Short Introduction to Cryo-Pumps and Refrigerators

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Cryo Pumps

Topics

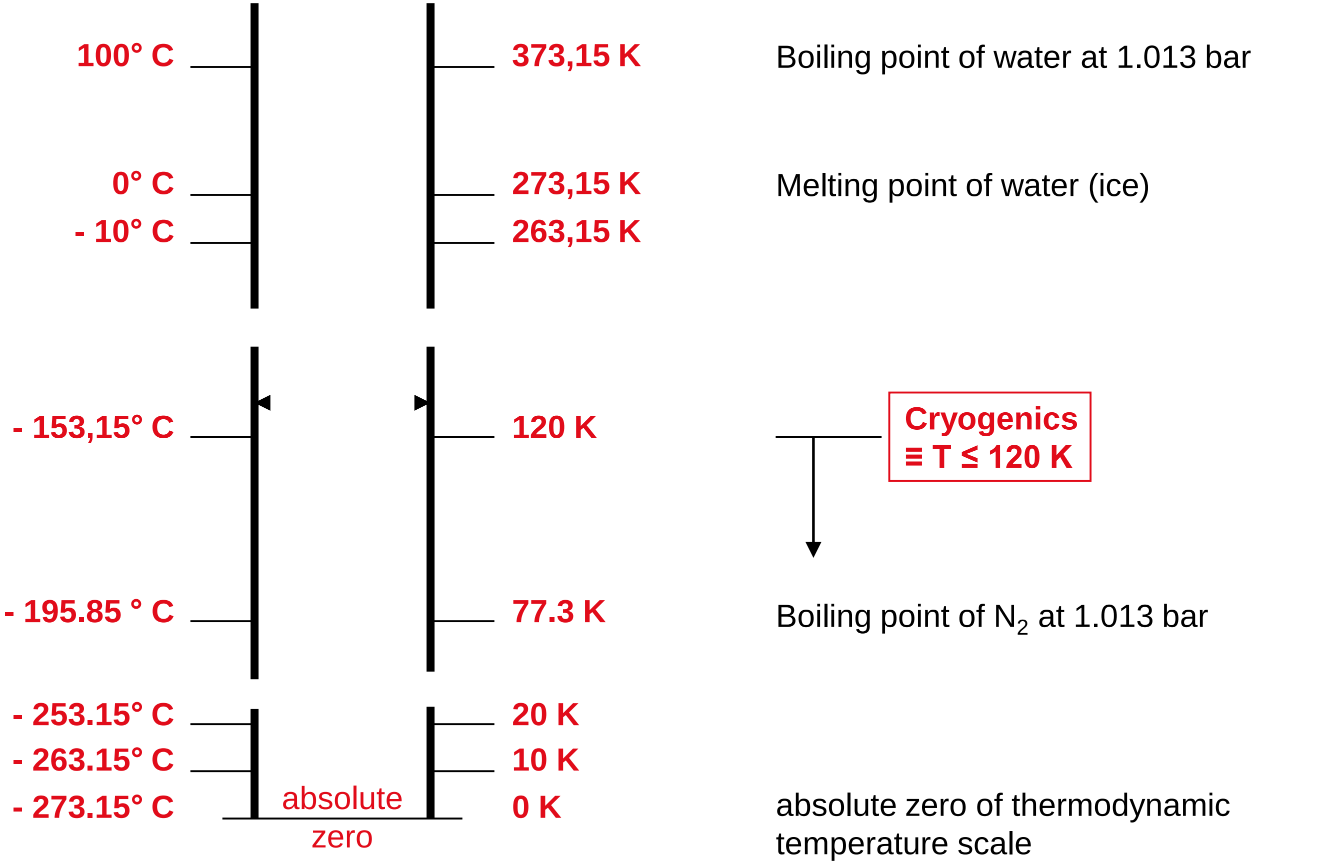
- Physical principles of cryo-pumping
- Design and control of modern refrigerator cryo-pumps
- UHV and XHV cryopumps
- Advantages – Disadvantages of cryo-pumps
- Typical applications in industry and research

Cryogenics – Temperature Scales

formula: T [K] = (t [°C] + 273.15) K
t [°C] = (T [K] - 273.15) °C

Celsius Temperature Scale (t)
Degrees Celsius (°C)

