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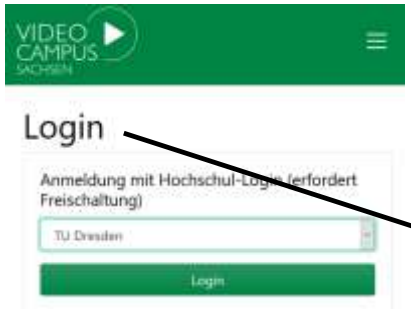

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Vacuum Technology
WS 20/21
Virtually presented
Lecture 10, Jan. 11, 2021

Prof. Dr. Johann W. Bartha

Inst. f. Halbleiter und Mikrosystemtechnik
Technische Universität Dresden

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Review L9

0. Introduction

Air pressure as a force to the walls of an empty container

1. Gas kinetic

Pressure as momentum transfer, Mol & Molvolume, Pressure units Partial pressure, Boltzmann Velocity&Energy distribution, Impingement rate, monolayer coverage time, mean free path collision rate

2. Pressure Ranges

Viscous, Knudsen, Molecular flow, Rough-, Medium-, High-, Ultrahigh-Vacuum, Heat conduction

3. Vacuum technical terms

Pumping speed, pumping power, gas-flow, residence time, gas flow conduction, impact on tube dimension

4. Vacuum generation

5. Pressure measurement

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1 sccm = 1,8 Pa·l/s = 18 10^{-3} m·Bar·l/s = 2,89 ·10^{19} Particle / min

Residence Time $T_R = V/S = P \cdot V/P \cdot S = P \cdot V/Q$

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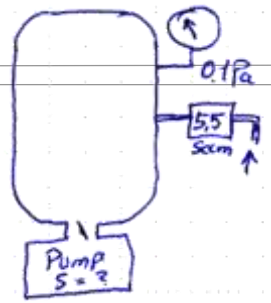

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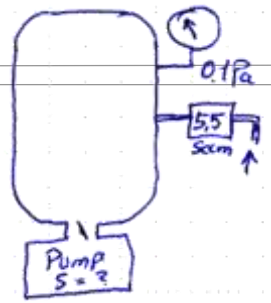

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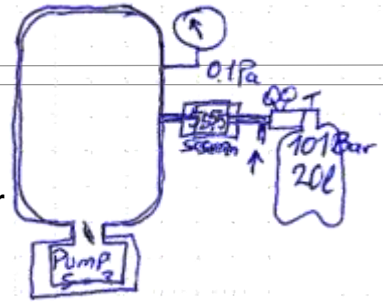

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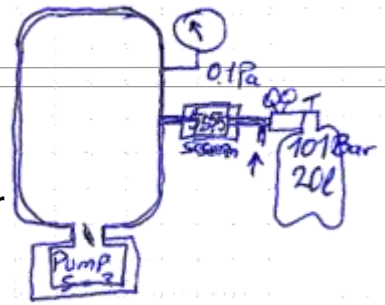

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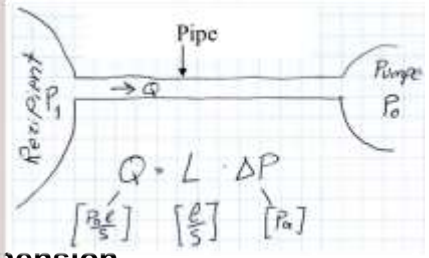

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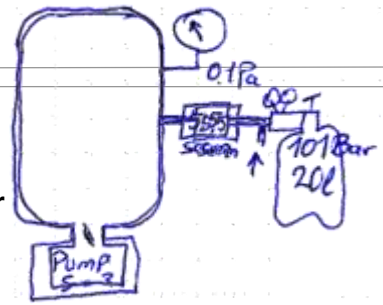

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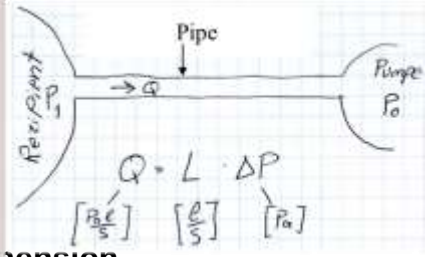

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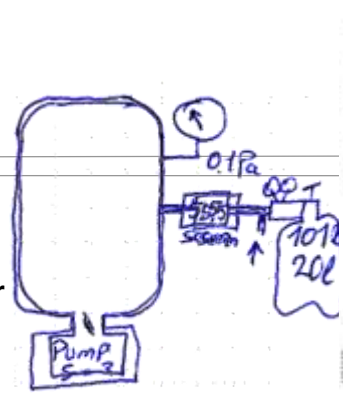

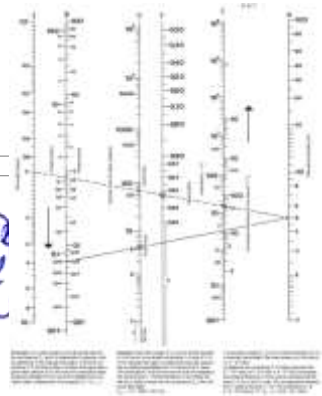

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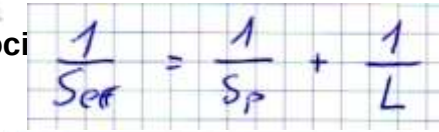

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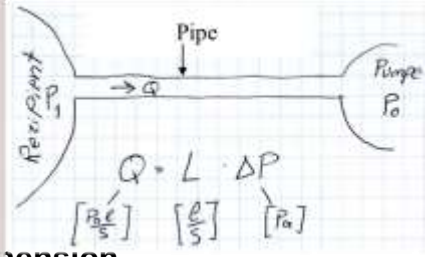

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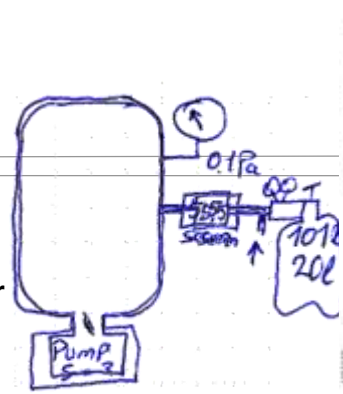

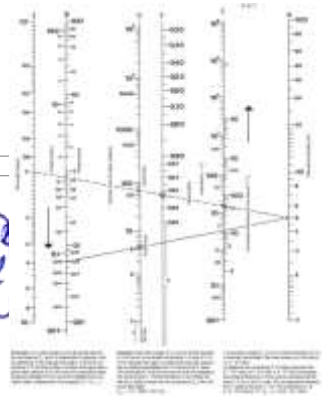

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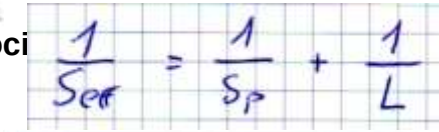

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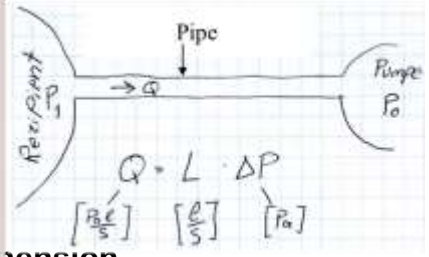

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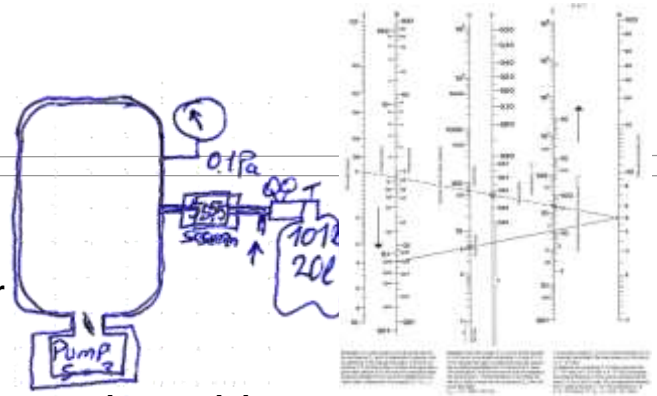

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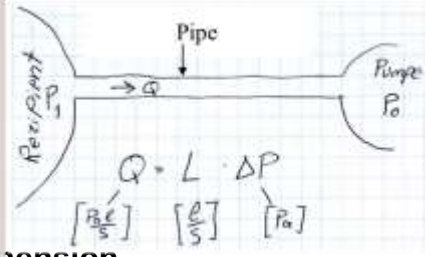

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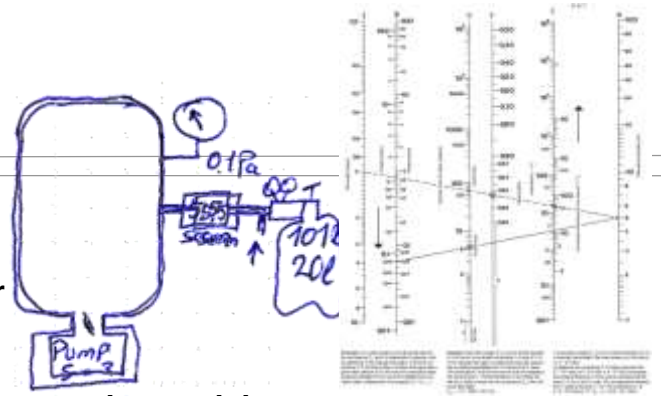

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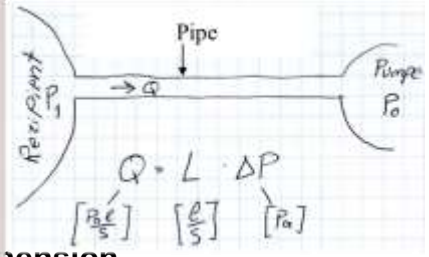

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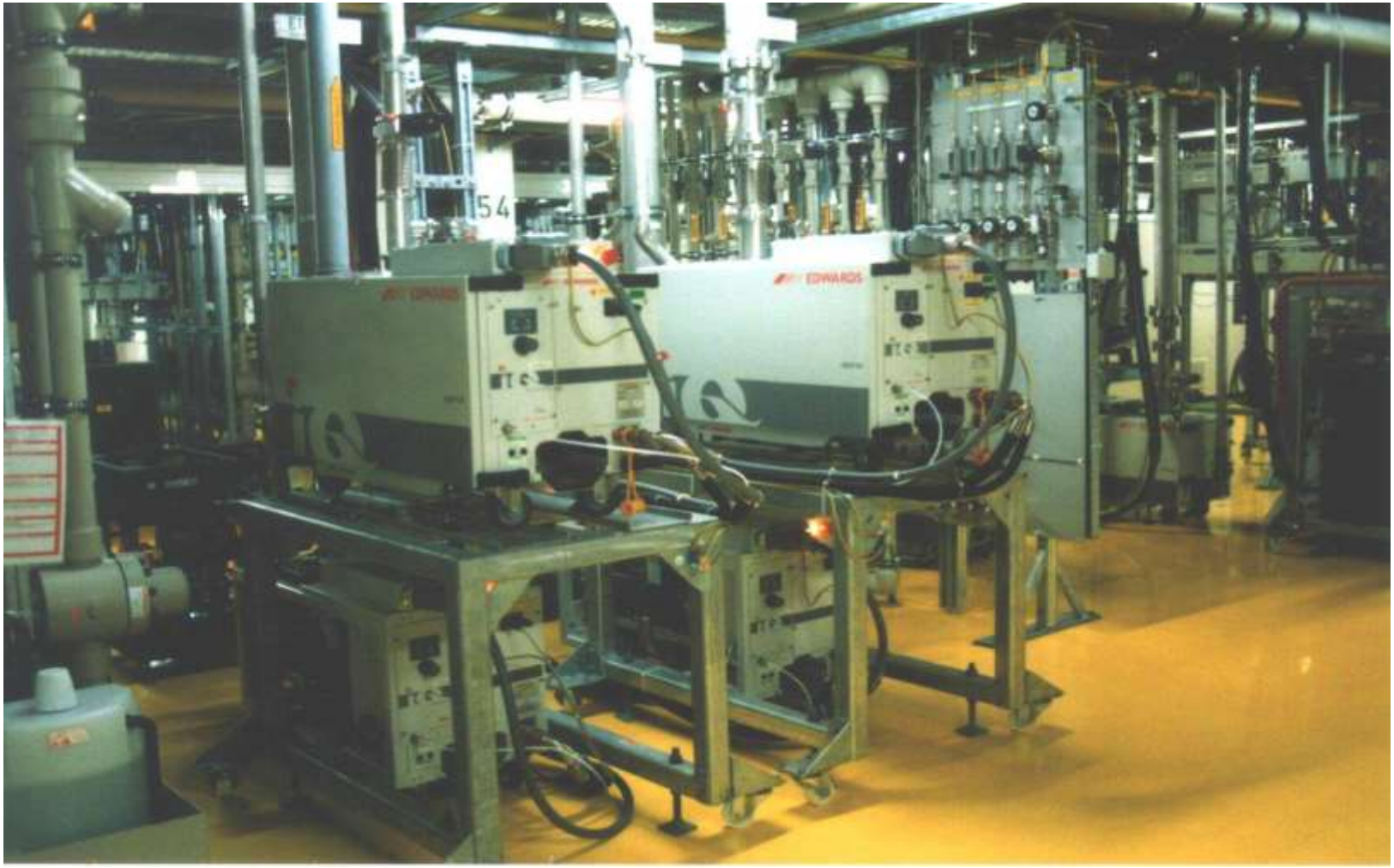
Cleanroom - Clean Subfab Area - Basement



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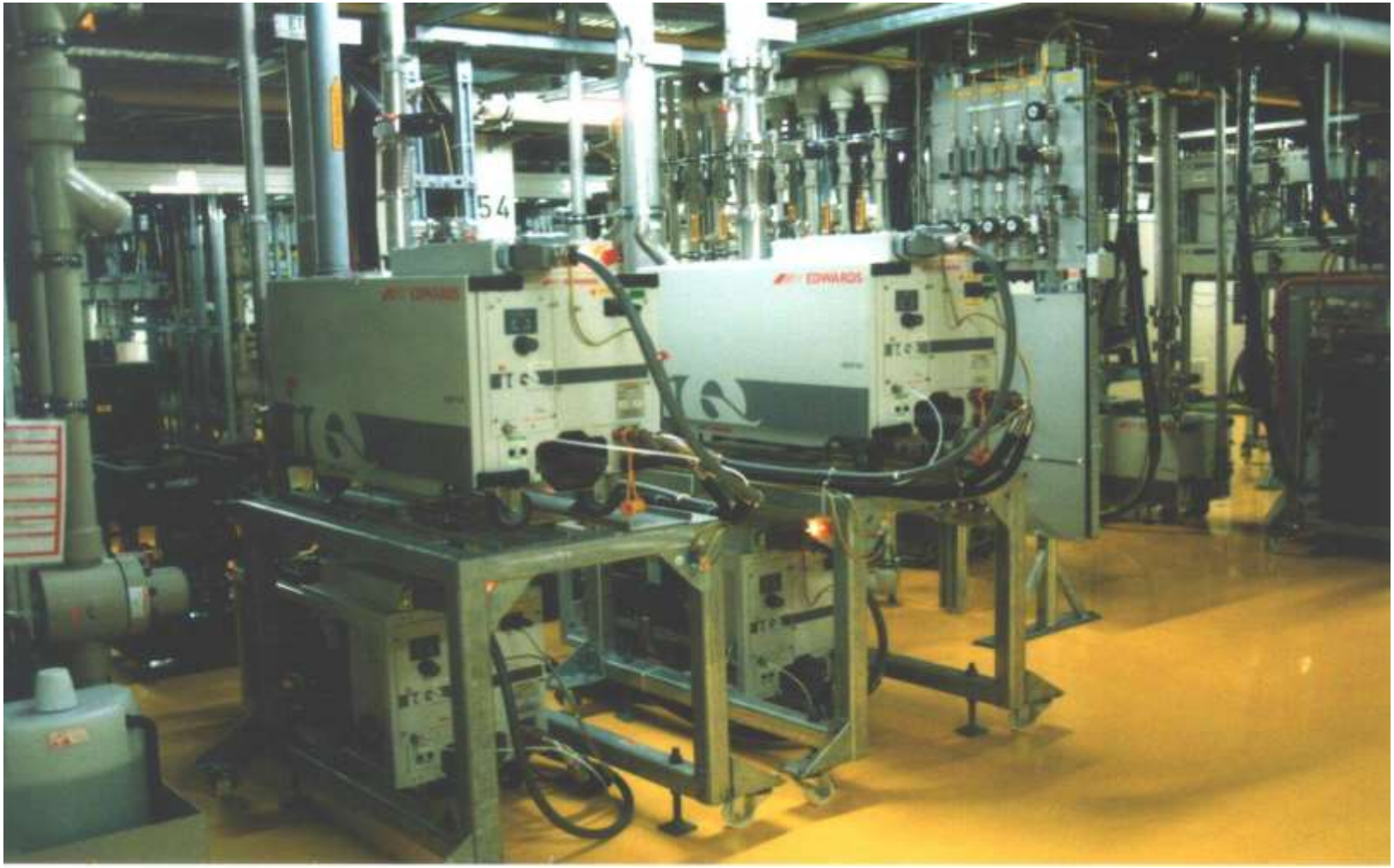

Expl
Prcess

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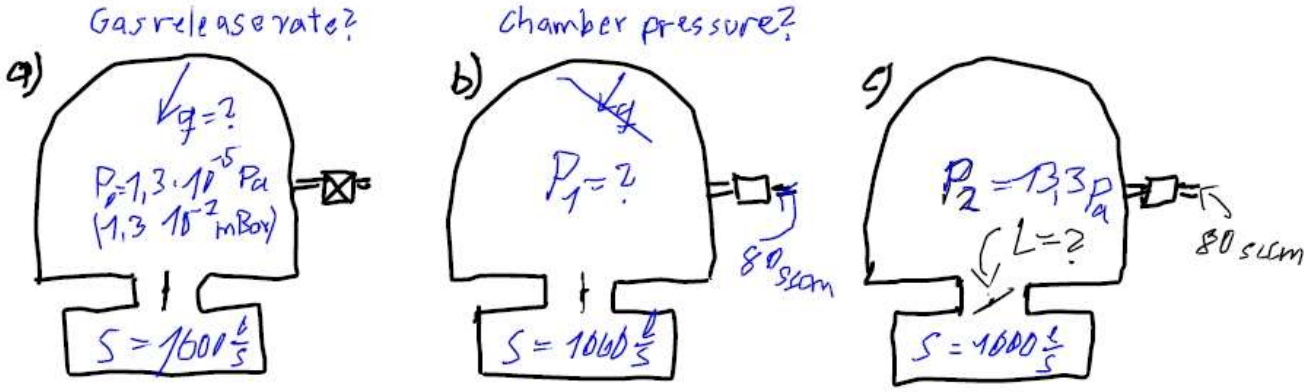

$q = p_0 \cdot S$

$q = 1{,}3 \cdot 10^{-2}\ \frac{Pa\,l}{s}$

$q = 7{,}2 \cdot 10^{-3}$ sccm

$q = 2{,}1 \cdot 10^{17}\ \frac{\text{Partikel}}{\text{min}}$

$p_1 = \frac{q + Q}{S}$

80 sccm $\hat{=}$ 144 $\frac{Pa\,l}{s}$

$p_1 = 0{,}144$ Pa

$Q = L \cdot \Delta p \leftarrow 13{,}3\ Pa$

$L = \frac{Q}{\Delta p} = \frac{144\ \frac{Pa\,l}{s}}{13{,}3\ Pa}$

$L = 10{,}8\ \frac{l}{s}$

Which is the effective pumping speed in combination Pump/Valve?

