Ultra High Vacuum at Ess and MAX IV in Lund

Day 3 (24 Oct. 2019). Practical demonstrations – leak detection

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Leaks and leak detection - definition

- A leak is defined as **a hole, a gap, or a crack** through which gases flow from one side of the wall to the other **due to a difference in pressure**

- Leak detection means finding leaks out from different possible sources in a vacuum system

- It is important to **specify an acceptable leak rate** for each vacuum system. After manufacturing of a vacuum vessel it must be proven that the tightness specifications are fulfilled.

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Leak detection - solutions

- Method: helium leak detector

- Why helium?
  - ✓ small mass
  - ✓ small atom volume, it allows the detection of very small leaks
  - ✓ very low content in air
  - ✓ unambiguous signal in the mass spectrum of the residual gas
  - ✓ chemically and physically inert, non explosive and cheap
  - ✓ easily removable by pumping
  - ✓ it does not contaminate the system

Leak detection - solutions

- Method: helium leak detector

- How?

✓ Using a mass spectrometer
with 180° magnetic sector field
optimized for the detection of mass 4.

Leak detection - solutions

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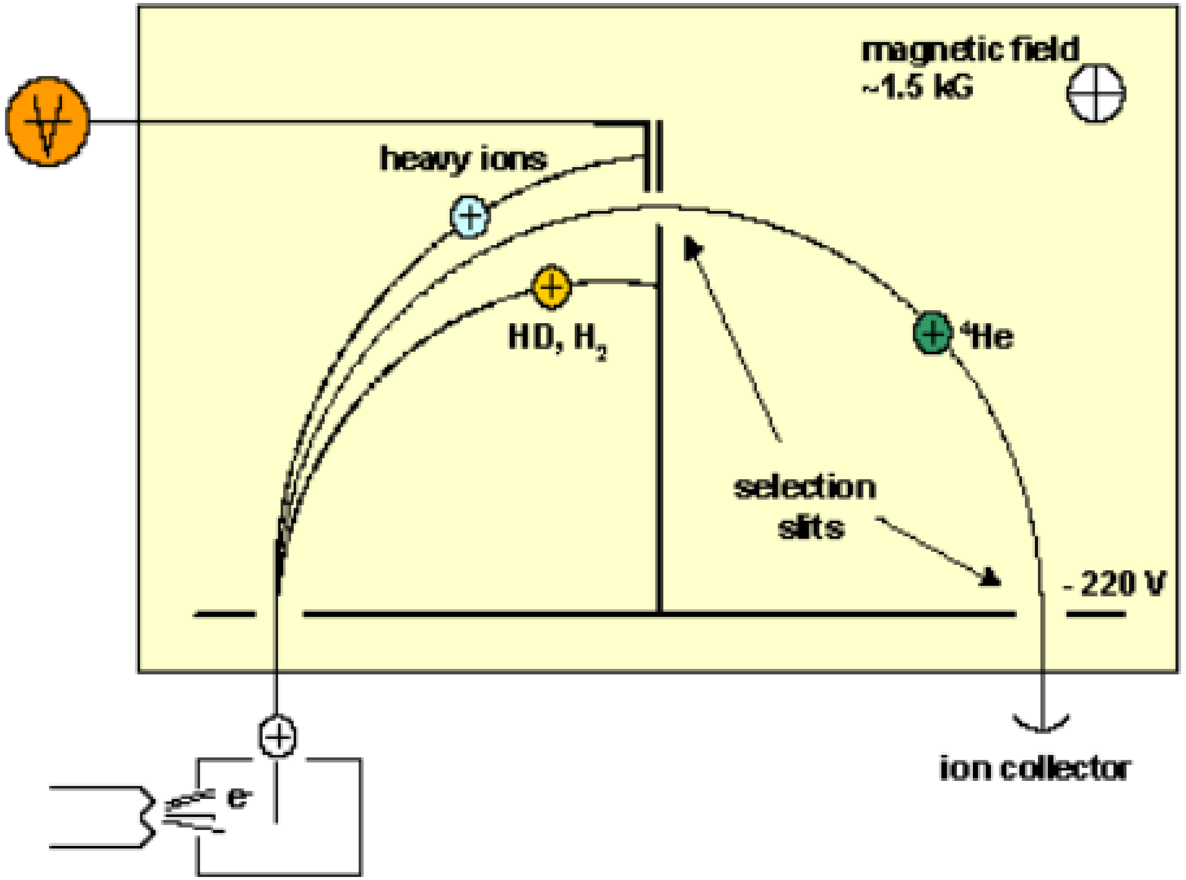

K. Zapfe, "Leak Detection", Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany pp227-240

Leak detection - solutions

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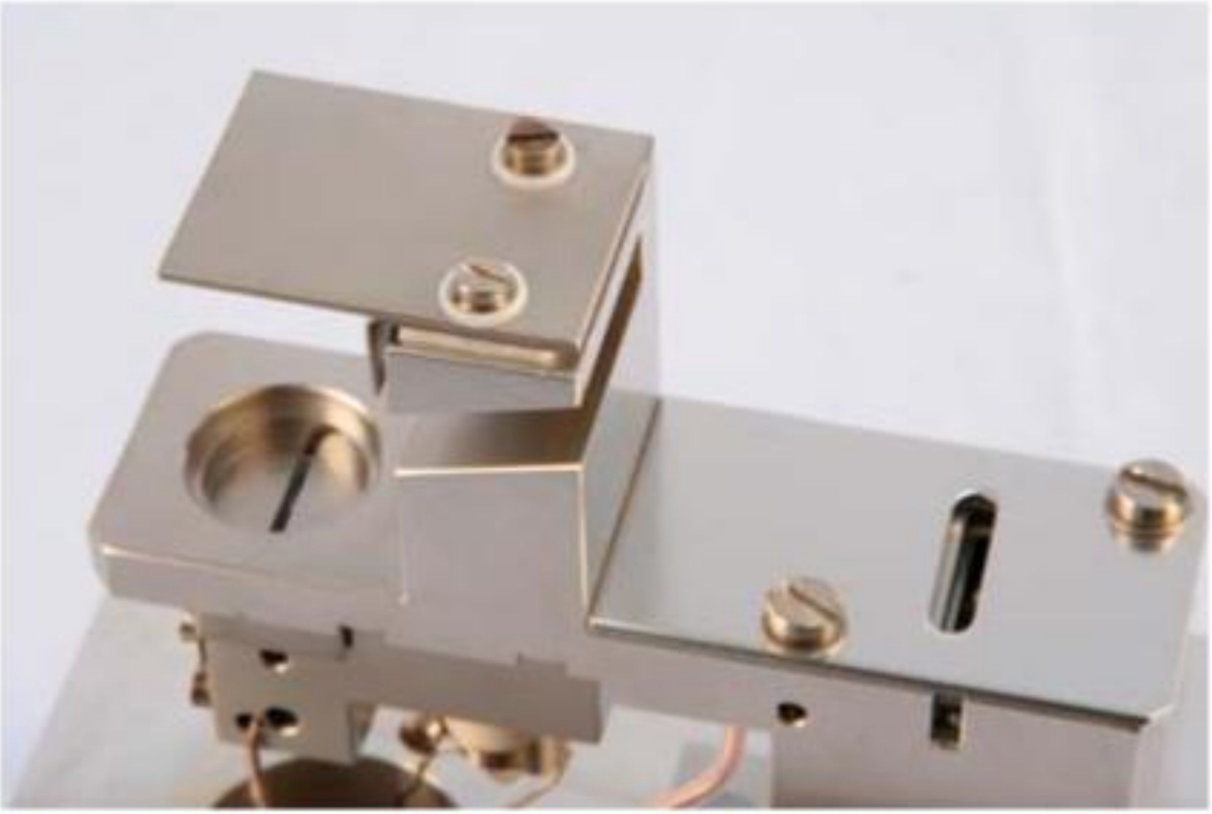

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Leak detection - applications

- Method: helium leak detector

- Where?

