</sub> RATING, (KV)  
 FIGURE 1038-1. Voltage requirement.

4. Summary. The test condition letter (A or B) and the following details shall be specified in the applicable detail specification.

4.1 Test condition A, HTRB.

- a. Test temperature (see 3.1).
- b. Test conditions (see 2.1 and 3.1).
- c. Test time (see 3.1).
- d. Preburn-in and post burn-in measurements (see 3. and 3.1).
- e. Time for completion of post burn-in measurements, if other than 24 hours (see 3.1).
- f. Criteria for failure (see 3.).

4.2 Test condition B, steady-state operating power.

- a. Test temperature (see 3.2).
- b. Test conditions (see 2.2 and 3.2).
- c. Burn-in time if other than 96 hours (see 3.2).
- d. Pre-burn-in and post burn-in measurements (see 3. and 3.2).
- e. Time for completion of post burn-in measurements, if other than 96 hours (see 3.2).
- f. Criteria for failure (see 3.).

## BURN-IN (FOR TRANSISTORS)

1. Purpose. This test is performed to eliminate marginal devices or those with defects resulting from manufacturing aberrations that are evidenced as time and stress dependent failures. Without the burn-in, these defective devices would be expected to result in early lifetime failures under normal use conditions. It is the intent of this test to operate the semiconductor device at specified conditions to reveal electrical failure modes that are time and stress dependent.

2. Procedure. The semiconductor device shall be subjected to the burn-in at the temperature and for the time specified herein. Preburn-in measurements shall be made as applicable. The failure criteria shall be as specified.

2.1 Mounting. Devices with leads projecting from the body shall be mounted by their leads at least .250 inch (6.35 mm) from the seating plane. Unless otherwise specified, devices with studs or case shall be mounted by the stud or case.

2.1.1 Test condition A, steady-state reverse bias. The transistor primary blocking junction, as specified, shall be reverse biased for 48 hours minimum, except PNP bipolar transistors shall be 24 hours, at the ambient temperature specified (normally +150°C) and at 80 percent of its maximum rated collector-base voltage. For bipolar transistors, the  $V_{CB}$  base is not to exceed the maximum collector-emitter voltage rating. For field-effect (signal or low power) transistors, the gate to source voltage, with drain to source shorted, shall be as specified. At the end of the high-temperature test time, specified herein, the ambient temperature shall be lowered. The test voltage shall be maintained on the devices until  $T_C = +30^\circ\text{C} \pm 5^\circ\text{C}$  is attained. After room ambient temperature has been established, the bias voltage shall be removed. After removal of the bias voltage, no other voltage shall be applied to the device before taking the post burn-in reverse-current measurement(s). Unless otherwise specified, after burn-in voltage is removed, post burn-in measurements shall be completed within 24 hours. If measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before post test measurements are performed.

2.1.2 Test condition B, steady-state power. All devices shall be operated at the maximum rated power related to the test temperature for 160 hours minimum at the specified test conditions (excluding microwave).

- a. For bipolar transistors, the temperature and power shall be specified. Unless otherwise specified, the temperature shall be as follows:

$T_A$  = room ambient as defined in the general requirements, 4.5 herein. for small signal, switching, and medium power devices intended for printed circuit board mounting;  $T_J$  = maximum rated temperature, +0°C, -25°C, for devices intended for chassis or heat sink mounting. Case temperature burn-in at maximum ratings (typically  $T_C = +100^\circ\text{C}$ ) may be substituted on the chassis or heat sink mounted devices at the supplier's option. If the voltage conditions specified herein cause the SOA rating to be exceeded, then the voltage shall be decreased until the SOA rating is met while maintaining the full rated power condition. For microwave bipolar transistors, the temperature, voltage, and current shall be as specified in the detail specification.

- b. For unijunction and field-effect (signal and low power) transistors, the temperature, voltage, and current shall be as specified.
- c. Post burn-in measurements shall be as specified.
- d. Unless otherwise specified, post burn-in readings shall be taken within 96 hours. If measurements cannot be performed within the specified time, the devices shall be subjected to the same test conditions for a minimum of 24 additional hours before post test measurements are performed.

3. Summary. Test condition letter and the following conditions shall be specified in the detail specification.

3.1 Test condition A:

- a. Junction to be reverse biased (see 2.1.1).
- b. Gate to source voltage for FETs (see 2.1.1).
- c. Test temperature (see 2.1.1).
- d. Test time for FETs (see 2.1.1).
- e. Voltage for post burn-in reverse current measurement (see 2.1.1).
- f. Time for completion of post burn-in measurements, if other than 24 hours (see 2.1.1).
- g. Criteria for failure (see 2.).

3.2 Test condition B:

- a. Test temperature, if other than as specified in 2.1.2.
- b. Test conditions (see 2.1.2).
- c. Power for bipolar transistors (see 2.1.2).
- d. Voltage and current for unijunction and FETs (see 2.1.2).
- e. Preburn-in and post burn-in measurements (see 2.1.2).
- f. Time for completion of post burn-in measurements, if other than as specified in 2.1.2.
- g. Criteria for failure (see 2.).

## METHOD 1040

BURN-IN (FOR THYRISTORS  
(CONTROLLED RECTIFIERS))

1. **Purpose.** The purpose of this test is to eliminate marginal or defective semiconductor devices by operating them at specified screening conditions which reveal electrical failure modes that are time and stress dependent. In the absence of burn-in, these defective devices would be expected to result in early lifetime failures under normal use conditions.

2. **Procedure.** Lead mounted devices shall be mounted by the leads at least .375 inch (9.5 mm) from the body or lead tubulation, if the lead tubulation projects from the body. Unless otherwise specified, stud or case mounted devices shall be mounted by the stud or case respectively. The devices shall then be subjected to the burn-in screen(s) at the temperature and for the time specified. Preburn-in and post burn-in measurements shall be made as specified.

2.1 **Test condition A (ac blocking voltage).** The rated peak reverse and the rated peak forward blocking voltage shall be alternately applied, each in the form of a 60 Hz half wave sinusoidal pulse using the circuit of figure 1040-1. The test temperature shall be as specified. At the end of the specified high temperature test time, the ambient temperature shall be lowered. The test voltage shall be maintained on the devices until  $T_C = +30^\circ\text{C} \pm 5^\circ\text{C}$  is attained. After bias is removed and prior to post test measurements, the devices shall be maintained at room ambient temperature and no voltage shall be applied prior to that voltage specified for the post test measurements. The post test end points shall be completed within the specified time after the bias voltage is removed. Any device which switches from the off-state to the on-state as indicated by a blown fuse shall be removed from the lot.

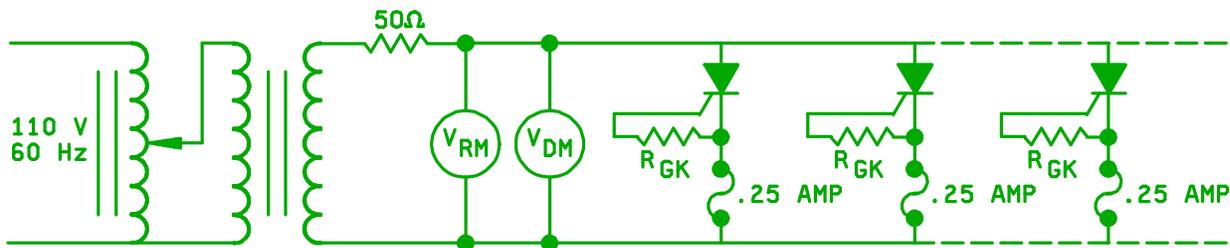


FIGURE 1040-1. AC blocking voltage circuit.

2.2 **Test condition B (dc forward blocking voltage).** The rated dc forward blocking voltage shall be applied as indicated in the circuit on figure 1040-2. The test temperature shall be as specified. At the end of the specified high-temperature test time, the ambient temperature shall be lowered. The test voltage shall be maintained on the devices until  $T_C = +30^\circ\text{C} \pm 5^\circ\text{C}$  is attained. After bias is removed and prior to post test measurements, the devices shall be maintained at room ambient temperature and no voltage shall be applied prior to that voltage specified for the post test measurements. The post test end points shall be completed within the specified time after the bias voltage is removed. Any device which switches from the off-state to the on-state as indicated by a blown fuse shall be removed from the lot.

3. **Measurements.** Initial readings shall be taken prior to burn-in. Post-test readings shall be taken within 96 hours.

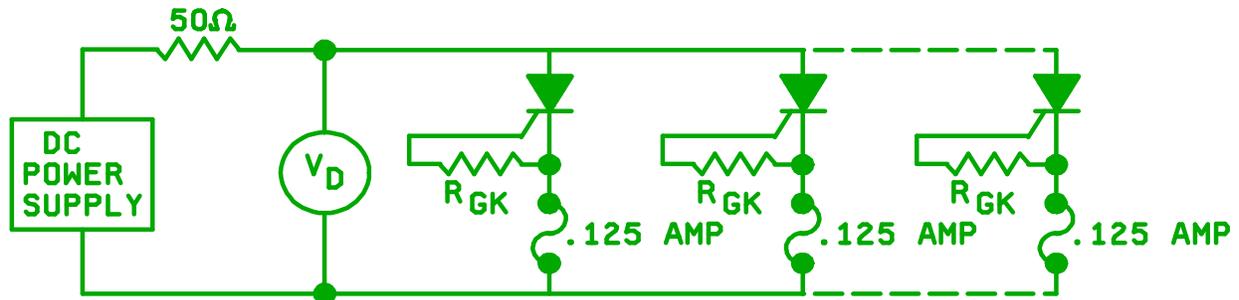


FIGURE 1040-2. DC forward blocking voltage circuit.

4. Summary. The test condition letter and the following conditions shall be specified in the detail specification:

- a. Test condition A:
  1. Peak forward and reverse blocking voltage (see 2.1).
  2. Test temperature (see 2.1).
  3. Duration of burn-in (see 2.1).
  4.  $R_{GK}$  (see figure 1040-1).
  5. Preburn-in and post burn-in measurements (see 3.).
- b. Test condition B:
  1. DC forward blocking voltage (see 2.2).
  2. Test temperature (see 2.2).
  3. Duration of burn-in (see 2.2).
  4.  $R_{GK}$  (see figure 1040-2).
  5. Preburn-in and post burn-in measurements (see 3.).

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METHOD 1041.3

SALT ATMOSPHERE (CORROSION)

1. Purpose. This test is an accelerated laboratory corrosion test simulating the effects of seacoast atmospheres on devices.
2. Apparatus. Apparatus used in the salt-atmosphere test shall include the following:
  - a. Exposure chamber with racks for supporting devices.
  - b. Salt-solution reservoir.
  - c. Means for atomizing the salt solution, including suitable nozzles and compressed-air supply.
  - d. Chamber-heating means and controls.
  - e. Means for humidifying the air at a temperature above the chamber temperature.
3. Procedure. The device shall be placed within the test chamber. Unless otherwise specified, a salt atmosphere fog having a temperature of +35°C (+95°F) shall be passed through the chamber for a period of 24 +2, -0 hours. The fog concentration and velocity shall be adjusted so that the rate of salt deposit in the test area is between 10 and 50 g/m<sup>2</sup>/day.
4. Examinations. Unless otherwise specified, upon completion of the test, and to aid in the examinations, devices shall be prepared in the following manner: Salt deposits shall be removed by a gentle wash or dip in running water not warmer than +37°C (+100°F) and a light brushing, using a soft-hair brush or plastic bristle brush. A device with illegible markings, leads missing, broken, or partially separated, evidence (when examined with 10X magnification) of flaking or pitting of the finish or corrosion exceeding five percent of the package area or five percent of the lead shall be considered a failure. Discoloration of the plating or lead finish shall not be considered a failure. The marking legibility requirement shall not apply to characters with a height of less than .030 inches (0.76 mm).
5. Summary. The following conditions shall be specified in the detail specification:
  - a. Time of exposure, if other than that specified (see 3.).
  - b. Measurements and examinations after test (see 4.).

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METHOD 1042.3

BURN-IN AND LIFE TEST FOR POWER MOSFET's OR  
INSULATED GATE BIPOLAR TRANSISTORS (IGBT)

1. Purpose. Test conditions A, B, and C are performed to eliminate marginal devices or those with defects resulting from manufacturing aberrations that are evidenced as time and stress failures under normal use conditions. Test condition D is performed to eliminate marginal lots with manufacturing defects. For the IGBT, replace the drain and source MOSFET designations with collector and emitter IGBT designations, D = C and S = E.

2. Procedure. The semiconductor device shall be subjected to the burn-in at the temperature and for the time specified herein. Preburn-in measurements shall be made as applicable. The failure criteria shall be as specified.

2.1.1 Test condition A, steady-state reverse bias. All devices shall be operated at 80 percent of the maximum rated drain to source voltage at the specified test temperature for 160 hours minimum, at the specified test conditions. The drain to source voltage, with gate to source shorted, shall be as specified. At the end of the high-temperature test time, specified herein, the ambient temperature shall be lowered. The burn-in voltage shall be maintained on the devices until  $T_C = 30^\circ\text{C} \pm 5^\circ\text{C}$  is attained. The interruption of bias for up to one minute for the purpose of moving devices to cool down positions separate from the chamber within which life testing was performed shall not be considered removal of bias.

After removal of the burn-in voltage, no other voltage shall be applied to the device before taking the post burn-in reverse current measurement(s). After burn-in voltage is removed, post burn-in measurements shall be completed within 96 hours, unless otherwise specified. (See figure 1042-1.) Unless otherwise specified, the burn-in temperature shall be  $T_A = 150^\circ\text{C}$ . The  $V_{DS}$  burn-in voltage shall be as follows. For IGBT devices, burn-in temperature shall be  $T_J = 150^\circ\text{C}$ ,  $-15^\circ\text{C}$  to  $+0^\circ\text{C}$ , and test time shall be 96 hours minimum.

If $V_{(BR)DSS}$ is	$V_{DS}$ shall be
20 V	16 V
30 V	24 V
40 V	32 V
60 V	48 V
80 V	64 V
90 V	72 V
100 V	80 V
120 V	96 V
150 V	120 V
170 V	136 V
200 V	160 V
240 V	192 V
350 V	280 V
400 V	320 V
450 V	360 V
500 V	400 V
600 V	480 V

$V_{(BR)DSS}$  voltages in between shall revert to the next lower  $V_{DS}$  burn-in voltage.

2.1.1.1 Temperature accelerated test details. In an accelerated test devices are subjected to bias conditions at a temperature exceeding the maximum rated junction temperature. The maximum ambient temperature for MOSFETs is  $+175^\circ\text{C}$  for a minimum of 48 hours. It is recommended that an adequate sample of devices be exposed to the high temperature while measuring the voltage(s) and current(s) of the devices to assure that the applied stresses do not induce damaging overstress. An adequate sample which has completed the accelerated test should also be subjected to a 1,000 hour steady state reverse bias at standard test conditions to assure the devices have not been deleteriously affected. Details of the accelerated test will be found in the detail and/or general specification.

2.1.2 Test condition B, steady-state gate bias. All devices shall be operated at 80 percent of the maximum rated gate to source voltage at the specified temperature for a minimum of 48 hours. (See figure 1042-2.) For MOS power transistors, the temperature and voltage shall be as specified. Unless otherwise specified, the temperature ( $T_A$ ) shall be 150°C.

If maximum rated $V_{GS}$ is 10 V	Burn-in voltage ( $V_{GS}$ ) shall be 8 V
15 V	12 V
20 V	16 V
30 V	24 V
40 V	32 V

$V_{GS}$  voltages in between shall revert to the next lower voltage.

2.1.3 Test condition C, steady-state power. All devices shall be operated at the maximum junction temperature +0°C, 24°C by means of applying power to the device while maintaining an ambient temperature of +25°C +10°C, -5°C. The junction temperature shall be verified by means of measuring junction temperature using the change in body diode voltage drop or calculated by applying the following equations:

$$T_J = R_{\theta JA} \times P_D + T_A \quad \text{Not heat sink used}$$

$$T_J = R_{\theta JC} \times P_D + T_C \quad \text{Heat sink used}$$

$T_C$  = Temperature of case

$T_A$  = Ambient air temperature

$T_S$  = Temperature of heat sink

$$P_D = V_{DS} \times I_D$$

$V_{DS}$  = Drain-source voltage

$I_D$  = Drain-source current

Note: The power indicated by the safe operating curve shall not be exceeded.

2.1.4 Test condition D, intermittent power. 1/ All devices shall be subjected to the number of cycles as specified. A cycle shall consist of applying power to the device for the time necessary to achieve a +100°C +15°C, -10°C minimum rise in junction temperature followed by an off period for the time necessary for the junction to cool. Forced air cooling is permitted during the off period only.

The power level, power-on time, and heat sink used, if any, shall be chosen to ensure that at the end of the heating cycle, the case temperature is not more than 15°C below the junction temperature. The rise in junction temperature during the on period shall be verified by means of measuring junction temperature using the change in body diode voltage drop or calculated by applying the following equations.

$$\Delta T_J = P_T R_{\theta JA} (1 - \text{Exp} - t/T_p) \text{ where } P_T = V_{DS} I_D$$

$T_p$  = thermal time constant of device package, and the heat sink used.

$t$  = heating time,  $R_{\theta JA}$  = thermal resistance junction to ambient, for the period of heating time specified, of the device and any necessary heat sink used.

This test is intended to allow the case temperature to rise and fall appreciably as the junction is heated and cooled; thus, it is not appropriate to use a large heat sink or a high power short pulse.

1/ This test condition is destructive.

3. Summary. Test condition letter and the following details shall be specified in the individual specification.

3.1 Test condition A.

- a. Drain to source voltage for MOS power field-effect transistors ( $V_{DS}$ ) (see 2.1.1).
- b. Test temperature, if other than specified in 2.1.1.
- c. Test time, if other than specified in 2.1.1.
- d. Voltage for post burn-in reverse current measurement (see 2.1.1).
- e. Criteria for failure.