$\frac{1}{S_{eff}} = \frac{1}{L} + \frac{1}{S_p}$

$S_{eff} = 10{,}7\ \frac{l}{s}$

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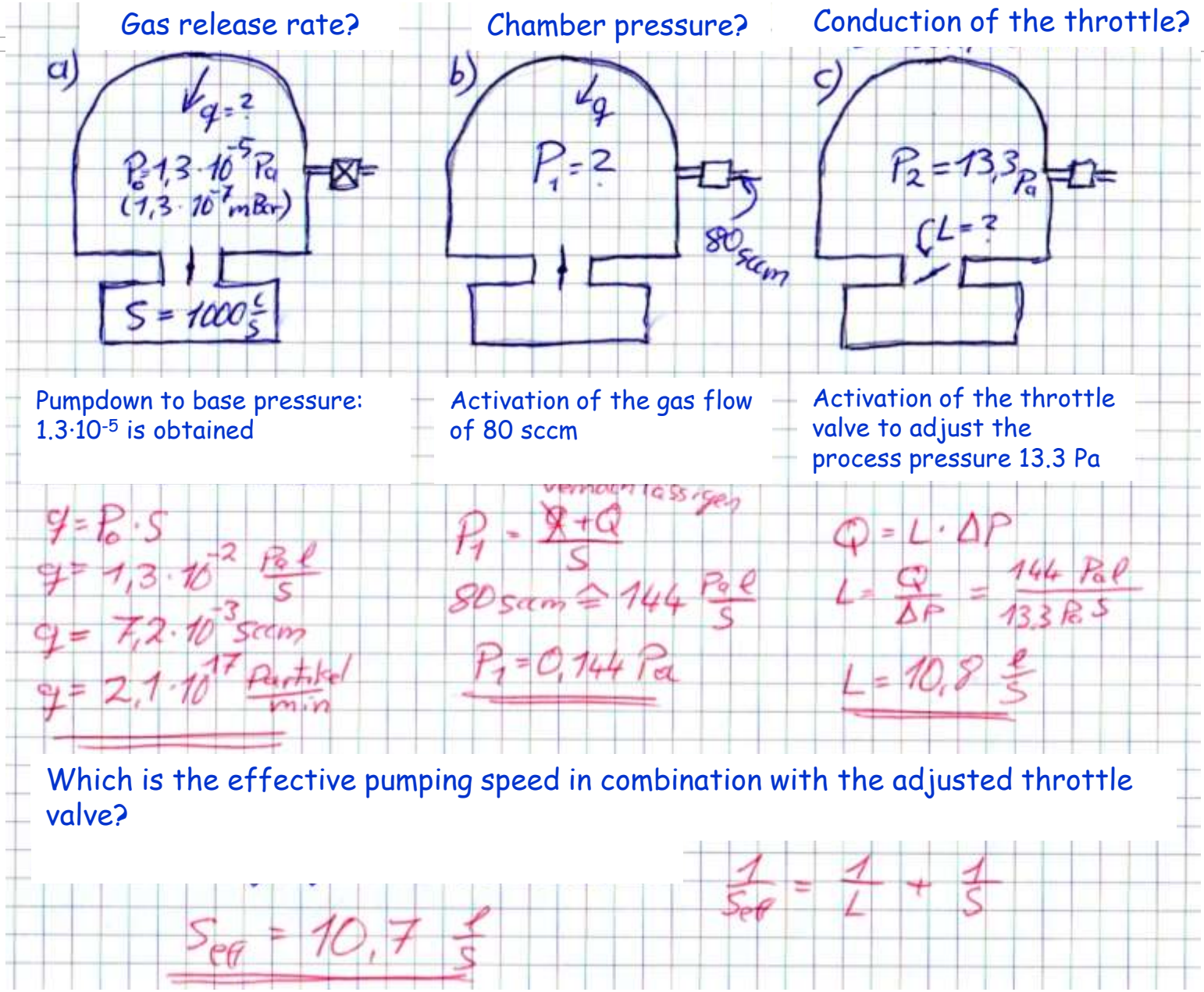
Process flow in a chamber using a gas inlet:



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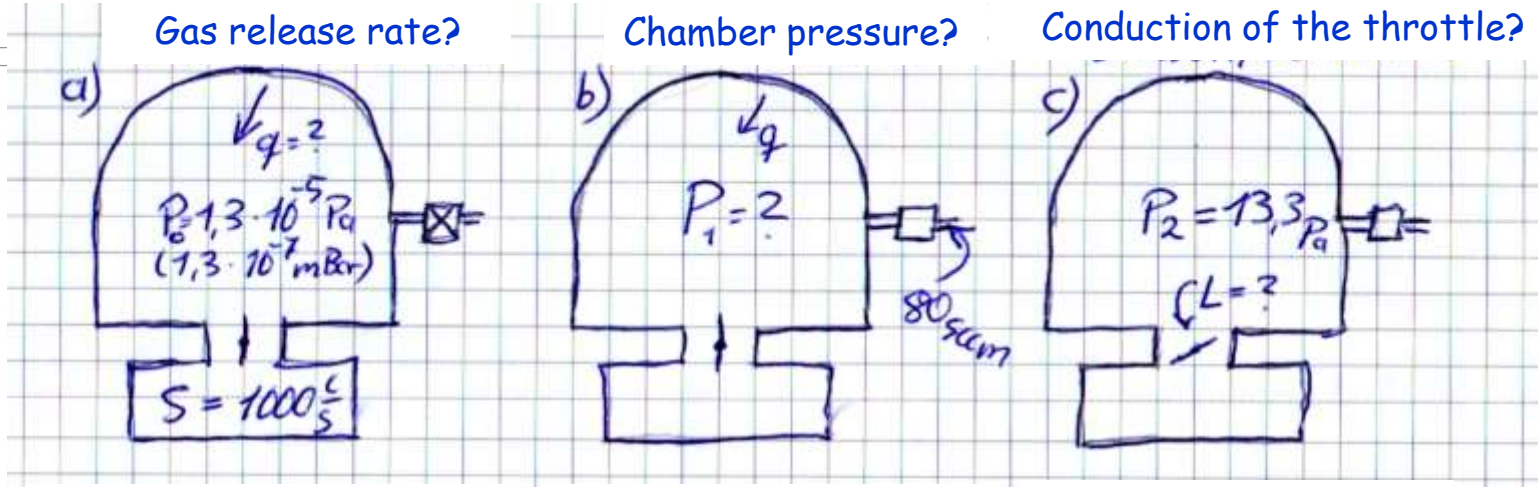

Pumpdown to base pressure: $1.3 \cdot 10^{-5}$ is obtained

Activation of the gas flow of 80 sccm

Activation of the throttle valve to adjust the process pressure 13.3 Pa

$q = p_0 \cdot S$

$q = 1{,}3 \cdot 10^{-2} \frac{Pa\,l}{s}$

$q = 7{,}2 \cdot 10^{-3}$ sccm

$q = 2{,}1 \cdot 10^{17} \frac{\text{Partikel}}{\text{min}}$

$p_1 = \frac{X + Q}{S}$ (vernachlässigen)

$80\,\text{sccm} \triangleq 144 \frac{Pa\,l}{s}$

$p_1 = 0{,}144$ Pa

$Q = L \cdot \Delta p$

$L = \frac{Q}{\Delta p} = \frac{144\ Pa\,l}{13{,}3\ Pa\,s}$

$L = 10{,}8 \frac{l}{s}$

Which is the effective pumping speed in combination with the adjusted throttle valve?

$\frac{1}{S_{eff}} = \frac{1}{L} + \frac{1}{S}$

$S_{eff} = 10{,}7 \frac{l}{s}$

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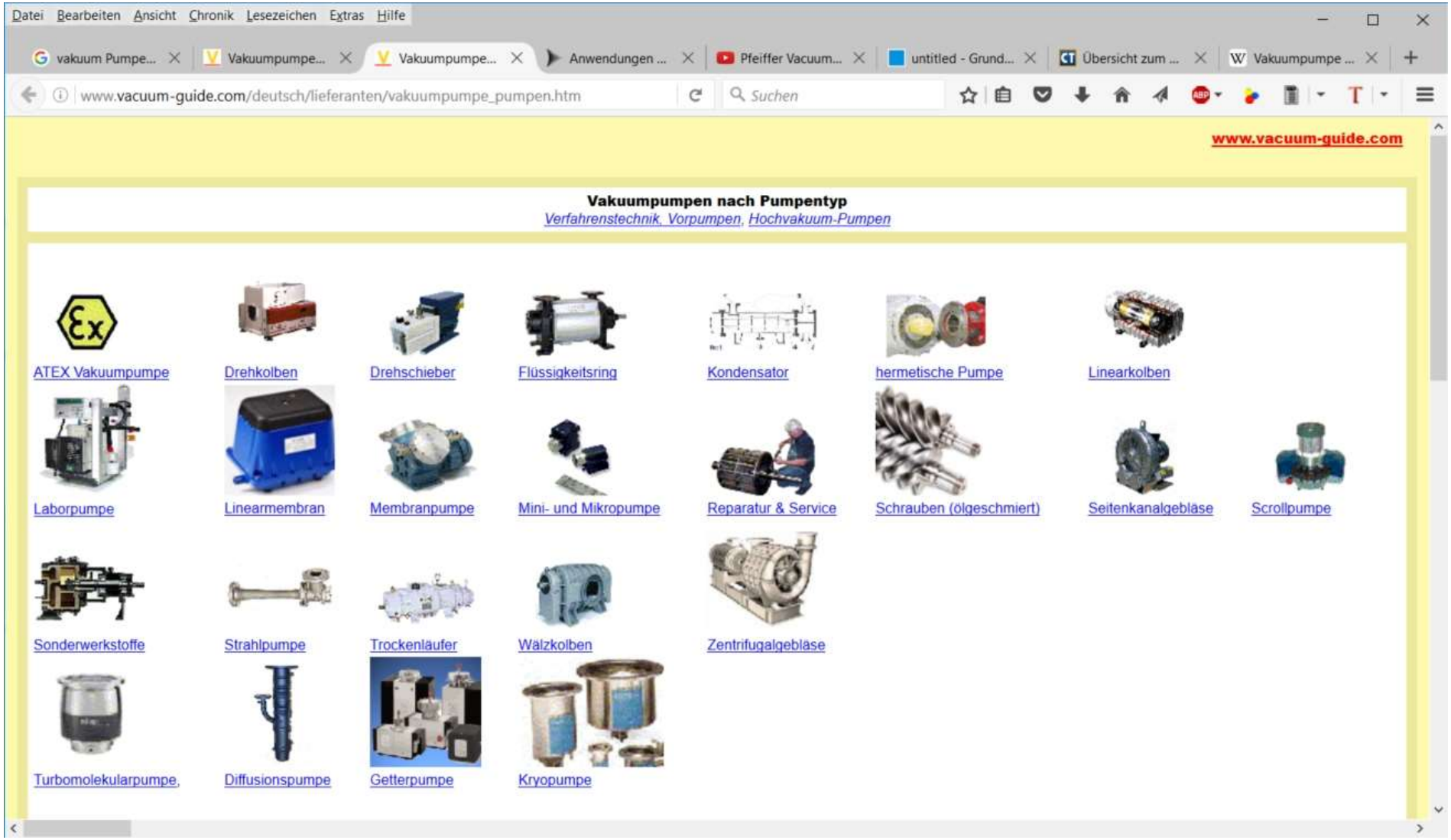
4. Vacuum Pumps



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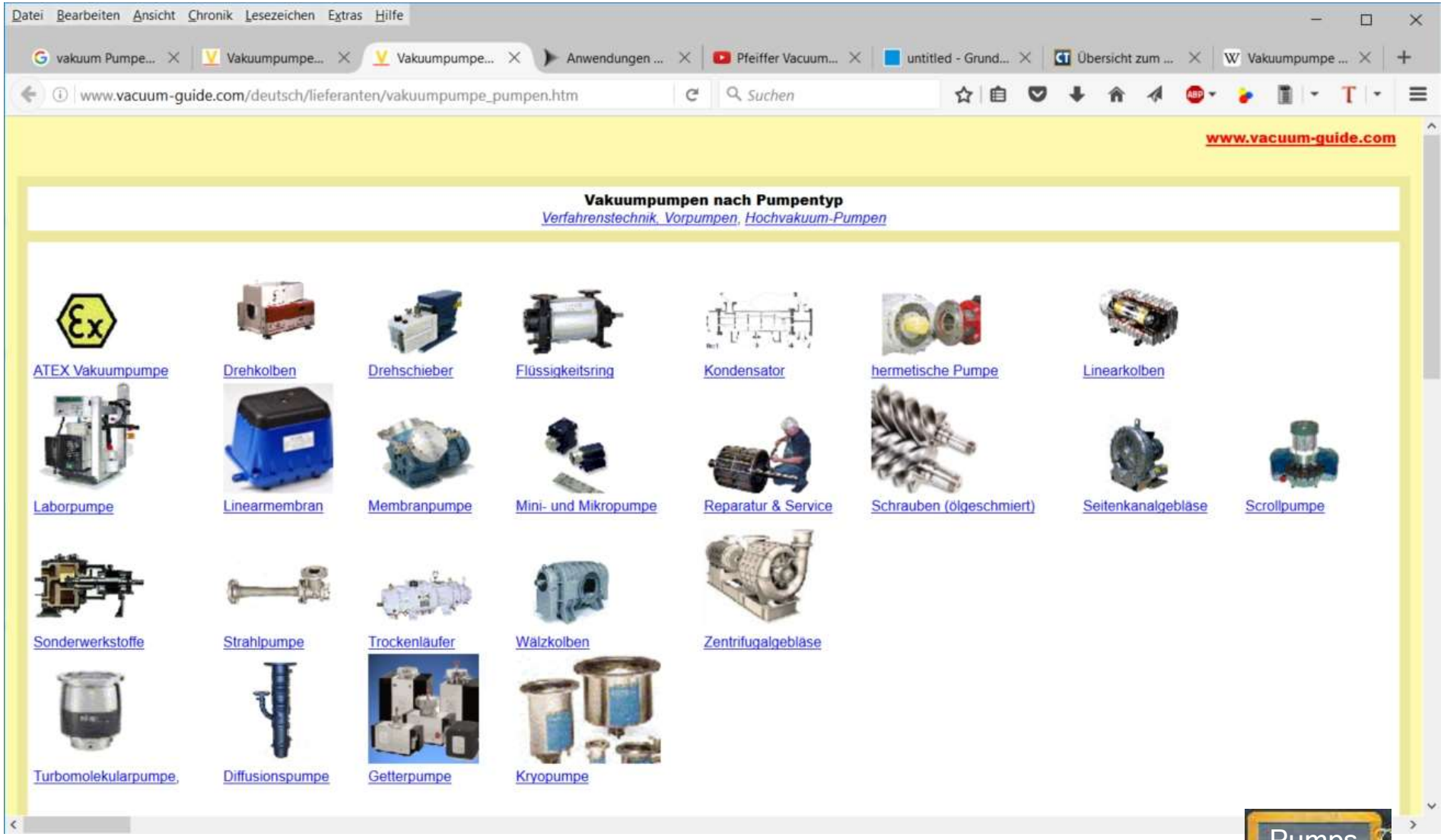

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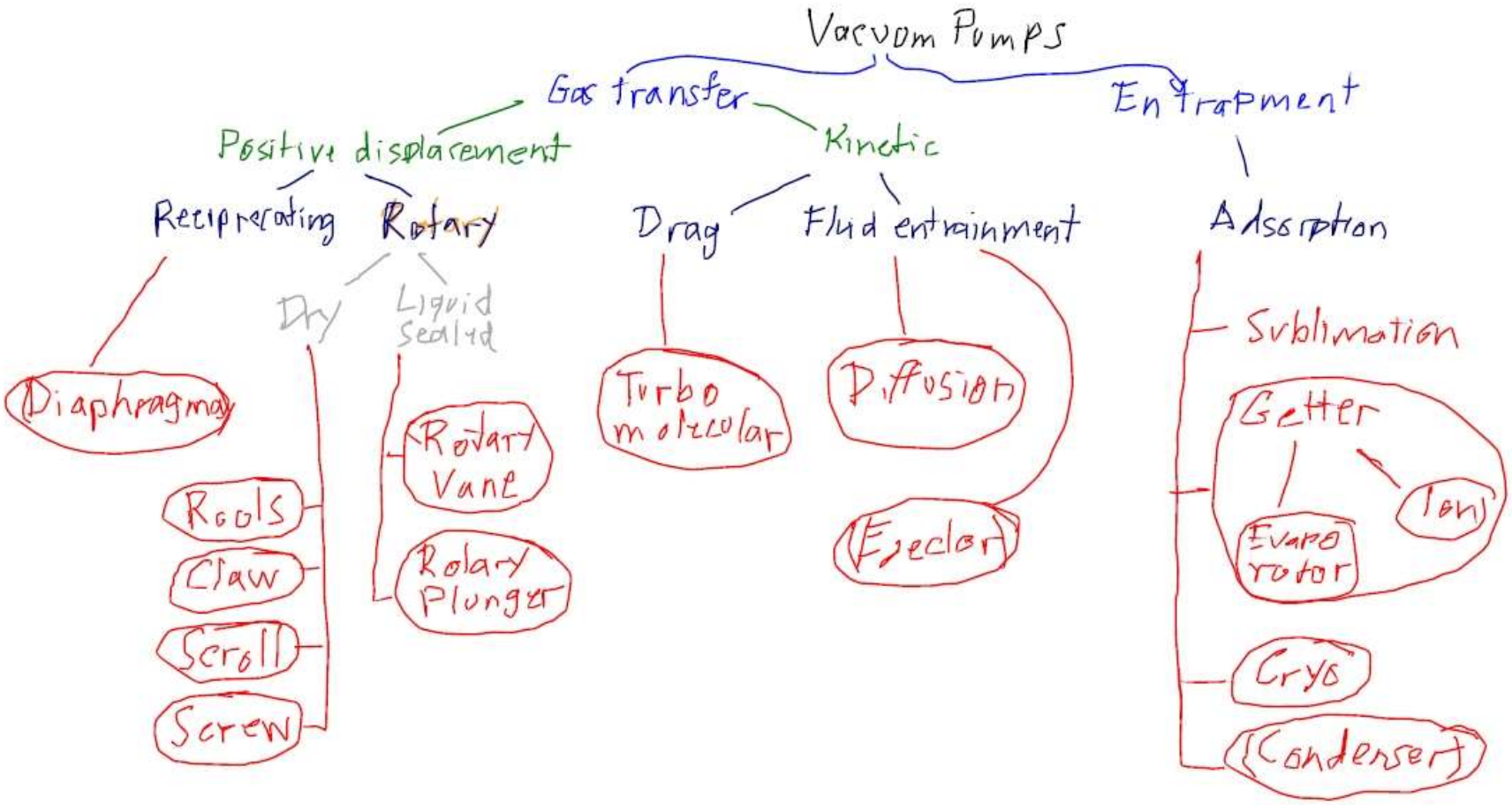

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Vacuum pump
(Operating principle)

- **Gas transfer vacuum pump**
  - **Positive displacement vacuum pump**
    - Reciprocating positive displacement vacuum pump
      - Diaphragm vacuum pump
    - Rotary vacuum pump
      - Liquid sealed vacuum pump
      - Rotary vane vacuum pump
      - Rotary plunger vacuum pump
      - Dry compressing vacuum pump
      - Roots vacuum pump
      - Claw vacuum pump
      - Scroll pump
  - **Kinetic vacuum pump**
    - Drag vacuum pump
      - Turbomolecular pump
    - Fluid entrainment vacuum pump
      - Ejector vacuum pump
      - Diffusion pump
- **Entrapment vacuum pump**
  - Adsorption pump
  - Sublimation pump
  - Getter ion pump
  - Cryopump
  - Condenser

oerlikon

Fundamentals of Vacuum Technology

Page 19

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Pumps – links:

https://www.youtube.com/user/PPlusVac/videos

Rotary plunger:
https://www.youtube.com/watch?v=fEO8LEGfdgc

Rotary vane :
https://www.youtube.com/watch?v=AFHogF-9eGA
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https://www.youtube.com/watch?v=oXgdnnkIKZ4
https://www.youtube.com/watch?v=1SaB4aKi574
https://www.youtube.com/watch?v=PyYNJDzePCs

Screw:
https://www.youtube.com/watch?v=3iiSfo9h_Fc
https://www.youtube.com/watch?v=BsogR3t6VFs
https://www.youtube.com/watch?v=X1xwd-vsv-8

Roots:
https://www.youtube.com/watch?v=aAeilhp_Gog
http://www.mekanizmalar.com/roots2.html
https://www.youtube.com/watch?v=zbiwSqtEdTg

Claw:
https://www.youtube.com/watch?v=8NCjM-GOLJg
https://www.youtube.com/watch?v=DnK3VzgZv_M

Scroll:
https://www.youtube.com/watch?v=s3xulCRrjos

Diaphragm:
https://www.youtube.com/watch?v=Ljb7R09f-8k
https://www.youtube.com/watch?v=jOjwsKECDFg

Turbomolecular:
https://www.youtube.com/watch?v=f1SErZyhMe4
https://www.youtube.com/watch?v=x3XaW7UFIjI
https://www.youtube.com/watch?v=A0v3tNCLqkA
https://www.youtube.com/watch?v=xIfOHrXyoJo
https://www.youtube.com/watch?v=8gNDDItrlBc

Diffusion:
https://www.youtube.com/watch?v=Y0xKZPhMS30
https://www.youtube.com/watch?v=-uVWlmF1rhI
https://www.youtube.com/watch?v=KNsM1pbbvOo

Ejector:
https://www.youtube.com/watch?v=8MvHplOIQCI
https://www.youtube.com/watch?v=0yK4Mzv7ei0

Ion getter:
https://www.youtube.com/watch?v=_snzYepQTjI
https://www.youtube.com/watch?v=5d0T1DYI1t0

Cryo:
https://www.youtube.com/watch?v=TTwxhzVxvk8

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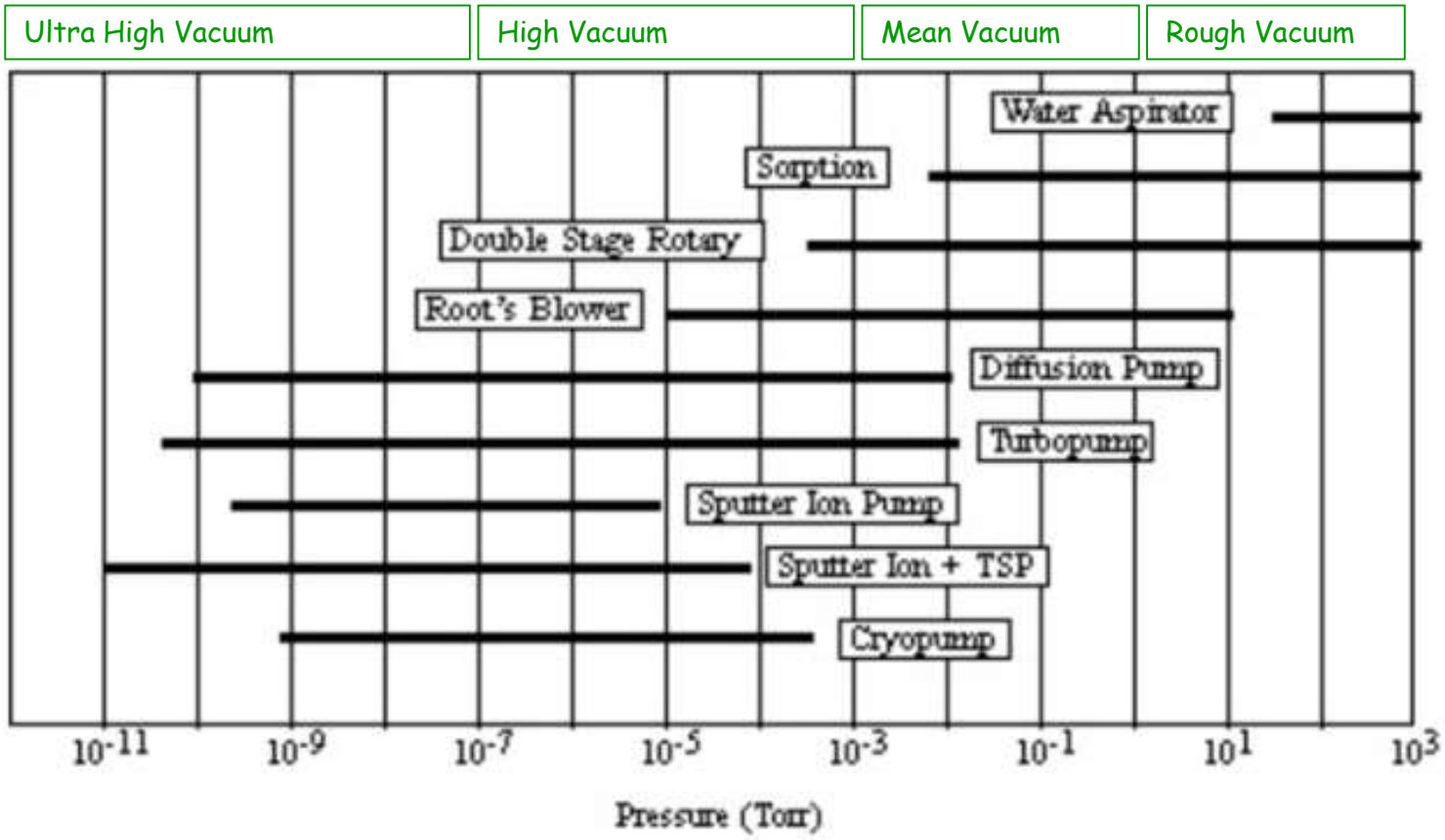

