Product Note, PN 442
Interpreting Leak Rates

December 13, 2018

Introduction

Nothing is truly completely Helium leak tight, everything leaks to some degree. Quantifying leak rates can be an elusive challenge. The goal of this product note is to explain the various leak testing methods of high purity (HP) and ultra high purity (UHP) gas delivery devices and provide an understanding of the test results – which may or may not be an easily quantifiable leak rate.

Pressure Decay

The most common method of leak testing in general is a simple pressure test with Nitrogen (N2). Valves and pressure measurement devices are attached to the device under test (DUT) to enable pressurization with the DUT in the fully open position and pressure monitoring. The trapped volume, time and pressure differential determine the test sensitivity to detect leaks, with least volume and longest time having the greatest sensitivity. This is termed a N2 static pressure decay test. PN 435 Quantifying Bubble Tight posted to AP Tech's web site explains a few other test methods used in general industry and also provides a means of calculating a leak rate based upon a given test's parameters and results. A 24 hour static pressure decay test is a common final leak check of a piping installation.

Inboard Helium

Inboard Helium leak testing is the single most common method of Helium leak testing in the semiconductor industry. The DUT is connected to a Helium leak detector (mass spectrometer), all other ports are capped, adjusted to fully open position and the leak detector applies vacuum to the inside (wetted area) of the DUT. Helium is sprayed outside the DUT and the pressure differential across the DUT (outside DUT to vacuum) will pull Helium through a leak path to the leak detector. Detection is improved by placing a bag over the DUT and spraying Helium into the bag. The leak detector reports a value of a leak rate based upon the amount of Helium detected. It is a simple and effective method which produces a leak rate value.

Outboard Helium Sniffer Probe

Outboard sniffer probe testing is less common than inboard testing, though preferred by AP Tech. It is basically the opposite with Helium applied inside DUT rather than outside. In this case, the DUT is pressurized with Helium and a vacuum wand (sniffer probe) is connected to the leak detector. The leak detector pulls atmospheric air from around the DUT through the wand to the leak detector. The limitation of this test method is the background reading of Helium in the air which is in nominally in the range of 10^{-5} atm cc/sec. The word nominally means that the background level of Helium in the air varies. The test criteria is generally no rise above the background reading of Helium in the air as the sniffer probe is placed near leak test ports, mechanical joints, welded joints, etc. This method does not produce a leak rate value, per se, only detecting that there is a rise in the atmospheric background level of Helium. A

limitation to outboard sniffer probe testing is that a leak rate below the background level of Helium in the air will not be detected.

Comparing Inboard to Outboard Sniffer Probe

Comparing and contrasting inboard to outboard sniffer probe testing, inboard is pulling molecules through a leak path with vacuum with a pressure differential of atmosphere to the vacuum level applied (a maximum differential of approximately 15 psig (~1 bar) for the sake of simplicity). Outboard testing, the device is pressurized with Helium and the differential pressure is the difference between test Helium pressure applied and atmosphere. In the case of a pressure regulator, the low pressure side is generally pressurized to the outlet rating of the device. The most common outlet range is 100 psig (7 bar), so the pressure differential in this case is 100 psi (7 bar), or more than seven times that of inboard testing. It is also important to note that outboard testing is stressing the parts the same as they would be in service and pushing the molecules through the leak path rather than trying to pull with vacuum.

Interestingly, it is possible to have a DUT pass one test yet fail the other. A device can pass an inboard test with a leak rate achieved of 1×10^{-10} yet fail a sniffer probe test. One might first think the inboard test was done incorrectly because the DUT failed a lower sensitivity sniffer probe test. In reality it is simply that different test methods and conditions, such as time and pressure, yield different results. This also points out why specifying leak test method with a leak rate is important.

Outboard Helium Bell Jar Test

The more stringent test is an Helium outboard bell jar test. This test is very similar to the outboard sniffer probe test as the DUT is pressurized with Helium. The difference is that the DUT is in a vacuum bell jar connected to the leak detector which eliminates the background Helium in the environment surrounding the DUT. The disadvantages of this method are several. Whatever being tested needs to fit in a vacuum chamber which means testing large manifolds or gas piping systems are not practical. In addition, the method detects a leak but unlike inboard or sniffer probe testing, the location of the leak is unknown and could simply be a test fitting connection.

To complicate things further, leaks are pressure and time dependent. A leak might not be detected at one pressure though is found at a higher pressure or might not be detected in 5 minutes but found in 30 minutes or some longer time period. These leak characteristics are affected by variables such as cross sectional area and length of the leak path among other factors.

Ranking of Test Methods

If one were to rank leak test methods on sensitivity to finding leaks, inboard would occupy the bottom, least sensitive. Sniffer probe testing next above inboard. A 24 hour N2 static pressure test is next with Helium outboard bell jar testing the best. However depending upon the test time and test gas pressure, a N2 static pressure test can be better than an outboard bell jar test.

It must also be stated that there is another drawback to Helium outboard testing, the Helium itself. Helium tends to permeate plastic materials, such as the regulator or valve seat material. The higher the pressure and longer the time, the more difficult it is to remove the Helium that permeates (penetrates) into the seat material. An inboard test performed after an outboard test can (and often does) fail due to the Helium residual from the previous test. Reducing pressure, time and Helium percentage in test gas can each help

reduce Helium permeation at the expense of test sensitivity. For example, the smaller the Helium percentage from 100%, the less test sensitivity.

AP Tech performs a 3 to 5 minute Helium outboard sniffer probe test. If test time were increased there would be an associated increase in number of leaks detected, such that 30 minutes could be considered better than 5 minutes, and one day better than a few hours, and a week better than one day, etc. One could argue that you need to test for a year to truly find all leaks – but this is simply not practical. Test time and other parameters are designed and generally accepted to detect leaks with high confidence.

Conclusions

As explained, a DUT may pass one test yet fail another. Hopefully, it is now understood that this does not necessarily mean the passing test was done improperly. It simply means that the leak was detectible by one test method and not the other. Though it is possible to perform a test improperly and yield an erroneous passing grade, test sensitivity to a given leak is more often the culprit.

Many question if products in production are tested to published specifications. The simple answer is no. Manufacturers employ test methods to provide confidence that products meet all published specifications. This is not the same as testing to guaranteed specifications.

More than leak rate specifications, the customers leak testing methods define their piping systems leak integrity. Stated differently, if a product passes testing it is considered leak tight to the specifications though the test may not produce a given value. It should also be noted that if a product passes leak testing, it will remain with this leak integrity throughout its life unless improper use or wrong product selection for the application lead to failure.