

# Managing the Background Signal in Helium Leak Detection

## Abstract

One of the distinct advantages of using helium as a trace gas in leak detection is its rarity in the air around us, only approximately five parts-per-million (ppm). Low background, as it is called, is desirable as it makes it easier to differentiate the helium escaping from a leak from the helium already present in the atmosphere. Understanding and managing the contribution of the helium background is critical to the leak test process because:

- An elevated background can limit the sensitivity of test equipment, indicate false rejects, and create unnecessary downtime.
- Product test requirements are becoming more and more stringent, and if the background is not dealt with properly, it can prevent users from achieving their test criteria.
- Today's helium mass spectrometer leak detectors are extremely sensitive, capable of detecting a leak so small it would take a few thousand years to allow just one cubic centimeter of gas to escape. The ability of a leak detector to effectively ignore the background when working in these more sensitive ranges is crucial for an accurate test.

## What is helium background, why it is important

As mentioned above, the nominal amount of helium in air is approximately 5 ppm. In areas where helium is being liberally used as part of the test process, it is not uncommon to have ambient helium concentrations exceed 1,000 ppm. In highly sensitive applications, ambient helium levels of as little as 25 ppm can have a detrimental effect on the leak detector and the testing process. High background manifests itself as an elevated displayed leak rate (above what is considered normal) on the leak detector, even when no leak is present. This can make it difficult to determine if a leak exists in the product or system being tested.

In addition to a higher than normal ambient concentration of helium, the magnitude of the background signal depends on the leak detector configuration (type of vacuum pumps, sealing material, etc.). The background signal is always added to the helium signal, escaping through the leak we are trying to detect. Depending on the sensitivity required and on the background present (signal-to-noise ratio) we can conclude that helium leak detectors will always display a background signal, which interferes with the measurement of a true leak. This often becomes an issue when trying to measure leaks smaller than  $10^{-9}$  mbar  $\times$  L/sec. (For comparison to other units, see the conversion tables at the end of this document)

Before going into details describing the process and benefits of subtracting the background signal on a leak detector, we should first analyze the various sources of background helium.

### First, the helium in the ambient air and present in the leak detector itself

1. In normal conditions, the 5 ppm concentration gradually decreases when evacuating the inlet of the detector (including the part to be tested). This type of background is primarily dependent on the environment around the leak detector. Maintaining proper environmental conditions is therefore very important.
2. Helium trapped inside elastomer seals and o-rings (typically Viton and Buna-n) used in the leak detector.
3. Helium trapped or accumulated inside the leak detector and its pumps.

### Second, helium from the part or system under test (we're only talking about background – this does not include the contribution from any leaks in the part or system)

1. Helium trapped on the surface of the part.
2. Helium trapped in the elastomer seals or o-rings of the part.
3. Permeation of helium through materials. The permeation rate is dependent on the material in question and the helium concentration on the exterior of the part.
4. Helium trapped in cavities, known as virtual leaks. These are small volumes, capillaries, fissures or small cracks that can be present in the construction of the vacuum system or any component inside it. An additional problem with these cavities is that they can become clogged or unclogged at any time and thus create background fluctuations. Virtual leaks cannot be found with leak testing.

### Calculating background

Under the conditions above (either individually or combined) the value of the background in ppm can be calculated by using the following equation:

$$\text{He} = \frac{Q}{P \times S \times 1 \times 10^6}$$

Where: He = Concentration of helium in ppm

Q = Helium background signal displayed on the leak detector in mbar  $\times$  L/sec

P = Air partial pressure in mbar

S = Helium pumping speed in L/sec

**Note:** Particular attention should be paid to helium pumping speed. Pumping performance for helium varies substantially, depending on operating pressure and type of pump.

If the leak detector is displaying a leak rate of  $2.0 \times 10^{-8}$  mbar  $\times$  L/sec, the test pressure in the leak detector is 0.001 mbar, and the helium pumping speed of the leak detector is 1.8 L/sec, then the concentration of helium is:

$$\text{He} = \frac{2.0 \times 10^{-8}}{0.001 \times 1.8 \times 1 \times 10^6} = 11 \text{ ppm}$$

You can see that even a slight increase in helium concentration, in this case roughly double that normally found in atmosphere, can create a significant leak rate signal that effectively masks a real leak.

