



- Chemistry / Physics – points to remember
- Cryopump hardware – what are things called
- Cryopump operation – what's going on
- Cryopump health – problems & early indicators
- Compressor - overview
- Time for questions + see / touch / feel

Sea level – 760 torr – “0” inches of Hg

5,000 ft. - 632 torr - 5.1” Hg

10K ft. - 522 torr - 9.4” Hg

Mt. Everest 236 torr - 21.7”Hg

150K ft. - 1.1 torr - 29.98” Hg

50 miles - 6 mtorr

100 miles - 2×10^{-5} torr

250 miles – 5×10^{-7} torr

i.e. we want to process in the “trillionths” of Atmosphere

At 50 % RH and 20 degrees celcius.

Nitrogen 78.1%

Oxygen 20.93%

Argon 0.93%

CO₂ 0.03%

Traces of Ne, He, CH₄, Kr, N₂O, Xe, O₃

Water Vapor 1.15% or 11.7 torr P.pressure

1 cubic centimeter has 2.5×10^{19} molecules

250,000,000,000,000,000,000

Two hundred and fifty million trillion *or* Two hundred and fifty Quintillion

Vacuum range	Pressure in hPa (mbar)	Molecules / cm^3	Mean free path
Ambient pressure	1013	2.7×10^{19}	68 nm ^[2]
Low vacuum	300 – 1	$10^{19} - 10^{16}$	0.1 – 100 μm
Medium vacuum	$1 - 10^{-3}$	$10^{16} - 10^{13}$	0.1 – 100 mm
High vacuum	$10^{-3} - 10^{-7}$	$10^{13} - 10^9$	10 cm – 1 km
Ultra-high vacuum	$10^{-7} - 10^{-12}$	$10^9 - 10^4$	1 km – 10^5 km
Extremely high vacuum	$<10^{-12}$	$<10^4$	$>10^5$ km

The high vacuum pump is just a 'hole' in the chamber, waiting for molecules to enter the inlet flange.

Molecules are bouncing around at 1,000mph

Specific heat capacity = J/g°C

To cool 250g of copper to 10K takes $0.385 \times 250 \times (300-10) = 28,000$ Joules

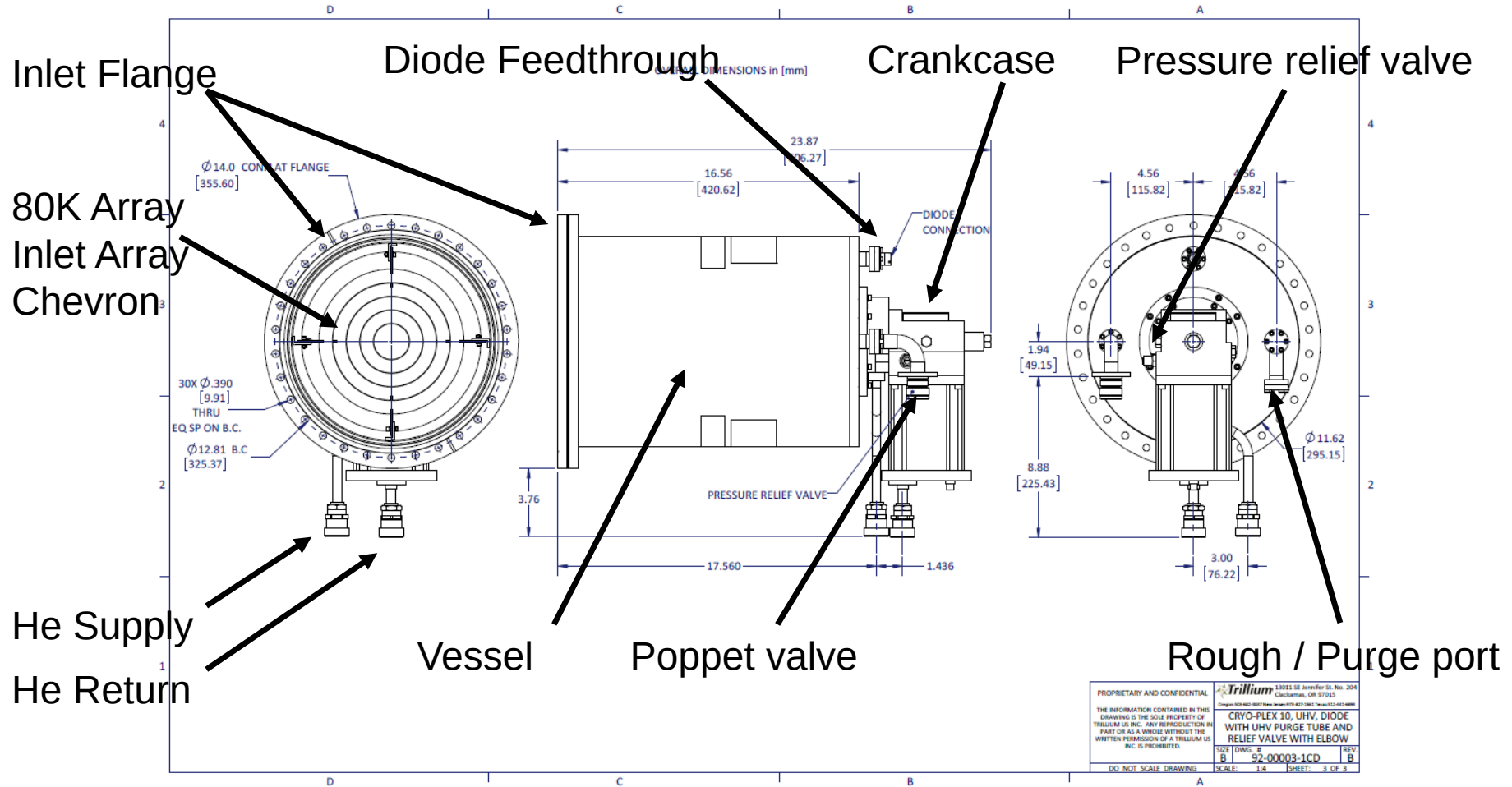
To do it within a period of time: $1\text{J/S} = 1\text{W}$.