Figure 6.1: Pressure Ranges of Vacuum Pumps

Taken from:
https://people.rit.edu/vwlsps/LabTech/Pumps.pdf

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Vacuum generation

Pumps covered in the following

- rotary plunger pump
- rotary vane pump
- roots pump
- claw pump
- scroll pump
- screw pump
- diaphragm pump
- ejector pump
- diffusion pump
- turbo molecular pump
- (condenser pump)
- sublimation pump
- cryo pump

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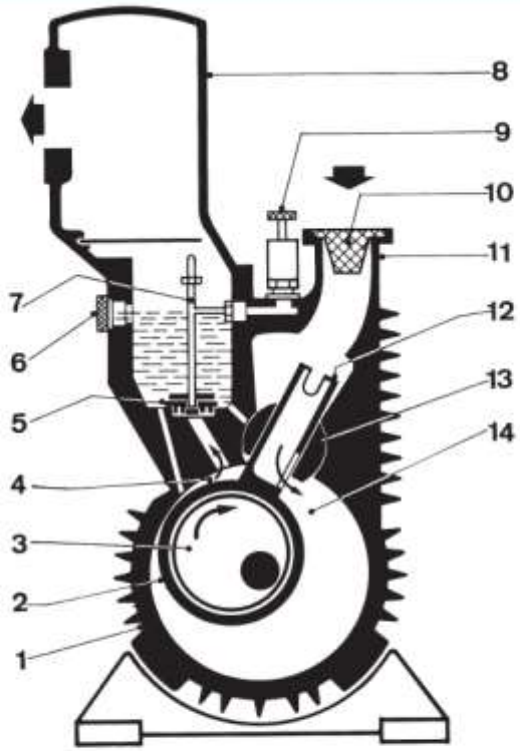
Rotary plunger

Atmosphere to ~ 10^{-3} mbar



1 Casing
2 Cylindrical piston
3 Eccentric
4 Compression chamber
5 Oil sealed pressure valve
6 Oil-level sight glass
7 Gas ballast channel
8 Exhaust pot
9 Gas ballast valve
10 Dirt trap
11 Intake port
12 Slide valve
13 Hinge bar
14 Pumping chamber (air is flowing in).

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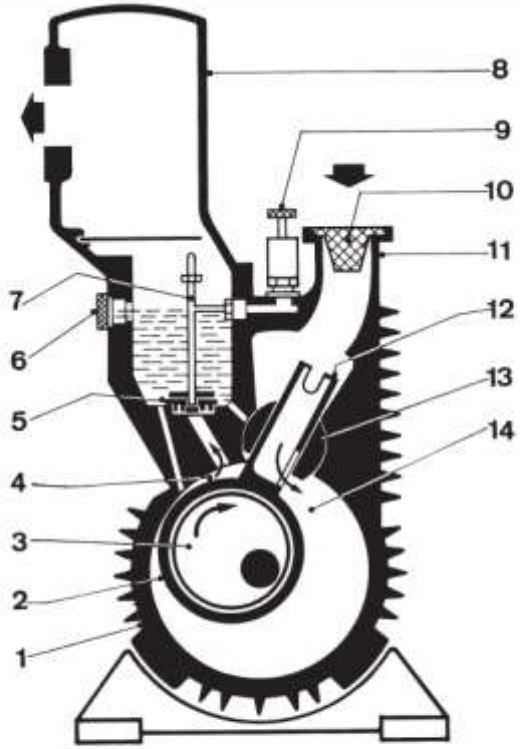
Rotary plunger

Atmosphere to ~ 10^{-3} mbar



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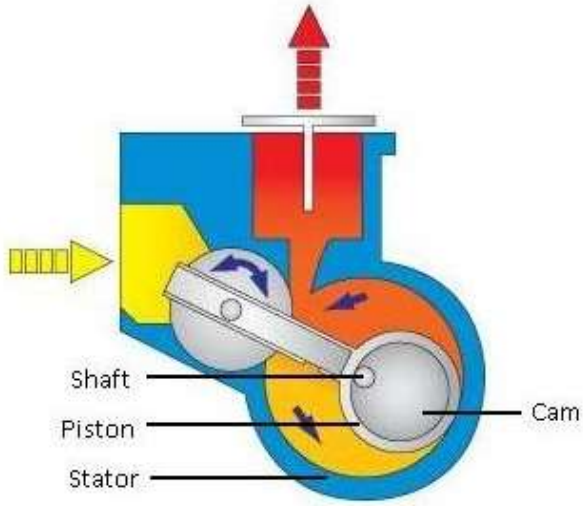

https://www.youtube.com/watch?v=fEO8LEGfdgc

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Rotary plunger

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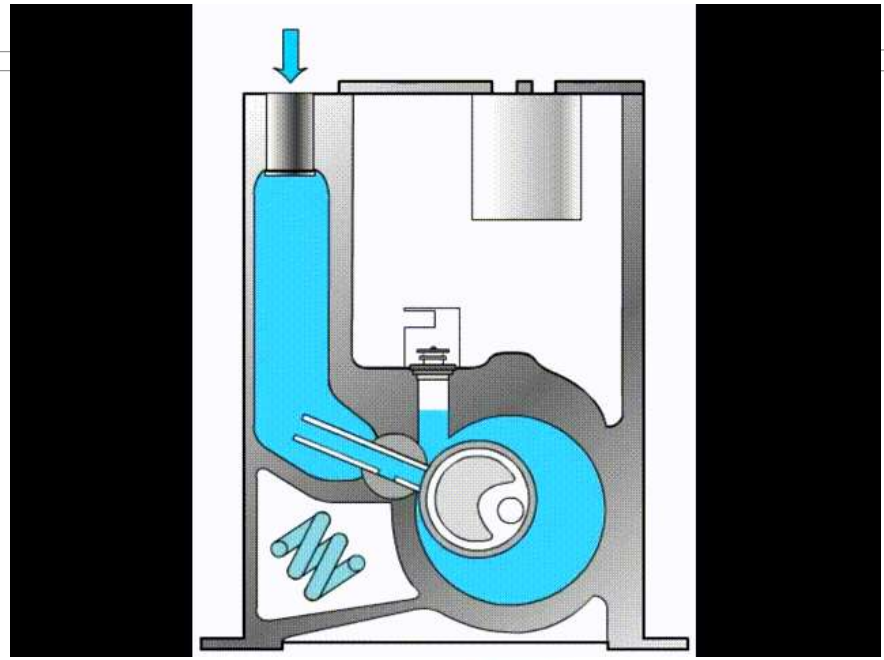

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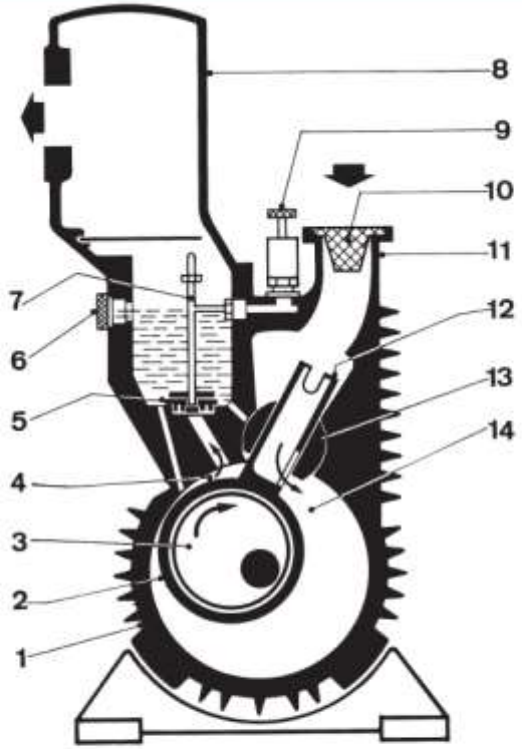

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Rotary plunger

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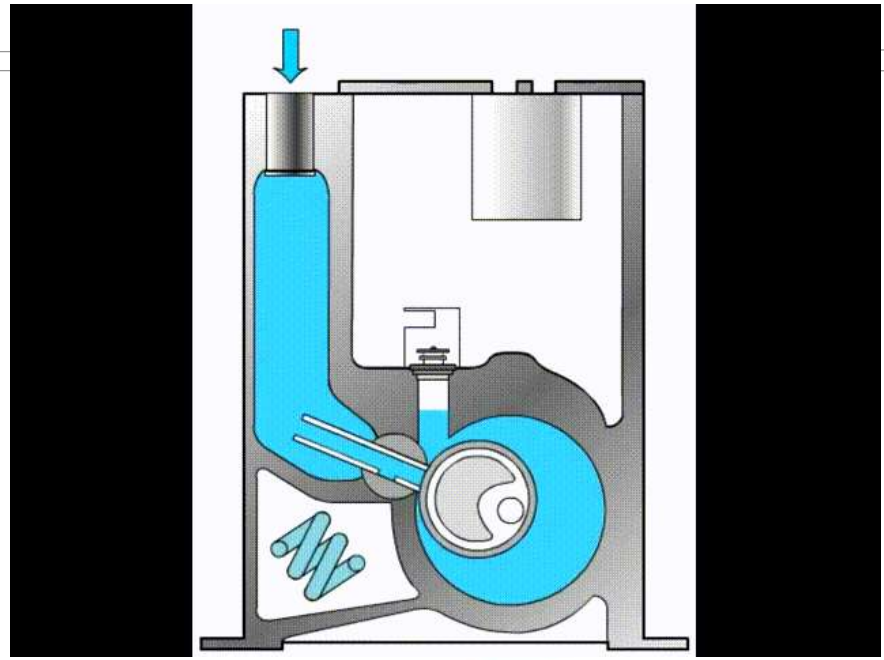

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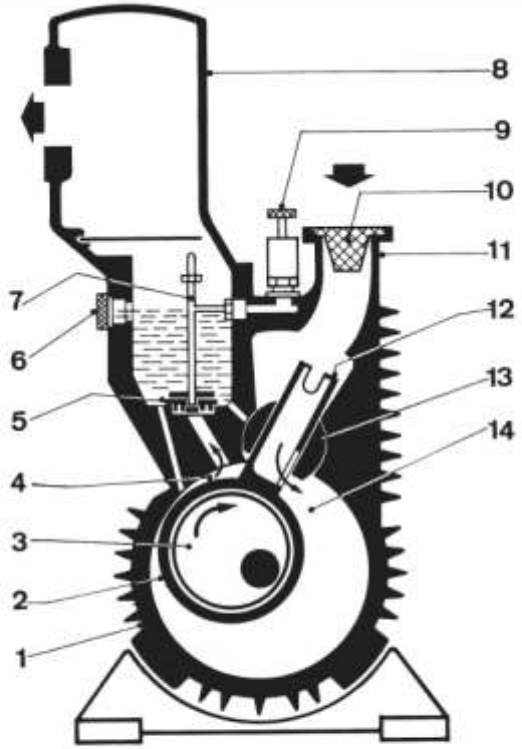

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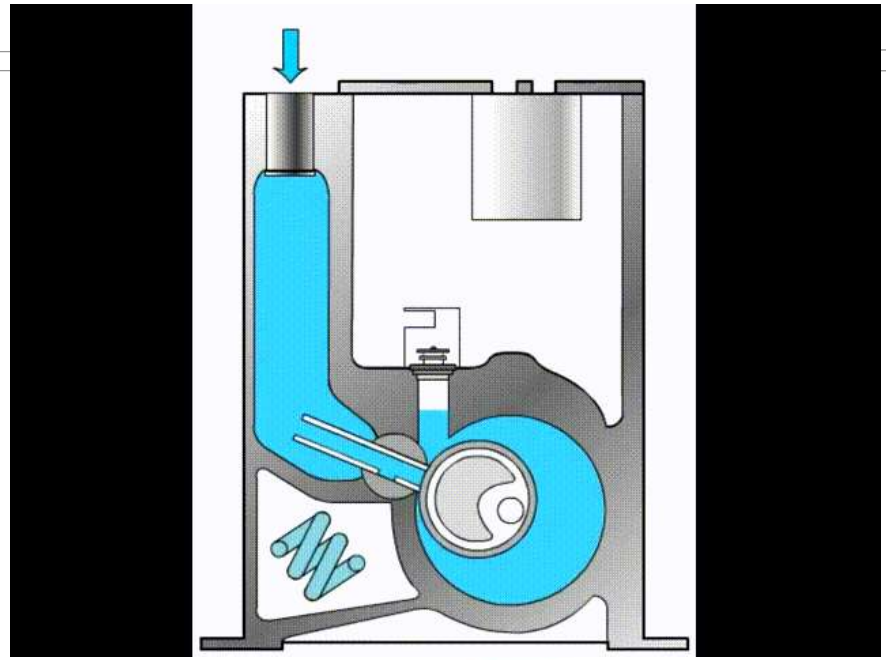

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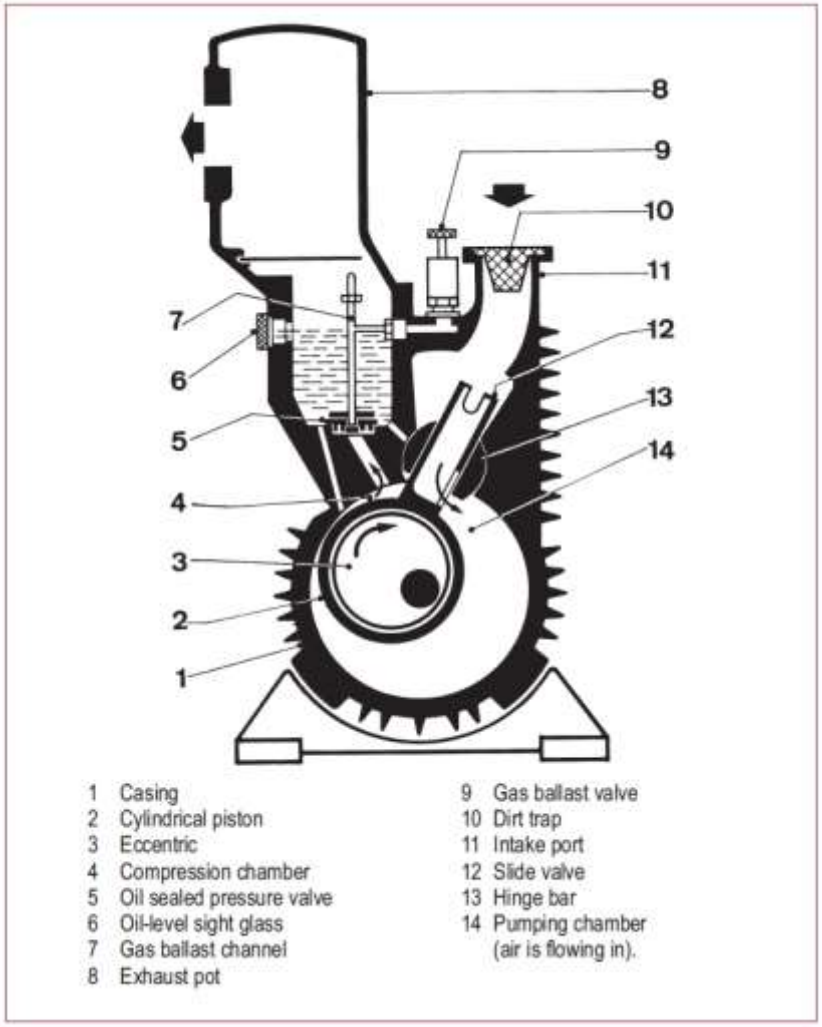

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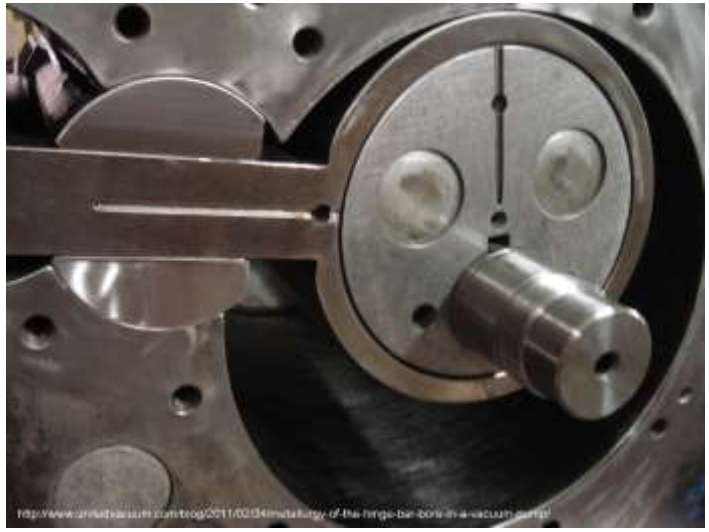

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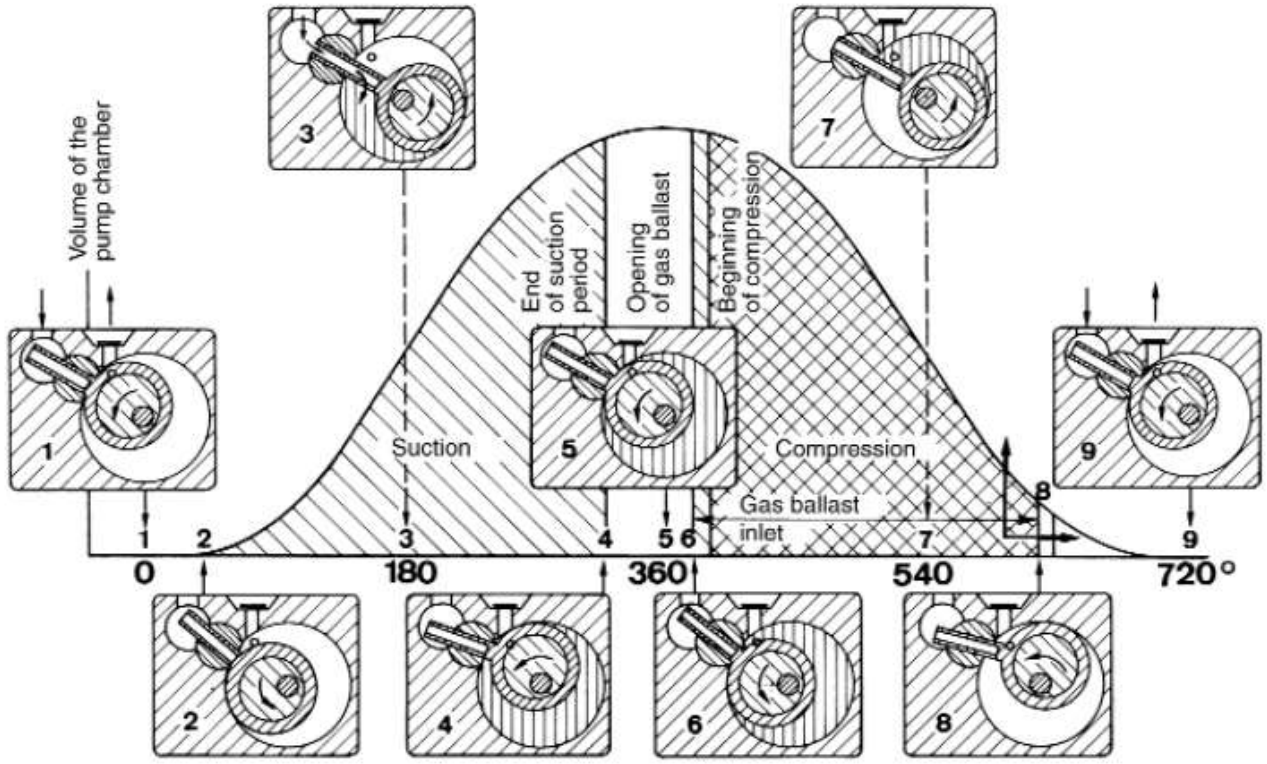
Rotary plunger



1 Upper dead point
2 Slot in suction channel of slide valve is freed – beginning of suction period
3 Lower dead point – slot in suction channel is quite free, and pumped-in gas (arrow) enters freely into the pumping chamber (shown shaded)
4 Slot in suction channel is closed again by swivelling hinge bar – end of suction period
5 Upper dead point – maximum space between rotating piston and stator
6 Shortly before beginning of compression period, the front surface of the rotating plunger frees gas ballast opening – commencement of gas ballast inlet
7 Gas ballast opening is quite free
8 End of gas ballast inlet
9 End of pumping period.