## Background fluctuations

During leak testing an operator might observe that the helium background is gradually, or sometimes quickly, increasing. This is usually the result of the leak detector being exposed to a large leak, or by an increase in the ambient concentration of helium in the work area. Examples of the latter include spraying too much helium on the part being tested, or if a part with pressurized helium is allowed to vent into the work area and is not properly exhausted. In these instances it might take a long time before the leak detector fully recovers or purging the system is required to clean out the system. Once the leak detector is “saturated” with helium the high background signal will strongly interfere with the objective of measuring/detecting the true leak because the leak is much smaller than the background signal.

## How background can mask a leak

In the calculations above the slight increase in background induces a leak rate reading of  $2.0 \times 10^{-8}$  mbar  $\times$  L/sec. If the part being tested has a leak of  $5.0 \times 10^{-9}$  mbar  $\times$  L/sec it will be very difficult to find the leak. The graphs in Figure 1 demonstrate this. The chart on the left is reading the true leak as an additive signal to the existing background. The true leak is difficult to spot as it is just a small component of the total value displayed. This can be compounded by the fact that background by its nature is variable and therefore can add to the instability of the reading. The chart on the right demonstrates how much easier it is to see the leak if the true leak signal can be separated from the background. Later we'll discuss how features in Agilent's leak detectors can separate these signals.

## How to minimize/manage background helium

First though we'll talk about ways to control background. Many of today's applications are for high sensitivity leak testing in the range of  $10^{-9}$  mbar  $\times$  L/sec and smaller. As we have shown, helium background in the testing area can greatly affect the ability of the leak detector to successfully find leaks this small. Any helium leak detector in sniffing mode can measure the ambient helium concentration in the test area and also help locate the source of helium contamination.

To minimize the effects of helium background on the operation of the leak detector, any number of the following methods can be used:

1. Use dry nitrogen or argon as venting gas instead of room air.
2. The leak detector's mechanical pumps do not pump helium well, especially at low pressure. They may need to be purged with nitrogen to prevent helium from accumulating in the pump.

3. Connect the rough pump discharge to an externally vented air exhaust system. Preferably an active system with some type of pump to ensure that the helium is removed.
4. If parts are pressurized with helium for testing, consider using a lower pressure or concentration of helium. In this case you will need to recalculate your reject set point.

**Note:** The behavior of a leak is not always linear with respect to pressure; make sure you properly recalculate set points.

5. Ensure that the part is vented to an air exhaust system as in No. 3, or recovered by a recycling system, so the spent helium does not contaminate the test area.
6. If helium is being sprayed on an evacuated part or system, make sure a very low flow of helium is used. If you stick your spray probe in a glass of water, you should see no more than two or three bubbles per second.
7. Ensure that the leak detector is well maintained and free of leaks in its own vacuum system.

The following table can serve as a general guide for different helium background conditions:

Leak Rate Testing Range	Test Area Helium Concentration		
	5 ppm	50 ppm	500 ppm
$10^{-8}$ mbar $\times$ L/sec	OK	See Note 1	See Note 2
$10^{-9}$ mbar $\times$ L/sec	OK	See Note 2	See Note 3
$10^{-10}$ mbar $\times$ L/sec	See Note 2	See Note 3	Not recommended

**Note 1:** Appropriate machine preparations such as external pump exhausting and nitrogen venting may be necessary.

**Note 2:** Appropriate machine preparations such as external pump exhausting, pump purging, and nitrogen venting are probably required.

**Note 3:** Problems may be encountered even with machine preparations.

## How to make a leak detector ignore background

What about less stringent applications, or test processes that still suffer moderate effects from background helium even after employing some of the corrective measures described in the previous section? In many instances background helium can be managed by features built into the leak detector. The ability to disregard the background and still deliver required sensitivity and accuracy can be as easy as pressing a button.