3.2 Test condition B.

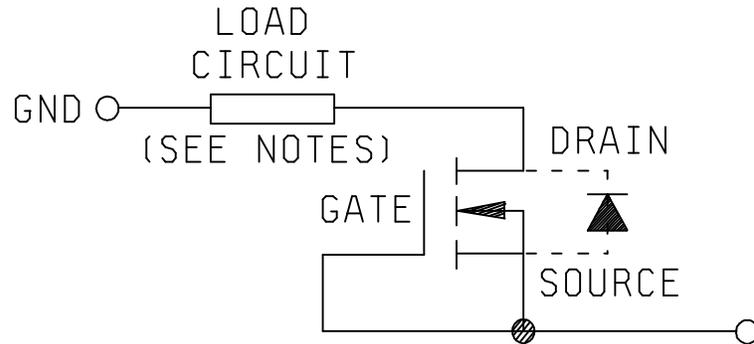
- a. Test temperature, if other than as specified in 2.1.2.
- b. Test conditions (see 2.1.2).
- c. Voltage for MOS power field-effect transistors (see 2.1.2).
- d. Preburn-in and post burn-in measurements.
- e. Criteria for failure.

3.3 Test condition C.

- a. Ambient temperature and thermal resistance (see 2.1.3).
- b. Voltage and current, if other than specified in 2.1.3.
- c. Preburn-in and post burn-in measurements.
- d. Total test time (see 2.1.3).
- e. Criteria for failure.

3.4 Test condition D.

- a. Ambient temperature (if one is desired) and thermal resistance (see 2.1.4).
- b. Voltage and current, if other than specified in 2.1.4.
- c. Pretest and post test measurements.
- d. Number of cycles (see 2.1.4).
- e. Criteria for failure.
- f. Minimum heating time.



NOTES:

1. The load circuit shall be selected or designed to ensure that the voltage across the load circuit of each acceptable device shall not exceed 10 percent of the specified test voltage. The load circuit may be a resistor, fuse, or circuit which:
  - a. Protects the power supply.
  - b. Isolates the defective devices from the other devices under test.
  - c. Insures a minimum of 98 percent of the specified test voltage is applied across the DUT.
2. If the circuit does not maintain bias on a failed device, then means must be provided to identify that device.

FIGURE 1042-1. High temperature reverse bias test circuit.

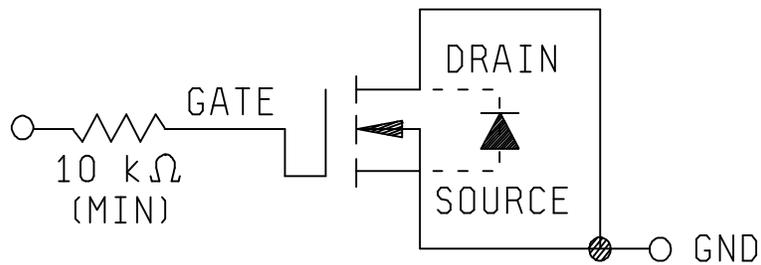


FIGURE 1042-2. High temperature gate bias circuit.

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METHOD 1046.3

SALT SPRAY (CORROSION)

1. Purpose. This test is proposed as an accelerated laboratory corrosion test simulating the effects of seacoast atmosphere on devices. This test can also be used to detect the presence of free iron contaminating the surface of another metal, by inspection of the corrosion products.

2. Apparatus. Apparatus used in the salt-spray test shall include the following:

- a. Exposure chamber with racks for supporting specimens.
- b. Salt-solution reservoir with means for monitoring an adequate level of solution.
- c. Means for atomizing the salt solution, including suitable nozzles and compressed-air supply.
- d. Chamber-heating means and control.
- e. Means for humidifying the air at a temperature above the chamber temperature.

2.1 Chamber. The chamber and all accessories shall be made of material which will not affect the corrosiveness of the fog, such as glass, hard rubber, or plastic. Wood or plywood should not be used because they are resiniferous. Materials should not be used if they contain formaldehyde or phenol in their composition. In addition, all parts which come in contact with test specimens shall be of materials that will not cause electrolytic corrosion. The chamber and accessories shall be so constructed and arranged that there is no direct impinging of the spray or dripping of the condensate on the specimens, so that the spray circulates freely about all specimens to the same degree, and so that no liquid which has come in contact with the test specimens returns to the salt-solution reservoir. The chamber shall be properly vented to prevent pressure build up and allow uniform distribution of salt spray. The discharge end of the vent shall be protected from strong drafts which can cause strong air current in the chamber.

2.2 Atomizers. The atomizer of atomizers used shall be of such design and construction as to produce a finely divided, wet dense fog. Atomizing nozzle shall be made of material which does not react with the salt solution.

2.3 Air supply. The compressed air entering the atomizers shall be free from all impurities such as oil and dirt. Means shall be provided to humidify and warm the compressed air as required to meet the operating conditions. The air pressure shall be suitable to produce a finely divided dense fog with the atomizer or atomizers used. To insure against clogging the atomizers by salt deposition, the air should have a relative humidity of 95 to 98 percent at the point of release from the nozzle. A satisfactory method is to pass the air in very fine bubbles through a tower containing heated water. The temperature of the water should be +95°F (+35°C) and often higher. The permissible temperature increased with increasing volume of air and with decreasing heat insulation of the chamber and temperature of its surroundings. It should not exceed a value above which an excess of moisture is introduced into the chamber (for example, +110°F (+43.3°C) at an air pressure of 12 pounds per square inch), or a value which makes it impossible to meet the requirement for operating temperature.

2.4 Salt solution. The salt-solution concentration shall be 5 percent by weight. The salt used shall be sodium chloride containing on the dry basis of more than 0.1 percent of sodium iodide, and not more than 0.5 percent of total impurities. The 5-percent solution shall be prepared by dissolving 5 ±1 parts by weight of salt in 95 parts by weight of distilled or other water. Distilled or other water used in the preparation of solutions shall contain not more than 200 parts per million of total solids. The solution shall be kept free from solids by filtration using a filter similar to that shown on figure 1046-1, and located in the salt solution reservoir in a manner such as that illustrated on figure 1046-2. The solution shall be adjusted to and maintained at a specific gravity in accordance with figure 1046-3. The pH shall be maintained between 6.5 and 7.2 when measured at temperature between +93°F and +97°F (+33.9°C and +36.1°C). Only dilute cp grade hydrochloric acid or sodium hydroxide shall be used to adjust the pH. The pH measurement shall be made electrometrically using a glass electrode with a saturated potassium-chloride bridge or by a colorimetric method such as bromothymol blue, provided the results are equivalent to those obtained with the electrometric method.

2.5 Filter. A filter fabricated of noncorrosive materials similar to that shown on figure 1046-1 shall be provided in the supply line and immersed in the reservoir in a manner such as shown on figure 1046-2.

2.6 Preparation of specimens. Specimens shall be given a minimum of handling, particularly on the significant surfaces, and shall be prepared for test immediately before exposure. Unless otherwise specified, uncoated metallic or metallic-coated specimens shall be thoroughly cleaned of oil, dirt, and grease as necessary until the surface is free from water break. The cleaning methods shall not include the use of corrosive solvents nor solvents which deposit wither corrosive or protective films, nor the use of abrasives other than a paste of pure magnesium oxide. Specimens having an organic coating shall not be solvent cleaned. Those portions of specimens which comes in contact with the support and, unless otherwise specified in the case of coated specimens or samples, cut edges and surfaces not required to be coated, shall be protected with a suitable coating of wax or similar substance impervious to moisture.

3. Procedure. The following exceptions shall apply:

- a. At the conclusion of the test, the device will be dried for 24 hours at  $+40^{\circ}\text{C} \pm 5^{\circ}\text{C}$  before the examination. A device with illegible marking, evidence (when examined without magnification) of flaking or pitting of the finish or corrosion that will interfere with the application of the device shall be considered a failure.
- b. Unless otherwise specified, salt solution shall be 20 percent by weight.

3.1 Location of specimens. Unless otherwise specified, flat specimens and, where practicable, other specimens shall be supported in such a position that the significant surface is approximately  $15^{\circ}$  from the vertical and parallel to the principal direction of horizontal flow of the fog through the chamber. Other specimens shall be positioned so as to insure most uniform exposure. Whenever practicable, the specimens shall be supported from the bottom or from the side. When specimens are suspended from the top, suspension shall be by means of glass or plastic hooks or wax string; if plastic hooks are used, they shall be fabricated of material which is nonreactive to the salt solution such as Lucite. The used of metal hooks is not permitted. Specimens shall be positioned so that they do not contact each other, so that they do not shield each other from the freely settling fog, and so that corrosion products and condensate from one specimen do not fall upon another.

3.2 Operating conditions.

3.2.1 Temperature. The test shall be conducted with a temperature in the exposure zone maintained at  $+95^{\circ}\text{F} +2^{\circ}\text{F}$ ,  $-3^{\circ}\text{F}$  ( $+35^{\circ}\text{C} +1.1^{\circ}\text{C}$ ,  $-1.7^{\circ}\text{C}$ ). Satisfactory methods for controlling the temperature accurately are by housing the apparatus in a properly controlled constant-temperature room, by thoroughly insulating the apparatus and preheating the air to the proper temperature prior to atomization, and by jacketing the apparatus and controlling the temperature of the water or of the air used. The use of immersion heaters for the purpose of maintaining the temperature within the chamber is prohibited.

3.2.2 Atomization. The conditions maintained in all parts of the exposure zone shall be such that a suitable receptacle placed at any point in the exposure zone will collect from 0.5 to 3.0 milliliters of solution per hour for each 80 square centimeters of horizontal collecting area (10 centimeters diameter) based on an average run of at least 16 hours. The 5-percent solution thus collected shall have a sodium-chloride content of from 4 to 6 percent (specific gravity) in accordance with figure 1046-3 when measured at a temperature between  $+93^{\circ}\text{F}$  and  $+97^{\circ}\text{F}$  ( $+33.9^{\circ}\text{C}$  and  $+36.1^{\circ}\text{C}$ ). At least two clean fog-collecting receptacles shall be used, one placed near any nozzle and one placed as far as possible from all nozzles. Receptacles shall be fastened so that they are no shielded by specimens and so that no drops of solution from specimens or other sources will be collected. The specific gravity and quantity of the solution collected shall be checked following each salt-spray test. Suitable atomization has been obtained in boxes having a volume of less than 12 cubic feet with the following conditions:

- a. Nozzle pressure of from 12 to 18 pounds per square inch.
- b. Orifices of from 0.02 to 0.03 inch in diameter.
- c. Atomization of approximately 3 quarts of the salt solution per 10 cubic feet of box volume per 24 hours.

When using large-size boxes having a volume considerably in excess of 12 cubic feet, the above conditions may have to be modified in order to meet the requirements for operating conditions.

3.3 Length of test. The length of the salt-spray test shall be that indicated in one of the following test conditions, as specified:

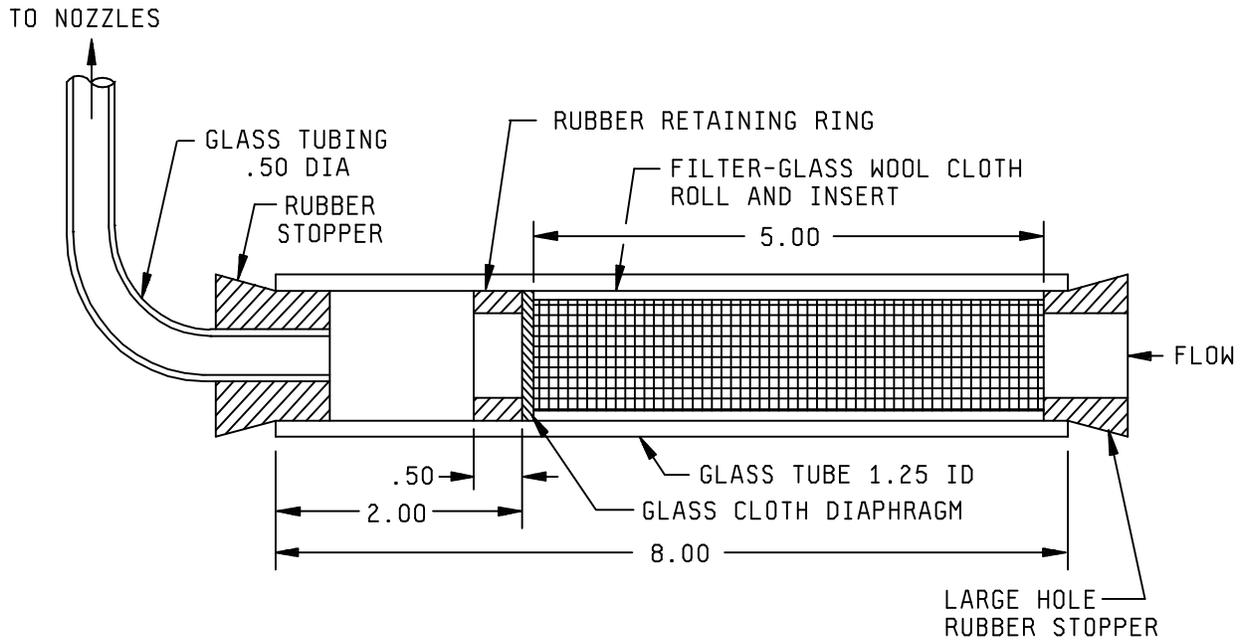
<u>Test condition</u>		<u>Length of test</u>
A	-----	96 hours
B	-----	48 hours

Unless otherwise specified, the test shall be run continuously for the time indicated or until definite indication of failure is observed, with no interruption except for adjustment of the apparatus and inspection of the specimen.

4. Measurements. At the completion of the exposure period, measurements shall be made as specified. To aid in examination, specimens shall be prepared in the following manner, unless otherwise specified: Salt deposits shall be removed by a gentle wash or dip in running water not warmer than +100°F (+37.8°C) and a light brushing, using a soft-hair brush or plastic-bristle brush.

5. Summary. The following details are to be specified in the individual specification:

- a. Special mounting and details, if applicable (see 3.1)
- b. Test condition letter (see 3.3)
- c. Measurements after exposure (see 4).



Inches	Millimeters
0.50	12.70
1.25	31.75
2.00	50.80
5.00	127.00
8.00	203.20

FIGURE 1046-1. Salt solution filter.

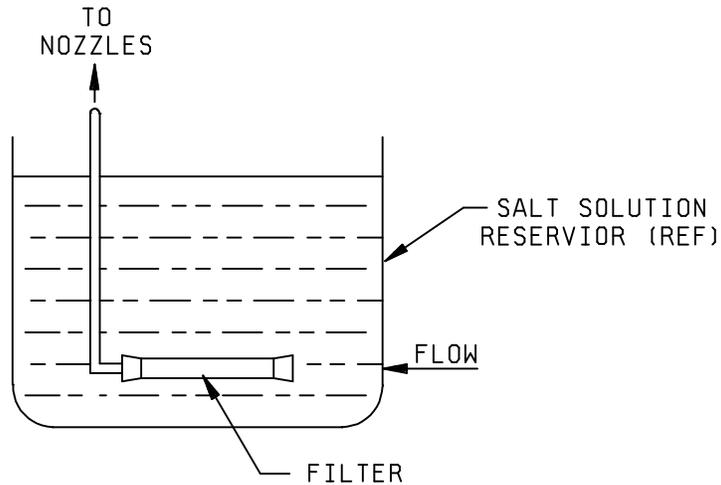


FIGURE 1046-2. Location of salt solution filter.

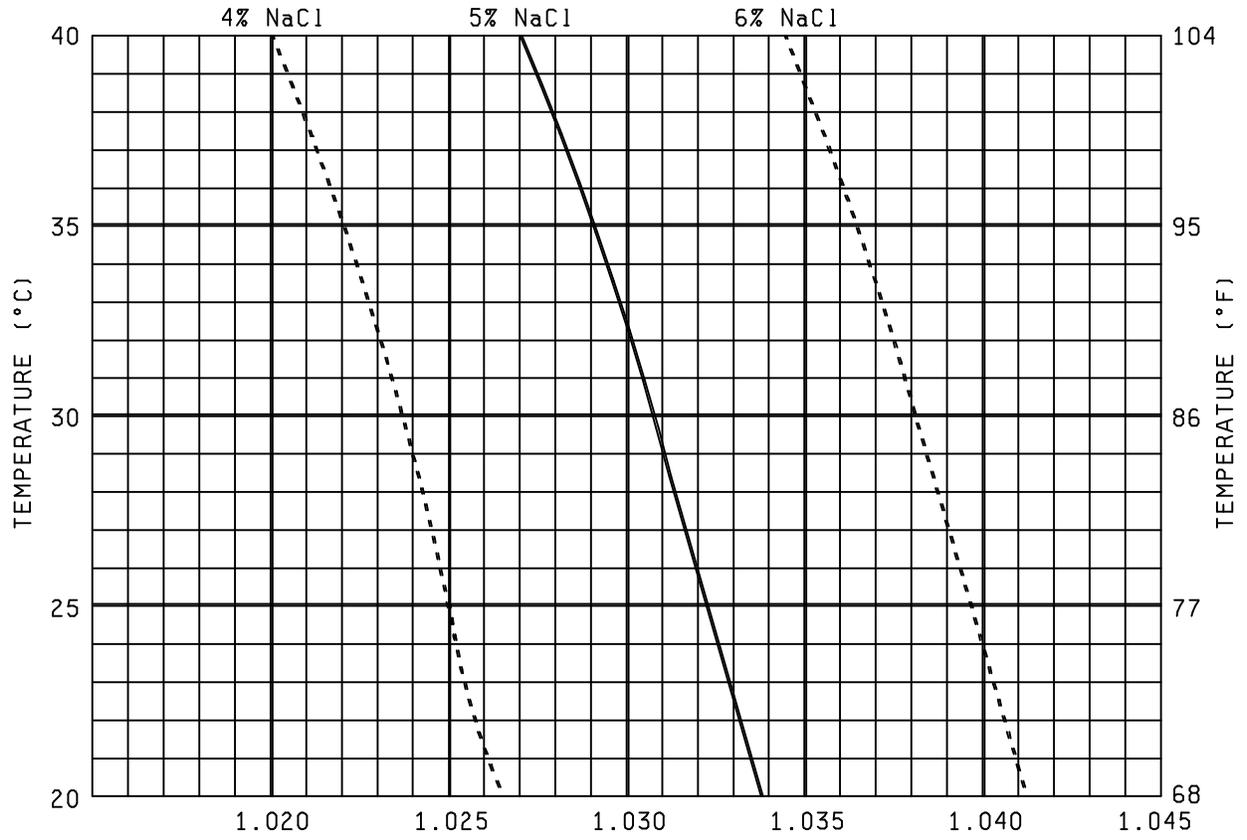


FIGURE 1046-3. Variations of specific gravity of salt (NaCl) solution with temperature.

