# Development, Testing and Application of the Indigenously Built 80 K Sorption Cryopump

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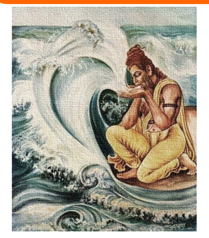
ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Material Conference 2024

**POSTER ID: 499**

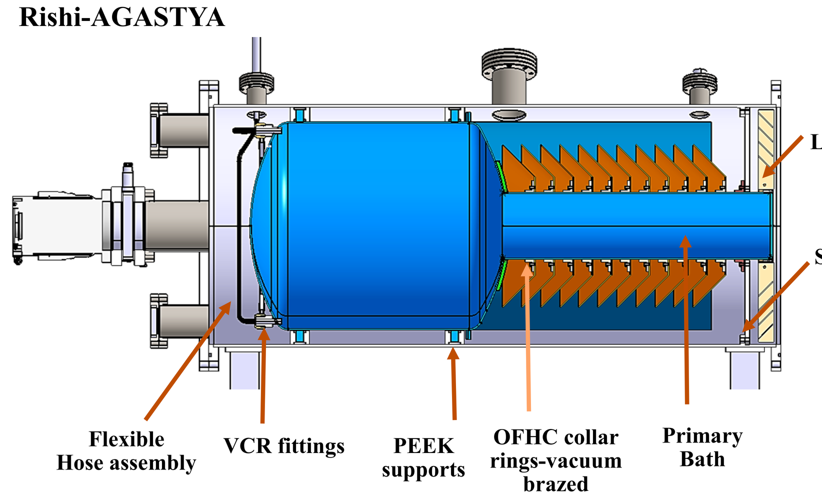
**Abstract:** Cryopump finds application in space research, fusion research, and LIGO etc. To achieve high vacuum in the large volume vessels like ITER, helium cooled cryopumps are used. For pumping the gases like nitrogen, oxygen, water vapour, argon except for hydrogen and helium, 80 K sorption cryopump can be used. A temperature of ~ 20 K is required for pumping nitrogen gas by condensation and ~ 80 K temperature for pumping by adsorption on the activated charcoal coated surfaces. Various 80 K sorption pumps (AGASTYA) are developed indigenously at Institute for Plasma Research (IPR) and finding applications for pumping water vapour in the thermo-vac chamber of SAC-ISRO and SST-1 at IPR, India. SST-1 has the vacuum vessel of ~ 23 $m^3$ volume that encloses Plasma Facing Components (PFCs) of surface area ~ 40 $m^2$ exposed to plasma. During baking of PFCs, major evolved gas is water vapour, a customized AGASTYA 500 was designed, fabricated, tested and installed on the radial port of the SST-1. The design was analyzed for the temperature of the different components using ANSYS™ and also, the pumping speed was estimated using Molflow+ simulations. Experimentally, the pumping speed for water vapour and nitrogen gas was found to be ~ 26000 litre/sec and ~ 3300 litre/sec, respectively. Integration of the AGASTYA with the existing vacuum system of SST-1 resulted in reduction of the partial pressure of water vapour from $4.4 \times 10^{-6}$ to $1.3 \times 10^{-7}$ mbar during baking of the PFCs at 230 °C temperature. The design, thermo-structural analysis, molflow analysis, experience of, testing and operations will be discussed systematically to show the applicability of the AGASTYA pump in large volume vacuum chambers.

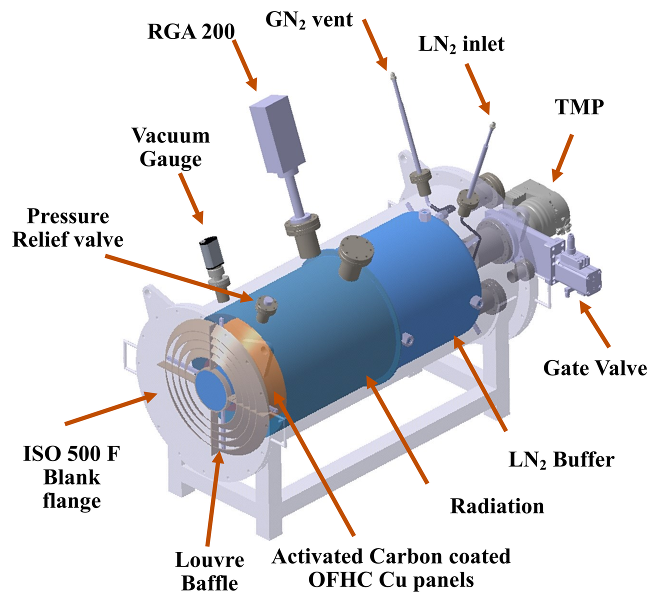
## Development of 80 K Sorption Cryopump: AGASTYA 500

