Progress in the performance test of key components in the helium cooling system for nuclear fusion reactors

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1. Introduction

In the nuclear fusion reactor, the breeding blanket system is essential for continuously supplying the fuel, tritium, which is difficult to procure externally. The primary role of the Helium Cooling System (HCS) is to maintain a specific high-temperature environment to facilitate effective breeding of tritium and simultaneously transfer the heat generated during the breeding process to the heat sink [1]. In addition, it removes the heat transferred through the first wall in contact with the tokamak. Part of the HCS is connected to a Coolant Purification System to remove permeated tritium and other impurities, thus maintaining a pure helium environment [2]. Furthermore, the HCS operates in various scenarios during plasma operation and maintenance, ensuring stable system operation under each condition. The HCS operates in a wide range of temperatures, from room temperature up to 500°C, in an environment of 8 MPa pressure. Given the significant roles of the components within the HCS, this study aims to experimentally evaluate the performance of key components.

2. Test facility and methods

The Helium Supply System (HeSS), established at the Korea Atomic Energy Research Institute, serves the purpose of experimentally verifying the performance of key components in the HCS and executing operational scenarios [3]. Key components include the helium circulator, economizer, and water cooler. As there is considerable pressure drop within the system, validating the performance of the helium circulator is crucial for ensuring enough compression ratio and stable cooling. The helium circulator in HeSS, a domestically developed device, can circulate approximately 1.5kg/s of helium with a compression ratio of about 1.1 under high-pressure conditions. Although it can operate up to 10 MPa, its temperature capability is limited to 200°C, preventing direct use with temperatures exceeding this threshold. Hence, an economizer is used to divide the HCS into high-temperature and low-temperature loops, forming an eight-shaped configuration. This design allows the helium to cool the breeding blanket to 500°C using the circulator in the low-temperature loop. The water cooler, positioned after the economizer, transfer residual heat to a heat sink, and lowering the temperature of the helium entering the circulator to below 50°C. Additionally, control valves regulate flow rates in each loop, and a pre-heater adjusts helium temperatures. The experiments initially focus on verifying the performance of individual devices, aiming to obtain performance curves for flow rate versus compression ratio of the circulator, pressure drop curves, and effectiveness for various flow rates in the heat exchanger. Subsequently, experiments will proceed to operational scenarios and transient tests for the HCS.

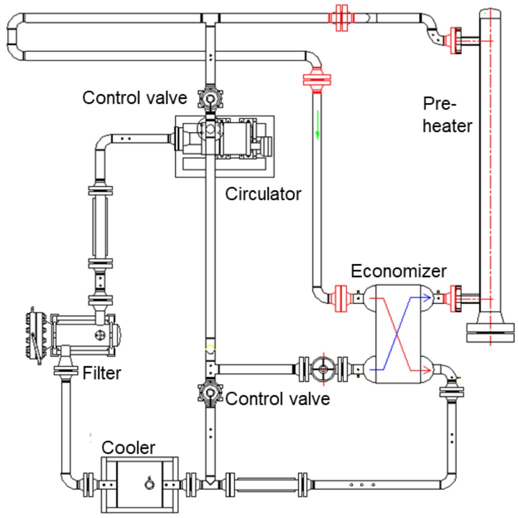

Fig. 1. Detailed diagram of Helium Supply System

3. Conclusion

In the development of the essential ancillary system for the breeding blanket system, the HCS, performance validation experiments for key components and scenario-based operations have been conducted by establishing the HeSS. Upgrades to the HeSS facility have been carried out, including the application of a newly developed circulator and heat exchanger, to operate under severe conditions and reduce pressure drop. Reconstruction is nearing completion. Through scheduled experiments, we anticipate enhancing reliability in HCS design and optimizing operating conditions for each component through precise evaluations.

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