TECHNISCHE UNIVERSITÄT DRESDEN

Vacuum Technology
WS 20/21
Virtually presented
Lecture 11, Jan. 19, 2021

Prof. Dr. Johann W. Bartha

Inst. f. Halbleiter und Mikrosystemtechnik
Technische Universität Dresden

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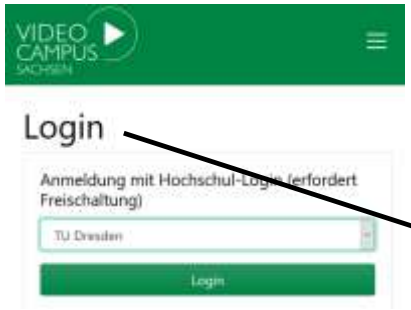

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Review L10

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

Genealogy of pumps, working principle, rotary plunger, rotary vane, roots

5. Pressure measurement

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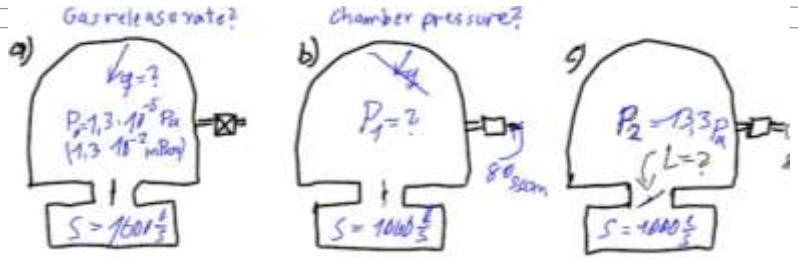

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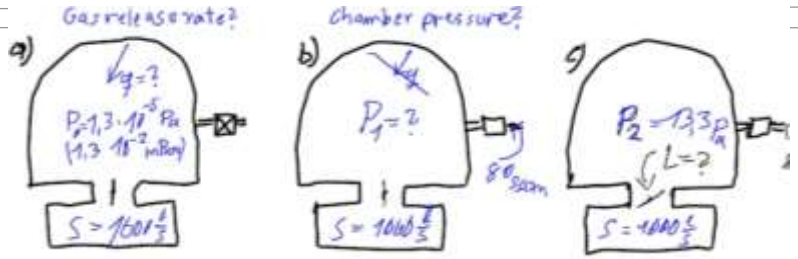

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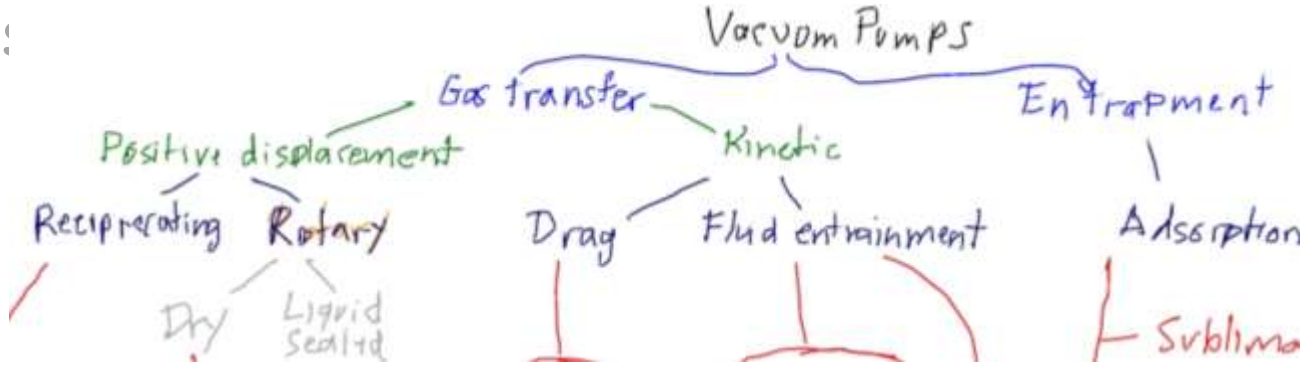

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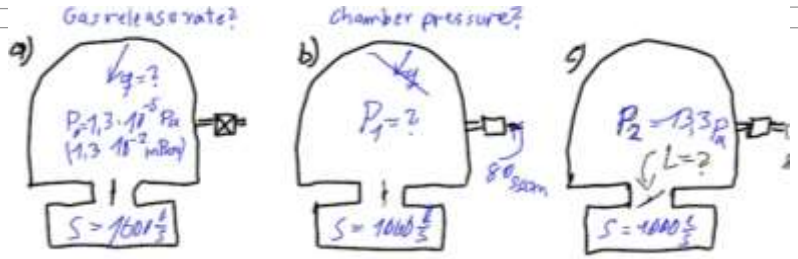

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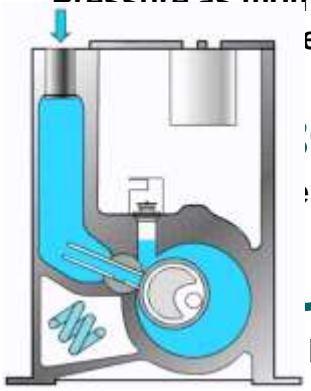

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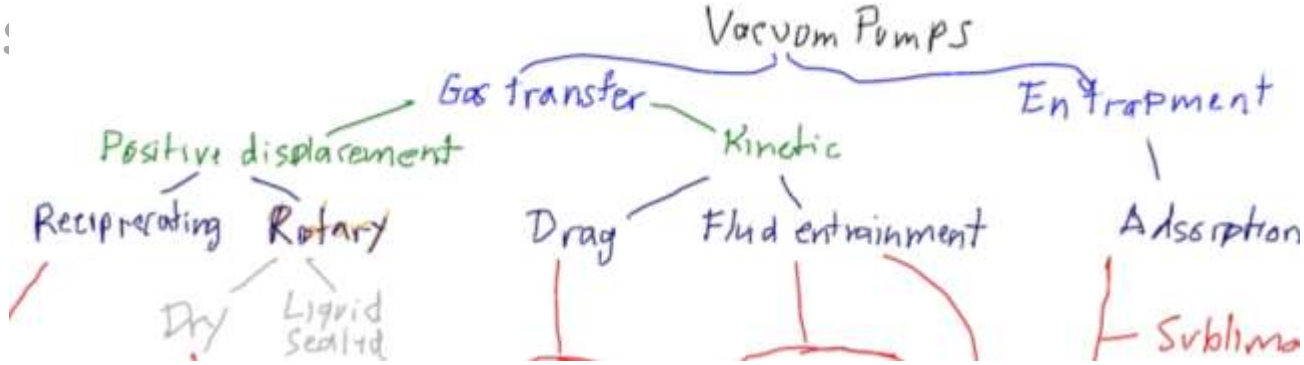

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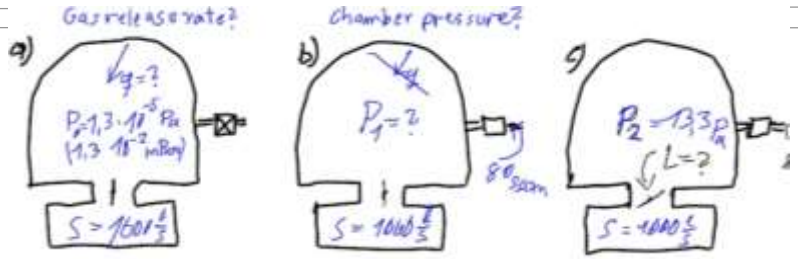

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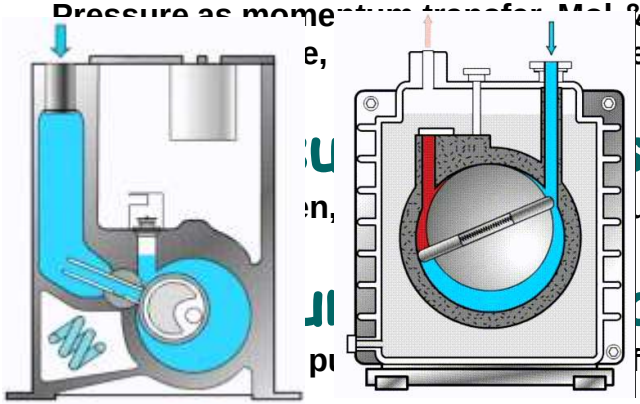

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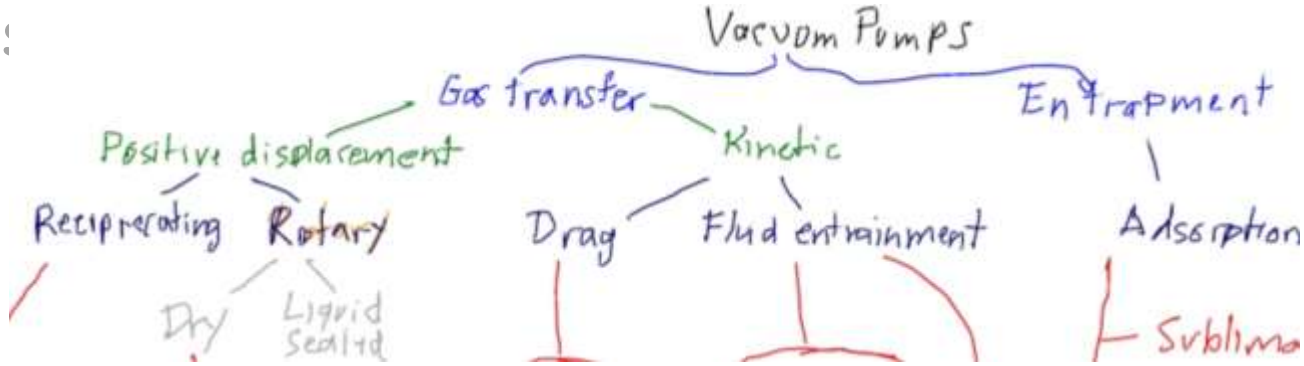

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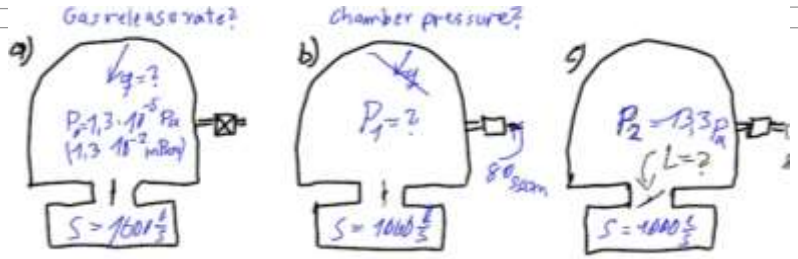

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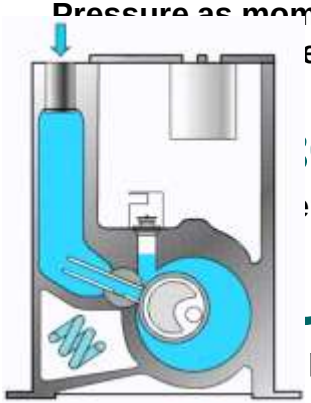

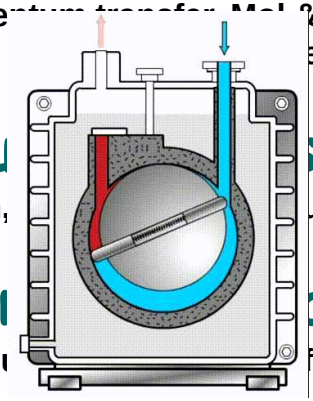

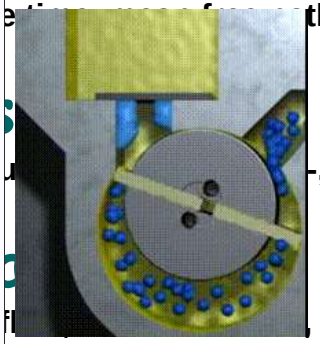

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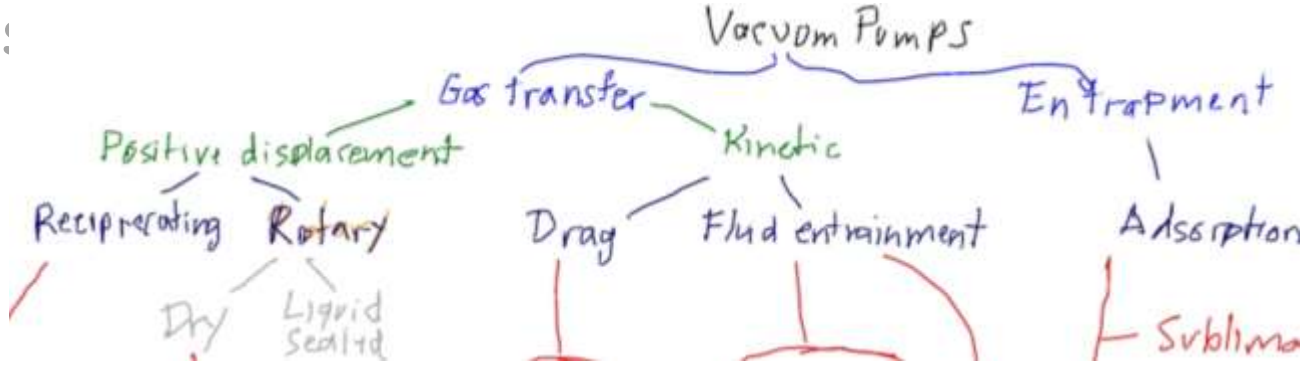

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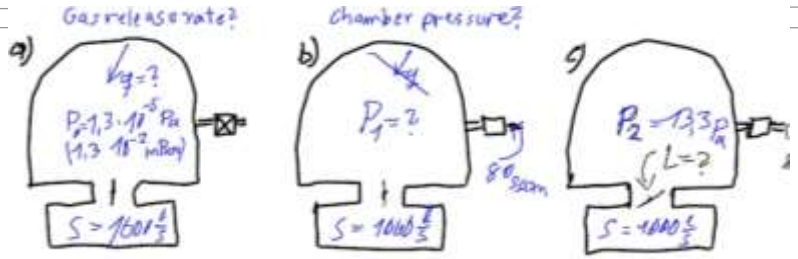

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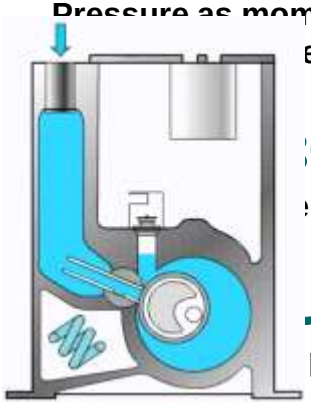

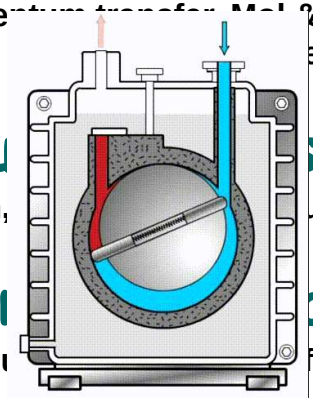

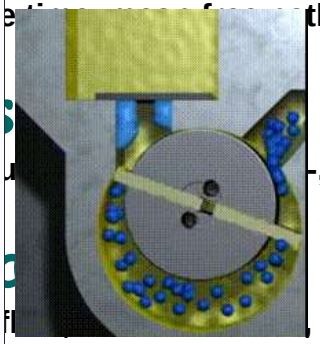

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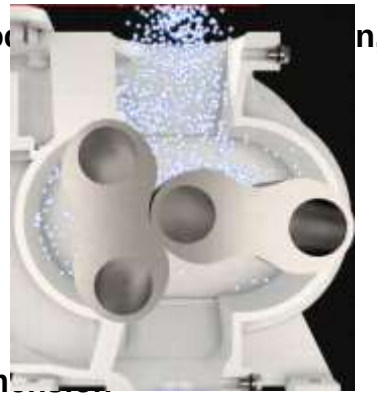

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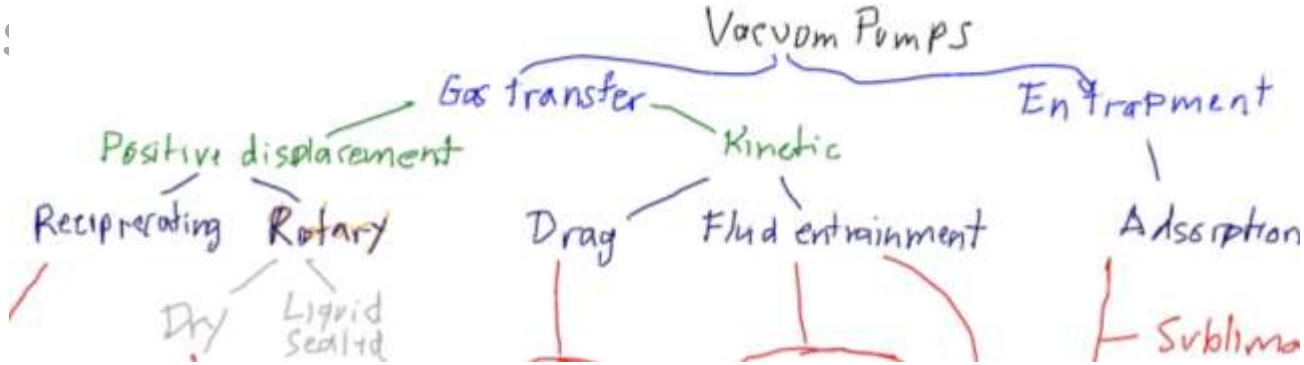

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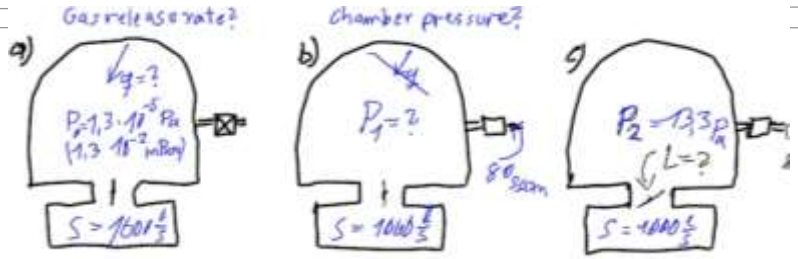

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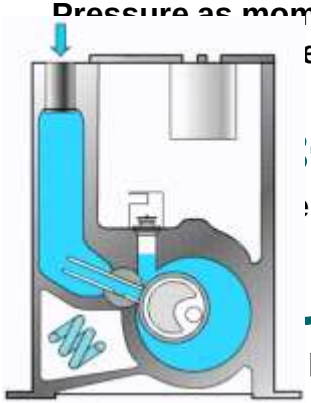

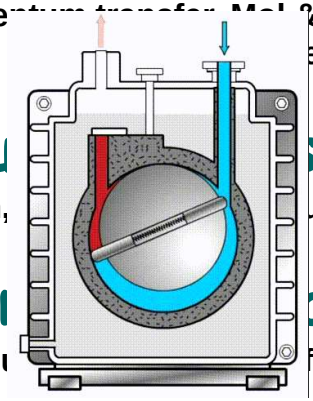

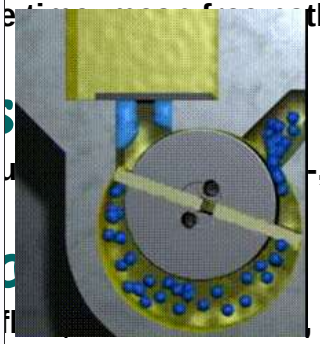

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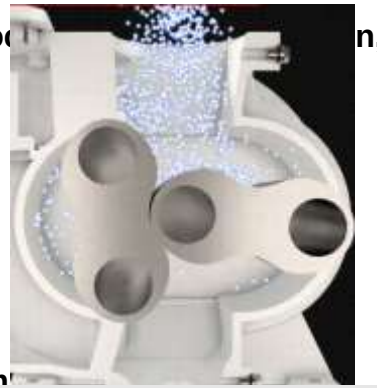

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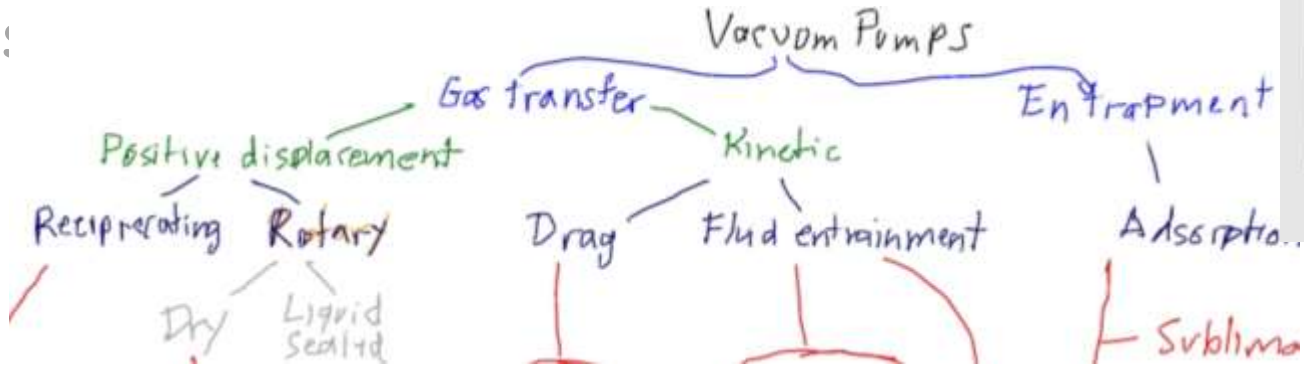

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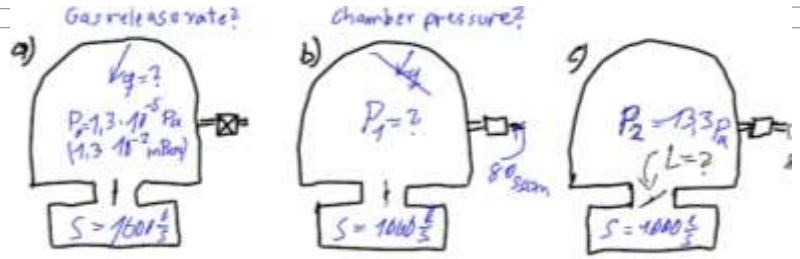

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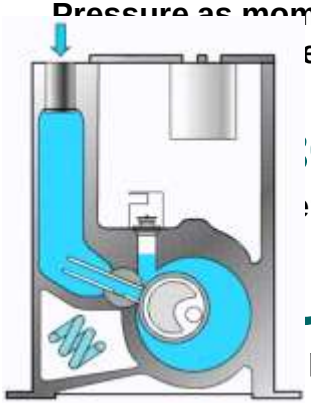
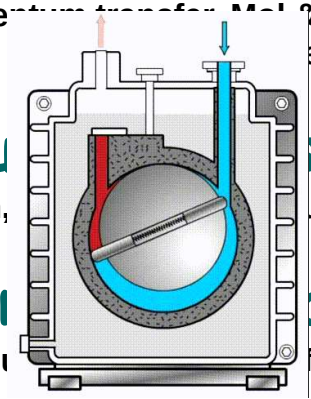
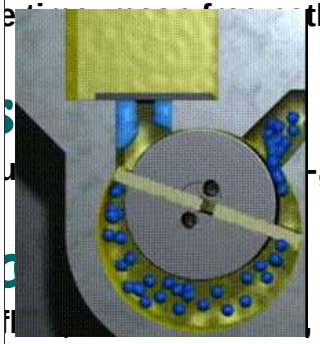
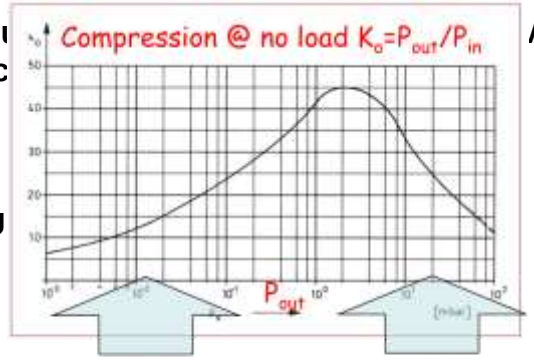


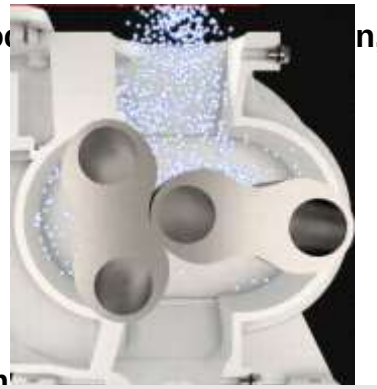






MFP very large but gas back flow by adsorption/desorption at/from the rotating pistons

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



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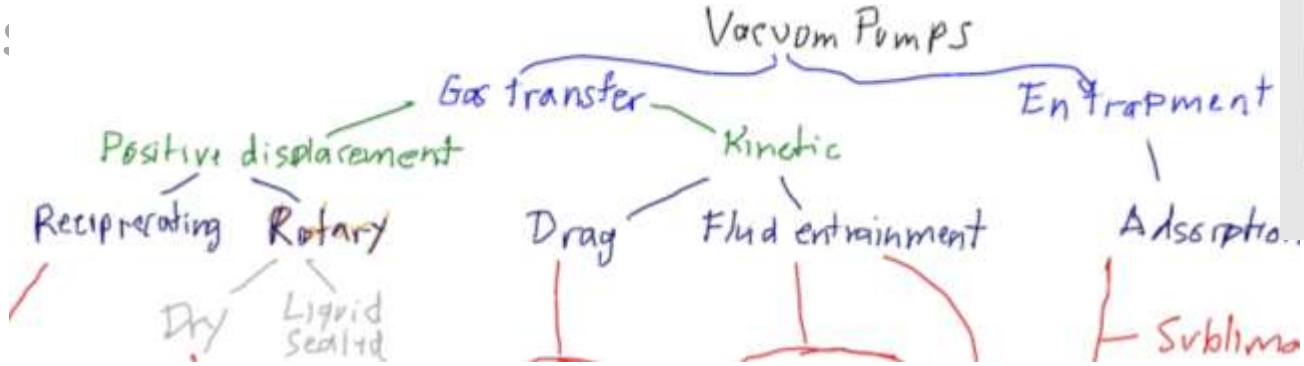

