The US Particle Accelerator School
Estimating Gasloads

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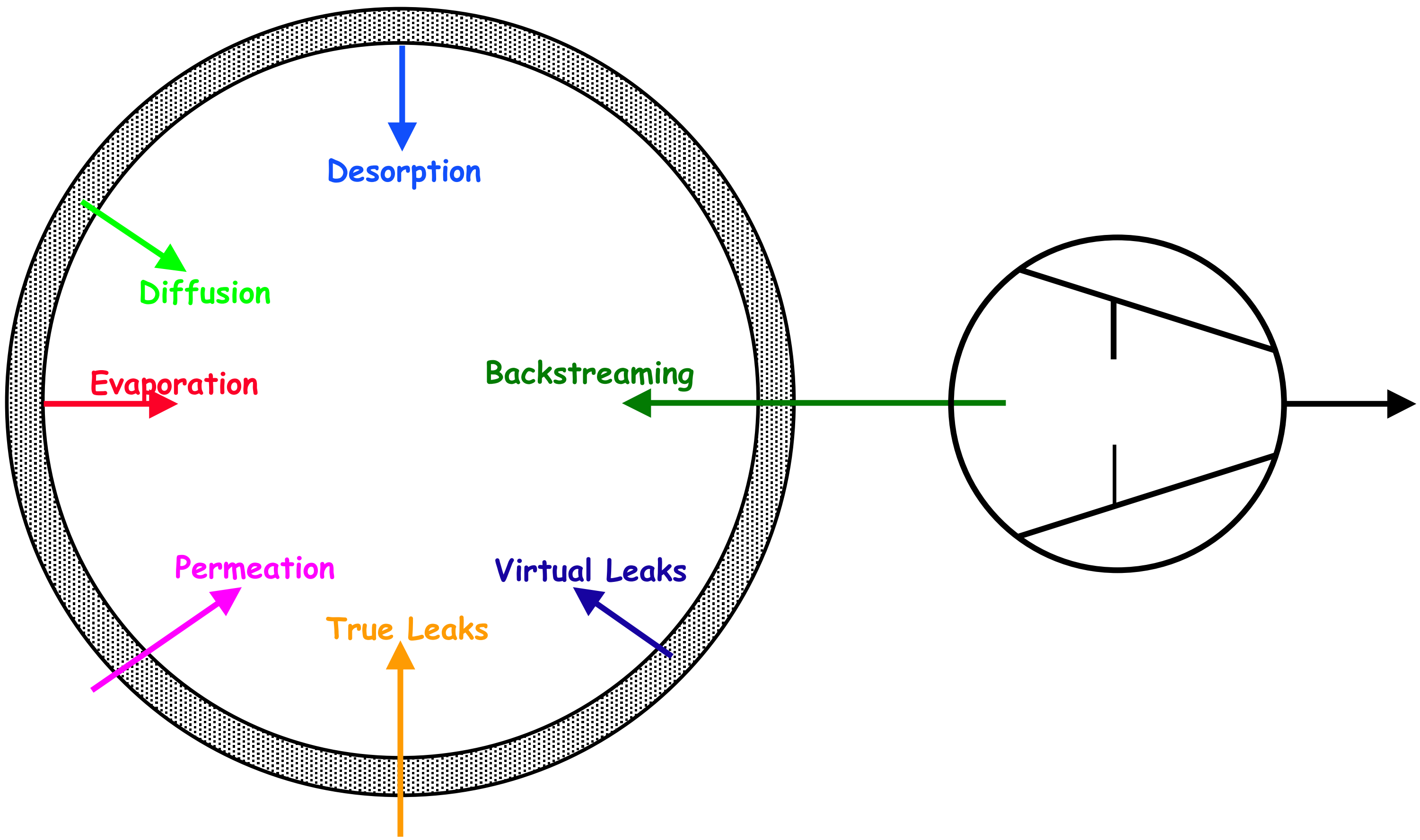
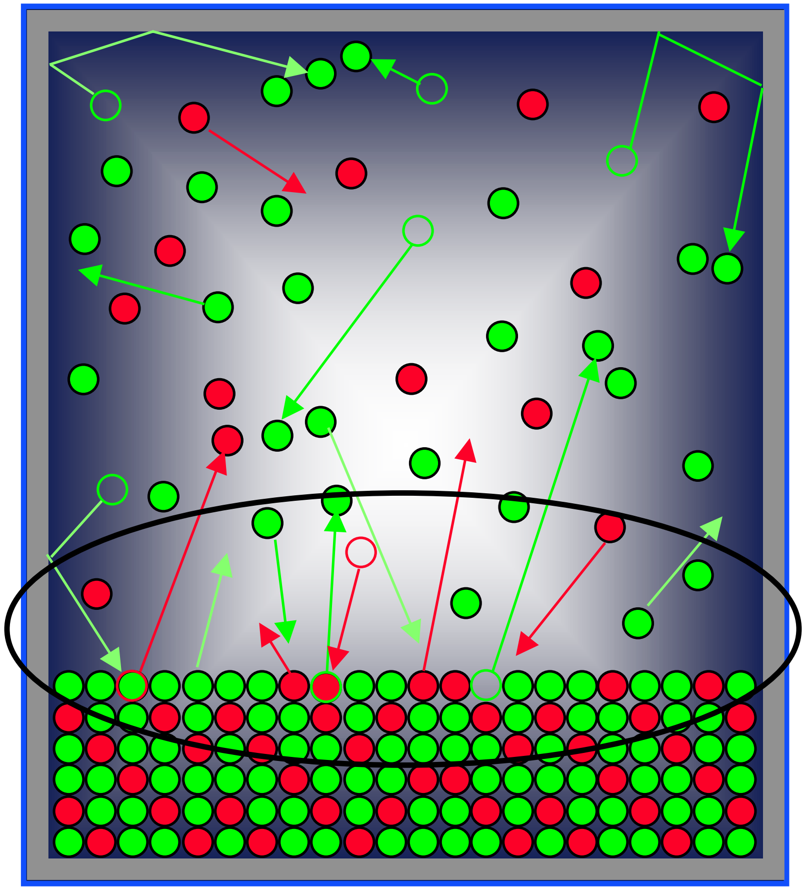
Sources of Gas in a Vacuum System



