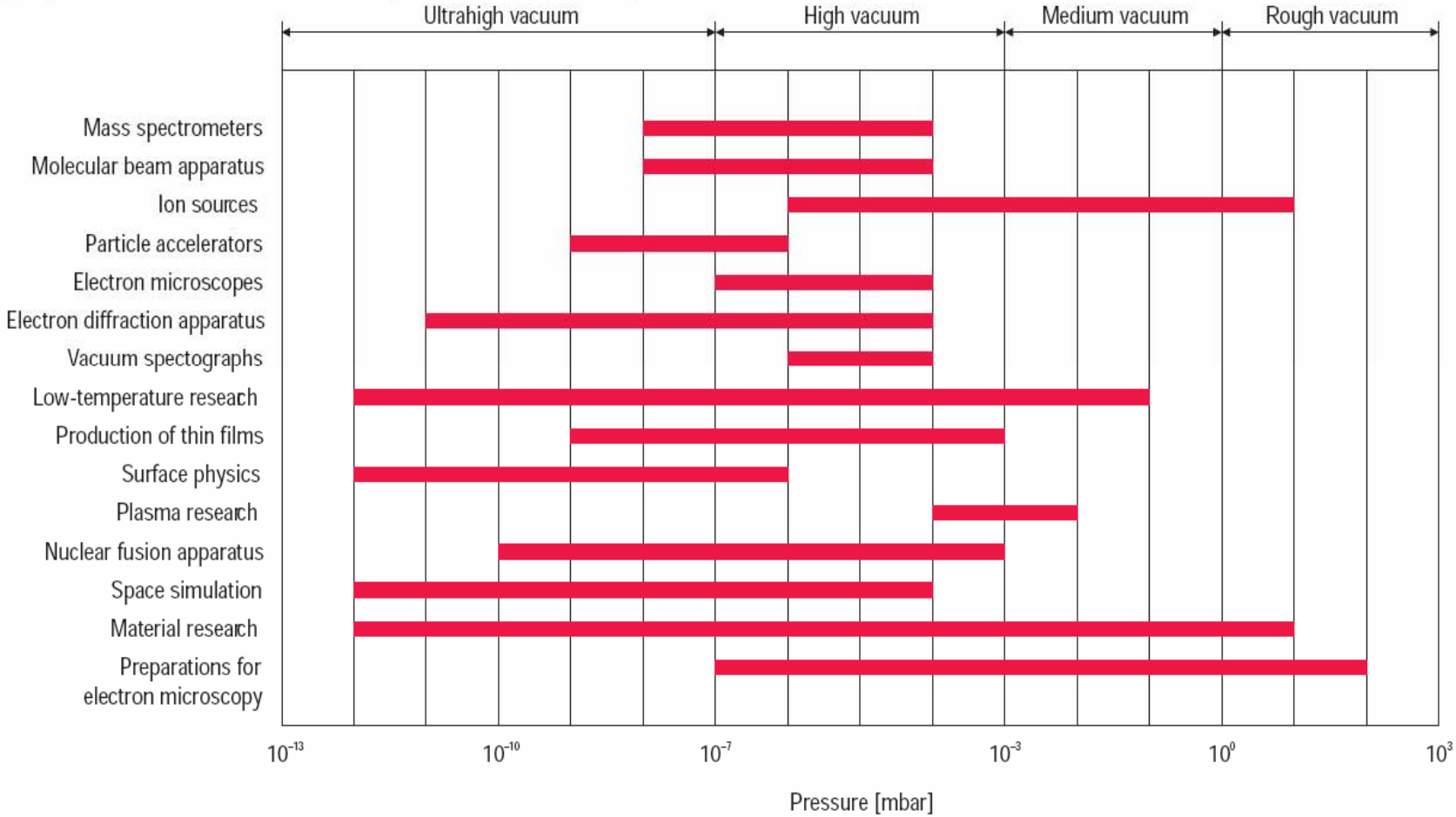
Industrial Applications of Vacuum

- overview applications of vacuum technology
- motivation of vacuum design in industrial applications
- examples of solutions in Coating
- example of solution in Process Industry
- examples of solutions in Analytical (mass spectrometry)
- outlook

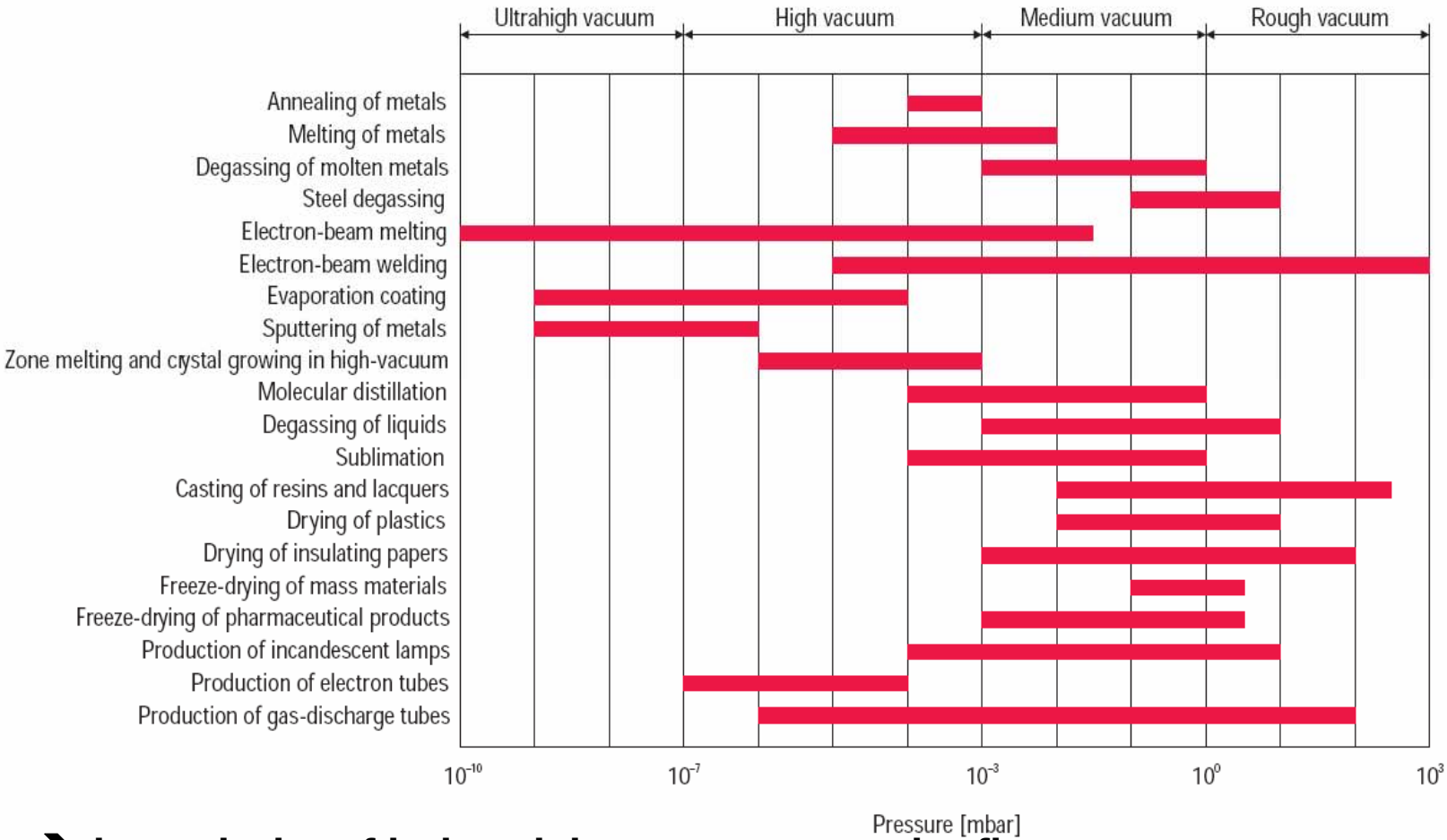
Pressure ranges of analytical methods

(physical and chemical; p < 1000 mbar)



➔ **most analytical intruments require HV/UHV**

Pressure ranges of industrial vacuum processes



➔**the majority of industrial processes require fine vacuum**

Drivers for design of industrial vacuum system

(i.e. 90% of all systems)

- Analytical Instruments:
  reach required vacuum quality within specified time

- Coating/Semiconductor/Process Industry
  fulfill given production yield

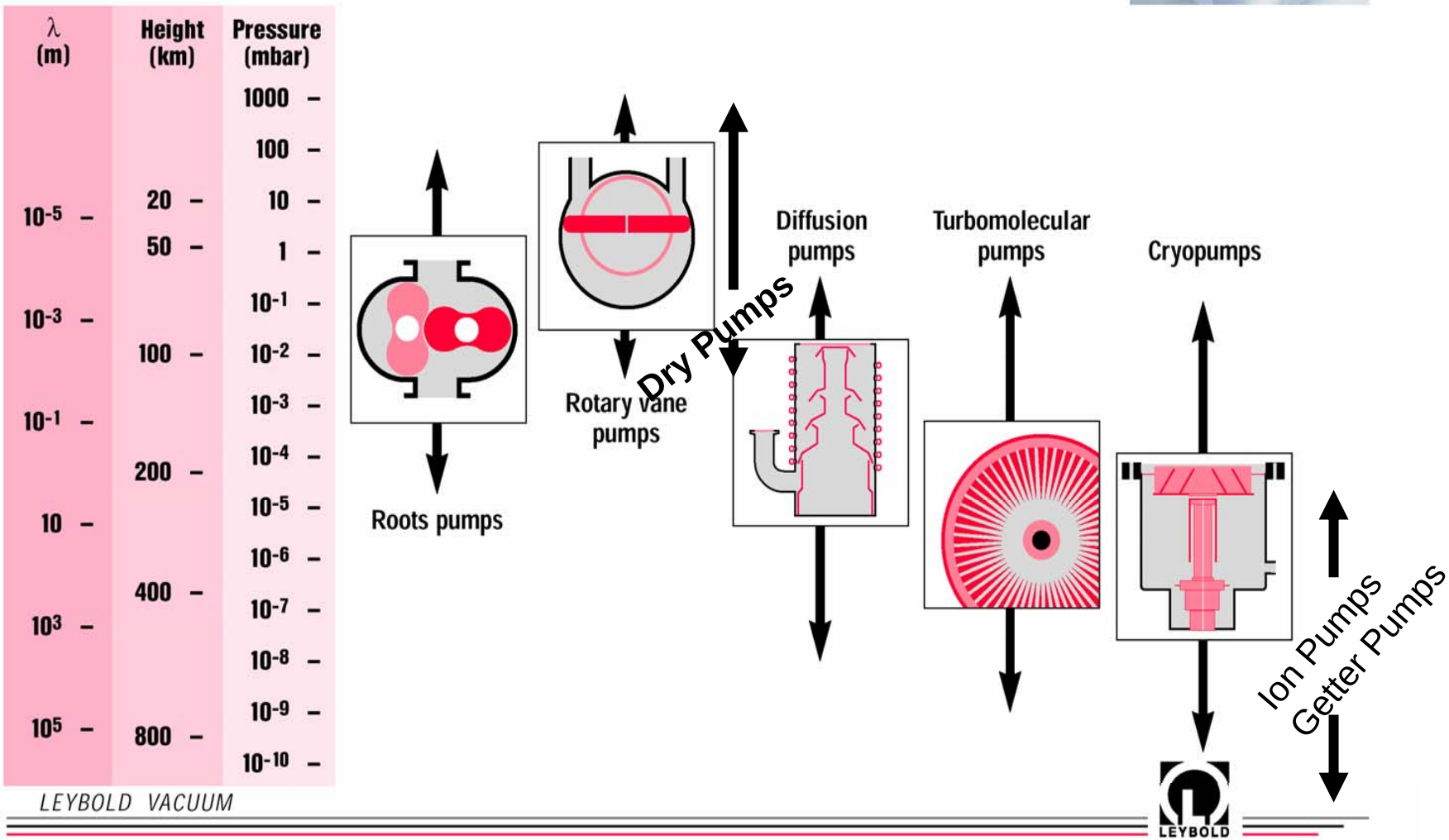
system uptime

better vacuum performance only tolerated if better competitiveness can be archieved (and paid by market)

