Leak detection techniques
Helium Leak Testing Techniques for Industry

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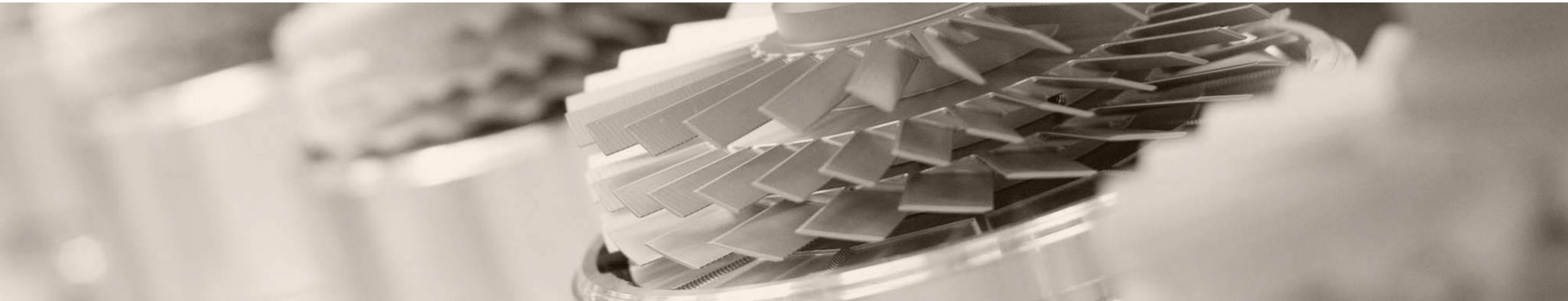

Leak detection techniques

Reasons for Leak Testing

- Environmental
- Safety ISO 9000
- Product life
- Reliability
- Product specifications
- Marketing advantage

Leak detection techniques
Application list

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Analytical

- Mass spectrometer systems
- Electron beam microscopes

Medicine technology

- Pacemaker
- Electron microscope
- X-ray tubes
- Ampulla

IT

- Transfer chambers
- Load looks
- Tubing

Automotive

- AC
- Brake tubing
- Heat exchanger
- Fuel tanks
- Compressors
- Evaporators
- Valves
- Thermostat

Power engineering

- Power turbine
- Power condenser
- High voltage components

Vacuum equipment

- Whole vacuum program
- Pump housings

R&D

- He bath cooler
- 3He cooler
- Lon beam accelerators
- UHV ^/XHV systems
- He transfer lines

Process industry

- Furnaces
- Soldering ovens
- High pressure valves

Leak detection techniques
Types of Leaks

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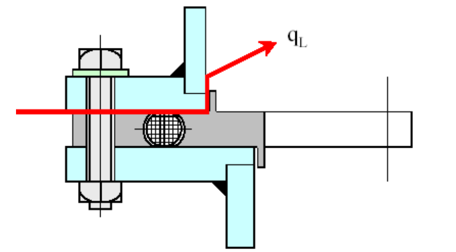
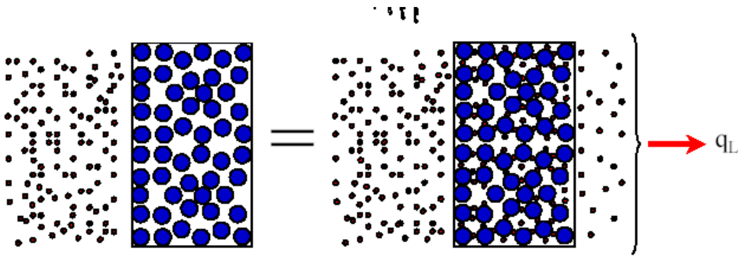
Leaks at connections

- Flanges, welding, soldering, grindings (glass fittings)



