

Tutorial

Choosing a hermetic connector depends on many different technical considerations. This tutorial includes important theoretical explanations to help you make the most appropriate choice for your hermetic assembly.

HERMETICITY: DEFINITION & NEED

The word "hermetic" is commonly used to define a system or component that is completely gastight. However in reality, perfect hermeticity cannot be achieved. Consequently, hermetic solutions are characterized by their leak rate, and designing a hermetic system essentially consists in keeping that leak rate manageable.

Three main applications require hermeticity. Some advantages of using appropriate hermetic components in each case are presented in the table below:

Application	Advantages of reducing leaks
Vacuum barrier	- Reach lower/higher pressures
Pressure barrier	- Reduce pumping times - Reduce energy consumption - Avoid valuable gas losses
Sensitive equipment protection	- Improve reliability & performances of sensitive sensors, electronics or optical components - Increase component life time - Avoid system maintenance

For vacuum and pressure applications, the acceptable leak rate can be defined by taking into account the system lifetime and its operating pressure.

For sensitive equipment, moisture and contaminant ingress must be avoided. This is especially true in systems exposed to extreme temperatures. Indeed, a certain moisture level inside the system can cause corrosion when cooling down because of condensation. As a consequence, the acceptable leak rate must be determined by taking into account the surrounding environment, the lifetime and sensitivity of components.

Hermetic connectors are not necessarily waterproof. Please consult us!

LEAK RATE DEFINITION

A leak rate is a quantity of a gas escaping/entering per unit of time, ie. a flow:

$$\text{Leak rate} = \frac{\text{amount of gas}}{\text{time}}$$

Using the general gas equation, the quantity of gas can be expressed as follows:

$$n = \frac{P.V}{R.T}$$

Where:

- n: quantity of gas (mol);
- P: pressure (Pa);
- V: volume (m³);
- R: general gas constant (about 8.3 J.K⁻¹.mol⁻¹);
- T: temperature (K).

As a consequence at a fixed temperature, the quantity of gas entering/escaping a system can be defined by the pressure drop multiplied by the system volume.

For example, a leak rate of 1 mbar.l/s is the amount of gas removed from a 1 litre system in 1 second to reduce its pressure by 1 mbar.

Some common units and their conversion rates are presented in the table below.

	Leak rate				
	atm.cc/s	mbar.l/s	torr.l/s	Pa.m ³ /s	sccm
1 atm.cc/s	1	1	0.76	0.1	60
1 mbar.l/s	1	1	0.76	0.1	60
1 torr.l/s	1.3	1.3	1	0.13	80
1 Pa.m³/s	10	10	7.5	1	600
1 sccm	0.016	0.016	0.0125	0.0016	1

A leak rate is given for a particular gas and pressure differential. Each gas has a different leak rate through the same hole or pore due to molecular size and possible interactions with materials.

HELIUM LEAK DETECTION

The most commonly used technique and the one that allows for easy low leak rate measurement is the Helium Leak Detector (HLD). Helium is the ideal gas for testing because it is inert, small and only present at 5 ppm in the atmosphere. The test is thus safe and highly sensitive.

Axon' follows well-known standards for connector testing, for example the MIL-STD-883, method 1014.13, condition A4. The connector is fixed onto the machine port. The machine is pumped down to create a vacuum, and so the measurement is therefore carried out with a nearly 1 bar of differential pressure. Helium is then sprayed around the outside of the connector. Any helium atoms passing through the connector are then detected and measured by the mass spectrometer inside the HLD.



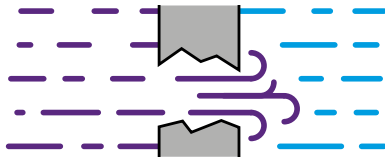
Calibration of the HLD machine is carried out every day to ensure the right leak measurement. Axon's hermetic connectors are **tested 100%** with this method and a test certificate is provided upon request.

LEAKS, MATERIALS & PROCESSING

Multiple phenomena can lead to leaks:

- Openings

When the size of the particles is smaller than the opening, they can leak through. Openings can be in materials (porosity, puncture...) or at the interface between different materials (lack of adhesion, gap, unseated O-ring...).



