Prediction of the Room 1 Pressure for the HELB of the 3-Pin Fuel Test Loop

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1. Introduction

3-pin fuel test loop (FTL) is under development in HANARO (High-flux Advanced Neutron Application Reactor). It is an experimental facility that provides fuel irradiation and burn up tests under the operational conditions of commercial PWR and CANDU plants. This paper deals with the prediction of the room 1 pressure for the high energy line break of the 3-pin fuel test loop. All pipe and equipment containing the coolant of high energy are placed in the room 1. The room 1 is isolated when design basis accidents occur.

2. Methods and Results

2.1 Modeling of the Fuel Test Loop

The fuel test loop consists of an in-pile test section (IPS) and an out-pile system (OPS). The IPS installed at the IR1 hole of HANARO core [1] has 3 rod test fuels. The OPS is a processing and control system for sustaining proper test conditions. It is categorized into the main cooling water system, emergency cooling water system, letdown, make-up and purification system etc. The emergency cooling water system provides a passive cooling capability for the test fuels subsequent to anticipated operational occurrences (AOO) and design basis accidents (DBA).

MARS computer code has been used for the prediction of the room 1 pressure for high energy line break (HELB) [2, 3, 4]. The main cooling water system including the IPS, the emergency cooling water system, and the room 1 were modeled in the MARS code.

The test fuel zone was modeled with a pipe having 7 sub-volumes. The IPS vessel, flow divider, and fuel transport legs were modeled as a heat structure component because of gamma heating. The test fuels were modeled as a heat structure component having 7 axial nodes and 11 radial meshes. The test fuels are 700mm long and the diameters are 9.5mm. The maximum and average linear heat rates are 41.6 and 30.0kW/m respectively.

The fuel test loop has two protection systems. One is HANARO protection system which provides fast scram from the trip parameters such as the high flow, low flow, high pressure, low pressure and high temperature of the IPS. The other is FTL protection system which isolates the IPS from the OPS and injects the emergency cooling water to the IPS from the trip parameters such as the high flow, low-low flow, low-low pressure, and high-high temperature of the IPS.

2.2 Modeling of the Room 1

The OPS of the fuel test loop is placed in the room 1 and room 2, and all high energy line and equipment are arranged in the room 1. The room 1 was modeled a single volume. The volume of the room 1 was about 123m^3, and the initial pressure and temperature were conservatively assumed atmospheric pressure and 40℃ respectively.

Heat structure was implemented in the MARS model, in order to calculate the condensation heat transfer on the vertical wall for the room 1. The area is approximately 266.6m^2. The conductivity of 1.4W/mK was used for the concrete wall with 1200mm thick. Natural convection was applied for the outside thermal boundary condition for the room 1 wall. The ambient temperature of the room 1 outside was assumed 30℃.

2.3 Modeling of High Energy Line Break

The normal operating temperature and pressure for the main cooling water system are generally 300.3℃ and 15.6MPa respectively. The double-ended guillotine break was assumed at the downstream pipe of the main cooling water pump. The discharge coefficient of 1.0 was used and Henry-Fauske model for the critical flow prediction.

2.4 Results

The HANARO is tripped by the low pressure of the IPS in 0.64 second after the high energy line break, and then the FTL protection system is also actuated by the low-low pressure of the IPS right after. The FTL protection system closes loop isolation valves and opens high pressure injection valves and depressurization vent valves.

The loop isolation valves are open for normal operation, and become close for the accident so that the mass and energy release of the high energy coolant in the part of nuclear safety class to the room 1 is prevented. The loop isolation is completed in about 3 seconds after the pipe break. The high pressure injection valves isolate the accumulators of emergency cooling water system from the main cooling water system for normal operation, while the depressurization vent valves separate the waste disposal tank from the main cooling water system. As the high pressure injection valves and the depressurization vent valves become open, the pressurized emergency cooling water in the accumulators is injected to the IPS and then discharged to the waste disposal tank.