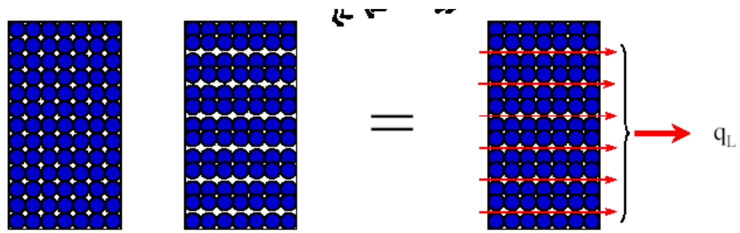
Permeation leaks

- Gas transport through materials e.g. elastomeric seals, glass



Porosity leaks

- Castings

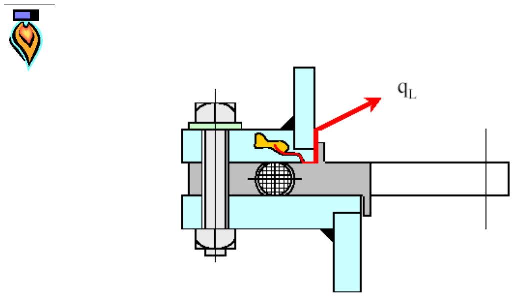


Virtual leaks

- Gaps, small volumes in castings, evaporation of liquids, sintered metal, plastic parts

Hot /cold leaks

- Cracks open or close due to thermal tensions



Leak detection techniques
Definition of mbarl/s

In a volume of 1 liter the pressure rises from 1mbar within 1 second to 2 mbar, that is a leak rate of