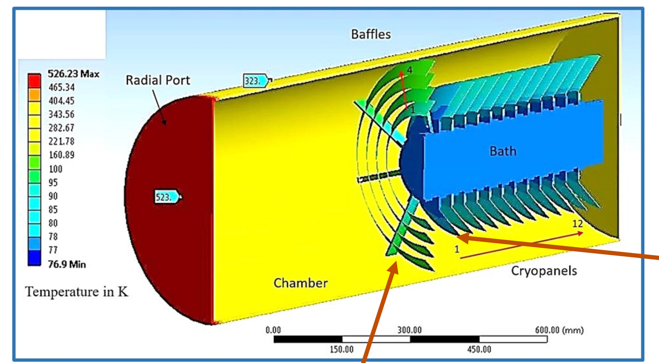


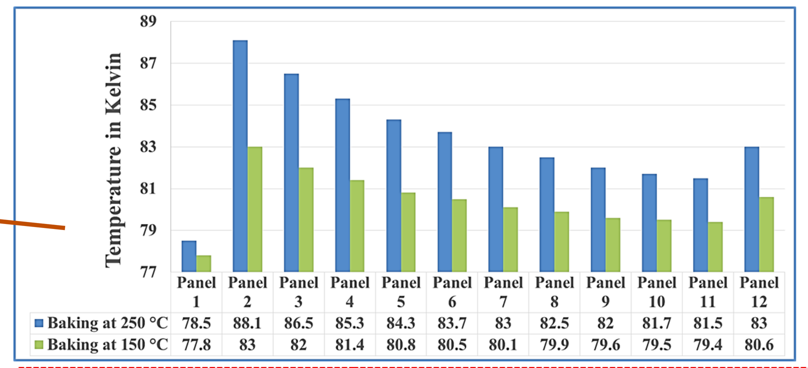
Rishi-AGASTYA

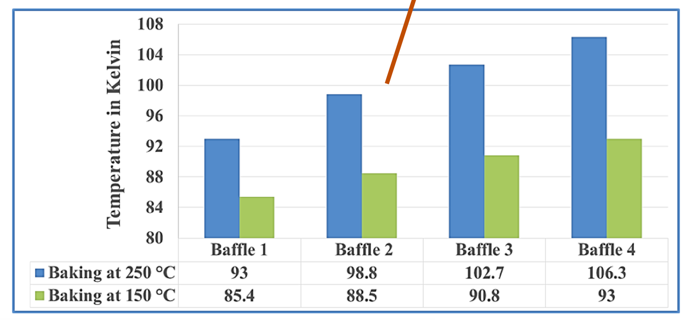
**80 K Sorption Cryopump named as AGASTYA based on the story of 'Padma Purna' in which a Rishi had immense absorption power to drink the entire ocean. The developed 80 K sorption pump have an immense pumping capacity to evacuate the water vapour. Additionally, it can pump all the gases by adsorption except hydrogen and helium gas.**

