PFEIFFER VACUUM

HOW TO SELECT THE IDEAL LEAK TESTING METHOD FOR YOUR APPLICATION

Professional support is crucial

Every application and production process has its own demands and requirements when it comes to leak detection. In different industries, different standards are set in terms of quality control and maximum leak rates. Therefore, it is crucial to select the best leak detection method for every single application.

Within the last years, significant advances were made in the electronic leak testing technology, using either air or a tracer gas. New techniques, improved sensitivity and faster test cycles – all of these technical evolutions have increased the quality and reliability of the different leak testing methods. The pros and cons of these methods and their suitability for different leak detection applications as well as professional advice on selection criteria will be presented in the following.

Leak detection technologies – an overview

Before providing a guideline on how to select the right leak testing method for your application, the different technologies dealt with in this article will be presented in a general overview:

- **Air leak testing with Micro-Flow sensor at pressure conditions**
  This technology is based on an integrated micro sensor working with an accelerated flow. When air leaks from the unit or assembly under test, the emitted air is replenished via the Micro-Flow sensor to maintain a constant pressure (see Figure 1). The loss causes an electrical signal proportional to the volume, respectively to the mass flow. The

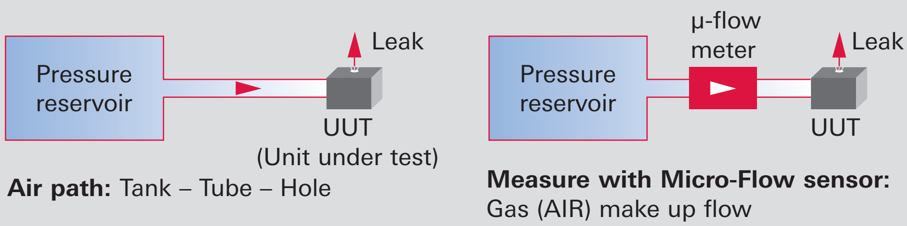


Figure 1: Air leak testing with Micro-Flow sensor at pressure conditions

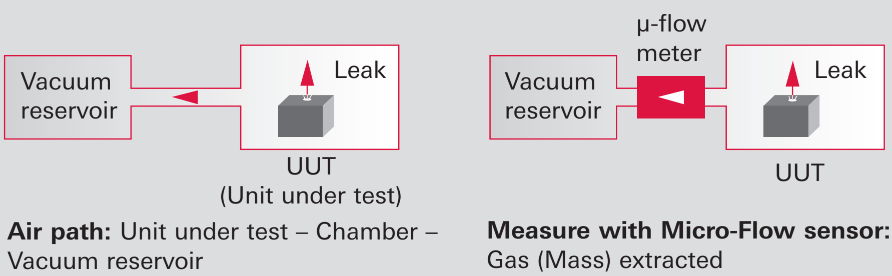


Figure 2: Mass extraction test method (vacuum test)

Micro-Flow sensor thereby operates with a pressure reservoir, which is used to pressurize the unit under test (UUT) and has a sensitivity of $5 \cdot 10^{-4}$ mbar l/s. Usually, only simple fixtures are necessary for this type of testing method.

- **Air leak testing with Mass Extraction (vacuum conditions)**
  A special form of the Micro-Flow sensor technology is the so-called Mass Extraction technique. The basic principle is similar to the Micro-Flow approach, but in order to achieve higher sensitivity, the test is performed under vacuum conditions. This method incorporates sensor designs that operate at continuum/slip flow condition (lower vacuum) and transitional/molecular flow regimes (higher vacuum). This technology can be used for the leak testing of closed containers such as packages or electronic enclosures. The unit under test is placed into a vacuum chamber with pressure conditions of 1 mbar or less. After the chamber is evacuated, the remaining flow between the chamber and the vacuum reservoir is used to determine the leak rate of the tested part (see Figure 2). With this method, a sensitivity of up to $6.7 \cdot 10^{-7}$ mbar l/s can be reached.

- **Helium leak detection**
  Due to their comparatively simple and robust design, sector field mass spectrometers are used for leak detection with tracer gas. Typically tuned to a detection mass of 4 u for helium, the gas molecules are ionized in an ion source through electron bombardment and then accelerated into a magnetic sector field using electronic voltage. Alternatively, also hydrogen with a mass of 2 u can be used for this leak testing method.