$$1\,\text{mbar}\,.\,\text{l}\,.\,\text{s}^{-1}$$

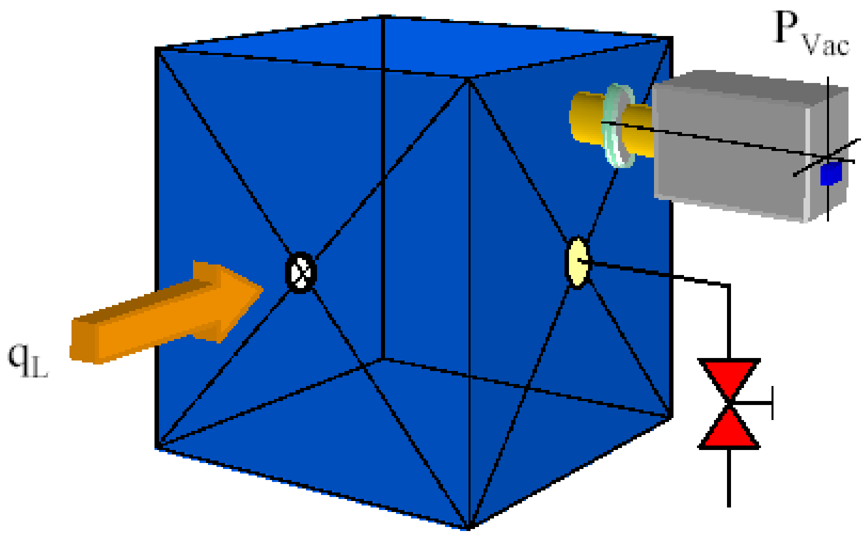
$$Q = \frac{\Delta p}{\Delta t}\,.\,V$$

Q = Troughput

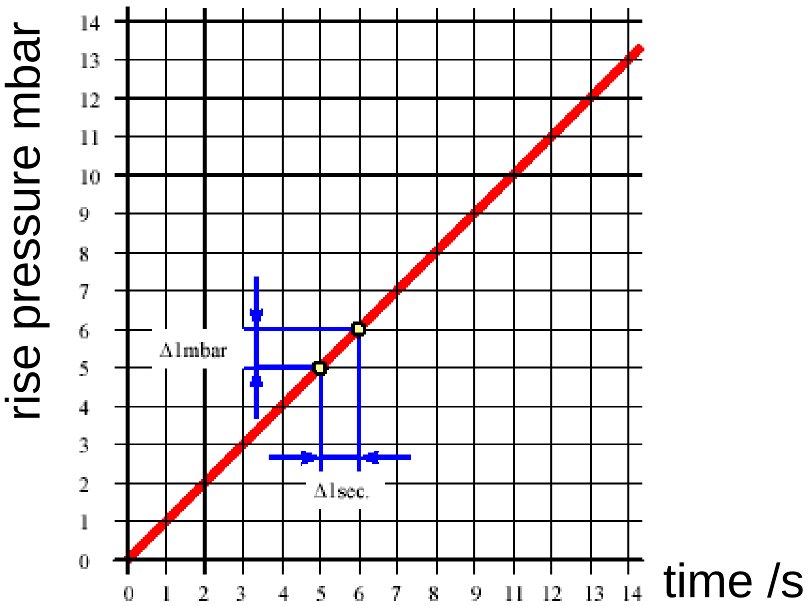
V = Volume

Δp = pressure difference

Δt = time difference



Volume of 1 liter



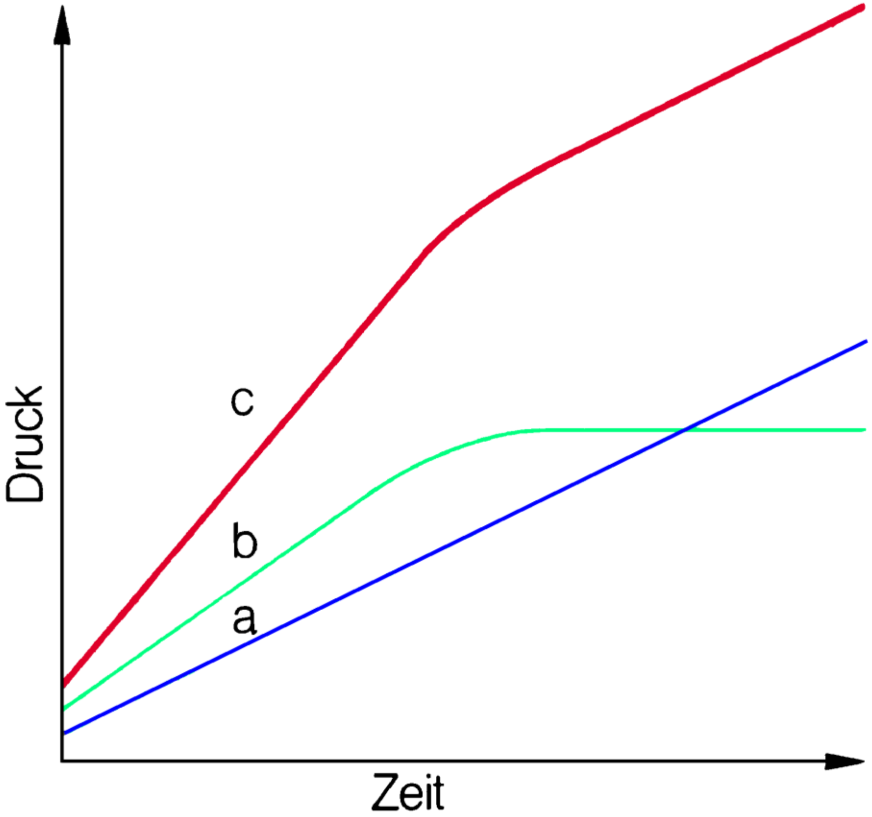
Leak detection techniques
Examples of well known leaks

Water tap 1 drip per second	$1{,}7 \times 10^{-1}$ mbarl/s
Hair between O-ring and flange	1×10^{-3} - 5×10^{-2} mbarl/s
Bicycle tube in water (bubble test, 1 bubble/sec)	1×10^{-2} mbarl/s
Car wheel loses air 1,8 ➘ 1,6 bar in 6 month	4×10^{-5} mbarl/s