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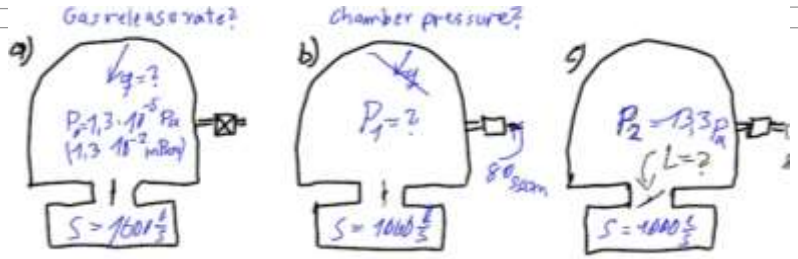

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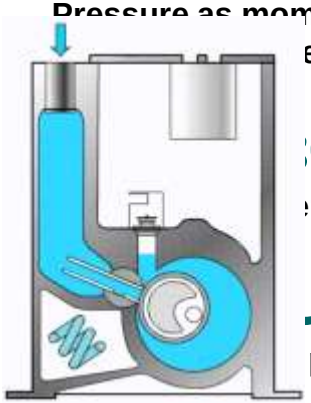

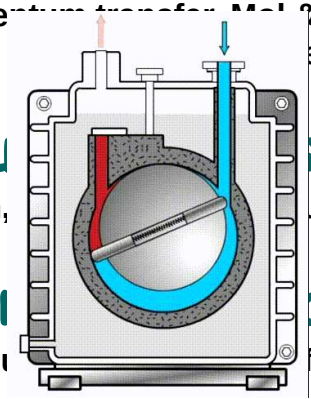

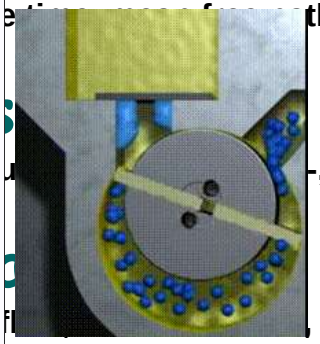

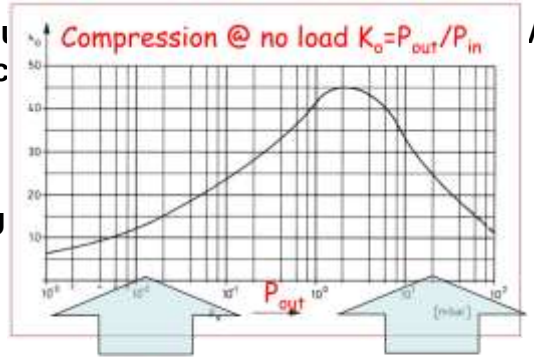

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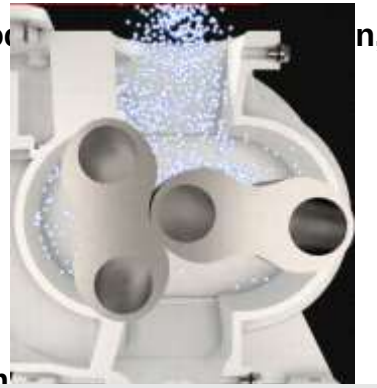

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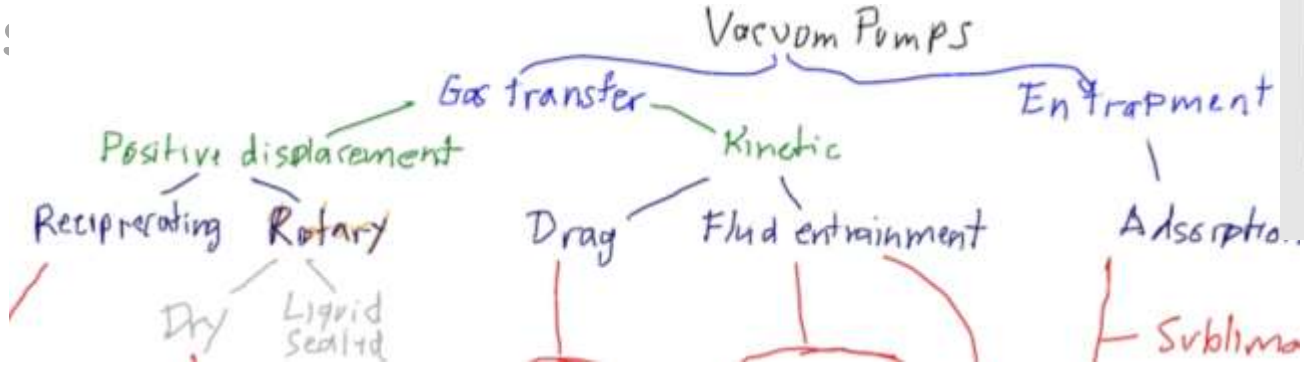
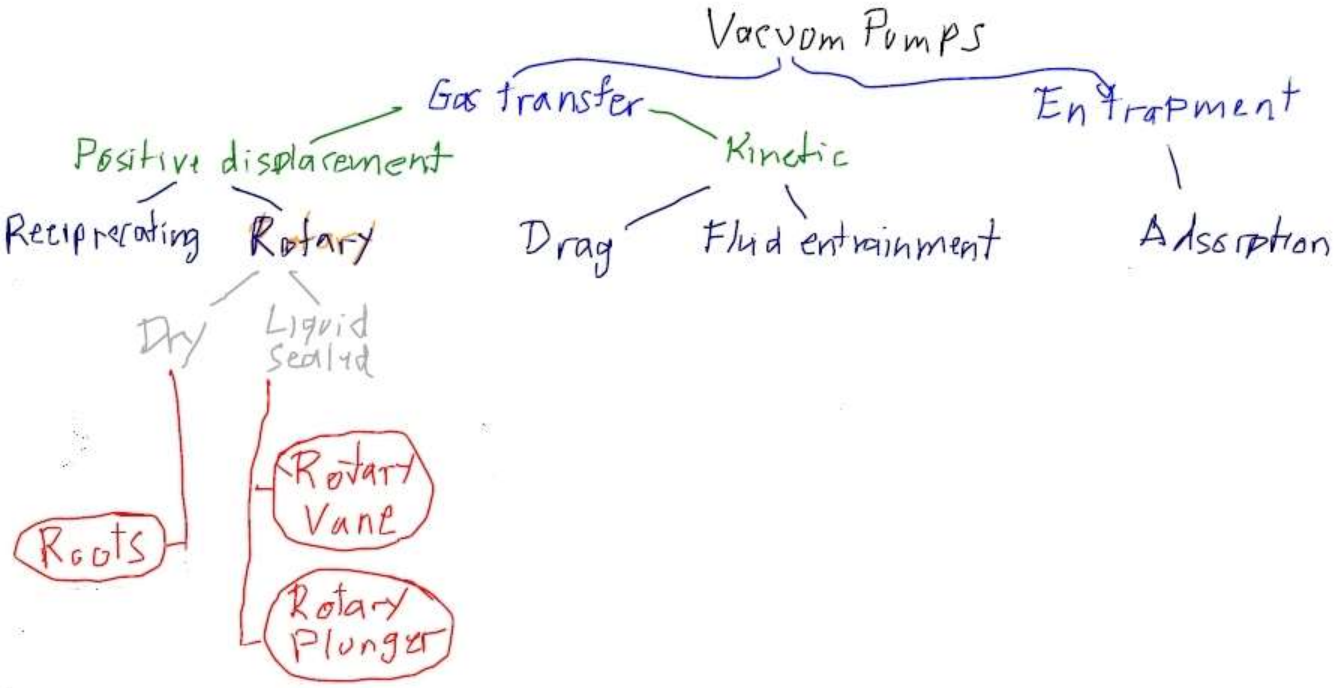
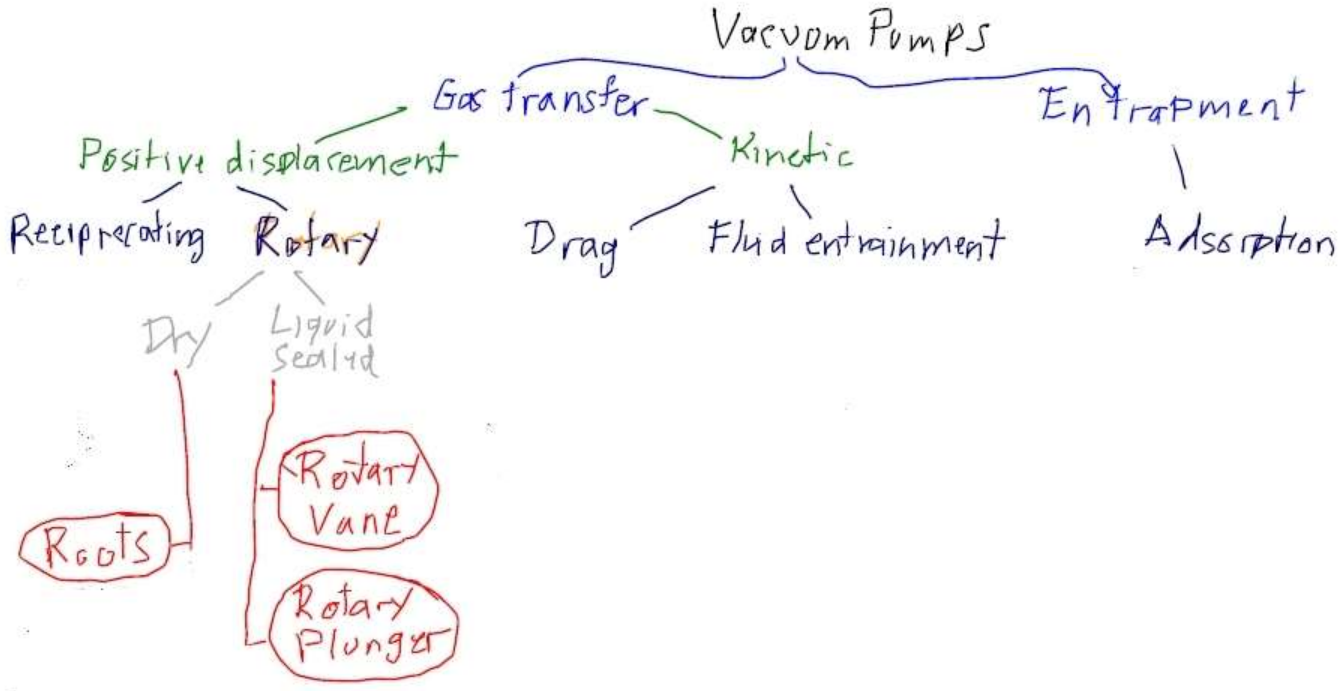
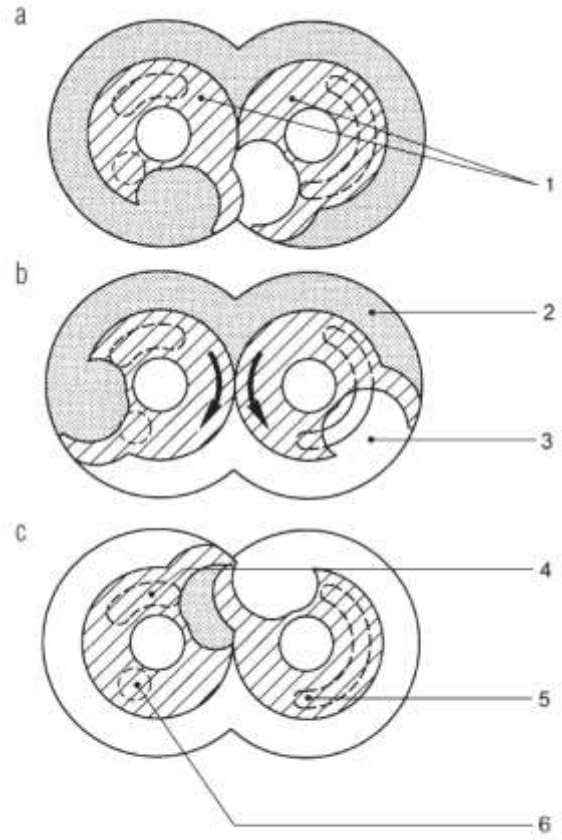






We continue with the dry pumps!

Claw pump

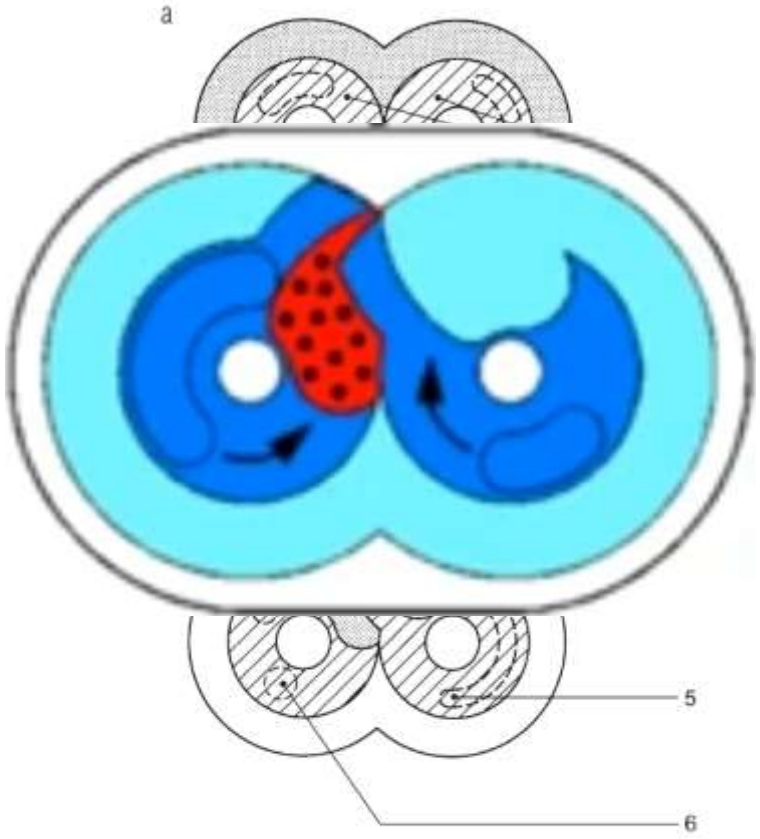


1 Rotoren
2 Verdichtungsraum
3 Ansaugraum
4 Auspuffschlitz
5 Ansaugschlitz
6 Zwischenstufen-Spülgas

Atmosphere down to ~ 10^{-3} mBar

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

Claw pump



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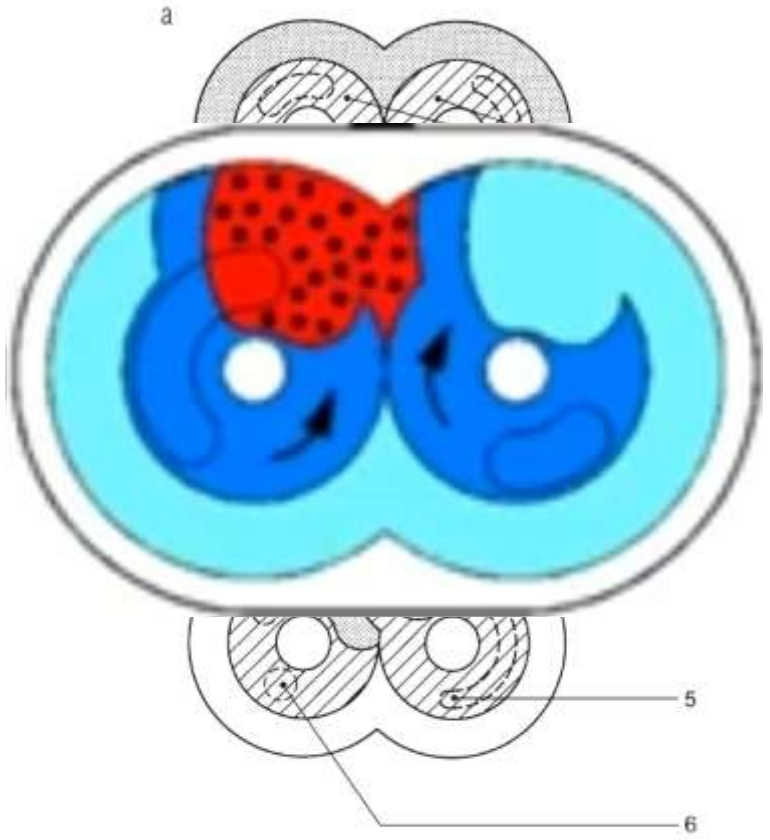

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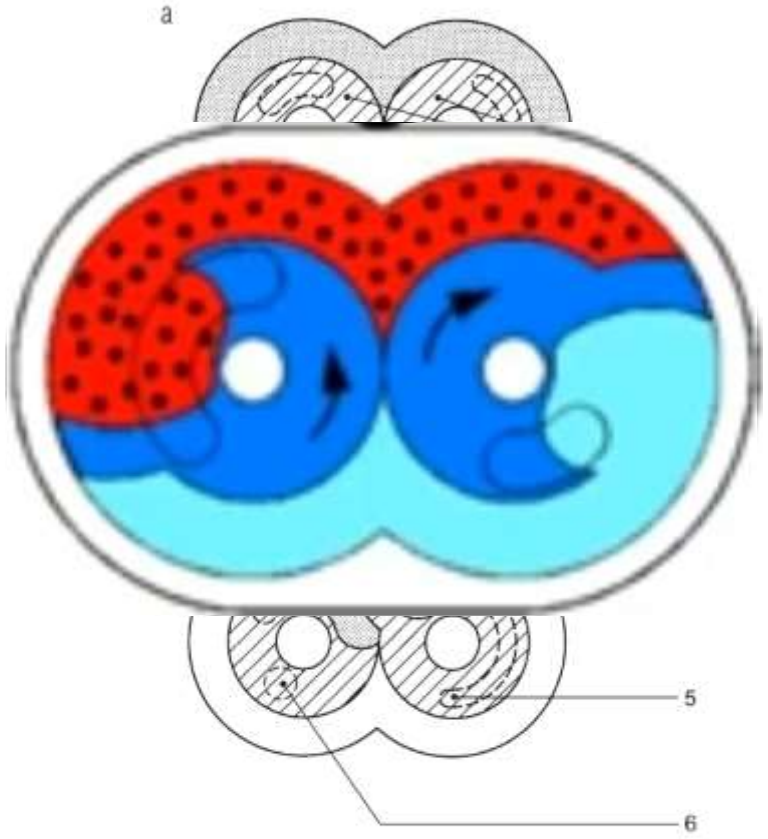

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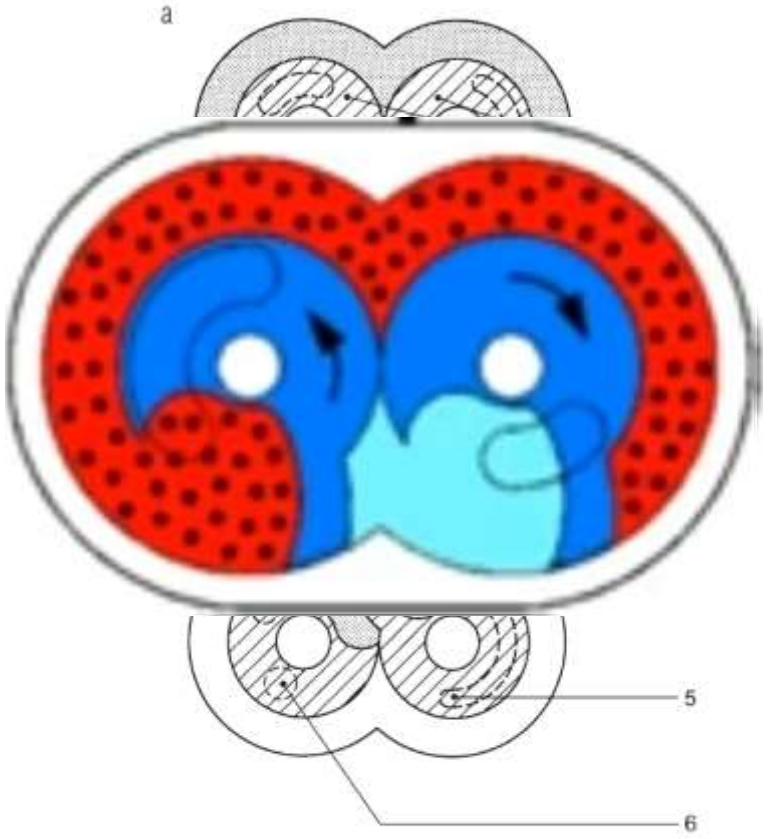
Claw pump

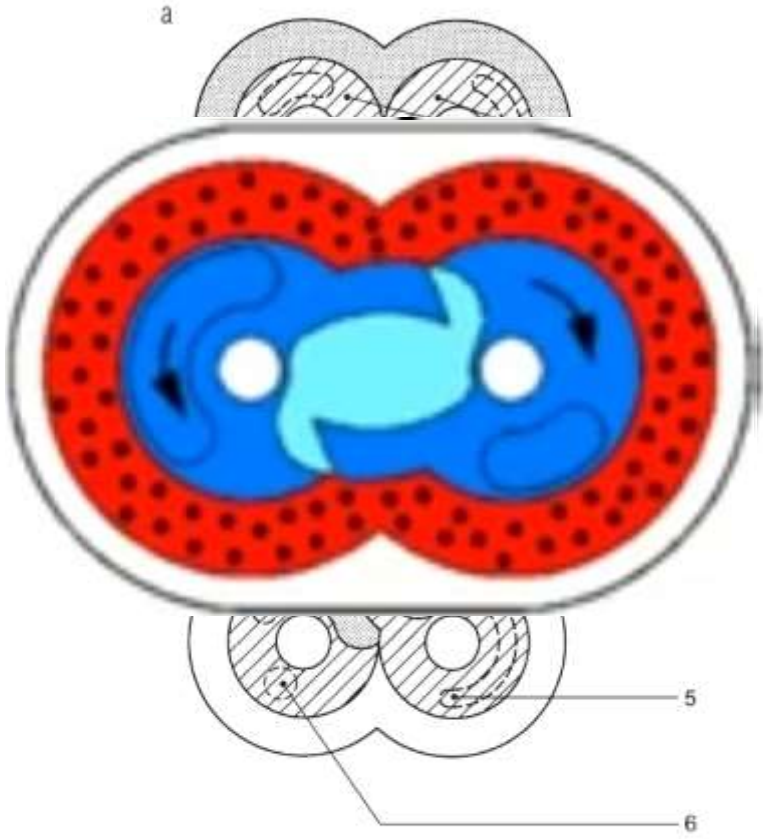


1 Rotoren
2 Verdichtungsraum
3 Ansaugraum
4 Auspuffschlitz
5 Ansaugschlitz
6 Zwischenstufen-Spülgas

Atmosphere down to ~ 10^{-3} mBar

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

Claw pump



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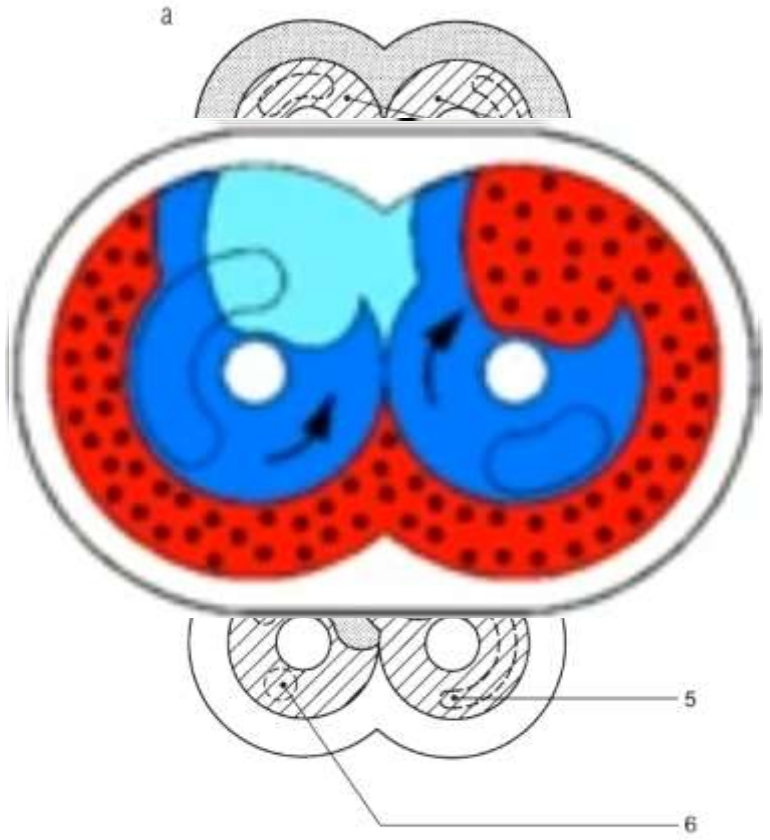

