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Prerequisite for Adopting a Passive Safety System with a Safeguard Vessel for SMART

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1. Introduction

Owing to its native characteristics, the application area of the Small and Medium sized Reactors (SMR) can be easily expanded to a non-electricity field such as a sea water desalination and a district heating. SMRs have beneficial advantages of a reactor safety and economics by an easy implementation of advanced design concepts and technology [1]. SMART, a small sized integral type PWR with a rated thermal power of 330 MWt is one of the advanced SMR [2]. Major components of the reactor coolant system such as the pressurizer, reactor coolant pump, and steam generators are located inside the reactor vessel as shown in Fig. 1. The SMART can fundamentally eliminate the possibility of large break loss of coolant accidents, improve the natural circulation capability, and better accommodate and thus enhance a resistance to a wide range of transients and accidents.

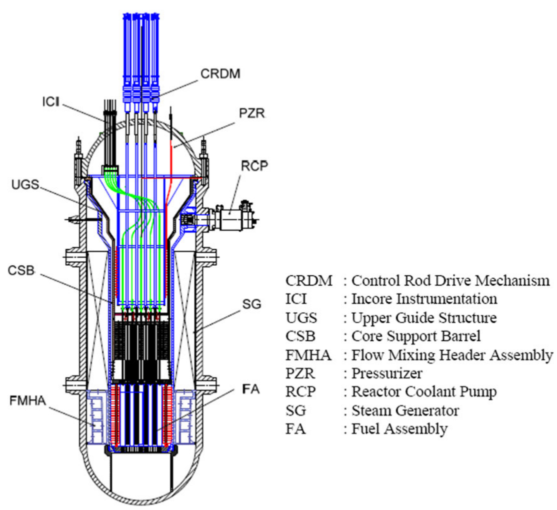

Fig. 1. SMART Reactor Assembly

The safety of SMART can be significantly enhanced through adopting the passive safety system with the safeguard vessel. However several engineering works are required not only for the evaluation of safety functions but also for the non-safety aspects such as the construction, component maintenance and refueling. First, the passive safety systems with the safeguard vessel for the SMART are described in this study. Then prerequisites for adopting the passive safety system with the safeguard vessel for SMART are reviewed from the viewpoint of a construction, component maintenance, and refueling.

2. Passive Safety Systems with Safeguard Vessel

The passive safety system is designed to perform the safety functions passively for 72 hours without any operator's intervention or off-site support and let the reactor system reach a safe stable condition within 36 hours. The passive safety system consists of following systems:

- Safeguard vessel
- Passive safety injection system
- Boron injection system
- Passive residual heat removal system
- Overpressure protection system
- Severe accident mitigation system

Fig. 2 shows a schematic drawing of the passive safety systems with the safeguard vessel. The safeguard vessel is a steel-made, leak-tight pressure vessel housing the RPV, SIT, and the associated valves and pipelines. A primary function of the safeguard vessel is to confine any radioactive release from the primary circuit within the vessel under DBAs related to loss of the integrity of the primary system. The pressure suppression pools are used to limit the initial pressure peak within acceptable limits.

When the loss of coolant accident occurs, the blow-down flow rate is reduced by the pressure equilibrium between the reactor coolant system and the safeguard vessel. Initially the borated water is injected from both the safety injection tanks and boron injection tanks passively. The condensed water from the inner surface of the safeguard vessel and the discharged water from the pressure suppression pools are collected in the recirculation sumps and injected to the reactor by gravity. The outer surface of the safeguard vessel is cooled by the air or the water. Four independent passive residual heat removal systems with 50 % capacity each remove core decay heat by natural circulation at any design bases events, and have capability of keeping the core undamaged for 36 hours without any corrective action by operators. The reactor overpressure at the postulated design basis accidents related with a control failure can be reduced through the opening of the pressurizer safety valve.