Desorption (outgassing)

- Desorption is the evolution of adsorbed gas from the internal surfaces of a vacuum vessel.
- Desorption is a function of :
  - Gas molecule characteristics
  - Surface material
  - Surface treatment
  - Surface temperature
  - Exposure time at vacuum
- High temperature bakeout under vacuum is required to desorb gasses in the shortest possible time.

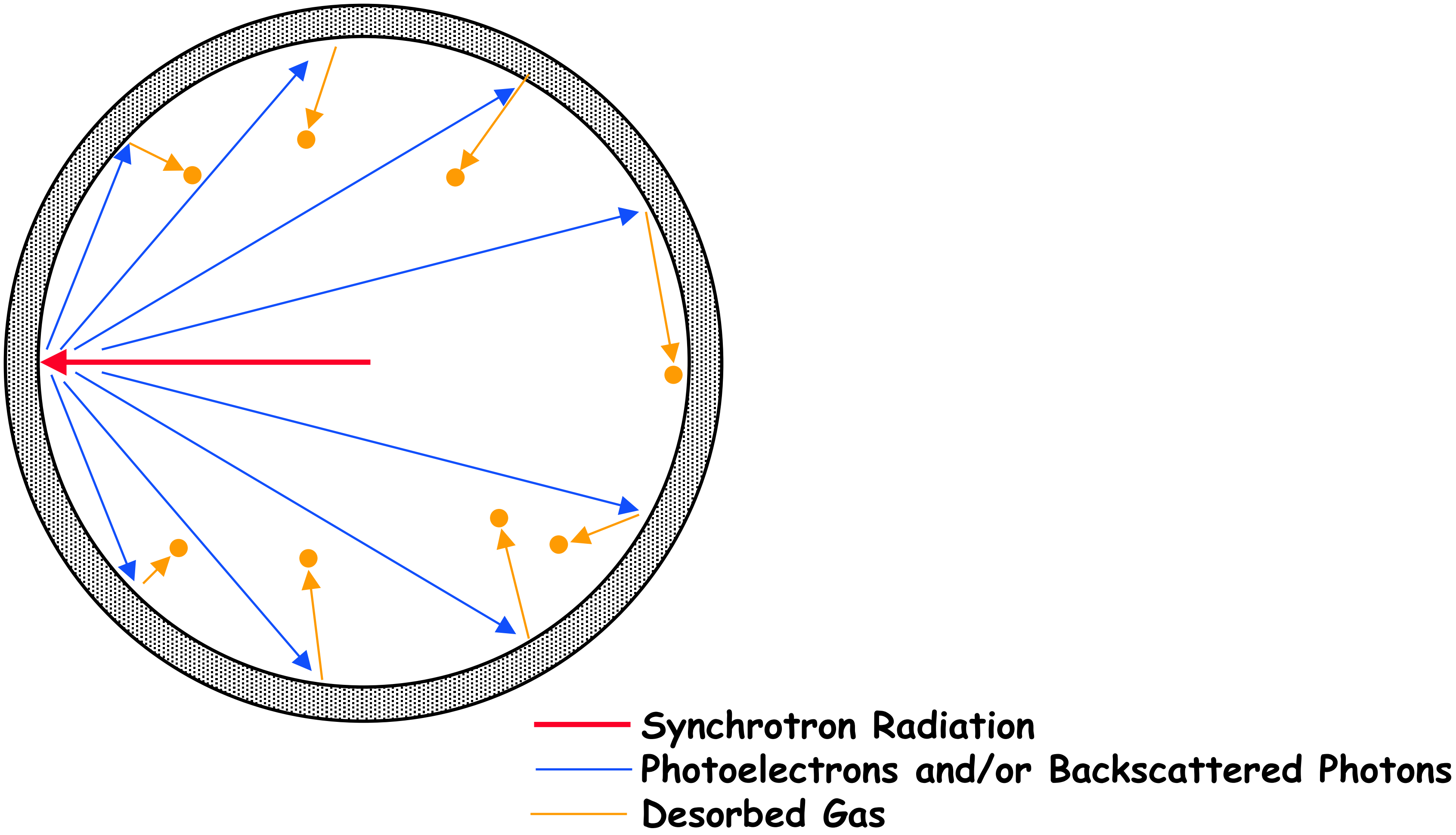


Use Published Desorption Data for comparative purposes only

Metals and Glasses	Desorption Rate (mBar-l/sec- cm^2 x 10^{-10}) 1 hr @ vacuum	4 hrs @ vacuum
Aluminum	80	7
Copper (mech. polished)	47	7
OFHC Copper (raw)	266	20
OFHC Copper (mech. polished)	27	3
Mild Steel, slightly rusty	58,520	199
Mild Steel, Cr plate (polished)	133	13