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METHOD 1048

BLOCKING LIFE

1. Purpose. The purpose of this test is to determine compliance with the specified lambda for devices subjected to the specified conditions.

2. Mounting. The method of mounting is usually optional for blocking life tests since little power is dissipated in the device. (Devices with normally high reverse leakage current may be mounted to heat sinks to prevent thermal run-away conditions.)

3. Procedure. Blocking life is performed with the primary blocking junction, or insulation, reverse biased at an artificially elevated temperature for the time period in accordance with the life test requirements of MIL-S-19500 and herein; at the temperature specified (normally +150°C and at 80 to 85 percent of the rated voltage relevant to the device ( $V_R$ ,  $V_Z(\min)$ ,  $V_{CB}$ ,  $V_{AG}$ ,  $V_{DG}$ , and  $V_{GS}$ ).

At the end of the high-temperature test time, as specified, the ambient temperature shall be lowered. The test voltage shall be maintained on the devices until a case temperature of  $+30^\circ\text{C} \pm 5^\circ\text{C}$  is attained. After this ambient temperature has been established, the bias voltage shall be maintained until testing is performed; testing shall be completed within 24 hours after the removal of power. After removal of the bias voltage, no other voltage shall be applied to the device before taking the post test leakage current measurement. Post test measurements shall be taken as specified.

4. Summary. The following details shall be specified in the applicable detail specification:

- a. Test temperature (see 3.).
- b. Test conditions: Voltage and terminals to be biased (see 2. and 3.).
- c. Test time (see 3.).
- d. Pre and post test measurements (see 3.).
- e. Time for completion of post test measurements, if other than 24 hours.

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METHOD 1051.5

TEMPERATURE CYCLING (AIR TO AIR)

1. Purpose. This test is conducted to determine the resistance of a part to extremes of high and low temperatures, and to the effect of alternate exposures to these extremes.

1.1 Terms and definitions.

1.1.1 Load. The specimens under test and the fixtures holding those specimens during the test. Maximum load shall be determined by using the worst case load temperature with specific specimen loading. Monolithic loads used to simulate loading may not be appropriate when air circulation is reduced by load configuration. The maximum loading must meet the specified conditions.

1.1.2 Monitoring sensor. The temperature sensor that is located and calibrated so as to indicate the same temperature as at the worst case indicator specimen location. The worst case indicator specimen location is identified during the periodic characterization of the worst case load temperature.

1.1.3 Worst case load temperature. The worst case load temperature is the temperature of a specific area in the chamber when measured by thermocouples located at the center and at each corner of the load. The worst case load temperature shall be determined at periodic intervals.

1.1.4 Working zone. The volume in the chamber(s) in which the temperature of the load is controlled within the limits specified in table 1051-I.

1.1.5 Specimen. The device or individual piece being tested.

1.1.6 Transfer time. The elapsed time between specimen removal from one temperature extreme and introduction into the other.

1.1.7 Maximum load. The largest load for which the worst case load temperature meets the timing requirements (see 3.1).

1.1.8 Dwell time. The time from introduction of the load into the chamber until the load is transferred out of the chamber.

2. Apparatus. The chamber(s) used shall be capable of providing and controlling the specified temperatures in the working zone(s) when the chamber is loaded with a maximum load. The thermal capacity and air circulation must enable the working zone and loads to meet the specified conditions and timing (see 3.1). Worst case load temperature shall be continually monitored during test by indicators or recorders reading the monitoring sensor. Direct heat conduction to specimens shall be minimized.

3. Procedure. Specimens shall be placed in such a position with respect to the air stream that there is substantially no obstruction to the flow of air across and around the specimen. When special mounting is required, it shall be specified. The specimen shall then be subjected to the specified condition for the specified number of cycles performed continuously. This test shall be conducted for a minimum of 20 cycles using test condition C. One cycle consists of steps 1 and 2 or the applicable test condition to be counted as a cycle. Completion of the total number of cycles specified for the test may be interrupted for the purpose of test chamber loading or unloading of device lots or as the result of power or equipment failure. However, if for any reason the number of incomplete cycles exceed 10 percent of the total number of cycles specified, one cycle must be added for each incomplete cycle.

3.1 Timing. The total transfer time from hot to cold or from cold to hot shall not exceed one minute. The load may be transferred when the worst case load temperature is within the limits specified in table 1051-I. However, the dwell time shall not be less than 10 minutes and the load shall reach the specified temperature within 15 minutes.

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TABLE 1051-I. Temperature-cycling test conditions.

Step	Minutes	Test condition temperature (°C)						
		A	B	C	D	E	F	G
1 Cold	≥ 10	-55 +0 -10	-55 +0 -10	-55 +0 -10	-65 +0 -10	-65 +0 -10	-65 +0 -10	-55 +0 -10
2 Hot	≥ 10	85 +10 -0	125 +15 -0	175 +15 -0	200 +15 -0	300 +15 -0	150 +15 -0	150 +15 -0

NOTE: Steps 1 and 2 may be interchanged. The load temperature may exceed the + or - zero (0) tolerance during the recovery time. Other tolerances shall not be exceeded.

4. Summary. The following details shall be specified in the applicable detail specification:

- a. Special mounting, if applicable (see 3.).
- b. Test condition letter, if other than test condition C (see 3.).
- c. Number of test cycles, if other than 20 cycles (see 3.).
- d. End-point measurements and examinations, e.g., end-point electrical measurements, seal test (method 1071), or other acceptance criteria).

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METHOD 1054.1

POTTED ENVIRONMENT STRESS TEST

1. Purpose. The purpose of this test is to determine device design susceptibility to intermittent open failures in conformally coated circuit boards environments while under thermal cycle. The destructive effects of tension and compression are magnified in the potted condition allowing for early detection of design weakness.

2. Equipment.

- a. Container of three cubic inches minimum with rigid walls of .125 inch (3.18 mm) minimum.
- b. Devices for testing corrected to a common bussbar arranged in a common cathode or common anode configuration (see figure 1054-1).
- c. Thermal cycling chamber.
- d. Hot plate capable of maintaining +70°C.
- e. Curve tracer, Tektronix 576 or equivalent.
- f. Potting medium, Emerson and Cuming Stycast 2851 MT or equivalent.

3. Procedure:

- a. Place devices in a common connection configuration into the container with provisions made to ensure device clearance of .125 inch (3.18 mm) minimum from the container walls.

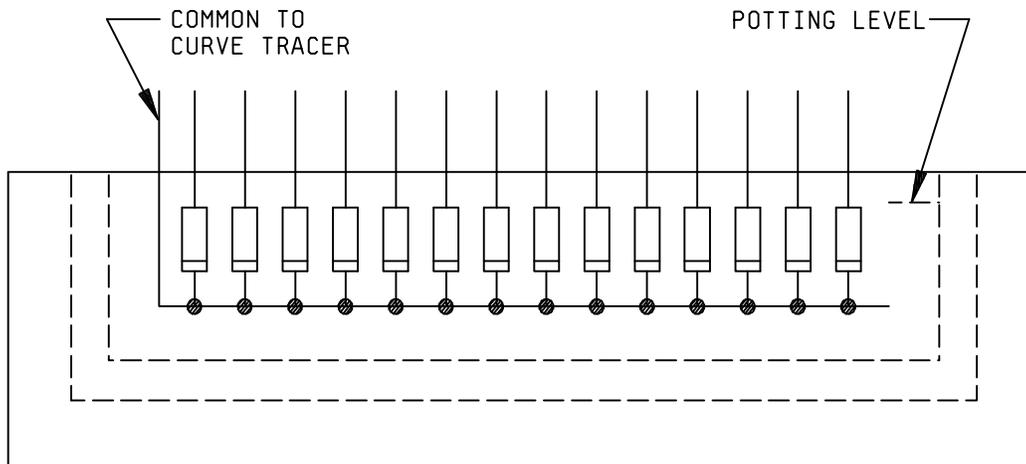


FIGURE 1054-1. Potted diodes.

- b. Pour stycast potting compound into shell and allow to cure while following all manufacturer's recommendations.

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- c. Place cured assembly on a hot plate and allow the assembly to reach thermal equilibrium of +70°C. Unless otherwise specified, observe the forward voltage trace of each device at a current level of 100 mA. Forward voltage trace should show no incidence of instability or open condition. Record all failures by serial number.
- d. Allow assembly to cool at room temperature and place into a thermal shock chamber to perform 20 shocks in accordance with method 1051 herein. Remove assembly and allow to reach room temperature.
- e. Repeat 3.c. and record failures.

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METHOD 1055.1

MONITORED MISSION TEMPERATURE CYCLE

1. Purpose. This test is to determine the ability of devices to withstand the effect of thermal stress and rapid dimensional change on internal structural elements caused by the application of power in rapidly changing temperature environments as in mission profile system testing.
2. Apparatus. The equipment required shall consist of that listed below and shall have the stated capabilities.
  - a. A chamber of sufficient temperature range and change rate capability with cabling exiting through insulated barriers to external bias and monitoring electronics. Cabling for all monitoring equipment shall provide Kelvin connections.
  - b. Electronic regulated power supply(s) capable of maintaining the stated bias tolerances.
  - c. Electronic voltage monitoring device with capability of indicating an open circuit of 20 ms or more in duration.
3. Procedure.
  - a. Devices conforming to all electrical and mechanical parameter requirements shall be first subjected to high temperature stabilization bake of method 1032 herein. They shall then be subjected to non-operational thermal shock of method 1051 herein, except that no dwell time is required at +25°C. Test condition "C" shall be +175°C, +5°C, -0°C. Temperature shall remain at the stabilized extremes for 10 minutes minimum.
  - b. Electrical measurements shall be performed to ensure that proceeding to the monitored thermal cycle portion of this test all devices have remained within specification.
  - c. Unless otherwise specified, the temperature extremes shall be as stated below (from worse case mission profile requirements of table I in MIL-STD-781).
  - d. The temperature and operating profile shall be specified on figure 1055-1. Temperature change rate shall average not less than 5°C per minute, but not greater than 10°C per minute.
  - e. The device(s) shall be placed individually or in series connection within the chamber. The device(s) shall be connected to a constant current power supply capable of supplying current to raise the device junction(s) to +125°C minimum, +150°C maximum temperature during the high temperature portion of each cycle.

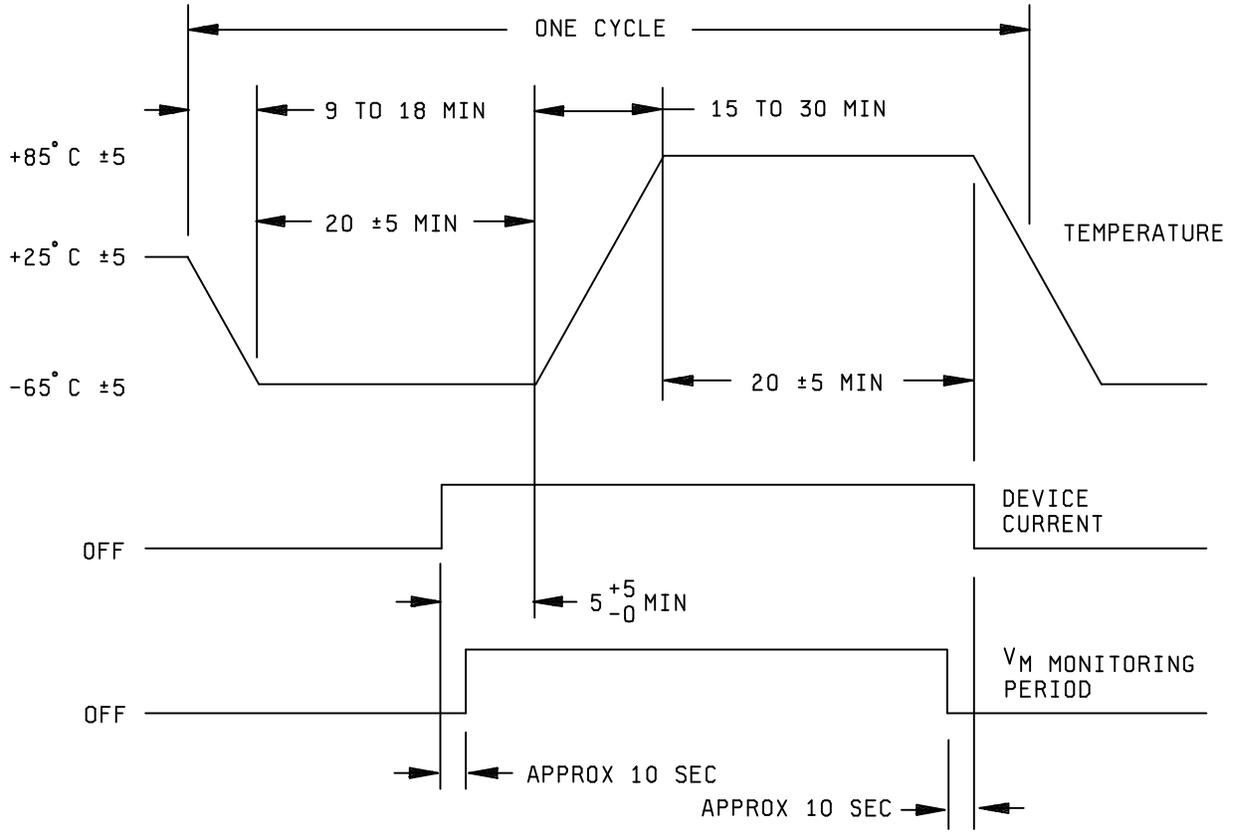


FIGURE 1055-1. Monitored mission cycle.

3.1 **Electrical monitoring.** Connect electrical monitoring volt meter leads to the extremes of the device(s) and series resistor (see figure 1055-2). Apply the current to raise each junction temperature approximately +50°C. The value of R shall be chosen to cause a 10 ±3 percent increase in monitoring voltage,  $V_M$ , if open circuit occurs. Open switch S1 and verify an increase in  $V_M$  to verify circuit operation. Remove power.

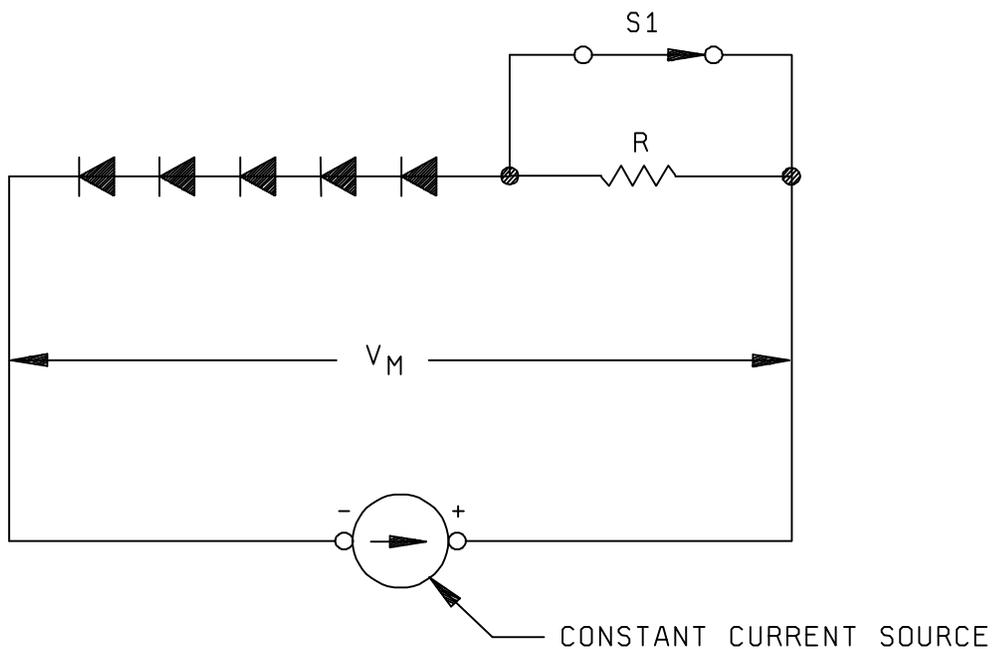


FIGURE 1055-2. Monitored mission cycle.

3.2 **Monitoring voltage increase.** Close S1 and perform six cycles of figure 1055-1 while monitoring for increases in voltage level above the highest (cold temperature) value.

3.3 **Failures.** Failures in the first two cycles may be considered non-chargeable de-bug events, if analysis finds fault with test circuitry. The last four cycles shall be failure free.

NOTE: Unless otherwise specified, a momentary, or continuous, open circuit (indicated by an increase in the monitored voltage) in any of the last four cycles, shall be considered failure.

METHOD 1056.7

THERMAL SHOCK (LIQUID TO LIQUID)

1. Purpose. This test is conducted to determine the resistance of the part to sudden exposure to extreme changes in temperature and to the effect of alternate exposures to these extremes.

1.1 Terms and definitions.

1.1.1 Cycle. A cycle consists of starting at ambient room temperature, proceeding to step 1, then to step 2, or alternately proceeding to step 2, then to step 1, and then back to ambient room temperature without interruption.

