Tip of the month/No. 16

Limitations of leak testing using the pressure change method

Question: The tightness requirements for my components are becoming more stringent. This is often the result of increasingly strict environmental regulations. For my process, I use testing technology based on the pressure change method. What are the limitations of this method?

Answer: There is no general answer to this question. The limitations of the pressure change method are dependent on the following factors: minimum detectable leakage rate, the volume and elasticity of the specimen, the resolution of the pressure gauge used, the permitted test time, and the temperature constancy during the measurement.

Background: Let us take a closer look at the unit S cm^3/min commonly used in the pressure change method, i.e., "standard cubic centimeters per minute": The "standard conditions" contain temperature and pressure influence, the "cubic centimeters" contain the volume, including the stability of the volume. "Minutes" stand for time. This also applies to the units "mbar l/s" or "Pa m^3/s" commonly used in the community of tracer gases.

The individual physical values have the following effects on the tightness:
Colloquial expressions such as "technically tight", "gas tight", "virus tight", "bacteria tight", "water tight" and "liquid-tight" are not sufficient to describe a tightness requirement. To illustrate the limitations of the pressure change method with an example, we still use the expression "liquid tight" even with a leakage rate in the range of 10^{-6} mbar l/s. In a container with a volume of 5 liters, such leakage causes a pressure loss of $2.0 \cdot 10^{-7}$ mbar per second. This would be $1.2 \cdot 10^{-5}$ mbar per minute, $7.2 \cdot 10^{-4}$ mbar per hour, $1.7 \cdot 10^{-2}$ mbar per a day, and 6.3 mbar per year. The instruments used must therefore be able to resolve these pressure changes.

$$Q_L = \frac{\Delta p \cdot V}{\Delta t}$$

$$\Delta p = \frac{\Delta t \cdot Q}{V}$$

Δp	=	change in pressure	[Pa] or [mbar]
V	=	volume	[m^3] or [l]
Δt	=	measuring time	[s]
Q	=	leakage rate	[Pa m^3/s] or [mbar l/s]

Resolution limitations of measuring instruments:
The actual test with air as the test medium is often carried out at absolute pressures ranging between 2 and 5 bar. If a testing time of one hour is permitted, this would mean that a change in pressure of $7.2 \cdot 10^{-4}$ mbar should be displayed on a scale of 5 bar. However, measuring instruments with such a high resolution are not available.

Impact of volume:
The smaller the container, the greater the change in pressure, and vice versa. With very small components, the use of commercially available measuring instruments for the above leakage rate limit may still be possible. However, the larger the container, the greater the chances that a leak test based on a pressure change method will fail.

Dimensional stability:
The testing of elastic containers may also pose a problem. A volume change in a plastic container can compensate for pressure loss and make it impossible to carry out such test.

Cycle time:
It is very rare to have a cycle time of one hour during an in-process test. The demand for short cycle times with test objects from of a certain size upwards does not permit the use of the pressure change method.

Influence of temperature:
A quantity of gas enclosed in a container is subjected to the ideal gas law:

$$p \cdot V = \frac{m}{M} \cdot R \cdot T$$

p	=	pressure	[Pa]
V	=	volume	[m^3]
m	=	mass	[kg]
M	=	molar mass	[kg $kmol^{-1}$]
R	=	general gas constant	[kJ $kmol^{-1}$ K^{-1}]
T	=	absolute temperature	[K]

The pressure in the container is therefore dependent on the absolute temperature; its scale starts at -273.15 °C. The scale range corresponds to the Celsius scale. This means that a change in temperature of just 1 °C equals a pressure change of approximately 1/273. If we heat the 5 bar container in our example above by only 0.1 °C, we create an increase in pressure of 1.8 mbar. This is more than a hundred times the pressure drop generated by the leak per day. This shows that by designing a pressure decay test system with borderline values, a test result can be influenced merely by touching the test specimen. Thermally insulating materials on supporting devices and sealing tools, as well as mathematical temperature compensation can expand the limitations of pressure change methods, but they are not effective indefinitely. Measurements of components that come directly from heat treatment stations (such as welding, soldering, washing or drying) must be tested with the pressure change method only after undergoing cooling processes which include long waiting periods.

Leak detection and leak testing with test gases
Tracer gas methods, in which the gas flow of a test gas is passed through a leak with a selective detection device, offer a solution for the above-mentioned limitations. Tracer gas methods are

- several orders of magnitude more sensitive than pressure change and bubble test methods
- largely resistant to temperature changes
- resistant to changes in volume in the case of elastic components
- not subject to restrictions where the specimen volume is concerned
- fast measurement methods, which allow short cycle times

Tracer gas methods also allow a high degree of automation, as well as an objective and operator-independent test result according to standard-compliant test methods.

For more information about leak detection with test gases, please visit “http://www.pfeiffer-vacuum.com/know-how/leak-detection/technology.action?chapter=tec5“. Our application specialists are happy to assist you with an analysis of your measurement needs.

Do you have a question yourself which you would like us to answer on this page as a new tip of the month? If so, please let us know. (info@pfeiffer-vacuum.de)

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