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03-2018

UNDERSTAND, FIND AND PREVENT LEAKAGE

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*In this document, the word **media** has been used to indicate various substances such as gases and/or liquids.*

1. BACKGROUND

1.1 WHAT IS A LEAK?

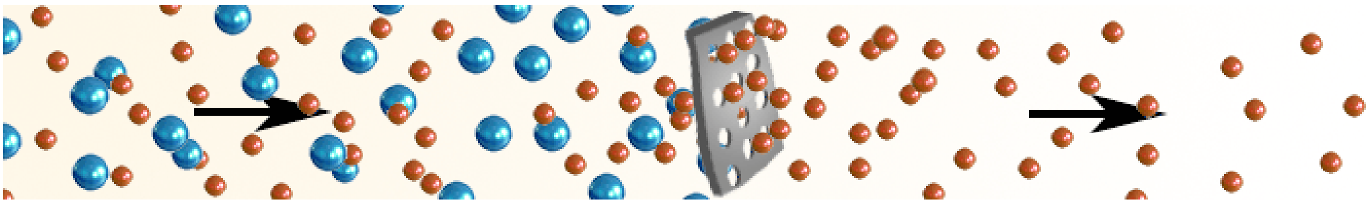
A leak is a flow or opening in the wall of an object which allows gases or liquids to pass from one side of a wall to the other. This structure can be a simple hole, permeable material or any other type.

Leakage is the flow of a fluid or gas through a hole or permeation through a material and typically occurs as a result of a pressure difference between one side of the wall and the other side of the wall

1.2 LEAK TIGHT?

Does leak tight exist? The answer is simple: No, or at least not on earth. 'Leaktight' is an expression often heard, but because every material has its technical imperfections or a measure of porosity we cannot expect that there is no transportation of media through a wall.

Concepts such as 'watertight' or 'gastight' do exist and are often intended.



1.3 CAUSES OF LEAKAGE

Most of the leakages that occur are caused by a simple understandable error and can be easily fixed simply by changing sealing material, replacing a fitting, adding a bracket to avoid torque, making the right choices and of course training employees to detect and prevent them.

Examples of causes:

- The sealing method, for example an o-ring:
    - Damaged/worn-out o-ring
    - Wrong material
    - Wrong o-ring size and/or groove dimensions
    - Rough surface finish
- A hole, crack or burst:
    - Wrong wall thickness
    - Wrong overpressure or underpressure calculation
    - Unregulated pressure
    - Torque
    - Temperature change (results in expansion and contraction)
    - Corrosion
    - Material in combination with the media
- Bad workmanship:
    - Unqualified installer
    - Inappropiate material
    - Fittings are not mounted correctly. Not tight enough or overtightened.

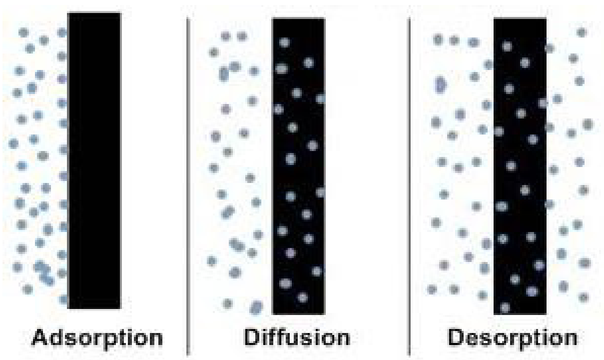
1.4 PERMEATION

There is not necessarily a hole required for media to be transported through a wall or solid product. Gases can be transported through, for example, an elastomer seal or hose, but also through metals. However, the permeability of metals is much lower than that of ceramics and polymers.

<u>How does it work?</u>

Permeation is the penetration of a liquid or gas through a solid. It consists of adsorption on one side of the wall, diffusion through the wall and desorption from the other side of it. The interaction between the gas or liquid and the solid material are strongly dependent on the materials and gases used.

1. Adsorption
   The adhesion or sticking of molecules of a gas or liquid to the surface of a solid.
2. Diffusion
   The process of mixing two substances kept in contact.
3. Desorption
   The release of attached molecules of a gas liquid, or dissolved solids, from the other side of surface.

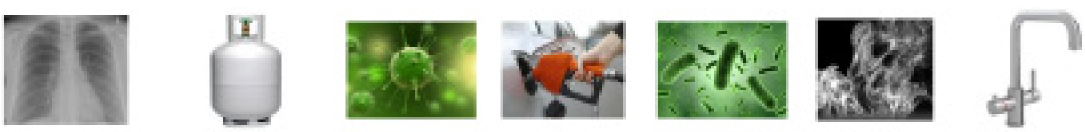


1.5 LEAKAGE RATE

Flow transportation through a wall can be described with a 'leakage rate'. The leakage rate indicates how much gas or liquid passes through a wall at a given differential pressure during a defined time.

In an overpressure situation a leakage rate of 1 mbar·l/s means that in a volume of 1 liter, the pressure drops by about 1 millibar every second.

In Europe, the unit mbar·l/s has been widely accepted. It is very common to use the helium leakage rate as reference. It can be measured with other media though.