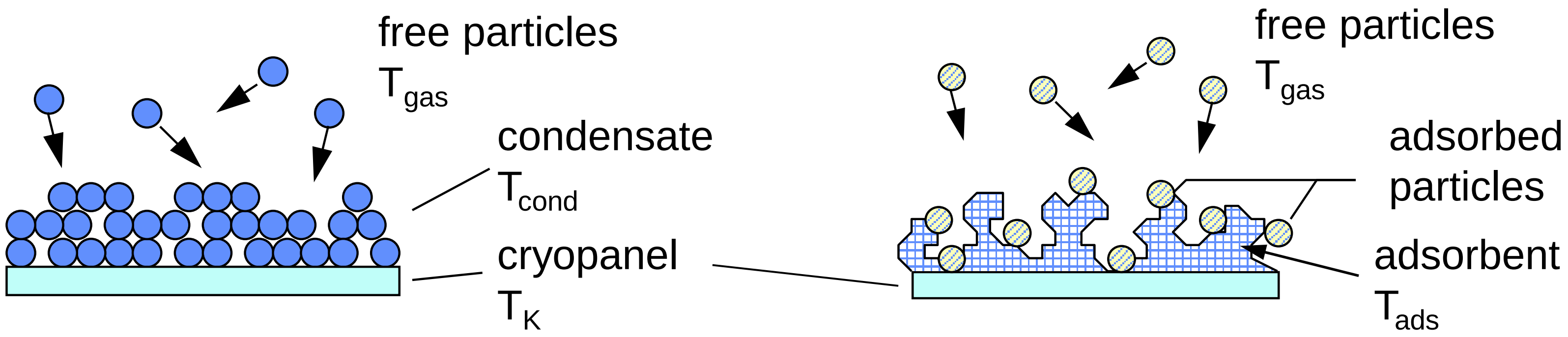
Thermodynamic Temperature (T)
(Degrees) Kelvin (K)



Physical Effects Active In A Cryopump

1. Condensation

2. Adsorption



several layers of molecules, thickness up to > 10 mm example: N_2, Ar, H_2O

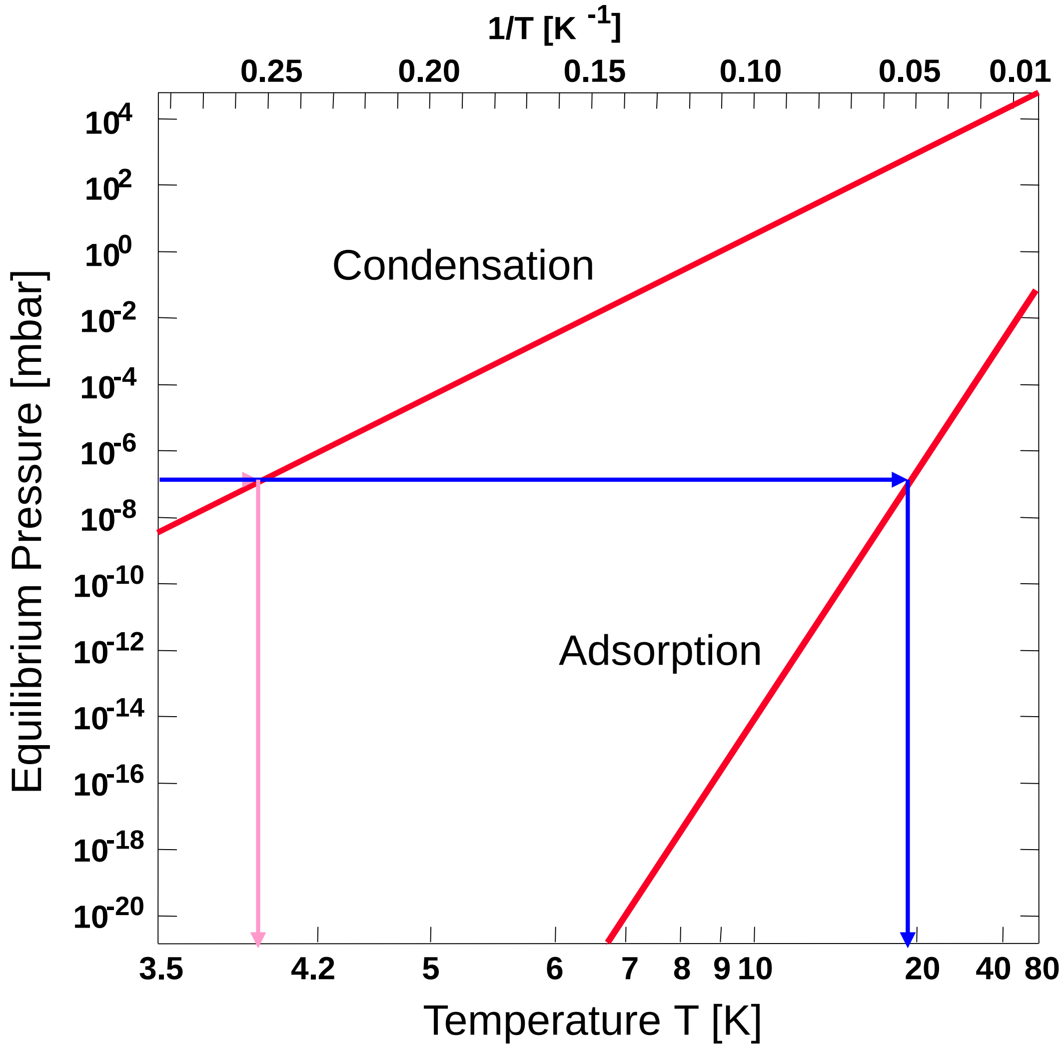
only monolayers
example: H_2, He, Ne on charcoal

