An Implementation of Safety Requirements for a Hydrogen-moderated Cold Neutron Source in HANARO

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1. Introduction

A development of a cold neutron source has been in the process since 2003 to enhance the basic research and utilization of HANARO. As the cold neutron source contains flammable hydrogen and it will be installed in the reactor tank, it should be assured that the reactor safety will not be impaired by the cold neutron source or any of its systems. A basic idea of the engineering implementation is a defence-in-depth approach to avoid any accidental hydrogen-oxygen reaction caused by a hydrogen release outward or an air ingress inward. This manuscript summarizes the status of the system design for the cold neutron source, and explains how to implement the safety requirements in the design.

The HANARO CNS consists of a hydrogen system, vacuum system, gas blanket system, and helium refrigeration system, electrical and instrumentation & control system. Considering that an In-Pool Assembly (IPA) containing explosive hydrogen will be installed in the reactor tank, some design requirements for reactor safety should be applied to the CNS design.

2. System Classification

Structures, components and systems required for assuring a reactor's safety and/or for the protection of lives and relevant facilities should be designed, fabricated, erected and tested by predefined standards commensurate with the importance of the safety functions to be performed. To increase the level of confidence in their performances, classification requirements are imposed in areas of safety, seismic and quality grade. The classification rule stated was guided by the HANARO practices, specifically from a reactor safety point of view. [1] Figure 1 shows a relationship of the classes.

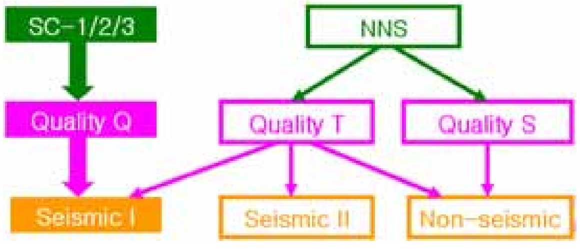

Figure 1. Relationship of the Classification

The IPA is classified to the highest grade of safety, seismic and quality category.

3. System Implementation

The design philosophy relies on simple and passive features that minimize the possibility of a system failure or a procedural problem. The principles of a conservatism, simplicity, redundancy, fail-safe design, and passive safety features are included in the design as much as possible. Figure 2 shows a system flow diagram of the HANARO CNS.

All the hydrogen systems are surrounded by a helium blanket for physical separation. The vacuum containment containing the liquid hydrogen is designed to keep its structural integrity against the H_2-O_2 reaction. A high vacuum, 1×10^{-5} torr, is unavoidably required for a thermal insulation of the low-temperature thermo-siphon loop for a cold neutron source in HANARO.[2]

All the components for vacuum system are blanketed by an inert gas, to avoid an accidental hydrogen-air contact. The vacuum pumping sets and valves are duplicated for an operational flexibility. All the valves in the vacuum environment are actuated with pressurized nitrogen to avoid the hydrogen-air mixture.

Since the blanket system is static, no significant pressure variation is expected. A pressure monitoring will be an effective way of detecting a leakage. The operating pressure should be higher than the atmospheric pressure but lower than the hydrogen system pressure. The blanket area is intentionally divided into a few compartments to avoid a common cause failure.

The IPA shall be designed to maintain its structural integrity even under a H_2-O_2 explosion in it. Considering that the pressure wave from the explosion would reach components or tanks through connecting pipes, the hydrogen buffer tank and Vacuum box etc., shall be designed with 5 bar of design pressure based on a hydrogen system calculation.

Considering that the CNS I&C system serves the function of a reactor shutdown, it should have the best quality in order to enhance the reliability. The safety design requirements like the redundancy, independence, diversity and fail-safe etc., shall be applied to the design of the CNS protective instrument and control. The following events will requests a reactor shutdown.

- Hydrogen pressure high
- Hydrogen pressure low
- Vacuum pressure high

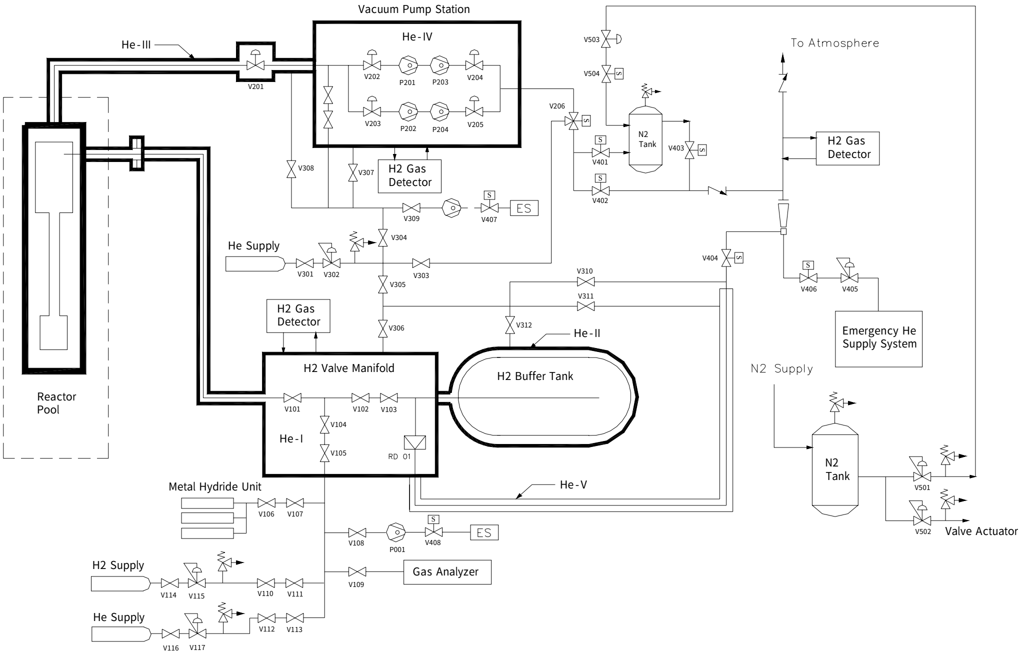

Figure 2. System Flow Diagram of HANARO CNS

There are three operation modes in HANARO CNS : (1) Shutdown Mode, (2) Start-up Mode and (3) Normal Operation Mode. The CNS operation modes should coexist with the reactor operation modes. Table 2 shows the relationship of both the operating modes.

Table 1. CNS Operating Modes

Modes	Shutdown (SD)	Start-up (SU)	Normal (NO)
Reactor	shutdown	Shutdown	operation
Hydrogen	Vapor	Liquid	Liquid
He refrigerator	stop	Operation	Operation

4. Future Works and Conclusion

The design of the cold neutron source should be guided as much by the safety aspects as by the needs of the user's group. The design objective is an efficient system, which can be operated safely with regards to the reactor and personnel. This paper introduces how to implement the safety requirements in the engineering design of the systems and facilities for the HANARO CNS by establishing a structural robustness as well as an design elaboration, and establishes a baseline reference for the next design stage. Although validations will continue, this paper provides the basis by which a detailed design of the HANARO CNS will proceed.

Acknowledgements

This study has been carried out under the Nuclear R&D Program by Korean Ministry of Science and Technology.

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