Description	Technically tight	Gastight	Virustight	Fuel/ oiltight	Bacteria-tight	Vaportight (sweat)	Watertight
Helium leak rate	$<10^{-10}$ mbar l/s	$<10^{-7}$ mbar l/s	$<10^{-6}$ mbar l/s	$<10^{-5}$ mbar l/s	$<10^{-4}$ mbar l/s	$<10^{-3}$ mbar l/s	$<10^{-2}$ mbar l/s
1 cm^3 gas leakage	In 300 years	In 100 days	In 10 days	Per day	In 3 hours	In 15 minutes	In 100 seconds

Leakage rates are usually displayed as exponential numbers. For example: <10^{-2} mbar·l/s is the leak rate for watertight, but this value can also be written out as <0.01 mbar·l/s. Both are easy to read. Gastight < 10^{-7} mbar·l/s, can also be written out as <0.0000001 mbar·l/s, but the number of zeros make it more difficult to read than the leakage rate displayed in exponential numbers.

billion			million	hundred thousand	ten thousand	thousand	hundred	tens	single	tenth	hundredth	thousandth	ten-thousandth	hundred-thousandth	millionth			billionth	prefix	exponential
1	0	0	0	0	0	0	0	0	0										giga	1 - 10^{9}
			1	0	0	0	0	0	0										mega	1 - 10^{6}
				1	0	0	0	0	0											1 - 10^{5}
					1	0	0	0	0											1 - 10^{4}
						1	0	0	0										kilo	1 - 10^{3}
							1	0	0										hecto	1 - 10^{2}
								1	0										deca	1 - 10^{1}
									1											1 - 10^{0}
									0.	1									deci	1 - 10^{1}
									0.	0	1								centi	1 - 10^{2}
									0.	0	0	1							mili	1 - 10^{3}
									0.	0	0	0	1							1 - 10^{4}
									0.	0	0	0	0	1						1 - 10^{5}
									0.	0	0	0	0	0	1				micro	1 - 10^{6}
									0.	0	0	0	0	0	0	0	0	1	nano	1 - 10^{9}

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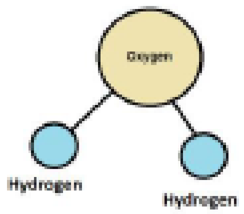
1.6 LIQUID AND GAS

1.6.1 DIFFERENCE BETWEEN LIQUID AND GAS

There is a difference between a liquid flow and a gas flow. Gas tight ($<10^{-7}$ mbar·l/s) will always be water tight ($<10^{-2}$ mbar·l/s), but inversely if an object is watertight it doesn't also mean it is gastight.

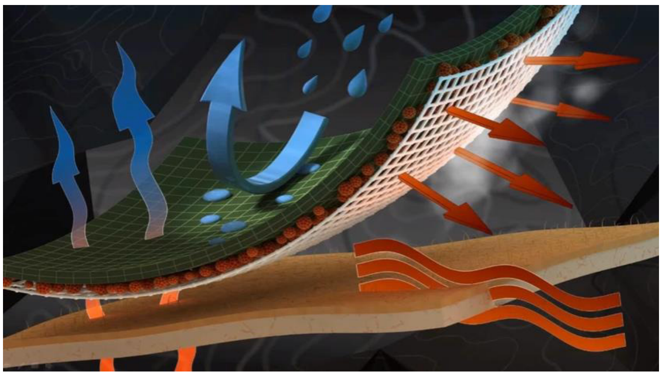
There is a simple explanation for this. Liquid water molecules are, relatively speaking, quite large. Especially in comparison with hydrogen gas molecules, and so liquid water passes through the same size leak more slowly than hydrogen gas.

Water molecule (H_2O) versus hydrogen molecule (H_2):



It is easier to have a seal that has a maximum gap smaller than a H_2O molecule, but this gap is larger than a H_2 molecule. Helium and hydrogen gases are impossible to keep contained without some leakage because their molecules are the smallest possible size, therefore they are good gases to use when performing a tracer gas leakage test.

Sometimes the different sizes of molecules can be used in technical innovations that take advantage of one-way permeability. There are shoes and jackets available on the market that will not let the liquid water in if the wearer steps into a pond or when it's raining. But air and water vapor will pass through to provide ventilation.



1.6.2 VISCOSITY

There is another way of explaining the difference between liquid flow and gas flow. 'Viscosity' is a numeric representation of liquid or gas flow. Viscosity is the internal friction of molecules of a liquid or gas and it characterizes the resistance to flow at a given temperature. High viscosity indicates a greater resistance to flow and low viscosity indicates less resistance to flow. Therefore fluids with a low viscosity have a higher probability of leaking or flowing at a higher rate.

For example: water has a viscosity that is approximately 55 times greater than air, therefore at low pressure the volume of water flow will be 55 times less than that of air.

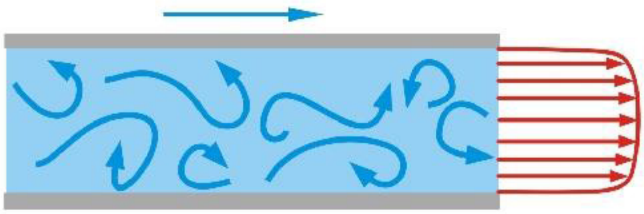
Medium	Dynamic viscosity at 20°C (centipoise/mPa·s)
Water	1.0016
Helium	0.0194
Air	0.01827
Hydrogen	0.00876

1.7 FLOW TYPES

There are at least two types of movement:

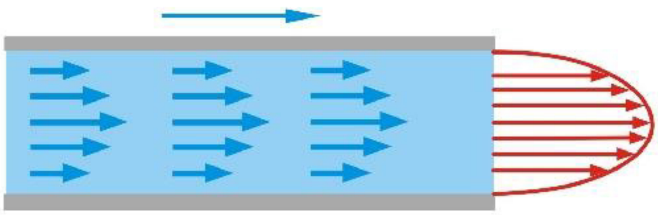
Turbulent flow (viscous flow): Completely random motion of fluid/gas, but the overall direction is one way. Leaks with turbulent flow are large and can be readily located and repaired. This is flow through a passage that is typified as a large leak and at high pressure differentials.

Leakage rate greater than 1.0 x 10^{-2} mbar·l/s



Laminar flow: Orderly motion of fluid/gas, motion in straight lines parallel to the pipe walls. Leaks with a laminar flow are typified by slow movement of fluid in a relatively straight path along the centerline of a passage.