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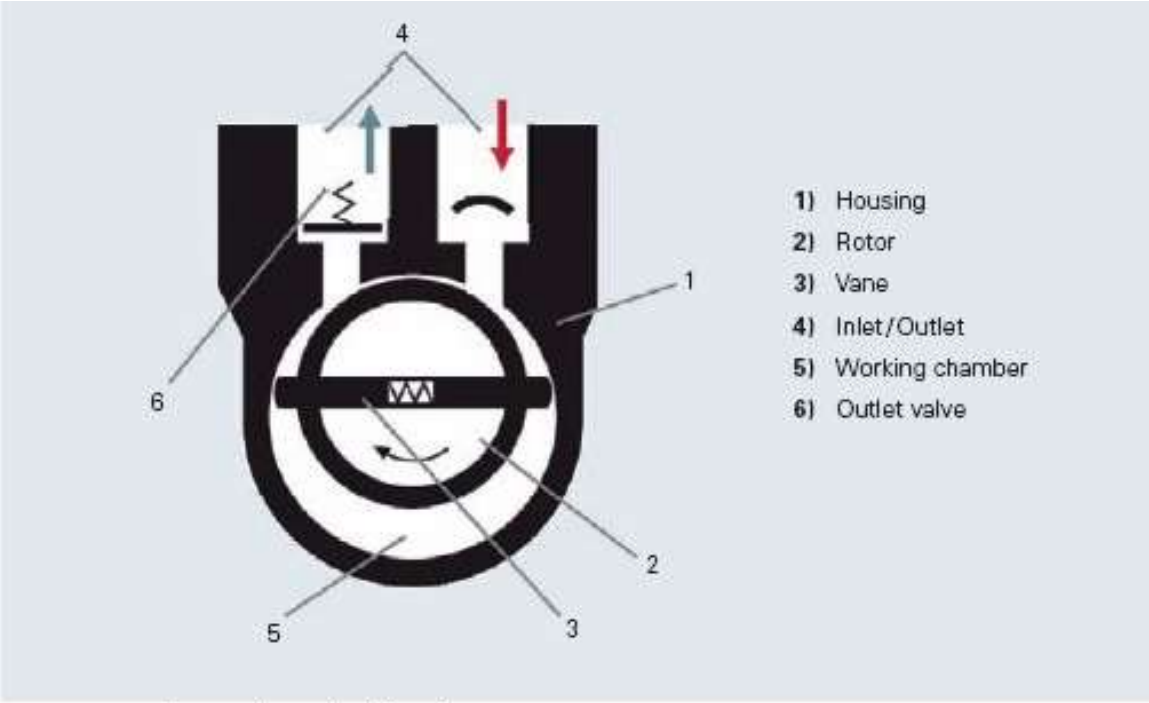
Rotary vane pump

Atmosphere to ~ 10^{-3} mbar



Operating principle of a rotary vane pump

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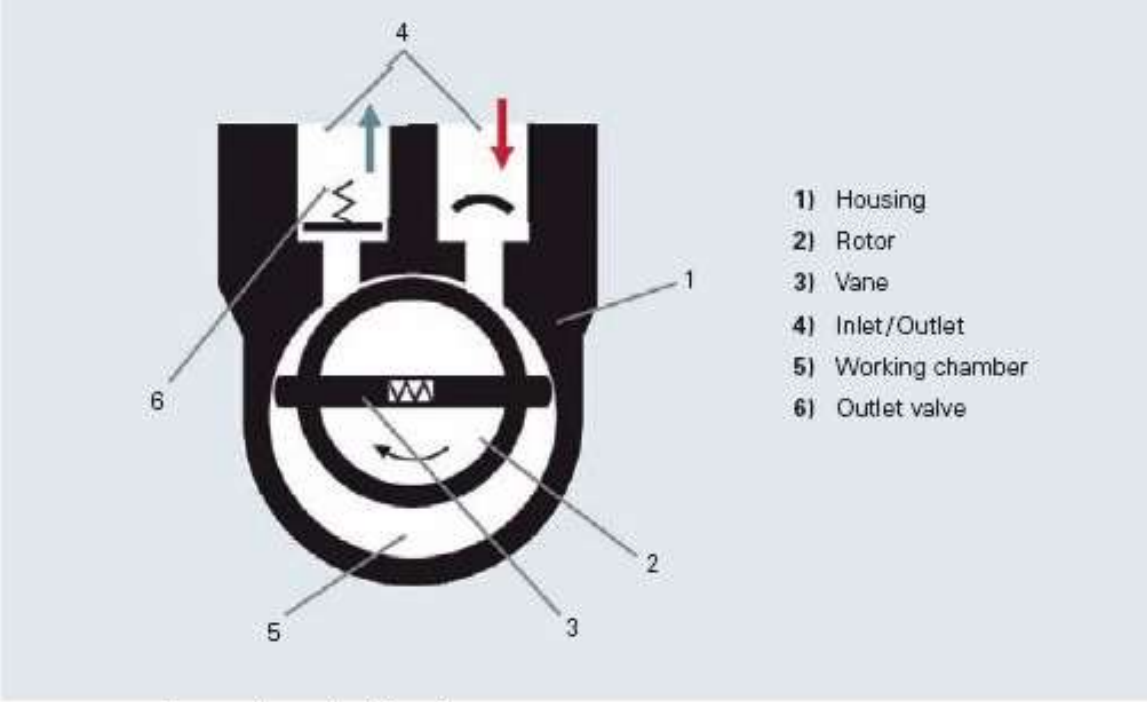
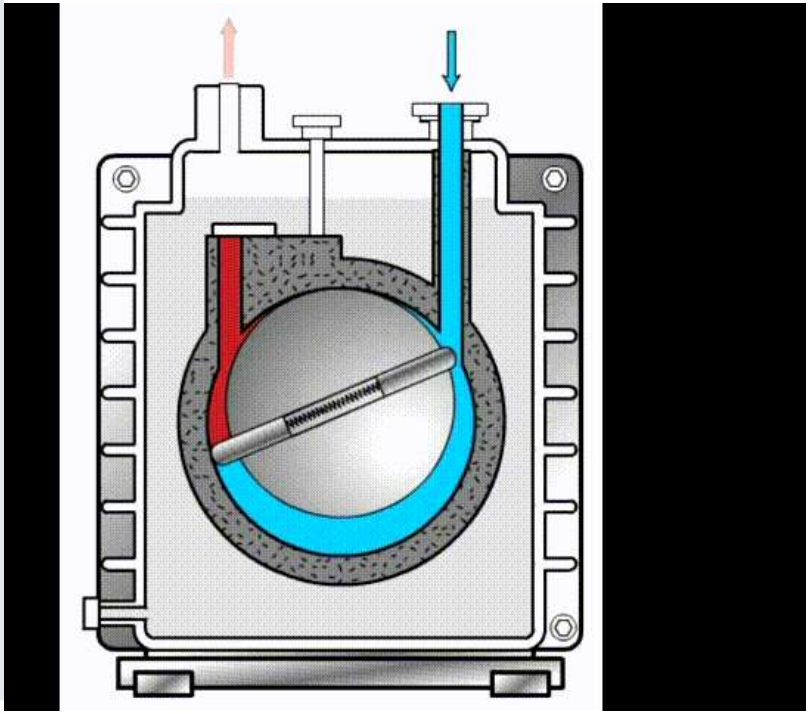
Rotary vane pump

Atmosphere to ~ 10^{-3} mbar



Operating principle of a rotary vane pump



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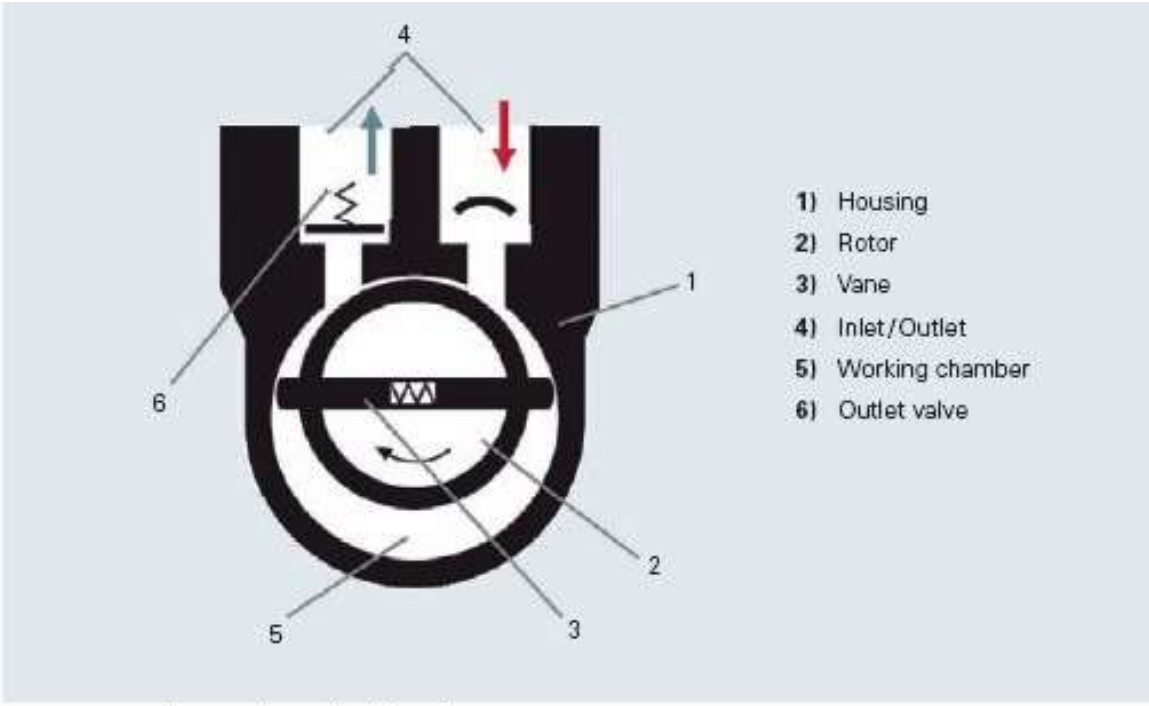
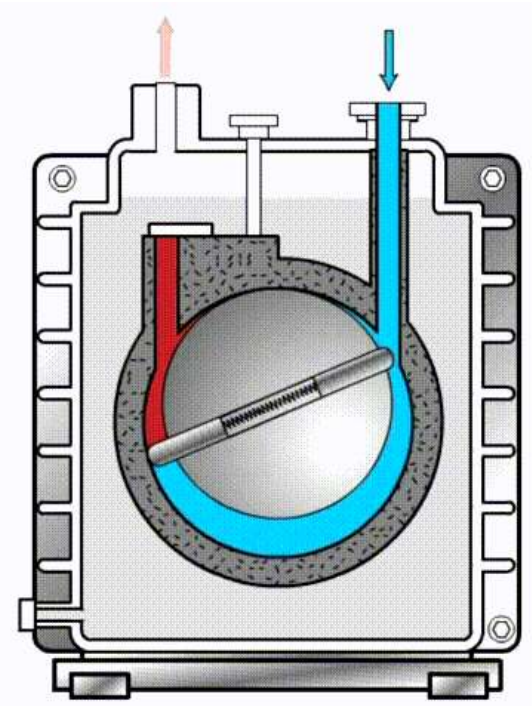
Rotary vane pump

Atmosphere to ~ 10^{-3} mbar



Operating principle of a rotary vane pump



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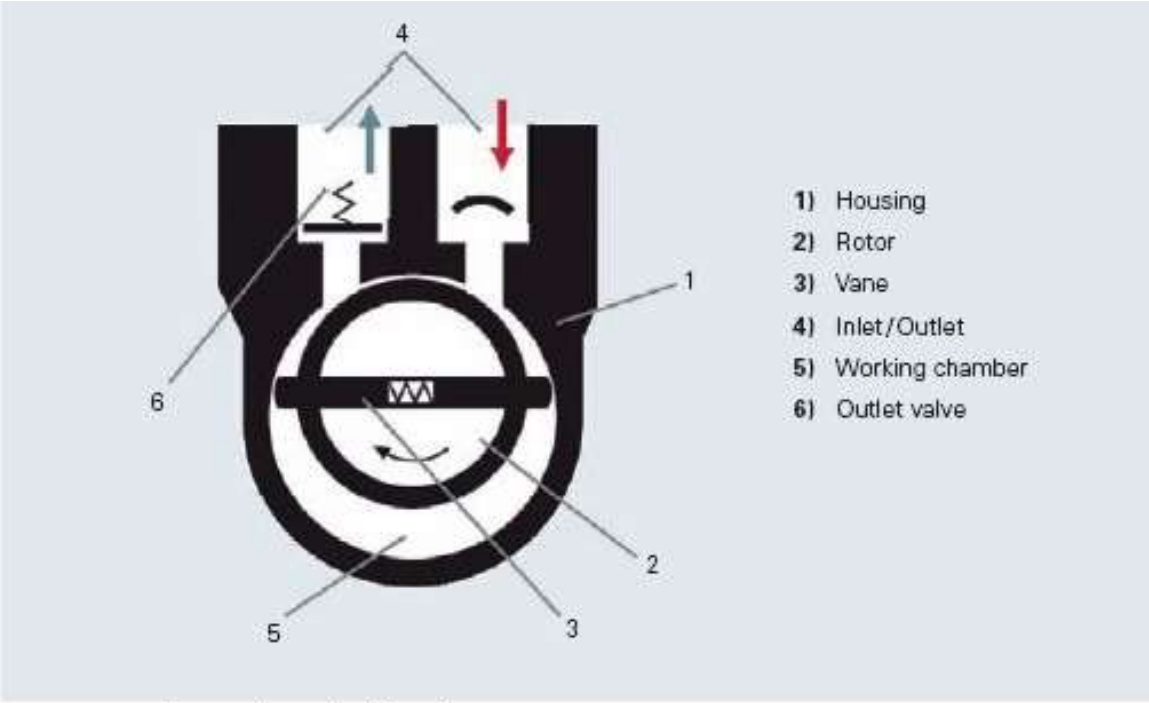
Rotary vane pump

Atmosphere to ~ 10^{-3} mbar



Operating principle of a rotary vane pump

https://www.youtube.com/watch?v=AFHogF-9eGA
https://www.youtube.com/watch?v=IIKOx0JqE08
https://www.youtube.com/watch?v=oXgdnnkIKZ4

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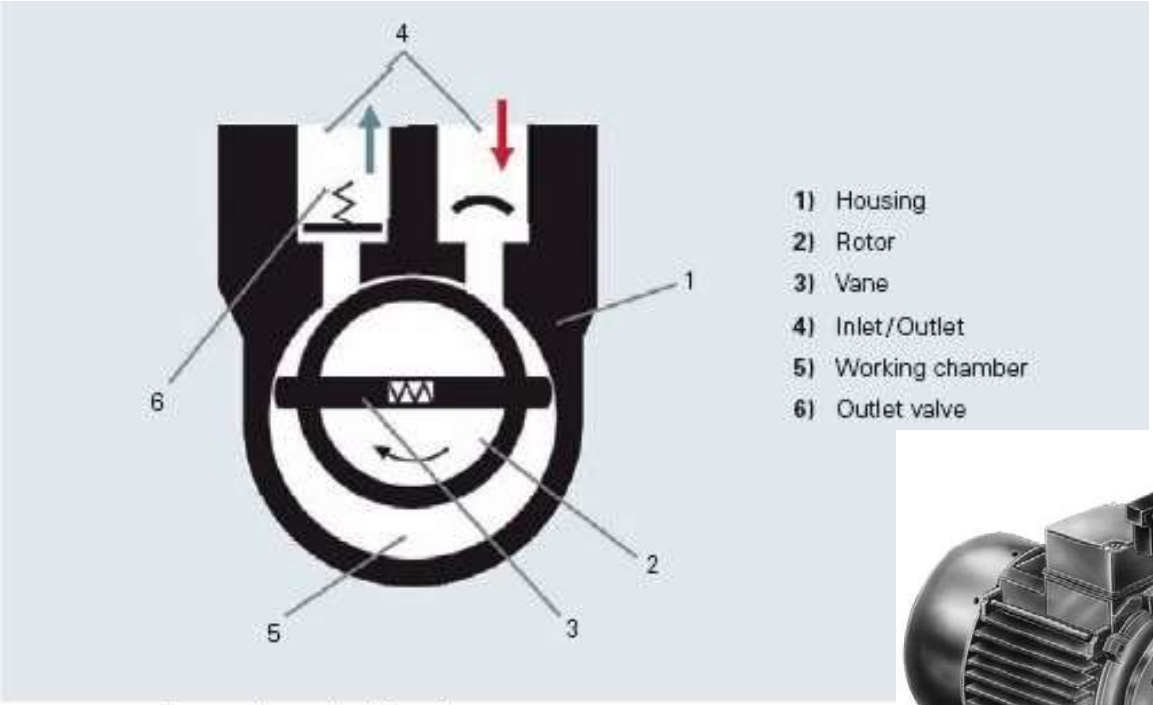
Rotary vane pump

Atmosphere to ~ 10^{-3} mbar



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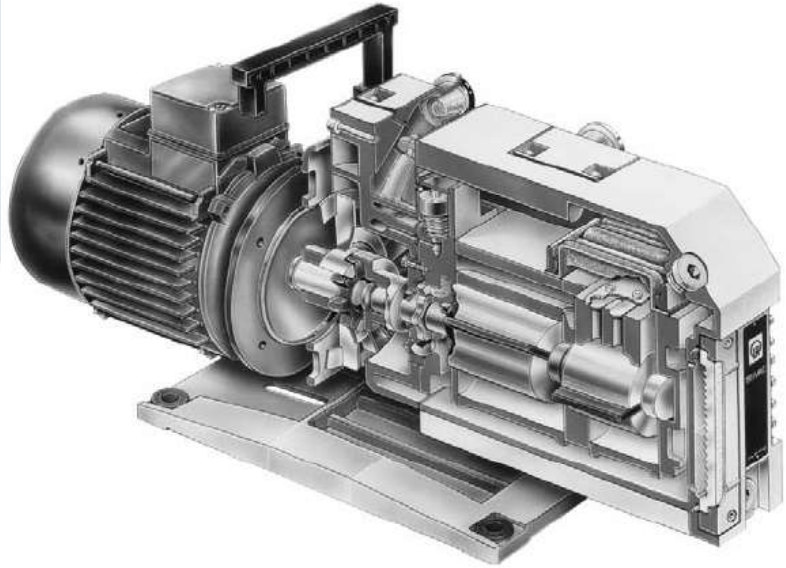

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Rotary vane pump

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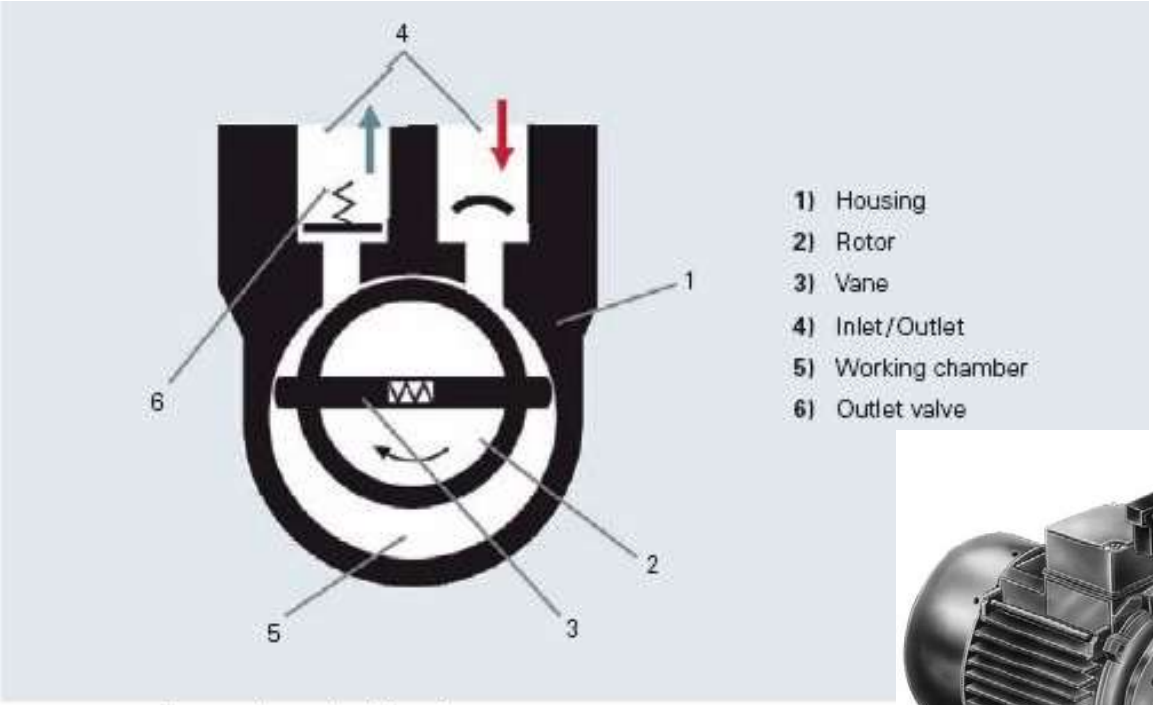
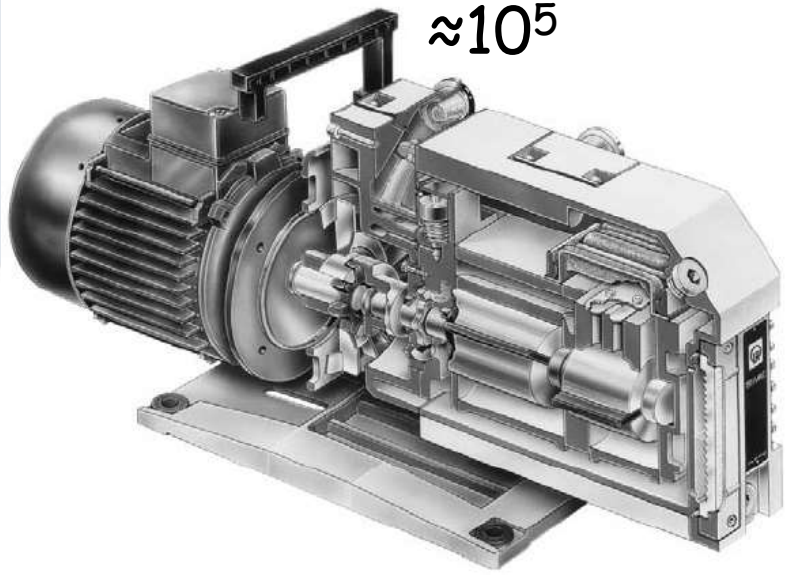


