

PT 105
Leak testing
ultra high purity (UHP) gas systems
March 3, 2026



Overview

Few things are absolute and without exception. The fact that nothing is completely leak tight and leaks to some degree is one. There are various methods for determining leak rates in UHP gas systems, as follows:

Bubble test

One of the oldest and easiest leak test methods is a bubble test. A leak detection solution, typically soap based, is applied to the exterior of an internally pressurized joint and one watches for bubbles to form, which would indicate a gas leak. Most consider this method to be in the range of 1×10^{-4} and no visible bubbles is declared 'bubble tight'.

This method is generally employed for non-critical and lower purity applications, such as pneumatic systems or lower grade N₂ where NPT connections are common.

A component can also be immersed in water while pressurized to detect bubbles. This is typical of components for liquid service rather than gas.

An across the seat test can also be performed utilizing a beaker of water. A plastic tube connected one end to the outlet of the device under test (DUT) with the other end in the water is used to watch for bubbles. The DUT is closed and bubbles indicate an across the seat leakage.

Helium leak test methods

Helium (He) leak testing utilizes a mass spectrometer (He leak detector) to detect the level of the tracer gas, He. There are different He leak test methods, as follows:

Inboard He leak testing is the most common and easiest test to perform. One connects the DUT to the leak detector which pulls vacuum while He is applied, sprayed, to the exterior. The typical test duration is one minute. The differential pressure is from atmospheric pressure on the exterior to the vacuum level of the interior. The leak detector displays a leak rate. The path for the He tracer gas is

outside to inside, thus the inboard name. Leak rates are typically tested to the 1×10^{-9} range or higher.

Outboard He leak testing has two primary methods, sniffer probe and bell jar. It is the opposite of inboard He leak testing as the He pressurizes the interior the DUT and vacuum is utilized on the exterior. The differential pressure is a function of the He pressure, typically 100 psig, compared to atmospheric pressure, which is several times that of an inboard test. The He molecules are pushed with pressure through a leak path resulting in more force than created by pulling via vacuum.

Sniffer probe testing has a vacuum wand attached to the leak detector. The DUT is pressurized with He and the sniffer probe is held closely to potential leak points. The operator use of the wand does impact the test sensitivity, as how closely it is held or moved effects results. The atmosphere surrounding the DUT contains He, which is the background level of He. The probe detects the background level and any rise above the background level is considered a leak, the He escaping from the DUT. The limitation of this test is the background level of He which is often in the 1×10^{-6} range. Another downside to this test method is He saturation of the wetted parts. A soft seat can be difficult to remove He after testing to be able to perform an inboard test.

Bell jar testing is the most sensitive He leak test. Like the sniffer probe test, the DUT is pressurized with He. The difference is that the DUT is in a bell jar, vacuum chamber to remove He in a vacuum environment which is connected to the leak detector. Similar to inboard testing, leak rates are typically 1×10^{-9} or higher. However, the higher differential pressure of the He makes this a more sensitive test. A limitation to this method is that the DUT must fit in a vacuum chamber, which precludes manifolds or gas systems from a practical standpoint.

He 'bombing' is another test method. The exterior of a device is pressurized with He and then placed in a bell jar after a dwell time to allow He molecules to break free of the exterior surface. The bell jar is connected to the leak detector and vacuum is pulled. Any He trapped inside the DUT will escape via a leak path. The method is common for testing something fully encapsulated which must be leak tight, such as a capsule.

A variation to bombing is selectively applying He to the exterior of a joint and connecting the DUT to a leak detector. It is a combination of inboard testing and selective bombing. The advantages to this test over inboard testing is the larger pressure differential across the leak path and the He molecules are pushed by

gas pressure rather than pulled by vacuum through the leak path. Pure T utilizes this method, named inboard X, to signify the more extreme test of increased pressure differential (X for multiple).

