Vacuum Technology II: Kinetic & Entrapment Pumping

Corbyn Mellinger

Xu Group Meeting

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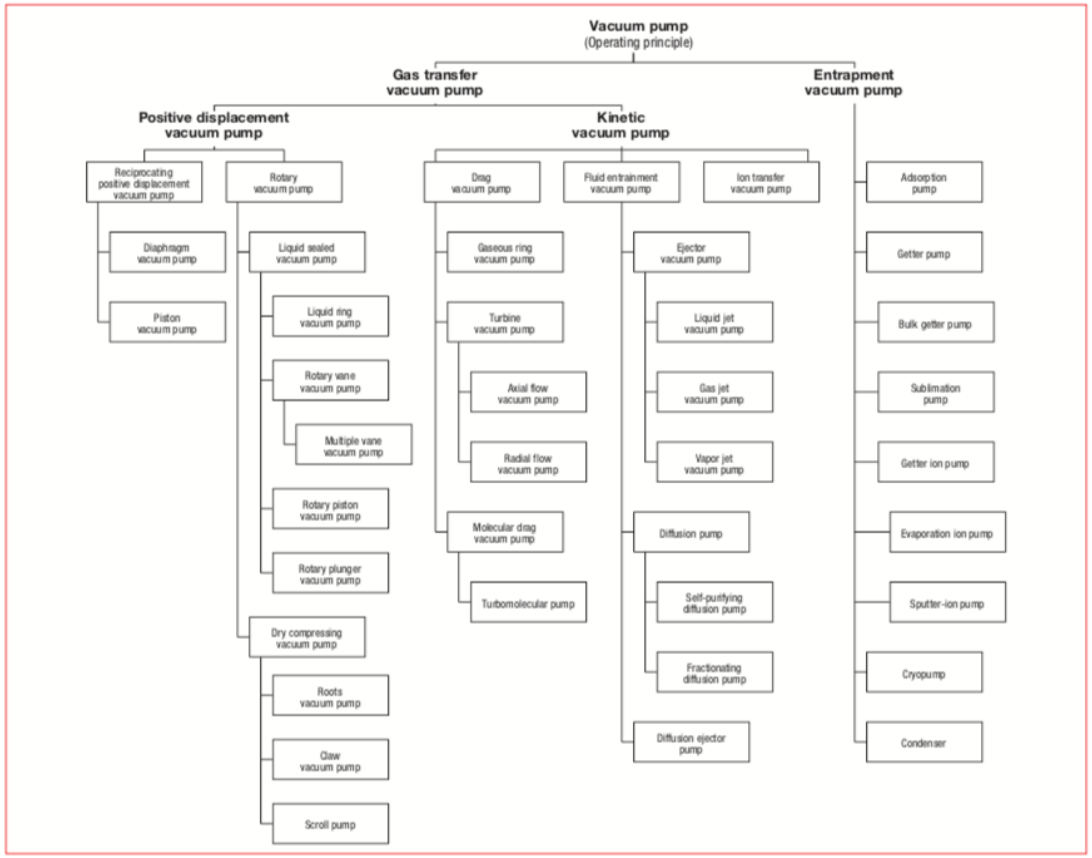
Classification of Pumping Mechanisms

- Lots of mechanisms to consider!
- Main mechanisms:

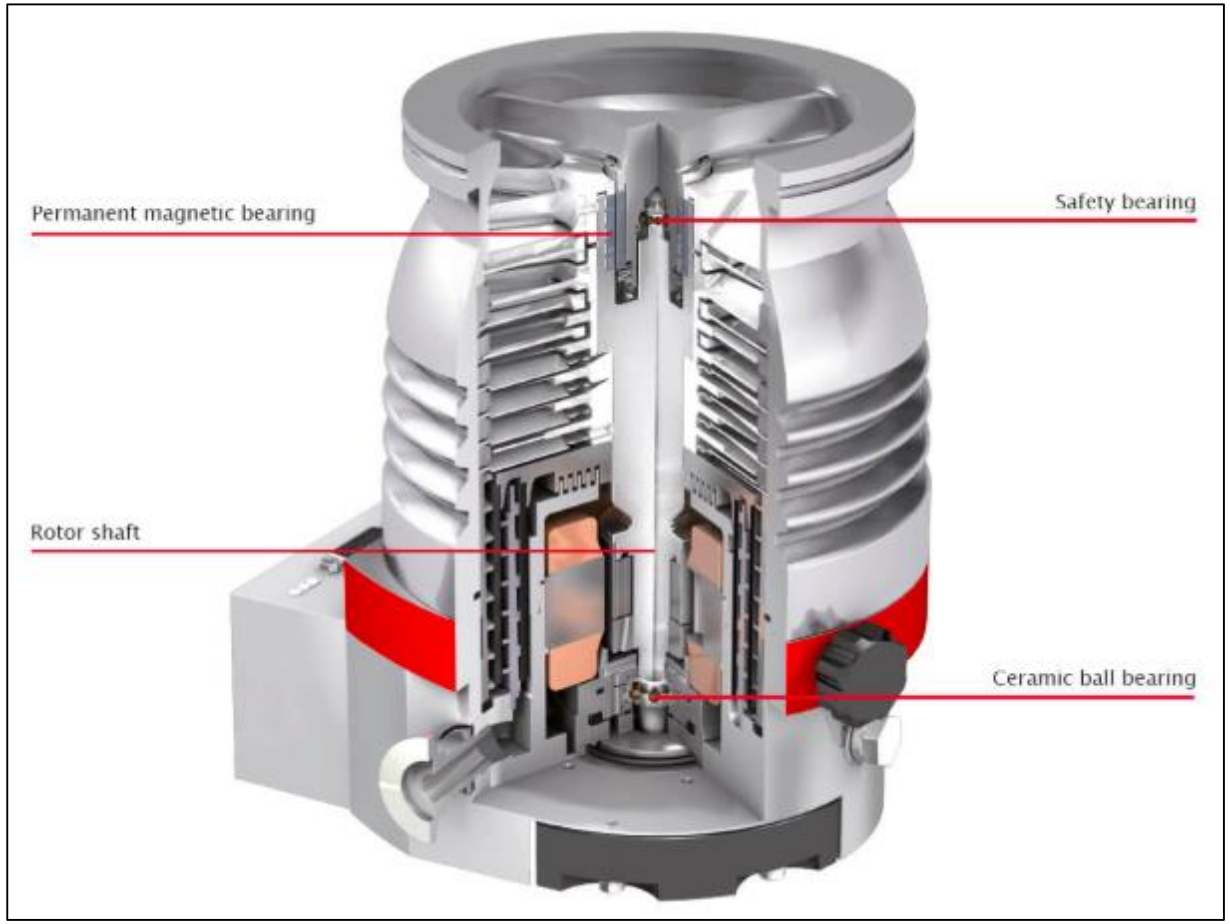
Last time:
- Periodic change of chamber volume

This time:
- Direct gas without change of chamber volume
- Diffusion into a jet vapor
- Condensation of gasses
- Absorption to surfaces

