White Paper

Hermetically sealed connectors

1. Introduction: sealing categories and scope of document

Sealed connectors are used in many applications where leakage into or out of an equipment must be avoided. Sealing is a very complex science by itself as it involves many physical aspects including mechanical design, materials science, surface science and fluid behavior.
Practically three major application groups exist which require different sealing levels and therefore different solutions.

- **Environmental sealing**
  Typically for outdoor application, one side of the connector might be exposed to rain, dust and other aggressive environments. The exposure is in general limited in time and pressure.
  Fischer Connectors product range for these applications include receptacles sealed in mated or unmated state, for example styles DEU, DBEU, DBPU etc. as well as plugs in association with sealed clamp sets.
  These products are designed to offer sealing up to IP68.

- **Hermetic sealing**
  Hermeticity is required for gas tightness. Such connectors are used for example in vacuum applications or pressurized vessels. This requires a high level of sealing to prevent gas leaks over longer periods of time. These products ranges, for example styles DEE, DBEE, DBPE etc, are designed specifically and undergo a 100% leak test. Such connectors can be used also in other severe conditions like immersion for longer periods of time or exposed to strong jets. They achieve IP69K rating.

- **High pressure sealing**
  For applications requiring exposure for extended period of time towards liquids under high pressure (for example deep submarine applications) special designs can be proposed combining hermeticity with adequate high strength mechanical design. Fischer Connectors design center can assist customers for such special requests.

This document focuses on the hermetic sealing and particularities encountered in vacuum applications

