



# Explosion Proof Requirements, Testing and Safety Considerations

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at

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# Explosions cause damage, death & injury

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TWA Flight 800, July 17, 1996

# Explosion Proof - Requirements

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**Explosion Proof tests are required by the following FAA regulations:**

- **§25.863 Flammable fluid fire protection: (a) In each area where flammable fluids or vapors might escape by leakage of a fluid system, there must be means to minimize the probability of ignition of the fluids and vapors, and the resultant hazards if ignition does occur.**
- **§25.869 Fire protection: systems. (a) Electrical system components: (1) Components of electrical system must meet the requirements of § 25.863.**
- **§25.981 Fuel tank explosion prevention: (a) No ignition source may be present at each point in the fuel tank or fuel tank system where catastrophic failure could occur due to ignition of fuel or vapors.**
- **§25.1181 Designated fire zones: (b) Each designated fire zone must meet the requirements of §25.863.**
- **§25.1435 Hydraulic systems. b(4) Meet the applicable requirements of §25.863 if a flammable hydraulic fluid is used.**
- **§25.1723 Flammable fluid fire protection: EWIS Components located in each area where flammable fluid or vapors might escape by leakage must meet the requirements of §25.863.**

# Explosion Proof – Requirements

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- **Explosion-proof is when COMPONENTS are INSTALLED IN AN AIRPLANE ENVIRONMENT THAT may have flammable FLUIDS AND / OR flammable VAPORS present**
  - During normal operation (fuel tanks)
  - Due to system leakage from component wear (e.g., actuator with worn seals)
  - DUE TO A SINGLE FAILURE
- **Two aspects of explosion-proof requirements**
  - EXPLOSIVE CONTAINMENT
  - EXPLOSIVE ATMOSPHERE

# Explosion Proof – Test Standards

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- **RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment, Section 9: Explosion Proofness**
  - Containment, 9.6.1
  - Non ignition, 9.6.2 (explosive atmosphere)
  - Components or surface temperature test, 9.6.3
- **DEPARTMENT OF DEFENSE TEST METHOD STANDARD, ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS MIL-STD-810G, METHOD 511.5:**
  - Procedure I – Explosive Atmosphere
  - Procedure II – Explosion Containment
  - Latest MIL-STD-810H, METHOD 511.7 Issued January 2019

# Explosion Proof – Test Std DO-160G

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- **RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment, Section 9: Explosion Proofness**
- **RTCA DO-160G Categories of equipment and requirements, Section 9:**
- **Category A:**
  - In normal operation, the surface temperature and any operating part will not cause ignition, as **demonstrated by test (section 9.6.2, DO-160G) (Explosive Atmosphere Test)**
  - Ignition of an explosive mixture is contained within the unit without igniting the atmosphere, as **demonstrated by test. (section 9.6.1, DO-160G) (Containment Test)**
  - Hermetically sealed components need not be tested for containment
- **Category E:**
  - In normal operation, the surface temperature and any operating part will not cause ignition, as **demonstrated by test (section 9.6.2, DO-160G) (Explosive Atmosphere Test)**
  - For equipment that is not hermetically sealed
- **Category H:**
  - In normal operation, the surface temperature will not cause ignition, as **demonstrated by test (section 9.6.3, DO-160G) (Surface Temperature Test)**
  - For non-spark producing equipment, with or without hermetic seal

# Explosion Proof – Test Std MIL-STD-810G

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- **MIL-STD-810G, METHOD 511.5:**

- Procedure I – Explosive Atmosphere
- Procedure II – Explosion Containment

- **Procedure I:**

- ✓ In normal operation, the surface temperature and any operating part will not cause ignition in a fuel vapor environment, as demonstrated by test

- **Procedure II:**

- ✓ Ignition of an explosive mixture is contained within the unit without igniting the atmosphere, as demonstrated by test.

