Technical Overview

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# Leak Detection of Lithium-Ion Batteries and Automotive Components

## Helium leak testing for the automotive industry

### The lithium-ion battery industry is thriving

High voltage, high specific energy, long cycle life, environmental friendliness, good energy density, and good power density are some advantages of lithium-ion (Li-ion) batteries in providing the best overall performance for power batteries. Li-ion batteries are widely used in fields such as:

- Consumer electronics for mobile phones and laptops
- Mobility for rail transit and new energy vehicles
- Energy storage including small-scale and uninterruptible (UPS) power supplies, communication base stations, and new energy

## Why leak test lithium-ion batteries and electrical vehicle (EV) cooling components?

Lithium-ion chemistry is not inherently safe as lithium reacts rapidly with water in a single displacement reaction producing hydrogen gas and lithium hydroxide. Lithium hydroxide dissolves in the water, and the hydrogen gas, which is extremely flammable, escapes.

lithium + water → lithium hydroxide + hydrogen
$2\ Li(s) + 2\ H_2O(l) \rightarrow 2\ LiOH(aq) + H_2(g)$

The most common types of cells used for lithium batteries are cylindrical, prismatic, and pouch cells. Regardless of type, all batteries must be air and watertight to avoid catastrophic breakdown due to the reaction of lithium ions with water.


**Figure 1.** Common lithium-ion battery types.

Testing for leak tightness requires some form of leak detection. Although various leak detection methods are available, helium mass spectrometer leak detection (HMSLD) is the preferred and is being used broadly to ensure low air and water permeation rates in cells.

Even though battery leak rate standards have yet to be established, HMSLD is the preferred choice as the leak rate required to ensure battery tightness is in the $10^{-6}$ to $10^{-10}$ atm-cc/s range or lower.

To help determine the required leak rate for batteries or other automotive components, the following formula are used to convert helium leak rates to water leak rates and, conversely, water leak rates to helium leak rates.

## Converting leak rates (LR)

Molecular flow leaks typically occur under vacuum conditions. Molecular leaks are typically smaller than $10^{-5}$ atm-cc/s. Viscous flow leaks typically occur in systems leaking at atmospheric or larger pressure conditions. Viscous leaks are typically larger than $10^{-5}$ atm-cc/s, but can occur at lower leak rates.

## Converting helium leak rates to water leak rates

- Molecular regime (mbar-l/s):
  $He_{LR} \times ((He_{mass} \div H_2O_{mass})^{0.5}) = H_2O_{LR}$
- Viscous regime (mbar-l/s):
  $He_{LR} \times (1.93^{-10} \div H_2O_{viscosity}) = H_2O_{LR}$

## Converting water leak rates to helium leak rates

- Molecular regime (mbar-l/s):
  $H_2O_{LR} \times ((H_2O_{mass} \div He_{mass})^{0.5}) = He_{LR}$
- Viscous regime (mbar-l/s):
  $(H_2O_{viscosity} \div 1.93^{-10}) \times H_2O_{LR} = He_{LR}$

Not only must the batteries be water and airtight, but the battery cooling systems and final housing must not allow the ingress of moisture.

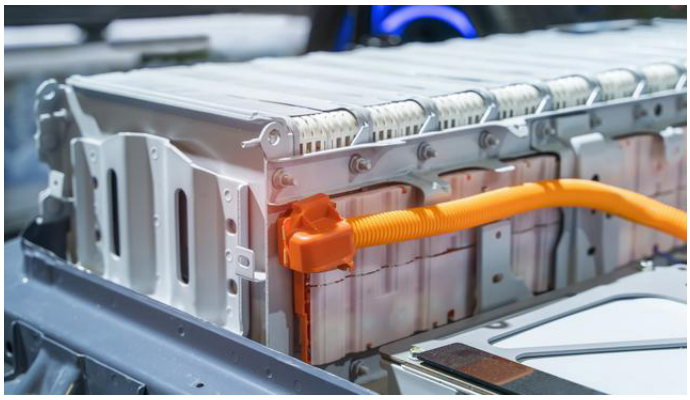


**Figure 2.** An electric vehicle battery system.

More stringent leak test requirements are forcing manufacturers of lithium-ion batteries and automotive products to introduce more sophisticated leak detection technologies. Widely used test methods, such as pressure decay and bubble testing technology, are insufficient, unreliable, and very slow processes.

In contrast, HMSLD enhances sensitivity and productivity and allows precise measurement to NIST-traceable standards. HMSLD uses helium as the tracer gas, which is:

- Nontoxic
- Nonflammable
- Environmentally friendly

## Components tested

### Electric vehicle (EV) batteries

Rigid cells, flexible pouches, and polymer cases

**Leak specification:**
No loss of electrolyte, no moisture ingress

**Helium equivalent:**
$10^{-6}$ to $10^{-8}$ atm·cm³/s

### Engine cooling

Radiators, heater core, oil, and transmission coolers

**Leak specification:**
Bubble test, pressure decay

**Helium equivalent:**
$>10^{-4}$ atm·cm³/s

## Leak test equipment

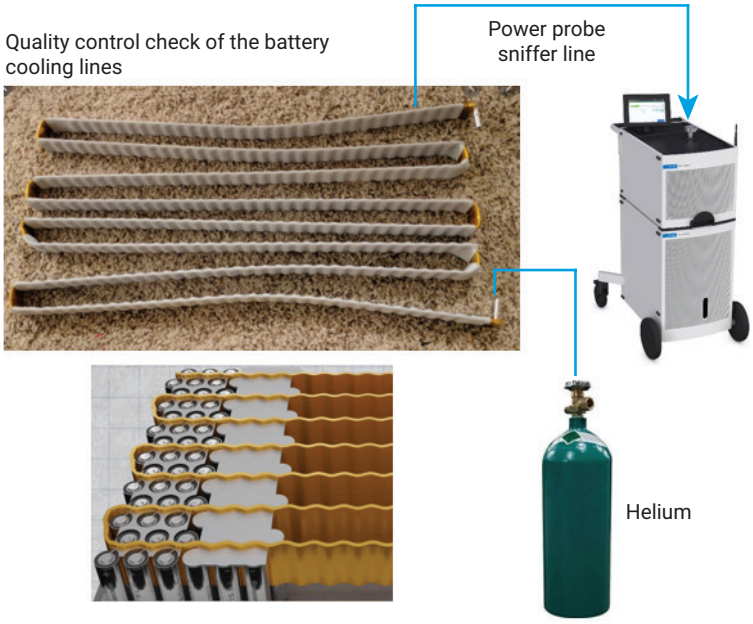




**Figure 3.** Using helium leak detection with lithium ion batteries.

As Figure 4 shows, HMSLD:

- Is a clean, dry test method
- Provides 100-times greater sensitivity
- Can be used to locate and measure leaks
- Is not temperature dependent

## Locating and measuring leaks

Agilent leak detectors may be used in any of several ways to find or measure leaks.

The most common method used with parts that are pressurized is to scan them with a sniffer probe attached to the inlet of the leak detector, paying special attention to areas prone to leaks such as welds, seams, seals, or feedthroughs. When a leak is encountered, helium is captured through the probe and detected by the sensor. Leak sites are identified quickly, thanks to fast response time.

When it is necessary to quantify the total leak rate of potential leak sites, parts are pressurized with helium and enclosed within an envelope connected to the inlet of the leak detector. In this configuration, helium can effectively be collected and quantified.

The range of Agilent helium mass spectrometer leak detection solutions ensure the safety, security, and consistent performance for research, quality control, and full-scale production test systems. The Agilent family of HLD leak detectors, PHD-4 portable sniffer leak detector, and C15 component leak detector are rugged, precise, and easy-to-use instruments that accurately and efficiently detect leaks and are ideally suited for testing batteries in any number of leak detection techniques, such as inside-out, outside-in, accumulation, and permeation rate measurements.

Agilent leak detectors feature automated start up and calibration for maximum productivity, built-in application setups, and an array of accessories to make any leak detection process simple.

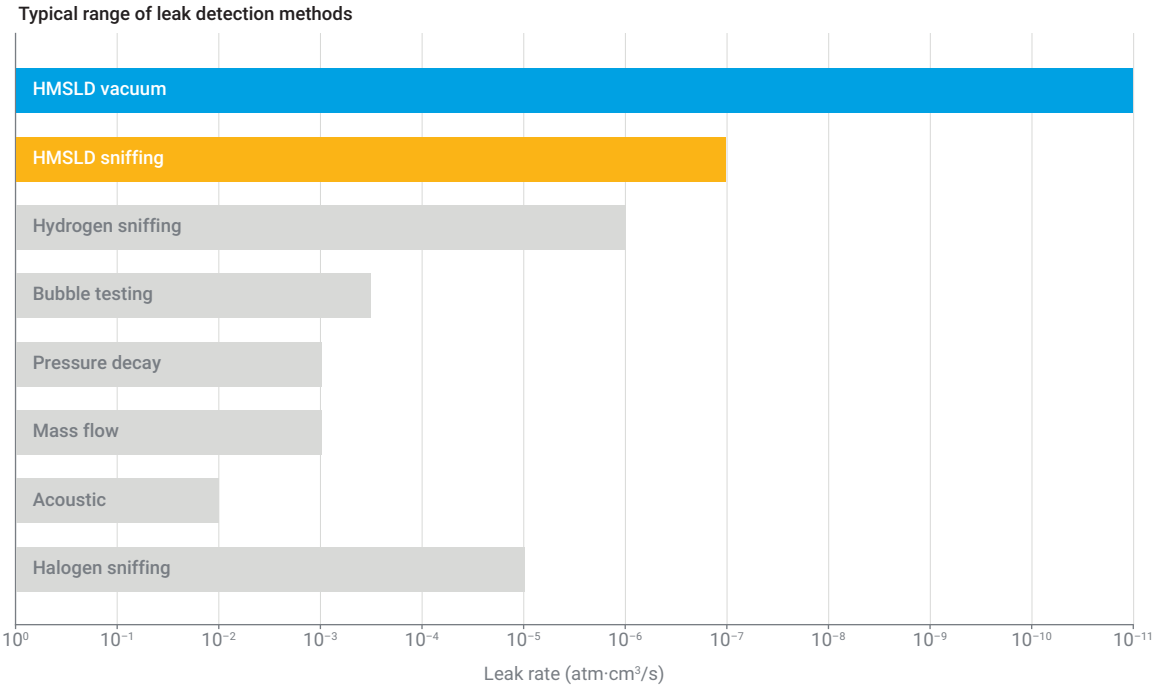
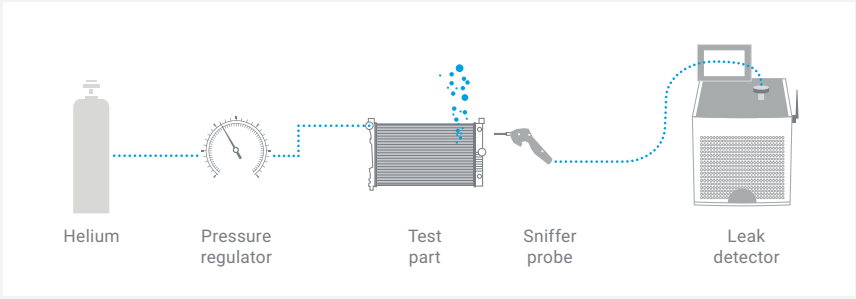