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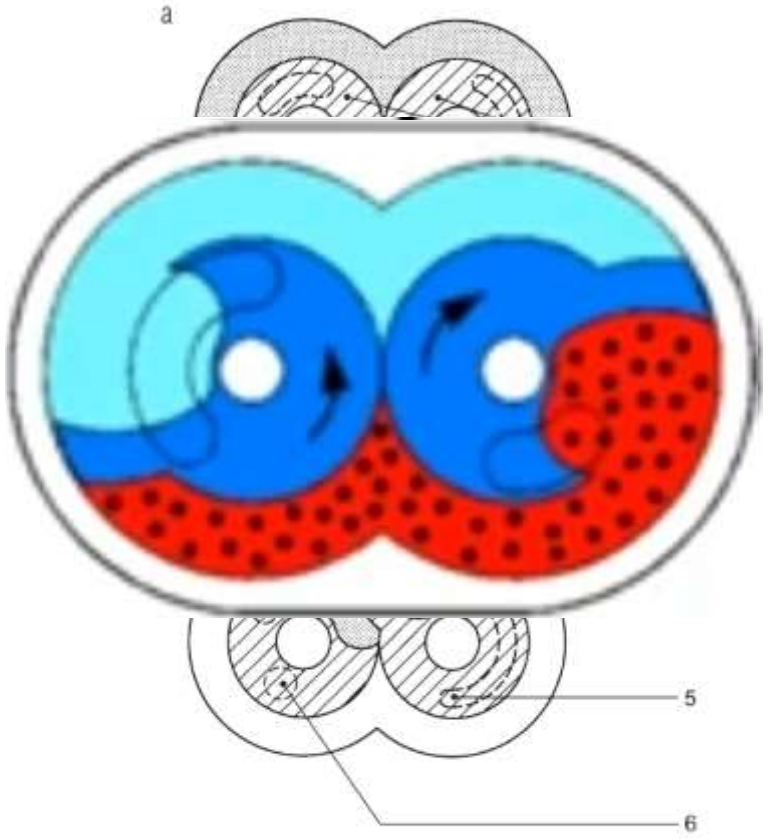

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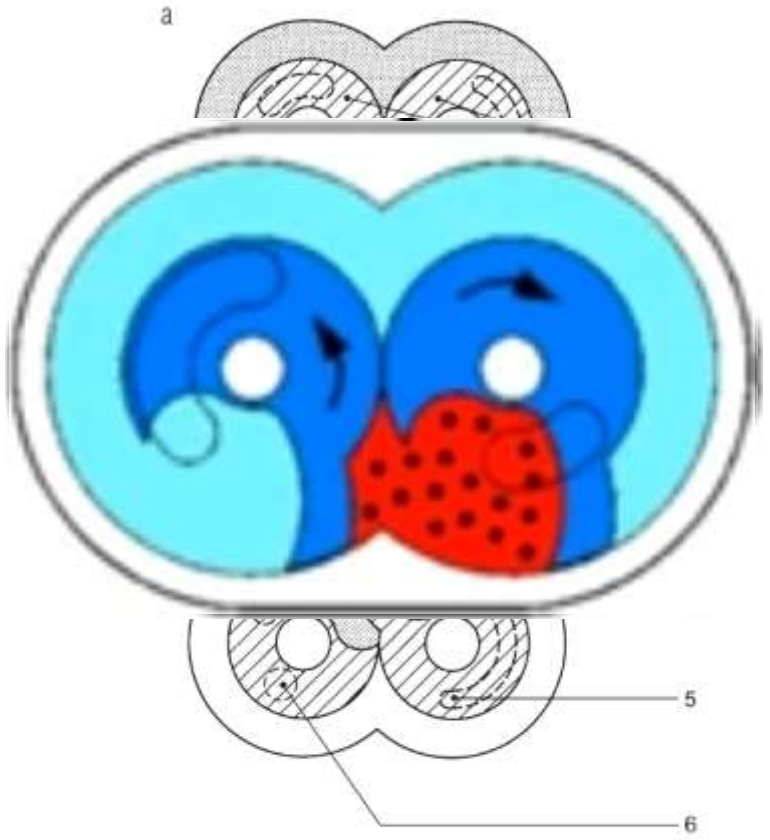

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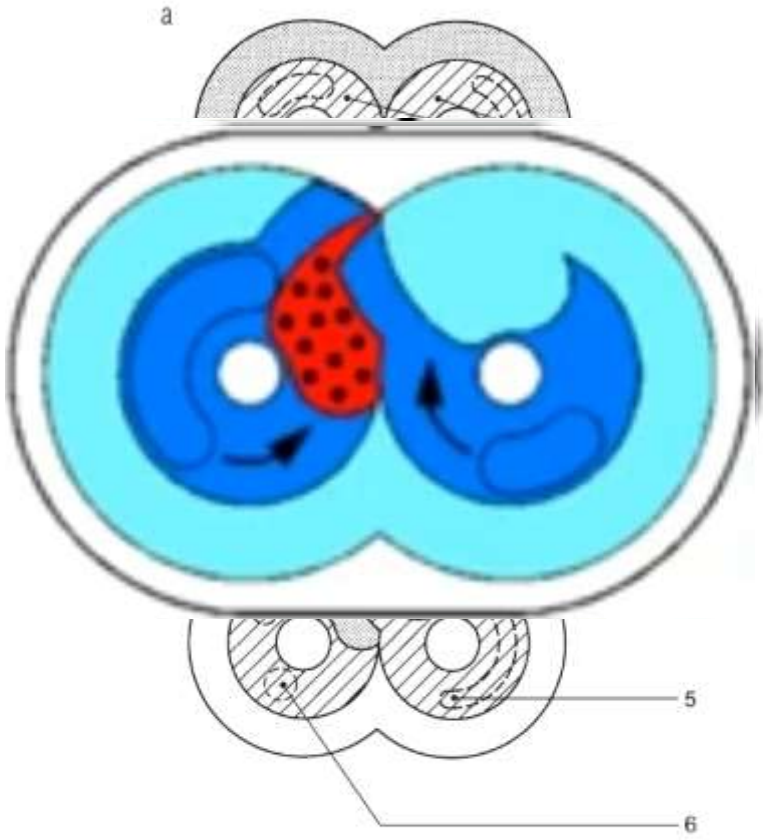

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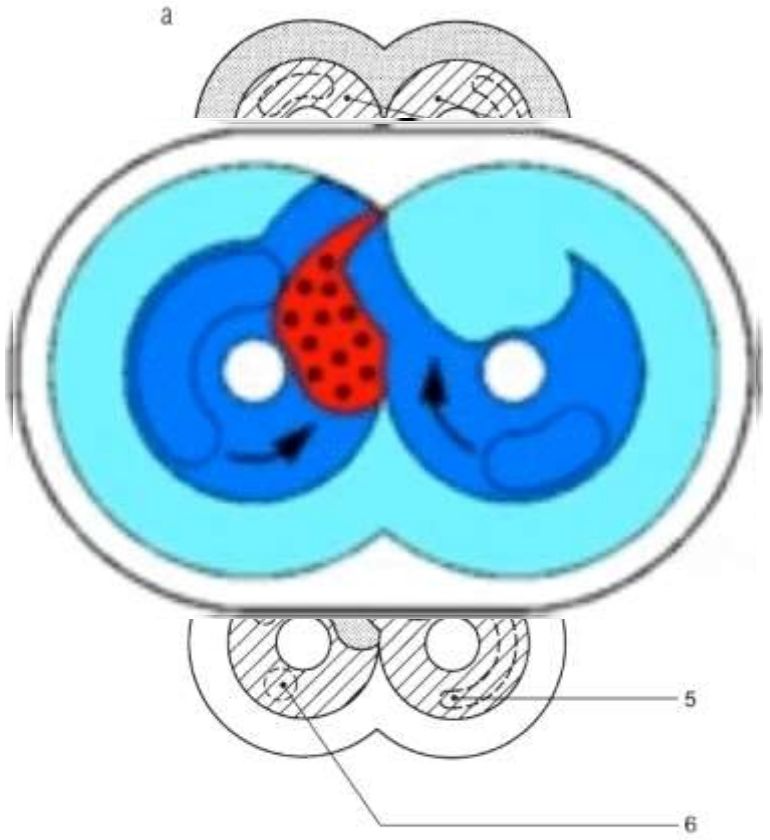

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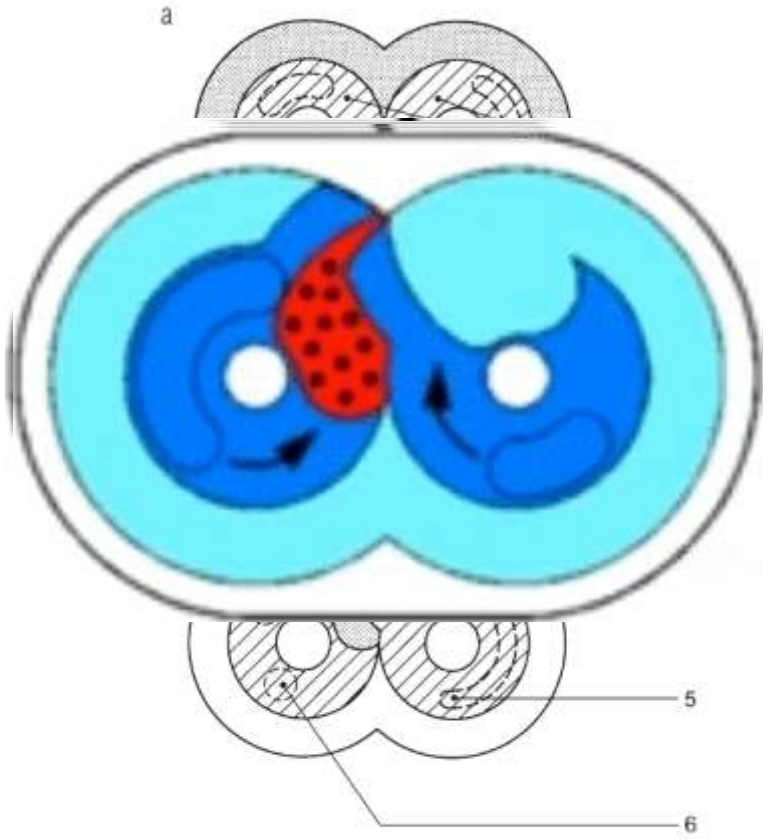

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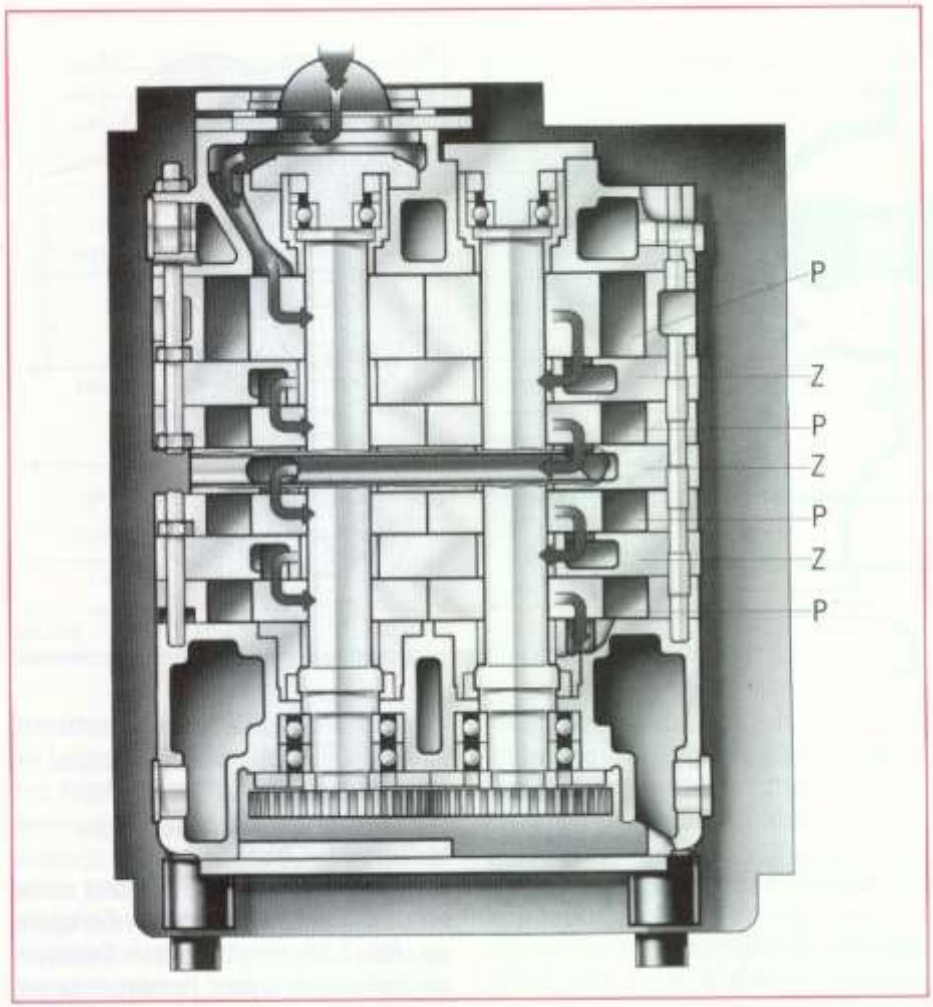
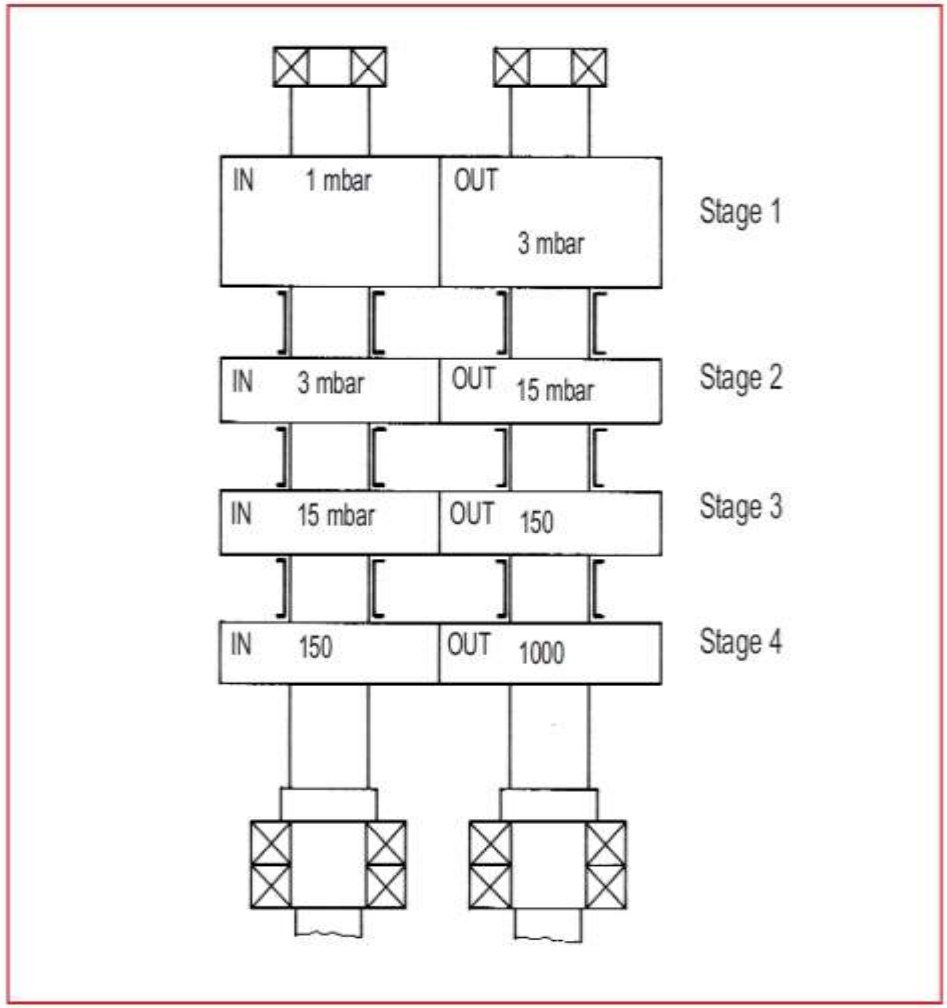
Claw pump (several pump stages)





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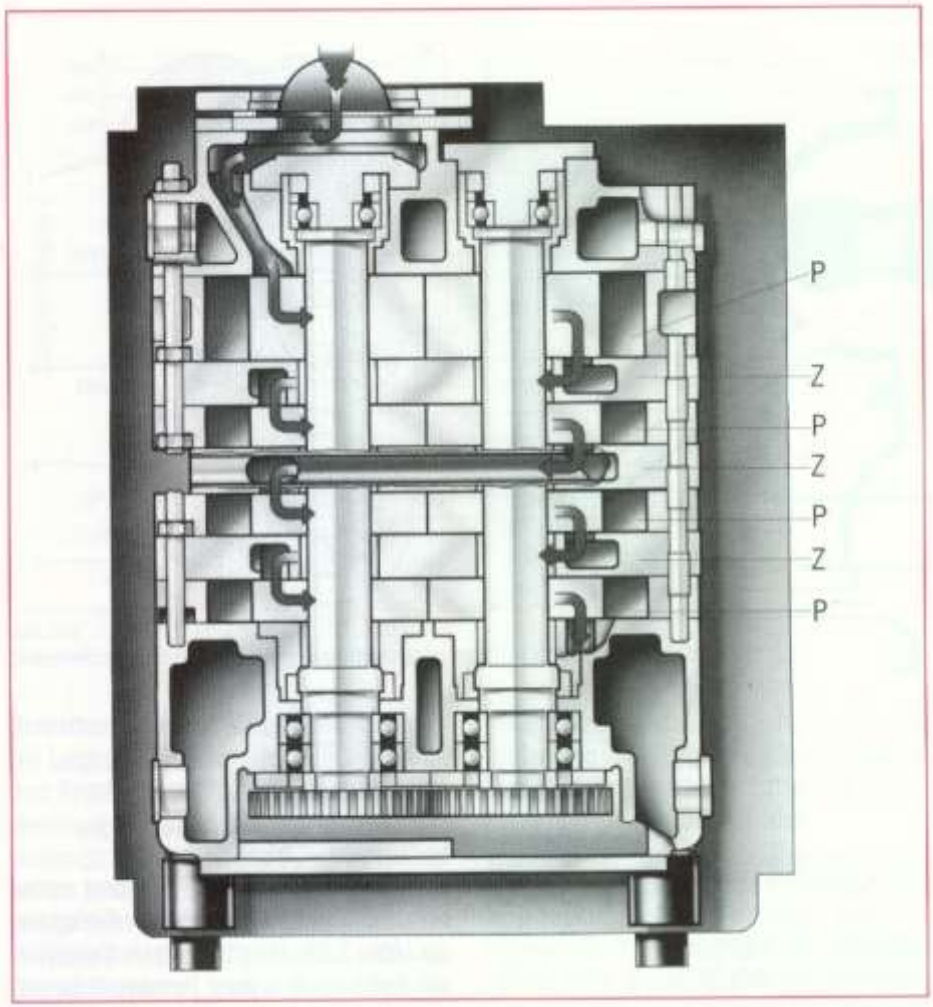

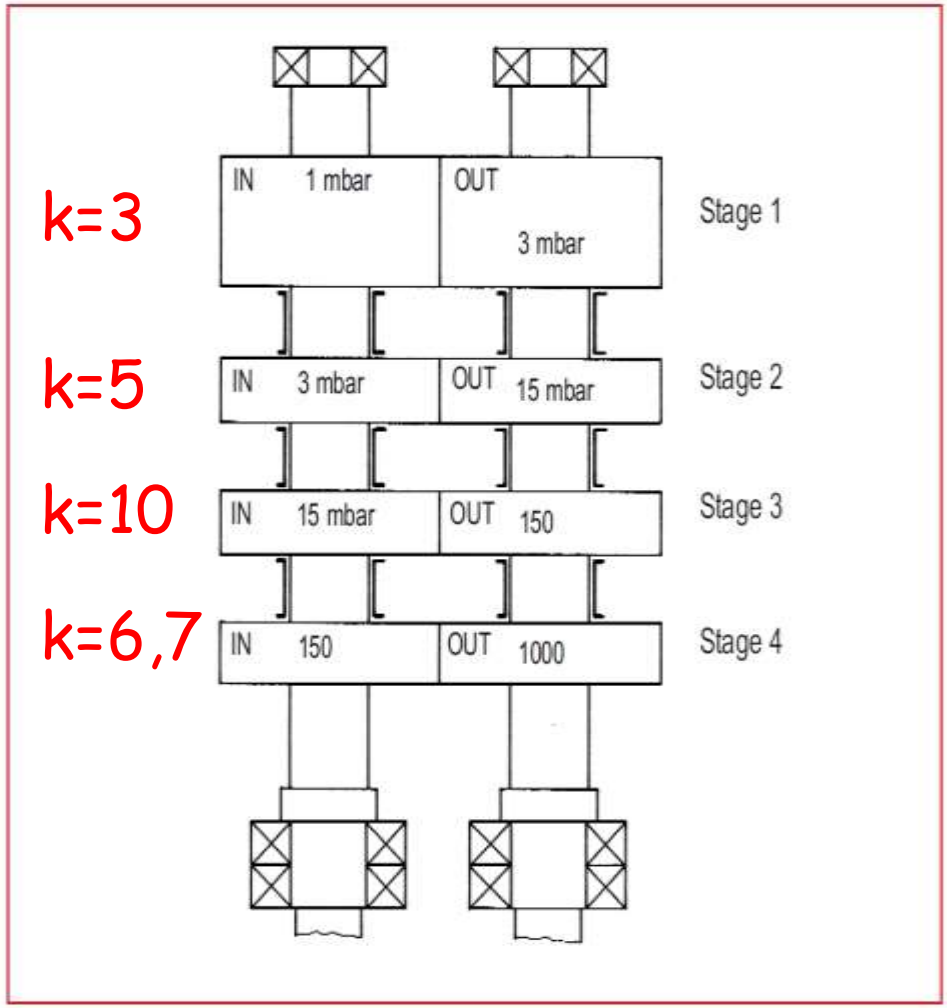

Claw pump (Different shape of claws)

https://www.youtube.com/watch?app=desktop&v=DnK3VzgZv_M

https://www.youtube.com/watch?v=VZvYTRJ6vGM

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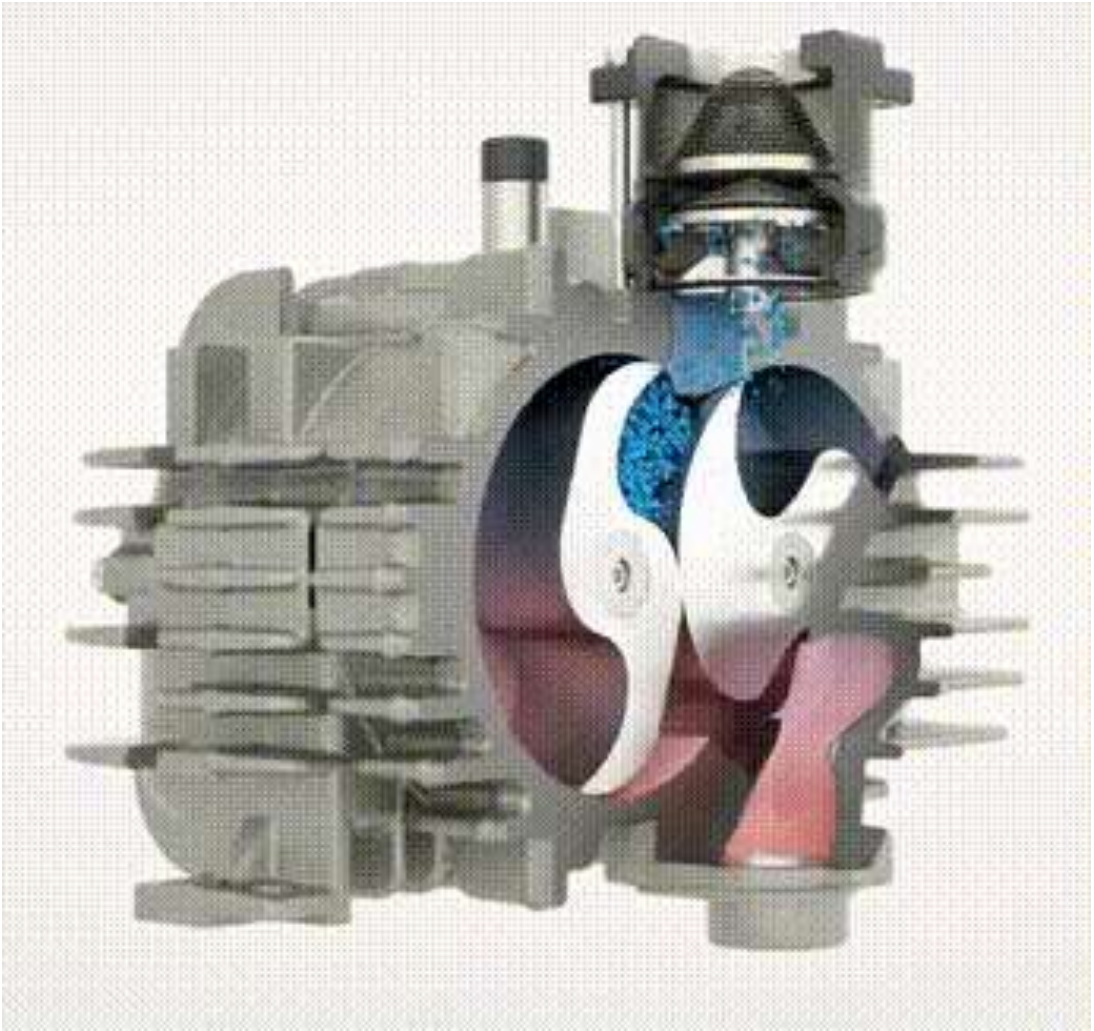