- In a cryopump, all gases are pumped by condensation at low temperatures
- The low temperatures are provided by a 2 stage cooling machine, the ‚cryo-refrigerator'

The temperatures required to pump all gasses in high vacuum are explained on the next slides

Equilibrium pressure for condensation

And adsorption of H2 on charcoal



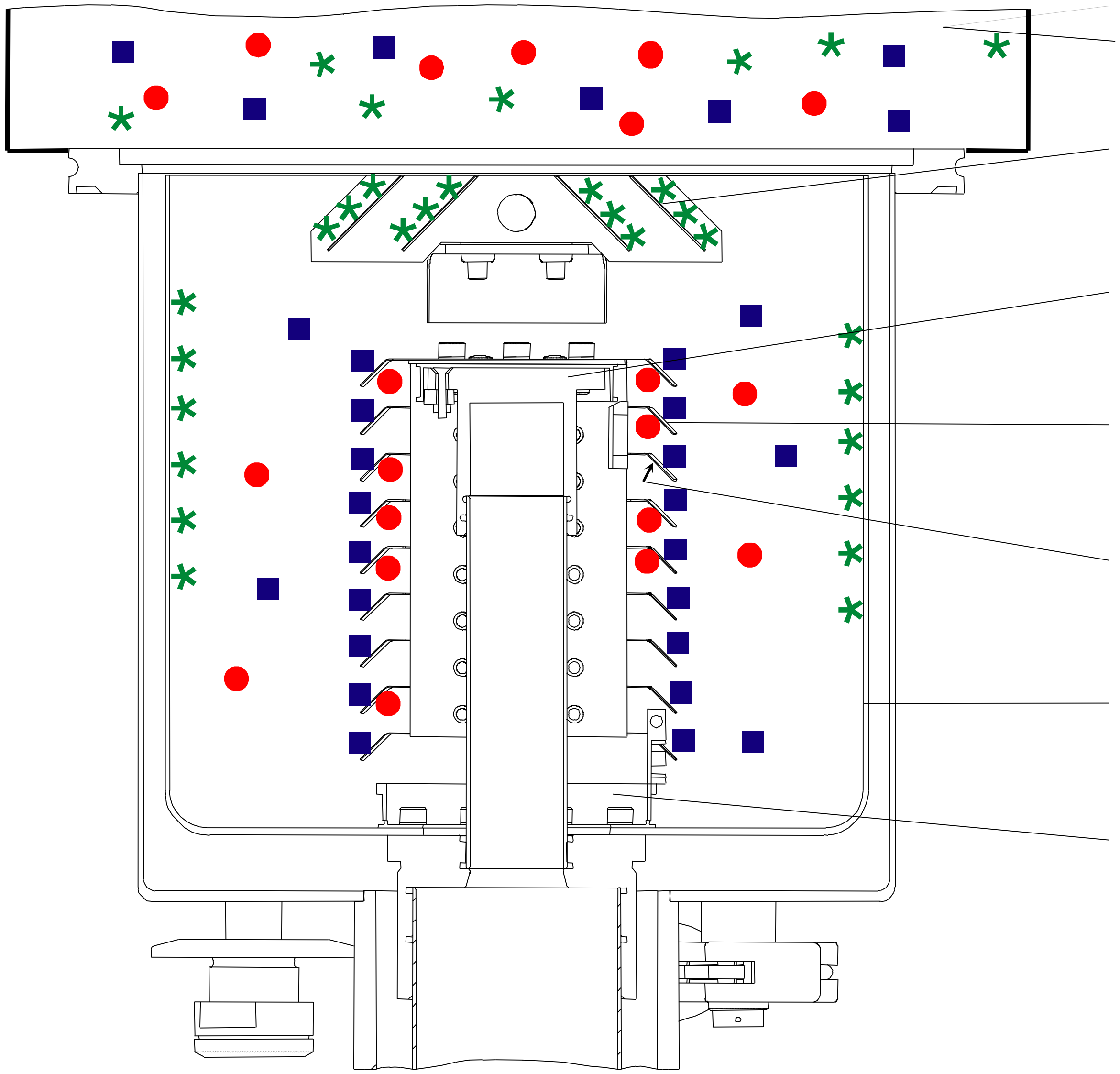
