진공의 발생과 측정

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Contents

진공의 발생

- **Throughput mechanisms:**
  - **Positive displacement**: Molecules are compressed into a smaller volume, raising the pressure
  - **Momentum transfer**: Molecules are given a preferred direction by very fast moving surfaces or oil molecules

- **Capture mechanisms:**
  - **Chemical combination**: Molecules react with active metal surfaces and are converted to a solid
  - **Condensation**: Molecules land on a very cold surface and freeze into a solid
  - **Adsorption**: Molecules land on a surface and remain there
  - **Absorption**: Molecules land on a surface and dissolve into the bulk material
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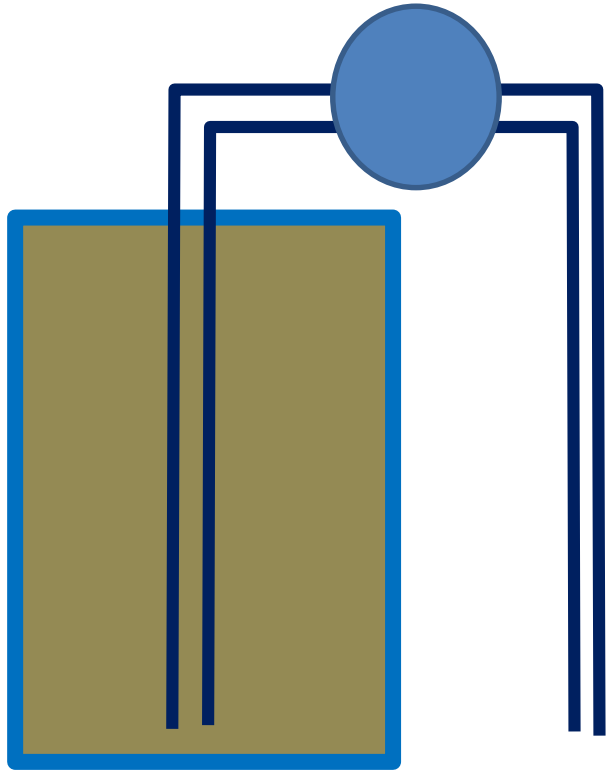
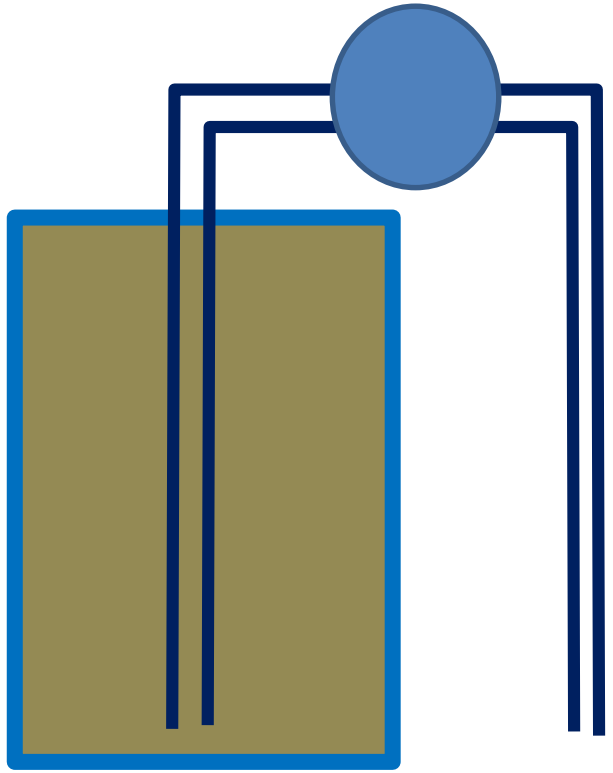
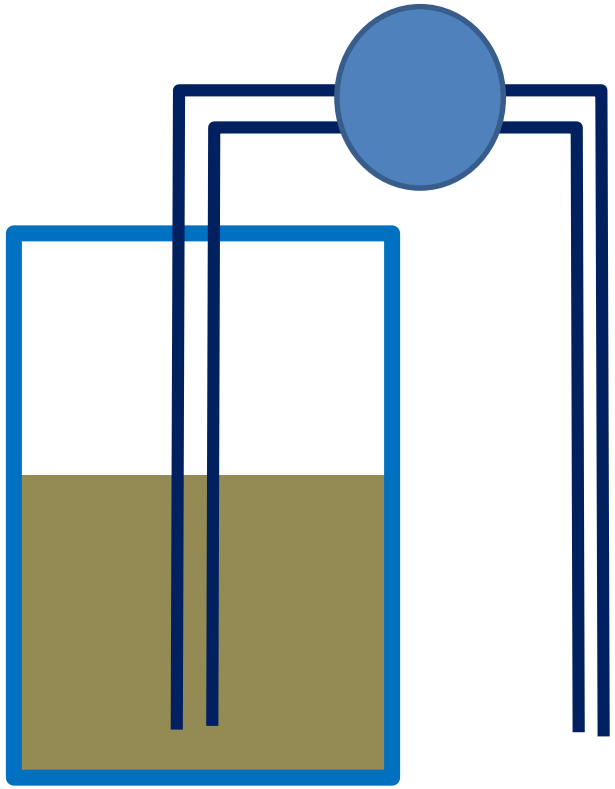
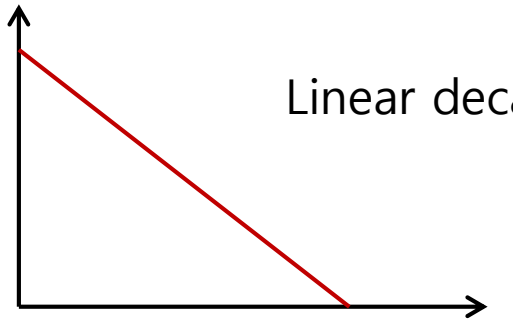
물펌프와 진공펌프



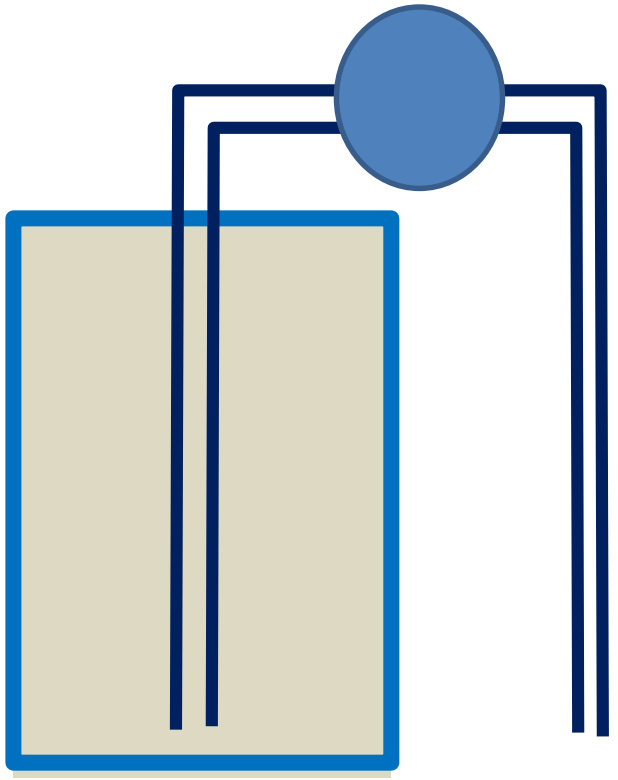


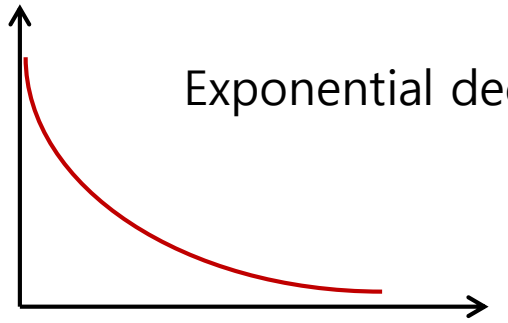
❖ Water pump

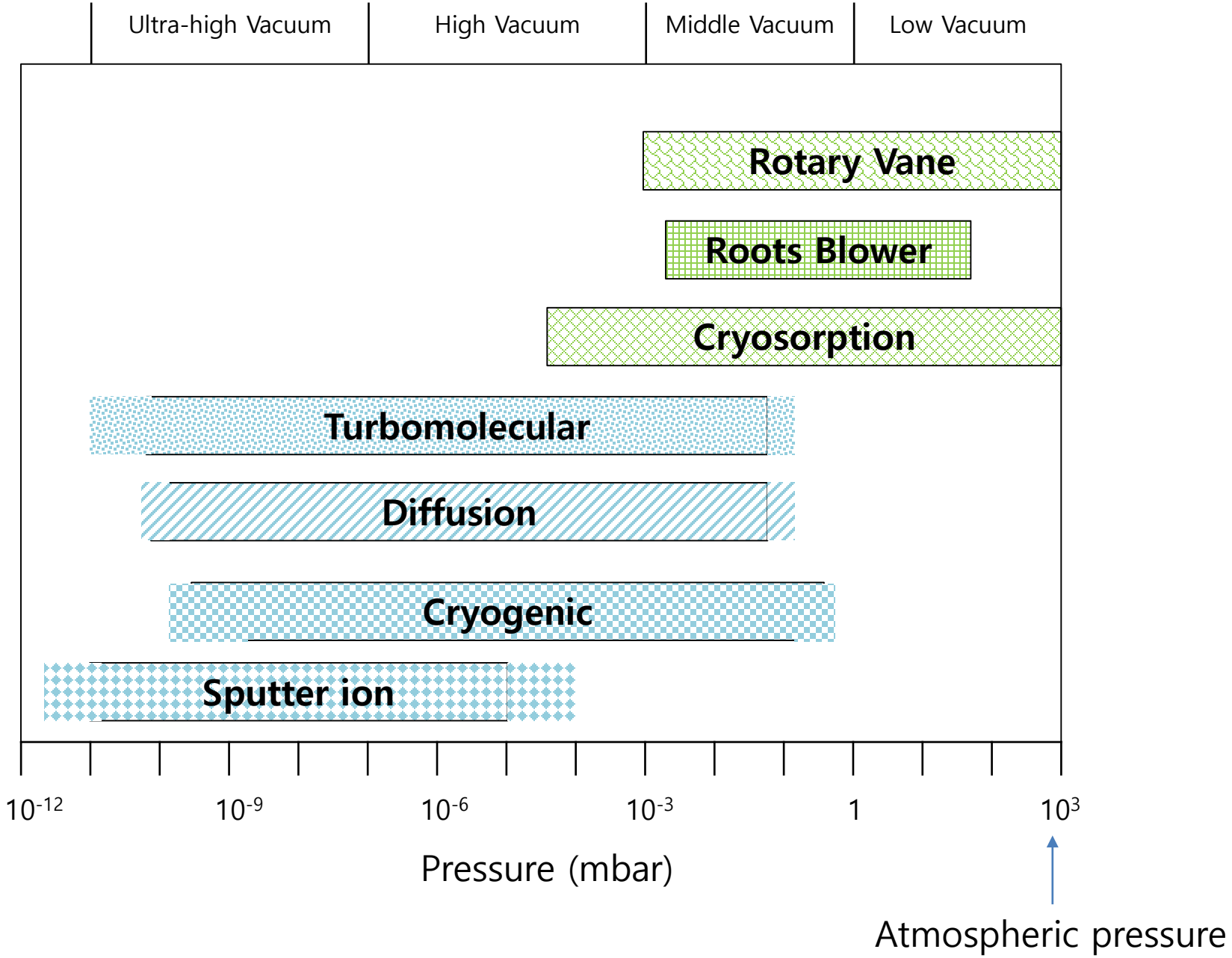




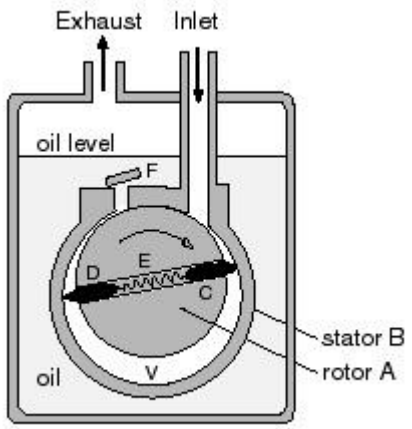
❖ Vacuum pump



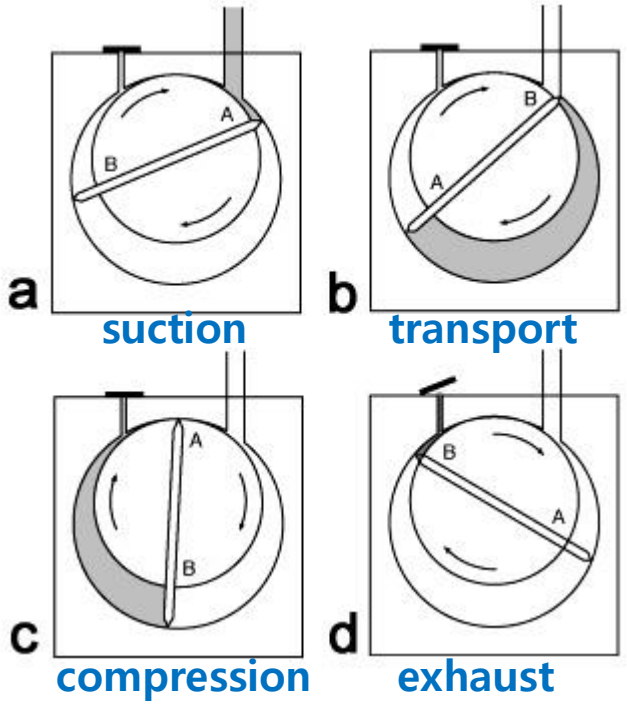



Ultra-high Vacuum
High Vacuum
Middle Vacuum
Low Vacuum
Rotary Vane
Roots Blower
Cryosorption
Turbomolecular
Diffusion
Cryogenic
Sputter ion
10-12
10-9
10-6
10-3
1
103
Pressure (mbar)
Atmospheric pressure