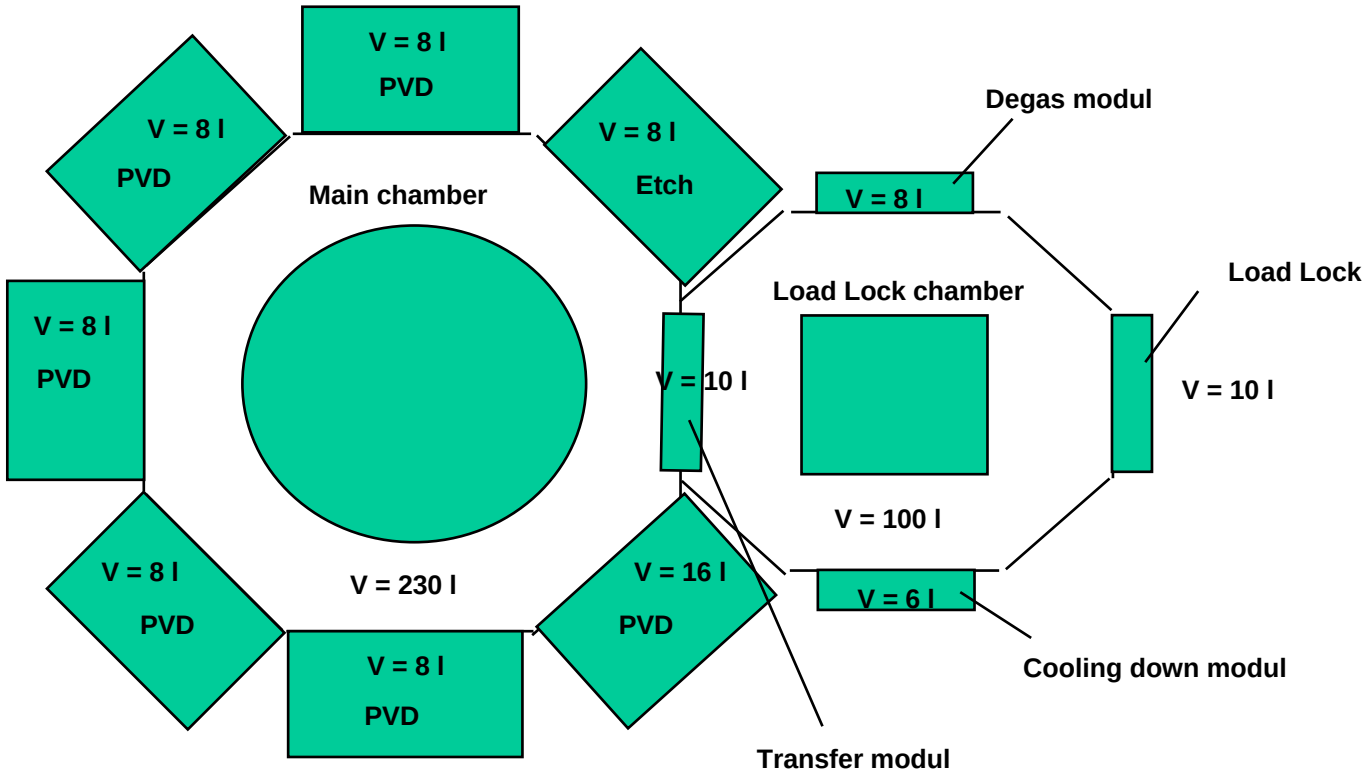
reduction of manufacturing costs and/or lower CoO drive design of machines after innovation phase

environment-friendly production

Vacuum pump technology for different pressure ranges



Example Coating Industry
Layout of a coating system for 300 mm Wafers

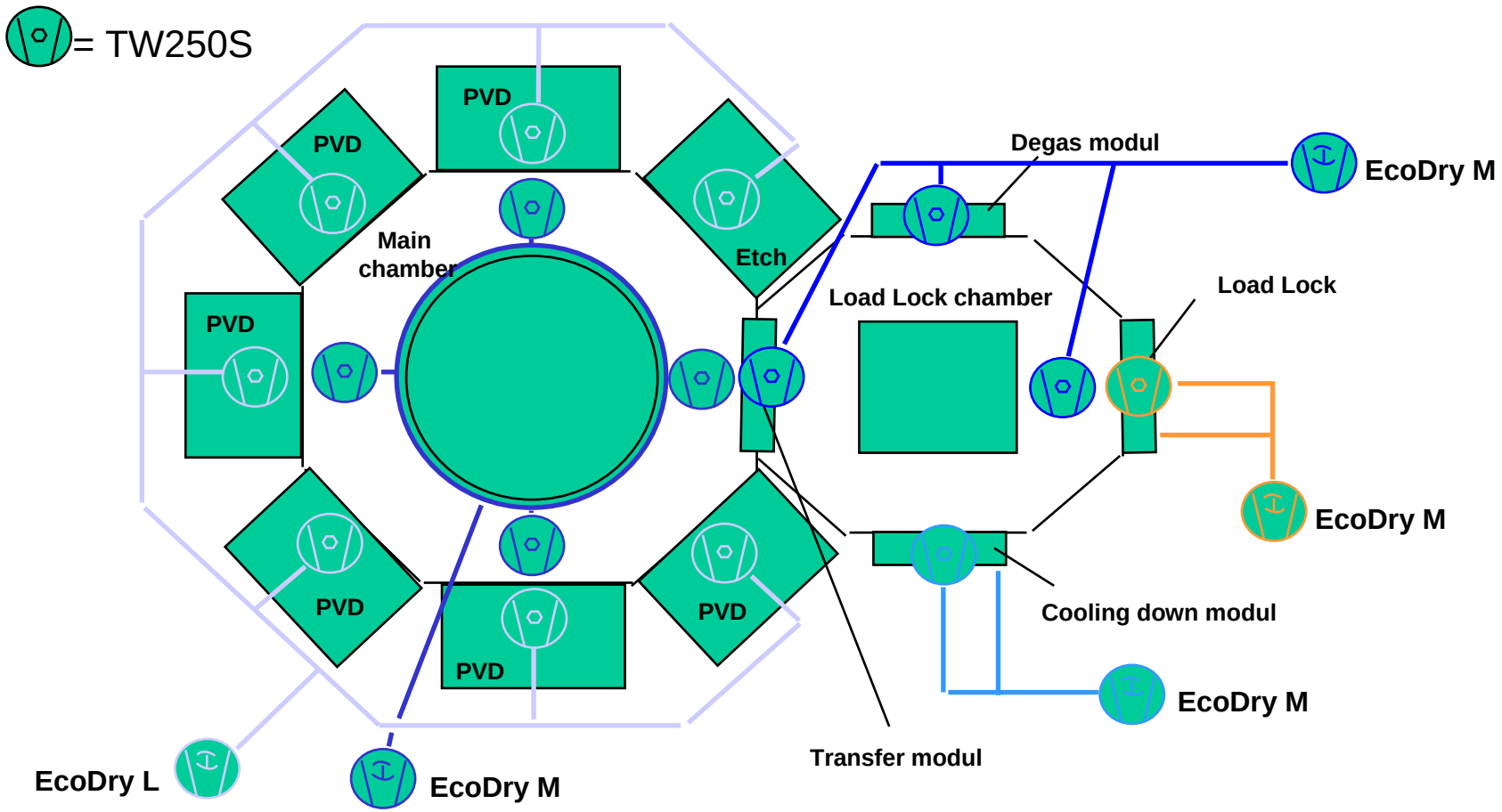


market requirements

initial evacuation time to $1x10^{-07}$ mbar base pressure: < 24 hours
process time per wafer and process chamber: 30 s
pressure during sputtering: $6x10^{-03}$ mbar
base pressure in main chamber during processing: < $1x10^{-06}$ mbar

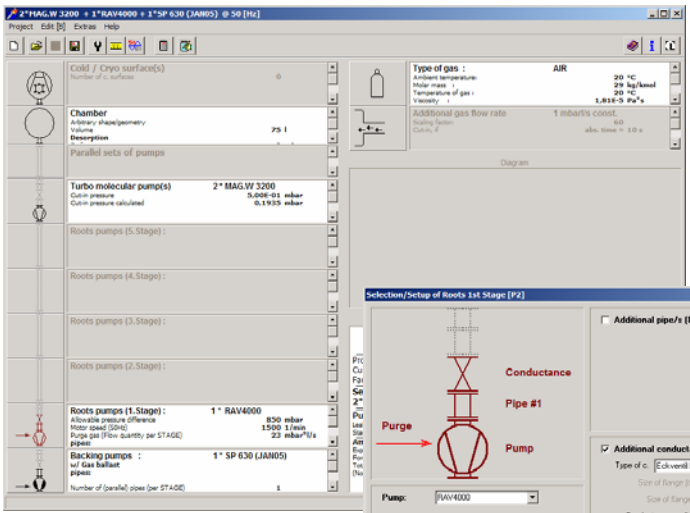
Main chamber:
50% Aluminium, 50% stainless steel
all other chambers: Aluminium

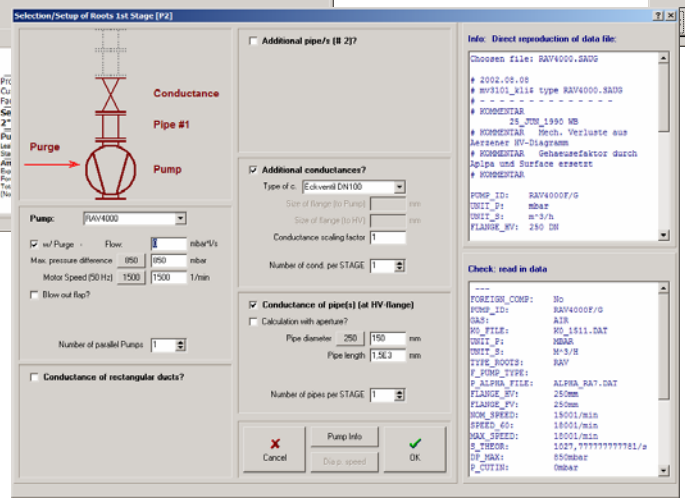
first draft of vacuum schematics:

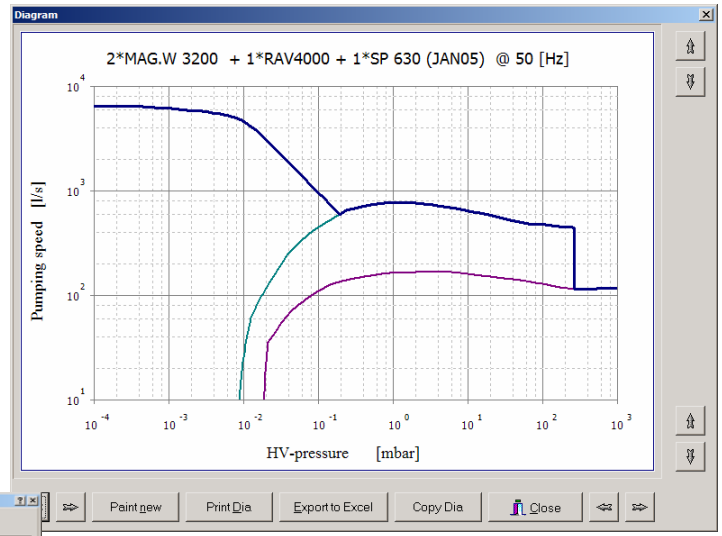


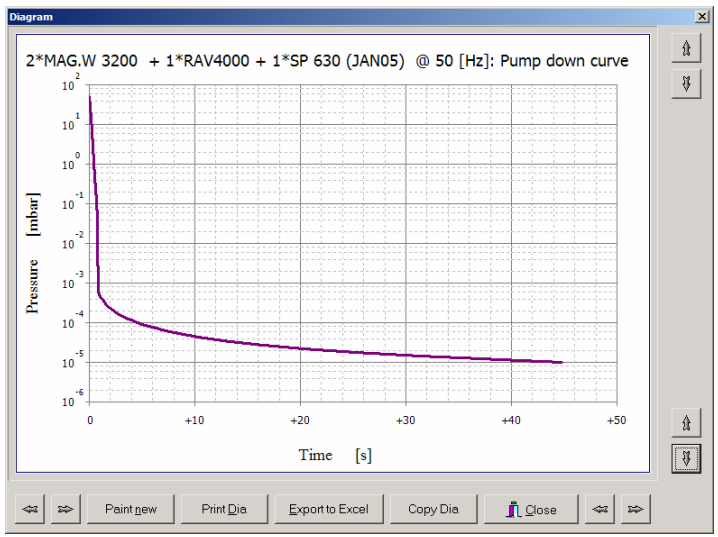
necessary computing possibilities

CompuVac © NT for Windows™





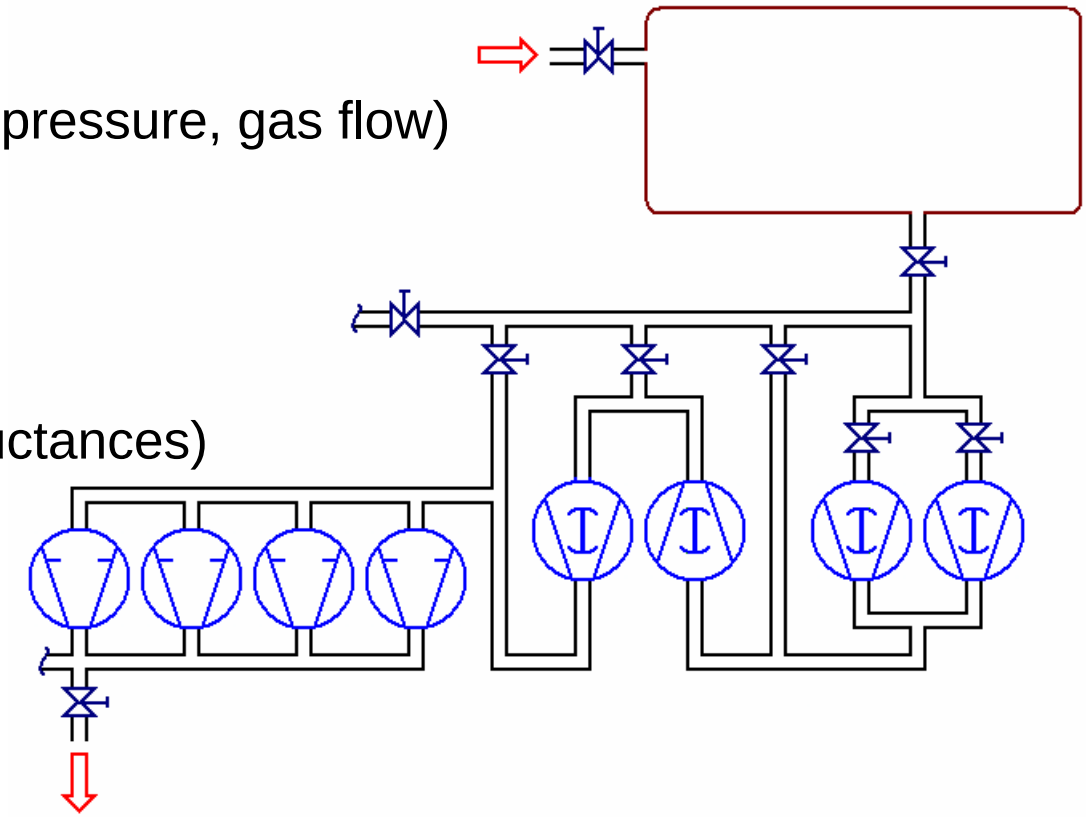




3 - Describing a vacuum system

Setup in principle:

- Chamber (Process: pressure, gas flow)
- Pump stages
- Components (conductances)
- (Medium)



3 - Describing a vacuum system: Pumps

A) Backing pumps

- pumping speed: $S = f(p_{HV})$

B) Roots pumps

- compression: $K = f(Q, K_0, p_{FV})$

C) High vacuum pumps (turbomolecular, diffusion, cryo)