1.1.2 Dwell time. The total time the load is immersed in the bath.

1.1.3 Load. The DUTs and the fixtures holding those devices.

1.1.4 Maximum load. The maximum mass of devices and fixtures that can be placed in the bath while maintaining specified temperatures and times.

1.1.5 Specimen. The device or individual piece being tested.

1.1.6 Transfer time. The elapsed time measured from removal of the load from one bath until insertion in the other bath.

1.1.7 Worst case load temperature. The body temperature of a specific device located at the center of the load.

2. Apparatus. The baths used shall be capable of providing and controlling the specified temperatures in the working zone(s) when the bath is loaded with a maximum load. The thermal capacity and liquid circulation must enable the working zone and loads to meet the specified conditions and timing (see 3.1). Worst case load temperature shall be continually monitored during test by indicators or recorders reading the monitoring sensor(s). The worst case load temperature under maximum load conditions and configuration shall be verified as needed to validate bath performance. Perfluorocarbons that meet the physical property requirements of table 1056.II shall be used for conditions B and C.

3. Procedure. Specimens shall be placed in the bath in a position so that the flow of liquid across and around them is substantially unobstructed. The load shall then be subjected to condition A or as otherwise specified (see 4b) of table 1056.I for a duration of 15 cycles. Completion of the total number of cycles specified for the test may be interrupted for the purpose of loading or unloading of device lots or as the result of power or equipment failure. However, if the number of interruptions for any given test exceeds 10 percent of the total number of cycles specified, the test must be restarted from the beginning.

3.1 Timing. The total transfer time from hot to cold or from cold to hot shall not exceed 10 seconds. The load may be transferred when the worst case load temperature is within the limits specified in table 1056.II. However, the dwell time shall not be less than 2 minutes and the load shall reach the specified temperature within 5 minutes.

4. Summary. The following details shall be specified in the applicable detail specification.

- a. Special mounting, if applicable.
- b. Test condition, if other than test condition B (see 3.).
- c. Number of test cycles, if other than 15 cycles (see 3.).
- d. End-point measurements and examinations such as end-point electrical measurements, seal test (method 1071), or other acceptance criteria).

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TABLE 1056.I. Physical property requirements of perfluorocarbon fluids. <sup>1/</sup>

Test condition		B	C	ASTM test method
Step 1	Boiling point, °C	>125	>150	D1120
	Density at 25°C gm/ml	>1.6		D941
	Dielectric strength volts/mil	>300		D877
	Residue, microgram/gram	<50		D2109
	Appearance	Clear, colorless liquid		Not applicable
Step 2	Density at 25°C gm/ml	>1.6		D941
	Dielectric strength volts/mil	>300		D877
	Residue, microgram/gram	<50		D2109
	Appearance	Clear, colorless liquid		Not applicable

<sup>1/</sup> The perfluorocarbon used shall have a viscosity less than or equal to the thermal shock equipment manufacturer's recommended viscosity at the minimum temperature.

TABLE 1056.II. Thermal shock temperature tolerances and suggested fluids. <sup>1/</sup>

Test conditions		A and B	C	D
		Temperature	Temperature	Temperature
Step 1	Temperature tolerance, °C	100 +10 -2	125 +10 -0	150 +10 -0
	Recommended fluid	Water <sup>2/</sup> or perfluoro-carbon <sup>3/</sup>	Perfluoro-carbon <sup>3/</sup>	Perfluoro-carbon <sup>3/</sup>
Step 2	Temperature tolerance, °C	-0 +2 -10	-55 +0 -10	-65 +0 -10
	Recommended fluid	Water <sup>2/</sup> or perfluoro-carbon <sup>3/</sup>	Perfluoro-carbon <sup>3/</sup>	Perfluoro-carbon <sup>3/</sup>

<sup>1/</sup> Ethylene glycol shall not be used as a thermal shock test fluid.

<sup>2/</sup> Water is indicated as an acceptable fluid for this temperature range. Its suitability chemically shall be established prior to use. When water is used as the fluid of for condition A and the specified temperature tolerances are insufficient due to altitude considerations, the following alternate test conditions may be used.

a. Temperature: +100°C -6°C, 0°C +6°C.

b. Cycles shall be increased to 20.

<sup>3/</sup> Perfluorocarbons contain no chlorine or hydrogen.

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NOTICE 5

METHOD 1057

RESISTANCE TO GLASS CRACKING

1. Purpose. This method provides a means of judging the relative resistance of glass encapsulated electronic components to cracking under conditions of thermal stress. It employs immersion in a hot liquid then water to simulate the thermal stresses associated with both device manufacturing processes and end user assembly procedures.

2. Apparatus. Liquid baths shall be used which are capable of providing and maintaining the specified temperatures in the working zone when loaded with a maximum load. Bath temperatures under maximum load conditions shall be verified as needed to validate bath performance. Liquid composition shall be as specified herein.

3. Procedure. Remove any paint or other surface coatings. Clean test specimens using a general purpose cleaner/degreaser and rinse in water then acetone. Subsequent to cleaning, specimens shall be placed into the baths defined in table I for the applicable test condition using a dipping tool that will not significantly heat sink the body of the device under test. Specimens shall be fully immersed in the first bath for the specified period of time then transferred immediately to and fully immersed in the second bath. Unless otherwise specified, the test shall be considered complete upon removal of the specimen from the second bath.

3.1 Timing. Specimens shall be immersed into and removed from the first (hot) bath at a rate of  $1.0 \pm 0.5$  inch ( $25.4 \pm 12.7$  mm) per second. The maximum dwell time above the hot bath prior to immersion shall be 7.0 seconds. Dwell time in the hot bath shall be  $6 \pm 1.0$  seconds. Specimens shall be released completely into the second bath within 3 seconds of their removal from the hot bath.

4. Failure criteria. Specimens that fail to meet the glass crack criteria of method 2074 of MIL-STD 750 shall be considered rejects.

5. Summary. The following shall be specified in the applicable performance specification.

- a. Sample size and acceptance number.
- b. Test condition.
- c. Special fixturing as applicable.
- d. Number of test cycles if other than 1 cycle.

TABLE I. Conditions and temperatures.

Step		Test condition and temperatures	
		A	B
1	Temperature and tolerance	100°C ±5°C	235°C ±5°C
	Recommended fluid	Water	Molten solder
2	Temperature and tolerance	0°C ±5°C	25°C ± 5°C
	Recommended fluid	Water	Water

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METHOD 1061.1

TEMPERATURE MEASUREMENT,  
CASE AND STUD

1. Purpose. This proposal covers a method of measuring case temperature of hex-base devices.

2. Test equipment.

2.1 Type of thermocouple. The thermocouple material shall be copper-constantan, as recommended by the "Standard Handbook for Electrical Engineers", for the range of -190°C to +350°C. The wire size shall be no larger than AWG size 30. The junction of the thermocouple shall be welded together to form a bead rather than soldered or twisted.

2.2 Accuracy. The thermocouple shall have an accuracy of  $\pm 0.5^\circ\text{C}$ . Under load conditions, slight variations in the temperature of different points on the case may reduce this accuracy to  $\pm 1.0^\circ\text{C}$  for convection cooling, and  $\pm 2.0^\circ\text{C}$  for forced air ventilation.

3. Procedure.

3.1 Method of mounting. A small hole, just large enough to insert the thermocouple, shall be drilled approximately .031 inch (0.79 mm) deep into the flat of the case hex at a point chosen by the manufacturer. The edge of the hole should then be peened with a small center punch to force a rigid mechanical contact with the welded bead of the thermocouple. If forced air ventilation is used, the thermocouple shall be mounted away from the air stream and the thermocouple leads close to the junction shall be shielded.

3.2 Other methods of mounting. Other methods of mounting thermocouple, with the possible exception of the thermocouple welded directly to the case, will result in temperature readings lower than the actual temperature. These deviations will result from:

- a. Inadequate contact with the case using cemented thermocouples.
- b. External heat sink in contact with the thermocouple using pressure contacts.

4. Summary. The following conditions shall be specified in the detail specification:

- a. Method of mounting (see 3.).
- b. Test equipment, if required.

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METHOD 1066.1

DEW POINT

1. Purpose. The purpose of this test is to monitor the device parameter for a discontinuity under the specified conditions.
2. Apparatus. The apparatus used in this test shall be capable of varying the temperature from the specified high temperature to -65°C and return to the specified high temperature while the parameter is being measured.
3. Procedure. The voltage and current specified in the detail specification shall be applied to the terminals and the parameter monitored from the specified high temperature to -65°C and return to the specified high temperature. The dew point temperature is indicated by a sharp discontinuity in the parameter being measured with respect to temperature. If no discontinuity is observed, it shall be assumed that the dew point is at a temperature lower than -65°C and the DUT is acceptable.
4. Summary. The following conditions shall be specified in the detail specification:
  - a. Test temperature (high) (see 2.).
  - b. Test voltage and current (see 3.).
  - c. Test parameter (see 3.).

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NOTICE 4

METHOD 1071.7

HERMETIC SEAL

1. Purpose. The purpose of this test is to determine the hermeticity of semiconductor devices with designed internal cavities.

2. Definitions.

- a. Standard leak rate. Standard leak rate is defined as that quantity of dry air at +25°C in atmospheric cubic centimeters flowing through a leak or multiple leak paths per second when the high-pressure side is at 15 psi (101 kPa) and the low-pressure side is at a pressure of not greater than .0193 psi (133 pA). Standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm<sup>3</sup>/s air).
- b. Measured leak rate. Measured leak rate (R<sub>1</sub>) is defined as the leak rate of a given package as measured under specified conditions and employing a specified test medium. Measured leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm<sup>3</sup>/s of the gas medium used for the test). For purposes of comparison with rates determined by other methods of testing, the measured leak rates must be converted to the equivalent standard leak rates, (converted to air equivalents).
- c. Equivalent standard leak rate. The equivalent standard leak rate (L) of a given package, with a measured leak rate (R<sub>1</sub>), is defined as the leak rate of the same package with the same leak geometry, that would exist under the standard leak rate. The equivalent standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm<sup>3</sup>/s) (air).

NOTE: The leak rate measurements are not necessarily performed with a one atmosphere differential, as implied by the standard leak rate. The equivalent conversion represents gas medium only.

3. Test conditions.

- a. Gross leaks. Test conditions A, B, C, D, E, J, K, or L should be specified for gross leaks.
  - (1) Test condition A: Radioisotope wet gross leak test (see 4.).
  - (2) Test condition B: Radioisotope dry gross leak test (see 5.).
  - (3) Test condition C: Liquid (fluorocarbon) gross leak (see 6.).
  - (4) Test condition D: Bubble test (see 3b).
  - (5) Test condition E: Penetrant dye gross leak (see 8.).
  - (6) Test condition J: Weight gain gross leak (see 11.).
  - (7) Test condition K: Fluorocarbon vapor detection gross leak (see 12.).
  - (8) Test condition L<sub>1</sub>: Optical gross leak (see 13).
- b. Gross leaks. Test condition D may be specified when a sensitivity of 1 x 10<sup>-3</sup> atm cm<sup>3</sup>/s or greater will satisfy reliability requirements. This condition shall not be used for devices that have internal free volumes of less than 1 cm<sup>3</sup>.

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NOTICE 4

- c. Fine leak. Test condition G, H, or L should be specified for the fine leak test.
  - (1) Test condition G: Radioisotope fine leak test (see 9.).
  - (2) Test conditions H<sub>1</sub> and H<sub>2</sub>: Tracer gas leak test (Helium) (see 10.).
  - (3) Test conditions L<sub>2</sub>: Optical fine leak test (see 13.).
- d. Obsolete.
- e. Fine and gross leak test procedure. Unless otherwise specified by applicable detail specification, tests shall be conducted in accordance with table 1071-I. When specified (see 14.) measurements after test shall be conducted following the leak test procedures. Where bomb pressure specified exceeds the device package capability, alternate pressure, exposure time, and dwell time conditions may be used provided they satisfy the leak rate, pressure, and time relationships which apply and provided no less than 30 psi (207 kPa) bomb pressure is applied in any case, or for condition L<sub>1</sub>, a minimum 10 psi differential test pressure is applied.

Fine and gross leak tests shall be conducted in accordance with the requirements and procedures of the specified test condition. Testing order shall utilize only the all-dry gas tests first, followed by any liquid immersion gross leak test (i.e.; the option to use the radioisotope gross and fine leak test conditions B and G<sub>1</sub>, may be used together, or in succession, as long as the minimum test requirements are met). Optical gross leak test (L<sub>1</sub>) is an all-dry gas test and can be used before any fine leak test. If any other gross leak test is used, (condition A, C, D, E, F, J, or K), the sequence of testing must use the dry gas fine leak test first, followed by the gross leak test except in accordance with 15a. When batch testing (more than one device in the leak detector at one time) is used in performing test condition G, H<sub>1</sub>, H<sub>2</sub>, and a reject condition occurs it shall be noted as a batch failure. Each device may then be tested individually one time for acceptance if all devices in the batch are retested within one hour after removal from the tracer gas pressurization chamber. For condition G, only, devices may be batch retested for acceptance providing all retesting is completed within one hour after removal from the tracer gas pressurization chamber. For condition K only, devices that are batch tested, and indicate a reject condition, may be retested individually one time using the procedure of 12.2 herein, except that repressurization is not required if the devices are immersed in detector fluid within 20 seconds after completion of the first test, and they remain in the bath until retest.

TABLE 1071-I. Required test sequence.

Volume (cm <sup>3</sup> )	Fine leak condition	Gross leak condition
≤0.4	G, H <sub>1</sub> , H <sub>2</sub> , L <sub>2</sub>	A, C, D, E, J <u>1/</u> , K <u>2/</u> , L <sub>1</sub>
>0.4	G, H <sub>1</sub> , H <sub>2</sub> , L <sub>2</sub>	A, B, C, D, E, K, L <sub>1</sub>
>0.4	J <u>3/</u>	J <u>3/</u>

- 1/ Condition J cannot be used for packages whose internal volume is <0.001 cm<sup>3</sup>.
- 2/ Condition D cannot be used for packages whose internal volume is ≤ 1 cm<sup>3</sup>.
- 3/ Condition J may be used as a single test for devices with an internal cavity volume of >0.4 cm<sup>3</sup> provided the specified requirements can be satisfied by a leak rate of 1 x 10<sup>-6</sup> atm cm<sup>3</sup>/s.

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4. Test condition A, radioisotope wet gross leak test.

4.1 Apparatus. The apparatus required for the seal test shall be as follows:

- a. Radioactive tracer gas activation console.
- b. Counting equipment consisting of a scintillation crystal, photomultiplier tube, preamplifier, ratemeter, and krypton-85 reference standards. The counting station shall be of sufficient sensitivity to determine through the device wall the radiation level of any krypton-85 tracer gas present within the device. The counting station shall have a minimum sensitivity corresponding to a leak rate of  $10^{-9}$  atm cc/s of krypton-85 and shall be calibrated at least once every working shift using krypton-85 reference standards and following the equipment manufacturer's instruction.
- c. A container of sufficient volume to allow the devices to be covered with oil and to be degreased with a suitable solvent.
- d. Solutions:
  - (1) Hydrocarbon vacuum pump oil. The solution shall be kept clean and free of contaminants.
  - (2) Solvent capable of degreasing the devices.
- e. A tracer gas consisting of a mixture of krypton-85 and dry nitrogen. The concentration of krypton-85 in dry nitrogen shall be no less than 100 microcuries per atmospheric cubic centimeter. This value shall be determined at least once each 30 days, following manufacturer's procedure, and recorded in accordance with the calibration requirements of this standard.

4.2 Procedure. The devices shall be immersed in the oil and evacuated to a pressure of 10 torr or less, for 10 minutes, and then pressurized for one hour at 310 kPa (45 psi) minimum. The devices shall be removed from the oil and flushed with solvent to remove all of the surface oil. The devices shall then be placed in the radioisotope pressurization tank, and the tank evacuated to a pressure of  $9.72 \times 10^{-3}$  psi (67 Pa). The devices shall then be pressurized to a minimum of three atmospheres absolute pressure of krypton-85/nitrogen gas mixture for two to five minutes. The gas mixture shall then be evacuated to storage until a pressure of 0.0387 to 0.0483 psi (267 to 333 Pa) maximum exists in the tank. This evacuation shall be completed in two minutes maximum. The tank shall then be filled with air, and the devices immediately removed from the tank and leak tested within 15 minutes after gas exposure, with a scintillation crystal equipped counting station. Any device indicating 1,000 c/m or greater above the ambient background of the counting station shall be considered a gross leak.

4.2.1 Personnel precautions. Government regulations require a license for the possession and use of krypton-85 leak test equipment. These regulations should be followed carefully. The personnel should be properly instructed and monitored in accordance with the licensing requirements.

5. Test condition B, radioisotope dry gross leak. This test shall be only to test devices that internally contain some krypton-85 absorbing medium, such as electrical insulation, organic, or molecular sieve material. This test shall be permitted only if the following requirements are met:

- a. A 5 to 10 mil diameter hole shall be made in a representative unit of the devices to be tested.
- b. The device shall be subjected to this test condition with a count rate from 200 to 250 counts per minute above ambient background. The count rate shall be made two hours after removal from the activation tank. If the device fails, this test condition may be used, but only for those devices represented by the test unit. If the device does not fail, this test condition shall not be used.

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5.1 Apparatus. Apparatus for this test shall consist of the following:

- a. Radioactive tracer gas activation console containing krypton-85/dry nitrogen gas mixture.
- b. Counting station with a minimum sensitivity of 12,000 counts per minute per microcurie of krypton-85 tracer gas and a minimum detectable count rate of 100 counts per minute above background level.
- c. Tracer gas mixture of krypton-85/dry nitrogen with a minimum allowable specific activity of 100 microcuries per atmospheric cubic centimeter. The specific activity of the krypton-85/dry nitrogen mixture shall be determined on a once-a-month basis as a minimum.