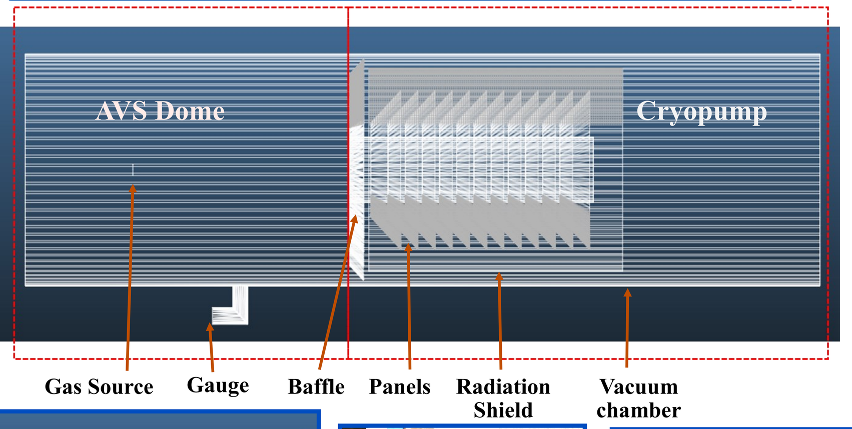


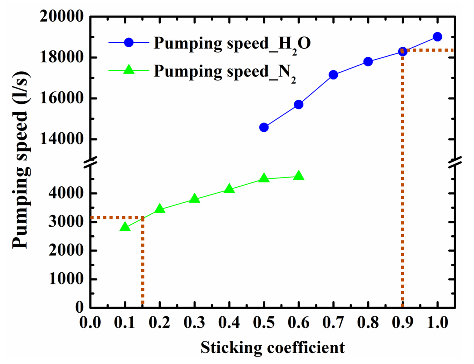



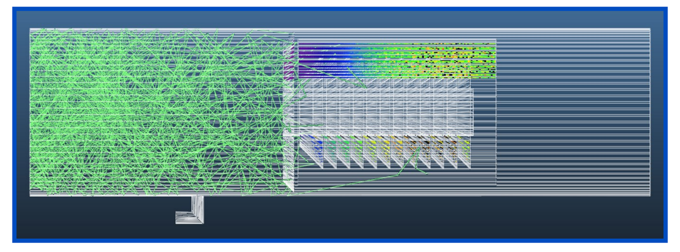



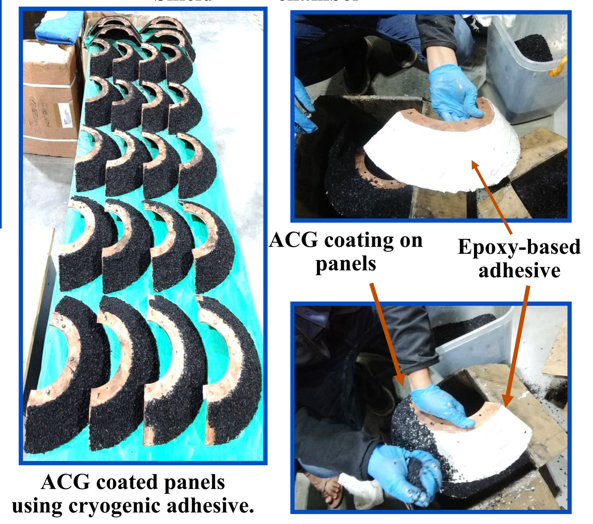




Molflow+ pumping speed simulation



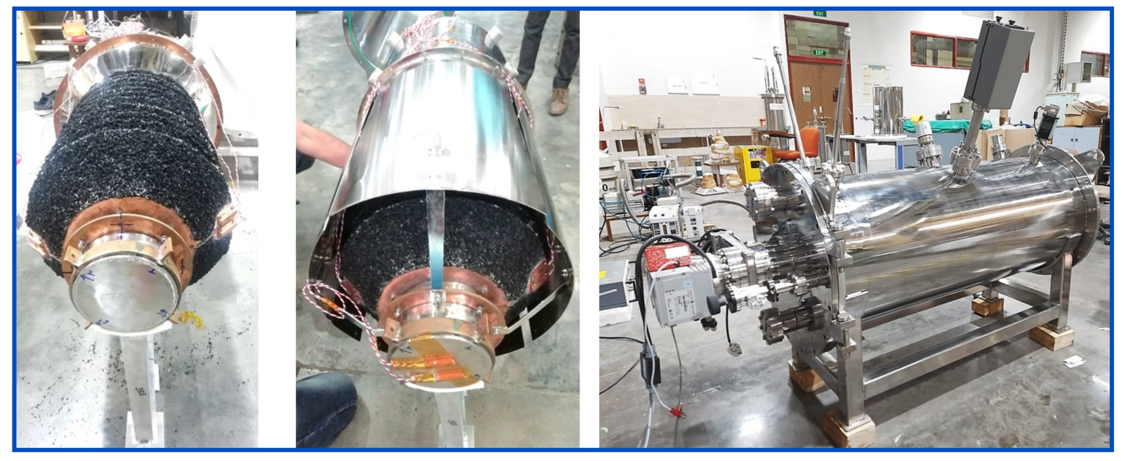
Snapshot of simulation for water vapour at dosing of 1E-2 mbar-l/s



ACG coating on panels

Epoxy-based adhesive

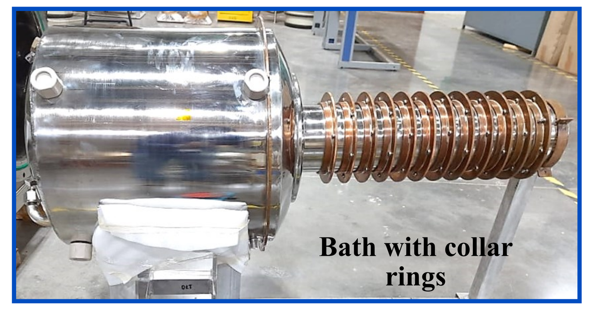
ACG coated panels using cryogenic adhesive.