- pumping speed: $S = f(p_{HV})$

D) Cryo surfaces

- pumping speed: $S = f(p_{HV})$

3 - Describing a vacuum system: Conductances

E) Pipes

- w/ or w/o apertures

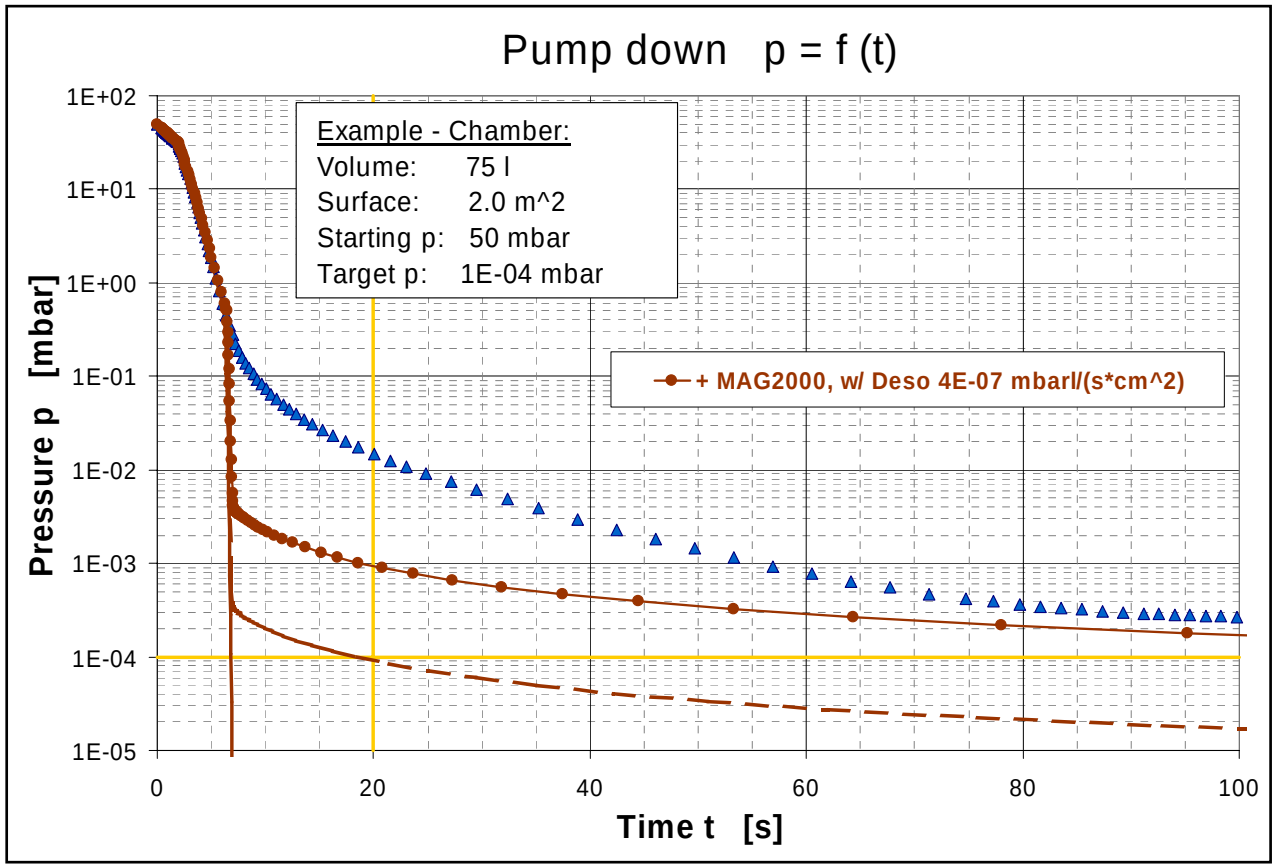
F) Rectangular ducts

- transformation into circular pipes; w/ or w/o apertures

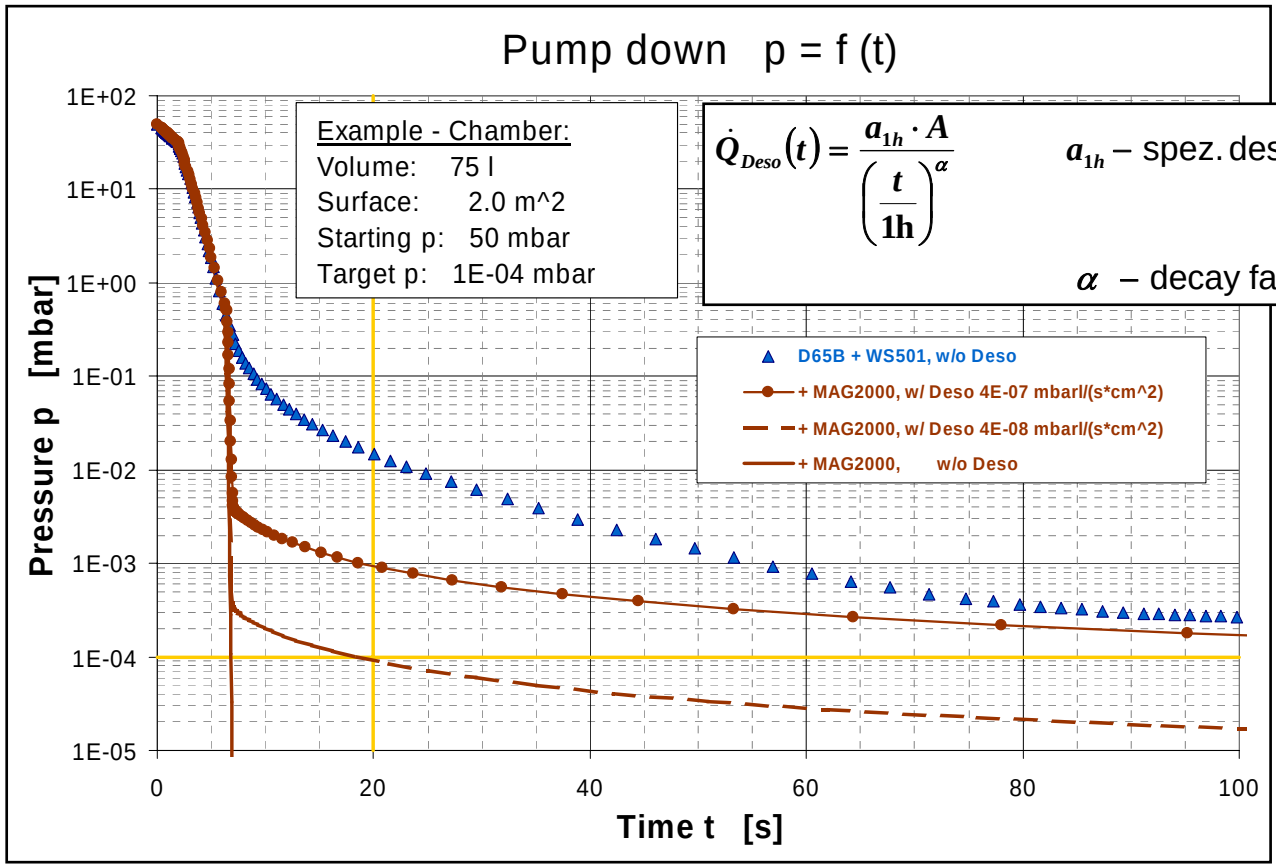
G) (Other) components - elbows, valves, filters..

- Transformation into circular pipe equivalents
- Direct function of conductance C = f (p)

4C - Influence: Gas load caused by desorption

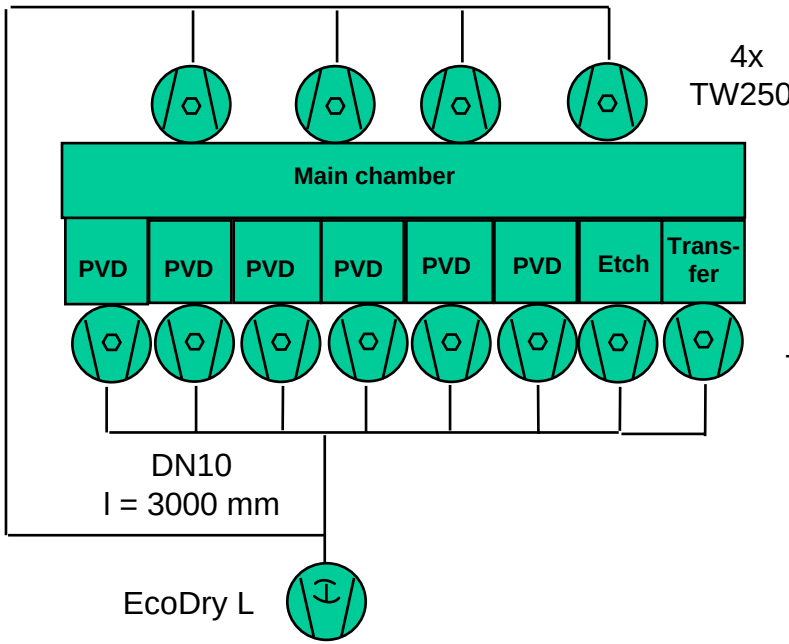


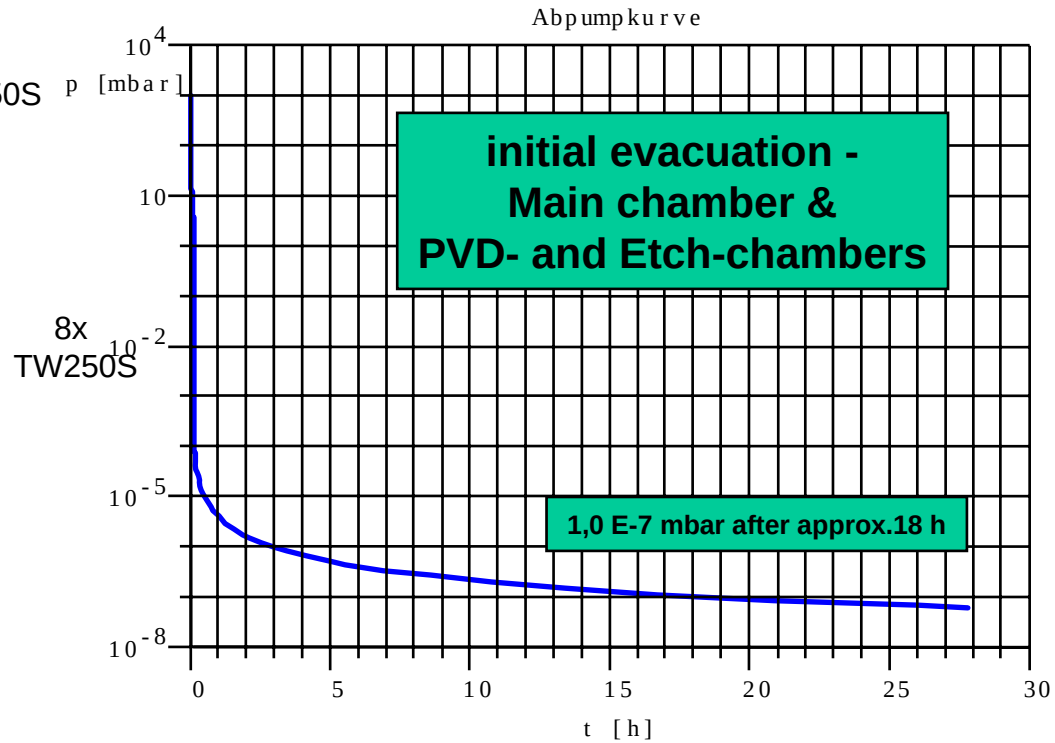
4C - Influence: Gas load caused by desorption



assumptions: degassing rates
steel 2x10^{-08} mbarl/scm²
aluminium 6x10^{-08} mbarl/scm²
no further desorption, permeation, or leaks

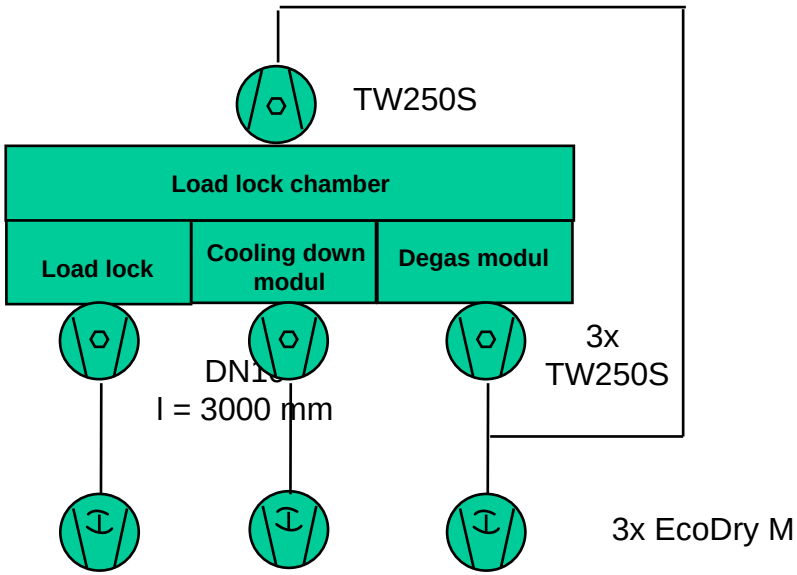
calculation model:

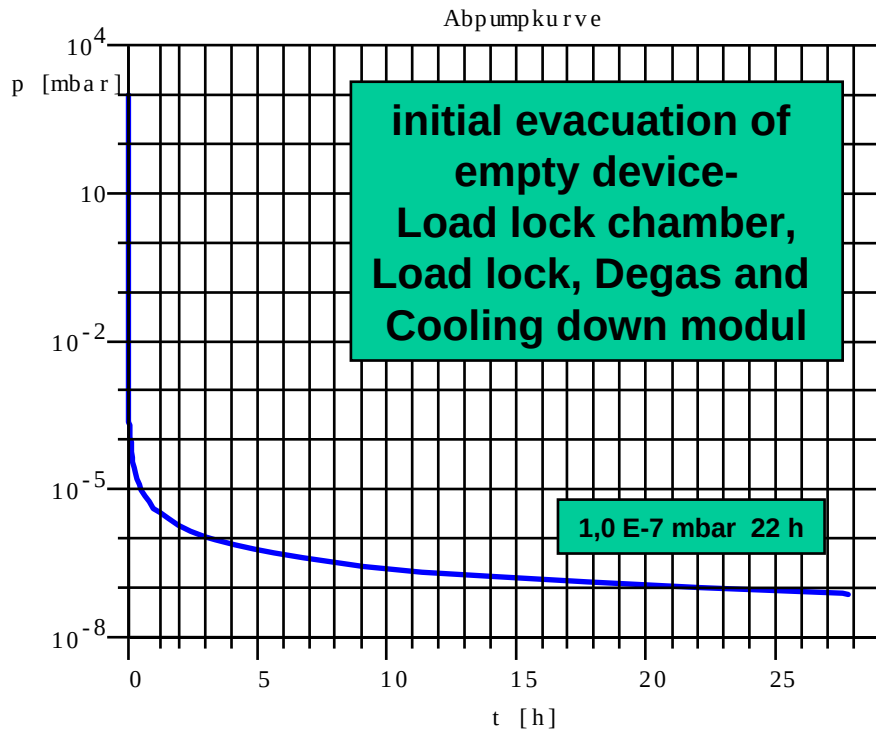




conditioning ofLoad Lock chamber, Degas module, Cooling down modul

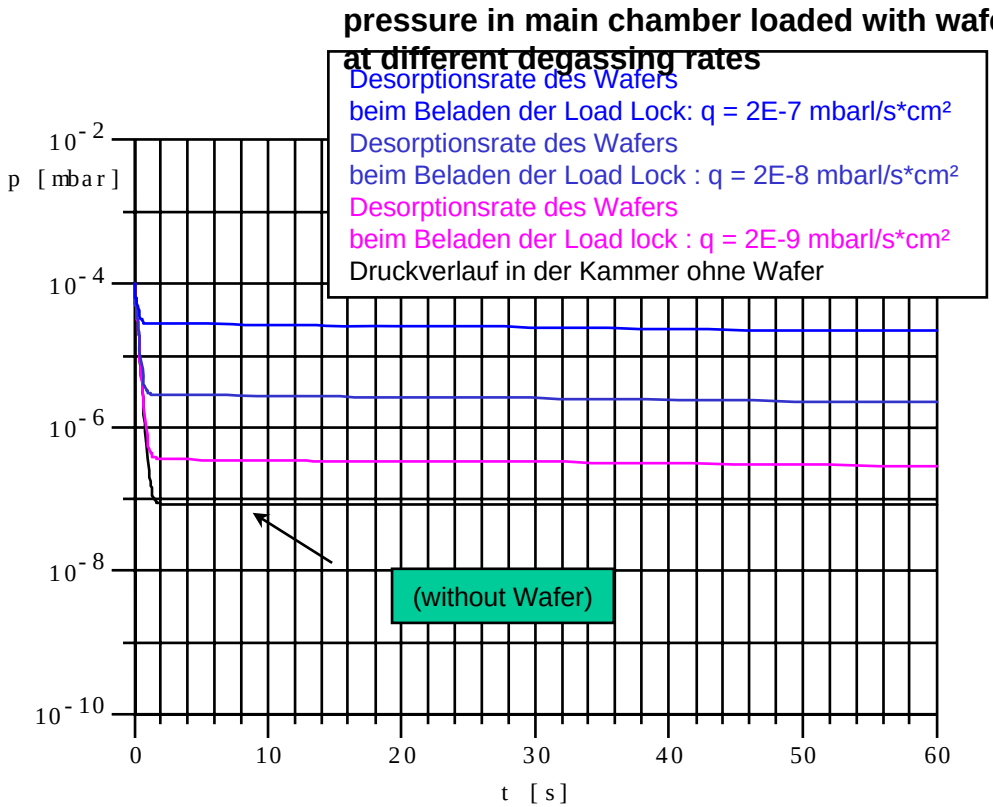
calculation modell:





➔ positive results calculated for empty chamber

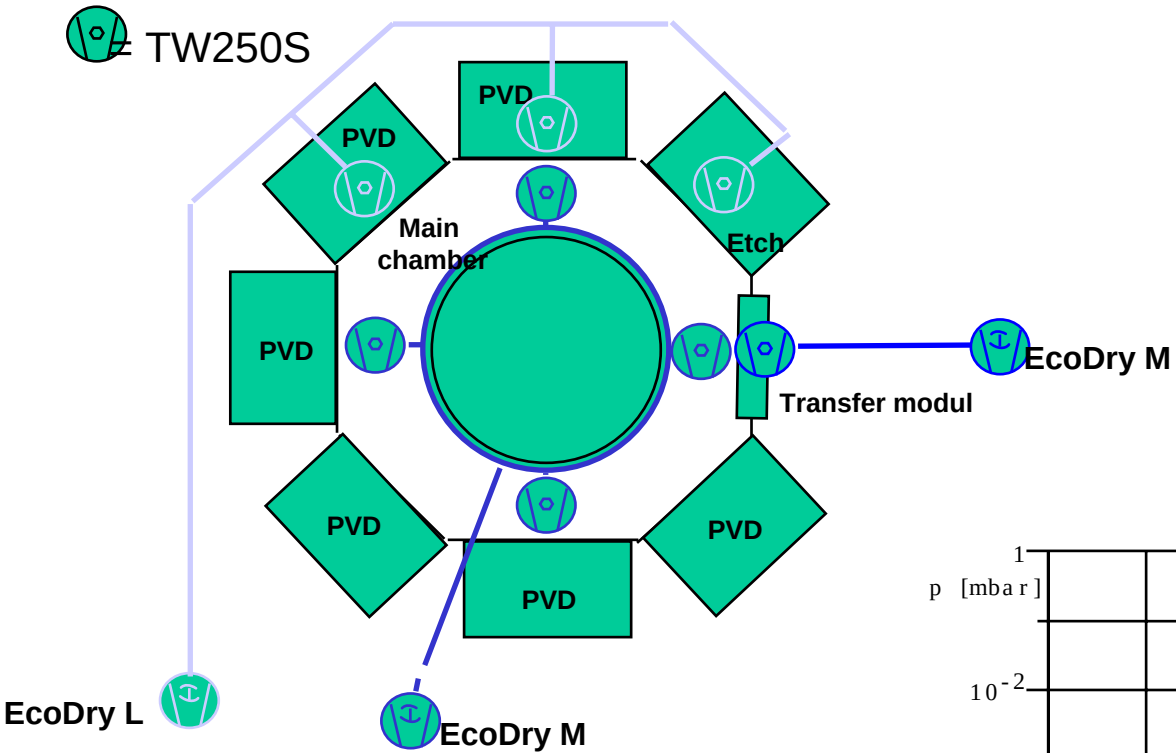
next step: chamber loaded with wafer

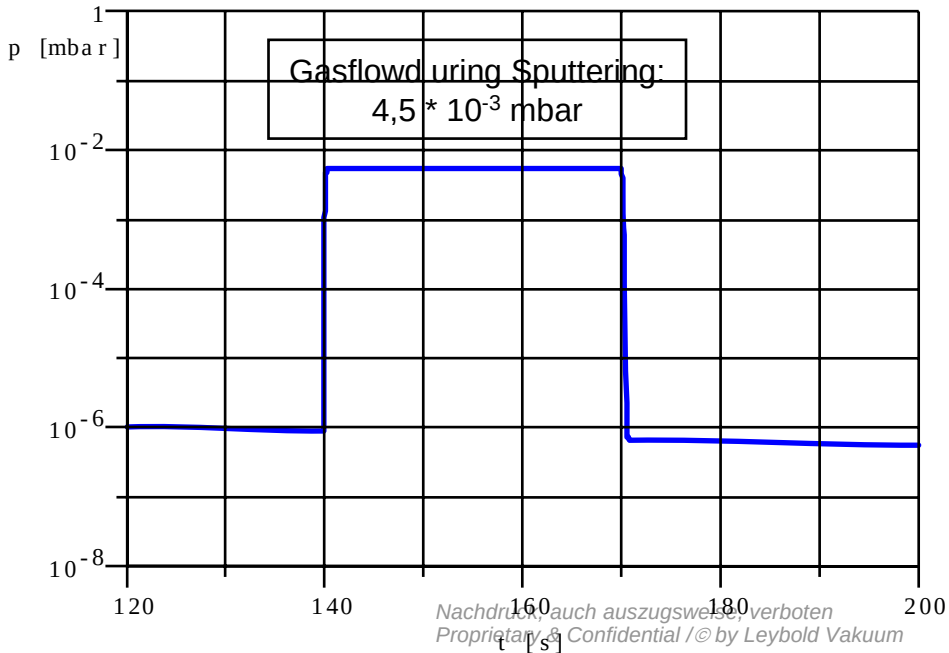


degassing rate of wafer will decline during time in chamber

➔ high impact from unknown/non-reproduceable degassing rate of wafer
➔ degas module highly recommended

next step: manufacturing of laboratory device without load-lock chamber





results:
cycle times verified
pumps archieve specified pressures
degassing chamber necessary

finally: picture of a commercial machine

Picture: Unaxis, Data Storage Coating System

short movies:

data storage

web coating

Typical industrial applications in Process Industry

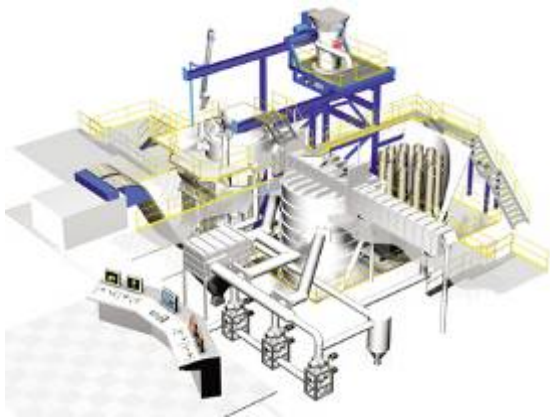
- Industrial Furnaces
- Metallurgical Systems
- Coating
- Packaging
- Distillation
- Drying

Distillation

Leak Testing

Heat Treatment

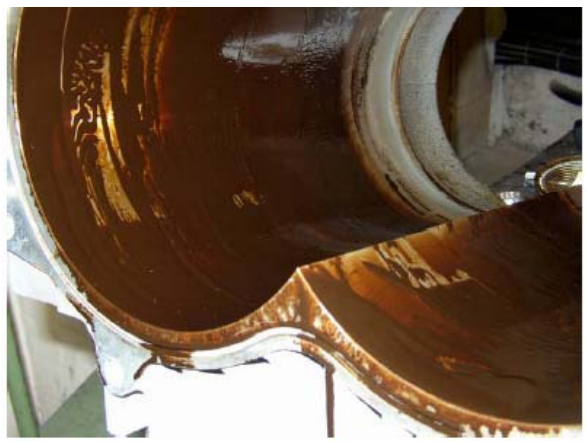
Cleaning and Vacuum Drying



Re-melting of special alloys

Typical environment for industrial vacuum pumps

- High dust or particle load
- Corrosive media can enter pump
- Vapors (e.g. water, oil, fluxing agents, waxes, resins, oligomers) need to be pumped
- Pumping of pure Oxygen gets more usual, e.g. in Coating applications



