Background behavior and measurement of small leak rates with the PHOENIX 4

The smallest detectable leak rate of our PHOENIX leak detectors is $5x10^{-12}$ mbarl/s. How can these small leaks actually be measured and what internal background values can be perceived as “clean”?

Summary:

- The only method with which leaks smaller than $1x10^{-7}$ mbarl/s can be detected is with a helium leak detector.
- The background has an influence on the accuracy and possibilities of detecting very small leaks.
- This application note refers to measurement of very small leak rates below $1x10^{-10}$ mbarl/s and explains the optimal setting of ambient conditions and the leak detector

Measurement principle of the PHOENIX

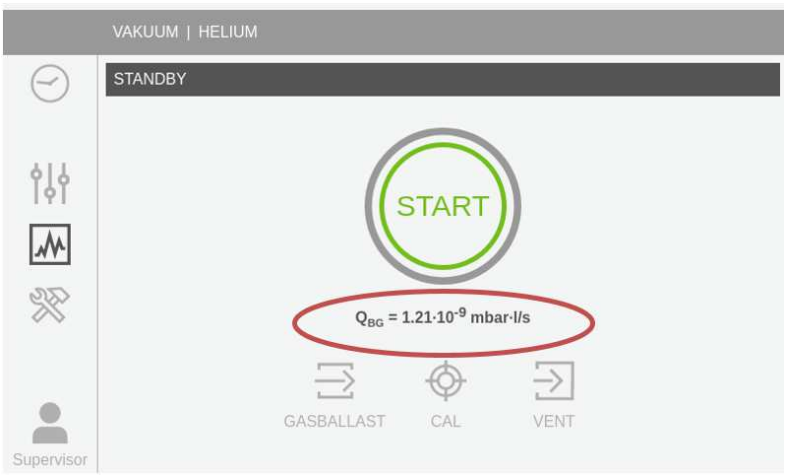
All PHOENIX leak detectors are based on the same measurement principle. The mass spectrometer, ion source, and ion trap is the same in the new PHOENIX 4 and L300i versions.

Helium is used as a tracer gas and will be pumped into the mass spectrometer as soon as it enters the leak detector. Helium molecules will be ionized and “trapped” in the ion trap where the ion current is measured. The ion current is the reference for the helium leak rate that will then be shown by the leak detector.

Helium is everywhere, that is why we see different leak rates and background values even without actively spraying or using helium.

Internal Background in Standby

The measurement system of the leak detector contains a residual amount of helium and hydrogen. On the surfaces inside the leak detector there are hundreds of layers of molecules, containing helium molecules. Additionally, air might still be in the inner system and also o-rings might save helium, just like a sponge. This creates an internal measurement signal component in standby - before even pressing the START button. For all leak rate measurements, this internal background is a good indicator of how clean the unit is. In standby, the value of the internal background appears on the start screen:



The following criteria continuously affect the internal background calculation:

- Inner design: The size and number of parts inside the leak detector determines how much helium can be “trapped” inside. The more parts and the bigger the surfaces, the higher is the amount of helium inside the leak detector.
- Helium pumping speed: The gas inside the system will be pumped out by the TMP and fore pump. The pumping speeds of both pumps influence the ability to clean up the system. The higher the pumping speed of the pumps the better the helium can be pumped out (until a certain amount). Desorption of helium molecules from the surfaces is independent from the pumping speed and will appear below pressures of 10^{-1} mbar.
- Helium conditions: A lot of helium in the environment will enter the leak detector and lead to a higher internal background. This can only show an effect when the ambient is helium contaminated, but not under normal conditions.

This internal helium signal can be ignored, it doesn’t affect measurements because it will be suppressed. The PHOENIX 4 and L300i series offer three different settings for the internal background suppression:

1. **Internal only:** Factory setting. The internal measurement signal of the leak detector is deducted by pressing the START button. The accuracy of the measurement results are not impaired by the internal background.
2. **Inlet area:** Like internal only but additionally the background of the inlet area is deducted. This requires a calculation of the inlet area first.
3. **Switched off:** No background suppression.