2. Hermeticity

2.1 Vacuum

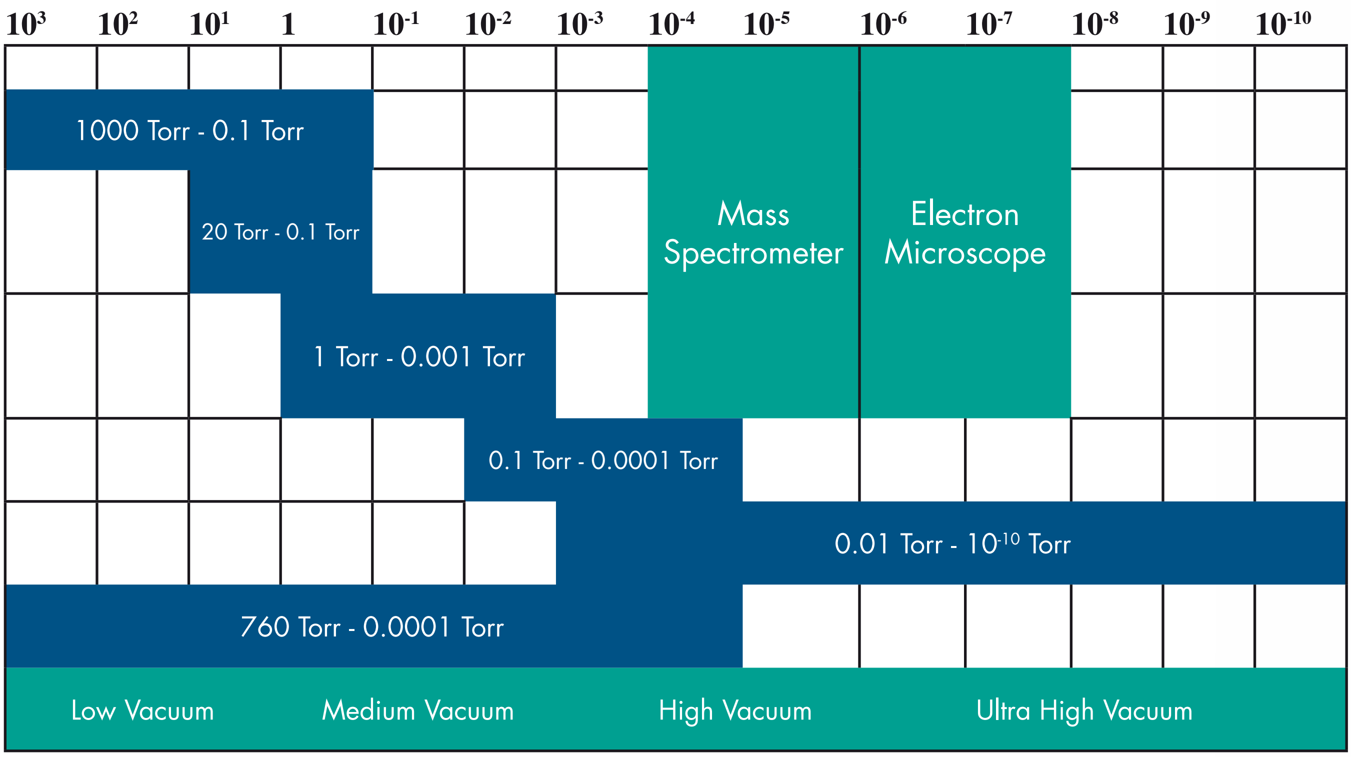
2.1.1 Definition

A vacuum is made when gas molecules are taken out from a volume. In order to achieve specific physical reactions, a vacuum has to be created in a chamber because air molecules will act as barrier for other molecules or electrons. For example, the equipments designed to trace a gas (mass spectrometers) or electron microscopes need a vacuum chamber.

2.1.2 Vacuum units

The "atmospheric" pressure is one bar, or 1000 millibars (1000mbar). Depending on the application, different vacuum levels have to be achieved (10 mbar as "low vacuum", 1E-5mbar as "high vacuum" or 1E-7mbar as "ultra-high vacuum").

Terminology versus vacuum (mbar)



2.2 Hermetic connectors and leak unit

2.2.1 Hermetic connectors

If a connector is placed on the vacuum chamber, the air going through it versus time must be as small as possible. The connector has to be "hermetic". If the connector is not hermetic, it will allow air molecules to enter into the vacuum chamber and increase the residual pressure, preventing the equipment to work properly.

2.2.2 Leak unit

The quantity of air (or other gas) going through the connector is a “leak”. In order to quantify a leak, the unit is based on a “certain volume of gas per second going through it”. ***The scientific unit is the mbar.l/s.*** In the vacuum industry, 1E-4mbar.l/s is considered as “big leak” and only very rare low vacuum applications can support such a leak in the vacuum chamber, while 5E-7mbar.l/s is considered as a very small leak sufficient for most of the vacuum applications.

2.3 Leak vs. pressure gradient and gas type

2.3.1 Pressure gradient

A low vacuum of 10mbar will induce a “pressure differential” with the atmospheric pressure (1000mbar) of 990mbar.
An ultra high vacuum of 1E-7mbar (0.0000000001 bar) will induce a differential of 0.9999999999 bar. It is never possible to achieve more than 1 bar differential pressure because a vacuum chamber cannot have “less than zero air molecule” in it. That is why the “standard gradient” is 1 bar. A given leak for a given connector will not be the same if the connector is exposed to an overpressure. If the vacuum chamber is replaced by a “10 bar pressurized chamber”, the leak will be bigger.

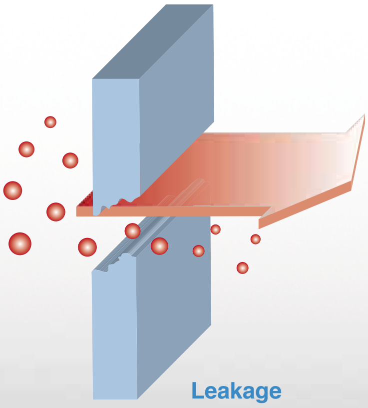
2.3.2 Gas type

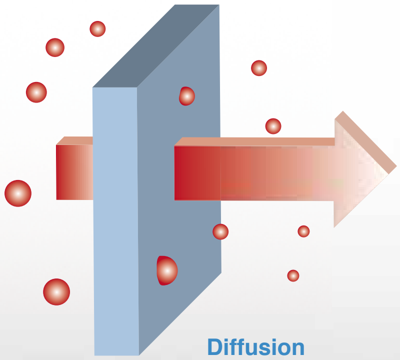
Since the most common leak measurement equipment is the “helium tracer”, the leak is often given as being the “helium leak”. Nevertheless, the vacuum applications are not working with helium; that is why the leak can be as well given for air molecules. The air leaks “2.6 times less” than helium (standard calculation based on square root quotient of molecular mass of N_2 and He). If a connector leak is measured under a helium atmosphere as being 4E-7mbar.l/s, the real vacuum application (air) will have a leak of 1.5E-7mbar.l/s.