Leak detection techniques
Methods of Leak Tests

Procedure	Medium	Limit of leak rate mbarl/s	Pressure range	Quantifiable
Rise pressure	Air & others	10^{-4}	Vacuum	Limited
Pressure drop	Air & others	10^{-4}	Overpressure	Limited
Foaming agent	Air & others	10^{-5}	Overpressure	No
Bubble test	Air & others	10^{-4}	Overpressure	Limited
Supersonic	Air & others	10^{-2}	Overpressure/ Low pressure	No
Thermal conductivity	Air & others	10^{-5}	Overpressure/ Low pressure	No
Mass spectrometer quadruppole	Refrigerents; gases	10^{-7}	Overpressure	Yes
Mass spectrometer magnet sector field	Helium Hydrogen	$<10^{-7}$	Overpressure	Yes
Mass spectrometer magnet sector field	Helium Hydrogen	$<5 \times 10^{-12}$	Vacuum	Yes

Leak detection techniques
Pressure rise effects in a chamber



a) Leak

b) Desorbtion

c) Leak + Desorbtion

Leak detection techniques
Pressure rise method with vacuum (no Helium)

Example:

Test volume: V = 1m³

Δ p: p = 1 · 10^{-3} mbar until 8 · 10^{-3} mbar

Time : t = 5 min

QL = ??

$$Q = \frac{v}{t}.\Delta p[\mathrm{mbar} \cdot \mathrm{I} \cdot \mathrm{s}^{-1}]$$

$$= \frac{1000I}{300S}\ 7 \cdot 10^{-3}\mathrm{mbar}$$

Air leak rate

$$= 2{,}33.10^{-2}\, mbar.I.s^{-1}$$

$$\Delta p = p_2 - p_1 = 8.10^{-3} - 1.10^{-3} = 7.10^{-3}\, mbar$$

Leak detection techniques

Why is Helium a good Test Gas?

- Low concentration in air , only 5 ppm, so low natural background
- Inert gas, non toxic, non- explosive, environmentally friendly
- Good separation in a mass spectrometer (no cross sensitivity to other gases and no mass fragments
- Lighter than air
- Very small gas molecule, can easily pass through small holes/gaps

Leak detection techniques
Principle Methods of Leak Detection

Vacuum method

- Global detection (He outside)
- Global detection (He inside)
- Local detection

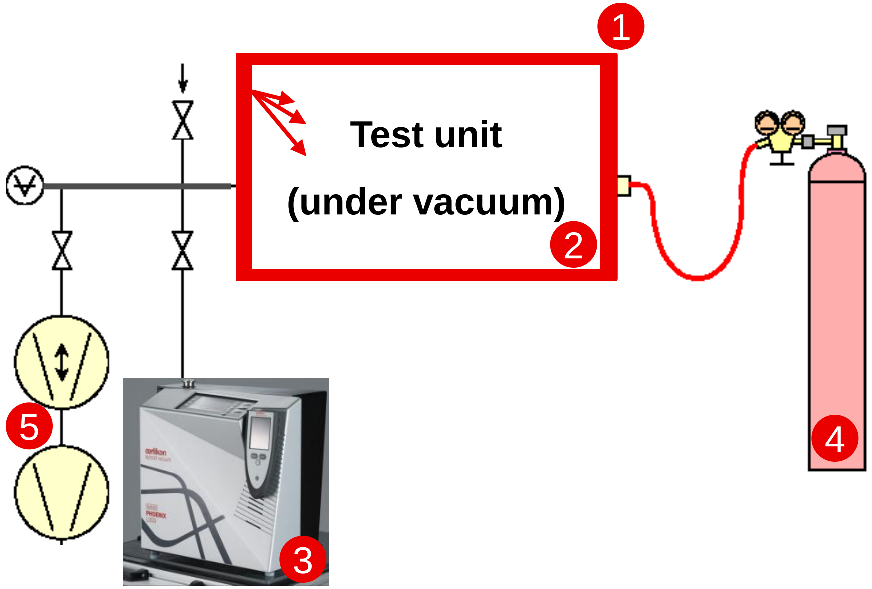
Overpressure method

- Local detection (sniffing)