5.2 Procedure. The devices shall be placed in a radioactive tracer gas activation tank and the tank shall be evacuated to a pressure not to exceed  $9.72 \times 10^{-3}$  psi (67 Pa). The devices shall then be subjected to a minimum of 25 psi (173 kPag) of krypton-85/dry nitrogen gas mixture for 2 to 5 minutes. The gas mixture shall then be evacuated to storage until a pressure of 0.0972 psi (670 Pa) maximum exists in the activation tank. This evacuation shall be complete in three minutes maximum. The activation tank shall then be backfilled with air (air wash). The devices shall then be removed from the activation tank and leak tested within 30 minutes after gas exposure with a scintillation-crystal-equipped counting station. Any device indicating 200 counts per minute or greater above the ambient background of the counting station shall be considered a gross leak failure.

5.2.1 Personnel precautions. See 4.2.1.

6. Test condition C, liquid (fluorocarbon) gross leak.

6.1 Apparatus. Apparatus for this test shall consist of the following:

- a. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to 90 psi (618 kPa) for a maximum of 24 hours.
- b. A suitable observation container with provisions to maintain the indicator fluid at a temperature of  $+125^{\circ}\text{C} \pm 5^{\circ}\text{C}$  ( $+100^{\circ}\text{C}$  for Germanium transistors with temperature rating of  $+100^{\circ}\text{C}$  maximum) and a filtration system capable of removing particles greater than one micrometer in size from the fluid.
- c. A magnifier capable of magnifying an object 1.5 to 30 times its normal size (4 to 120 diopters) for observation of bubbles emanating from devices when immersed in the indicator fluid.
- d. Sources of type I detector fluids and type II indicator fluids as specified in table 1071-II.

TABLE 1071-II. Physical property requirements of perfluorocarbon fluids. 1/

Property	Type I	Type II	Type III	ASTM test method
Boiling point ( $^{\circ}\text{C}$ )	50-95	140-200	50-110	D-1120
Surface tension (dynes/cm) at $+25^{\circ}\text{C}$		< 20		D-971, D-1331
Density at $+25^{\circ}\text{C}$ (gm/ml)	> 1.6	> 1.6	> 1.6	D-941
Density at $+125^{\circ}\text{C}$ (gm/ml)		> 1.5		D-941
Dielectric strength (volts/mil)	> 300	> 300	> 300	877
Residue (Tgm/gm)	< 50	< 50	< 50	D-2109
Appearance	Clear colorless			N/A

1/ Perfluorocarbons contain no chlorine or hydrogen.

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- e. A lighting source capable of producing a collimated beam of at least 161,000 luxes (15,000 foot candles) in air at a distance equal to that which the most distant device in the bath will be from the source. The lighting source shall not require calibration, but shall be placed for best detection of bubbles, without excessive incident or reflective glare being directed toward observer.
- f. Suitable calibrated instruments to indicate that test temperatures, pressures, and times are as specified.
- g. Suitable fixtures to hold the device(s) in the indicator fluid.

6.2 Procedure. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 0.0972 psi (670 Pa) or less and maintained for 30 minutes minimum, except for devices with an internal volume  $\geq 0.1 \text{ cm}^3$  this vacuum cycle may be omitted. A sufficient amount of type I detector fluid shall be admitted to cover the devices. When the vacuum cycle is performed, the fluid will be admitted after the minimum 30 minute period but before breaking the vacuum. The devices shall then be pressurized in accordance with table 1071-III. When the pressurization period is complete the pressure shall be released and the devices removed from the chamber without being removed from a bath of detector fluid for greater than 20 seconds. A holding bath may be another vessel or storage tank. When the devices are removed from the bath they shall be dried for 2 minutes  $\pm 1$  minute in air prior to immersion in type II indicator fluid, which shall be maintained at  $+125^\circ\text{C} \pm 5^\circ\text{C}$ . The devices shall be immersed with the uppermost portion at a minimum depth of 2 inches (50.80 mm) below the surface of the indicator fluid, one at a time or in such a configuration that a single bubble from a single device out of a group under observation may be clearly observed as to its occurrence and source. Unless rejected earlier, the device shall be observed against a dull, nonreflective black background through the magnifier, while illuminated by the lighting source, from the instant of immersion until expiration of a 30-second minimum observation period.

TABLE 1071-III. Condition C and K pressurization conditions.

Pressure psia (minimum)	Minimum pressurization time (hour)	
	Condition C	Condition K
30	23.5	12
45	8	4
60	4	2
75	2	1
90	1	0.5
105	0.5	N/A

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6.2.1 Failure criteria. A definite stream of bubbles, or two or more bubbles originating from the same point shall be cause for rejection.

6.2.2 Precautions. The following precautions shall be observed in conducting the fluorocarbon gross leak test:

- a. Perfluorocarbons fluids shall be filtered through a filter system capable of removing particles greater than one micrometer prior to use. Bulk filtering and storage is permissible. Liquid which has accumulated observable quantities of particulate matter during use shall be discarded or reclaimed by filtration for re-use. Precaution should be taken to prevent contamination.
- b. Observation container shall be filled to assure coverage of the device to a minimum of 2 inches (50.80 mm).
- c. Devices to be tested shall be free of foreign materials on the surface, including conformal coatings and any markings which may contribute to erroneous test results.
- d. Precaution should be taken to prevent operator injury due to package rupture or violent evolution of bomb fluid when testing large packages.

7. Test condition D, bubble test (type II indicator fluid as specified in table 1071-II.) (NOTE: These fluids replace ethylene glycol as a medium for the gross leak bubble test.)

7.1 Apparatus. Apparatus for this test shall consist of the following:

- a. A device internal free volume of greater than 1 cm<sup>3</sup>.
- b. Container of sufficient volume to allow the devices to be covered with solution to a minimum depth of 2 inches (50.80 mm). The container shall have flat sides to minimize reflections and distortions (example of an acceptable container is a battery jar).
- c. Liquid of sufficient volume maintained at no less than +125°C ±5°C for the duration of the test.
- d. A light source capable of producing a collimated beam of at least 161,000 luxes (15,000 foot candles) in air at a distance equal to that which the most distant device in the bath will be from the source. The lighting source shall not require calibration.

7.2 Procedure. The devices shall be placed in the container of liquid at +125°C, immersed to a minimum depth of 2 inches (50.80 mm) for a minimum of one minute, and observed during the entire immersion period for bubbles or bubbling. Side lighting (see 7.1d) shall be used to facilitate viewing the bubbles, and the devices shall be observed against a black nonreflective background.

7.2.1 Failure criteria. Any device that shows one or more nonreflective attached growing bubbles, one continuous stream, or a succession of two or more from the same point shall be considered a failure.

8. Test condition E, penetrant dye gross leak.

8.1 Apparatus. Apparatus for this test shall consist of the following:

- a. Ultraviolet light source with peak radiation at approximately the frequency causing maximum reflection of the dye (3650Å for Zyglo; 4935Å for Flurosecein; 5560 Å for Rhodamine B).
- b. Pressure chamber capable of maintaining 104 psi (719 kPa).
- c. Solution of fluorescent dye, (such as Rhodamine B, Fluorescein, Dye-check, Zyglo, FL-50 or equivalent), mixed in accordance with the manufacturer's specification.
- d. A magnifier capable of magnifying an object 1.5 to 30 times its nominal size (4 to 120 diopters).

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8.2 Procedure. This test shall be permitted only on transparent glass encased devices or for destructive verification of opaque devices. The pressure chamber shall be filled with the dye solution to a depth sufficient to completely cover all the devices. The devices shall be placed in the solution and the chamber pressurized at 104 psi (719 kPa) minimum for three hour minimum. For device packages which will not withstand 105 psi (724 kPa), 60 psi (414 kPa) minimum for 10 hours may be used. The devices shall then be removed and carefully washed, using a suitable solvent for the dye used, followed by an air jet dry. Transparent devices may be examined under magnification capable of magnifying an object up to 1.5 times its normal size (4 diopters) using ultraviolet light source of appropriate frequency for evidence of the dye penetration. For the destructive examination of opaque devices, the devices shall be delidded and examined internally under the magnifier using an ultraviolet light source of appropriate frequency.

8.2.1 Failure criteria. Any evidence of dye in the cavity of the device shall constitute a failure.

8.2.1.1 Opaque devices. After de-lidding or separation of the device (as applicable), any evidence of dye penetration shall be cause for rejection. Area of examination shall be as shown in figures 1071-1 and 1071-2.

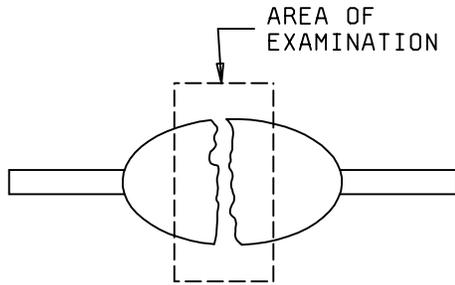


FIGURE 1071-1. Opaque construction.

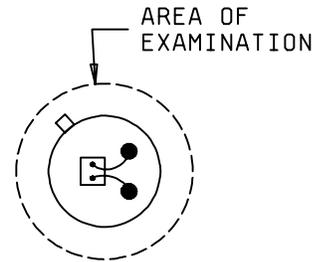


FIGURE 1071-2. Metal can construction.

8.2.1.2 Transparent glass, with large cavity (i.e. S-Bend, C-Bend, or straight-through constructions). Any evidence of dye penetration in the device cavity shall be cause for rejection. Area of examination shall be as shown in figure 1071-3.

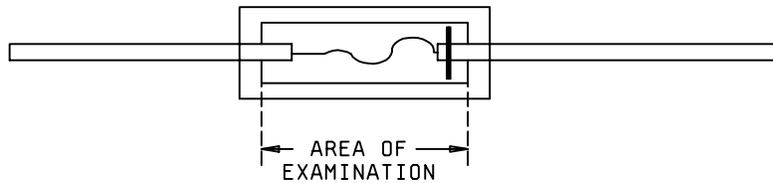


FIGURE 1071-3. Transparent glass or straight through construction.

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8.2.1.3 Transparent glass, double plug construction (-1 and tungsten). Any evidence of dye penetration in the die area shall be cause for rejection. In addition, evidence of dye penetration into a crack, fracture, void, etc., which is closer to the die than 50 percent of the designed seal length shall be rejected. Area of examination shall be as shown in figure 1071-4.

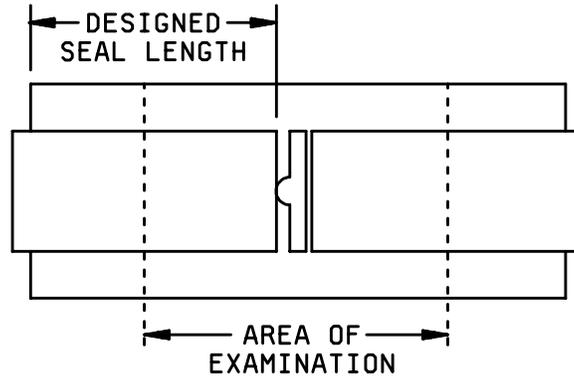


FIGURE 1071-4. Transparent glass double plug construction.

9. Test condition G<sub>1</sub>. Radioisotope fine leak.

9.1 Apparatus. Apparatus for this test shall be as in 5.1.

9.2 Activation parameters. The activation pressure and soak time shall be determined in accordance with the following equation:

$$Q_S = \frac{R}{S K T \bar{P}} \quad (1)$$

The parameters of equation (1) are defined as follows:

- $Q_S$  = The maximum leak rate allowable, in atm cc/s Kr, for the devices to be tested.
- $R$  = Counts per minute above the ambient background after activation if the device leak rate were exactly equal to  $Q_S$ . This is the reject count above the background of both the counting equipment and the component, if it has been through prior radioactive leak tests.
- $S$  = The specific activity, in microcuries per atmospheric cubic centimeter, of the krypton-85 tracer gas in the activation system.
- $K$  = The overall counting efficiency of the scintillation crystal in counts per minute per microcurie of krypton-85 in the internal void of the specific component being evaluated. This factor depends upon component configuration and dimensions of the scintillation crystal. The counting efficiency shall be determined in accordance with 9.3.
- $T$  = Soak time, in hours, that the devices are to be activated.
- $\bar{P}$  =  $P_e - P_i$ , where  $P_e$  is the activation pressure in atmospheres absolute, and  $P_i$  is the original internal pressure of the devices in atmospheres absolute. The activation pressure ( $P_e$ ) may be established by specification or if a convenient soak time ( $T$ ) has been established, the activation pressure ( $P_e$ ) can be adjusted to satisfy equation (1).

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t = Conversion of hours to seconds and is equal to 3,600 seconds per hour.

NOTE: The complete version of equation (1) contains a factor  $(P_O^2 - (\Delta P)^2)$  in the numerator which is a correction factor for elevation above sea level.  $P_O$  is sea level pressure in atmospheres absolute and  $\Delta P$  is the difference in pressure, in atmospheres between the actual pressure at the test station and sea level pressure. For the purpose of this test method, this factor has been dropped.

9.3 Determination of counting efficiency (k). The counting efficiency (k) of equation (1) shall be determined as follows:

- a. Five representative units of the device type being tested shall be tubulated and the internal void of the device shall be backfilled through the tubulation with a known volume and known specific activity of krypton-85 tracer gas and the tubulation shall be sealed off.
- b. The counts per minute shall be directly read in the shielded scintillation crystal of the counting station in which the devices are read. From this value, the counting efficiency, in counts per minute per microcurie, shall be calculated.

9.4 Evaluation of surface sorption. All device encapsulations consisting of glass, metal, and ceramic or combinations thereof, including coatings and external sealants, shall be evaluated for surface sorption of krypton-85 before establishing the leak test parameters. Representative samples of the questionable material shall be subjected to the predetermined pressure and time conditions established for the device configuration as specified by 9.2. The samples shall then be counted every 10 minutes, with count rates noted, until the count rate becomes asymptotic with time. (This is the point in time at which surface sorption is no longer a problem.) This time lapse shall be noted and shall determine the "wait time" specified in 9.5.

9.5 Procedure. The devices shall be placed in the radioactive tracer gas activation tank. The activation chamber may be partially filled with inert material to reduce pumpdown time. The tank shall be evacuated to  $9.7 \times 10^{-3}$  psi (67 Pa). The devices shall be subjected to a minimum of 29 psi (203 kPa) absolute pressure of krypton-85/dry nitrogen mixture of 12 minutes. Actual pressure and soak time shall be determined in accordance with 9.2. The R value in counts per minute shall not be less than 600 above background. The krypton-85/dry nitrogen gas mixture shall be evacuated to storage until  $9.7 \times 10^{-3}$  psi (67 Pa) to 0.039 psi (270 Pa) pressure exists in the activation tank. The storage cycle shall be completed in three minutes maximum as measured from the end of the activation cycle or from the time the activation tank pressure reaches 60 psi (414 kPa) if a higher bombing pressure is used. The activation tank shall then immediately be backfilled with air (air wash). The devices shall then be removed from the activation tank and leak tested within one hour after gas exposure with a scintillation-crystal-equipped counting station. Device encapsulations that come under the requirements of 9.4 shall be exposed to ambient air for a time not less than the "wait time" determined by 9.4. In no case will the time between removal from the activation chamber and test exceed one hour. This air exposure shall be performed after gas exposure but before determining leak rate with the counting station. Device encapsulations that do not come under the requirements of 9.4 may be tested without a "wait time". (The number of devices removed from pressurization for leak testing shall be limited such that the test of the last device can be completed within one hour.)

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The actual leak rate of the component shall be calculated with the following equation:

$$Q = \frac{(\text{Actual readout in net counts per minute}) \times Q_S}{R} \quad (2)$$

Where Q = Actual leak rate in atm cc/s, and  $Q_S$  and R are defined in 9.2.

NOTE: CAUTION: Discharge of krypton 85 into the atmosphere must not exceed limits imposed by local and Federal regulations.

9.5.1 Failure criteria. Unless otherwise specified, devices that exhibit a leak rate equal to or greater than the test limits of table 1071-IV shall be considered as failures.

NOTE: CAUTION: Devices which do not exhibit a leak rate sufficient to fail seal test, may retain radioactive tracer gas in sufficient concentration to cause soft errors in complex, small geometry devices.

TABLE 1071-IV. Test limits for radioisotope fine leak method.

Volume of package (cc)	$Q_S$
< 0.01	$1 \times 10^{-8}$
$\geq 0.01, \leq 0.4$	$5 \times 10^{-8}$
> 0.4	$5 \times 10^{-7}$

9.5.2 Personnel precautions. See 4.2.1.

10. Test condition H<sub>1</sub> or H<sub>2</sub> tracer gas (H<sub>e</sub>) fine leak. Test condition H<sub>1</sub> is a "fixed" method with specified conditions in accordance with table 1071-V that will ensure the test sensitivity necessary to detect the required measured leak rate ( $R_1$ ). Test condition H<sub>2</sub> is a "flexible" method that allows the variance of test conditions in accordance with the formula of 10.2.1.2 to detect the specified equivalent standard leak rate (L) at a predetermined leak rate ( $R_1$ ).

10.1 Apparatus. Apparatus required for test conditions H<sub>1</sub> and H<sub>2</sub> shall consist of suitable pressure and vacuum chambers and a mass spectrometer-type leak detector properly calibrated for a helium leak rate sensitivity sufficient to read measured helium leak rates of  $1 \times 10^{-9}$  atm cm<sup>3</sup>/s and greater. The volume of the chamber used for leak rate measurement should be held to the minimum practical, since this chamber volume has an adverse effect on sensitivity limits. The leak detector indicator shall be calibrated using a diffusion-type calibrated standard leak at least once every working shift.