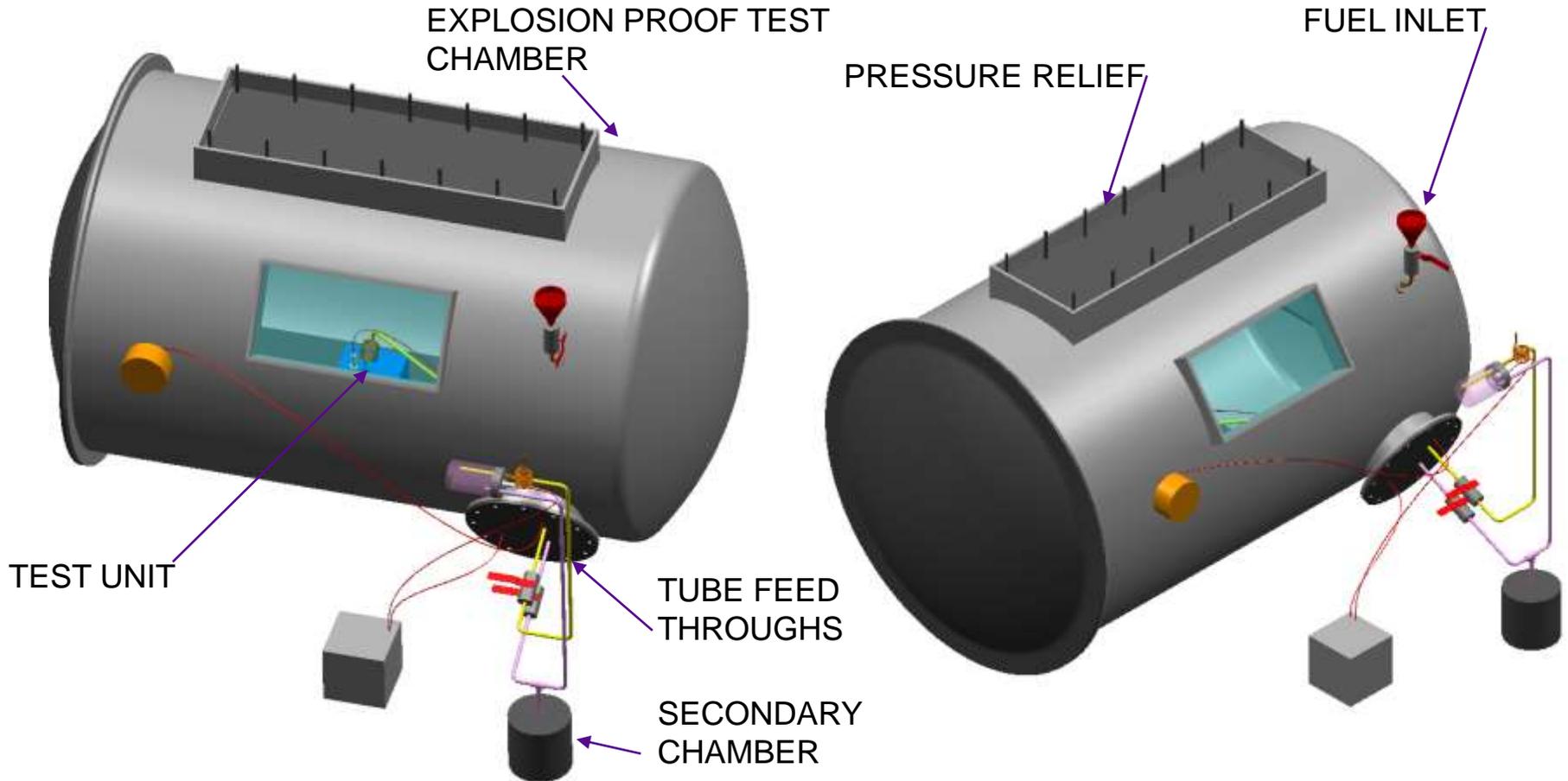
# Test Standard Issues

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Standard	Weakness
DO-160G	<ul style="list-style-type: none"><li>a) Categories may be unclear to component manufacturers; tailoring by installer is critical</li><li>b) Does not address maximum ambient temperature for explosive containment</li><li>c) Does not address altitude for explosive atmosphere</li></ul>
MIL-STD-810G	<ul style="list-style-type: none"><li>a) Does not address surface temperature directly, only indirectly through explosive atmosphere</li></ul>