✓ having a pressure increase

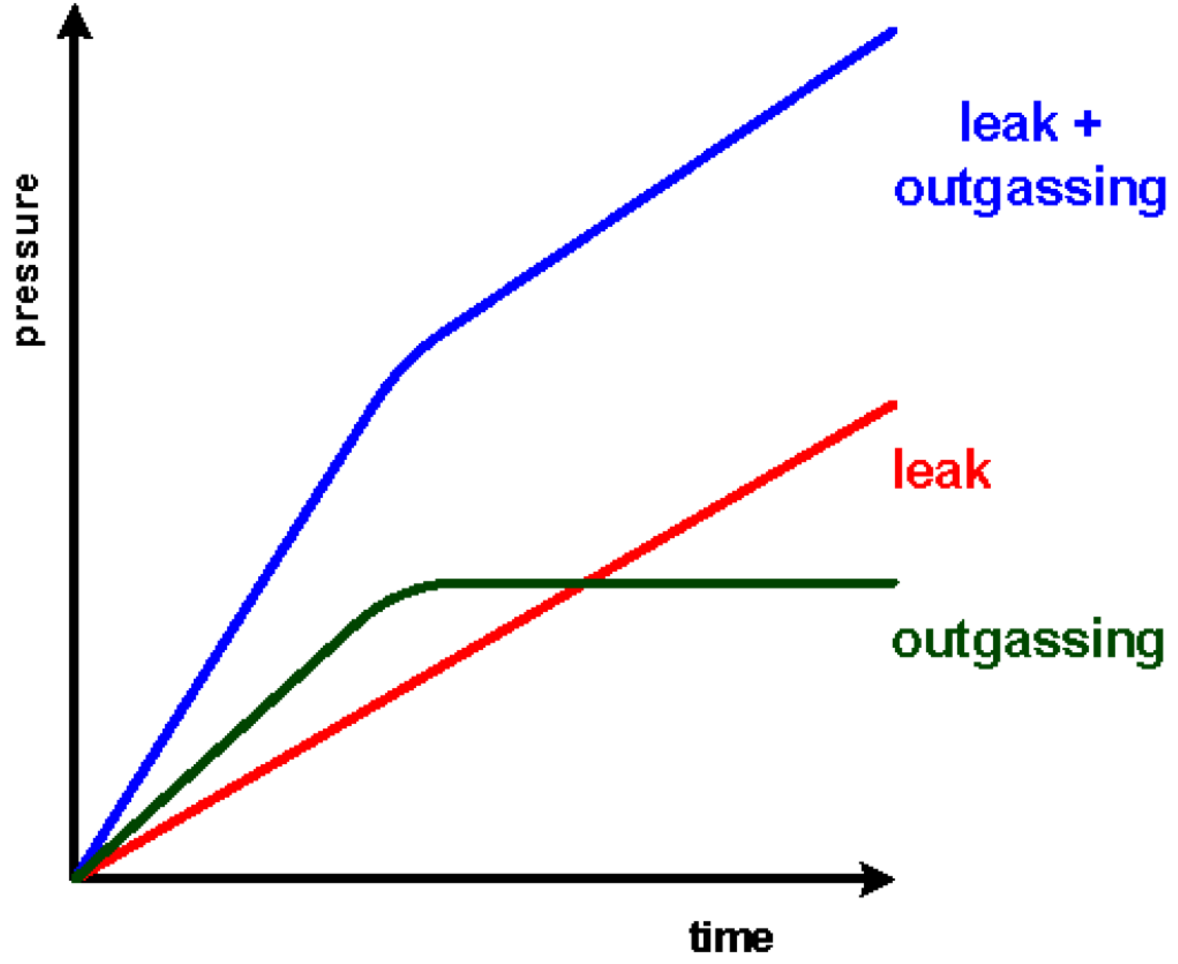
Leak detection - applications

- ❑ Method: helium leak detector

- Where?

- ✓ having a pressure increase

due to outgassing, a leak, and the combination of outgassing and a leak



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Leak detection - leak rate

The leak rate is defined as the *pV* throughput of a gas through a leak. It is a function of the type of gas, pressure difference, and temperature. In a system of volume *V* the leak rate Q_l is given by

$$Q_l = V \cdot \frac{\Delta p}{\Delta t}$$

Here Δp is the pressure rise during the time interval Δt .

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Leak detection - leak rate

Commonly used units for leak rates

	$mbar \cdot l/s$	$Torr \cdot l/s$	$Pa \cdot m^3/s$	cm^3/s^*
mbar l/s	1	0.75	0.1	0.99
Torr l/s	1.33	1	0.133	1.32
Pa m^3/s	10	7.5	1	~10
cm^3/s^*	1.01	0.76	0.101	1

* STP - standard temperature and pressure (0°C, 1 atm)

K. Zapfe, "Leak Detection", Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany pp227-240

Leak detection - leak rate

for a **high vacuum (HV)** system one can take the leak rates given below as a rule of thumb:

– $Q_l < 10^{-6}$ mbar l/s: very tight system

– $Q_l \sim 10^{-5}$ mbar l/s: tight system

– $Q_l > 10^{-4}$ mbar l/s: leaky system.

K. Zapfe, "Leak Detection", Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany pp227-240

Leak detection - leak rate

for an **ultra high vacuum (UHV)** system one can take the leak rates given below as a rule of thumb:

– $Q_l < 10^{-11}$ mbar l/s: very tight system

– $Q_l \sim 10^{-10}$ mbar l/s: tight system

– $Q_l > 10^{-9}$ mbar l/s: leaky system.

K. Zapfe, “Leak Detection”, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany pp227-240

Leak detection - leak rate

The following examples illustrate the relationship between the size of a hole, the corresponding leak rate and the amount of gas entering into a vacuum system. For simplification it is assumed that

the hole is a straight channel of circular shape. A diameter of 0.01 mm, e.g. a hair,

→

corresponds to a leak rate of 10^{-2} mbar l/s.

For a tiny hole with a leak rate of $Q_l = 10^{-10}$ mbar l/s = 10^{-10} cm^3/s*, an amount of **1 cm^3 of gas** needs **317 years** to flow through the leak channel.

