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Fabrication Test of an Engineering Model Cryo-Sorption Pump of KAERI Test Stand for KSTAR NBI*

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Abstract

The neutral beam injection system for KSTAR tokamak requires a pumping speed of > 2×10^3 m^3/s to evacuate hydrogen/deuterium gases in the beam line chamber. In order to develop the KSTAR NBI system in KAERI test stand, that does not have a liquid He plant for the cryo-condensation pump, the cryo-sorption pump is being developed. An engineering model cryo-sorption pump, that will be a module of the pump for KAERI test stand, are designed, fabricated, and tested. The basic concept of the design is to obtain a maximum pumping speed with one refrigerator and minimum depth. The measured pumping speed of the engineering model is 80 m^3/s for hydrogen at the panel temperature of 12 K. This pump will be used for the KAERI NBI Test Stand.

Keywords:

Neutral Beam Injection, KSTAR tokamak, Cryo-Sorption Pump

1. Introduction

The neutral beam injection system for KSTAR tokamak [1] is developed in KAERI (Korea Atomic Energy Research Institute) test stand. For the test of an ion source, a pumping speed of more than 500 m^3/s is required to evacuate hydrogen/deuterium gases in the test chamber. But KAERI test stand does not have a liquid He plant for the cryo-condensation pump, that is well developed in the many other NBI systems. Due to this reason, the cryo-sorption pump, that are used and developed in the limited NBI systems [3-4], is being developed.

The design concepts of cryo-sorption pump for KAERI test are that

1) It can be used in two existing NBI test chambers at KAERI. One is 1.2 × 1.2 × 2.4 m ion source chamber, the other is 5 × 4 × 3 m NBI vacuum chamber,
2) Because the test chambers have enough surface area for pump installation, it should have minimum depth for space saving of the vacuum chambers.
3) From the view point of cost saving, it should have the maximum pumping speed per cooler.
4) It can be fabricated easily.

The basic design of the cryo-sorption pump is shown in Fig. 1. The cryo-sorption panel is made of rectangular oxygen-free copper. The contact point with the G-M (Gifford-MacMahon) cooler is located in the center of the cryo-sorption panel. This configuration can reduce the thermal resistance to the G-M cooler, so the panel can be easily cooled and the temperature distribution of the panel can be established uniformly.

For the radiation shield, chevron baffle is used because it can minimize the depth of the pump and be

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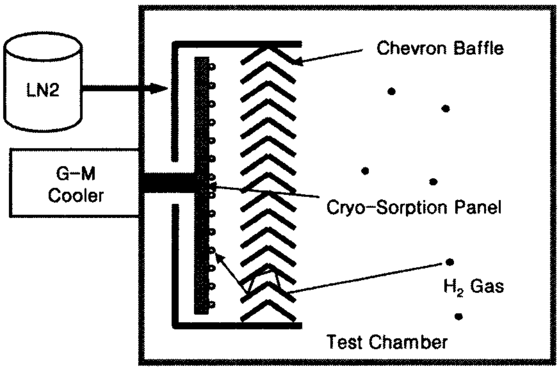

Fig. 1 Schematic diagram of cryo-sorption pump.

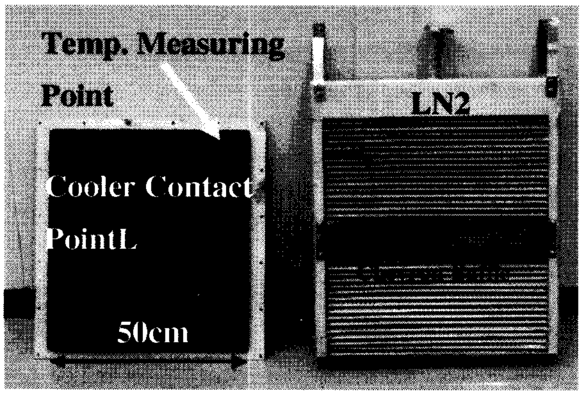

Fig. 2 POP model of cryo-sorption pump.

easily fabricated.

2. Proof-of-Principle (POP) Model Cryo-Sorption Pump [2]

The 30 m^3/s (hydrogen) POP model to check the design and the fabrication of the cryo-sorption pump had been fabricated, and the test result confirms the design.

The POP model cryo-sorption pump is shown in Fig. 2, 3, and 4. To check the thermal design of the cryo-sorption pump, cool-test had been performed before blackening the chevron baffle. The result, that is good agreement with 28 K of calculation, is shown in Fig. 5.

After blacking the chevron baffle, the pumping test had been performed. The hottest temperature in the cryo-sorption panel had reached to 10 K. The achieved base pressure without any pump is 3×10^{-6} Pa, that is due to the epoxy for charcoal adhesion, and the measured pumping speed with constant flow method is 30 m^3/s in the range of gas load $1 \sim 10 \times 10^{-3}$ Pa m^3/s and pressure $\sim 1 \times 10^{-4}$ Pa. The pumping speed has good agreement with the calculated value. Due to the trouble of charcoal adhesion by epoxy, the brazing of charcoal is tested for the ENG model.