# Explosion Proof Chamber

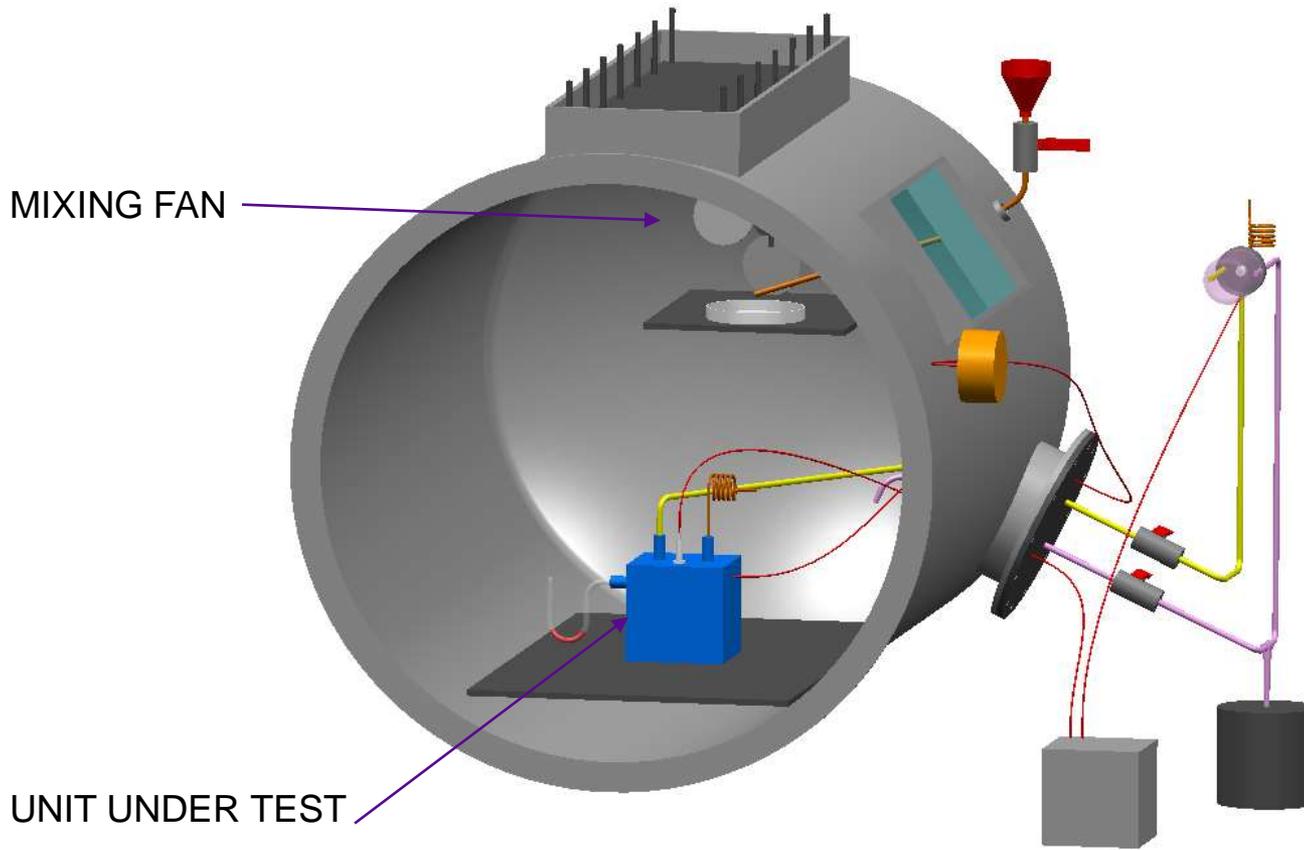
## ■ Explosion Proof Test Chamber



# Explosion Proof Chamber

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- Explosion Proof Test Chamber



# Explosion Proof Test Equipment

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## ▪ Typical Equipment Required:

- A sealed altitude test chamber for testing at different altitudes with pressure relief device, a vacuum pump, fuel inlet, sealed inlets for air, wires, and necessary controls.
- A secondary chamber with shut-off valves, a sparking device, and thermocouples through which flammable mixture from the test unit or test chamber is circulated
- A vacuum pump to circulate the flammable mixture through the test unit or through test chamber as required by the test.
- A heater to get the chamber to required internal environmental temperature and a heater to get test unit to the required temperature
- A mixing fan to circulate the flammable mixture in the chamber
- Thermocouples for measuring the chamber temperature, and the test unit surface temperature and temperature internal as required
- Sparking device/s for installation in the test unit internal cavities.

# Explosion Proof Test Equipment

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## ■ Typical Equipment Required (Cont.):

- Pressure transducers and recording devices for measuring internal pressure rise of the test unit as required.
- Controls for activating or running the test unit at different altitude and temperatures,
- Controls for activating sparks and for measuring temperature rise and pressure rise
- Fuel (propane or N-Hexane to the required grade. (N-Hexane for MIL-STD-810G)
- Portable temperature, humidity, dew point and environmental pressure reading devices
- Timers
- Recording devices for recording all parameters and test results
- Graduated cylinder for measuring the fuel volume

# EXPLOSION PROOF TESTING SAFETY CONSIDERATIONS

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## EXPLOSION PROOF TESTING CAN BE HAZARDOUS

- **The test chambers used for these tests vary in size, and must be capable of safely withstanding an explosion. The chambers incorporate some type of pressure relief feature which vents the chamber to ambient in the event of an explosion. This pressure relief feature is a source of dangerous high energy, high noise, high velocity air and/or debris, high temperature, and flames.**
- **In addition to the pressure relief features, the chamber will have a number of other features such as viewing windows, doors, penetrations, pass-throughs, cover plates or similar hardware. Any of these features could be compromised and fail during an actual explosion, releasing dangerous high energy, high pressure or high temperature air, high noise and high energy fragments and debris.**

# EXPLOSION PROOF TESTING SAFETY CONSIDERATIONS

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## EXPLOSION PROOF TESTING CAN BE HAZARDOUS (Cont.)

- For safety of all personnel including lab technicians, the following safety concerns need to be addressed before the test:
- Verify that the pressure chamber is designed to withhold the explosive pressure.
- Verify that the pressure relief system for the pressure chamber is designed adequately and is operational. Verify the records when it was last tested.
- Verify that the wiring and tubing feed throughs into the pressure chamber are built to take the explosive pressure. Some labs use putty to seal the leak paths.
- Verify that the wires and wire connections in the pressure chamber are properly sleeved (ends) and secured and will not contact structure due to vibration and spark, and result in an explosion.
- Verify that all electrical equipment, i.e., fan, blower, impeller, motor are tested to be explosion proof. Request and verify the test records.
- Verify that all tubing for air and N-Hexane have been leak tested. Request test records.

# EXPLOSION PROOF TESTING SAFETY CONSIDERATIONS

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## EXPLOSION PROOF TESTING CAN BE HAZARDOUS (Cont.)

- **Verify that the N-Hexane container is adequately protected and away from electrical equipment. N-Hexane is very volatile and combustible and can ignite with sparks from static energy.**
- **Verify that the N-Hexane is injected remotely from the control room or adequately protected.**
- **Verify that any tubes and pipes entering the test chamber are protected by a flame arrester, including a flame arrester between the secondary chamber and the main test chamber.**
- **Verify that there is a blast wall or structure between the pressure chamber and control room.**
- **Verify that the test chamber, if inside a building is protected by building pressure relief.**
- **Verify that the explosion proof testing is conducted remotely from a control room and no personnel are allowed in the pressure chamber area during the test.**
- **Finally, verify that the test area is secured during the test and no personnel are allowed in the vicinity during the test.**

## Explosion Proof Testing



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# DO-160G Test Procedure Summary