- Gas permeation

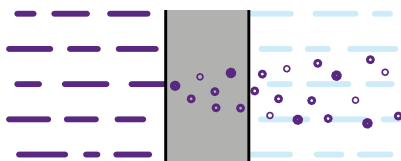
This phenomenon is complex and implies adsorption, diffusion and subsequent desorption of gas atoms or molecules. Gas will travel through the bulk of the material, even when there is no opening.

Permeation depends highly on:

- The materials & gases involved: permeation mechanisms can be different from one to another,
- Temperature.

This phenomenon is generally slow and cannot be measured by a helium test of 1 minute. It is characterized by permeability:

$$\text{permeability} = \frac{\text{amount of gas} \times \text{material thickness}}{\text{material surface area} \times \text{time} \times \text{differential pressure}}$$



Material choices, their processing and assembly are key factors to limit leaks in connectors and other hermetic components.

Metals and glasses are favored when low leak rates are required because of their lower gas permeation compared to plastics & rubbers. However, appropriate rubbers & plastics can be used in less severe applications.

- Outgassing

Some material or surface can act as a sponge and store gaseous material, this gas is then released when the system is heated or put under vacuum. This kind of leak is a "virtual leak" because the gas is evolving from the material itself due to its nature, manufacturing or storage. To avoid this, an appropriate cleaning and degassing procedure, consisting of heating in a vacuum, must be performed before system use. All materials and different gases are concerned by this phenomenon but rubbers and plastics are again the most critical.

For some applications, outgassing can be a material selection criteria. Databases from ESA (<http://esmat.esa.int/materialframe.html>) and NASA (<https://outgassing.nasa.gov/>) are available.

Outgassing is expressed as a leak rate per surface area, in mbar.l/(s.m²) for example.

HERMETIC CONNECTORS

Hermetic connectors are gas barriers that provide a way for electrical signals or power to go in and out of the system. For that, electrical insulation is key and that is why insulating materials such as glass, ceramic or polymers are typically used in conjunction with the conductive metals.

Three main families of hermetic connector exist on the market, based on different insulation materials. The table below sums up their usual characteristics.

Characteristics	Potted	Glass-to-metal seal	Ceramic brazing
Insulation material	Polymer, usually epoxy resin	Glass or glass-ceramic	Ceramic
Shell material	Aluminum, titanium, brass, stainless steel	Steel, Kovar®, stainless steel, titanium, aluminum	Kovar®, titanium, steel, Inconel
Contact material	Usual copper alloys	Kovar®, iron-nickel alloys, copper alloys	Molybdenum, platinum, copper
Best helium leak rate achieved (mbar.l/s)	10 ⁻⁸	10 ⁻¹¹	10 ⁻¹¹
Max. use temperature (°C)	80-135°C	125-300°C	>300°C
Price	€	€€	€€€

Potted connectors are a cost-effective solution when a helium leak rate lower than 10⁻⁸ mbar.l/s is not required.

Axon' offers standard ranges of potted and glass-to-metal sealed connector solutions. As an expert in the design and manufacture of cable assemblies and complex harnesses, Axon' supplies a large range of hermetic connectors, in particular with **copper alloy contacts** which are particularly recommended for their high level of conductivity.

Ceramic brazing is suitable for larger connector sizes and higher temperatures, and such applications often require a specific design. Axon' can offer ceramic brazed connectors upon request.

HIGHLY HERMETIC MICRO MINIATURE CONNECTORS

For micro miniature connectors (Micro-D) with low leak rate requirements, glass or glass-ceramic solutions are widely used. Glass and glass-ceramic can withstand high compression stresses but tensile stress must be avoided. This can be achieved in two ways:

- Matched seal

In this case, a low expansion iron-nickel-cobalt alloy called Kovar® is used for both the shell and the contacts. Thanks to a metal oxidation step, a chemical bond is made between the glass and metal. Kovar®'s thermal expansion coefficient (CTE) follows closely the CTE of the borosilicate glass insulation across a wide temperature range, making sure stress is kept to a minimum.

- Compression seal

In this case, materials are chosen so that **CTE contact** ≤ **CTE glass** ≤ **CTE shell**, in order to ensure that only the stresses of compression are applied to the glass.

The contacts are thus low expansion metals such as iron-nickel or iron-cobalt alloys. The shells are generally steel, stainless steel or Inconel. This technology makes it possible to produce bigger, thicker and more complex designs more economically.