Assembled panels

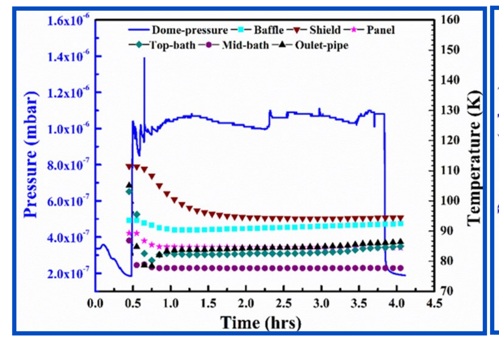
Assembled Shield

AGASTYA 500

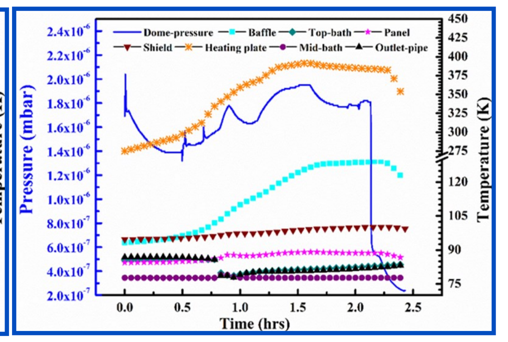


Bath with collar rings

## Pumping Speed Testing of AGASTYA 500



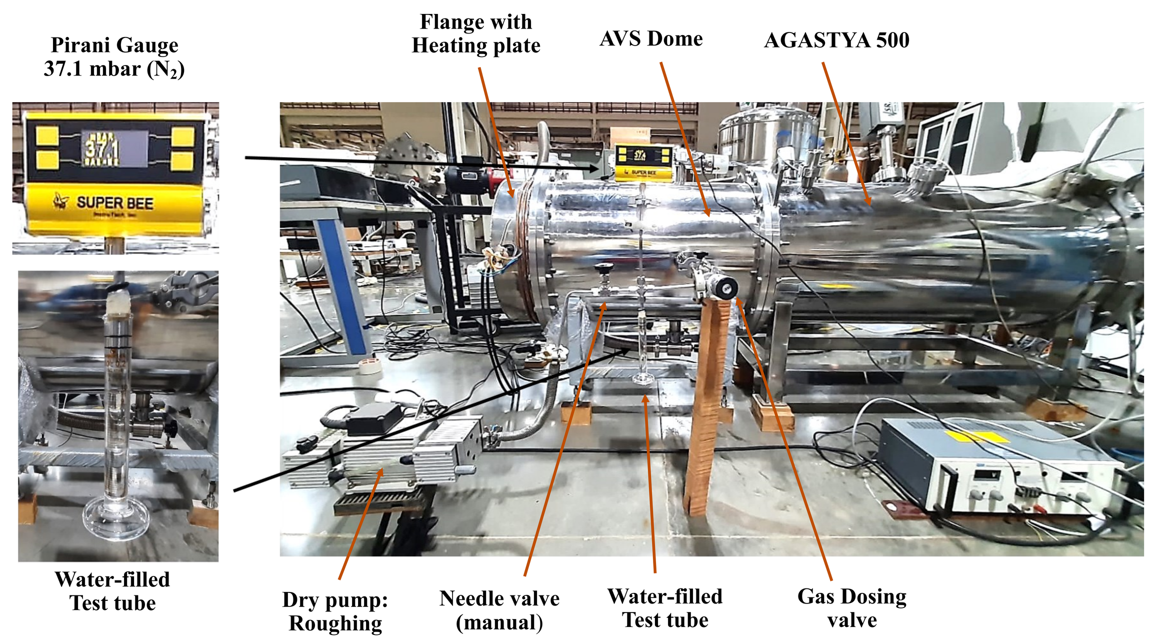

Water vapour pumping at 293 K temperature

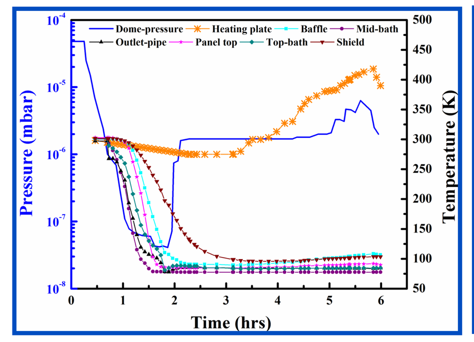



Water vapour pumping at 393 K temperature

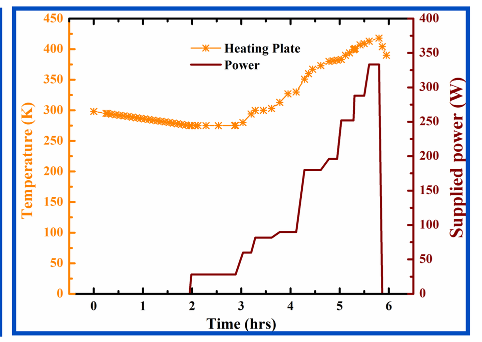
- ⇒Pumping speed for water vapour was observed to be 26000 l/s maintaining the dome pressure as ~ 1E-6 mbar.
- ⇒Temperature of panels was maintained at ~ 83 K measured by Pt-100 temperature sensor.
- ⇒A black painted copper plate in the front of the dome was heated to 393 K temperature, an external heat load of 258 Watt was taken by the sorption pump. The pumping speed was reduced to 17000 l/s based on the average dosing rate.
- ⇒It can be observed that the temperature of baffle was increasing with the supplied heat and also, due to increase in the emissivity of baffle during the water vapour pumping.