Operating principle of a rotary vane pump

Compression ≈10^5



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Rotary vane pump

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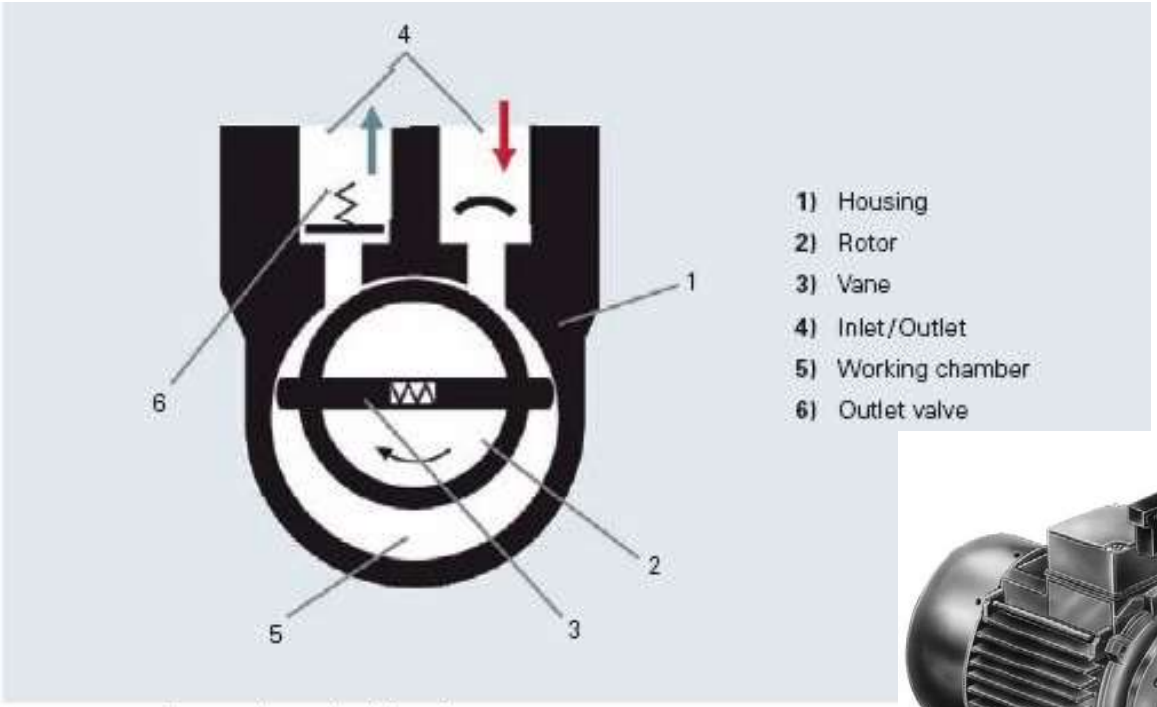

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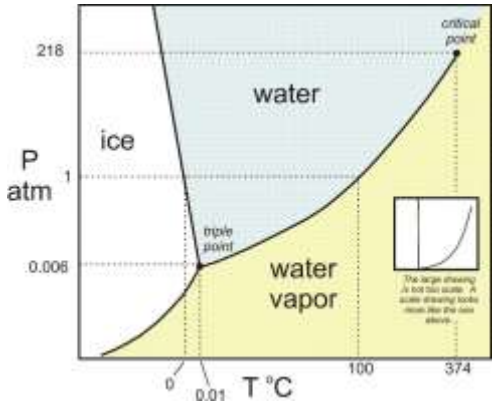

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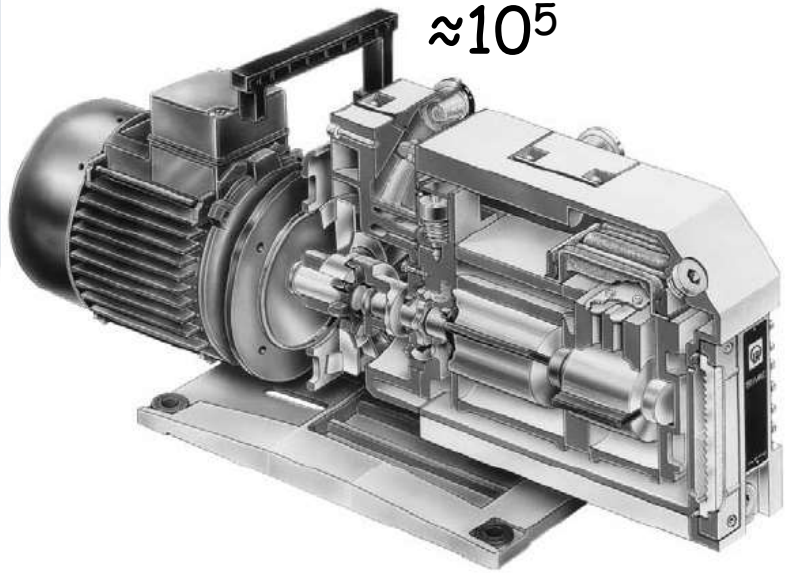

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Rotary vane pump

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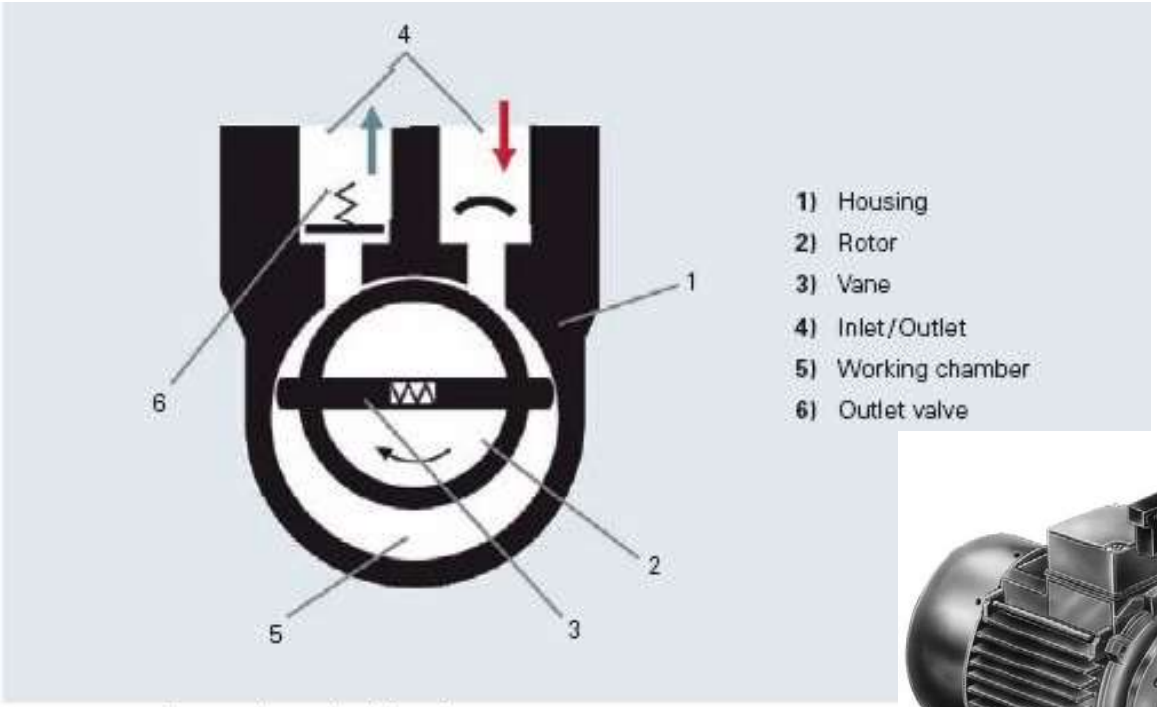

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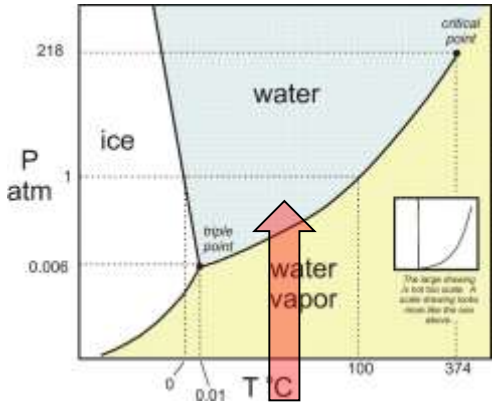

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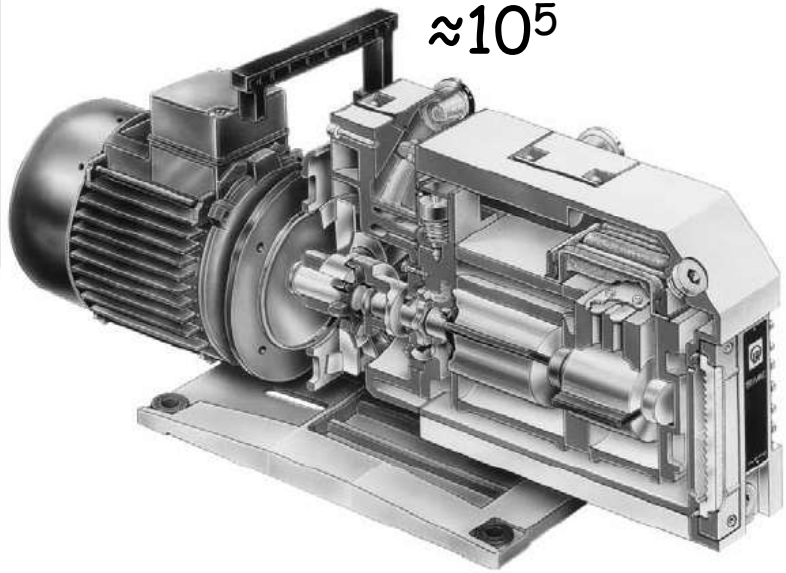

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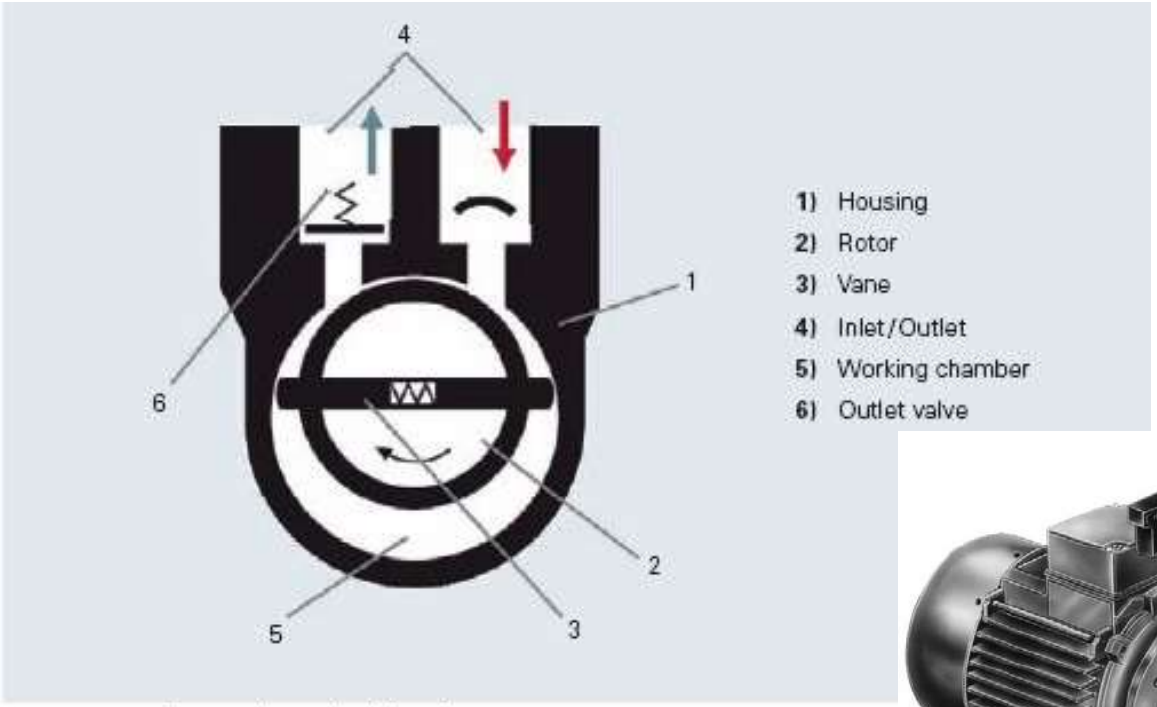

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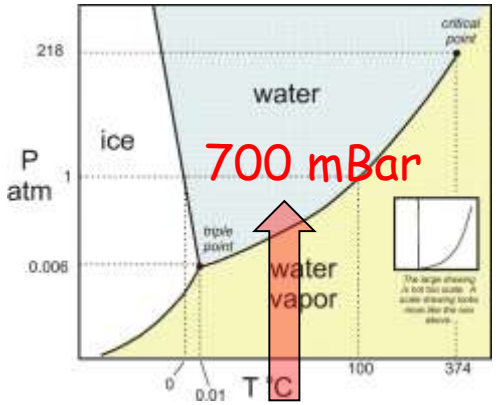
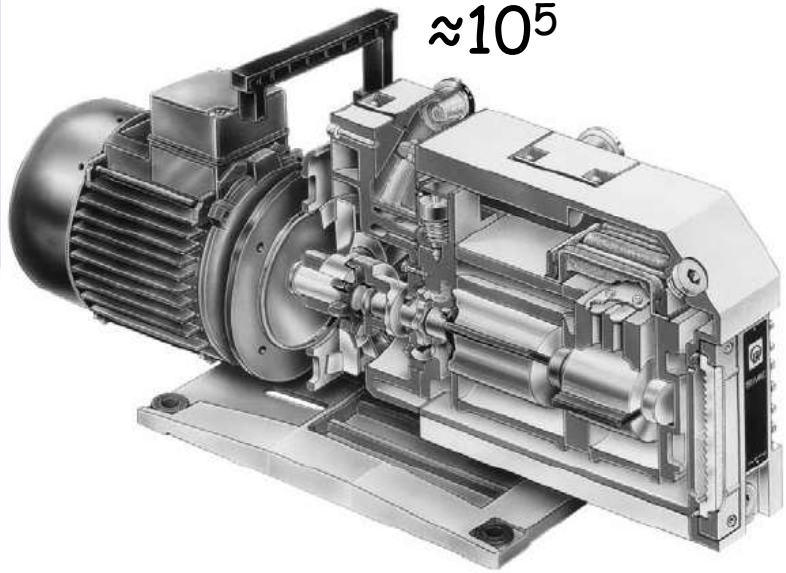


$7 \cdot 10^{-3}$ mBar

Compression $\approx 10^5$



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Rotary vane pump

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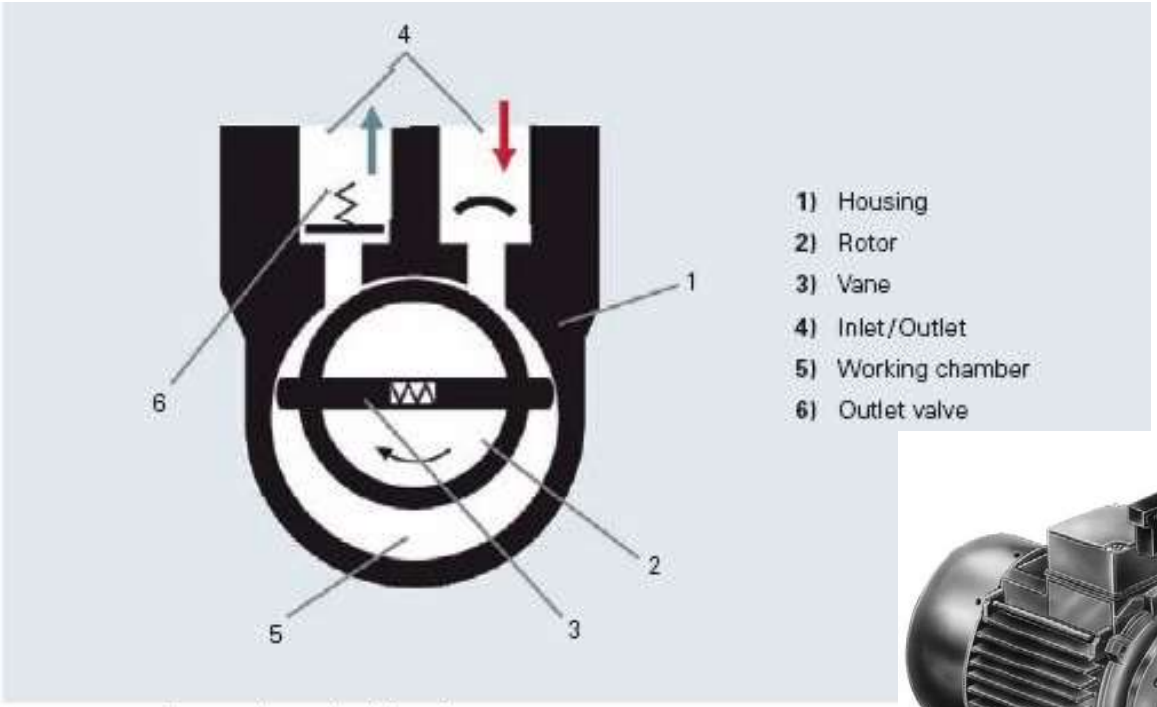

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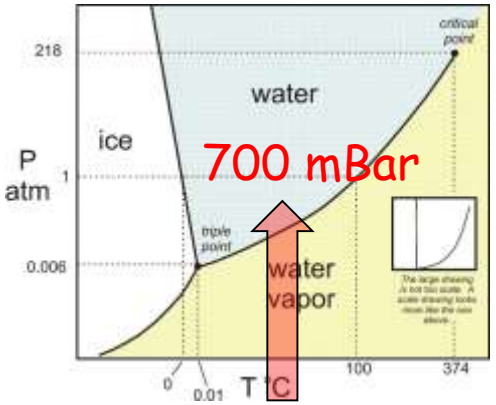

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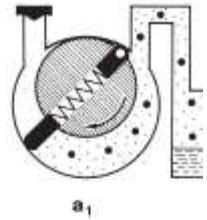
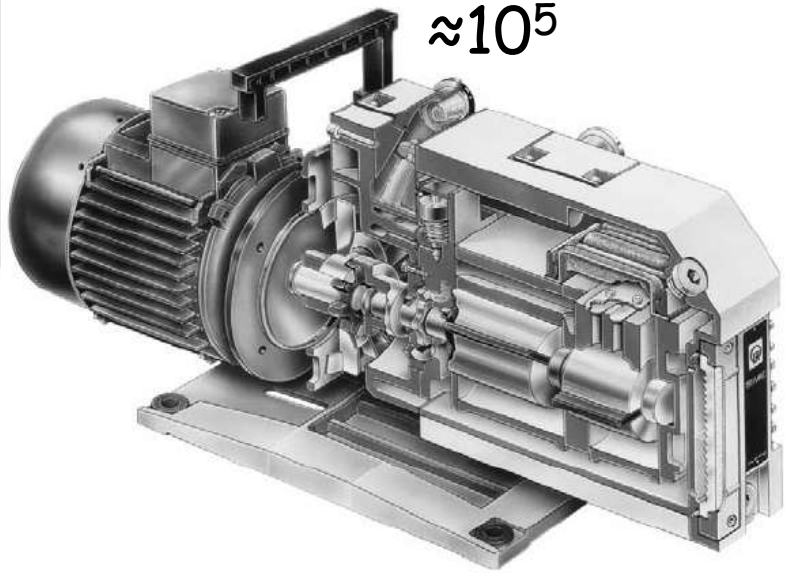