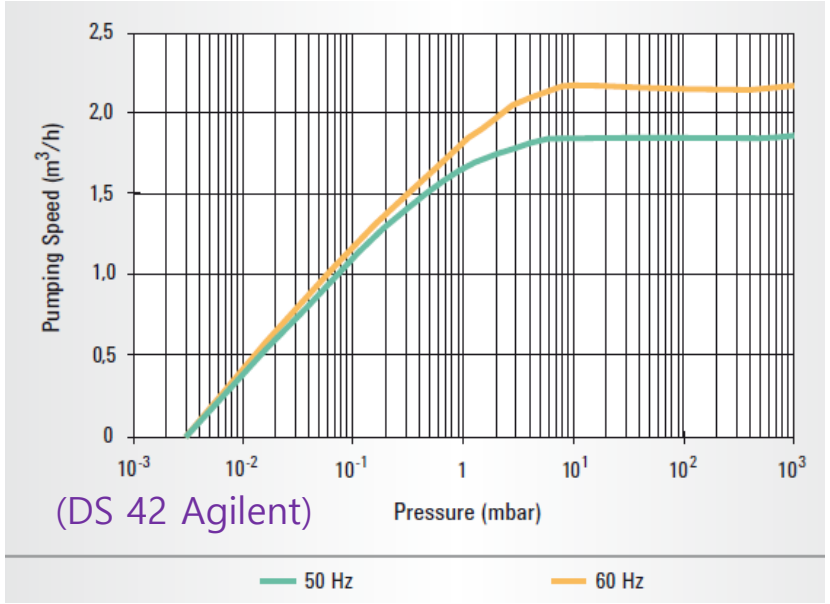
회전베인펌프 (Rotary Vane Pump)



Positive displacement



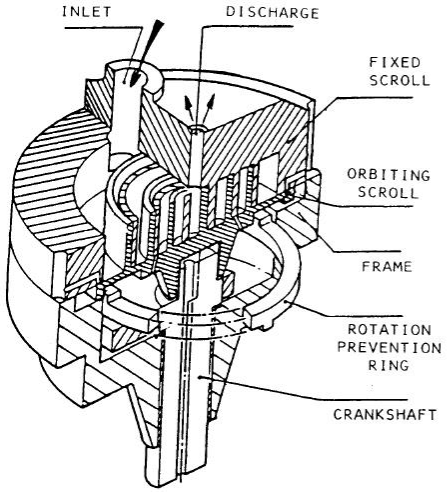
Typical pumping speed curve

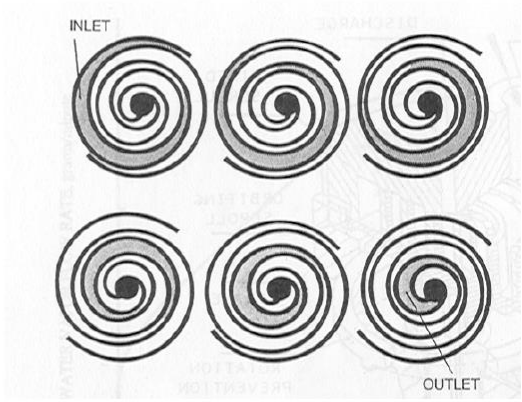


(DS 42 Agilent)

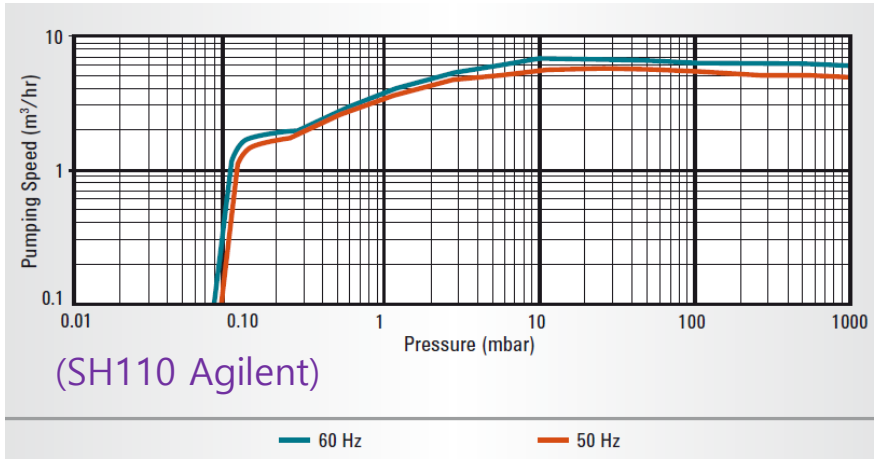
스크롤 펌프 (Scroll Pump)

Positive displacement





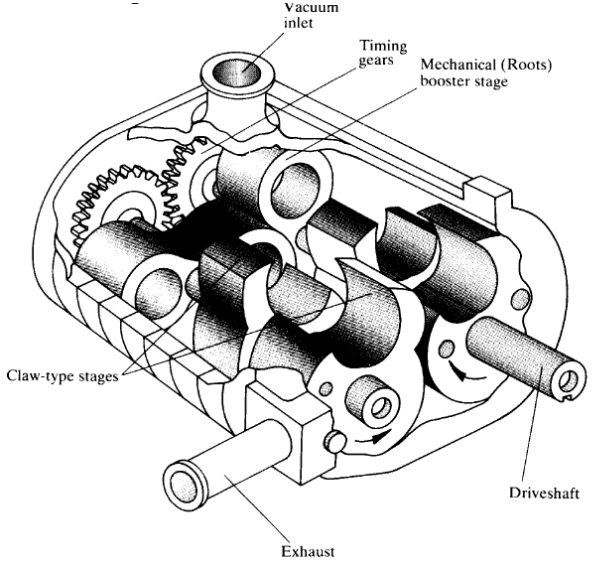
Typical pumping speed curve



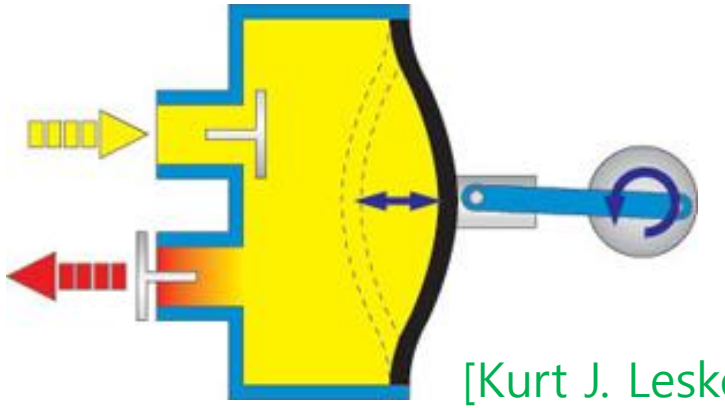
(SH110 Agilent)

[Wikipedia]

Claw Pump

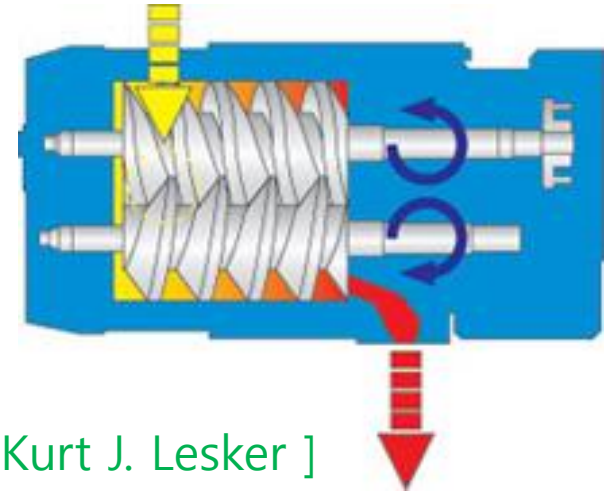


Diaphram Pump



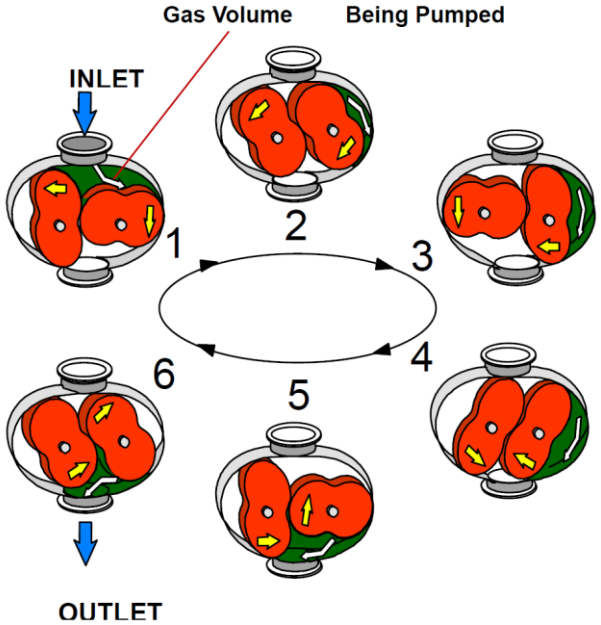
[Kurt J. Lesker]

Screw Pump



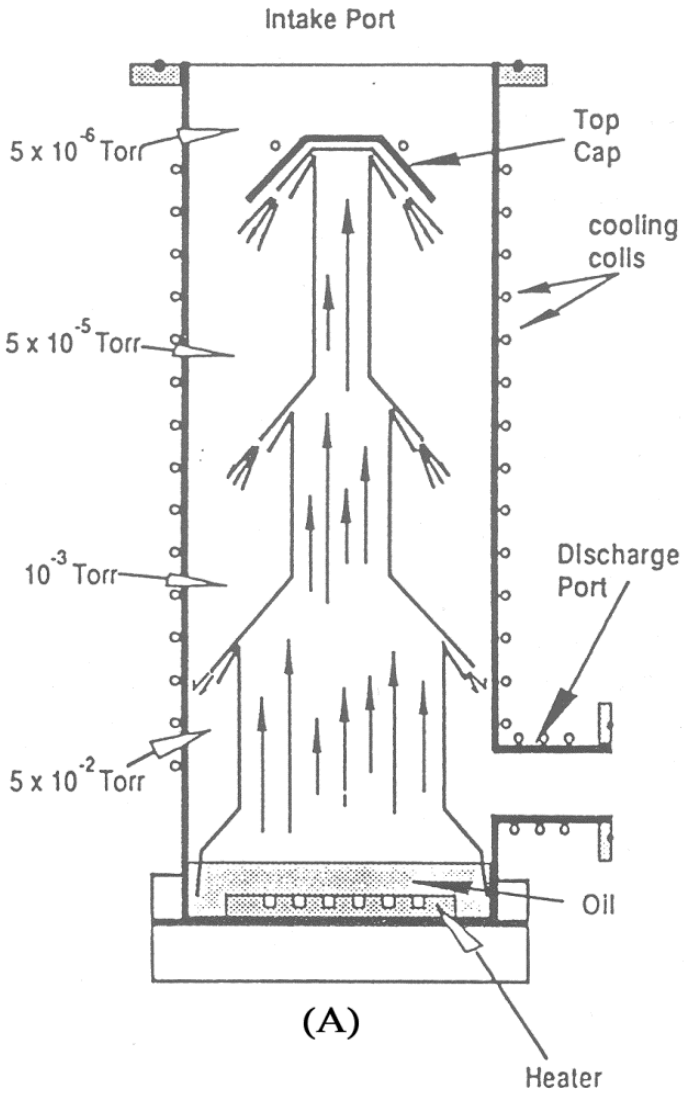
[Kurt J. Lesker]

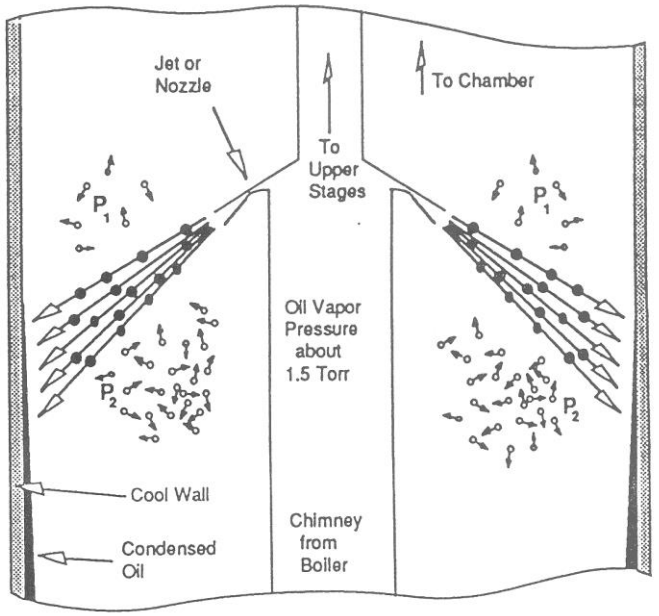
Roots Pump



확산펌프 (Diffusion Pump)

Momentum transfer

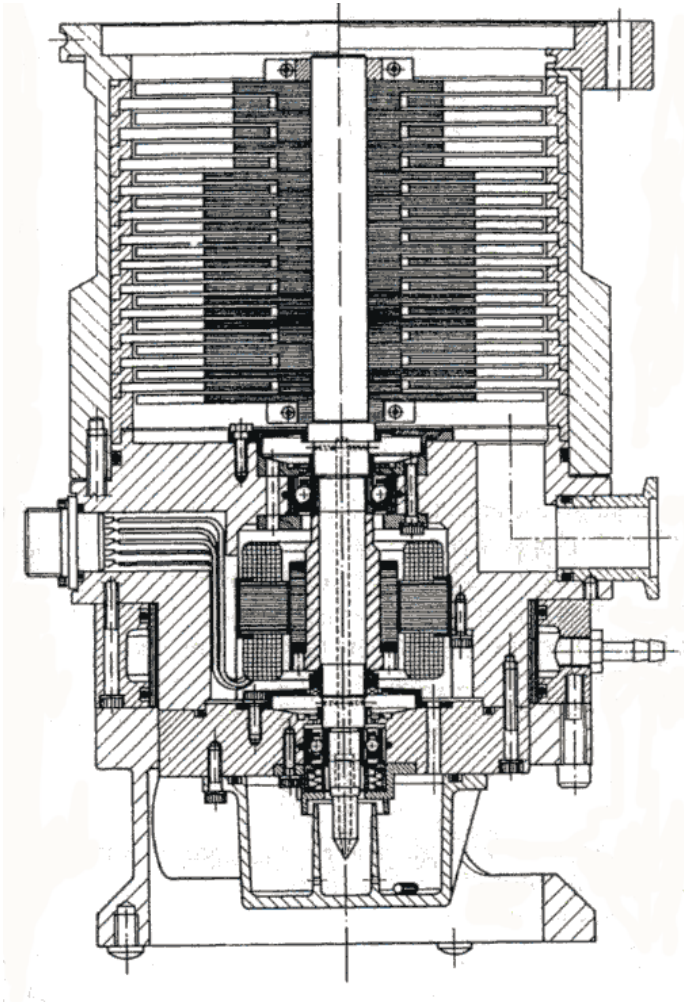




터보분자펌프 (Turbo Molecular Pump: TMP)

