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Pumping Simulation of the Vacuum System for HANARO CNS

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1. Introduction

In order to design the Cold Neutron Source (CNS) in HANARO, a vacuum system is required for the thermal insulation of the low-temperature thermo-siphon loop in a moderator cell. The moderator cell is filled with the liquid hydrogen to be used to lower the temperature of the thermal neutron. When the liquid hydrogen is transformed by the gamma heating, it goes up to the heat exchanger, where it is re-liquefied and returned to the moderator cell by gravity force, which is called a thermo-siphon loop. [1] Therefore, the vacuum system is required for the thermal insulation of the low-temperature thermo-siphon loop in a moderator cell.

The main function of the vacuum system in the vacuum containment is to act as a thermal insulation for the cold part of the in-pile assembly and to act as a safety barrier against the irruption of liquids and/or gases from the outside. The thermal insulation is of relevance to the performance of the in-pile assembly cooling. The vacuum is achieved by means of two vacuum pumping sets. One of the pumping sets is in operation while another is on standby.

In order to design the vacuum system, it is very important to know how long it takes to reach the required pressure, which is called pumping speed. The pumping speed means the own conductance of each vacuum pump depending on the operation mode of the vacuum system. In this paper, it was reviewed to find the proper capacity and pumping speed of the vacuum pump to be used for a backing pump to the high vacuum pump. And, it was intended to determine the P&ID of the vacuum system.

2. Basic Condition

The assumed vacuum volume was calculated in 55.5 liters. The volume may be changed slightly in later as its final design is not finished. The required vacuum is assumed at lower than or equal to 1.33×10^{-3} Pa (1×10^{-5} Torr). The length of pipeline is approximately 20 m, while its diameter assumed as 52.7 mm.

The pumping simulation for the backing pump was carried out by solving a simultaneous equation, as shown in equation (1) ~ (3). First of all, the Reynolds number is required to determine the flow type in the initial conditions, which is in atmosphere and room temperature. According to the Reynolds number, the vacuum flow is classified into three types such as viscous, transition and molecular flow.

As results of the limit pressure, the limit of the viscous flow is higher than or equal to 0.075 and that of the transition flow is from 0.022 to 0.075, and that of the molecular flow is lower than or equal to 0.022. After then, the conductance is calculated for each flow type and finally the system suction velocity is calculated by combining the system conductance with the pump velocity as shown equation (3).

$$\mathrm{Re} = \frac{D\ v\ \rho}{\mu} \qquad (1)$$

$$S = 2.3\left(\frac{V}{t}\right)\log\frac{(P_i - P_b)}{(P_o - P_b)} \qquad (2)$$

$$S = \frac{1}{\frac{1}{C} + \frac{1}{S_b}} \qquad (3)$$

3. Simulation by Operation

The vacuum system is composed of several equipment such as a vacuum containment, a vacuum box which contains two vacuum pumping sets and etc., and a discharged gas collection tank, as shown in Fig. 1.

There are two vacuum disposal tanks, which are intended to collect the vented out gas from the vacuum containment during the normal operation.

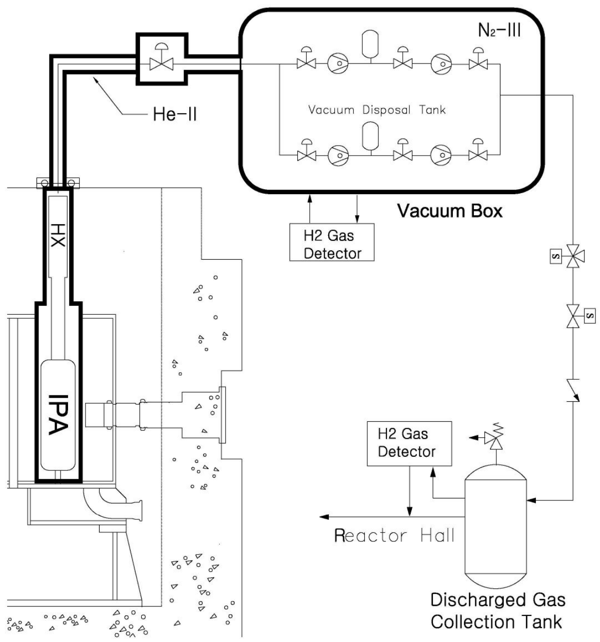

Fig. 1. Flow sheet of the vacuum system

The vacuum disposal tank is installed between high vacuum pump (TMP) and low vacuum pump (Dry). The backing pump will be used for two different aims. First one is to lower the pressure of the vacuum system from atmosphere to low vacuum level. And, another one is to transfer the collected gas inside the vacuum disposal tank into the Discharged Gas Collection Tank (DGCT). The vacuum disposal tank collects the gas vented from the vacuum containment.