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- **CONTAINMENT TEST: CONDUCT THREE TIMES AT SEA LEVEL OR SITE LEVEL**
  - The test unit is drilled, modified and sealed to flow the fuel mixture through the unit and a spark device/s installed. Test unit volume cannot be changed by more than  $\pm 5\%$
  - Use Propane or N-Hexane as fuel, Concentration per formula
  - At site level environmental pressure and raise chamber internal environmental temperature to 77°F (25°C)
  - Circulate the air/fuel mixture through the system (specify circulation time)
  - Shut off the valves to the secondary chamber and verify ignition in the secondary chamber. (verification by sound, temperature or pressure increase)
  - Activate sparking device in the test unit, verify ignition inside the test unit by temperature increase and no ignition in the test chamber
  - Continue circulating the flammable mixture and conduct the ignitions for FIVE TIMES, without purging the system. If the fuel in secondary chamber does not ignite, purge the system and start over
  - Success is considered when there is ignition inside the test unit and no ignition of the test chamber in all cases.

# DO-160G Test Procedure Summary

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## ■ NO IGNITION TEST (EXPLOSIVE ATMOSPHERE TEST)

- Install the test unit with cover screws loosened and connected and operable from outside the test chamber through sealed connections. All mechanical loads during operation need to be applied or justified.
- Use Propane or N-Hexane as fuel, Concentration per formula
- Test is conducted at site pressure level
- Raise the internal environmental temperature to operating high temperature for the test unit (listed in DO-160G). The temperature of the test unit and chamber walls may be raised to within 51.8°F (11°C), before fuel is introduced. Circulate the fuel for a minimum of three minutes.
- Operate the test unit at its full potential (verify there is no ignition in the test chamber) (specify time). Operate the unit continuously making and breaking electrical contacts as frequently as possible.
- Shut off the valves to the secondary chamber, activate the spark device and verify ignition in the secondary chamber. If no ignition occurs, purge the system and start over.
- Success is considered when there is no ignition inside test chamber and there is ignition in the secondary chamber.

# DO-160G Test Procedure Summary

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## ■ COMPONENTS OR SURFACE TEMPERATURE TEST

- Install the test unit in the test chamber as installed in service. Attach thermocouples with a range of 149°F (65°C) to 500°F (260°C) on the surface.
  - Operate the test unit at the highest operating temperature (specified in DO-160G) (Specify time)
  - Monitor and record the surface temperature.
  - Temperatures equal to or less than 400°F (204°C) are considered pass.
- **NOTE: Additional requirements may be specified as required for surface temperatures, such as shorting of upstream wiring and measuring the maximum surface temperature to account for short circuits. This is not listed in DO-160G, but highly recommended and used.**

# MIL-STD-810G

## METHOD 511.5 Test Procedure Summary

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### ▪ EXPLOSIVE ATMOSPHERE (Procedure I) SET-UP

- The explosive atmosphere test (Procedure I) is performed to demonstrate the ability of components to operate in fuel-air explosive atmospheres without igniting the environment, applicable to sealed and unsealed components through altitudes of 16 km, (52493 feet).
- Test is to be conducted after vibration, shock and temperature tests are completed.
- Fuel used is N-Hexane reagent grade, 3.8 percent by volume of test atmosphere, for each altitude, calculated by equations in Method 511.5.
- Temperature is the highest operating for component, without any cooling.
- Dew point in test chamber to be 10°C (50°F) or less.
- Altitude simulation: 40000 feet (12200 meters) to sea level (altitudes in between specified).
- On/off cycling rate at each altitude (to be specified).
- Thermocouples to be installed on the test unit (at the highest temperature location) and at least two thermocouples in the test chamber environment.
- Record all parameters e.g. Dew point, temperature, altitude, cycling rate, quantity of fuel, ignition of chamber atmosphere.