Mild Steel, Ni plate (polished)	40	4
Mild Steel, Al spray coating	798	133
Molybdenum	67	5
Stainless Steel (unpolished)	266	20
Stainless Steel (electropolished)	66	5
Molybdenum glass	93	5
Pyrex (Corning 7740) raw	99	8
Pyrex (Corning 7740) 1 mo. At Atm.	16	3

Ref. “Modern Vacuum Practice”, Nigel Harris, pg 240

Photon Stimulated Desorption



Photon Stimulated Desorption

$$N_\alpha = \frac{(P_{SR})(l)(6.242\text{x}10^{15}\ \text{KeV/Joule})}{\varepsilon}$$

where N_a = photon dose (photons/sec)

P_{SR} = Synchrotron Radiation Power (Watts/cm)

l = element length (cm)

ε = average photon energy = $0.308(2.218\ E^3/r)$ (keV/photon)

E = beam energy (GeV)

r = magnetic bend radius (m)

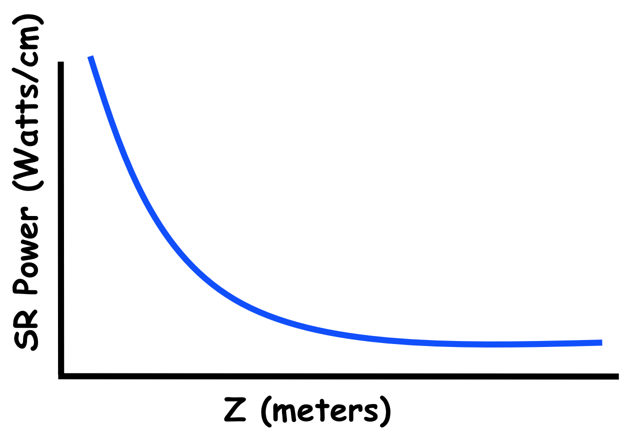
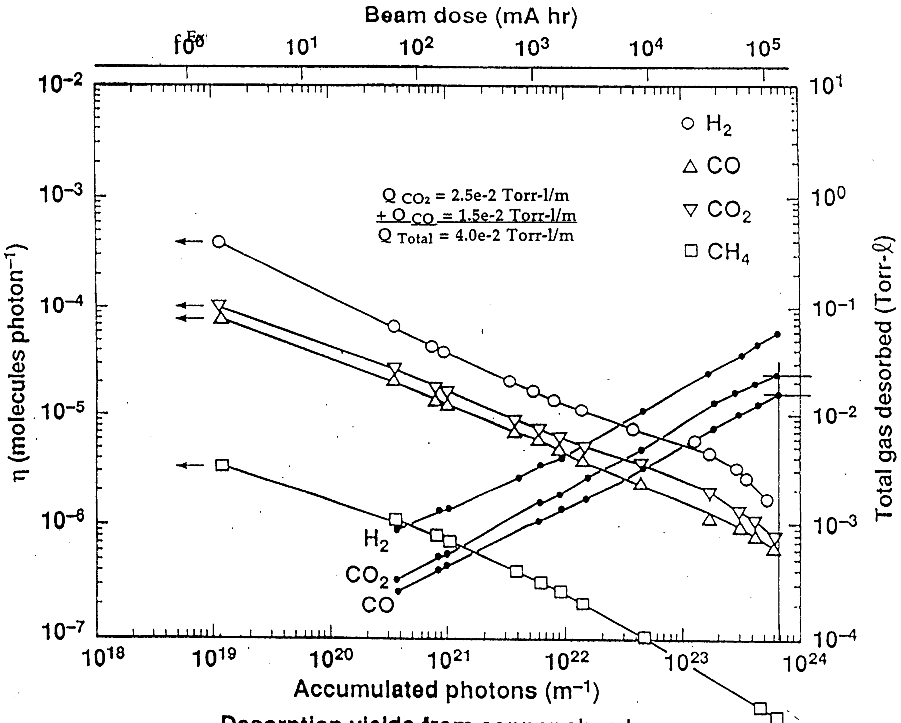