Example: H_2

To reach partial pressures in the high vacuum regime by condensation, temperatures of <4 K are required.

The same pressure regime can be reached much easier by cryo-sorption on activated charcoal at significantly higher temperatures

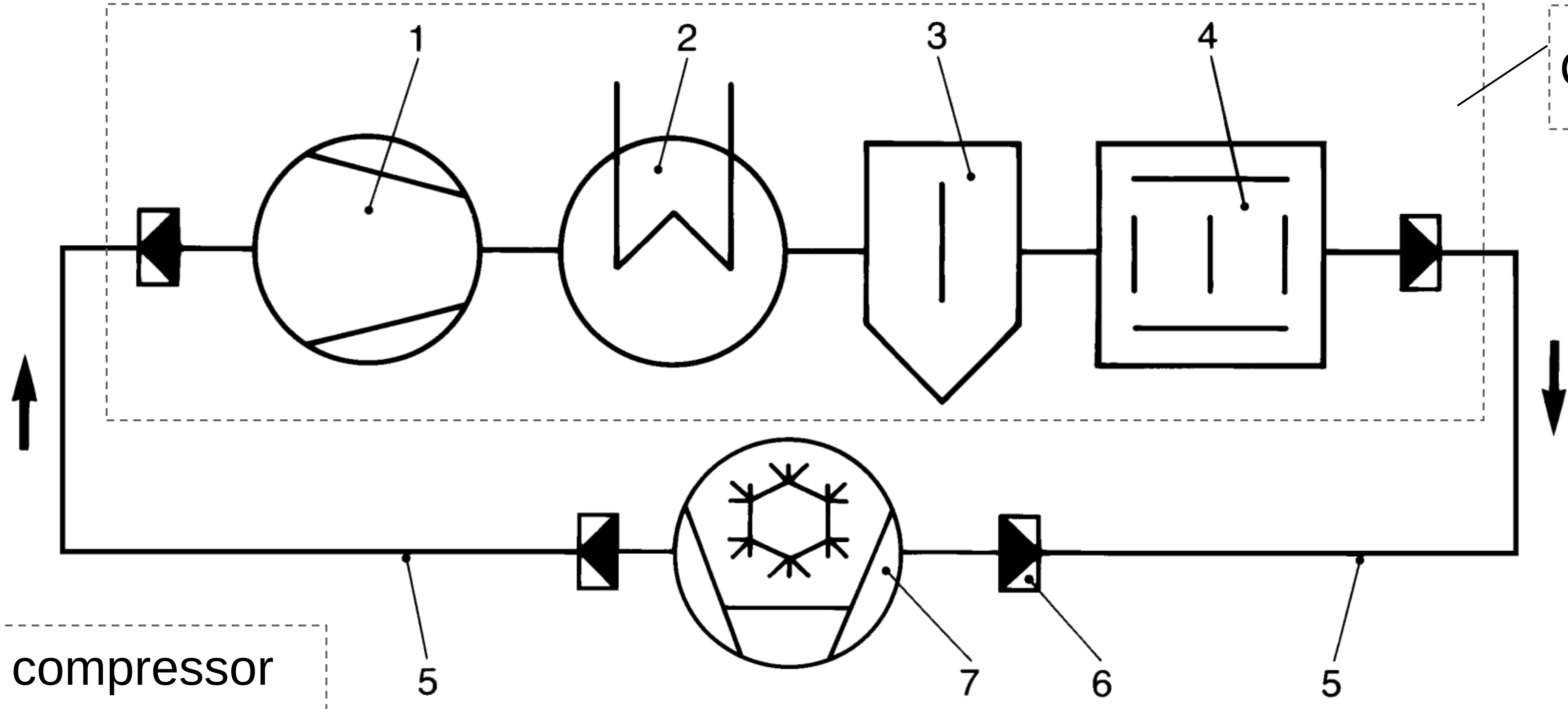
Temperatures which can be reached with standard cryo-refrigerators: ≤10 K

