Current Trends in Leak Testing Technology

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Abstract

Leak detection techniques are not exclusively used for the vacuum products but are finding increasing applications in almost all industrial areas. Therefore, leak definition is evolving to accommodate the industry point of view. A leak always requires a flow of mass though the walls of a volume intended to be sealed. It usually results in escape or admission of liquids or gases from sealed components or systems.

Leak detectors range in complexity from the simple bubble test to highly sophisticated systems using tracer gases. Commercial helium mass spectrometer leak detectors can commonly detect leaks down to 10^{-12}mbar.L.s^{-1} range. These techniques allow manufacturers to quantify and measure maximum acceptable leak rates for their products, instead of traditional qualitative evaluation.

In this work we summarize the most suitable leak detection methods according to the specific applications and the maximum admissible leak rate. Typical solutions to detect leaks in several products ranging pharmaceutical blisters to large fuel containers are described.

Keywords

Leak detection, leaks, sealing.

1. Introduction

Nowadays, certified sealed products have strictly controlled requirements. Indeed, quality standards concerning leak rate are becoming more and more demanding. In this work we review how vacuum technology can help in providing solutions.

There are well known sealing requirements for vacuum products especially for ultra high vacuum. Nevertheless, severe requirements regarding sealing are also required from a very large numbers of systems or products in industry and research, in areas not related with vacuum technology. Among these, many assemblies and processes are in the automotive and refrigeration industries. Working pressure in this case is often atmospheric pressure or above and "hermetically sealed" is defined only as the relative "absence of leaks".

Generalized statements often made, such as "no detectable leaks" or "leak rate zero", no more represent an adequate basis for acceptance tests. Sealing must be quantified with an upper limit of an admissible leak rate. Experienced engineers know that properly formulated acceptance specifications will indicate a certain leak rate under defined conditions. Which leak rate is acceptable can be determined by the application itself.

Other important matter in sealing tests is how to choose the proper leak detection technique taking in account the volumes or containers one whish to test. For example, which method is more adequate for leak detection in small volumes, or in large volumes? Is it possible to use the same method for different kinds of test pieces? What is the most suitable method?

Leak detection techniques are well described in the literature, mainly in vacuum related books [1-6]. Furthermore, large containers manufacturers, often refer to the same techniques in their reference codes [7].

In this paper we summarize some of the main leak detection techniques emphasizing their suitability to each type of application or product.

2. Types of leaks

It is not easy to ascertain a wide-ranging definition for leaks. Nevertheless, a leak may be described as an unwanted path through an enclosure or a wall. Even in the absence of a pressure difference, one may talk about leaks if is it expected that the concentration in each side should be constant as for example in food packaging.

It is possible to group leaks, depending on the nature of the material or joining fault: leaks are very often due to welding defects or other permanent joining techniques; o-rings and other sealing areas are also a common sources of leak; porosity and materials defects can be an other group of leaks; materials permeability also contribute for the quality of sealed volume; virtual leaks can appear in a volume to be tested but are not detectable from outside.

Although most leaks may be found in both, vacuum and pressurized systems, some are typical for one kind of system. For example, leaks due to porosity are more typical to appear in the pressurized system owed to very high-pressure difference, while virtual leaks are more common in vacuum systems.

3. Leak detection techniques

To find and measure leaks there are a wide range of methods available (table1). These methods include a variety of technology from simple to highly sophisticate one, with a corresponding range of equipment.

It is necessary to choose a leak detection method, which fulfills the defined needs of sensitivity and speed; the chosen method should not be more complicated and expensive than necessary.

Presently bubble testing is the most prevalent method of leak detection in industry. The idea of bubble testing consists of pressurizing a part, placing it in water bath and looking for a stream of bubbles from it. This can also be accomplished by applying a soap solution to the part being tested. To evaluate the sensibility of method one may consider the bubble volume V produced by a pressure difference Δp during a time Δt. The leak size is then given by:

$$\frac{\Delta p}{\Delta t} V$$

For instance, taking 1mm^3 as the volume of the smallest detectable bubble within a testing time of 10s and a pressure difference of 1bar, then the smallest detectable leak is 10^{-4} mbar.L.s^{-1}. However, this limit is very sensitive to the operator.