Leakage rate from 1.0 x 10^{-1} mbar·l/s to 1.0 x 10^{-6} mbar·l/s



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*In this section, '**test piece**' indicates an object that undergoes a leak test.*

1.8 FACTORS THAT CAN INFLUENCE LEAK DETECTION

1.8.1 TEMPERATURE

Temperature fluctuations can affect the leak rate negatively especially for pressure decay tests. If the temperature changes in the testing phase, it is difficult to determine if the change in pressure results from leakage or from a temperature change. When performing multiple pressure decay tests on the same test piece in an uncontrolled environment over time, the difference in results can mean not passing the test or passing the test, only as a result of temperature changes.

An increase in temperature leads to an increase in pressure and a reduction in temperature to a pressure drop. It is advised that you carry out pressure decay tests in a temperature-controlled environment. If this is not possible try to avoid sunlight, heaters, or other sources of heat or cold.

1.8.2 LEAKS BLOCKED BY LIQUIDS

If an object has already been in contact with oil or water, there is a possibility that small leaks have been clogged. When performing a leakage test with compressed air or a tracer gas, it is possible that the gas cannot escape the test piece anymore. To avoid this, the test piece needs to be cleaned and dried thoroughly.

1.8.3 MATERIAL FLEXIBILITY

The size of a leak is also influenced by the expansion behavior of the material to be tested. If flexible material is pressurized, the volume inside expands and the pressure drops. This pressure drop can result in a rejected pressure drop test while there is nothing wrong with the product as such.

The other problem with material flexibility is that the wall thickness reduces because of volume expansion during pressurizing. It is possible that leakages occur because of this decrease in wall thickness. A simple example is the use of a hose combined with hose pillar and hose clamp.

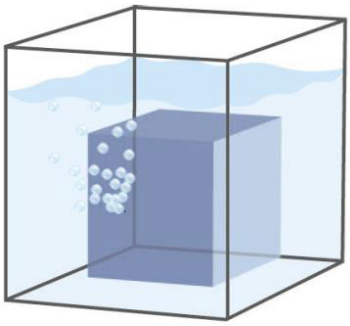
1.8.4 SEAL AND SURFACE TREATMENT

The leak is not only influenced by the media used, the temperature or the flexibility of the materials, but also by the sealing method chosen and surface treatment.

Therefore it is important to establish a leakage rate based on the normal operating conditions. This way a suitable seal can be selected as well as a suitable surface treatment in the design phase. An unrealistic leakage rate requirement can lead to costly attempts at sealing. If the wrong seal and/or surface treatment is chosen, the required leakage rate cannot be achieved.

2.1 BUBBLE TEST

One of the most traditional and simplest methods of leak detection is a bubble test. In the bubble test method, the test piece is first filled with compressed air and then submerged in a tank of water. The tester observes whether bubbles rise. This is quite a reliable way to locate a leak and it will give some information about the size of the leak.



Leakage rates up to 10^{-2} mbar·l/s can be easily identified with this method. At this leakage rate there is a continuous stream of bubbles. The theoretical limit of detection is better, but the smaller the leak, the more time the test piece needs to stay under water to produce just one bubble. The most important thing to keep in mind is that whether bubbles are detected or not depends on the individual tester.

It is also possible that a leak with a leakage rate lower than 10^{-4} mbar·l/s can be detected with the bubble test (significant hole) or cannot (porous material). With porous material, it is possible that the bubble will not pass through due to the surface tension of the water on the test piece. Porosity leaks are often made up of millions of very small holes instead of one bigger hole.

One of the disadvantages of the bubble test is that afterwards the test piece is wet and must be dried. This is time consuming but needs to be done to avoid damage by corrosion. The water test can only be performed with test pieces that tolerate water/fluids.

2.2 SOAP SPRAY METHODS

The soap spray leak detection method is a bit like the bubble test method. The test piece is first filled with compressed air, only instead of immersing the test piece in water, the tester sprays a foaming liquid on the places where a leak is suspected. Then the tester observes if bubbles form. If air leaks at the sprayed location, the soap will begin to foam. The success of this test also depends on the individual tester, his skills and his alertness.

Theoretically leak rates up to 10^{-4} mbar·l/s can be identified with this method.

This test has the same disadvantage as the bubble test. The test piece will get wet due to the soap spray and must be dried afterwards. An advantage compared with the bubble test is that the test piece doesn't need to be submerged in a tank of water. If a leak is big, this test will not work well because the compressed air will blow away the foaming agent before bubbles can form. Also, detecting leaks on the bottom of the test piece is difficult because the soap spray simply drips off.

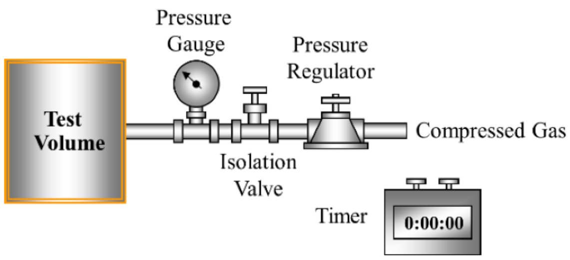
2.3 PRESSURE TEST WITH AIR

There are a few different methods to identify leaks through measuring pressure changes. Of these methods, the pressure decay test is the most common. This method is therefore explained more in detail and the others more briefly.

2.3.1 PRESSURE DECAY TEST

In the pressure decay test method, the test piece is filled with compressed air and then the pressure is measured over a defined time interval. If the pressure decreases over time, there is a leak.

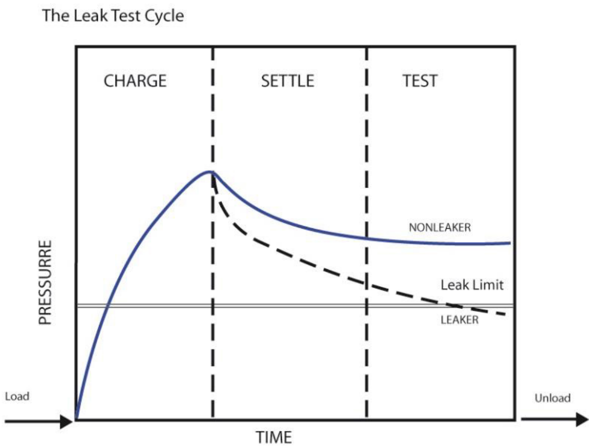
This detection method cannot detect the leakage better than the bubble and soap spray tests, and often only values of 10^{-4} mbar·l/s or higher can be achieved. These measurement results have a large degree of uncertainty.



