

MIL-STD-202G

CLASS 100
ENVIRONMENTAL TESTS

METHOD 101E

SALT ATMOSPHERE (CORROSION)
(formerly Salt Spray (Corrosion))

1. **PURPOSE.** The salt-spray test, in which specimens are subjected to a fine mist of salt solution, has several useful purposes when utilized with full recognition of its deficiencies and limitations. Originally proposed as an accelerated laboratory corrosion test simulating the effects of seacoast atmospheres on metals, with or without protective coatings, this test has been erroneously considered by many as an all-purpose accelerated corrosion test, which if "withstood successfully" will guarantee that metals or protective coatings will prove satisfactory under any corrosive condition. Experience has since shown that there is seldom a direct relationship between resistance to salt atmosphere corrosion and resistance to corrosion in other media, even in so-called "marine" atmospheres and seawater. However, some idea of the relative service life and behavior of different samples of the same (or closely related) metals or of protective coating-base metal combinations in marine and exposed seacoast locations can be gained by means of the salt atmosphere test, provided accumulated data from correlated field service tests and laboratory salt atmosphere tests show that such a relationship does exist, as in the case of aluminum alloys. (Such correlation tests are also necessary to show the degree of acceleration, if any, produced by the laboratory test). The salt atmosphere test is generally considered unreliable for comparing the general corrosion resistance of different kinds of metals or coating-metal combinations, or for predicting their comparative service life. The salt atmosphere test has received its widest acceptance as a test for evaluating the uniformity (specifically, thickness and degree of porosity) of protective coatings, metallic and nonmetallic, and has served this purpose with varying amounts of success. In this connection, the test is useful for evaluating different lots of the same product, once some standard level of performance has been established. The salt atmosphere test is especially helpful as a screening test for revealing particularly inferior coatings. When used to check the porosity of metallic coatings, the test is more dependable when applied to coatings that are cathodic rather than anodic toward the basic metal. 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 atmosphere test shall include the following:

- a. Exposure chamber with racks or fixtures 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 controls.
- 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 that will not affect the corrosiveness of the salt atmosphere, such as glass, hard rubber, or plastic. All parts of the test setup that 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 atmosphere 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 chamber shall have a suitable means of heating and maintaining the required test temperature.

2.2 **Salt solution reservoir.** The salt solution reservoir shall be made of material that is non-reactive with the salt solution, e.g., glass, hard rubber, or plastic. The reservoir shall be adequately protected from the surrounding environment and shall have a means to monitor the solution level. The reservoir shall include a means to filter the salt solution in the supply line to the atomizers. When long duration test conditions are specified (e.g. test condition D), the reservoir may be refilled via auxiliary reservoirs so that the test cycle shall not be interrupted.

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(s) 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) or higher. The permissible temperature increases 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 (e.g. 110°F (43.3°C) at an air pressure of 12 pounds psi), or a value that makes it impossible to meet the requirement for operating temperature.

3. SALT SOLUTION. The salt used shall be sodium chloride (NaCl) containing on the dry basis not more than 0.1 percent of sodium iodide, and not more than 0.5 percent of total impurities. Do not use sodium chloride (NaCl) containing anti-caking agents because such agents may act as corrosion inhibitors. Unless otherwise specified, the salt solution concentration shall be 5 ± 1 percent. The 5 percent solution shall be prepared by dissolving 5 ± 1 parts by weight of salt in 95 parts by weight of distilled or deionized water. Water used in the preparation of solutions shall contain not more than 200 parts per million of total solids. The salt solution shall be kept free from solids by filtration. The solution shall be adjusted to and maintained at a specific gravity in accordance with figure 101-1. The pH shall be maintained between 6.5 and 7.2 when measured at a temperature of 95°F ± 5 °F (35°C ± 3 °C). Only dilute cp grade hydrochloric acid or sodium hydroxide shall be used to adjust the pH.

4. 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 either 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 come 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.

5. PROCEDURE.

5.1 Maintenance and conditioning of test chamber. The chamber shall be cleaned each time the salt solution in the reservoir has been used up to assure that all materials that could adversely affect the results of subsequent tests are removed. However, no test shall be interrupted for the purpose of chamber cleaning. After the cleaning cycle, upon restarting the chamber, the reservoir shall be filled with salt solution and the chamber shall be stabilized by operating it until the temperature comes to equilibrium, see 5.3. Intermittent operation of the chamber is acceptable, provided the pH and concentration of the salt solution are kept within limits, see 3.

5.2 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 degrees 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 that is non-reactive to the salt solution such as lucite. The use 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.

5.3 Chamber operation. A salt fog having a temperature of 95°F minimum (35°C minimum) shall be passed through the chamber for the specified test duration (see 5.4). The exposure zone of the chamber shall be maintained at a temperature of 95°F ±5°F (35°C ±3°C). 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 (0.5-3ml/hr/80cm²) of horizontal collecting area (10 centimeters diameter). At least two clean fog-collecting receptacles shall be used; one placed at the perimeter of the test specimens nearest to the (any) nozzle, and the other at the perimeter of the test specimens farthest from the nozzle(s). Receptacles shall be fastened in such a manner that they are not shielded by specimens and so that no drops of solution from specimens or other sources will be collected. The 5 percent solution thus collected shall have a sodium chloride (NaCl) content of from 4 to 6 percent (specific gravity in accordance with figure 101-1) when measured at a temperature of 95°F ±5°F (35°C ±3°C). The specific gravity and quantity of the solution collected shall be checked following each salt atmosphere 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 psi.
- 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 for each 24 hour period of test.

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.

5.4 Length of test. The length of the salt atmosphere 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
C -----	24 hours
D -----	240 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.

6. MEASUREMENTS. Upon completion of the salt exposure, the test specimens shall be immediately washed with free flowing deionized water (not warmer than 100°F (38°C)) for at least 5 minutes to remove salt deposits from their surface after which they shall be dried with air or inert gas. As an option, the test specimens may be subjected to a gentle wash or dip in running water (not warmer than 100°F (38°C)) and a light brushing, using a soft hair brush or plastic bristle brush, after which they shall be dried with air or inert gas. The test specimens shall then be subjected to the inspections specified.

7. SUMMARY. The following details are to be specified in the individual specification:

- a. Special mounting and details, if applicable (see 5.2).
- b. Test condition letter (see 5.4).
- c. Measurements after exposure (see 6).

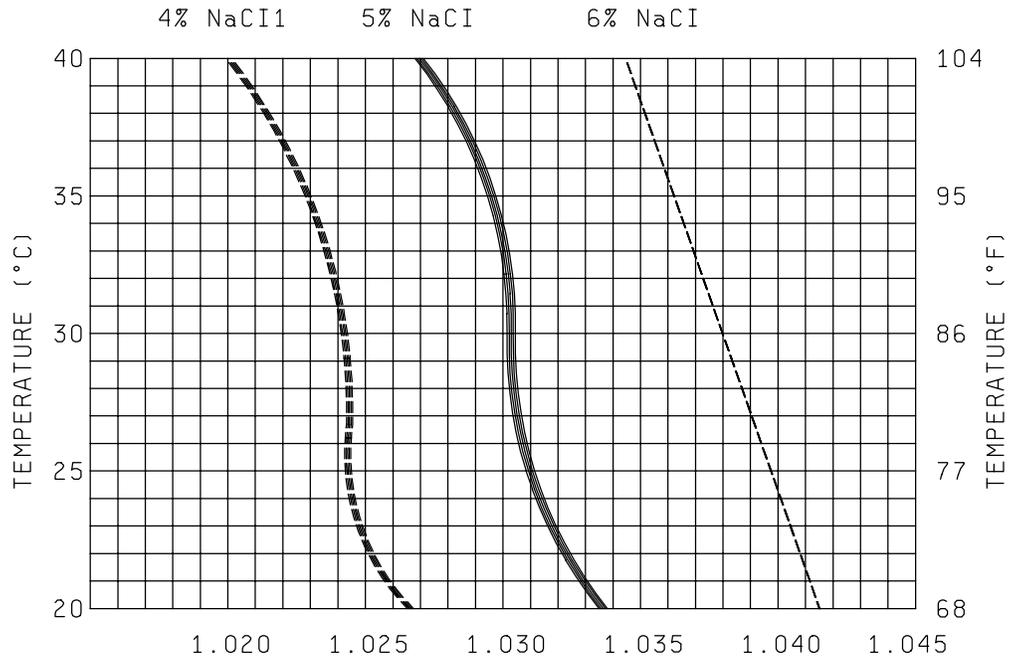


FIGURE 101-1. Variations of specific gravity of salt (NaCl) solution with temperature.

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METHOD 102A

TEMPERATURE CYCLING
(CANCELED)

When Method 102 Is specified	Use Method 107
Test condition A, B and D C	Test condition A B

METHOD 103B

HUMIDITY (STEADY STATE)

1. **PURPOSE.** This test is performed to evaluate the properties of materials used in components as they are influenced by the absorption and diffusion of moisture and moisture vapor. This is an accelerated environmental test, accomplished by the continuous exposure of the specimen to high relative humidity at an elevated temperature. These conditions impose a vapor pressure on the material under test which constitutes the force behind the moisture migration and penetration. Hygroscopic materials are sensitive to moisture, and deteriorate rapidly under humid conditions. Absorption of moisture by many materials results in swelling, which destroys their functional utility, and causes loss of physical strength and changes in other important mechanical properties. Insulating materials that absorb moisture may suffer degradation of their electrical properties. This method, while not necessarily intended as a simulated tropical test, is of use in determining moisture absorption of insulating materials.

2. **PROCEDURE.**

2.1 **Conditioning.** The specimens shall be conditioned in a dry oven at a temperature of $40^{\circ} \pm 5^{\circ}\text{C}$ for a period of 24 hours. At the end of this period, measurements shall be made as specified.

2.2 **Chamber.** The chamber and accessories shall be constructed and arranged in such a manner as to avoid condensate dripping on the specimens under test, and such that the specimens shall be exposed to circulating air.

2.3 **Exposure.** The specimens shall be placed in a chamber and subjected to a relative humidity of 90 to 95 percent and a temperature of $40^{\circ} \pm 2^{\circ}\text{C}$ for the period of time indicated in one of the following test conditions, as specified:

<u>Test condition</u>	<u>Length of test</u>
A -----	240 hours
B -----	96 hours
C -----	504 hours
D -----	1,344 hours

When specified, a direct-current potential of 100 volts or as specified shall be applied to the specimens during the exposure period. The length of time for the application of voltage and the points of application shall be as specified.

3. **FINAL MEASUREMENTS**

3.1 **At high humidity.** Upon completion of the exposure period, and while the specimens are still in the chamber, the specified measurements shall be performed. These measurements may be compared to the initial measurements (see 2.1), when applicable.

3.2 **After drying period.** Upon completion of the exposure period or following measurements at high humidity if applicable, the specimens shall be conditioned at room ambient conditions for not less than 1 hour, nor more than 2 hours unless otherwise specified, after which the specified measurements shall be performed at room ambient conditions.

4. SUMMARY. The following details are to be specified in the individual specification:
- a. Measurements after conditioning (see 2.1).
 - b. Test condition letter (see 2.3).
 - c. The length of time and points of application of polarizing voltage, if applicable (see 2.3).
 - d. Final measurements:
 - (1) At high humidity, if applicable (see 3.1).
 - (2) After drying period (see 3.2).

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METHOD 104A

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. This 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° +5°, -0 °C (149° +9°, -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 104-1, as specified.

TABLE 104-1 Immersion test conditions.

Test condition	Number of cycles	Duration of each immersion	Immersion bath (cold)	Temperature of cold bath
		<u>Minutes</u>		<u>°C</u>
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).