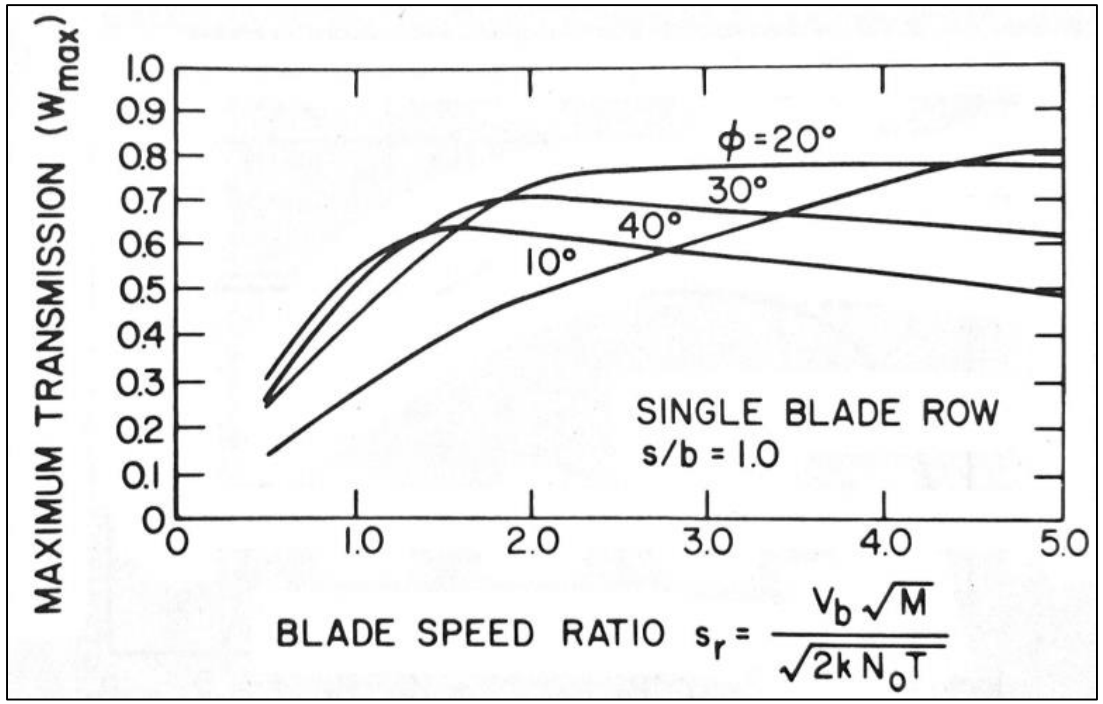


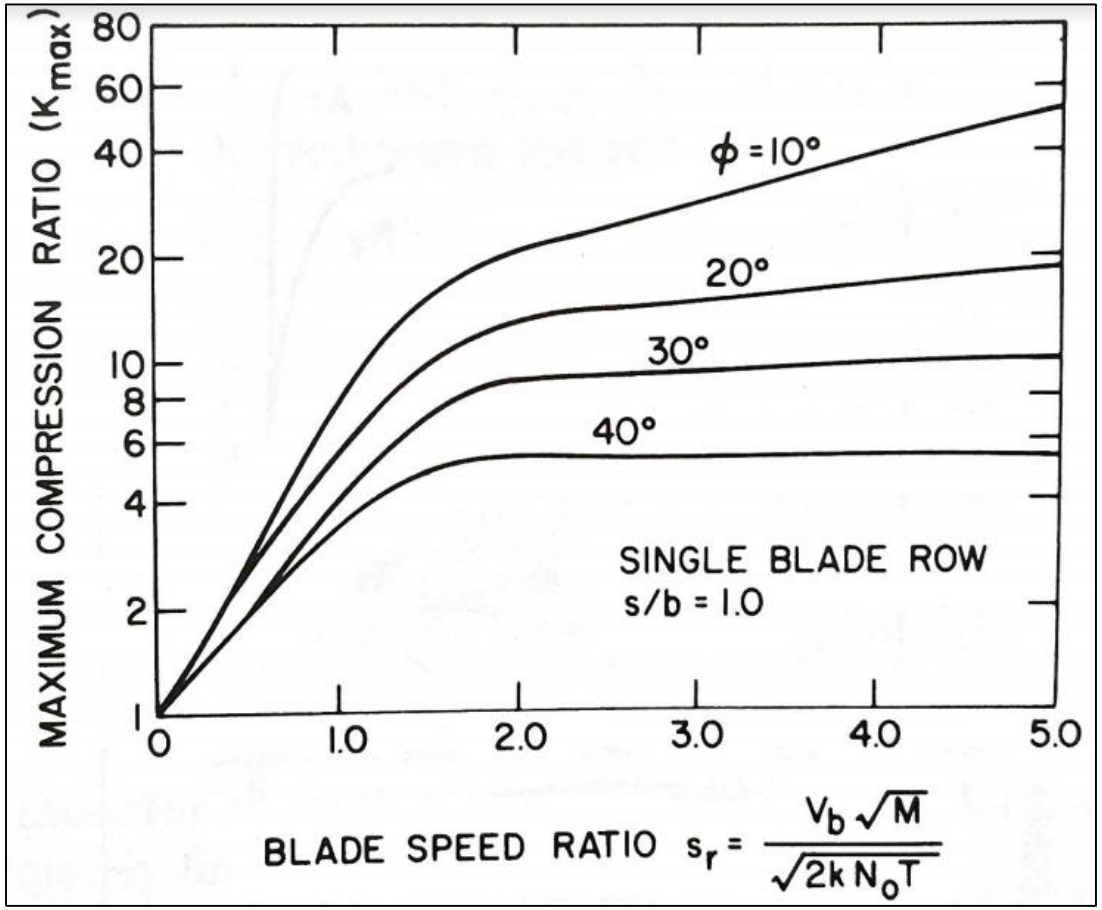
Turbomolecular Pumping

- Turbine-like blades physically ”strike” gas molecules (oil free)
- Maximum compression:
  - $K_{max} \propto \exp\left(\frac{v_b\sqrt{M}}{\sqrt{2k_B N_0 T}}\right)$
- Bearings (steel or ceramic) for rotors
- Magnetic levitation used for some systems
  - Hybrid: bearing and levitation systems
- Ultimate pressure: ~10^{-10} Torr