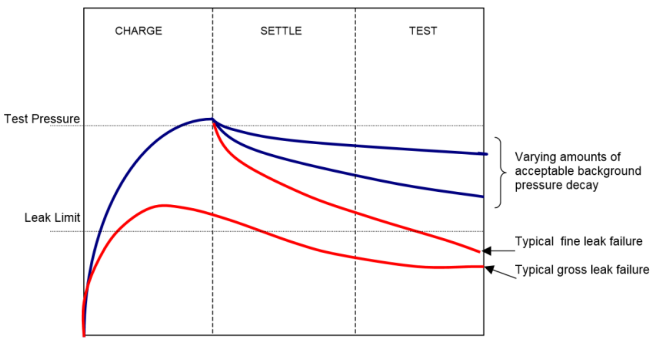
One of the disadvantages of the pressure decay test is that the sensitivity to temperature fluctuations is greater. It is also not possible to detect the location of the leakage with this method. On the other hand, the product does not get wet.

Important to know when performing a pressure decay test is the test cycle. The pressure decay leak cycle can be broken down into three phases:

- During the CHARGE phase the test piece is being pressurized to the predetermined test pressure.
- During the SETTLE phase, the volume of the pressurized test piece can change and stabilize due to the stresses that are introduced by pressurization. This part is crucial in the case of flexible materials whose volume may change under the influence of pressurization. The SETTLE period also allows time for the temperature to stabilize, heat generated through compression of a gas.
- During the TEST phase the pressure can be measured and pressure decay can be detected.

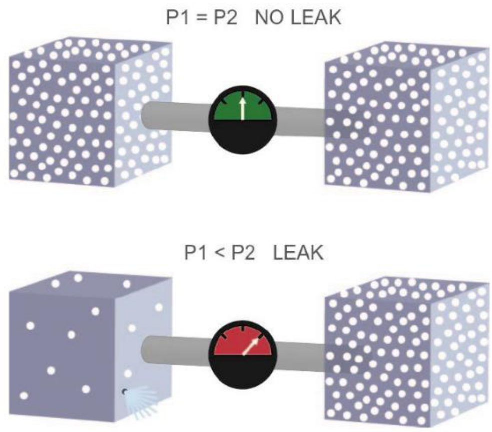


To achieve a reliable test result it is important to wait before measuring until the pressure has settled and the parameters such as temperature have stabilized. As previously explained, there will always be some amount of background leakage, even if it is only molecules permeating a rigid container.



2.3.2 DIFFERENTIAL PRESSURE TEST

The differential pressure test also measures pressure differences. It compares the pressure in the test piece with the pressure in a reference object whose tightness is known.
Both pieces are simultaneously filled with the same overpressure. Pressure differences are measured with a differential pressure sensor and the leak rate can be calculated.



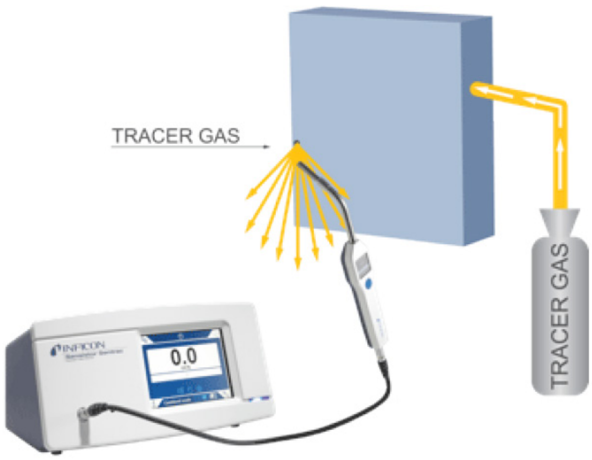
This test method can detect a leakage better than the pressure decay test, but this is because temperature fluctuations have less influence on the differential pressure, as long as the fluctuations act to the same extent and at the same time on both the test piece and the reference piece.

The filling itself affects the reference piece temperature so it is advised to swap the reference piece every test to let it settle.

2.3.3 PRESSURE INCREASE TEST/VACUUM DECAY TEST

In the pressure increase test a vacuum is created inside the test piece. That is why this is also called the vacuum decay test. Over a given period the pressure is measured to see how much it rises within the test piece.

Most components are overpressurized in use. Therefore, the pressure increase test does not always match the final application. Some leaks only occur in one direction and can therefore not be detected using the pressure increase test. Another limiting factor is the test piece itself, it depends on the rigidity of the test piece (it needs to function under vacuum) and the size of the volume.



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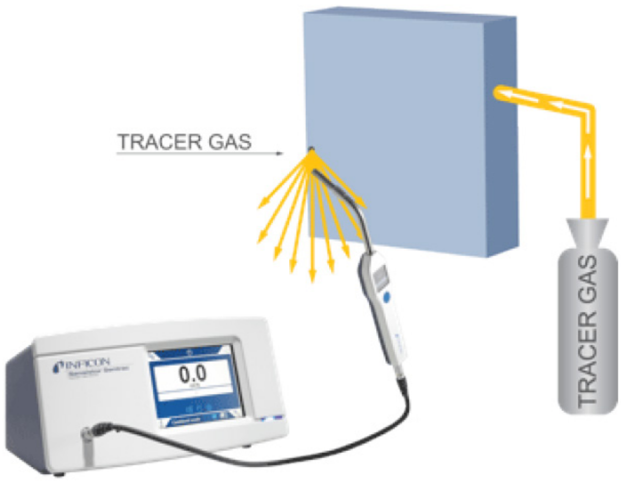
2.4 TRACER GAS LEAK DETECTION

This method is among the most sensitive leak testing methods. In this leak detection method, the test piece is filled with a tracer gas. Leak testing and sniffer leak detection with tracer gases use the pressure difference that is created between the interior and surroundings of the test piece so that the tracer gas can flow through a possible leak and be detected.