Photo-desorption rates vary with dose



Desorption yields from copper chamber (C10100) with glow discharge cleaning

"Eta-Leveling"

$$\eta_i = \eta_{base}\left(\frac{Peak\ P_{SR}}{P_{SR_i}}\right)^n$$

where η = photo-desorption coeff. (molecules/photon)

P_{SR} = Synch. Rad. Power (Watts/cm)

Photon Stimulated Desorption

$$Q_i = N_\gamma \eta_i \left(\frac{22.4 \text{ liters} \times 760 \text{ Torr}}{6.02 \times 10^{23} \text{ molecules}} \right)$$

where Q_i = Photon Stimulated Desorption (Torr - liters/sec)

N_γ = Photon Dose (photons/sec)

η_i = Photo - desorption Rate (molecules/photon)

Evaporation

$$Q_E = 3.639\sqrt{\frac{T}{M}}(P_E - P)A$$

where Q_E = gasload due to evaporation (Torr-liters/sec)
T = temperature (K)
M = molecular weight (grams/mole)
P_E = vapor pressure of material (Torr)
P = pressure (Torr)
A = surface area of material evaporating (cm^2)

Leakage

True Leaks are steady-state gas loads, which limit the ultimate pressure of a vacuum system.

There are two categories of leaks in a vacuum system:

1. External Leaks or True Leaks (Q_{Lt})

   $Q_{Lt} > 10^{-5}$ Torr-liter/sec   laminar flow leak

   $Q_{Lt} < 10^{-8}$ Torr-liter/sec   molecular flow leak

Ref. "Vacuum Technology and Space Simulation", Santeler et al, NASA SP-105, 1966

Leakage (continued)

2. Internal Leaks or Virtual Leaks (Q_{Lv})

$$Q_{Lv} = \frac{P_a V}{et}$$

where Q_{Lv} = gasload due to virtual leak (Torr-liters/sec)

P_a = pressure of trapped gas (Torr)

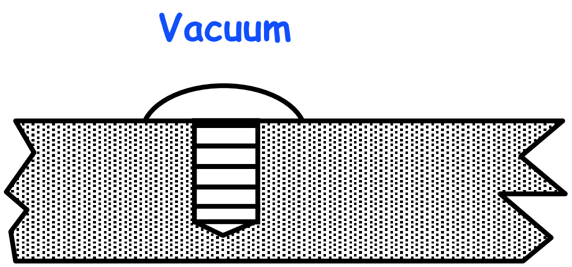
V = volume of trapped gas (liters)

e = 2.7183 base to natural logarithm

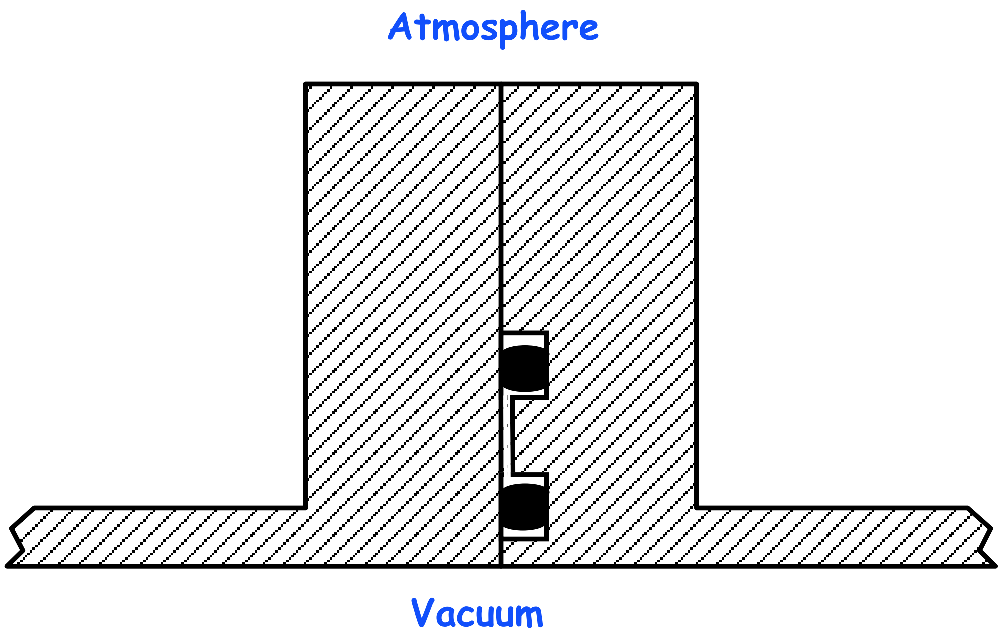
t = time (sec)