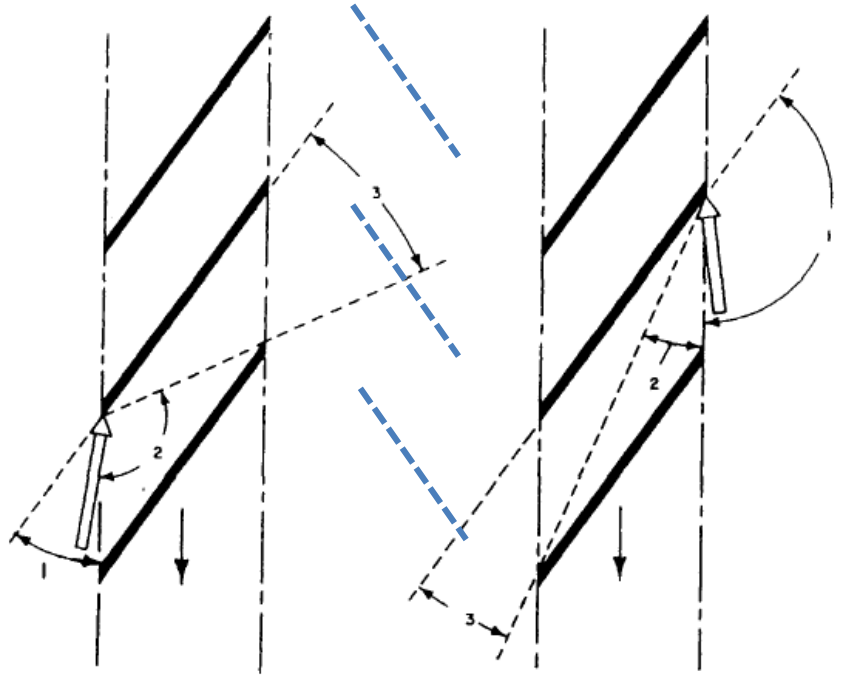
Momentum transfer

- Operate in the molecular flow regime
- Operating range 10^{-2} to 10^{-10} Torr
- Pumping speed 10 to 10,000 l/s
- Infinite pumping capacity
- Blade rotation speed ranges from 14,000 to 90,000 rpm (mechanically vulnerable)

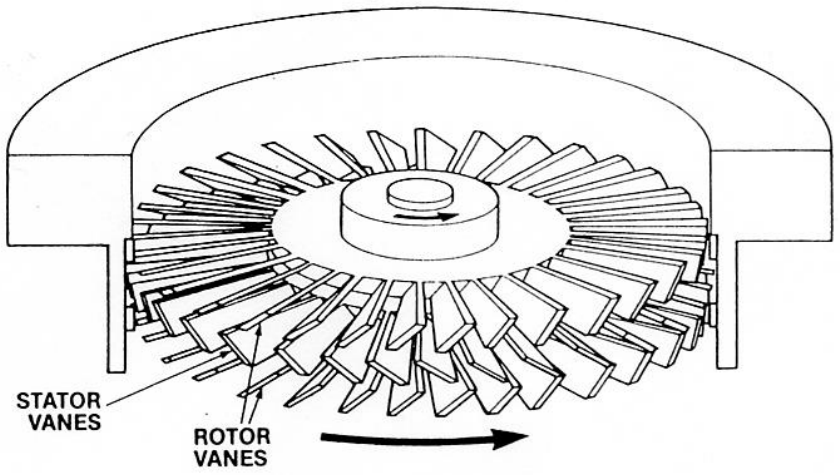


❖ TMP의 배기 원리

Vacuum side

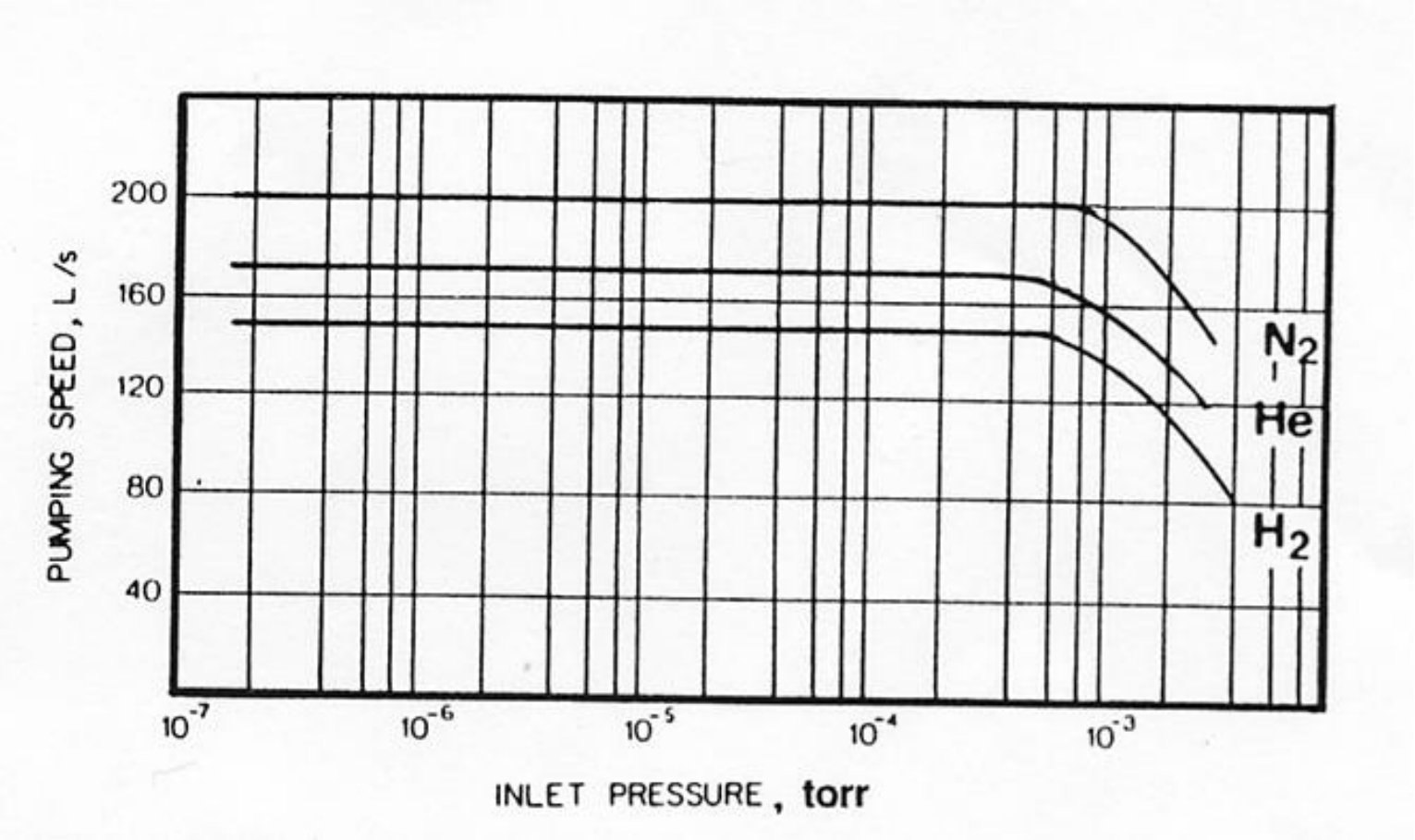


Air side



"Stators redistribute directions of molecules at each stage"

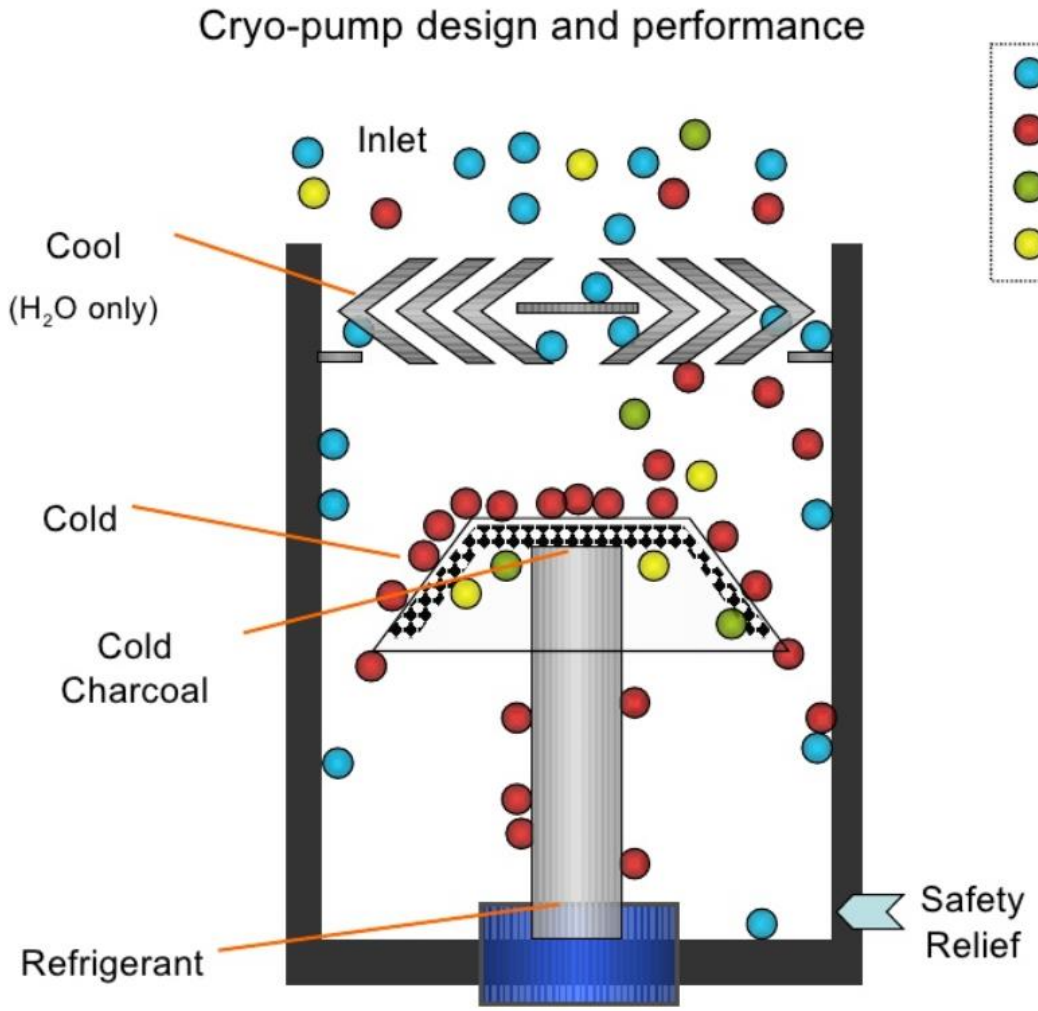
❖ TMP의 배기속도



$$v_a = \int_0^\infty v f(v) dv = \sqrt{\frac{8kT}{\pi m}} = 146\sqrt{\frac{T}{M}}$$

크라이오펌프 (Cryo-pump)

Physical combination

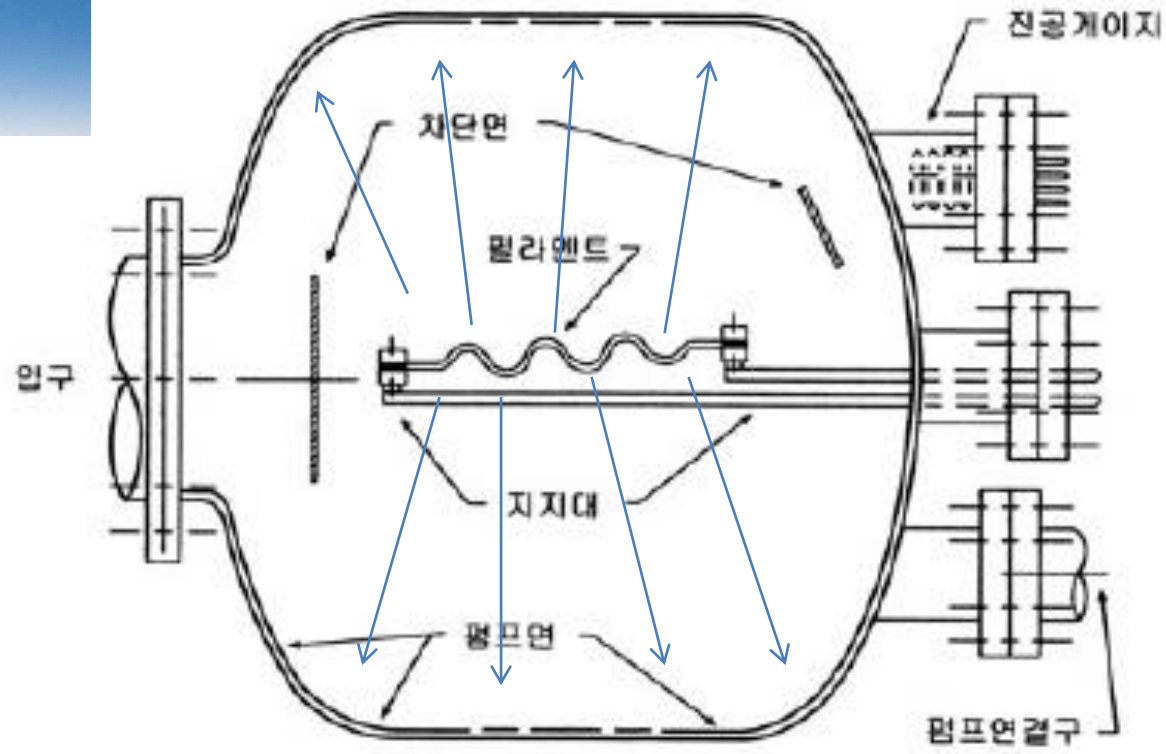


- Water
- Nitrogen and Oxygen
- Helium
- Hydrogen

티타늄 승화펌프 (Titanium Sublimation Pump: TSP)