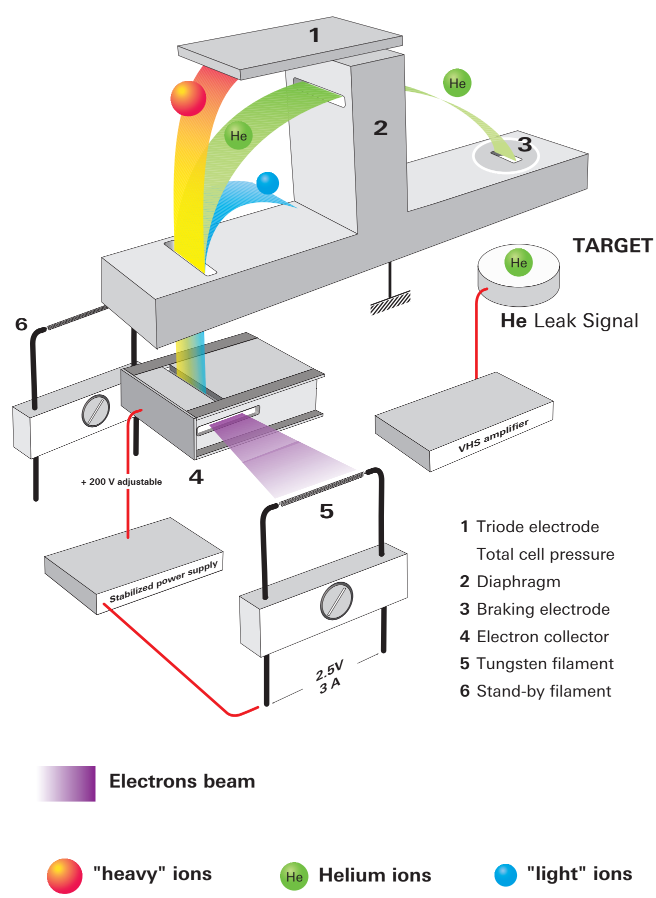
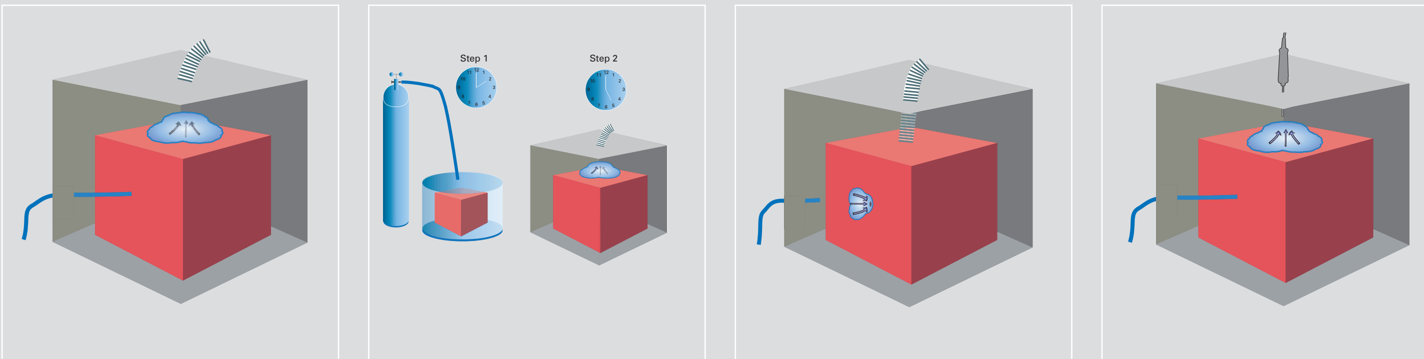


Figure 3: Working principle of a sector field mass spectrometer



Integral vacuum test

Vacuum test: Bombing test

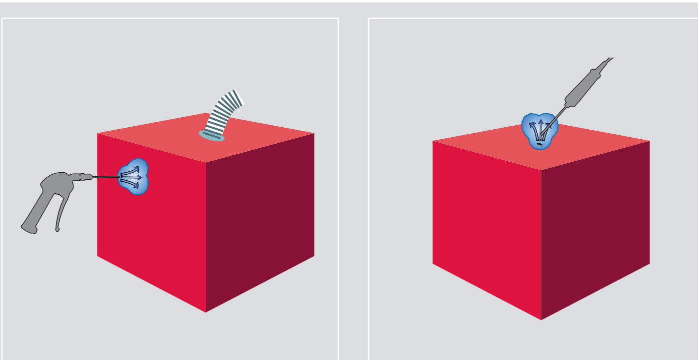
Integral test of enclosed parts under vacuum