Sophisticated electronics and software on most leak detectors allow for manual or automatic background subtraction, usually referred to as zeroing. They can also employ techniques where the subtracted signal is

automatically corrected if the background signal diminishes and drops below the system's "Zero" level. These methods are used on Agilent's leak detectors.

In principal the ability to electronically ignore the background sounds very attractive; however, if misused, the potential exists to pass leaking parts. As a matter of fact, some machines can be set to automatically "Zero" when going into test providing a background reading as small as  $10^{-12}$  mbar  $\times$  L/sec in only a few seconds. Of course this makes a great impression on the user, but what the machine does not show is its inability to find a  $10^{-10}$  mbar  $\times$  L/sec leak.

Typically, electronic background suppression, zeroing, works as follows:

1. The leak rate displayed on the leak detector increases or is at a higher than normal baseline after a test and it is known that the detector is not exposed to a leak. This observation may be noticed by the operator or detected by design either where a helium leak test process is integrated into an automated production line, or during an automated calibration cycle.
2. The zero function is then activated by the operator or is carried out in an automatic mode. The machine interprets the current leak rate reading as a background signal and stores the value and resets the display to the most sensitive scale.
3. The operator/machine continues to work and resets this zero level each time the background signal interferes with measurements.

In simplest terms, the background signal in Figure 1 (blue bars) is electronically ignored. As testing continues the detector only displays the added helium of any leaks encountered, and it is able to display it on a scale that can be easily read. At any time the zeroed value can be recalled by turning the zero function off.

## Issues and concerns

Each circumstance below could result in incorrect leak indications. Depending on the leak detector design, test parameters and the software algorithms, the operator needs to know what the effect on the measurements will be when:

1. The detector has software controlled automatic zeroing routines that are activated during the evacuation process of a part being tested by the outside-in method. The leak detector will display minimum levels in only a few seconds.
2. The operator activates the zero function immediately after a machine start-up and wants to perform high sensitivity measurements without waiting for the system to clean and stabilize.
3. The detector is still recovering from a high helium background signal (the leak rate reading is not stable) when the zero function is activated. Will the operator/machine know if the measurements are correct after the background signal dissipates?