# MIL-STD-810G

## METHOD 511.5 Test Procedure Summary

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- **EXPLOSIVE ATMOSPHERE TEST METHOD Procedure I (Cont.)**
  - With the test unit installed in the test chamber, stabilize the test unit and chamber walls temperature to the highest operating temperature  $\pm 2^{\circ}\text{C}$  ( $\pm 4^{\circ}\text{F}$ ).
  - Adjust the chamber altitude to the highest operating altitude for the test unit plus 6600 feet, (2000 meters).
  - Introduce the N-Hexane as the altitude begins to drop.
  - Circulate for three minutes and continue to reduce the altitude to 3300 feet (1000 meters) above the test altitude.
  - Shut off the valves of the secondary chamber and test with a spark for explosiveness. If no explosion occurs, purge the test set-up and repeat.
  - Operate the test unit and slowly reduce the altitude at a rate no higher than 100 meters per minute. MAKE and BREAK electrical contacts as frequently and as reasonably possible.
  - Stop decreasing the altitude, 3300 feet (1000 meters) below the operating altitude or ground level which occurs first. Conduct an operational check and switch off power.
  - Verify the explosiveness of the fuel by circulating through the secondary chamber and igniting.
  - Purge the system. Adjust the altitude to 6600 feet (2000 Meters) above site pressure and REPEAT the test from addition of N-Hexane.
  - Document the test results.

# MIL-STD-810G

## METHOD 511.5 Test Procedure Summary

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- **EXPLOSIVE CONTAINMENT (Procedure II) SET-UP, TEST CONDUCTED AT SEA LEVEL OR SITE LEVEL**
  - This procedure is used to determine the ability of the test unit's case or other enclosures to contain an explosion
  - Test is to be conducted after vibration, shock and temperature tests are completed.
  - Make provision to circulate the fuel-air mixture into the case of test unit being tested. The test unit internal volume cannot be altered by more than  $\pm 5$  percent to facilitate the introduction of ignitable vapor.
  - Drill test unit and install a sparking device ensuring that the ignition points are not more than 0.5 inch from any vent holes or flame arresting devices.
  - Insert thermocouples in the drilled cavities and attach to recording devices for detecting the explosion.
  - Fuel used is N-Hexane reagent grade, 3.8 percent by volume of test atmosphere, for each altitude, calculated by equations in Method 511.5.
  - Temperature is the highest operating for component, without any cooling.
  - Dew point in test chamber to be 10°C (50°F) or less.

# MIL-STD-810G

## METHOD 511.5 Test Procedure Summary

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- **EXPLOSIVE CONTAINMENT (Test Procedure II) TEST METHOD (Cont.)**
  - Place the test item unit in the test chamber.
  - Ensure the air within the test chamber has a water vapor dew point lower than 10°C (50°F).
  - Seal the test chamber, and raise the ambient air temperature inside the chamber to the high operating temperature of the test unit.
  - Record all parameters e.g. dew point, temperature, altitude, quantity of fuel, ignition temperature of the test unit inner cavity, pressure if required.
  - When the temperature of the both the test item and the test chamber inner walls come to within 11°C (51.8°F) of the chamber ambient air temperature, reduce the chamber air pressure to 6600 feet (2000 meters) of simulated altitude above the site ambient pressure (i.e., ground level).
  - Slowly introduce the required quantity of n-hexane into the test chamber, then introduce it into the interior of the test unit
  - Slowly decrease the simulated chamber altitude (no faster than 328 feet or 100 meters per minute) to return the pressure altitude to site ambient pressure (i.e., ground level).

# MIL-STD-810G

## METHOD 511.5 Test Procedure Summary

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- **EXPLOSIVE CONTAINMENT (Test Procedure II) TEST METHOD (Cont.)**
  - Energize the internal spark generator and confirm the occurrence of an explosion within the test Unit using the installed thermocouple. If no explosion occurs, purge the test chamber and the test unit and return to reheating the test chamber.
  - If an explosion does occur inside the test unit and does not propagate into the test chamber, repeat from step requiring lowering the test chamber pressure, **FOUR TIMES**, if the test unit volume is less than 0.02 times the chamber volume.
  - If the test unit volume is equal to or greater than 0.02 times the test chamber volume, purge the test chamber and test unit and repeat Steps from depressurizing to the end, **FOUR TIMES**.
  - Check the explosiveness of the air/fuel vapor mixture by igniting the mixture in the secondary tank.
  - Internal explosions in the test unit constitute a test pass.
  - Document the test results.

# EXPLOSION PROOF TESTING

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