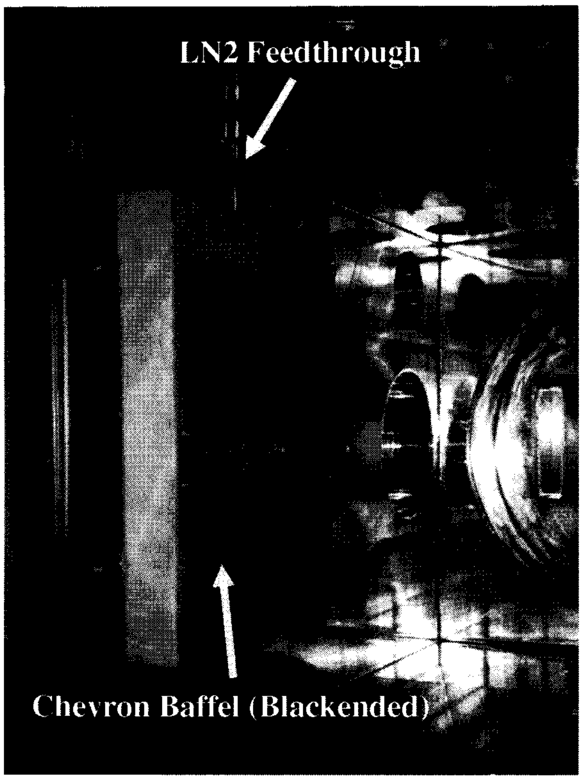

Fig. 3 Installed POP model of cryo-sorption pump.

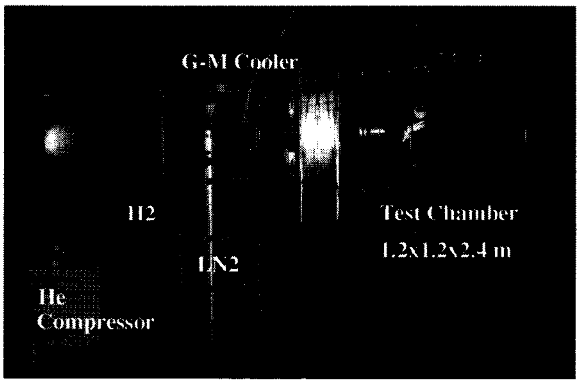

Fig. 4 Experimental Set-up of cyro-sorption pump test.

After the all experiment of the POP model cryo-sorption pump with good results, the construction of the ENG model cryo-sorption pump as a pump for the KAERI test stand is decided.

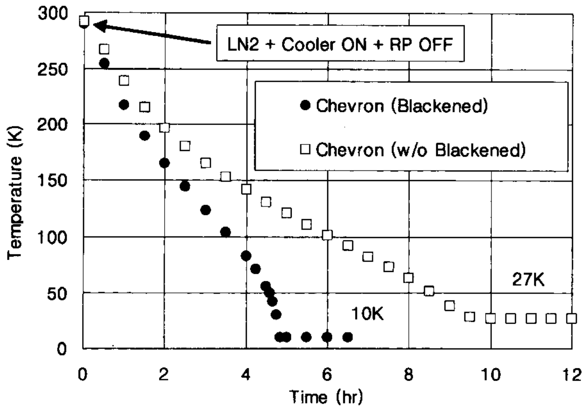

Fig. 5 Cool-down curve of POP cryo-sorption pump.

3. Design and Fabrication of Engineering Model Cryo-Sorption Pump

The engineering model cryo-sorption pump, that will be a module of the pump for KAERI test stand, are designed with the data from the POP cryo-sorption pump. The basic idea of the design is to obtain a maximum pumping speed with one refrigerator, and to have a minimum heat capacity for easy regeneration that is good for the long pulse operation. The model consists of a 15 K cryo-sorption panel, an 80 K chevron baffle, and an 80 K radiation shield. The determined dimensions of the cryo-sorption panel are 1.2 m wide and 0.8 m high. Activated coconut charcoal is brazed on oxygen free copper plate and cooled with a G-M refrigerator of 8 W at 15 K. The cryo-sorption panel is suspended by the Glass/Epoxy composite strips, that can be absorbed the movement of the panel during the cool-down. To reduce the heat capacity of the cryo-sorption panel for easy regeneration, the minimum thickness of the copper plate, with that the temperature difference is less than 1 K, is determined with 5.3 W heat load. The calculated hydrogen pumping speed is 80 m^3/s with the equation for the ideal 2-dimensional pump.

The fabricated ENG model cryo-sorption pump is shown in Fig. 6. A 25×10^{-3} m^3/s rotary pump is used for evacuating down below 1×10^{-1} Pa. The temperature is measured with silicon diode thermometer (Leybold), the pressure is measured with cold cathode gauge (Balzers), and the hydrogen gas, that is feed by a leak valve, is measured with mass flow meter (MKS).

4. Test Results of ENG Model

After the installation of the ENG model cryo-sorption pump, the test had been performed. Fig. 7 shows the cool-down curve of ENG cryo-sorption pump. The final hottest temperature on the cryo-sorption panel is 12 K, that is enough temperature for the hydrogen pumping.