According to the simulation, it takes a pumping time within about 15 minutes to reach the required vacuum pressure, 2×10^{-3} kPa, that TMP can be surely operated, as shown Fig. 3. The reasonable capacity of dry pump is determined as 100 m^3 per hour.

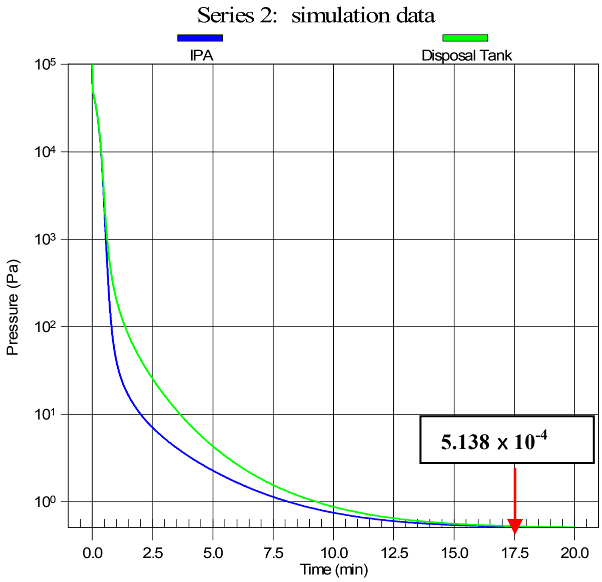

Fig. 2. Simulation for lowering from atmosphere

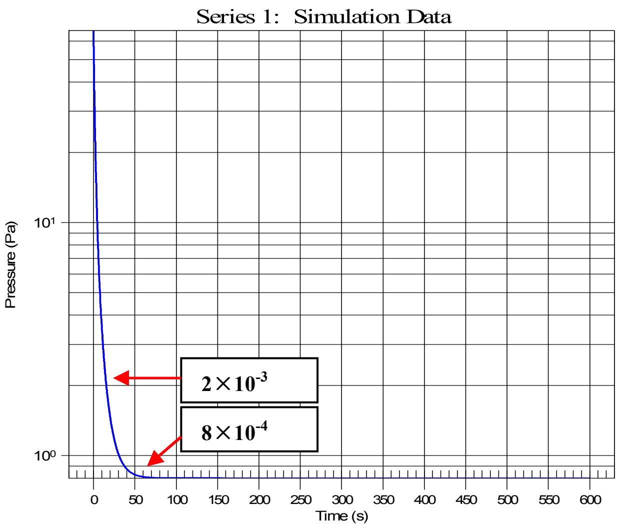

Fig. 3. Simulation for transferring into DGCT

The pressure inside vacuum disposal tanks shall be always kept to lower than inlet pressure, 2×10^{-3} kPa, of high vacuum pump during normal operation. If it is over the pressure limit, the dry pump shall be automatically operated and then the inside gas is transferred into a discharged gas collection tank. At this point of view, the simulation result of dry pump is presented to reach enough within 18 seconds meeting the re-operating requirement of TMP, as shown Fig. 3.

These results are not including the out-gassing rate on the surface roughness of the vacuum containment. In general, the pumping speed was almost governed by the vacuum properties of the materials [4]. The required vacuum of this system will be enough at lower than or equal to 10^{-3} Pa during a normal operation. Therefore, it is not required to add the effect of the out-gassing rate to the calculation.

4. Conclusion

This paper was reviewed to find the proper capacity and pumping speed of the vacuum pump to be used for a backing pump to the high vacuum pump. Therefore, the pumping simulation for the backing pump was carried out by considering the operation procedure and basic condition of the vacuum system.

In order to act as a backing pump of the high vacuum pump, it was sufficed that the capacity of the backing pump shall be higher than 100 m^3 per hour.

In case of inside pressure of the vacuum disposal tank being over the pressure limit, it is found that the pumping time is surely enough within 18 seconds to satisfy again the operating condition of high vacuum pump.

Conclusively, it is supposed that theses results will be used properly for determining the capacity of high vacuum pump and to calculate the volume of the vacuum disposal tank.

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