LACO TECHNOLOGIES

TECHNICAL REFERENCE GUIDE

LEAK TESTING

VISCOUS VS. MOLECULAR FLOW LEAKS

The flow regime encountered in leak testing is often difficult to determine. It can, however, be estimated by calculating the average mean free path of the gas molecule (l) divided by the estimated leak path diameter (d). Use the following guidelines to determine the flow regime.

VISCOUS FLOW leaks typically occur in systems leaking at atmosphere or larger pressures ($l/d < 0.01$). Viscous leaks are typically larger than 10^{-5} atm-cc/sec, but can occur at lower leak rates.

MOLECULAR FLOW leaks typically occur under vacuum conditions ($l/d > 1.00$). Molecular leaks are typically smaller than 10^{-5} atm-cc/sec.

TRANSITIONAL FLOW occurs between viscous and molecular flow regimes ($0.01 < l/d < 1.00$).

HELIUM LEAK RATE VS. OTHER GASES

CONVERT TO	MULTIPLY HELIUM LEAK RATE BY:	
	VISCOUS FLOW	MOLECULAR FLOW
Argon	0.883	0.316
Neon	0.626	0.447
Hydrogen	2.23	1.41
Nitrogen	1.12	0.374
Air	1.08	0.374
Water Vapor	2.09	0.469

LEAK RATE VS. PRESSURE

Viscous Flow: $Q_V = K/n\,(P_1^{\,2} - P_2^{\,2})$

Molecular Flow: $Q_M = K(T/M)^{1/2}\,(P_1 - P_2)$

Where:

- Q = Leak Rate
- K = Constant relating leak path geometry
- n = Gas Viscosity
- M = Gas Molecular Weight
- T = Absolute Temperature
- $P_{1,2}$ = Upstream and Downstream Absolute Pressure

Example: A helium leak in the viscous flow regime with 10 atm upstream (internal) and 1 atm downstream pressure has a leak rate of 0.001 atm-cc/sec. If the upstream pressure was doubled to 20 atm the new leak rate would be:

$$Q_{V'NEW} = Q_{V'OLD}\,((P_{1'NEW}^{\;2} - P_{2'NEW}^{\;2})/(P_{1'OLD}^{\;2} - P_{2'OLD}^{\;2}))$$

$$Q_{V,NEW} = 0.001\,((20^2 - 1^2)/(10^2 - 1^2)) = 0.004 \text{ atm-cc/sec}$$

Using the table above the equivalent leak rate for air under the same conditions is: $Q_{V,AIR} = 0.004\,(1.08) = 0.0043$

LEAK RATE CONVERSIONS

CONVERT FROM	MULTIPLY BY	CONVERT TO
atm-cc/sec	1.013	mbar-liter/sec
atm-cc/sec	0.76	torr-liter/sec
torr-liter/sec	1.13	mbar-liter/sec
Pa-M3/sec	9.87	atm-cc/sec
Air oz/yr	6.96×10^{-4}	atm-cc/sec
atm-cc/sec	60	sccm

EQUIVALENT LEAK RATES

Freon R12 Leakage (oz/year)	Immersion (Time to form 1 bubble)	Helium Leak Rate (atm-cc/sec)	Bubble Air Leak Rate* (atm-cc/sec)
10.00	13.3 seconds	1.8×10^{-3}	6.7×10^{-4}
3.00	44.3 seconds	1.5×10^{-3}	2.0×10^{-4}
1.00	133 seconds	1.8×10^{-4}	6.7×10^{-5}
0.50	266 seconds	9.0×10^{-5}	3.3×10^{-5}
0.10	22.2 minutes	1.8×10^{-5}	6.7×10^{-6}
0.01	222 minutes	1.8×10^{-6}	6.7×10^{-7}

NOTE: Leak rates are approximate and based on similar test conditions.
* Leak rates calculated based on molecular flow

COMPARISON OF COMMON PRODUCTION LEAK TESTING METHODS

METHOD	MINIMUM DETECTABLE LEAK*	LEAK RATE MEASUREMENT	LEAK LOCATION
Air Pressure Decay	0.001**	Yes	No
Air Mass Flow	0.01	Yes	No
Bubble Immersion	10^{-4}	No	Yes
Helium Mass Spec Sniffing	10^{-7}	Yes	Yes
Helium Mass Spec Accumulation	10^{-4}**	Yes	No
Helium Mass Spec Hard Vacuum	10^{-9}	Yes	No