Matched seals have excellent resistance to thermal shocks while compression seals can withstand higher mechanical shocks & pressure.

Both technologies use contacts with low electrical conductivity, consequently the current carrying capacity is limited to 1A or 1.5A in a Micro-D instead of the usual 2.5A to 3A. Furthermore, those materials are heavyweight and strongly magnetic, which is a drawback for most airborne applications and environments sensitive to magnetism.

HERMAX®: HIGH CONTACT CONDUCTIVITY AND LEAD FREE

Axon' has developed a new technology that does not meet the definition of standard "matched" or "compression" seals and has all the advantages of both: a strong chemical bond **plus** a compression from the shell material.

This technology relies on a lower sealing temperature and the use of an innovative glass-ceramic compound to deliver a number of advantages:

- Enables the use of **copper alloy contacts** which:
- Allow 3A per contact (non-derated) as specified in the Micro-D standard MIL-STD-83513;
- Have a lower electrical resistance compatible with very low voltage signals;
- Offers excellent intrinsic electrical and mechanical properties;
- Creates a highly hermetic interface with various metals (copper alloys, stainless steel, Inconel and aluminum);
- Achieves exceptionally low leak rates for harsh environment applications.

Axon's patented glass-ceramic solution is the only one on the market that is fully lead-free and **RoHS compliant**.

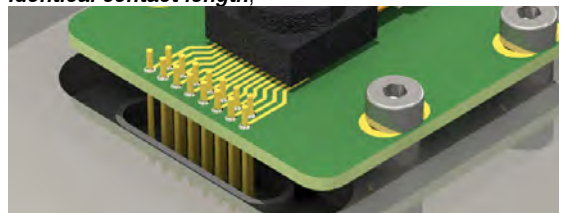
Furthermore, Axon' manufactures HermAx® connectors in Europe with **no** components subject to export regulation (**ITAR, ECL**). The connectors are fully compliant with MIL-STD-83513 tests and comfortably exceed the requirements.

Axon' is equipped with in-house testing capabilities which enable the company to perform custom qualifications according to customers' needs. Axon' can test and qualify connectors to typical environments. Do not hesitate to contact us for further information.

PCB INTEGRATION

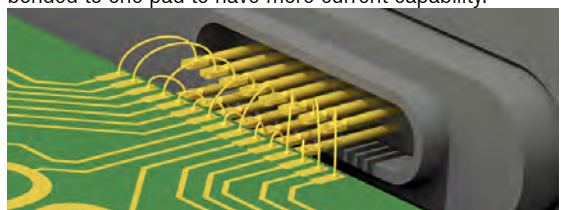
Axon' offers pin connectors with several rear termination configurations:

- Identical contact length,

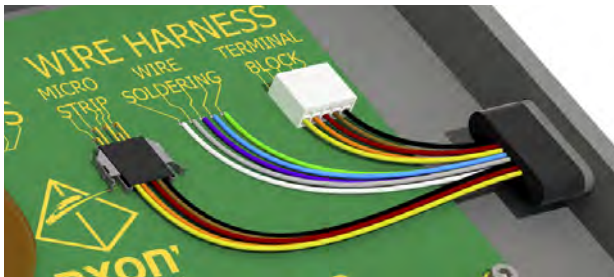


▲ Example of PCB mounted behind a connector welded to a flange

- **Stepped contact length** facilitate row-by-row insertion into the PCB holes,
- **Stepped diameter ends** for direct PCB mount with thinner diameter pin end, allowing only the tip to pass through the PCB hole for soldering,
- **Flat ends** (see hereafter) with a special pure gold plate for wire bonding applications. Multiple wire can be bonded to one pad to have more current capability.



Pigtail connectors (pre-terminated to a specified length of wire) or harnesses are also available.



▲ Example of Hermax® pigtail integration inside a package

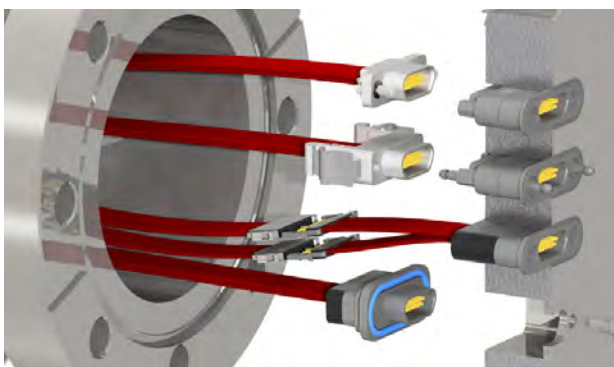
Microstrip (see our Micro-D & Nano-D catalogue) has the advantage to get through the connector welding hole and to be fast to connect.