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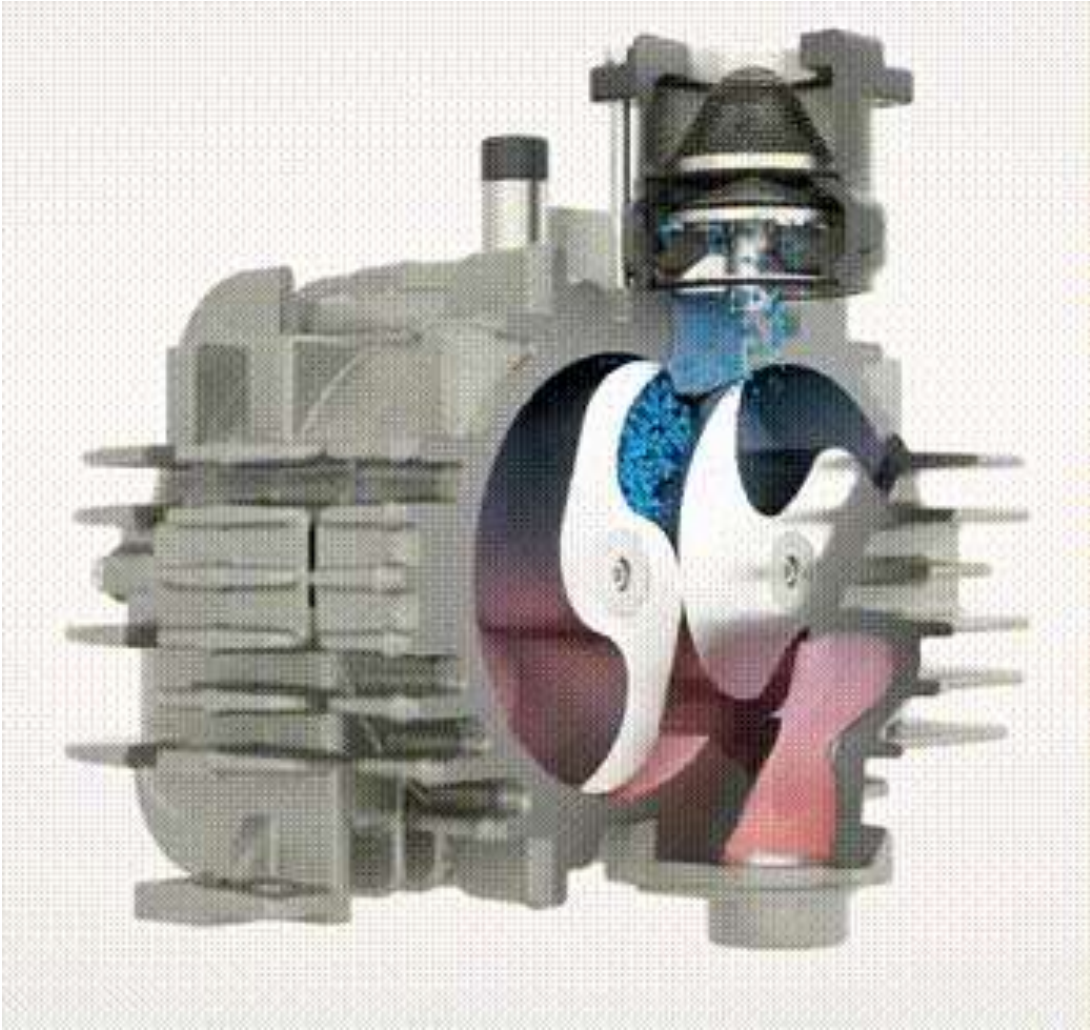

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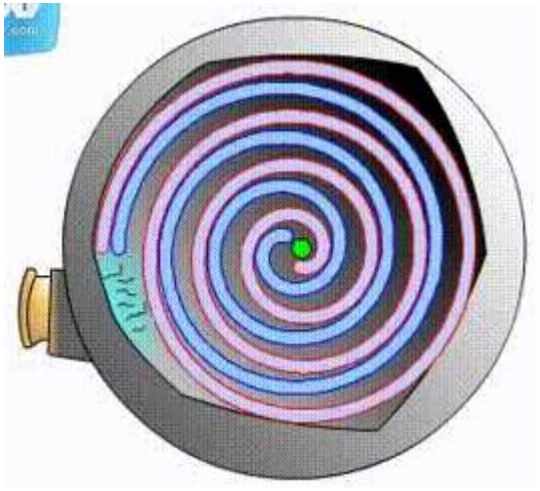
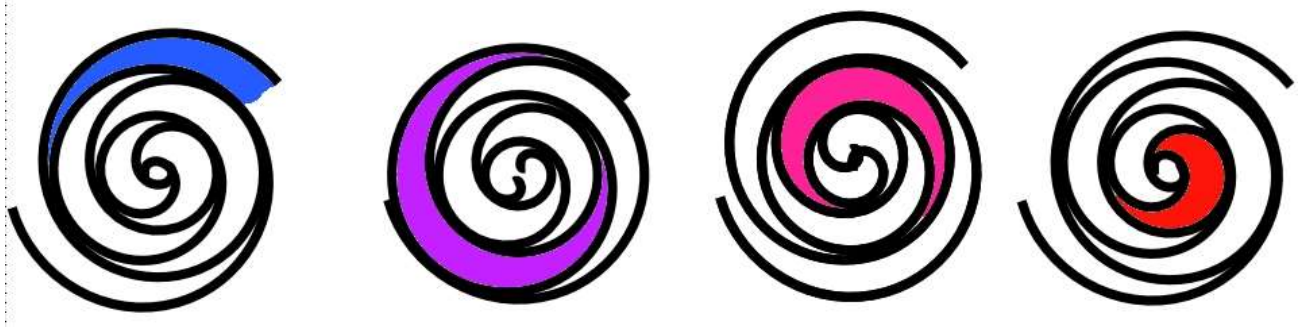
Scroll pump

Atmosphere down to ~ 10^{-2} - 10^{-3} mBar

"VT L11 c 12:36

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





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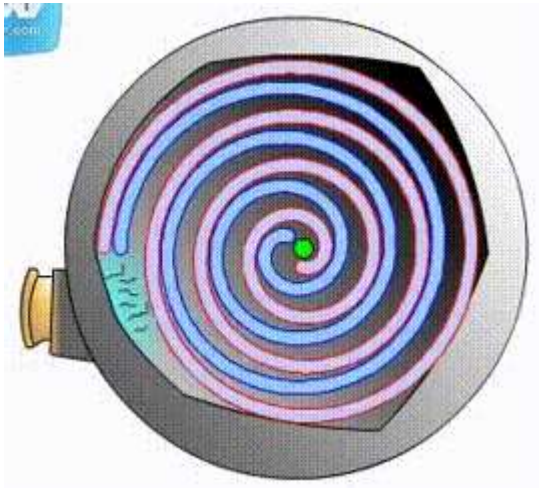

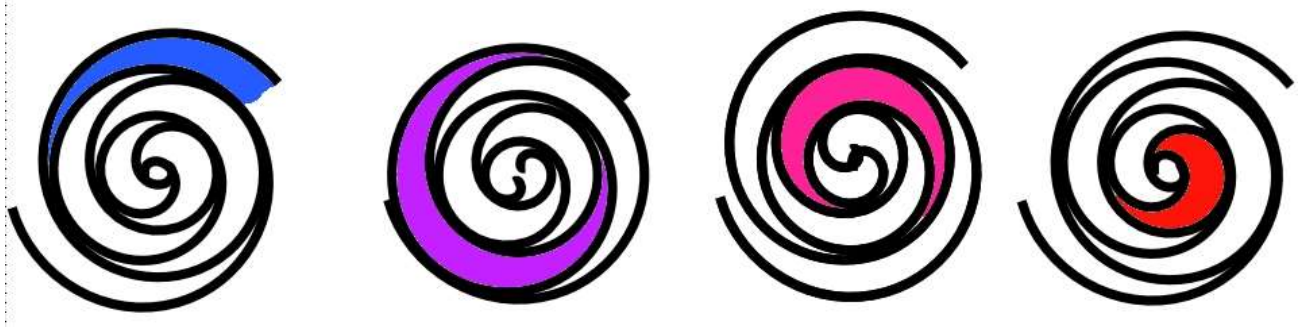

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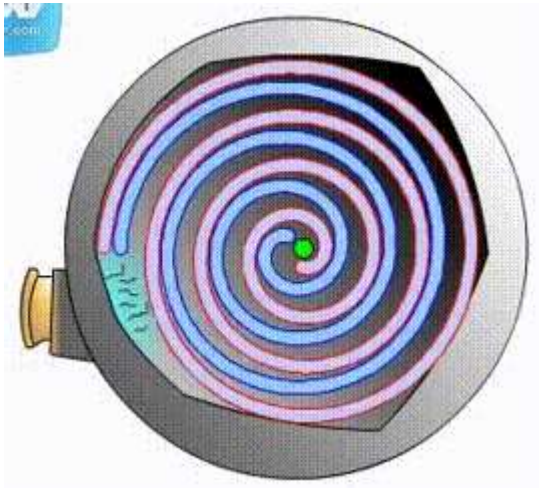
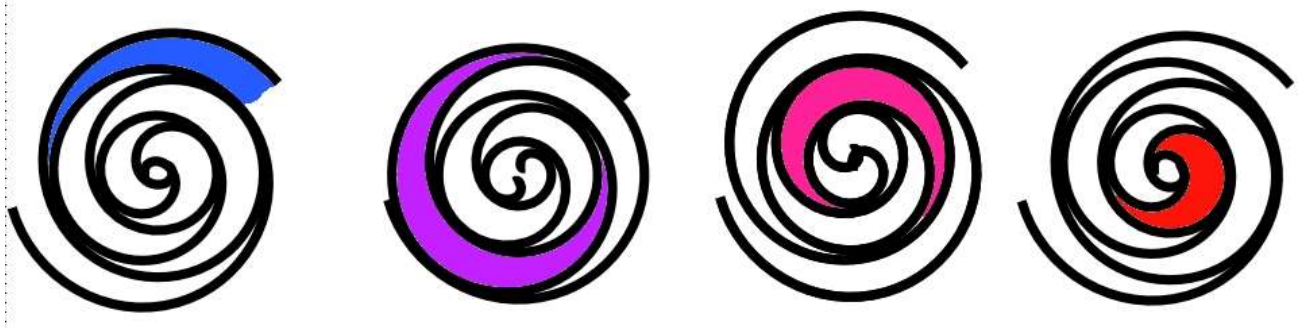




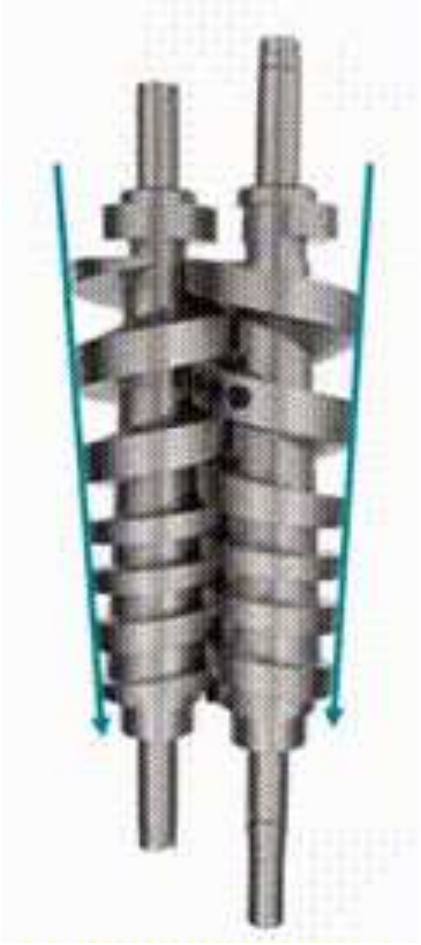
https://www.youtube.com/watch?v=gd8PZYrvqAk

Screw pump

Atmosphere down to ~ 10^{-2} - 10^{-3} mBar

Screw pump

Atmosphere down to ~ 10^{-2} - 10^{-3} mBar



Screw pump

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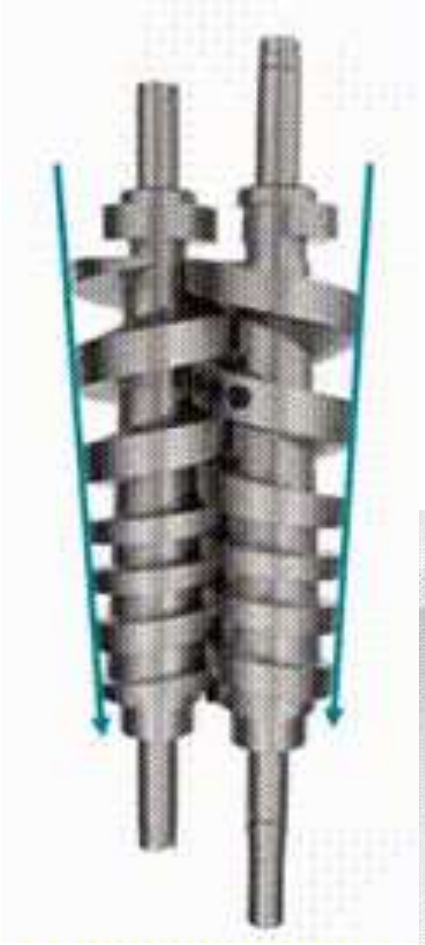

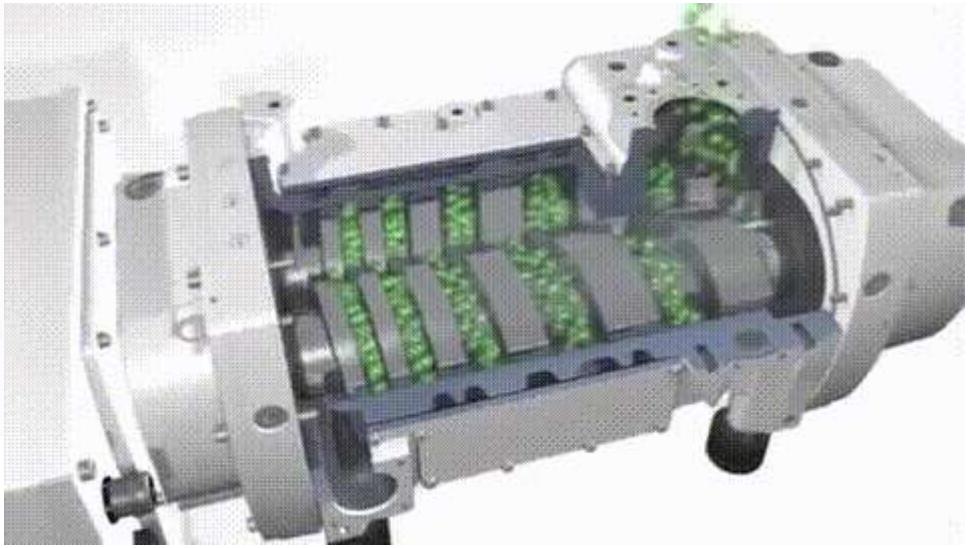

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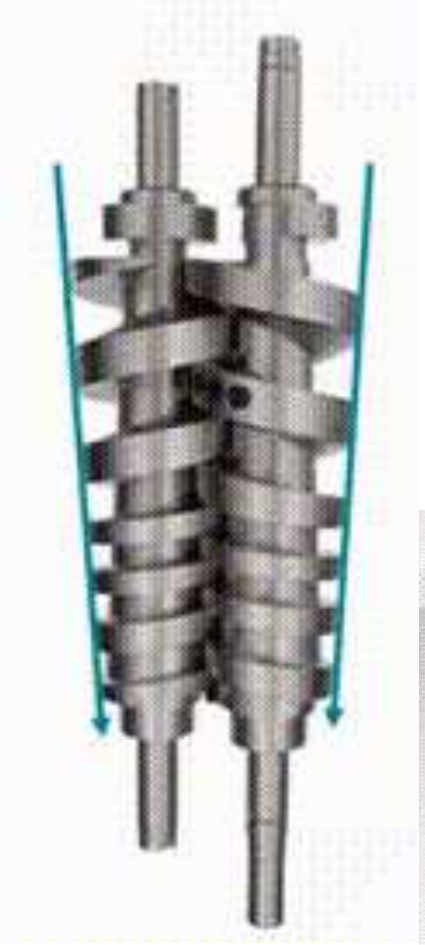

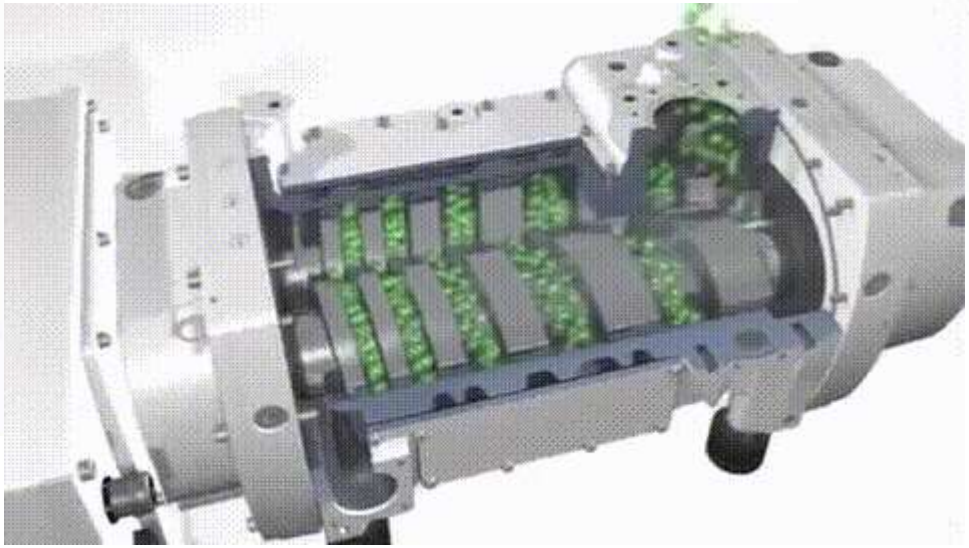

Screw pump

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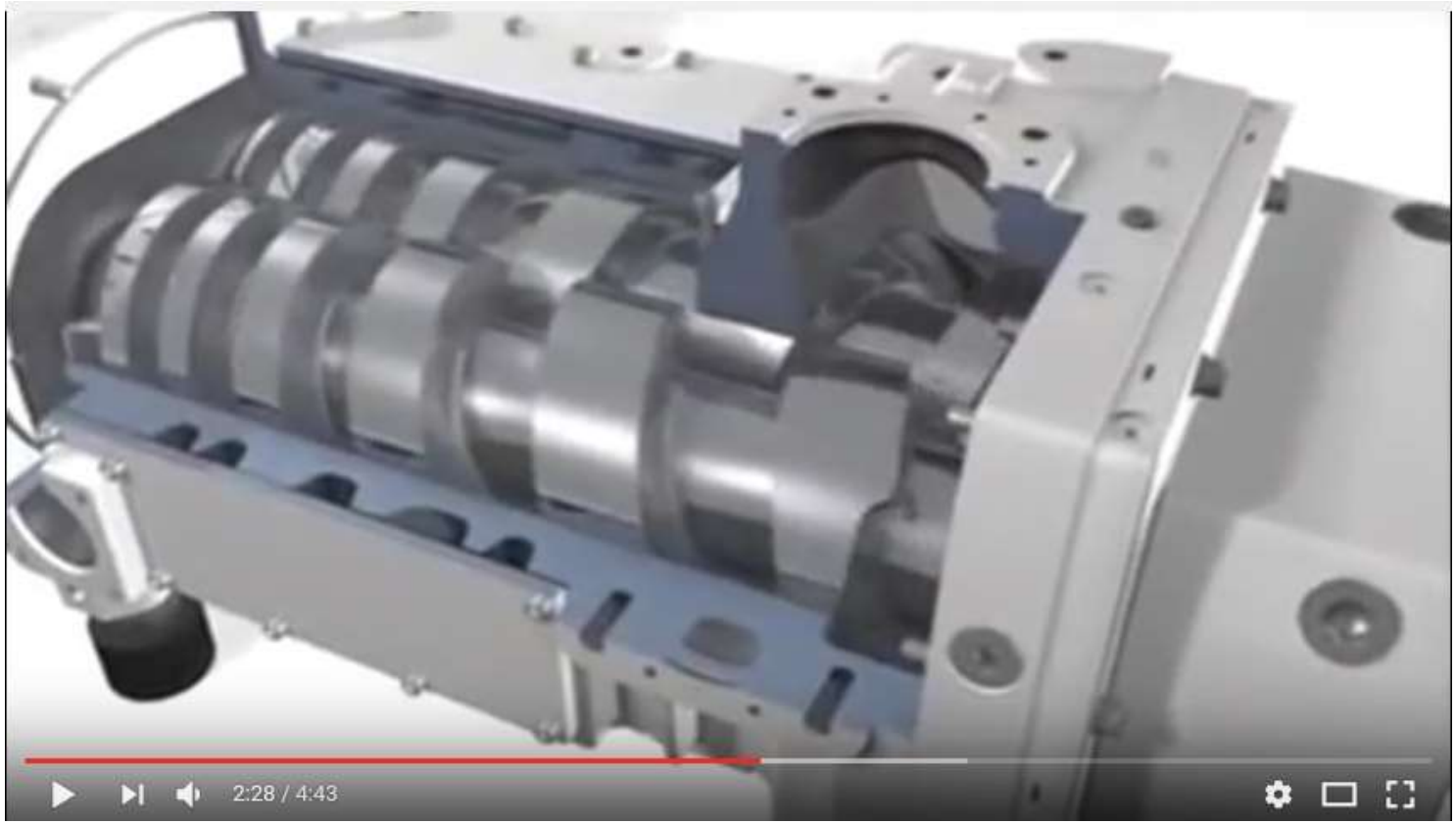
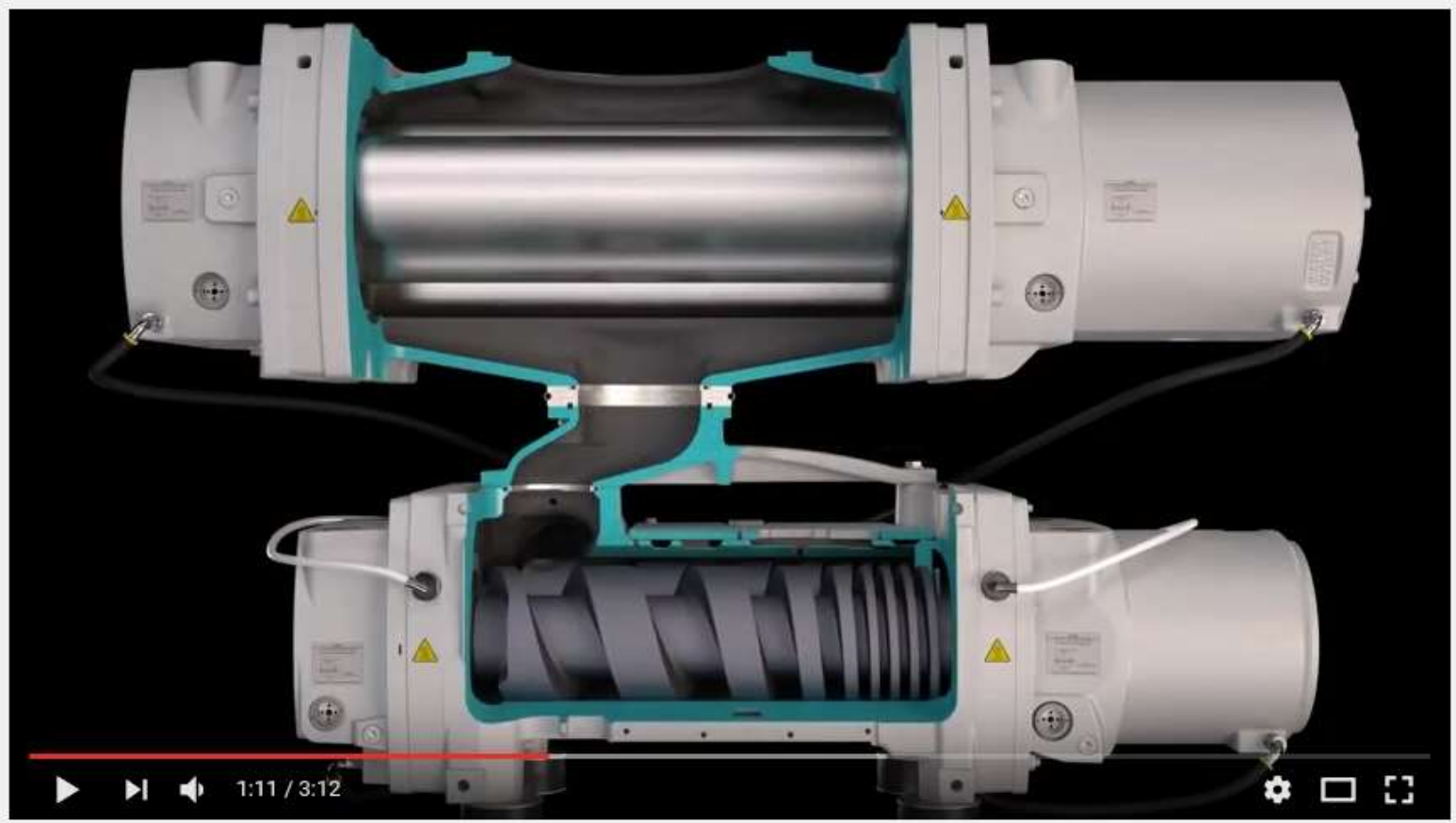