* STP - standard temperature and pressure (0°C, 1 atm)

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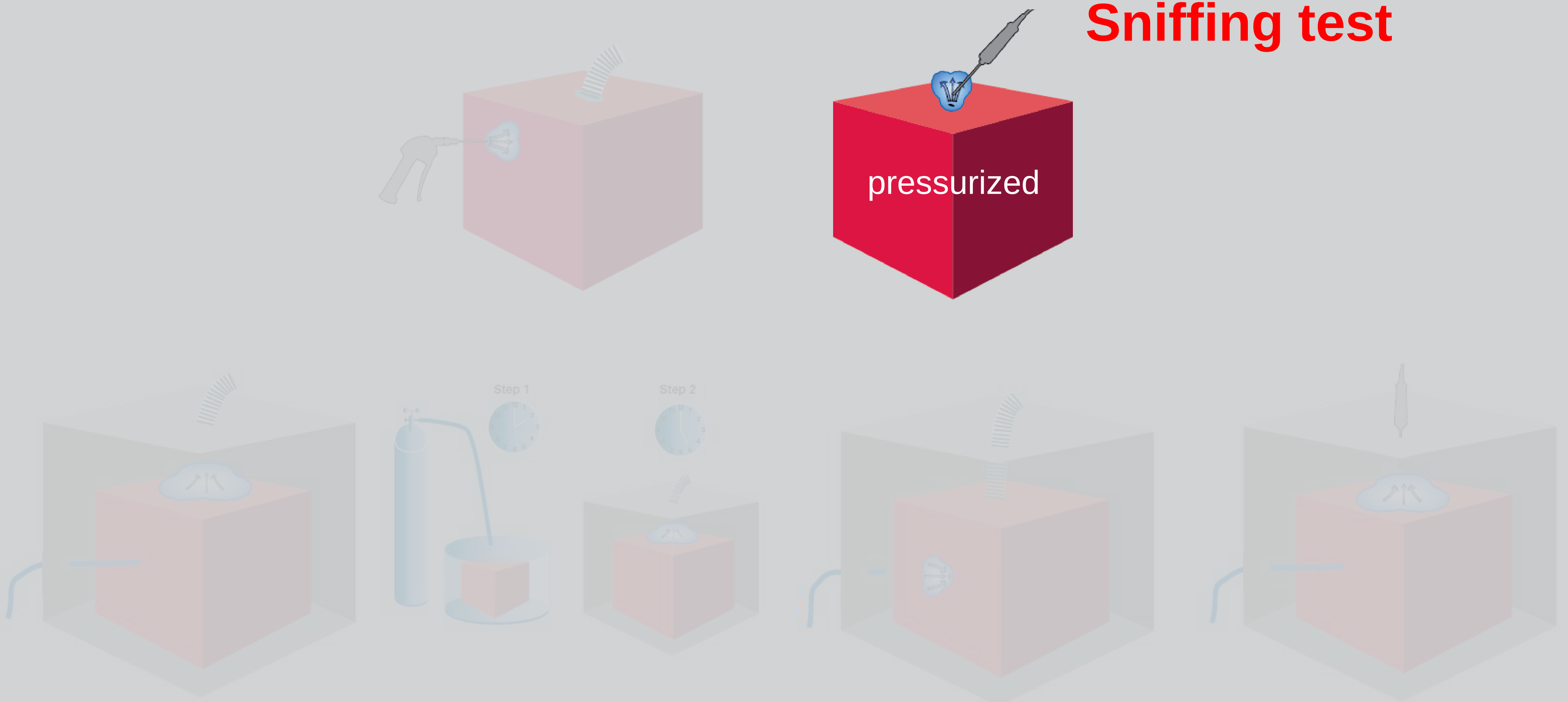
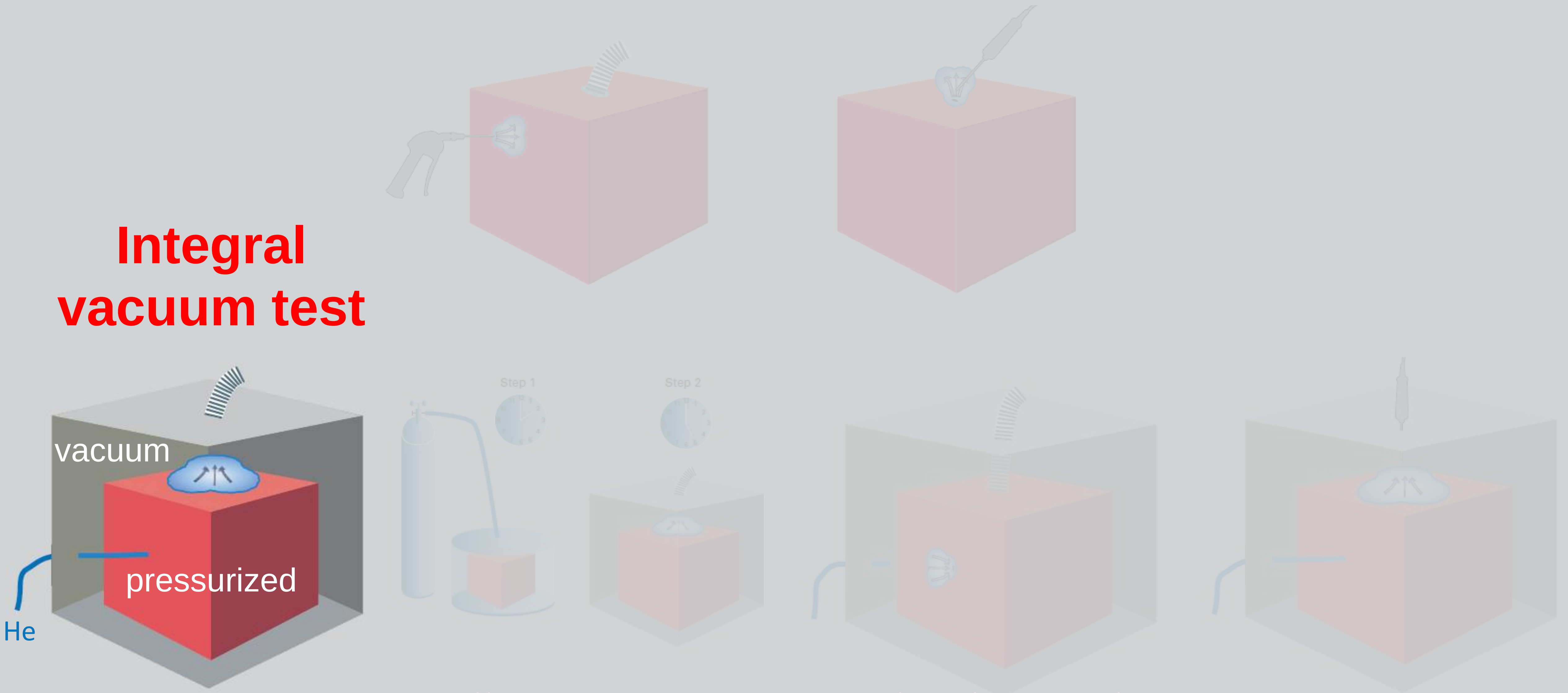
Leak detection - test methods

Sniffing test



https://leak-testing.pfeiffer-vacuum.com/static/downloads/EN-Leak-Detection-Compendium.pdf