Sniffing test: Integral test at atmospheric pressure

Figure 4: Different leak detection methods in an overview

The helium or hydrogen molecules are able to pass through a dedicated slit in order to reach the detector while all other present molecules are unable to pass through and are thus re-neutralized. The measured ion current is proportional to the gas partial pressure. The helium sensitivity in a vacuum environment is $5 \cdot 10^{-12}$ mbar l/s.

In helium leak detection, different procedures are available to perform the measurement. Moreover, various test directions can be applied (see Figure 4). Among them, the integral vacuum test is the most sensitive test method. Here, the unit to be tested is placed inside a vacuum chamber, first evacuated and then filled with helium.



Vacuum test: Spraying test

Sniffing test

Figure 5: Principle of the spraying and the sniffing test leak detection method

For locating a leak, either the helium spray or the sniffer method are most suitable. When using the spray technique, the unit under test is connected to a leak detector and vacuum is drawn while the test unit is sprayed with helium from the outside.

For the sniffing test method, the unit under test is pressurized with helium and scanned at the outside with a sniffer probe, which is connected to the leak detector (see Figure 5).

How to select the right method?
When choosing the optimal leak testing method for a specific application, the required tightness criteria – i.e. the maximum leak rate – need to be set first. A big challenge here is the fact that different units are at hand to define the leak rates (see Table 1). Usually, leak rates are specified in flow rate units. Table 1 outlines the common flow rate measurement units and their conversion.

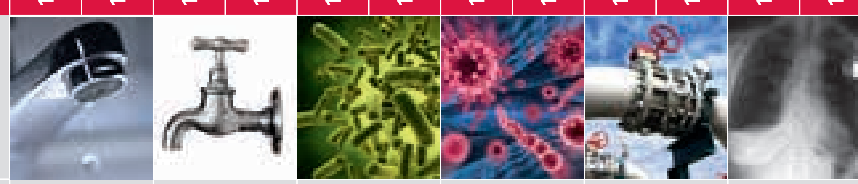
Another way of defining the required tightness for an application is to determine the maximum defect size (pin-hole or microchannel type). The leak test must assure that this value is not exceeded.

If the application or general standards require a leak tightness in the range of $1 \cdot 10^{-7}$ mbar l/s or less, helium leak detection is the method of choice. No other commercial technology can reach these sensitivities.

If the required leak rate lies above this value, the number of possible technologies at hand increases. Table 2 gives an overview of potential leak test methods and some of their most important characteristics.

	Pa m^3 s^{-1}	mbar · l s^{-1}	Torr · l s^{-1}	atm cm^3 s^{-1}	sccm	slm	Molecules s^{-1}
Pa m^3 s^{-1}	1	10	7.5	9.87	5.92 · 10^{2}	5.92 · 10^{-1}	2.651 · 10^{20}
mbar · l s^{-1}	1 · 10^{-1}	1	7.5 · 10^{-1}	9.87 · 10^{-1}	5.92 · 10^{1}	5.92 · 10^{-2}	2.651 · 10^{19}
Torr · l s^{-1}	1.33 · 10^{-1}	1.333	1	1.32	7.89 · 10^{1}	7.89 · 10^{-2}	3.535 .10^{19}
atm cm^3 s^{-1}	1.01 · 10^{-1}	1.01	7.5 · 10^{-1}	1	5.98 · 10^{1}	5.98 · 10^{-2}	2.679 · 10^{19}
sccm	1.69 · 10^{-3}	1.69 · 10^{-2}	1.27 · 10^{-2}	1.67 · 10^{-2}	1	1 · 10^{-3}	4.486 · 10^{17}
slm	1.69	1.69 · 10^{1}	1.27 · 10^{1}	1.67 · 10^{1}	1 · 10^{3}	1	4.486 · 10^{14}
Molecules s^{-1}	3.77 · 10^{-21}	3.77 · 10^{-20}	2.83 · 10^{-20}	3.72 · 10^{-20}	2.23 · 10^{16}	2.23 · 10^{19}	1