Ti filament

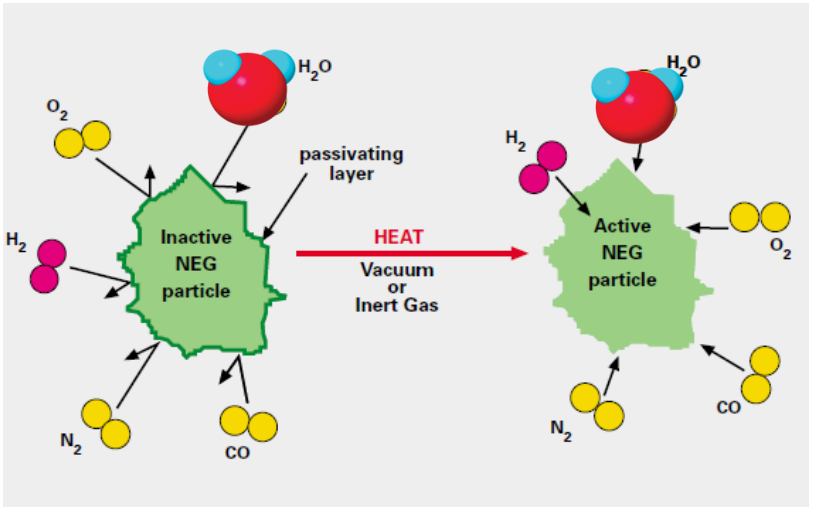
Chemical combination

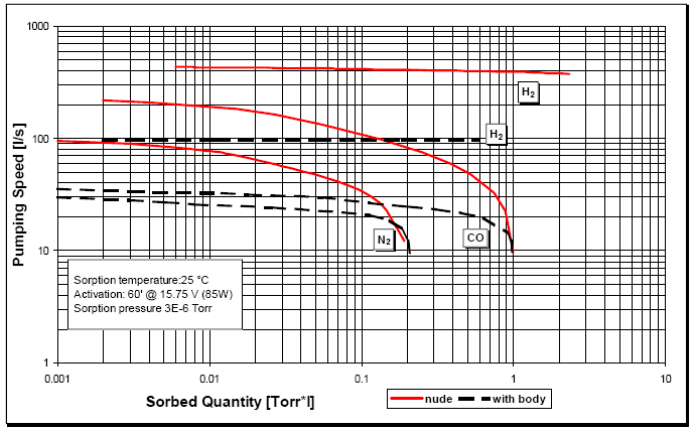


- ✓ Ti evaporation → Deposited fresh Ti layer → Gas-Ti chemical combination
- ✓ No pumping ability for inactive gas (Ar, He, CH4)

NEG 펌프 (Non Evaporable Getter)

Chemical combination

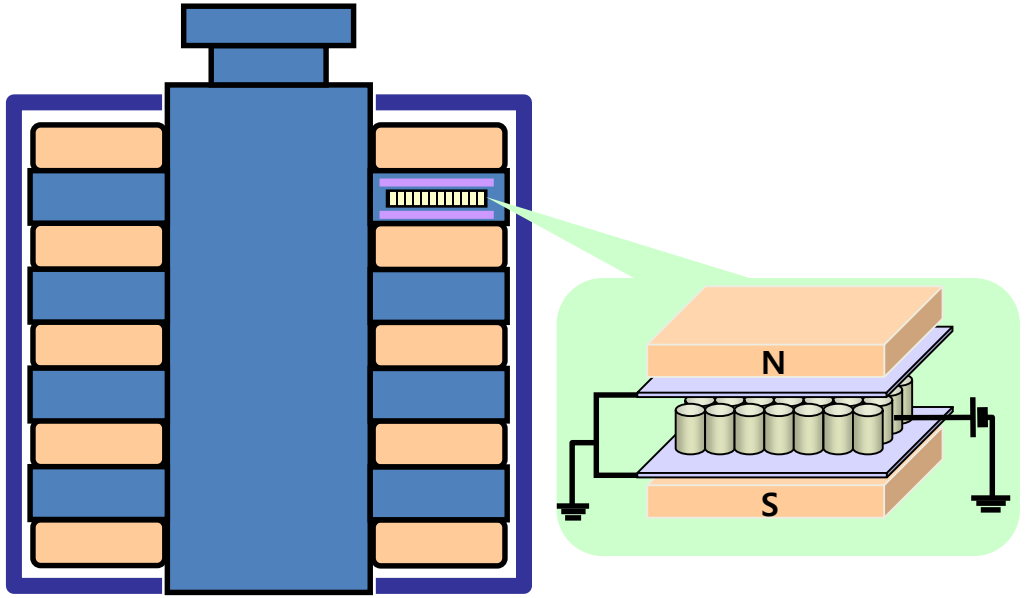




- ✓ **Activation** of surface (by heating) → **chemical combination**
- ✓ No pumping ability for inert gas (Ar, He, CH4)

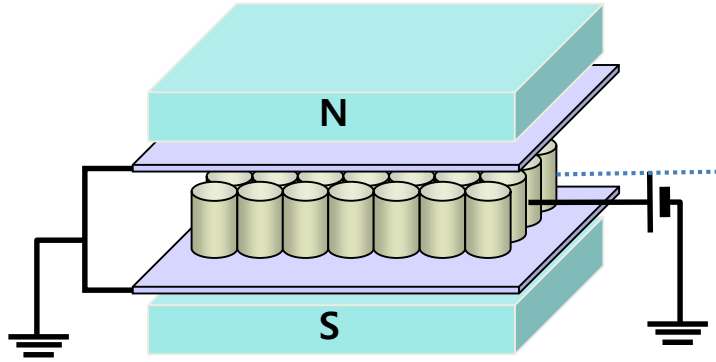
스퍼터 이온펌프 (Sputter Ion Pump: SIP)

Chemical combination

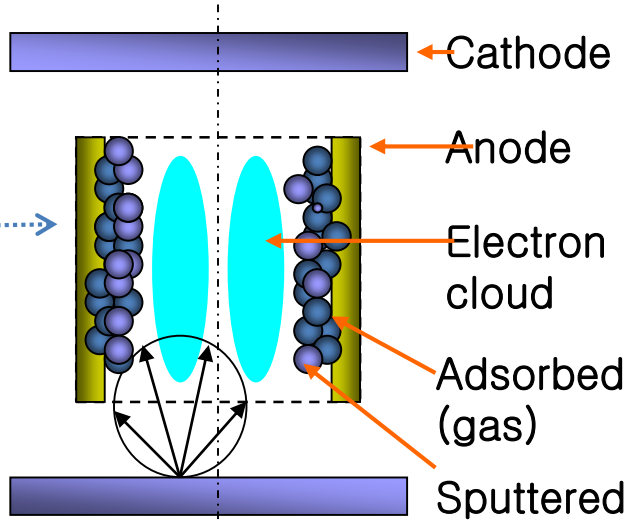


- ✓ Electron cloud → ionization → high energy impact on Ti plate → Ti Sputtering → Deposited fresh Ti layer → chemical combination
- ✓ Pumping ability for CH4
- ✓ Low pumping speed for noble gas (Ar, He)

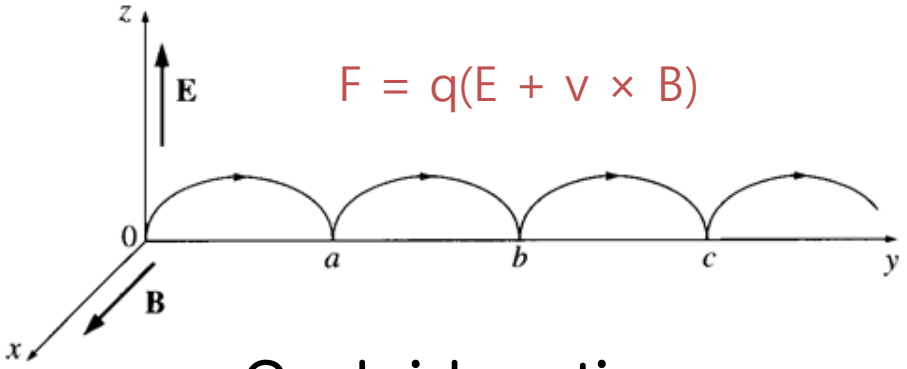
❖ 이온펌프의 배기원리



SIP cell module

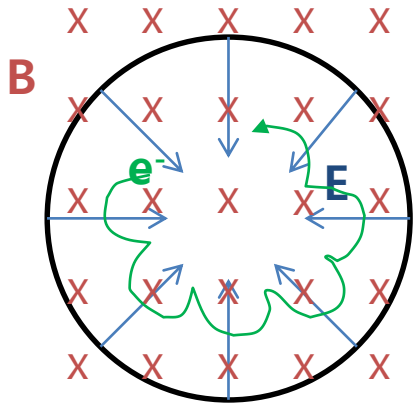


Penning cell



$F = q(E + v \times B)$

Cycloid motion in cross field



❖ 아르곤 불안정성 (Argon instability)

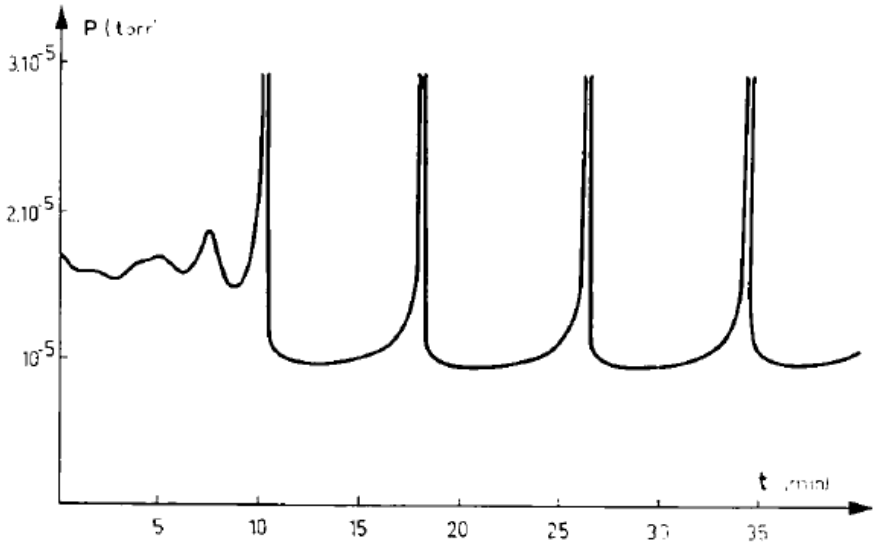
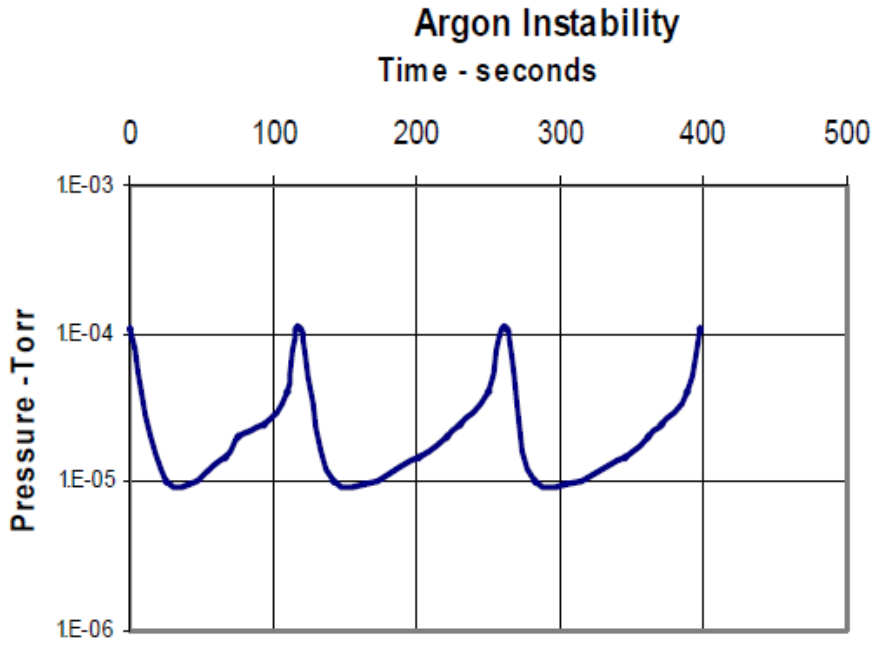
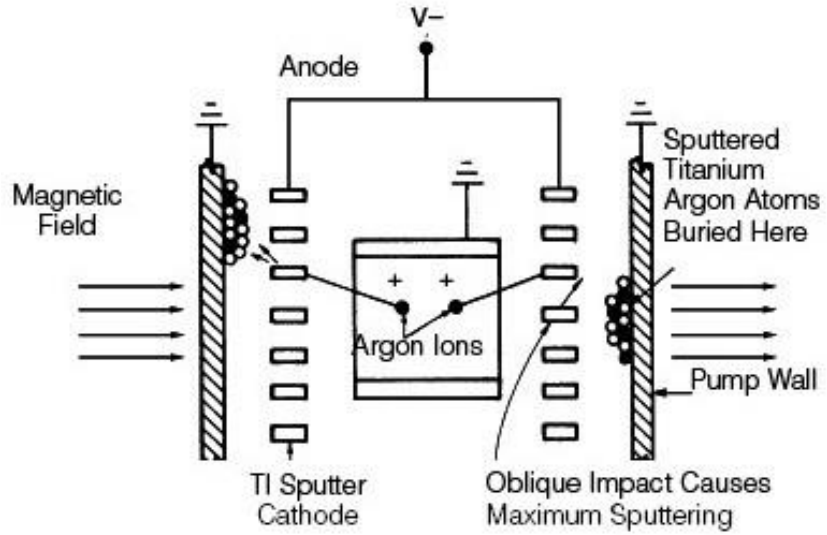


Figure 1. Cyclic instability of Penning pump with a tantalum cathode and a titanium cathode pumping a continuous leak of xenon.