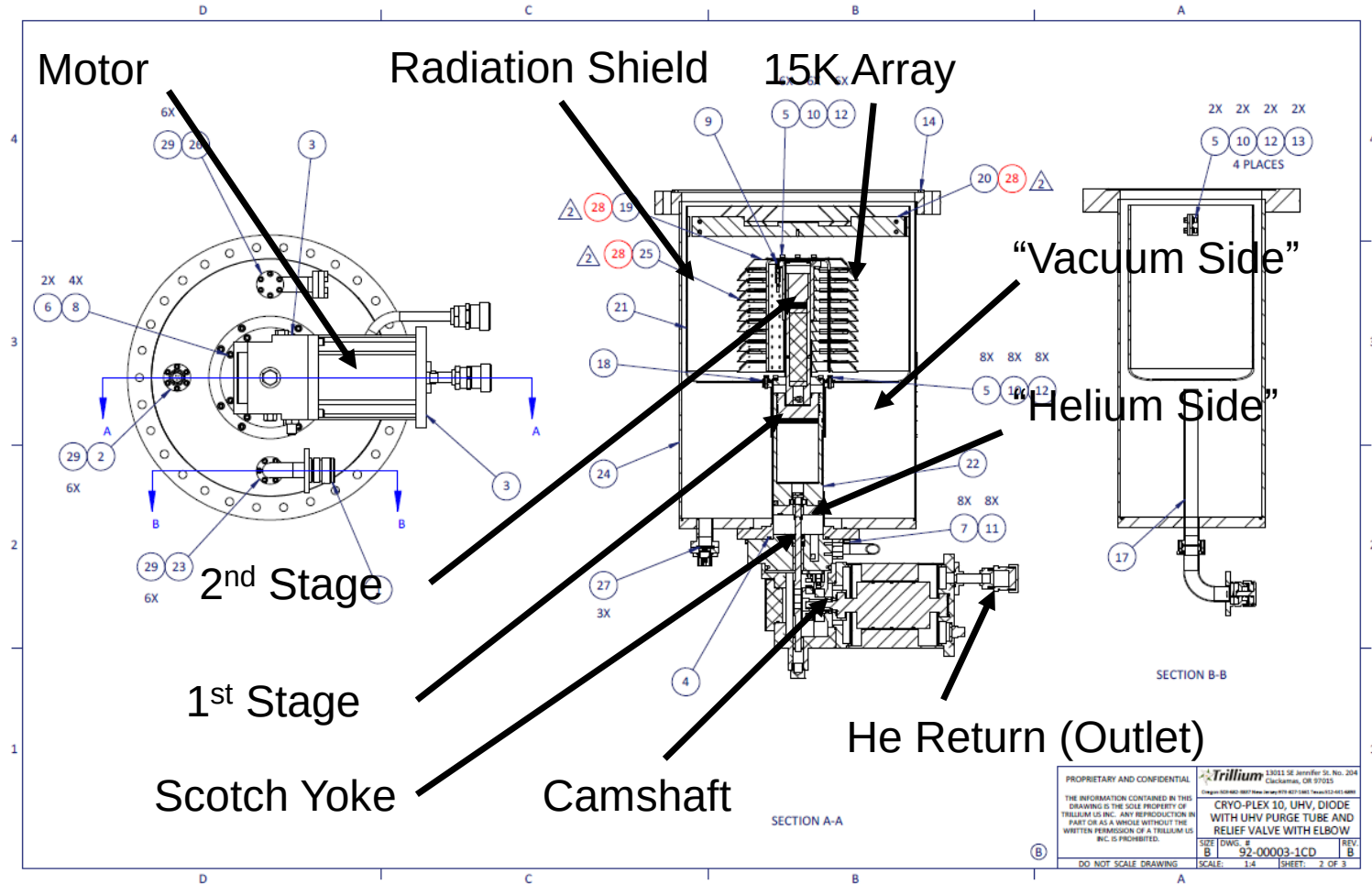
To cool it down within 60 minutes (3600 seconds) requires 8W of cooling power

i.e. After a regeneration it takes time to re-cool the cryopump

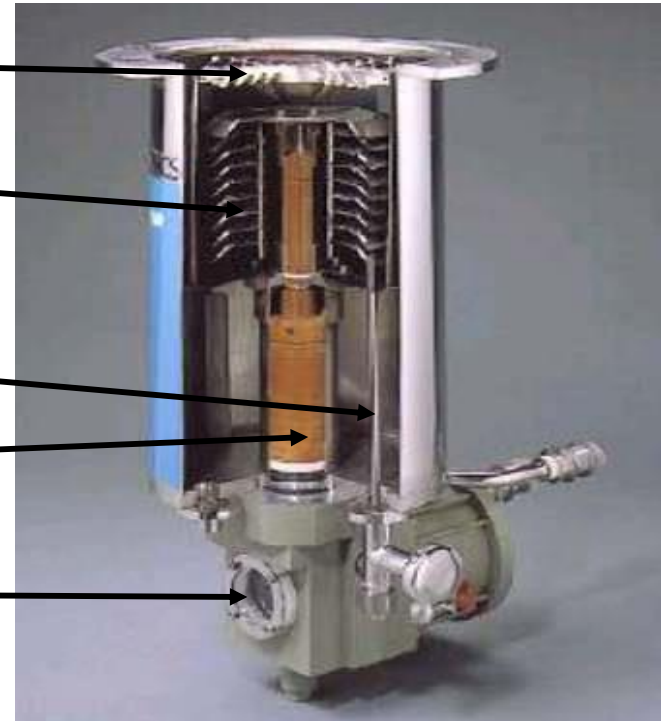
Dual Stage Cold Head Specifications			
Refrigeration Capacity*	350CS	1020CS	1050CS
First Stage (77 Kelvin)	20 Watts	35 Watts	65 Watts
Second Stage (20 Kelvin)	5 Watts	12 Watts	7 Watts
Physical Specifications			
Weight	22 lbs (10 kg)	30 lbs (13.5 kg)	30 lbs (13.5 kg)
Inlet Flange Size	ISO, ANSI, Conflat®, Standard O-ring. Custom sizes available upon request.		
Cooldown Time (20 Kelvin)*			
50Hz	65 Minutes	50 Minutes	
60Hz	50 Minutes	40 Minutes	