Direct wire soldering or connecting to a terminal block can be used for prototyping or low volume production.

Hermax® Micro-D can accommodate Flex or Flat Flexible Cables.



FEEDTHROUGH INTEGRATION



Combined with the male Twist Pin connectors, a complete solution withstanding the harshest of environments can be offered by Axon'.



▲ Twist pin contact

As a solution for dismantability from each side of the system or panel, a Hermax® saver or dual socket connector is recommended.



For quick & secure connection/disconnection of connectors, fast-latching D-Click versions are available in sizes up to 37 ways.



As a vertically integrated company, Axon' has specialized not only in the design of connectors but also in the manufacture of conductors, cables and complex harnesses for 50 years. Axon' engineers are then able to integrate hermetic connectors into the design of tailor-made assemblies.



▲ Example of a Micro-D Hermax® connector terminated with two microstrip connectors

Any termination can be added to the wire end, providing that it can go through the laser welding cutout.



▲ Example of a Micro-D Hermax® O-ring feedthrough terminated with a standard Micro-D connector

SEALING SOLUTIONS

Hermetic connectors can only be as good as their mounting on the panel.

O-ring feedthrough can be assembled and removed from the panel, thus assuring great reparability.

Rubber seals have a high permeability and a reduced lifetime. It is recommended to use them only with **potted connectors** or in applications where the connector must be dismantable. In most cases, laser welding is the preferred option for Hermax® connectors. **Laser welding** delivers the most compact solution and covers a higher temperature range.

Axon's stainless steel 304L connector shells allow reliable and repeatable welding onto systems or panels in both 304L and 316L with well-known laser technologies.

When a rubber gasket cannot be avoided, the material should be chosen to reduce permeation but should also be adapted to the system temperature range.

FKM (fluoroelastomer), is a widely used rubber for hermetic integration. Its temperature range goes from -30°C to +200°C. However, because of permeation, even when using FKM the best helium leak rate we could expect would be around 10⁻⁷mbar.l/s. And any increase in temperature would increase that leak rate still further.

For applications requiring lower temperatures, the use of a silicon O-ring can be considered, with a temperature range spanning -55°C to +200°C. However, silicone exhibits faster permeation and higher permeability to most gases, leading to a drop in hermeticity. Oxygen permeability is even higher in silicone than helium permeability, whatever the temperature. Silicone must therefore be avoided for protection against oxygen.

***HermAx® connector integration:
laser welding versus O-ring mounting***

	Laser welding	O-ring mounting
Dismountability	No	Yes
Helium leak rate	As specified for connector <1.10 ⁻⁹ mbar.l/s	Depending on material choice Example for FKM: < 5.10 ⁻⁷ mbar.l/s
Temperature range	As per connector -55° to +125°C (and higher)	Depending on material choice Example for FKM: -30° to +125°C (and higher)
Compactness	++	+
Reliability	++	+

Axon' can advise on the most suitable integration solution for your application. In addition, Axon' can take care of laser welding our **HermAx® connectors** directly on to your system or panel or supply the connectors already welded onto standard or specific flanges.



▲ Laser welded HermAx® connector

**KEY DATA TO DESIGN
THE VERY CONNECTOR YOU NEED**

In order to offer you the most appropriate hermetic connector solution, our engineers will ask you the following questions:

- Maximum acceptable helium leak rate;
- Temperature range;
- Material used for panel or system enclosure;
- Pressure or vacuum applied on each side;
- Number of contacts needed;
- Electrical integration considered (connector/contact type), type & value for voltage & current;
- Connector panel integration considered (laser welding or O-ring);
- Requested lifetime.

For Axon' to be able to fully optimize the design of our HermAx® connectors in your application, please let us know if your system is exposed to special environmental conditions including:

- Special thermal shock;
- Special vibration & mechanical shock;
- Other special environments (such as fluids, radiation, etc.)

Contact: sales@axon-cable.com