### Water Vapour Pumping Speed Test Set-up

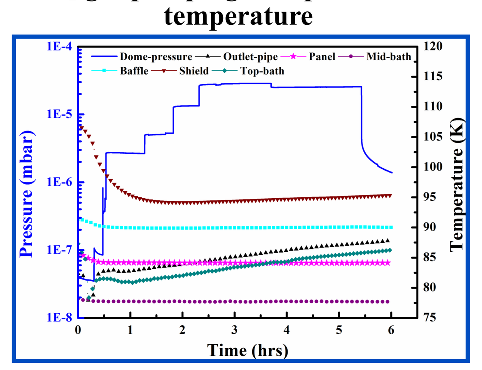



N₂ gas pumping for up to 413 K temperature




Temperature vs Supplied power ($N_2$ gas experiment)

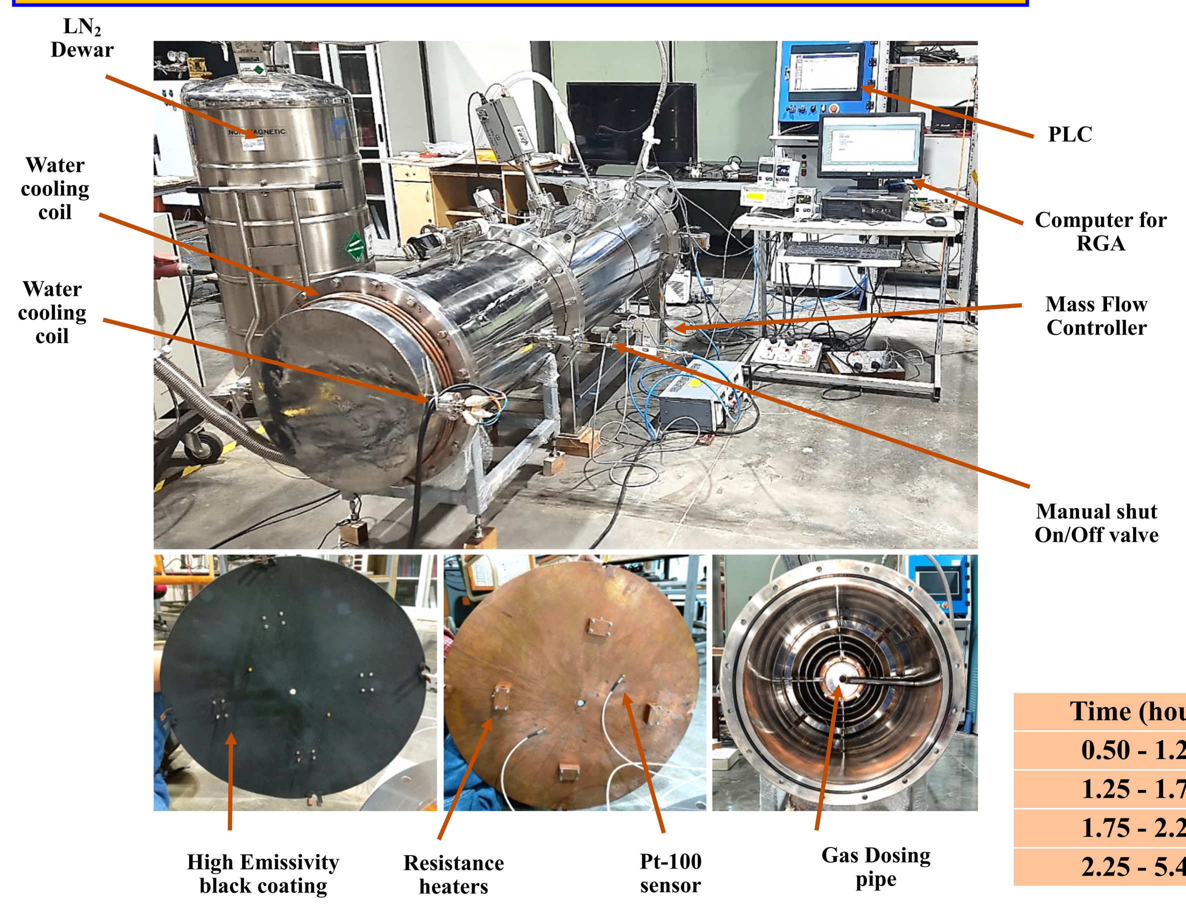


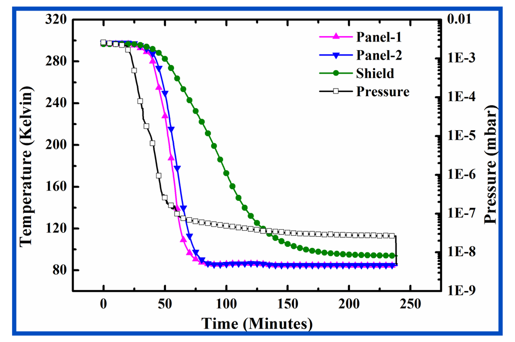

Adsorption capacity experiment for $N_2$ gas

- ⇒Pumping speed for $N_2$ gas was observed to be 3125 l/s with a dosing of 5E-3 mbar.l/s.
- ⇒Temperature of the black coated plate was increased to 383 K and pumping speed reduced to 2400 l/s with an heat load of 196 Watt.
- ⇒Adsorption capacity test was performed and test maximum adsorption capacity is > 15000 mbar.l.

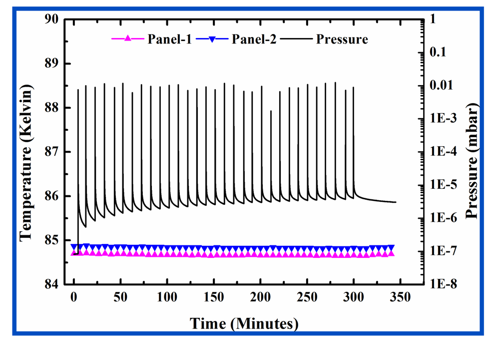
| Time (hour) | Dosing rate (mbar.l/s) | Dome pressure (mbar) | Pumping speed (l/s) |
|---|---|---|---|
| 0.50 - 1.25 | 8.0E-3 | 2.7E-6 | 2963 |
| 1.25 - 1.75 | 1.6E-2 | 4.9E-6 | 3265 |
| 1.75 - 2.25 | 4.0E-2 | 1.3E-5 | 3077 |
| 2.25 - 5.42 | 8.0E-2 | 2.5E-5 | 3200 |