**Figure 4.** HMSLD is a clean, dry test method. It provides 100-times greater sensitivity, can be used to locate and measure leaks, and is not compromised by temperature fluctuations.

# Locating and measuring leaks

Agilent leak detectors may be used in any of several ways to find or measure leaks.

Sniffing method

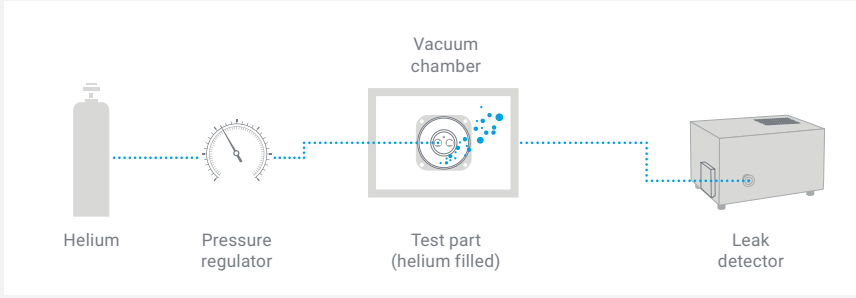



When a leak is encountered, helium is captured through the probe and detected by the sensor. Leak sites are identified quickly thanks to fast response time.

## Locating leaks

The most common method for locating leaks is to scan them with a sniffer probe attached to the inlet of the leak detector, paying special attention to areas prone to leaks, such as welds, seams, seals, or feedthroughs.

Vacuum method

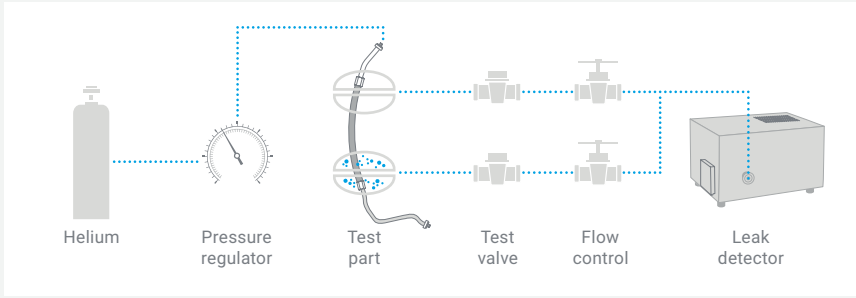



In this configuration, a cumulative leak rate can be determined quickly and accurately.

## Measuring leaks

When it is necessary to quantify the total leak rate, parts are filled with helium and enclosed in a vacuum chamber that is evacuated and analyzed by the HMSLD.

Accumulation method




Accumulation is advantageous because it does not require evacuation of the outside of the part, as depicted above, and does not depend heavily on the operator's precise use of the sniffer probe.

## Accumulation method

The accumulation method is used to automate the sniffing process and uses fixturing to collect helium from leak sites. Fixtures that have multiple parts or potential leak sites can be isolated sequentially to locate leaks.

**Figure 5.** Locating and measuring leaks.

## Agilent automated MSLD options available

## LT HLS leak detection testing systems

The leak detection testing systems, LT HLS, are designed and manufactured by LABTECH. These systems have been developed for a wide range of industrial applications and are suitable for serial production lines, prototypes, and new products testing in R&D stages.

Every leak detection testing station is designed according to the customer's specific demands and is tailored to the individual product being tested.

## Agilent Technologies components

Due to the long-term collaboration between LABTECH and the Agilent Technologies Vacuum Product Division, the LT HLS systems boast the following two design elements:

- Helium leak detector; this incorporates the proven design, which is based on the mass spectrometer principle
- Vacuum pumps with the latest in cutting-edge vacuum technologies




**www.agilent.com/en/product/vacuum-technologies/helium-leak-detectors**

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