Energy required to vaporize a gas (from liquid) is more than energy given up to condense
But the condensing gas will still give up heat





- Inlet array – chevron. —————→
- Cross section thru charcoal array. —————→
- Purge tube assembly. —————→
- Displacers. —————→
- Sight glass. —————→



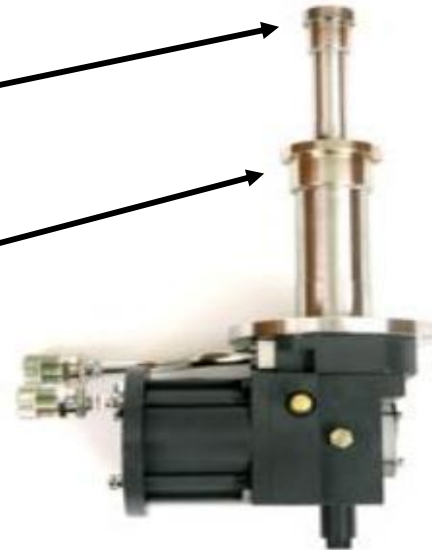


- Coldhead relief valve – for helium overpressure
- Cryopump relief valve – for condensed gases to exit the pump on regeneration

- Two-stage Gifford-McMahon refrigerator.
- Second stage achieves 10 kelvin.
- First stage 77 kelvin or lower.

20 watts at 77K

5 watts at 20 K



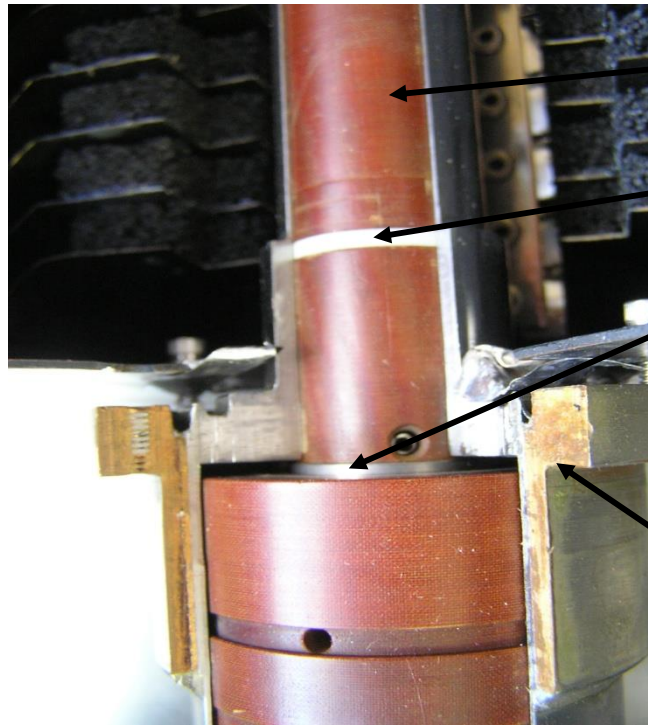


Heart of the cryopump
Is a cryocooler



- Scotch yoke drive rod.
- Cap attached to #1 displacer.
- First stage seal.
- #1 displacer – cap, seal and displacer are one unit.



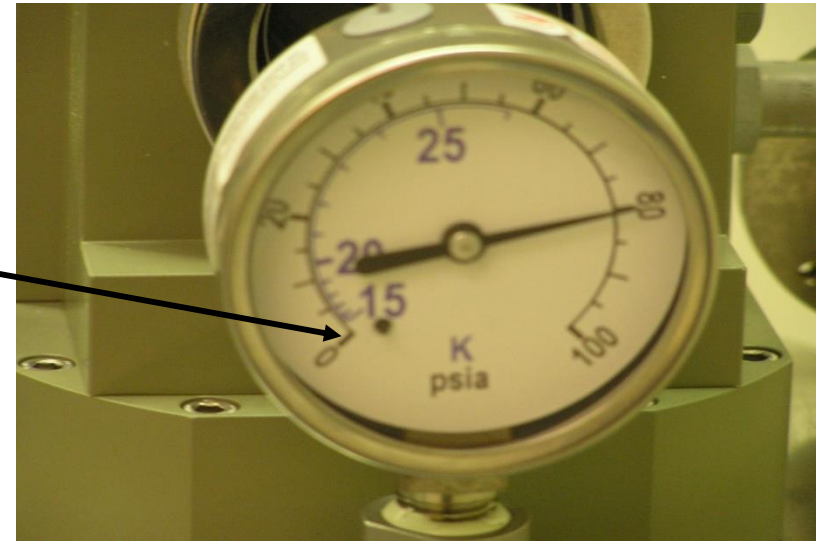


- #2 displacer.
- Second stage seal.
- Seal insertion tool, pushed down to bottom when displacer goes in cylinder.
- First stage cold station.