3. Prerequisites for Adopting the Passive Safety System

For adoption of the passive safety system, its functional capability should be verified though safety analyses and validation experiments. A designer also

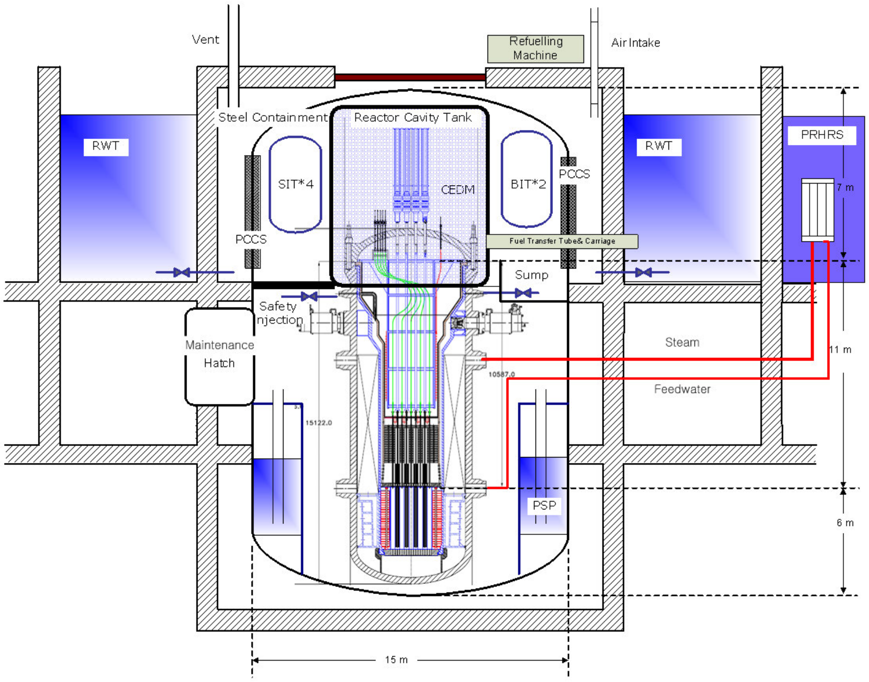

Fig. 2. Schematic Diagram of the SMART Safety System

needs to consider other non-safety aspects such as the construction and maintenance of passive systems. Following points are discussed in this study:

- Safeguard vessel construction
- Main component maintenance
- Refueling

The steel safeguard vessel is manufactured in the factory and welded in the field. The main issue related to the steel safeguard vessel is the requirement of post-weld heat treatment (PWHT) which is required for the steel structure thicker than 1.75 inch. An injection method of combustibles gas or a local treatment by electric heating band can be applied for the PWHT of the safeguard vessel. The PWHT requirement may increase cost and period for the safeguard vessel construction, so an effective and economical PWHT method should be developed.

The main components of reactor coolant system should be inspected and repaired periodically. The free volume of the safeguard vessel is very confined and is not enough for the conventional inspection & maintenance procedures. The Fig. 2 shows the maintenance concept for the internal components with the safeguard vessel. The steam generators and the reactor coolant pumps can be inspected and repaired through the maintenance hatch during an overhaul period. Especially the tubes of steam generator are the pressure boundary of reactor coolant system and are required to be inspected and plugged periodically. As the once-through steam generators are located inside the reactor vessel, it is difficult for men to access the steam generators directly. Automatic inspection and plugging machines should be developed in the future.

The refueling procedure is different from that of currently operating nuclear plants. The reactor internals are withdrawn from the reactor with dry casks and sent to the wet storing pots. The refueling cavity is located inside the safeguard vessel. The burned fuels are transferred to the fuel compartment through the fuel transfer tube & carriage. The long distance between the refueling machine and the top of the core requires development of new refueling machine.

4. Conclusions

An adoption of a passive safety system with a safeguard vessel can enhance the safety of SMART significantly. Several prerequisites for adopting the passive safety system with the safeguard vessel were reviewed from the viewpoint of the safeguard vessel construction, component maintenance and refueling.

REFERENCES

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