Static pressure testing

Another very old leak test and common method is static pressure testing, trapping a gas inside a DUT and monitoring for a pressure change. In UHP gas systems, a 24 hour static pressure test with N₂ is common for a final test prior to start up. This test can detect leaks which are not detected by inboard or outboard sniffer probe testing. Test durations of fewer hours decreases test sensitivity and will get to the point that other tests are superior.

Leak testing considerations

There are variables to consider when leak testing.

The duration of the test impacts what is detected – the longer the test, the higher the probability of detecting a leak. A DUT may pass a one minute test, but fail a 10 minute test. A test duration must be established that is reasonable. Testing for weeks, months or years might detect a leak not previously found, but that is not practical. One minute is common for inboard He testing, five minutes for He sniffer probe and 24 hours for N₂ static pressure decay.

Internal volume is a consideration for static pressure testing. The larger the volume, the smaller the pressure loss will be.

Test pressure impacts outboard testing, inboard X and static pressure testing. The higher the pressure forcing the test gas molecules, the more apt one is to detect a leak. However, from a practical standpoint, such as a regulator's outlet pressure rating, a typical pressure is 80 to 100 psig of either He or N₂.

Tracer gas molecule size impacts the gas's ability to pass through a leak path. He is utilized due to the gas being inert, unlike H₂, and having a very small molecule size. N₂ is utilized for longer duration static pressure testing from a practical standpoint, though the molecule size is larger than He, it will not saturate the gas system and is less expensive.

Temperature impacts a static pressure test, as changes in temperature cause changes in gas pressure. There are time constants for a device temperature to change, but temperature must be monitored and changes compensated.

Leak testing comparison

The most stringent, meaning best detection, leak test method is outboard He bell jar. The least sensitive test is the bubble test. Inboard He leak testing is roughly equivalent to outboard sniffer probe testing. However, though an inboard test can detect a leak undetected by a sniffer probe test, the opposite is more common. A 24 hour N₂ static pressure decay test and inboard X are also roughly equivalent and superior to inboard or sniffer probe He testing.

Leak rate importance

The test method really determines the leak integrity of a system, passing the test means an acceptable leak rate. Stating a leak rate can be difficult in tests other than inboard or outboard bell jar. One can determine a leak rate for a static pressure test, but the calculation is very complicated. A sniffer probe test leak rate is the background level. In addition, a DUT can pass an inboard He test at 1×10^{-11} yet fail a sniffer probe test with a higher He background reading, such as 1×10^{-6} .

The test method and protocol, test parameters, really determine the leak integrity of a system, more than a leakage rate.

Regulator across the seat leak testing considerations

Pressure regulator across the seat leak testing has some challenges. An inboard test connected to the outlet of a closed regulator, pulls vacuum on the diaphragm which tends to open the DUT across the seat. Pulling vacuum on the inlet, can also cause a closed DUT to open across the seat. Though some DUT may pass the test, inboard style He leak testing should never be utilized to test a regulator for leak integrity across the seat. Outboard He sniffer probe testing works well, as vacuum is not applied to the device. Bell jar He leak testing also works well across the seat with He applied to the inlet, because the diaphragm has vacuum to both the wetted and non-wetted sides of the diaphragm, equal forces. The simplest method is static pressure testing. Pressure is trapped and an increase in outlet pressure is monitored. This can be done with the regulator adjusted to a set point, closed, or adjusted to a set point and the adjustment backed off a ¼ turn. This is also the only test that can be performed with the regulator installed in a gas system.

A further complication to regulator across the seat testing is permeation with He leak testing. He will pass through, permeate, a soft seat such as one of PCTFE, PTFE, PFA, etc. The permeation rate varies with material, typically between 15

and 30 seconds. This means any he across the seat test with pressurized He must be limited to 15 to 30 seconds to preclude He being detected that passed through the material itself rather than across the seat.

Conclusion

The test method really determines the acceptable leak integrity more than a leak rate per se. Understanding leak detection methods, their advantages and limitations, is imperative for UHP gas systems. Employing multiple leak test methods on a gas system is wise, as different methods have different leak detection abilities. Thus, inboard He testing followed with a 24 hour static pressure decay test is the industry standard.