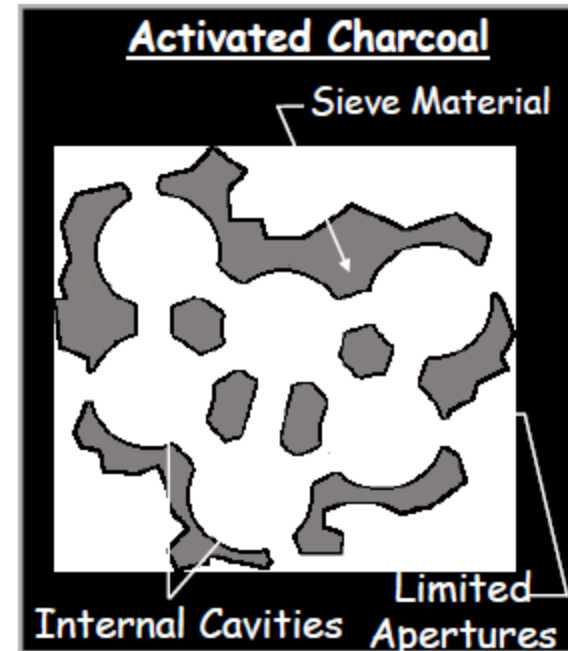
- Inlet and exhaust valve bearings.
- Scotch yoke drive.
- Main drive bearing, pushing Scotch yoke up and down.
- Valve rocker arm assembly.

- Simple temperature indication
- Dial gauge goes to zero at 10 kelvin
- Doesn't start to indicate until below 50 kelvin

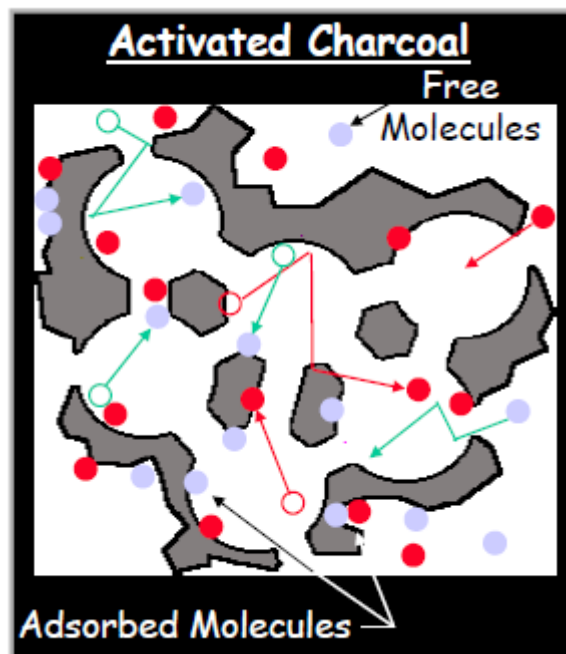


- Cryopumps are cooled by compressed helium.
- Condensing arrays are attached to the cold head to expand the surface area available for condensation
- The cryopump has to cool the components AND deal with the heat load from the gas & radiated heat load from inside the chamber / outside the vessel.
- The cryopump is a “capture” pump – there is no throughput and eventually it will become “full”
- The cryopump provides fast, clean pumping of all gases in the 10^{-3} to 10^{-11} Torr range.

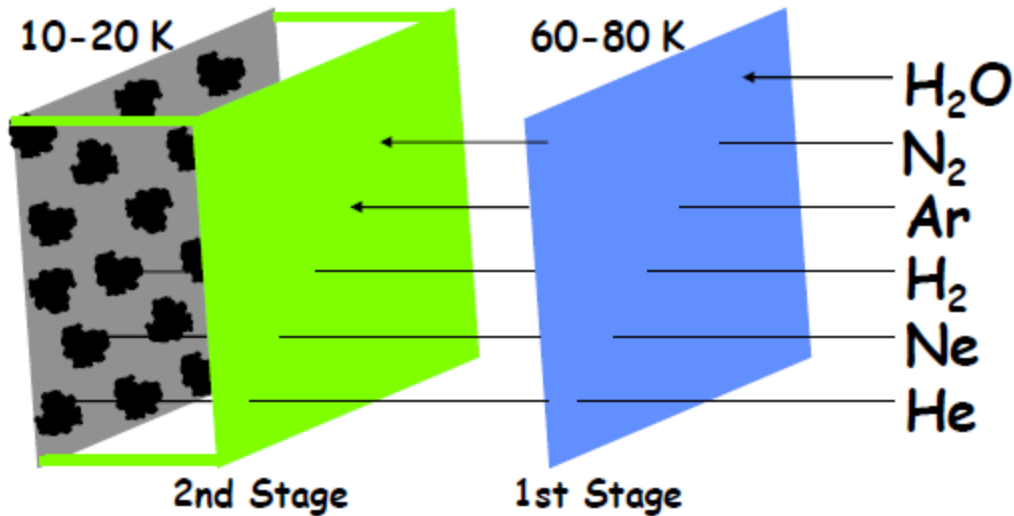
- Sieve material, such as charcoal, provides greater surface area and limited apertures.
- Large surface area capacity;
1150-1250 m²/gm

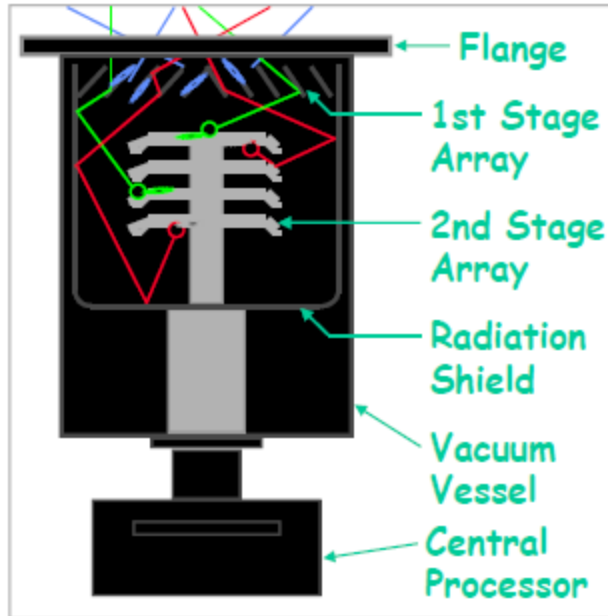


- Increased surface area provides greater capacity.
- Released molecules remain confined.
- Irregular surface constricts motion.
- Cryosorption of hydrogen, neon, and helium accomplished.