Leak detection - test methods



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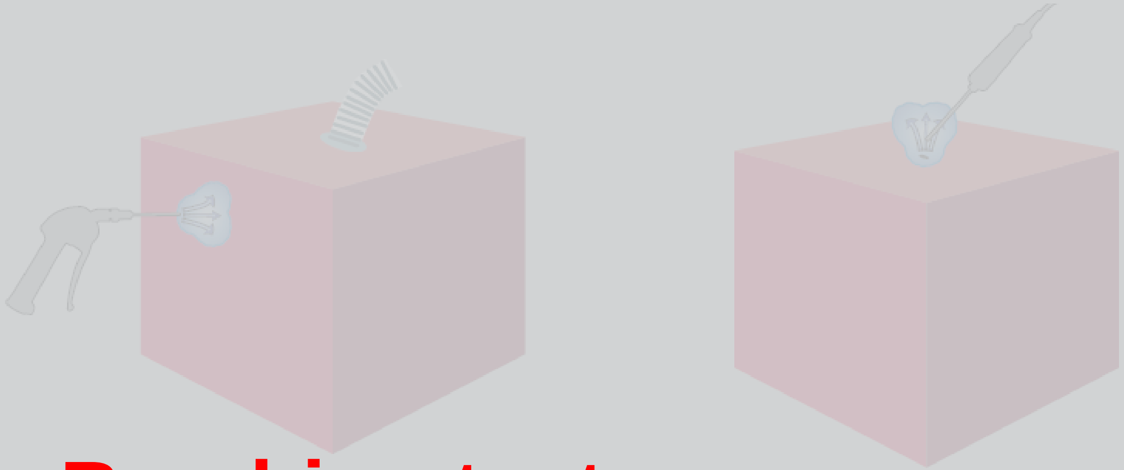
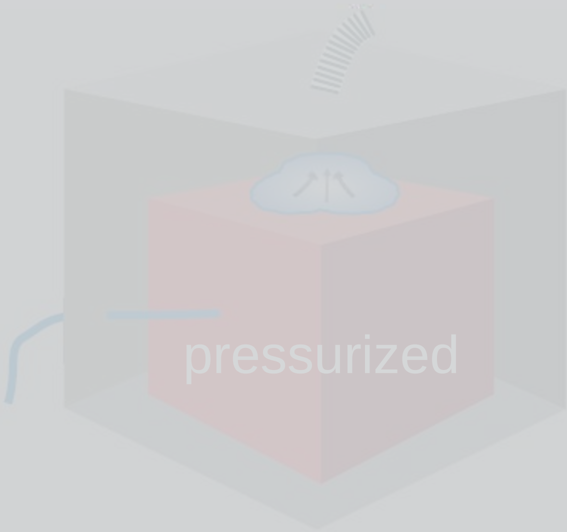
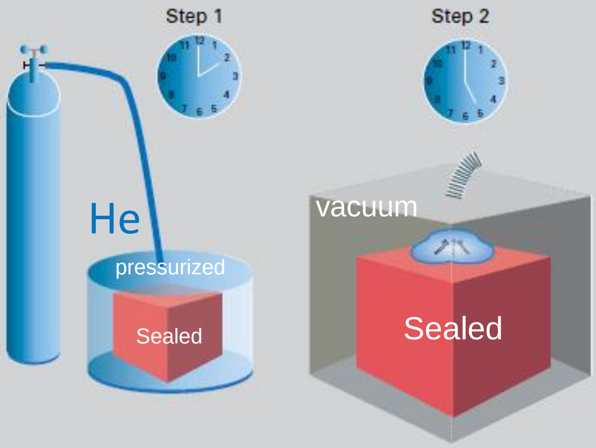


