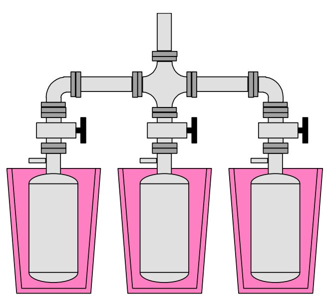
EE 527 MICROFABRICATION

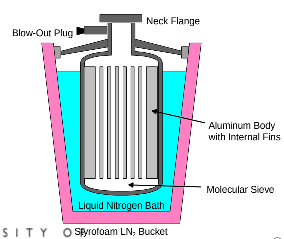
Lecture 27

Tai-Chang Chen
University of Washington

UNIVERSITY OF WASHINGTON

SORPTION PUMPS - 1

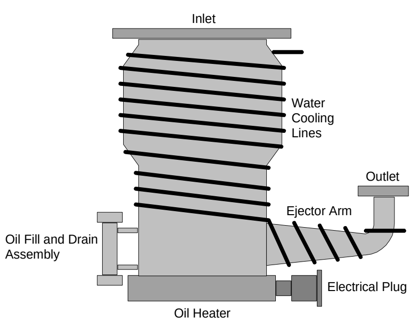


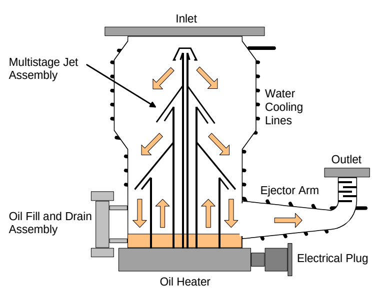


SORPTION PUMPS - 2

- Gases are pumped by
  - Cryocondensation: gases freeze into solid phase on cold surfaces
  - Cryosorption: gases are trapped in a porous molecular sieve
- The vessel is cooled by immersion in liquid nitrogen (LN_2) which reaches -196° C, or 77° K.
- Pumping is completely oil free and has no moving parts.
- Each sorption pump requires about 2-3 gallons of LN_2 and about 20 minutes to cool down.
- Several sorption pumps are often combined on a manifold.
- Pumps must be regenerated by heating to 250° C for 30 mins. to melt frost and degas the molecular sieve material.

DIFFUSION PUMPS - 1





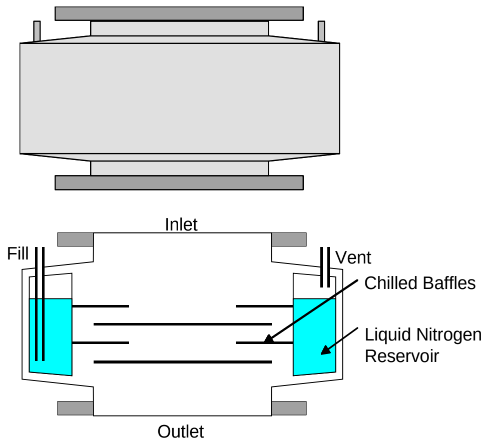
DIFFUSION PUMPS - 2

- Oil is vaporized and propelled downward by an internal boiler and multistage jet assembly.
- Oil vapor reaches speeds of 750 mph or more (supersonic).
- Oil vapor streams trap and compress gases into bottom of pump, which are then ejected out into the foreline arm.
- Oil vapor is condensed on sides of pump body which are water cooled.
- Can only operate at foreline pressures of ~100 millitorr or less.
- A mechanical foreline pump is required for operation.
- Very high reliability pumps, since there are no moving parts.
- Gravity collects oil in the base, so pumps must be mounted pointing upwards.

DIFFUSION PUMPS - 3

- Potential Problems:
  - Backstreaming of oil vapor can occur if forepressure becomes too large.
    - Backstreaming occurs for pressures of 1 to 10 mTorr.
    - A liquid nitrogen filled cryotrap also helps to reduce this.
    - The maximum tolerable foreline pressure (critical fore pressure) must not be exceeded, or pump will “dump” or “blow-out”, sending oil up into the chamber.
  - Pump can overheat if cooling water fails
    - Most pumps have a thermal cutout switch.
  - Pumping requires low vapor pressure oil
    - Water, dirt, or other impurities will raise vapor pressure.
    - Only special oils are suitable for diffusion pump use.