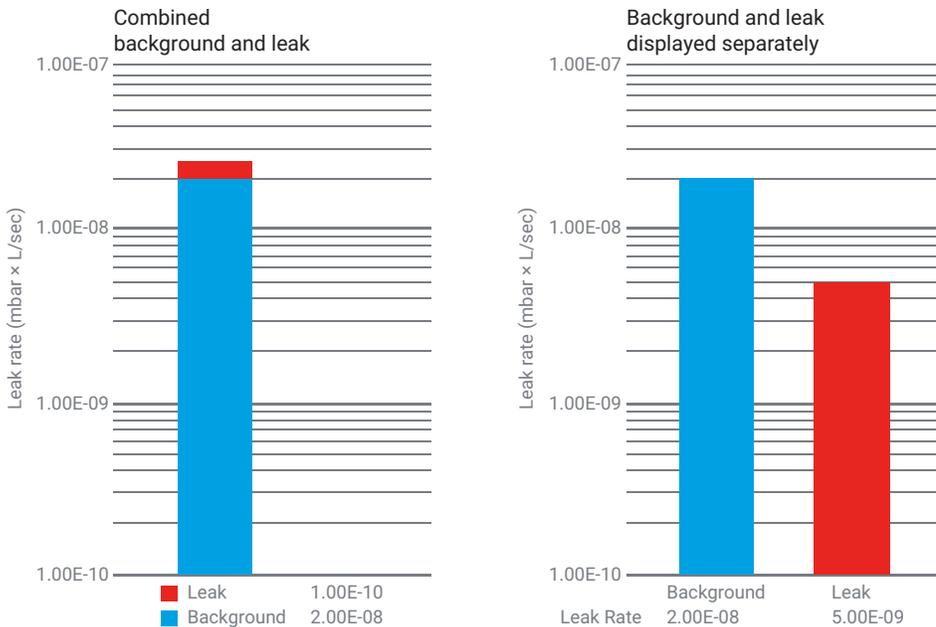


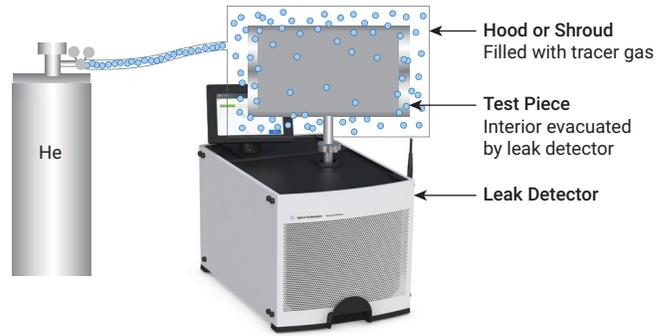
Figure 1. How background can mask a leak.

**The risk of accepting leaking parts or making inaccurate measurements**

In a helium leak test, regardless of method (outside-in or inside-out), the operator is only interested in the true helium signal coming through the leak. Therefore the background signal must be subtracted. But subtracting the background value at the wrong time, as in the three actions immediately above, may also subtract the portion of the signal escaping from an actual leak. The following example demonstrates how this can happen.

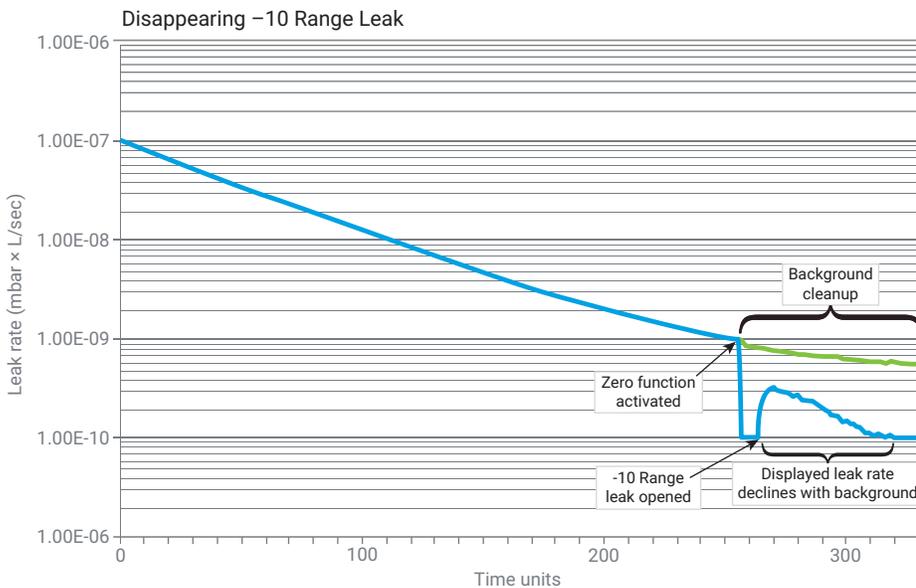
Take a typical outside-in test (Figure 2). In this application, the integrity of a sealed volume must not allow helium to penetrate from the outside of the part to the inside. To test this, the part under test is evacuated by the leak detector, and then helium is either introduced in a volume that surrounds the part or is sprayed around the outside of the part. If an increase in helium is detected, then there is leak.

During evacuation the background is continuously changing (in this case, decreasing) because the leak detector is pumping away all of the gasses inside the part, including background helium present. The chart in Figure 3 displays a conventional dissipation of the background helium signal as the volume is pumped to a lower pressure. This is represented by the blue line. In this example the zero function of the leak detector is activated when the leak rate signal reaches  $1.0 \times 10^{-9}$  mbar  $\times$  L/sec. This causes the remaining background signal to be ignored and the indicated leak rate drops to  $1.0 \times 10^{-10}$  mbar  $\times$  L/sec.