Air gases and water vapor are condensed,
noncondensable gases are captured.





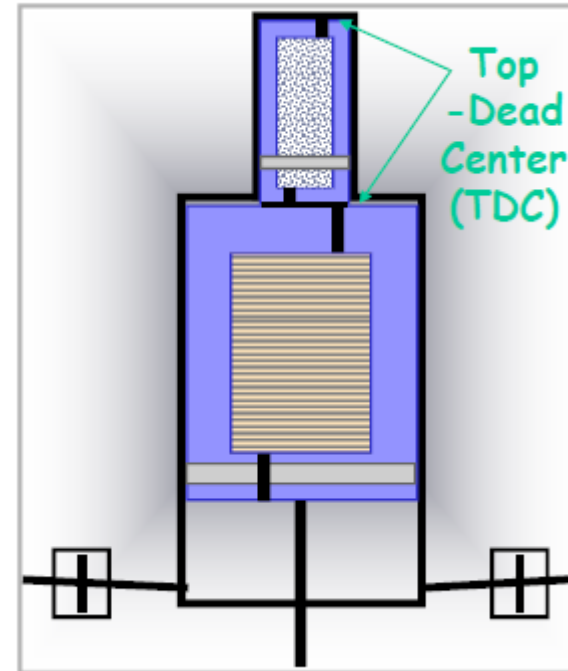
Capture Type Pump

Characteristics:

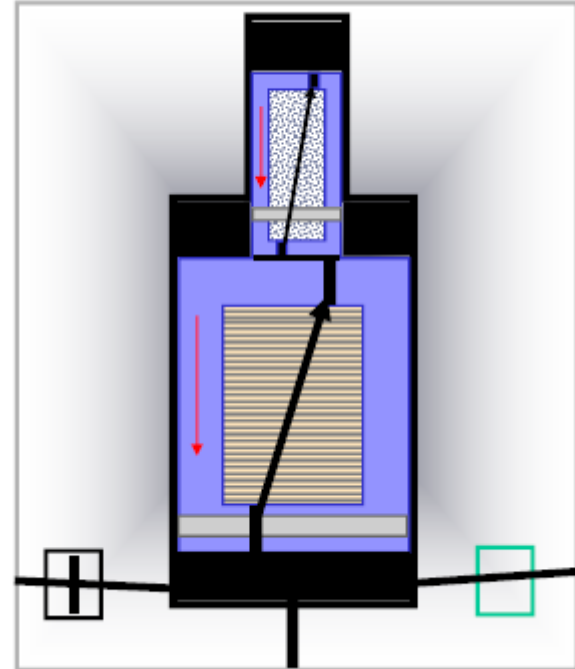
- No fluids, lubricants, or moving parts
- High crossover capability minimizes backstreaming
- High water pumping speed
- Tailorable pumping speeds
- Operate in all orientations
- Continuous backing not required

Sublimation allows the trapped gasses to migrate further onto the lower fins & charcoal

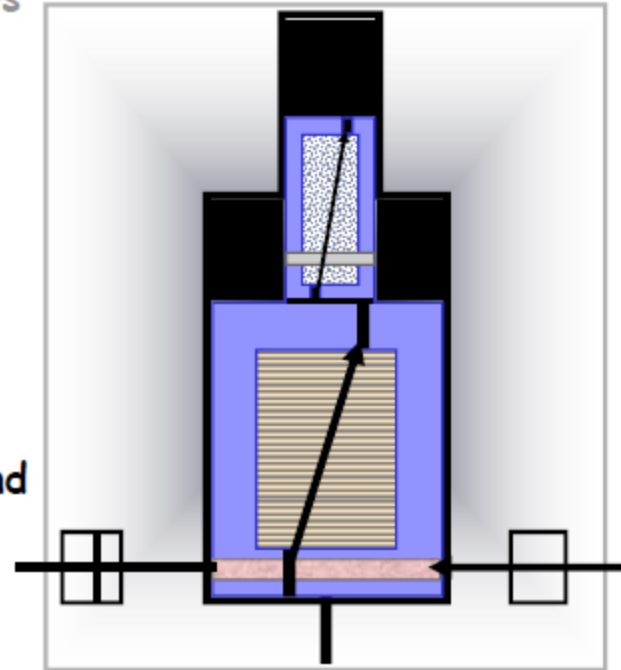
- Cycle begins with both displacers at TDC.



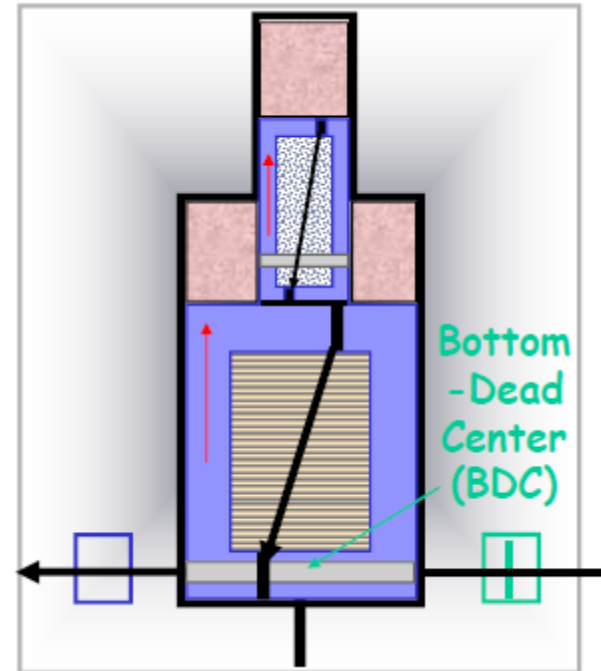
- Cycle begins with both displacers at TDC.
- Inlet valve opens.
- Displacers move downward.