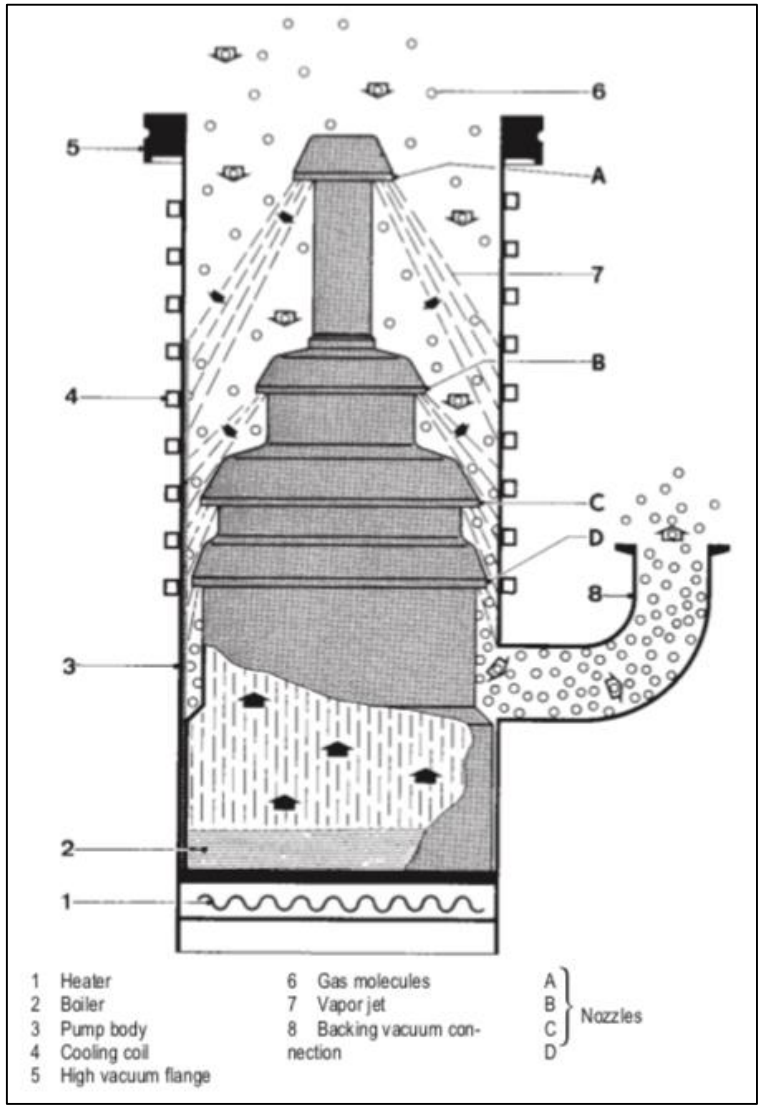
Turbomolecular Pumping





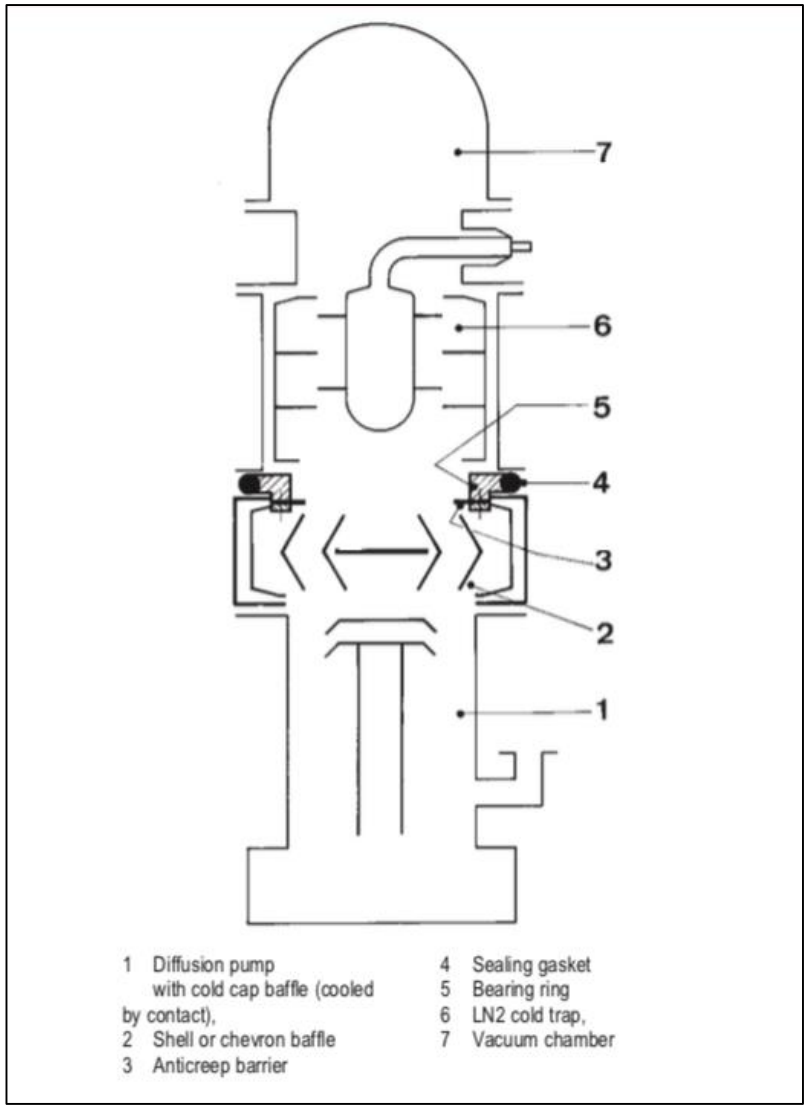
Diffusion Pumping

- Jet of liquid shot at high speed from nozzle
  - Physically impinge on molecules
  - Gasses diffuse into stream and are removed from system
- Water jet (~10 Torr), vapor jet (~10^{-3} Torr), oil jet (~10^{-10} Torr)
- Pump walls chilled to condense jet and prevent backflow of oil