Leak detection techniques
Vacuum Method

Global Detection

Lowest detectable leak rate
< 5×10^{-12} mbarl/s

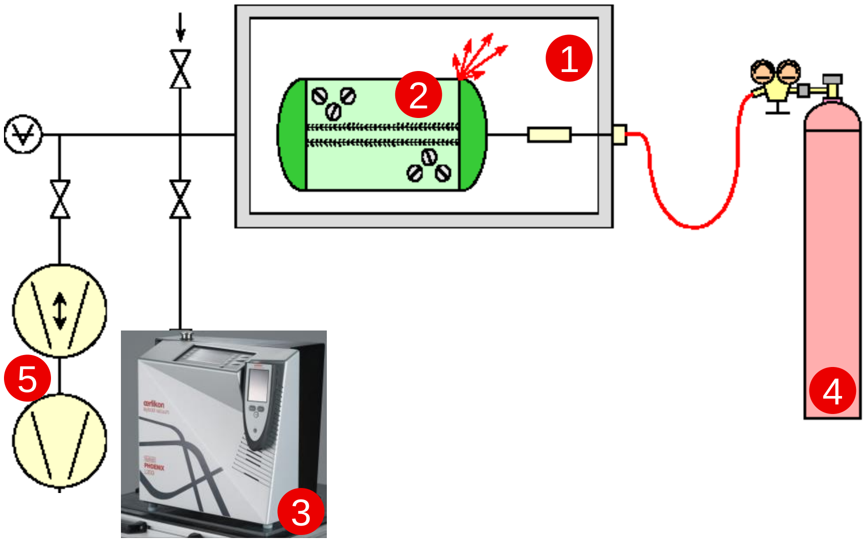


1. Pressure chamber w Helium
2. Test vessel
3. Leak detector
4. Helium
5. Auxiliary Pump System

Leak detection techniques
Vacuum Method

Global Detection

Lowest detectable leak rate
$< 5 \times 10^{-12}$ mbarl/s

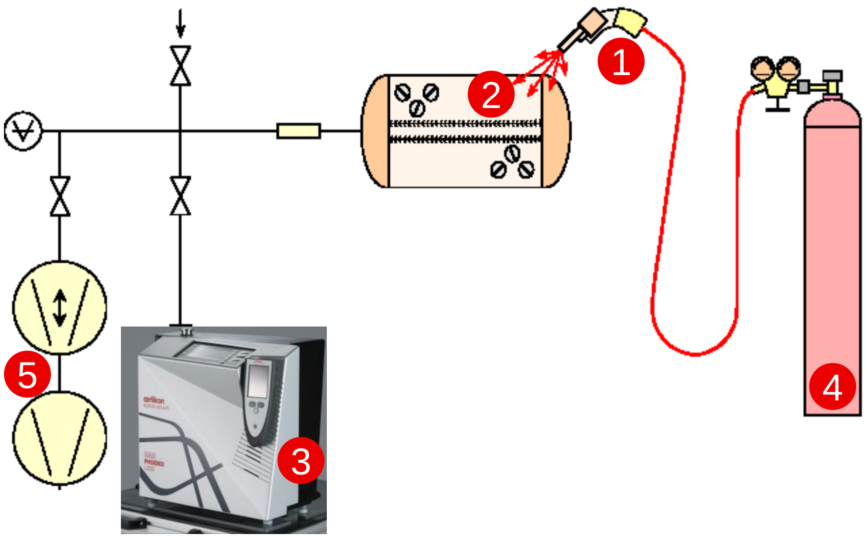


1. Vacuum chamber
2. Test body
3. Leak detector
4. Helium
5. Auxiliary Pump System for huge vessels