* atm-cc/sec
** Minimum detectable leak is volume dependent

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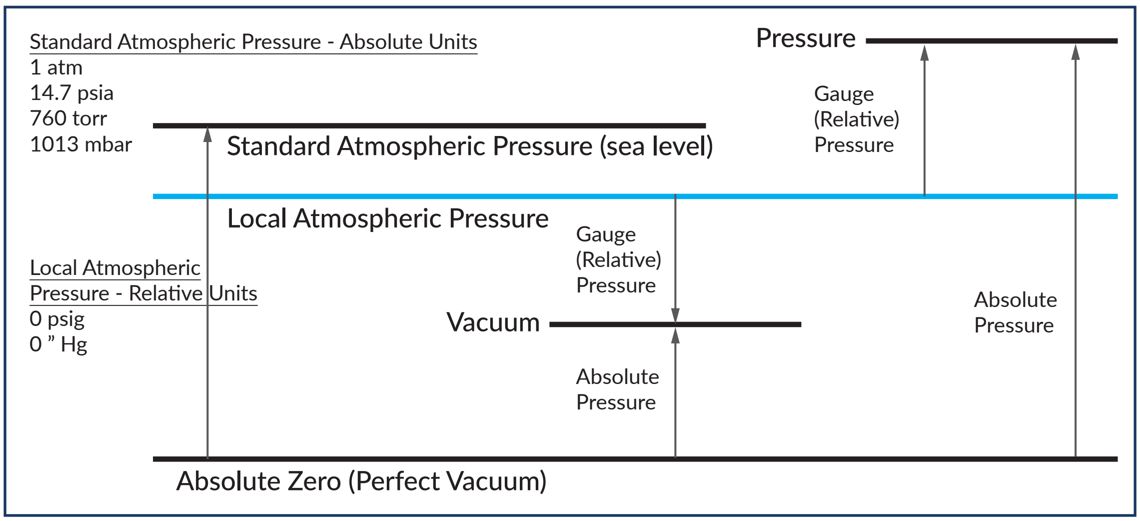
PRESSURE CONVERSIONS

TO / CONVERT FROM	pascal	torr	atm	mbar	micron	psia	in. Hg Ab.
pascal (newton/m^2)	1	7.5x10^{-3}	9.87x10^{-6}	0.01	7.5	1.45x10^{-4}	2.95x10^{-4}
torr (mm Hg)	133	1	1.315x10^{-3}	1.333	1000	0.01934	0.0394
atmosphere (atm)	1.013x10^{5}	760	1	1013	7.6x10^{5}	14.7	29.92
millibar (mbar)	100	0.75	9.87x10^{-4}	1	750.1	0.0145	0.0295
micron	0.1333	0.001	1.316x10^{-6}	1.333x10^{-3}	1	1.934x10^{-5}	3.94x10^{-5}
psia	6.89x10^{3}	51.71	0.068	68.9	5.171x10^{4}	1	2.036
in.Hg Ab	3.39x10^{3}	25.4	0.03342	33.9	2.54x10^{4}	0.4912	1

ELEVATION VS VACUUM LEVEL

Elevation (ft.)	Max. Relative Vacuum (in Hg)	Percent Loss
0 (sea level)	29.92	0
1,000	28.85	3.6
2,000	27.82	7.0
3,000	26.82	10.4
4,000	25.84	13.6
5,000	24.89	16.8
6,000	23.98	19.9
7,000	23.06	22.9
8,000	22.20	25.7
9,000	21.38	28.5
10,000	20.58	31.2

ABSOLUTE VS RELATIVE VACUUM/PRESSURE



Quick Rules of Thumb

- Torr = 75% of Mbar
- 1000 millitorr = 1 Torr
- 1000 millibar = 1 bar
- 1 bar = 1 atmosphere
- Millitorr = Micron
- 1 psi = 2" Hg
- 25 torr = 25 mm Hg = 1" Hg
- mm Hg = Torr

GAS FLOW (PUMPING SPEED) CONVERSIONS

TO / CONVERT FROM	m^3/sec	liter/sec	m^3/hr	cfm
m^3/sec	1	1.000	3,600	2.12 x 10^3
liter/sec	0.001	1	3.6	2.12
m^3/hr	2.78 x 10^{-4}	0.278	1	0.589
cfm (feet^3/min)	4.72 x 10^{-4}	0.47	1.70	1

Conductance

- Components In Series: $1/C_T = 1/C_1 + 1/C_2$
- Components In Parallel: $C_T = C_1 + C_2$
- Effective Pump Speed: $1/S_e = 1/C + 1/S$

Quick Rules of Thumb

- 2 liter/sec = 1 CFM
- 60 liter/sec - 1 liter/min
- 2 CFM = 1 m^3/hr

Determining Flow Regime in a Vacuum System

Multiply pressure (mbar) X pipe diameter (cm)

- Viscous Flow = > 0.66
- Conductance decreases with pressure
- Molecular Flow = < 0.02
- Conductance is constant
- Transitional Flow is between Viscous and Molecular Flow

Basic Gas Laws

- Boyle's Law: $P_1V_1 = P_2V_2$ at constant Temperature
- Charles' Law: $V_1/T_1 = V_2/T_2$ at constant Pressure
- Dalton's Law of Partial Pressures: In a mixture of gases that do not react chemically, each gas exerts its own pressure, as if no other gas were present. The total pressure of the mixture is the sum of the partial pressures of the constituent gases.

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