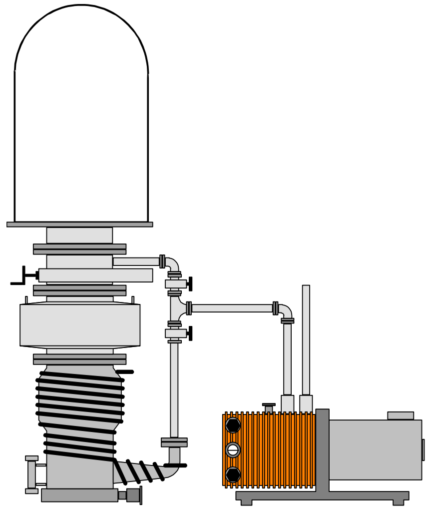
LIQUID NITROGEN TRAPS / BAFFLES - 1



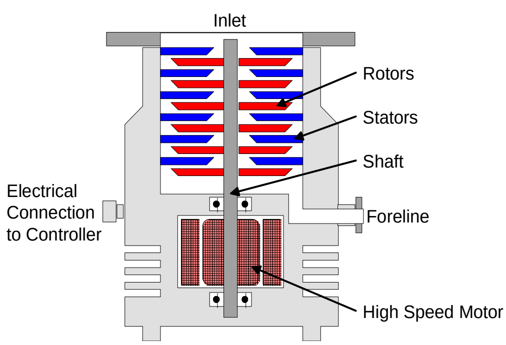
LIQUID NITROGEN TRAPS / BAFFLES - 2

- Baffles and traps in the pumping lines can greatly help to reduce backstreaming:
- LN_2 cryotraps should not experience air pressure above 100 millitorr, or they will frost completely over.
- Residual water in a cryotrap can be frozen and cause trap to break, causing catastrophic failure of vacuum system.
  - Blow out any water vapor with dry N_2 before filling with LN_2.
- LN_2 cryotraps require constant refilling.
  - Expensive, but autofill valves are available.

DIFFUSION PUMPED HIGH VACUUM BELL JAR SYSTEM



TURBOMOLECULAR PUMPS - 1



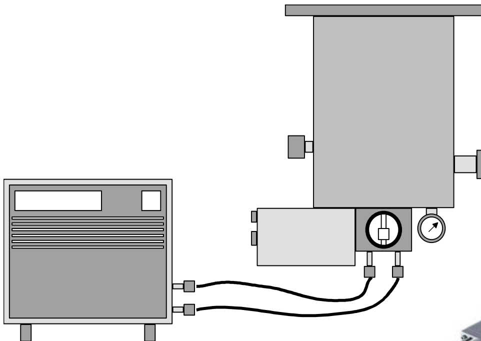
TURBOMOLECULAR PUMPS - 2

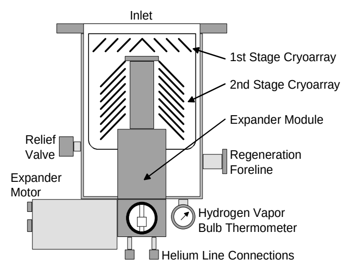
- These are very clean mechanical compression pumps.
- They use high speed rotational blades to impart velocity and direction to gas molecules.
- They operate ONLY at mid- to high-vacuum pressures.
- Typical motor speeds are 9,000 to 90,000 rpm!
- Similar to a diffusion pump, each requires a constantly running mechanical foreline pump.
- They are ideal for hydrocarbon free applications.
- The base pressure is usually limited by H_2.