2.4 Leak vs. time

2.4.1 Diffusion effect

Connectors for high vacuum applications usually have Viton® O-rings. The very good material allows having very small residual leak. The residual leak is induced because of the diffusion phenomenon: when exposed to a pressure gradient, gas molecules (nitrogen, helium, oxygen…) will progressively “diffuse” into the O-ring. In other words, the gas molecules will slowly go through the O-ring. This phenomenon cannot be observed after a few seconds but will become predominant after a few minutes. The phenomenon of a “leak” is due to a physical space where the gas can go through, while the diffusion is when the gas is “going through” the material. In other words, there are two major mechanisms by which a gas can get through a hermetic barrier, leakage and diffusion.





The presence of defects or cracks in the barrier will cause gasses to flow through. In general, those types of defects will result in gross leakage and failure of the device.
But even a barrier without defects will allow gasses do diffuse through it, this is called permeation or diffusion. Diffusion is known to occur generally in most plastics and rubber materials, allowing extremely small quantities of gas to migrate through the hermetic barrier.

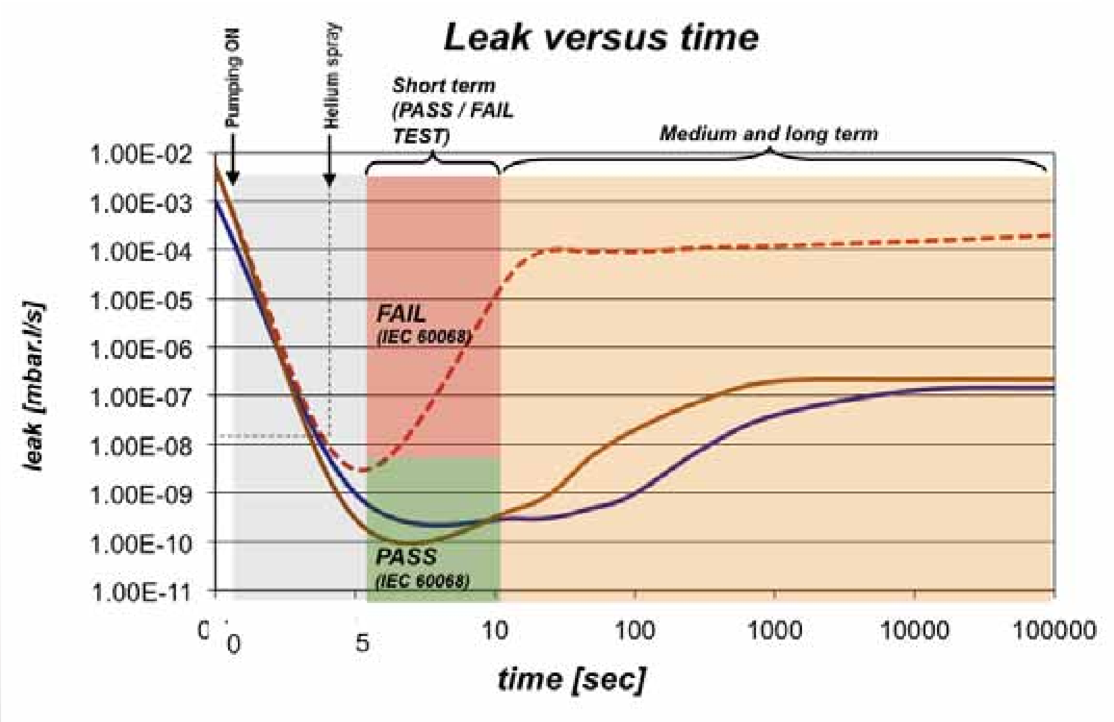
For this reason, components like connectors or other devices mounted on hermetic systems will exhibit a residual leakage resulting from gas diffusion through the sealing material. The optimized design of these components and adequate material selection allows the residual leakage rate to remain at extremely low values, suitable for most ultra vacuum applications.