Compression ≈10^5



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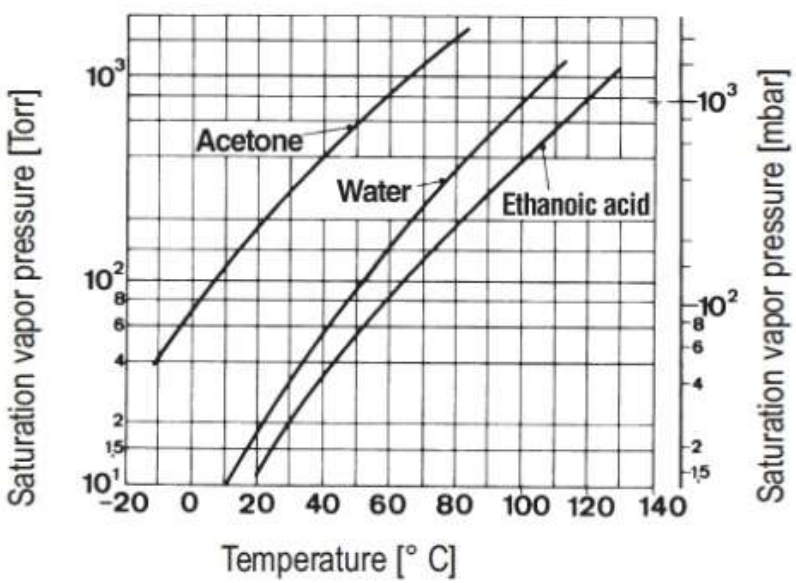
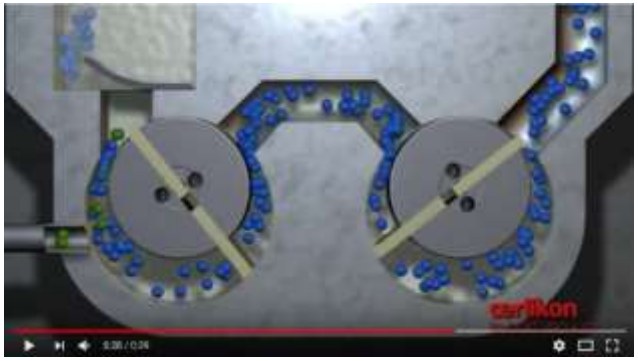
Gas ballast function





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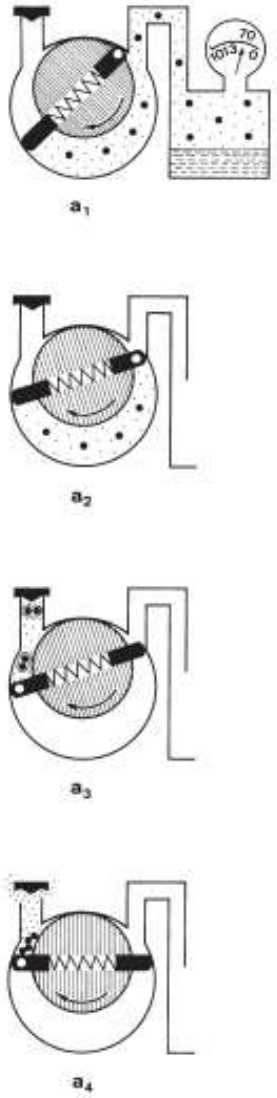

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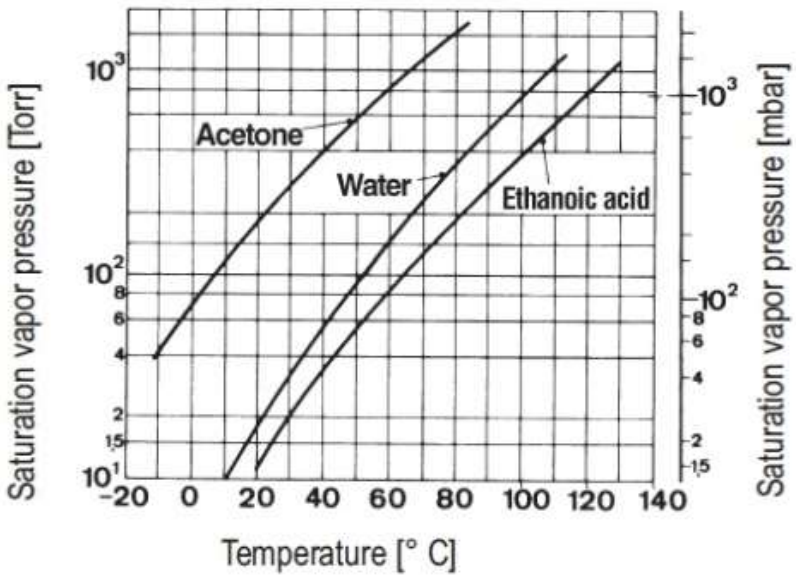

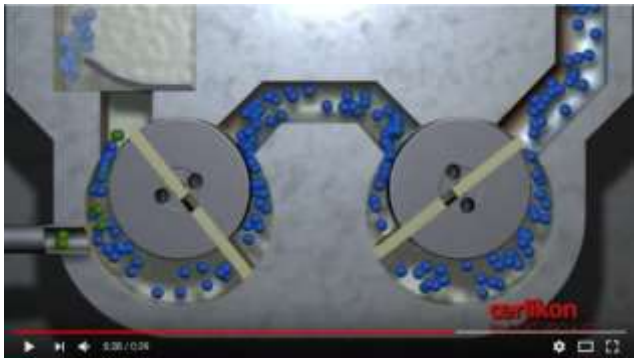

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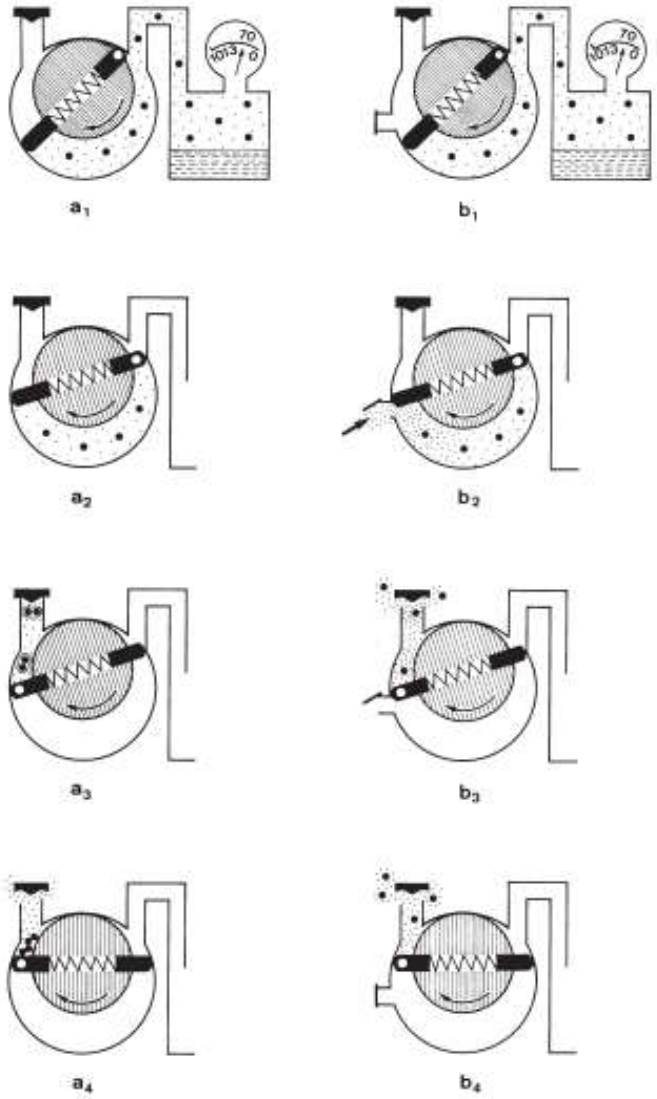

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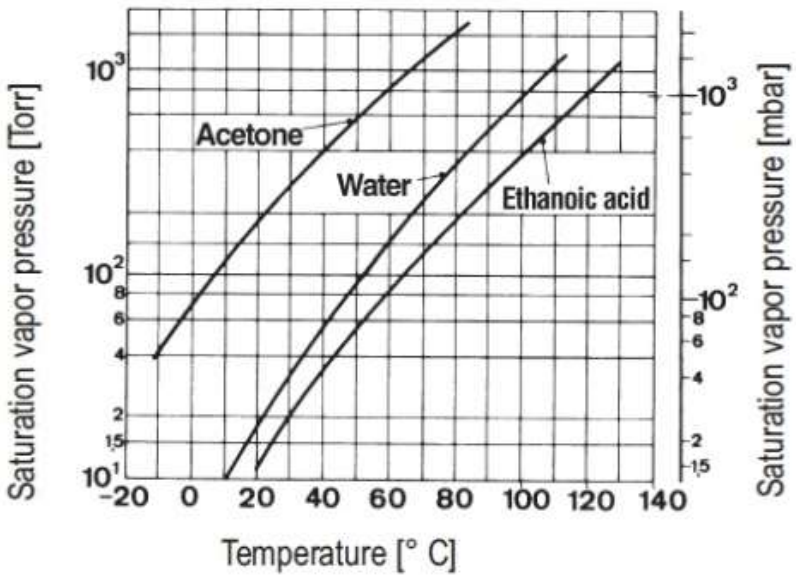
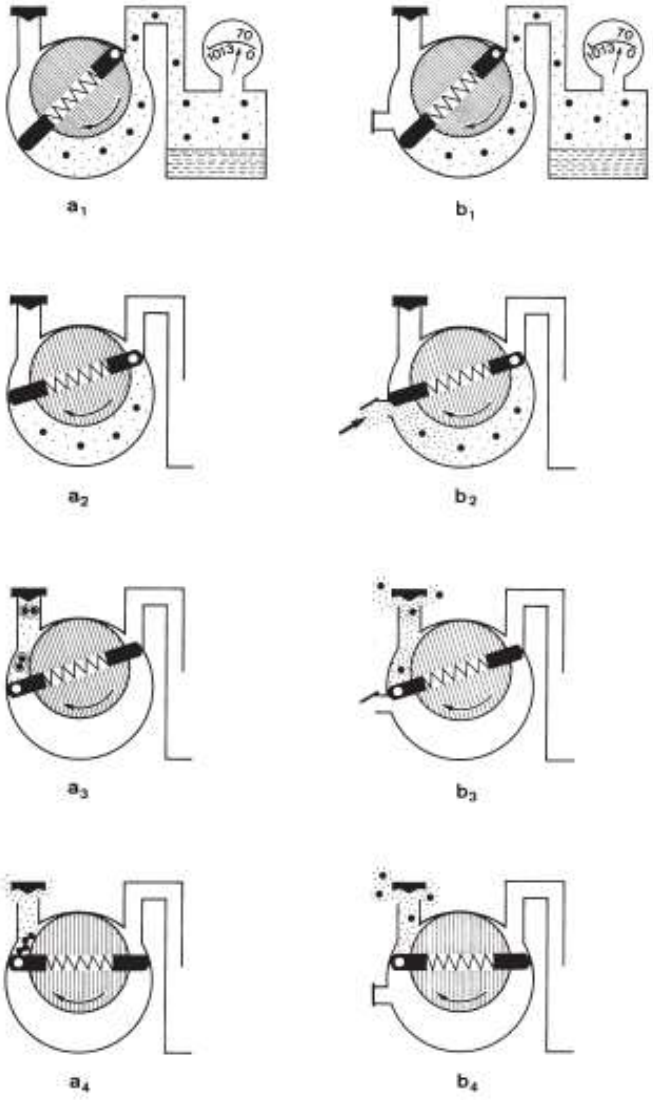
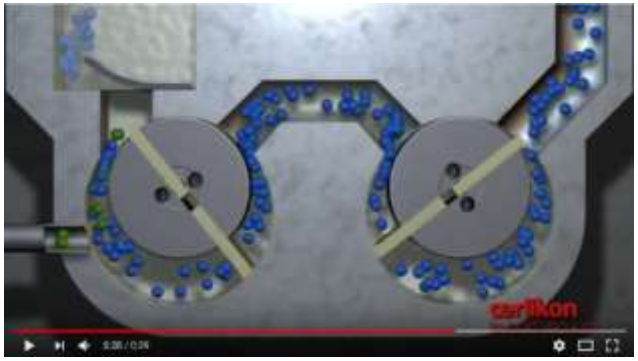
Gas ballast function







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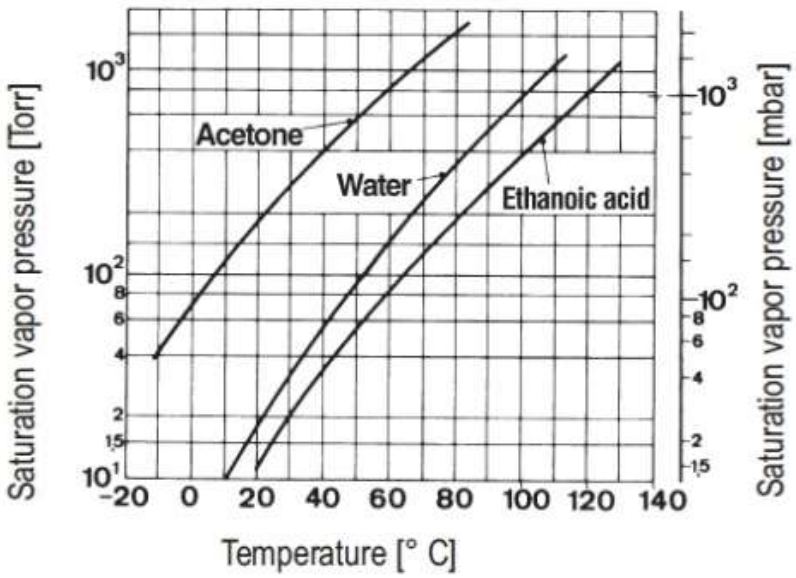
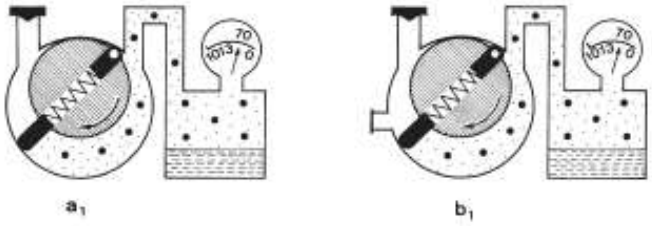
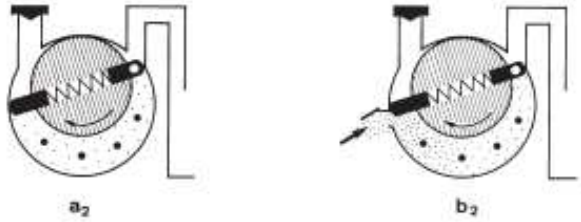
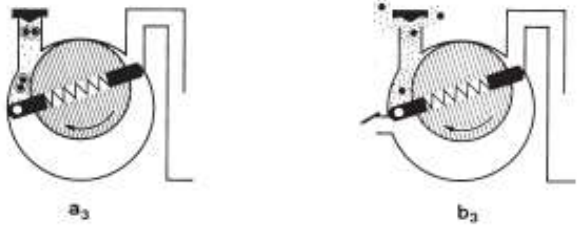
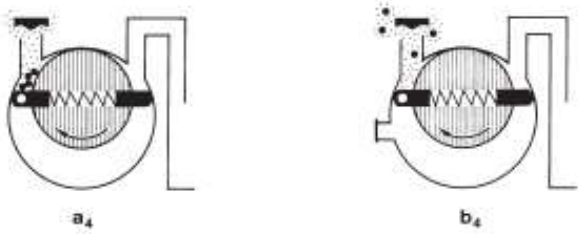
Gas ballast function

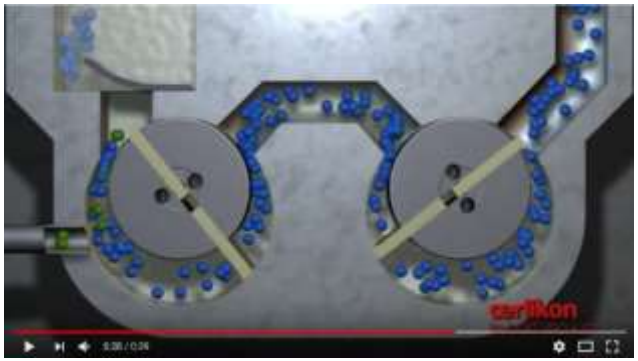












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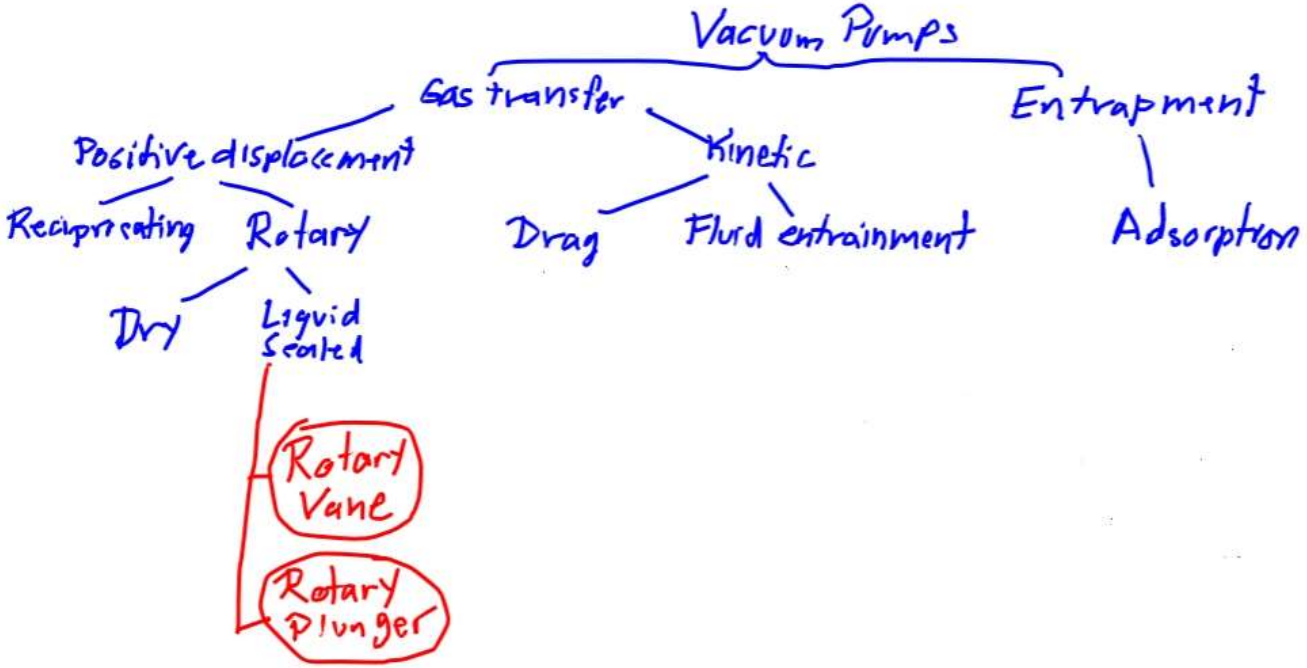

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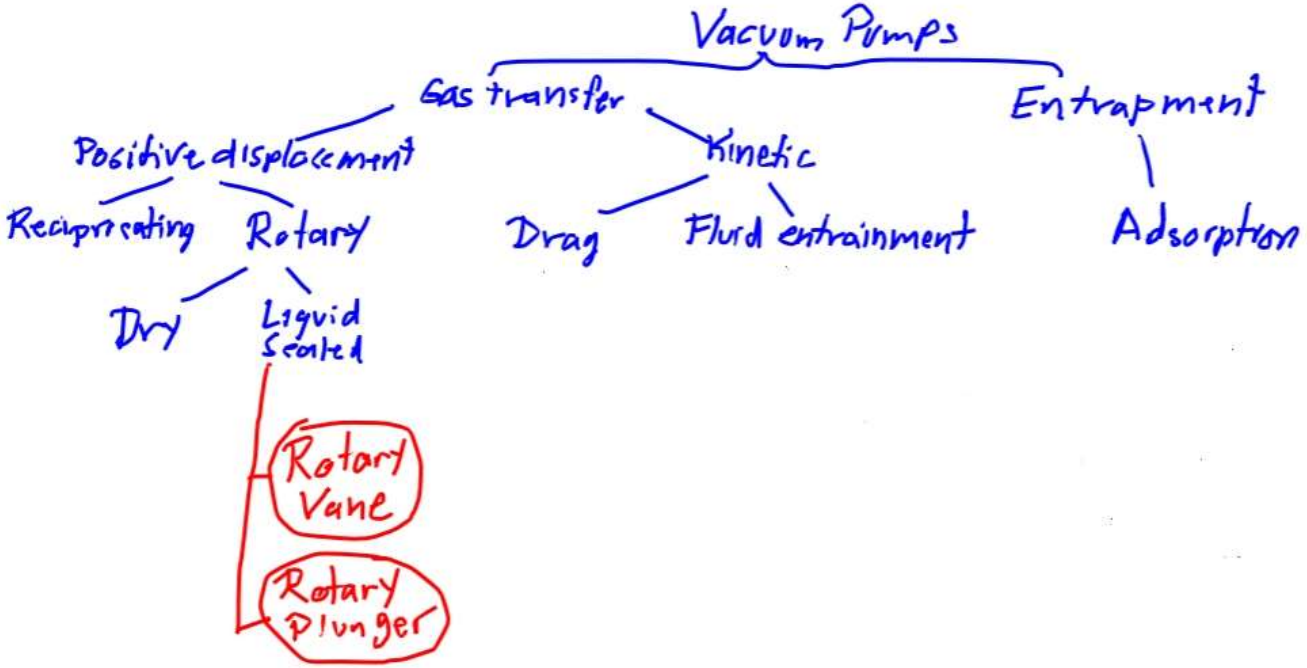

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Next: Roots Pump

"VT L10 e mm:ss

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Next: Roots Pump

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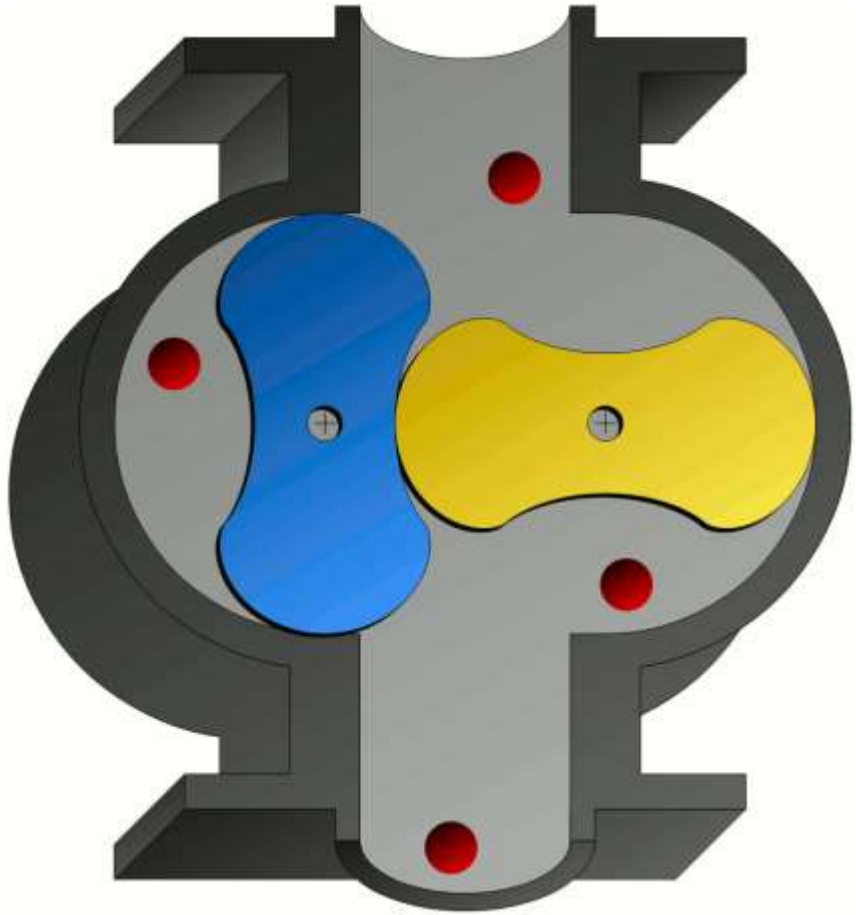
Next: Roots Pump

"VT L10 e mm:ss

Gap between rotary pistons and housing ≈ 100 µm. No oil sealing!