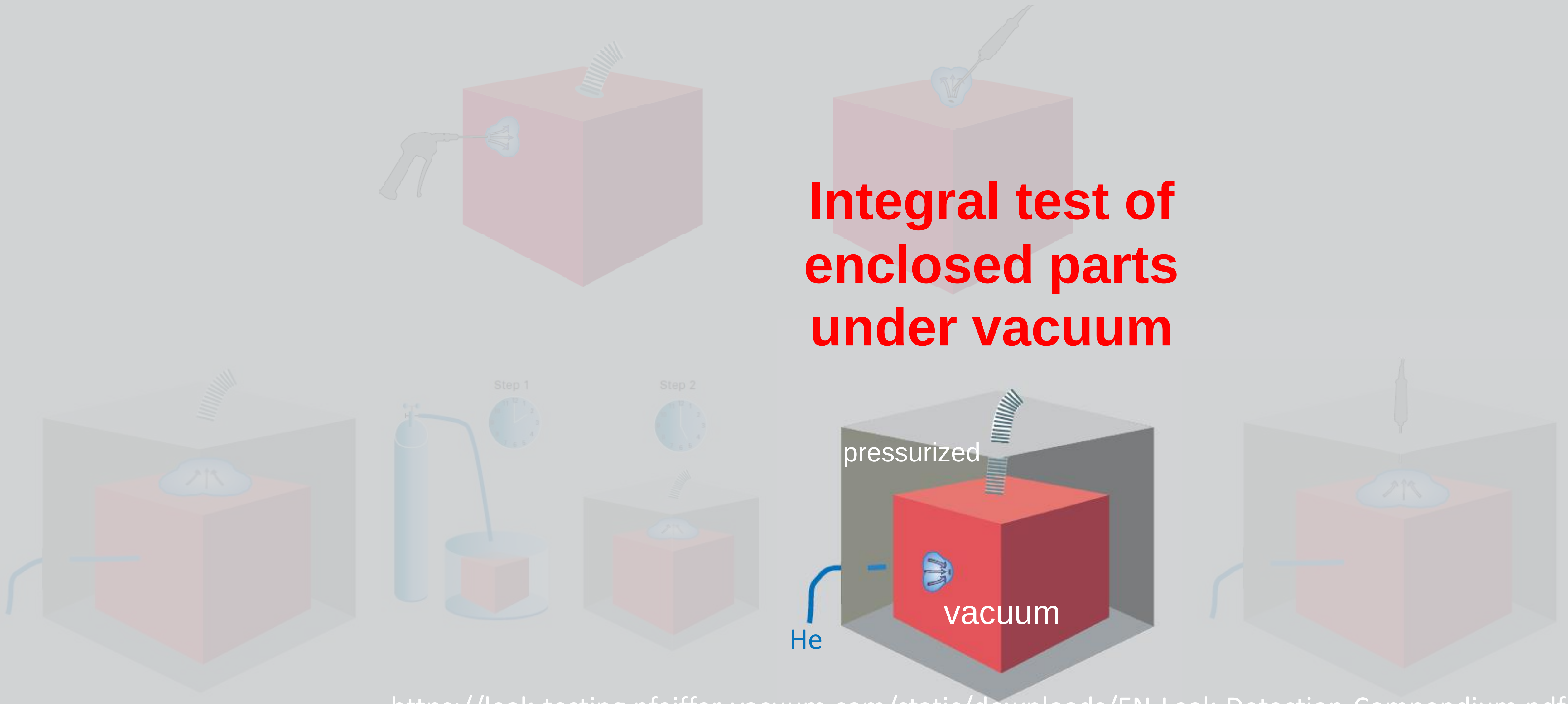
Bombing test





A solution to test sealed components

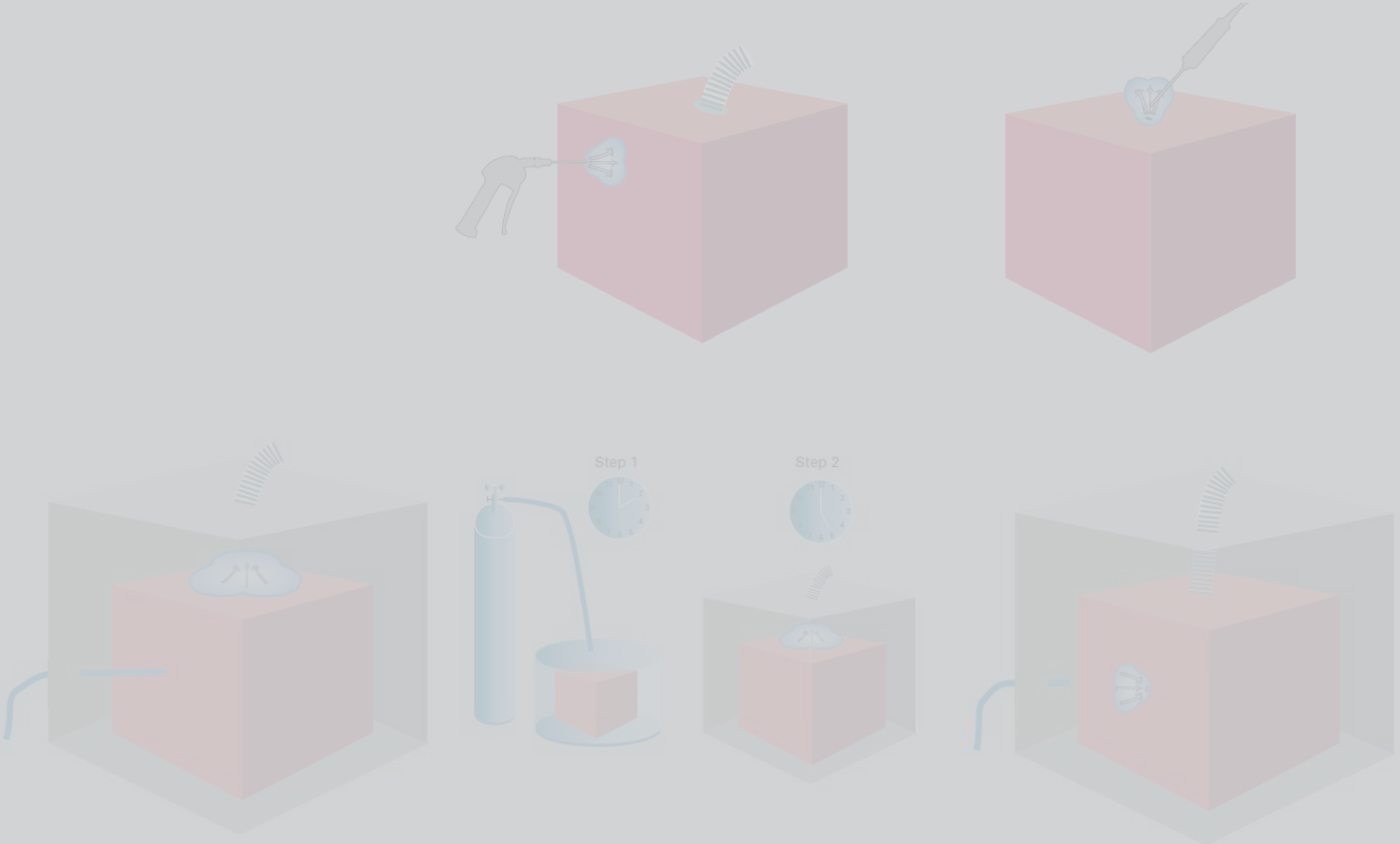
Leak detection - test methods



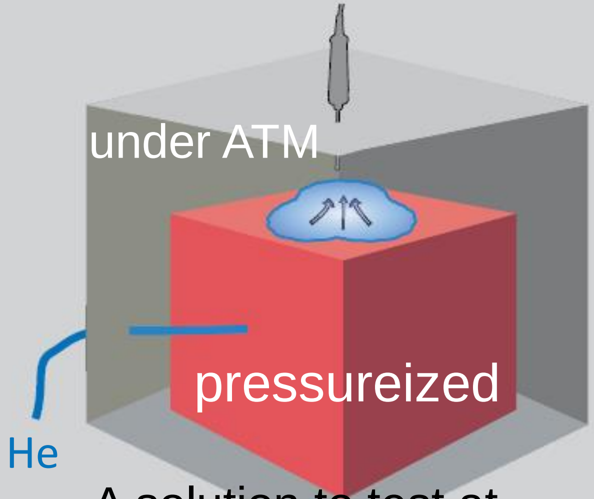
Integral test of enclosed parts under vacuum

https://leak-testing.pfeiffer-vacuum.com/static/downloads/EN-Leak-Detection-Compendium.pdf