Atmosphere down to ~ 10^{-2} - 10^{-3} mBar

Combination Roots + Screw



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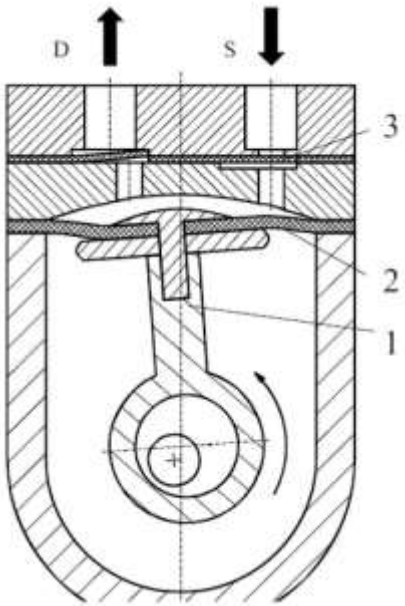
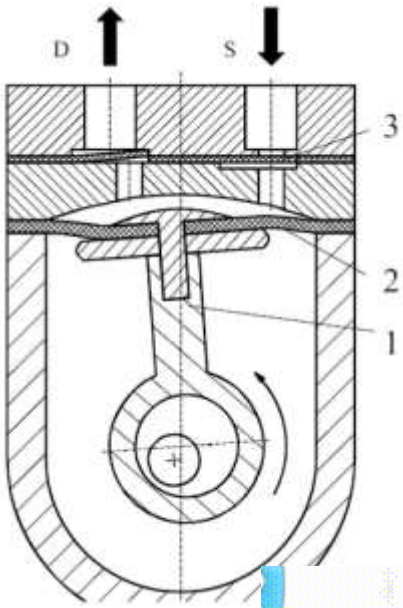
Diaphragm pump



Atmosphere down to ~ a few (2-8) mBar

Diaphragm pump



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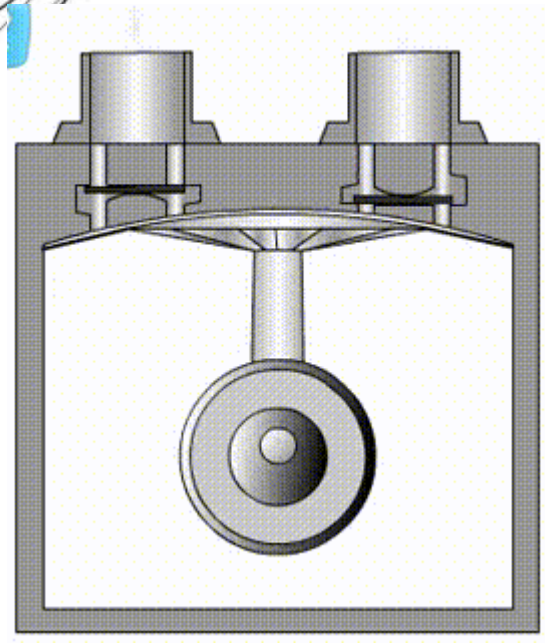

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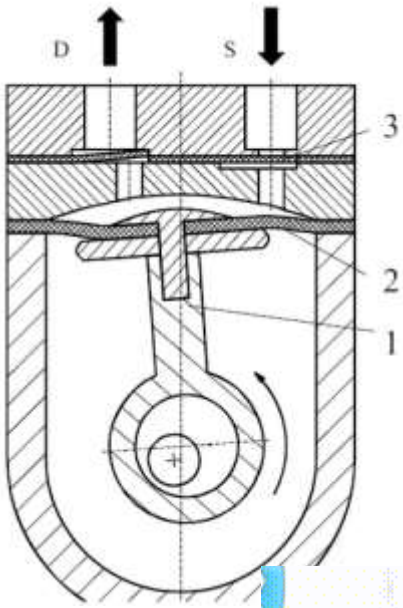

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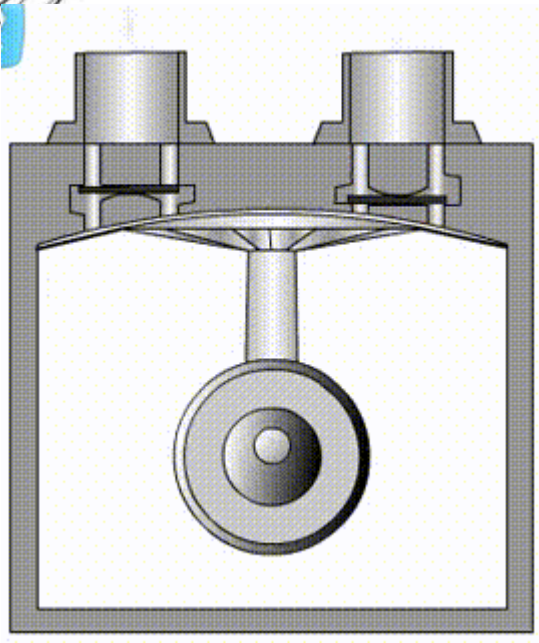

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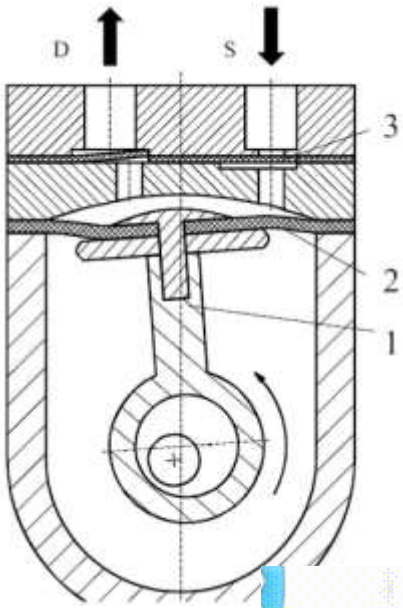

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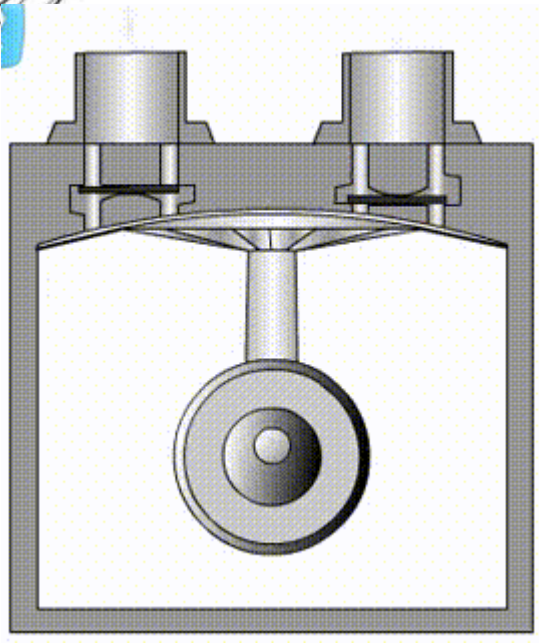
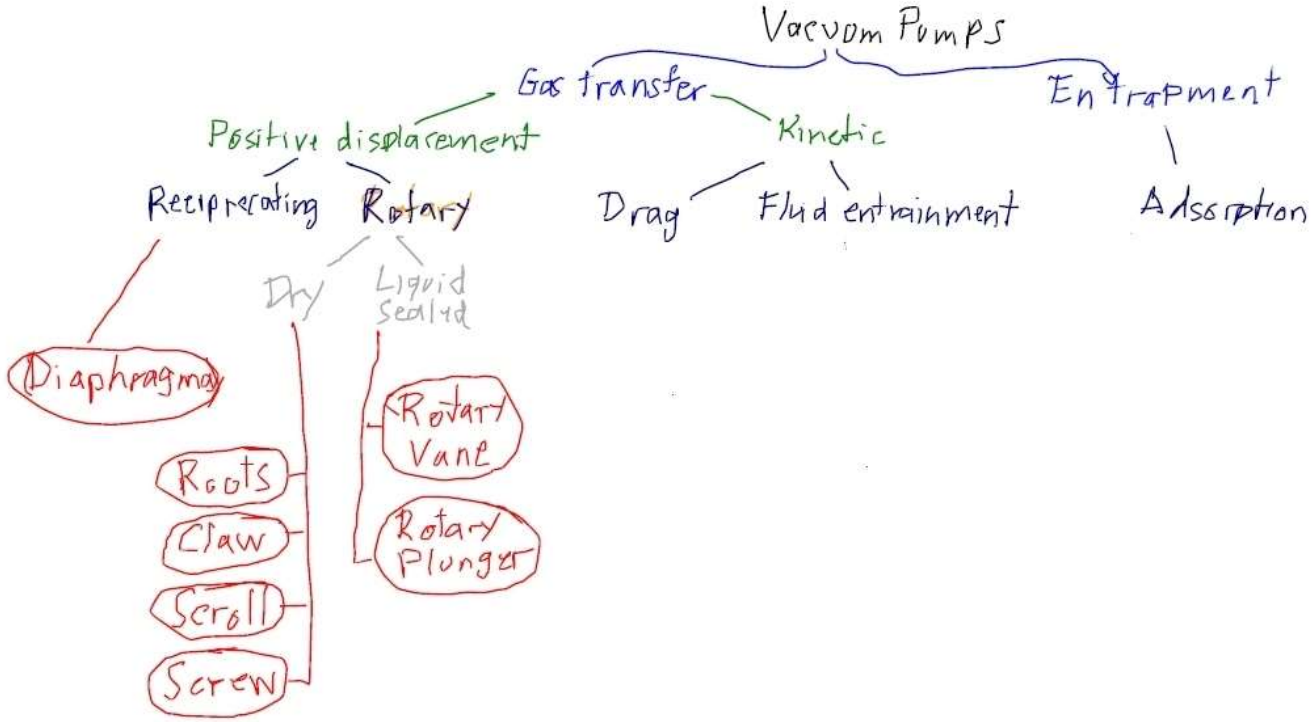
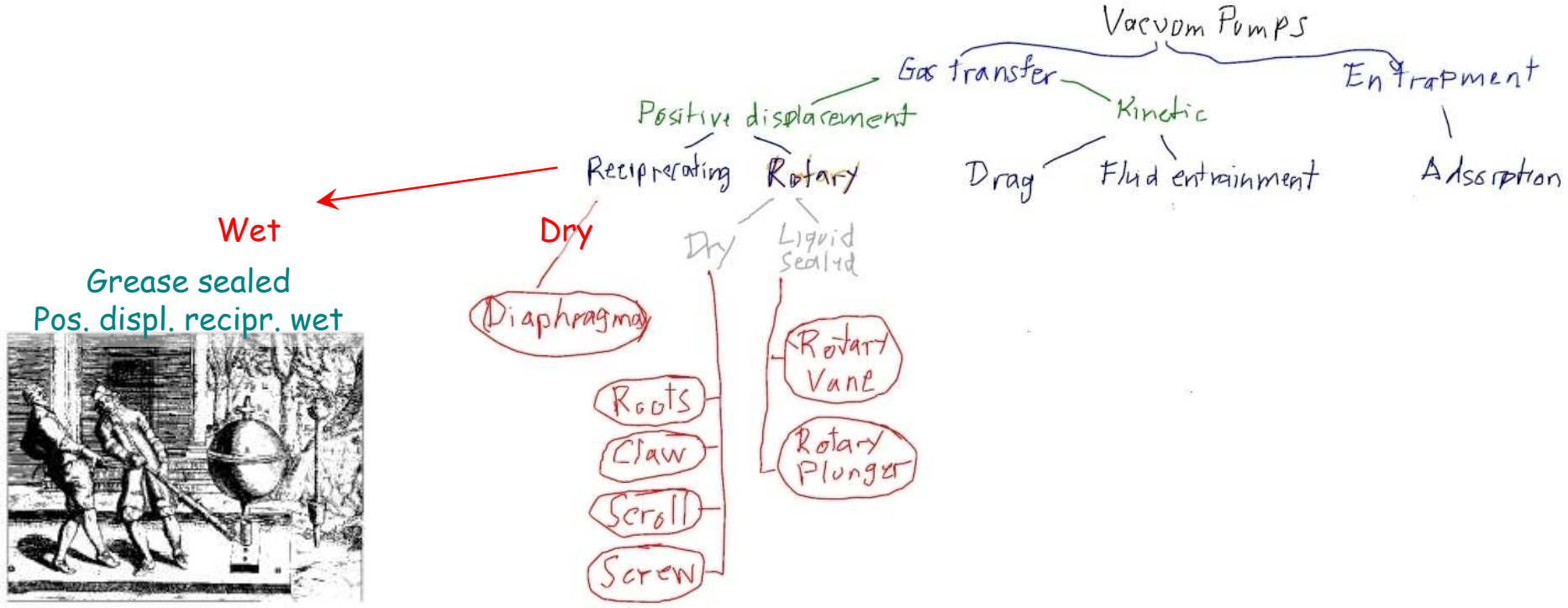
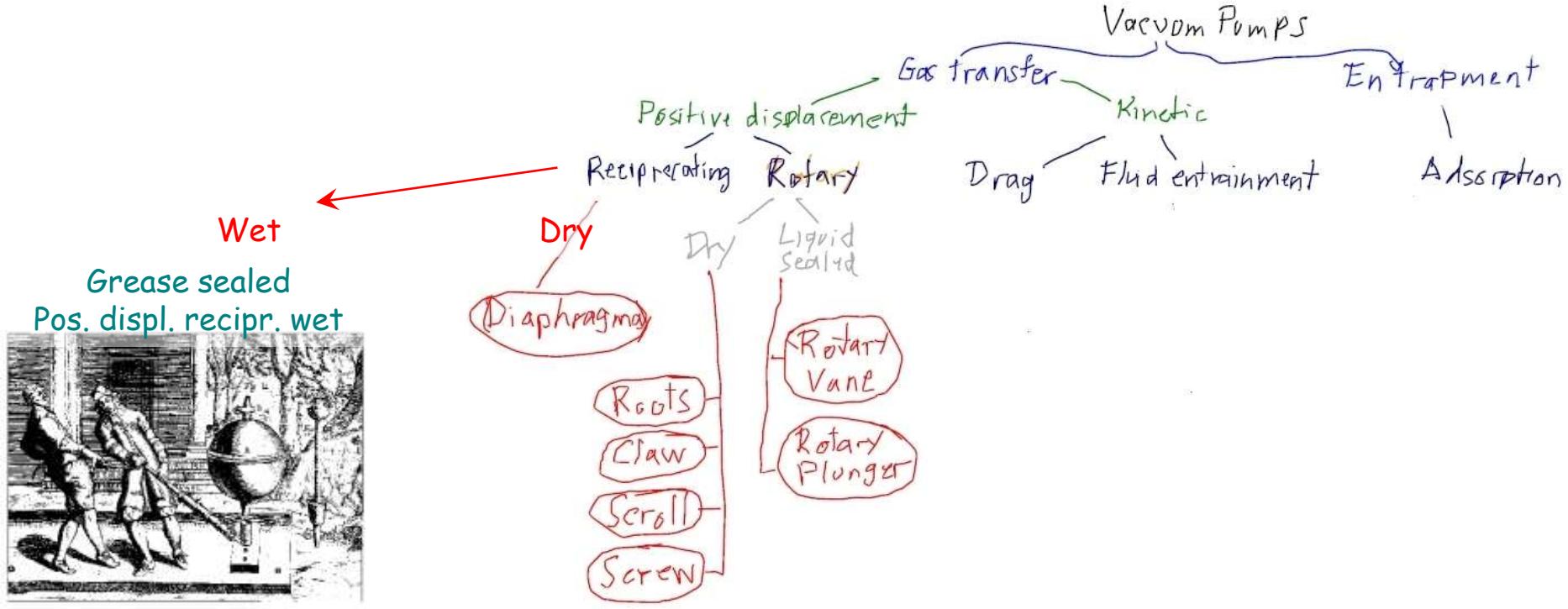






Grease sealed
Pos. displ. recipr. wet



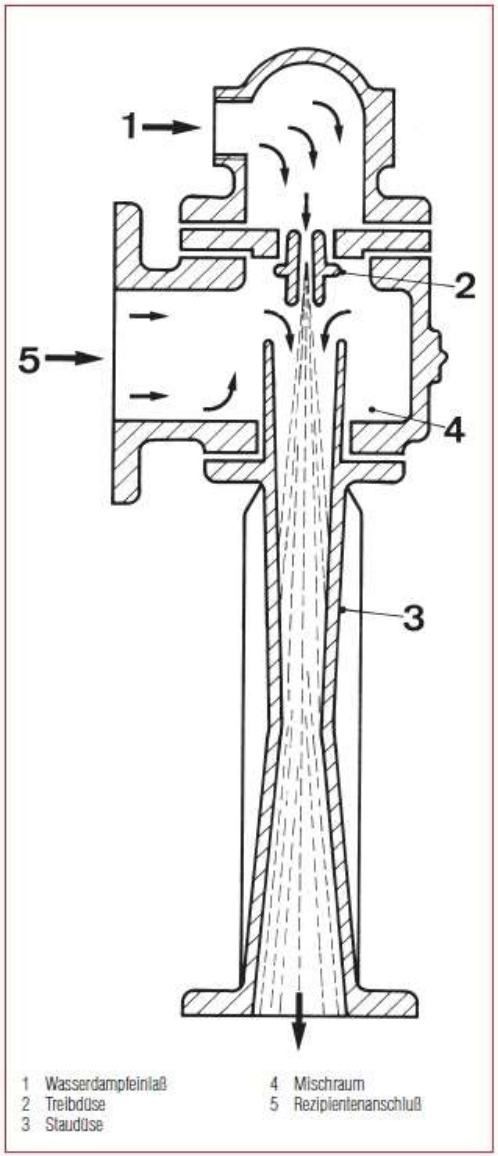
Grease sealed
Pos. displ. recipr. wet

We turn over to: Gas transfer - kinetic

Zauberhafte Physik: Bernoulli Effekt

https://www.youtube.com/watch?v=K0aPuLn76H0

Ejector pump



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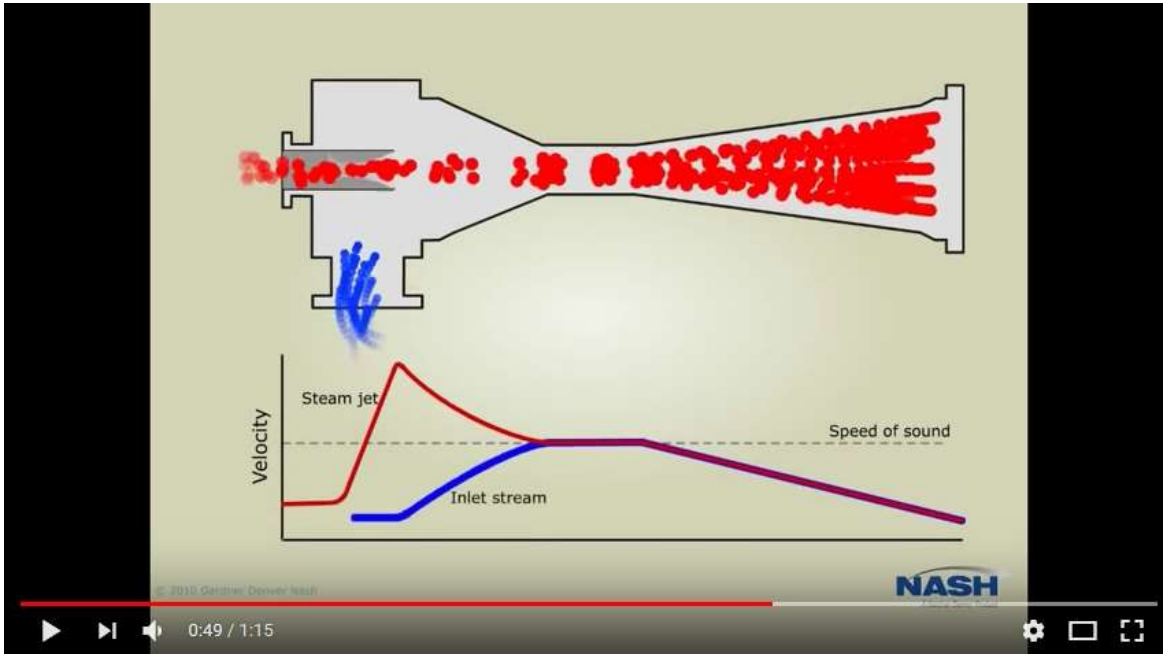

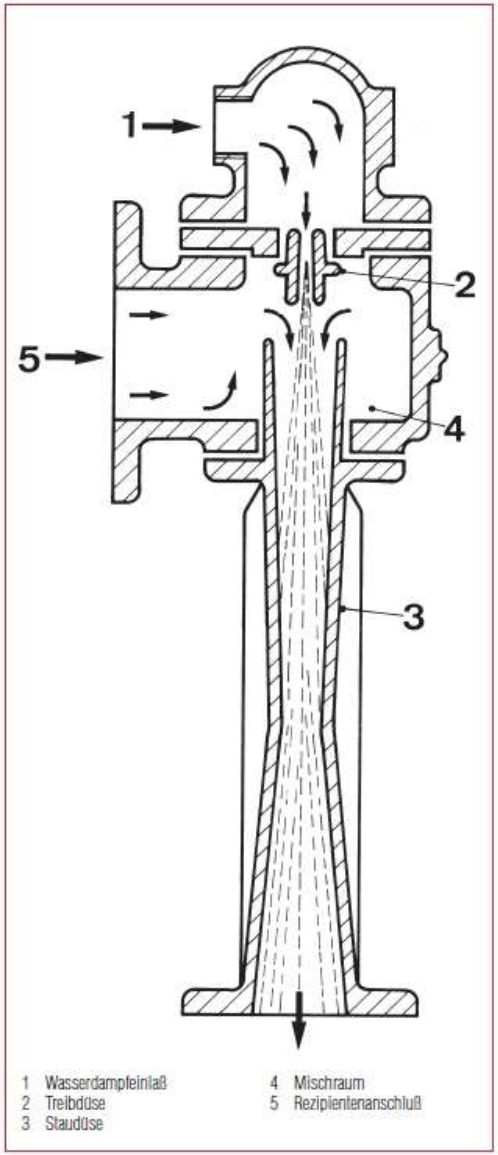

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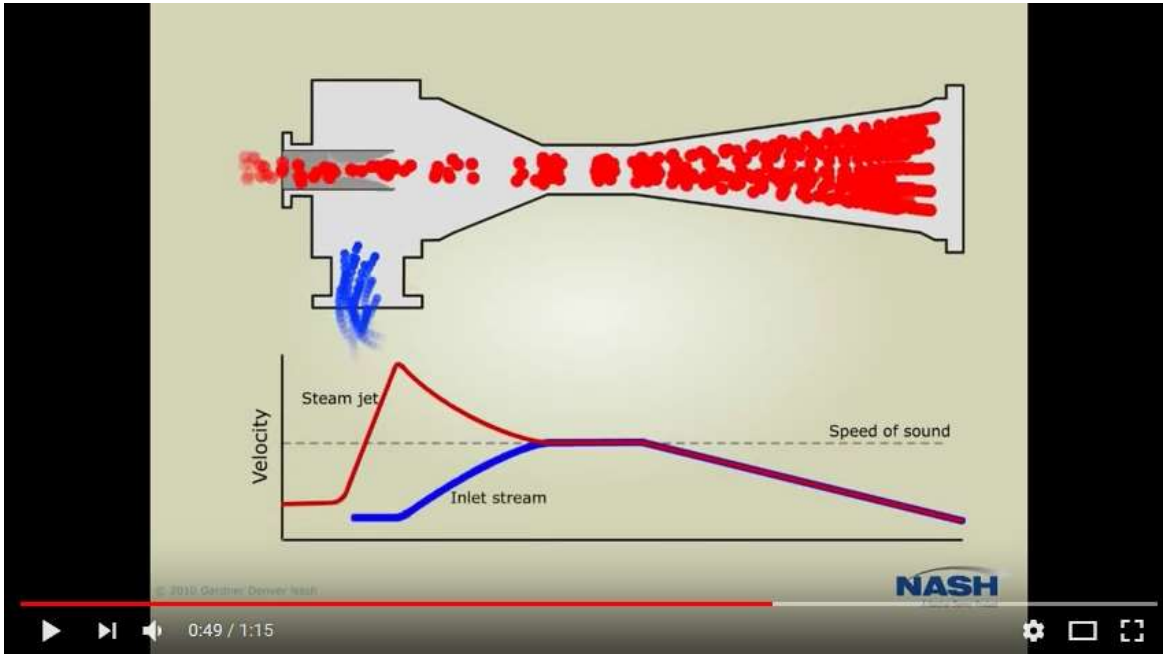