  - Oil degassed before repumping



Diffusion Pumping

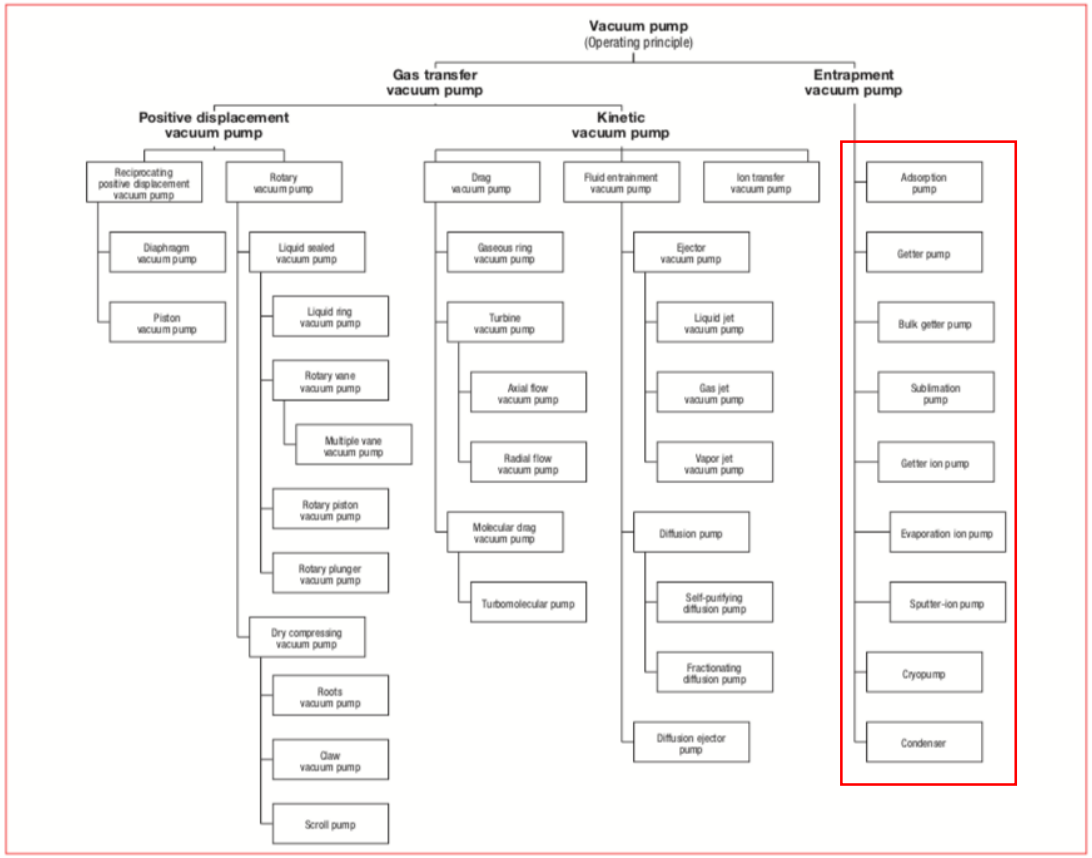
- Hydrocarbon contamination from oil hard to control
  - Control geometry of jet and pump body to minimize contamination
  - Efficient condensation & removal of oil at pump body
  - Use of (cooled) baffles to block backstreaming (reduction in pumping efficiency)
- Critical forepressure ~ 500 mTorr