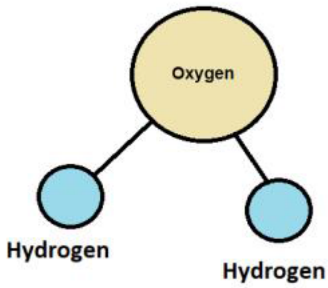


This method and the tracer gases will be explained more in detail in Section 3.

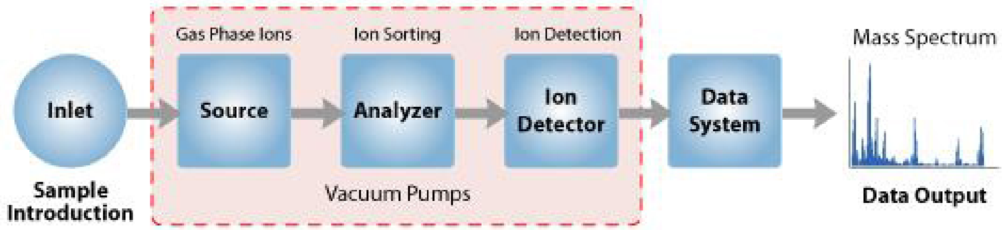
2.5 MASS SPECTROMETER ANALYSIS (RESIDUAL GAS ANALYSIS)

To investigate leakages in a high vacuum a mass spectrometer can be used. With this method, under the best conditions, helium leak rates to as low as 4 x 10^{-12} mbar·l/s can be detected. Theoretically, it is possible to detect all gases using mass spectrometry.

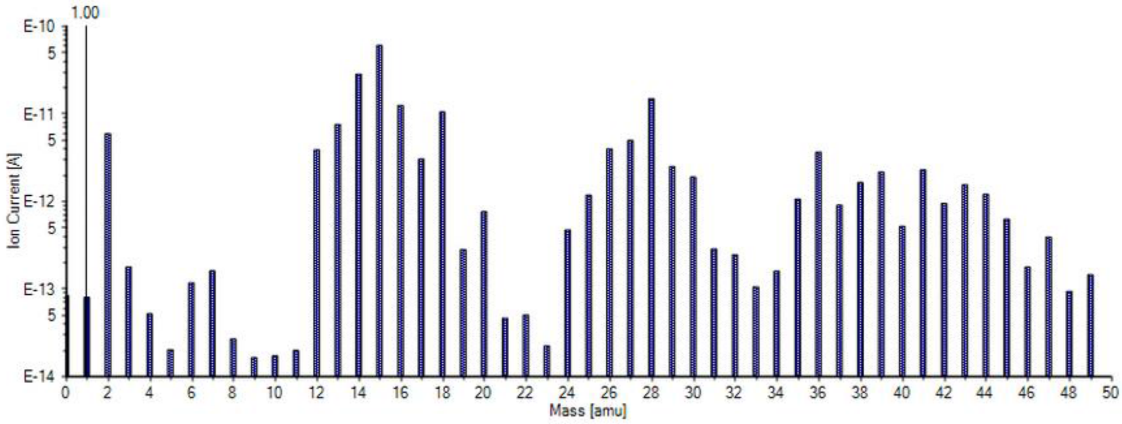
To understand a mass spectrometer analysis, a little chemistry explanation is required. H_2O (water) is a molecule that consists of an oxygen atom and two hydrogen atoms. Every atom is composed of particles called protons, neutrons and electrons. Protons carry a positive electrical charge, electrons carry a negative electrical charge and neutrons carry no electrical charge at all. An ion is an atom in which the total number of electrons is not equal to the total number of protons, giving the atom or molecule a positive or negative electrical charge.



Simply said: a mass spectrometer generates multiple ions from the test piece. The mass analyzer separates these ions according to their mass-to-charge ratio. The detector converts the ions into electrical signals and the recorder processes the signals and sends them to the computer. Results are displayed on a chart.

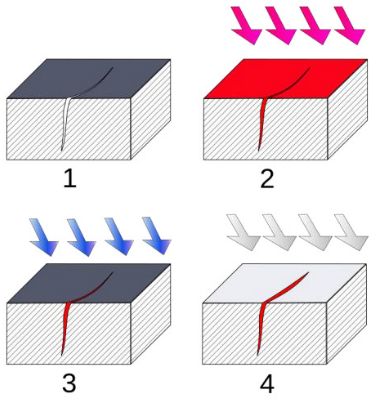


The output data is difficult to interpret, but for an experienced user this is a great instrument that immediately tells them what is in their vacuum system.



2.6 DYE PENETRATION TEST

The dye penetration test is not really a leakage test, but it can detect defects which can lead to leakages and is therefore interesting to mention. It is an easy test to inspect surface defects in all non-porous materials such as metals, plastics, ceramics.



This test will be done as followed: The surface of the test piece is cleaned. The penetrant is then applied to it and given time, up to 30 minutes, to flow into flaws. Then the surface is cleaned again and a special powder is applied to the surface to draw the penetrant out of the defects onto the surface. The tester can then observe the test piece for visible dye penetrant. If the penetrant is fluorescent, UV-A light will be used.

3.1 TRACER GAS

The simplest gas for leak detection is air. Compressed air is used for pressurizing samples and measuring pressure decay with a gauge or just by performing a simple soap spray or bubble test.

If a leak is relatively small it is difficult to locate the leakage through these methods, a special tracer gas can be used. In this section helium and hydrogen (forming gas mixture) will be mentioned. There are several other tracer gases, but they have serious limitations and are therefore not mentioned in this document.