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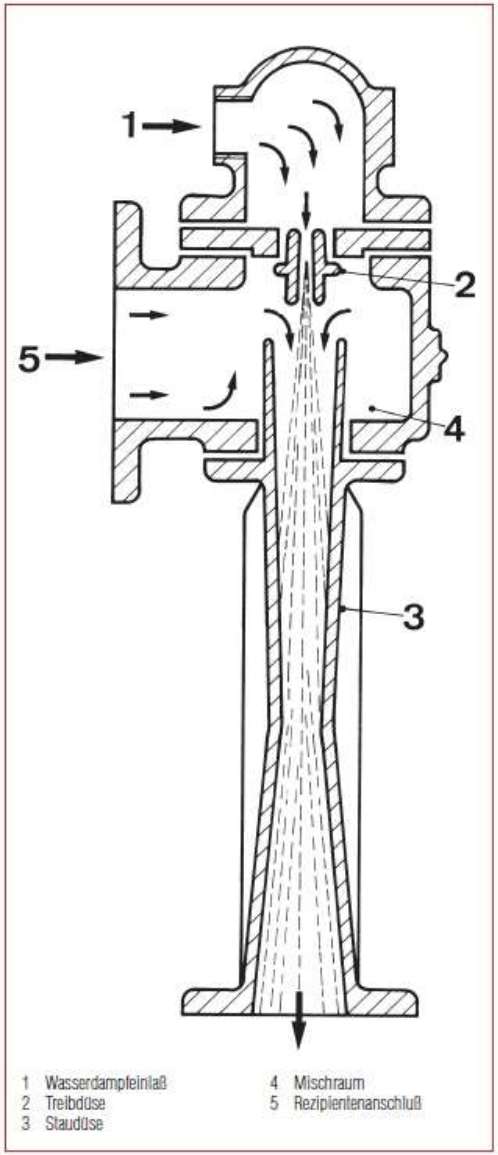
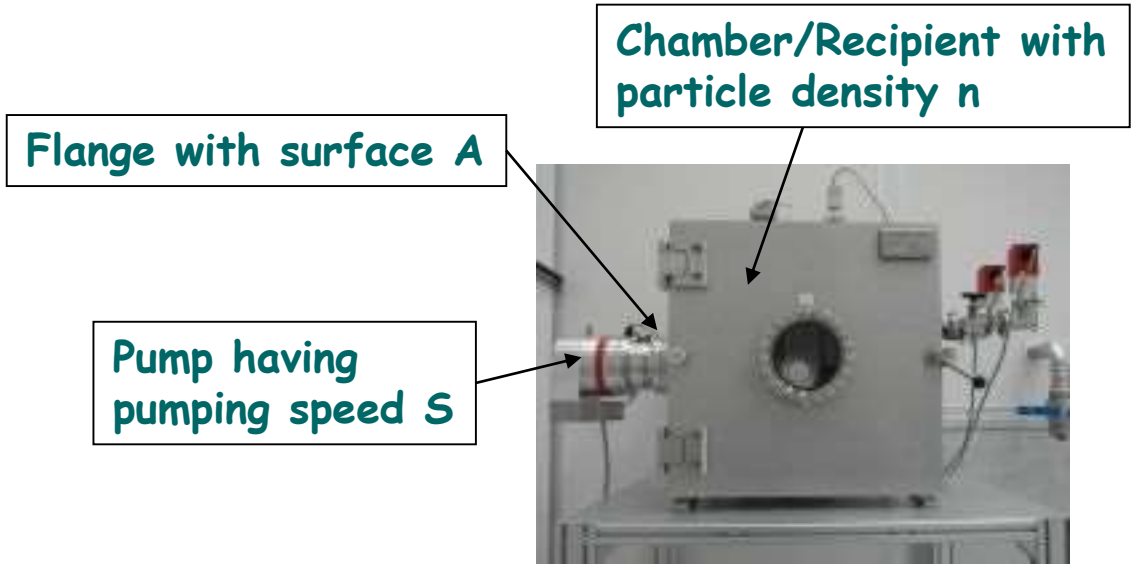
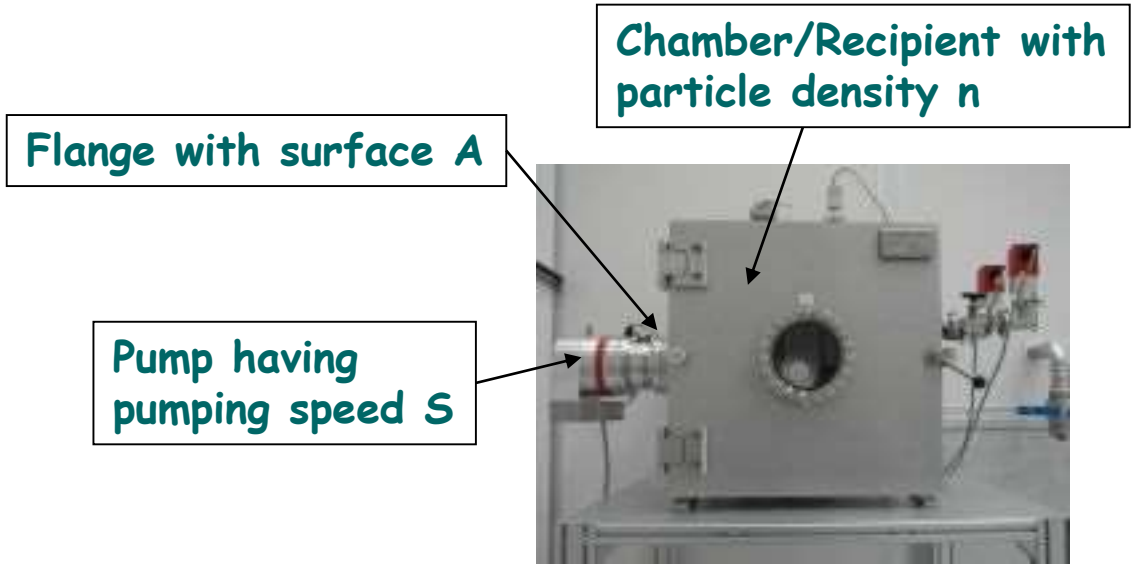


General consideration on kinetic pumps



General consideration on kinetic pumps

Pump considered as "black hole" for gas particles
(Every particle passing the pump flange is disappeared from the chamber!)



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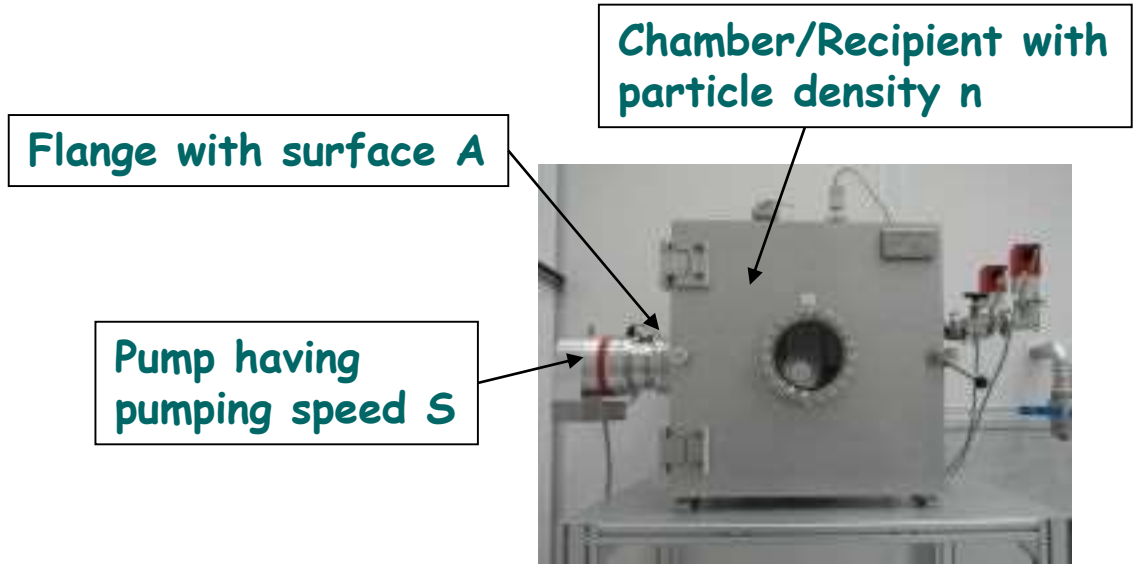
Continuity:
Particle number into the pump = particle number out of the chamber



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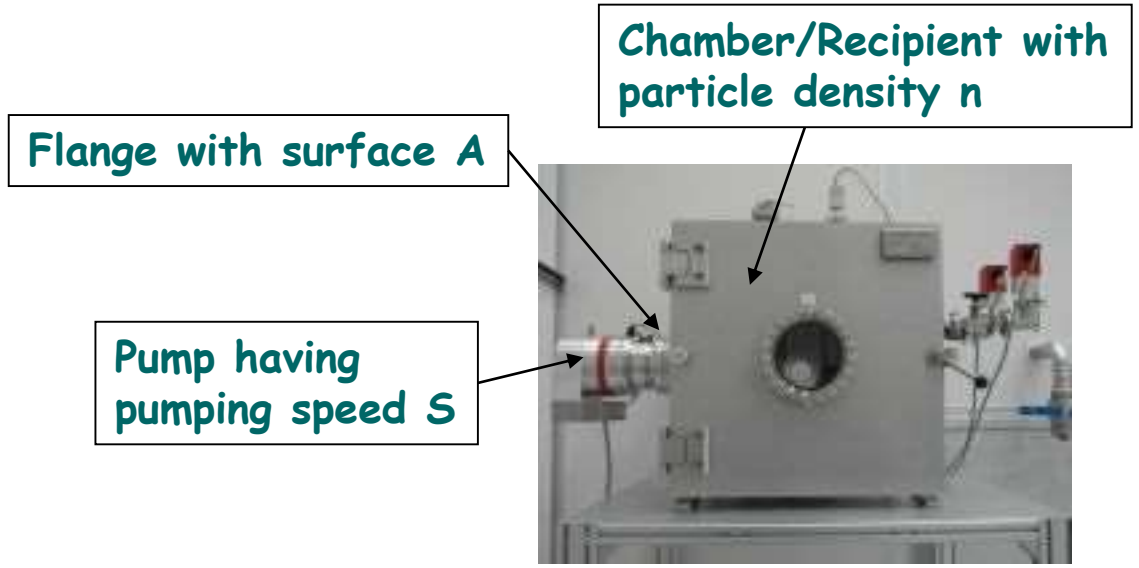

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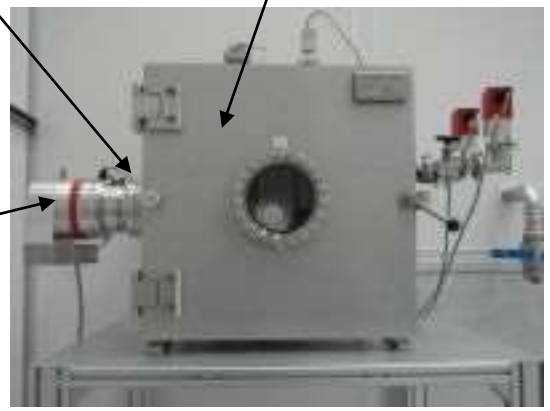
Particle number into the pump = particle number out of the chamber

Particle number approaching A per time unit: $N_a = Z_a \cdot \Delta t \cdot A$

Chamber/Recipient with particle density n

Flange with surface A

Pump having pumping speed S



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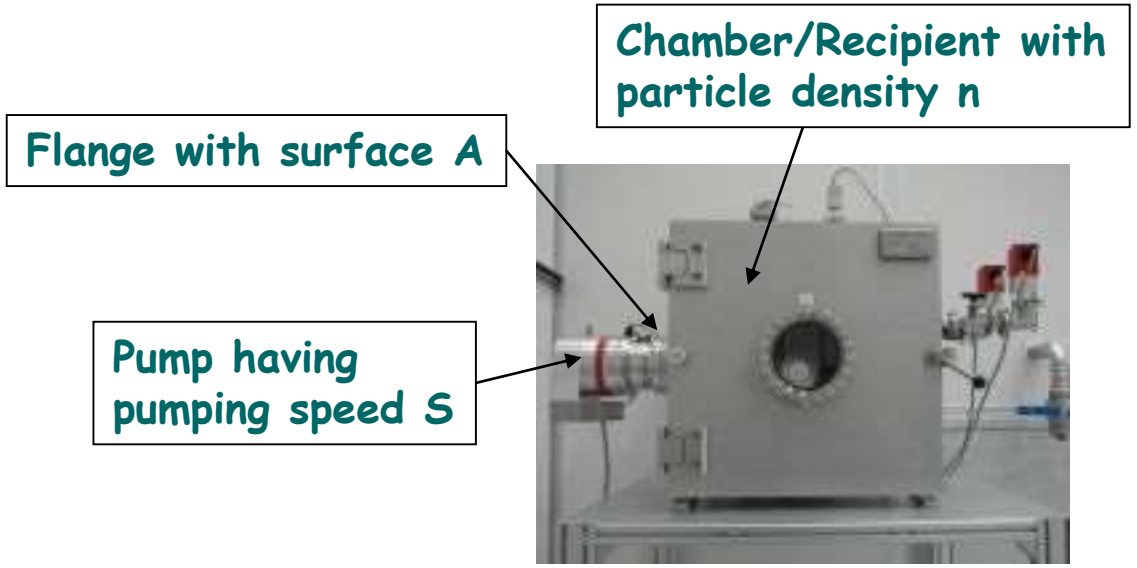
These particles occupied the volume: $\Delta V = N_a / n$



General consideration on kinetic pumps

Pump considered as "black hole" for gas particles
(Every particle passing the pump flange is disappeared from the chamber!)

Continuity:
Particle number into the pump = particle number out of the chamber

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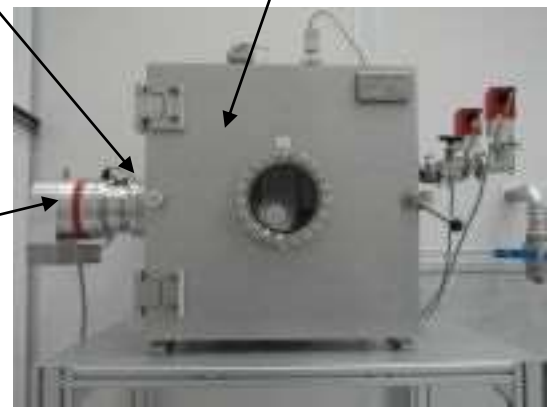

Therefore: $Z_a \cdot \Delta t \cdot A = n \cdot \Delta V$ and the $S_{max} = \Delta V / \Delta t = A \cdot Z_a / n = A \cdot \frac{1}{4} \cdot u_{mean} \cdot n / n = A \frac{1}{4} \cdot u_{mean}$

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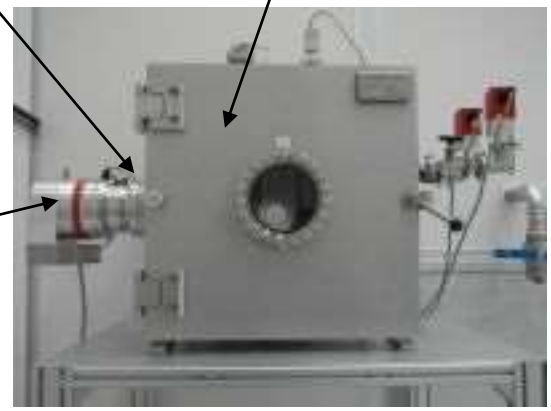

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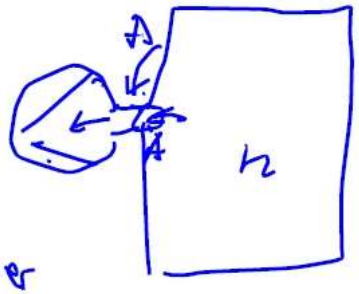
The „specific" (surface related) pumping speed of an ideal pump is though

$s_{max} = S_{max} / A = \frac{1}{4} u_{mean}$ for example in $l/(s \cdot cm^2)$

Board 1



Particle into the Pump = Particles out of chamber

$N_a = Z_a \cdot \Delta T \cdot A$

These particles occupied the volume: $\Delta V = N_a / n$ ← Part. Density

$N_a = Z_a \cdot \Delta t \cdot A = n \cdot \Delta V$

$S_{max} = \Delta V / \Delta t = A \cdot Z_a / n = A \cdot \frac{1}{4} \cdot u_{mean} \cdot n / n = A \frac{1}{4} u_{mean}$

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$s_{max} = S_{max} / A = \frac{1}{4} u_{mean}$ l/(s·cm²)

How large is the specific pumping speed for Ar? (@RT)

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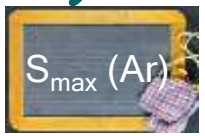

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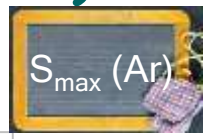

$s_{max} = \frac{1}{4} u_{mean}$

$u_{mean}(Ar) = 394\ m/s = 3940\ dm/s$

$s_{max} = \frac{1}{4} u_{mean} = 985\ dm/s \cdot dm^2/dm^2 = 985\ l/(s \cdot dm^2) =$

$9.85\ l/(s \cdot cm^2)$

The specific pumping speed of an ideal pump depends on the gas species. In this sense, lighter gases show a higher specific pumping speed. However due to the working principles of real pumps, this advantage is mostly not realized. (see later turbo- or cryo pump)

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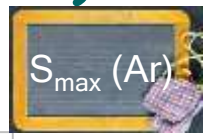

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Board 2

How large is the specific pumping speed for Ar @ RT ?

$s_{max} = \frac{1}{4}\bar{u}$

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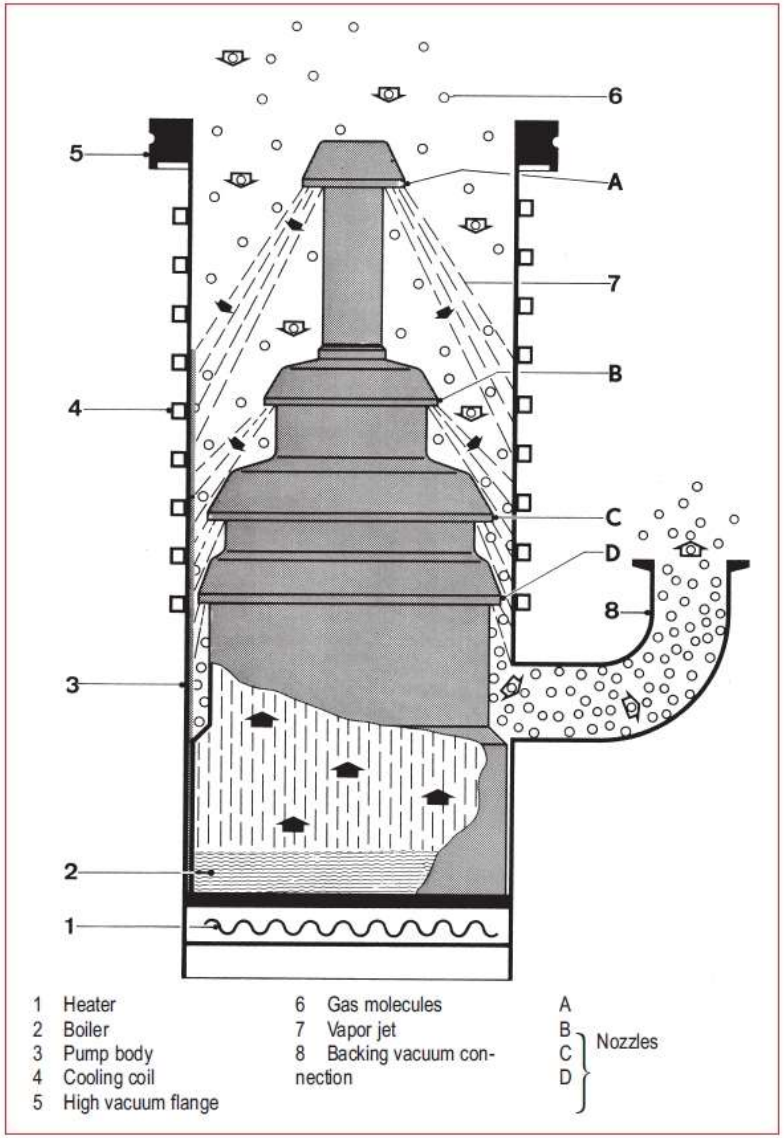
Diffusion pump: 10^{-3} – below 10^{-7} mBar

"VT L11 f 13:16



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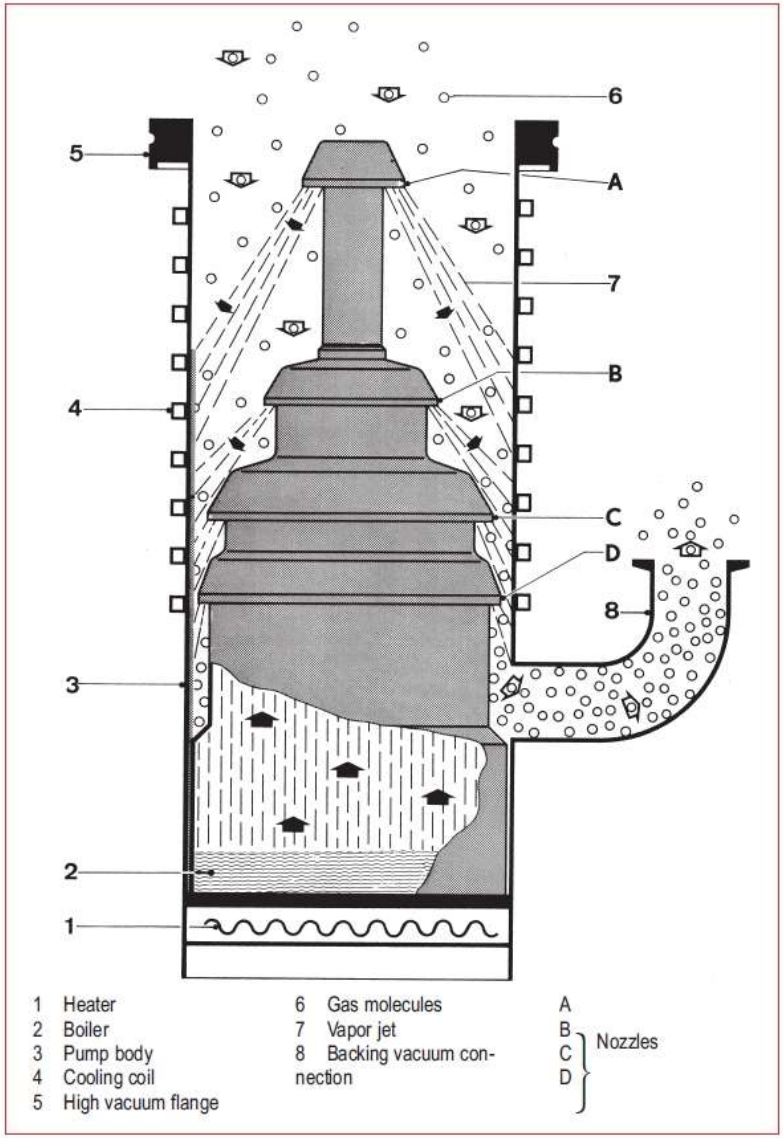
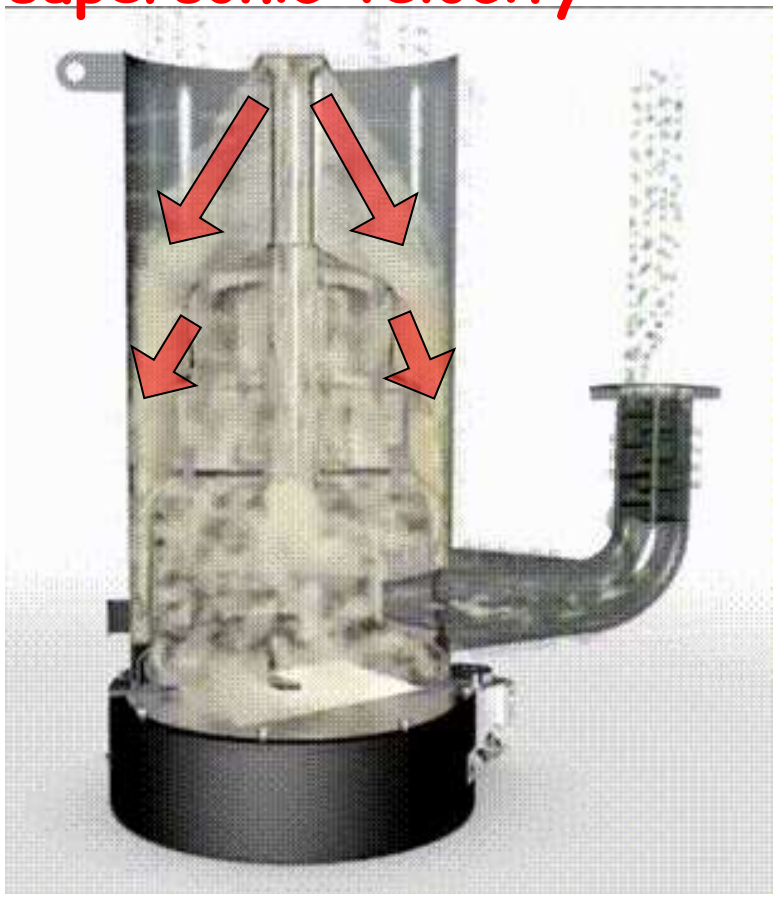