The pressure change technique is based on the fact that a leak will produce a pressure change in a closed volume. The starting pressure may be above or bellow the atmospheric pressure therefore leading to two similar methods: pressure rise and pressure drop methods.

In the pressure rise method, the system is evacuated to the testing pressure. This pressure should be chosen in such a way that in certain time interval the pressure remains constant in the absence of very short leaks. This is the case when degassing from the walls is negligible and the test pressure is above the vapor pressure of all materials. For most 'dry' materials, pressure above 1mbar fulfills this requirement providing transient times bellow 1s. Then the test volume is isolated from the pumping system and the pressure is monitored as function of the time. If a leak is present, a linear increase of the pressure will be observed (for small pressure changes). The absence of leaks should lead to a constant pressure.

The sensitivity of this technique for a 10L volume, using a gauge accurate enough to resolve a pressure difference Δp of 1mbar within a testing period of 100s is given by:

$$Q = \frac{1}{100} * 10 = 10^{-1} mbar \cdot L \cdot s^{-1}$$

This value can be improved if one wait for a longer period and use a better gauge. However, it is hard to achieve sensitivities better then 10^{-4} mbar.L.s^{-1} with this method.

A similar leak testing method is the pressure drop technique. This technique is commonly employed in tank engineering. The volume is pressurized and the pressure is monitored as function of time. The absence of leaks gives a constant pressure. If the testing pressure is not much higher then 1bar, then this technique may also be used for vacuum components. Although very high pressures improve sensitivity, such pressures are not suitable for many products. When dealing with large containers and long test periods, effects of temperature changes may need to be taking into account.

In both, pressure rise and pressure drop methods, differential gauges are often used to improve sensibility. A well known sealed volume is evacuated/pressurized to a certain value, and the differential pressure is measured.

Leak detection with mass spectrometers is the most sensitive technique (down to 10^{-12} mbar.L.s^{-1}). It detects a probe gas (usually Helium) in the lower pressure side of the volume under test, when this gas is in the higher-pressure side. Its extreme sensitivity in combination with its capability for reliable quantitative measurement has made this technique popular for many industrial applications where leak rate limits should be achieved.

The use of a known leak (sniffer) connected to the leak detector allows the application of the technique to non-evacuated volumes. It allows easy localization of leaks when the volume is slightly pressurized with helium, however without quantification.

During the last decade, this method has been simplified and automated, and it can be even adapted to in line production. This method is now used for testing hermetic seals, sealed components, assemblies, vacuum systems, and is the most versatile of industrial and laboratory leak detection testing methods.

There are basically four different methods for finding leaks: exposed test piece, hooded test piece, detector probe and bombing, depending if the test piece is evacuated or pressurized.

The advantages of the helium test method, from the industrial point of view, are:

- Leak rates can be detected and measured for all practical requirements;
- It is possible to automate the testing and sequence procedure;
- Helium (any purity) as tracer gas is non-toxic, cheap and safe.
- Leak rates for every test piece can be recorded and quantitative certification can be issued.

In this paper we are not discussing others techniques such as halogen detection, Tesla coil and defect finding methods (penetrant liquids, ultrasounds and X-ray).

4. Products suitable for leak test and leak rate limits

Virtually, everything can be leak tested. Expertise may be needed to select the appropriate technique for the product to be tested. In principle the appropriated technique, is the simplest technique to achieve the specified leak rate limit.

For instance, to detect leaks on a package of chips or on a pill blisters; one can enclose the test volume within helium and then using a sniffer look for leaks. This may be useful just to test the production materials and procedures. If quantification is needed, the package or the blister should be closed in a 1bar helium atmosphere.

Then, if the sniffer is connected to an enclosed volume (also at 1bar) the helium leak detector provides a quantitative measurement of the leak. In this case, the pressure drop in the outside volume due to sniffer pumping is negligible. If necessary, produce a pressure difference and then the leak rate can be measured.

We shall now consider leak testing of large containers, for example fuel tanks. A suitable technique is the pressure drop technique. The tank should be pressurized achieving a safe pressure of about 1.5bar. An accurate manometer is then used to monitor the pressure drop. The leak rate is calculated from the pressure drop in the tank volume during the testing. If a leak, larger than the admissible limit is found, it can be located with the bubble technique or with the helium leak detector. With this last technique, the tank should be slightly pressurized with helium allowing the sniffer to localize the leak.