The understanding of these mechanisms is important ; the leaking through tiny cracks is often related to the failure of the hermetic device, whereas diffusion is natural phenomenon existing in most systems and that can only be limited with very special technologies.

2.4.2 Leak measurement in accordance with the norm

The ***standard IEC60068-2-17-Qk method 3*** for leak measurement is a “short term leak”. Spraying helium on the connector and measuring with a helium tracer the quantity of helium going through it is usual to qualify connector hermeticity. This test allows detecting “leaking” connectors without measuring the real long term leak value. If the threshold is put at 1E-8mbar.l/s (like done at Fischer Connectors), it can very efficiently sort out the connectors that would have been problematic for vacuum applications. Lower thresholds (1E-9mbar.l/s or 1E-10mbar.l/s) are not relevant because the diffusion leak through O-rings will in any case go to higher values after some minutes. Even if the diffusion effect depends on many factors, a value for standard size connectors of 1.5E-7mbar.l/s (air) can be given as “medium and long term leak value” (equivalent to a leak of 4E-7mbar.l/s for helium).

Graph caption: after 10 seconds, the leaking connectors can be sorted out with helium spray method IEC6068-2-17-Qk method 3, but the real leak measure for the long term cannot be quantified.



2.5 Virtual leaks and outgassing

Gas trapped between assembled components, or contained inside materials will slowly migrate out of the device into the vacuum area. This common phenomenon will impact the rate at which the desired vacuum level will be attained; such factors must be taken into account especially during initial pump down until all these gases are released.

2.5.1 Virtual leaks

Virtual leaks result from trapped volumes. They are called virtual leaks as their effects is similar to a small leak for a short period of time during which gas is released, and in some circumstances they can hardly be distinguished from a real leak.
Typical virtual leaks result from trapped air in bores for screws or between assembled parts showing large surfaces in contact. Normally, virtual leaks will not be identified using tracer gas methods, as this gas applied to the outside will not penetrate into the trapped cavity. Virtual leaks will increase the gas load and affect pump down time or in some cases the gas can exit the trap resulting in a sudden increase of pressure in the chamber.
When installing a connector onto a vacuum system it is important to verify that no gas is trapped in the mounting area.

2.5.3 Outgassing

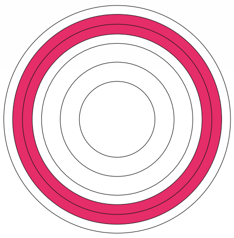
Many material used in connector design, insulating plastics, sealing resins and elastomeric seals, will absorb naturally a small quantity of water. The water molecules, as well as other gases in solution, will be released under vacuum, also called desorption, increasing the gas load in the initial pumping phase. Polymer materials contain typically 0.1-0.5% humidity, depending on grade and of course storage history. Desorption can be accelerated by baking (heating).

Fischer Connectors hermetic products are designed to minimize both effects.

3. Connector installation

Correct panel sealing can only be achieved if the contact surface for seal “a” is correctly prepared. Special care must be taken depending on manufacturing techniques. Following aspects are most commonly encountered in seal designs:

- The surface flatness shall be designed in such a way that sealing can be achieved without excessive torque required to mount the connector. Typical recommended flatness is < 0.05mm, usually not problematic for modern machining techniques.
- Machining grooves shall be circular and not perpendicular to the O-ring seal.



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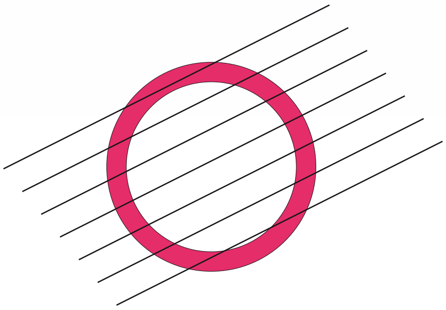

NO

If however circular machining is not possible, reasonable sealing performance can be obtained if surface roughness is < Ra 0.8 µm. Use of a vacuum grease is to be evaluated depending on the application.

- Edges and burrs of panel cut-out shall be carefully cleaned.