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METHOD 105C

BAROMETRIC PRESSURE (REDUCED)

1. PURPOSE. The barometric pressure test is performed under conditions simulating the low atmospheric pressure encountered in the nonpressurized portions of aircraft and other vehicles in high altitude flight. This test is intended primarily to determine the ability of component parts and materials to avoid dielectric-withstanding-voltage failures due to the lowered insulating strength of air and other insulating materials at reduced pressures. Even when low pressures do not produce complete electrical breakdown, corona and its undesirable effects, including losses and ionization, are intensified. Low barometric pressures also serve to decrease the life of electrical contacts, since intensity of arcing is increased under these circumstances. For this reason, endurance tests of electro-mechanical component parts are sometimes conducted at reduced pressures. Low-pressure tests are also performed to determine the ability of seals in component parts to withstand rupture due to the considerable pressure differentials which may be developed under these conditions. The simulated high altitude conditions of this test can also be employed to investigate the influence on component parts operating characteristics, of other effects of reduced pressure, including changes in dielectric constants of materials; reduced mechanical loading on vibrating elements, such as crystals; and decreased ability of thinner air to transfer heat away from heat-producing components.

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 tests.

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	17.3	439.00	15,000	4,572
G	9.436 x10 ⁻⁸	2.40 x 10 ⁻⁶	656,000	200,000

4. SUMMARY. The following details are to be specified in the individual specification:

- a. Method of mounting (see 3).
- b. Test condition letter (see 3).
- c. Tests during subjection to reduced pressure (see 3).
- d. Tests after subjection to reduced pressure, if applicable.
- e. Exposure time prior to measurements, if applicable.

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METHOD 106G

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, physical distortion and decomposition of organic materials, leaching out and spending of constituents of materials; and detrimental changes in electrical properties. This test differs from the steady-state humidity test (method 103 of this standard) 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 low temperature and vibration subcycles (when applicable, see 3.4.2) that act as accelerants to reveal otherwise indiscernible evidence of deterioration since stresses caused by freezing moisture and accentuated by vibration tend to widen cracks and fissures. As a result, the deterioration can be detected by the measurement of electrical characteristics (including such tests as dielectric withstanding voltage 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 electro-chemical corrosion. Results obtained with this test are reproducible and have been confirmed by investigations of field failures. This test has proven reliable for indicating those parts which are unsuited for tropical field use.

2. **APPARATUS.**

2.1 **Chamber.** A test chamber shall be used which can meet the temperature and humidity cycling specified on figure 106-1. The material used to fabricate the platforms and standoffs, which support the specimens, shall be non-reactive in high humidity. Wood or plywood shall not be used because they are resiniferous. Materials shall not be used if they contain formaldehyde or phenol in their composition. Provisions shall be made to prevent condensate from the chamber ceiling dripping onto the test specimens.

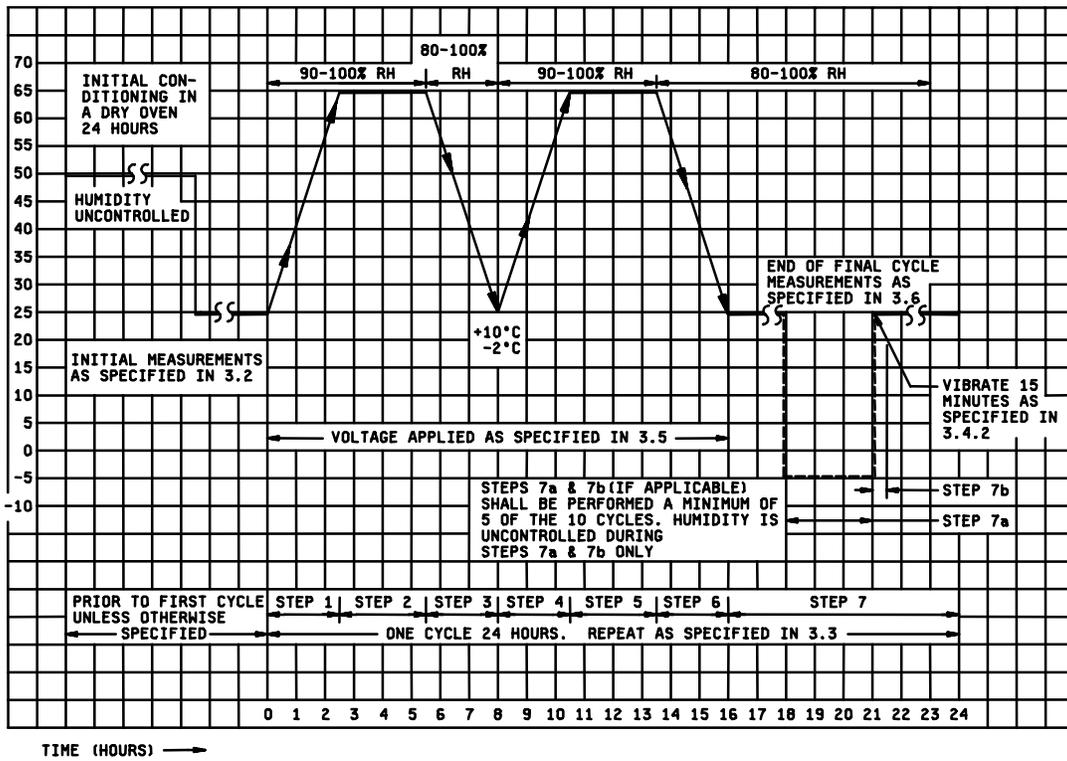
2.1.1 **Opening of the chamber door.** During the periods when the humidity is ascending or descending, the chamber door should not be opened. If the chamber door must be opened, it should be opened during the 16th hour through the 24th hour of an individual cycle. While the chamber is at 25°C (77°F), and the relative humidity tolerance must be maintained, the chamber door should be opened only for a short period of time.

2.1.2 **Water.** Steam, or distilled and demineralized, or deionized water, having a pH value between 6.0 and 7.2 at 23°C (73.4°F) shall be used to obtain the specified humidity. No rust or corrosive contaminants shall be imposed on the test specimens by the test facility.

3. **PROCEDURE.**

3.1 **Mounting.** Specimens shall be mounted by their normal mounting means, in their normal mounting position, but shall be positioned so that they do not contact each other, and so that each specimen receives essentially the same degree of humidity.

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.



NOTES:

1. Allowance of 100 percent RH is intended to avoid problems in reading values close to 100 percent RH, but actual chamber operation shall be such so as to avoid condensation.
2. Unless otherwise specified, the steady state temperature tolerance is $\pm 2^{\circ}\text{C}$ at all points within the immediate vicinity of the specimens and the chamber surfaces.
3. Rate of change of temperature is unspecified; however, specimens shall not be subjected to radiant heat from chamber-conditioning processes.
4. Circulation of air in the chamber shall be at a minimum cubic rate per minute equivalent to 5 times the volume of the chamber.

FIGURE 106-1. Graphical representation of moisture-resistance test.

3.3 Number of cycles. Specimens shall be subjected to 10 continuous cycles, each as shown on figure 106-1. 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 a complete retest.

3.4 Subcycle of step 7. During at least 5 of the 10 cycles, a low temperature subcycle and, if applicable, a vibration subcycle shall be performed.

3.4.1 Step 7a. 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. Specimens shall then be conditioned at $-10^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($14^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$) with humidity not controlled, for 3 hours minimum as indicated on figure 106-1. When a separate cold chamber is not used, care should be taken to assure that the specimens are held at $-10^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($14^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$) for the full 3 hour period. (If step 7b is not applicable, the specimens shall be returned to 25°C (77°F) at 80 percent relative humidity minimum and kept there until the next cycle begins.)

3.4.2 Step 7b (when applicable). Within 15 minutes after completion of step 7a and with humidity not controlled and temperature at room ambient, specimens shall be vibrated for 15 minutes, using a simple harmonic motion having an amplitude of 0.03 inch (0.76 mm), (0.06 inch (1.52 mm) maximum total excursion), the frequency being varied uniformly between the approximate limits of 10 and 55 hertz (Hz). The entire frequency range, from 10 to 55 Hz and return to 10 Hz, shall be traversed in approximately 1 minute. After step 7b, the specimens shall be returned to 25°C (77°F) at 80 percent relative humidity minimum and kept there until the next cycle begins.

NOTE: Step 7b is not applicable to parts that include test schedules with vibration requirements (such as method 201 or method 204 of this standard). These parts must routinely be subjected to, and pass, these requirements.

NOTE: Allowance of 100 percent RH is intended to avoid problems in reading values close to 100 percent, but actual chamber operation shall be such so as to avoid condensation.

3.5 Polarization and load. When applicable, polarization voltage shall be 100 volts dc, or as specified. The loading voltage shall be as specified.

3.6 Final measurements.

3.6.1 At high humidity. Upon completion of step 6 of the final cycle (or step 7 if the subcycle of 3.4 is performed during the tenth cycle), when measurements at high humidity are specified, the specimens shall be maintained at a temperature of $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($77^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$), and a RH of 80 percent minimum for a period of 1½ to 3½ hours, after which the specified measurements shall be made. Due to the difficulty in making measurements under high humidity conditions, the individual specification shall specify the particular precautions to be followed in making measurements under such conditions.

(NOTE: Allowance of 100 percent RH is intended to avoid problems in reading values close to 100 percent, but actual chamber operation shall be such so as to avoid condensation.)

3.6.2 After high humidity. Upon removal from humidity chamber, final measurements shall be made within a period of 1 to 2 hours after the final cycle. During final measurements, specimens shall not be subjected to any means of artificial drying.

3.6.3 After drying period. Following step 6 of the final cycle (or step 7 if the subcycle of 3.4 is performed during the tenth cycle), or following measurements at high humidity, if applicable, specimens shall be conditioned for 24 hours at the ambient conditions specified for the initial measurements (see 3.2) after which the specified measurements shall be made. Measurements may be made during the 24 hour conditioning period; however, any failures which occur shall be considered as failures and shall not be retested later for the purpose of obtaining an acceptable result.

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4. SUMMARY: The following details are to be specified in the individual specification:
- a. Initial measurements and conditions, if other than room ambient (see 3.2).
 - b. When applicable, the polarization voltage if other than 100 volts (see 3.5).
 - c. Loading voltage (see 3.5).
 - d. Final measurements and measurement conditions (see 3.6).

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METHOD 107G

THERMAL SHOCK

1. PURPOSE. This test is conducted for the purpose of determining the resistance of a part to exposures at extremes of high and low temperatures, and to the shock of alternate exposures to these extremes, such as would be experienced when equipment or parts are transferred to and from heated shelters in arctic areas. These conditions may also be encountered in equipment operated noncontinuously in low-temperature areas or during transportation. Although it is preferred that the specimen reach thermal stability during the exposure specified, in the interest of saving time, parts may be tested at the minimum exposure durations specified, which will not insure thermal stability but only an approach thereto. Permanent changes in operating characteristics and physical damage produced during thermal shock result principally from variations in dimensions and other physical properties. Effects of thermal shock include cracking and delamination of finishes, cracking and crazing of embedding and encapsulating compounds, opening of thermal seals and case seams, leakage of filling materials, rupturing, or cracking of hermetic seals and vacuum glass to metal seals, and changes in electrical characteristics due to mechanical displacement or rupture of conductors or of insulating materials.

2. APPARATUS. Suitable temperature controlled systems shall be used to meet the temperature requirements and test conditions specified in table 107-I or table 107-III. The liquid method is more severe and may damage some components that might not be degraded by the air method. It is not intended for use on nonhermetically sealed components.

2.1 Environmental chambers. A system of sufficient thermal capacity shall be used to change ambient chamber conditions to meet test requirements and to reach specified temperature conditions of steps 1 and 3 of table 107-I. The supply air temperature of the chambers shall reach the specified temperature within a recovery time of 5 minutes after the specimens have been transferred to the appropriate chamber.

2.2 Liquid baths. Suitable temperature controlled baths containing liquids (see table 107-IV) shall be chosen to maintain the specified test conditions (see table 107-III) within the indicated tolerances. A liquid media shall not be used without prior approval of the qualifying activity.