Leak detection - test methods



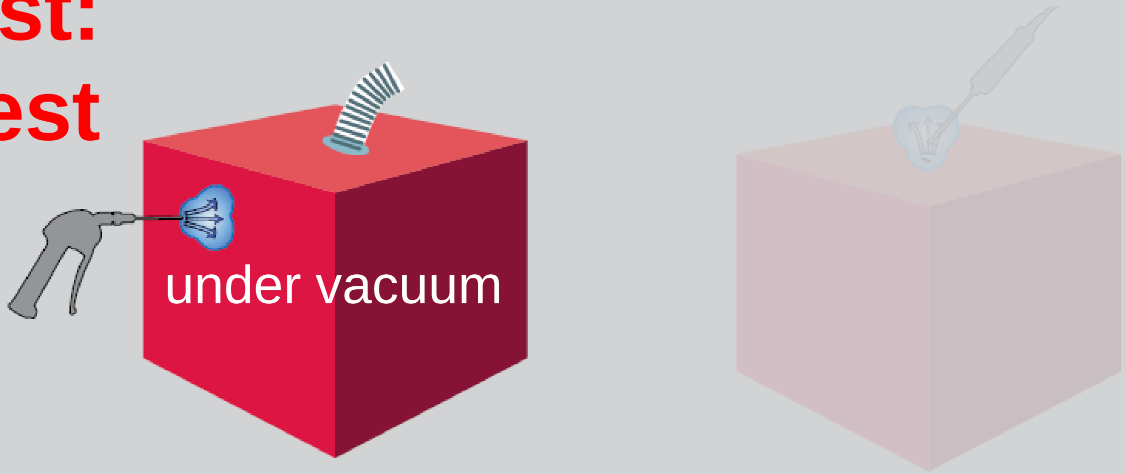
Integral sniffing test

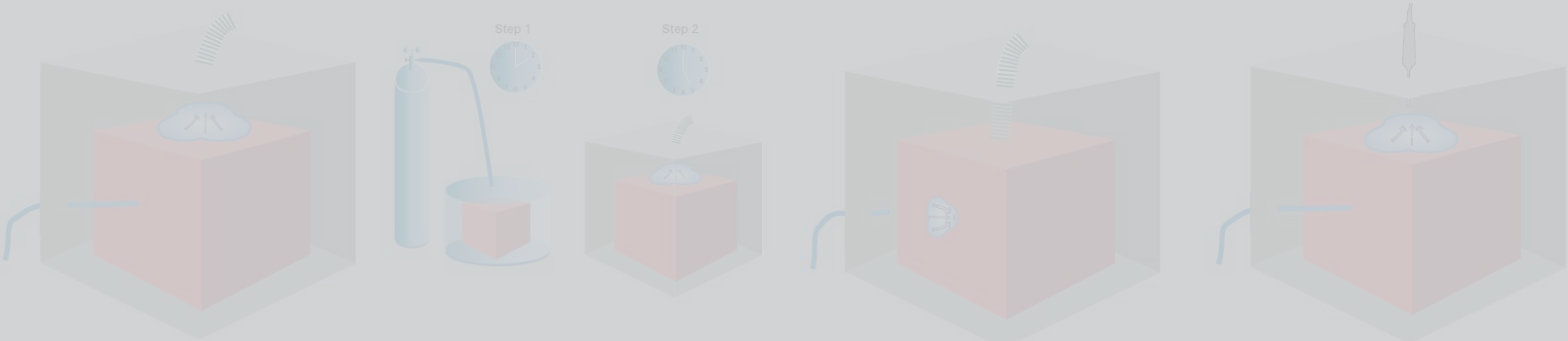


A solution to test at atmospheric pressure

Leak detection - test method using in MAXIV

Vacuum test:
spraying test





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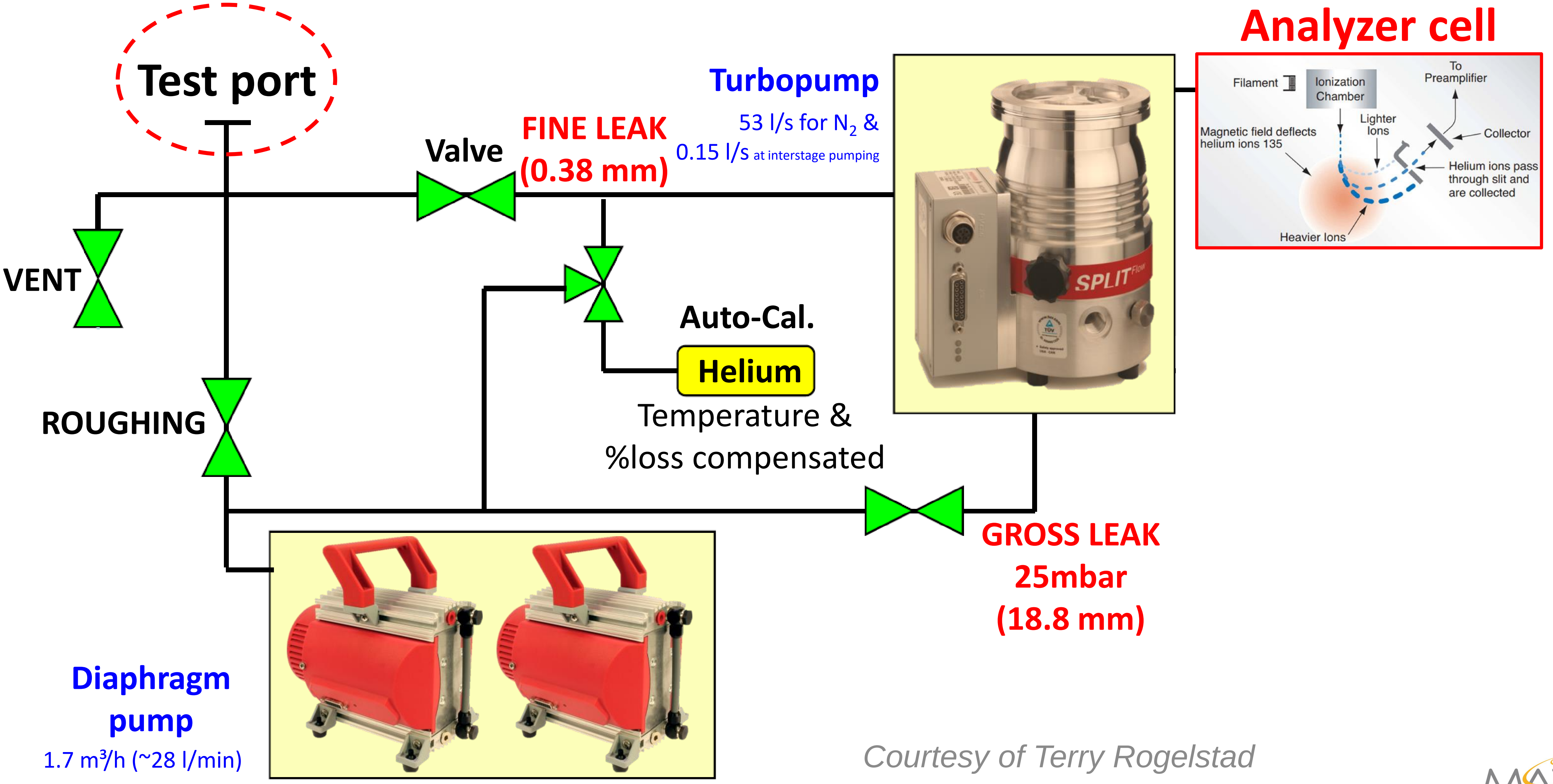
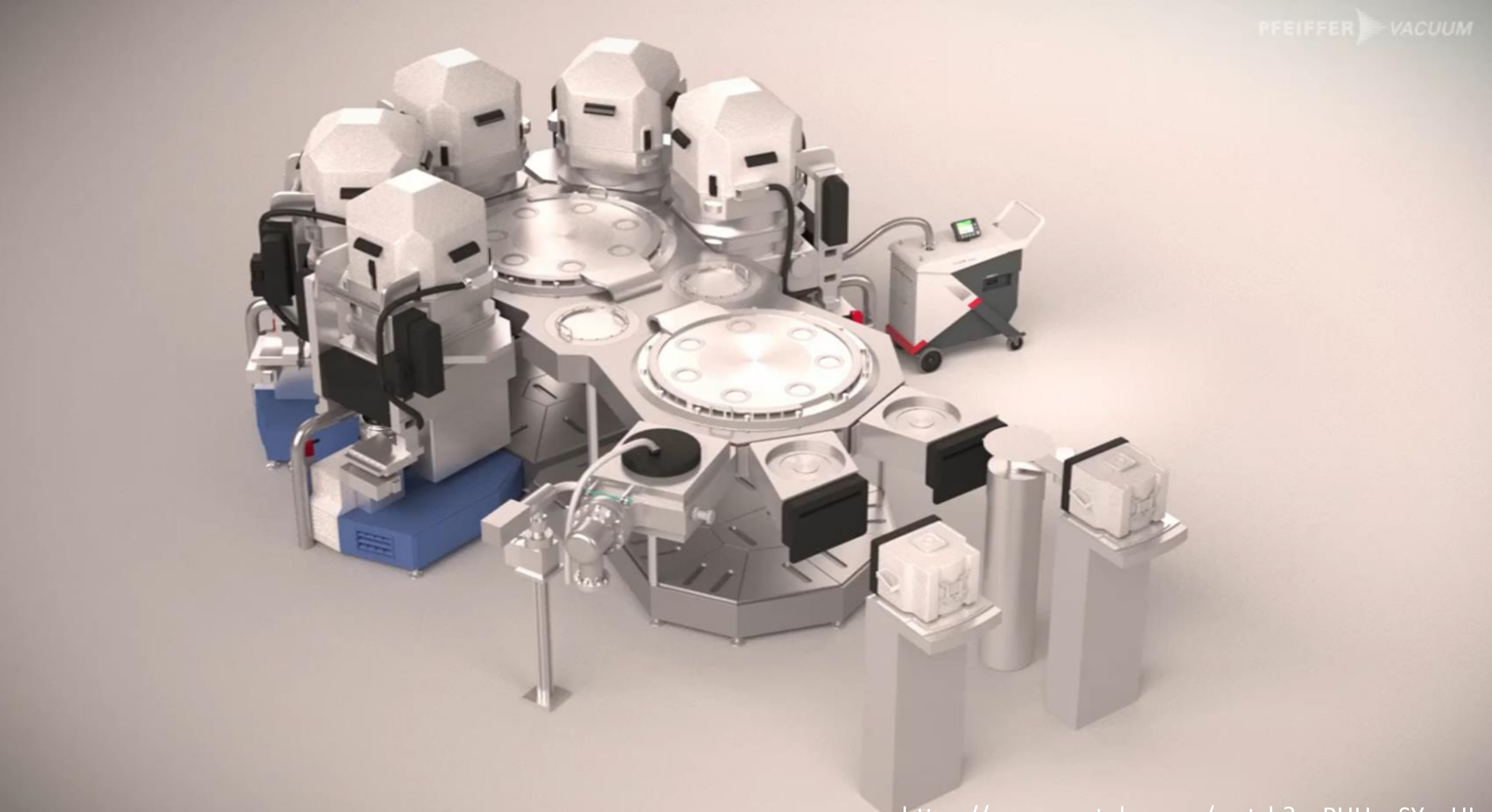
Leak detector vacuum schematic