O_2

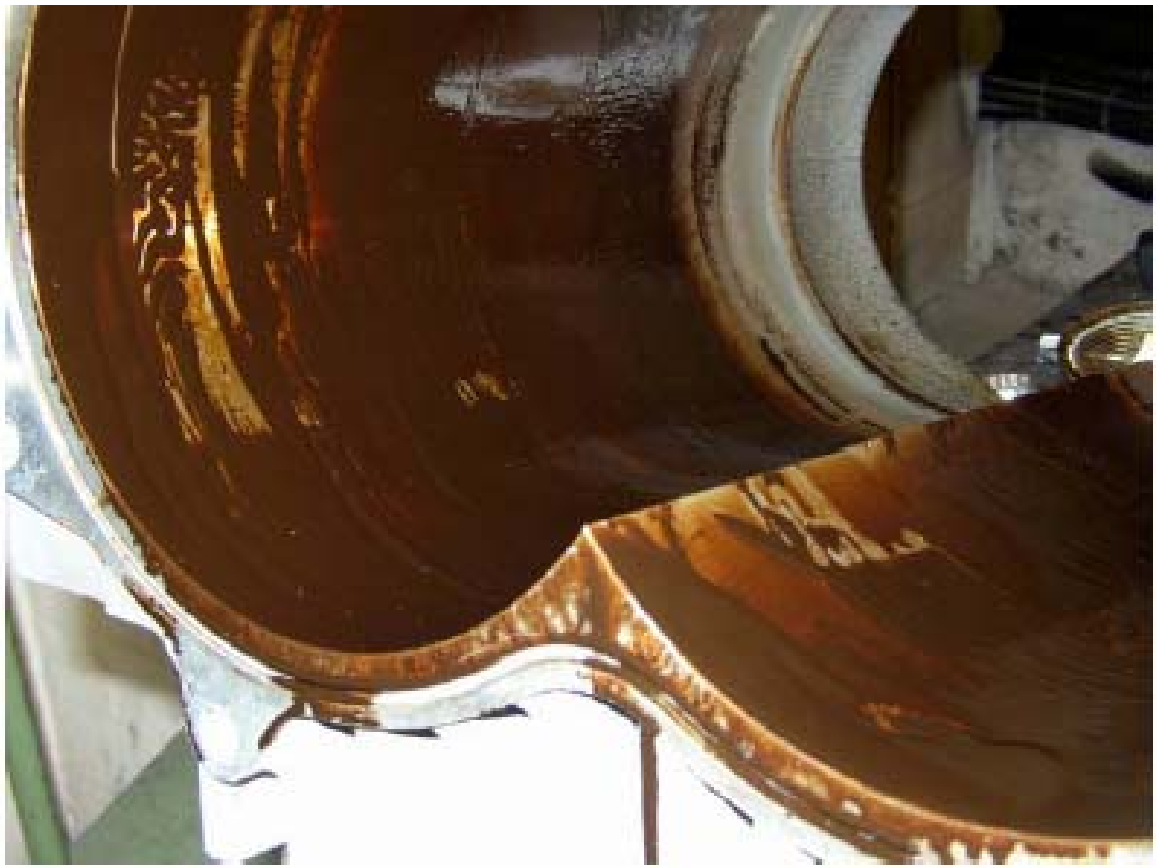
Application Example

Vacuum Sintering of cutting tools

Sintering of cutting tools. Dewaxing process under vacuum.

Vacuum Sintering of cutting tools

PEG used as binding material is found within the pumping chamber and the rotors. Rotary Vane Pumps failed due to accumulation of this material inside the oil circuit.



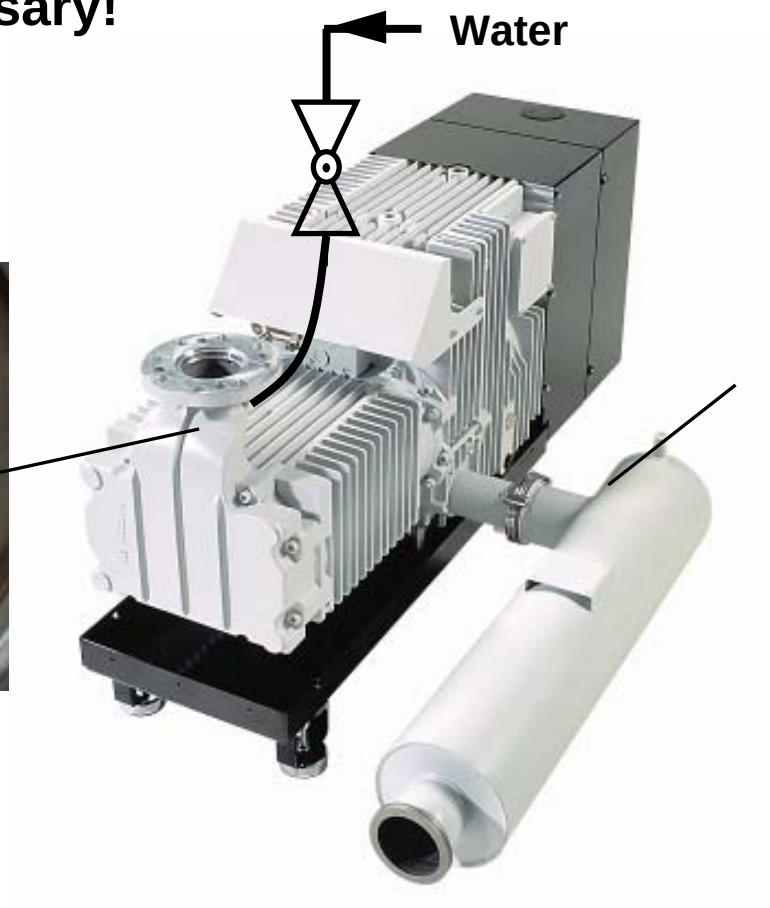
Vacuum Sintering of cutting tools

Rotors and pumping chamber can be cleaned manually by acetone which is reasonable for infrequent cleaning (6 – 8 weeks)

Dismantling the pumping chamber is necessary.

Vacuum Sintering of cutting tools

For frequent cleaning purpose a flushing kit can be used when rotors turning.
No dismantling of the pump chamber is necessary!



Vacuum Sintering of cutting tools

Before cleaning

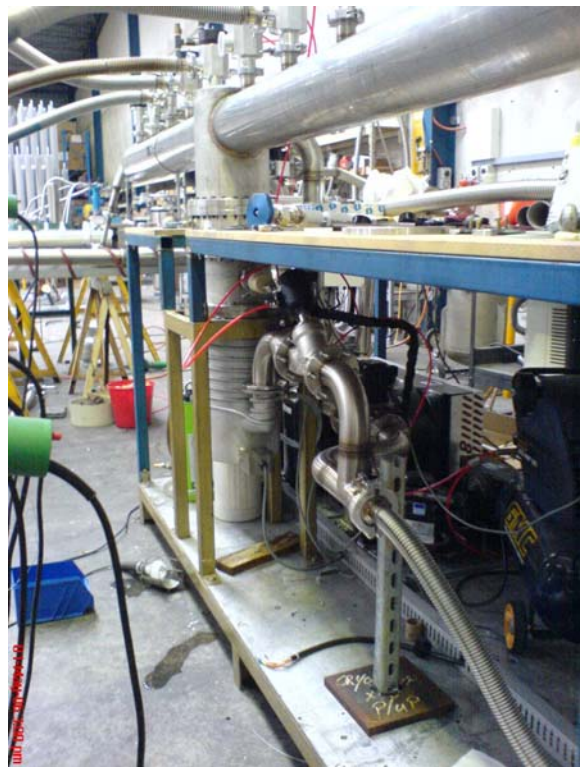
Cleaning results after flushing with 8 litres water.

After cleaning

➔ Dry pump can handle process related layers!
Manual cleaning or flushing are possible!

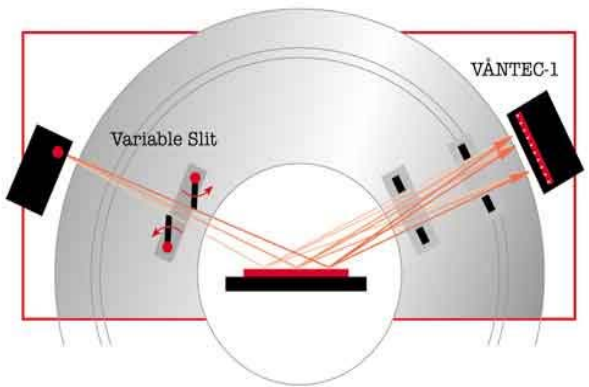
education level in industry may be lower than in large research facilities

example: conductance losses unknown in evacuation of cryogenic lines?



Typical Analytical Instruments

- Mass Spectrometers
- Electron Microscopes
- X-Ray Analyser



Vacuum Pumps for Analytical Instruments

Definition :

Analytical Instruments are used to investigate and identify substances and/or structures.

Vacuum is needed

- to isolate the species from the environment in order to get a clear signal. The lower the pressure, the better;

- to produce the necessary free length of path in order to achieve high resolution images and spectra or to warrant the required lifetime of the electrodes at X-ray guns

Vacuum Pumps for Analytical Instruments

Some Applications for Analytical Instruments

		Mass-Spectrometer	Electron Microscopes	Leakdetector	X-ray analyser
Health Care	Genomics				
	Proteomics				
	Drug Discovery				
	Metabolism				
Defense / Security	Bomb Detection				
	Forensic				
Qualiy Control	Semiconductor				
	Automotive				
	Food				
	Enviromental Control				

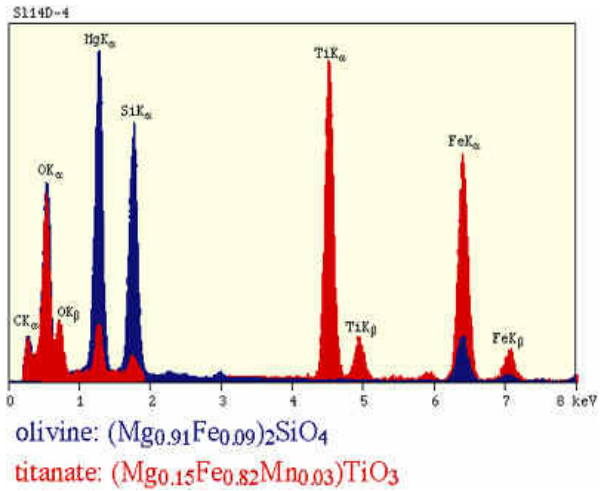
the sum of the processes in the buildup and destruction of protoplasm