Other example is leak test oil pans used in automotive industry. A suitable technique is the pressure rise method. The oil pan is placed in a flat rubber surface and evacuated to the test pressure, for example to 0.5bar. The pressure is then monitored during a typical test time of 10s. If the pressure rises above the specified limit, then the part is rejected.

Criteria to establish the maximum acceptable leak rate for a given product depend upon its application. Since the cost of sealing and leak detection increases as the specified leak rate decreases, it follows that testing for very small leaks can incur unnecessary expenses.

Table 2 summarizes how several items may be leak tested. Depending on the allowed leak rates more than one technique may be used.

5. Summary

Vacuum leak testing techniques provide the most sensitive and flexible solutions to evaluate sealing requirements. Quantification of leaks is easy to achieve down to limits far beyond practical requirements. This allows manufacturers to use leak rates to specify the quality of sealing instead of ambiguous qualitative descriptions.

It seems there are almost no limitations on the type of products to be leak tested. From products made of soft materials to huge containers, pressurized, evacuated, or at atmosphere pressure, all can be tested and quantitative leak limits may be defined and measured.

Many techniques are suitable for serial production. They can be used not only to find small leaks but as well large leaks in all kind of containers. Helium mass spectrometry is the most sensitive technique with a limit down to 10^{-12} mbar.L.s^{-1}. The use of this method results in a considerable increase in efficiency and lead to a significant enhancement in testing reliability.

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References

[1] N.G. Wilson and L.C. Beavis, Handbook of Vacuum Leak Detection, Ed. By W.R. Bottoms, AVS Monograph Series, 1988.

[2] W. Umrath, Fundamentals of Vacuum Technology, (available online in focuslab.lfp.uba.ar/E_Library/Vacuum%20Technology%20UmrathW.pdf) 1998.

[3] Introduction to Helium Mass Spectrometer Leak Detection, ed. Varian Vacuum Products, 1995.

[4] A. Chambers, Modern Vacuum Physics, Ed. Chapman & Hall/CRC, 2005.

[5] D.M.Hoffman, B. Singh and J.H. Thomas III, Handbook of Vacuum Science and Technology, Academic Press, 1998.

[6] L.N. Rozanov, Vacuum Technique, ed. M.H. Hablanian, Taylor & Francis Inc. 2002

[7] Nondestructive examination, 2004 ASME Boiler & Pressure Vessel Code

Captions

Tables

Table 1- Comparison of leak detection methods.

Table 2 – Suitability of the main leak detection techniques to several products.

Main classification	Test type	Sensitivity (mbar l/s)	Limitations	Remarks
Pressure change	(Bubble test)	10^{-4}	requires wetting, not quantitative	Localization of large leaks
	Pressure drop	10^{-4}	Volume should stand test pressure	Quantification of large leaks
	Pressure rise	10^{-4}	Volume should stand test pressure (vacuum)	Quantification of large leaks
Helium mass spectrometry	Evacuated volume	10^{-12}	Expensive, vacuum is needed	Quantification and localization of small leaks
	Sniffer with pressurized volume	10^{-7}	Quantitative only if the sniffer is connected to a closed volume	Mainly localization of small leaks

Table 1- Comparison of leak detection methods.

Products/volume	**Typical acceptable leak rate** (mbar.L.s^{-1})	**Examples**	**Suitable techniques**
Vacuum hardware	10^{-8}	Chambers, valves, fittings	Helium MS
Small containers	10^{-7}	Bottles and cans	Bubble test
			Helium MS
Large containers	10^{-4}	Fuel reservoirs	Pressure change
			Bubble test
			Helium MS
Sealed packages	10^{-7}	Blisters (pharmaceutical) and food packaging	Helium MS
Membranes and soft materials	10^{-7}	Prophylactics	Helium MS
Large pipes and valves	10^{-4}	Gas plants and networks	Pressure change
			Bubble test
			Helium MS
Medical implants	10^{-9}	Pacemakers	Helium MS
Pressurized vessels	10^{-6}	Gas bottles	Pressure rise
			Bubble test
			Helium MS

Table 2 – Suitability of the main leak detection techniques to several products.