10.2 Procedure applicable to "fixed" and "flexible" methods. The completed devices(s) shall be placed in a sealed chamber which is then pressurized with a tracer gas of 100 +0, -5 percent helium for the required time and pressure. The pressure shall then be relieved (an optional air nitrogen wash may be applied) and each specimen transferred to another chamber or chambers which are connected to the evacuating system and a mass-spectrometer-type leak detector. When the chamber(s) is evacuated, any tracer gas which was previously forced into the specimen will thus be drawn out and indicated by the leak detector as a measured leak rate ( $R_1$ ). (The number of devices removed from pressurization for leak testing shall be limited such that the test of the last device can be completed within 60 minutes for test condition H<sub>1</sub> or within the chosen value of dwell time  $t_2$  for test condition H<sub>2</sub>.)

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10.2.1 Evaluation of surface sorption. All device encapsulations consisting of glass, metal, and ceramic or combinations thereof including coatings and external sealants, shall be evaluated for surface sorption of helium before establishing the leak test parameters. Representative specimens of the questionable devices should be opened and all parts of each device as a unit shall be subjected to the predetermined pressure and time conditions established for the device configuration as specified in table 1071-V and 10.2.1.2. The measured leak rate for each device shall be monitored and the lapsed time shall be determined for the indicated leak rate to fall to  $\leq 0.5 R_1$  as specified in table 1071-V for test condition H<sub>1</sub> or as predetermined for test condition H<sub>2</sub>. The average of the lapsed time following the release of pressure will determine the minimum usable dwell time. Note that the sensitivity of measurement increases as this background indicated-leak-rate decreases relative to the R<sub>1</sub> reject level. Alternately, whole (unopened) specimens of the questionable devices shall be subjected to the same process; then, the shorted value of lapsed time so obtained will determine the minimum dwell time. The fixed method will not be used if the consequent dwell time exceeds the value specified in table 1071-V. It is noted that sorption may vary with pressure and time of exposure so that some trial may be required before satisfactory exposure values are obtained.

10.2.1.1 Test condition H<sub>1</sub>, fixed method. The device(s) shall be tested using the appropriate conditions specified in table 1071-V for the internal cavity volumes of the package under test. The t<sub>1</sub> is the time under pressure and time t<sub>2</sub> is the maximum time allowed after the release of pressure before the device shall be read. The fixed method shall not be used if the maximum standard leak rate limit given in the detail specification is less than the limits specified herein for the flexible method.

TABLE 1071-V. Fixed conditions for test condition H<sub>1</sub>.

Volume of package (cm <sup>3</sup> )	Bomb condition			R <sub>1</sub> reject limit (atm cm <sup>3</sup> /s)
	kPa $\pm 15$ (psi) $\pm 2$	Exposure time in hours (t <sub>1</sub> ) (+1.0 - 0.0)	Maximum dwell time (hour)	
< 0.05	517 (75)	2	1	5 x 10 <sup>-8</sup>
> 0.05 < 0.5	517 (75)	4	1	5 x 10 <sup>-8</sup>
> 0.5 < 1.0	310 (45)	2	1	1 x 10 <sup>-7</sup>
> 1.0 < 10.0	310 (45)	5	1	5 x 10 <sup>-8</sup>
> 10.0 < 20.0	310 (45)	10	1	5 x 10 <sup>-8</sup>

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10.2.1.2 Test condition H<sub>2</sub>, flexible method. Values for bomb pressure, exposure time, and dwell time shall be chosen such that actual measured tracer gas leak rate (R<sub>1</sub>) readings obtained for the DUTs (if defective) will be greater than the minimum detectable leak rate capability of a mass spectrometer. The devices shall be subjected to a minimum of 29 psi (203 kPa) of helium atmosphere. The chosen values of pressurization and time of pressurization, in conjunction with the value of the internal volume of the device package to be tested and the maximum equivalent standard leak rate (L) limit as specified in 10.2.2, shall be used to calculate the measured leak rate (R<sub>1</sub>) limit using the following formula:

$$R_1 \frac{2.69 L P_e}{P_o} \left[ 1 - \exp \left( - \frac{2.69 L}{P_o V} \cdot t_1 \right) \right] \exp \left( - \frac{2.69 L}{P_o V} \cdot t_2 \right) \quad (3)$$

Where: R<sub>1</sub> = The measured leak rate of tracer gas (He) through the leak in atm cm<sup>3</sup>/s.

L = The equivalent standard leak rate in atm cm<sup>3</sup>/s.

P<sub>e</sub> = The pressure of exposure in atmospheres absolute.

P<sub>o</sub> = 1 standard atmosphere.

t<sub>1</sub> = The time of exposure to P<sub>e</sub> in seconds.

t<sub>2</sub> = The dwell time between release of pressure and leak detection in seconds.

V = The internal volume of the device package cavity in cubic centimeters.

The minimum detectable leak rate shall be determined as in 10.2.1 and shall be taken as the indicated value corresponding to a lapsed time t<sub>0</sub> < t<sub>2</sub>. The lapsed time t<sub>0</sub> shall be taken as the minimum usable dwell time, and leak testing shall be accomplished in the interval between t<sub>0</sub> and t<sub>2</sub>. Alternately, pressurization parameters may be chosen from the fine leak approximate solution of equation (3) for L < 1 x 10<sup>-5</sup> as

$$L = \frac{P_o}{2.69} \left( \frac{R_1 V}{P_e t_1} \right)^{1/2} \quad (4)$$

with a graphical representation given on figure 1071-5. If chosen dwell time t<sub>2</sub> is greater than 60 minutes, equation (2) shall be used to determine an R<sub>1</sub> value which will assure a maximum detectable standard leak rate large enough to overlap with the selected gross leak test condition. Alternately, the largest detectable leak rate L as a function of dwell time may be obtained from the approximate solution

$$L \max = \frac{P_o V}{2.69 t_2} \ln \left( \frac{2.69 L P_e}{P_o R_1} \right) \quad (5)$$

with graphical representation given on figure 1071-6. In each case (equations (4) and (5)) R<sub>1</sub> shall be taken large compared to the minimum detectable value. <sup>1/</sup>

<sup>1/</sup> From "Standard Recommended Practices for Determining Hermeticity of Electron Devices with a Helium Mass Spectrometer Leak Detector," ASTM Designation F134, Annual book of ASTM Standards, Pt. 43 November 1980.

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10.2.2 Failure criteria. Unless otherwise specified, devices with an internal cavity volume of 0.01 cm<sup>3</sup> or less shall not be accepted if the equivalent standard leak rate (L) exceeds 5 x 10<sup>-8</sup> atm cm<sup>3</sup>/s. Devices with an internal cavity volume greater than 0.01 cm<sup>3</sup> and equal to or less than 0.5 cm<sup>3</sup> shall not be accepted if the equivalent standard leak rate (L) exceeds 1 x 10<sup>-7</sup> atm cm<sup>3</sup>/s. Devices with an internal cavity volume greater than 0.5 cm<sup>3</sup> shall not be accepted if the equivalent standard leak rate (L) exceeds 1 x 10<sup>-6</sup> atm cm<sup>3</sup>/s.

11. Test condition J, weight gain gross leak.

11.1 Apparatus. Apparatus for this test shall consist of the following:

- a. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to 90 psi (618 kPa) for up to 10 hours.
- b. An analytical balance capable of weighing the devices accurately to 0.1 milligram.
- c. A source of type III detector fluid as specified in table 1071-II.
- d. A filtration system capable of removing particles greater than one micrometer in size from the fluid.
- e. Suitable calibrated instruments to measure test pressures and time.
- f. A suitable solvent.

11.2 Procedure. The devices shall be cleaned by placing them in a container of a suitable solvent at +25°C and allowed then to soak for two minutes minimum. The devices shall then be removed and placed in an oven at +125°C ±5°C for one hour minimum, after which they shall be allowed to cool to room ambient temperature. Each device shall be weighed and the initial weight recorded or the devices may be categorized into cells as follows: Devices having a volume of ≤0.01 cm<sup>3</sup> shall be categorized in cells of 0.5 milligram increments and devices with volumes >0.01 cm<sup>3</sup> shall be categorized in cells of 1.0 milligram increments. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 0.0967 psi (667 Pa) and maintained for one hour except that for devices with an internal cavity volume ≥0.1 cm<sup>3</sup>, this vacuum cycle may be omitted. A sufficient amount of type III detector fluorocarbon fluid shall be admitted to the pressure chamber to cover the devices. When the vacuum cycle is performed, the fluid shall be admitted after the one hour period but before breaking the vacuum. The devices shall then be pressurized to 75 psi (517 kPa) except that 618 kPa (90 psia) shall be used when the vacuum has been omitted. The pressure shall be maintained for two hours minimum. If the devices will not withstand the 75 psi (517 kPa) test pressure, the pressure may be lowered to 45 psi (310 kPa) with the vacuum cycle and pressure maintained for 10 hours minimum. Upon completion of the pressurization period, the pressure shall be released and the devices removed from the pressure chamber and retained in a bath of the fluorocarbon fluid. When the devices are removed from the fluid they shall be air dried for 2 minutes ±1 minute prior to weighing. The devices shall be transferred singly to the balance and the weight or weight category of each device determined. All devices shall be tested within four minutes following removal from the fluid. The delta weight shall be calculated from the record of the initial weight and the post weight of the device. Devices which were categorized shall be separated into two groups, one of which shall be the devices which shifted one cell or less, and the other devices which shifted more than one cell.

11.3 Failure criteria. A device shall be rejected if it gains 1.0 milligram or more and has an internal volume of ≤0.01 cm<sup>3</sup> and 2.0 milligrams or more if the volume is >0.01 cm<sup>3</sup>. If the devices are categorized, any device which gains enough weight to cause the device to shift by more than one cell shall be considered a reject. A device which loses weight of an amount which, if gained, would cause the device to be rejected may be retested after it is baked at +125°C ±5°C for a period of 8 hours minimum.

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12. Test condition K, fluorocarbon vapor detection.

12.1 Apparatus. Apparatus for this test shall consist of:

- a. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to 90 psi (620 kPa) for up to 12 hours.
- b. A fluorocarbon vapor detection system capable of detecting vapor quantities equivalent to 0.28 milligram of type I fluid.
- c. A source of type I detector fluid specified in table 1071-II.
- d. Suitable calibrated instruments to indicate that test, purge times, and temperatures are as specified. The detection system shall be calibrated at least once each shift when production occurs by introducing 1 microliter of type I detector fluid into the test chamber. The resulting reading shall be adjusted in accordance with the manufacturer's instructions.
- e. The vapor detector used for condition K shall be calibrated at least once each working shift using a type I fluid calibration source, and following the manufacturer's instructions.

12.2 Procedure. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 5 torr or less and maintained for 30 minutes minimum. A sufficient amount of type I detector fluid shall be admitted to the pressure chamber to cover the devices. The fluid shall be admitted after the 30 minute vacuum period but before breaking the vacuum. The devices shall then be pressurized and maintained in accordance with table 1071-III. Upon completion of the pressurization period, the pressure shall be released, the devices removed from the pressure chamber without being removed from the detector fluid for more than 20 seconds and then retained in a bath of fluorocarbon fluid. When the devices are removed from the fluid they shall be air dried for a minimum of 20 seconds and a maximum of 5 minutes prior to the test cycle. If the type I detector fluid has a boiling point of less than +80°C, the maximum drying time shall be 3 minutes. The devices shall then be tested with a fluorocarbon vapor detection system that is calibrated in accordance with 12.1. "Purge" time shall be in accordance with table 1071-VI. Test time shall be a minimum of 3.5 seconds unless the device is rejected earlier. The system's purge and test chambers shall be at a temperature of +125°C ±5°C. Test time shall be 2.5 seconds minimum with the purge and test chambers at a temperature of +150°C ±5°C.

NOTE: Test temperature shall be measured at the chamber surface that is in contact with the DUT.

12.3 Failure criteria. A device shall be rejected if the detector instrumentation indicates more than the equivalent of 0.28 milligrams of type I detector fluid in accordance with table 1071-II.

TABLE 1071-VI. Purge time.

Package with internal free volume (cm <sup>3</sup> )	Purge time at +125°C ±5°C (seconds)
≤0.01	≤5
≥0.01 ≤0.10	≤9
≥0.1	≤13

NOTE: Purge time shall be defined as the total time the device is heated prior to entering the test mode. Maximum purge time can be determined by cycling a device with a .02 inch to .05 inch (0.51 mm to 1.27 mm) hole and measuring the maximum purge time that can be used without permitting the device to escape detection.

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13. Test condition L<sub>1</sub> or L<sub>2</sub> - optical gross or gross/fine leak.

13.1 Apparatus:

- a. An optical inspection station capable of evacuation and/or pressurization, and subsequent detection of package lid deformation.
- b. Suitable calibration instrumentation to indicate test results, times and pressures are as specified.

13.2 Lid stiffness. Test condition L<sub>1</sub> and L<sub>2</sub> are valid only for packages with thin lids (thickness < 0.025 typically for metallic lids). The test sensitivity is related to the extent of deformation of the lid due to the specific pressure change and the test time used. For a specific lid material and size the following formula must be met:

$$\text{For condition L}_1: R^4 / E T^3 > 1.0 \times 10^{-4} \quad (1).$$

$$\text{For condition L}_2: R^4 / E T^3 > 1.0 \times 10^{-3} \quad (2).$$

Where: R = The minimum width of free lid (inside braze or cavity dimension in inches).

E = The modulus of elasticity of the lid material.

Aluminum: E = 10 x 10<sup>6</sup> lb/in<sup>2</sup>.

Kovar: E = 20 x 10<sup>6</sup> lb/in<sup>2</sup>.

Ceramic: E = 60 x 10<sup>6</sup> lb/in<sup>2</sup>.

T = The thickness of the lid (inches).

13.3 Leak sensitivity. The optical leak test shall be performed with a test pressure (P<sub>o</sub>) and time (t), which will provide the leak rate sensitivity required. The leak rate sensitivity is provided by the following equation:

$$L = (-V_o / k_2 t) \ln(1 - dY_t / P_o L_o).$$

Where: L = The leak rate sensitivity of the test (atm-cc/sec).

V<sub>o</sub> = The volume of the package cavity (in<sup>3</sup>).

k<sub>2</sub> = The leak test gas constant (air = 1.0, He = 2.67).

t = The test duration time (seconds).

dY<sub>t</sub> = The measured deformation of the package lid (inches).

P<sub>o</sub> = The chamber pressure during the test (psig).

L<sub>o</sub> = The lid stiffness constant calculated from the package dimensions (inch/psi).

13.4 Test condition L<sub>1</sub> - optical gross leak. The completed device(s) shall be placed in the sealed test chamber. The optical interferometer shall be set to observe the package lid. The chamber shall then be evacuated while the deformation of the lid is being observed with the optical interferometer. The deformation of the lid with pressure change, and the lack of continued deformation of the lid with reduced pressure held for time t<sub>1</sub> (or equivalent procedure), will be observed for each package in the field of view simultaneously.

13.4.1 Failure criteria. A device shall be rejected if the optical interferometer did not detect deformation of the lid as the chamber pressure was initially changed, or if the interferometer detects the lid deforming as the chamber pressure is held constant (or equivalent procedure).

13.5 Test condition L<sub>2</sub> - optical gross/fine leak. The completed device(s) shall be placed in the sealed test chamber. The optical interferometer shall be set to observe the package lid. The chamber shall then be evacuated while the deformation of the lid is being observed with the optical interferometer. The deformation of the lid with pressure change, and the lack of continued deformation of the lid with reduced pressure held for time t<sub>1</sub> (or equivalent procedure), will be observed for each package in the field of view simultaneously. The sealed test chamber is then pressurized with Helium gas to no more than 2 atmospheres. The lack of deformation of the lid is then observed with an optical interferometer to time t<sub>2</sub> (or equivalent procedure).

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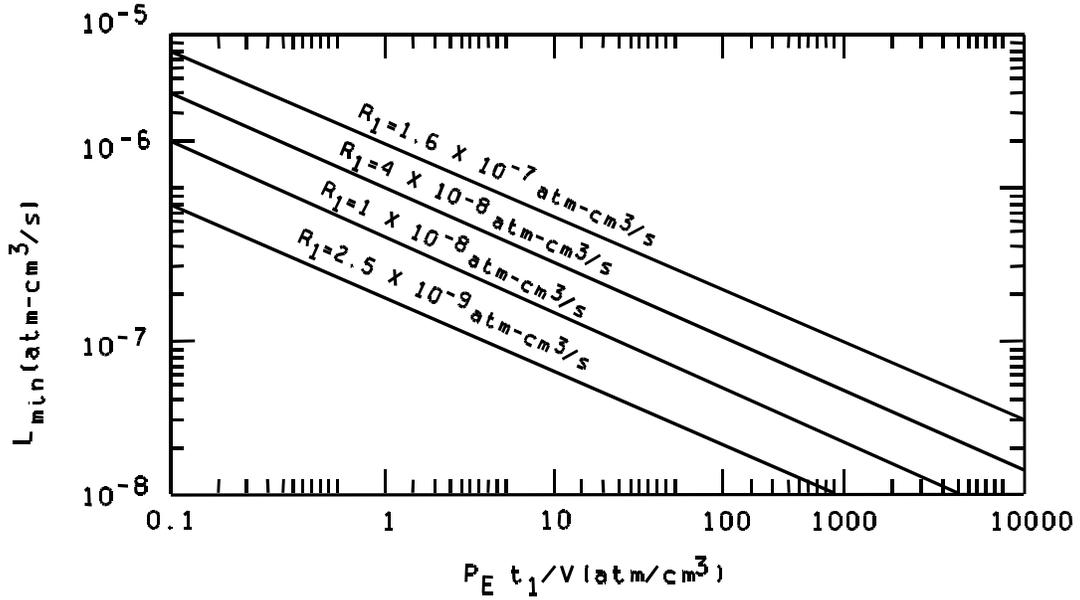
13.5.1 Failure criteria. A device shall be rejected for any of the three following criteria: If the interferometer did not detect deformation of the lid as the chamber pressure was initially changed; or, if the interferometer detects the lid deforming from the package leaking its entrapped internal pressure during time  $t_1$  as the pressure is held constant (or equivalent procedure); or, if the interferometer detects the lid deforming from the package leaking in the pressurized Helium gas during time  $t_2$  as the pressure is held constant (or equivalent procedure).