Cryo-Pump – Schematic



- gases condensated at high temperatures (H_2O, CO_2)
- gases condensated at low temperatures (N_2, Ar, O_2)
- gases adsorbed on activated charcoal (H_2, He, Ne)

Gifford McMahon Refrigerator System – Symplified Schematic For Helium Circuit



Compressor unit

1. Helium compressor
2. Heat exchanger
3. Oil separator
4. Oil adsorber
5. Flexlines
6. Self-sealing couplings
7. Cold head or cryo pump

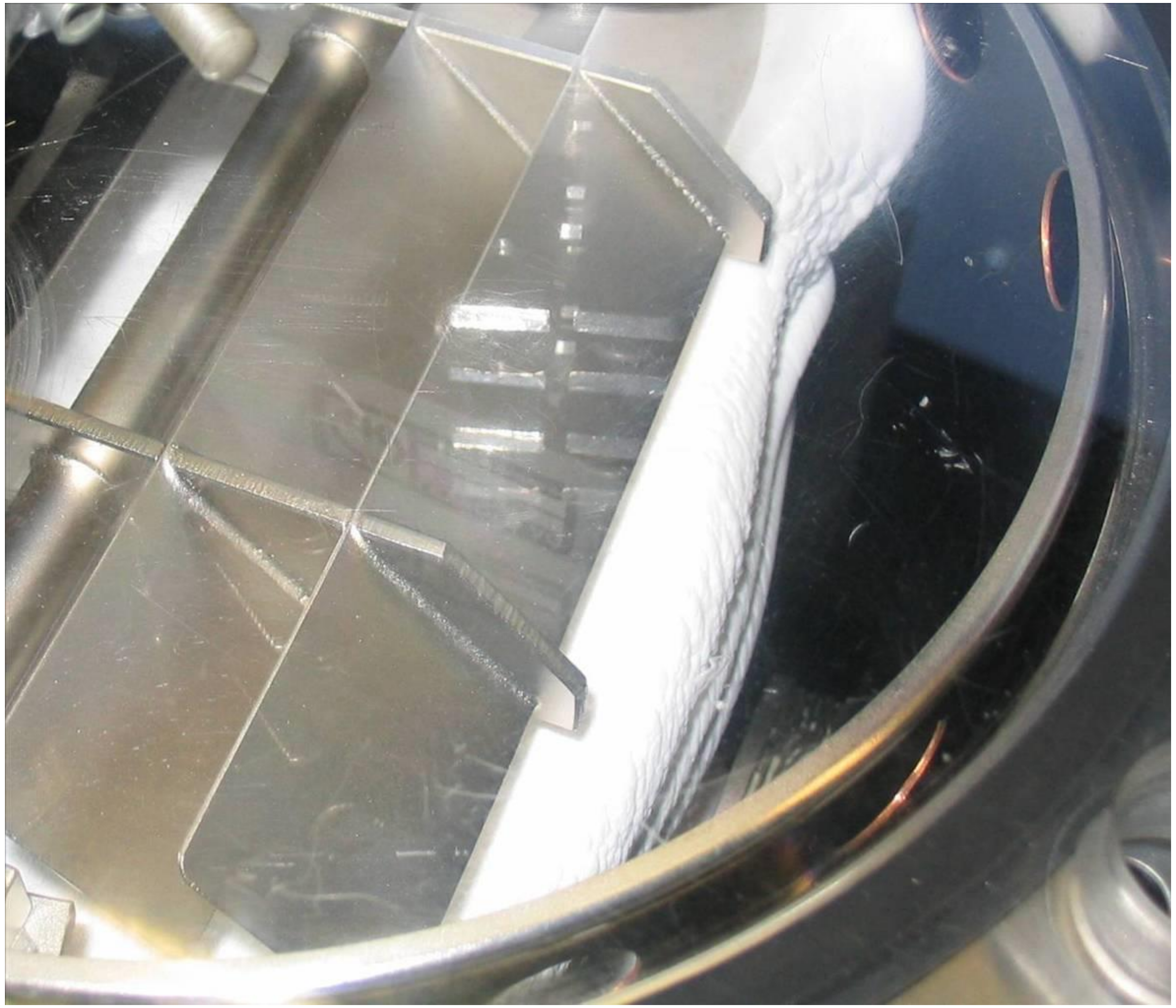
Compressor Unit

Important parameters for use of cryopumps

Starting pressure (mbar)

- Basically a start at atmosphere would be possible, but the heat load for the cold panels would be too high and the pump panels would be coated by frozen air (water vapour and nitrogen), which disables them to pump e.g. hydrogen to reach low ultimate pressure
- **If pressure in the lower UHV regime need to be reached, it is recommended to start cryo-pumps at pressures < 10-3 mbar.**
- Else evacuation of the cryopump to typically 0.1 ... 0.05 mbar is sufficient before starting the cooldown.

How does it look like in the cryopump, when it is loaded with gas, and when it needs to be regenerated?



Important operation parameters of cryopumps

- **Cooldown time**
  Time to cool the internal parts by the refrigerator (60 – 180 minutes)
- **Regeneration interval**
  Operation time for an individual gas until the pump is saturated and has to be regenerated (warm to room temperature to evaporate the condensate, evacuate the cryopump with a roughing pump and cool down again)
  pump operated at 10^{-08} mbar: approx. 300 years
  10^{-06} mbar: approx. 3 years