**Figure 2.** Typical outside-in test configuration.

At this point a  $3.0 \times 10^{-10}$  mbar  $\times$  L/sec calibrated leak mounted to the test volume is opened – a calibrated leak was used as it allows better control of the demonstration. But will the leak be detected and accurately measured? Even though the background has been zeroed and is no longer displayed, it is still there and the leak detector is pumping it away. So while the helium from a leak has been added to the signal, the detector is also pumping away the background helium signal. The reduction in background signal is represented by the green line in Figure 3. This is just a continuation of the signal that was erased when the zero function was activated. Since the background is much larger than the leak itself and the leak detector measures only one helium signal, the sum of the background and the true leak, the total signal will continue to decrease – at the rate the background is decreasing and the leak “disappears” in a matter of seconds.



**Figure 3.** Decreasing background can hide a leak.

## How to use the background management features of an Agilent leak detector

We have seen how not zeroing makes it difficult to discern a leak from the background, and zeroing at the wrong time can erase the background and the leak. But used properly, zeroing functions can improve the leak test process. Agilent's leak detectors offer two distinct features that help users deal with their helium background.

First, the Zero command can negate up to two decades (orders of magnitude) of background and still maintain an accurate leak rate reading. By zeroing the background, it effectively does what is shown in Figure 1: allows the user to separate the background from the true leak. Zeroing is an on-demand function and is performed manually by pressing the "Zero" button on the instrument's touch screen. The zeroed value is stored and can be recalled at any time. After

the background is zeroed it is easier for the user to identify leaks because the response indicated on the display is now 100 times more sensitive than before zeroing.

The second feature, called Auto Zero Less Than Zero (Auto 0 <0), automatically compensates for background that is cleaning up and works in conjunction with the zero feature to insure that the most sensitive scale viewed on the leak detector does not lose sensitivity. We have seen how using the zero function can ignore background. But what if that level of background decreases? The chart in Figure 4 demonstrates what can happen. After zeroing the background continues to clean up, but if a small leak were encountered the leak rate display would not show it unless it is larger than the decrease in background that has occurred. Figure 5 demonstrates how Auto 0 <0 resets the zero level every few milliseconds, so the leak detector is better able to display a leak if one is found.

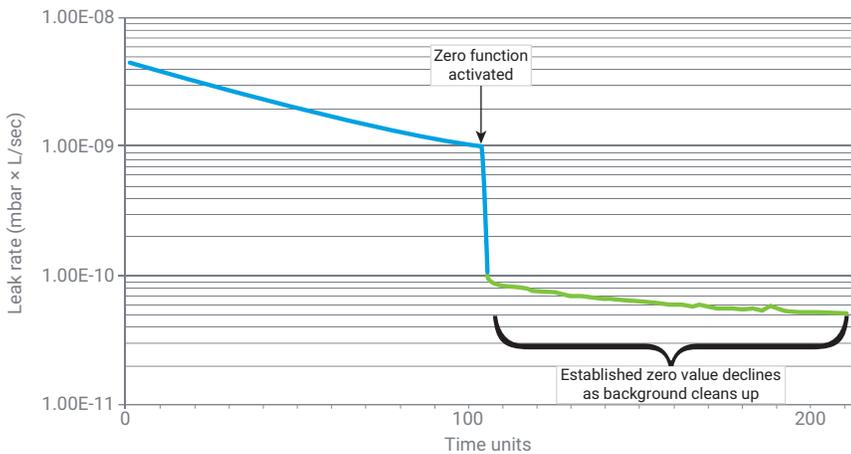


Figure 4. Loss of sensitivity due to background cleanup.

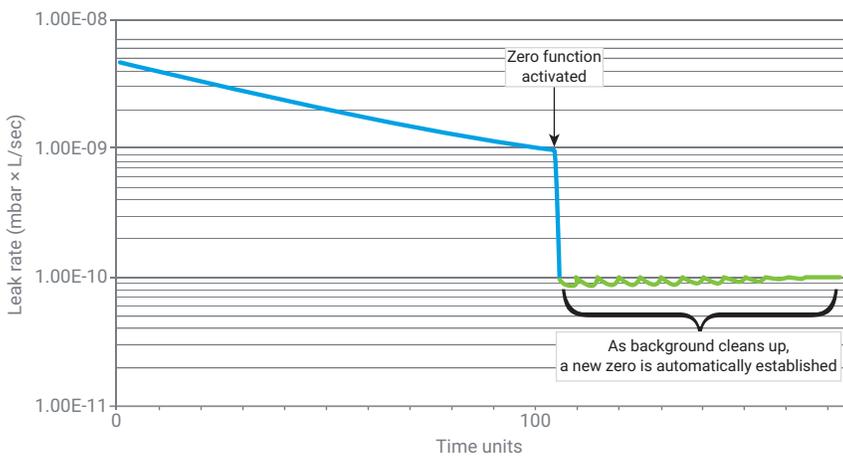


Figure 5. Auto zero function resets baseline.