14. Summary. The following conditions shall be specified in the applicable detail specification:

- a. Test condition letter when a specific test is to be applied (see 3.).
- b. Accept or reject leak rate for test conditions G, H<sub>1</sub>, or H<sub>2</sub> when other than the accept or reject leak rate specified herein applies (see 9.5.1, 10.2.1.1, and 10.2.2).
- c. Where applicable, measurements after test (see 3.).
- d. Retest acceptability for test conditions G and H (see 9.). For K, see 3e.
- e. Order of performance of fine and gross if other than fine followed by gross (see 3.).

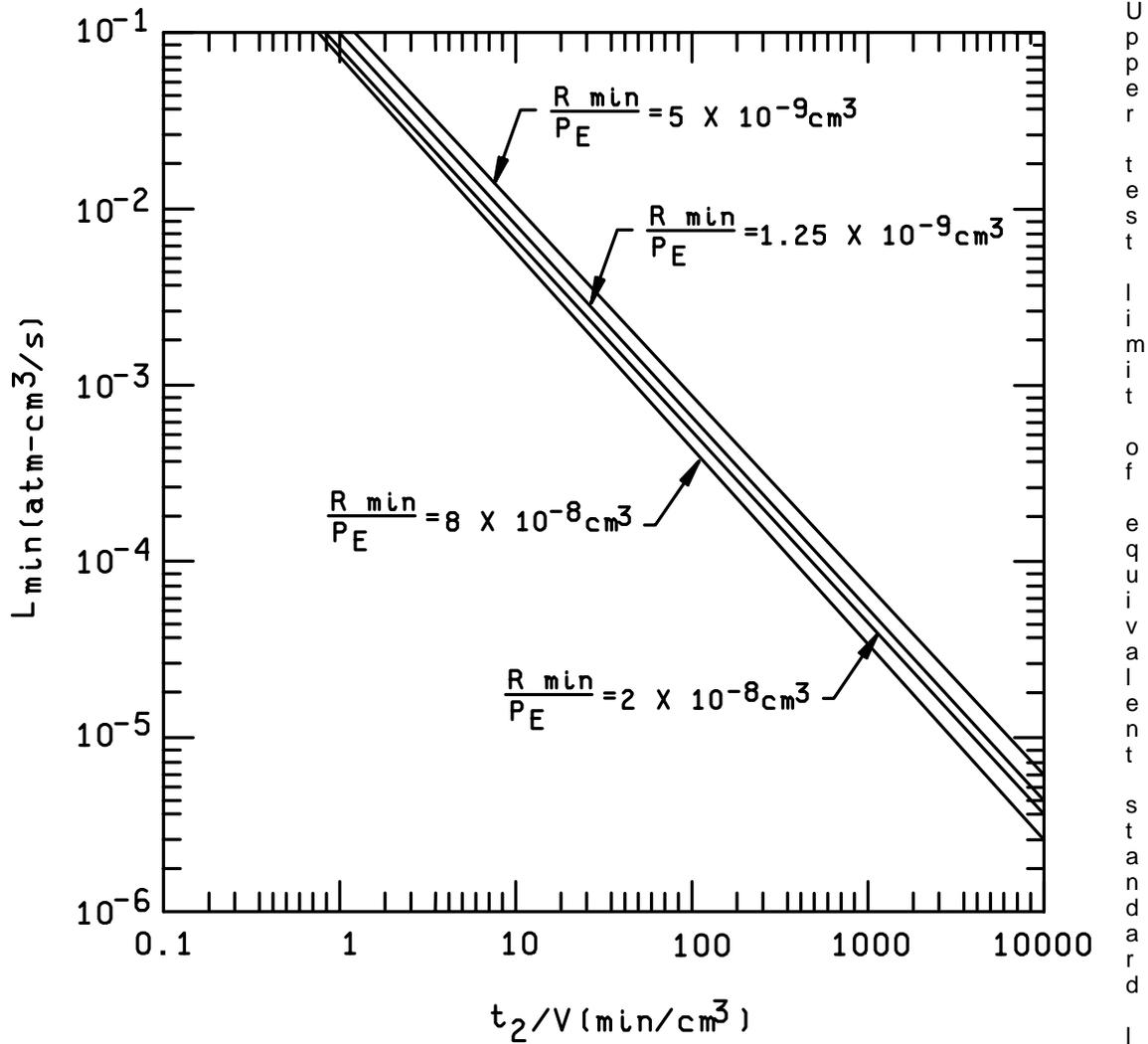
15. Notes.

- a. The fine leak test shall be performed first if condition A, B, or E is used for gross leak. Gross leak may be performed prior to fine leak if condition C, D, J, K, or L is used for gross leak and provided that the vapor pressure of the fluorocarbon material used in condition C, J, and K (which may be inside the device) is greater than 59 psi (406 kPa),  $T_A = +125^\circ\text{C}$ . The devices shall be subjected to a bake at this temperature for a minimum of one hour prior to performing the fine leak test. This sequence should be true regardless of whether the leak tests are part of a screening sequence or are included as group B or group C requirements.
- b. For test conditions A through E, K, and L<sub>1</sub>, the maximum allowable leak rate should not be specified because these tests are "go"/"no-go" type tests that do not provide an indication of actual leak rate. (Although test conditions A, B, K, and L<sub>1</sub> have a definite quantitative measurement to be met, they are still considered "go"/"no-go" tests.)
- c. When retesting devices to test conditions G and H, the history of device exposure to helium and krypton-85, including dates, backfilling performed, tracer gas concentrations, pressure, and time exposed, should be known in order to ensure reliable results.



Reject value of equivalent standard leak rate as a function of pressurization conditions and indicated leak rate as computed from the approximate solution, for small leaks where dwell time  $t_2$  is not a significant factor. The reject level  $R_2$  shall be taken larger relative to the minimum detectable  $R$  value.

FIGURE 1071-5. Smallest detectable leak.



ak rate as a function of dwell time, pressurization, and indicated leak rate as computed from the approximate solution, (e.g., for larger leaks where internal pressurization is complete).

FIGURE 1071-6. Largest detectable leak.

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METHOD 1080

SINGLE-EVENT BURNOUT AND SINGLE-EVENT GATE  
RUPTURE TEST METHOD

1. Purpose. The purpose of this test method is to describe the procedure for conducting heavy ion irradiation of power MOSFETs. This test method establishes a procedure for characterization and for verification (acceptance or qualification) of discrete power MOSFETs for single-event burnout (SEB) and single-event gate rupture (SEGR). In principle, this test method may be applicable to testing where neutrons, protons, or other light particles are used.

1.1 Definitions. The following symbols and terms shall apply for the purpose of this test method:

- a. Cross-sectional area: Calculated as the number of events per unit fluence.
- b. DUT: Device under test.
- c. Fuence: The ion flux integrated over the time required for the run, expressed as ions/cm<sup>2</sup>.
- d. Flux: The number of ions passing through a one cm<sup>2</sup> area perpendicular to the ion beam per unit of time, expressed as ions/cm<sup>2</sup>•s.
- e. I<sub>DS</sub>: The measured drain-to-source current (amps).
- f. I<sub>GS</sub>: The measured gate-to-source current (amps).
- g. Linear energy transfer (LET): The amount of energy transferred per unit length as the ion travels through a material, expressed as MeV/(mg/cm<sup>2</sup>) in this test method.
- h. Single-event burnout (SEB): A single-ion-induced condition that causes a localized high-current state resulting in a catastrophic device failure characterized by an increase in drain current that exceeds the manufacturer's rated leakage current at the drain electrode.
- i. Single-event gate rupture (SEGR): A single-ion-induced condition that causes a localized defect in the gate dielectric resulting in a catastrophic device failure, characterized by an increase in gate current that exceeds the manufacturer's rated leakage current at the gate electrode.
- j. SEB circumvention: A technique used to prevent the device from catastrophically failing during an SEB event.
- k. SEB cross-sectional area: Calculated as the number of SEB events per unit fluence.
- l. SEGR cross-sectional area: Calculated as the reciprocal of the fluence required to induce the SEGR event.
- m. SEGR post gate-stress test: After the heavy ion irradiation, a test is conducted to verify the gate integrity by applying the maximum specified V<sub>GS</sub>.
- n. Threshold LET: The minimum LET required to cause a single-ion-induced failure under the specified bias conditions.
- o. V<sub>DS</sub>: The applied drain-to-source voltage (volts).
- p. V<sub>GS</sub>: The applied gate-to-source voltage (volts).
- q. V<sub>TH</sub>: The value of V<sub>GS</sub> where the inversion layer is formed and the device turns on.

1.2 Applicable documents. The following documents form part of this test method. The most current revision of these documents shall take precedence over those cited.

EIA/JESD57	- Test Procedures for the Measurement of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation.
ASTM F-1192	- Standard Guide for the Measurement of Single-Event Phenomena from Heavy Ion Irradiation of Semiconductor Devices.

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1.3 Device handling. Special care shall be taken to ensure that the devices are not damaged before testing. Since the lids are removed before irradiation, extra precautions shall be taken to protect the exposed die. Otherwise, devices shall be handled in accordance with standard operating procedures to protect against damage and electrostatic discharge. Use of anti-static foams, grounding straps, and other precautions is recommended.

NOTE: Some power MOSFETs may require voltages that exceed 500 volts and voltages in excess of 32 volts can present a safety hazard. Safety precautions shall be taken to ensure safe operation of all equipment and personnel. Note that conformal coatings may interfere with the test, changing the penetration depth of the ion as well as degrading the ion energy. The effect of conformal coatings shall be evaluated. Conformal coatings, such as polyamide, should be chemically removed before testing.

2. Apparatus. The apparatus required for SEB/SEGR testing consists of a heavy ion source, a vacuum chamber system, DUT test instrumentation, test circuit board(s), cabling, switching system (if required), an x-y-z stage system (if required), and dosimetry measurement instrumentation. Precautions shall be taken to obtain an electrical measurement system with sufficient insulation, shielding, and grounding to measure a gate current,  $I_{GS}$ , of 10 nA or less (measurement resolution).

2.1 Heavy ion source. The heavy ion source shall be a cyclotron, Van de Graaff accelerator, or other suitable source. The heavy ion source shall be capable of providing an average ion flux up to 100,000 ions/cm<sup>2</sup>•s. The average beam uniformity should be maintained within ±15 percent over the die area unless otherwise specified. The ion beam energy shall provide sufficient ion penetration depth to induce the SEGR response or as agreed to by both parties to the test. Note that the accelerator design determines the maximum ion beam energy; and, therefore, some accelerators may be inadequate to perform a worst-case test condition. Also, note that some accelerators are rf-type machines (e.g. cyclotrons) and may have higher instantaneous fluxes.

2.2 Vacuum chamber system. The chamber shall have a test circuit board mounting frame and cable feed-through. The vacuum chamber system should be capable of accepting an x-y-z stage mechanism. The pumping system shall be capable of evacuating the vacuum chamber below  $1.3 \times 10^{-1}$  Pa ( $10^{-3}$  torr). Precautions shall be taken to ensure that any component placed in the vacuum chamber does not interfere with the vacuum system. Note that certain materials can out-gas, affecting the vacuum quality. Also note that some capacitors (e.g., electrolytic capacitors) can explode, fail, or out-gas when placed in a vacuum.

2.3 Test instrumentation. Standard electrical test instruments capable of establishing the required test conditions and measuring the required electrical parameters shall be used. Note that many power MOSFETs may require operating voltages in excess of 32 volts and safety precautions shall be followed to ensure safe operation of all equipment and personnel."

2.3.1 SEB instrumentation. Test instrumentation to bias and monitor the DUT may consist of one or more of the following types of instruments:

- a. Power supply.
- b. Ammeter.
- c. Voltmeter.
- d. Counter.
- e. Oscilloscope.

2.3.2 SEGR instrumentation. Test instrumentation to bias and monitor the DUT may consist of one or more of the following types of instruments:

- a. Power supply.
- b. Ammeter.
- c. Voltmeter.

2.4 Test circuit board. The test circuit board contains the test socket, delidded DUT, any additional wiring, and any auxiliary components. The test board provides a mounting surface and interface between the test instrumentation and the DUT, applying  $V_{GS}$  and  $V_{DS}$ , while monitoring  $I_{GS}$  and  $I_{DS}$ . Figure 1 shows a representative test circuit and figure 2 shows a typical SEB circumvention and monitoring technique. Any auxiliary components, such as the resistors, capacitors, or current probes, shall be included in the final test circuit. Any accepted SEB circumvention and monitoring technique is acceptable. The test board can have multiple test sockets to minimize the time required to vent and evacuate the vacuum chamber. The test socket, in which the DUT is inserted, is mounted in such a way that the DUT surface shall be perpendicular (nominally within ±5°C) to the heavy ion beam. The DUT is delidded prior to testing, and the entire die shall be irradiated.

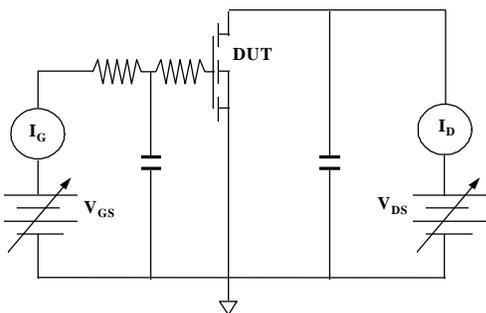


FIGURE 1080-1. Basic SEB/SEGR test circuit.

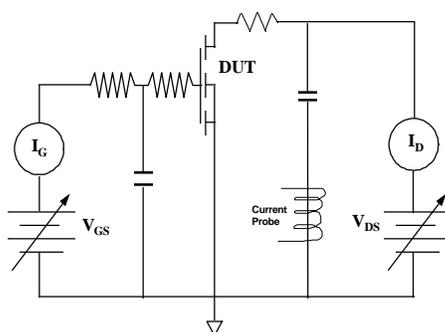


FIGURE 1080-2. SEB circumvention and monitoring circuit.

2.5 Cabling. Cables are typically used to connect the test circuit board, located in the vacuum chamber, to the test instrumentation, normally placed outside the vacuum chamber. The cable length shall be minimized to prevent interference with the desired measurement. However, the actual cable length is dictated by the size of the vacuum chamber, the spatial location of the test board with respect to the cabling feed-throughs, and the minimum distance from the cabling feed-throughs to the DUT test instrumentation. Observation of SEB pulses shall be performed using properly terminated shielded cables to minimize reflections and other signal/noise interference.

2.6 Switching system. A switching system can be used when multiple devices are placed on the test board. The switching system shall provide electrical isolation between the gate and drain electrodes of the various test devices on the test board. Inclusion of a switching system shall not interfere with the electrical measurement system, as specified in 2.

2.7 X-Y-Z stage system. If multiple devices are placed on the test board, an x-y-z stage system can be used to provide a mechanical mechanism to move the device into and out of the heavy ion beam.

2.8 Dosimetry system. The dosimetry system shall be used to determine the ion beam energy, LET, average ion beam flux, fluence, and average ion beam uniformity. Note that many facilities provide this dosimetry system.

3. SEB/SEGR prediction. To assist in the preparation of the test plan and the selection of initial bias conditions, an appropriate SEB/SEGR prediction method may be utilized to predict the SEB/SEGR failure thresholds. The preferred prediction method is to use previous measurements on similar device types. Test personnel should use these predicted failure thresholds to help verify that the SEGR and SEB test measurements are valid. If a significant difference (nominally greater than a  $\pm 30$  percent deviation from the predicted response) is observed, the test personnel should verify the test setup including the ion specie, ion energy, bias conditions, and device type. These predictions can help to develop the overall test plan.

3.1 SEB prediction. Currently, there are not any accurate prediction models available for SEB. Predictions based upon previously obtained SEB data are helpful, but, due to the nature of the failure mechanism, cannot be used to accurately predict SEB.

3.2 SEGR prediction. Predictions of SEGR can be made from previous SEGR data or calculated using currently accepted models. If previous test results are unavailable or the device layout, design, or process has been modified, then SEGR failure thresholds can be predicted using an empirical prediction method or an analytical prediction method.

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3.2.1 SEGR empirical prediction. The empirical prediction method uses an empirically derived equation to predict the SEGR failure threshold of the oxide capacitor when  $V_{DS} = 0$  volts, as expressed by Equation (1).

$$V_{GS} = \frac{(E_{OX\_BR})(T_{OX})}{\left(1 + \frac{LET}{53}\right)}$$

Where:  $E_{OX\_BR}$  is the breakdown field strength of the oxide (V/cm),  
 $T_{OX}$  is the thickness of the gate oxide dielectric (cm), and

LET\_PEAK is the maximum LET value of the given ion species in MeV/mg/cm<sup>2</sup>.

An approximation of the substrate response for the case when  $V_{DS}$  is biased can be obtained by using an expanded form of equation 1. This expanded equation is expressed by equation (2).

$$V_{GS} = (0.84)\left(1 - e^{-\frac{LET}{17}}\right)(V_{DS}) - \frac{(E_{OX\_BR})(T_{OX})}{\left(1 + \frac{LET}{53}\right)}$$

Where:  $E_{OX\_BR}$  is the breakdown field strength of the oxide (V/cm),  
 $T_{OX}$  is the thickness of the gate oxide dielectric (cm), and  
LET is the linear energy transfer in (MeV/mg/cm<sup>2</sup>).

LET PEAK is the maximum LET value of the given ion species in MeV/mg/cm<sup>2</sup>

3.2.2 SEGR analytical prediction. Analytical predictions can be obtained using sophisticated numerical simulations to predict the SEGR failure threshold response. Additional information concerning these predictions can be found in the literature.