Table 1: Common leak flow measurement units and their conversion

Method / Detector	Tracer gas	Tested object under overpressure	Tested object under vacuum	Quantitative test	Localization	mbar · l s^{-1}											
						10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}
																	
Description						Water dropping		Water tight		Bacteria tight		Virus tight		Gas tight		Technically tight	
Leak diameter						100 µm		30 µm		10 µm		3 µm		0.8 µm		0.1 µm	
Escape time of a bubble with 1 cc						10 s		> 15 min		> 1 day		> 100 days		> 30 years		> 1000 years	
Bubble Test	any	+	–	–[1]	+	■	■	■									
Sonic or ultrasonic sensor	any	+	–	–	+	■	■										
Ultrasonic bubble detection	any	+	–	+	+	■	■	■	■	■	■	■	■				
Pressure rise	any	–	+	+	–	■	■	■	■								
Pressure decay	any	+	–	+	–	■	■										
Micro-Flow	various	+	–	+	–	■	■	■	■	■							
Mass Extraction	various	–	+	+	–	■	■	■	■	■	■	■	■				
Optical Emission Spectroscopy	various	–	+	+	–	■	■	■	■	■	■	■	■				
Magnetic sector field mass spectrometer, sniffing	Tracer gas ^4He, ^3He, H_2	+	–	+[2]	+	■	■	■	■	■	■	■	■				
Magnetic sector field mass spectrometer, vacuum	Tracer gas ^4He, ^3He, H_2	–	+	+	+	■	■	■	■	■	■	■	■	■	■	■	■

[1] Possible with bubble collection and volumetric analysis
[2] Accumulation test method only

Table 2: Comparison of different leak test methods

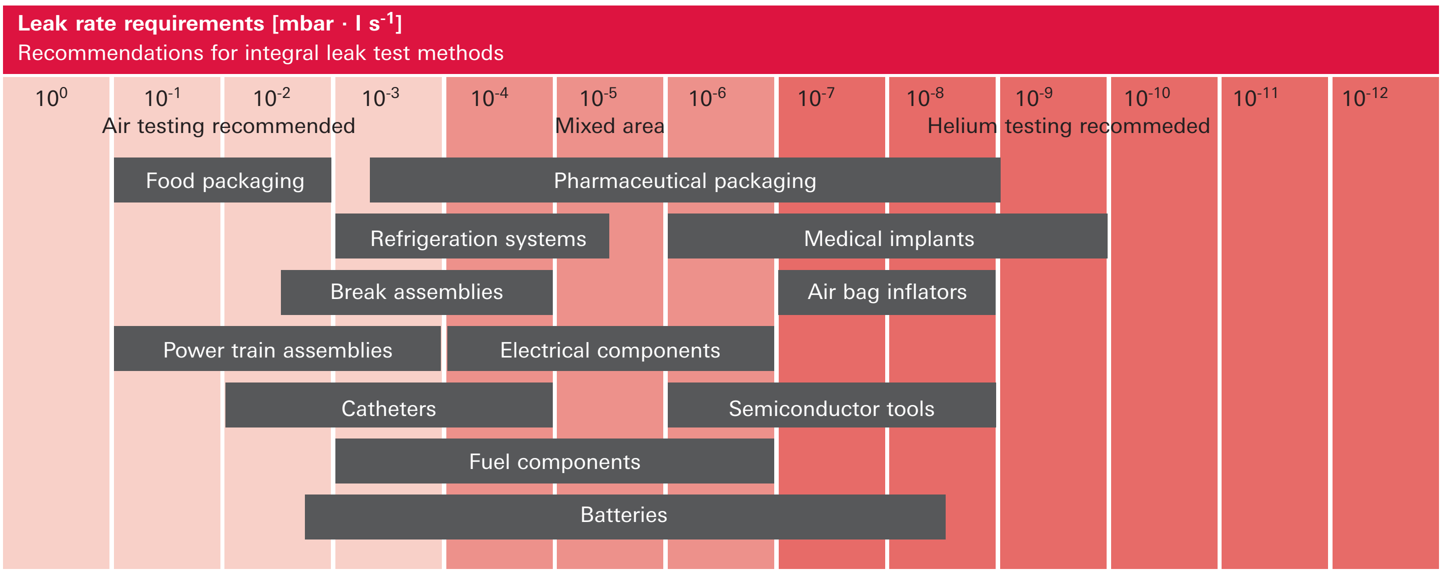


Table 3: Overview of test methods by required leak rates

If the requirements of the specific application allow several of the mentioned methods, the following key aspects should be considered prior to selecting the optimal leak testing method:

- **Throughput and cycle times**
  If the leak test procedure takes place in a production environment where 100% of the parts are leak tested, throughput or cycle times are important parameters. For sample testing and laboratory applications, cycle times are though a less important parameter.

- **Leak test conditions**
  In many cases, the design of the product and the specific sealing set the requirements for the applied pressure and the leak testing procedure (inside or outside of the part). Some seals are more suitable for higher pressures, others for leaks under vacuum. Thus, leak testing here often includes pressurizing the part to the maximum operating pressure to assure the parts´ integrity at maximum operation conditions.

- **Environmental considerations**
  Environmental conditions can affect several leak test methods as, for example, pressure decay testing. Here, stabilization times and temperature control are critical to ensure a reliable measurement. For testing products that are presented hot (e.g. after brazing/welding), or for conducting tests in an environment with rapid temperature changes, vacuum air test (as Mass Extraction) or helium test are recommendable methods.

- **Costs**
  Last but not least, there are the economic aspects of the test methods. It is important not only to look at the purchasing costs, but also to consider the different overall costs connected to the process. Here, a key point in the decision making process is again the test time, which is directly associated with the capacity of a test station. Also stabilization and/or drying times may be considered. Helium leak testing thereby provides the shortest possible test times for industrial applications. But also the Micro-Flow technology is an alternative when having or wanting to use an air test method, especially for the detection of larger leaks. It generates lower initial costs than a helium test system and still provides faster test times compared to other air testing methods such as pressure decay.

Distinction of applications

As mentioned before, it can be challenging to define a general guideline for the selection of the right leak testing method. In fact, there are some applications in which only helium leak detection can be applied due to the high sensitivity demands. These applications are semiconductor tools, air bag ignitors, nuclear facilities or tools and several medical implants, just to name a few. All of these applications set high demands on the leak tightness level.

However, most applications can be leak tested with air or helium test methods. For example, typical applications in automotive and aerospace are heat exchangers, AC components, batteries, brake systems and their components, power train systems and their components, machined castings and welded assemblies as well as electronic enclosure. In the medical industry, implanted products, disposables such as catheters or drug delivery devices, life science instruments and components can be named as examples. The pharmaceutical industry uses helium leak detection for MALL (maximum allowable leak level) tests during the development of packages like syringes or glass vials where leaks constitute a microbial contamination risk and the loss of drug properties. Other fields of application are consumer electronics and utilities. Here, electronic systems must meet various water ingress specifications (e.g. IPX7 for water ingress into smart phones).

A combination of air and helium leak testing can commonly be found in applications with very expensive components where leaks must be localized in order to repair the part or to initiate corrective actions. Good examples are aerospace applications, e.g. hydraulic system assembly or fuel systems. Here, it is very important to localize the leak as leaking parts can be repaired and do not need to be scrapped.

In Table 3, the leak rate requirements are assigned to the different applications. This overview can serve as a starting point for discussions to select the optimal test method for the particular application. In addition, also the abovementioned considerations should be born in mind.

Pfeiffer Vacuum provides expertise and support

Before making a decision on which technology is the very best solution for your specific application, several questions need to be answered. Most of them require a close cooperation with your equipment supplier. It is thus crucial to select a leak test supplier that has the knowledge, experience and product portfolio to offer the best solution in order to save costs and provide a reliable, long-term solution. With more than 50 years of experience in leak detection, Pfeiffer Vacuum is your ideal partner when it comes to designing and realizing individual leak detection solutions. Not only does our comprehensive portfolio include leak detectors and components for every application and requirement. Our experts also have a sound know-how on leak detection technology and are happy to provide you with professional support from the design stage up to the final implementation of your solution.

Figure 6: Extract of the leak detection portfolio from Pfeiffer Vacuum

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