The advantages of a tracer gas leak test are as follows:

- It repairs only what needs to be repaired.
- It gives fast feedback.
- It can detect a leak that is not visible to the naked eye.
- It makes the leak quantifiable.
- There are no problems having to dry/clean your products after the leak test.
- It allows testing of hot/warm products.

3.1.1 HELIUM

Helium is the second most common element in the universe and is the most widely used tracer gas. It is non-toxic and non-flammable. Helium has a low molecular weight, and the natural concentration of helium in air is 5 ppm, a low concentration (ppm is explained in section 3.5).

3.1.2 HYDROGEN (FORMING GAS MIXTURE)

Even though helium has a low concentration of only 5 ppm in air, the concentration of hydrogen in air is even lower at only 0.5 ppm. Hydrogen is the lightest element but a big disadvantage of pure molecular hydrogen gas (H_2) is its flammability. For this reason, pure hydrogen is never used as a tracer gas, but is mixed with nitrogen (N_2). This mixture is called forming gas and consists of 95% nitrogen and 5% hydrogen. Forming gas is non-flammable.

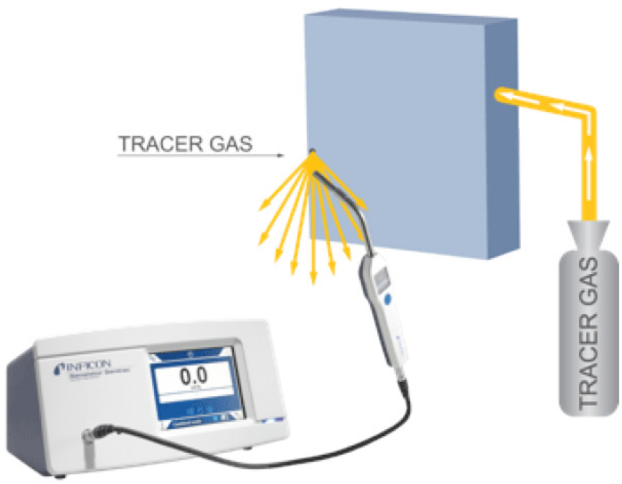
3.1.3 COMPARISON

Helium versus hydrogen (forming gas):

- Hydrogen has both a lower atomic mass and gas viscosity compared with helium.
- Hydrogen has a lower natural concentration (0.5 ppm) in ambient air compared with helium (5 ppm).
- The sensitivity of a hydrogen measurement instrument can be influenced by an increase of the natural hydrogen concentration. This increase can be caused by one of the many sources of hydrogen, for example cigarette smoke, combustion engines, aluminum machining, and in some cases, compressed air systems.
- Helium is usually more expensive than forming gas.

3.2 SNIFFER LEAK DETECTION

The test part is pressurized with tracer gas and the sniffer probe is moved around the part. If a leak is present, the leak detector will detect the escaping tracer gas, allowing leak localization. The sniffer probe should always be located as close to the leak as possible. The sniffing test is regarded as a localization method, because the distance from the leak and the tilt of the sniffer probe have an influence on the test result. The tracer gas does not have to be sucked into the device. Therefore 'sniffing' is not a strictly accurate method.

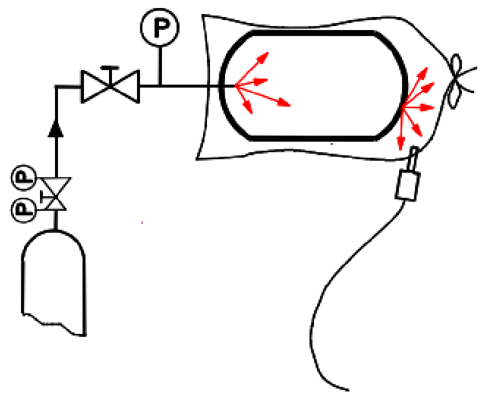


Advantages:

- The location of the leak can be detected.
- The item to be tested does not need to be placed under vacuum.
- Easy to perform.
- Detector cost only, no tooling.
- If the leak detector is portable, operators can perform tests at various locations.

3.3 INTEGRAL LEAK TEST

The test piece is pressurized with tracer gas. The increase in tracer gas concentration is measured in a known volume created around the test piece. The duration of the test depends on the permissible leakage rate and on the specific volume involved. Depending on the application the known volume is created using either a flexible hood or a solid enclosure.



3.4 CALIBRATION

Test equipment needs to be calibrated periodically. This process is important to maintain instrument accuracy.

Over time the sensitivity of the leak detector changes. How often the leak detector needs to be calibrated depends on the measuring situation and leakage rate.

Tracer gas leak detectors can be calibrated using calibration gas or through a calibration leak. Calibration gas is a gas with a known concentration of hydrogen/helium. A calibration leak is an object with a fixed leakage rate.

3.5 PPM

Tracer gas leak detectors can display leakage rates and test gas concentrations, which represent different physical values.

As explained in Section 1.5 of this document a leak rate is the volume of a medium flow through a wall in a specific time. This value is expressed as "pressure * volume / time," normally shown as mbar·l/s.

The unit of measure ppm indicates a gas concentration, parts per million. This value represents a part of a whole number in units and is a dimensionless quality. 1 ppm is 1/1000000 = 0.0001%

For sniffer leak detection, operators often use ppm to describe the leakage rate. The reason why ppm is a unit used for gas concentrations and not for a gas flow is due to the sniffer line where the leakage rate mixes with the ambient air. The resulting concentration is a ratio of the amount of gas flowing through the leak and the total airflow through the sniffer line:

$$concentration = \frac{leak\ rate\ gas\ flow}{total\ gas\ flow\ sniffer\ line}$$

A different sniffer line with a different gas flow results in a different concentration and a probe tip blocked by dirt can also change the total gas flow and concentration.

Two examples to show the difference: Both examples have a leakage rate of 1 x 10^{-4} mbar·l/s. In the first example there is total gas flow through the sniffer line of 5 mbar·l/s. The displayed concentration is 20 ppm. In the second example there is a total gas flow through the sniffer line of 50 mbar·l/s. The displayed concentration is 2 ppm.