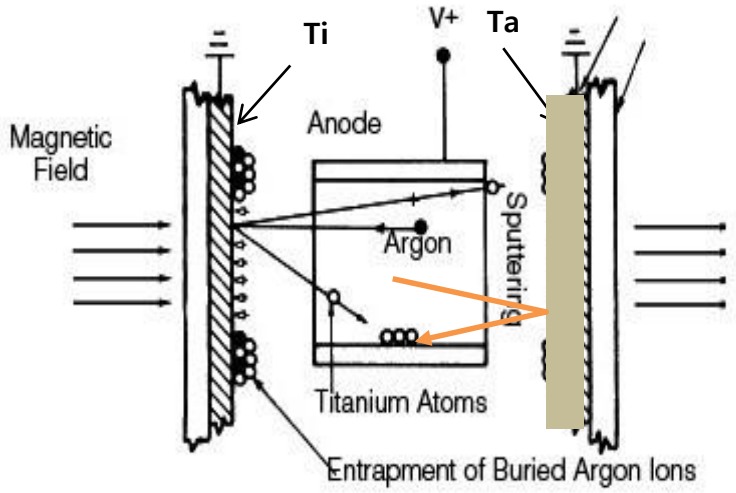
[VACUUM 20(3) 1970, Pages 109–111]



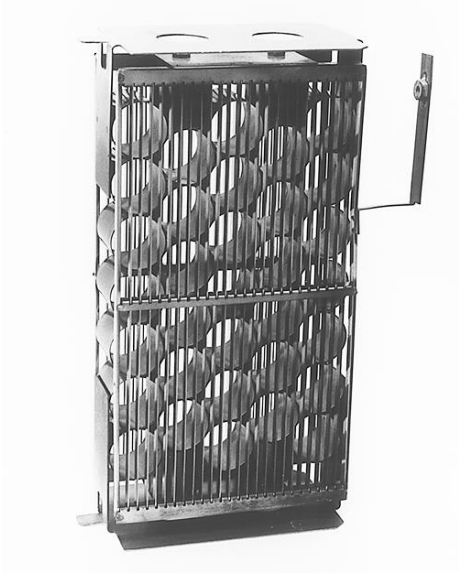
[www.duniway.com]



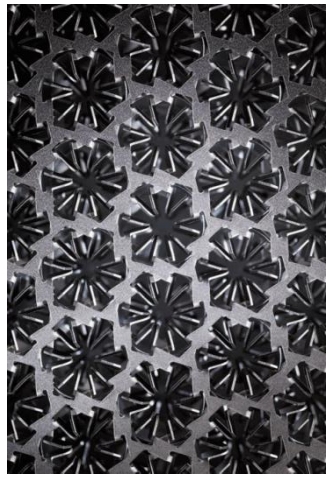
Triode Ion Pump



Noble diode pump



triode

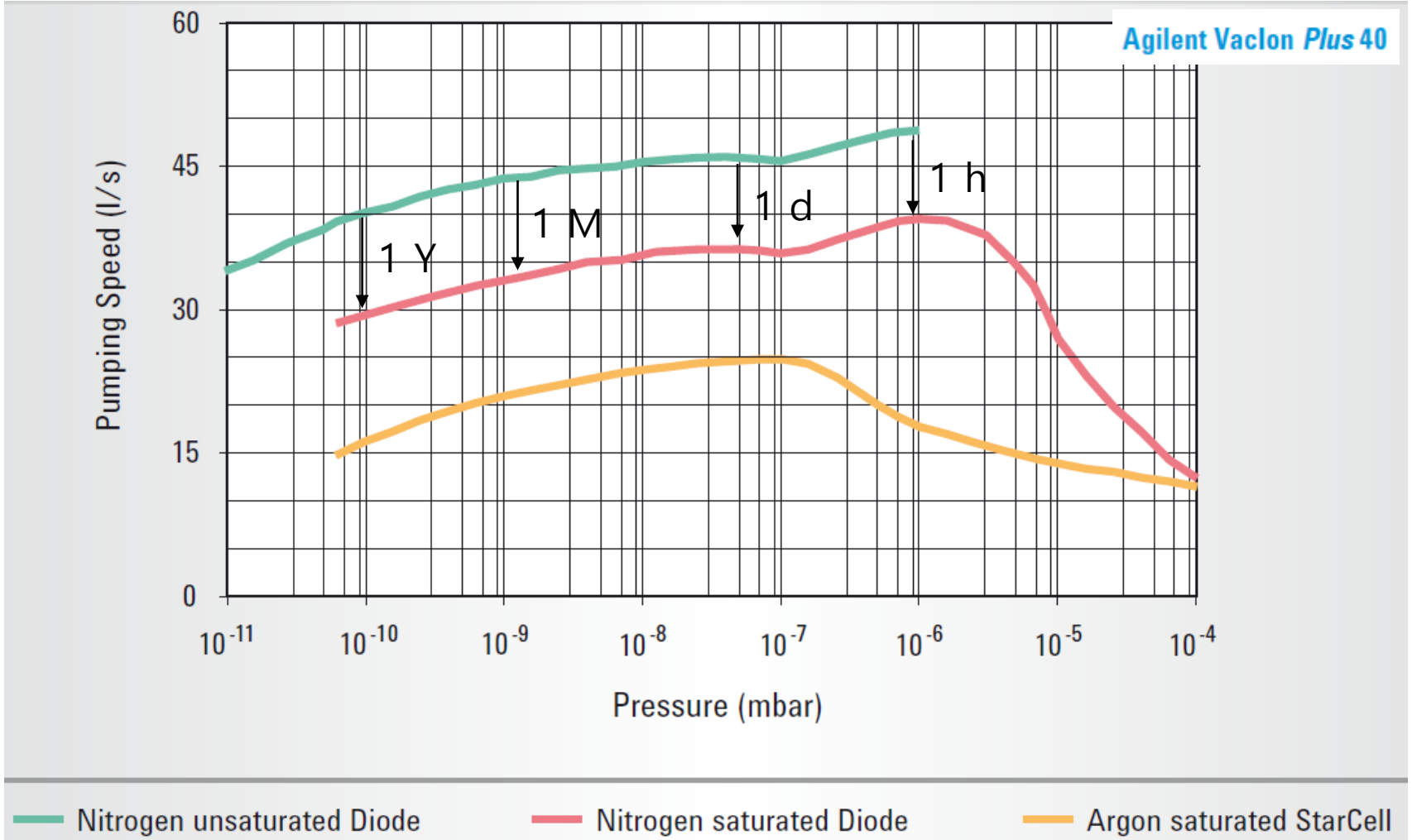


Triode (starcell)

Triode (galaxy)

diode

❖ 이온펌프의 배기속도


Agilent Vaclon Plus 40
Pumping Speed (l/s)
60
45
30
15
0
1 Y
1 M
1 d
1 h
10-11
10-10
10-9
10-8
10-7
10-6
10-5
10-4
Pressure (mbar)
Nitrogen unsaturated Diode
Nitrogen saturated Diode
Argon saturated StarCell

진공의 측정

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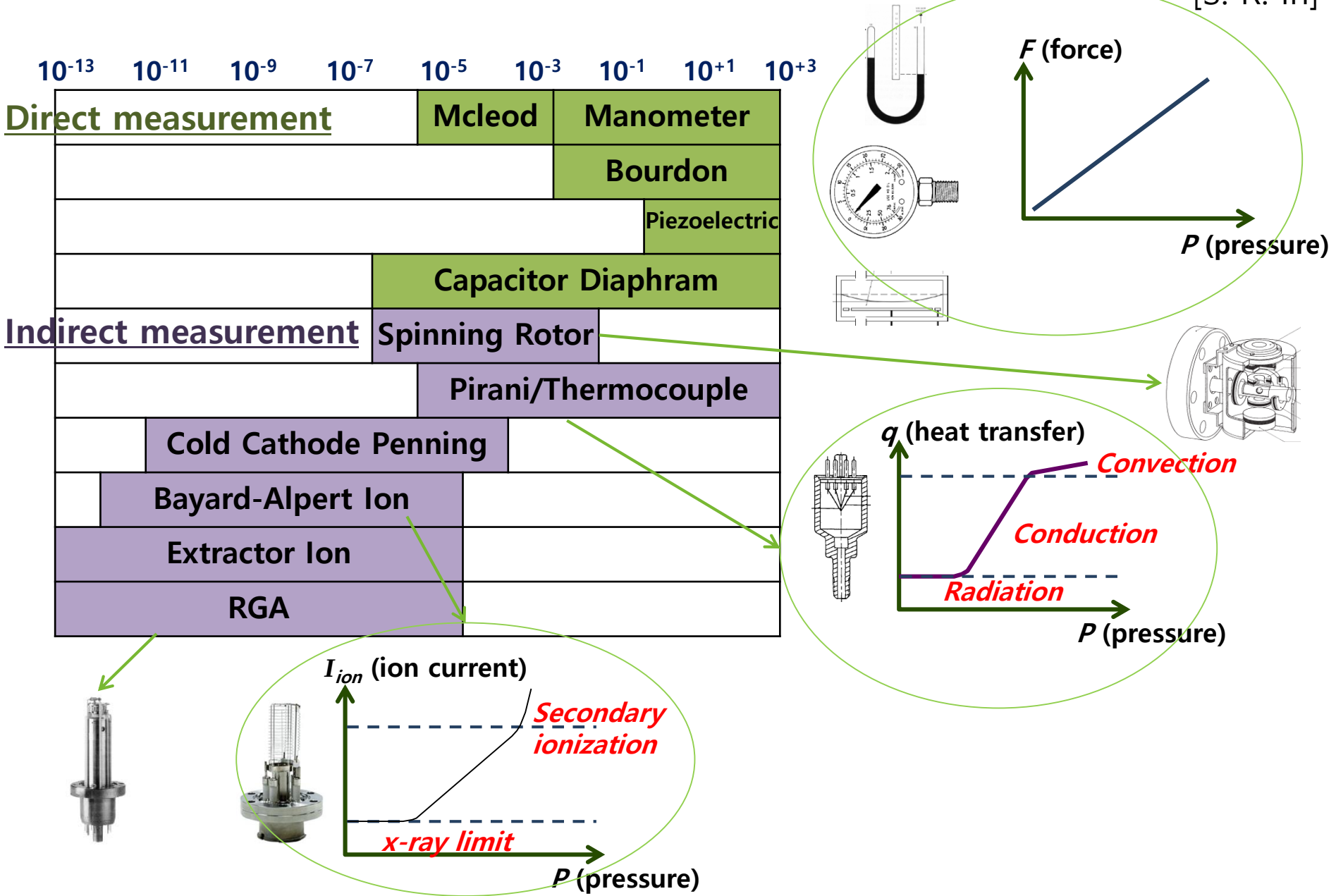
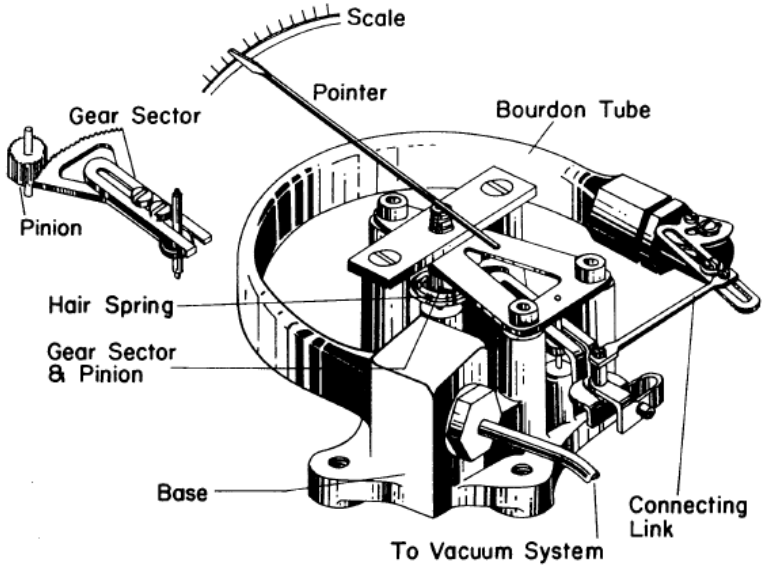
진공영역과 진공게이지

[S. R. In]