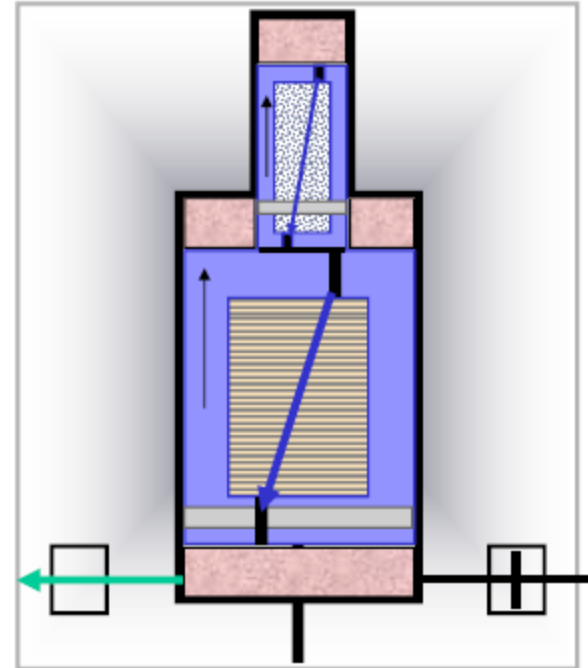
- Cycle begins with both displacers at TDC.
- Inlet valve opens.
- Displacers move downward.
- Helium fills void above primary displacer and passes through secondary displacer to fill second void.



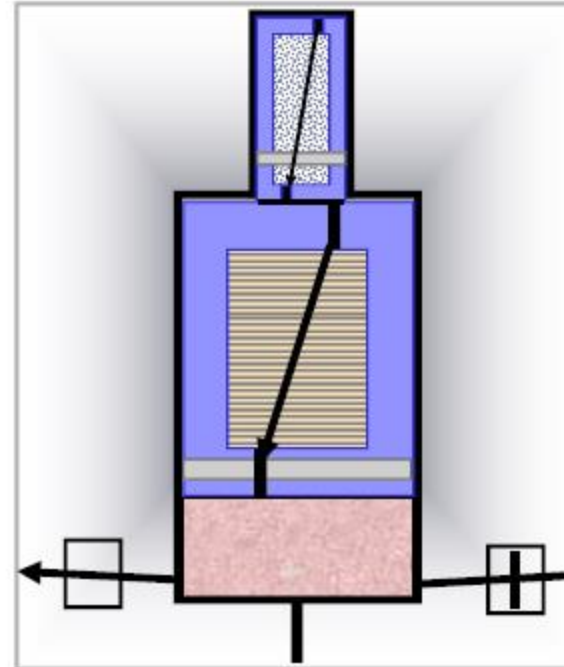
- At BDC, inlet valve closes.
- Exhaust valve opens.
- Gas has expanded in both voids and cools.
- Displacers move upward.



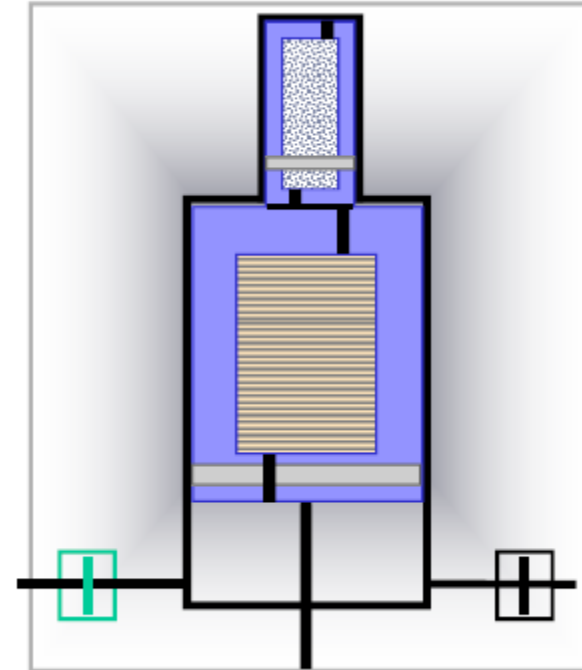
- Cooled gas flows down through both displacer matrices removing heat from thermal masses.
- Gas exits through exhaust valve.



- Displacers again at TDC.

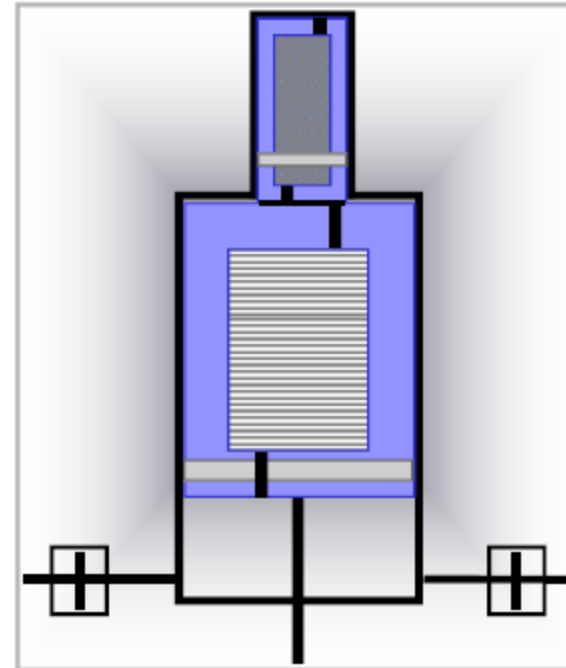


- Displacers again at TDC.
- Remaining gas exits.
- Exhaust valve closes.
- Cycle repeats at 72 rpm.