Courtesy of Terry Rogelstad



https://www.youtube.com/watch?v=PHHnySYpyHI

Leak detectors in MAXIV

ASM 340 D & HLT 570

- ❑ Completely oil free leak detection
- ❑ Ability to detect large leaks between 100hPa and the inlet test pressure
- ❑ Available with interface board for automation through an external system (PC or PLC)

#	Applications	model
Set 1	UHV	ASM 340 DRY
Set 2	UHV	ASM 340 DRY
Set 3	UHV	ASM 340 DRY
Set 4	HV	ASM 340 DRY
Set 5	HV	HLT 570

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Set 5	HV	HLT 570

Technical Data	ASM 340 dry version, universal voltage
Backing pump capacity	3.4 m^3/h
Detectable gases	^4He, ^3He, H_2
Flange (in)	DN 25 ISO-KF
I/O interfaces	1 Digital input (Start test); 2 Digital outputs (Test mode ok, Helium signal above reject set point); 3 Analog outputs (Configurable : Helium signal l og, Mantissa, Exponent, Inlet pressure)
Interface	RS-232
Max. inlet test pressure	25 hPa
Minimum detectable leak rate for helium (sniffing leak detection)	$5 \cdot 10^{-10}$ Pa m^3/s
Minimum detectable leak rate for helium (vacuum leak detection)	$5 \cdot 10^{-13}$ Pa m^3/s
Noise level	52 dB(A)
Operating temperature (hard vacuum test)	0-35 °C
Operating temperature (sniffing test)	0-35 °C
Power consumption max.	600 W
Protection category	IP20
Pumping speed for He	2.5 l/s
Start-up time (20°C) without calibration	~ 3 min
Supply	90-240 V, 50/60 Hz
Test method	Vacuum and sniffing leak detection
Warranty: Year(s)	2
Weight	45 kg | 99.21 lb

Leak detection - references

- Pfeiffer Vacuum, Vacuum-Technology-Book-II-Part-2 or Leak Detection Compendium
- Leybold, Fundamentals of Leak Detection
- K. Zapfe, "Leak Detection", Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany pp227-240
- DIN EN 1330-8:1998-7 Zerstörungsfreie Prüfung – Terminologie – Teil 8: Begriffe der Dichtheitsprüfung
- A. Preglj, M. Drab, M. Moztic, "Leak Detection Methods and Defining the Sizes of Leaks", NDT.net -February 1999, Vol.4, No2
- N. Hilleret, "Leak Detection", CERN, Geneva-Switzerland pp203-212

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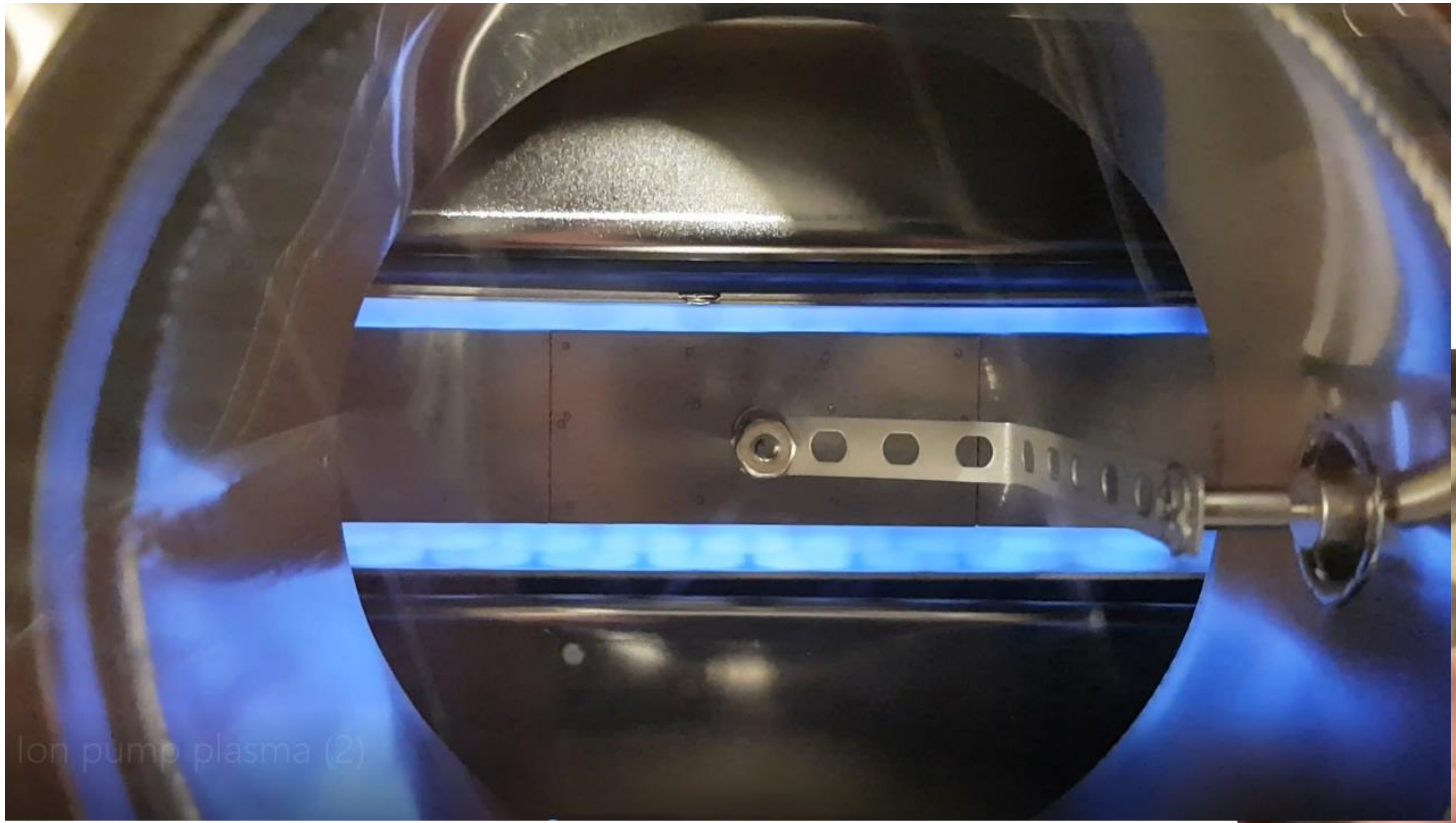
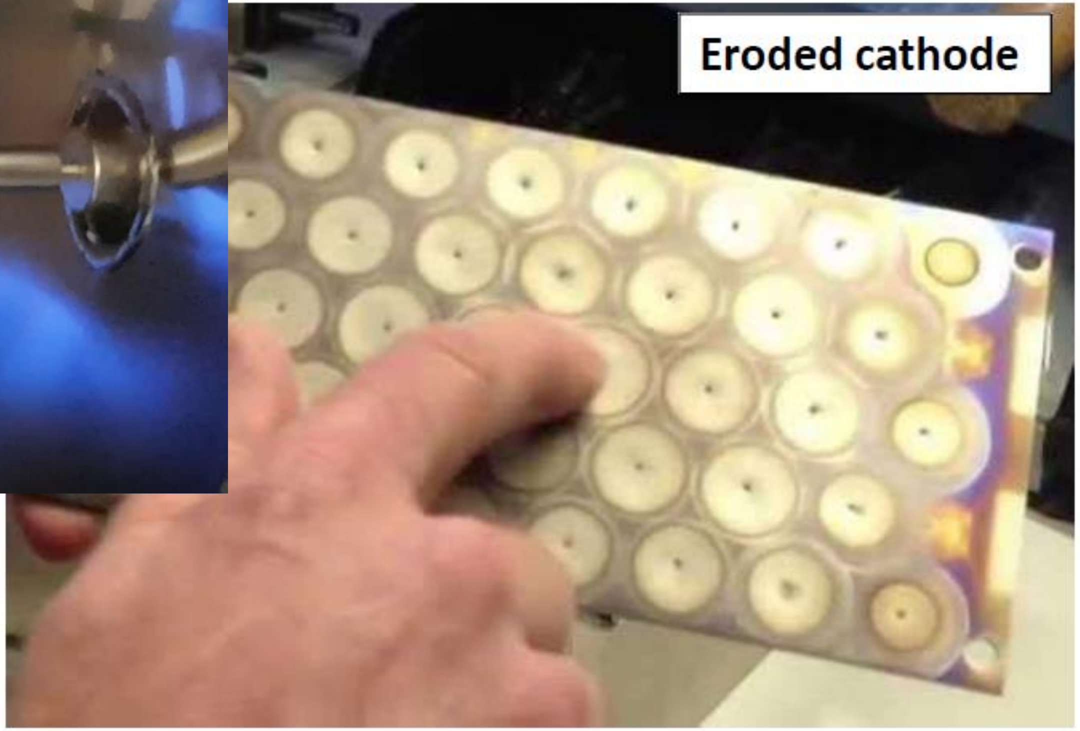
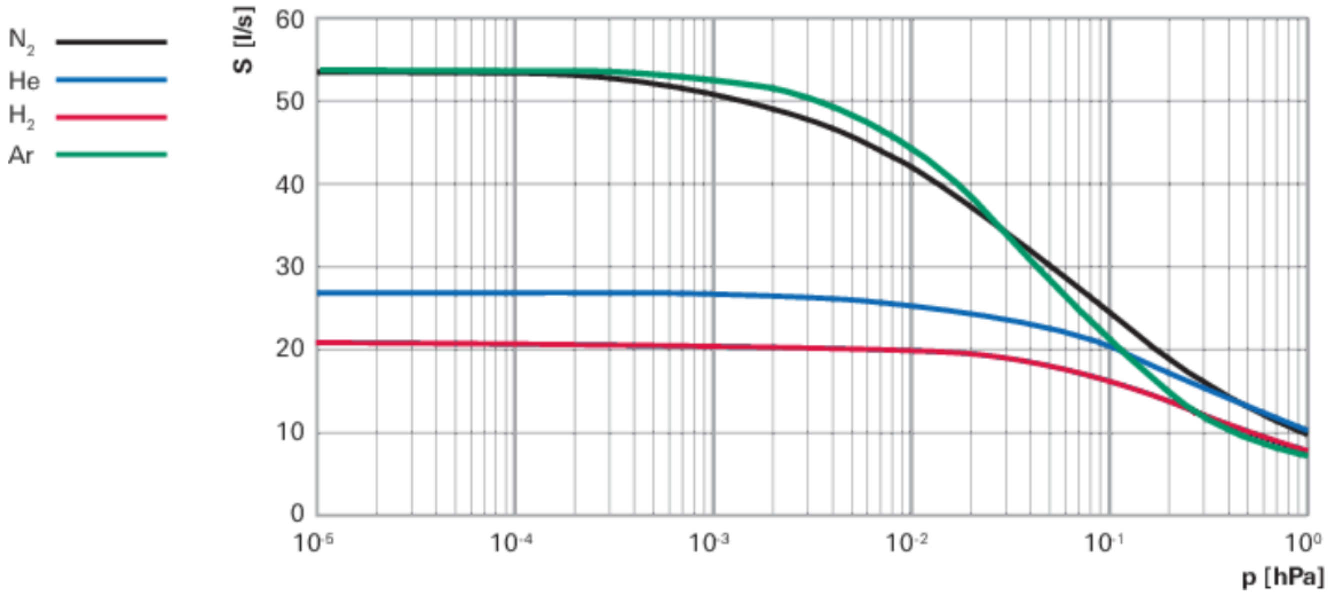
Practice for leak detection
There is a leak! Can you locate it?