Mapped the human genome and develop new drugs based on their research

separation and identification of proteins

Vacuum Pumps for Analytical Instruments

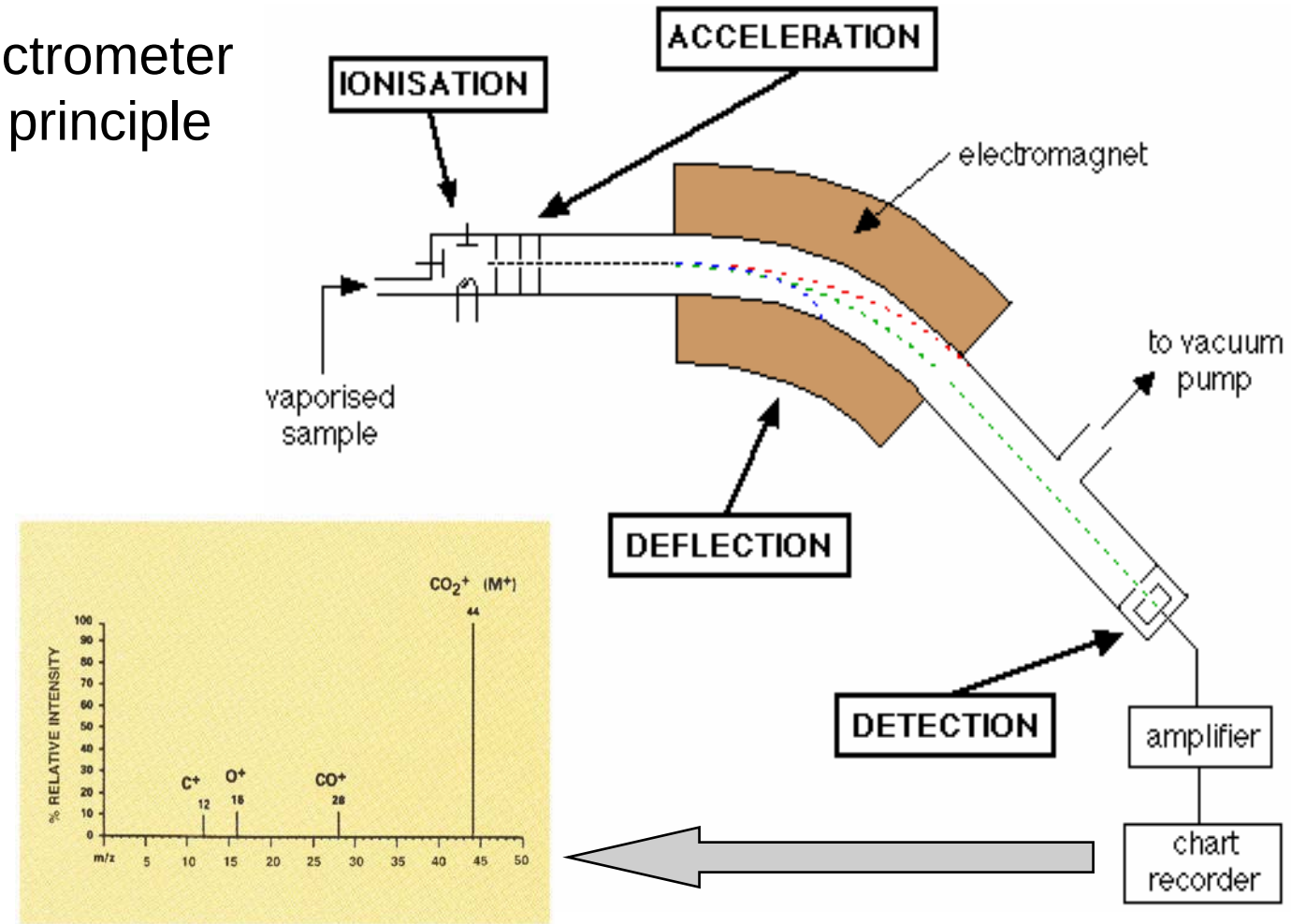
<u>Mass Spectrometer:</u> Defined as a machine, that determines what substances are and/or how much there is



Sample of substance → **Mass Spectrometer** → **What it is and how much**

Vacuum Pumps for Analytical Instruments

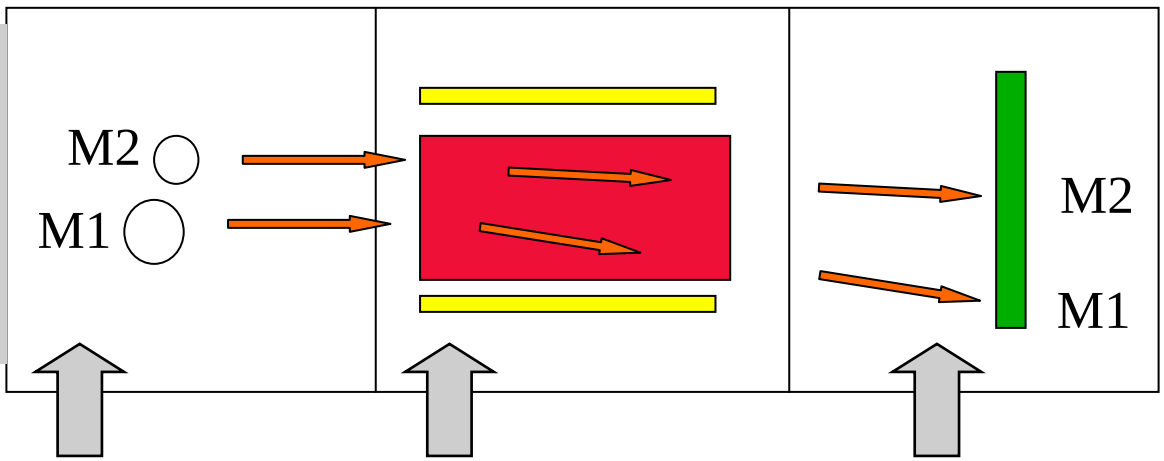
Mass Spectrometer functional principle



Vacuum Pumps for Analytical Instruments

Mass Spectrometers consist of 3 main components

Solid or liquid samples will be evaporated



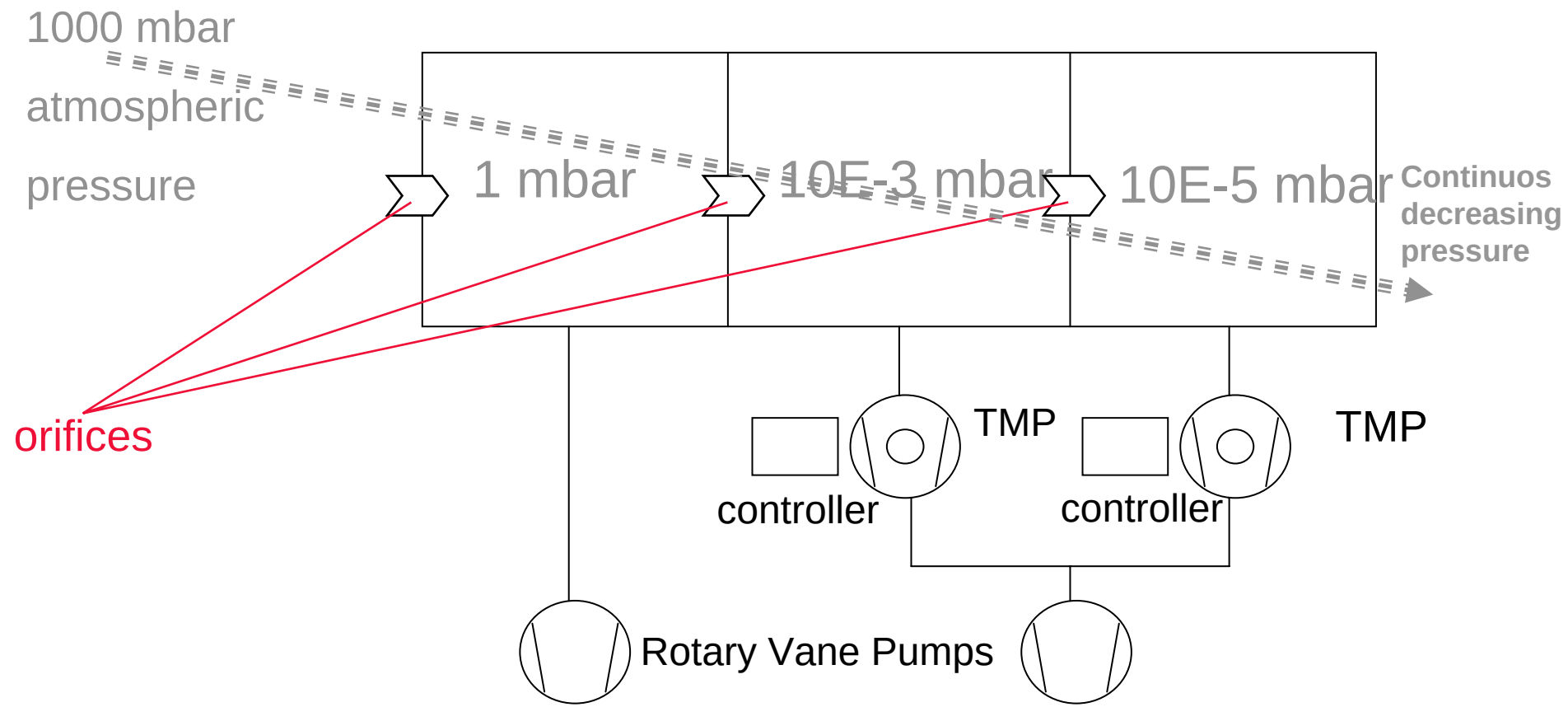
1) Sample Inlet
- **GC** gas chromatograph
- **LC** liquid chromatograph
- **ICP** ion coupled plasma
- **MALDI** matrix assisted laser desorption/ionisation

2) Mass seperator
this can be
- **Quadrupole,**
- **Ion Trap,**
- **Magnetic sector,**
- **Time of Flight Tube**

3) Detector
this can be
- **Electron Multiplier,**
- **Channelplate**

Vacuum Pumps for Analytical Instruments

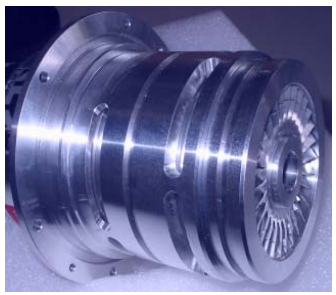
Typical Vacuum Schematic of a Mass Spectrometer