Leak detection techniques
Vacuum Method

Local
Detection

Lowest detectable leak rate
< 5x10^{-12} mbarl/s



1. Spray gun
2. Test body
3. Leak detector
4. Helium
5. Auxiliary Pump System (for large vessels)

Leak detection techniques
Overpressure Method

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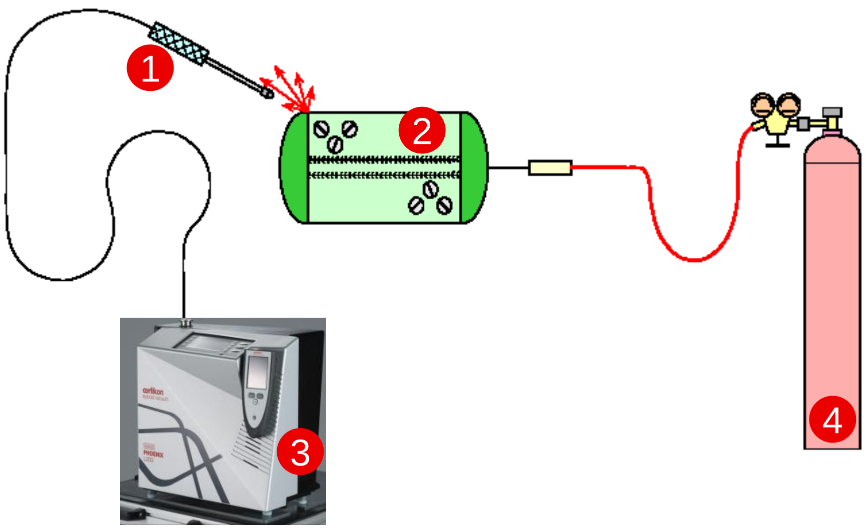
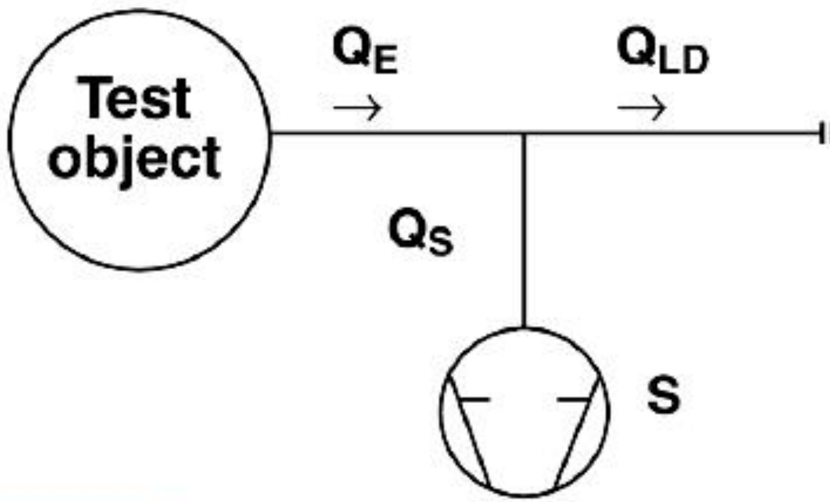
Local
Detection
(sniffing)

Lowest detectable leak rate
< 1x10^{-7} mbarl/s!!!