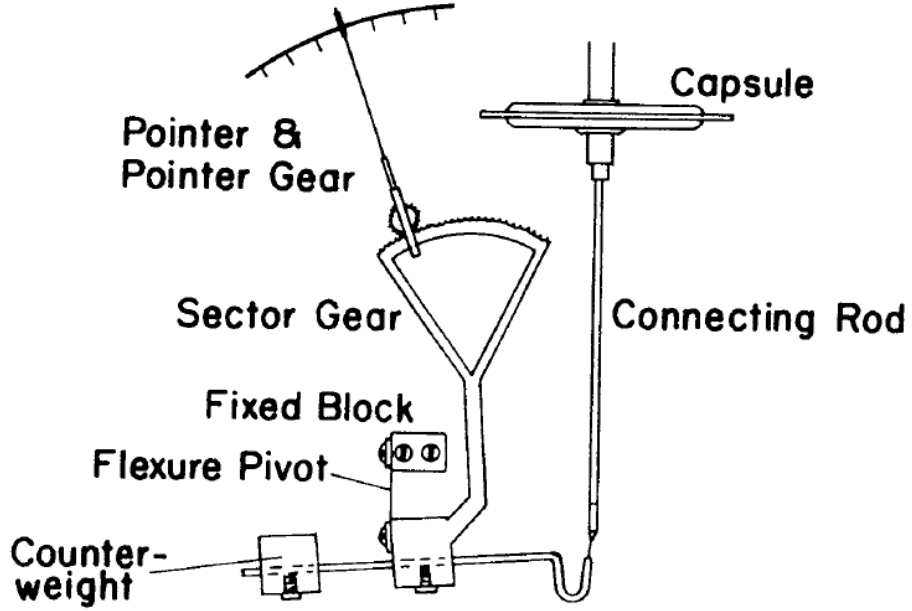


압력의 직접 측정

Direct force on surface



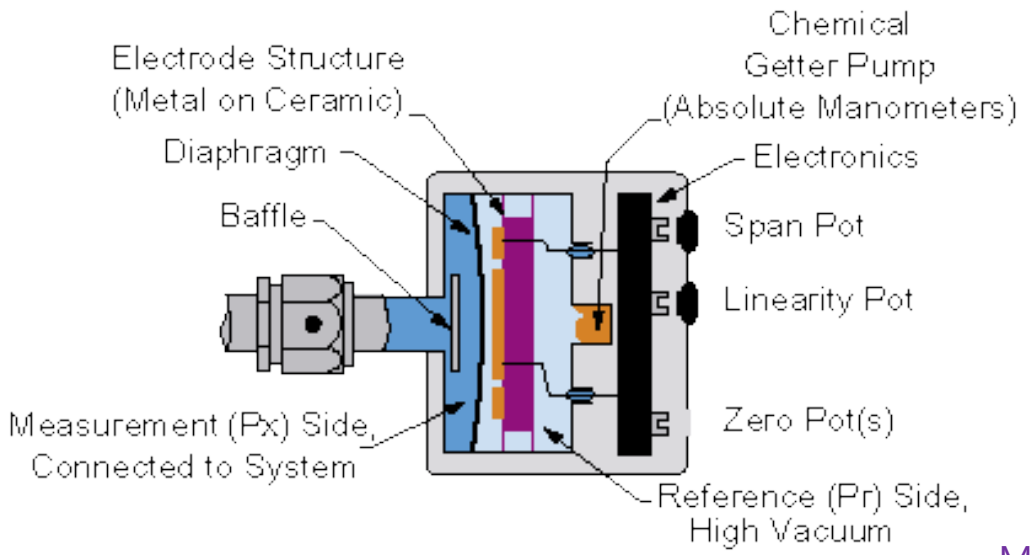
Burdon gauge



Diaphram gauge

정전용량 다이어프램 게이지(CDG)

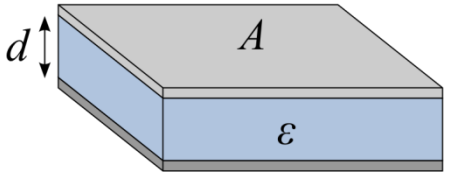
Direct force on surface



MKS

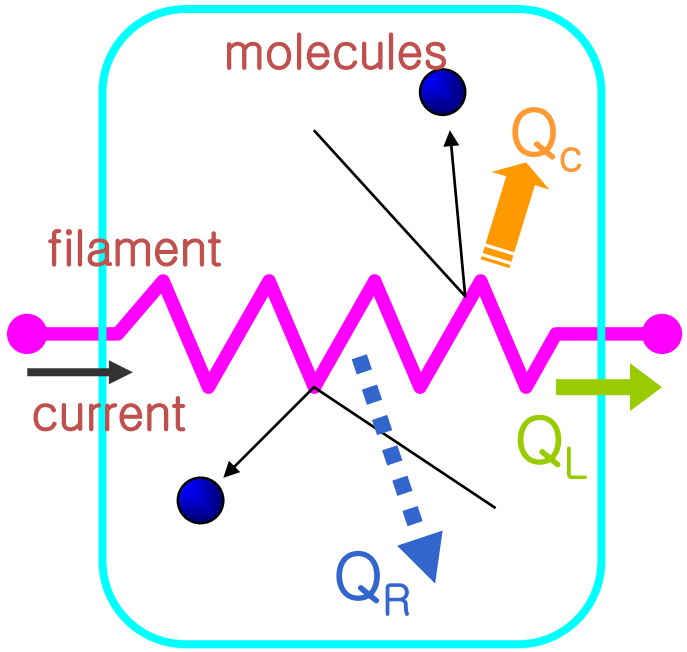
$$C = \varepsilon A/d$$

↑ capacitance



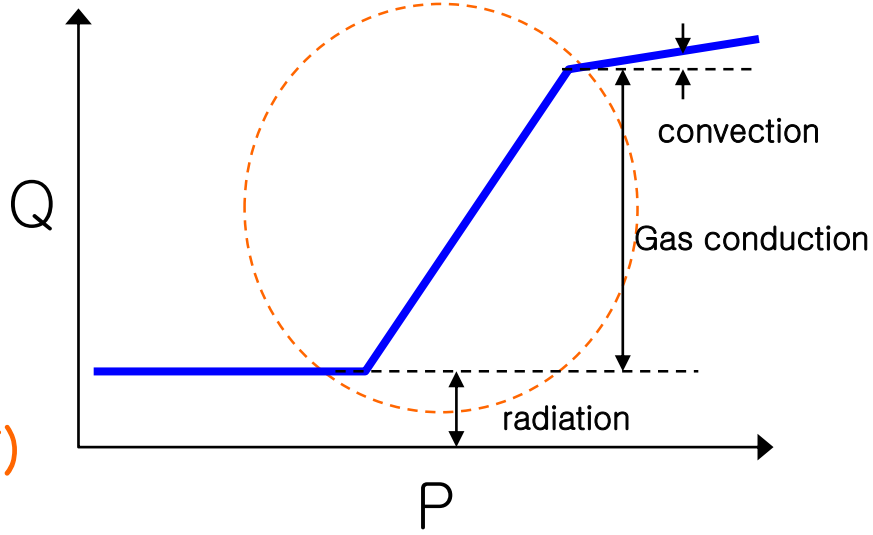
열전도 게이지

Indirect (neutral gas)



$$Q_S = Q_R + Q_L + Q_C$$

Q_R : radiation ($\propto T^4$)
Q_L : wire conduction ($\propto \Delta T$)
Q_C : gas conduction ($\propto P\Delta T$)



Circuit for Pirani type

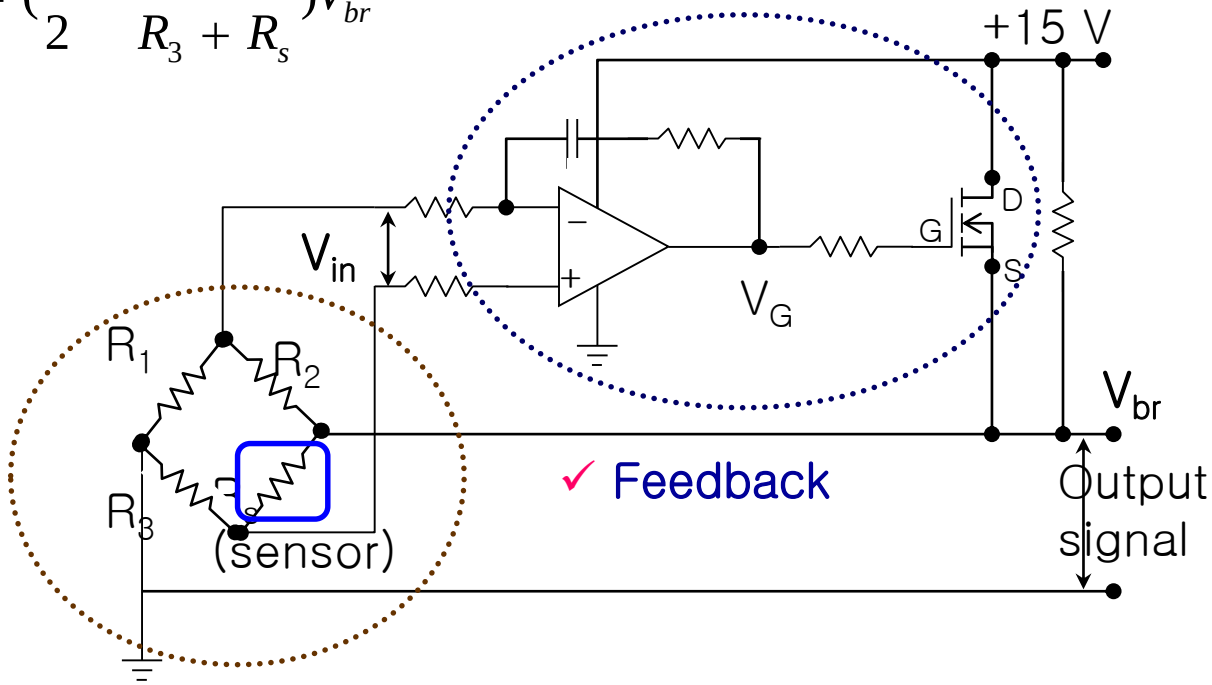
✓ Wheatstone bridge

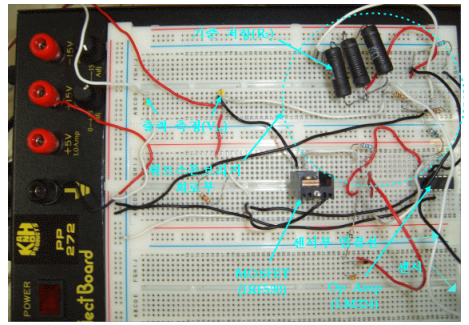
$$V_{in} = \left(\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_s}\right)V_{br}$$

$$= \left(\frac{1}{2} - \frac{R_3}{R_3 + R_s}\right)V_{br}$$

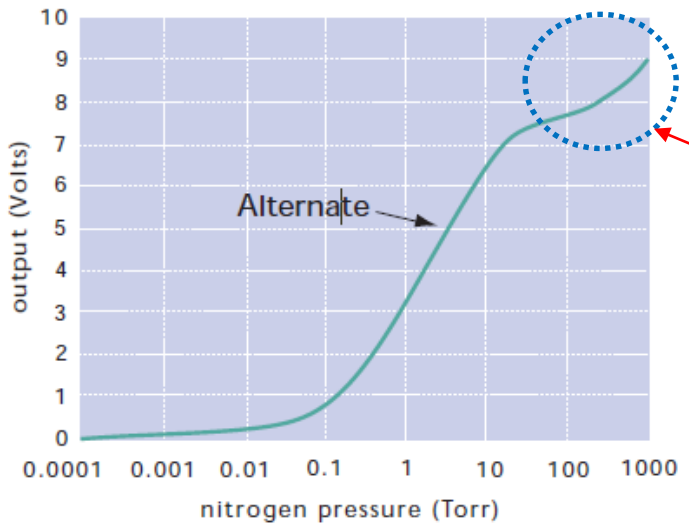
✓ Feedback

- $R_s < R_3 \rightarrow V_{in} < 0 \rightarrow V_G > 0 \rightarrow I_{DS} > 0 \rightarrow R_s > R_3$
- $R_s > R_3 \rightarrow V_{in} > 0 \rightarrow V_G = 0 \rightarrow I_{DS} = 0 \rightarrow R_s < R_3$

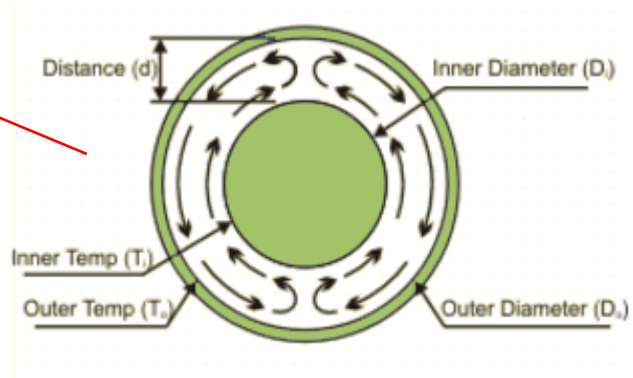




컨벡션 게이지



Indirect (neutral gas)



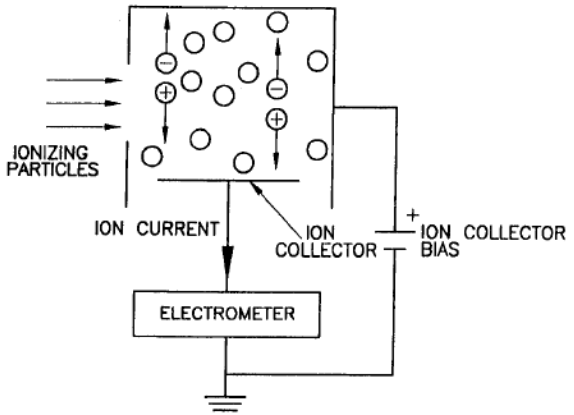
(O)

(X)

열음극형 이온게이지

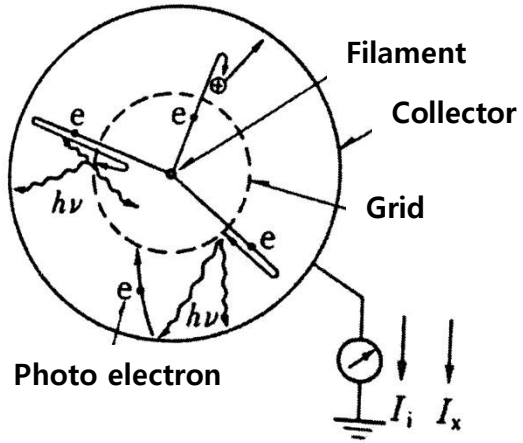
Indirect (ionized gas)