Ref. "Vacuum Technology and Space Simulation", Santeler et al, NASA SP-105, 1966

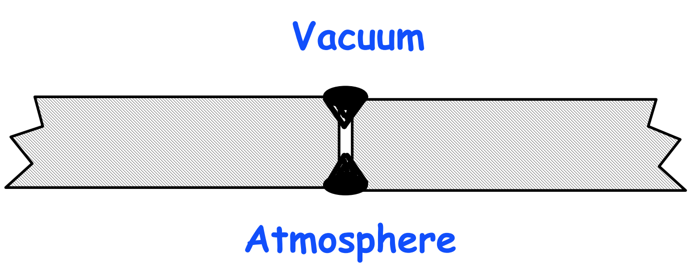
Examples of Virtual Leaks



Unvented Screw



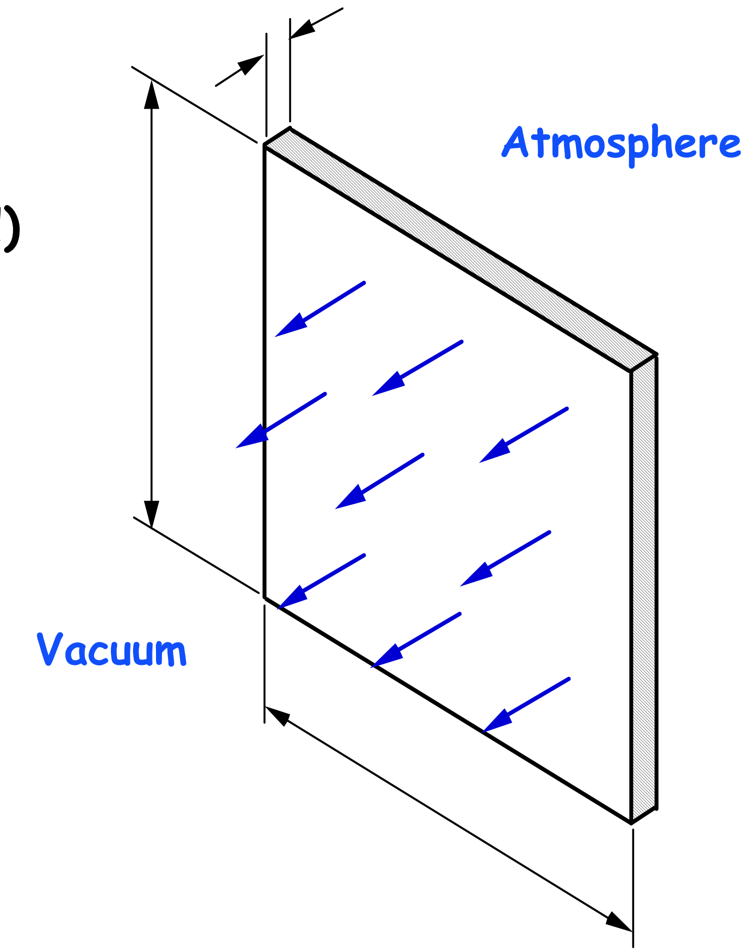
Unvented Double O-rings



Two Welds in Series

Permeation is the transfer of a fluid through a solid

- Material combination (fluid & solid)
- Temperature
- Permeation thickness
- Area
- Pressure differential



O-rings

- Fluorocarbon Rubber (Viton , Kalrez)
  Working temperature range -40 to 200°C
  Hardness: Shore A-78

- Nitrile (Buna N)
  Working temperature range -55 to 135°C
  Hardness: Shore A-70

- Silicone Rubber (Silastic, Silplus)
  Working temperature range -114 to 232°C
  Hardness: Shore A-72