4. Characterization tests. Characterization testing is that testing required to obtain an SEB cross-sectional area curve, an SEGR cross-sectional area curve, or an SEGR failure threshold curve. Data points are taken to describe the response of the discrete MOSFET as a function of  $V_{GS}$  and/or  $V_{DS}$  over the operating range of the device and/or over a range of LET values. Characterization testing should be conducted initially to define the worst-case operating conditions of the device or to identify the sensitive die area. Additional characterization testing may be required after process and/or design changes have been made to the device. Characterization tests are useful for establishing the conditions for subsequent verification tests. Characterization testing does not have to be performed as a part of the verification testing unless fabrication changes have been made that might invalidate the initial technology characterization. Note that angling the die surface away from the plane where the ion beam is perpendicular to the die surface to produce an effective LET is invalid and shall not be used. It has been reported that the ion energy can influence the measured SEGR failure thresholds, suggesting that the ion energy shall be considered when a worst-case test condition is specified. The maximum allowable  $V_{DS}$  bias increment for a DUT shall be no more than 10 percent of the device's rated drain voltage. The maximum allowable  $V_{GS}$  bias increment for a DUT shall be no more than 5 volts. Smaller  $V_{DS}$  and  $V_{GS}$  bias increments are recommended. Also, note that increasing the DUT's operating temperature has been demonstrated to increase the LET threshold for SEB but not for SEGR, indicating that lower operating temperatures are a worst-case test condition.

4.1 SEB characterization. Characterization requires that an SEB circumvention method be utilized. SEB characterization produces a cross-sectional area curve as a function of LET for a fixed  $V_{DS}$  and  $V_{GS}$ . SEB is not sensitive to changes in the gate bias,  $V_{GS}$ . The  $V_{GS}$  bias shall be sufficient to bias the DUT in an "off" state (a few volts below  $V_{TH}$ ), allowing for total dose effects that may reduce the  $V_{TH}$ . Multiple SEB cross-sectional area curves may be required, expressing different operating conditions for  $V_{DS}$ . Note that p-channel devices have not been demonstrated to be sensitive to SEB.

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4.1.1 SEB cross-sectional area If specified as a test requirement and if SEB is observed, one of the many reported techniques can be used to circumvent catastrophic SEB failure, such as a current-limiting resistor placed between the drain stiffening capacitor and the drain electrode. Then, to obtain an SEB error count, a current probe (Tektronix CT-2, sense resistor, or other suitable current probe) shall be inserted between the source electrode and ground. Using this setup, an SEB event will produce current pulses. SEB occurrence can be monitored using an electronic oscilloscope to record the shape of the SEB pulse(s), if required, and a pulse counter to record the number of SEB occurrences. A point on the SEB cross-sectional area curve is then obtained by dividing the number of SEB events by the fluence for that given test condition. The SEB cross sectional curve is subsequently found by finding points at several different LET values. After the DUTs have been delidded and the chamber evacuated, apply the specified  $V_{GS}$  and  $V_{DS}$  bias condition; and irradiate the DUT to the specified fluence level (typical ranges are between  $10^5$  and  $10^7$  ions/cm<sup>2</sup>). If SEB occurs, record the event by incrementing the counter. The flux shall be adjusted so that the number of SEB events is no more than 100 events per second. When the desired fluence is achieved, the beam is shuttered; and the total number of SEB events are recorded. This process is continued, selecting different ions to obtain the required LET values. Repeat this process for the specified samples and conditions.

4.2 SEGR characterization. SEGR characterization may produce three unique curves: an SEGR cross-sectional area curve as a function of LET for a fixed  $V_{GS}$  and  $V_{DS}$  bias condition, an SEGR threshold curve of  $V_{GS}$  as a function of  $V_{DS}$  for a fixed LET value, or an SEGR threshold curve of  $V_{DS}$  as a function of LET at a fixed  $V_{GS}$ . Multiple SEGR cross sectional area curves may be required to express different  $V_{DS}$  and  $V_{GS}$  conditions. Multiple SEGR threshold curves may be required to express different  $V_{GS}$ ,  $V_{DS}$ , or LET conditions. SEGR characterization may be performed in conjunction with SEGR verification.

4.2.1 SEGR cross-sectional area. If specified in the test requirements and if SEGR occurs, an SEGR cross-sectional area curve can be obtained. However, SEGR cannot be circumvented. Hence, to obtain an SEGR cross-sectional area curve requires the destruction of numerous devices. For a given device, the ion irradiation would be terminated upon detection of SEGR. One point on the SEGR cross-sectional area curve can be obtained by dividing one SEGR event by the measured fluence to induce that event. After the DUTs have been delidded and the chamber evacuated, apply the specified  $V_{GS}$  and  $V_{DS}$  bias condition; and irradiate the DUT to the specified fluence level. If SEGR occurs, immediately terminate the exposure; and record the accumulated fluence. Note that the ion flux can be lowered to obtain a more accurate fluence. If the maximum fluence is achieved and the DUT passes the post gate-stress test, a new test condition or a new DUT is selected. If SEGR occurs, a new DUT is selected. Apply the new test condition (incrementing  $V_{GS}$ ,  $V_{DS}$ , or changing the ion specie). This process is repeated until the desired curve is obtained. Repeat this process to obtain the required curves. Note that characterization results in device failure and only represents a single data point for that device. For the special case where the applied dc field across the gate dielectric is less than 1 MV/cm, the procedure to obtain a cross-sectional area curve should be modified as follows:

- a. An incremental fluence should be set at one-third of the die area or less;
- b. After each irradiation step, a post gate-stress test shall be performed to verify device functionality;
- c. If SEGR is not detected, continue irradiation steps until SEGR occurs or until the maximum accumulated fluence is obtained; and
- d. Select new device and bias condition and repeat test procedure until the desired curve is obtained.

4.2.2 SEGR post gate-stress test. If the gate bias is small (typically  $V_{GS} < 10$  volts) during irradiation, SEGR may or may not produce a catastrophic failure until sufficient gate bias is applied. If an insufficient gate bias is applied, SEGR may only produce a latent defect site. Therefore, after the irradiation, a post gate-stress test shall be performed on each test device. The post gate-stress test shall apply a gate bias equal to the maximum operating gate voltage (nominally  $\pm 10$  percent) or as specified.

5. Verification tests. Verification testing requires the irradiation of the DUT to specified test conditions (e.g. gate bias, drain bias, ion species, ion energy, ion LET, ion range, ion flux, and ion fluence). Verification testing is useful for hardness assurance and qualification testing of discrete power MOSFETs to determine their suitability at the specified test conditions. These tests use a "pass"/"no pass" criterion and can be destructive. Note that angling the die surface away from the plane where the ion beam is perpendicular to that surface to produce an effective LET is invalid and shall not be used to conduct these tests. It has been reported that the ion energy can influence the measured SEGR failure thresholds, suggesting that the ion energy should be considered to achieve a worst-case test condition. Also, note that increasing the DUT's operating temperature has been demonstrated to increase the LET threshold for SEB but not for SEGR, indicating that lower operating temperatures are a worst-case test condition.

5.1 SEB verification tests. For SEB verification, a sufficiently large capacitance is placed at the drain electrode to produce catastrophic failure. Note that no circumvention techniques are used in this test. After the DUTs have been delidded and the chamber evacuated, apply the specified  $V_{GS}$  and  $V_{DS}$  bias condition and irradiate the DUT to the specified fluence level. If failure occurs, the exposure can be terminated. Record SEB results. Repeat for the specified samples and conditions.

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5.2 SEGR verification tests. For SEGR verification, this test is a two-step process. After DUTs have been delidded and the chamber evacuated, apply the specified VGS and VDS bias condition and irradiate the DUT to the specified fluence. If failure occurs, the exposure can be terminated. The second step requires a post gate-stress test to be performed after irradiation, if the gate bias during irradiation was less than the maximum operating gate voltage. Record SEGR result. Repeat for the specified samples and conditions.

6. SEB/SEGR test procedure. The test plan should document the proper steps to be followed before, during, and after heavy ion irradiation. Sufficient samples shall be obtained to conduct the test. Samples with conformal coatings, such as polyamide, should be chemically removed before testing. SEB and SEGR both can result in catastrophic failure that produces large leakage currents, destroying the device. In SEB testing, a capacitance sufficient to hold the bias voltage within  $\pm 10$  percent may be required to induce damage during an SEB event. For characterization testing, SEB can be circumvented and recorded producing an SEB event count, which then can be used to produce a point on the cross-sectional area curve. To help select the proper biases, an SEB/SEGR prediction shall be made. The required ion specie is selected and the ion beam energy shall be tuned and verified using the dosimetry system. The test circuit board, cabling, and instrumentation shall be connected and its operation verified. Before irradiation, test devices shall be delidded and inserted into the test board. The drain and gate currents,  $I_{GS}$  and  $I_{DS}$ , shall be monitored before, during, and after the irradiation(s), as well as during the post gate-stress test, to verify the condition of the DUT. After completion of the test run, the results of the test shall be recorded and documented.

6.1 Test plan. A test plan shall be devised that supports each test. The test plan shall be used as a guide for the procedures and decisions during irradiation. The test plan shall be developed, and the following conditions shall be outlined.

6.1.1 Ion specie and energy. The test plan shall identify the ion specie and an appropriate energy to perform the test. Selection of a specific ion specie and its energy determines the LET value. Obtaining a range of LET values requires using different ion species at different energies. Note that using angles to modulate the LET value is unacceptable. Selection of a different ion specie and energy by test personnel requires verification that the ion LET and its range meet the test requirements. Verification can be made using the TRIM code or other suitable simulation codes for the given device material. Also, note that the energy of the ion beam has been shown to influence the SEGR failure thresholds. Therefore, determination of the worst-case test condition can require multiple irradiations with the same ion at different energies.

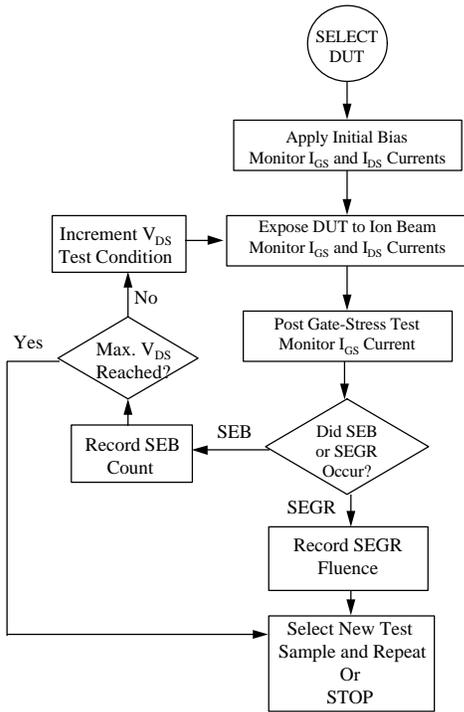
6.1.2 Device information. The test plan shall provide a description of the devices to be tested and the number of test samples required for each test. The test plan shall identify the device type, acceptance lot, and other critical information. Devices shall be marked for traceability so that lids can be removed. Identification markers should be placed on the flange and not on the lid. Only devices that have passed the pre-electrical tests shall undergo heavy ion testing. Test samples shall be randomly selected from the parent population. The number of samples shall be specified to meet the test requirements. For the purposes of verification testing, a representative sample should be selected from the lot.

6.1.3 Electrical parameters. The test plan shall specify the electrical parameters to be measured before and after irradiation.

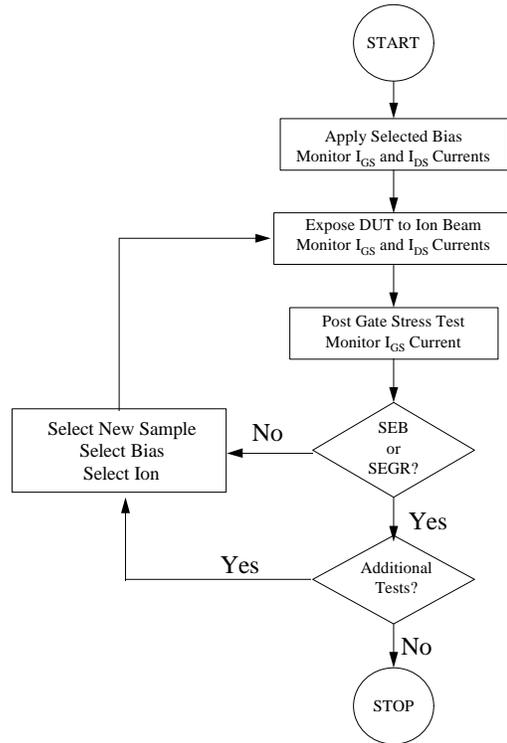
6.1.4 Test configuration. The test plan shall specify the bias and exposure conditions for each test sample. The test plan shall specify the case temperature of the DUT if it is required to be set at other than the room ambient temperature.

6.1.5 Test sequence. The test plan should specify a test sequence similar to figure 1080-3. For characterization testing, the test plan shall define an initial bias condition and the bias increment. The  $V_{DS}$  bias increment shall not exceed 10 percent of the device's rated drain breakdown voltage. For verification testing, the test plan shall define the specified biases, the minimum number of samples that shall be tested at each bias, and the handling of the devices after testing. Any additional electrical tests shall be specified and any special handling requirements shall be specified.

6.1.6 SEB/SEGR detection. The test plan shall specify the procedure to monitor the drain and gate currents,  $I_{GS}$  and  $I_{DS}$ , before, during, and after the irradiation(s). In addition, the gate and drain currents shall be monitored during the post gate-stress test to verify that the DUT was not damaged during the previous irradiation.



Characterization flowchart sample.



Verification flowchart sample.

FIGURE 1080-3. Test plan flowcharts.

6.1.7 Data recording. The test plan shall specify the necessary parameters that shall be recorded during the test.

6.1.8 Reporting requirements. The test plan shall specify the test documentation as required by 7 herein.

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6.2 Radiation test procedure. The test plan shall be used as a guide to perform the radiation test. A typical SEB/SEGR test procedure is given here as an example.

- a. Test personnel shall specify the selected ion specie and energy to the facility operators as defined in the SEGR/SEB test plan specifying the desired flux, fluence, LET, range, and beam uniformity. Dosimetry shall be performed to verify that the ion beam characteristics are as specified.
- b. The SEGR/SEB test board shall be mounted in the test fixture mounting frame. All necessary test cables shall be connected to the test board and vacuum feed-through inside the vacuum chamber.
- c. The test instrumentation shall be set up as close as possible to the vacuum chamber. All necessary test cables shall be connected to the test hardware and vacuum feed-through outside the vacuum chamber.
- d. When the test system is set up, the operation of the test system shall be verified for continuity and operation. Note that a quick check can be performed by applying a  $V_{GS}$  and  $V_{DS}$  and verifying the presence of these voltages with a voltmeter.
- e. After test system verification is completed, ground all electrodes; and insert the devices for test. Handling of devices shall be in accordance with normal ESD practices. If lids were not removed before placement on the test board, remove the device lids. To verify that the devices were not damaged during the delidding process or insertion into the test board, a simple electrical check of  $I_{GS}$  and  $I_{DS}$  should be performed.
- f. After device verification is completed, the device to be tested shall be aligned to the ion beam. With the beam shuttered and the DUT biases set at 0 volts, perform an alignment of the DUT to the ion beam. Note that some facilities provide a laser alignment system for this task.
- g. When positional alignment is complete, turn off any lighting systems and laser systems in the vacuum chamber. Apply the selected bias conditions to the DUT; and begin monitoring the gate and drain leakage currents,  $I_{GS}$  and  $I_{DS}$ . Note that excitation by lights or laser may produce photocurrents which may interfere with the measurements.
- h. When ready, open the ion beam shutter, exposing the DUT to the heavy ion beam. Note that most facilities include instrumentation to monitor the ion beam characteristics monitoring the average flux, fluence, and beam uniformity which should be recorded. When the desired fluence level is achieved, shutter the ion beam, terminating the irradiation.
  - (1) If performing an SEB characterization test, the test circuit shall include an appropriate circumvention technique and a current-sensing circuit. The number of current pulses for each irradiation shall be recorded (see 4.1).
  - (2) If performing an SEGR characterization test, the ion beam shall be shuttered immediately following the detection of SEGR- any significant gate current change. The ion fluence at failure shall be recorded. Note that detection of SEGR may require the test personnel to make a judgment concerning the SEGR status of the device.
  - (3) If performing an SEGR or SEB verification test, the gate and drain leakage currents,  $I_{GS}$  and  $I_{DS}$ , shall be monitored. If a current change is recorded (typically, a flag can be set, e.g. an  $I_{GS} > 10^{-7}$  amps), document the observed conditions.
- i. After the ion beam is shuttered, a post gate-stress test shall be performed. During the post gate-stress test (the rated gate voltage is applied), the gate current shall be monitored. If a current change is detected (typically, a flag can be set, e.g. an  $I_{GS} > 10^{-7}$  amps), document any observed conditions.
- j. Upon completion of the post gate-stress test, record all pertinent test data. Record run number, ion specie, ion energy, range, LET, average flux, fluence, and test conditions ( $V_{GS}$ ,  $V_{DS}$ ). Record any changes in the drain or gate currents ( $I_{GS}$  and  $I_{DS}$ ) before, during, and after the ion irradiation. Record any changes in the drain and gate currents,  $I_{GS}$  and  $I_{DS}$ , during the post gate-stress test. Determine the status of the test run. If the test is a characterization test, increment the test condition or select new device as required. Repeat test procedure. If the test is a verification, select next device and test conditions. Repeat test procedure.

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7. Data formatting reporting. Test data/test reports shall be maintained and shall include the following information:
- a. Device type, identification marker, lot identification, and date code.
  - b. Test date and test personnel names.
  - c. Facility, accelerator type, identification of ion, energy, average flux, LET, range in device material, and fluence.
  - d. Schematic of test circuit or test board.
  - e. Dosimetry output of each ion beam used.
  - f. Bias condition of each exposure run.
  - g. Record of observed SEGR or SEB (current changes).
  - h. Device case temperature (only if required at other than room ambient)