Entrapment Pumping

- Principle: force gasses to react chemically or via phase change to remove them from the volume

- Several subclasses:
  - Adsorption (sublimation)
  - Sputter-ion
  - Cryogenic



Adsorption Pumping

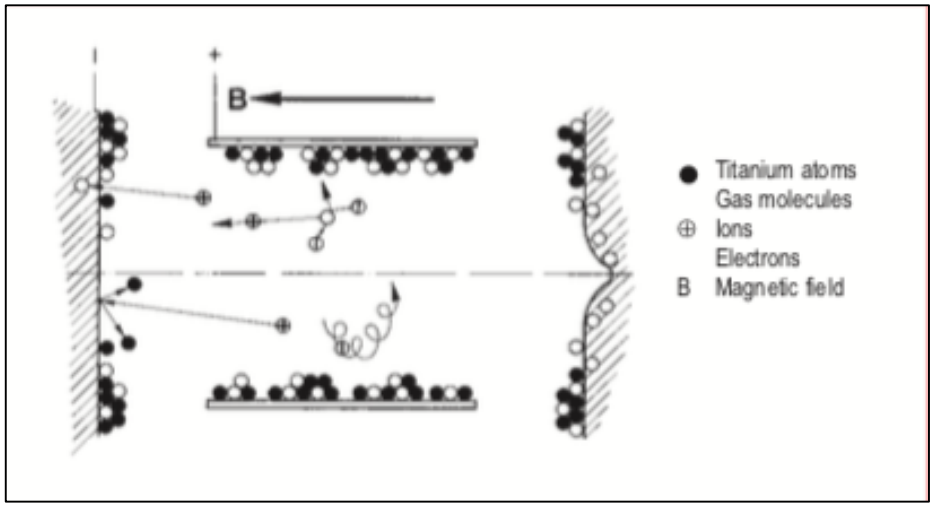
- Gasses adsorbed to chilled, porous materials
  - e.g. Zeolite 13X: pore size ~13 Å
- Gasses removed depend on molecule size (Zeolite misses H, He, Ne)
- Material able to be regenerated
  - Heat to RT and exhaust trapped gas
  - Heat to ~200˚C to remove more gasses and to dry