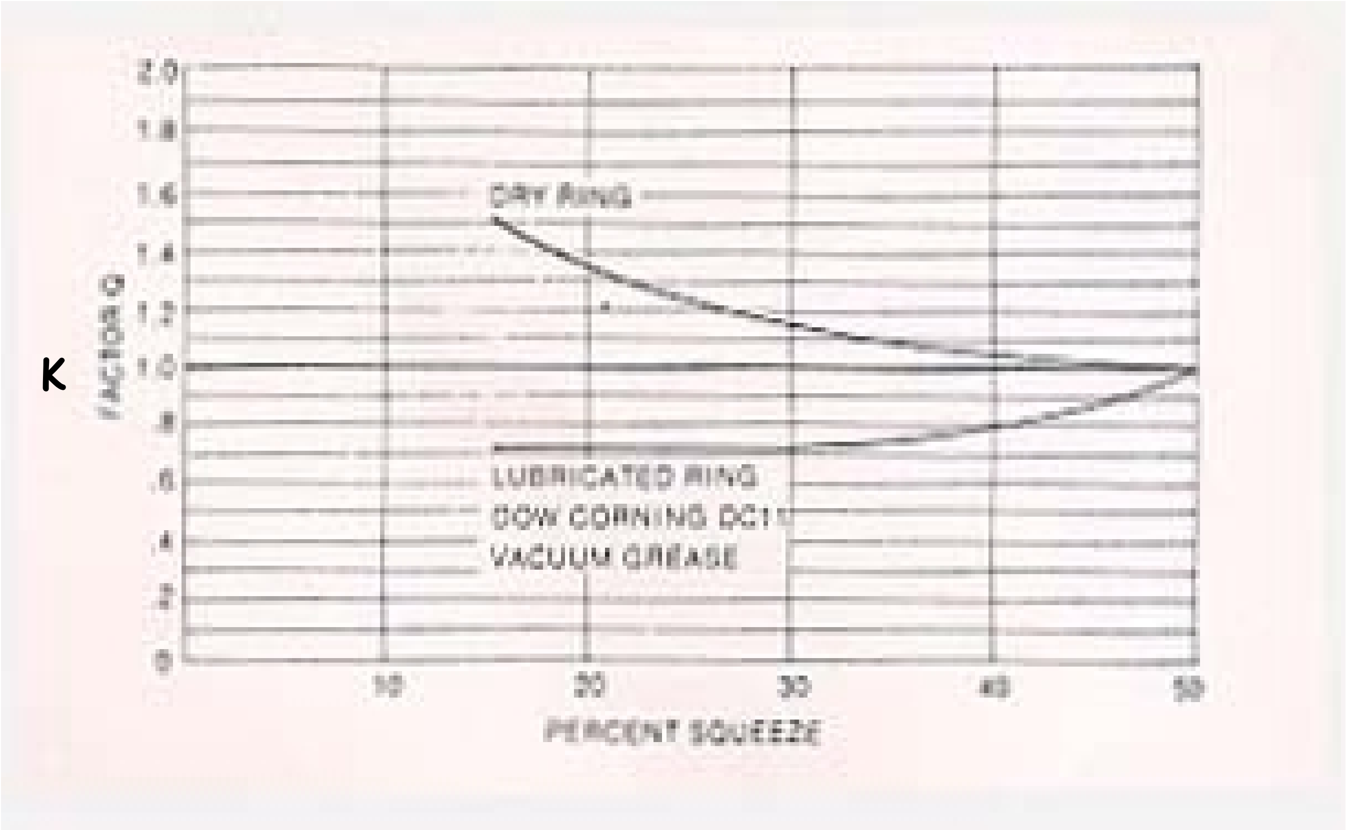
O-ring Permeation Leak Rate Approximation

$$Q_P = 0.7FD(\Delta P)\,K(1 - S)^2$$

where	Q	=	leak rate (std cc/sec)
	F	=	permeability rate for a specific gas through a specific elastomer at a specific temperature (std cc-cm/cm^2 sec bar)
	D	=	o-ring dia. (in)
	DP	=	pressure differential across o-ring (psi)
	K	=	factor depending on % squeeze and lubrication (see next slide)
	S	=	% squeeze

Ref. Parker O-ring Handbook

Effect of Squeeze and Lubrication on O-ring Permeability Leak Rate



Ref. Parker O-ring Handbook

Example Calculation of O-ring Permeability

What is the approximate H_2 permeability rate of a 10" diameter Viton o-ring (no lubrication, with a 20% squeeze) at a Δp = 14.7 psi?

F = 160×10^{-8} std cc-cm from Parker Table A2-4

D = 10" diameter

Dp = 14.7 psi

K = 1.35 from Parker Figure A2-2

S = 0.20

$$Q = 0.70FD(\Delta P)K(1 - S)^2$$

$$Q = 0.70\left(160 \times 10^{-8}\ \frac{\text{std cc - cm}}{\text{cm}^2 - \text{sec} - bar}\right)(10")(14.7\ \text{psi})(1.35)(1 - 0.20)^2$$

$$Q = \left(1.42 \times 10^{-4}\ \frac{\text{std cc}}{\text{sec}}\right)\left(\frac{liters}{1000\ cc}\right)\left(\frac{760\ \text{Torr}}{\text{Std Atm}}\right)$$

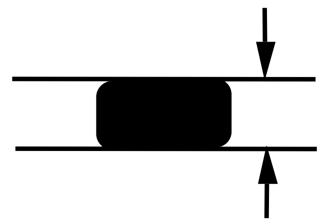
$$Q = 1.08 \times 10^{-4}\ \frac{\text{Torr - liters}}{\text{sec}}$$

O-ring Seal Design Considerations

- The leak rate through an o-ring is dependent on the following:
  1. % squeeze
  2. Lubricated or dry

- Increased o-ring squeeze decreases permeability by increasing the path length the gas has to travel.

- Increased o-ring squeeze also decreases the exposed area available for gas entry.