It is always recommended to proceed with the “internal only” background suppression for measurements.

What background value is “normal”?

➔ For the PHOENIX 4 (Quadro, Magno, Vario) the internal background is between ~$2x10^{-9}$ and ~$1x10^{-10}$ mbarl/s.

➔ The inner construction of the L300i is different to the new PHOENIX that is why the internal background of the L300i was usually lower.

As soon as the START button is pressed, the internal background is suppressed and does not have any influence on the leak rate measurements and the accuracy.

Control of ambient conditions

Ambient helium will influence leak rate measurements. The leak detector does not have a tight housing so helium can enter the system through the exhaust and venting ports and permeate through the o-rings. A clean environment in terms of helium is an important factor for accurate leak testing. If a lot of helium is used in the factory it is highly recommended to connect a nitrogen supply to the purge of the leak detector.

Leak detector behavior, settings and procedure

The behavior described to the following refers to a blank flanged leak detector after pressing START.

The leak detector will measure the leak rate up to the inlet port, which is blanked off. It takes some minutes until the leak rate goes down to <$5x10^{-12}$ mbarl/s and dependent on the above-mentioned conditions the leak rate can be fluctuant in the -12 range.

This is a normal behavior of the PHOENIX 4 and shows the real leak rate measurements. The L300i did not show these fluctuations in the low decades. The L300i had a different calculation, which “softened” these fluctuations, and the resolution of the display was too low to show these very small fluctuations.

In case the leak detector takes a long time to reach the -12 range a light contamination might be the cause. For measurements of “normal” leak rates (-8 range or higher) a background in the -10 range is totally fine and not unusual. Remember: We have o-rings in the system that might save helium, there is helium in the inner system and on the surfaces. This helium causes a leak rate signal, which leads to a higher leak rate value.

For the measurement of very small leak rates a clean system is needed. In case the leak detector won’t reach the -12 range, the leak detector should run over night (not stand-by!) and the o-ring in the inlet flange should be exchanged. This cleaning procedure will get the helium out of the system and improve the background and shown leak rates.

After the proof that the leak detector is clean, the test part can be connected to measure leak rates in the -11 range. The customer can e.g. connect an external calibrated leak with a leak rate in the -11 decade (not available at Leybold!). To ensure a clean system the leak detector purge should be connected to a nitrogen supply with 1000 mbar pressure. Before starting the test with helium, the ZERO needs to be activated although the leak detector is in the -12 range! It is recommended to activate ZERO already a couple of minutes before the leak test is started.

ZERO Function:

In a way the factory setting suppresses the internal background, the ZERO function allows the background suppression of the connected sample or test part. The leak detector calculates the leak rate and remembers this as the background value when pushing the ZERO button. With ZERO, low leak rates can be detected even for big volume samples and small leaks can be detected quicker as it is not necessary to wait until a certain background value of the connected sample is reached.

The leak detector does not ignore the background leak rate. The intelligent ZERO function keeps checking leak rate changes a couple of times per second.

A couple of minutes after pressing the ZERO button, the leak detector is able to detect even very small leaks in the range of 10^{-11} mbarl/s.

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Result

Before starting with leak rate measurements, the internal background is a good indicator for the cleanliness of the leak detector. But even if the internal background value seems to be higher than expected, this does not affect measurements as the internal background is suppressed as soon as START is pressed.

For very small leak rates the control of the ambient is important and ZERO needs to be activated prior to the measurements. The following steps should be considered when measuring very small leak rates:

- Ensure a low background of the test part (-12 mbarl/s range)
- Connect a nitrogen supply to the leak detector purge
- Start the leak detector enough time in advance
- Press the ZERO button a couple of minutes before measurements
- Start the helium spraying to the test part / helium supply to the test chamber

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