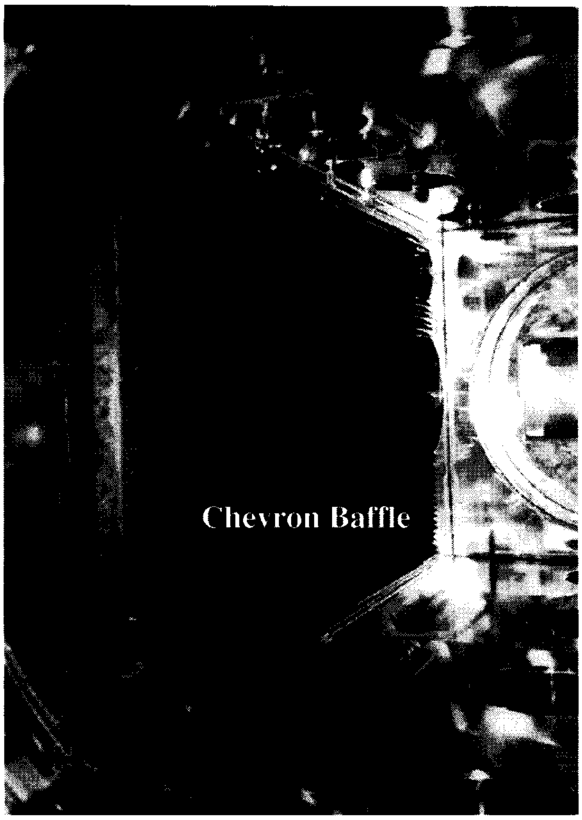

Fig. 6 ENG model cryo-sorption pump.

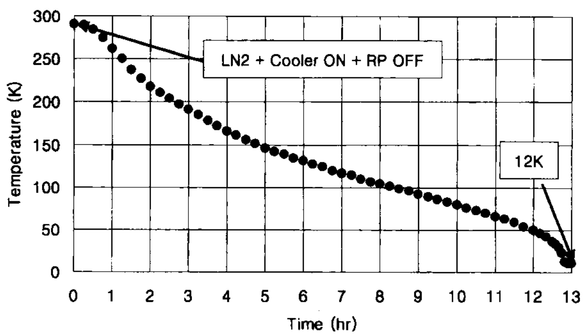

Fig. 7 Cool-down curve of ENG cryo-sorption pump.

Fig. 8 shows the pressure vs. temperature plot during the cool-down. The obtained base pressure is 8×10^{-7} Pa, that is better value than POP cyro-sorption due to the charcoal brazing. As shown in this figure, the residual pressure depends on the temperature, and shows

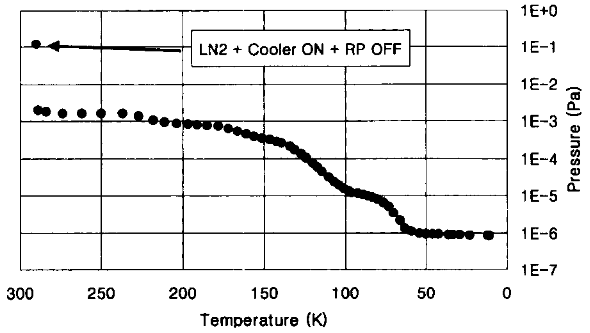

Fig. 8 Pressure vs. temperature during cool-down.

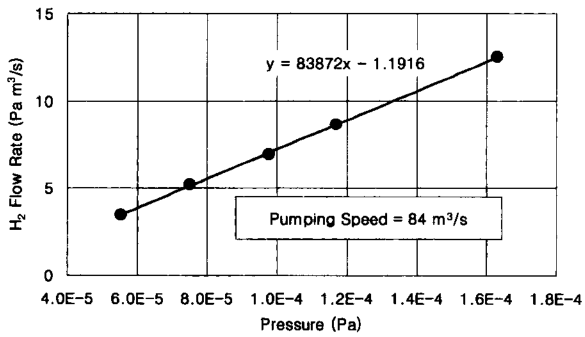

Fig. 9 Pumping speed of ENG model cryo-sorption pump

the step-wise form due to the temperature dependence of the absorption of charcoal for the specific gas. These data will be used for the determination of regeneration temperatures for the specific gases. The residual gas analysis will be performed for this purpose.

The measured pumping speed of the ENG model cryo-sorption pump is 84 m^3/s, as shown in Fig. 9. Due to the explosive limit of the test stand chamber for the hydrogen gases, the pumping capacity of the ENG-model was not be measured. The pumping capacity measurement can be performed in the NBI vacuum chamber with a prototype cryo-sorption pump as next stage.

5. Conclusion

The ENG model cryo-sorption have been designed and fabricated. The performances of the pump are acceptable for the pump of KAERI test stand. But, more tests for pumping capacity, reliability of charcoal brazing, etc are necessary.

This pump will be used for KAERI NBI test stand. And also the cryo-sorption pump can be the main pump of KSTAR NBI. The cryo-sorption pump has the advantage for long pulse operation due to the easy regeneration. But the main pump will be selected by the other condition, such as cost, LHe availability, and schedule of the project.

Acknowledgement

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