3. PROCEDURE.

3.1 Environmental chambers. Specimens shall be placed so 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 be subjected to the specified test condition of table 107-I. The first five cycles shall be run continuously. After five cycles, the test may be interrupted after the completion of any full cycle, and the specimens allowed to return to room ambient temperature before testing is resumed. One cycle consists of steps 1 through 4 of the applicable test condition. Specimens shall not be subjected to forced circulating air while being transferred from one chamber to another. Whether single or multiple chambers are used, the effective total transfer time from the specified low temperature to the specified high temperature, or the reverse, shall not exceed 5 minutes. Direct heat conduction to the specimen should be minimized. In the case of multiple chambers, the transfer time shall be defined as the time between withdrawal from the low temperature chamber and introduction into the high temperature chamber or the reverse.

NOTE: In single compartment chambers, in which the temperature extremes of steps 1 and 3 are achieved without physical movement of the specimens, steps 2 and 4 are not applicable.

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3.2 Liquid baths. Specimens shall be immersed in a suitable liquid that shall be approved by the qualifying activity (see table 107-IV), at the temperature in step 1 of the specified test condition (see table 107-III) for the time specified in table 107-V. Immediately upon the conclusion of step 1, the device shall be transferred to a suitable liquid at the temperature specified in step 2 of the specified test condition. The device shall remain at the high temperature for the time specified in table 107-V. These two steps, step 1 and 2, constitute one cycle of the applicable test condition. Repeat the required number of cycles without interruption as specified in table 107-III. Transfer time from low to high temperature and from high to low temperature shall be less than 10 seconds.

TABLE 107-I. Thermal shock test conditions (air).

Step	Test condition	Number of cycles		Test condition	Number of cycles		Test condition	Number of cycles
	A	5		B	5		C	5
	A-1	25		B-1	25		C-1	25
	A-2	50		B-2	50		C-2	50
	A-3	100		B-3	100		C-3	100
	Temperature	Time		Temperature	Time		Temperature	Time
1	$^{\circ}\text{C}$ -55 +0, -3	See table 107-II		$^{\circ}\text{C}$ -65 +0, -5	See table 107-II		$^{\circ}\text{C}$ -65 +0, -5	See table 107-II
2	25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum
3	85 +3, -0	See table 107-II		125 +3, -0	See table 107-II		200 +5, -0	See table 107-II
4	25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum

Step	Test condition	Number of cycles		Test condition	Number of cycles		Test condition	Number of cycles
	D	5		E	5		F	5
	D-1	25		E-1	25		F-1	25
	D-2	50		E-2	50		F-2	50
	D-3	100		E-3	100		F-3	100
	Temperature	Time		Temperature	Time		Temperature	Time
1	$^{\circ}\text{C}$ -65 +0, -5	See table 107-II		$^{\circ}\text{C}$ -65 +0, -5	See table 107-II		$^{\circ}\text{C}$ -65 +0, -5	See table 107-II
2	25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum
3	350 +5, -0	See table 107-II		500 +5, -0	See table 107-II		150 +3, -0	See table 107-II
4	25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum		25 +10, -5	5 minutes maximum

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TABLE 107-II. Exposure time in air at temperature extremes.

Weight of specimen	Minimum time (for steps 1 and 3)
1 ounce (28 grams and below)	<u>Hours</u> 1/4 (or as specified)
Above 1 ounce (28 grams) to .3 pound (136 grams), inclusive	1/2
Above .3 pounds (136 grams) to 3 pounds (1.36 kilograms), inclusive	1
Above 3 pounds (1.36 kilograms) to 30 pounds (13.6 kilograms), inclusive	2
Above 30 pounds (13.6 kilograms) to 300 pounds (136 kilograms), inclusive	4
Above 300 pounds (136 kilograms)	8

TABLE 107-III. Thermal shock conditions (liquid).

Step	Test condition	Number of cycles						
	AA	5	BB	5	CC	5	DD	5
	AA-1	15	BB-1	15	CC-1	15	DD-1	15
	AA-2	25	BB-2	25	CC-2	25	DD-2	25
	Temperature	Time	Temperature	Time	Temperature	Time	Temperature	Time
	<u>°C</u>		<u>°C</u>		<u>°C</u>		<u>°C</u>	
1	-0 +2, -10	See table 107-V	-65 +0, -10	See table 107-V	-65 +0, -10	See table 107-V	-65 +0, -10	See table 107-V
2	100 +10, -2	See table 107-V	125 +10, -0	See table 107-V	150 +10, -0	See table 107-V	200 +10, -0	See table 107-V

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TABLE 107-IV. Suggested thermal fluids. 1/ 2/

Test condition	AA, AA-1, AA-2 fluids	BB, BB-1, BB-2 Fluids	CC, CC-1, CC-2 fluids	DD, DD-1, DD-2 fluids
Step 1	FC40 <u>4/</u> or Water <u>3/</u> D02 } D02-TS } <u>6/</u> D/80 }	FC77 <u>4/</u> D02 } D02-TS } <u>6/</u> D/80 }	FC77 <u>4/</u> D02 } D02-TS } <u>6/</u> D/80 }	FC77 <u>4/</u> D02 } D02-TS } <u>6/</u> D/80 }
Step 2	FC40 <u>4/</u> Water <u>3/</u> D02 } D02-TS } <u>6/</u> D03 }	FC70 } FC40 } <u>4/</u> UCON-WS <u>5/</u> D02 } D02-TS } <u>6/</u> D03 }	FC70 } FC40 } <u>4/</u> UCON-WS <u>5/</u> D02 } D02-TS } <u>6/</u> D03 }	FC70 <u>4/</u> UCON-WS } <u>5/</u> D05 } LS/230 } <u>6/</u> LS/215 }

1/ See 2.2.

2/ Ethylene glycol shall not be used as a thermal shock test fluid.

3/ Tap water is indicated as an acceptable fluid for this temperature range. Its suitability chemically shall be established prior to use. A mixture of water and alcohol may be used to prevent freezing at the low temperature extreme. The water shall not be allowed to boil at the upper temperature extreme.

4/ FC77, FC70, FC40 are the registered trademark of 3M.

5/ UCON-WS process fluid is the registered trademark of Union Carbide Corporation.

6/ D02, D02-TS, D03, D05, D/80, LS/215 and LS/230 are the registered trademark of Ausimont (Division of Montedison).

TABLE 107-V. Exposure time in liquid at temperature extremes.

Weight of specimen	Minimum time (for steps 1 and 2)
.05 ounce (1.4 grams) and below	1/2
Above .05 ounce (1.4 grams) to .5 ounce (14 grams)	2
Above .5 ounce (14 grams) to 5 ounces (140 grams)	5

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4. MEASUREMENTS. Specified measurements shall be made prior to the first cycle and upon completion of the final cycle, except that failures shall be based on measurements made after the specimen has stabilized at room temperature following the final cycle.

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

- a. Recovery time if other than 5 minutes (see 2.1).
- b. Special mounting, if applicable (see 3).
- c. Type test (air or liquid) and test condition (see 3).
- d. Transfer time if other than specified in 3.1 or 3.2.
- e. Measurements before and after cycling (see 4).

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METHOD 108A

LIFE
(AT ELEVATED AMBIENT TEMPERATURE)

1. **PURPOSE.** This test is conducted for the purpose of determining the effects on electrical and mechanical characteristics of a part, resulting from exposure of the part to an elevated ambient temperature for a specified length of time, while the part is performing its operational function. This test method is not intended for testing parts whose life is expressed in the number of operations. Evidence of deterioration resulting from this test can at times be determined by visual examination; however, the effects may be more readily ascertained by measurements or tests prior to, during, or after exposure. Surge current, total resistance, dielectric strength, insulation resistance, and capacitance are types of measurements that would show the deleterious effects due to exposure to elevated ambient temperatures.

2. **APPARATUS.** A suitable chamber shall be used which will maintain the temperature at the required test temperature and tolerance (see 3.2) to which the parts will be subjected. Temperature measurements shall be made within a specified number of unobstructed inches from any one part or group of like parts under test. In addition, the temperature measurement shall be made at a position where the effects of heat generated by the parts have the least effect on the recorded temperature. Chamber construction shall minimize the influence of radiant heat on the parts being tested. Chambers that utilize circulating liquid as a heat exchanger, free-convection (gravity type) chambers, and circulating air chambers may be used providing that the other requirements of this test method are met. When specified, this test shall be made in still air. (Still air is defined as surrounding air with no circulation other than that created by the heat of the part being operated.) The employment of baffling devices and the coating of their surfaces with a heat-absorbing finish are permitted. When a test is conducted on parts that do not have the still-air requirement, there shall be no direct impingement of the forced-air supply upon the parts.

3. **PROCEDURE.**

3.1 **Mounting.** Specimens shall be mounted as specified by their normal mounting means. When groups of specimens are to be subjected to test simultaneously, the mounting distance between specimens shall be as specified for the individual groups. When the distance is not specified, the mounting distance shall be sufficient to minimize the temperature of one specimen affecting the temperature of another. Specimens fabricated of different materials, which may have a detrimental effect on each other and alter the results of this test, shall not be tested simultaneously.

3.2 **Test temperature.** Specimens shall be subjected to one of the following test temperatures with accompanying tolerances, as specified:

Temperature and tolerance ^{1/}	
<u>°C</u>	<u>°F</u>
70 ±2	158 ±3.6
85 ±2	185 ±3.6
100 ±2	212 ±3.6
125 ±3	257 ±5.4
150 ±3	302 ±5.4
200 ±5	392 ±9
350 (± as specified)	662 (± as specified)
500 (± as specified)	932 (± as specified)

^{1/} For tests on resistors only, in a still-air environment, the maximum temperature tolerance shall be ±5°C (±9°F).

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3.3 Operating conditions. The test potential, duty cycle, load, and other operating conditions, as applicable, applied to the specimen during exposure shall be as specified.

3.4 Length of test. Specimens shall be subjected to one of the following test conditions, as specified:

<u>Test condition</u>	<u>Length of test, hours</u>
A -----	96
B -----	250
C -----	500
D -----	1,000
F -----	2,000
G -----	3,000
H -----	5,000
I -----	10,000
J -----	30,000
K -----	50,000

NOTE: Test condition E (1,500 hour test) has been deleted from this test method.

4. MEASUREMENTS. Specified measurements shall be made prior to, during, or after exposure, as specified. If applicable, frequency of measurements, and portion of the duty cycle in which measurements are to be made, while the specimen is subjected to test, shall be as specified.

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

- a. Distance of temperature measurements from specimens, in inches (see 2).
- b. Still-air requirement, when applicable (see 2).
- c. Method of mounting and distance between specimens, if required (see 3.1).
- d. Test temperature and tolerance (see 3.2).
- e. Operating conditions (see 3.3).
- f. Test condition letter (see 3.4).
- g. Measurements (see 4).
 - (1) Prior to, during, or after exposure (see 4).
 - (2) Frequency of measurements, and portion of duty cycle during test, if applicable (see 4).

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METHOD 109C

EXPLOSION

1. **PURPOSE.** The purpose of this method is to determine if a part, while operating, will ignite an ambient explosive atmosphere. This environment is prevalent in aircraft; therefore, the test is conducted at ground level and various reduced barometric pressures. The parts subjected to this type of test are not enclosed in casings designed to prevent flame or explosion propagation.

2. **APPARATUS.**

2.1 **Test facility.** The test apparatus consists of a test chamber or cabinet together with associated equipment, safety provisions, and auxiliary instrumentation necessary to establish, maintain, and monitor the specified test conditions. The chamber should be equipped with a system for mixing and circulation of the explosive air-fuel mixture, a means to ignite the air-fuel mixture such as a spark-gap device, as well as a means to collect and determine the explosiveness of a sample of the mixture such as a spark gap or glow plug ignition source with sufficient energy to ignite a 3.82 percent hexane mixture. An alternative method of determining the explosive characteristics of the vapor is use of a calibrated explosive gas meter that verifies the degree of explosiveness and the concentration of the air-fuel mixture. The chamber or cabinet should include provisions for the electrical and mechanical operation of the specimen under test.