  10^{-04} mbar: approx. 10 days
- **Cryopumps** have higher pumping speeds than TMP or diffusion pumps with comparable flanges sizes (4 times higher for H_2O!)

The cryopump is ideal for low pressure applications where large pumping speeds especially for water vapour are required

Limits for ultimate pressure of cryopumps

Classic cryopumps

Ultimate pressure limited by

- Restricted baking possibilities of chamber
- Leak rate of O-rings of safety valve, feed-throughs etc.
- Degassing from wiring of diode, heaters

⇒ $P_{ult} < 1 \times 10^{-9}$ mbar

UHV cryopumps

Measures: all metal-sealed (rupture disk, feed-through, special diode)
Ultimate Pressure still limited by

- Unbaked cryopump
- Limited baking possibilities of chamber

⇒ $P_{ult} = 1 - 3 \times 10^{-11}$ mbar

Limits for ultimate pressure of cryopumps

Special solution suitable to reach XHV:

Cryopump with additional LN2-cooling during baking

- Allows baking of chamber and pump housing to >180 C
- During bakeout
  P_{ult} 1 x 10^{-9} ... 1 x 10^{-10} mbar
- After bakeout
  P_{ult} < 1 x 10^{-12} mbar

Cryopump is used during bakeout

⇒ much more effective to pump water vapour

Cryogenic Applications

Semiconductor Industry

- Sputtering (PVD) Systems
- Ion Implanters
- Transfer Chambers
- Load Lock Chambers

Cryogenic Applications

Coating

Precision Optics

- Lenses
- Optical Filters
- Mirrors
- Displays

Electronics

- Hard Disks
- Magneto-optical (MO) Disks
- Magnetic Heads

Cryogenic Applications

Process Industry

- Electron Beam Welding
- Furnace

Research and Development

- Space Simulation Chambers
- Big Testing Chambers

Thank you for your attention!