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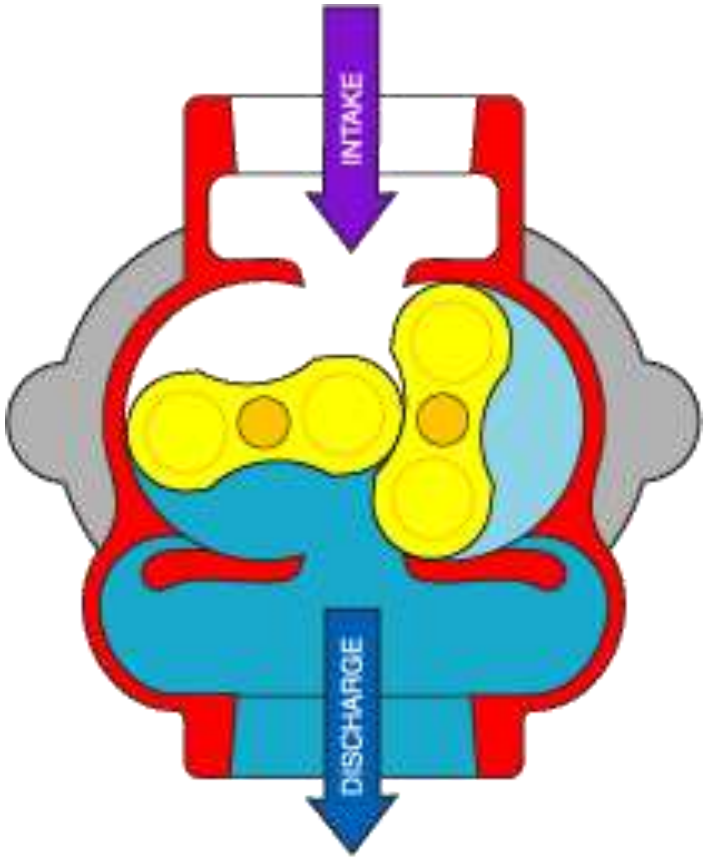

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Roots Pump

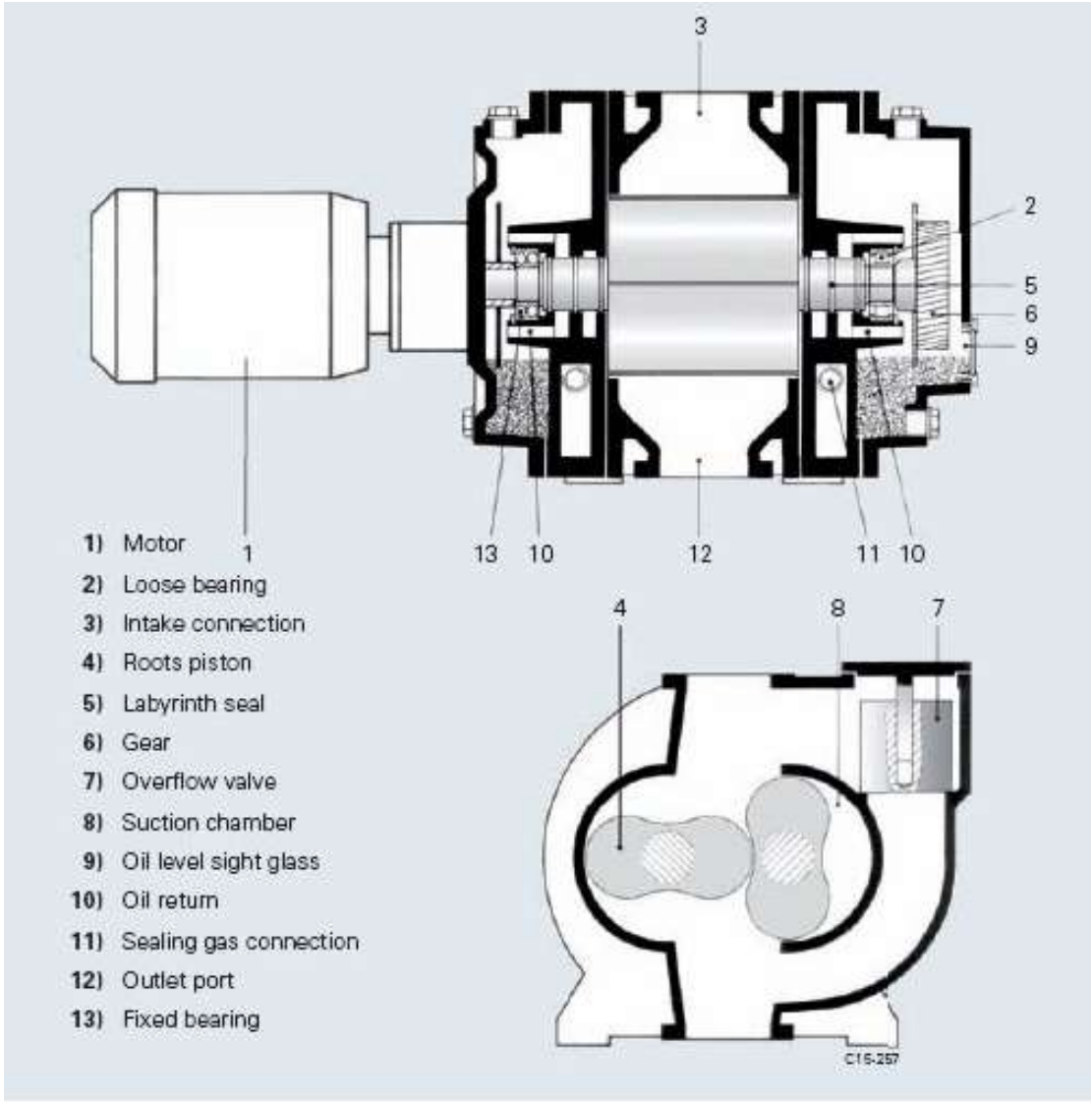
Working range
~ 10 ~ 10^{-2} mbar

High pumping speed!

Used for high gas flows in CVD processes.

https://www.youtube.com/watch?app=desktop&v=_-fwWrFLiyY

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



Operating principle of a Roots pump

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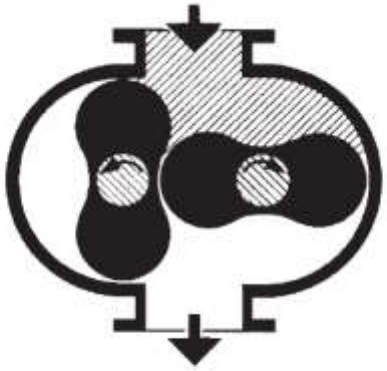
Roots Pump



1 Intake flange
2 Rotors
3 Chamber
4 Exhaust flange
5 Casing

Fig. 2.17 Schematic cross section of a Roots pump

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Roots Pump

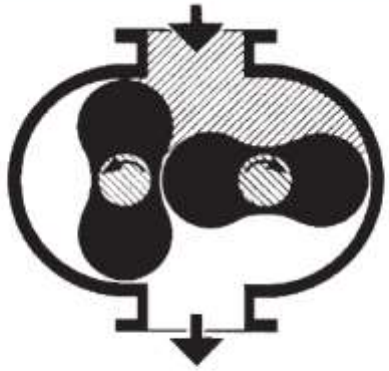

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Fig. 2.17 Schematic cross section of a Roots pump

Roots pump requires a backing pump!

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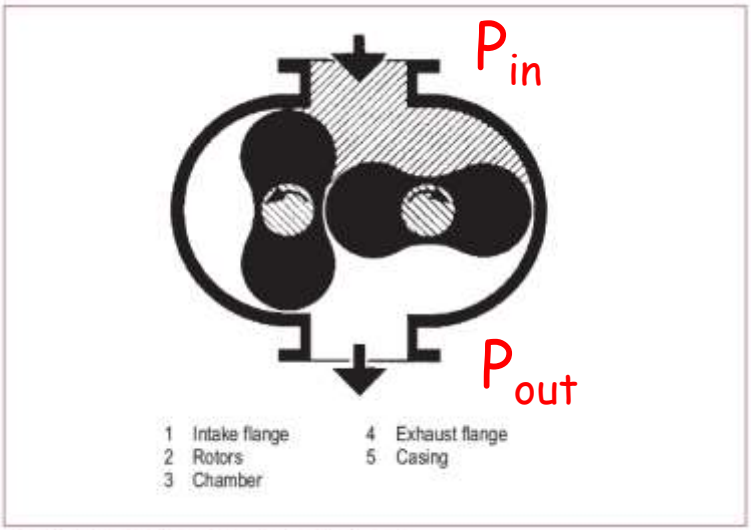
Roots Pump



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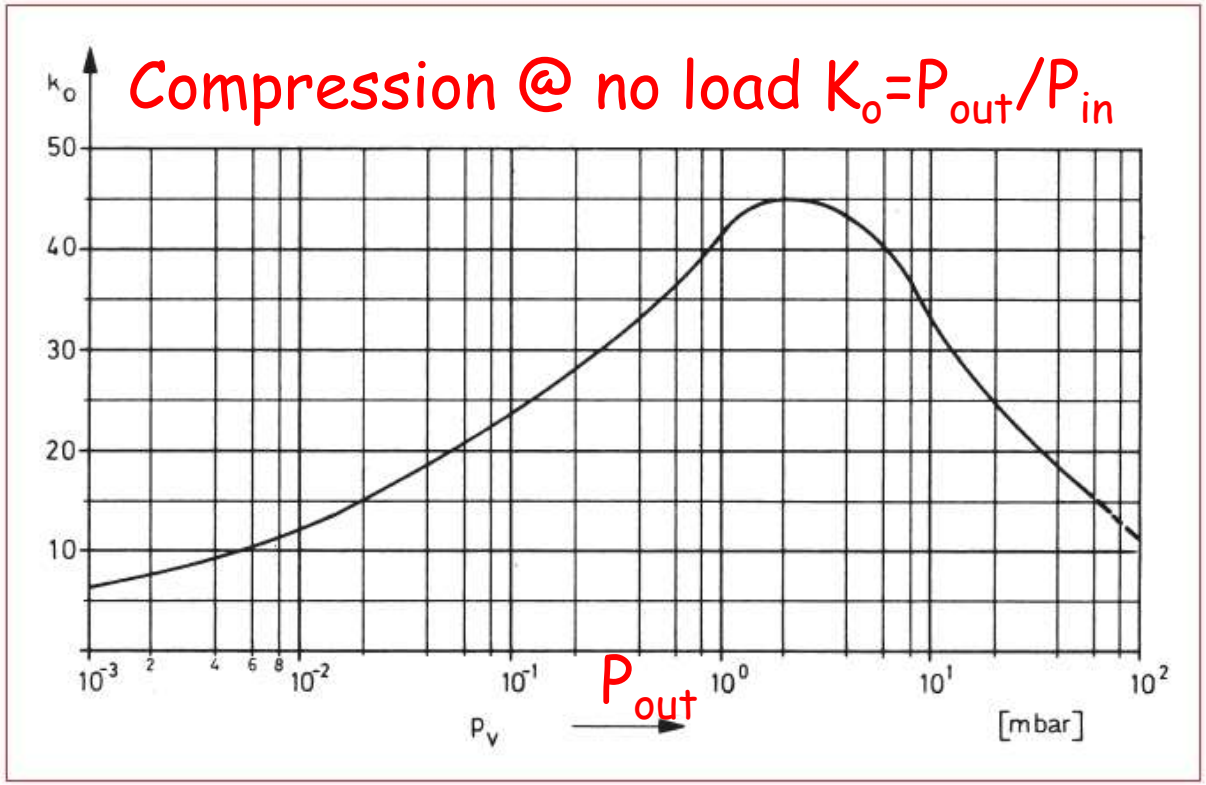

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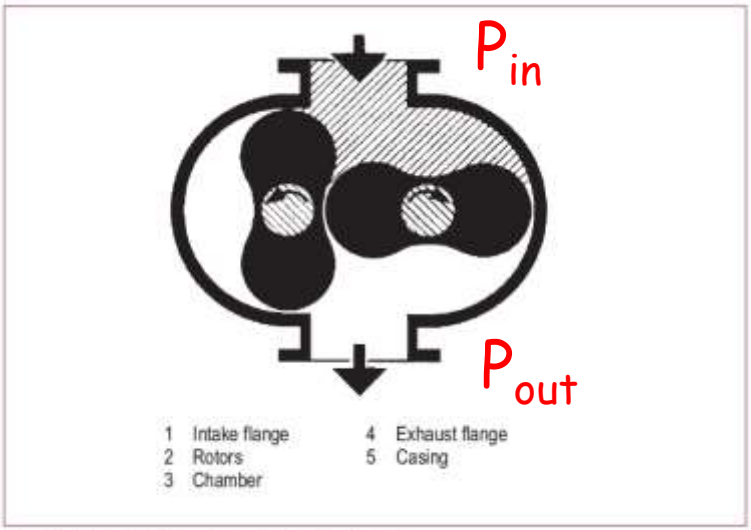
Roots Pump



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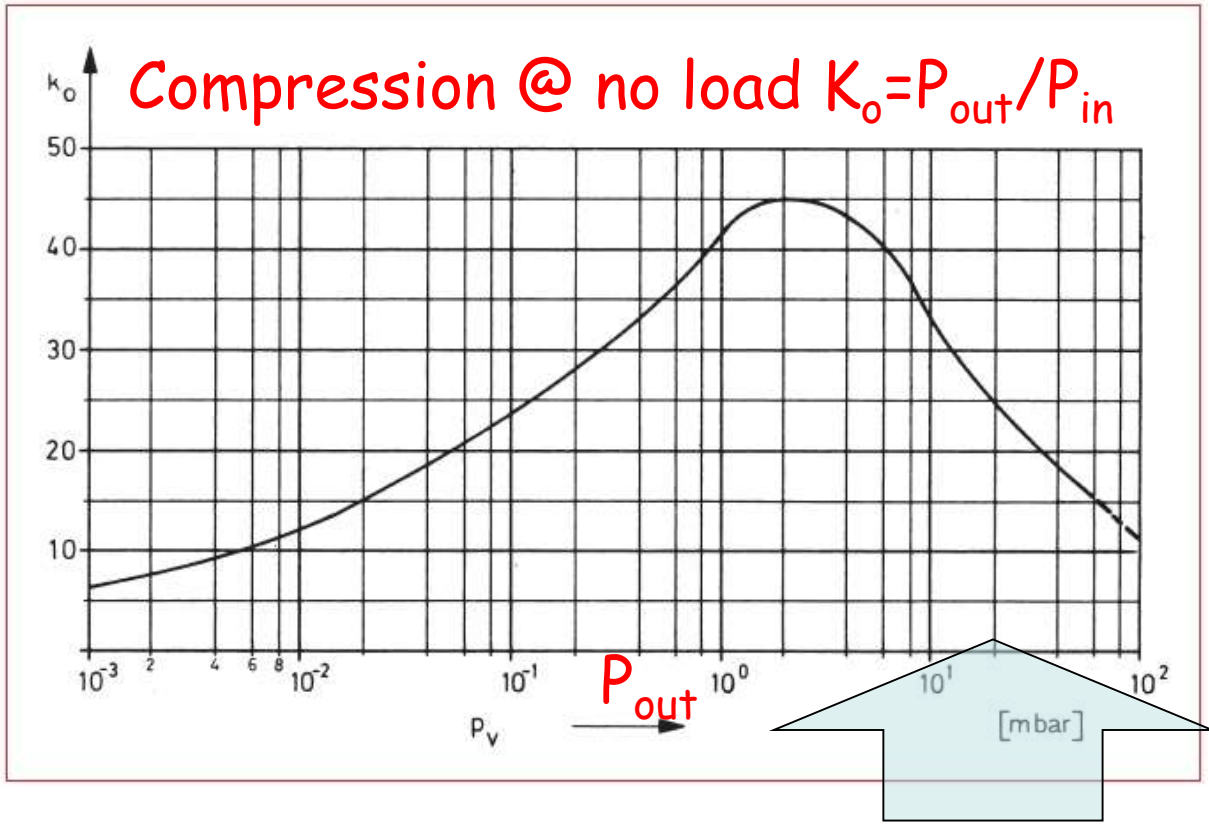

Roots pump requires a backing pump!

Gas leaking through the gaps (~100 µm) MFP very small

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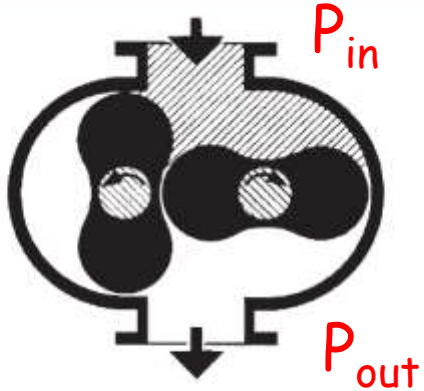
Roots Pump



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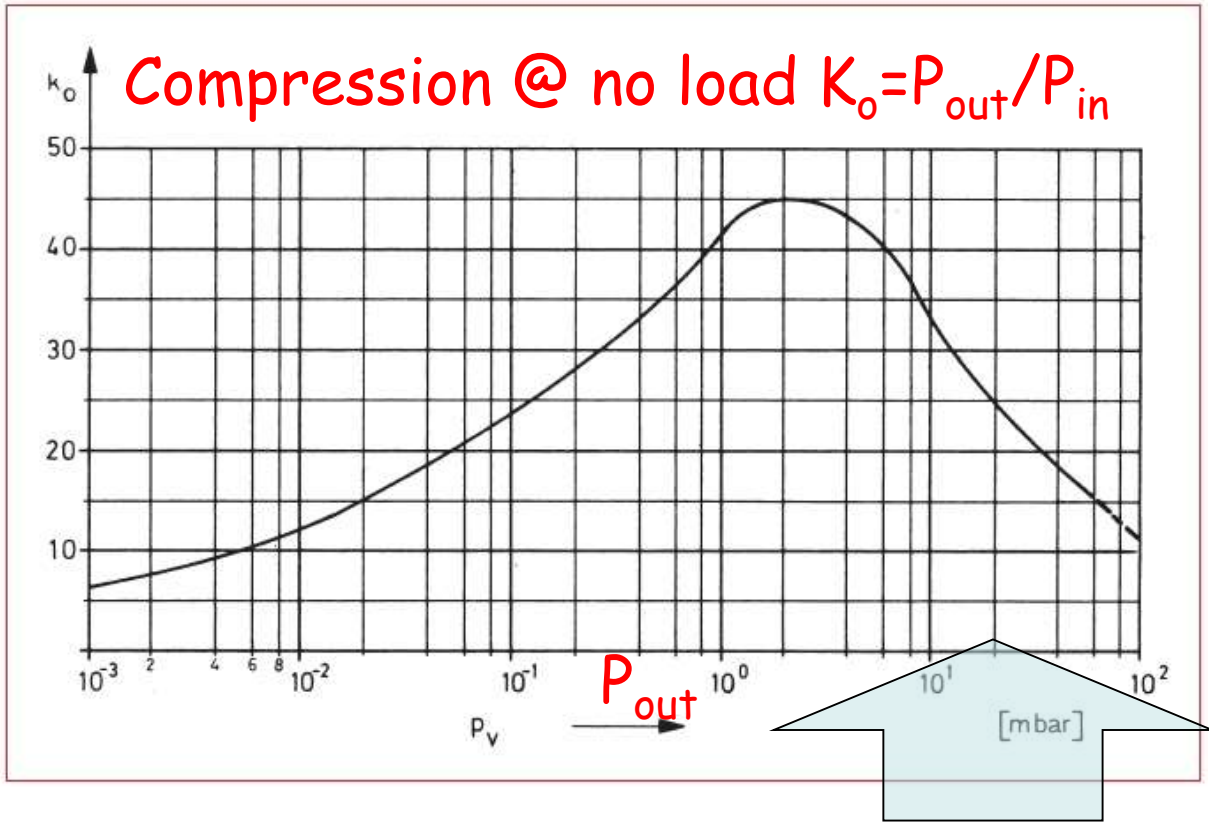