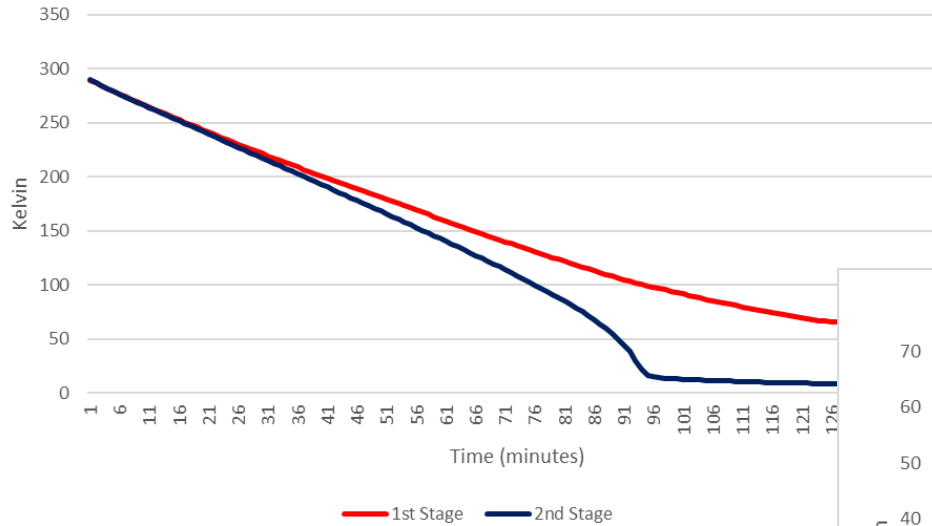


After each cycle both displacer matrices (thermal masses) are colder, with the secondary mass colder than the primary ...

... incoming helium is pre-cooled accordingly BEFORE expansion.

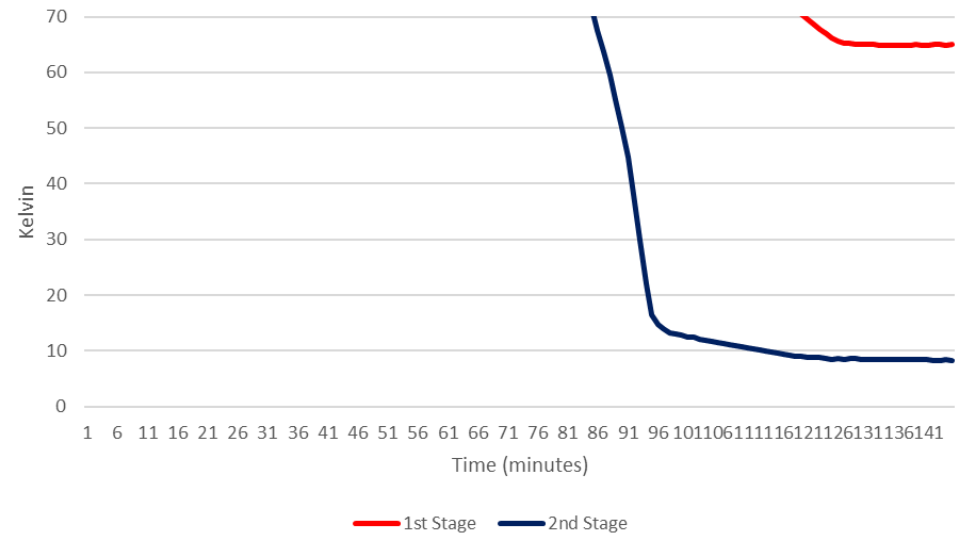


OnBoard 8F



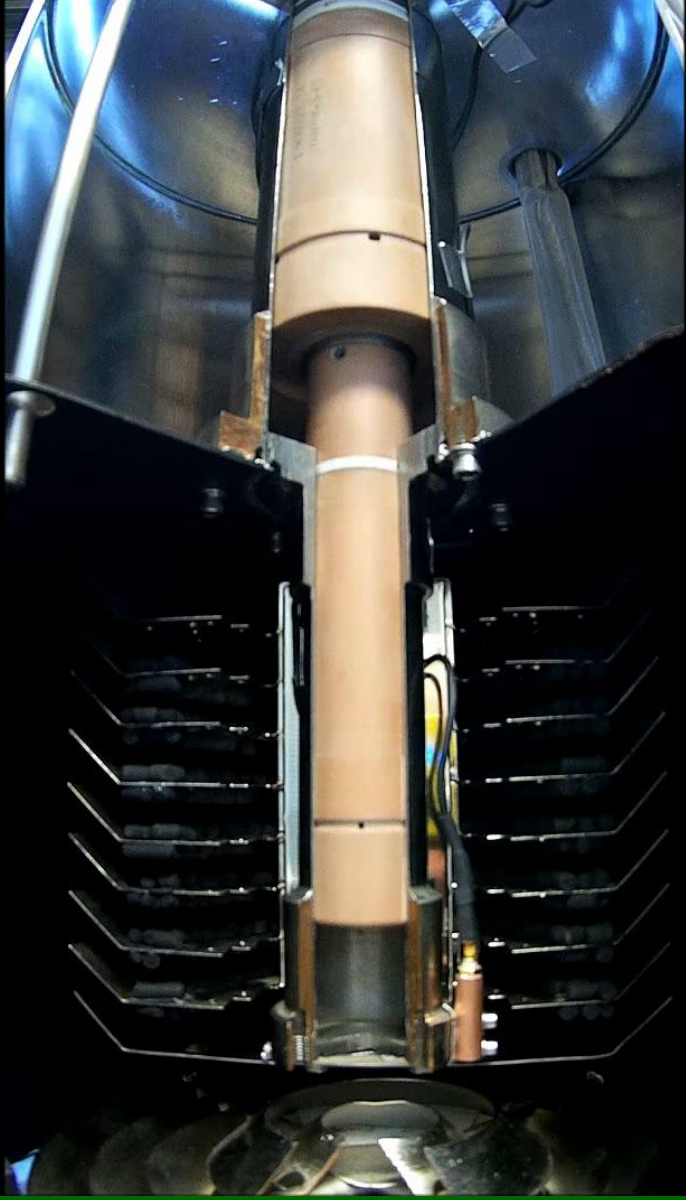
- Time-to-temperature refers to how long it takes the 2nd stage to get <12K.
- 1st Stage is held at 65K with a heater