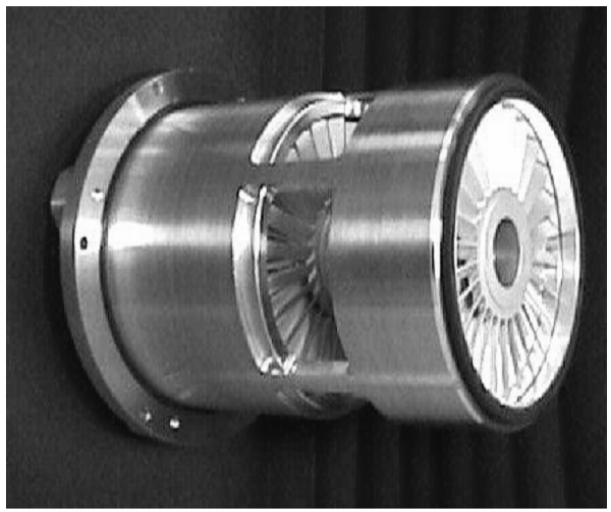
Vacuum Pumps for Analytical Instruments

Special Vacuum Pumps for Mass Spectrometers

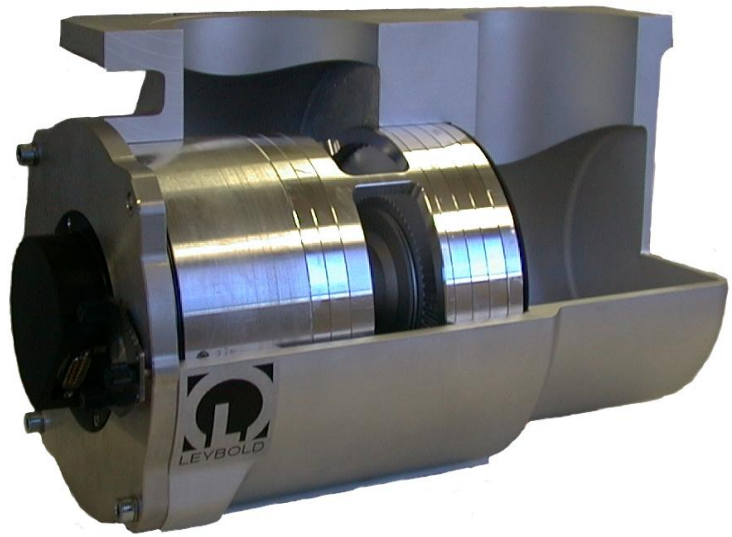
1 mbar	10E-3 mbar	10E-5 mbar



TW
70LS
cartridge



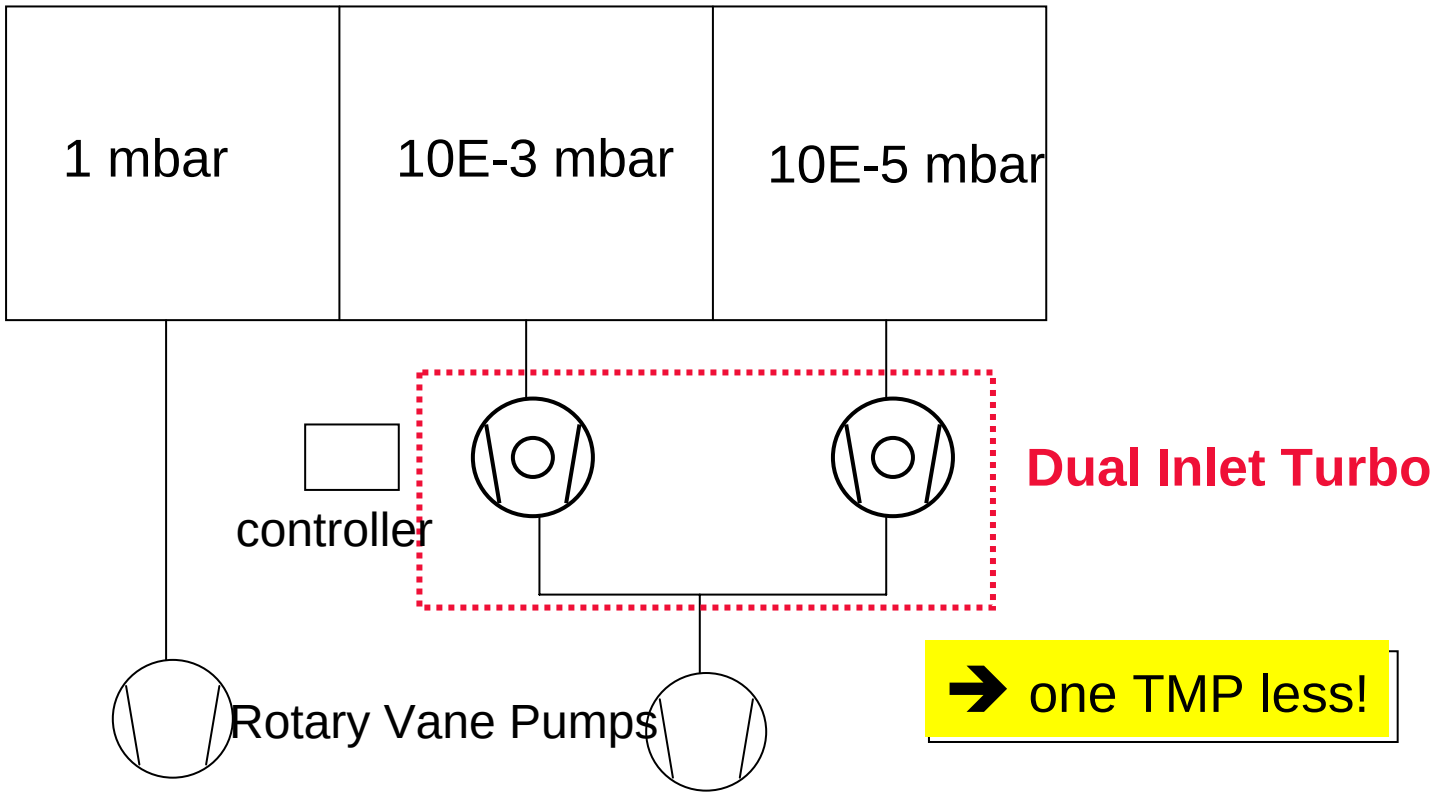
TW 220/150
cartridge



TW 220/150
with customised housing

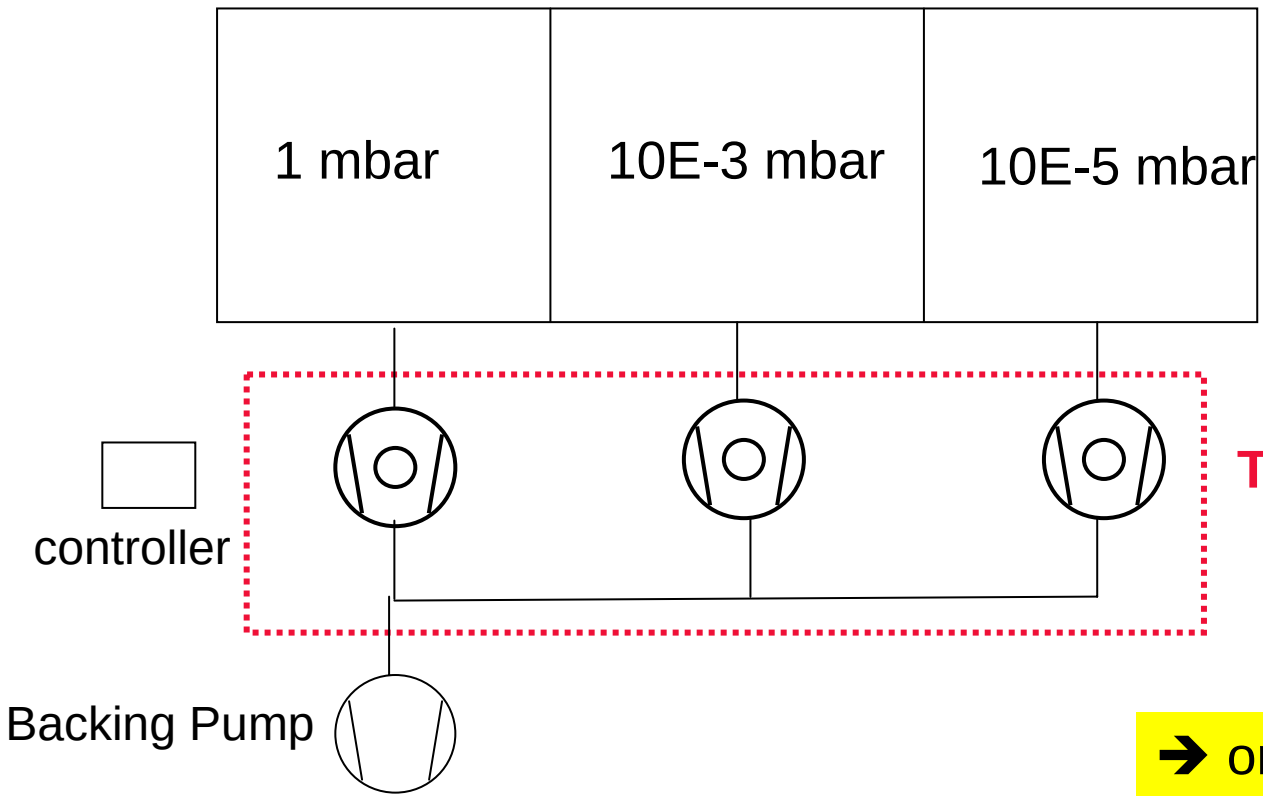
Vacuum Pumps for Analytical Instruments

customer requirement: cost/size/weight – reduction:
(Multiple Inlet Turbo)



Vacuum Pumps for Analytical Instruments

Typical Vacuum Schematic
(Multiple Inlet Turbo)



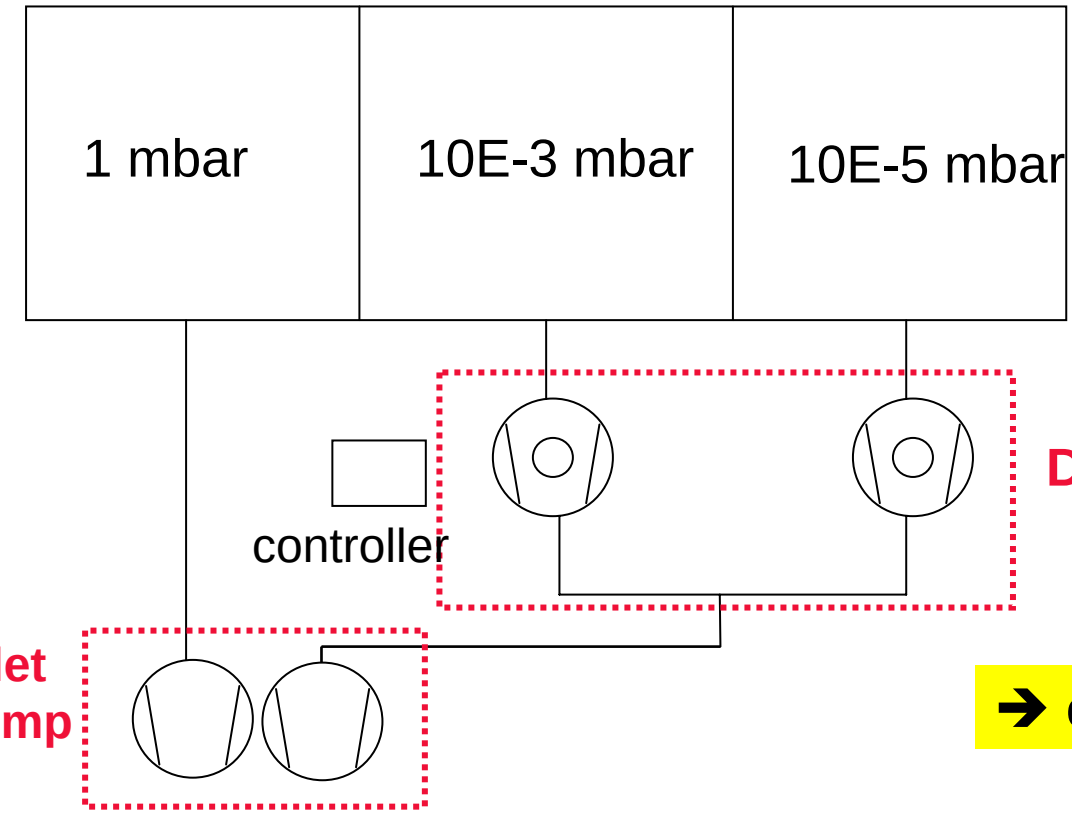
Triple Inlet Turbo

➔ one more TMP less!

Vacuum Pumps for Analytical Instruments

Typical Vacuum Schematic

(Multiple Inlet Turbo and Twin Inlet Vane Pump)



➔ one RVP less!

Vacuum Pumps for Analytical Instruments

Typical Vacuum Pumps for a Mass Spectrometer

TW 220/150
with customised
housing
integrated into a MS
of Thermofinigan

displayed on
ANALYTICA show
Munich 2004

Thank You !