Diffusion pump: 10^{-3} – below 10^{-7} mBar

Particle beam of supersonic velocity



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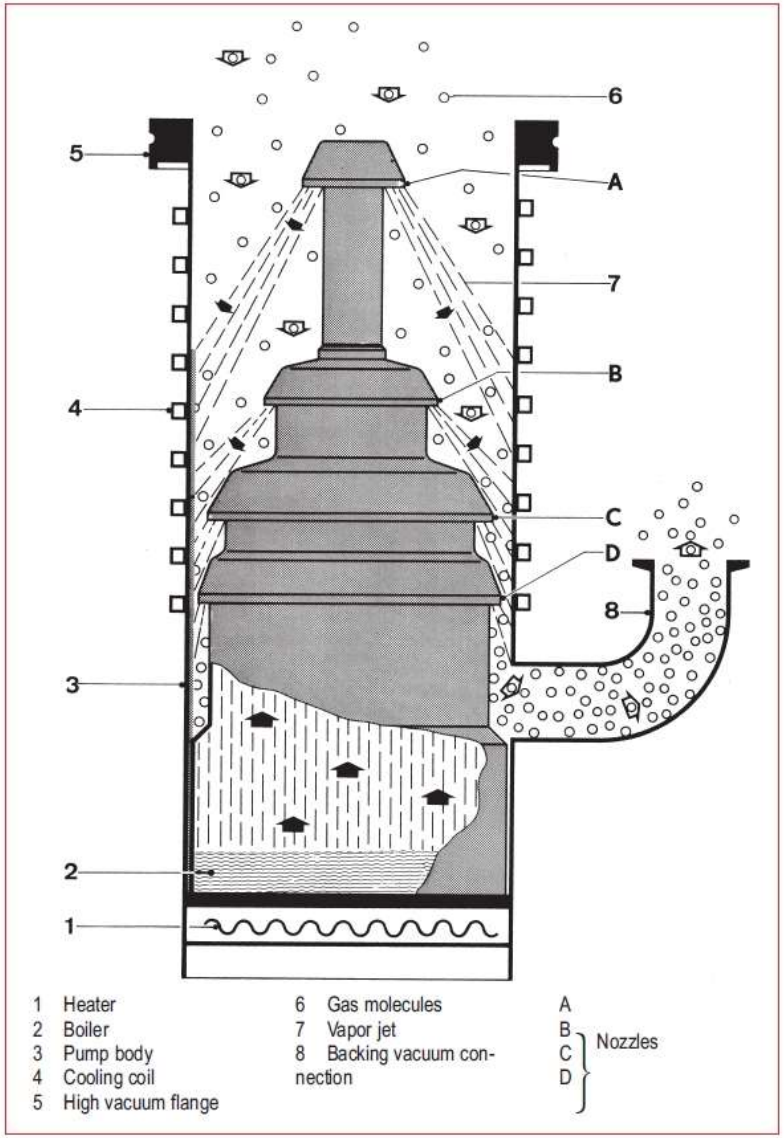
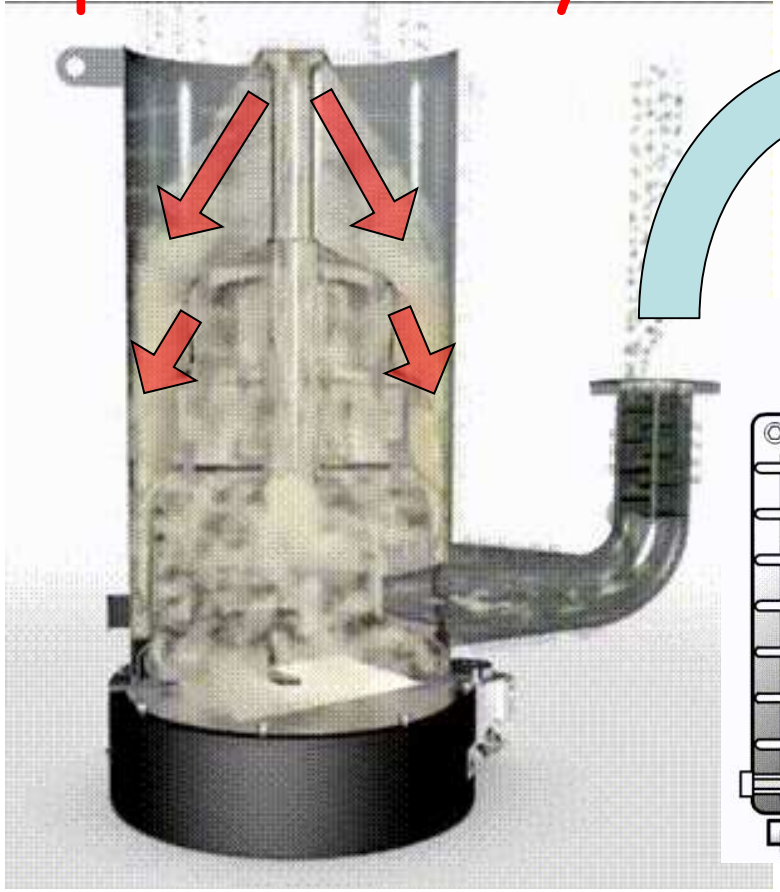
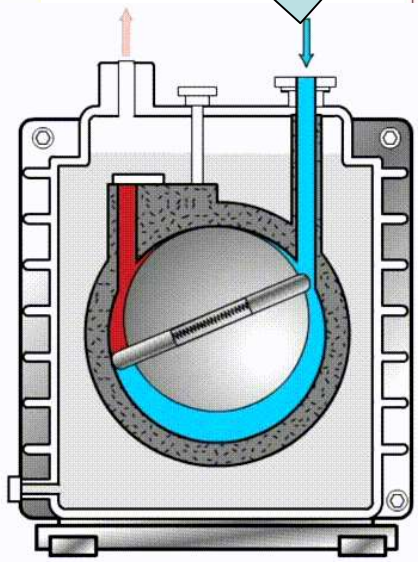


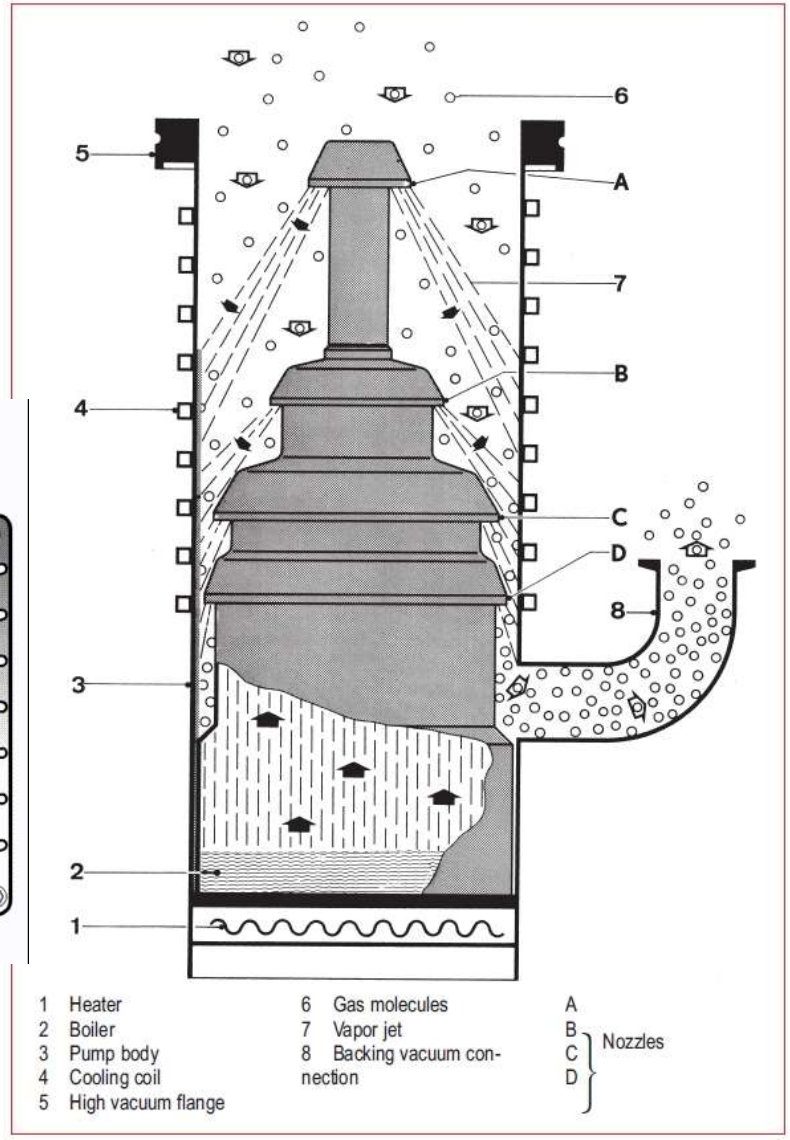
Diffusion pump: 10^{-3} – below 10^{-7} mBar

Particle beam of supersonic velocity

A roughing pump is required!







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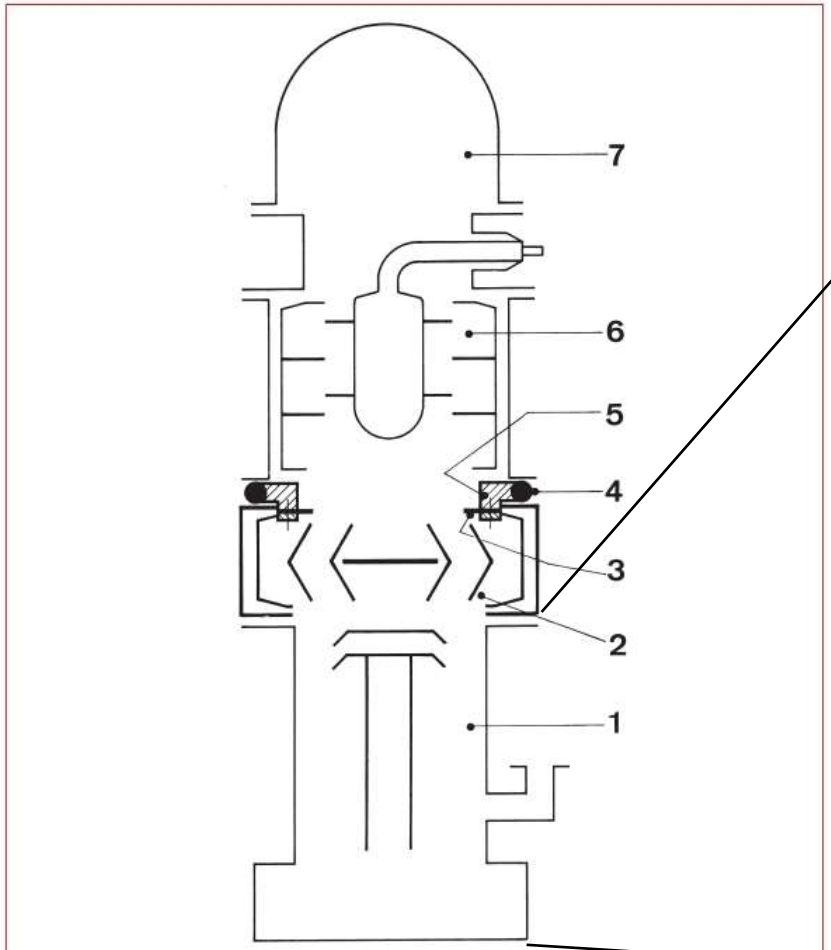
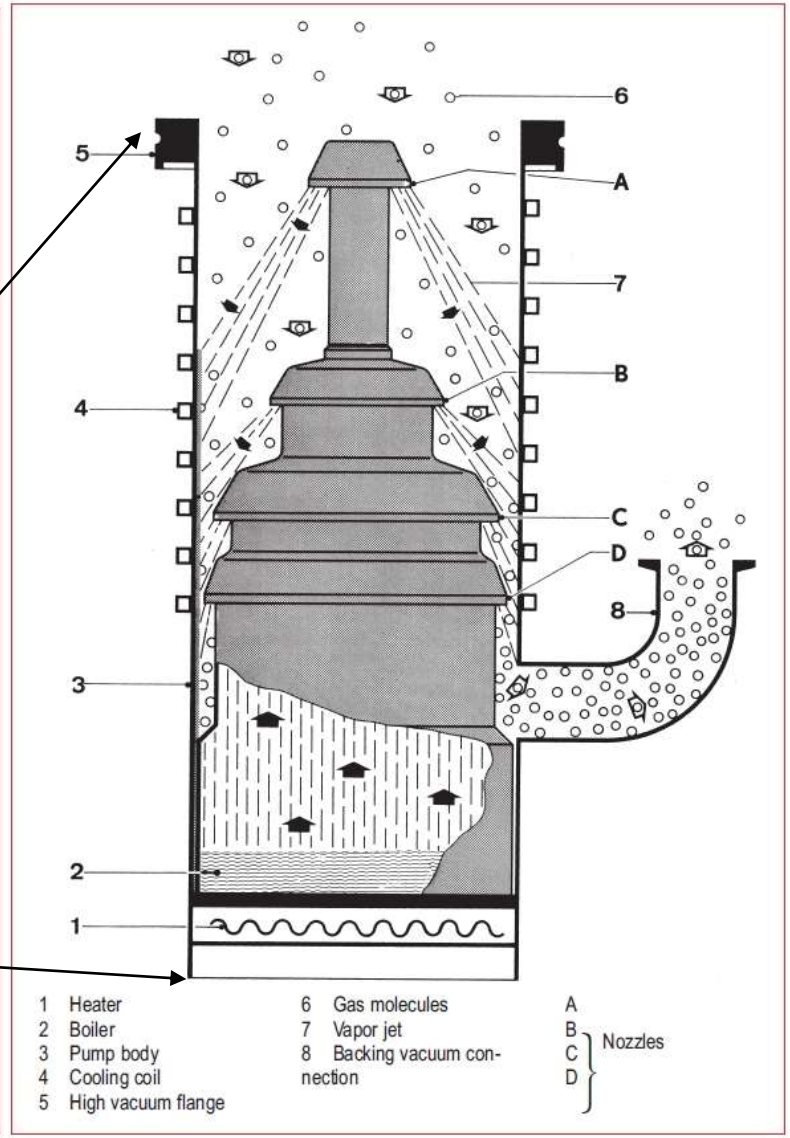
Diffusion pump: 10^{-3} – below 10^{-7} mBar

Baffles and cold traps are necessary to prevent oil from back diffusion



1 Diffusion pump with cold cap baffle (cooled by contact),
2 Shell or chevron baffle
3 Anticreep barrier
4 Sealing gasket
5 Bearing ring
6 LN2 cold trap,
7 Vacuum chamber



1 Heater
2 Boiler
3 Pump body
4 Cooling coil
5 High vacuum flange
6 Gas molecules
7 Vapor jet
8 Backing vacuum connection
A, B, C, D Nozzles

For diffusion pumps, flange sizes of 1m diameter are possible. Assuming an efficiency of 50% (S_{real}=0.5 S_{max}) how large is the effective pumping speed of such a diffusion pump with a flange size of 1m in diameter for Ar @ RT?

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s_{real}= 5 l/(s·cm²)

$A=r^2\pi$ = 7854 cm2

$S = s_{real} \cdot A$ = 39270 l/s

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Board 3

For diffusion pumps, flange sizes of 1m diameter are possible. ($\rightarrow T = 50\,cm$)
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Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar

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"VT L11 g 10:35

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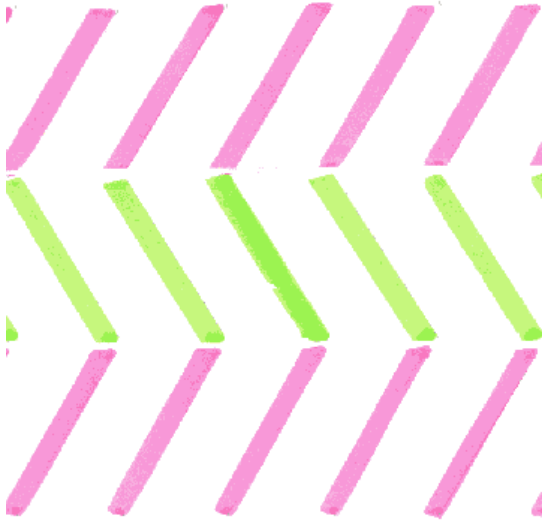

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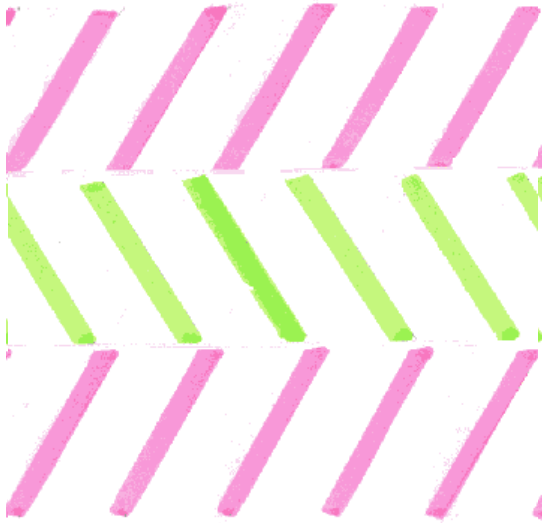

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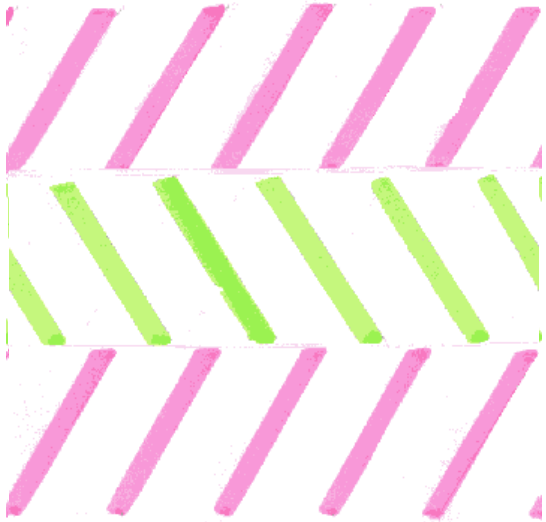

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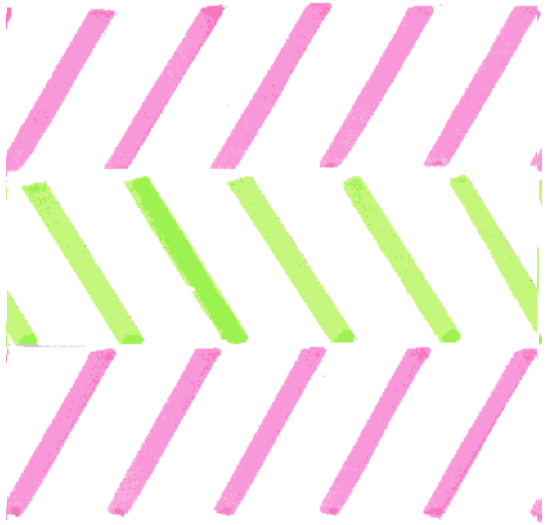

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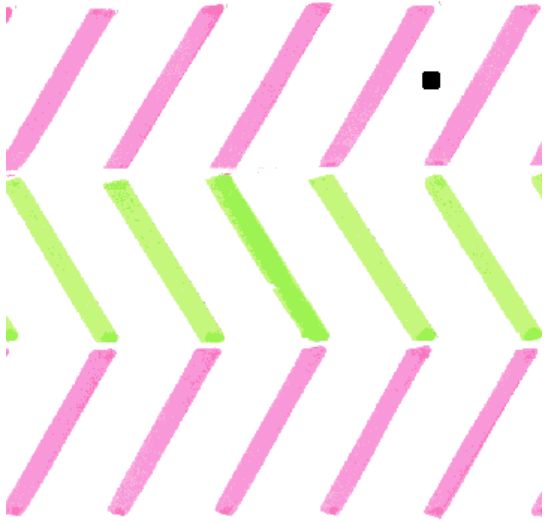

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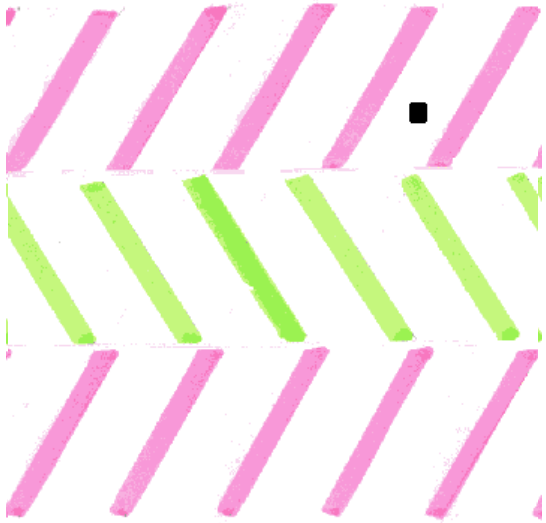

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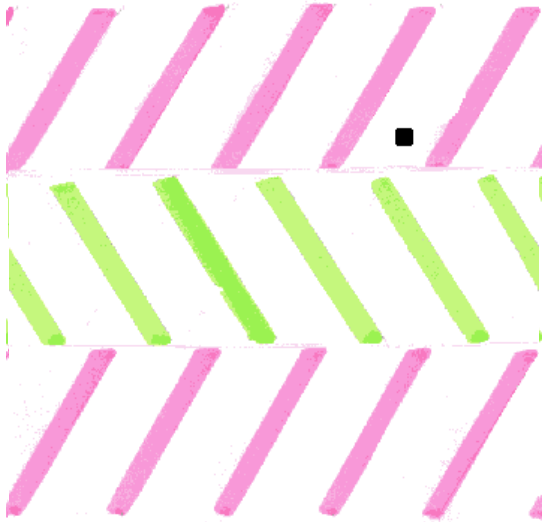

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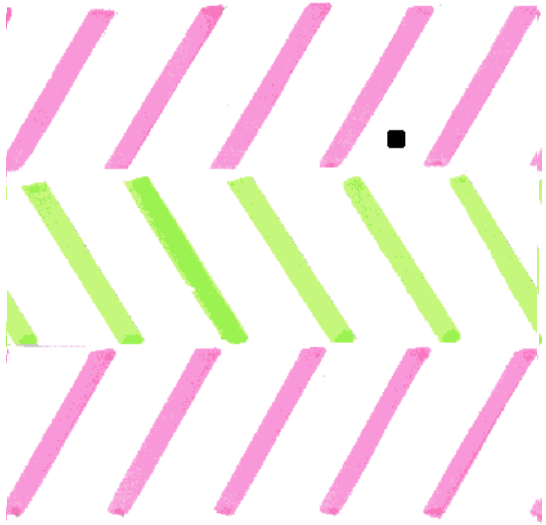

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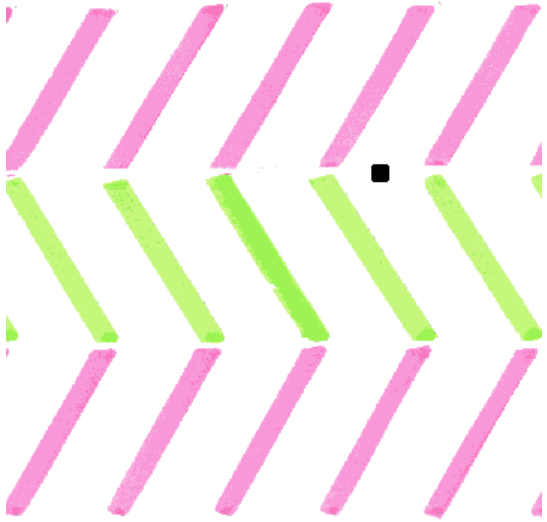

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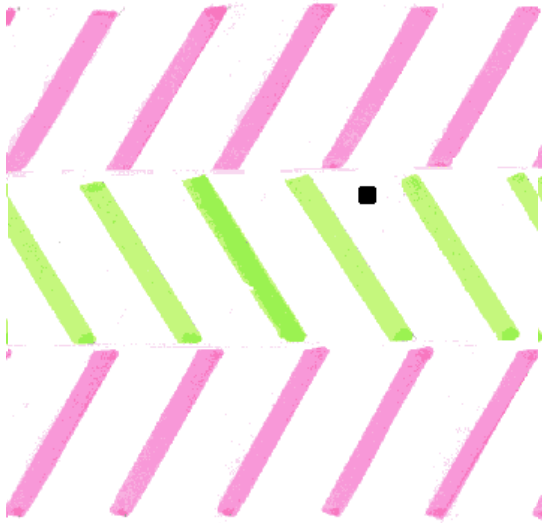

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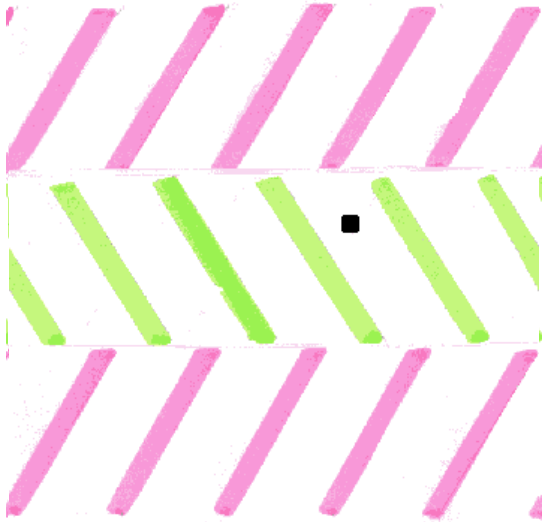

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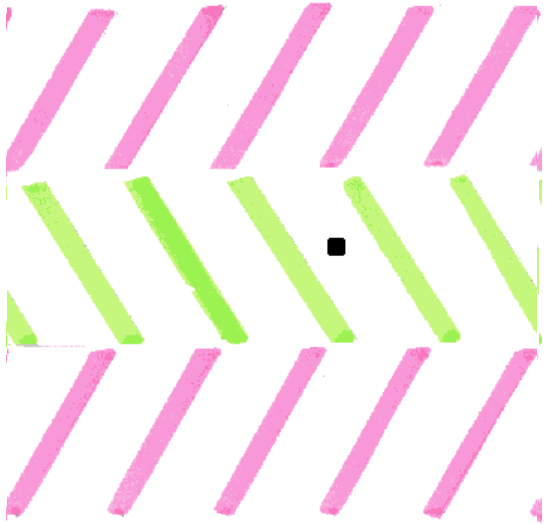

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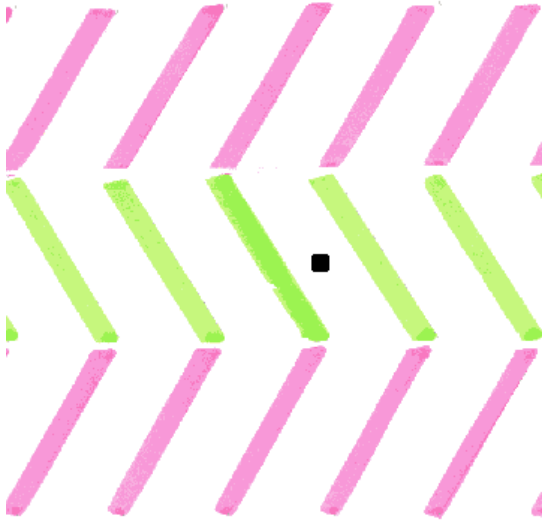