2.1.1 **Test facility performance requirements.**

2.1.1.1 **Chamber design pressure.** The test chamber shall be capable of withstanding any explosion pressure up to and including 300 pounds per square inch (2 megapascals).

2.1.1.2 **Pressure altitude.** The test chamber shall be capable of maintaining any desired pressure altitude from sea level to 60,000 feet (18,250 meters) \pm 2 percent.

2.1.1.3 **Chamber air temperature.** The air temperature within the test chamber shall be uniform and shall be controllable between $20^{\circ}\text{C} \pm 3^{\circ}\text{C}$ and $240^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

2.2 **Fuel.** Unless otherwise specified, the fuel for explosive atmosphere testing shall be the single-component hydrocarbon n-hexane, either reagent grade or 95% n-hexane with 5% other hexane isomers. This fuel is used since its ignition properties for flammable atmosphere testing are equal to or more sensitive than the similar properties of both 100/130 octane aviation gasoline, JP-4, and JP-8 jet engine fuel. Optimum mixtures of n-hexane and air will ignite from hot-spot temperatures as low as 223°C (433°F) while optimum JP-4 jet engine fuel-air mixtures require a minimum temperature of 230°C (445°F) for auto-ignition, and 100/130 octane aviation gasoline and air requires 441°C (825°F) for hot-spot ignition. Minimum spark energy inputs for ignition of optimum fuel vapor and air mixtures are essentially the same for n-hexane and for 100/130 octane aviation gasoline. Much higher minimum spark energy input is required to ignite JP-4 or JP-8 jet engine fuel and air mixtures. Use of fuels other than hexane is not recommended. CAUTION: If the individual specification allows the use of an alternate fuel, the specification must also provide all the specific details associated with the alternate fuel, such as safety precautions and fuel-air mixture equation.

2.3 **Fuel vapor mixture.** Use a homogeneous fuel-air mixture in the correct fuel-air ratios for the explosive atmosphere test. Fuel weight calculated to total 3.8 percent by volume of the test atmosphere represents 1.8 stoichiometric equivalents of n-hexane in air, giving a mixture needing only minimum energy for ignition. This yields an air/vapor ratio (AVR) of 8.33 by weight.

a. Required information to determine fuel weight:

- (1) Chamber air temperature during the test
- (2) Fuel temperature
- (3) Specific gravity of n-hexane (see figure 109-1)
- (4) Test altitude: (e.g. 20,000 feet (6100 meters)). Atmospheric pressure in pascals: 46.6 kPa (6.76 psia)
- (5) Net volume of the test chamber: free volume less test item displacement expressed in liters or cubic feet.

b. Calculation of the volume of liquid n-hexane fuel for each test altitude:

(1) In metric units:

$$\text{Volume of 95 percent n-hexane (ml)} = (4.27 \times 10^{-4}) \left[\frac{(\text{net chamber vol (liters)} \times (\text{chamber pressure (pascals)}))}{(\text{chamber temp (K)} \times (\text{specific gravity of n-hexane}))} \right]$$

(2) In English units:

$$\text{Volume of 95 percent n-hexane (ml)} = (150.41) \left[\frac{(\text{net chamber vol (ft}^3\text{)}) \times (\text{chamber pressure (psia)})}{(\text{chamber temp (R)} \times (\text{specific gravity of n-hexane}))} \right]$$

2.3.1 Effect of humidity on flammable atmosphere. Humidity is always present in an explosive atmosphere test. The effect of humidity upon the fuel-air composition need not be considered in the test if the ambient air dewpoint temperature is 10°C (50°F) or less because this concentration of water vapor only increases the n-hexane fuel concentration from 3.82 percent to 3.85 percent of the test atmosphere. If the atmospheric pressure is cycled from an equivalent of 5000 feet (1525 meters) above the test level to 5000 feet below (a 34 percent change in pressure), the volume of n-hexane will decrease from 4.61 percent to 3.08 percent. This decrease will compensate for the fuel enrichment effect that results from water vapor dilution of the test air supply.

2.4 Altitude simulation. The energy required to ignite a fuel-air mixture increases as pressure decreases. Ignition energy does not drop significantly for test altitudes below sea level. This test is not appropriate for test altitudes above approximately 52,000 feet (≈16,000 meters) where the lack of oxygen inhibits ignition.

3. PROCEDURE.

3.1 Test preparation.

3.1.1 Controls. Before each test, verify the critical parameters. Ensure spark devices function properly and the fuel atomizing system is free from deposits that could inhibit its functioning. Adjust the empty test chamber to the highest test altitude, shut off the vacuum system and measure the rate of any air leakage. Verify that any leakage will not prevent the test from being performed as required; i.e., introduce the test fuel and wait three minutes for full vaporization, yet still be at least 3300 feet (≈1000m) above the test altitude.

3.1.1.2 Mounting. The specimen to be tested shall be mounted in the test chamber in such a manner that normal electrical operation is possible and so that the mechanical controls may be operated through the pressure seals from the exterior of the chamber. All external covers of the test specimen shall be removed or opened to insure adequate circulation of the explosive mixture. The test specimen shall then be operated to determine that it is functioning properly and to observe the location of any sparking or high temperature spots that may constitute potential explosion hazards.

3.1.2 Loading. Applicable mechanical and electrical loads applied to the specimen shall be as specified in the individual specification. Proper precaution shall be taken to duplicate the normal load in respect to torque, voltage, current, inductive reactance, etc. In all instances it shall be considered preferable to operate the specimen as it normally functions during service use.

3.2 Test execution. The following provides the procedural steps for execution of the explosive atmosphere test;

- a. With the test item installed, the test chamber shall be sealed and the test item and chamber inner walls stabilized to $71^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($160^{\circ}\text{F} \pm 5^{\circ}\text{F}$), or to a lower temperature as specified, if the specimen is designed to operate at a lower temperature.
- b. Adjust the chamber air pressure to simulate the desired test altitude (see 3.3) plus an additional 10,000 feet to allow for introducing, vaporizing, and mixing the fuel with the air as described in 2.3.
- c. Slowly introduce the required volume of n-hexane into the test chamber.
- d. Circulate the test atmosphere and continue to reduce the simulated chamber altitude for at least three minutes to allow for complete vaporization of fuel and the development of a homogeneous mixture.
- e. At a pressure equivalent to 5,000 feet (1525 meters) above the test altitude, verify the potential explosiveness of the fuel-air vapor by attempting to ignite a sample of the mixture taken from the test chamber by using a spark-gap device or glow plug ignition source with sufficient energy to ignite a 3.82 percent hexane mixture. If ignition does not occur, purge the chamber of the fuel vapor and repeat steps a through e. (An alternative method of determining the explosive characteristics of the vapor is by using a calibrated explosive gas meter that verifies the degree of explosiveness and the concentration of the fuel-air mixture.)
- f. Operate the test specimen and continue operation through step g. Make and break electrical contacts as frequently and reasonably possible.
- g. If no explosion occurs as a result of operation of the test specimen, slowly reduce the simulated chamber altitude to 5,000 feet (1525 meters) below the test altitude (at a rate no faster than 330 feet (100 meters) per minute by bleeding air into the chamber). Perform one last operational check and switch off power to the test specimen.
- h. If no explosion has occurred as the result of operation of the test specimen by the time the simulated altitude has reached 5,000 feet (1525 meters) below the test altitude, verify the potential explosiveness of the air-vapor mixture as in step e. If ignition does not occur with the sample, purge the chamber of the fuel vapor, and repeat the test from step a.
- i. Repeat steps b through h for the required test altitudes (see 3.3).

3.3 Test altitudes. Unless otherwise specified, the test shall be accomplished at simulated test altitudes of local ground level to 5,000 feet, 20,000 feet, and 40,000 feet. However, if an explosion occurs at an altitude of less than 40,000 feet, further testing shall be discontinued.

4. SUMMARY. The following details are to be specified in the individual specification.
- a. Fuel, if other than that specified and all specific details associated with the fuel (see 2.2).
 - b. Mechanical and electrical load (see 3.1.2).
 - c. Chamber temperature condition, if lower than $71^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($160^{\circ}\text{F} \pm 5^{\circ}\text{F}$) (see 3.2 a).
 - d. Test altitudes, if other than those specified (see 3.3).

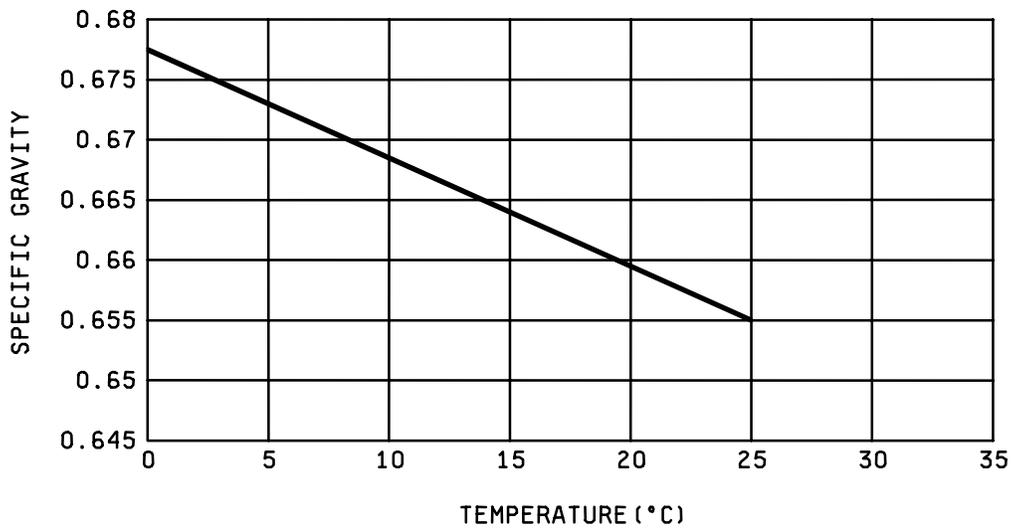


FIGURE 109-1. Specific gravity of n-hexane

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METHOD 110A

SAND AND DUST

1. PURPOSE. The dust test is used during the development, test, and evaluation of equipment to ascertain their ability to resist the effects of a dry dust (fine sand) laden atmosphere. This test simulates the effect of sharp edged dust (fine sand) particles, up to 150 microns in size, which may penetrate into cracks, crevices, bearings, and joints, and cause a variety of damage such as fouling moving parts, making relays inoperative, forming electrically conductive bridges with resulting "shorts" and acting as a nucleus for the collection of water vapor, and hence a source of possible corrosion and malfunction of equipment. This test is applicable to all mechanical, electrical, electronic, electrochemical, and electromechanical devices for which exposure to the effects of a dry dust (fine sand) laden atmosphere is anticipated.

2. APPARATUS. The test facility shall consist of a chamber and accessories to control dust concentration, velocity, temperature, and humidity of dust-laden air. In order to provide adequate circulation of the dust laden air, no more than 50 percent of the cross-sectional area (normal to air flow) and 30 percent of the volume of the chamber shall be occupied by the test item(s). The chamber shall be provided with a suitable means of maintaining and verifying the dust concentration in circulation. A minimum acceptable means for doing this is by use of a properly calibrated smoke meter and standard light source. The dust-laden air shall be introduced into the test space in such a manner as to allow it to become approximately laminar in flow before it strikes the test item.

2.1 Dust requirements. The dust used in this test shall be a fine sand (97-99% by weight SiO_2) of angular structure, and shall have the following size distribution as determined by weight, using the U.S. Standard Sieve Series.