Triode ionization gauge



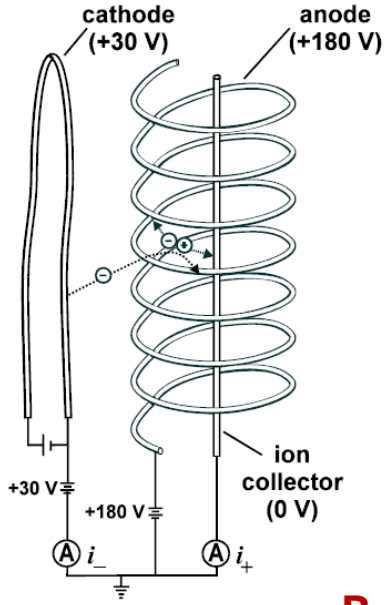
principle

$$I_i = S\, I_e\, P$$

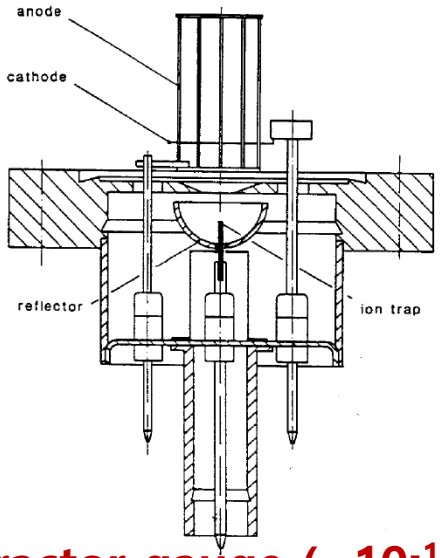


X-ray limit

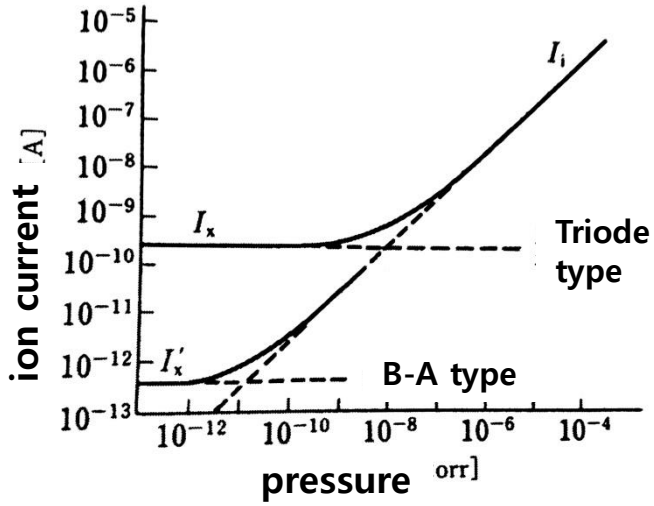
Lower limit of ion gauge



B-A gauge (<10^{-10} mbar)

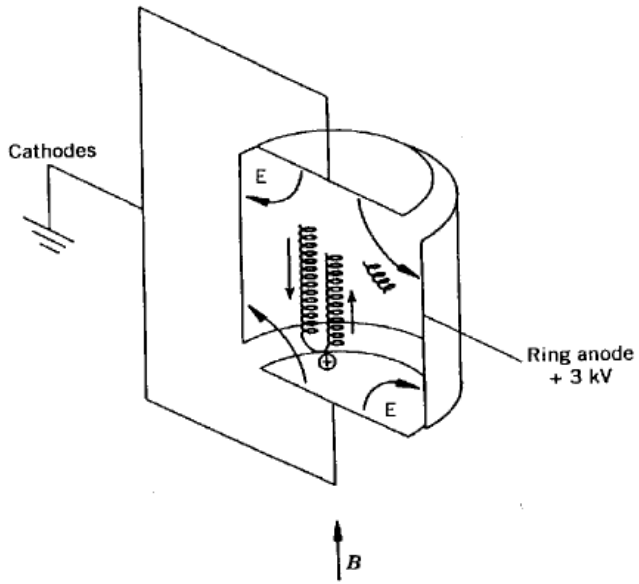


Extractor gauge (~10^{-12} mbar)



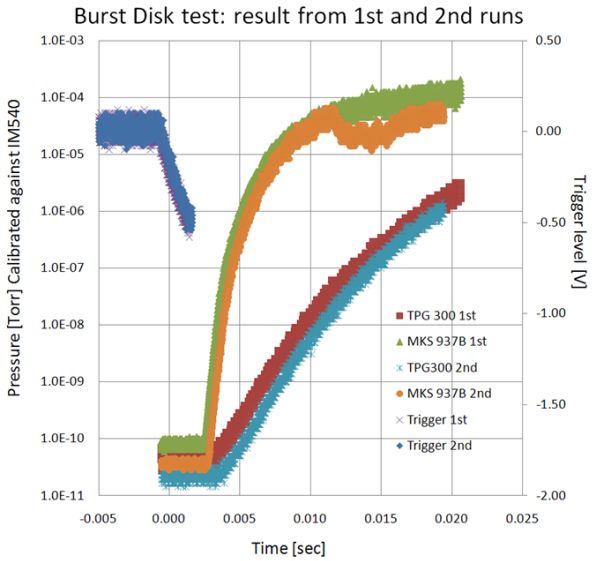
3B gauge (<10^{-14} mbar)

냉음극형 이온게이지



Penning discharge

Fast response time

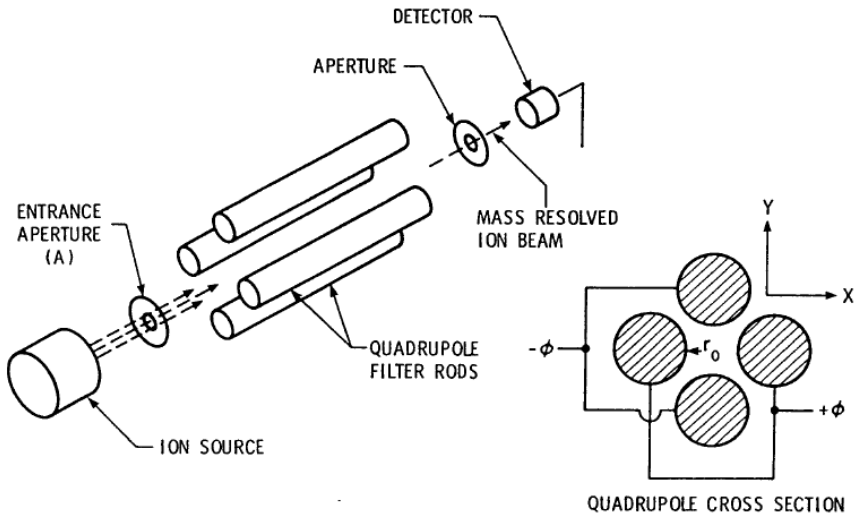


Time interval upto 1 x 10^{-7} Torr:
- MKS 937B 1st run = 4.8 ms
- MKS 937B 2sd run = 5.2 ms
- TPG 300 1st run = 13.8 ms
- TPG 300 2st run = 15.0 ms

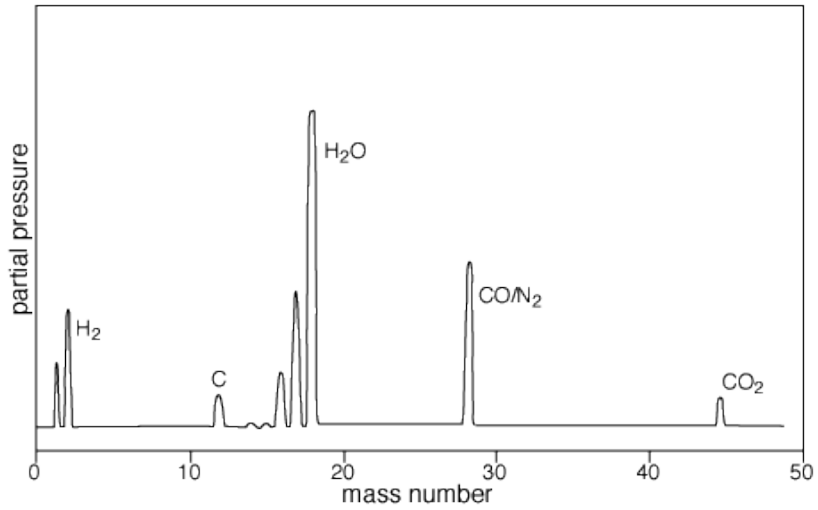
Time travel for the gas reach the gauge using the most probable velocity equation:
Temp = 24 C
M = 28 g/ mol (N_2)
Distance = 100 cm
Time = 2 ms

Time response of the controllers at analog port:
MKS 937B = 3-4 ms
TPG300 = 12-13 ms

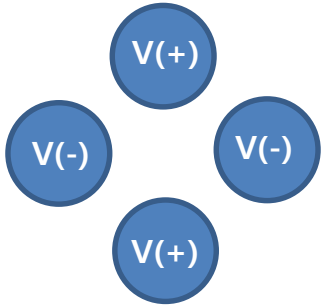
4중극 잔류기체분석기 (RGA)

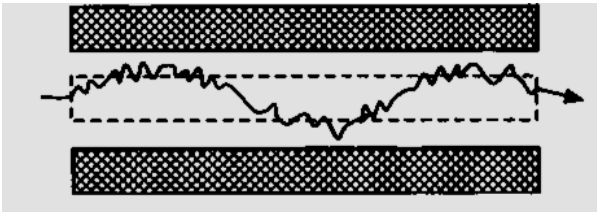


Quadrupole mass filter.



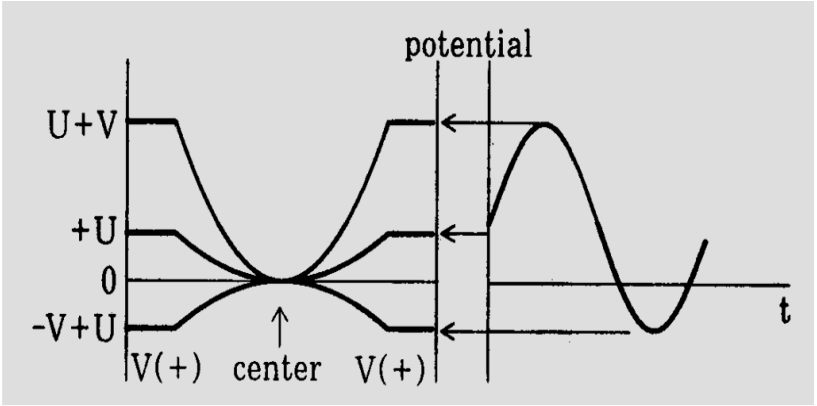
Quadrupole mass filter (RGA)



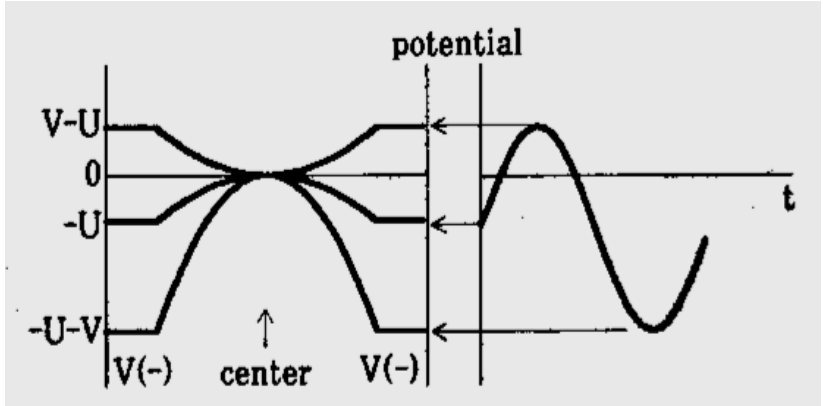


$V(+) = U + V\cos(wt)$

$V(-) = -U - V\cos(wt)$



High pass filter

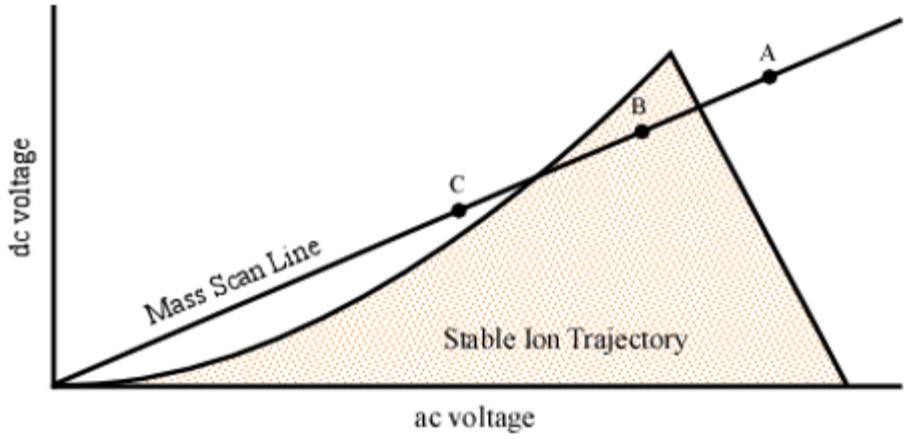


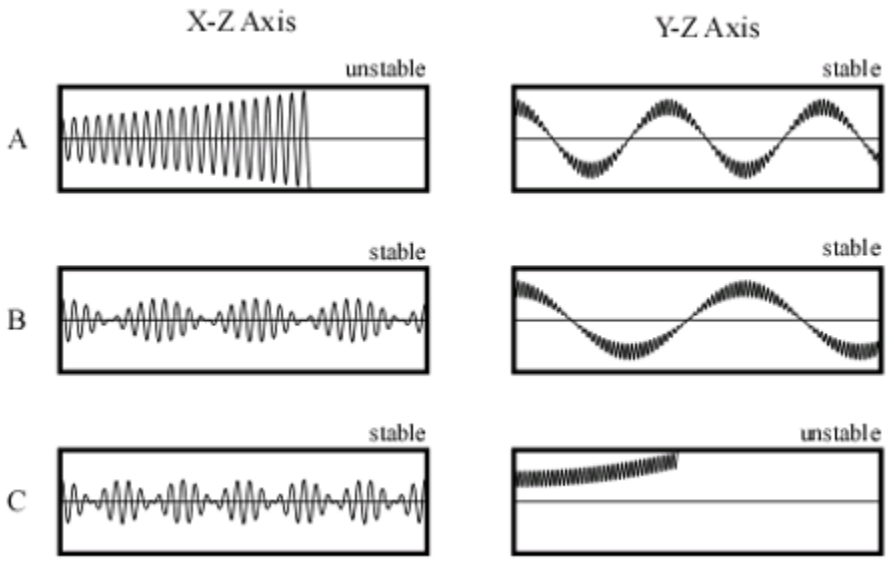
Low pass filter

Quadrupole mass filter (RGA)