1. Sniffer probe
2. Test vessel
3. Leak detector
4. Helium

Leak detection techniques
Partial Flow System

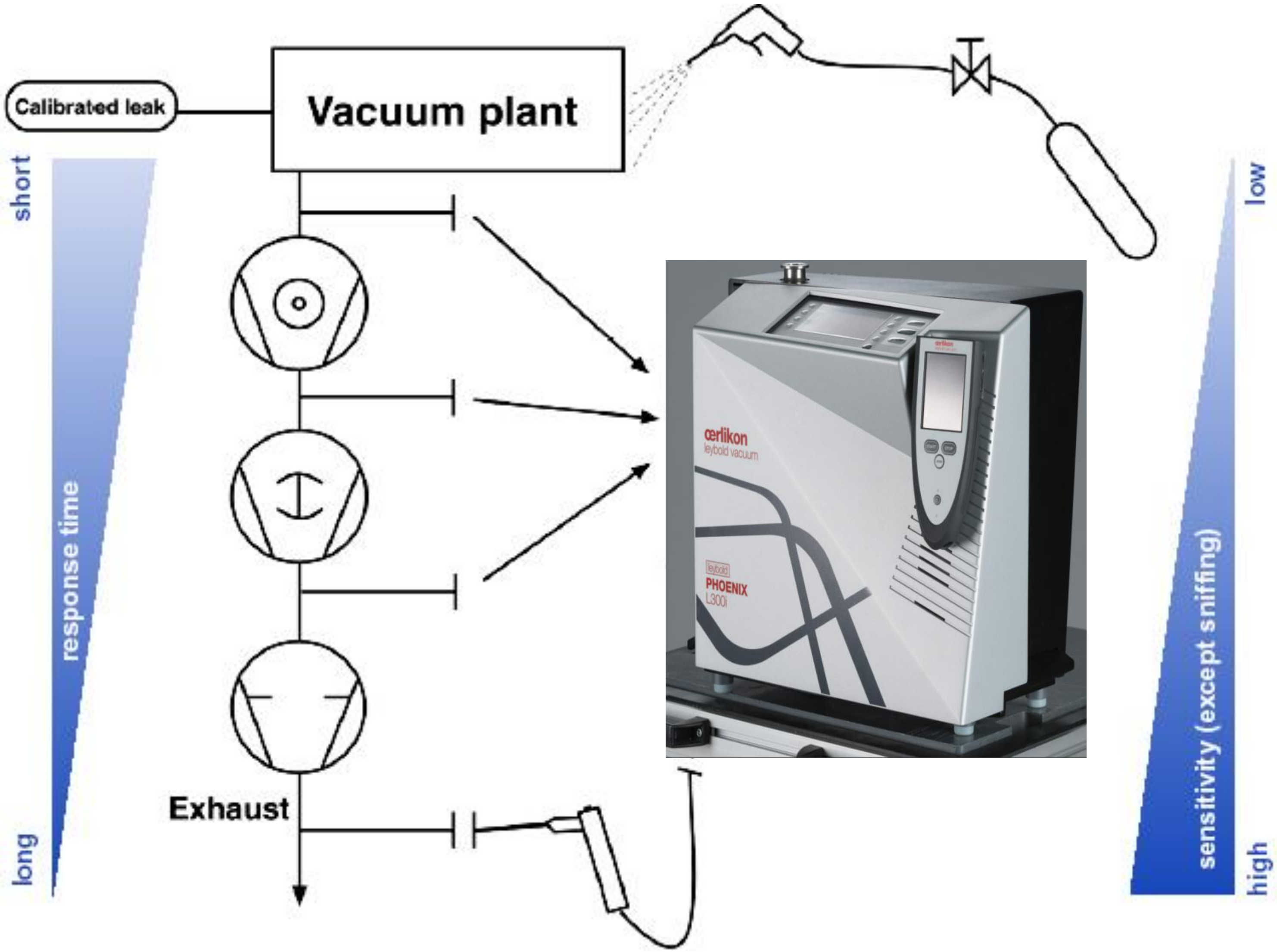


Partial Flow Pump

$$Q_{LD} = \gamma \cdot Q_E$$

γ = partial flow factor

Leak detection techniques
Partial Flow System



Leak detection techniques
Conversion of mass flowes – (Leak Rates)