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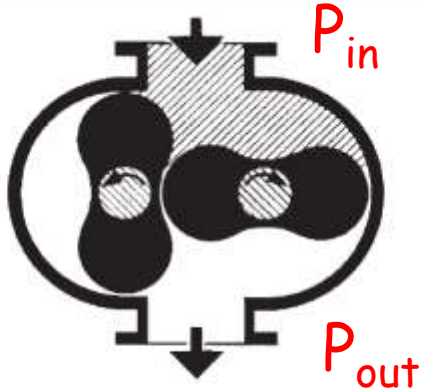
Roots Pump



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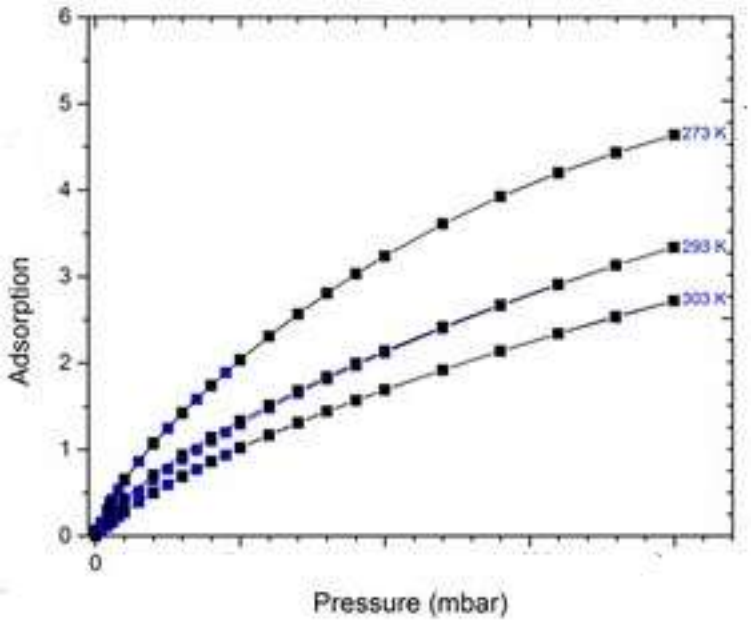

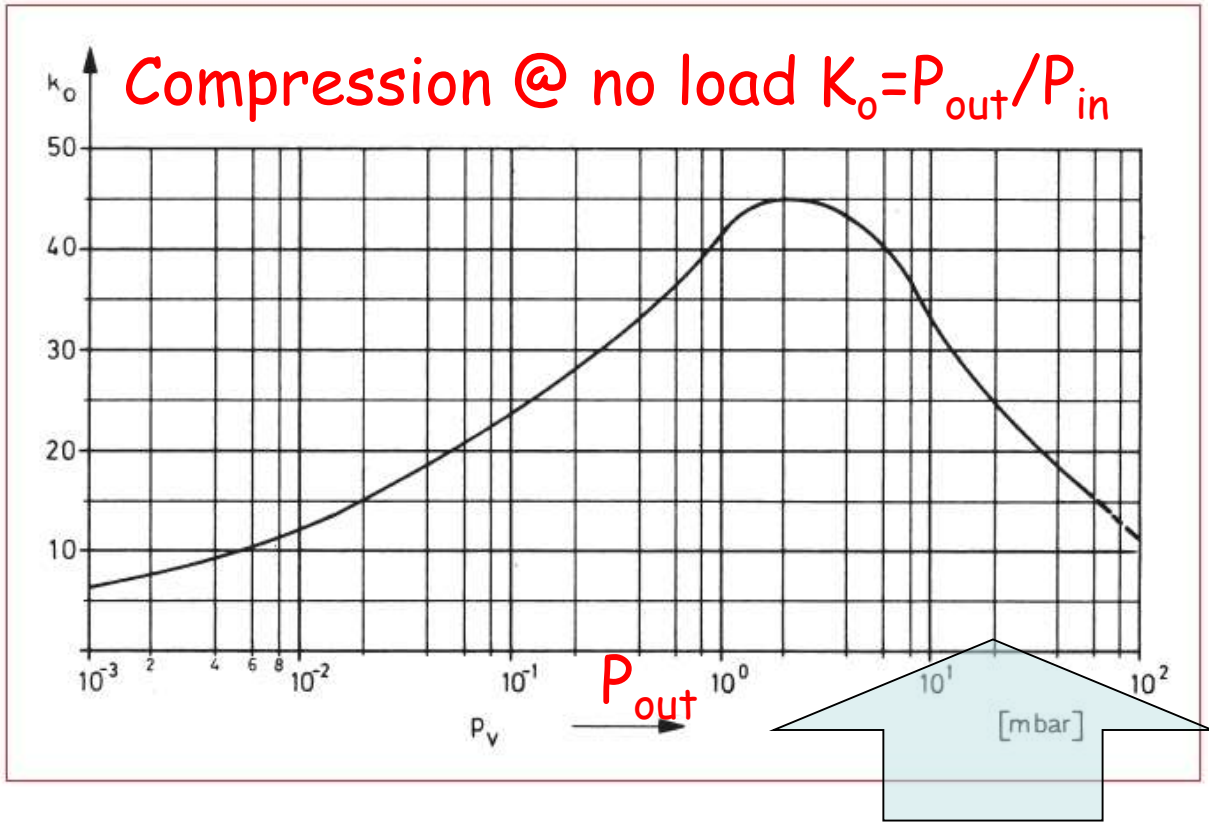

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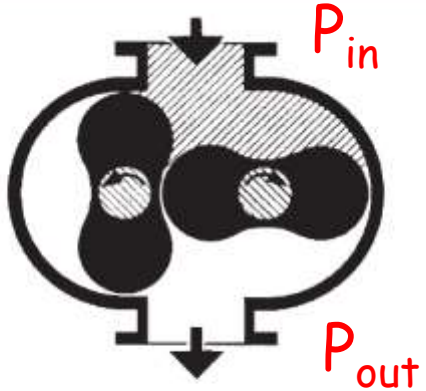
Roots Pump



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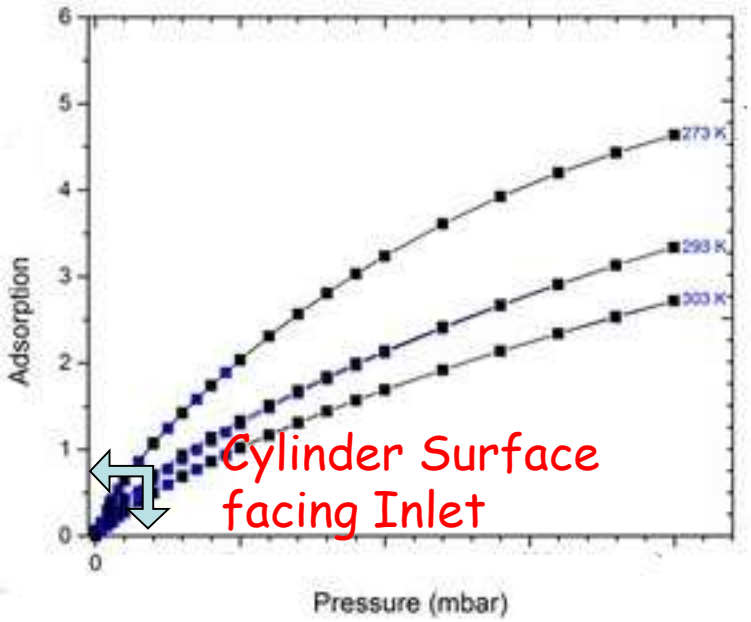

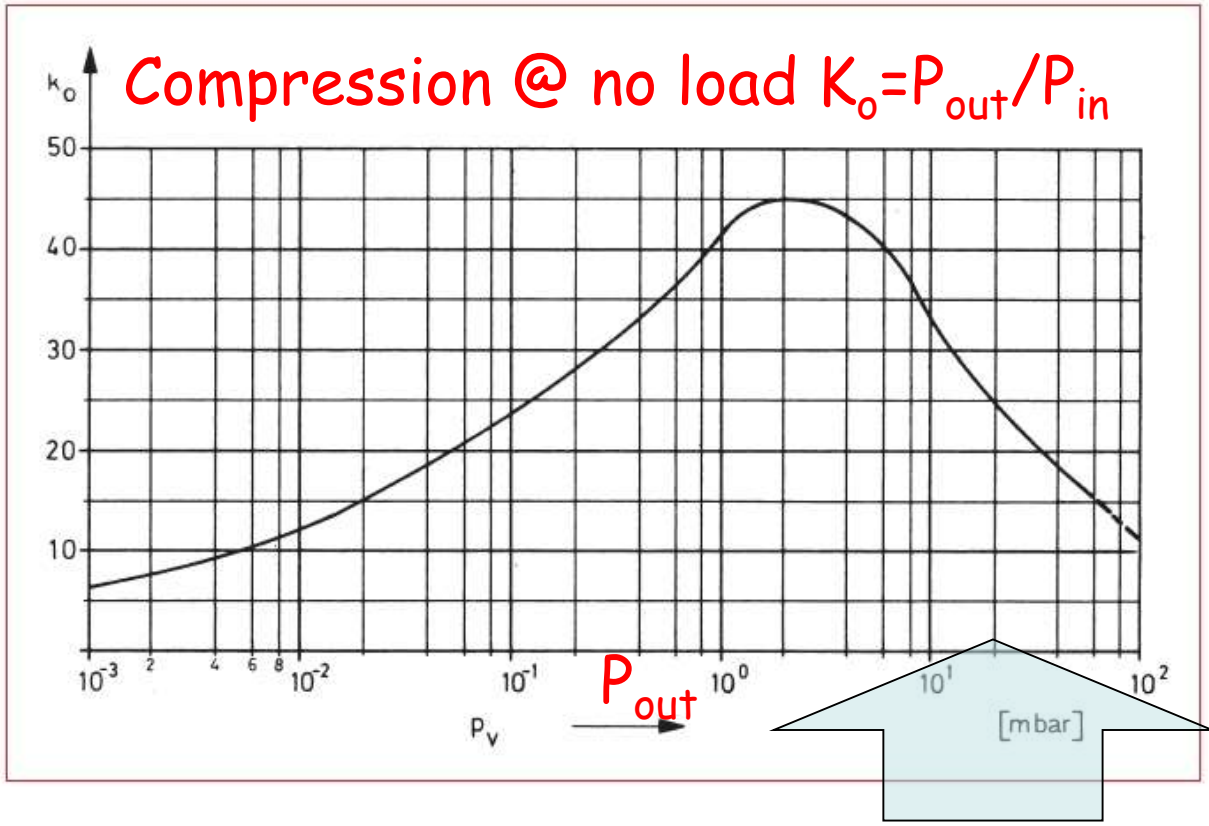

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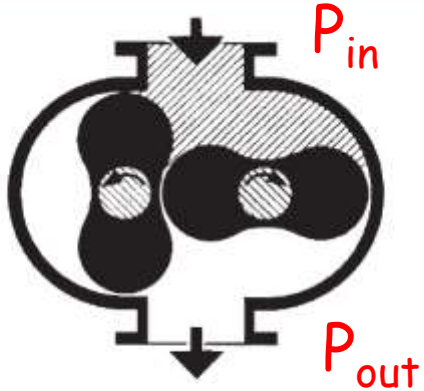

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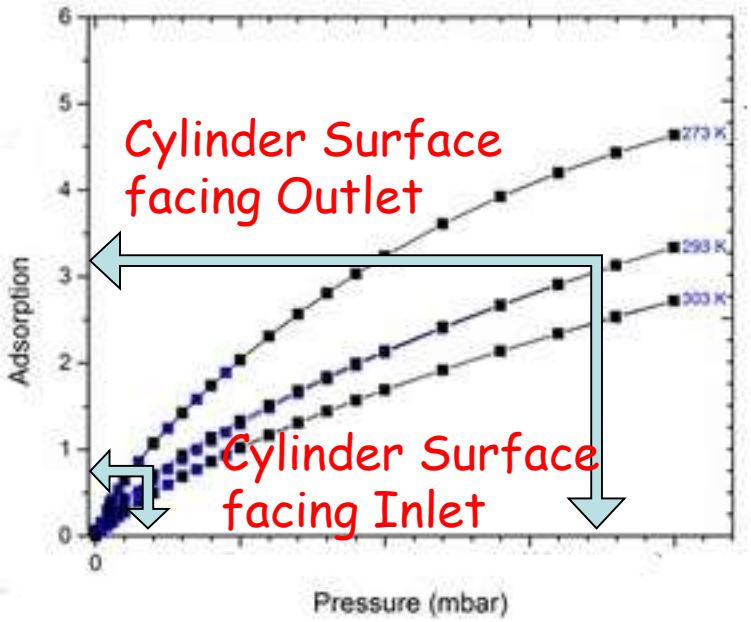

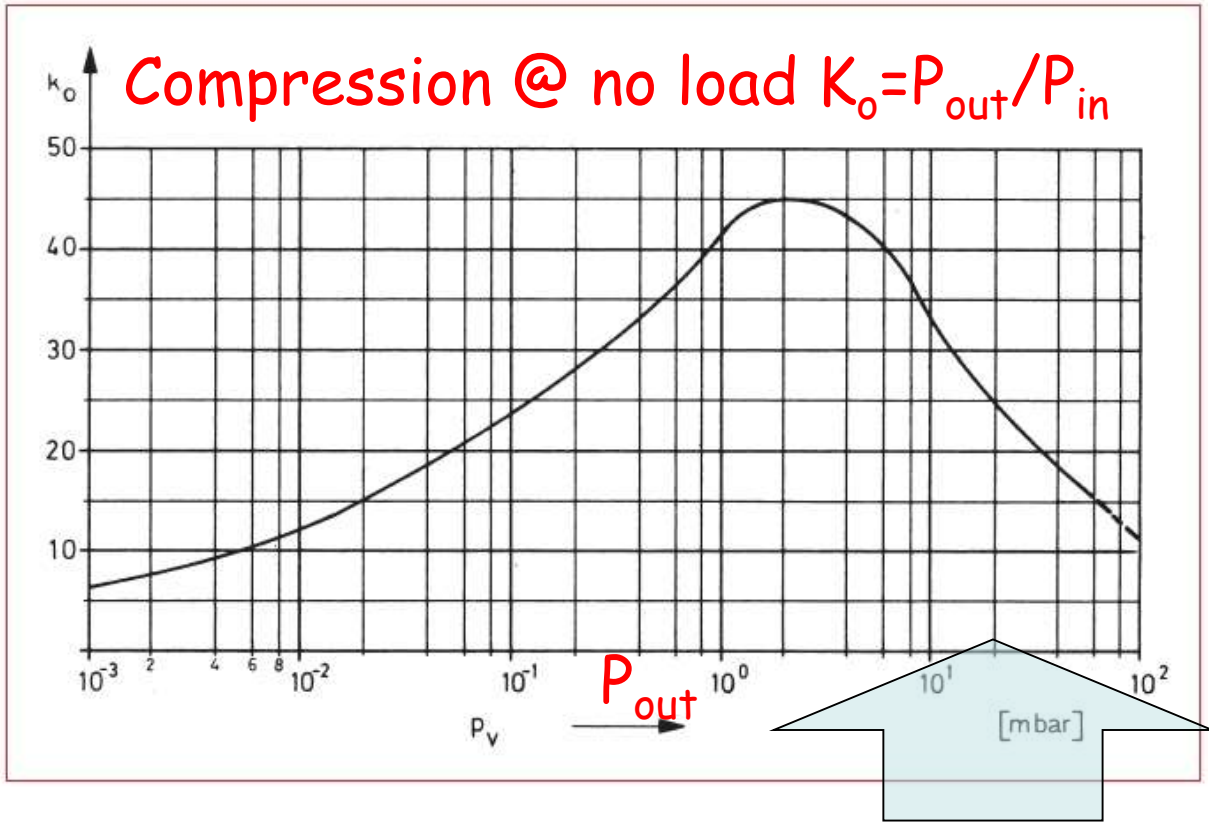

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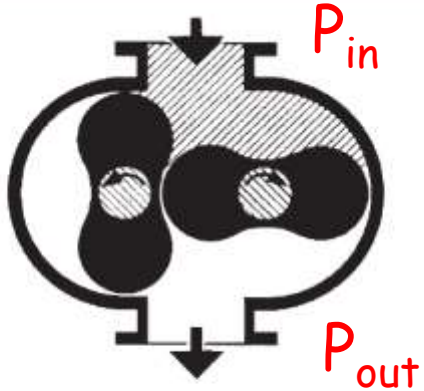

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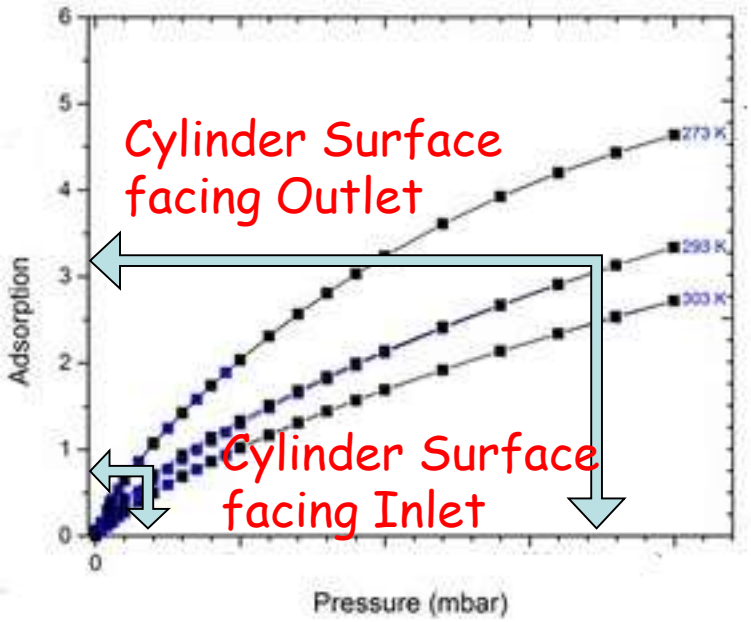

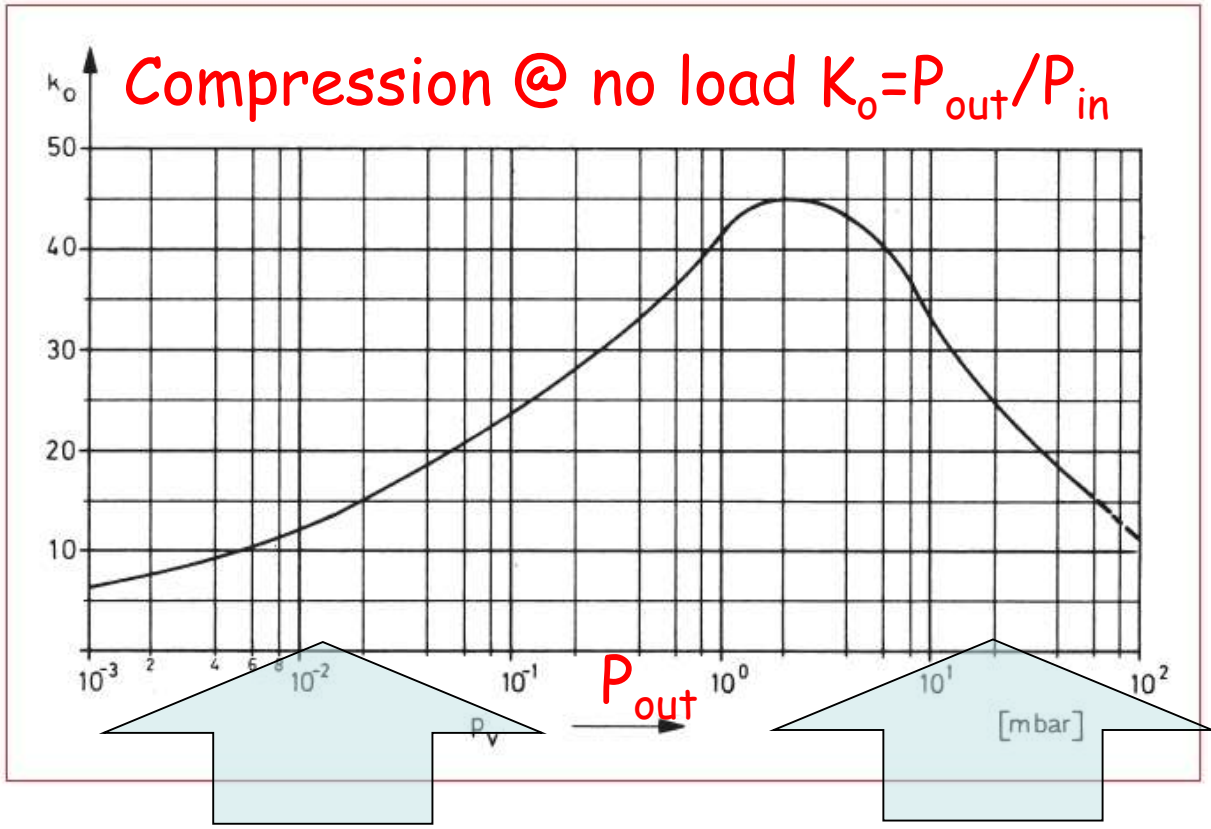

MFP very large but gas back flow by adsorption/desorption at/from the rotating pistons

Gas leaking through the gaps (~100 µm) MFP very small

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»Wissen schafft Brücken.«

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