Figure 1 shows mass flow rates from the broken pipe. The solid and dashed lines indicate the flow rate from the upstream and downstream pipes respectively. Most coolant in the pipes and equipment such as pressurizer, main cooler, main heater, purification cooler and purification regenerator is released to the room 1 in about 30 seconds. Because most equipment except main heater is placed upstream from the break location and the release from the part of nuclear safety class is prevented from the loop isolation valves, the mass and energy release from the downstream pipe is ended in about 10 seconds.

Figure 2 shows the transient pressure of the room 1. The peak pressure is about 0.23MPa. The pressure increases drastically up to the peak pressure and decreases very slowly after the peak pressure. The room 1 has no active cooling system for cooling the ejected steam from the broken pipe. The way of the heat removal from the room 1 is an only conduction heat transfer through the concrete wall. The outside heat transfer on the wall is also natural convective heat transfer. They are why the pressure decreases extremely slowly.

The existing design of the ceiling of the room 1 is that several shield plugs just lie on the vertical wall of the room 1. The shield plugs are supposed to be lifted at the 0.127MPa. A new design that twenty anchor bolts fix tightly the shield plugs to the vertical wall has been developed. The new design guarantees the structural integrity of the room 1 up to the room 1 pressure of 0.25MPa.

3. Conclusion

The analysis of high energy line break in the room 1 of the fuel test loop has been carried out by MARS code, in order to evaluate the structural integrity of the existing room 1 and provide hydraulic load for the pipe whip calculation. The maximum pressure of the room 1 is predicted approximately 0.23MPa. Therefore the ceiling of the room 1 is newly designed to take account of the room 1 pressure.

Acknowledgements

This wok was performed under the Nuclear R&D Program of the Ministry of Science and Technology of Korea.

References

[1] "HANARO Safety Analysis Report," KAERI/TR-710/96, Korea Atomic Energy Research Institute, Daejeon, (1996).

[2] W.J. Lee, et. al., "Improved Features of MARS 1.4 and Verification," KAERI/TR-1386/99, Korea Atomic Energy Research Institute, (1999).

[3] RELAP5/MOD3.3 Code Manual Volume IV: Models and Correlations, NUREG/CR-5535/Rev 1, 2001.

[4] MARS 2.1 Code Manual, Input Requirement, KAERI, 2002.

[5] "FTL Room #1 Shielding Cover Evaluation for HELB Loads," HAN-FL-E-072-DC-H101, KAERI, (2004).

[6] "FTL Room #1 Wall & Slab Evaluation for HELB Loads," HAN-FL-E-072-DC-H102, KAERI, (2004).

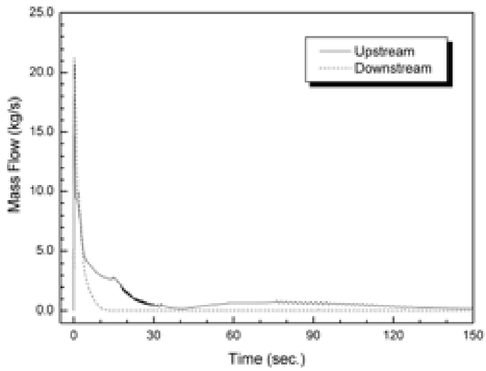

Figure 1 Flow rates at the broken pipe.

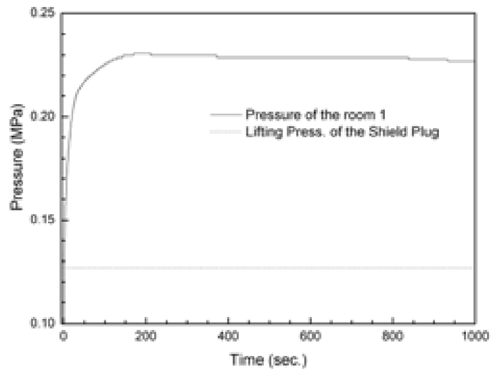

Figure 2 Pressure of room 1 for high energy line break.