A HAZOP Analysis on the Design of Coolant Purification System for Breeding Blanket

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1. Introduction

Various conceptual designs for breeding blankets have been proposed for nuclear fusion reactors. Among these, the helium-cooled type with ceramic pebbles for tritium breeding is currently under development [1]. To support this breeding blanket, various ancillary systems are being designed and developed, where the Coolant Purification System (CPS) has a crucial role in removing impurities from the helium coolant [2, 3]. Therefore, ensuring the safe and reliable operation of the CPS is essential for maintaining the overall efficiency and stability of the breeding blanket.

In this study, a Hazard and Operability (HAZOP) analysis is conducted on the CPS design to systematically identify potential hazards and enhance safety.

2. HAZOP Methodology

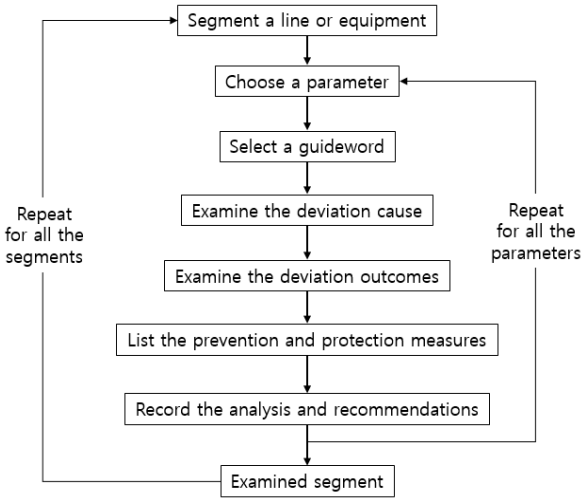

Fig. 1. Flow diagram of the HAZOP analysis

HAZOP is a structured and systematic technique used to identify potential risks and operability issues in complex systems. The general process follows Fig. 1. The system is segmented into key components and process lines. Each segment is analyzed based on its function and potential failure modes. A deviation coverage matrix is applied to assess hazards associated with key parameters such as coolant flow rate, pressure, temperature, impurity concentration, and other relevant operational variables. The identified deviations then correspond to each consequence of interest (COI) and are categorized into predefined hazard classifications.

3. HAZOP Analysis

The analysis reveals several critical risks based on more than 1700 deviations. Fig.2 presents an overview of HAZOP CPS analysis. Among these deviations, 25% are associated with events leading to a loss of CPS performance. In addition, 33% of deviations affect CPS components or other subsystems. 11% contribute to hazards for workers or the environment, including risks associated with the specific purification process. 27% of deviations are identified as credible to occur without COI, whereas only 2.5% correspond to deviations considered not credible. To mitigate these risks, design modifications and safety measures such as additional sensors and switches with monitoring, redundant components, and optimized process lines are proposed. Also, additional analyses are required to ensure more precise risk assessment and mitigation strategies.

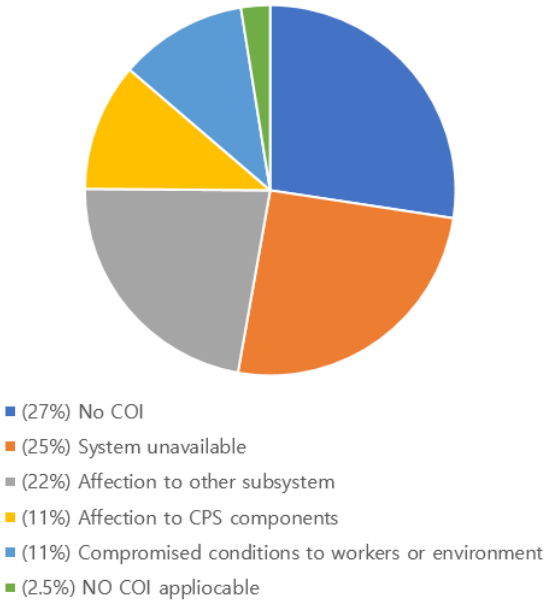

Fig. 2. An overview of HAZOP CPS analysis

4. Conclusions

This comprehensive HAZOP analysis ensures that potential risks associated with the CPS are systematically identified and mitigated. The proposed design enhancements derived from the HAZOP analysis contribute to a more consolidated CPS design, leading to improved system safety, reliability, and operational efficiency.

Acknowledgments

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