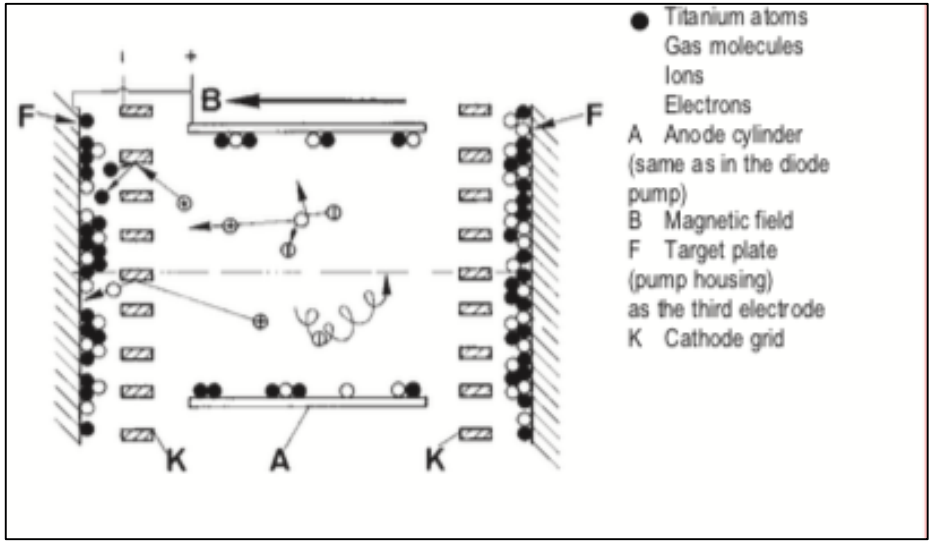
Getter Pumping

- Getter material (e.g. Ti) reacts with gas to form stable compound
- Heating filament re-evaporates Ti over used layer
- Non-evaporable Getter pumps: films reacts → diffusion through bulk

Sputter-Ion Pumping

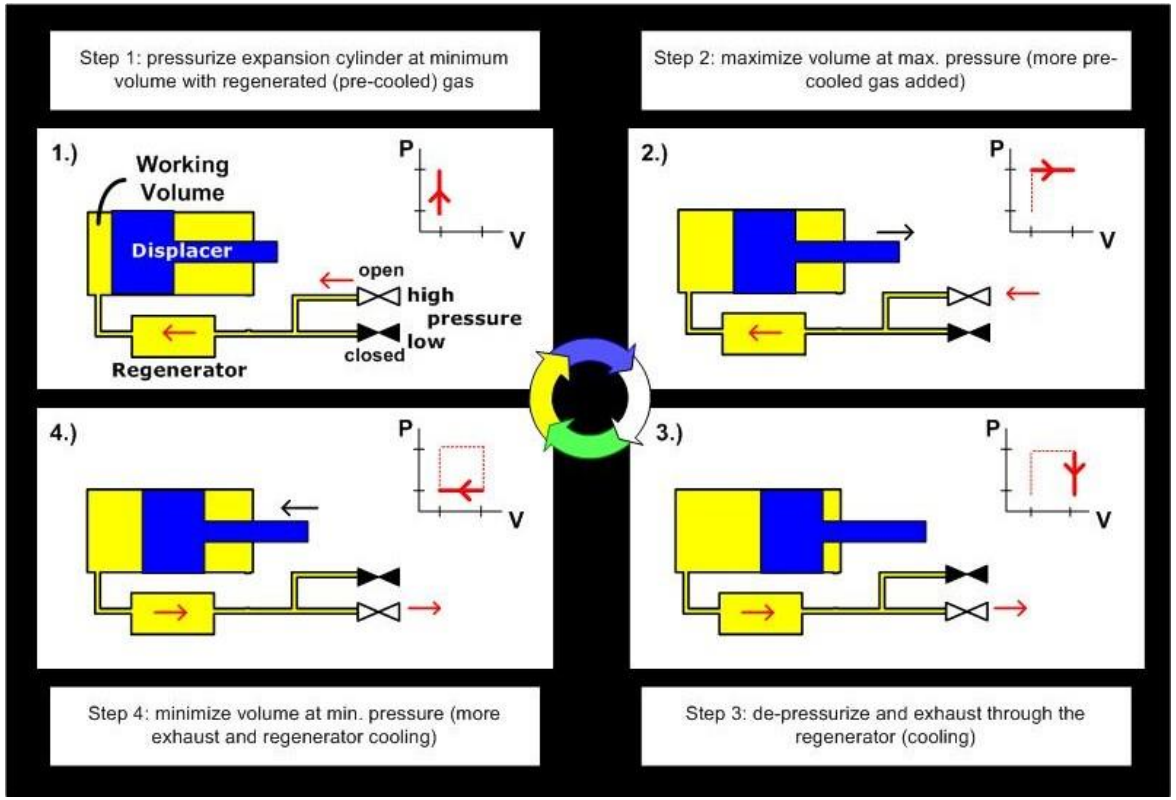
- Gas ionizes from electron plasma and is trapped
  - Active gas: getter on anode, ion burial in cathode
  - H_2: bulk reaction with cathodes; damage over time
  - Nobles: ion implantation in cathodes
    - Triode configuration increases efficiency
- Ultimate pressure: 10^{-6} – 10^{-10} Torr