TURBOMOLECULAR PUMPS - 3

- Potential Problems:
  - Very high speed rotor blades have close-mating stator blades.
    - Slight imbalances can cause vibration and bearing wear problems.
    - A sudden blast of atmospheric pressure can bend the blades down, causing catastrophic failure, "crashing the pump."
  - Lubrication of the high speed rotor is an engineering problem.
    - Circulating oil is most reliable, but pump must be right-side-up.
    - Grease-lubricated bearings are less reliable, but allow pump to be placed at any orientation.
  - A mechanical foreline pump must be used

CRYOPUMPS - 1





CRYOPUMPS -2

- These use a closed-loop helium cryogenic refrigerator.
- The primary parts are:
  - Compressor: uses He for its high heat capacity.
  - Expander: uses Joule-Thompson expansion of He gas for cooling
  - Cold Head: thermally insulated from pump bucket, 2+ stages
- Gases are pumped by two processes:
  - Cryocondensation (H_2O, CO_2, N_2, O_2, Ar, solvent vapors)
    - Gases are condensed into a solid phase on cryogenically cooled surfaces. (They become frost!)
  - Cryosorption (H_2, He, Ne)
    - Non-condensable gases are adsorbed onto surfaces of cryogenically cooled porous media, usually activated charcoal or zeolites.

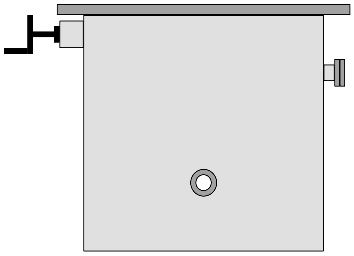
CRYOPUMPS - 3

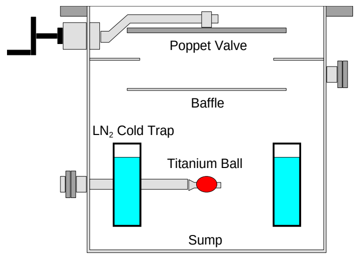
- The first stage array operates at 50 to 80 K.
  - Primarily used for pumping water vapor and carbon dioxide.
- The second stage array operates at 10 to 20 K.
  - Primarily used for pumping other condensable gases.
- Activated charcoal in the second stage provides cryosorption.
  - Primarily used for pumping other non-condensable gases.
  - Charcoal and zeolites have about 8000 ft^2/cm^3 of surface area.
- They offer completely oil free operation.
- They can operate from any orientation.
- They offer very clean vacuum with high pumping speed.

CRYOPUMPS - 4

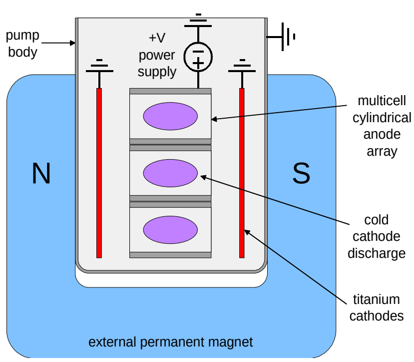
- Potential Problems:
  - They must be regenerated to extract the trapped gases.
    - Allow to warm to room temperature (slow), or
    - Use a built-in heater to warm to 250 C and outgas (fast).
    - Regeneration takes the pump off-line for several hours.
  - They must be started from below 100 millitorr.
    - They require the use a mechanical roughing pump to initially pump out the bucket, but once done, the rough pump is no longer needed.

TITANIUM SUBLIMATION PUMPS - 1





ION PUMPS - 1



Diode Ion Pump

SPECIAL CONSIDERATIONS FOR ULTRA-HIGH VACUUM SYSTEMS

- Achieving pressures below ~10^{-7} torr requires:
  - Extreme attention to the cleanliness of all surfaces
  - Elimination of all virtual leaks
  - Baking out of chamber to allow inside wall surfaces to desorb
    - Usually ~200-300°C for 6-12 hours
    - Special baking blankets or heater tapes are used on the exterior of the chamber
  - Patience to achieve the base pressures
    - Can sometimes take >24 hours
  - UHV systems often have a load-lock system so that the main chamber does not need to come up to full atmospheric pressure to load and unload samples

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