- a. 100 percent of this dust shall pass through a 100-mesh screen.
- b. 98 ± 2 percent of the dust shall pass through a 140-mesh screen.
- c. 90 ± 2 percent of the dust shall pass through a 200-mesh screen.
- d. 75 ± 2 percent of the dust shall pass through a 325-mesh screen.

"140-mesh silica flour" as produced by the Ottawa Silica Company, Ottawa, Illinois, or equal, is satisfactory for use in the performance of these tests.

3. PROCEDURE. Place the test item in the chamber, positioned as near the center of the chamber as practicable. If more than one item is being tested, there shall be a minimum clearance of 4 inches between surfaces of test items or any other material or object capable of furnishing protection. Also, no surface of the test item shall be closer than 4 inches from any wall of the test chamber. Orient the item so as to expose the most critical or vulnerable parts to the dust stream. The test item orientation may be changed during the test if so required by the component specification.

Step 1 - Set the chamber controls to maintain an internal chamber temperature of 23°C (73°F) and a relative humidity of less than 22 percent. Adjust the air velocity to $1,750 \pm 250$ feet per minute. Adjust the dust feeder to control the dust concentration at 0.3 ± 0.2 grams per cubic foot. With test item nonoperating, maintain these conditions for 6 hours.

Step 2 - Stop the dust feed and reduce the air velocity to 300 ± 200 feet per minute. Raise the internal chamber air temperature to 63°C (145°F) and adjust humidity control to maintain a relative humidity of less than 10 percent. Hold these conditions for 16 hours.

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Step 3 - While holding chamber temperature at 63°C (145°F) adjust the air velocity to 1,750 ±250 fpm, maintain a relative humidity of less than 10 percent. Adjust the dust feeder to control the dust concentration at 0.3 ±0.2 grams per cubic foot. With the test item nonoperating, maintain these conditions for 6 hours.

Step 4 - Turn off all chamber controls and allow the test item to return to standard ambient conditions. Remove accumulated dust from the test item by brushing, wiping, or shaking, care being taken to avoid introduction of additional dust into the test item. Under no circumstances, shall dust be removed by either air blast or vacuum cleaning.

NOTE: 1. This test specimen may be operating during either or both of the 6-hour test periods (step 1 or 3) if so required by the component specification.

2. When the component specifications reference test conditions A, B, or C of the previous version of this test method, steps 1 through 4 of this test will be used unless otherwise specified.

4. SUMMARY. The following details are to be specified in the component specification.

- a. Change in orientation during test, if required.
- b. Whether component is to operate during test and length of time required for operation and measurements.
- c. Whether the second 6-hour test at 63°C (145°F) shall be performed immediately after reaching stabilization in step 2.

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METHOD 111A

FLAMMABILITY (EXTERNAL FLAME)

1. **PURPOSE.** This test is performed for the purpose of determining the flammability of a part exposed to an external flame. Flammability is defined as the ability of a part to support combustion. This can be determined by the following: the time it takes for a part to become self-extinguishing after application of a flame; that the part does not support violent burning; that exposure of a part to a flame does not result in an explosive-type fire; or that spreading of surface burning on larger parts is deterred. The principal factors which affect the results of an external flame test are -- the heat of the flame at the point of impingement; the size of the flame; the time of exposure to the flame; the volume of the part and other heat-sink effects; the presence of circulating materials and surfaces of the parts.

2. **APPARATUS.**

2.1 **Test chamber.** An enclosure protected from air currents, but provided with means for venting fumes and admitting an adequate supply of fresh air at the bottom, shall be used. A standard chemistry hood with the exhaust fan turned off, or a metal box about 2 feet wide by 3 feet high and 2 feet deep, with a removable front, a viewing window, and holes for air intake and venting of fumes, is satisfactory. Adequate safety precautions should be taken to protect personnel from possible explosion of the test specimens.

2.2 **Mounting apparatus.** Within the test chamber, a support stand with suitable adjustable vertical brackets or other mounting clamps shall be used to hold the specimens at the specified distance and position (see 3) with respect to the applied flame. Mounting clamps, in order not to act as heat sinks, shall be thermally insulated from the specimens. The flame shall not impinge on the clamp(s) or other devices which hold the specimens.

2.3 **Propane torch.** A propane torch, having a nozzle assembly conforming to Model TX-1 of "Bernzomatic Corporation", or equal, shall be the source of the flame. "Cracked" propane gas shall be used as the fuel. A suggested torch assembly is shown on figure 111-1, Burner head.

2.4 **Timing device.** A timing device, which can indicate time in seconds, shall be used to determine the time of application of the flame and the time of burning of visible flame on the specimen.

3. **PROCEDURE.** The specimen shall be mounted in the test chamber (see 2.1) with the mounting apparatus therein (see 2.2) and at the distance and position specified. The torch shall be placed so that the axis of the flame is in the vertical direction, unless otherwise specified in the individual specification. When the torch is ignited, and after the flame is stable, the flow of gas through the nozzle of the torch (see 2.3) shall be adjusted so that the inner-cone length is 1/2 inch between the inner-cone tip and a point in the plane of the nozzle rim. The specimen shall be placed so that the point of impingement of the flame on the specimen is 1-1/2 inches from the nozzle rim along the flame axis. The point of impingement of the flame shall be as specified in the individual specification. The flame shall be applied to the specimen for a period of 15 seconds unless specified in the individual specification, as determined by the timing device (see 2.4), and then removed. Upon removal of the applied flame, the time of burning of visible flame on the specimen, as determined by the timing device, shall be recorded. The recorded time shall then be compared with the allowable time specified in the individual specification. Any violent burning of the specimen or explosive-type fire shall be recorded.

4. **CLEANING.** In order to clearly observe the burned area; carbon from the propane gas may be removed by brushing or buffing the specimen.

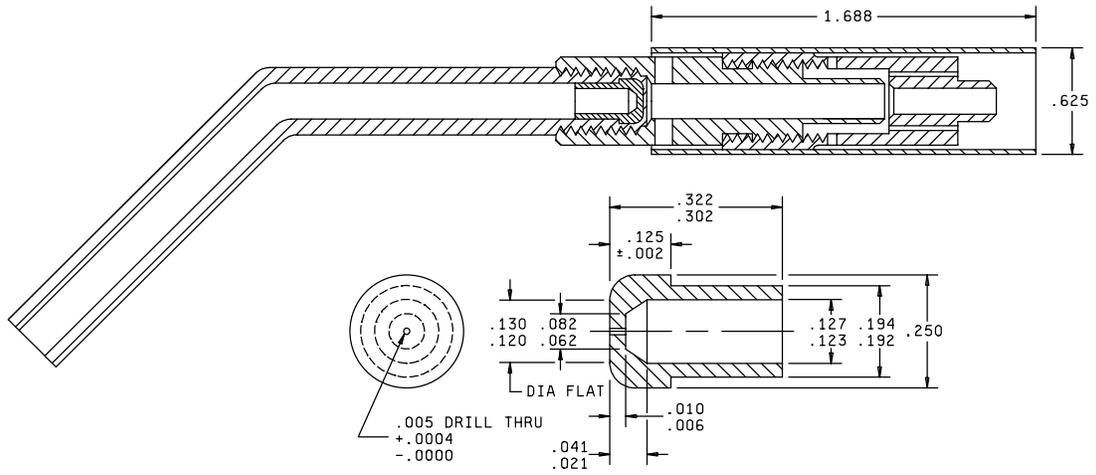
5. **MEASUREMENTS.** Upon completion of the test, measurements shall be made as specified in the individual specification.

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6. SUMMARY. The following details are to be specified in the individual specification:

- a. Direction of axis of flame, if other than vertical (see 3).
- b. Point of impingement of applied flame (see 3).
- c. Time of application of flame, if other than 15 seconds (see 3).
- d. Allowable time for burning of visible flame on specimen (see 3).
- e. Measurements after test (see 5).



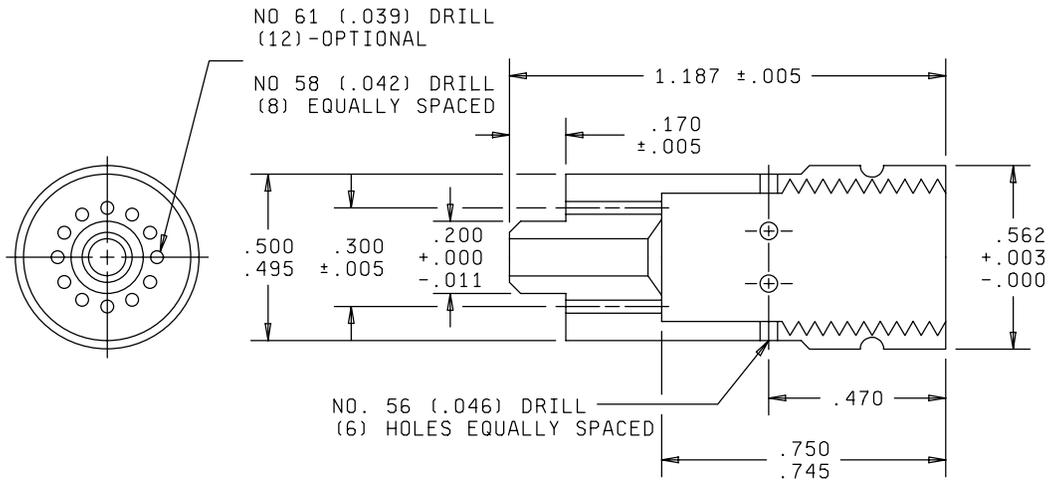
Inches	mm	Inches	mm
.0004	0.01	.125	3.18
.002	0.05	.127	3.23
.005	0.13	.130	3.30
.006	0.15	.192	4.88
.010	0.25	.194	4.93
.021	0.53	.250	6.35
.041	1.04	.302	7.67
.062	1.57	.322	8.18
.082	2.08	.625	15.18
.120	3.05	1.688	42.88
.123	3.12		

MATERIAL: BRASS

FIGURE 111-1. Burner head.

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Inches	mm	Inches	mm
.003	0.08	.300	7.62
.005	0.13	.470	11.94
.011	0.28	.495	12.57
.039	0.99	.500	12.70
.042	1.07	.562	14.27
.046	1.17	.745	18.92
.170	4.32	.750	19.05
.200	5.08	1.187	30.15

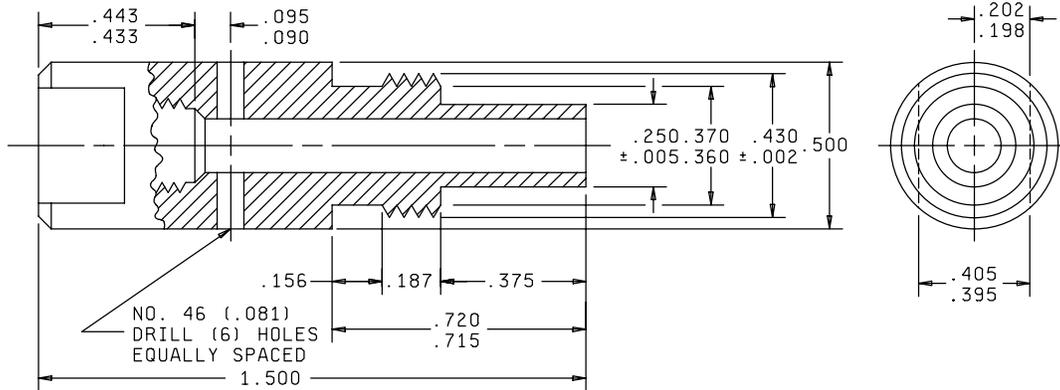
MATERIAL: BRASS

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BODY-BURNER

FIGURE 111-1. Burner head - Continued.