### Nitrogen gas Pumping Speed Test Set-up

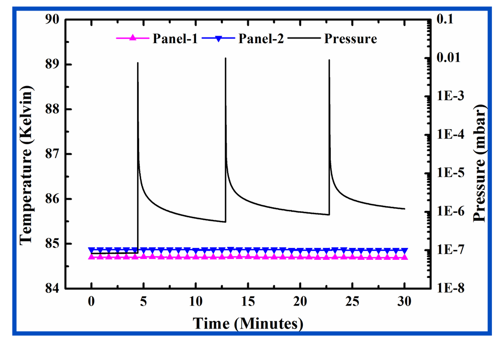


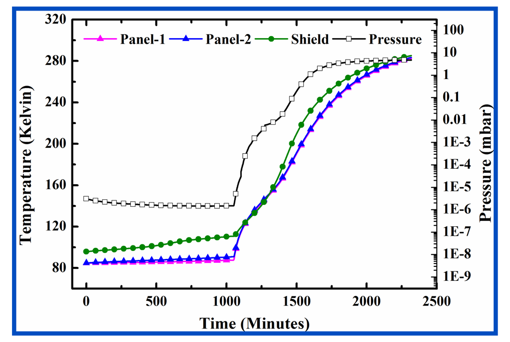

Cool down and ultimate pressure of the pump