3.6 INFICON SENSITOR SENTRAC

Teesing can test a product or assembly with tracer gas. The leak detector used is the Sensistor Sentrac, a portable model, allowing for on-site tests by Teesing at the customer's request.

Technical data

Lowest detectable leakage rate	0.5 ppm H_2
Measurement range	5×10^{-7} mbar·l/s with 5% H_2
Time until ready for operation	1 minute
Battery operating time	12-20 hours
Calibration	2x per year or more often if necessary

Other data

Dimensions	200×330×280 mm
Weight	4.8 kg

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4.1 FREQUENTLY ASKED QUESTIONS

4.1.1 WHY SHOULD I PERFORM A LEAKAGE TEST?

To avoid damages caused by a leak, such as damaged products or assemblies and production downtime. Financial consequences are more serious when a machine cannot produce according to schedule than the costs of leak testing itself.

The customer expects good quality and if the product has passed the test, both parties know that problems caused by leakages later on are not caused by the supplier of this product.

4.1.2 WHAT IS THE REASON THAT THE TEST PRESSURE IS ALWAYS HIGHER OR THE SAME AS THE OPERATIONAL PRESSURE?

Many seals and some material or production defects have a pressure limit at which they open. If the test is performed at lower pressures than the maximum pressure occurring during operation some leaks may not be open yet. If the test is performed at higher pressures it is possible that leaks are detected which do not show under real operation. This is often a safety factor customers would like to have implemented in their system.

4.1.3 CAN I ASSUME THAT IF I DON'T SEE BUBBLES DURING THE BUBBLE TEST THAT THERE IS NO LEAK?

No, nothing on earth is leaktight. Due to technical imperfections in the wall there is always some transportation of media, but this does not mean that the object will not function for its designed application.

Whether or not bubbles are detected strongly depends on the individual tester and the test time. If in doubt, let a second individual check the test set-up to back up the conclusion that there are no bubbles. If the test time is too short it is possible that the test piece has not had time to settle and the bubbles have not had time to form.

If bubbles are not detected and in the final application the medium is for example water (leakage rate is $<10^{-2}$ mbar·l/s), then the test piece is leaktight for its application. If bubbles are not detected and in the final application the medium is, for example, helium (leakage rate of gas is $<10^{-2}$ mbar·l/s) it is not certain that the test piece is leaktight for its application and an additional test need to be performed.

That is why it is so important to choose the appropriate test method for the application.

4.1.4 DO I HAVE TO PERFORM A LEAKAGE TEST WITH AIR BEFORE PERFORMING A TRACER GAS TEST?

We advise performing a quick test for large leaks before testing the test piece with tracer gas. In this way the tracer gas will not be spilled and contamination of the testing area is prevented.

It is also important to ventilate the testing area sufficiently. This will prevent released tracer gas that would otherwise contaminate the testing area ascending to the ceiling and moving around as a cloud.

4.1.5 DO I HAVE TO FLUSH THE TEST PRODUCT WITH TRACER GAS BEFORE STARTING THE REAL LEAKAGE TESTING?

For a reliable test result it is important to evacuate air inside the test piece. If the test piece is immediately filled with tracer gas and tested, the air in the test piece will simply be pushed to the end of the construction and no tracer gas will get to this area. This way potential leaks will only release air and cannot be detected with the tracer gas leak detector.

If the test needs to be perfomed with low pressure it is even more important because the leftover air will be mixed with the tracer gas. This way it is possible that the tracer gas concentration in the test piece is only 50%. If a leak is detected the wrong value will be displayed by the tracer gas leak detector.

4.1.6 IS THE LEAKAGE RATE OF HELIUM THE SAME AS THE LEAKAGE RATE OF HYDROGEN?

No, therefore it is important to note the gas that belongs to the leakage rate instead of the leakage rate only.

To convert a helium leakage rate of 6.0 x 10^{-5} mbar·l/s towards a hydrogen leakage rate, only the viscosity difference needs to be considered. Helium has a dynamic viscosity at 20°C of 0.0194 millipascal per second. Hydrogen has a dynamic viscosity at 20°C of 0.00876 millipascal per second. Therefore hydrogen wil leak (0.0194/0.00876) = 2.21 times faster. The helium leakage rate of 6.0 x 10^{-5} mbar·l/s converted to a hydrogen leakage rate will thus be 13.28 x 10^{-5} mbar·l/s = 1.33 x 10^{-4} mbar·l/s.

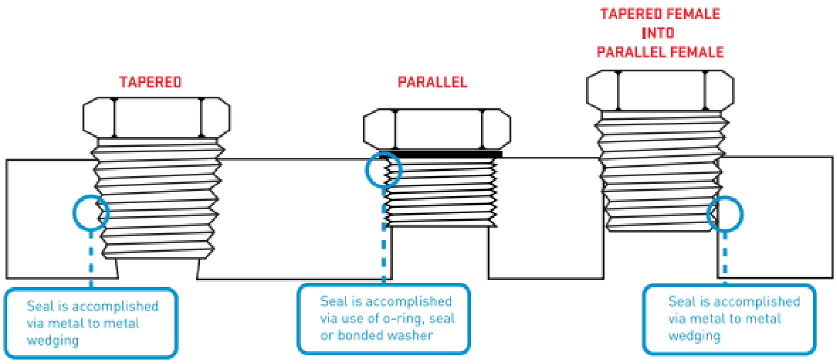
Media	Dynamic viscosity at 20°C (centipoise/mPa·s)
Water	1.0016
Helium	0.0194
Air	0.01827
Hydrogen	0.00876
Forming gas mixture	0.0172

4.2 SEALING METHODS

4.2.1 THREAD SEAL TYPES

Parallel and tapered threads require different sealing solutions.