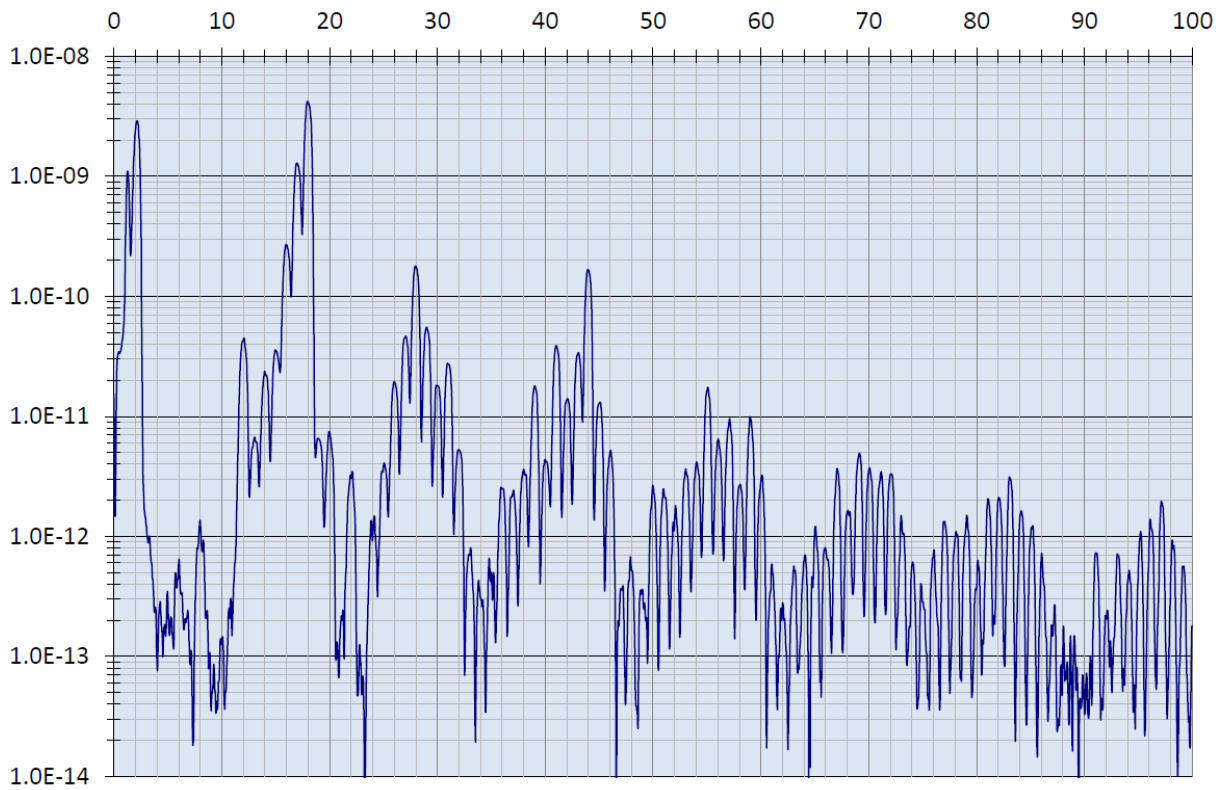
"Mathieu Equation"

$$\frac{d^2u}{d\xi^2} + (a_u - 2q_u \cos 2\xi)u = 0 \qquad a_u = \frac{8eU}{mr_0^2\Omega^2} \qquad q_u = \frac{4eV}{mr_0^2\Omega^2}$$

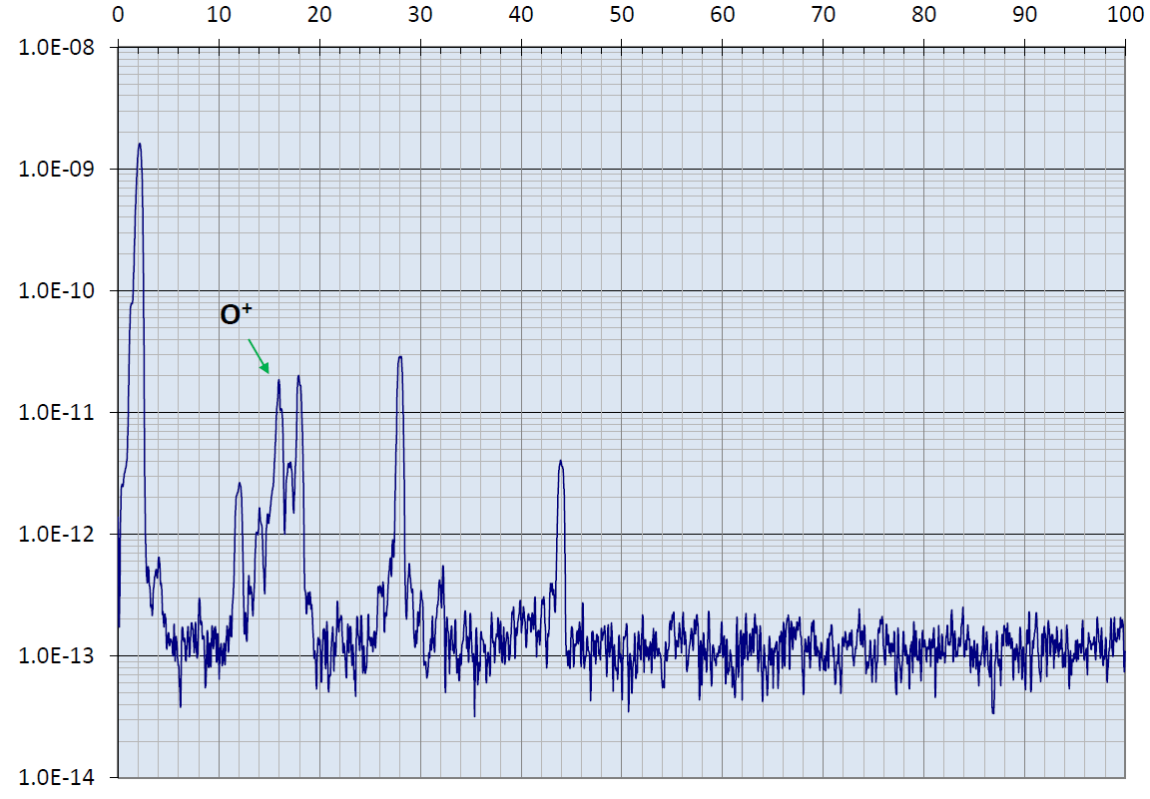




Example

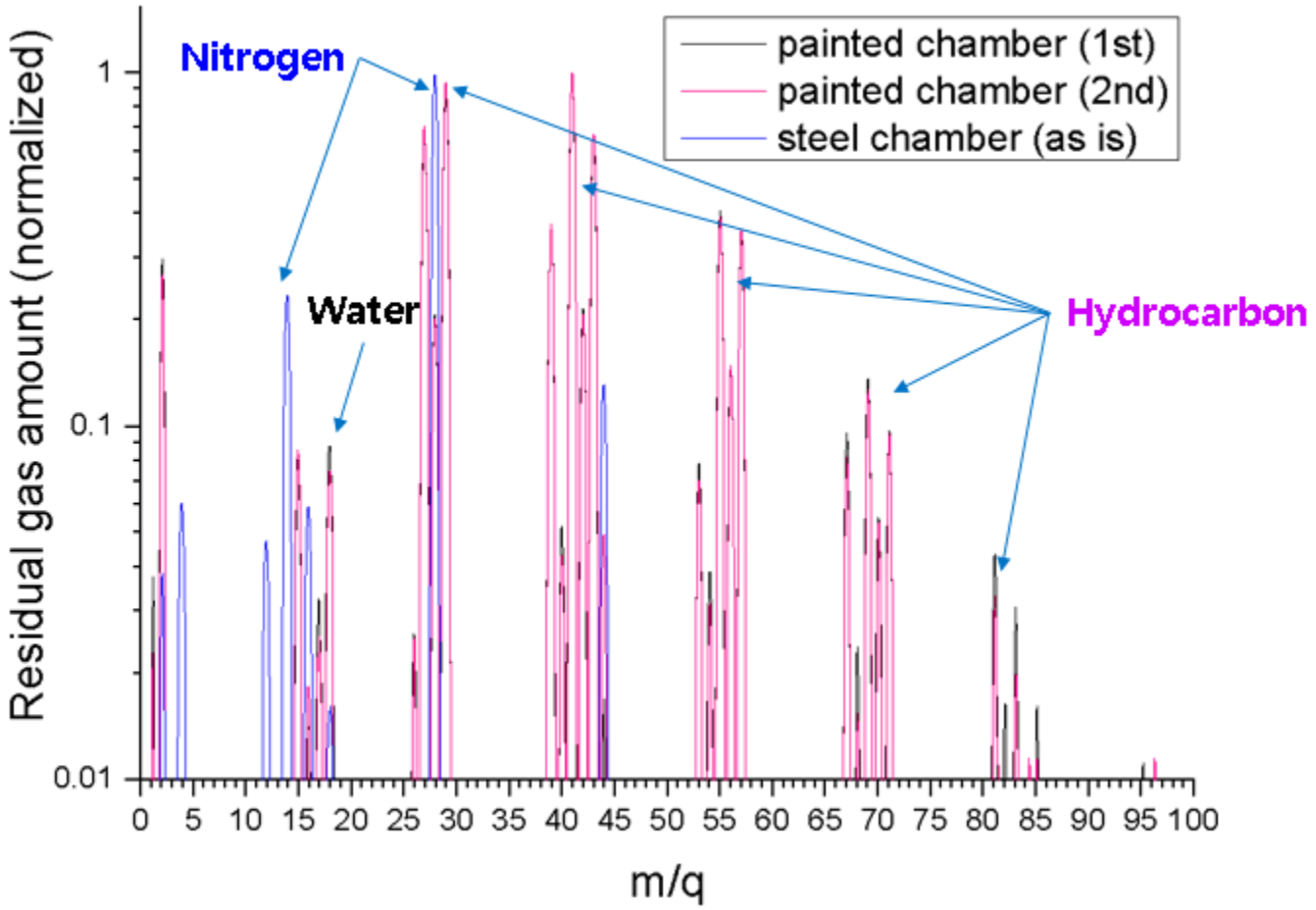


[가열탈기체 전]

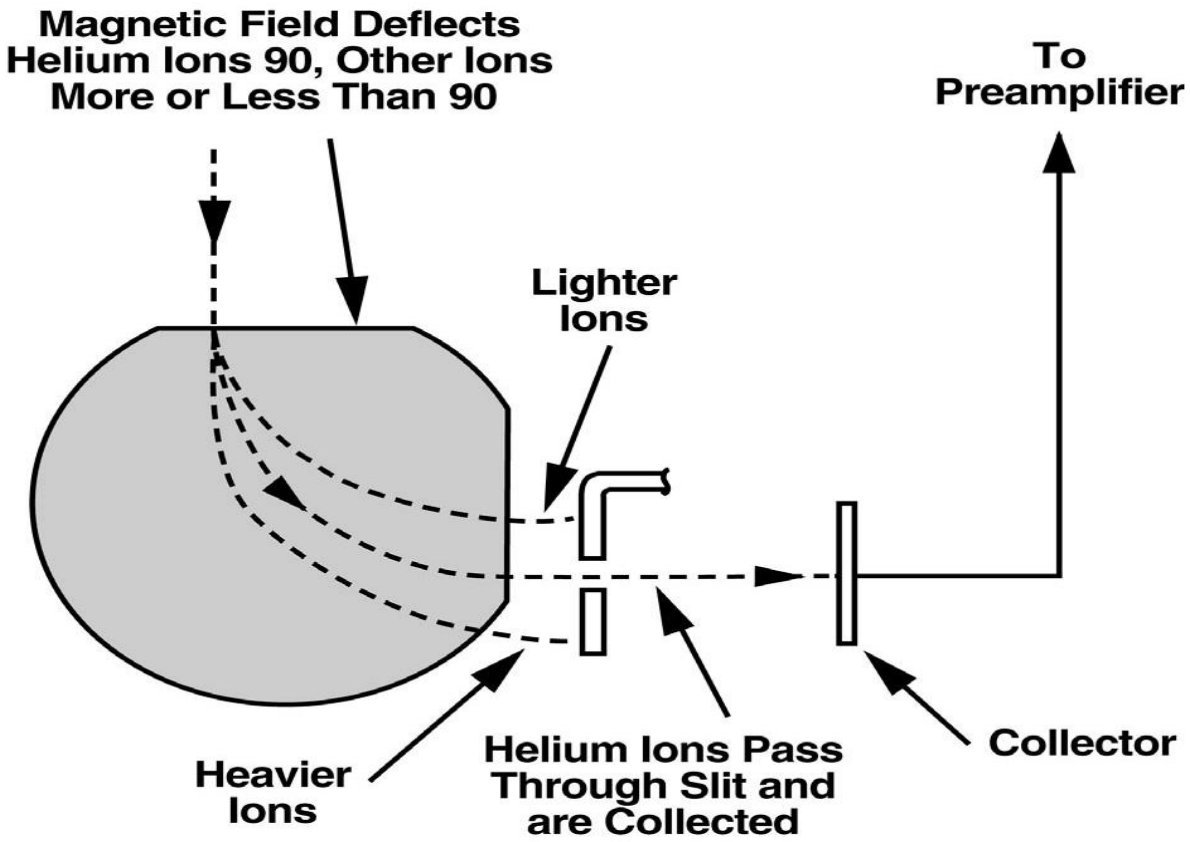


[가열탈기체 후]

Example (탄화수소 오염)



헬륨 누출검출기


Magnetic Field Deflects
Helium Ions 90, Other Ions
More or Less Than 90
To
Preamplifier
Lighter
Ions
Heavier
Ions
Helium Ions Pass
Through Slit and
are Collected
Collector