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Inches	mm	Inches	mm
.002	0.05	.370	9.40
.005	0.13	.375	9.53
.081	2.06	.395	10.03
.090	2.29	.405	10.29
.095	2.41	.430	10.92
.156	3.96	.433	11.00
.187	4.75	.443	11.25
.198	5.03	.500	12.70
.202	5.13	.715	18.16
.250	6.35	.720	18.29
.360	9.14	1.500	38.10

MATERIAL: BRASS

3

BASE-BURNER

FIGURE 111-1. Burner head - Continued.

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METHOD 112E

SEAL

1. PURPOSE. The purpose of this test method is to determine the effectiveness of the seal of a component part which has an internal cavity which is either evacuated or contains air or gas. A defect in any portion of the surface area of a sealed part can permit entrance of damaging contaminants which will reduce its effective life. This test will detect leaks due to the use of inferior sealing materials, or to the manufacturing processes used to form the seal. The degree of completeness of the seal can be verified by testing in the "as received" condition or after submission to other environmental or physical-characteristics tests, such as thermal shock, physical shock, or vibration. This test method does not include the many existing versions of lesser-sensitivity seal tests now appearing in some specifications, which verify such requirements as "water tightness", "moisture proofness", etc. In those lesser-sensitivity seal tests, parts are submerged to various depth in water, heated water, water or alcohol with a vacuum, water with a wetting agent, etc; all these tests depend on observation of bubbles as the criterion for failure.

1.1 Definitions.

- a. Standard leak rate. Standard leak rate is defined as the 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 1 atmosphere (760 mm Hg absolute) and the low-pressure side is at a pressure of not greater than 1 mm Hg absolute. Standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm³/s).
- b. Measured leak rate. Measured leak rate (R_1) 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 cm³/s). For the purpose of comparison with rates determined by other methods of testing, the measured leak rates must be converted to equivalent standard leak rate.
- c. Equivalent standard leak rate. The equivalent standard leak (L) rate of a given package, with a measured leak rate (R_1), is defined as the leak rate of the same package with the same leak geometry, which would exist under the standard conditions of 1.1a. The formula (does not apply to procedure IIIb) in 5.4.3.2.3 represents the L/R_1 ratio and gives the equivalent standard leak rate (L) of the package with a measured leak rate (R_1) where the package volume and leak test conditioning parameters influence the measured value of (R_1). The equivalent standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm³/s).
- d. Sensitivity. (Minimum detectable leak rate). Sensitivity is the smallest leak rate that an instrument, method, or system is capable of measuring or detecting under specified conditions. To compare sensitivities of two or more different test conditions, the sensitivity should be converted to sensitivity under standard conditions by using the appropriate conversion factors.
- e. Ambient background. For a scintillation-crystal counting station, ambient background is the oscillatory reading obtained on the meter readout due to electrical noise plus the reading in counts per minute due to cosmic radiation that penetrates the lead shielding of the closed crystal system. This value must be determined just before device counting.

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11 October 1988

2. TEST CONDITIONS.

2.1 Selection. There are six test conditions (A, B, C, D, E, and F) in this method. Test conditions A and B utilize oil as a means to detect gross leaks by the observation of bubbles. Both of these tests will detect leaks of a nominal value of 10^{-5} atm cm^3/s . Test condition B is used to test parts which will not withstand the temperature required in test condition A. Test condition C detects fine leaks by using a tracer gas and apparatus to measure a leakage rate (R_1) to a nominal of 10^{-8} atm cm^3/s . The apparatus can be calibrated for any leakage rate within its range. Test condition D utilizes a fluorocarbon liquid at $125^\circ\text{C} \pm 5^\circ\text{C}$ ($257^\circ\text{F} \pm 9^\circ\text{F}$) at ambient pressure and detects gross leaks by the observation of bubbles. This latter test condition provides an alternate gross leak test to test condition A. Test condition E utilizes two fluorocarbon liquids; one under pressure followed by the other at $125^\circ\text{C} \pm 5^\circ\text{C}$ ($257^\circ\text{F} \pm 9^\circ\text{F}$) at room ambient pressure and detects gross leaks by the observation of bubbles. This test condition provides a measure of leakage rate of a nominal value of 10^{-5} atm cm^3/s . Test condition F utilizes a fluorocarbon liquid and a fluorocarbon vapor detector to detect gross leaks. Test condition F provides a measure of leakage rate of a nominal value of 10^{-5} atm cm^3/s . Both test conditions C and F require more expensive commercial equipment and trained personnel, but the equipment provides automatic and quantitative readings. The selection of a test condition to perform the seal test depends on the state of the art of component part manufacturing, the leakage rate which can be tolerated for the desired reliability, the frequency of testing, range of test conditions, cavity size, and whether the testing is to be on a 100 percent production or on a periodic basis. The individual specification shall specify the test condition letter required. When test condition C is specified, the procedure number (see 5.4) and the degree of leakage rate sensitivity required shall be included. The following is included as a sensitivity and applicability guide:

Test condition A (bubble test - mineral oil or peanut oil at $125^\circ\text{C} \pm 3^\circ\text{C}$ ($257^\circ\text{F} \pm 6^\circ\text{F}$)). Use when a nominal sensitivity of 10^{-5} atm cm^3/s is sufficient.

Test condition B (bubble test - silicone oil at room ambient temperature $25^\circ\text{C} \pm 2^\circ\text{C}$ ($77^\circ\text{F} \pm 3.6^\circ\text{F}$), with a vacuum resulting in an absolute pressure of not greater than 1.5 inches of mercury (not greater than 38.1 torr). Use to test parts which cannot withstand the temperature of test condition A, and when a nominal sensitivity of 10^{-5} atm cm^3/s is sufficient.

Test condition C (tracer gas test). Use when a nominal sensitivity of 10^{-8} atm cm^3/s is sufficient.

Procedure I - (For parts having an evacuation tube which is unsealed and is to be connected to the leak detector for test purposes.)

Leak from outside of part to inside. Check the seal of evacuation tube by backfilling with air or gas. Then subject to procedure IIIa, IIIb, IIIc or IV.

Procedure II - (For parts having an evacuation tube which is unsealed to permit pressurizing with a tracer gas.)

Leak from inside of part to outside. Check the seal of evacuation tube by backfilling with air or gas. Then subject to procedure IIIa, IIIb, IIIc, or IV.

Procedure III - (For parts which are to be tested without breaking their seals.)

Fixed method (IIIa) - Part not filled with tracer gas. Force gas into leaks, then detect its escape. Then subject to test condition A, B or D (see 5.4.3.2.1 permitting use of water), as applicable, to check for gross leaks.

IIIb - Part not filled with tracer gas. Force radioactive gas into leaks, then use a radioactivity counter to determine gas that has entered part. Then subject to test condition A, B, or D (see 5.4.3.2.2.4 permitting use of water), as applicable, to check for gross leaks.

Flexible method (IIIc). Part not filled with tracer gas. Force gas into leaks then detect its escape. Then subject to test condition A, B or D (see 5.4.3.2.3 permitting use of water), as applicable, to check for gross leaks.

Procedure IV - (For parts which are to be tested without breaking their seals.) Parts backfilled with tracer gas as normally supplied.

Leak from inside of part to outside, then subject to test condition A, B or D (see 5.4.4 permitting use of water), as applicable, to check for gross leaks.

Test condition D (gross leak bubble test - Fluorocarbon liquid at 125°C ±5°C (257°F ±9°F). Use as an alternate when test condition A is specified as a gross leak test.

Test condition E (bubble test - two fluorocarbon liquids - one at pressure followed by immersion in a second liquid at 125°C ±5°C (257° ±9°F). Use when a nominal sensitivity of 10⁻⁵ atm cm³/s is sufficient.

Test condition F (fluorocarbon vapor detection test). Use when a nominal sensitivity of 10⁻⁵ atm cm³/s is sufficient.

2.2 Substitution. The individual specification should specify the lowest sensitivity test condition which is practical; a higher sensitivity test which can be calibrated shall be permitted, i.e., if a test is specified such as test condition A requiring a sensitivity of 10⁻⁵ atm cm³/s, test condition C may be used since it can be calibrated to read this leakage rate. Substitution of test condition B or C should be made to test condition A when parts are rated at a temperature lower than 130°C (266°F). Test condition D may be substituted for test condition A.

3. TEST CONDITION A.

3.1 Materials.

3.1.1 Mineral oil or peanut oil. The oil used for the bath shall be clear mineral oil or peanut oil having a universal Saybolt viscosity of 175 to 190 seconds when tested at 38°C (100°F).

3.2 Apparatus.

3.2.1 Heated oil container. The container for the oil bath shall be of sufficient depth to immerse the uppermost portion of the enclosure or seal to be tested to a depth of 1 inch (25.4 mm) below the surface of the bath. The container shall be capable of maintaining the oil at the required temperature.

3.3 Precautions. This condition shall not be used for parts rated at a temperature lower than 130°C (266°F). It shall not be used for parts which contain seals made of materials which will outgas due to the temperature of the bath.

3.4 Preparation of specimens. Immediately before immersion it shall be determined that the specimen is at room ambient temperature and free of any foreign (including labels) matter. If applicable, the critical side of the specimen shall be determined. The critical side is defined as the side having the greatest number of seals or length of seal.

3.5 Procedure. This test consists of one immersion of the specimen or groups of specimens into a bath of clear mineral oil or peanut oil (see 3.1.1) maintained at a temperature of $125^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($257^{\circ}\text{F} \pm 6^{\circ}\text{F}$). The specimen shall be placed in the oil bath with the critical side (or side of special interest) in a horizontal position facing up. If the specimen has no critical side, it shall be placed in the bath with its major axis in a horizontal position. The specimen shall be completely submerged in the bath, with the uppermost portion of the enclosure or seal at a depth of 1 inch (25.4 mm), and left in that position for a minimum duration of 1 minute. The specimen shall be carefully observed during the entire duration of the immersion for indication of a poor seal as evidenced by a continuous stream of bubbles emanating from the specimen. After the test is completed, the specimen shall be cleaned in a suitable degreaser and permitted to dry thoroughly before any additional tests are performed.

4. TEST CONDITION B.

4.1 Materials.

4.1.1 Silicone oil. The oil used for the bath shall be clear silicone oil having a viscosity of 20 centistokes at 25°C (77°F).

4.2 Apparatus.

4.2.1 Reduced pressure vessel. The vessel for the oil bath shall be of sufficient depth to immerse the uppermost portion of the enclosure or seal to be tested to a depth of 1 inch (25.4 mm) below the surface of the bath, over which can be drawn a vacuum resulting in an absolute pressure of not greater than 1.5 inches of mercury (not greater than 38.1 torr).

4.2.2 Vacuum pump. The vacuum pump shall be capable of evacuating and holding a vacuum resulting in an absolute pressure of not greater than 1.5 inches of mercury (not greater than 38.1 torr) for a minimum duration of 1 minute in the reduced pressure vessel (see 4.2.1).

4.2.3 Degassing of silicone oil. The silicone oil shall be placed in the test fixture and a pressure of 1 inch (25.4 mm) of mercury or less attained over the fluid for as long as is necessary to degas the fluid. Such degassing is complete when no further bubbling or frothing is present in the fluid. Throughout the test, components shall be lowered gently in the fluid to prevent aeration of the fluid. The fluid shall not be poured from one container to another without first being degassed again before testing.

4.3 Preparation of specimens. As specified in 3.4.

4.4 Procedure. This test consists of one immersion of the specimen or group of specimens into a bath of clear silicone oil (see 4.1.1) maintained at room ambient temperature. The specimen shall be placed in the oil bath with the critical side (or side of special interest) in a horizontal position facing up. If the specimen has no critical side, it shall be placed in the bath with its major axis in a horizontal position. The specimen shall be completely submerged in the bath with the uppermost portion of the enclosure or seal at a depth of 1 inch (25.4 mm). A vacuum resulting in an absolute pressure of not greater than 1.5 inches of mercury (not greater than 38.1 torr) shall be drawn and held over the bath for a minimum duration of 1 minute. The specimen shall be carefully observed during the entire duration of the immersion for indication of a poor seal as evidenced by a continuous stream of bubbles emanating from the specimen. After the test is completed, the specimen shall be cleaned in a suitable degreaser and permitted to dry thoroughly before any additional tests are performed.