When the female thread and the male thread are both parallel an o-ring or bonded seal is often used. An o-ring is one of the most common seals because it is inexpensive, easy to make, reliable and has simple mounting requirements. When the male thread is tapered an o-ring seal cannot be used because the thread can only be screwed in only partially. Without an additional sealant all tapered threads leak. Seal reduces the potential for threads to gall. Loctite or PTFE can be used for this.



O-rings

Bonded seals

4.2.2 SURFACE SEAL TYPES

There are many sealing products and connection types on the market. Therefore it is impossible to discuss them all in this document. There are permanent seals made by welding, soldering, swaging, crimping, chemical seals include coating and gluing, and impermanent and sometimes flexible types of seals such as o-rings, metal gaskets and tape.

4.3 OTHER TEST METHODS

There are other tracer gas test methods which are not mentioned in this document but can also be carried out.

• Spray test	Any tracer gas
• Integral vacuum test	Any tracer gas
• Bombing test	Any tracer gas
• Sonic or ultrasonic sensor	Any tracer gas
• Ultrasonic bubble detection	Any tracer gas
• Flow controller	Any tracer gas
• Photo-acoustic detection after later adsorption	Tracer gases like SF_6, CO_2, N_2O, H_2
• Field effect transistor	Tracer gas containing hydrogen
• Quartz window sensor	Tracer gas helium
• Quadruple mass spectrometer	Any tracer gas
• Other, not named above	

For more information about these test methods, please contact a specialized leak test company.

APPENDIX 1: CONVERSION FACTOR

Equivalent	atm cm^3/s	$Pa \cdot m^3/s$	mbar·l/s	Torr·l/s	Lusec	sccm
atm cm^3/s	1	0.1	1	0.76	760	60
$Pa \cdot m^3/s$	10	1	10	7.5	7500	600
mbar·l/s	1	0.1	1	0.76	760	60
Torr·l/s	1.3	0.13	1.3	1	1000	78.7
Lusec	1.3×10^{-3}	1.3×10^{-4}	1.3×10^{-3}	10^{-3}	1	7.87×10^{-2}
sccm	1.66×10^{-2}	1.66×10^{-3}	1.66×10^{-2}	1.27×10^{-2}	12.7	1

For example: 1 mbar·l/s = 0.1 $Pa \cdot m^3/s$

APPENDIX 2: COMPARISON TABLE

Comparison of the most important leak detection methods

Method	Test gas	Smallest detectable leak rate mbar·l/s	Pressure range	Leak localisation	Quantitative measurement
Foaming liquids	Air or process gas	10^{-4}	Positive pressure	Yes	No
Bubble test in water tank	Air or process gas	10^{-4}	Positive pressure	Yes	With large measurement uncertainty
Water pressure test	Water	10^{-2}	Positive pressure	Yes	No
Pressure rise test	Air or process gas	10^{-4}	Vacuum	No	With large measurement uncertainty
Pressure drop test	Air or process gas	10^{-4}	Positive pressure	No	With large measurement uncertainty
Ultrasound microphone	Air or process gas	10^{-2}	Positive pressure	Uncertain	No
Thermal conductivity leak detector	Process gas, no air	10^{-3} - 10^{-5}	Positive pressure and vacuum	Yes	No
Halogen leak detection	Substances containing halogens	10^{-6}	Positive pressure	Yes	With restrictions
Hydrogen (5%) leak detection	Forming gas mixture (5% H2)	10^{-7}	Positive pressure	Yes	With traceable calibration according to requirements in ISO 9000
Helium leak detection	Helium	10^{-12}	Vacuum	Yes	With traceable calibration according to requirements in ISO 9000
		10^{-7}	Positive pressure		

APPENDIX 3: TEST CERTIFICATE

TEESING

INSPECTION CERTIFICATE

GENERAL INFORMATION

PART NAME:

TEESING PART NUMBER:

TEST INFORMATION

TEST METHOD:

PERFORMED BY:

DATE:

REFERENCE / SERIAL NUMBER:

MEDIUM:

TEST PRESSURE:

TEST RESULT:

CERTIFICATION

We herewith confirm that the part has passed the tests and has been approved for certification.

Teesing b.v.
Quality engineer
Verrijn Stuartlaan 40
2288 EL RIJSWIJK
The Netherlands

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LIST OF TERMINOLOGY

A list of terms with the definitions of those terms used in this document.

Absorption	The passage of molecules of a gas, liquid, or dissolved solid into or through the bulk of another substance. Cannot be reversed by simple means although it may also be temporary.
Accurate	Correct or true in every detail
Adsorption	The adhesion or sticking together of molecules of a gas, liquid, or dissolved solid to the surface of a solid or liquid
Calibration	The process of checking a piece of equipment used for measuring things
Contraction	The process of becoming smaller
Corrosion	The process of gradual destruction of a solid (metal) caused by its environment
Differential	The difference between two or more things, forces, motions, etc.
Elastomer	A natural or synthetic polymer having elastic properties
Expansion	The process of becoming larger
Friction	The resistance that one surface or object encounters when moving over another
Leak detector	Instrument to detect and measure leakage
Leakage rate	A number which indicates how much gas or liquid passes through a leak at a given differential pressure during a defined time
Medium	A gas or liquid
Molecule	The simplest unit of a chemical substance, usually a group of two or more atoms
Overpressure	Pressure above normal atmospheric pressure
Penetrant	A colored liquid used to detect cracks
Polymers	A compound or mixture of compounds, most plastics are manmade polymers.
ppm	Parts per million = 1/1000000 = 0,0001%
Rigidity	Notable to be bent or to be forced out of shape
Test piece	In this document it refers to a product or assembly that will undergo a leak test
Tester	A person that tests the quality of something
Tracer gas	Gas: hydrogen, helium, or another gas. with a low ambient concentration combined with the use of a tracer gas leak detector used to locate leak and measure leakages.
Under pressure	Pressure below normal atmospheric pressure, vacuum
Viscosity	Resistance of a fluid to flow at a given temperature. High viscosity indicates a greater resistance to flow and low viscosity indicates a lower resistance to flow.

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