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1 ↓ =…→	mbar · l/s	$kg \cdot h^{-1}$ (20 °C)	$kg \cdot h^{-1}$ (0 °C)	Cm^3/h (NTP)	Cm^3/s (NTP)	Torr. l/s	g/a (F12.20°C)	g/a (F12.25°C)	m.cfm	lusec	Pa.1/s	slpm
mbar.l/s	1	$4.28.10^{-3}$	4.59.10-3	3554	0.987	0.75	1.56.105	$1.54.10^{5}$	1593	$7.52.10^{2}$	100	$59.2.10^{-3}$
$Kg.h^{-1}$(20°c)	234	1	1.073	$8.31.10^{5}$	231	175	-	-	$37.2.10^{4}$	$1.75.10^{5}$	$23.4.10^{3}$	13.86
Kg.h-1 (0°c)	218	0.932	1	$7.74.10^{5}$	215	163	-	-	$34.6.10^{4}$	$1.63 \cdot 10^{5}$	$21.8 \cdot 10^{3}$	12.91
Cm3/h (NTP)	$2.81 \cdot 10^{-4}$	$1.20 \cdot 10^{-6}$	$1.29 \cdot 10^{-6}$	1	$2.78 \cdot 10^{-4}$	$2.11 \cdot 10^{-4}$	44	-	$44.7 \cdot 10^{-2}$	$2.11 \cdot 10^{-1}$	$2.81 \cdot 10^{-2}$	$1.66 \cdot 10^{-5}$
cm3/s (NTP)	1.013	$4.33.10^{-3}$	$4.65.10^{-3}$	3600	1	0.760	1.58.105	-	1611	760	101	6.10^{-2}
Torr.1/s	1.33	$5.70.10^{-3}$	$6.12.10^{-3}$	4727	1.32	1	2.08.105	$2.05.10^{5}$	2119	1.10^{3}	133	$78.8.10^{-3}$
g/a (F12.20°C)	$6.39.10^{-6}$	-	-	$2.27.10^{-2}$	$6.31.10^{-6}$	$4.80.10^{-6}$	1	-	$10.2.10^{-3}$	$4.8.10^{-3}$	$6.39.10^{-4}$	$37.9.10^{-8}$
g/a (F12.25°C)	$6.50.10^{-6}$	-	-	-	-	$4.88.10^{-6}$	-	1	$10.4.10^{-3}$	$4.89.10^{-3}$	$6.5.10^{-4}$	$38.5.10^{-8}$
m.cfm	$6.28.10^{-4}$	$2.69.10^{-6}$	$2.89 . 10^{-6}$	2.24	$6.21.10^{-4}$	$4.72.10^{-4}$	98.16	96.58	1	0.472	$6.28.10^{-2}$	$37.2.10^{-6}$
Lusec	$1.33.10^{-3}$	$5.70.10^{-6}$	$6.12.10^{-6}$	4.737	$1.32.10^{-3}$	1.10^{-3}	208	205	2.12	1	$13.3.10^{-2}$	$78.8.10^{-6}$
Pa.l/s	1.10^{-2}	$4.28.10^{-5}$	$4.59.10^{-5}$	35.54	$9.87.10^{-3}$	$7.5.10^{-3}$	$1.56.10^{3}$	$1.54.10^{3}$	15.93	7.50	1	$59.2.10^{-5}$
slpm	16.88	$72.15.10^{-3}$	$77.45.10^{-3}$	$60.08.10^{3}$	16.67	12.69	$2.64.10^{6}$	$2.60.10^{6}$	$26.9.10^{3}$	$12.7.10^{3}$	$16.9.10^{2}$	1

- 1 cm^3 (NTP)=1 cm^3 under normal condition (T=273.15K; P=1013.25 mbar)
- NTP=Normal temperature and pressure (1atm; 0° C) R=83.14 mbar.1.mol-1. K-1
- 1cm^3 (NTP) h^{-1} = 1 atm. $cm^{3.}$ h^{-1} = $Ncm^{3.}$ h^{-1} = 1 std cch
- 1sccm=10^{-3} slpm=10^{-3} N.l.min^{-1}=60sccs
- SI-System kohärent: 1 pa.m^3. s^{-1} = 10 mbar.1.s^{-1}; R=8.314 pa.m^3.mol^{-1}.K-1 ;M in kg / mol
- 1 cm^3 (NTP) . s^{-1}= 1 sccs = 60cm^3 (NTP). Min^{-1} 60 SCCM =60 Std ccm = 60 Ncm^3. min^{-1}
- 1 lusec =1 l.μ.$s.^{-1}$ 1.μ=1 micron =10^{-3} Torr 1 lusec = 10^{-3} Torr.I.s^{-1}
- Freon F 12 (CC12FC) M=120.92 g.mol^{-1}; Luft M=28.96g. Mol^{-1}
- Achtung: Anglo-amerikanische Einheiten werden uneinheitlich abgekürzt! Beispiel: Standard cubic centimeter per minute → sccm = sccpm = std ccm = std ccpm

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Thank you for listening