4.5 Precaution. This test condition should not be used either as a separate test or a gross leak test for component parts which are to be subsequently attached to printed circuit board assemblies. Since complete removal of silicone oil residues is difficult, the oil will be transferred unknowingly to other parts during assembly processes. Traces of silicone can result in poor solder wettability of component part leads, poor adhesion to sealants, and mealing of the conformal coating on the printed circuit board.

5. TEST CONDITION C.

5.1 Materials.

5.1.1 Tracer gases. When performing tests in accordance with procedures I, II, and IV of this condition, tracer gases, i.e., helium, argon, or other rare gas, or a mixture of a gas with nitrogen (such as 90 percent nitrogen and 10 percent helium) shall be used. The tracer gas used in procedures IIIa and IIIc shall be helium. The tracer gas used in procedure IIIb shall be the radioactive gas, krypton 85.

5.2 Apparatus. For all the procedures of this test condition, the test apparatus, exclusive of pressurization equipment, shall be calibrated using a diffusion type calibrated standard leak at least once each working shift.

5.2.1 Mass-spectrometer-type leak detector. For procedures I, II, IIIa, IIIc, and IV of this test condition, a commercially available mass-spectrometer-type leak detector, preset to read a tracer-gas content, shall be used to measure the leakage rate of gas through a faulty seal. Another instrument may be used if it can be demonstrated to the Government that the instrument, properly calibrated to read tracer-gas content, has the required leakage-detection sensitivity (see 2.1).

5.2.1.1 Chambers. Depending on which procedure is used (see 5.4), suitable pressure or vacuum chambers are required.

5.2.1.2 Pumps. Depending on which procedure is used (see 5.4), suitable pressure or vacuum pumps are required.

5.2.2 Radioactive-gas detection apparatus. Apparatus for procedure IIIb shall consist of:

- 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, in c/m per μCi , corresponding to a leak rate of 10^{-9} atm cm^3/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 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 and recorded in accordance with the calibration requirements of this standard.

5.3 Supplementary tests. When parts to be tested are normally evacuated through a tube and are sealed in some manner prior to delivery, procedures I and II (see 5.4.1 and 5.4.2) will require a separate verification of the seal of the evacuation tube in conjunction with this test method, using the mass-spectrometer-type leak detector (see 5.2.1). The verification may be accomplished by backfilling the specimen with air or gas at a specified pressure and then submitting the specimen to either procedure IIIa, IIIb, IIIc, or IV.

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5.4 Procedures. This test condition consists of five procedures (see 5.4.1 to 5.4.4, inclusive), the choice of which must be specified in the individual specification. Procedure IV is the preferred method of performing this test for parts that are not evacuated.

5.4.1 Procedure I. The mass-spectrometer-type leak detector shall be coupled to the unsealed evacuation tube of the specimen, and a vacuum created within the specimen. It is extremely important that the coupling connections between the specimen and the leak detector be perfectly sealed. The specimen shall then be subjected to a gas atmosphere either by surrounding the specimen with the gas or by spraying the specimen thoroughly with a jet of the gas. If a defect exists in the specimen, an amount of gas that depends upon the size of the defect will be drawn through it and passed into the leak detector, which will read the leakage rate. When this portion of the procedure is completed, the specimen shall be filled with air or gas at a specified pressure and having a known percentage of tracer gas. The evacuation tube shall then be pinched off and sealed. After sealing, the seal of the tube shall be verified by either procedure IIIa, IIIb, IIIc or IV, if filled with tracer gas.

5.4.2 Procedure II. The mass-spectrometer-type leak detector shall be coupled to the chamber. The specimen shall be placed in the chamber, and a tube leading from the gas source and having a known percentage of tracer gas shall be connected to the unsealed evacuation tube of the specimen. It is extremely important that the coupling connections between the specimen and the leak detector be perfectly sealed. The chamber shall then be evacuated and the gas forced under pressure into the specimen. If a leak exists, the gas passes through the specimen into the chamber and then into the leak detector, which will read the leakage rate. If pressure cycling is required, the individual specification shall specify the number of times that a pressure cycle shall be applied. When this portion of the procedure is completed, the specimen shall be filled with air or gas at a specified pressure and having a known percentage of tracer gas. The evacuation tube shall then be pinched off and sealed. After sealing, the seal of the tube shall be verified by either procedure IIIa, IIIb, IIIc or IV, if filled with a tracer gas.

5.4.3 Procedure III. The tests shall be conducted in accordance with procedure IIIa, or IIIc. When bomb pressure specified exceeds the device capability, alternate pressure, exposure time and dwell time may be used provided they satisfy the leak rate pressure, time relationships which apply and provided no less than 30 psig bomb pressure is applied in any case.

5.4.3.1 Testing precautions.

- a. These precautions are applicable to procedures IIIa, IIIb, and IIIc. To avoid spurious indications, contaminants and surface coatings that may conceal existing leaks, and tracer gas that may be absorbed or adsorbed on the surfaces of the specimen, shall be removed. These test procedures shall not apply to organic-coated parts.
- b. Test procedure IIIa is a "fixed" method with specified conditions per table I that will insure the test sensitivity necessary to detect the required leak rate (R1).
- c. Test procedure IIIc is a "flexible" method that allows the variance of test conditions in accordance with the formula of 5.4.3.2.3 to detect the specified equivalent standard leak rate at a predetermined leak rate (R1).

5.4.3.2 General procedure. For IIIa and IIIc the completed device(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 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 (R1). 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 procedure IIIa or within the chosen value of dwell time (t_z) for procedure IIIc.

5.4.3.2.1 Procedure IIIa. The device(s) shall be tested using the appropriate conditions specified in table I for the internal cavity volume of the package under test. The time (t) is the time under pressure and time (t_z) is the maximum time allowed after release of pressure before the device(s) shall be read. This method shall not be used if the maximum equivalent standard leak rate limit given in the procurement document is less than the limits specified herein for procedure IIIc. Upon completion of this procedure, the specimen shall be checked for gross leaks by subjecting the specimen either to test condition A, B, or D. Water, at room ambient temperature and a pressure of 2.5 inches (63.5 mm) of mercury, may be used in place of silicone oil, if test condition B is used to verify gross leaks.

TABLE I. Fixed conditions procedure IIIa.

Volume of package (cm ³)	Bomb condition			R1 Reject limit (atm cm ³ /s He)
	1bf/in ² gage	Exposure time hours	Maximum dwell hours	
V < 0.40	60 ±2	2 +0.2, -0	1	5 x 10 ⁻⁸
V ≥ 0.40	60 ±2	2 +0.2, -0	1	2 x 10 ⁻⁷
V ≥ 0.40	60 ±2	4 +0.4, -0	1	1 x 10 ⁻⁷

5.4.3.2.2 Procedure IIIb.

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

$$Q_s = \frac{R}{skTPt}$$

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

- Q_s = The maximum calculated leak rate allowable, in atm cm³/sKr, 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 5.4.3.2.2.2.
- T = Soak time, in hours, that the devices are to be activated.
- \bar{P} = P_e² - P_i², 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).
- t = Conversion of hours to seconds and is equal to 3,600 seconds per hour.

5.4.3.2.2.2 Determination of counting efficiency (k). The counting efficiency (k) of equation in 5.4.3.2.2.1 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.

5.4.3.2.2.3 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 5.4.3.2.2.1. The samples shall then be counted every 10 minutes, with count rate 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 5.4.3.2.2.4.

5.4.3.2.2.4 Specific procedure IIIb. The devices shall be placed in 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 0.5 torr. The devices shall be subjected to a minimum of 2 atmospheres absolute pressure of krypton 85/dry nitrogen mixture for the time necessary to satisfy the equation. Actual pressure and soak time shall be determined in accordance with 5.4.3.2.2.1. The R value in counts per minute shall be not less than 600 above ambient background. The krypton 85/dry nitrogen gas mixture shall be evacuated to storage until 0.5 torr vacuum exists in the activation tank. This evacuation shall be completed within 3 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 1 hour after gas exposure with a scintillation-crystal-equipped counting station. Device encapsulations that come under the requirements of 5.4.3.2.2.3 shall be exposed to ambient air for a time not less than the "wait time" determined by 5.4.3.2.2.3. In no case will the time between removal from the activation chamber and test exceed 1 hour. This 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 5.4.3.2.2.3 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 1 hour.) The actual leak rate of the component shall be calculated with the following equation:

$$Q = \frac{(\text{ACTUAL READOUT IN NET COUNTS PER MINUTE}) \times Q_S}{R}$$

Where Q = Actual leak rate in atm cm³/s, and Q_S and R are defined in 5.4.3.2.2.1.

Unless otherwise specified, devices that exhibit a leak rate equal to or greater than 1 x 10⁻⁸ atmospheric cubic centimeters of krypton 85 per second shall be considered a failure.

Upon completion of this procedure, the specimen shall be checked for gross leaks by subjecting the specimen either to test condition A, B, or D. Water, at room ambient temperature and a pressure of 2.5 inches (63.5 mm) of mercury, may be used in place of silicone oil, if test condition B is used to verify gross leaks.

5.4.3.2.2.5 Personnel precautions. A Nuclear Regulatory Commission (NRC) license is necessary for possession and use of the krypton 85 leak-test equipment. In the use of gas, code of Federal regulations Nuclear Regulatory Commission Rules and Regulations, Title 10, Chapters 1, 20, 30, 31, and 32 should be followed and the maximum permissible tolerance levels prescribed by the National Committee on Radiological Protection should be observed.

5.4.3.2.3 Procedure IIIc. Values for bomb pressure exposure time and dwell time shall be chosen such that actual measured tracer gas leak rate (R_1) reading obtained for the device under test (if defective) will be greater than the minimum detection sensitivity capability of the mass spectrometer. The devices shall be subjected to a minimum of 2 atmospheres absolute of helium atmosphere. If the chosen dwell time (t_2) is greater than 60 minutes, graphs shall be plotted to determine an R_1 value which will assure overlap with the selected gross leak test condition. The chosen values, 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 shown below or as specified in the applicable procurement document), shall be used to calculate the measured leak rate (R_1) limit using the following formula:

$$R_1 = \frac{LP_E}{P_O} \left(\frac{M_A}{M} \right)^{1/2} \left\{ 1 - e^{-\left[\frac{Lt_1}{VP_O} \left(\frac{M_A}{M} \right)^{1/2} \right]} \right\} e^{-\left[\frac{Lt_2}{VP_O} \left(\frac{M_A}{M} \right)^{1/2} \right]}$$

- R_1 = The measured leak rate of tracer gas (He) through the leak in atm cm³/s He.
- L = The equivalent standard leak rate in atm cm³/s air.
- P_E = The pressure of exposure in atmospheres absolute.
- P_O = The atmospheric pressure in atmospheres absolute (1 atmosphere).
- M_A = The molecular weight of air in grams (28.7 grams).
- M = The molecular weight of the tracer gas (helium) in grams (4 grams).
- t_1 = The time of exposure to P_E in seconds.
- t_2 = The dwell time between release of pressure and leak detection in seconds.
- V = The internal volume of the device package cavity in cubic centimeters.

Unless otherwise specified, devices with an internal cavity volume of 0.01 cm³ or less shall be rejected if the equivalent standard leak rate (L) exceeds 5×10^{-8} atm cm³/s. Devices with an internal cavity volume greater than 0.01 cm³ and equal to or less than 0.4 cm³ shall be rejected if the equivalent standard leak rate (L) exceeds 1×10^{-7} atm cm³/s. Devices with an internal cavity volume greater than 0.4 cm³ shall be rejected if the equivalent standard leak rate (L) exceeds 1×10^{-6} atm cm³/s.