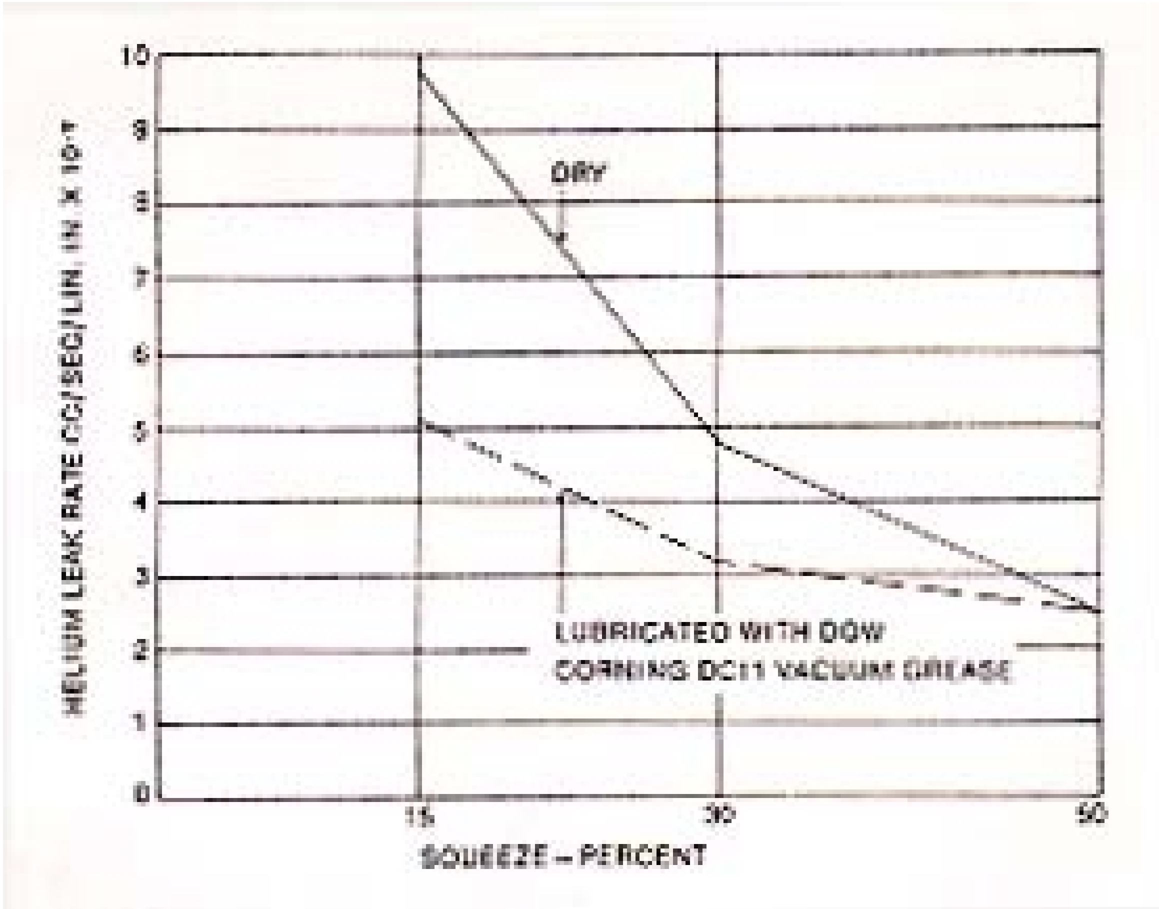


- Increased o-ring squeeze also forces the elastomer into the microscopic irregularities in the sealing surface.

O-ring Seal Design Considerations

- Face-type o-ring seals are recommended.
- Use as heavy a squeeze as possible on the o-ring cross-section.
- When a heavy squeeze is not possible, then (and only then) consider lubrication.
- A heavy squeeze requires heavy flange construction .
- Two o-rings in series can drastically reduce permeation.

