Progress in the performance evaluation of key components in coolant purification system for nuclear fusion reactors

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1. Introduction

In a fusion reactor, the Coolant Purification System (CPS) serves as an essential auxiliary system that effectively removes tritium and other impurities in the helium cooling system [1]. The CPS is comprised of several columns, including an oxide bed to oxidize Q_2 to Q_2O, a Molecular Sieve Bed (MSB) to adsorb the Q_2O, a reduction bed to reduce the Q_2O back to Q_2, and a heated getter to eliminate other impurities. In order to evaluate the performance of each column, we have designed and established a Research Apparatus for Vapor Adsorption and Desorption (RAVAD). Prior study has examined the effects of water concentration, gas velocity, and MSB geometry on performance. We are currently in the process of expanding the RAVAD facility to evaluate the performance of an oxide bed and a reduction bed, which represents the subsequent objective of this research.

2. Test facility and methods

RAVAD was developed as a testing facility to investigate the adsorption-desorption properties of MSBs, which are key components of the CPS in nuclear fusion reactors [2]. RAVAD is a once-through loop test facility that can operate in various carrier gas environments, and the test sections are designed interchangeably to evaluate MSBs of varying geometries. Previous studies have evaluated the effects of water concentration and gas velocity as well as MSB geometry effects. By utilizing the bed depth service time model, it is possible to establish a methodology for predicting MSB performance [3]. The primary objective of evaluating the MSB has been accomplished, and RAVAD is currently expanding to include performance testing of the oxide bed and the reduction bed.

The oxide bed is a fixed column containing copper oxide, which features a heater at the front and a cooler at the back. The carrier gas, containing hydrogen from a cylinder tank, passes through the heater and is heated to over 250 °C before being supplied to the column. After the oxygen is consumed, the oxide bed can be regenerated by injecting additional oxygen. The oxide bed testing facility can be installed together with RAVAD, but individual experiments can also be performed. For this purpose, a vapor analyzer and a hydrogen concentration analyzer were added.

The RAVAD can also conduct performance tests of the reduction bed. When the MSB becomes saturated, it shifts to the desorption process and sends water to the reduction bed. The reduction bed reduces the water molecules back to hydrogen isotopes before sending them to the tritium accounting system. RAVAD can generate gas with vapor under high temperature and low pressure conditions, but it was unable to measure the hydrogen concentration after reduction. However, by replacing the MSB with a reduction bed module in the test section where the MSB is located, it is feasible to conduct tests in the reduction bed with a hydrogen measurement system.

3. Conclusion and further works

MSB testing with RAVAD has been completed, and further modifications and expansion of the facility are underway to verify the performance of the oxide bed and reduction bed as the next objective. The integration of experiments and regeneration experiments, as well as individual experiments of each device, will facilitate the development of a more accurate CPS design.

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