The background management features described above are the keys to successful and accurate testing in the presence of a high helium background, even when testing in very high sensitivity ranges. When used properly they improve accuracy, prevent false rejects, and increase productivity. But when and how to use these tools? The scenarios below detail some common leak testing applications and demonstrate when and how to invoke the Zero command and the Auto Zero Less Than Zero feature.

## Vacuum applications

### ZERO function: ENABLED Auto 0 <0 function: ENABLED

**Typical applications:** Outside-in tests where helium is manually sprayed on the outside of the part and the user may be interested in even the slightest upward indication on the leak rate display. Spraying helium can lead to high, and variable, background. Using the zero function ignores the background, and the baseline sensitivity is not affected as Auto 0 <0 will reset the zero level as background cleans up.

### ZERO function: ENABLED Auto 0 <0 function: DISABLED

**Typical applications:** Repetitive inside-out tests (sealed part charged with helium in a vacuum chamber) where the conditions (pump speed, pressure, test time) do not change from one test to the next. Once the zero value is established, it should not be changed by the Auto Auto 0 <0 function. In this type of test, rejects are based on a fixed value and the Auto 0 <0 function offers no benefit. In this case it is imperative that background helium remain low and stable.

## Sniffing applications

### ZERO function: ENABLED Auto 0<0 function: DISABLED

**Typical applications:** Applications where a sniffer probe is connected to the leak detector. When sniffing, the flow rate through the probe can vary, which in turn causes the background to fluctuate as discussed at the beginning of this paper. Ambient background is also subject to variability due to leaking parts or helium being released from tested parts. Under these conditions the background could drop slightly below the established baseline, but usually not a significant amount. If Auto 0 <0 is used, the operator will likely have to deal with frequent upward indications on the leak rate display and may find themselves frequently zeroing the machine. By not using Auto 0 <0, the test process is more efficient.

**Note:** The Zero function is usually only disabled momentarily when the user wants to know the magnitude of the background that has been zeroed out. Therefore it is not common to disable the zero feature. However, Agilent's leak detectors do allow the zero function to be password protected, so that the zero process is carried out by qualified personnel only.

While the above descriptions cover a wide range of applications, each has its share of nuances that may necessitate additional modifications to the machine set-up and test procedure. Agilent sales and applications engineers are trained and qualified to assist in evaluating your leak test process and recommending the proper equipment and setup.

For assistance in contacting your local salesperson or for more information call 781-861-7200 or visit:

[www.agilent.com/chem/leakdetection](http://www.agilent.com/chem/leakdetection).

## Conversion tables

### Pressure

	Torr	mbar	micron	psi	atm	Pa
Torr	1	1.33	1000	0.0193	0.00132	133.32
mbar	0.751	1	750	0.0145	0.000987	100
micron	0.001	0.00133	1	0.0000193	1.32e-6	0.133
psi	51.72	68.96	51710	1	0.07	6894.76
atm	760	1013	760000	14.7	1	101325
Pa	0.0075	0.01	7.5	0.000145	9.87e-6	1

### Leak rate

	atm·cc/s	mbar·L/s	Torr·L/s	Pa·m <sup>3</sup> /s	sccm
atm·cc/s	1	1.013	0.759	0.101	59.8
mbar·L/s	0.987	1	0.75	0.1	59.2
Torr·L/s	1.32	1.33	1	0.133	78.9
Pa·m <sup>3</sup> /s	9.87	10	7.5	1	592
sccm	0.0167	0.0169	0.0127	0.00169	1

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