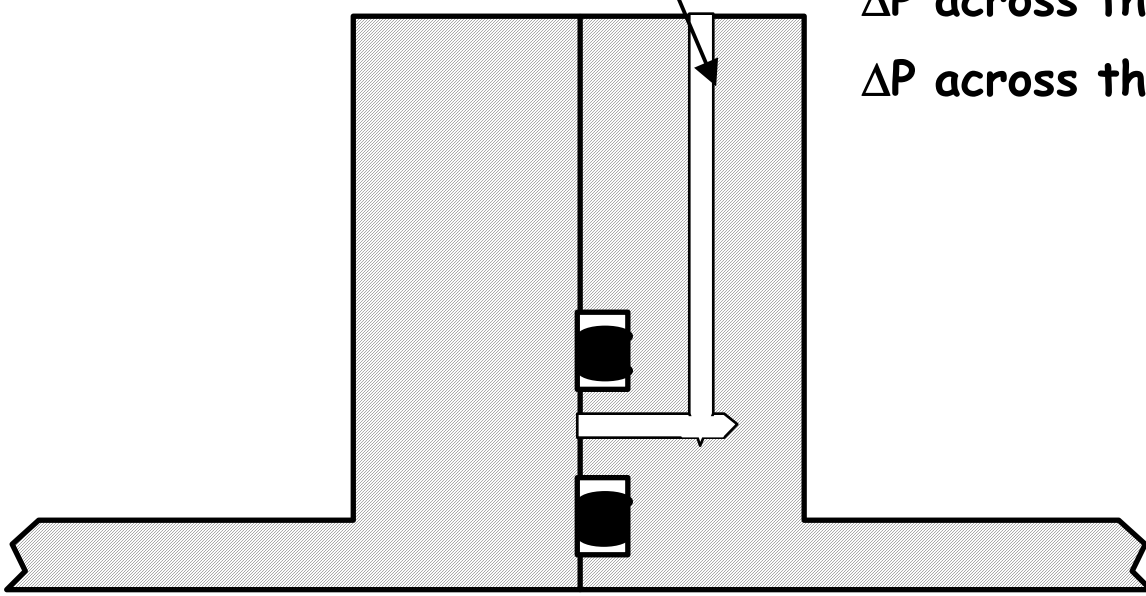
Helium Permeation Rate vs. % Squeeze



Ref. Parker O-ring Handbook

Multiple O-ring Seals

Connect to guard vacuum



$$Q_P = 0.7FD(\Delta P)\,K(1 - S)^2$$

ΔP across the 1st o - ring = 760 Torr

ΔP across the 2nd o - ring = 10^{-2} Torr

Force Required to Compress O-rings

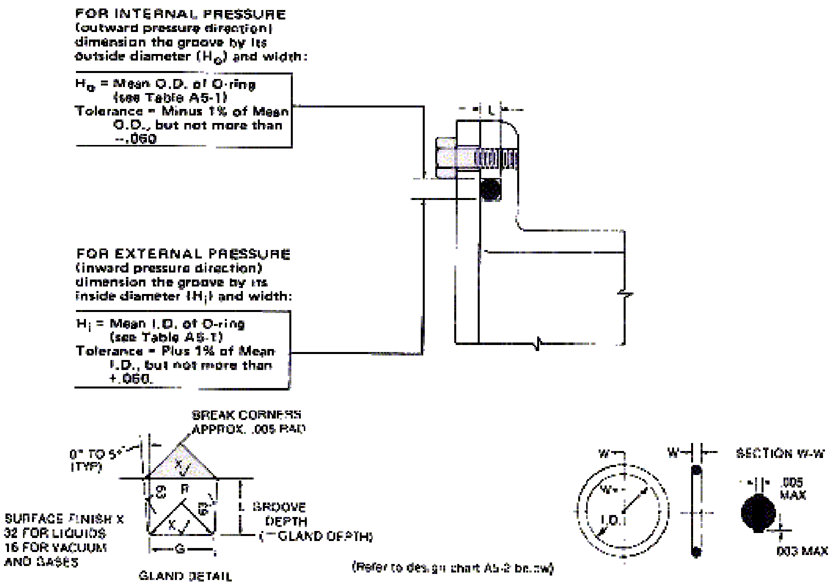
The compression force (per linear inch of o-ring) is dependent on:

1. Hardness of the o-ring
2. O-ring cross-section
3. % squeeze

Variations in material properties will cause the compression forces to vary though the three attributes are the same.

Typical O-Ring Groove Dimensions

face seal glands



(Refer to design chart A5-2 below)

DESIGN CHART A5-2

FOR O-RING FACE SEAL GLANDS

These dimensions are intended primarily for face type seals and low temperature applications.

O-RING SIZE PARKER NO. 2	CROSS SECTION		GLAND DEPTH	SQUEEZE		GROOVE WIDTH		GROOVE RADIUS
	NOMINAL	ACTUAL		ACTUAL	%	LIQUIDS	VACUUM AND GASES	
004 through 050	1/16	.070 ±.003	.050 to 054	.013 to .023	19 to 32	.101 to .107	.084 to .089	.005 to .015
102 through 178	3/32	.103 ±.003	.074 to .080	.020 to .032	20 to 30	.136 to .142	.120 to .125	.005 to .015
201 through 284	1/8	.139 ±.004	.101 to .107	.028 to .042	20 to 30	.177 to .187	.158 to .164	.010 to .025
309 through 395	3/16	.210 ±.005	.152 to .162	.043 to .063	21 to 30	.270 to .290	.239 to .244	.020 to .035
425 through 475	1/4	.275 ±.006	.201 to .211	.058 to .080	21 to 29	.342 to 362	309 to .314	.020 to .035
Special	3/8	.375 ±.007	.276 to .286	.082 to .108	22 to 28	.475 to .485	.419 to .424	.030 to .045
Special	1/2	.500 ±.008	.370 to .380	.112 to .138	22 to 27	.636 to .645	.560 to .565	.030 to .045

"0" preferred

A5-13

Ref. Parker O-ring Handbook