Upon completion of this procedure, the specimen shall be checked for gross leaks by subjecting the specimen either to test condition A, B, or D. Water, at room ambient temperature and a pressure of 2.5 inches of mercury, may be used in place of silicone oil, if test condition B is used to verify gross leaks.

5.4.4 Procedure IV. The specimen, which is backfilled and sealed during production with a known percentage of tracer gas, shall be placed in a chamber connected to the mass-spectrometer-type leak detector, and the chamber evacuated. The internal pressure of the specimen shall be one atmosphere or greater. If a leak exists, the gas passes through the specimen into the chamber and then into the leak detector which will read the leakage rate. If specified, the specimen shall be perforated to determine if a gas is actually present. Upon completion of this procedure, the specimen shall be checked for gross leaks by subjecting the specimen either to test condition A, B, or D. Water, at room ambient temperature and a pressure of 2.5 inches (63.5 mm) of mercury, may be used in place of silicone oil, if test condition B is used to verify gross leaks.

6. TEST CONDITION D.

6.1 Materials.

6.1.1 Fluorocarbon liquid. The fluid shall be D02, D02-TS, D03, FC-40 1/ or FC-43 2/.

6.2 Apparatus.

6.2.1 Heated fluid container. The container for the fluid shall be made of pyrex glass and shall be sufficient size to hold the test specimen in the fluid and to maintain a temperature of 125°C ±5°C (257°F ±9°F).

6.2.2 Filter. A filter shall be used which is capable of removing particles greater than 1 micron in size from the fluid.

6.2.3 Magnifier. A 3X minimum magnifier or a stereo zoom microscope shall be used for observation of bubbles emanating from the test specimens when immersed in the indicator fluid.

6.3 Precautions. The following precautions shall be observed:

- a. Fluorocarbon liquids shall be filtered as specified in 6.2.2. Bulk filtering and storage is permissible. Leak indicator fluids, which have accumulated observable quantities of particulate matter during use, shall be discarded or reclaimed by filtration for reuse. Leak detecting fluids shall not be used for more than one eight-hour shift without being refiltered.
- b. The observation container shall contain sufficient fluid to assure coverage of the test specimen to a minimum depth of two inches.
- c. Illumination shall be a lighting source capable of providing at least 15,000 foot candles at the test specimen position. The lighting source shall not require calibration but the light level shall be verified at the test specimen position. The background behind the glass observation container should be a dull, non-reflective black material.
- d. The observation container should be covered at all times when not in use to minimize evaporation losses and moisture adsorption.
- e. Test specimens to be tested should be free from foreign material on the surface, including conformal coatings and markings which may contribute to erroneous test results.

6.4 Procedure. The test specimens, mounted on specified fixtures to hold them in the fluid, shall be immersed, with the uppermost portion at the minimum depth of 2 inches below the surface of the fluid, lid downward, one at a time (or in such a configuration that a single bubble from a single specimen out of a group under observation may be clearly observed as to its occurrence and source). The fluid shall be maintained at a temperature of 125°C ±5°C (257°F ±9°F). The specimens shall be observed against a dull non-reflective black background through the magnifier (see 6.2.3) from the instant of immersion until 20 seconds after immersion. Leakers will be identified by a single bubble or a stream of bubbles. Specimens from which a single bubble is observed is considered to be a reject.

1/ D02, D02-TS, and D03 are the registered trade mark of Ausimont (Division of Montedison).

2/ Minnesota Mining Co. (3M) registered trade name.

7. TEST CONDITION E.

7.1 Materials.

7.1.1 Fluorocarbon liquid. The fluids shall be D/80, FC-72 or PP-1 fluorocarbon detector fluids, and D02, D02-TS, D03, FC-40, FC-43, PP-7 or PP-9 fluorocarbon indicator fluids.

7.2 Apparatus.

7.2.1 Heated fluid container. The container for the fluid shall be made of pyrex glass and shall be of sufficient size to hold the test specimen in the fluid and to maintain a temperature of $125^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ($257^{\circ}\text{F} \pm 9^{\circ}\text{F}$).

7.2.2 Filter. A filter shall be used which is capable of removing particles greater than 1 micron in size from the fluid.

7.2.3 Magnifier. A magnifier with a magnification in the range between 3X to 30X for observation of bubbles emanating from devices when immersed in the indicator fluid.

7.2.4 Chamber. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of device up to 75 lbf/in^2 up to 10 hours.

7.2.5 Lighting source. A lighting source capable of producing at least 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.

7.2.6 Instruments. Suitable calibrated instruments to indicate the test temperature pressures and times are as specified.

7.2.7 Fixtures. Suitable fixtures to hold the device(s) in the indicator fluid.

7.3 Precautions. The following precautions shall be observed.

- a. Fluorocarbon liquids shall be filtered as specified in 7.2.2. Bulk filtering and storage is permissible. Leak indicator fluids, which have accumulated observable quantities of particulate matter during use, shall be discarded or reclaimed by filtration for reuse. Leak detecting fluids shall not be used for more than one eight-hour shift without being refiltered.
- b. The observation container shall contain sufficient fluid to assure coverage of the test specimen to a minimum depth of two inches (50.8 mm).
- c. Illumination shall be a lighting source capable of providing at least 15,000 foot candles at the test specimen position. The lighting source shall not require calibration but the light level shall be verified at the test specimen position. The background behind the glass observation container should be a dull, non-reflective black material.
- d. The observation container should be covered at all times when not in use to minimize evaporation losses and moisture adsorption.
- e. Test specimens to be tested should be free from foreign material on the surface, including conformal coatings and markings that may contribute to erroneous test results.
- f. Precautions should be taken to prevent operator injury due to package rupture or violent evolution of bomb fluid when testing large packages.

7.4 Procedure. The test specimens mounted on specified fixtures to hold them in the leak detecting fluid shall be inserted into the combination vacuum-pressure vessel and the applied ambient pressure shall be reduced to less than 5 torr for 1 hour. Then without breaking vacuum, a sufficient quantity of leak detecting fluid (see 7.1.1) to cover the test specimens, shall be drawn into the vacuum/pressure vessel by inserting a transfer tube from the vacuum/pressure vessel into a container of leak detecting fluid and opening a valve in the tube. For test specimens with an internal cavity volume of 0.1 cm³ or less, the pressure in the vessel shall be increased to 90 lbf/in² and maintained at that pressure for 3 hours minimum. For test specimens with an internal volume in excess of 0.1 cm³, the pressure shall be increased to 50 lbf/in² and maintained at that pressure for 3 hours minimum. After pressurization, the pressure shall be released from the pressure vessel and the test specimens shall be removed from the pressure vessel, and retained in a bath containing the leak detecting fluid. Then they shall be dried for 3 ±1 minutes in air prior to immersion in the indicator fluid. The test specimens shall be immersed with the uppermost portion at a minimum depth of 2 inches (50.8 mm) below the surface of the indicator fluid, lid downward, one at a time (or in such a configuration that a single bubble from a single specimen out of a group under observation may be clearly observed as to its occurrence and source. The leak indicator fluid shall be maintained at a temperature of 125°C ±5°C (257°F ±9°F). The test specimens shall be observed against a dull non-reflective black background through the magnifier (see 7.2.3) from the instant of immersion until 20 seconds after immersion. Leaks will be identified by a single bubble or a stream of bubbles. Specimens from which a single bubble is observed is considered to be a reject.

8. TEST CONDITION F.

8.1 Materials.

8.1.1 Fluorocarbon liquid. The fluid used shall be FC-84 or D/80 fluorocarbon detector fluid.

8.2 Apparatus.

8.2.1 Chamber. A vacuum/pressure chamber capable of the evacuation and subsequent pressure bombing of devices up to 75 psig and maintaining pressure up to 12.5 hours.

8.2.2 Filter. A filtration system capable of removing particles greater than 1 micron in size from the fluorocarbon fluid.

8.2.3 Detector. A fluorocarbon vapor detection system with a nominal sensitivity of 10⁻⁵ atm cm³/s. The sensitivity of the detector shall be better than 14 micrograms of FC84 or D/80. The detector shall have a linear response to 280 micrograms and a response time of better than 1 second.

8.2.4 Instruments. Suitable calibrated instruments to indicate that test, pressure times and temperatures are as specified. The detection system shall be calibrated using a calibration source of fluorocarbon at least once each shift to an accuracy of at least ±15 percent.

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

- a. Fluorocarbons shall be filtered through a filter system capable of removing particles greater than 1 micrometer prior to use. Bulk filtering and storage is permissible. Liquid that has accumulated observable quantities of particulate matter during use shall be discarded or reclaimed by filtration for re-use. Precautions shall be taken to prevent contamination.
- b. Precautions should be taken to prevent operator injury due to package rupture or violent evolution of bomb fluid when testing large packages.

8.4 Procedure. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 5 torr or lower and maintained for 30 minutes minimum. A sufficient amount of FC-84 or D/80 detector fluid shall be admitted to the pressure chamber to completely cover the devices. The fluid shall be admitted after the 30 minute minimum vacuum period but before breaking the vacuum. The devices shall then be pressurized in accordance with table II. Upon completion of the pressurization period, the pressure shall be released and the devices removed from the pressure chamber without being removed from the detector fluid for more than 20 seconds. When the devices are removed from the fluid for testing, they shall be air dried for a minimum of 20 seconds and a maximum of 5 minutes prior to the test cycle. The devices shall then be tested with a fluorocarbon vapor detector in accordance with the system operating instructions and as follows. Devices shall be admitted to the purge chamber and purged (heated to remove any remaining surface fluorocarbon and to initiate vaporization of any internal fluorocarbon fluid). Purge time shall be in accordance with table III. Test time shall commence immediately after purge either in the same chamber (single chamber system) or an adjoining test chamber (dual chamber system). Test time shall be a minimum of 3.5 seconds (unless the device is rejected earlier) with the fluorocarbon vapor detector purge and test chambers at a temperature of 125°C ±5°C or 2.5 seconds minimum with the purge and test chambers at 150°C ±5°C. During test time, the amount of fluorocarbon outgassing is measured and the total integrated value is compared to the alarm level.

NOTE: Air dry, purge, and test time limits for each device shall be complied with in all cases, whether the device is handled individually or in plastic or metal tubes.

8.4.1 Failure criteria. A device shall be rejected if the detector instrumentation indicates more than 280 micrograms of fluorocarbon gas.

TABLE II. Test pressure and duration for condition F.

Test pressure	Duration
75 psig	.5 hr
60 psig	1.0 hr
30 psig	2.5 hr
15 psig	12.5 hr

TABLE III. Purge time for condition F.

Package with internal free volume (cm ³)	Purge time ^{1/} (seconds)
≤ 0.01	3 1/3-5
>0.01 ≤0.10	6-9
>0.10	8 2/3-13

^{1/} With purge chamber at 150°C, minimum and maximum purge times should be reduced by 1/3.

NOTE: If necessary, due to device construction or materials, maximum purge time can be determined by cycling a device with a 0.02 to 0.05 inch diameter hole and measuring the maximum time that can be used without permitting the device to escape detection during the test cycle.

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9. Measurements. Upon completion of the test, measurements shall be made as specified.
10. Summary. The following details are to be specified in the individual specification.
 - a. Test condition letter (see 2.1).
 - (1) For test condition C.
 - (a) Procedure number and accept and reject leak rate.
 - (b) Backfilling pressure when verification of seal is required (see 5.3, 5.4.1 and 5.4.2).
 - (c) Number of pressure cycles if applicable (see 5.4.2).
 - (d) For procedure IV.
 1. Reduced pressure of the chamber and duration of pressurization (see 5.4.4).
 2. Whether perforation of specimen is required (see 5.4.4).
 - (e) For procedures III and IV.
 1. Applicable gross leak conditions.
 - (2) For test conditions D and E.
 - (a) Test mounting fixtures (see 6.4 and 7.4).
 1. Measurements after test (see 9).