Technical Overview

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Accuracy in Helium Mass Spectrometer Leak Testing

Introduction

How accurate is helium mass spectrometer leak testing? Since helium leak testing is primarily a quality control measurement, it is not surprising that this is a common inquiry. However, this straightforward question often does not have an equally concise answer. When compared to other quality measurements, helium leak testing is unique. While dimensional tolerances may be specified to three or four decimal places, it is not unusual for a leak rate measurement to be carried out to eight or nine decimal places, or more. These small values, when combined with the fact that outside influences can potentially impact them by an order of magnitude or more, means that a process must be thoroughly understood and controlled to maintain accuracy. This technical overview will explain what factors affect leak testing accuracy, and suggests how to establish proper test criteria.

Factors affecting helium leak test accuracy

The accuracy of helium leak detection measurements can be influenced by several factors. Each will contribute a degree of variability and uncertainty to the measurement. These factors can be grouped into three categories:

- The reference standard
- Ambient conditions
- The leak detector itself

Each of these will influence the test result and in some cases, variabilities in one area will influence another. For example, there is a positive correlation between temperature (an ambient condition) and the leak rate of a calibrated leak (reference standard).

Here are some details on the potential for each of these three to influence the measurement result.

Reference standard

A helium leak detector relies on a reference leak to correlate the output signal with a known flow of helium. They are typically traceable to a reference standard certified by an accredited laboratory. Agilent standards are calibrated to a reference certified by the US National Institute of Standards and Technology (NIST). Here are some of the variables in the standard:

The internal standard in an Agilent leak detector specifies an uncertainty of ±5.7%.

Calibration standards leak continuously. Depletion rates vary, but ~ 3% per year is typical. However, decay is a function of usage conditions and storage temperature, which may vary considerably.

Temperature variations influence the leak rate of the standard by approximately 3 to 4% per °C. The Agilent internal standard has a thermistor to compensate for temperature deviations, but this can still introduce additional variability.

Ambient conditions

The biggest influences on accuracy and repeatability are 1) environmental conditions in which the leak detector operates and 2) the components, test chamber, or system the leak detector is connected to. Here are key points to remember regarding each:

- As noted above, temperature can affect the calibrated leak. While the temperature of a reference standard is compensated for by the leak detector's operating system, the temperature of the component or system under test usually is not. Nor is an external calibrated leak temperature compensated if one is used. At a rate of 3 to 4% per °C, a temperature change of a few degrees can have a noticeable effect.
- Background helium can have a profound effect on testing accuracy. Normally our atmosphere has a helium concentration of five parts per million. However, in facilities where helium is used for leak testing, it is not unusual for the background to be significantly higher, even as much as one or two orders of magnitude higher. If the background is not known or controlled, it can add to the signal the leak detector is measuring.
- The integrity of the components or system can also introduce errors. For example, if you are testing a sealed part inside a vacuum chamber, and the chamber has a small leak, the background helium that comes through the leak is added to the helium emanating from the part.

Instrument variability

A helium mass spectrometer leak detector is an electronic measurement device, and even with modern digital electronics, there is a small degree (<2%) of variability.

Determining a leak rate specification

Taking all of the above variabilities into account and arriving at a total tolerance of a leak rate measurement can be difficult. Especially when some factors, like helium background, can be highly variable and introduce order of magnitude errors. It is also possible to mitigate some detrimental effects. Again, helium background is a good example. Controlling how much helium is used, how it is removed from the test area, improvements in ventilation, and venting or purging the leak detector with nitrogen can significantly improve accuracy and precision.

Other factors like temperature, the decay of a calibration standard over time, and tooling variability can be challenging to accurately monitor or calculate.

A true measure of uncertainty can only be determined with a gauge repeatability and reproducibility study. However, there are some guidelines to follow when determining your test parameters:

- Depending on your reference standard certification, variability will likely be in the range of 5–10%. If the certification is out of date, depletion of the helium will introduce additional error of a few percent per year.
- Even with a tightly controlled process and the effect of background variations and tooling/fixturing used for the test, a variability of ±30% is not unusual.
- Temperature variations could introduce another 5 to 10% error.

Added together, the accuracy of a leak test can be as high as ±50%.

Consider a leak test specification of 5.0×10^{-7} atm·cc/s. Applying ±50% to the specification, the leak detector can measure anywhere between 2.5×10^{-7} atm·cc/s and 7.5×10^{-7} atm·cc/s.

To allow for the variability of the system and to introduce an additional safety factor, a common practice for manufacturers is to set the leak rate specification 5 to 10 times lower than the required specification.

Applying this factor to the above leak test specification of 5.0×10^{-7} atm·cc/s results in a test specification of:

1.0×10^{-7} atm·cc/s

or

5.0×10^{-8} atm·cc/s

Conclusion

Using a mass spectrometer and helium as a trace gas to detect leaks offers unsurpassed sensitivity and selectivity. Ensuring accuracy requires requires an in-depth understanding of the factors that influence variability, and the proper process controls to reduce their impact. Applying an appropriate tolerance to a leak rate specification can help ensure product integrity. Contact Agilent if you have additional questions.

References

1. Understanding Minimum Detectable Leak in Helium Testing. *Agilent Technologies technical overview*, publication number 5994-2193EN, **2020**.
2. Calibrated Helium Leaks: Uncertainty, Tolerances, and Test Uncertainty Ratios. *Agilent Technologies technical overview*, publication number 5994-3020EN, **2021**.

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