Dosing of 30-40 mbar.l $N_2$ gas using fast opening valve



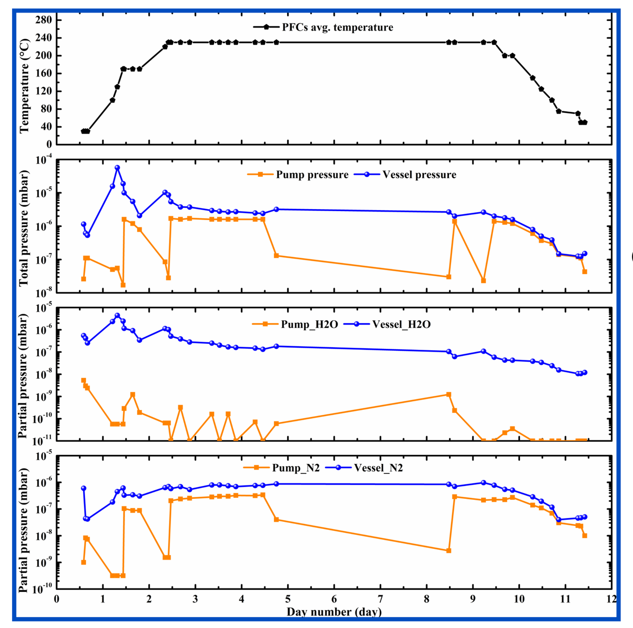

Zoomed view of the pulse dosing experiment



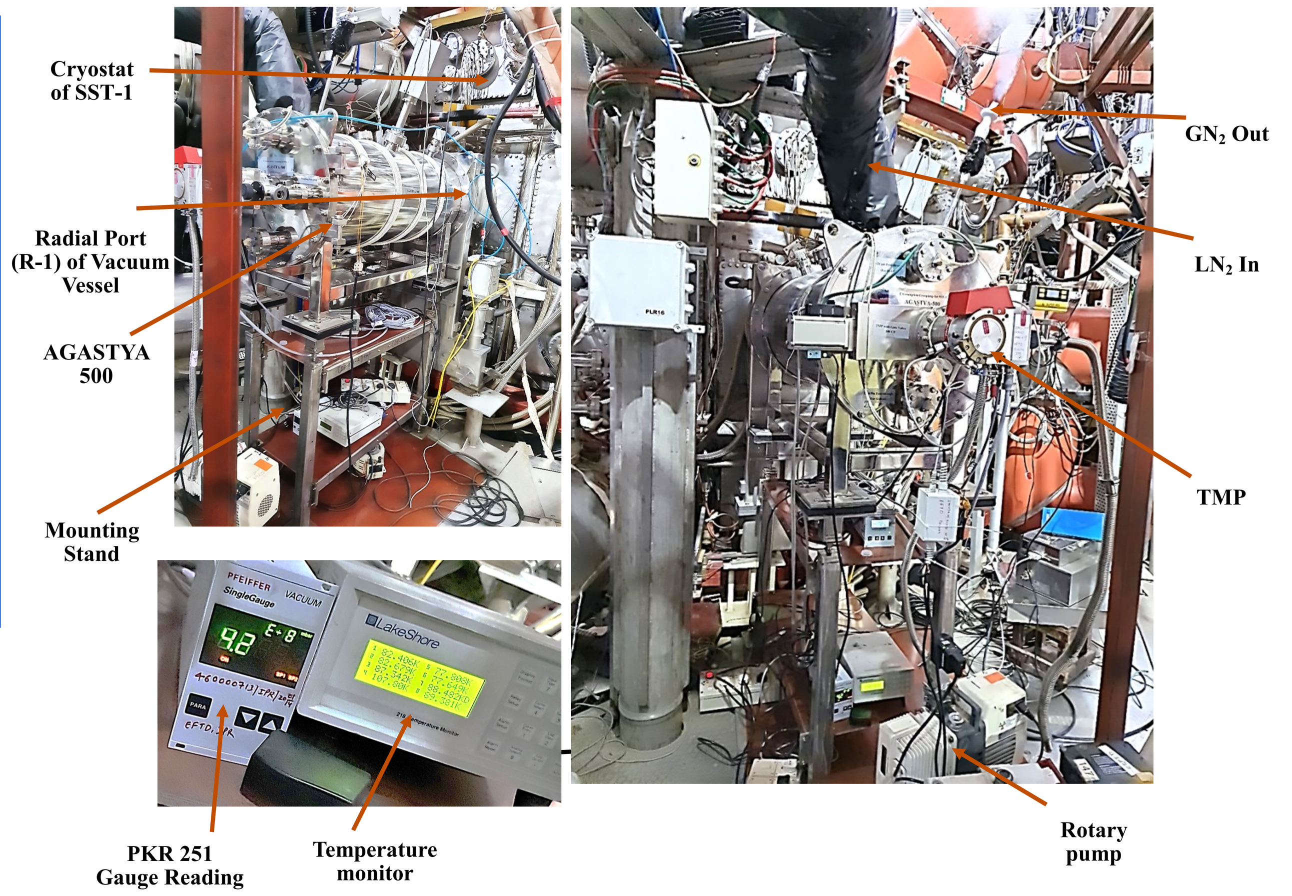

Warm-up of the pump for the exhaust study.