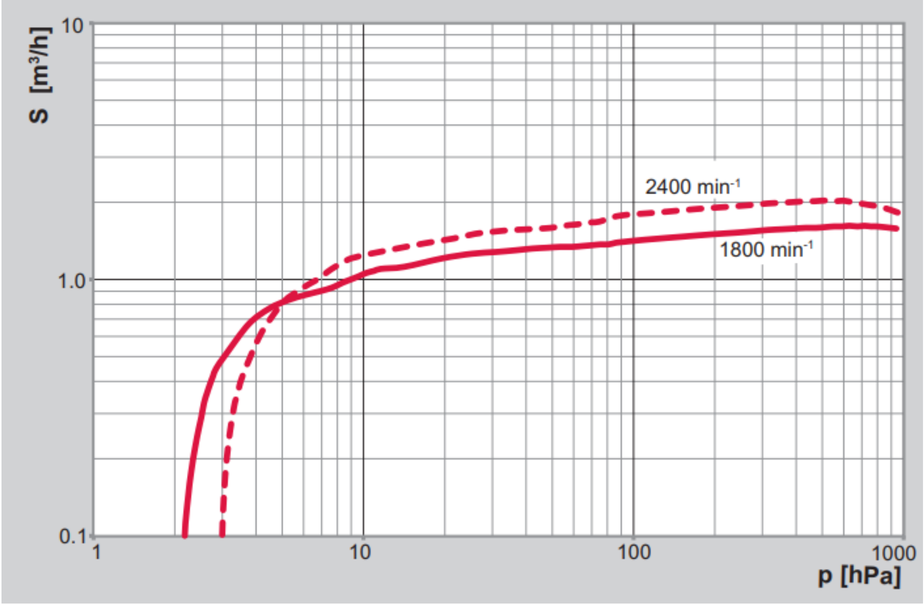
Lifetime: cathode is sputtered away (eroded) by impacting ions. If operating at high pressures (10^{-4} mbar) the pump lifetime is 400 h whereas at 10^{-6} it is 40000 h (4.5 year).

Compression ratio (interstage pumping/fore-vacuum) for Ar	$1.5 \cdot 10^3$
Compression ratio (interstage pumping/fore-vacuum) for H_2	$2 \cdot 10^1$
Compression ratio (interstage pumping/fore-vacuum) for He	$5 \cdot 10^1$
Compression ratio (interstage pumping/fore-vacuum) for N_2	$9 \cdot 10^2$
Compression ratio for Ar	$2.1 \cdot 10^{10}$
Compression ratio for H_2	$1.3 \cdot 10^6$
Compression ratio for He	$1.8 \cdot 10^6$
Compression ratio for N_2	$1 \cdot 10^8$



https://www.pfeiffer-vacuum.com/en/products/vacuum-generation/turbopumps/hybrid-bearing/splitflow-50/5722/splitflow-50-with-tc-110-dn-63-iso-k

Pumping speed	1.8 m³/h | 1.06 cfm | 30 l/min
Ultimate pressure with gas ballast	≤ 3 hPa | ≤ 2.25 Torr | ≤ 3 mbar
Ultimate pressure without gas ballast	≤ 2 hPa | ≤ 1.5 Torr | ≤ 2 mbar



https://www.pfeiffer-vacuum.com/en/products/vacuum-generation/diaphragm-pumps/mvp-030/30880/mvp-030-3-dc-diaphragm-pump-24-v-dc