Cryopumping

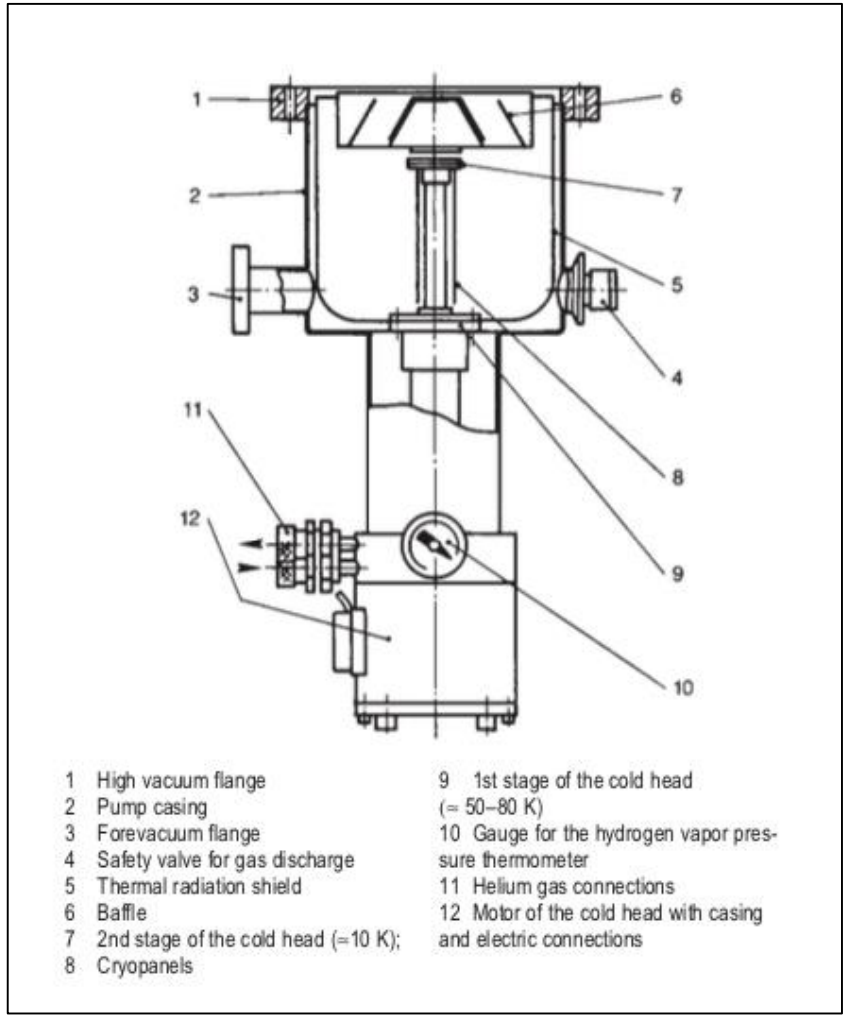
- Gasses cooled by LN_2, LHe & removed from volume
- Most common is refrigerator cryopumping
  - Cold head process (with refrigerant) achieves cooling



Gifford-McMahon Cycle

Cryopumping

- Multistage cold head traps different gasses
  - Baffle to 50K (H_2O, CO_2)
  - Cryopanel to 10K (N_2, O_2, Ar)
  - Cryosorption panel captures remaining H_2, He, Ne
- Ultimate pressure: ~10^{-10} Torr



1 High vacuum flange
2 Pump casing
3 Forevacuum flange
4 Safety valve for gas discharge
5 Thermal radiation shield
6 Baffle
7 2nd stage of the cold head (≈10 K);
8 Cryopanels
9 1st stage of the cold head (≈ 50–80 K)
10 Gauge for the hydrogen vapor pressure thermometer
11 Helium gas connections
12 Motor of the cold head with casing and electric connections

Next time: Measuring the vacuum

Thank you