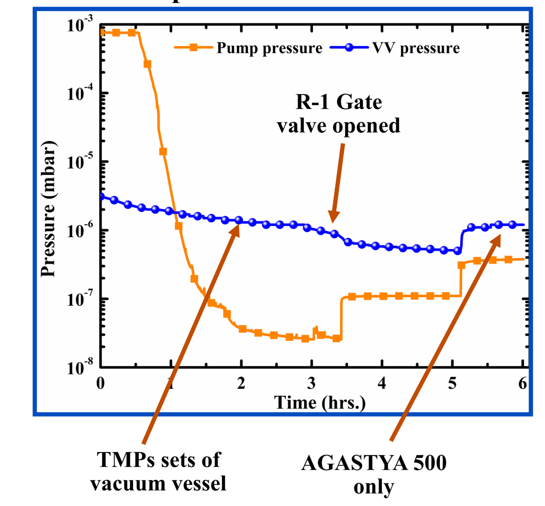
- ⇒The dosing of 30-40 mbar.l was given to AGASTYA 500 using the fast-opening valve in 1.1 ms.
- ⇒The pressure rises to the order of ~1E-2 mbar pressure and started to decrease due to the pumping of gas. These shots were repeated till the dome vacuum reached to ≤ 5E-6 mbar.
- ⇒Cryopanels of AGASTYA 500 was heated without any active vacuum systems. Pressure of vacuum chamber of AGASTYA rises to 4.7 mbar that conforms to supplied gas.
- ⇒The charcoal coated panels started to outgas the adsorbed $N_2$ gas at the temperature of ~ 92 K measured using Pt-100 temperature sensor.

## Installation of AGASTYA 500 to SST-1 Tokamak

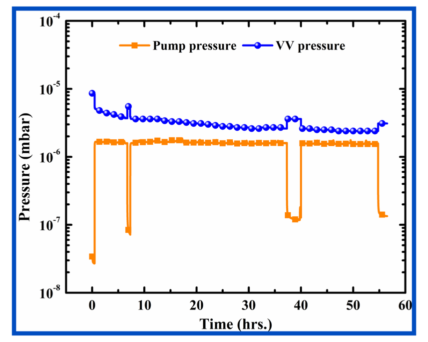



Complete baking cycle of the Plasma Facing Components of SST-1

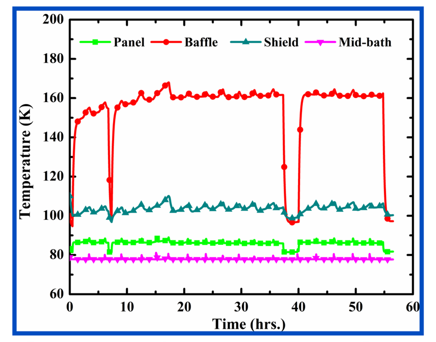


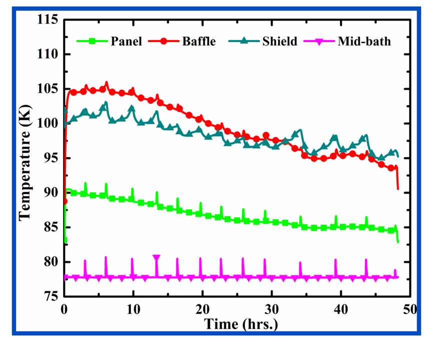

Pressure of the vacuum vessel and 80 K sorption pump before baking.




Pressure of vacuum vessel at 230 °C baking temperature.




Component's temperature of pump at 230 °C baking temperature.




Component's temperature of pump during ramp down to 50 °C.

- ⇒It was the first time that the 80 K sorption pump was operated facing the Plasma Facing Components (PFCs). The experiment was successful in the high radiation heat load and pumping of water vapour, nitrogen gas etc. were observed.
- ⇒Closed refrigeration-cycle based cryopump has smaller cold surfaces to pump water vapour than the developed 80 K sorption pump. The developed cryopump has continuously pumped water vapour for more than 48 h at the baking temperatures.
- ⇒The target to bake PFCs of the SST-1 is to get lower Z-impurities to the possible extent The baking was done for few days to remove impurities from monolayers and pores of PFCs surfaces. During the plasma operations, high energy particles can hit the PFCs that results in increase of the impurities.

## Conclusion

- ⇒The pump was designed for the pumping speed of ~ 20,000 l/s for the water vapour and the achieved pumping speed was ~ 26,000 l/s at 293 K.
- ⇒Pumping speed of the $N_2$ gas was expected to be low as the baffle in the front of the pump reduces the molecular conductance of the incoming gas. Maximum pumping speed of ~ 3265 l/s was observed at 293 K and ≤ 2400 l/s at 383 K.
- ⇒The pump was fabricated to achieve the ultimate vacuum of ~1.0E-7 mbar in the vacuum vessel of the SST-1. The experimental results were comparable with the design parameters and thermal analysis results.
- ⇒ The partial pressure of the water vapour was reduced from 4.4E-6 to 1.1E-8 mbar using 80 K sorption pump and TMP sets after complete baking cycle of the SST-1 machine.

## References

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