OnBoard 8F

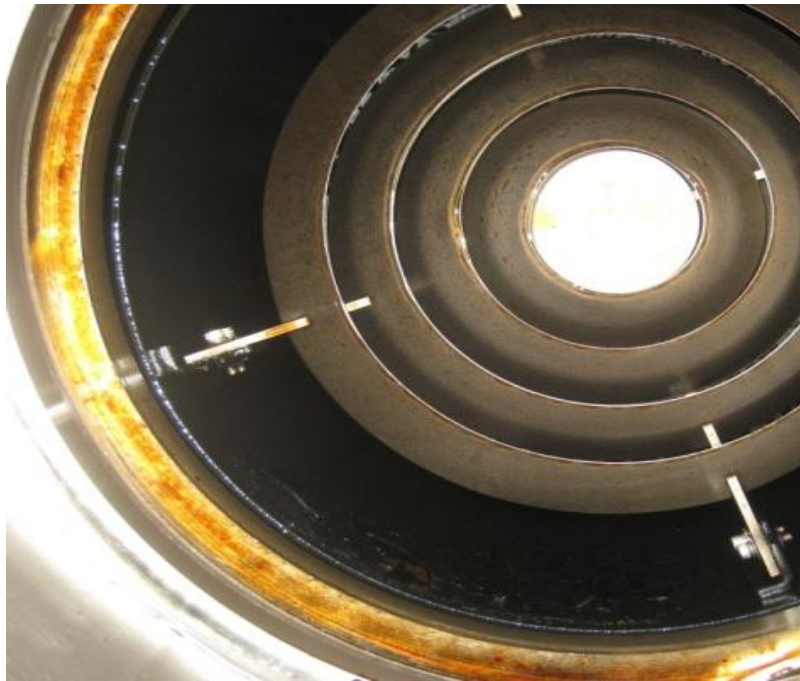


- Critical region is 2nd stage @ <17K and it must hold at a steady level
- In this case the temp levels out at 8.5K

Trillium Trillium



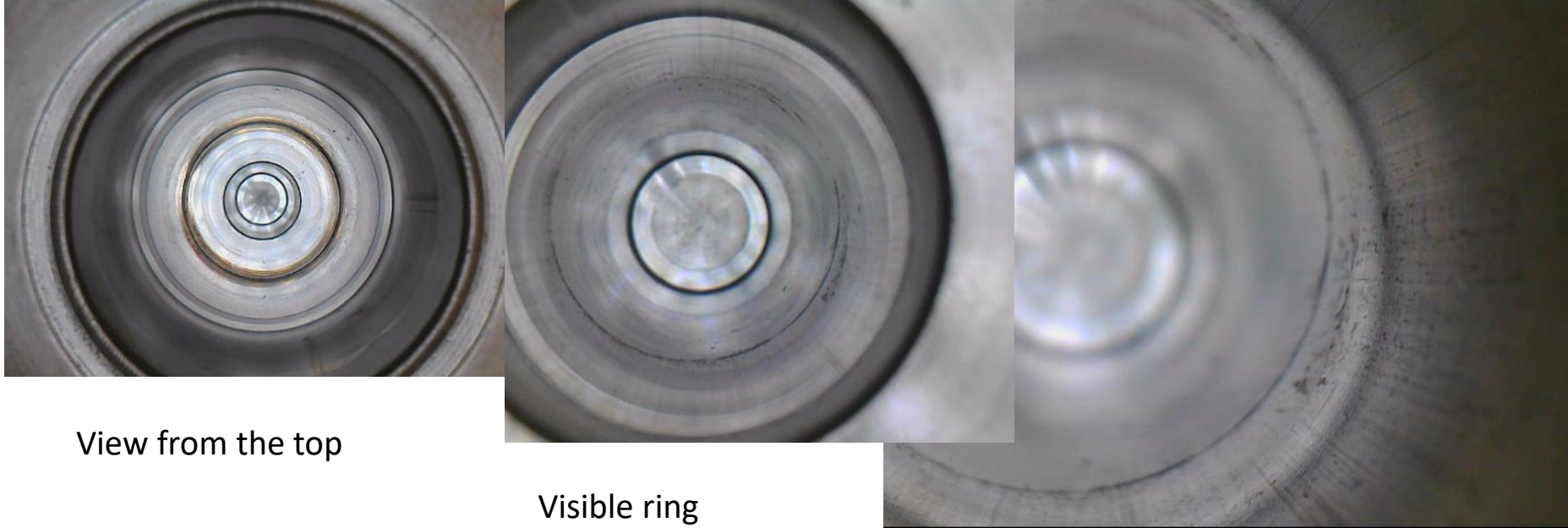
- Helium side contamination – water vapor and air gases in the helium stream.
- Vacuum side contamination – from the process/chamber/roughing pumps.
- Roughing pump contamination can also be called oil backstreaming



- The user had opened a valve accidentally to the oil-sealed mechanical pump
- While the cryo was at high-vac – throw away charcoal array, complete vacuum side rebuild after extensive clean.

- Easy to correct – by performing a running purge
- For some inexperienced users there is “Fear of the unknown” – cryopumps are “weird”
- If it doesn’t work initially, you can try again.
- Important to fully purge the supply line – otherwise the first thing you introduce is a slug of air (and water vapor)
- If it’s not corrected, the life of the pump can be significantly shortened
- Maintaining helium purity is essential
- Many symptoms we see on teardown are as a result of running with long-term correctable problems

Dirt / contamination



View from the top

Visible ring

Scuffs & damage to the sealing surface

In most cases this is ball-honed and polished to recover a good sealing surface but prolonged use can make the displacer cylinder beyond salvage

