Potential Safety Research Issues to Improve Severe Accident Preparedness in CANDU-6

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1. Introduction

In Korea, Pressurized Heavy Water-cooled Reactors (PHWR) account for more than 10% of operating units and have taken an important role in providing national energy supply. During a severe accident, an analysis of a plant performance including the fission product behavior is an essential part of Severe Accident Management (SAM) and emergency planning. For the analyses of this performance, studies for safety issues related with level 2 probabilistic safety assessments or SAM enhancing technologies have been made.

In typical characteristics, the progression of a severe accident in PHWR is a slow process compared with Pressurized Water-cooled Reactor (PWR). This comes from the fact that the PHWR fuel is surrounded by a larger quantity of light and heavy water, which acts as a heat sink to remove the decay heat under severe accident conditions. Fig.1 demonstrates the disassembly of the core inside a calandria vessel being progressed slowly.

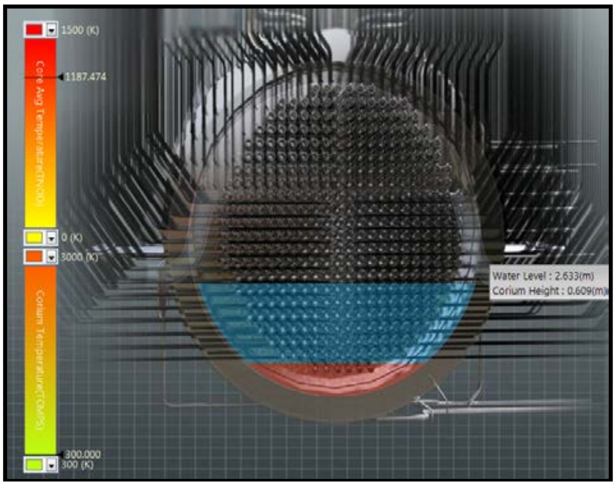

Fig. 1 Core Disassembly inside a Vessel

The following three issues are introduced as potential safety research issues to improve current severe accident preparedness of Wolsong PHWR in Korea. These are not regulatory issues yet but need to be considered as safety enhancing way which can be adapted on the basis of cost-benefit analysis.

- PHTS overpressure protection capability
- Containment overpressure protection capability
- Steam Generator Tube Rupture (SGTR) bypass source term

2. PHTS overpressure protection capability

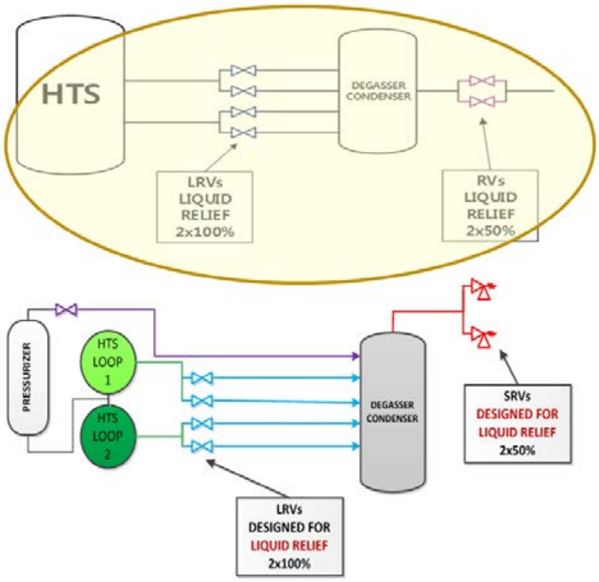

Fig. 2 Typical PHWR SRV configurations

In PHWRs, once thermosyphoning breaks down upon depletion of water inventory in the steam generators, the PHTS re-pressurizes. In CANDU-6, an uncontrolled over-pressurization of the Primary Heat Transport System (PHTS) will likely occur during high pressure severe accident conditions, which could increase the probability for an unplanned and uncontrolled pressure boundary rupture somewhere. This results from an insufficient capacity to relieve decay heat equivalent of steam through the engineered safety relief valves [1], called Degasser Condenser tank Relief Valve (DCRVs) as shown in Fig.2, which separated from the PHTS by another series of liquid relief valves in their discharge path.

3. Containment overpressure protection capability

Fig. 3 Airlocks in PHWR

First, the containment system is designed to control the release of radioactivity to the environment to within the maximum permissible dose limits. The CANDU-6 containment envelope comprises reactor building (R/B), airlocks (see Fig.3), containment isolation system, and fuel transfer. Airlocks are provided for personnel and equipment transfer to the interior of the R/B without breaching containment. They are designed to withstand loss of coolant accident (LOCA) or Main Steam Line Break conditions with door on the R/B end open or closed. Electrical and pneumatic interlocks ensure that only one door of an airlock can be open at a time. Each door is provided with dual inflatable seals whose failure size is smaller but the dual seal failure pressure is known to be lower than the hoop failure case, which is about 38 psig of median pressure [2].

Secondly, in PHWR, slow and/or rapid steam over pressurization is a significant threat to the R/B integrity if no recovery action can be taken for a long period of time, as in the Fukushima accident. Containment filtered vent system (CFVS) is introduced in CANDU-6 to deal with the threat of this over-pressurization (particularly slow steam pressurization). When CFVS is introduced in Wolsong-1, the R/B has been protected from the over pressurization in most time of severe accident scenarios. Specifically, if the venting strategy is successful, the probability of no R/B failure is evaluated to increase from 35% to about 90% even after core damage occurs [3]. But according to this study, for rapid steam generation or spike, the effectiveness of CFVS strategy is not clarified as shown in Fig.4 [4], which needs to be validated.

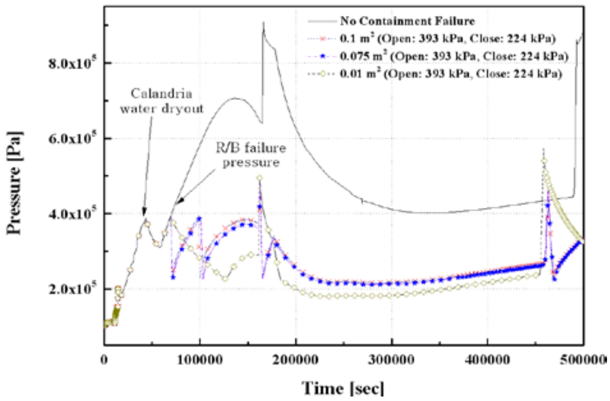

Fig. 4 R/B pressure trend under CFVS operation

4. SGTR (bypass) source term

An SGTR accident, leading to severe core damage, can become a bypass scenario because of the potential for a direct release of fission products into the environment. Fission products located in the steam generator (SG) can be released into the environment through the main steam safety valves (MSSVs) if the valves (1) open passively due to high SG pressure, or (2) are locked open for a crash cooldown manually by operator action or when LOCA signal is generated by a drop in the PHTS pressure. In the latter case, there is a potential for a continuous discharge of fission products into the environment. An operator can mitigate the release of fission products through the open MSSVs by closing all valves, or at least the valves in the broken SG, but this would require an enhanced specification in SAM guidelines, or significant operator intervention.

5. Summary

While the fraction of electric power from a PHWR is more than 10% in Korea, the establishment of PHWR safety enhancement based on the SAM technology is still weak. Under this situation, the current research shows a vision to strengthen the unique value of a PHWR by resolving the key severe accident issues weakening the PHWRs' accident preparedness. This study is believed to make a fundamental contribution to the enhancement of the PHWR safety via listing technical weakness items, and can be utilized to develop the technology to prepare the severe accident thoroughly in CANDU-6.

ACKNOWLEDGMENTS

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