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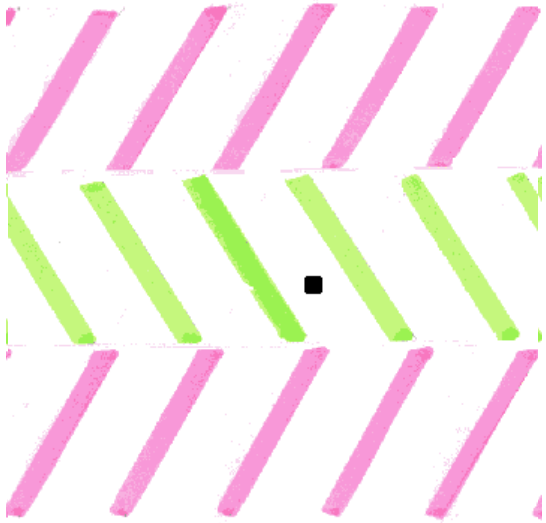

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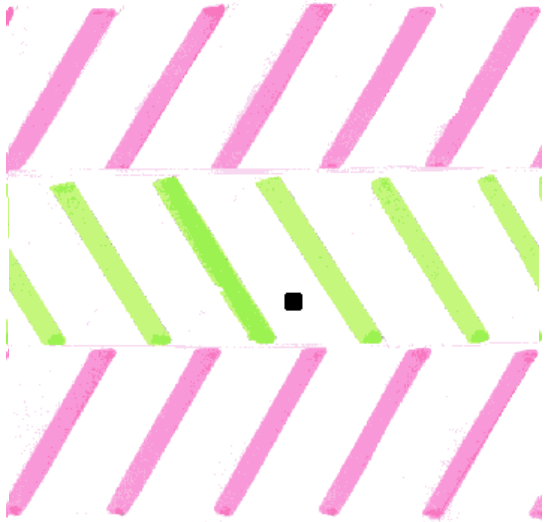

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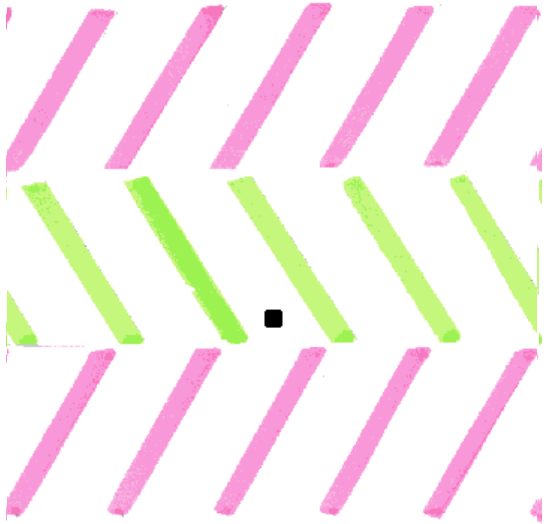
Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar



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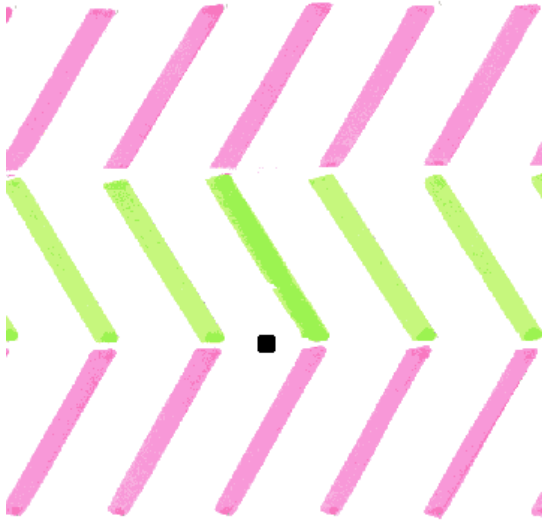

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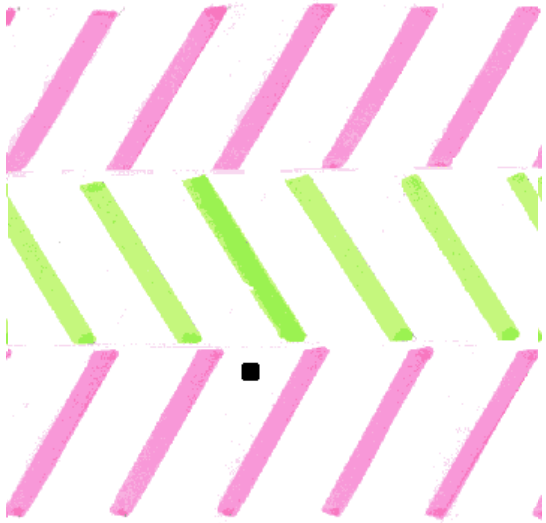

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Turbo molecular pump

Working range
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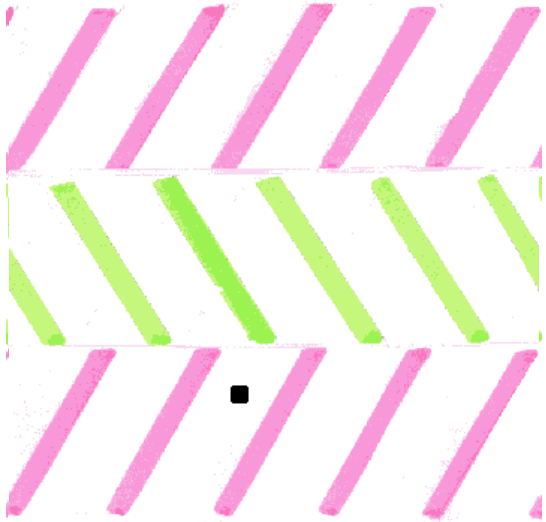

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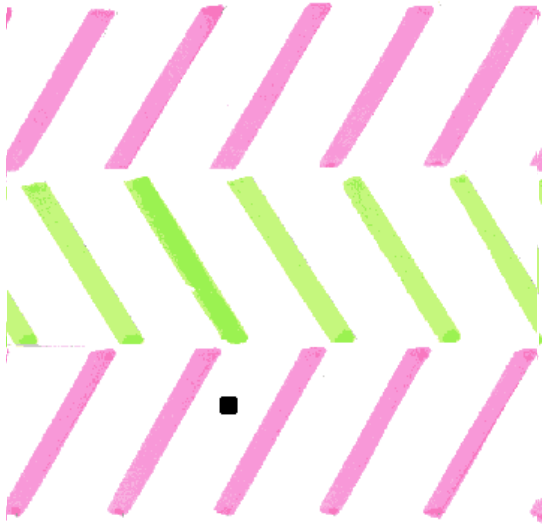
Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar



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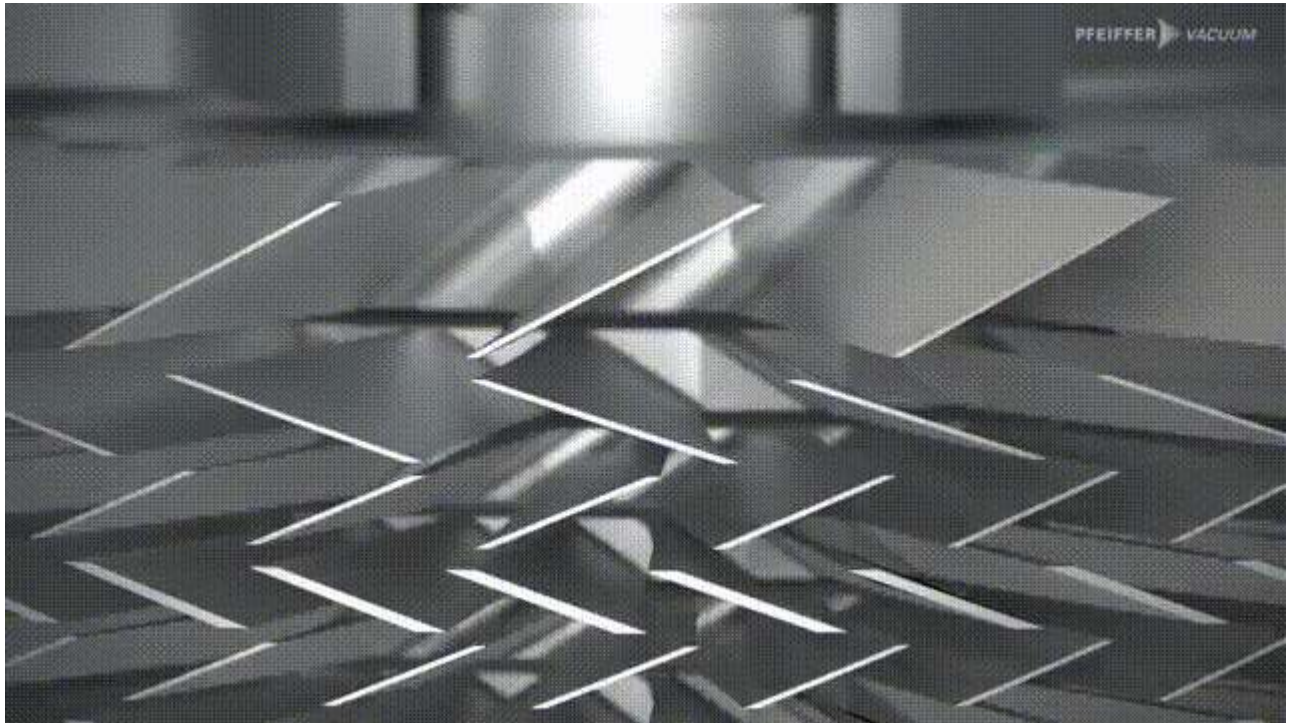
Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar



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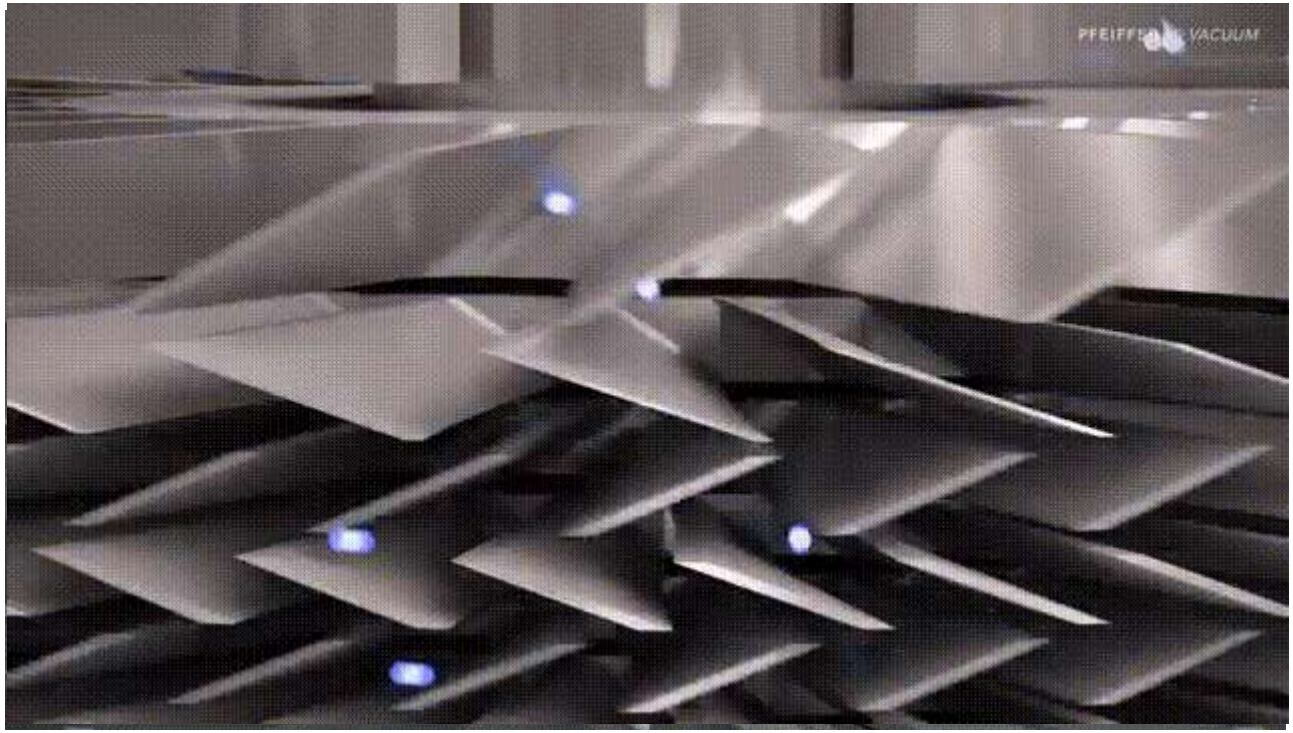
Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar



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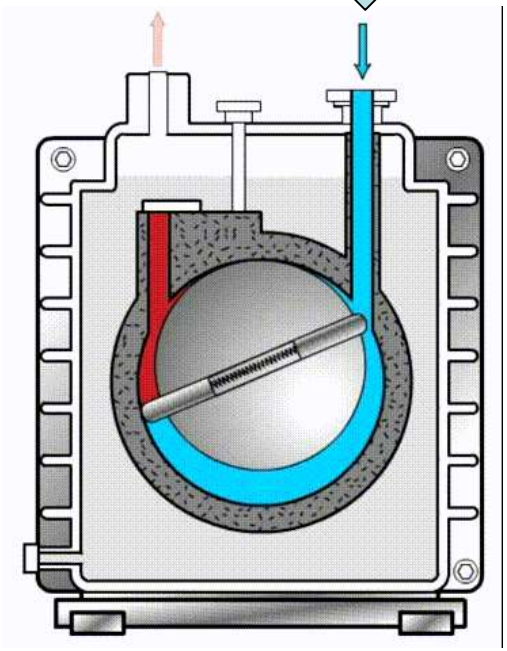
Turbo molecular pump

Working range
10^{-2} to 10^{-9} mbar

Turbo molecular pump

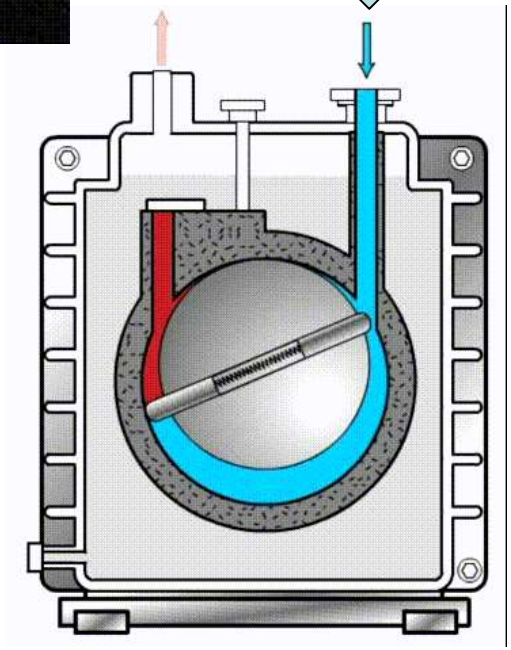
Working range
10^{-2} to 10^{-9} mbar



Turbo molecular pump

TMP with integrated drag stage

Working range 10^{-2} to 10^{-9} mbar



Turbo molecular pump

Compression and pumping speed are molecule specific!

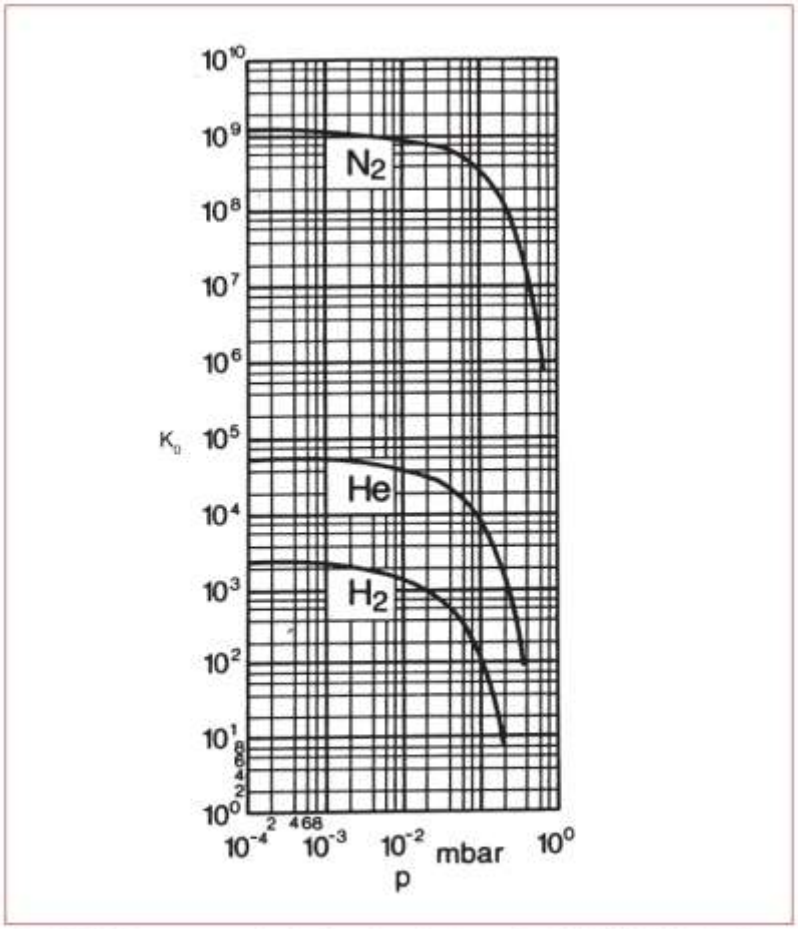


Fig. 2.56 Maximum compression k_0 of a turbomolecular pump TURBOVAC 340 M for H_2, He and N_2 as a function of backing pressure

Turbo molecular pump

Compression and pumping speed are molecule specific!

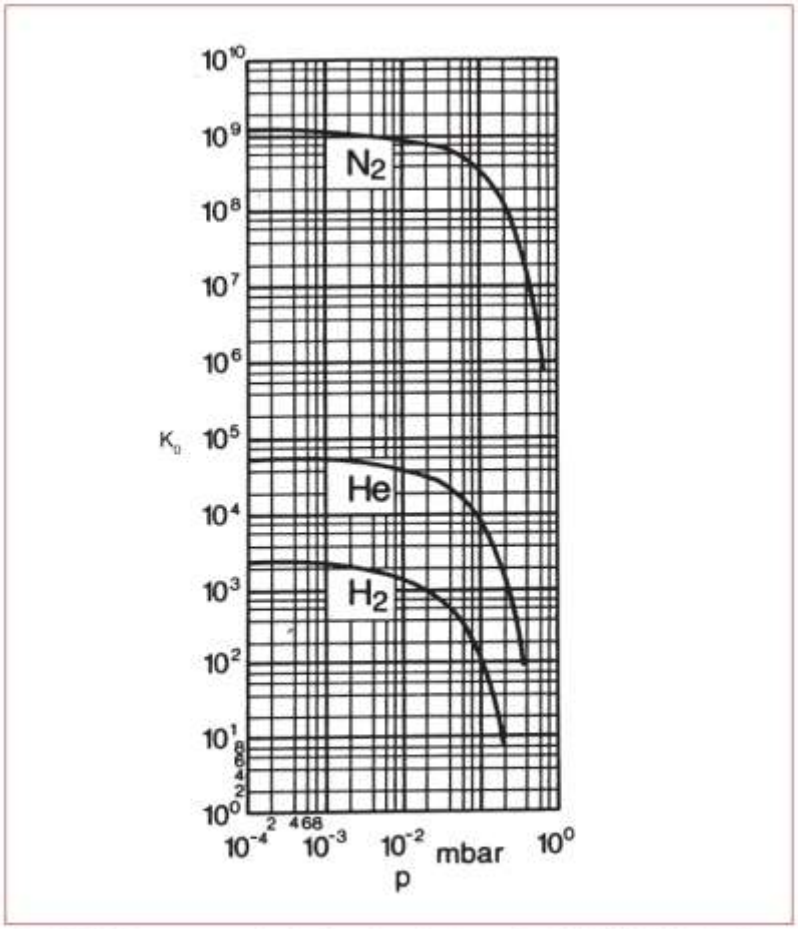
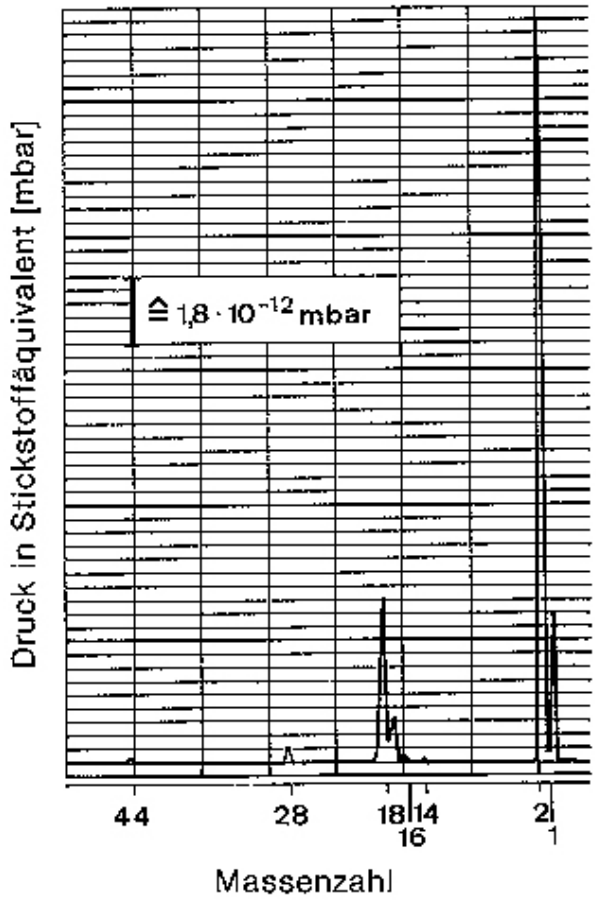
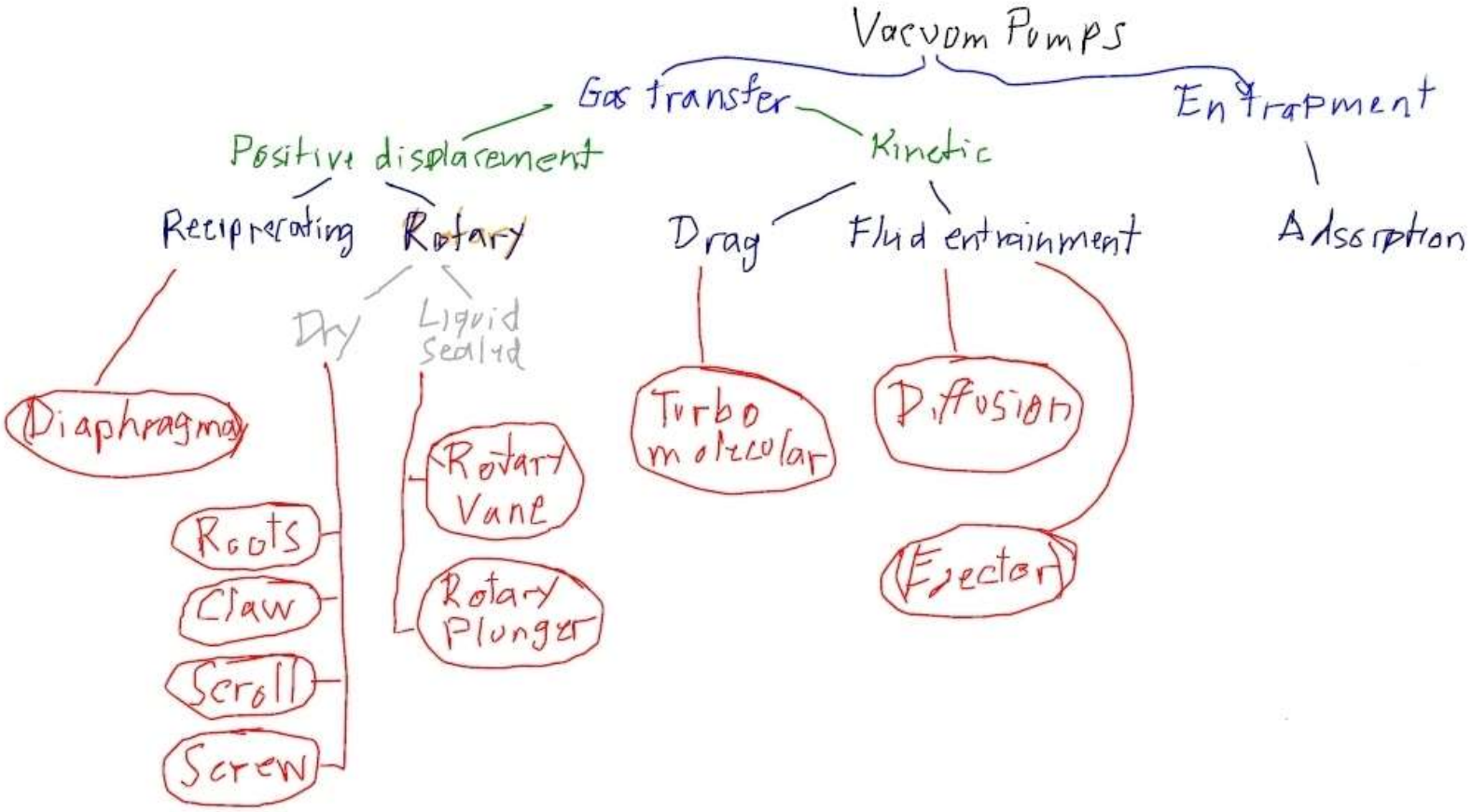


Fig. 2.56 Maximum compression k_0 of a turbomolecular pump TURBOVAC 340 M for H_2, He and N_2 as a function of backing pressure



Partial pressure of residual gas as function of mass number



»Wissen schafft Brücken.«