

Understanding Leakage

Leakage is the flow of a fluid through an orifice or permeation through a material and typically occurs as a result of a pressure differential. It is important to understand that all materials and mechanical joints permit some leakage over a period of time. This leakage may range from as much as several gallons or cubic feet per minute to as little as a bubble of air in several years.

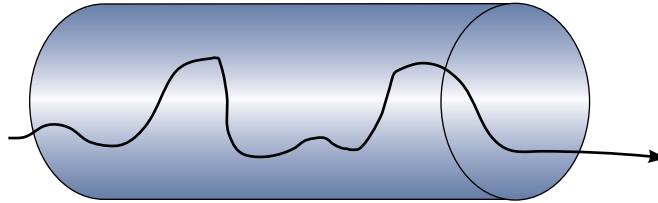
Helicoflex designs and manufactures a wide range of seals to satisfy a broad range of sealing requirements including leakage rate. Therefore, it is necessary to establish leakage rate criteria so that a suitable seal can be selected or designed. A specification that defines a “no leak” or “zero leakage” requirement is, in a technical sense, unrealistic and may lead to costly attempts at sealing. Leak tightness must be considered in relation to the medium being sealed, the normal operating conditions, and the sealing requirements regarding safety, contamination, and reliability.

Gas Flow

Gas flow is used in characterizing leakage and performing leakage testing. Even at very low pressures, gases behave and flow like fluids. Gas flow is categorized into different types of flow modes as follows:

Flow Mode	Flow Description	Leakage Rate (std cc/sec)
Turbulent Flow (Viscous Flow)	Flow through a passage that is typified as a large leak and at high pressure differentials. Leaks with turbulent flow are large and can be readily located and repaired.	Greater than 10^{-2}
Laminar Flow (Viscous Flow)	Flow in a passage that is typified by slow movement of fluid in a relatively straight path along the centerline of a passage.	10^{-1} to 10^{-6}
Transitional Flow	Flow that occurs between the laminar and molecular flow regimes.	10^{-4} to 10^{-7}
Molecular Flow	At molecular flow each molecule travels independently of other molecules. However, the general flow is in direction of the lower pressure.	Less than 10^{-7}

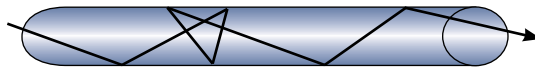
Note: Both turbulent flow and laminar flow are types of viscous flow.



Path of a molecule through a leak path in turbulent flow.



Path of a molecule through a leak path in laminar flow.



Path of a molecule through a leak path in molecular flow.

Viscosity: Why liquids and gases have different leakage rates

Viscosity is the internal friction of molecules of a liquid or gas and characterizes the resistance of a fluid to flow at a given temperature. High viscosity indicates a greater resistance to flow and low viscosity indicates a lesser resistance to flow. Therefore, fluids with a low viscosity have a higher probability of leaking or flowing at a higher rate.

Examples of typical fluid viscosities at room temperature (68°F, 20°C):

Fluid	Viscosity (in centipoises) at 68°F, 20°C
SAE 10 Grease	65
Water	0.95
Gasoline	0.6
Liquid Propane	0.11
Helium	0.019
Air	0.018
Hydrogen	0.009

From the above viscosity values it can be seen that at ambient temperature, water has a viscosity that is approximately 53 times greater than air. Therefore, at low pressure, the volume of water flow will be 53 times less than that of air.

Equivalent Leakage Rates

Std cc/sec*	mbar-l/sec	Torr Liters/sec	Time for one cc to Leak	Time for one bubble** to leak
10 ⁻¹	1.01 x 10 ⁻¹	7.6 x 10 ⁻²	10 seconds	0.25 seconds
10 ⁻²	1.01 x 10 ⁻²	7.6 x 10 ⁻³	100 seconds	2.5 seconds
10 ⁻³	1.01 x 10 ⁻³	7.6 x 10 ⁻⁴	16.7 minutes	25 seconds
10 ⁻⁴	1.01 x 10 ⁻⁴	7.6 x 10 ⁻⁵	2.8 hours	4 minutes
10 ⁻⁵	1.01 x 10 ⁻⁵	7.6 x 10 ⁻⁶	28 hours	40 minutes
10 ⁻⁶	1.01 x 10 ⁻⁶	7.6 x 10 ⁻⁷	11.5 days	7 hours
10 ⁻⁷	1.01 x 10 ⁻⁷	7.6 x 10 ⁻⁸	3.8 months	3 days
10 ⁻⁸	1.01 x 10 ⁻⁸	7.6 x 10 ⁻⁹	3.2 years	1 month
10 ⁻⁹	1.01 x 10 ⁻⁹	7.6 x 10 ⁻¹⁰	32 years	9 months
10 ⁻¹⁰	1.01 x 10 ⁻¹⁰	7.6 x 10 ⁻¹¹	320 years	8 years
10 ⁻¹¹	1.01 x 10 ⁻¹¹	7.6 x 10 ⁻¹²	3200 years	80 years

* Std cc/sec = One cubic centimeter of gas flow per second at 14.7 psi of pressure and a temperature of 77°F

** Bubble diameter is 3mm

Leak Legend	Approximate Leak Rates per meter of circumference	Actual leak rate in service will depend on the following:
Ultra-Helium	≤ 1 x 10 ⁻¹¹ std.cc/sec He	Seal Load: Wall Thickness or Spring Load Surface Finish: Seal and Cavity Surface Treatment: Coating/Plating/Jacket Material
Helium	≤ 1 x 10 ⁻⁹ std.cc/sec He	
Bubble	≤ 1 x 10 ⁻⁴ std.cc/sec He	
Low Bubble	≤ 25 cc/sec @ 50 psig Nitrogen per inch of diameter	

Conversion of helium leakage rate to leakage rates of other gases

To Convert to Leakage Rate of:	Multiply Helium Leakage Rate by:	
	Laminar Flow	Molecular Flow
Argon	0.88	0.316
Air	1.08	0.374
Nitrogen	1.12	0.374
Water vapor	2.09	0.469
Hydrogen	2.23	1.410

Sources:

1. Leakage Testing Handbook, Prepared for Liquid Propulsion Section, Jet Propulsion Laboratory, National Aeronautics and Space Administration, Pasadena, California
2. Nondestructive Testing Handbook, Volume One, Leaktesting, American Society for Nondestructive Testing.
3. Leakage Testing Handbook, Revised Edition, July 1969, General Electric.
4. Fluid Flow in Small Passages, Mars Hablanian, J.W.Marr, Varian